BCRA TRANSACTIONS

BRITISH CAVE RESEARCH ASSOCIATION

Volume 4 Combined Numbers 1 & 2 March 1977

DAN YR OGOF

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A very short summary of the principal conclusions should accompany every contribution.

References to other published work should be cited in the text thus . . . (Bloggs, 1999, p.66) . . . and the full reference with date, publishers, journal, volume number and page numbers, given in alphabetical order of authors at the end, thus . . .
Bloggs, W., 1999. The speleogenesis of Bloggs Hole. Bulletin X Caving Assoc. Vol. 9, pp. 9-99.

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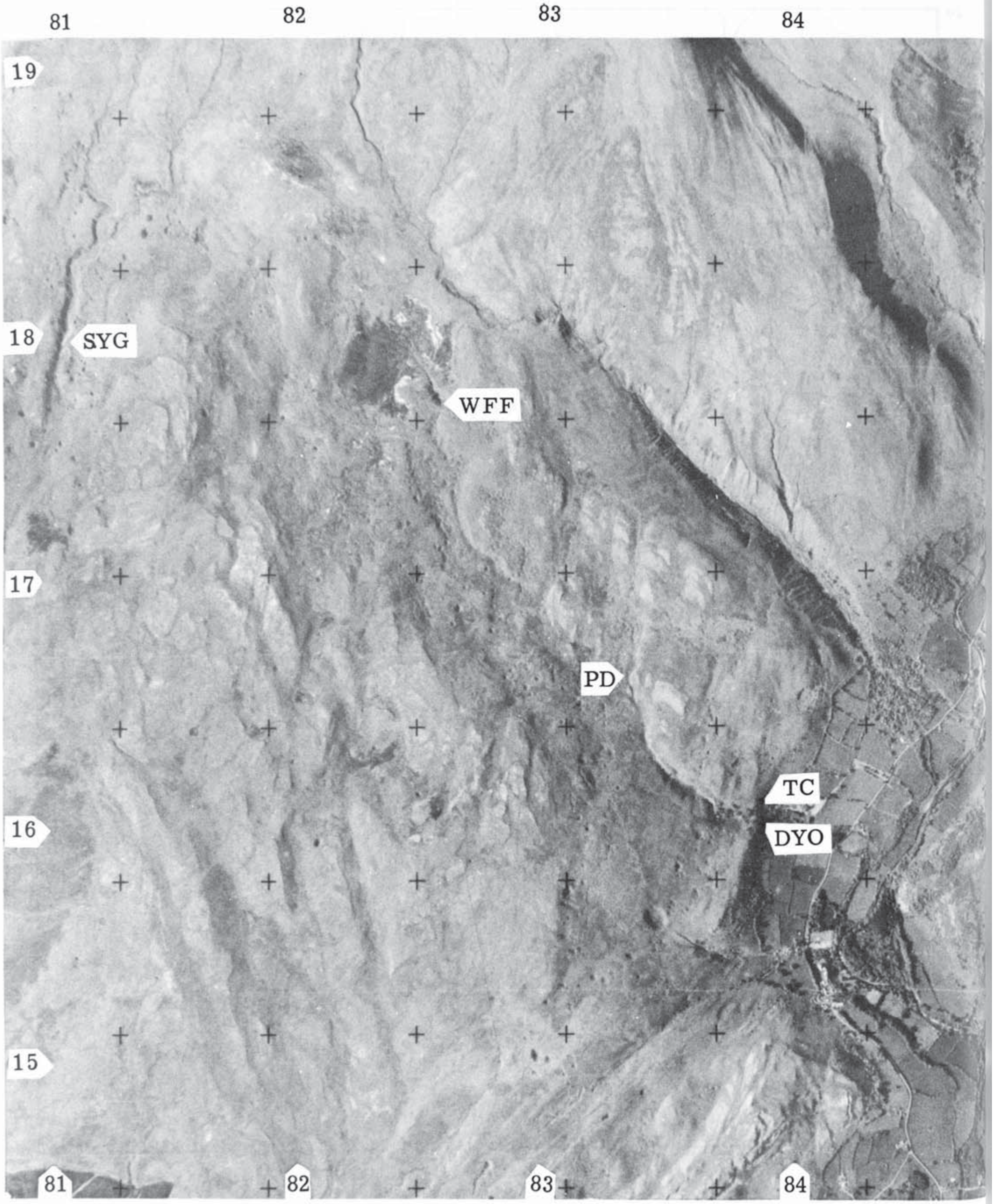

PLATE 1. AERIAL PHOTOGRAPH OF THE DAN YR OGOF CATCHMENT AREA.

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DAN YR OGOF AND ITS ASSOCIATED CAVES
I
INTRODUCTION

This study is concerned with the caves of the Dan yr Ogof catchment area, a complex area lying on the western side of the Upper Swansea (or Tawe) Valley of South Wales. (Fig. 1 & Plate 1). The two principal caves within the catchment area are Dan yr Ogof (totalling about 15 kilometres in explored length) and Tunnel Cave (over 2 kilometres long, now also known as Cathedral Cave). There are other important caves and potholes within the area and there is no doubt that a large part of the Dan yr Ogof system remains undiscovered. The lesser caves include the archaeologically important Ogof yr Esgyrn (the "Bone Cave"). Pwll Dwfn (the "Deep Pot") and Sink y Giedd, an active and immature rift cave. One or two major digs have been pursued over a long period, notably that at Waen Fignen Felen, and there is little doubt that other caves and potholes will be discovered in the future.

The caves are located within the Dinantian limestones of the northern outcrop of the South Wales Coalfield, on the dip slope of the Carmarthen Fan known as Mynydd Ddu or the Black Mountain. The catchment area is well demarcated on the east and south-east by faulting and on the north and north-east by the River Haffes. To the west it lies within an ill-defined anticline west of the River Giedd, while to the south and south-west the limits are concealed by overlying Namurian strata.

These relationships and those between them and the main caves, sinks and the resurgence are shown in summary form in Fig. 1 and in the aerial photograph, Plate [1]. The two main hydrological input points for Dan yr Ogof are at Sink y Giedd (810179), (Plates 2 and 3) and at Waen Fignen Felen (826177) (Plate 4) though it should be emphasised that the latter is now only a major source in wet weather conditions. The former is some 3350 metres from the resurgence in a roughly northwesterly direction (304°) while the latter is a little over 2 kilometres from the same point in a slightly more northerly direction (323°). The resurgence at Dan yr Ogof (Plate 5) is approximately 220 metres O.D. while approximate surface altitudes at Sink y Giedd and Waen Fignen Felen are 448 and 438 metres respectively.

Both of these sinks are and were fed from mainly sandstone sources but the grits above the cave are also important hydrologically. Although no streams of the order of the Giedd or Haffes are developed on them there are many smaller streams and quite extensive peat bogs which are known to contribute to the cave waters. Changes have occurred in the relationship and relative boundaries of the limestone and the adjoining rocks and significant modifications to the drainage network have also resulted from the action of ice in both erosive and depositional terms. Partly for this reason Tunnel Cave is now largely dry in that its only known streams are small misfit streams whose present sources are principally percolation waters rather than specific sinks.

Definitions and nomenclature

The main cave is divided into Dan yr Ogof One, Two and Three, as a result of stages in the history of the exploration rather than as geomorphological units. However, as these terms are frequently referred to and shown on the Cave Plan, further explanation is necessary.

Dan yr Ogof One refers to the passages between the entrances and the end of the Long Crawl. These passages are sometimes further subdivided as the "1912 Cave" and the "1937 Cave" as the Lakes were not crossed until the latter year. Later discoveries have been made in each of the areas but these have not been sufficiently significant to alter the overall terminology.

Within Dan yr Ogof One, reference is occasionally made to the "River Cave" and this refers to the stream passages at the resurgence. These lie below the artificial entrance to the Show Cave and form, in the strictest sense, an exit rather than an entrance. The "Show Cave" consists of the main passages discovered in 1912 and subsequently modified with concrete flooring, steps, hand rails, electric lighting, etc.

Dan yr Ogof Two includes the passages between the far end of the Long Crawl and the Rising. It is subdivided in this analysis into the Upper, Lower and Further Series, the last named being the passages beyond the Green Canal. Discovery of this series dates from Easter 1966 and like "Three", first entered in September of the same year, is by no means fully explored.

Dan yr Ogof Three refers to the area beyond the Rising and consists principally of the Great North Road, and the Far North, the latter being further subdivided into Left-Hand and Right-Hand Series.

Reference has already been made to the existence of the two "entrances" and it is also necessary to remove any possible confusion concerning references to the "Giedd Series". This refers to the as yet unentered, cave network believed to be between the further parts of the synclinally controlled passages in "Two" (i.e. Hangar Passage Extensions and Mazeways Two) and Sink y Giedd.

Confusion could also be caused by reference to caves known as Cathedral and Tunnel, lying slightly to the north of the Dan yr Ogof resurgence. These are in fact one cave, initially named Tunnel Cave by the discoverers in 1953 but recently re-christened Cathedral Cave by the owners on opening it as a commercial showplace. The original name is retained herein.

A.C.C.

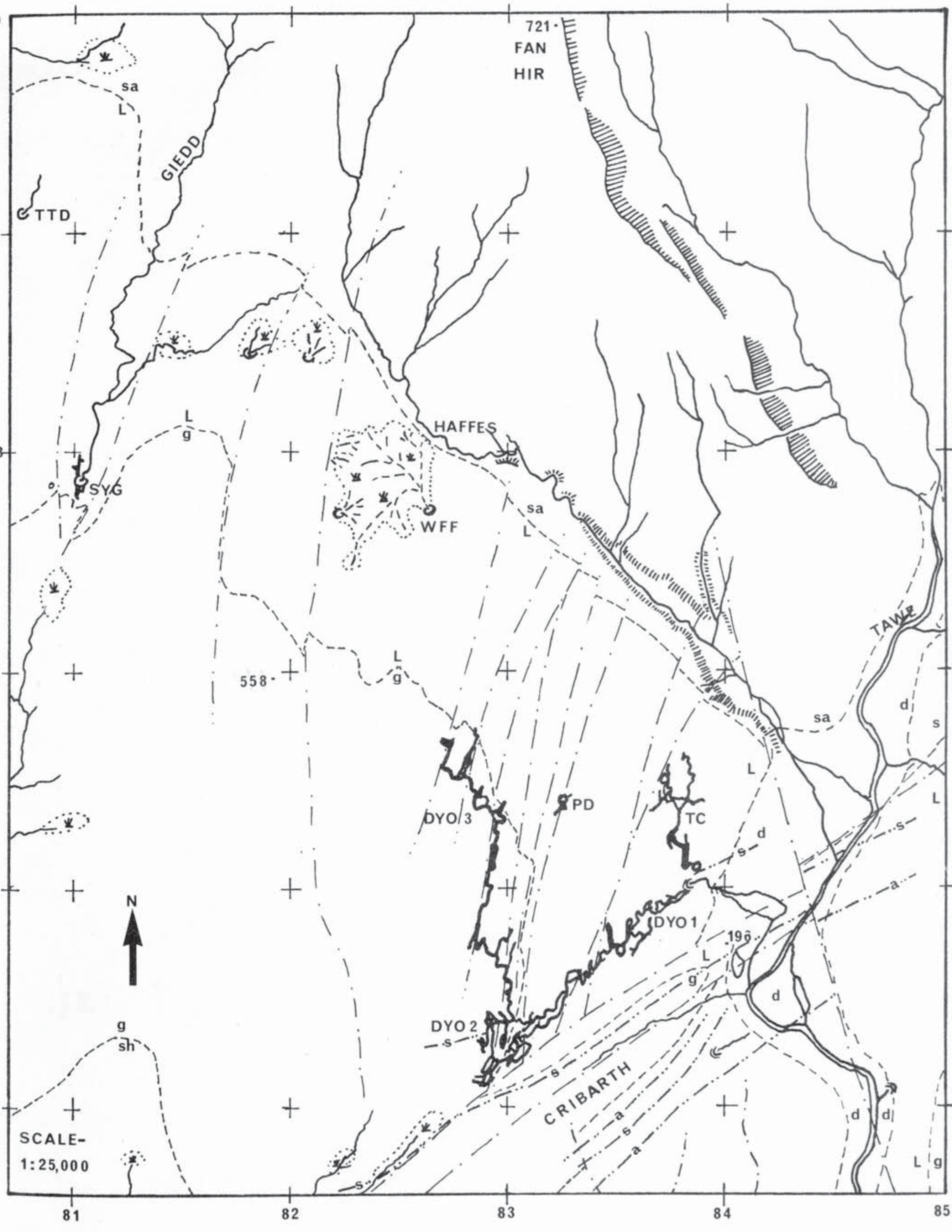


FIG. 1 CAVES, DRAINAGE AND GEOLOGY IN THE DAN YR OGOF CATCHMENT AREA.

DYO - DAN YR OGOF
TC - TUNNEL CAVE
PD - PWLL DWFN
WFF - WAEN FIGNEN FELEN
SYG - SINK Y GIEDD
TTD - TWYN TAL DRAENEN

GEOLOGICAL BOUNDARY
FAULT
FOLD —··-a-··— anticline, —··-s-··— syncline
PEAT BOG
721 · SPOT HEIGHT (metres)

L - LIMESTONE
sa - SANDSTONE
g - GRIT
sh - SHALES
d - DELTAIC & OTHER DEPOSITS

Plate 2. The Giedd stream flowing into Sink y Giedd.

Plate 3. The entrance to Sink y Giedd during a dry spell

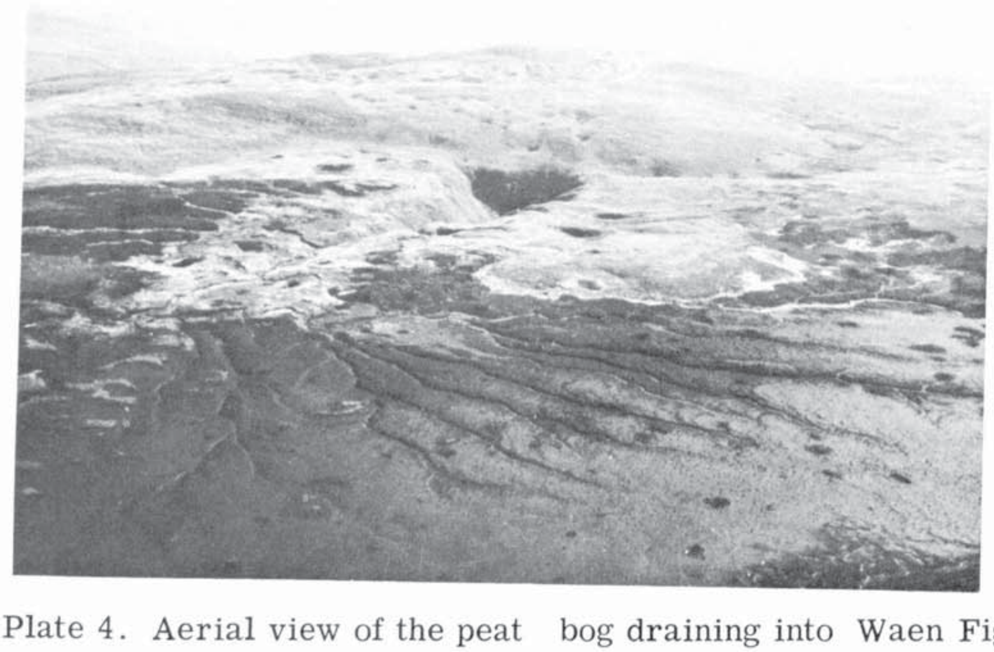


Plate 4. Aerial view of the peat bog draining into Waen Fignen Felen.

II

THE EXPLORATION HISTORY OF DAN YR OGOF AND ITS ASSOCIATED CAVES

Introduction

The following summary of discoveries in the caves of the Dan yr Ogof catchment area is divided into three parts while a fourth section looks briefly at future prospects. The first is concerned with the principal discoveries in Dan yr Ogof itself, excluding the more detailed account of cave diving in part two. The third contains the history of exploration of the other caves and digs in the catchment area. In each case the principal break-throughs are given by date, wherever possible the explorers are named and a contemporary account of the major discoveries is included. References are given to important articles or records but fuller details are usually best obtained from the publications of the South Wales Caving Club (notably its Newsletter and the Tenth and Twenty-First Anniversary Publications); of the Cave Diving Group; of the Cave Research Group of Great Britain (especially the publication and survey of "Tunnel Cave", 1958) and of the British Speleological Association (particularly the 1967 Conference proceedings). Two important early articles are those by Lumbard entitled "The 1937 Exploration of Dan yr Ogof" in Caves and Caving, Vol. 1, No. 4, April 1938, and that by Roberts on "Dan yr Ogof and the Welsh Caves", in the Yorkshire Rambler's Club Journal, Vol. 7 No. 23, 1928.

A. The Discovery and Exploration of Dan yr Ogof

The discovery and exploration of the Dan yr Ogof Caves can be divided into three main phases though there will undoubtedly be more to add at a later date and it may well be that a start to the fourth has already been made.

The First Phase – 1912

The story started in June 1912 when the cave was first entered by two brothers, Ashwell and Jeff Morgan of Ty-mawr, Abercrave. After entering the river cave they investigated each bank until Jeff discovered an opening on the right hand side just large enough to squeeze through. This led into a large well-decorated passage high above the river, which continued as a sandy-floored passage until the way on was barred by a deep pool. They realised the need for a boat or raft and so returned to the entrance making plans for a further trip which they accomplished next day. This time they were accompanied by Edwin another brother, and Morgan Richard Williams, their gamekeeper. A small raft enabled them to cross the still pool and they made further progress through large sandy passages until they reached a point where a number of alternative routes began to appear.

Next day they made a third visit aided this time by William Lewis and with their candles supplemented by night lights. On this trip a thermos flask and a bottle containing the names of the party were deposited on a shelf of rock opposite the most beautiful discovery they had so far made, a 6ft high stalagmite column which they christened the Alabaster Pillar. The remains of the thermos and jar are still apparent on the ledge though in poor condition due to their age. Also evident are the pencilled date and names of the two Morgan brothers responsible for the discovery (that of the gamekeeper being further round the corner!).

The Alabaster Pillar proved to be only the first of a series of magnificent formations found on subsequent explorations. Just beyond the Pillar was the 'Flitch of Bacon' with a little further on Dagger Chamber with its 'Angel', 'Daggers', 'Pillar of Salt' and the now famous 'Nuns'. Finally they entered a large chamber containing a massive Curtain high in the roof, though their dim lights did little more than outline this. In any case their attention was drawn to the distant noise of water that came from the foot of the boulder strewn slope at whose top they stood. Carefully descending this they encountered thick deposits of sand and beyond, the dark waters of a deep lake. While this flowed quite gently the dull but incessant roar of a waterfall could be heard in the distance. They realised that they were back at the river and were again in need of a boat. On their way out they discussed their discoveries and the best form of boat to transport through the sometimes difficult passages. Fortunately they found an easier low-level passage leading back to the first major divide (later known as the 'Parting of the Ways') and this reduced their need to make difficult climbs.

After further discussions a coracle was obtained from Carmarthen and the explorations recommenced. Jeffrey Morgan described their subsequent efforts:-

> "Placed on the lake it appeared a frail craft to be entrusted with the mission of carrying a human being into the stygian darkness into which the lake disappeared. A deafening roar of water could be heard in the distance. Was it a waterfall pouring water into the lake, or was it a waterfall caused by surplus water leaving the lake? This was important to the intrepid adventurers. Would the coracle be washed over the brink of such a waterfall or would it be swamped? Would it be sucked down by a whirlpool or carried away by the stream through low passages?
>
> What would happen if a heavy fall of rain on the surface made the underground river swell suddenly and abnormally? All these considerations would make the bravest hesitate. Yet Mr. T. Ashwell Morgan ventured into the coracle and with a rope attached to one end and paid out by his younger brother he manoeuvred the boat along a narrow channel and discovering that not one lake but three lakes, 80 yards in length, had to be thus negotiated. He finally reached a mighty waterfall whose awe-inspiring roar, in such a small space, was almost overpowering. He gave the signal for the return and he was steadily pulled back to safety".

The Second Phase — 1937

It was not until 1937 that further exploration work was carried out and this time it was by experienced cavers from Yorkshire and Mendip who were well equipped with tackle, which included rubber boats, ladders and powerful acetylene lamps (Plate 5). Their efforts, which form the second chapter in the history of exploration arose from a visit to the area by Ernest Roberts in September 1936. Roberts, a noted early Yorkshire potholer, visited the area mainly for a walking holiday and afterwards he wrote:

> "I did the Vans and came down to Dan yr Ogof rising. A cave indeed! I could not cross the flooded beck into the great cave entrance, but that did not matter, for at the Gwyn Arms I learnt that the owner and his brothers had been in ¾ mile and used a boat."

Later he met Jeffrey Morgan and after learning how their early exploration had finished he contacted some fellow enthusiasts — not very numerous in those days — including Gerard Platten of the Mendip Exploration Society (who was to play an important role in the forthcoming efforts). In wet weather the following May they made their first attempt . . .

> "The First Pool was deep and 12 yards long but Nelstrop showed us the way: somewhere ahead was a great roar of water. Over a steep bank was a shallower pool, some 20 yards, and then we stood on a narrow beach and looked at the third pool; it simply ran away into darkness. I confess that till we found the Three Pools it had never occurred to me that we were going to be up against lakes of the Marble Arch type. I had thought only of passages of ordinary width and short pools. With that ominous roar ahead we agreed that the Morgan's crossing of 1912 was a great effort."

Trouble with their inflatable boat, described by Roberts as a cross between "a baby's bath and a balloon tyre", and the strength of the current prevented them from more than viewing the waterfall at this first attempt.

> "However, during the summer Mr. T.A. Morgan's old enthusiasm blazed out. Using a two-man boat of wood and canvas with side air-chambers, he, Miss Coote and Mr. Ashford Price crossed the Coracle Pool. It must be recorded that Dr. Coote swam the whole way back. Climbing the side of the cataract they went 50 yards through deep water, and climbing another cataract came under a lower roof to a fourth pool stretching into the distance."

This was in August 1937 and on September 19th and 20th further "attacks" were made with Platten bringing an "army" from Somerset, as well as an awful flood and fog. All told, with Roberts and his Yorkshiremen, a total of seventeen entered the cave but it wasn't until Sunday that any progress was possible and then the Fourth Pool was finally crossed. It appeared to be

> "a backwater without visible inlet, but Miss Coote noticed a passage just where one emerged from the low roof. Here was an excellent landing and the ferry only 15 yards. Ten people crossed . . . they were pretty quick and came back reporting marvels; (Plate 7) they had reached a great Boulder Chamber and stopped beyond at some awful mud.
>
> "The ten making up this first party were P. Backhouse, Baker, F. Brown, Miss Coote, Foskitt, C.W. Harris, Lawrence, D. Lumbard, P. Weaver and V. Wigmore. They reached Boulder Chamber and next day T. Ashwell Morgan, Miss Coote, Platten, A. Price, D. Price Roberts and Wigmore explored further, discovering Wigmore Hall, Ashford Hall and the start of a "terribly narrow crawl". Here T.A. Morgan and I struck while the other five went through to wallow in mud. A month later Platten's party got forward 100 yards to the sound of water and found extensions off the chambers.
>
> By the time we returned to the ferries only one acetylene lamp worked feebly; our retreat was made with candles and feeble electric lamps. The water had fallen yet more and one paddled out into the ocean of the Coracle Pool with the barring spike of Saturday high overhead. Meeting the ferryman and his glimmer reminded one of ships at sea." (E.E. Roberts).

Further trips were organised by Platten on September 30th, October 13th and 27th and November 19th and 24th. During these the cave was surveyed and numerous other finds were made (Plate 7). The two October trips were particularly rewarding and significant for Ashwell Morgan's palace (Straw Chamber), and Price's Hall were entered on the first, and notable extensions to two crawls were made on the second. Lumbard wrote very prophetically about the latter.

> "At last the end of the cave is reached . . . Platten and one or two others had been as far as seemed possible up a particularly filthy way called "the Mud Crawl". After many twists and turns around which there was a strong current of air, the way was blocked by what seemed an impossible squeeze at the top of an opening some 5ft high".

One person (Backhouse apparently) did however get through

> " . . . and so another 60 yards were added. It still went on but was like a drainpipe half full of water and here it was thought the river could be heard."

The point reached is still a matter of conjecture though the survey and description suggest that Backhouse got beyond the small chamber known as the Spectacles (after the bridge of rock dividing a near vertical squeeze into two smaller openings) and possibly even as far as the '1966 Squeeze'. On the same day Lumbard and Weaver investigated some high level passages near the beginning of the 'Mud Crawl' leaving their initials in sand at the furthest point reached. These were "re-discovered" by Coase and Judson on January 1st, 1970, in the course of the first journey through the Even Longer Crawl which they found from the "far" side!

In total the "Dragon Group", as the explorers became known, had more than doubled the known extent of the cave to a total of about 1½ miles by the end of 1937.

Plate 5. Exploring party at the Dan yr Ogof resurgence in 1937.

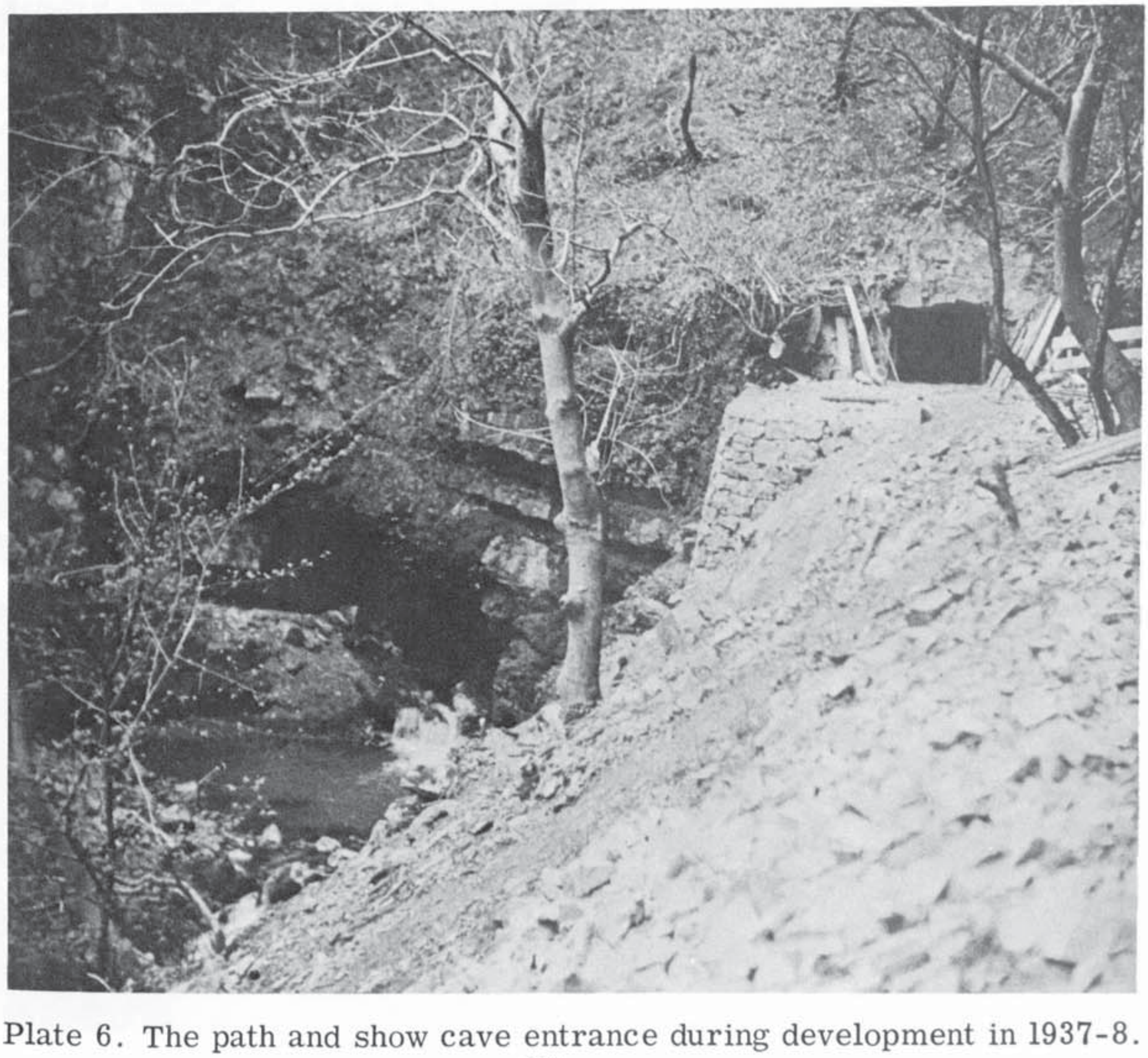


Plate 6. The path and show cave entrance during development in 1937-8.

Plate 8. One of the squeezes in the Long Crawl,

after widening, 1966

At about the same time the Morgan brothers began the commercial development of the Cave, as far as the First Lake, for public viewing. A new entrance was made almost above the resurgence leading directly into the upper dry passages (Plate 6). A concrete path was put down as far as "The Parting", and a loop of paths beyond. In places the floor was extensively excavated to give safe walking headroom (notably in Western Passage and beyond the Alabaster Pillar), steps and handrails were put in, and a D.C. lighting circuit fitted – this latter being supplied from a turbine and generator on the Llynfell Falls below the resurgence. Alterations were also made to Cauldron Chamber with the boulder floor being stabilised and quite extensive openings into Western Passage being sealed up.

The Show Cave was opened to the public in August 1939, and is reported to have received 5,000 visitors in its first week (Roberts 1947). It was closed by the onset of War, but even then it had its uses for it became, partly on Platten's advice, a government store. Unfortunately during these war years a number of formations were slightly damaged.

After the War legal and financial difficulties prevented the re-opening of the Show Cave until 1964, but a limited number of visits were made by cavers including teams from the newly formed South Wales Caving Club and some early diving attempts were made by Don Coase and Bob Davies. The latter efforts established that there were no obvious ways beyond the Fourth Lake and that the route below the Show Cave could not be pursued. Several small chambers were found however.

Very significant discoveries were being made elsewhere in the Dan yr Ogof catchment area in this post-war period and these are referred to subsequently. However, in the main cave, discoveries were relatively limited until the mid-1960's. The principal exceptions were the entry into Corbel's Chamber (behind Ashwell Morgan's Palace) in August 1950 by a party including the famous French geomorphologist, and five years later the discovery of high level passages above Boulder Chamber and Pot Sump by Dai Hunt, Peter Harvey and others (Hunt 1956).

The Third Phase – 1964 to 1976

This phase has proved to be most outstanding to date in terms of size of discoveries but it is necessary to emphasise how heavily it is based upon an agreement made between the Cave owners and the South Wales Caving Club. This agreement has been of vital importance to continued exploration and scientific investigation and provides an excellent example of co-operation of a type which is unfortunately an exception in some caving regions. The caving community owe much to Dr. A. Price and his co-directors and to the S.W.C.C. Committee of the time.

Thus the third chapter began at Whitsun 1964, when the Cave was re-opened to both cavers and the public. Some minor but encouraging discoveries were quickly made and the potential of the cave began to interest a number of members of the South Wales Caving Club, among them the writer who gathered together a team of enthusiasts for whom Dan yr Ogof formed a major goal. There were many early successes and in August 1964 considerable extensions were made to the high level series above Boulder Chamber (Anderson Coase and Powell) and in November, Coase, Charles Henson and Doug Baguley discovered Siphon Series between Lakes Three and Four. This was ultimately extended through the Mud Sump by Coase, Jon Dryden and Tony Iles and Lakes Five and Six were entered at Whitsun 1965. On a solo dive from Lake 6 in July, Charles George entered the larger lake 7 which had possibilities and a beach but despite several efforts by divers, including George supported by Coase in October; and Rod Stewart and Oliver Lloyd shortly afterwards, no further progress was made. This proved disappointing and dashed the initial hopes that the breakthrough to Dan yr Ogof II was imminent (Coase, June/July 1965). However, considerable efforts were being made elsewhere by these teams as well as by other groups of members, some leading regular visiting groups from Swansea University and others from Yorkshire, Mendip and the Midlands.

At this time, Coase, aided by senior pupils and staff from Hinckley Grammar School, started a detailed survey of the cave from Lake One. A very high grade one of the Show Cave was commenced by Doug Clissold and subsequently completed by Noel Christopher and Bryn Thomas. These surveys, the extent of the finds being made and the increased knowledge of the catchment area, quickly made clear the major potential of the system. Efforts became quite intensive, notably by Coase, Bill Little, Stewart and others, and in many cases very systematic. To most the Endless Crawl as it was then known, was the logical breakthrough point but despite many efforts the tight double-bend or Squeeze at its furthest point remained impassable. Some efforts were made to open this up by hammer and chisel, Coase, Neil Anderson, Bruce Foster and the Hinckley students trying on several occasions but without success. Thus, when Eileen Davies joined their efforts it was some months of trying in other areas, coupled with winter-long floods and competition for the Long Crawl (Plate 8) when the cave was accessible, which delayed her in being "put to the squeeze". She and Coase pushed it on the 3rd April 1966 and she passed the Squeeze without difficulty though the chimney beyond defeated her for the time being.

Detailed arrangements for a small follow up trip at Easter 1966 were put in hand by Coase but the holiday proved exceptionally wet and the Lakes remained impassable until Easter Tuesday, April 12th, 1966. The cave was then entered in very high water conditions by Anderson, Coase, Davies, Foster and Colin Graham. Eileen and Bruce were sent on through the Squeeze to see if the chimney went anywhere, while the remainder tackled an Aven at the near end of the Crawl and kept a check on water levels. The chimney did "go" and after a considerable struggle at the Squeeze by the largest and last member (Coase) all finally descended into the unknown. Eileen's comment was

> "I expected to find a chamber, but instead we walked into a vast passage. I just could not think of anything to say. It was what every caver dreams of".

Coase wrote more fully (1966):-

"The initial reconnaissance showed that this was far more than a single large chamber. With tremendous excitement we became aware of the sheer size of our discovery (Plate 9). We were overwhelmed by the beauty and variety of the calcite formations (Plate 10), the clarity of the streams and crystal pools and we alternated between noisy babblings and awestruck silences. In the end we decided that Neil and Colin should return to the surface to check conditions and mount a second team bringing spare lights and food for those of us who remained in the cave."

Stewart and Little eventually joined them and

"when so refurbished, our explorations continued into even larger passages until we were halted by a deep, winding lake (Plate 11). Here a quick ice-cold swim confirmed our need for a dinghy so we retraced our steps and with increasing weariness made our way back through the Crawl, across the lakes and back to the welcoming concrete paths of the Show Cave, finally 'surfacing' at 3 a.m."

In more sober terms this first trip reached the Green Canal, the end of Hangar Passage and discovered what was afterwards named Gerard Platten Hall, the Canyon, Monk Hall Cloud Chamber (Front Cover) and Flabbergasm Chasm and also entered the Lower Series (Plate 12).

The explorers were quite surprised by the publicity which met them on their exit and also puzzled by the initials P.O. which Eileen had found at the top of the chimney. It transpired that Peter Ogden, then of the Swansea University Club who had also been chipping away at the Crawl, had passed the squeeze in October 1965 but had not been able to descend the pitch.

On the following day (14th April) Anderson, Davies, Foster, George and Stewart crossed the Green Canal and reached the top of the Abyss (with a boat but no other tackle) and explored as far as the Rising. Coase, who had returned to Leicestershire for photographic equipment, was delayed by blizzards, entered the cave later with Gale and Holt from Hinckley, and Frank Baguley but the latter could not pass the Squeeze. The result was that Coase reached the head of the Abyss with tackle, but no support, but did at least obtain some photos for publication.

Heavy snowfalls and subsequent floods halted progress for some weeks though Foster, Laurie Galpin, Eric Inson and Little managed to get in in very marginal conditions on the 17th and "remove" the Squeeze. This greatly improved access as did the subsequent opening of the constricted entrance to the chimney and the large parties that entered on the weekend of 30th April must have wondered where the real difficulties had been. These parties included Bill Birchenough, Foster, Noel Dilly and Coase who all descended the Abyss (Plate 15) with the latter pair exploring much of the lower series to within sound of the Washing Machine.

Noel Dilly and Noel Christopher commenced a survey in May and during the course of this, they and a party containing Coase and Thomas, completed independent circuits of the Lower Series, climbing back into Platten Hall by the connection which had been found on the first visit. Various other connections were also made during May 1966 notably the Four Pots Area by John Bevan, Christopher and Thomas; Elliptic Passage by E. Davies, Graham, Chas Jay and Stewart; and Worm Way by Foster, Allan Murray and Thomas. A more significant find was made after an epic free climb from the Abyss by Inson towards the end of May. This led to the complex maze christened Dali's Delight by Thomas, who like Coase, Foster, Murray and Jem Rowland was glad of the life-line for the climb.

This was the end of the initial stage of discoveries in 1966 for the discoverers had formed an ad hoc committee after the breakthrough and had committed themselves to a careful policy of photography, taping and conservation from the outset. (Plate 16). Though not entirely popular either within the S.W.C.C. or with other clubs, it was supported by S.W.C.C. club committee when it met and by the committee of the Cave Research Group of Great Britain. Later the inadvertent violation of several of the biological reserves by the surveying and exploring teams in the lower series led to a firmer line being taken and the cave was closed to all but biological teams for two months. In the event summer floods and the S.W.C.C. Balinka Pit Expedition extended this until nearly the end of August.

From this time on so many unrecorded and minor finds were made that mention is only made of the most significant, chief of which was the discovery of Dan yr Ogof III on the weekend of 24/25th September 1966. Coase reported the discoveries thus (1967):-

"**Saturday 24th**
Terry Moon and myself led separate parties, mainly of Wessex C.C. into Dan yr Ogof 2 on a "working tour". Weather conditions were excellent and the water in the lakes exceptionally low thus providing an opportunity to tackle the water in the 'Rising' at the end of High Way. Here the two parties combined in digging in an attempt to lower the sump but despite strenuous efforts no significant progress was made as the gradient at this point is relatively low and the sump deep. However, a concurrent attempt to scale a tricky 30 feet climb immediately above the sump was successful (Plate 17) although it took over two hours and the use of pitons and an electron used as an etrier. At the top, the aven expanded considerably but an initial look for a way on proved fruitless. Eventually, however, after a somewhat exposed climb, Coase entered a small, well-scalloped tube later called "Windy Way" containing a draught two or three times that of the "Endless Crawl"

A quick wriggle through led, after approximately 150 feet, to a sharp-sided rift down which a free-climb was just possible. A beautifully decorated rift passage extended either way at its foot with that to the right ending some 25 feet above a small lake with a peat-rippled sandy bed. This was entered via a narrow rift, it proving unnecessary to despoil the fine helictites and flowstone at the obvious point of descent. A minute and narrow airspace led upstream while downstream was a deep sump. (As yet no attempt has been made to establish the length of this but it may well prove a possible free-dive once a line is established).

Upstream was left for a while for information from above (via Moon) indicated that the left hand passage "went". A careful squeeze along Birthday Passage (it being Alan's birthday) passed a complete wall covering

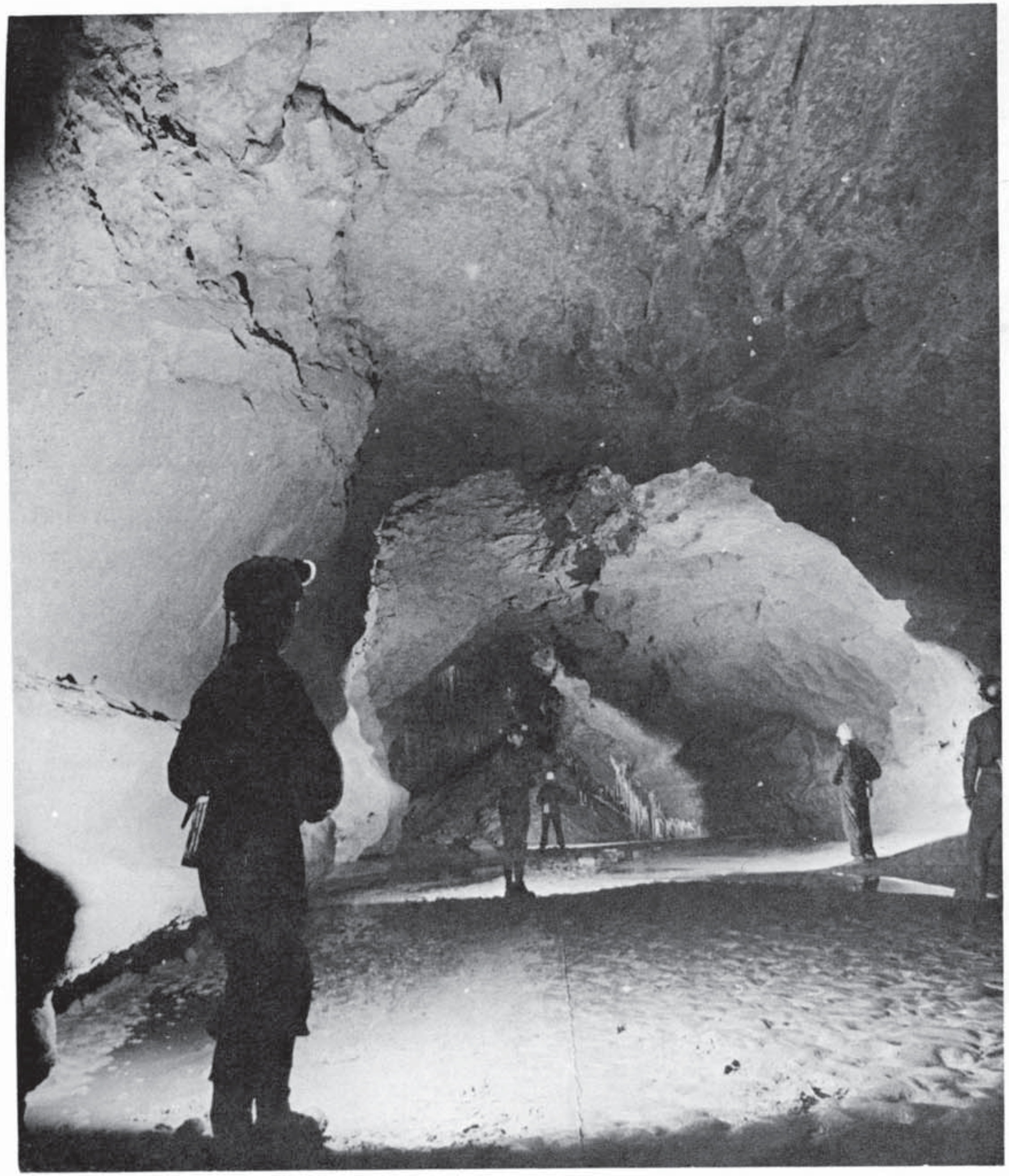


Plate 9. Part of the vast Hangar Passage.

Plate 10.

The Candlewax Columns

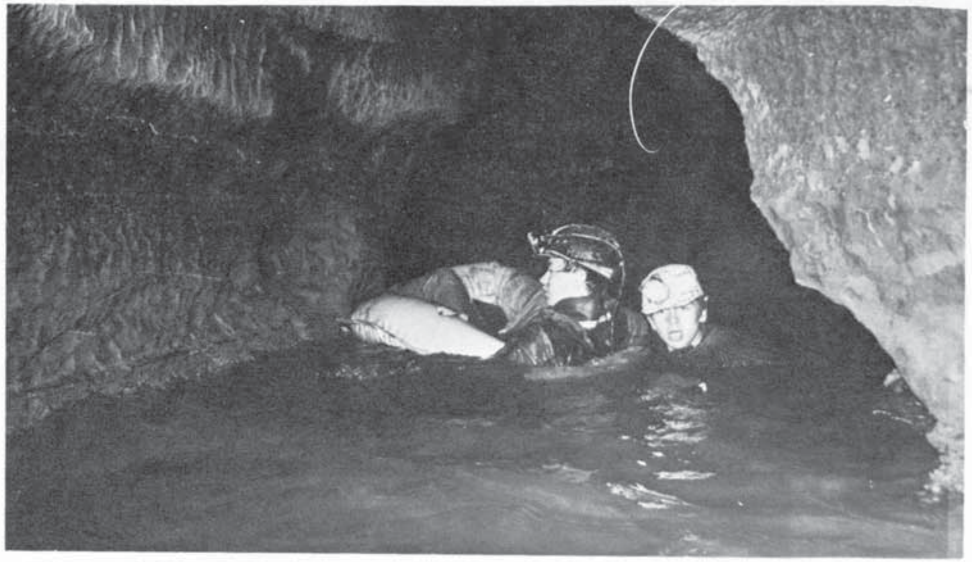
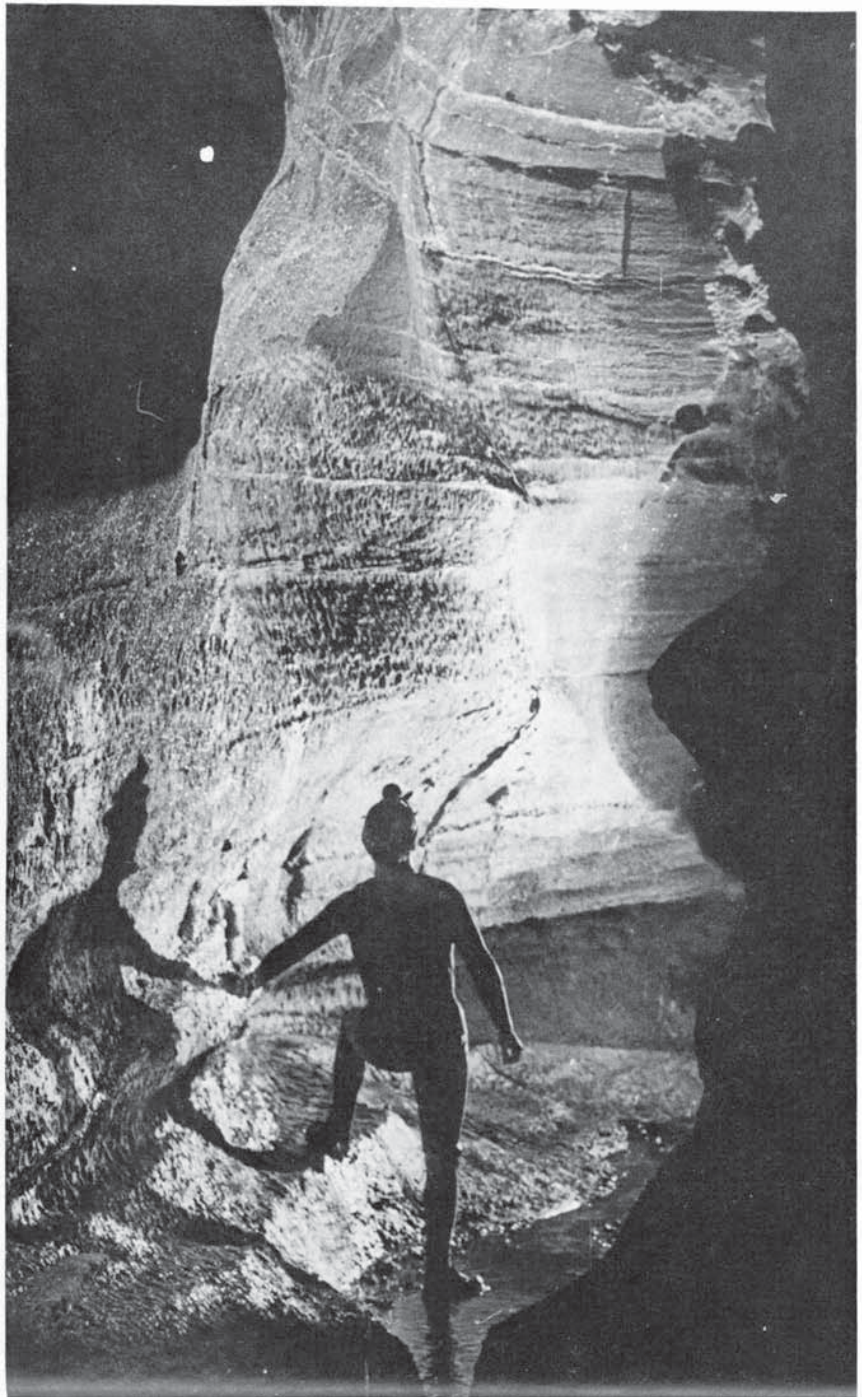


Plate 11. One of many shipwrecks in the Green Canal.

Plate 12. Straw stalactites in Cloud Chamber.



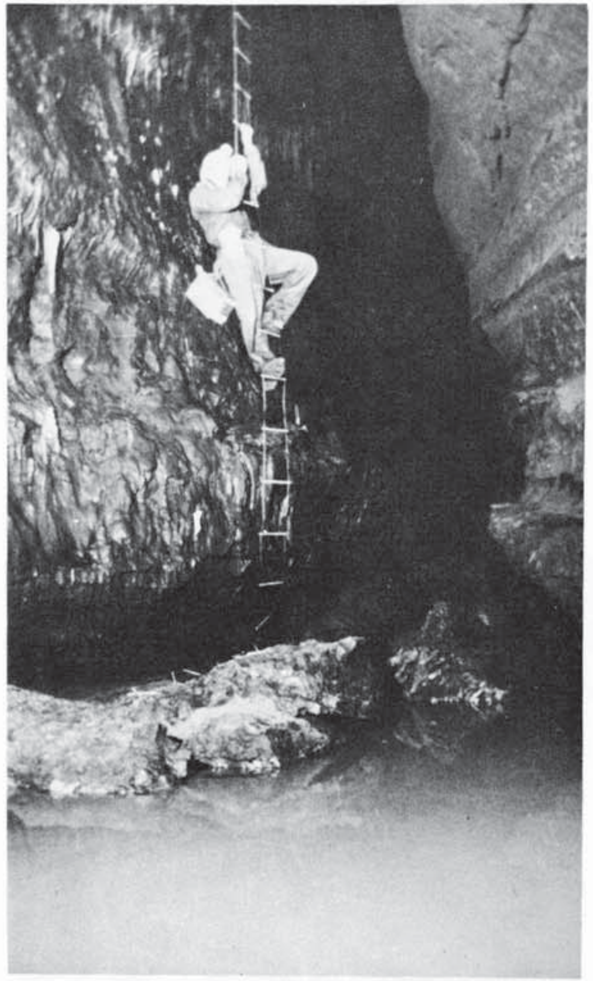


Plate 14. The descent into the Great North Road at the start of D Y O III.

Plate 15. The descent into the Abyss - a chamber more than 30m high

Plate 16. Flabbergasm - the path taped to preserve floor detail is visible to the left.

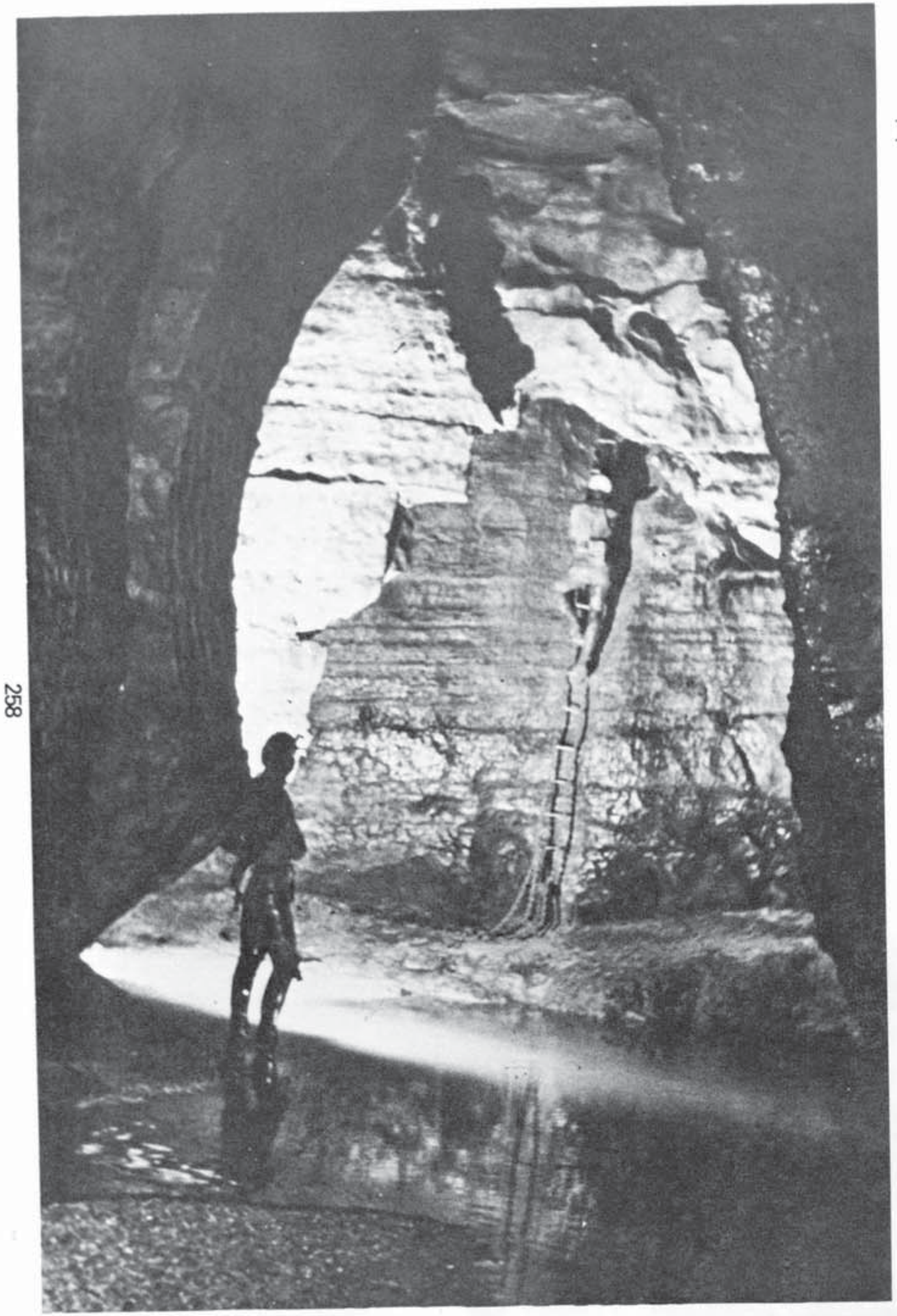


Plate 17. The climb above the Rising at the end of D Y O II
(photo: A.S.White).

Plate 18. Climbing over the boulders in the Great North Road.

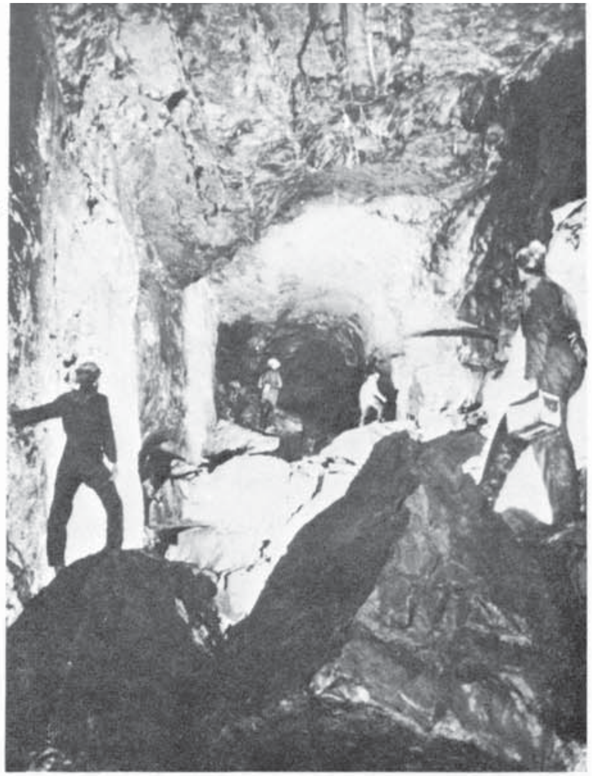
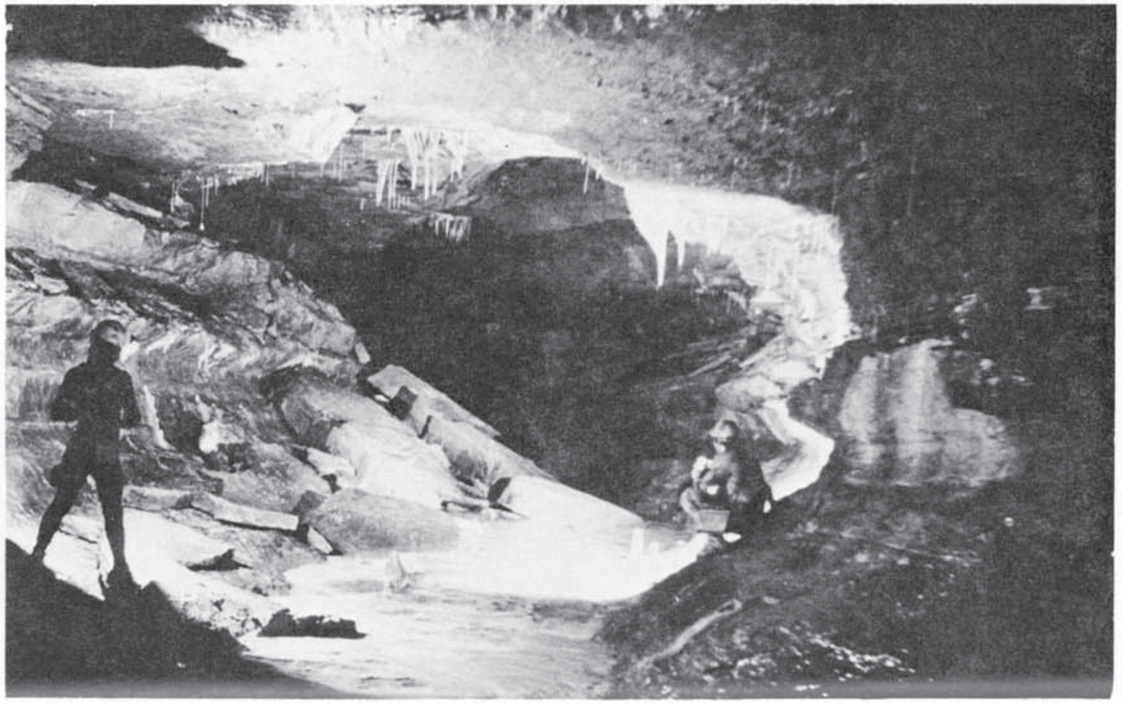


Plate 19. (below) The Mostest with its fine decorations.
(photo: A. Freem).



of helictites and led to a hole revealing a large passage with a stream flowing some 40 feet below. With regret, especially on Terry's part as he was unable to return on the Sunday, we returned being short of both time and tackle

Sunday 25th
Weather conditions remained excellent and we, Maire Unwin and Derek Tringham (Wessex), Gareth Jones (R.C.S. Dublin), and myself, returned, being joined by Susan Bradshaw and Alan Murray of S.W.C.C. Descent of the pitch proved most exhilarating for, upstream, the roof rose to well over 60 feet whilst downstream it came down to a low bedding plane and appeared to sump 'though later Maire ducked through into an air-bell and small 'lake' that was almost certainly the one I had entered on the previous day.

Movement upstream proved relatively easy and rapid at first for the passage remained high and wide though after a few hundred yards boulder piles became successively common (Plate 18). These at first were easily passed but became successively higher and more difficult until finally progress was halted at what appeared to be a collapsed two-level confluence. This area was partly filled with fine sand, in places with beds over 20 feet in thickness and being well decorated with sandcastles and drip-pockets: one of the latter was isolated and looking very like a gourd.

Formations were more common throughout this passage (called High Way Two or the Great North Road from its predominant trend) than in the area between the Green Canal and the Rising (High Way One) and became even more frequent towards the end. While good straws exist at a higher level more curtains (in parallel rows) are found and in a high level meander near the end magnificent crystals, overgrown gour pools, "flow-stone" and fine mudflows on the floor combine with a perfectly white "cascade" over ledges and good stalactites and curtains to create one of the finest passages in the whole system (Plate 19). A discussion among the somewhat overwhelmed discoverers ensued with every form of superlative suggested before the name "The Mostest" was hit upon.

Our return was again rather hurried although more notice was taken of the relatively few inlet passages which mostly descended as near vertical pots contributing small streams. Apart from these and a number of high avens, often co-incident with the large boulder piles, very few obvious passages enter the extension. The sides are so nearly vertical that some may be concealed on the well-defined ledges that occur at frequent intervals at a height of 20 feet – 30 feet above the stream."

Several trips were made into III over the winter but no major extensions were made there or elsewhere until around Easter 1967 when three important breakthroughs were made by different groups within a few weeks. Davies and Fairbairn took a closer look at Hangar Passage choke on 19th March (Plate 20) and succeeded in penetrating it and discovering large extensions (Hangar South) which were further added to (Hangar North) on the 25th by Sue Bradshaw, Colin Fairbairn, Paddy O'Reilly and Roger Thomas. On the same day Moon, checking water levels with Coase, Dryden and Graham Nicholson, entered Mazeways, an extensive network of large meandering passages which led to a number of important sumps.

The third find was made by a group of Yorkshire and Lancashire cavers led by David Judson and including Glyn Edwards, Harvey Lomas and John Whalley. The log-book account (O'Reilly, 1967) reads:

"On our return from the final choke we noticed a large aven which was subsequently climbed to a height of 40-50 feet to a passage leading back towards the choke. This climbed another 20-30 feet fall over a boulder pile, before opening out about 150 yards from the aven. After a descent of about 30 feet above boulders a large sandy cavern was reached (35 feet wide, and 20-30 feet high). From the lower left hand corner of this cavern an eye-hole between boulders gave access to the stream again – we were clear of the boulder choke. About 50 yards of narrow stream passage brought us to a 'T' junction; the major stream entered from the left.

"From this point a race ensued. Down the left hand series, through a wide oxbow with a flat roof, and back to the river and on up through a perfectly square passage with a flat gravel floor. After 100-200 yards this passage opened out till it had very considerable proportions (100ft wide, 30-50ft high) (Plate 21). We climbed 30-40ft to near roof level at this fabulous cavern to where a drop in the roof, marked by a long line of multi-coloured quivering straws formed a sort of curtain to yet another large cavern on the other side of the boulder heap. This was the start of Quivering Straw Passage. After several hundred yards a very solid and final boulder fall was met with – it consisted mainly of a large unsupported mass of clay and gritstone boulders."

". . . The right hand series was followed for about 150 yards through several low sandy chambers until it became rather small."

Further visits to the Far North were limited, partly due to high water levels and so extensions were very minor but a good deal of effort continued in other parts of the cave. Coase in particular was more interested in the possibility of extensions in a westerly or south-westerly direction towards the Giedd series, than of the almost certain connection between the Great North Road/Far North and Waen Fignen Felen and he expended a good deal more effort in the former areas. Dali's Delight also carried very considerable potential which was soon rewarded by the descent of Chamber Pot on Easter Tuesday 1967. Blasting associated with this by Inson also revealed a very strong draught which disappeared into the High Aven at the end of the series. This like the 'chokes at the end of Hangar extensions and at Avalanche Corner and the sumps in Mazeways became more and more enticing.

These sumps and the Lakes in the Lower Series and at the Rising all proved particularly attractive to the growing number of divers in the Club and to others in the Cave Diving Group. The full history of diving is outlined in more detail below, but it is important to emphasise the amount of activity that was devoted to these sites in 1967 and 68 by Richard Arculus, Mike Coburn, Fairbairn, Martyn Farr and Moon. The attempts met with only limited success but Farr and Moon in particular learnt a lot about techniques and the scale of the sumps that proved valuable later, both in Dan yr Ogof and elsewhere.

Adverse weather and a foot and mouth epidemic in the winter of 67/68 restricted other efforts for some time but a start was made to widen the Crawl to accommodate a rigid stretcher – with some success until just beyond Spectacles Chamber; to establish an emergency telephone link and to improve and replenish the emergency supplies which had been put in some years before. While the survey of 'I' had been completed by

Easter '66 the work in 'II' had fallen through and so Judson commenced a high grade survey in the Autumn of 1967. This was planned as a Grade 6 survey and was to incorporate Coase's survey of 'I' and Christopher's and Thomas's survey of the Show Cave. It had reached the Green Canal by Easter 1968 and its completion was one of the major objectives behind the Five Day Camp that Coase and Judson organised for Easter (Plate 24). Other aims were to co-ordinate surface and underground water sampling with George Bray, Christopher, Gareth Davies, Bob Hall and others; to carry out a programme of internal dye-testing and cave to surface radio location tests, and photographic work coupled with further exploration wherever appropriate but particularly in the Great North Road and Far North (Coase 1968).

This Camp proved successful in all but the intended location tests and here solely because at the last minute the apparatus was not available. Several members only managed one night at the campsite in Bat Chamber but Coase, Mick Day, Derek Holt, Dave Hume, Eric Inson and his wife Eileen (formerly Davies), survived all four very comfortably and achieved many of their objectives and a bonus besides.

The hydrological work was perhaps least satisfactory but it provided Bray and Christopher (1968) with an increased incentive to improve techniques and at least one dye test, from Pwll Dwfn, proved positive and important - in fact the campers emerged through green waters. Surveying, exploration and photography proved to work well together and jointly contributed to the bonus discovery for as Judson recorded (1968):-

"Surveying the Great North Road turned out to be a painfully slow and frustrating process. We lost one assistant after the first day. Glyn Edwards developed tonsilitis after an evening in the Windy Way. With various efforts at surveying through boulders, and under boulders (Plate 23) we eventually decided that the best method was to go over the top, no matter what the height! Thus numerous roof-tubes and avens came to our notice.

The most prolonged of these exploration halts came whilst we were in Pinnacle Cavern (Plate 22). Up at the far end of the Cavern, Coase had broken his tripod. After the protracted grumbling which followed this event, there was a marked silence — rather like when a small child has just perceived a new mischief. Coase was obviously up to something! Eric had a good idea what was afoot, and did an instant disappearing trip up a narrow vertical tube about 10 feet away from our station, (at the highest point of the floor of Pinnacle Cavern). Eric was quite right. Though via two different avens, they both appeared a few minutes later at a large window high in the East Wall of the Cavern, about 30 feet above our heads.

Above these new passages two more parallel avens were scaled, to reach an even higher level of passages about 100-150 feet above the stream. The main passage ran North, closely following the fault planes observed in Pinnacle Cavern (though a little to the East due to the hade). A superb example of false floor was found, the small stream having washed out glacial fill leaving behind a thin crust of stalactite suspended across the passage. The stream was traced back to an aven on the West side of the passage, and beyond this were several low gravelly sections. Progress was finally halted by a complicated zone of avens and shafts. Alan looked down into a large boulder strewn passage, where he could hear a stream, but could not see it. It was not until the following day that it was realised that this was **not** the main stream passage!

With Glyn Edwards and David Hume, I had started the survey work on the Friday evening, after the last of the portering work had been completed. We continued on the Saturday and pushed off out for an evening in the Gwyn. The full (camping) party of nine set out on the Sunday evening after the A.G.M. We had taken two full days in the Great North Road and reached a point just before the Spout. On the Wednesday we set off to survey past the Spout and through the Mostest; we were carefully observing the roof for Coase's aven of the day before. When we had found no aven by the start of the Mostest our ideas were confirmed. Mick Day went ahead and climbed up to the Mostest. He proceeded to traverse round above the stream passage, towards the Spout, on a broad ledge. After only a few yards the ledge widened out and ran into a high passage about 15 feet wide.

By 9.00 p.m. we had established a firm station at the start of Overpass Passage, and so decided to call it a day. On our return we were bound to have a look at Mick's discovery. Climbing over large boulders and mounds of sand, we entered a spacious chamber. A high passage ran off to the North, but we followed the larger passage running southwards. A stream entered from a small passage on the left, and disappeared into the boulders (presumably the Spout stream). The passage continued even larger than before, but we were soon halted in the same N-S faulting system as Pinnacle Cavern, and seems likely to terminate in the huge sand choke above the North end of this Cavern."

Judson continued his survey after the Camp and a number of radio location tests were carried out in following months, mostly by Judson's or Coase's groups underground with very practical skilled help from the O'Reilly's and friends on the surface. Coase commenced a detailed study of the cave's structure and geology, aided initially by Arculus on the latter and Bray and Christopher, helped by Day, G. Davies, Hall and schoolboys from Acton, continued with their detailed hydrological studies.

Partly because of these changes in emphasis, but also because the more obvious possibilities had been tackled, the rate of significant discoveries slowed. Sporadic digs were carried out, thus Coase aided by some London Venture Scouts was able to pass the sand choke at the end of Hangar South (July 1968) only to find a further choke within 50 metres. Judson crawled a similar distance into a very unstable choke in Hangar North and Inson succeeded in climbing the draughting Aven at the end of Dali's Delight. This in turn was extended by Farr through a suicidal choke and Coase and Judson endeavoured to achieve chemical short cuts in Avalanche Corner with somewhat frightening results. At about the same time Coase and Hall gained access to an awkward climb in the eastern-most of the Rottenstone Avens and the former entered a very narrow floorless rift leading from it, halting at a very narrow point well out of earshot of his companions. Arculus, Day and Judson passed beyond this point in September 1970 and eventually reached a window in another large Aven. However discoveries elsewhere, changes in club personnel and personal commitments and the inability to get large equipment, scaling poles, large digging tools etc, through the Crawl, all contributed further to a decline in the rate of progress.

The next important find came from Judson's surveying party in Dali's Delight on 30th August 1969. Judson, Edwards and Day discovered the large A2 Chamber at the end of a tricky and fairly arduous crawl. This was at first mistaken for the Abyss and indeed was proved to connect with this a few weeks later by Coase. The short crawl he found between the two enters the Abyss less than 5 metres above the floor of the latter and if further investigation is called for will make a much easier route into A2 than via Dali's Delight.


Plate 20. Boulder choke in Hangar Passage.

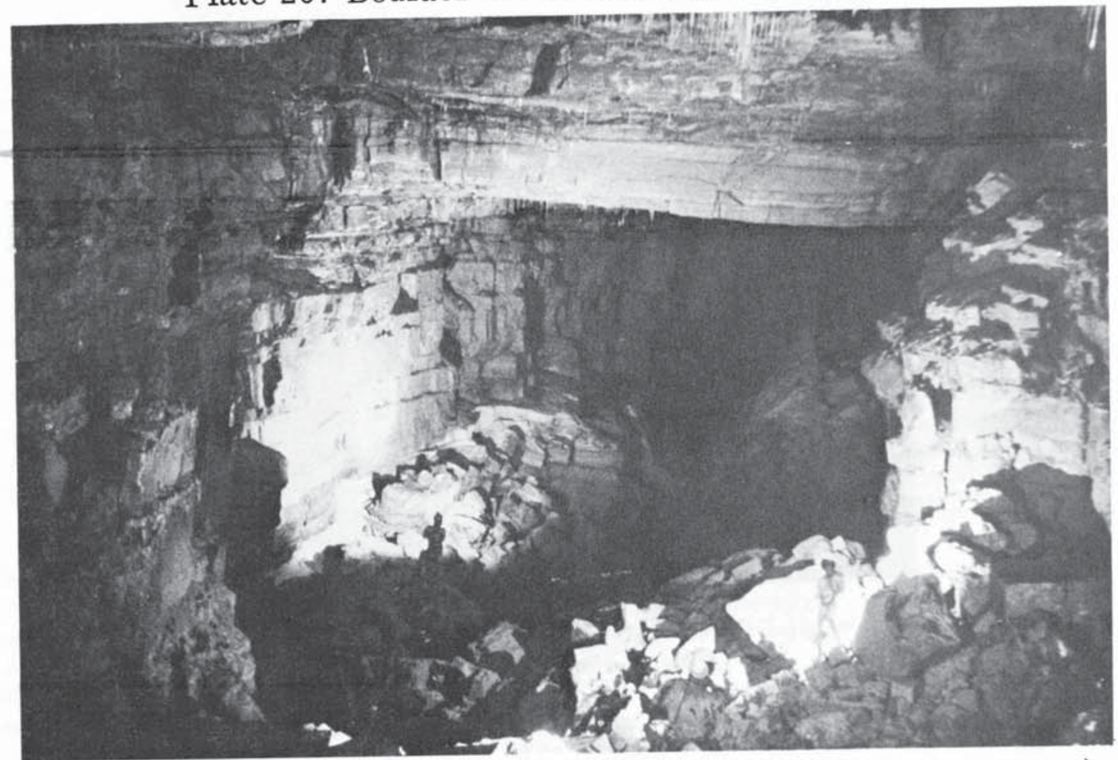


Plate 21. The Great Hall in the Left-Hand Series (photo: A. Freem).


Plate 22. Pinnacle Chamber in the Great North Road (photo: A. Freem).

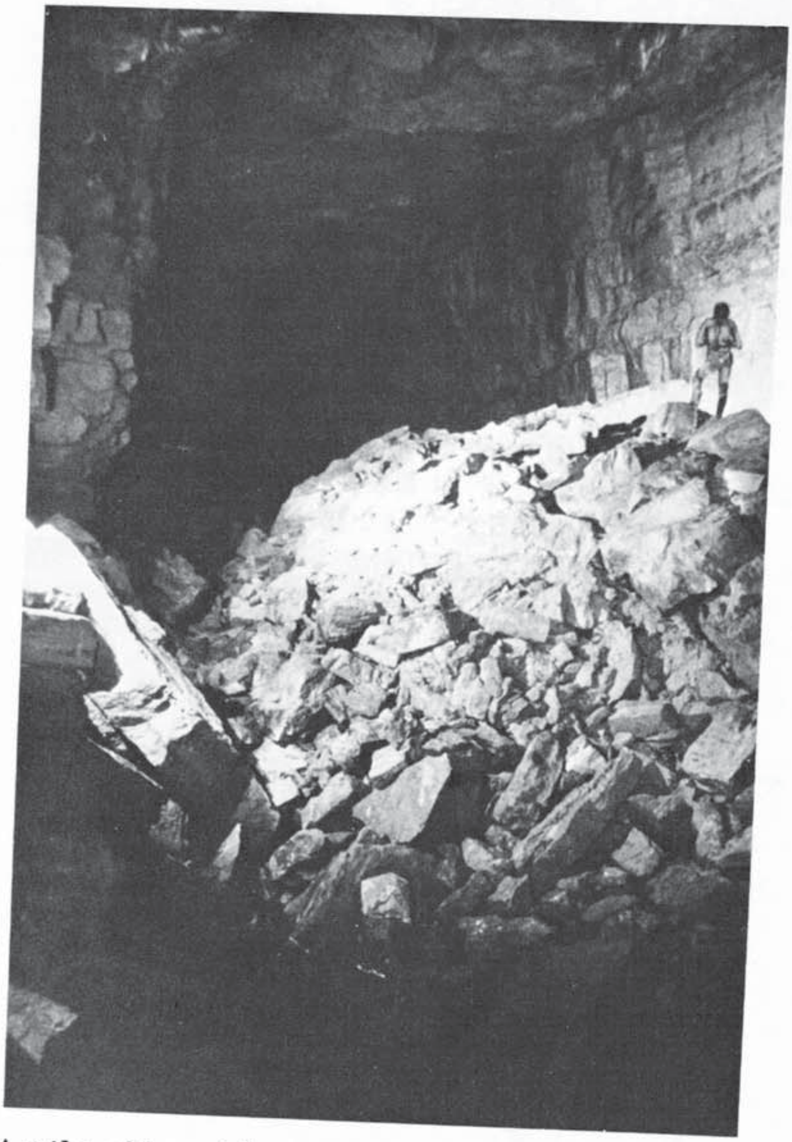


Plate 23. A pile of breakdown in the Great Hall (photo:A. Freem).

Plate 24. Camp in Bat Chamber, D Y O II. Easter 1968.

[The clear radio location link which was established between Mazeways II (Farr, Fairbairn and Roger Solari) and A2 Chamber (Coase) on 7th July 1973 suggests that such a development will prove extremely worthwhile].

A few months later (8th November 1969) Edwards and Middleton broke through a group of straws to enter a passage near Monk Hall that had been noted on an earlier trip by Coase and E. Davies. Some 90 metres of walking height passage were revealed and though ending abruptly in a tight squeeze, the passage could be seen to continue beyond and also was very draughty. On the first weekend of 1970 Coase and Judson removed the barrier by blasting and entered nearly 200 metres of narrow, twisting passages. They ultimately reached a small sandy chamber which had been discovered before the War and contained the initials of Lumbard and Weaver and the date 24.10.37. With some difficulty the link with Shower Aven and the 1937 cave was established and the second alternative route into D.Y.O.2 established. It became known as the Longer Crawl eventually, largely because it was too difficult to fit "Even Longer Bloody Crawl" onto the survey!

The following Easter Holiday again proved very productive although the weather was less clement than in 1968. Some significant dye tests were conducted by Coase and Eileen Inson at Sink y Giedd, the dye being detected in the Great North Road by members of the Leeds University Club. A party from this club led by Dave Brook and Tony White (of S.W.C.C. and U.L.S.A.) had a closer look at Pinnacle Series, which had still only been entered about three times, and found considerable extensions. (Crabtree, 1970). In the course of three trips (27th, 30th and 31st March 1970) they added something like 450 metres to the existing 350 in the series and moreover surveyed it to a very high grade.

The partial success in the easternmost of the Rottenstone Avens (Plate 25) prompted a renewed interest in its western partner and in June, Edwards and Judson made an unsuccessful attempt to scale it. With better equipment and support they succeeded on the weekend of 30/31st August 1970, reaching a strange area (Judson 1970) containing magnificent helictites and green and blue tinted aragonite and gypsum formations. Apart from the small and inaccessible passage from which the small stream enters the top of the other Aven there appear no prospects in this area which is at the top of the cavernous S2 limestones.

Since this date with the important exception of diving, few discoveries have been made although efforts have been made at digging and climbing particularly in the Far North. The potential of the fairly loose boulder choke in the Right Hand Series has received some attention from Davies, Farr and Freem among others but the greatest efforts have been focussed on safety measures and conservation. Of the former, further minor improvements have been made to the Crawl and the emergency telephone cable has been very conveniently re-routed through the Longer Crawl (not without misleading at least one "leader"!). There have also been continuing attempts to by-pass the Crawl via several short choked passages one at least of which has been proved vocally to connect with Platten Hall. (Coase 1970). Work initiated by Coase before Easter 1970 came to an abrupt end when Judson was buried by a sand and boulder fall, fortunately for only a short period on Good Friday. Work has since re-commenced on the passage, now known as Judson's Tomb, and slow progress is being made currently under the direction of Penny Tutt.

The divers however have made the greatest strides in the last six years and their account follows.

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B. The History of Diving in Dan yr Ogof

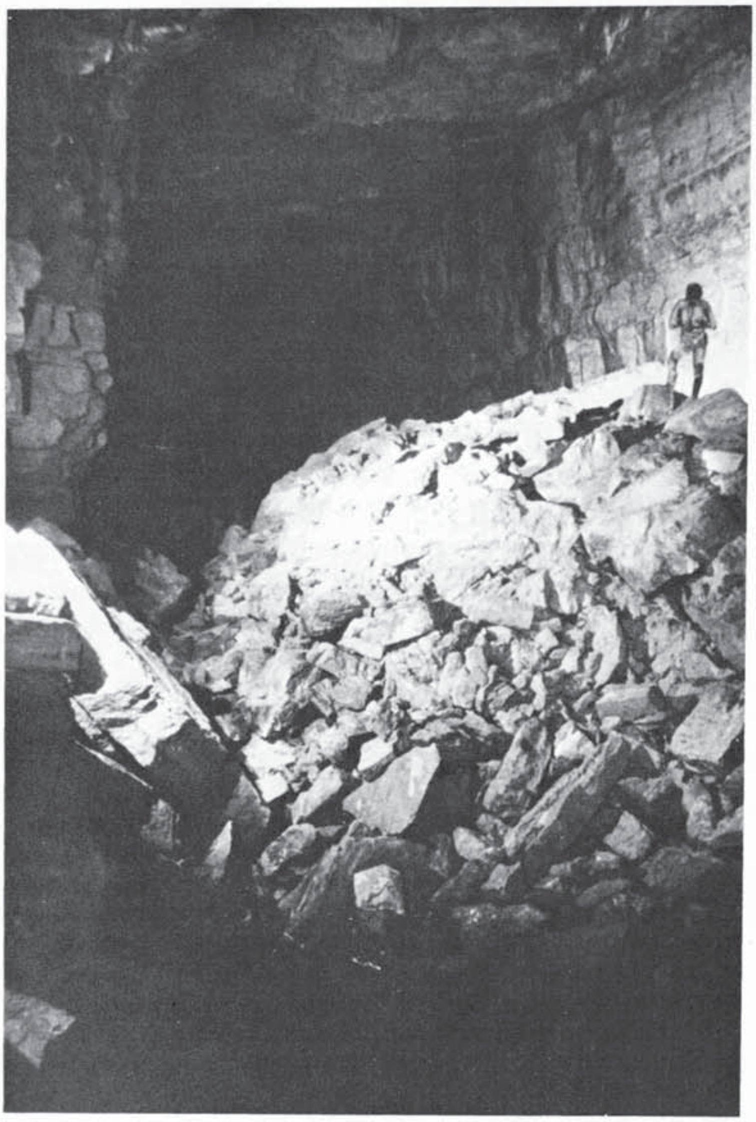
Ever since diving has been considered as a method of furthering the exploration of caves, Dan yr Ogof has presented a very formidable challenge. Bottom-walking oxygen-diving was the first step in the 1950's but it was bulky and limited in its application to a maximum depth of 30 feet. Early reviews by the Cave Diving Group record that Balcombe, Davies, Buxton, Hirst, Price and Thompson made major attempts on the resurgence and Lakes 3 and 4, on 21st/22nd March and 31st May/1st June 1953. Lake 4 was dived by Don Coase and R. Davies but it was quickly found to exceed the safe depth for exploration. However, some progress was made and a through route of about 55 metres was established between Lakes 3 and 1. This route contained a chamber with two small waterfalls entering from the roof (believed to be from Afrebag Passage) as well as an exit "leading down to the right". A further attempt was made in this area in March 1956 by Buxton, Price and Devenish but little new was discovered. Preliminary investigations were also made of the Lake by the Bridge which proved to contain a large submerged chamber upwards of 24 feet in depth.

However, the main explorations had to await a complete change of technique, to compressed air and fins. By this time, Lake 4 had been by-passed by way of the Siphon Series, which led to Lakes 6 and 5.

Lake 6 was first dived in October 1965 by C.O. George, who emerged after 12 metres into Lake 7. A further sump followed after only a few metres. A number of attempts were made by George and others in succeeding months but this sump was never passed. It became much less interesting after the major discovery of Dan yr Ogof II in April 1966.

In June 1965 O.C. Lloyd examined Pot Sump (near Black Passage), and found that a short dive led him back into Lake 3. It was to be 1967 before diving was thought of again, after the discovery of Mazeways.

Mazeways was thought to be the flood overflow channel of the mainstream and therefore a possible way into the projected Giedd System, or "D.Y.O. IV". A dry route into 'IV' was seemingly out of the question, so in June 1967 T. Moon and M. Coburn dived the terminal Right Hand Sump. Following a dive of 73m. along the left wall, they emerged at the Left Hand Sump. This loop was demoralising, but it was felt certain that the way on must lie somewhere along the other wall. During Easter 1968 Moon followed the right hand wall of the same sump for 40m. In June accompanied by C. Fairbairn clear water was reached 45m. into the sump. For this point a northward trending passage, about 4m - 5m in diameter was followed for 60m. until a leaking valve forced a return. A major onslaught was now planned. Consequently, in August 1968 Moon, Fairbairn and R.N. Arculus, diving from the Right reached "The Chamber" and found a steeply ascending passage leading off. This was followed for 45m. to an airbell; the passage again dipping and was at this point about 1m



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In June 1965 O.C. Lloyd examined Pot Sump (near Black Passage), and found that a short dive led him back into Lake 3. It was to be 1967 before diving was thought of again, after the discovery of Mazeways.

Mazeways was thought to be the flood overflow channel of the mainstream and therefore a possible way into the projected Giedd System, or "D.Y.O. IV". A dry route into 'IV' was seemingly out of the question, so in June 1967 T. Moon and M. Coburn dived the terminal Right Hand Sump. Following a dive of 73m. along the left wall, they emerged at the Left Hand Sump. This loop was demoralising, but it was felt certain that the way on must lie somewhere along the other wall. During Easter 1968 Moon followed the right hand wall of the same sump for 40m. In June accompanied by C. Fairbairn clear water was reached 45m. into the sump. For this point a northward trending passage, about 4m - 5m in diameter was followed for 60m. until a leaking valve forced a return. A major onslaught was now planned. Consequently, in August 1968 Moon, Fairbairn and R.N. Arculus, diving from the Right reached "The Chamber" and found a steeply ascending passage leading off. This was followed for 45m. to an airbell; the passage again dipping and was at this point about 1m in diameter; too small for divers with back mounted cylinders. Returning to "The Chamber", the northward trending passage was followed for 175m. to a large chamber, 15m in diameter, at a depth of about 10m. With no obvious way on the line was tied off. It was clear that there would be no easy or short dive through Mazeways. Sometime later "The Rising" was dived by Arculus, Fairbairn and R. Saunders, but apart from an airbell at 28m. little else was found. Arculus made another dive in Mazeways Right but owing to severe difficulties with the line proceeded no further than "The Chamber".

Following the 1968 activity interest declined for a while and efforts to find a dry route into IV predominated; mainly by either Hangar Passage or Dali's Delight.

By 1971 little progress had been made towards the discovery of the Giedd System, and a sudden upsurge of interest in the diving possibilities came about. On 21st August 1971, M. Farr dived in Mazeways Left for 27m. along the left wall, until a valve failure resulted in an emergency return to base. On the following weekend Moon dived Lake 10 for about 15 - 18m. Bakerloo Sump 1 was also examined and an airspace found after 7m. of smallish passage. Lake 10 was dived again on 5th September by Moon and Farr, but visibility was virtually nil and no progress was made. The divers next examined Bakerloo Sump 2; Moon finding it to end in bedding planes after only a few metres. In the search for D.Y.O. IV all sumps were to be tried, and on the following weekend Farr dived both the Upstream and Downstream sumps in Dali's Delight. Upstream the passage became impossibly tight after 1.5 - 2m. Downstream it descended rapidly in a spacious passage to a depth of 13m. from which point a horizontal tube about 1 - 1.5m. in diameter led off. This was only examined for about 8m. The depth and rapid depletion of air apparently ruled out any great hopes of an easy backdoor to the Giedd.

The following day Farr passed Lake 10 after a 27m. dive, but instead of heading due north the passage curved around and ran into the far end of Mazeways Entrance Pool. In October Lake 10 was dived again, and this time both walls were covered, to look for the mainstream rising. However, nothing was found except a small tube heading downstream. Diving again from the Mazeways end of the Entrance Pool, the stream rising was found in the south wall. A pot descended for over 7m. but was constricted at the bottom. In November the downstream sump below the Highway was dived for 11m. until it became too tight. This was to be the last chance of a backdoor to 'IV'. Following this the Rising sump was dived to the airbells along the left wall, but nothing new was found. It was thought that concentration should then be made on the Mazeways area.

On 30th December 1971 Mazeways Entrance Pool was dived; a pot 1.5m. in diameter, and about 5m. deep to boulders, being found. The only way forward was a small tube heading upstream. Unfortunately this led to Lake 10. There was thus no way of by-passing the constricted mainstream rising. The Left Hand Sump was then dived on base-fed line for 30m. to a chamber with a steeply ascending passage leading off. The Right Sump was dived in order to ascertain the direction of the lines, and the second, tied off in "The Chamber", was removed. The scene was now set for the longer dives, and on 22nd January 1972, in high water conditions, Mazeways Left was dived for 100m. Several inches of air were found near the termination and the line was belayed. The 45m. sump from Bakerloo to Lake 10 was also dived but nothing was found off either wall. On 26th February the newly discovered Mazeways Extension Sump was dived for 30m. on base fed line. This sump is static and perched about 9m. above the general water level in the area. About 1.5m. or less in diameter, it trends west and is very muddy. A further dive was made here on 25th March, penetrating for 50m. and reaching a depth of 7m. On 22nd April, 1972 Mazeways Entrance Pool rising was dived to 8m. depth, a tight squeeze precluding further progress. Bakerloo Sump 1 was then passed after a shallow 24m. dive in a restricted passage. Another sump (3) was met after 22m. (It should be noted that none of the three Bakerloo Sumps are on the Mainstream). Lake 9 "The Washing Machine" was examined by M. Ware, but the water outlet could not be found. It was surmised to lie in the southern half of the pool.

The small sump in Corbel's Chamber (D.Y.O.1) had also been dived on 25th March a distance of 10m. being achieved with airbells at 2m. and 7m. though the site was found to be tight and muddy. It was dived again on 23rd April, for 12m. to a boulder choke. Thus there now appears to be no easy route into the blank area north of Dan yr Ogof I. The sumps in both Pwll Dwfn and Tunnel Cave (Cathedral Cave) had been examined with this in view, but in neither instance was any significant ground to be gained. In the former case both C. George and later J. Parker had found the way on completely silted, while in the latter two sumps had eventually been passed (7m. and 33m. respectively), to yield over 100m. of passage. This was extended to 140m. in 1971, a substantial choke finally blocking the way.

On 24th June 1972 the downstream sump in D.Y.O. III (below Birthday Passage) was dived following the right hand wall. The aim was to follow the fault line, but this petered out after a couple of metres. Bearing left a large chamber was entered, but the reel jammed and necessitated a return. "The Rising" was then dived along the right hand wall, for 27m. and the same point reached. A through dive would therefore be about 40m.

One 22nd July Mazeways Left was dived to 110m. on a "Tadpole", and the way on found, Bakerloo Sumps 2 and 3 were dived for 9 and 12m. respectively; the whole area here is a complicated bedding zone and seems to offer little chance of any sizeable extensions.

On 30th July 1972 Mazeways Left was passed after a 128m. dive by R. Solari and M. Farr. About 300m. of passages were entered, and four more sumps encountered. The "Deep Sump" in the north of the extension was dived for 33m. at a depth of 12m. until a further deep shaft was found. The Mirky Sump, Lake 11, was also dived to a depth of 10m. in nil visibility. This is the mainstream and is constricted at depth. A large inlet issues from a sump in the south of the extension and this has been named Cribarth Inlet. Directly above Lake 11 a high level passage could be seen but not entered. The extension has been named Mazeways II.

A return was made on 12th August 1972 and entry to the high level passage gained. The Cribarth Inlet Sump was by-passed and about 60m. of streamway found before a boulder choke blocked the way on.

Near the initial climb, over 1 km. of complicated passages, on several levels, were entered. The following weekend a survey was commenced, showing that all the main passages were heading south and that all were terminated by boulder chokes. In all about a mile of passages had been entered, but not all avenues had been exhausted. Consequently it was hoped that the newly discovered sumps, in particular the Deep Sump and the mainstream Lake 11, would by-pass the chokes. 7th October 1972 therefore witnessed a strong assault on these sumps. Parker and J. Phillips achieved little success on the mainstream owing to heavily silted passages and nil visibility. Farr and Solari extended the Deep Sump to over 50 feet depth and in the course of the dive inadvertently discovered Moon's terminal belay point of 1968. The following weekend a dive from the Downstream Sump in Dali's Delight yielded a backdoor into Mazeways II by linking up with the furthest point reached in the Deep Sump. This dive is about 105m. but the depth is almost double that of the normal route from Mazeways I.

The most notable achievement at this time was however, the entry to Three O'Clock Series in July 1973. This required a semi-artificial climb of 50 feet and yielded over 220m. of high level passage. Once more, the inevitable: chokes were encountered and though no physical link was made with the Dali's Passages an important radio link was established with A2 Chamber on 7th July 1973. Work proceeded into 1974 until Solari was tragically lost on an epic dive in Agen Allwedd. A fine partnership was ended and enthusiasm waned.

Subsequent efforts in Mazeways II have yielded little. It had been hoped to establish a practical connection between Lake 4 and Lake 8 (beyond the Long Crawl), which would effectively reduce the number of porters necessary for the transport of gear to Mazeways. Dives from both Lake 7 and Lake 8 soon discounted this idea, as the route was over 50 feet deep and beset with obstacles. A complete traverse of this sump has yet to be achieved.

A dive in Lake 11 in October 1974 was likewise frustrating finding the upstream sump completely impassable. Future hopes are based therefore on digging the above-water chokes. A route from Dali's Delight or Hangar Passage in Mazeways '2' would assist progress greatly. If the draught in the latter area is anything to go by then great potential still exists.

M.F.

C. Other Caves and Digs in the Catchment Area

The other principal caves in the area are Pwll Dwfn pot, found in 1946, Sink y Giedd first entered in 1947 and the largest, Tunnel Cave, extended from less than 60 metres in 1953 to over 2 km. Of the other major efforts that at Waen Fignen Felen must still remain classified as a dig although it totals over a third of the depth of Pwll Dwfn. For the sake of clarity the main finds in each of the caves are covered in chronological order and further reference is then made to the surface digs.

Pwll Dwfn

This was first discovered by Dolphin and Low at Whitsun 1946 and sounds very much like the caver's impossible dream coming true. As they were walking along the old cart track after days of heavy rain they heard water running at the site of the present entrance even though there was no surface stream.

> "The sound was located as emerging from a small boulder-strewn hollow, but this did not excite undue interest as the ground was obviously saturated, and many shakeholes taking water.
>
> At a later date Low succeeded in forcing his way beneath a large boulder, reporting a small opening down which the traditional pebbles could be thrown, and in August 1946 we contrived to split this boulder, which then collapsed and filled the opening. We removed one portion but were unable to lift the other and no further work was done at this site until the S.W.C.C. Easter meet of 1947 when we were joined by Paddock and Lander.
>
> On Easter Monday, this party assisted by two caving widows and a small dog removed the offending boulder and Dolphin remarked 'we could spend a couple of hours digging and see how things looked then.' Prophetic, since it took just two hours of easy work to open up the entrance.
>
> The end of the system was not reached until July 5th but several visits were made in the interval, revealing a pitch for which ladders had to be made or borrowed before exploration could proceed. On these later trips we were joined by Weaver, Parkes and Harvey."

Surprisingly the pot (Plate 26) has not received much subsequent attention despite its sporting and training potential and almost literally no further finds have been made. The bottom sump has been dived, initially by Clarke and George on 25th January 1964 and more recently by John Parker but though promising, the bottom appears to be completely blocked by a choke of small boulders and sand and no progress has been made. (Clarke and George 1964). Dye tests (Plate 27) have been made and a probable connection with Dan yr Ogof established with the dye taking approximately 5 days to emerge at the Washing Machine during the 1968 camp (Coase and Hall, Easter, 1968).

Sink y Giedd

This is regarded as the principal active sink for Dan yr Ogof though this was not confirmed until Peter Harvey established the link by a dye test in 1948. Its anomalous geological position and potential are discussed elsewhere but the story of its exploration is a simple one. It was first entered in 1947 after a considerable amount of digging activity by Nixon, Harvey and others and explored to the bottom of its main pitch where several small chambers were entered. Finding that the water disappeared through narrow sand- and boulder-choked bedding planes and that possibilities for progress were very limited the project was allowed to lapse. Apart from a brief period in the 1950s it wasn't until Easter 1970 that the cave was again reopened by the O'Reilly's and Ogden (1970) (Plate 3). As well as covering the earlier ground, they surveyed the system and conducted a further dye-test which is discussed later. Subsequent work included efforts mainly by the O'Reilly's and Ogden to progress through the bedding planes and into the anticipated major passages below. Some extensions were made but not into significant new areas and this effort too was allowed to lapse. The entrance was soon blocked again and later attempts by Rowlands and others in 1975 showed blockage to be substantial.

Tunnel Cave

The existence of this small stream passage just north of the Dan yr Ogof resurgence had been known for some years when Brig. Glennie commented on the strength of draughts in the cave during some fauna collecting trips. Ashford Price had also noticed these and with the importance of draughts in the discovery of Ogof Fynnon Ddu still fresh in mind, work began on the boulder choke at the end of the stream passage late in 1953. Aslett, Clarke, Hunt, Jones, Little, Railton and Truman all played a significant part with progress becoming very promising near Christmas. Then

> "between 3 and 4 p.m. on Sunday, December 27th 1953, John Truman went up the ladder to do some careful gardening of the loose debris. After a short while he announced that he had a huge flat capstone above his head and a big flat-topped block at his side with a space about 8 inches high and 18 inches wide between them. He called to us that he was going to try to get through; a tricky operation to get from a vertical to a horizontal position in his situation without double-jointed knees. The rest of us got well out of the way, held our breath and hoped that nothing would shift – except John. After a little muffled grunting John shouted that he was through and standing up. I went next, followed by David Hunt and Edward Aslett. All I could see was a wall about 5 feet away and a flat roof about 8 feet above a floor of large jumbled blocks; in every other direction was a wall of whitish smoke, the product of our bangs. I set off at right angles to the wall and in about 15 feet found another wall. The others had swung off slightly to my left, while I swung right keeping close to the wall on my left. While I was groping along in the smoke a shout from the others indicated that the floor was sloping up to meet the roof their way and I called them to follow me. After about 100 feet I had reached a floor of mainly fine, white gravel and in the thinning smoke the passage seemed huge, as indeed it was. (Plate 28). The others soon joined me to paddle along a shallow stream meandering between flat topped mud banks about 2 feet high. We soon came to the end of the stream; it seeped out from the left hand wall. We went on up over a heap of boulders and down the other side to a stream flowing from right to left. We had reached a T junction with an even larger passage (Plate 29). Here again was a mud bank liberally adorned with fine examples of 'mud flowers' formed by drips from the high roof. All the banks have since been marked off with tape and all visitors are earnestly requested not to walk on or disturb these banks.
>
> The left hand passage soon petered out with the roof coming down close to the mud floor with just enough space for the water. Going the other way we were soon scrambling up over a mass of boulders, and at the top of these the scene changed abruptly and the way on was a relatively narrow passage, varying between 3 and 8 feet wide and in places 15 to 20 feet high. The floor was covered with small and large blocks which had fallen from the walls and progress along this section was slow, because in many places we had to climb up and crawl between blocks, jambed in the passage, and then get down to the floor again. A considerable amount of 'gardening' was done to remove many of the more insecure looking blocks. At last we found ourselves going along up near the roof with irregular fissures in the 'floor' and then we were confronted by an awkward looking 3 metre drop. Here, we called it a day; the folks outside would be worrying about us. We ought already to have been on the homeward road and some of us had headaches from the effects of the smoke. Thrilled with our discovery, it was agreed that we would continue the exploration on the following Saturday". (Railton 1956).

On that date there was quite a crowd with John Barrows, David Jenkins and Ashford Price added to the above group and the start was late because

> "we had been paying our last respects to the club's good old friend and member, Davy Price. It is to his memory that the huge passage we had broken into is named Davy Price's Hall. Most of the party followed the Steeple Aven route; in places progress was slow because of the loose poised blocks that had to be removed to make the climbs, both up and down, feasible and safe. At one place in Switchback Passage, beyond Steeple Aven, some work with a crowbar was necessary to break away part of a stalagmite barrier in order to make enough room to crawl past, and further on, a low passage had to be cleared of blocks for a few feet before we could make any progress; at Final Chamber we turned back and met two members of the party who had explored the route towards Cascade Aven until they had been stopped at the 15 foot Pot for want of a ladder. Scrambling, climbing and crawling, but always following the draught, Cascade Aven Chamber was reached. The calcite slope of the First Cascade was climbed and Balcony Passage was explored."

During the following weekends the 35 foot Pot Series and Marble Arch Passage were explored: the traverse between the 1st and 2nd Cascades of Cascade Aven was negotiated and the 2nd. Cascade was climbed; Xmas Grotto was discovered (Plate 30); the way to Whitsun Grotto was dug out and all the other easily accessible ramifications of this large cave system were discovered and explored.

During the summer of 1956 a new entrance to Davey Price's Hall was dug out: the original route being far from stable after Spring floods had undermined some of the supporting blocks. (Railton 1958). Soon afterwards an "Upit" was used by Hunt to reach a large passage 16m. up Steeple Aven although the discovery of Sisyphean Chamber was regarded as a poor reward for all the effort involved.

Cascade Aven was an obvious possibility and eventually after some valiant digging 300m of rabbit warren was entered on 28th August 1955. The Flood Rising in Davy Price's Hall also proved of interest especially as Clarke swam through what is normally the 1st Sump when a small airspace developed in drought conditions in June 1954. This led to a further 40m of 'dry' passages before the second sump was encountered but despite strenuous and ingenious baling and pumping attempts in 1955 and 1956 this was not extended until 1971 when divers succeeded in discovering 140 metres of passages ending in a further choke.

Difficulties over access from the original entrance led to use of an early radio-location device and to a great deal of hard work notably by Jones, Alexander, Clissold and Hartwell in the extensions above Cascade Aven. The object, to create an artificial entrance, was achieved and proved both survey and radio location techniques to be extremely accurate.

Apart from this development the greater part of the cave, about 2 km in all, had been almost totally explored by the end of 1955. For a long time the only find of any consequence was the relatively straightforward climb into a chimney at the end of Davy Price's Hall which in turn led into Anemone Passage.

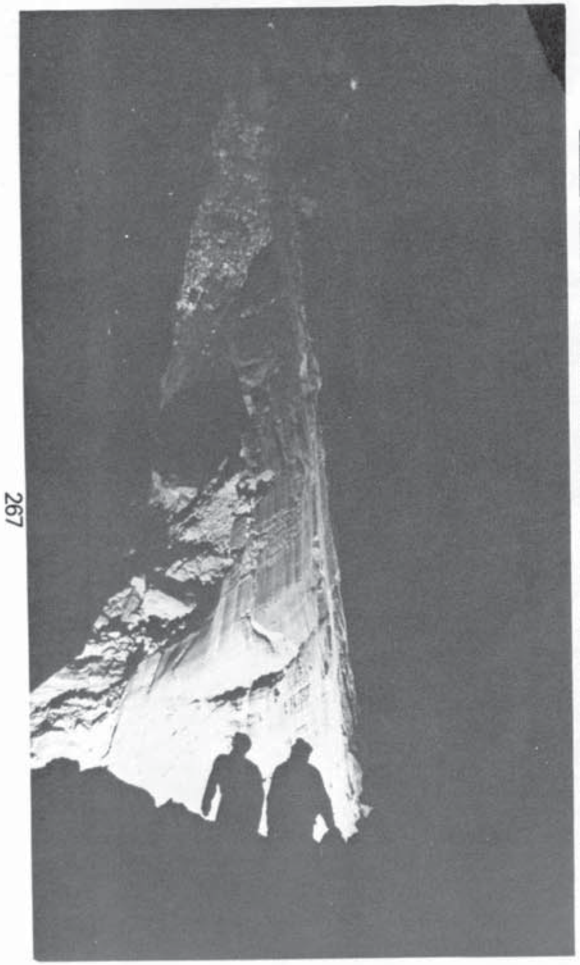


Plate 25. The most easterly of the Rottenstone Avens.

Plate 26. Eileen Davies in the entrance to Pwll Dwfn.

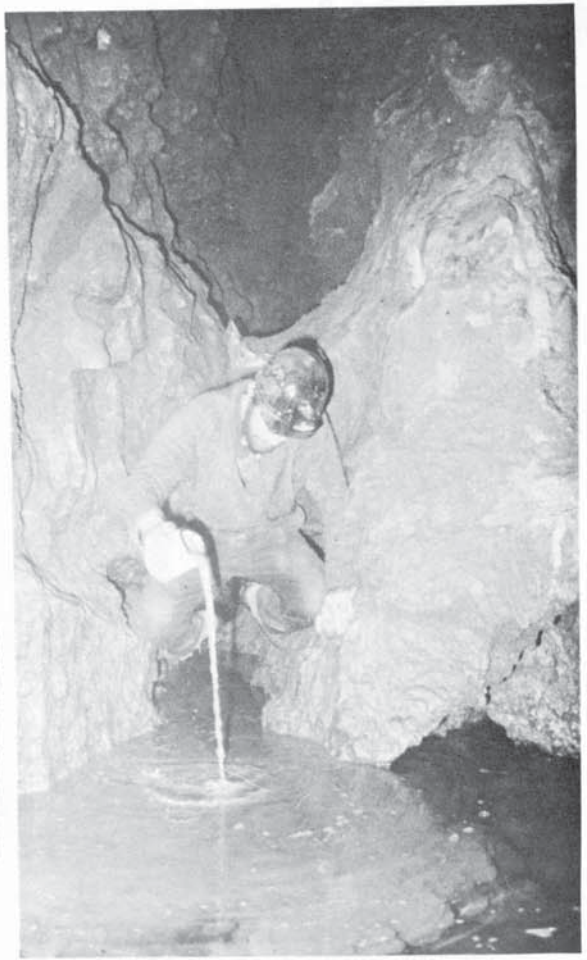


Plate 27. A dye test in the sump at the bottom of Pwll Dwfn.

Plate 28. Davy Price's Hall in Tunnel Cave (=Cathedral Cave) showing the sediment banks since destroyed (Photo: Ramsay Wood).

Plate 29. Drip fluting in Davy Price's Hall (Photo: T.D. Ford).

Plate 30. Christmas Grotto in Tunnel Cave (Photo: T.D. Ford).

Much more recently the Speleo Rhal club made a significant discovery off the 15 Foot Pot albeit initially believing that they were in Pwll Dwfn. (Haselden 1976). The discovery, named Paul and Barnabas Extension after its finders, was first entered in August 1974 though the more spectacular features were not found until May 26th 1975. The main feature of interest is probably the large collection of fine pearls in Pearl Aven but the find was also significant in geomorphological terms, confirming the existence of a fault already plotted on the Dan yr Ogof surface survey from aerial photos.

Waen Fignen Felen

Among the surface digs, pride of place is undoubtedly taken by Waen Fignen Felen. (Plate 4). The surprise is that the massive amount of effort put in here over the years has not met with any real success. The story began before the War when members of the Dragon Group regarded this as the principal, and possibly only, sink. The chief diggers were Dolphin and Paddock and one of their unpublished reports to Platten makes interesting reading.

> "We started work on Saturday, the 30th July (1938 presumably) at about 9.30 a.m. and carried on till rain stopped us at 3 p.m. The stream starts to rise appreciably about 45 mins to an hour after the onset of heavy rain and then rises very quickly; we did not measure it on this occasion. Anyway, this stopped us for that day: we were very glad to have our tent up there, to lie in for a bit before coming down and it kept the food dry, etc.
>
> Sunday was a drizzly sort of day, but we got out plenty of loose stuff and some biggish boulders.
>
> On Monday it did not rain until about 6 p.m. when we were very tired anyway and we got out a very large amount of stuff. We are now down about 20 feet and I feel sure we have no further down to go . . . With regard to the rate of rise of the stream, the following may interest you. On Thursday, 4th August, Arthur Price and I went up to get the tent down, and the ropes, etc. About half-way up, it started to thunder, and a bit further on, to rain heavily. We decided to go on and wait in the tent till it was over, there being plenty of towels and dry things there, and a stove and cocoa, etc. When we got there it had been raining very hard for about half an hour, but we were very surprised to find only a gentle stream going down the swallet (as a matter of fact, into a hole in the side of the peat). Anyway, we sat in the tent and dried, and watched the rain. After about 10-15 mins. the water suddenly rose. I timed it as best I could without a watch. In one minute it was 10ft. wide, and in about another ½ minute it was 20ft wide, and ALL THIS WATER WAS GETTING AWAY QUITE FREELY. It was going over the edge into our swallet in a stream 6ft. wide 1ft. thick, with no trace of stoppage anywhere. This of course, points to at least a man-sized hole down below, and to the danger of descent in any but fine weather without a telephone."

Dolphin's efforts were maintained through until 1948 but then interest flagged until:-

> "One Saturday night at the beginning of 1963 in the smoky beer-spilling atmosphere of the Gwyn it was decided that time was again ripe to tackle Waen Fignen Felen.
>
> On the Sunday morning a number of people were able to recall the spele of the night before and it was decided to go ahead with about ten people each contributing £2 and a week's work to the project.
>
> Work started on the Saturday of the August Bank Holiday with lots of enthusiasm. Unfortunately by this time only 12 feet of Dolphin's shaft remained and this was secured by timber shuttering. A large bucket in a tipping cradle was suspended over the shaft by a cable supported on sheer legs. At the end of the week "it was generally considered that only another 6-10 feet of digging was required to get to the valley floor and the cave. The stream which was then sinking near the dig, after a week of wet and windy weather, could be heard a little to the left of the bottom of the shaft (which) . . . wandered a little from the original one, the timbers of which were still in perfect condition. Once again "Dolphin's Folly" was a going concern . . . " (21st Anniversary Publication "By those involved").

Unfortunately again prognostications were wrong and enthusiasm waned, though Clive Jones who "was the chief digger", published theories about its formation and relationship with Dan yr Ogof and thus "stimulated a lot of back-breaking work in 1965". Many modifications were made including a new winch, and a telephone line was installed. The depth passed over 30 metres and a succession of small chambers were reached all of which infuriatingly failed to "go".

The dig effectively came to a halt after the passing of the Long Crawl the following year, but sporadic efforts have been made subsequently. With the proof of the dye tests, the proximity of the Far North and the enormous amount of shuttering that went into the dig it would be unwise to think that this part of the story is yet finished.

Other Digs

No other digs have experienced the amount of attention that Waen Fignen Felen has received and this is somewhat surprising for the area above Dan yr Ogof abounds with possibilities. Consistency of effort at some of these is almost certain to yield progress especially as we now know so much more about the geology of the area and the extent and trends of the main caves.

No review of the other digs could possibly be comprehensive, thus only the more noteworthy are mentioned. Among these are several small but active sinks which take substantial water flows in wet weather, and which are located on the other side of the Waen Fignen Felen bog. Close inspection shows there to be a marked watershed in the bog with a complex of small streams entering faulted strata on the western side. Several of these have been dug notably by Coase, G. and E. Davies and Inson in the late 1960s though Dai Hunt had a massive excavation known as the Quarry going at a dry site just to the north, in the late 1950s.

To the north, northwest of Sink y Giedd considerable efforts were made in the 1950s by Nixon, Harvey and others at Twyn Tal Draenen, an active sink containing a small stream which disappears near the entrance of the quite large sand-filled chambers. It has rarely been visited in the last 15 years and should repay further attention, especially if this includes carefully monitored dye tests in differing water conditions for the destination of its water is still unknown. Geologically and geomorphologically it is in an interesting position especially when the aerial photographs showing the marked terracing to the north of Sink y Giedd are taken into account.

Numerous efforts have been made in the dry valleys adjacent to Pwll Dwfn and one result was the discovery of a small cave adjacent to the rising, some 50 metres south of the pot. Further north, Chas. Jay and friends opened up a small entrance to enter a modest chamber with no obvious prospects and the late Edward Aslett pursued the "Gentlemans Dig", nearer to the Haffes, to a respectable depth.

Many other sites have been looked at over the years but records are sparse and few appear to have been dug consistently or with suitable equipment. Reference is made elsewhere to other promising areas and the work of the Hereford Caving Club and Mel Davies and colleagues to the west of the Giedd may prove of great significance.

D. Future Prospects

The belief that considerable extensions and new caves remain to be found in the catchment area was first voiced in the introduction and is re-echoed throughout this account. This section endeavours to point out a few of the more obvious possibilities though the history of cave exploration in this country contains numerous examples of "surprise" finds. It would also be foolish to overlook some of the better known areas, even in Dan yr Ogof One. Certainly in 'Two' or 'Three' there are many passages, squeezes, chokes and climbs that have not been really forced and very few digs beyond the Crawl have been 'professionally' tackled.

Surface endeavours have already been reviewed and it is very probable that continued efforts at the obvious sinks will be rewarded. Among other points of high potential are Twyn Tal Draenen and the relatively steep grit: limestone shoulder lying between the Pwll Dwfn Dry Valley and Castell y Giefr. Here, above the further passages of Dan yr Ogof III, in a well faulted and geologically favourable area lie a large number of dolines, several of which take considerable quantities of run-off in heavy rainfall periods. A number have been dug rather spasmodically by Coase and G. Davies and one with a narrow open shaft has recently attracted the former's attention.

The major sinks on the 'Grit further to the south also merit close scrutiny for the depressions are deep and generally occupied by large 'grit boulders. They take substantial amounts of water which is carried away much more rapidly than in the peat-filled sinks on the limestone.

Further south and just off the mapped area, are a number of smaller, very choked sinks located on an inlier of limestone adjacent to the Garth - Gwared faults. This was tackled in the 1950s with very limited success but its relationship with the Dan yr Ogof Syncline and the probable location of late ice and snow accummulations on the northern side of Cribarth make them of considerable interest.

Various caves, sinks and resurgences (notably Hospital Cave) exist on Cribarth and considerable progress may be possible in a highly contorted geological area. However the research of the past few years suggests that apart from those on the northern flanks they are unlikely to have been directly linked with the Dan yr Ogof system.

It is not possible to achieve a comprehensive review of the underground possibilities within the space available but a brief summary is attempted. Opportunities exist in many areas especially beyond the Crawl for what are likely to be minor extensions. Many side passages, chokes, crawls, climbs etc. have not been pushed to their final limits and given due regard for conservation, it may be that some of these will yield important surface or underground links (viz. the 'Even Longer Crawl'), information on stages of development or areas of fine and even unique formations. In respect of these possibilities it is clear that only a few of the high level initiatory tubes have been entered and it is also very probable that divers will establish other links in the saturated zones.

The greatest emphasis has so far been placed on attempts to achieve major breakthroughs at the end of the synclinal passages and at the furthest and highest extremes of Dan yr Ogof III. The writer and others including Farr and the other divers, have been most interested in the former and the recent history of exploration has seen an almost matching step by step progression. The divers are currently 'ahead' in Mazeways Two and it must be an early priority for both groups to establish a 'dry' link. This looks to be likeliest via A2 chamber though the chokes are massive and routes from top or bottom of Dali's Delight may prove easier. Certainly the draught at the top of the High Aven in Dali's needs to be followed as far as possible and to ease efforts in A2 the comparatively easy provision of a fixed ladder to the Abyss would save a long and awkward crawl.

Closer investigation of the chokes in Hangar Passage (including an attempt to pass over the original one on the right hand side) and in Avalanche Corner (including the choke behind and below the chimney into the Abyss) could also be extremely rewarding in the attempt to enter the Giedd series.

It would be a major oversight not to also mention under this heading, the extremely promising prospects of entry to this Series at its present source, Sink y Giedd. Efforts here have in effect been disappointing and the geological level reached is disheartening. However the main cavernous developments elsewhere in the area lie in beds estimated to be only 10-20 metres lower than the level reached. Water passes through the level reached extremely rapidly and does sink at several significant points upstream from Sink y Giedd itself. Perhaps efforts at these may be more productive.

The other main expectations lie in the further parts of Dan yr Ogof III, notably in the chokes at either limits of the Far North. That in the Left Hand Series appears massive and may require major operations but that at the furthest limit of the Right Hand Series (and a similar one associated with the fault line at the end of the Great Hall) is considerably looser and might well have been passed long since had it been nearer the entrance.

Many other possibilities exist in these areas and while some efforts have been reasonably well recorded, if only by word of mouth, others have only the evidence of sandy or muddy boot marks. From the former it seems nearly certain that most if not all of the Gritstone Avens have been scaled without yielding any open passages but there are large numbers of other inlet passages of which one at least (Pinnacle Aven) led to a very extensive and complex series.

More details of these possibilities have been given by the writer in a series of articles in the South Wales Caving Club Newsletters but one particular plea needing re-emphasis is the very real need for careful records to be kept. There are a variety of reasons for this, mostly obvious and connected with the need to avoid duplication of effort. This would be highly desirable if only on the grounds that there is so much to do in and above the system and that such duplication is time consuming and wasteful. It is also injurious to formations, deposits and the ecology of areas that might otherwise be left fairly untouched but perhaps most important is the safety aspect. It is well known that the rescue of any serious injured caver in the further parts (or indeed anywhere beyond the Crawl) is going to be an extremely prolonged and hazardous undertaking. The prospects of successful recovery are not high and thus though difficult climbs, dives and digs are inevitable, it would be foolish to hazard lives attempting what has already been proved unproductive. All groups are therefore encouraged to make the fullest report on such efforts. Future plans must co-ordinate future exploration, conservation and scientific investigation.

A.C.C.

Bibliography follows Chapter VI

Plate 31.

Crossing the First Lake by Dinghy.

Plate 32. The 1912 coracle in
a pool in the show cave.

Plate 33.

The cataracts leading to
Lake Four.

III

A DESCRIPTION OF THE MAJOR PASSAGES IN DAN YR OGOF

The Show Cave

Once behind the heavy steel door, 20 metres of man-made tunnel leads into a wide meandering tube of basically phreatic nature, 3-5 metres high and wide. The first steel door on the left marks the position of the original 1912 entrance from the River Cave below, and 25 metres beyond a steel grille with padlock marks the present day connection with the River Cave. This link is direct, with a rather tricky 4 metre climb down into the River on overhanging ledges and a tapering rift. After 250 metres the passage swings around to the right in a broad and strikingly undercut meander, revealing the Parting of the Ways. Beyond here the tourist route follows an anticlockwise direction, and cavers are asked to do likewise at all times when there are, or may be tourist parties in the cave. Up two flights of concrete steps there follows a smaller passage which must once have been very beautiful, with large gour pools spreading across its floor.

Beyond the Parting of the Ways both passages are much narrower, until the right hand passage opens out into Cauldron Chamber, with its magnificent curtain high in the roof and other stalactitic attractions, and the left hand passage opens into Bridge Chamber. The Show Cave loop is completed by a short inclined tunnel.

Show Cave to the Abyss – Main Route

Beyond the railings and gate, a flight of concrete steps leads beneath The Bridge directly to the edge of Lake One (Plate 31). The level of this Lake varies greatly with water conditions, from a small pool, passable on the left hand side with only a few centimetres of water, to a complete sump in very high water conditions. Indeed several parts of the Show Cave back to before the Parting of the Ways flood a number of times during an average Winter period. This always brings with it many tons of white sand, which has to be cleared from the Show Cave passages.

A loop on the right, from Bridge Chamber, by-passes Lake One in low to average water conditions. The passage straight ahead is a submerged link with Lake 3, and here a 1m climb to the left leads via an inclined tube, 3-5m high and 3-4m wide, into Lake Two. This is normally a shallow pool, little more than knee-deep, and separated from Lake Three by a sand bank. In high water conditions the two join, but by this stage Lake Three is likely to be impassable, or very nearly so. To the right is the water exit, and here the normal depth is 3-4 metres. The left wall should be followed until a low arch is met (about 2m wide). Airspace varies from about 1m to nil. It should not be entered, (other than for very short trips), if the airspace is less than 15cm, and if rain has fallen within the previous 24 hours. Minimum travel time of a flood pulse from Waen Fignen Felen, via the Great North Road, is thought to be in the region of 8-9 hours. Beyond the low arch it is best to cross over and follow the right hand wall, since from this point to the start of the cataracts there is a deep and sharp-edged submerged rift in the floor. Part of this can be seen in very low water conditions. The cataracts follow, with two short waist deep pools and then Lake Four (Plate 33). Here the right hand wall should be followed to climb out of the water into the rift passage beyond. After a few metres a straddle climb should be made, to gain access to the upper section of this passage which then quickly leads into the side of a much larger sandy floored passage. On the right, after a few metres, is a 6m drop into Pot Sump, (dived connexion with Lake Three), but the left hand passage should be followed. This is a partially mud filled tube and of stooping height in places; there are crawls to the left but the boulder slope should be climbed for the easier routes. At the top of the boulder pile either right or left walls can be climbed to give direct entry into Boulder Chamber. At the top of the right hand climb there is a short passage connecting with Wigmore Hall. Otherwise, a crawl through boulders straight ahead and then first right is a safer route into Boulder Chamber.

A complex higher level series runs over Boulder Chamber, but the main route on is obvious – up and to the right of a large scree slope. A number of right turns have to be made, in a stooping, semi-crawling height passage until another large chamber is entered. This is "Straw Chamber", there are fine formations here, and also in "Corbel's Chamber", which lies beyond it, but the main route is straight ahead, on across the head of the chamber and up to the left. A short length of walking height passage follows, with the telephone cable following a wide crawl on the right. After a few metres of crawling in a low arched passage littered with boulders, the roof lifts and a two metre climb gives access to "Shower Aven". The telephone cable has recently been re-routed at this point and now goes up into the roof of the Aven and follows the very tortuous "Longer Crawl" through to Crystal Pool Chamber. This route is not recommended other than for parties of midgets! Straight ahead the passage size gradually diminishes to the start of the "Long Crawl" at the Cattle Trough. A two metre climb into Spectacles Chamber marks the start of the Long Crawl proper.

Fifty metres of crawling follows, the outset being a right hand bend on a floor of sharp blasted debris. The end is marked by a three metre chimney descent, and then a short slippery chute to the head of the Gerard Platten Hall pitch, a fixed chain ladder of 6m. The latter needs particular care.

Gerard Platten Hall forms the start of the 1966 series – "Dan yr Ogof II". A small stream flows across the floor. Upstream leads quickly to a massive boulder fall, which is the foot of a 45m column of rubble at the centre of the great crater on the surface. A large passage continues downstream, with mud banks on either side. After 40m the stream falls away into a large stepped pot in the floor. This is the climb down into the Lower

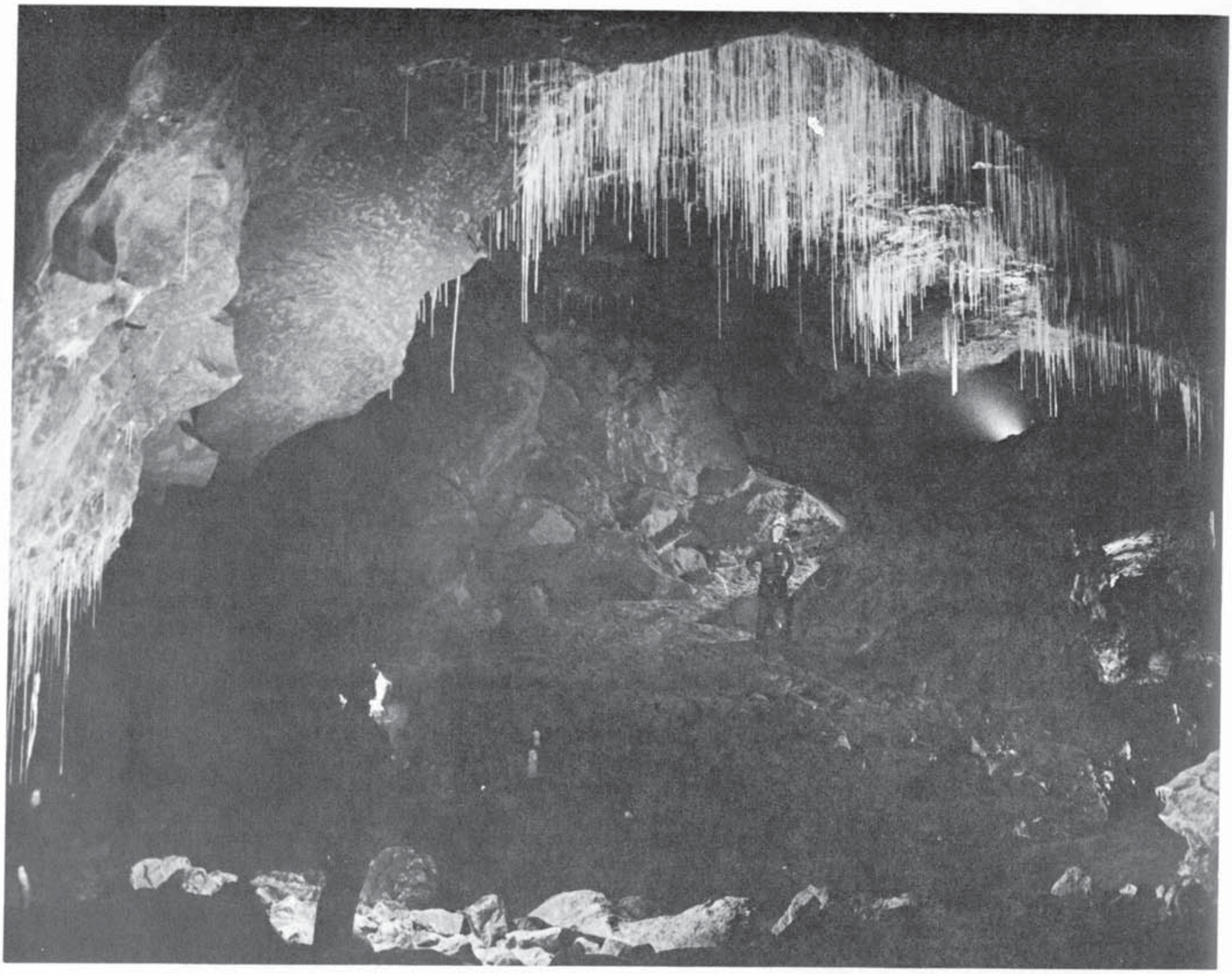


Plate 34. Cloud Chamber (photo: C. Westlake).

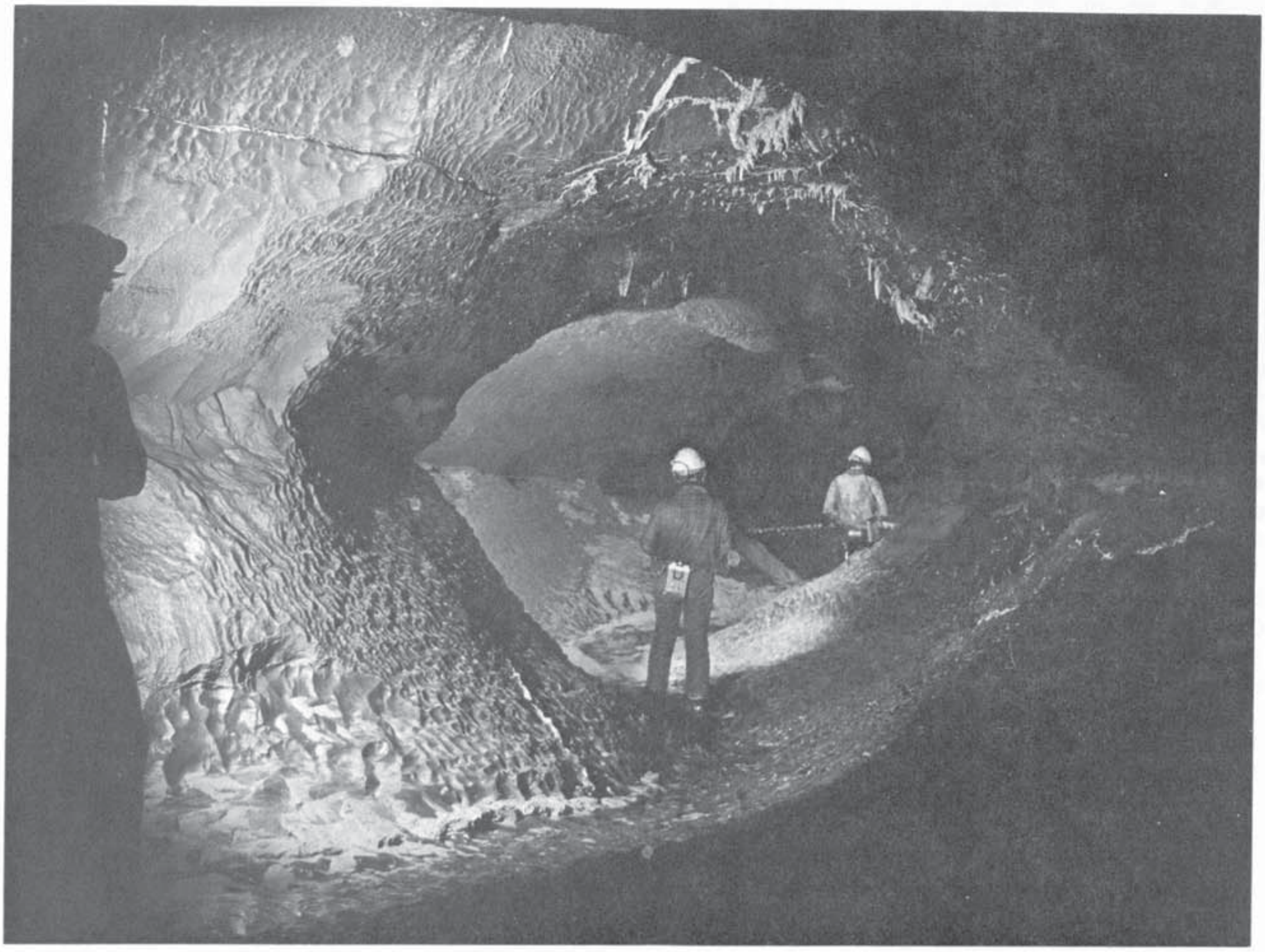


Plate 35 . The meandering Bakerloo Straight (Photo: J.Wooldridg e).

Series, (see Lower Series Loop). Just beyond an obvious arch across the passage is formed by a vein of galena and calcite. (Most of the large pieces of galena have now been removed). A few metres beyond is a beautiful crystal pool. Here the passage divides; straight ahead is Flabbergasm Oxbow, stopped abruptly after 90m by a 7m overhanging descent into the Grand Canyon beyond; to the left is the start of the Grand Canyon itself. The Oxbow contains some very fine straws and gypsum formations; care should be taken to keep to the marked paths, since there are also fine crystal pool and sand/drip formations on the floor. Grand Canyon starts out as a 3m high meandering tube, of similar size and characteristics to the earlier parts of the Show Cave. The height gradually increases through four corners to the point where the end of the Flabbergasm Oxbow enters from the right; beyond here the keyhole cross-section gradually reduces in height from 9m to 2m, but at the same time gains in width from 2m to 8m. The characteristic keyhole section gradually changes until the lower portion disappears into the floor. The character of the passage again takes a dramatic change on climbing up 2m into Monk Hall. This appears as the entry, (or re-entry), into a much larger and older cave passage altogether. Again a height, and also width, of 8 or 9m is typical both here and to the right, as the passage sweeps around to the left into Cloud Chamber – so called for its white 'cloud' of beautiful straw formations high in the roof above (Plate 34). To the left on entering Monk Hall, two large passages diverge, both ending quite quickly in boulder falls. However, a squeeze on the left, shortly before the choke in the left hand passage gives access to the start of the Longer Crawl–a tortuous route back into Dan yr Ogof I (Shower Aven).

A small stream is met with, flowing in its own small channel across the floor of Cloud Chamber. This disappears into the floor and can be followed as a tortuous route 'Fout Pots Passage' leading into the Lower Series Loop, (the Shower above the entrance to Mazeways). The passage rapidly diminishes in size and a waterfall can be heard. This is Cascade Aven, (water from Pwll-y-wydden Fawr, a major snake hole collapse feature on the surface); some of its water disappears immediately into the floor below and takes a shorter route into Thixotropic Passage in the Lower Series. At the side of the Aven, a slightly tricky 2m climb leads directly to the start of the Green Canal. On the left, above the start of the Canal is the low arch leading into the very spacious Hangar Passage. This has been extended through boulder chokes into two further larger passages, 'Hangar South' and 'Hangar North' – both ending in unstable boulder falls. The Green Canal starts out narrow and deep – about 1m wide and 2.2m deep (to soft mud of unknown depth), but widens out and becomes very gradually shallower until it can be walked at about 40m. Although it can be traversed, with some skill and a great deal of effort, it should not be regarded lightly unless you are wearing a wet suit, or are a very strong swimmer. (The Lower Series Loop provides an alternative route for non wet-suit wearers). A little beyond the end of the Green Canal, the passage suddenly opens out into the side of a much larger clean, dry passage – Trench Way – yet another change in character, the essence of Dan yr Ogof.

Going left leads quickly to the head of The Abyss – a fine, waterworn, fluted floor, abruptly curtailed in all directions by a huge black space. To the right is upstream (now a flood only water-route), leading eventually to The Rising, and Dan-yr-Ogof III. (See Green Canal to The Far North).

The Lower Series Loop

Three short free climbs, (the last one a little wet), lead from Gerard Platten Hall into the Lower Series. This is an interesting route, providing a somewhat athletic but rather drier alternative to the upper, (Green Canal), route to the Rising and beyond. It is interesting particularly on account of the variety of passage sections met with, as well as the little technical problems met with en-route.

From the foot of the final wet descent (3m), a sharp right turn, and a short muddy stooping height passage lead to a step up into the start of Virgin Passage. After a number of large gour pools a 30m long waist-deep pool has to be traversed in a walking height passage. There follows a muddy chamber with a static pool, (not always present), and a climb up a gour-fall, whereupon the incessant thrashing of the "Washing Machine" can be heard. A steep sandy descent leads to a bridge of rock forming the division between two deep pools – the left one being the Washing Machine itself, (the last upstream view of the full Dan yr Ogof river before dividing into its main Geidd and Waen Fignen Felen components) (Plate 38). This is the start of a complex zone of passages which largely flood in high water conditions. By keeping basically to the right from here, Bakerloo Straight (Plate 35) is eventually entered – a fine phreatic tube of 3 to 4 metres in diameter, notable for its clean and beautifully scalloped walls. This ends after 160m in a flooded section, Lake 10, (which can be swum in low water conditions), but the normal route is a spiral climb on the left. This leads via a mud-floored, stooping-height passage, to a small chamber which is the junction for the descent through boulders into the start of the Mazeways areas.

Stepping up and to the right in this chamber, and passing beneath a spectacular spout, (the stream from Cloud Chamber via Four Pots Passage), leads to the start of Thixotropic Passage – a pleasant, walking height muddy tube with a narrow trench between black mud-banks on either hand. Fortunately the thixotropy of the mud floor has now largely disappeared as a result of the passage of many feet. Small invading streams flow in various directions variously along different sections of this passage. Rounding a right hand bend with a shallow pool, the "Camel's Back" is met with. This is a steeply inclined ascent with a narrow slot in the floor, (passable by 'thinnies') – both routes lead into the lower, boulder strewn end of the Abyss. An awkward chimney climb on the right hand side, leads to Trenchway, and thus the completion of the Lower Series Loop.

A difficult, slippery rift climb of about 9m straight ahead from the foot of the main climb, (sometimes roped), gives access to Dali's Delight – an interesting series of muddy passages, rock mazes, crawls, high avens, and sumps (one now with a dived connexion with Mazeways 2). The deeply corroded and fluted limestones have fantastic forms which led to the name (Plate 36-37).

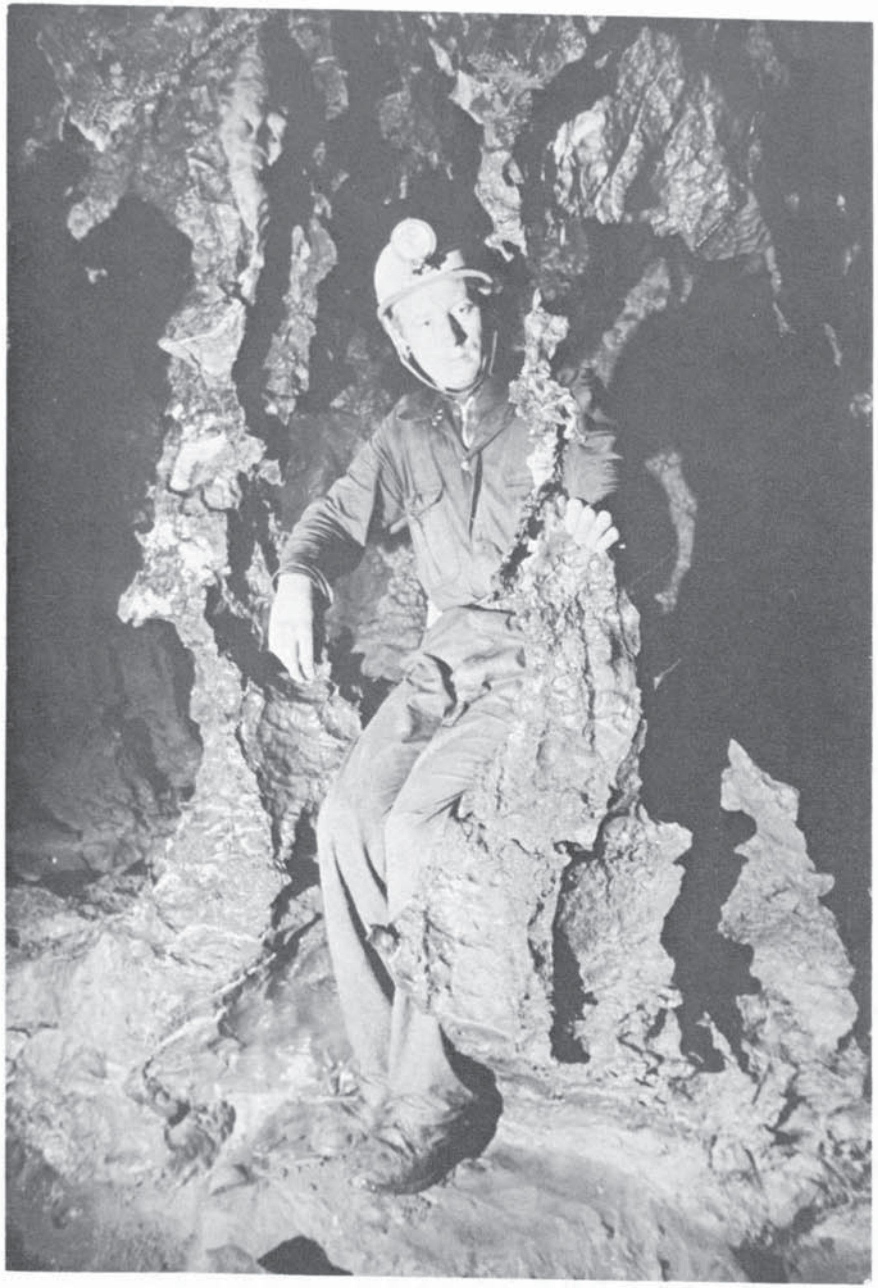


Plate 36. Corroded limestone in Dali's Delight.

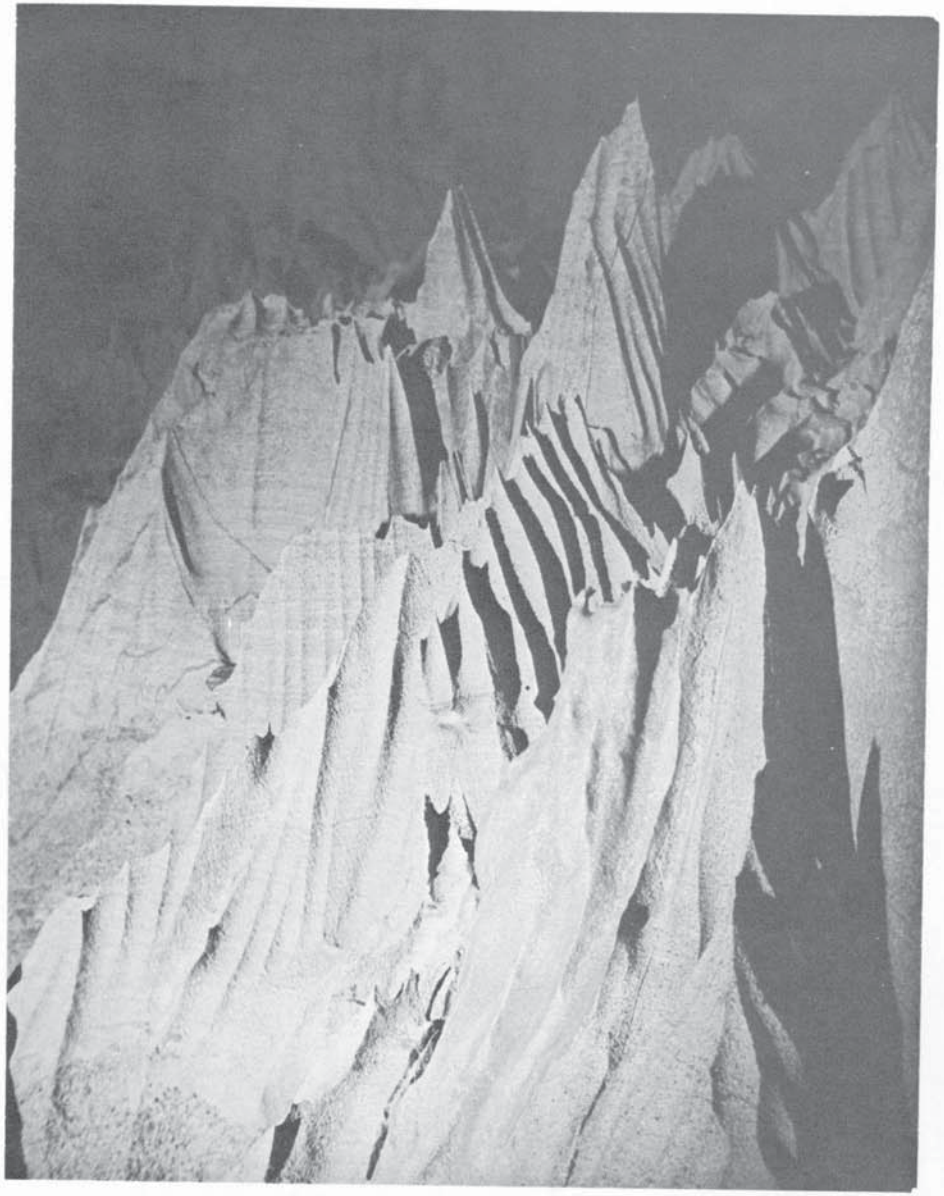


Plate 37 . Fluted karren in Dali's Delight.

Plate 38. The Washing Machine (photo: J.Wooldridge).

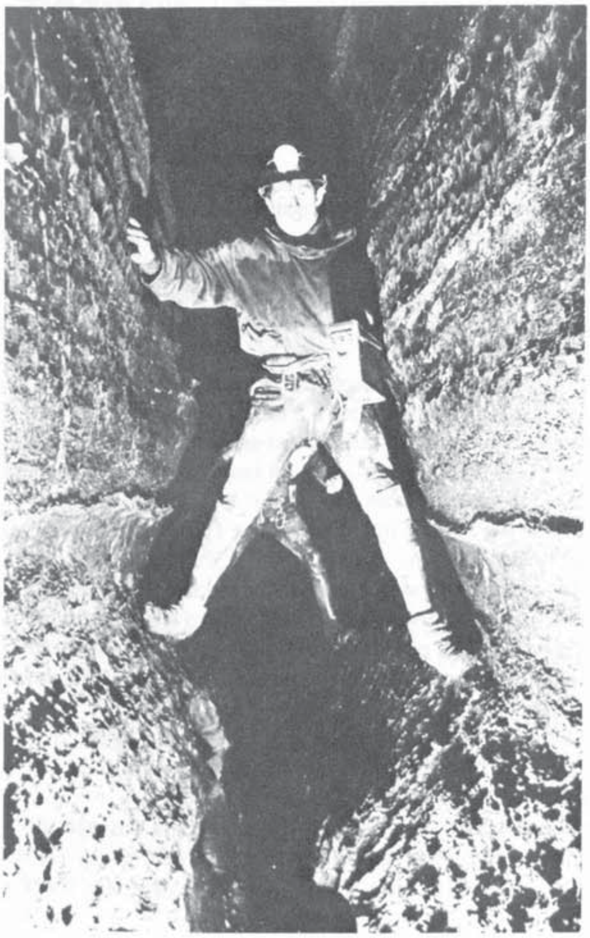


Plate 39. Go-Faster Passage.

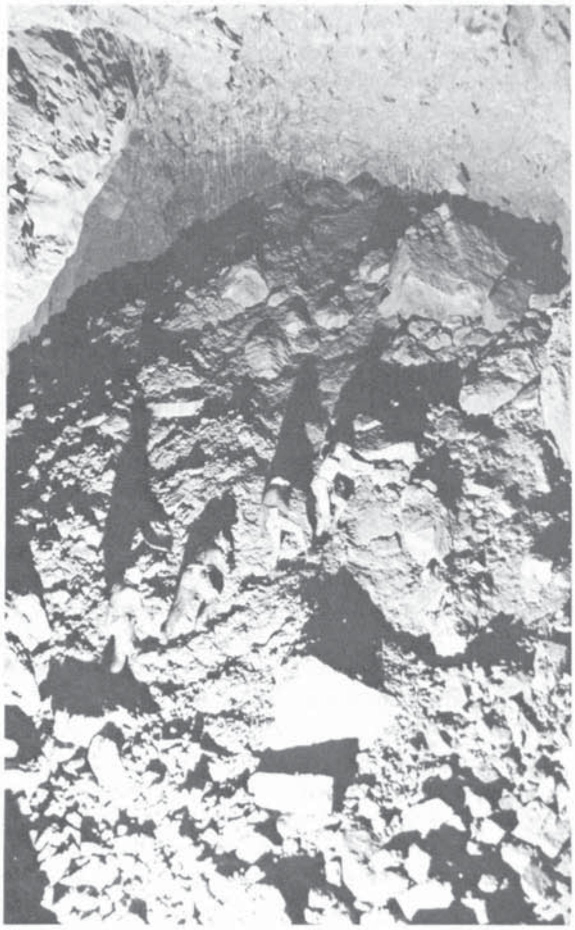


Plate 40. The choke at Avalanche Corner.

Green Canal to the Far North

From the end of the Green Canal passage, Go-Faster Passage (Plate 39) starts out with an inverted keyhole cross-section, 11m high and 5m wide, but this gradually changes to a wider and much lower tube and the slot in the floor also gradually disappears. The passage continues with sandy floor, (no stream now), to an end in "Surprise Chamber" but the route ahead lies to the right along a narrow slit just before the start of the sand-banks – "Go-Slower Passage". This starts out as a narrow traverse over a two metre deep slot, but gradually the ledges become larger and the slot disappears. After 90m the passage opens out abruptly at the foot of a huge aven, with boulders large and small. This is the Rottenstone Aven, 30m high to a large 'floorless' chamber with steeply inclined mud-banks. Descending to the same level as before, the passage continues beyond the debris, and there are three connexions with "Tunnel Two" before a shallow static canal section is entered. This ends after 25m with another slope of mud and boulders at the foot of "Bat Chamber".

From Bat Chamber the passage, "High Way", is much larger, starting out 7m wide and 15m high. After two sweeping bends, left then right, the stream is heard and then met with around the next corner, sinking amongst a large pile of boulders. It is clear from the clean-washed nature of the whole of the route from The Abyss that this passage floods regularly in varying degrees, with the stream occasionally reaching Trench Way and almost as far as the top of The Abyss. A fine stream passage follows for 70m, high and wide, but on passing beneath a fine arched flake of rock it is abruptly terminated by a sump known as "The Rising".

A 6m chain ladder now hangs down the first section of the climb over The Rising. It is followed by a free-climb rift ascent to a total height of 21m above the stream. At the top an awkward entry has to be gained into a hands and knees crawl, "Windy Way", in the overhanging face of the rift. After 40m of crawling a short drop heralds the entry into the north-south rift, and the top of a difficult climb down to the start of "Birthday Passage". This is an awkward 45° traverse, wide in places, and with deep black holes to the downstream sump, almost below. It is advisable to use a 15m rope here, especially if there are members of the party who have not done the traverse before. Birthday Passage is different again, a sand-floored rift passage with interesting blocks of fallen vein calcite on the floor, and helictites on the walls. Around a sharp double bend the stream is heard once again. This is the top of the 14m free hanging pitch which starts out as a narrow rift, but soon opens out impressively into the roof of a fine high river passage – "The Great North Road". Eye-bolts are provided for belays, but 15m of ladder and rope are required for the descent.

Downstream leads to a rapid reduction in roof height and then the sump pool. Upstream lies a long struggle over many masses of large boulders, in and out of the water, over and under the boulders. After many visits one comes to develop a favourite route, under, over, or through the various boulder piles. The Great North Road is controlled by a series of fault planes, and it persists on a bearing almost due north throughout its length. There are impressive sights where huge slabs of rock have peeled off from roof or walls, or where others are left hanging precariously in space. At 450m, (from the pitch), the stream appears from a narrow slot in the floor on the left of the passage. At this point it is expedient to follow an ascending boulder strewn ledge on the right. The stream passage, several metres below, is crossed twice on jammed blocks, and then a wide ledge followed on the right. The roof suddenly lifts, a step down followed by a short climb gives access to Pinnacle Chamber, almost at its highest point. The chamber is up to 10m wide and 20m high, formed as a collapse feature between two inclined fault planes. Two climbable avens on the right give access to two further series of passages at successively higher levels, both ending downstream with spectacular balconies overlooking the stream passage a long way below.

Beyond the tottering pinnacle of rock on the right, there is a choice of route; straight ahead through boulders – after a squeeze – leads to "The Meanders" – a superb section of undercut meandering stream passage; a climb on the left wall gives access to a higher level passage, "North Bypass", up to 6m high and 15m wide, with sandy floor and many fallen blocks. The two passages unite as a classic keyhole section, with the stream in the bottom, but the roof tube immediately meanders off to the right as the start of "The Mostest" oxbow. This is a very beautiful passage with colourful flows of calcite, gour pools and calcite flowers and crystal around a dried out pool, the latter now largely destroyed.

From the stream passage, entry to "The Mostest" is not quite so obvious as from the upper level. It is a 3m climb in a narrow slot in the right hand wall, 40m beyond the point where a large spout of water enters from near roof level. Beyond this point the stream passage takes on a rectangular cross-section and the stream is hidden for a while beneath a jumble of large fallen blocks. The two routes unite in a large chamber with several levels, complicated by masses of boulders and sand. The stream passes through at the lowest level and can be followed upstream to a very large boulder choke, (once the end of the known cave system). An intermediate level can be pursued upwards to a very large sand choke. The way ahead, however, is to the right, up two short climbs and into the base of "North Aven". This is a 17m chimney climb giving access to "Overpass Passage" – a route over the whole length of the Far North Choke, leading back down again to the stream beyond it. A broad, sandy section is met with, presumably the other end of the sand choke met with below, followed by a descent over boulders to the stream. Ten metres of traversing above the stream in a narrowing passage leads to the "Starting Gate".

At the "Starting Gate" two streams unite, the smaller from the "Right Hand Series", the larger from the "Left Hand Series". Going right, the passage soon diminishes from 5m high by 7m wide to an almost flat-out crawl. It eventually ends in a number of gritstone choked avens after 350 metres.

The "Left Hand Series" is much larger: after high avens, left and right, an almost square passage continues, (6m high, 7m wide), and beyond a sharp left turn the stream emerges from a short oxbow on the right. Beyond this, another group of four high avens are met with, "The Girtstone Avens" and beneath them there are remarkably large boulders of coarse gritstone and quartz conglomerate. Over "The Dunes" and into the "Grand Hall", the passage reaches its largest cross-section, 13m high and wide, and this is almost certainly the most spacious piece of passage in the whole of the Dan yr Ogof cave system. After a climb up a Continental scale boulder fall to the left, a further 50m of large boulder strewn passage leads to the final catastrophic boulder fall - the "Far North Choke", very much like that at Avalanche Corner (Plate 40). This is an enormous collapse which has been penetrated for considerable distances at two levels; in the stream, where it is clean washed, and at the upper level where it is a mixed mass of boulders of all sizes with a matrix of glutinous clay fill. This point is 900m almost due south of Waen Fignen Felen sink, and the stream emerges a little over 150m below the general surface level at that point.

D.M.J.

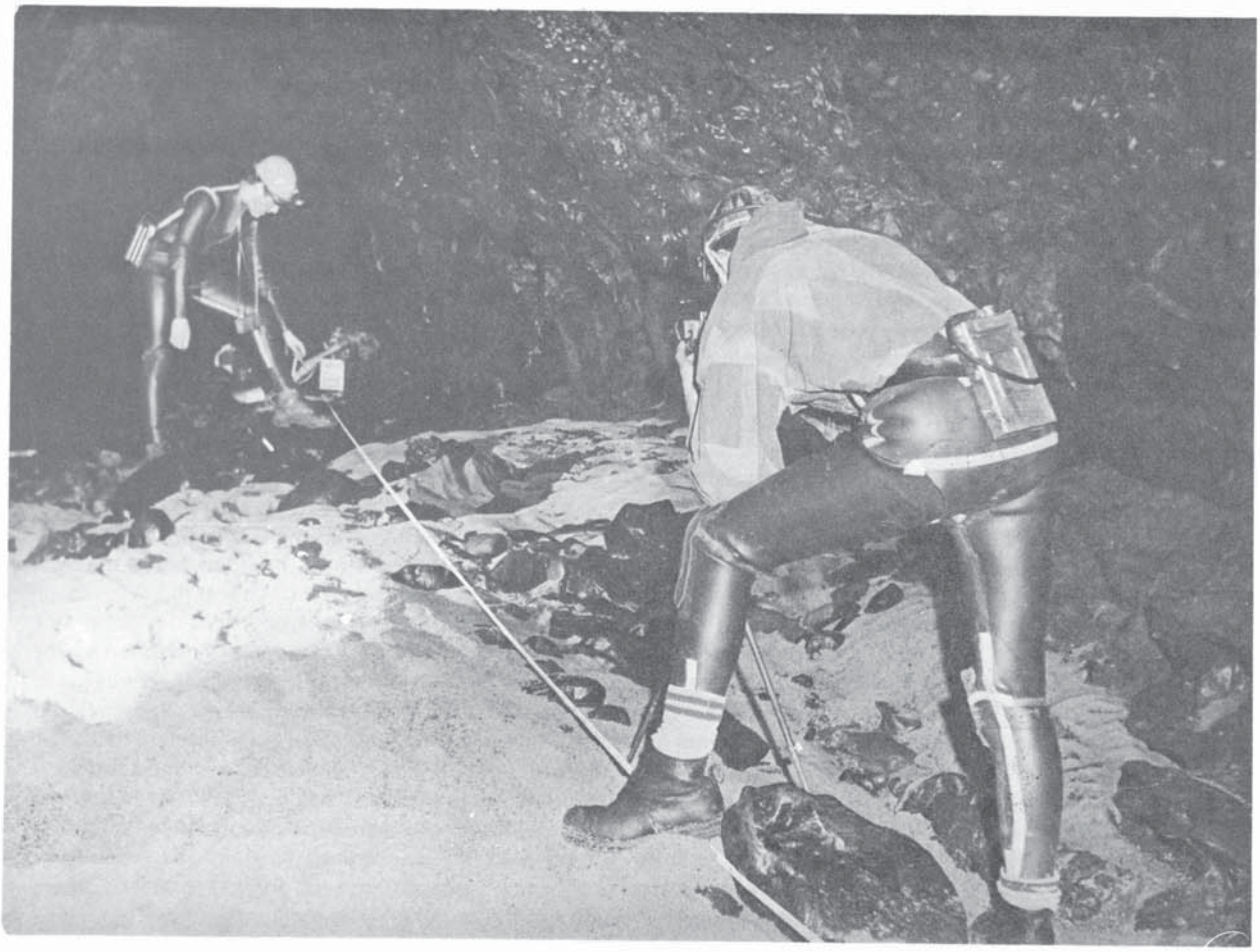


Plate 41. Surveying near the Second Lake.

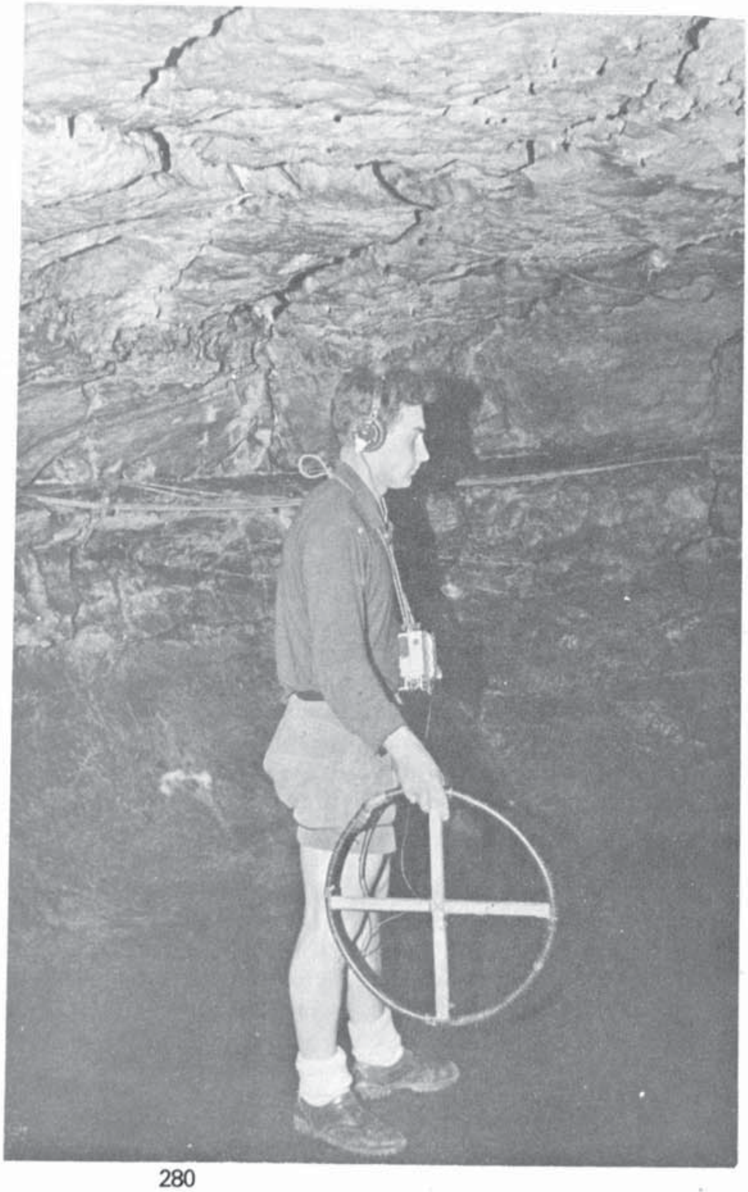


Plate 42. Testing the radio-location device in the show cave.

IV

NOTES ON THE SURVEY AND ACKNOWLEDGEMENTS

The cave survey published herewith was commenced by R. Arculus and D. Judson in August 1967. Thereafter work continued regularly so that by May 1970, all main passages had been completed. I was assited by various people, but principally they were: R. Arculus (to November 1967) D.Hume (to April 1968) M.C. Day to (August 1969) and A.C. Coase, G.Edwards, G. Davies and H.A. Lomas. Many other members and friends of the South Wales Caving Club also assisted from time to time with the laborious task and to all of them I extend my grateful thanks.

The survey commenced in Boulder Chamber and progressed inwards until The Far North was reached on 7th June 1968, (day 14). The survey was then extended outwards from Boulder Chamber as far as Bridge Chamber, (the farthest limit of the Show Cave). The Show Cave had to be treated as a special case due to the electrical wiring and various ironmongery which it contained.

The main traverses were undertaken using a type of 'survey-unit' which consisted of a liquid-filled prismatic compass (army marching type), permanently coupled to a stainless steel backed 90°–0–90° plumb-bob clinometer sighted through a 250mm long 12mm copper tube. The unit was mounted via a ball and socket head on to one of two ex-army wood and brass tripods, one 1000mm high, and the other cut down to 250mm high, for use in the smaller passages. A 3 metre hinged staff was used for sighting on to, and for taking height and cross measurements in the larger passages. A 30 metre "Fibron" tape was used for all centre line measurements. Back bearings were not normally taken. Leapfrogging was only used in difficult situations, particulary in the boulder fall areas of the Great North Road. The above equipment and methods were used for the main line from the end of the Show Cave through to Far North East and West, including the Lower Series Loop, Mazeways and the Flabbergasm Oxbow (Plate 41).

The Show Cave was surveyed by David St. Pierre using a Hilgar and Watts 20 sec. Theodolite at Easter 1973 when some important surface levelling was also completed (David St. Pierre assisted by his wife Shirley and by John Clements and Coase).

Radio-magnetic location checks were made at a number of points for both position and depth. (Plate 42). Principally these were in Painted Chamber, Pinnacle Series; Windy Way (above The Rising); and "100ft. Cascade". It is suggested therefore that these main traverses should be regarded as of BCRA Grade 6D/e. Other passages were surveyed by means of a hand held Suunto compass and clinometer, and for these BCRA Grade 5D is claimed.

The main passages were plotted manually at an enlarged scale of 1:250 and then reduced manually to a scale of 1:1000. At a later stage a computer run was carried out by E. Inson. When plotted this corresponded very precisely with the drawn out survey, so that no re-drawing was necessary. A 3% mis-closure error was found in the Green Canal – Lower Series Loop. This was distributed out using another computer program, and re-drawn accordingly.

Additional surveying by theodolite was carried out in order to 'fix' the radio location points in relation to the main features of the O.S.25 inch sheets. Most of the surface features were then plotted at the 1:2500 scale manually and variously from three sets of air photographs; RAF 1946, 1960 and 1969 (high altitude). Further information has also been added in from surface mapping, correlated to the air photo information.

The cave survey was originally drawn out by Judson in 1972. However, it was completely re-drawn by Arthur Champion in July 1974 after the discovery of Mazeways Two. The surface survey was also originally plotted and drawn by Judson during 1972 to 1974, and this was re-drawn with geological information in 1975 by Alan Coase, for the purpose of his Ph.D. thesis. It is this drawing, with minor topographical information added, that is printed herewith. The sections showing the cave in relation to the surface and the geology have been entirely plotted and presented by Coase. A detailed geological and geomorphological plan of the principal caves in the catchment area (namely Dan yr Ogof, Tunnel Cave and Pwll Dwfn) was also included in Coase's Ph.D. thesis (1975).

The Longer Crawl was surveyed in part by G. Edwards, and in part by Coase on successive weekends in November 1969. The many minor passages and side passages in Dan-yr-Ogof One and Two were all 'borrowed' from earlier surveys, principally from a detailed survey from Lake 1 to the Crawl by Coase and from that of the Show Cave by Christopher, D.B. Thomas and others (1964-6). Mazeways Two was surveyed by Martyn Farr during the diving explorations of August 1972.

Orientation was disregarded in the drawing out of the survey, the various 'sections' being fitted in between the entrance and the three main radio location fixes. Only very minor 'adjustments' had to be made, so it seems reasonable to assume that the survey is likely to be accurate to within a maximum error of about 5 metres in the horizontal plane, at any point on the surface. Vertical accuracy is much less predictable, since the accuracy of the radio location equipment is much less predictable, especially at considerable depths, viz. Pinnacle Series. Coase's sections were related to the surface on lithological and structural evidence though cognisance was also taken of the depth locations obtained by radio fixes. These fixes involved a large number of the surveyors and cavers mentioned but notably Coase, Judson and the O'Reilly's.

D.M.J.

FIG. 2. SUCCESSION OF STRATA IN THE DAN YR OGOF AREA

CARBONIFEROUS	SERIES and STAGES	SUBDIVISIONS	APPROX. THICKNESS IN METRES	APPROX. TOTAL THICKNESS IN METRES
WESTPHALIAN	Lower Coal Measures		440	440
NAMURIAN	Millstone Grit	Shale Group	90	165
		Basal Grit	75	
		UNCONFORMITY		
DINANTIAN	BRIGANTIAN	D_3 Zone	10 - 20	160 - 250
		D_2 Zone	25 - 35	
	ASBIAN	D_1 Zone	20 - 30	
	HOLKERIAN	S_2 Zone	90 -120	
		UNCONFORMITY		
	COURCEYAN	K Zone	15 - 30	
		UNCONFORMITY		
DEVONIAN	Old Red Sandstone	Grey Grits	20 - 50	375 - 515
		Plateau Beds	5 - 15	
		UNCONFORMITY		
		Brownstones	350-450	

(Dinantian Stage names after George et al. 1976).

FIG. 3. TABLE SHOWING LITHOLOGY OF THE LIMESTONE IN THE DAN YR OGOF AREA

(Based on Section X_2, Great North Road (829160)

		Approx. thickness in metres		Characteristics
	NAMURIAN			BASAL GRIT
				UNCONFORMITY
BRIGANTIAN	D_3	13		"Upper Limestone Shales". Alternating dark grey shales and sandy limestones with chert. Top beds weather into fine siliceous "Rottenstones".
BRIGANTIAN	PENWYLLT LIME-STONES D_2	26	7	Top: Medium grey crinoidal limestones with black, fine-grained cherty limestones.
			9	Middle: Dark grey and black limestones with banded and nodular chert. Bituminous.
			10	Bottom: Dark grey oolitic and fine grained cherty limestones.
ASBIAN	PENDERYN OOLITE D_1	20	18	Light grey, coarsely oolitic limestone. Massive beds, closely jointed with some false bedding and fragmented crinoids.
			2	"Honeycomb Sandstone" discontinuous, arenaceous, decalcified limestone.
HOLKERIAN	DOWLAIS LIME-STONE S_2	106	35	Top: Lighter grey oolitic limestones with some pisolites and calcareous mudstones. Stylolites common.
			71	Middle and Lower: Very dark, black or blue, fine crystalline limestone. Well bedded with thin shale partings. Some oolite. Dolomitised beds near base. Coarse grained grey-brown. Coral bed at or near base with many colonies of *Lithostrotion martini*.
				UNCONFORMITY
COURCEYAN	K	26		"Lower Limestone Shales". Massive grey-brown limestones interbedded with impure arenaceous and carbonaceous limestones.
				UNCONFORMITY
	DEVONIAN			OLD RED SANDSTONE

Vertical Scale 1:1000

V

GEOMORPHOLOGY OF THE DAN YR OGOF CATCHMENT AREA

This section reviews at some length the structure, geology and drainage of the catchment area as a background to the detailed analysis of the cave system which follows. A summary of the information is shown on Fig. 1 but is plotted in far greater detail on the large accompanying plan.

A. Introduction: Structure and Boundaries of the Catchment Area

A fairly moderate and uniform dip, generally towards the south or south-southwest, characterises all three rock types over most of the area. However, nearing the Cribarth ridge in the southeast major structural variations are encountered (Fig. 1 and Plate 1). These are associated with the folding and faulting of the Swansea Valley Disturbance and have been studied in detail recently by Weaver (1972). The variations are of very considerable importance to the geomorphology of the area and to the structure of the large part of Dan yr Ogof which occupies the shallow southwest-northeast trending syncline which appears to be the northernmost manifestation of the Cribarth folds. Although highly significant underground this syncline has not previously been recognised on the surface. Its southeastern flank is much steeper than its northern counterpart and this, coupled with the close proximity of the Garth-Gwared Splay Fault, has almost certainly acted as a barrier to more southerly development of the cave.

This fault is, in Weaver's view, a sinistral tear of some 420 metres with a nearly vertical fault plane and has a southeasterly downthrow of about 20 metres. At its nearest points to the known cave, in Mazeways One and Two and in the Hangar Extensions, there is considerable breakdown, bedding is thin and very shattered and the dip, at 17°-20°, is the steepest recorded underground. Figures have not been obtained from Mazeways Two which can only be reached by divers. However, their view is that the dip is "very steep" (Farr 1973) and their description suggests that much of this area is even more shattered and faulted than is the further parts of the Hangar Extensions. Furthermore less than 200 metres to the south of the Splay Fault lies the roughly parallel Garth-Gwared Fault and between the two a further very steep sided syncline.

The eastern boundary of the present catchment area is formed by another fault called the Henrhyd Fault. This Weaver also considers to be a sinistral tear fault although in this case the movement is a northward one of some 300 metres and the downthrow, of 30 metres near its northern limit and of 100 metres further south, is to the west. Although its nearest limit now lies several hundred metres west of the present point of debouchure for Dan yr Ogof there is a strong probability that the fault contributed to an earlier resurgence position. Certainly it provides a major interruption to the overall trend of the Disturbance and it also influences the adjoining cave system of Ogof Ffynnon Ddu (O'Reilly et al 1969).

The present northeastern boundary is just to the south of the Haffes Valley though in the past it seems almost certain that the upper parts of this river and its tributaries provided several major input streams to the cave system. This is still the case with the most northerly part of the catchment area for this reaches to the top of the sandstone dip-slope and is drained by the River Giedd and its tributaries.

To the west of the Giedd the actual boundary is much less certain though it would appear that an anticline and possibly further faulting, provides a subterranean watershed between the Giedd and the Twrch.

In the west and southwest the limestone is totally obscured by the overlying Namurian grits and shales and attempts to delimit the actual boundary of the catchment area can only be conjectural. However it will almost certainly correlate closely with the unentered parts of the cave which are provisionally termed the "Giedd series". Of these it can be positively stated that the stream covers a straight line distance of over 3,300 metres and a vertical difference of approximately 180 metres between its nearest underground sightings, at the foot of Sink y Giedd and in Mazeways Two. The results of dye-tests, knowledge of structural geology of the limestone and of the importance and occurrence of faulting in the area can be coupled with the implications of Thomas's work on inter-stratal karst (1974) to make prospects of further major discoveries highly likely.

The present catchment area as defined above forms a fairly regular rectangle measuring some 2½ kilometres by nearly 4 kilometres along its respective axes although an extension at its northern corner increases the total area to over 10 square kilometres. Somewhat under half is limestone with gritstone forming the majority of the remainder. The present small percentage of sandstone was almost certainly much larger in the past. Over nine-tenths of the whole area is covered with drift or other superficial deposits, including peat and solifluction materials.

B. Geology

The geology of the area is relatively straightforward and is summarised in Fig. 1 and shown in much fuller detail on the accompanying surface plan. The principal rock types of the area are shown in the Table, Fig. 2 and consist of sandstones, limestones and grits. With the exception of the southeast, where the folds and faults already referred to produce a complex pattern, the basic plan reveals three sub-parallel belts of strata running from northwest (or north-northwest in the case of the sandstone) to southeast where they are abruptly checked by a narrow northeasterly peninsula of basal grits and limestone.

These belts have significant scarps facing north, northeastwards or eastwards although those of both the Millstone Grit and Carboniferous Limestone areas pale into insignificance in comparison with that of the Old Red Sandstone scarp at Fan Hir. This lies just beyond the northern-most boundary of the present catchment area and is part of the impressive north facing scarp line of the Brecon Beacons – Carmarthen Fans. The sandstone dip slope dominates the northern skyline, provides at over 700 metres the highest relief in the area and in the past undoubtedly contributed much more input water to the caves than at present. The gradient is steeper than on the Carboniferous Limestone and generally consistent although the lower course of the Haffes, below Sgwd Ddu (180830), is both steep sided and deeply incised.

1. The Old Red Sandstone

This varies considerably in form and thickness with the Brownstones accounting for the greatest part. These include conglomerates, mudstones and shales as well as a very varied and colourful range of sandstones. The relatively thin exposure of the Plateau Beds contains a resistant 2 metre quartz conglomerate bed which is overlain by siltstone and sandstones. The Grey Grits also include coarse quartz conglomerates as well as sandstones.

The clearest exposures of these beds is at the base, on the northern side of the Haffes Valley for above they are masked by an extensive drift blanket. This cover also extends over much of the limestone to the south. Here, Old Red Sandstone erratics are scattered over much of the limestone pavement.

2. Carboniferous Limestone

This ranges between 208 and 520 metres above O.D., and presents a more varied landscape with an outstanding range of karstic phenomena. These include limestone pavements, dry valleys, a wide variety of dolines, (Plates 43, 44 & 45) swallow holes, caves and potholes. Most of the limestone, however, is covered by sandstone drift or extensive, though eroding, peat deposits themselves partly formed either on glacial drift or collapsed Millstone Grit (Thomas 1970). In the southeast the generally subdued relief is interrupted by the elongated and rugged ridge of Cribarth which is generally free of drift deposits and has much scree, and bare rock exposures.

In this description the 'standard Avonian' classification and terminology was initially used though Arculus (1970) introduced a classification based on the generally obvious distinctions between the Dark and Light Oolites. The Institute of Geological Sciences are currently remapping the area, and according to Thomas (1974) are also using the two-fold division, but perhaps this is unwise as the Honeycomb Sandstone is an easily recognisable horizon both on the surface and underground. The traditional classification of the Carboniferous Limestone into zones, D_1, D_2 etc. has very recently been revised in favour of "Stage" subdivisions as given in Figs. 2 & 3 (see George el al 1976 for details of this new system).

Within the catchment area of the caves the limestone is seen to vary from approximately 170 metres to over 200 in total thickness and it may be that on the further limits the total would have been greater before erosion. The accompanying Table (Fig. 3) provides a summary of the lithogical variations and these are shown on the large scale sections.

The limestone is divided into three main zones, namely the Kleistopora, the Seminula and Dibunophyllum zones with the second-named resting, in the absence of the Zaphrentis and Caninia zones unconformably on the former. The Kleistopora zone (K) itself rests on the quartzitic grits and conglomerates of the Old Red Standstone. As the cave is mostly developed within the Seminula beds, it is these which have been most closely observed and most fully described herein.

(a) K Zone (Courceyan)

The beds of the lowest zone are often referred to as the Lower Limestone Shales but this is a somewhat misleading term in the Dan yr Ogof area as the beds are quite massive and often include arenaceous and carbonaceous limestones, and conglomeratic mudstones as well as shales. Colour varies considerably, through various shades of grey and brown, and distinguishing the actual division with the Old Red Sandstone is extremely difficult. Field investigation reveals the presence of massive limestones through most of the Llynfell Falls and even below the Turbine House which is 20 metres further downstream. However, they are interbedded with shales and several of the beds are arenaceous and it is accepted that the basal beds of the S_2 zone are at or just above the head of the Falls. This would seem to be confirmed by the existence, just inside the resurgence of well defined exposures of the fossil coral Lithostrotion Martini whose beds are regarded as a significant marker for the lower part of S_2 zone. The coral bed outcrops in several significant places on the surface as well as in notable exposures in the caves of the Dan yr Ogof catchment area. These are at the far end of the Right Hand Series, Dan yr Ogof Three and at the foot of Pwll Dwfn. (Plate 46).

(b) S_2 Zone (Holkerian)

These lowest beds of the S_2 zone consist mainly of dark and very pure, fine-grained crystalline limestone, well-bedded with generally thin shale partings. The character of the rock is fairly consistent throughout the 65-80 metres of this part of the zone but the colour lightens fractionally towards the top and becomes more oolitic and sometimes quite thinly bedded. Arculus (1970) in classifying the S_2 as his "Dark Oolite" subdivision, described it as "composed of fairly well rounded ooliths of 0.1 to 1.0mm. in diameter and angular fossil fragments (including Bryozoa) all set in a recrystallised sparry matrix". A little above the shales and perhaps some 10 metres above the coral bed, though it is impossible to ascertain the consistency of this estimate in the cave, there are a series of slightly dolomitised beds. These vary in extent and thickness, are very coarse grained and are seen at their most outstanding in the Lakes where there is also much faulting. They are grey-brown in colour and much smoothed by erosion and corrasion and are likely to have had a considerable, if localised, influence on the cave.

Plate 43. Dolines and terraces
near Sink y Giedd.

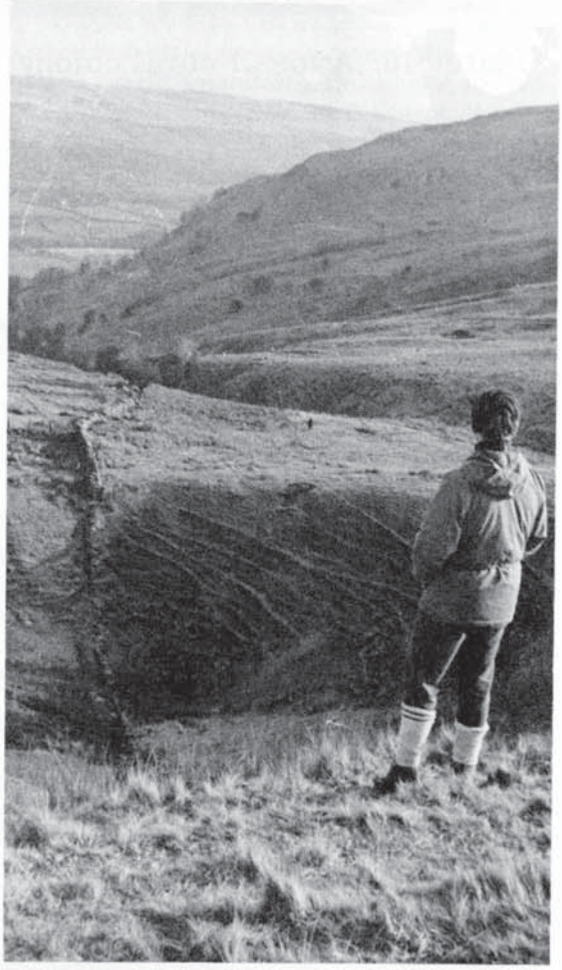


Plate 44. The Crater in the foreground
with the Dry Valley beyond and
Cribarth in the distance.

Plate 45. A limestone pavement showing
micro-jointing near Pwll Dwfn.

Plate 46. A fossil coral colony in the lowest limestones.

Plate 47. The gritsone escarpment showing sinkholes with rottenstone workings in the foreground.

Plate 48. The incised Haffes valley with the knickpoint in the middle distance.

The upper beds of the Zone are much lighter in colour and more oolitic with some pisolites. The sub division ranges between 25 metres and 35 metres and contains near, or possibly at, its base a small but speleogenetically significant sequence of shale-limestone-shale. The whole totals only a few centimetres in vertical extent but nonetheless appears to have exerted very considerable influence on the broad and flat platform at the top of the Abyss as well as in the adjoining entry to Dali's Delight and for some distance along Trenchway. It can be traced through quite extensive distances via Rottenstone Aven and High Way and a similar bed in Windy Way and the extensions above the Great North Road may relate to it.

c. The D Zone (Asbian)

The overlying Dibunophyllum Zone averages between 50 and 60 metres in total thickness and is generally divided into three sections though Arculus preferred to separate the two lower divisions from the third, the Upper Limestone Shales, and refer to them as the Light Oolite. The usual Avonian classification is retained here with the beds of the Lower Dibunophyllum Zone being separated into D_1, D_2 and D_3 subzones.

D_1 Zone

The beds of the D_1 zone total between 20 and 26 metres and justify the title Light Oolite for they are in general formed of a coarse, light grey oolite, massively bedded, closely jointed and containing some crinoidal fragments. At the base there is usually, but not always, an arenaceous limestone bed which contains a honeycomb of siliceous veinlets. This easily recognisable bed usually measures less than 1 metre and is known as the Honeycomb Sandstone. It is reached and very occasionally climbed through in the cave but more often found as rubble beneath high avens. Like the main D_1 beds above it seems insufficiently strong, structurally, to maintain any significant cave form. Nonetheless it is an invaluable marker which demarcates the Dibunophyllum zone from the Seminula.

D_2 Zone (Lower Brigantian)

The D_2 zone varies considerably within its 30-40 metre thickness with the lower half being primarily a dark grey oolite coupled with fine grained cherty limestone, the centre beds being a dark bituminous limestone with banded and nodular chert and the upper section containing a medium grey crinoidal limestone with dark, fine-grained cherty beds.

As yet the only significant cave development discovered within the D_2 subzone in the Dan yr Ogof catchment area is in the joint orientated Sink y Giedd. The 30 metre depth of this quite steeply dipping pothole displays most of the D_2 characteristics described above, including some very marked chert ledges. At the lowest point in the cave the water disappears into what, at least until now, have proved impenetrable bedding fissures, presumably the upper horizons of the D_1. If this is so, the implications are very significant for less than 25 metres below are the top-most beds of the cavernous S_2 zone.

D_3 Zone (Upper Brigantian)

The D_3 subzone is usually regarded as only a few metres in thickness although aerial photographs (Plate 44) and field plotting of the old rottenstone workings suggest that on the Black Mountain they may reach 10 metres or more, a point confirmed by Thomas (1974). The title, Upper Limestone Shales is again a generalisation for the division contains thinly bedded siliceous shales alternating with arenaceous limestones, muddy sandstones and massive dark limestones with chert. The upper few metres usually weather to provide highly siliceous materials which have been dug in the past as rottenstone. While apparently unimportant as a cavernous horizon their pock-marked appearance provides a valuable aid in locating the upper limits of the limestone.

3. Millstone Grit (Namurian)

Although also including shales the Namurian rock of greatest importance to the catchment area is the Basal Grit. This is highly quartzitic and contains several beds of coarse quartz conglomerate especially at the base. These create marked scarplets which contribute to a distinctive though barren, stepped profile. The grit is also highly jointed and at its margins with the underlying limestone a very clear opening of the joints, often associated with what appears to be a process of outward collapse and camberings frequently occurs. This may in part be due to the existence of intermediate shale beds, both in the Basal Grit and in the D_3 limestone (the "Upper Limestone Shales") but what is certain is that the exact grit: limestone boundary is generally very heavily masked by slumped and soliflucted grit boulders and scree.

This characteristic coupled with large solution depressions and collapse features is best seen along the east-facing scarp at Pwll y Wydden, below which are also some of the best exposures of old rottenstone workings. All are very clearly seen in Plate 47. The solutional depressions are understandably common on the limestone but their existence, varied size and location on the grit has led Thomas (1974) to include them as a special characteristic of what he described as "inter-stratal karst". Such dolines are particularly numerous where the grit is less than 30m. in thickness though Thomas further suggests that solution may be influential at depths of over 100 metres.

The east-facing escarpments at this point lie above parts of the cave which contain much evidence of faulting. Although this is not evident on the surface of the Millstone Grit there is a close relationship between the line of the escarpment, at a few degrees east of true north, and the line of the faults. Furthermore as other parallel faults lie a short distance to the east of the present escarpment it appears likely that a relationship exists between the fault line and the escarpment.

4. Pleistocene and Recent Deposits

The surface of the Millstone Grit is generally bare with extensive ice-worn rock platforms sometimes showing good examples of striations which are mostly orientated in a southerly or south-southwesterly direction. These, coupled with sandstone drift deposits on the limestone and extensive morainic deposits in the valley, with examples as close as in the Craig y Nos Hospital grounds, provide considerable evidence of ice movement at a relatively late period. Together with the extensive deltaic deposits of the Haffes and Llynfell, the peat deposits already mentioned and the recent alluvial deposits in the Tawe Valley, they provide an important veneer which conceals much of the solid geology.

C. Folding

In addition to the important Cribarth folds already described, that of greatest significance to speleogenesis in the area is the relatively shallow syncline which channels the direction of much of the outer part of the Dan yr Ogof system. It also provides a major influence on the orientation and form of Tunnel Cave. This syncline, hitherto unrecognised on the surface, is so important to the geomorphology of the caves that it is subsequently referred to as the Dan yr Ogof Syncline.

Its form is asymmetric with a relatively gentle dip normally between 2°-6° from the north and northwest but with dips of 12°-20° not uncommon from the southeast. The overall trend of the fold is approximately 050° between 83001535 and the resurgence at 83821500 but it is very much interrupted by the north-south faults described above and the character of the component parts is very different. These are most clearly seen in their full geological context on the structural plan of the cave contained within the Ph.D. thesis (Coase, 1975) although a reduced scale plan is included in this Transactions. (Fig. 4). From this it is clear that the individual sections are most commonly orientated between 070° and 089° with only two mirroring the overall trend at about 050°.

The location of the axis of the syncline has been plotted from the very large number of apparent dip readings taken throughout the cave and the axis of the syncline itself is shown as accurately as possible from these investigations. In most cases the location is fairly self-evident though in some sectors approximations have had to be drawn for lack of information or inaccessibility.

In the northeast, evidence from Tunnel Cave makes it clear that the syncline continues along the same trend although positive confirmation of its final orientation is impossible to find in the drift covered valley side. To the southwest the main trend of the syncline is beginning to approach the line of the Garth-Gwared Splay Fault and also to be strongly affected by the complex of closely parallel north-south faults, for this area is a zone of convergence of the two principal controlling influences.

There are a number of other minor folds within the catchment area and a few are identifiable within the caves. One within Dan yr Ogof forms a shallow syncline which appears to trend roughly north-south with a southerly plunge from the Mostest Meander initially west of, and parallel to, the northern part of the Great North Road and then east of the southern part of it. This crosses Highway at the point at which the active stream normally disappears into the lower series, and can then be traced to Trenchway, which it crosses just east of the Abyss. South of this its course is indeterminate and it may combine with or peter out at the Dan yr Ogof syncline. There is certainly no evidence of continuation beyond it, and, at the anticipated point of convergence, the structure takes the form of a broad and very shallow basin.

In general the dip into this Great North Road syncline is shallow, normally from 2°-4° though occasionally this increases to 6° or 7° from each side. The syncline is gently tilted from north to south and follows the general down-dip pattern already described. It is undoubtedly influenced by the complex north-south faulting of the area but as the majority of passages are orientated in the same direction dip readings in an east-west direction are relatively limited and detailed recording of the exact axis is therefore difficult.

Slightly to the east of this syncline, in the general area of the Green Canal, Hangar Passage and Mazeways One there appears to be another minor fold, probably a small anticline. Faulting however may contribute more to the apparent contrasts in dip orientation than folding for the area is heavily faulted and as Roberts (1966) pointed out faults could develop their own joint patterns with their dip towards the joint plane. This is also the probable cause of other obvious inconsistencies, including for example those near the beginning of the Long Crawl.

D. Faulting

Faulting in the area is far more complex than has previously been suggested. Apart from the major faults which have already been discussed and which are directly associated with the Swansea Valley Disturbance, two other main groups are distinguishable.

The first and most complex of these is a belt of six or seven sub-parallel faults running en echelon, generally between 008° and 015°. Several components of these have been identified before, by Weaver and Taylor among others, but it is considered that these have been wrongly attributed to one or two faults running in an almost due SW-NE direction. Close investigation of the surface, especially of the drift-free S_2 limestone pavements, careful examination of aerial photographs and analysis of the cave structure confirms the existence of the belt which is shown on Fig. 4. The full complexity of the belt is difficult to assess but what appears certain is that there is a series of near parallel tear, or splay, faults, mostly with a small down-throw to the east. This, to judge from evidence in the cave, is very small at the southern end, though the displacement may, in Weaver's opinion, measure up to 50 metres close to the Henryhd Fault.

FIG. 4

Plan view of the Dan yr Ogof Syncline showing cave location and surface features.

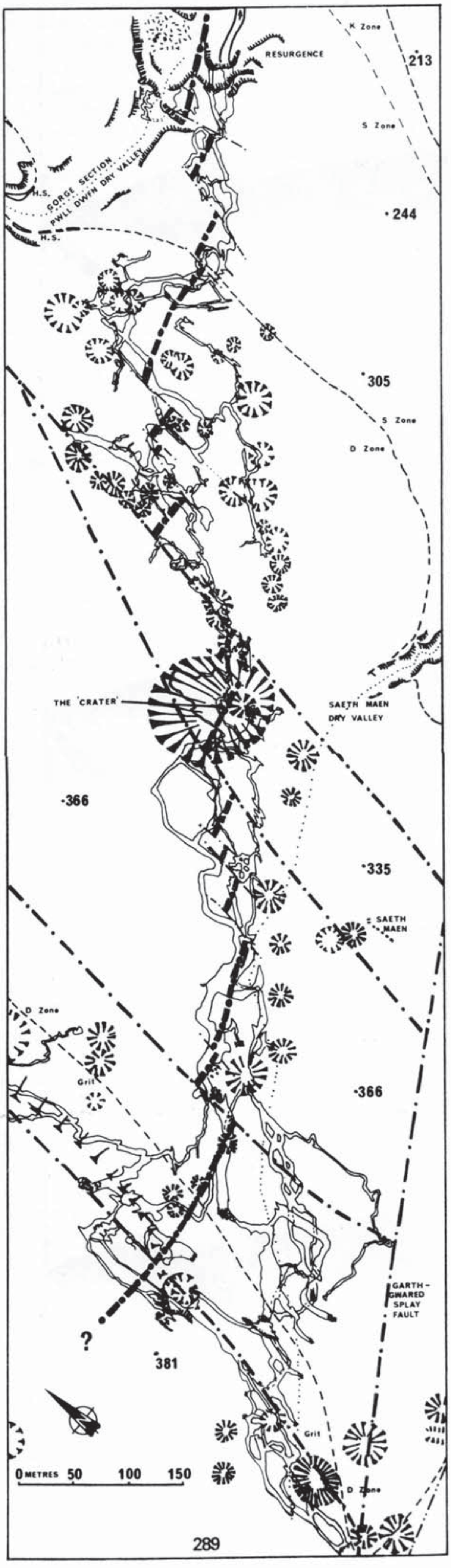
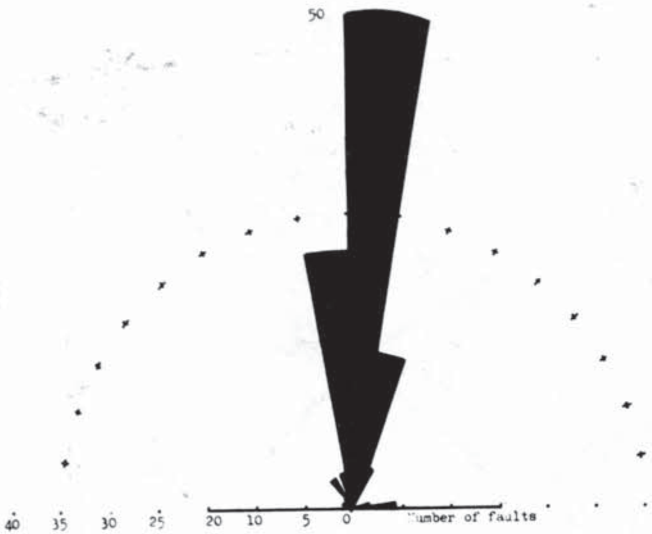
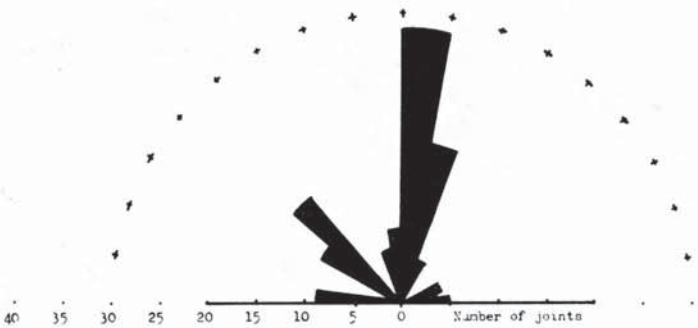


FIG. 5. Rose diagram showing orientation of faults observed in Dan yr Ogof.



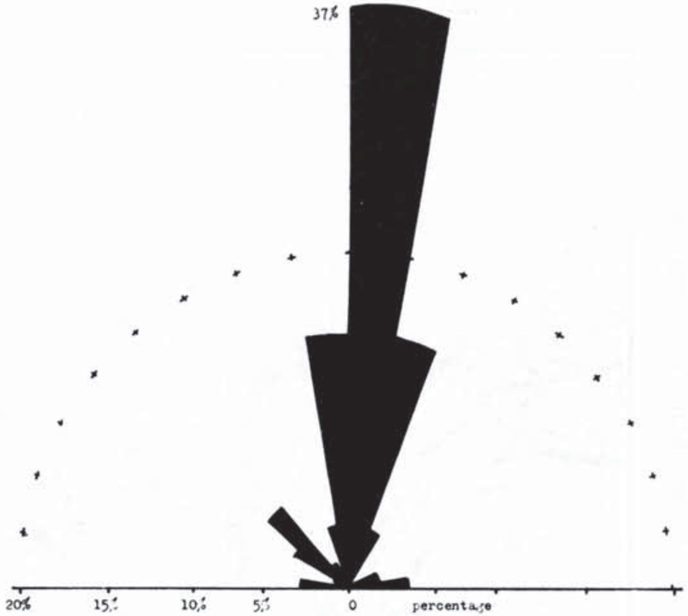
N.B. This represents the orientation of the total number of faults in Dan yr Ogof, and does not reflect their length or significance. However total recorded is 110 and this diagram almost doubles as a percentage distribution.

FIG. 6. Rose diagram showing orientation of underground joint pattern in Dan yr Ogof.



N.B. A random sample of 110 joints from all parts of Dan yr Ogof is represented.

FIG. 7. Joints and Faults in Dan yr Ogof as a Percentage distribution.



N.B. Orientation of all faults and random sample of joints on a percentage basis.

Underground over 100 separate instances of faulting have been recorded, the first major one encountered being that which crosses Gerard Platten Hall. This is mineralised and contains crystalline masses of galena weighing up to 250 grammes. The fault/vein consists of a fragmented detrital limestone cemented together with a carbonate matrix containing fairly abundant iron oxide and 1–2% very fine quartz grains. The weathered surface in the cave is coated with 0.5mm. skin of water-deposited and polished layer of iron-rich calcite which is held to account for its generally rusty-brown coloration.

The second outstanding example is that which runs for much of the length of the Great North Road but is best seen in Pinnacle Chamber (82921621). It contains spectacular slickensides although, as T.R. Owen (1967) has pointed out in discussing this fault, this may imply a very minimal throw. Certainly it is exceptionally difficult to measure any throw in this area for the walls are massive, generally 10 metres or more apart and frequently covered with calcite deposits or major sand or boulder chokes. The stretch known as Pinnacle Chamber reveals extensive horizontal grooving though Arculus has also suggested some evidence of vertical movement. Another characteristic of this fault is the very considerable vertical passage development associated with it (best seen in the sections 125-130 of the Cave Plan). Slickensides are not common elsewhere in the cave although one other good example, again reflecting mainly horizontal movement, is seen in a small fault chamber between Boulder and Straw Chambers in Dan yr Ogof One (83451574).

Other underground characteristics include extensive brecciation and shatter belts which range from less than 1 to a maximum of 5 metres in width and lie parallel or subparallel to the faults. Horizontal displacements are either minimal, ranging from a few centimetres to about a metre, or else impossible to establish. Many of the faults are well "decorated" with calcite formations in which the normally quite rare helictites are amongst the most prolific.

The abundance of faults detected underground reflects the complexity of the belt and confirms the belief that the true pattern is probably only partially delineated here. Indeed it seems probable that the main faults identified here are, particularly at the southern end in close proximity to the Garth-Gwared faults, but part of a fine network of parallel and sub-parallel fractures.

Also significant is the orientation of the faults identified in the cave for over 80% are located within the 30° sector 350°-020°. In the fault guided passages only 5 faults (10% of the total recorded) are more than 10° from True North and two of these only marginally so. In the synclinal sector however, 13 faults (i.e. over 20% of the total of 61) are outside this sector although they are fairly broadly spread. In all 92 of the 110 faults noted are within the 30° sector delineated and while there is a close, but not identical, relationship between underground faulting and the main joint set there appears to be little correlation between it and any secondary jointing. The relationship between faulting, jointing and passage orientation are discussed more fully below, but it should be emphasised that discussion of the fault orientations has been concerned solely with number rather than significance or extent of faults.

The second of the groups of faults lies to the west of the extensive Waen Fignen Felen peat bog. It would seem to consist of 4-5 faults in two groupings, though these are less positively identified than the first group for underground evidence is absent, only limited and somewhat negative information can be obtained from the Millstone Grit outcrops and almost all of the limestone is drift or peat covered.

The eastern-most group consists of two extensive faults which are virtually parallel although more curved. On the limestone they trend mainly along 010° with a swing to about 170° at their southern limits in the Millstone Grit. Weaver and Thomas both recognised the existence of the nothern part of the fault running through the western side of the huge peat bog at Waen Fignen Felen but Weaver suggested that it then trended more to the southwest. Thomas, on the other hand, traced the fault almost due south to and through the Millstone Grit boundary and thence in a sinuous curve slightly east of south. Ultimately it is lost just north of the drift and peat deposits adjacent to the Garth-Gwared Splay Fault. Williams (1960), also refers to a fault in this area although his reference, while very precise concerning the downthrow is equally vague about the location. He refers to "a fault having 70 foot easterly downthrow (which) occurs between Castell y Giefr and Carreg Goch". Aerial photographs and surface plotting support these views and also suggest that the fault which Weaver took to be part of this Waen Fignen Felen one is in fact a separate and parallel one. Evidence for this and further splay faults, is found in the very abrupt east facing scarp of Disgwlfa and the wide drift filled trough or valley to the south. Surface plotting is very tentative here and it is possible that the limestone may extend further to the south.

The westernmost faults of the second group are those associated with the river sink at Sink y Giedd. They were plotted and shown on the 1927 Geology Survey Map and suggest the form of a minor rift valley, a feature which was confirmed by Thomas (1954a). Underground evidence is relatively sparse in this sector particularly as the known cave is at present of limited extent and appears to be joint rather than fault orientated.

The rose-diagram (Fig. 5) summarises the information about the fault orientations recorded in the cave extremely succintly. Over 80% of the recorded faults are seen to lie within the northernmost sectors (350° - 019°) although they are almost equally distributed geographically, within the joint-aligned and synclinally controlled passages. This implies that a greater variety of structural influences affect the latter unit though in both cases the orientation of the faults within a narrow north-south belt is the most distinctive feature.

E. Jointing

Jointing in the area is well defined and relatively consistent between the main rock types and the subdivisions within the limestone. The surface jointing has been analysed closely by Weaver and Taylor in recent years and though their results do not exactly coincide the differences are relatively insignificant. The total picture that emerges is of one major set slightly east of north and another closely related to 090°-270° (Fig. 6).

Both correlate closely with the underground joint pattern, recorded by the writer entirely in beds of the S_2 zone. One significant difference however is that the underground findings also reveal a third set of some importance at 300°-310°. This is most marked in the joint controlled areas but it is also recorded in the synclinally directed ones. Surprisingly the reverse is true in regard to the other main sets, for there are a greater number of recorded joints relating to the north joint set in the synclinal areas than there are in the joint guided area and vice versa for the east-west set.

While there is clearly a close and not unexpected relationship between surface and underground jointing too much should not be read into these observations for although several hundred underground joint readings have been taken, far more, both random and selected, would have to be taken before major conclusions could be reached. Weaver (1973) in his analysis of the relationships between jointing and cave passage frequency also claimed that jointing remained consistent though his further observations about the relationship between the joints and the cave passages do invite criticism.

A close relationship is also detectable between joints and faults in the cave and particularly on the basis of work by Roberts (1966) in the Neath Valley it appears realistic to consider faults and the main joint set as being genetically related. Thus they have been plotted as a unit in Fig. 7 the main effect being a significant re-inforcement of the main north-south trend and a much smaller contribution to the easterly one.

Roberts also pointed out the facility for faults, in the limestone of this area to develop their "own" joint patterns which are usually parallel to the strike and dip towards the fault plane. These, it is suggested, are partly responsible for the breakdown and shattering in the passages located close to the more important faults. This would include the areas of characteristically thin bedding, multiple fracturing and breakdown apparent in chambers adjacent to the Garth Gwared Splay Fault and to the Platten Hall/Shower Aven faults.

Also of importance is the existence of well developed joint planes in the limestone. These are fairly common in most parts of the S_2 zone and in some cases, notably in the Pinnacle Series Extensions above the Great North Road, they are hard to distinguish from faults. They exist elsewhere in the cave with the varied tubes and rifts of Tunnel Two (Far Series, Dan yr Ogof Two) providing a good example. The 30 metres or so of vertical rift passages in the cave at Sink y Giedd also appear to be developed at a major joint plane, although in this example they are within limestones of the D_2 zone.

Calcareous mineral veins and tension gashes are also common within the limestone showing up particularly well within the black crystalline limestones of the lower parts of the S_2 zone. They parallel the main fault and joint trends and occasionally show some evidence of displacement themselves. One obvious and readily accessible example is found just a few yards on the entrance side of the Parting of the Ways in the Show Cave, and is of particular interest as adjacent to it is the only example of colonial coral known at this level.

F. Drainage: Surface Pattern

The present pattern of the area is shown in Fig. 1 and more detailed information about the actual catchment area is conveyed by Plan A. It results in part from a series of comparatively recent but complex changes in base level related particularly to the transgressions and regressions of the Pleistocene period. These have been studied in detail by Brown (1960), Bowen (1970) and by John and Ellis-Gruffydd (1970), though the general conclusion reached was best expressed by Synge (1970) in that "no complete agreement" is possible in the light of present knowledge. Indeed this lack of agreement extends backs to numerous theories on South Wales drainage evolution which have been postulated by such eminent workers as Strahan, Lake, O.T. Jones, Linton, R.O. Jones and T.N. George. Notwithstanding such disagreements and the controversy concerning the existence or otherwise of erosional platforms, there is general agreement that the successive falls in base level in the Pleistocene caused, in Brown's words, "waves of back-cutting to be transmitted up the rivers" and that "river capture was more common than at any other time". Thomas commented in 1959 that "every tributary of the Tawe shows definite evidence of rejuvenation before entering the main valley". While this would have been partly due, in the Upper Tawe Valley, to the rapid erosion of the Tawe along the line of the Cribarth Disturbance there is no doubt that glacial over-deepening of the main valley was also a major factor. A tentative attempt at a denudation chronology is made in a later section, but first a description of the most relevant developments is considered.

The key river in the pattern is of course the Tawe which has acted as the base level for the catchment area since its inception. Much has been written about its evolution and its possible link with rivers to the southeast such as the Pyrddin and Cynon (Jones R.O. 1939 and Williams 1969) and there is a great deal of evidence existing to support such theories, notably in the form of windgaps, beheaded streams and elbows of capture. However, the stage at which the Tawe became of major significance to the catchment area under scrutiny is when it began to exploit or adapt to the Cribarth shatter belt. This adaptation in Brown's view dates "almost entirely since Low Peneplain times", which places it early in the Pleistocene period, when local relief is identified as being between 214 and 335 metres. This appears to correlate with the present 220 metres resurgence level and possibly also with the existence of pronounced, although limited benches at about 335 metres. In short it is considered highly probable that the development of the Dan yr Ogof subterranean drainage pattern is related to the Tawe valley in approximately its present location and not to a period when it was flowing on a markedly different course or at a considerably higher level.

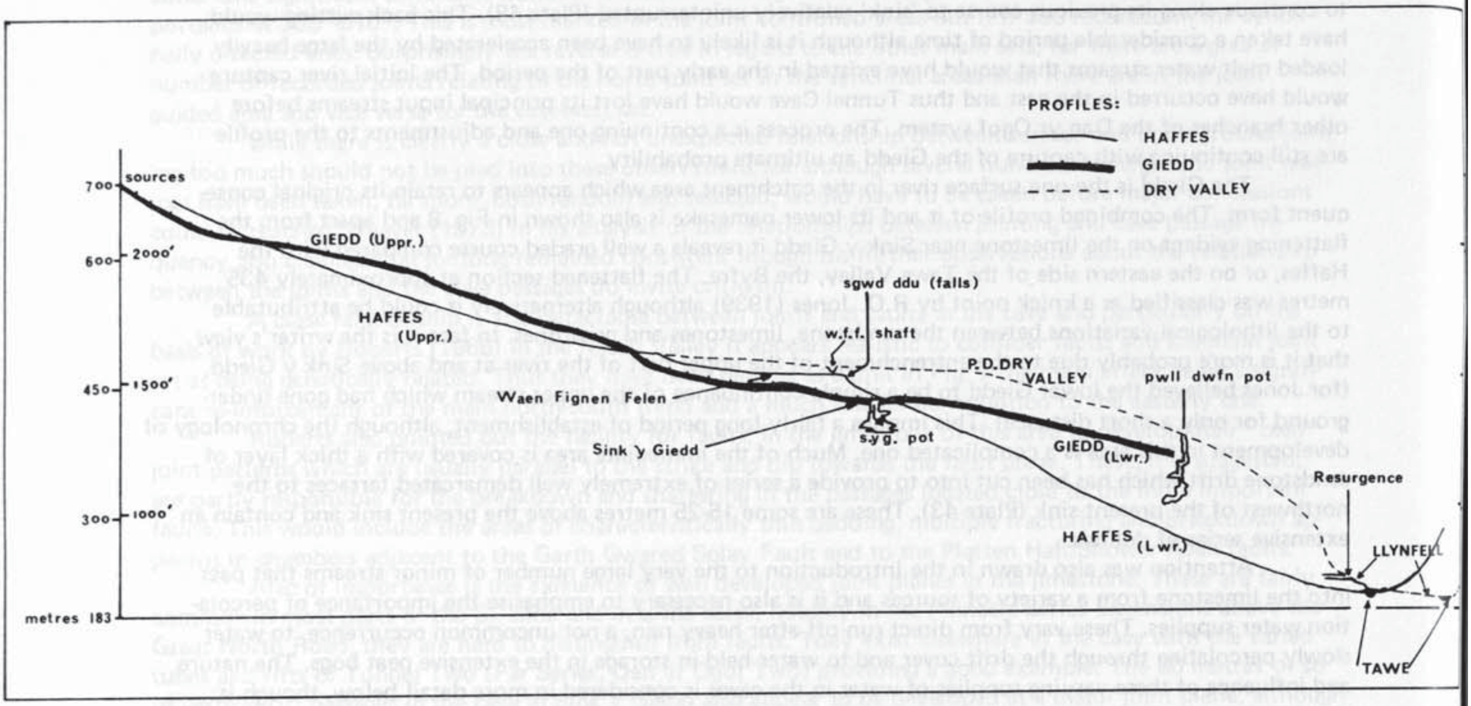
The other principal stream involved was the Haffes, although significant captures and diversions resulting from rejuvenation also took place elsewhere. The present course of the lower Haffes, (Plate 48), whose longitudinal profile is shown in Fig. 8, undoubtedly owes much to the over deepening of the Tawe Valley. Prior to that occurrence, which must have been an extended and discontinuous process, little evidence exists for any significant strike oriented stream. The present pattern shows that the Haffes has cut back intensively to capture virtually all of the consequents which now form its north bank tributaries, leaving only the Giedd to continue along its previous course to 'sink' relatively uninterrupted (Plate 48). This back cutting would have taken a considerable period of time although it is likely to have been accelerated by the large heavily loaded melt water streams that would have existed in the early part of the period. The initial river capture would have occurred in the east and thus Tunnel Cave would have lost its principal input streams before other branches of the Dan yr Ogof system. The process is a continuing one and adjustments to the profile are still continuing with capture of the Giedd an ultimate probability.

The Giedd is the one surface river in the catchment area which appears to retain its original consequent form. The combined profile of it and its lower namesake is also shown in Fig. 8 and apart from the flattening evident on the limestone near Sink y Giedd it reveals a well graded course compared with the Haffes, or on the eastern side of the Tawe Valley, the Byfre. The flattened section at approximately 435 metres was classified as a knick point by R.O. Jones (1939) although alternatively it could be attributable to the lithological variations between the sandstone, limestones and gritstones. In fact it is the writer's view that it is more probably due to the entrenchment of the upper part of the river at and above Sink y Giedd, (for Jones believed the lower Giedd to be a simple continuance of the upper stream which had gone underground for only a short distance). This implies a fairly long period of establishment, although the chronology of development in this area is a complicated one. Much of the immediate area is covered with a thick layer of sandstone drift which has been cut into to provide a series of extremely well demarcated terraces to the northwest of the present sink (Plate 43). These are some 15-25 metres above the present sink and contain an extensive series of dolines.

Attention was also drawn in the Introduction to the very large number of minor streams that pass into the limestone from a variety of sources and it is also necessary to emphasise the importance of percolation water supplies. These vary from direct run-off after heavy rain, a not uncommon occurrence, to water slowly percolating through the drift cover and to water held in storage in the extensive peat bogs. The nature and influence of these varying supplies of water in the caves is considered in more detail below, though it should be emphasised that they flow over a wide variety of siliceous material much of which, as Newson pointed out (1970), "is already weathered and easily transportable during flood".

Bibliography follows Chapter VI

Fig. 8.



Longitudinal profiles of principal rivers and valleys associated with the catchment area.

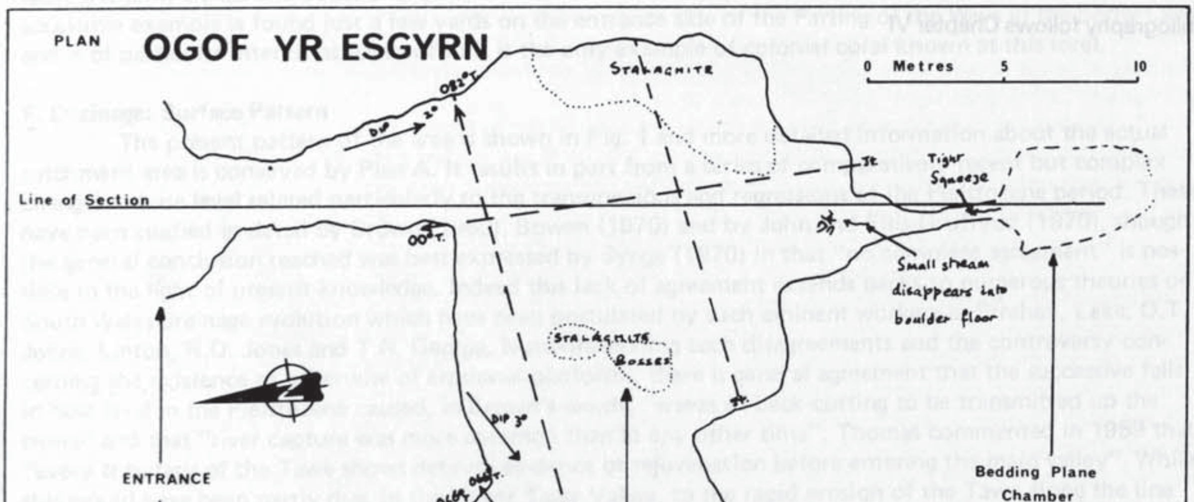


Fig. 10. Plan and section of Ogof yr Esgyrn (based on Mason, 1968).

VI

THE CAVE SYSTEM

This chapter should be used in conjunction with the short descriptive account of the cave given above, and is intended to provide a fuller analysis of the cave in structural, geological and hydrological terms. Attempts are also made to relate surface and cave features; to describe in very general terms the varied sediments found within it and to postulate a theory of evolution and development.

A. Structure

The structure of the caves within the catchment area is strongly influenced by their geological environment which has already been described in detail. Faulting, jointing and folding are of especial significance though the importance of dip and strike, and lithology must not be overlooked. All of these factors have influenced the initiation and development of the caves, although the relative importance of each varies in different parts of the system.

Detailed investigation shows the known caves to be mainly located within limestones of the S_2 zone. In Dan yr Ogof the lowest passages appear to be closely related to the Lower Limestone Shales (K zone) while the highest occasionally reach and once or twice even breach the lowest beds of the D_1 zone. However the majority of them are located within the middle and lower beds of the S_2 zone. Pwll Dwfn is seen to extend almost through the full vertical extent of the S_2 zone, but Tunnel Cave is limited mainly to the middle beds of the zone. Only Ogof Sink y Giedd is known to show cave passage development within beds of the Dibunophyllum zone. (O'Reilly et al. 1970).

The accompanying sections relate the caves to both surface and lithology and are based on both positive and inferred information. In the former case they are drawn from the certain knowledge of several marker horizons and positive surface locations and in the latter from information derived from aerial photographs, surface and underground dip readings etc. However the complexity of faulting and the extent of superficial deposits in the area must cast some doubt on the accuracy of specific areas especially when well away from established marker beds. With this in mind it is realistic to suggest that the average total thickness of the beds in the S_2 zone is between 100 and 120 metres although close to the synclinal axis this is reduced to about 95 metres.

a) Dan yr Ogof

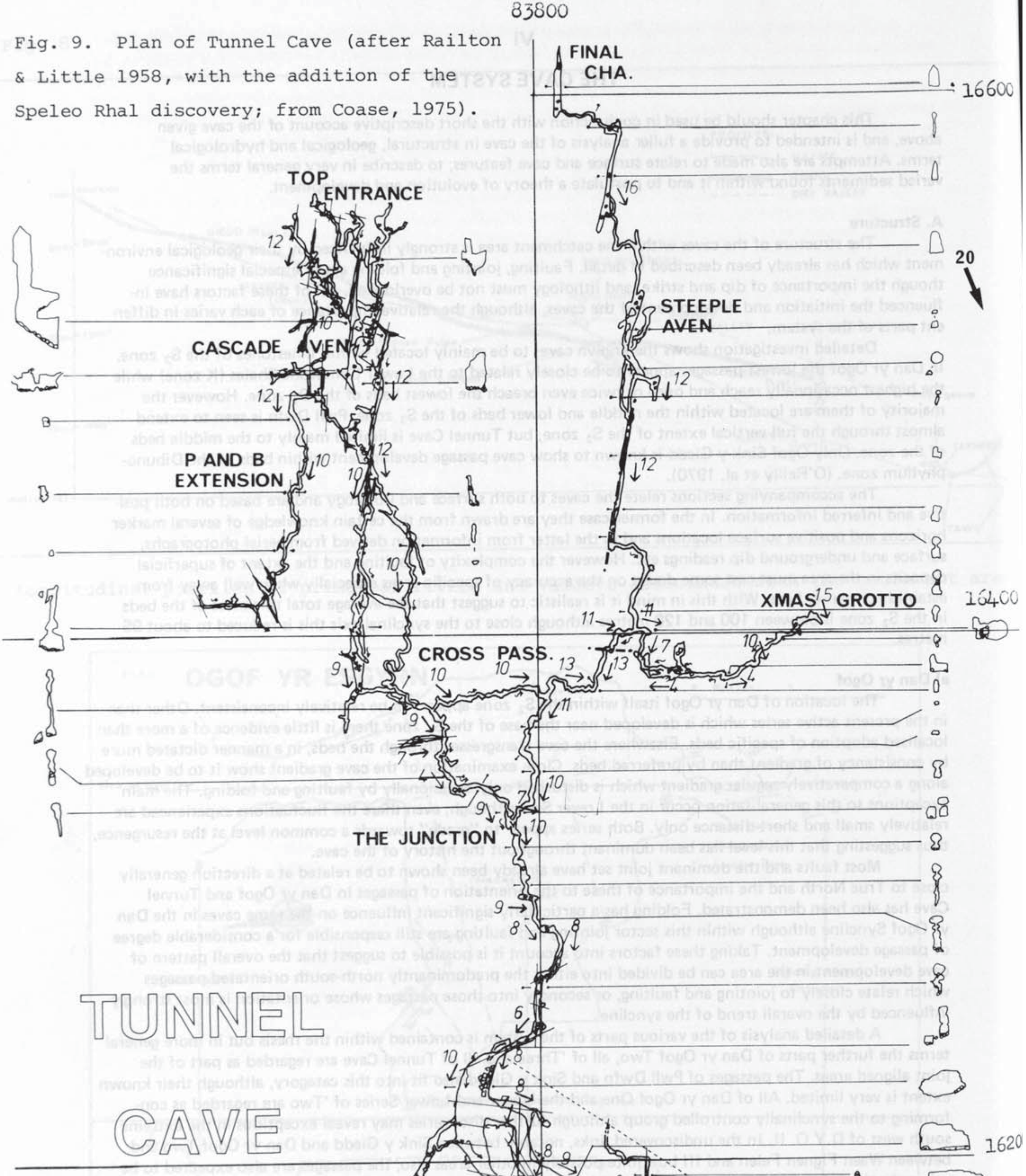
The location of Dan yr Ogof itself within the S_2 zone appears to be relatively inconsistent. Other than in the present active series which is developed near the base of the S_2 zone there is little evidence of a more than localised adoption of specific beds. Elsewhere the cave transgresses through the beds, in a manner dictated more by consistency of gradient than by preferred beds. Close examination of the cave gradient show it to be developed along a comparatively regular gradient which is disturbed only occasionally by faulting and folding. The main exceptions to this generalisation occur in the Lower Series though, even there the fluctuations experienced are relatively small and short-distance only. Both series appear to "grade" towards a common level at the resurgence, thus suggesting that this level has been dominant throughout the history of the cave.

Most faults and the dominant joint set have already been shown to be related at a direction generally close to True North and the importance of these to the orientation of passages in Dan yr Ogof and Tunnel Cave has also been demonstrated. Folding has a particularly significant influence on the same caves in the Dan yr Ogof Syncline although within this sector jointing and faulting are still responsible for a considerable degree of passage development. Taking these factors into account it is possible to suggest that the overall pattern of cave development in the area can be divided into either the predominantly north-south orientated passages which relate closely to jointing and faulting, or secondly into those passages whose orientation is most strongly influenced by the overall trend of the syncline.

A detailed analysis of the various parts of the system is contained within the thesis but in more general terms the further parts of Dan yr Ogof Two, all of 'Three and all of Tunnel Cave are regarded as part of the joint aligned areas. The passages of Pwll Dwfn and Sink y Giedd also fit into this category, although their known extent is very limited. All of Dan yr Ogof One and the Upper and Lower Series of 'Two are regarded as conforming to the synclinally controlled group although further discoveries may reveal exceptions in the extreme south west of D.Y.O. II. In the undiscovered links, notably between Sink y Giedd and Dan yr Ogof Two and between Waen Fignen Felen and III but quite possibly in other areas also, the passages are also expected to be primarily aligned in a north-south direction, although there is likely to be a certain degree of deflection towards the southeast. Part at least of the Giedd series is likely to occupy the Dan yr Ogof Syncline and though geological evidence suggests that this could continue for a significant distance (perhaps a kilometre or more) to the southwest, hydrological evidence in the form of the through-put time for water in flood conditions, suggests that the present route at least, may be very much more direct.

The passages in the southwest of the system, notably those of Mazeways One and Two and the Hangar Passage Extensions which are collectively termed the Cribarth Passages, have some rather individual characteristics and a more detailed review of their classification is necessary. They lie to the south of the synclinal axis, dip more steeply than other passages and do so in a northerly direction. Initially there was a temptation to regard them as the first manifestation of a new category of passages draining northwards from Cribarth. This may still prove to be the case though it is likely to depend upon the nature and trend of further exten-

Fig. 9. Plan of Tunnel Cave (after Railton & Little 1958, with the addition of the Speleo Rhal discovery; from Coase, 1975).



Large arrows = surface dip, small arrows = dip underground; bars across passages = joints. Grid squares are 200 metres wide.

sions of the Dan yr Ogof Syncline. Until further explorations have provided fuller information in this direction the area is regarded by the writer as a part, albeit a steeply dipping one, of the synclinal unit.

The adjacent series known as Dali's Delight is another problem area in terms of classification for it lies across the synclinal axis and yet shows very few of the characteristics of that zone. Because of the very close relationship between its passages and the dominant joint and fault patterns this series is regarded as part of the joint orientated group.

b) The Other Caves

Tunnel Cave (Fig. 9) has been referred to at a number of points previously as offering a close parallel to the further parts of Dan yr Ogof and as being fairly typical of the joint-orientated down dip systems that exist to the north of the Dan yr Ogof Syncline. These points are certainly valid but Tunnel also has characteristics of its own which make it relatively distinctive. These tend to be related more closely to its origins and level of development than to structure though this also has some distinctive features. The former are considered in the appropriate chapter but dealing with these latter factors is largely a matter of re-iterating points that have been made separately elsewhere. In lithological terms the cave differs from others in the system in that it tends to be formed fairly consistently in the middle beds of the S_2 zone, the dip of these beds also being closely related to the overall gradient. There are however exceptions in the highest and furthest passages of the system. The passages also relate closely to the prevailing dip and joint patterns, although as is discussed below the orientation of the passage does vary slightly from other components of Dan yr Ogof.

A full description of the cave was written by Railton (1958) and while some of his conclusions are challenged elsewhere it is not intended to provide a detailed description here. In brief, many of the passages beyond Davy Price's Hall reveal ample evidence of multi-phase development, notably in the alternation of one or more roof tubes with narrow rift sections. There appears to be a very much more direct and observable connection between passage and joint orientations throughout the system, but joint development through more than a few beds seems restricted to the more northerly passages such as Steeple Aven Passage and the Balcony etc. Faulting is a lot less evident than in Dan yr Ogof but it must be observed that the cave has not been subjected to the same close scrutiny and observations are made more difficult by the commonly encountered jumbles of boulders, the relative difficulty (or rather awkwardness) of some of the passages and the very common fills or coatings of sand or mud encountered.

The main chamber, Davy Price's Hall, has recently been opened to the public as Cathedral Cave (Plate 59) and numerous changes have been made, notably to floor deposits. Thus the small misfit stream now flowing through the chamber has been considerably re-directed and several small areas have been flooded, concealing the extensive sand, gravel and boulder deposits on the floor. Large scale lighting on the other hand has done much to reveal the true nature of the bedding and roof features. Particularly noticeable is one bedding plane which appears to have contributed considerably to the development of the chamber. This is discussed more fully below.

A plan and section of *Ogof yr Esgyrn* (the "Bone Cave") are shown in Fig. 10. It has links with a small cave, Step Cave, a few metres to the northwest and there are other small caves in the hillside above and a few rock shelters in the same beds to the south. Its excavation was fully described by Mason (1968 and 1972) a summary being contained in this Transactions (pp. 00) and has provided very important evidence of occupation between Bronze Age and Romano-British periods. From a chronological point of view this is useful evidence, although at first sight its value in geomorphological terms is limited. What did emerge to be of particular value was the excavation of Romano-British pottery dating back 1600 years for this was recovered from under a three inch (75mm. approximately) thickness of stalagmite. The cave in effect comprises one main chamber though there are several boulder chokes and calcited areas which suggest that other chambers, passages or avens may exist. The angles of dip are gentle and the roof is very flat apart from unusual decomposing calcite encrustations which occur along almost every joint and cross joint, which are well seen at 000°, 066° and 082°. The cave floor has been extensively disturbed by excavations, although the large stalagmite boss, from beneath which the pottery referred to above was obtained, still remains. While the cave contains a rather unpleasant collection of bones, mostly recent, mud, sheep droppings, etc. on the floor it is possible to recognise the limestone as being of a darkish grey, crystalline character belonging to the middle parts of the lower S_2 zone. It is located almost on the axis of the syncline.

Pwll Dwfn (the "Deep Pot") which lies roughly equi-distant between Pinnacle Series, Dan yr Ogof, and the Top Entrance, Tunnel Cave, has already been referred to as being developed through virtually the whole of the S_2 zone. The pothole whose relationship to both the Dan yr Ogof and Tunnel Caves is seen in Plan, the surface and sections is also shown in Fig. 11. This plan and section, based on work by Dolphin (1947), together with the map of the surface geology (Plan B), emphasises the structural influences on the pot which are referred to below. Lithologically the variations between the uppermost and lowest beds of the S_2 zone are fairly evident although identifying the exact level at which the change in character occurs is not easy. The vertical nature of the system, the wetness of most of the lower pitches and the high level sand deposits which obscure much of the walls make detailed investigation difficult and interpretation is further complicated by faulting. Nonetheless information contained in Fig. 11 confirms much of the pattern already described in Dan yr Ogof and the corals at the base are also very typical of the River Cave.

Pwll Dwfn also shares several of the characteristics of Dali's Delight though neither the wide range of lithologies which they have in common, nor the nature of the faults which must have contributed much of its initiation and development produce anything of the complexity of form or the variety of features of the latter. The pothole seems almost certainly to have been initiated and developed by water percolating along the

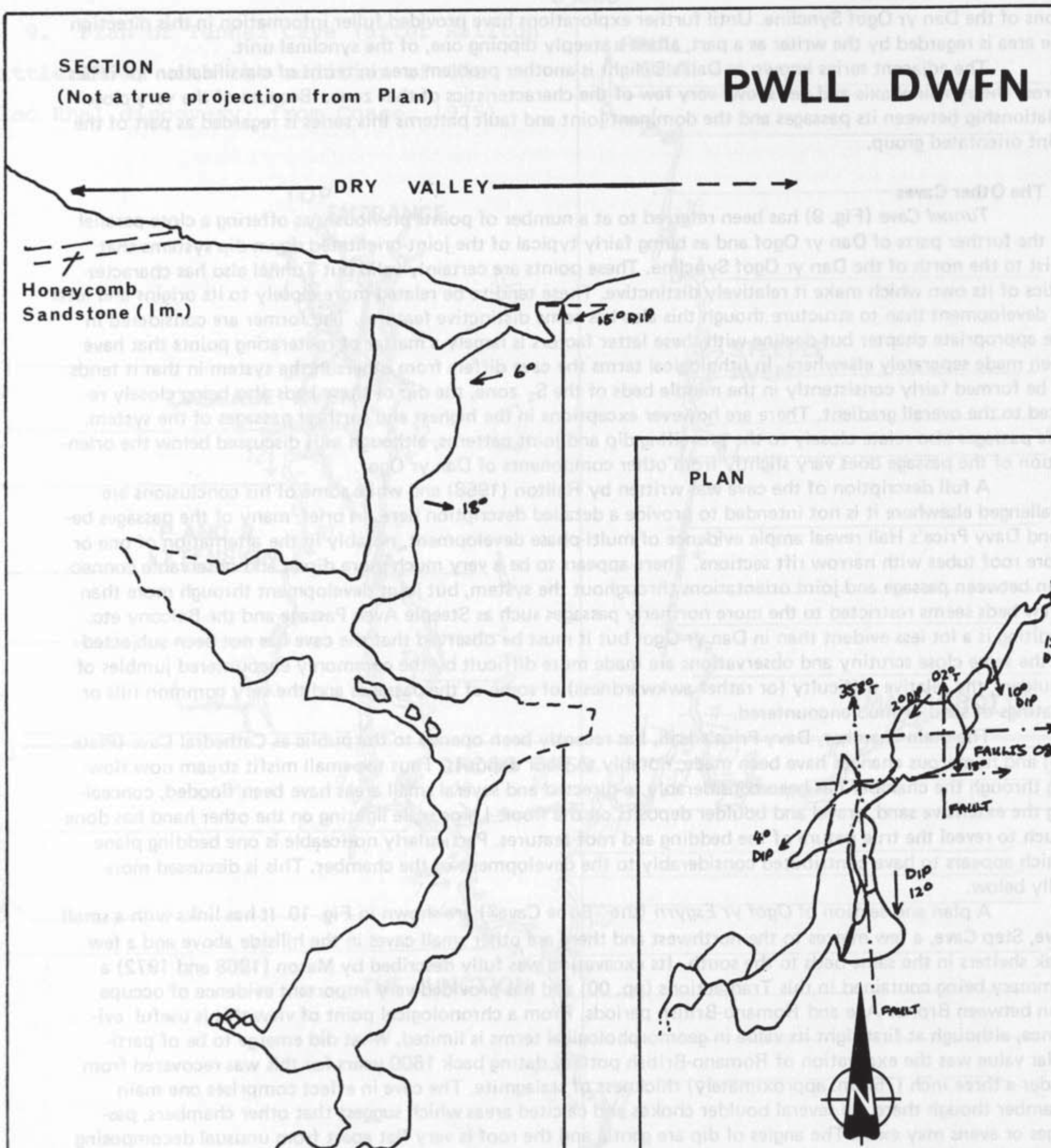


Fig 11. Plan and section of Pwll Dwfn (based on Dolphin & Low 1947).

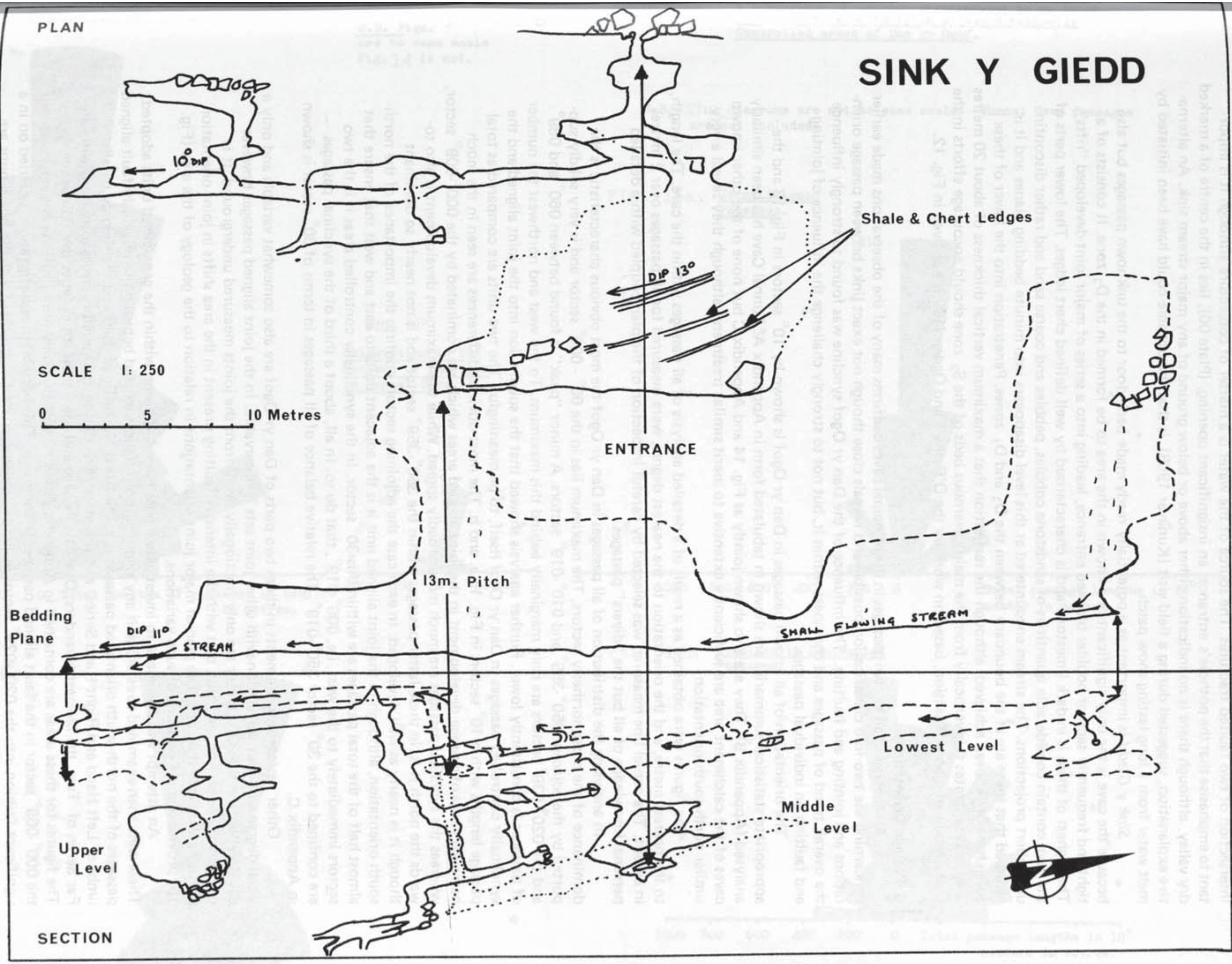


Fig. 12. Plan and section of Sink y Giedd (based on O'Reilly, O'Reilly & Ogden, 1970).

intersection of two faulted fractures. The source of the water is a matter of conjecture although it is important to emphasise that the pothole's entrance, an insignificant opening, (Plate 00), lies in the centre of a marked dry valley, although there is no indication either above or below ground of any major stream sink. An alternative explanation, suggested during a field visit (Kunavar 1968), is that the pothole could have been initiated by melt water from a long lasting snow patch.

Sink y Giedd is important as a potentially ready made back-door to the unknown passages but also because the cave is the only significant one known in the area to be formed in the D_2 zone. It consists of a tight and frequently sand or boulder blocked entrance, leading into a series of major joint-developed "rifts". The highest of these is in dark limestone and is characterised by well defined chert ledges. The lower parts of the cave contain considerable quantities of sandstone cobbles, pebbles and coarse sand and rather discontinuous chert projections. The stream encountered at this level disappears into minute bedding planes and it is assumed that these are at the boundary between the D_2 and D_1 zones. Penetration into the lower of these zones has not yet been achieved, although the realisation that a maximum vertical thickness of about 20 metres is all that separates this vertically from the main cavernous beds of the S_2 zone should encourage efforts in the area. Details of plan and section, based on work by the O'Reilly's and Ogden (1970) are given in Fig. 12.

B. Passage Orientations

An analysis of all known passages in the principal caves confirms many of the observations made earlier concerning the two-fold classification possible and reveals close though not exact links between passage orientations and jointing and faulting. The influence of the Dan yr Ogof syncline was found to strongly influence the overall trend of passages and chambers within it, but not to strongly challenge the influence of jointing and faulting on individual passages.

The orientation of all known passages in Dan yr Ogof is shown by 10° sectors in Fig. 13 and the appropriate statistical summaries are shown in tabulated form in Appendix A. Tunnel Cave has been similarly analysed (Appendix B). They are also shown jointly as Fig. 14 and Appendix C but none of the other known caves of the catchment area are sufficiently extensive to merit similar treatment, although they reveal a very similar north-south orientation.

The figures were obtained as a result of a detailed analysis of all passages within the cave. The length, to the nearest metre, and the orientation to the nearest degree, were measured for all passages over 2 metres in extent. The actual line measured was selected by careful inspection of the plan coupled with a detailed personal knowledge of all but the "divers" passages.

In analysing the distribution of all passages in Dan yr Ogof the most obvious characteristic is the dominance of the most northerly sectors. The maximum lies in the 00° - 009° sector and is very solidly supported by the adjacent 350°-359° and 010°-019° sectors. A minor "peak" is found between 060° and 069° and the 020°-039° sectors are only marginally behind this maximum. To the west and northwest the number of passages is consistently lower. Further analysis showed that the subdivision into the joint aligned and the synclinally controlled passages in Dan yr Ogof itself, to be meaningful. The two units are compared as total passage lengths within 10° sectors in Fig. 15 a. and b. The most obvious differences are seen in the much narrower range of passage development in the joint aligned areas which are dominated by the 000°-009° sector, whereas the synclinal passages are much more broadly spread. While the maximum development is also towards the north it is, in these latter passages within the 350°-359° sector and is not nearly so dominant though it is nearly as well developed. In each case the adjoining sectors confirm the importance of the north-south orientation, although in the joint aligned unit it is the adjacent units to east and west that ensure that almost half of the total passages are within this 30° sector. In the synclinally controlled areas it is the two sectors immediately to the west, i.e. 000°-019°, that do so. In all, about a third of the synclinal passages are confined to the 30° sector 350°-019°. The relative balance of all passages in terms of 30° sector is shown in Appendix C.

Other passage developments in these two parts of Dan yr Ogof are also somewhat variable and only a small degree of direct correlation with other joint sets is observable. In the joint aligned passages however developments in the 320° sector are only fractionally away from the joints measured underground. It is of course necessary to recognise that with the intensive faulting present in the area shifts in joint orientation are more probable than not. The plan of major joint orientations in relation to the geology of the area (Fig. 16) provides ample evidence of such variations.

An attempt was also made to investigate a possible sub-division within the generalised units adopted. These were then examined to establish if any significant differences existed between the obviously fault-aligned passages of the north-south orientated passages (i.e. the Great North Road itself and the roughly parallel limbs of Left Hand and Right Hand Series) and the more meandering and varied passages associated with the Far Series of 'Two, the Mostest Meanders, Overpass Passage and the Far North as far as the "Girtstone Avens". The figures for these areas are contained in Appendix A and suggest that only minor differences exist and that the 000°-009° sector in the fault aligned passages is dominant. This northward concentration is carried on in a significant fashion into the 020°-029° sector in the fault aligned passages but otherwise the two groups are very similar on the eastern side. In fact they are identical in the only other sectors of importance to the east (050°-059°). On the western side the faulted unit is only half as developed on average as are the synclinal passages, which are particularly well represented within the 320°-339° sectors.

Analysis of the orientation graph for Tunnel Cave reveals a similarly heavy development along the northern sector although unlike the Dan yr Ogof pattern this appears to be limited to a 20° sector (00°-019°)

FIG. 13a Orientation, in 10° Sectors of all passages in Dan yr Ogof

N.B. Figs. 13a and b are to same scale Fig. 14 is not.

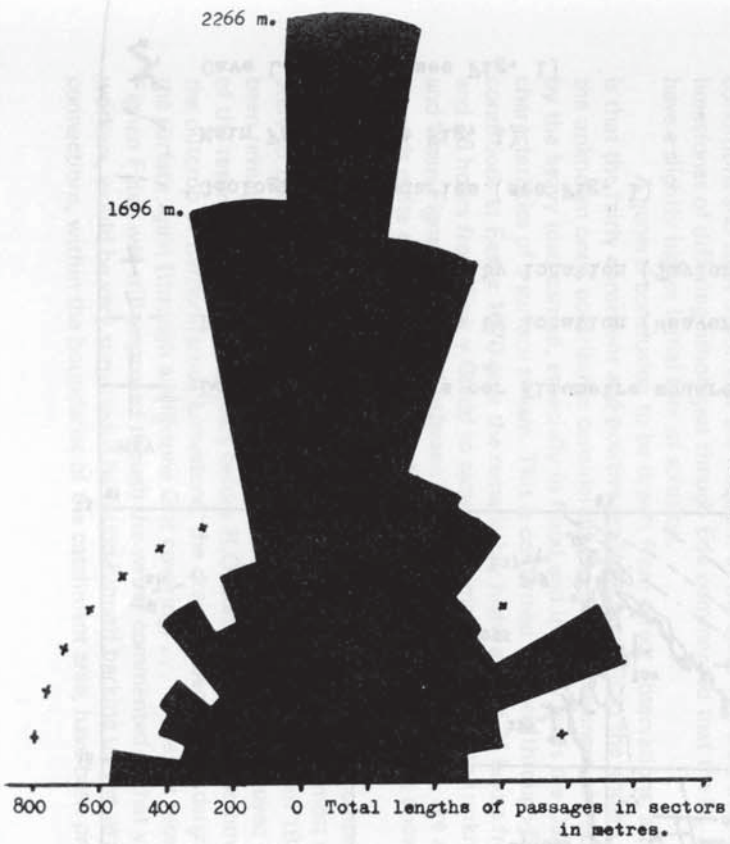


FIG. 13b Orientation in 10° Sectors of passages in Tunnel Cave.

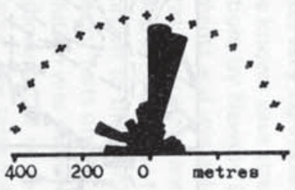


FIG. 14. Orientation in 30° Sectors in all passages in Dan yr Ogof and Tunnel Caves.

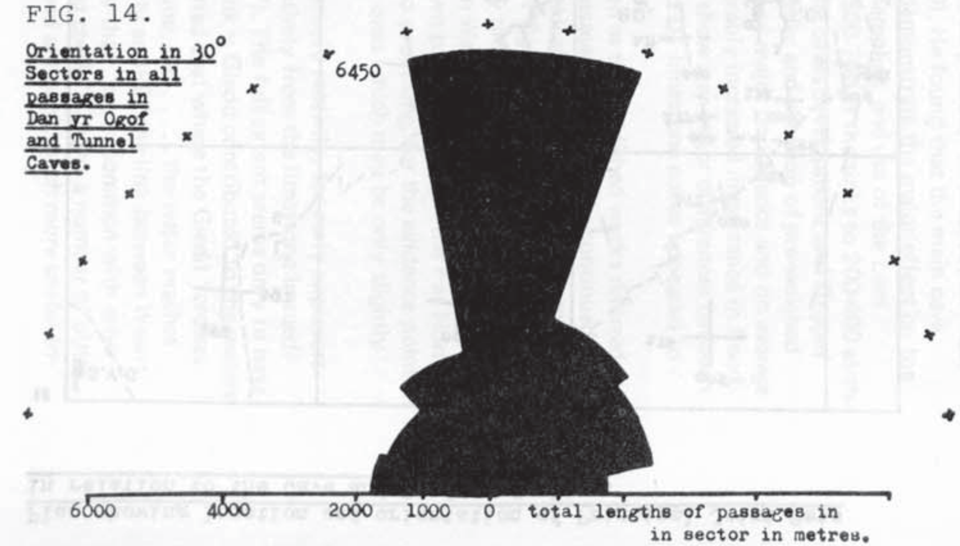


FIG. 15. A comparison of passage orientations in a. Joint Aligned area with those in b. the Synclinally Controlled areas of Dan yr Ogof.

N.B. The diagrams are not to same scale. Tunnel Cave passages are not included.

FIG. 15a. Joint Aligned Passages.

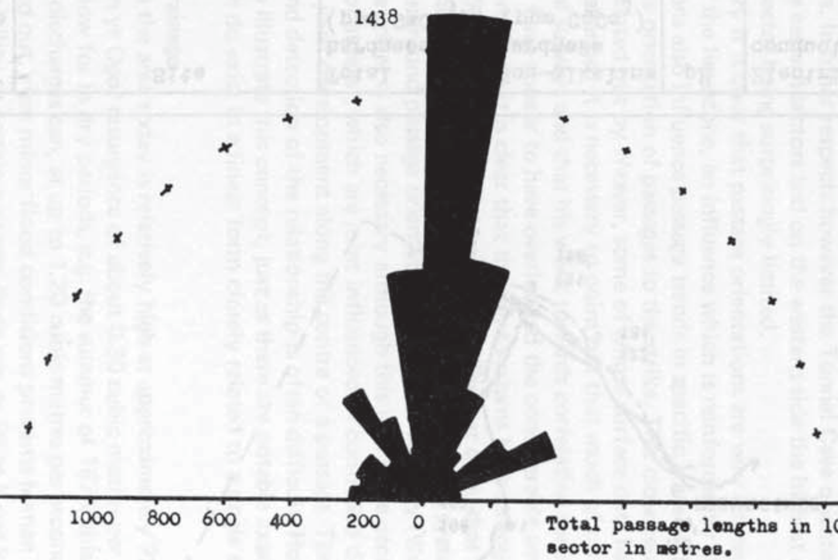


FIG. 15b Synclinally Controlled Passages.

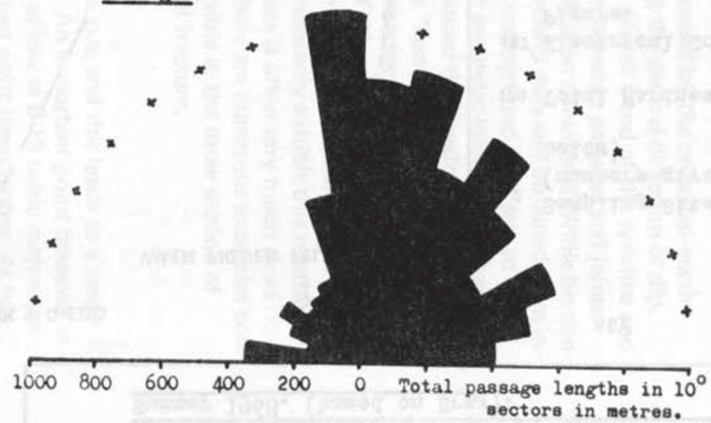


FIG. 16 **Plan showing location and orientation of Principal Joint Sets in relation to the Cave and Surface Geology.**

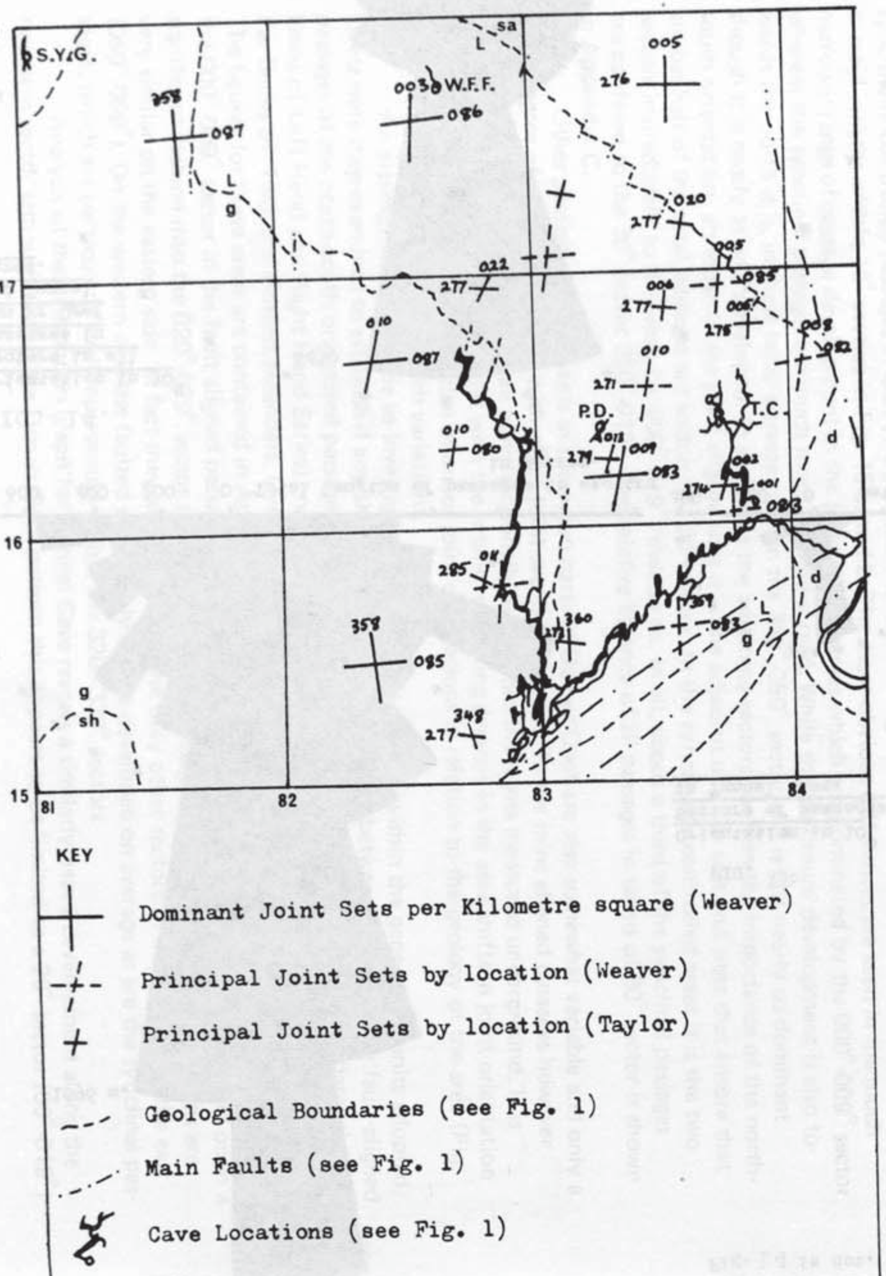
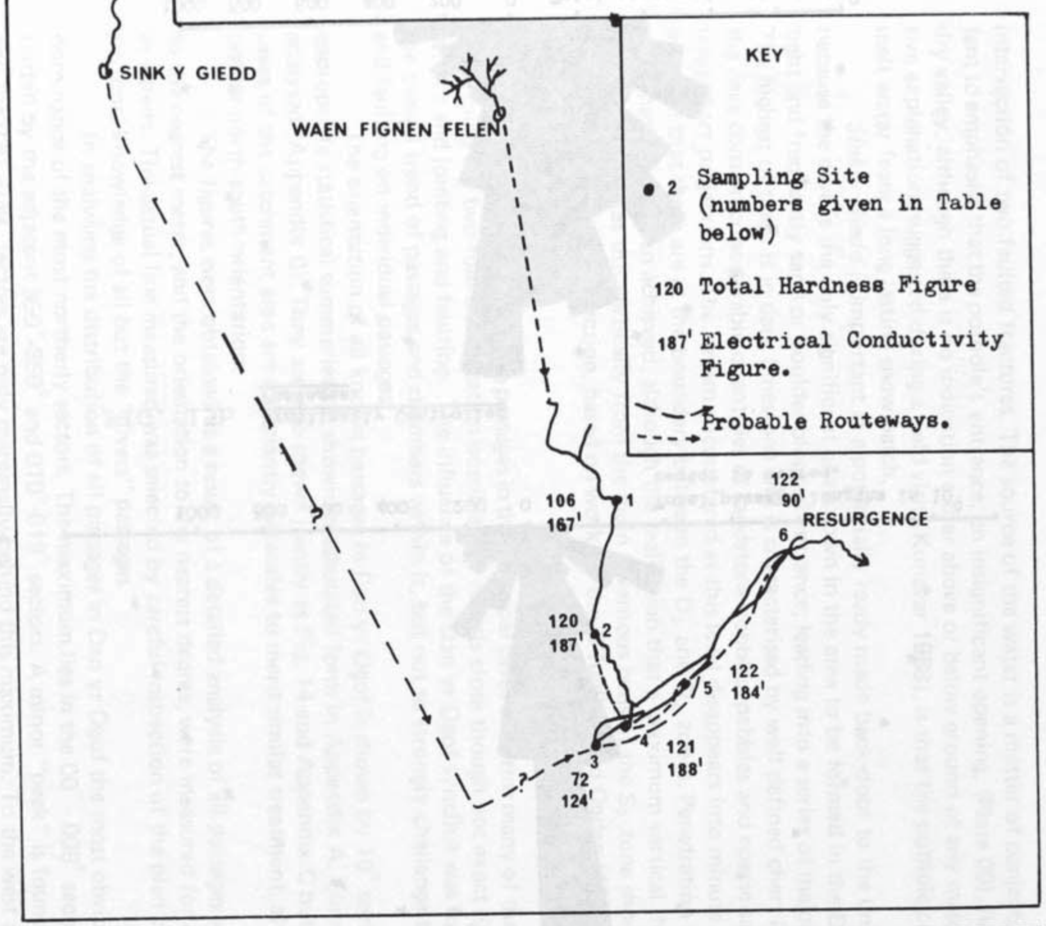


FIG. 17 a and b **Diagrammatic representation and table of selected results from analysis of Dan yr Ogof cave water Summer 1968. (based on Bray).**



No. of Site	Site	Total hardness (ppm $CaCO_3$)	Non-alkaline hardness (ppm $CaCO_3$)	pH	Electrical conductivity
1	Top of Great North Rd.	106	8	8.6	167
2	The Rising	120	8	8.1	187
3	Mazeways Sump	72	3	7.9	124
4	Mazeways Entr. Pool	121	9	7.8	188
5	Washing Machine	122	12	7.8	184
6	Resurgence	122	12	8.0	190

rather than to a 30° zone. The pattern is far closer to the characteristics of the joint and fault orientated passages than to the synclinally controlled ones in that this northerly development considerably exceeds the development in any other sectors. In other respects however the Tunnel Cave orientation is distinctive for there is very little development of the eastern sectors and on the western side the highest development is in the 290° sector, development of the 350° sector being surprisingly limited.

In summary it is clear that passage orientations are very strongly influenced by the principal north-south fracturing of the limestone, an influence which is reinforced by this being the general direction of dip. Other joint directions also influence passage trends in specific areas as does the overall trend of the syncline and quite frequently the orientation of passages to the strike. This close relationship between passages and joints has already been pointed out by Weaver, some of whose surface data has already been considered. While his conclusions are not challenged it is necessary to point out that much of his underground data was obtained from inaccurate provisional surveys and that his work towards correlating surface and underground joint sets in the Dan yr Ogof Show Cave appear to have overlooked the considerable amount of magnetic interference that is encountered therein. While it is clear that the joint systems have strongly influenced the development of the Cave, the writer would not go as far as to suggest, as Weaver does, that they are "controlled by" them, nor to extend the conclusions reached to the adjacent Ogof Fynnon Ddu system. Furthermore the writer views the "evidence" of underground passage orientations published recently (Weaver 1974) as quite misleading.

One further rider is also necessary although this is in more general terms. It is to emphasise that passages in Dan yr Ogof at least, which are joint influenced or controlled do not necessarily exhibit this relationship in terms of a single joint development along the centre of a passage. The influence is often very much more varied and subtle and detection of the relationship is often difficult. However there are numerous examples contained on Plan B to illustrate this concept, just as there are notable examples visible in the show section of Tunnel Cave, which do exist in a linear form closely related to a single structural fracture.

C. Underground Drainage

Rainfall in the area today is relatively high at approximately 2250 mm. p.a. and this leads to a mean discharge at the Dan yr Ogof resurgence of about 0.30 cubic metres per second. An important point however is the irregularity of flow for in dry periods, e.g. the summer of 1975, this can be as low as 0.15 cubic metres per second while flood discharges can, at up to 1.20 cubic metres per second be almost eight times higher. As has already been pointed out, even minor flood conditions prevents human access and while low water levels certainly ease accessibility to certain passages there are, as far as is yet known, no major new areas revealed at such times. The multi-layered nature of the active passages has also been referred to as has the fairly frequent invasion of the upper levels of the lower series of passages by flood water, even in the Show Cave. It is thought likely that this occupation of higher levels contributes very significantly to the rapid through-flow times in flood.

Water at the resurgence and through all the known cave streams is very turbid, an observation made by Coase in 1967 which led onto detailed investigations by Newson (1970). He found that the main cave system was undergoing a major throughput of sediments and was able to demonstrate the major effect on the roundness of sediments between the sinks and the resurgence by random sampling and use of the Lees index. The results showed reductions in the non-calcareous samples from 500-700 at the sinks to 200-400 at the the resurgence. The implications are of course important to the story of the caves development and Groom and Ede (1972) further demonstrated this by a series of tests on the solubility and abrasion of pre-weighed rock cubes. The results were not unexpected for solution was shown to be of major importance and on average mechanical erosion less so. However the latter was shown to be of considerably increased importance in flood conditions and such conditions are frequent in the area. The tests did not show any major differences between limestones of differing lithologies though Ede commented that the D_2 and D_3 limestone cubes appeared to have a slightly higher initial rate of solution.

A general conclusion to be drawn from direct observations, as well as the published works referred to, is that the fairly consistent and positive gradient revealed in the known passages and seemingly continued in the unknown ones, contributes considerably to the effectiveness of mechanical erosion. This is supplemented by the heavy load carried, especially in flood and in many ways the Dan yr Ogof streams show many of the characteristics of a surface stream. This is confirmed by their through-flow times which in moderately high conditions at Easter 1970 gave the remarkably high rates of 24 hours from Waen Fignen Felen to the resurgence and 36 hours from Sink y Giedd to same. The implications for the unknown passages between the Far North and Waen Fignen Felen, and between Mazeways and Sink y Giedd, are also promising, for the evidence points towards quite extensive vadose developments albeit as pointed out above, ones which may be only slightly above the "normal" saturated zone.

Surprisingly the links described above have been proved comparatively recently, for early explorers regarded the water resurging from Dan yr Ogof as being derived almost entirely from the limestone immediately to the west of the cave and from under the dry valley, (Platten 1937). The full extent seems only to have been revealed by a successful dye test in 1948 by Harvey which proved Sink y Giedd contributed to the waters of the resurgence. Not many years before R.O. Jones (1939) had commented that where the Giedd "crosses the outcrop of Carboniferous Limestone, the drainage becomes underground, but . . . . . the water reaches the surface again (through a Millstone Grit covering) . . . ". Even as recently as 1967 the link between Waen Fignen Felen was still unproved though the writer commented in that year that "he, in common with other workers, would be very surprised if he found himself barking up the wrong creek!" Today a number of other connections, within the boundaries of the catchment area, have been proved although much more useful information about minor sinks and surface to underground and underground to underground links could undoubtedly be obtained by the application of the sophisticated water tracing techniques developed elsewhere.

It should also be made clear that the main sinks described are not the only ones at which discrete streams sink underground, nor are sinking streams the only form of input water. A considerable number of small but significant streams flow into the limestone via swallow holes or swallets, particularly between the main sink at Waen Fignen Felen and the Giedd valley. A number of these drain peat bogs which are part of or are adjacent to the principal one at Waen Fignen Felen and many of them take water when the main sink remains inactive (at least in terms of a discrete stream flowing into it). It is also worth re-emphasising the size and importance of the peat bogs as storage systems for "flash-floods", arising from a prolonged build up of water in the peat, are a fairly commonly observed feature on the larger deposits (Jones 1966b). They can of course prove dangerous to speleologists underground if water levels were already marginal on entry.

Other streams flow into the limestone from the grit margins and some of these, notably that at Pwll y Wydden, provide very rapid run-off, in times of heavy rainfall. There are also several quite large sinks where streams enter directly into the grit. As yet only one of these has been proved to connect with the cave system, though in view of the openness of much of the jointing on the Millstone Grit, the general absence of surface streams on the bare rock pavements and Thomas's views on solution in the inter-stratal karst (1974) it seems that more are likely to do so.

In addition to water entering swallow holes or swallets as identifiable streams a large amount enters the limestone as percolation water via the hundreds of depressions covering the limestone. Thomas (1954) made a detailed study of these and attempted to classify them. They are of particular significance to the hydrology of the area for some contain obvious open joints into which rain water sinks immediately and visibly, whilst others appear to be completely choked and contain deep ponds or else are totally peat filled. In the former case there is little distinction from true swallets while in the latter cases percolation may be very slow. What has become apparent, particularly from work by Ede (1972) and Newson (1970) is that establishing the relative balance between swallet and percolation water, an important factor in other Welsh and Somerset caves, is less important in the Dan yr Ogof catchment area for the percolation water rapidly acquires the characteristics of swallet water. This appears to be largely the result of structure for the openness and complexity of the joints and micro-joints referred to by many observers (and notably by Thomas in his 1970 paper on the limestone pavements) permits the localising of channels and convergence of water into discrete routeways at a very early stage underground. The aggressiveness of much of the water entering the limestone also appears to be a contributory factor to this early establishment of discrete as opposed to diffused water routeways. The localising of channels also requires emphasis, for the recent discovery in Tunnel Cave of the Paul and Barnabas Extension re-affirms the view that movement of underground water, in this area at least, adopts, or adapts to, fault lines. This also appears to be the case in Pwll Dwfn for this pothole is developed at a confluence of faults and although located in the Dan yr Ogof dry valley carries no obvious evidence of development from a sinking stream. Yet the lowest sections are always quite wet and in heavy rainfall conditions they become virtually unclimbable. The new discovery in Tunnel contains the only significant stream in the area and this appears to flow from the fault immediately to the west of the Top Entrance. The area had already been identified as a fault partly by the elongated chain of linear depressions directly above it.

Considerable differences do occur between the two main types of input water as well as between different sources of the same basic type. A great deal of work has been done on the chemistry of these waters notably by Bray (Chapter VII herein) initially with the help of the writer and many other cavers, and by Newson and Ede. An attempt is made below to reach some valid conclusions from the results obtained from these tests, though it must be pointed out these are often incomplete or not directly comparable. Bray felt (1975) that the "attempt to work out the underground history" of the Dan yr Ogof waters had largely proved unsuccessful, but his work there and elsewhere has led to very considerable refinements in analytical techniques.

In general terms the water entering the main sinks or swallets at Waen Fignen Felen and Sink y Giedd is very aggressive; in Ede's experience (1972) that at the former being the most aggressive surface water he had ever tested. Marked differences do however exist between these two sites, particularly because of the geological and chemical composition of their immediate environments. Thus, that at Waen Fignen Felen, in an area of extensive peat bogs is considerably more aggressive and acid (with a pH of about 4.6-4.8) than that at Sink y Giedd where the streams run for the most part over slightly less acid boulder clays and quartzitic sands (pH. 5.6). Admittedly the Giedd's tributary stream, Pwll y Cig does pass through and obtain water from a peat bog but this is not as extensive as that at Waen Fignen Felen and results obtained suggest that this water barely differs chemically from the Giedd itself. For similar reasons the flow rate at Sink y Giedd is more regular than that at Waen Fignen Felen, though the Giedd in very dry weather conditions sinks into its bed almost as far back as its confluence with the Cig. (Plates 2 & 3). The peat bogs, of which there are numerous examples other than the two sites quoted here, also have the important capacity of acting as storage reservoirs. If their total capacity is reached rapidly, as after a continuous period of heavy rain, then run-off is immediate and the aggressiveness of the input water is then greatly reduced. A similar result is apparent in total hardness figures which are lowest in flood conditions.

Waen Fignen Felen (Plate 4) is also a difficult area to define for the name properly belongs to the extensive depression to the south of the upper Haffes stream, but to local cavers it has come to mean the actual swallet which exists at the end of the steep blind valley shown in the photographs. Here the norm is for there to be no actual water flowing directly into the sink, though very often in moderately wet weather a steeply descending stream is absorbed into the thick sand, peat and highly polished limestone cobbles immediately above the shaft. In dry weather conditions no water at all enters the valley, although other sinks marginal to the peat bog do remain active. One of the most important of these, the "Greenstick" Sink is located at the extreme southwestern corner of the main bog and has been proved by dye-test to link with the Dan yr Ogof system.

Water flowing underground at the grit margins, such as at Pwll y Wydden (Plate 41) is also very aggressive though the composition of the water differs in other ways, including electrical conductivity, from Waen Fignen Felen. This may be due to the decomposition of pyrites in the shales near the grit: limestone boundary and consequently the occurrence of strong acids such as H_2SO_4. This process has been described by Burke (1967) as important in pothole development beneath the grit beds in the Neath Valley.

True percolation water is somewhat harder to test for by definition little of it exists in measurable quantities at the surface and like swallet water it changes remarkably in chemical terms by the time that it reaches known caves passages. In the case of the pond-filled dolines, Newson (1970) found these to be quite aggressive except after heavy rain but in general both he and Ede regarded percolation water as non aggressive on entry. The rapidity of movement through the many open joints and micro-fractures has already been commented upon and this was confirmed by Ede who showed, via a pyranine dye test, that percolation water moved through a horizontal distance of 300 meters and a vertical distance of 175 metres in six days. He also suggested that the rapidity of this movement helps to explain the low total hardness at the resurgence.

Newson remarked on the comparative rarity of slow drips in the system, for percolation water normally appears to have amalgamated into fast heavy drips or else into discrete streams pouring rapidly, if diffusely, from such high points as in Dali's Delight, the Rottenstone Avens or the Girtstone (sic) Avens. The implications for the development of speleothems are particularly relevant to future studies for the main activity in this respect at present appears to be the relatively rapid growth of hollow "straw" stalactites. These are especially well represented in the cave with many reaching over 3 metres in length. One dateable development in this respect arises from the army occupation of the Show Cave between 1939 and 1945 when the lower tip of the "Dagger" (above the corresponding and interesting drip stalagmite known as "Lot's Wife") was broken. Approximately 5mm. of thin calcite deposit, possibly the origin of a "straw", have accumulated since that date, i.e. an average growth rate of at least 1mm. every 6 years.

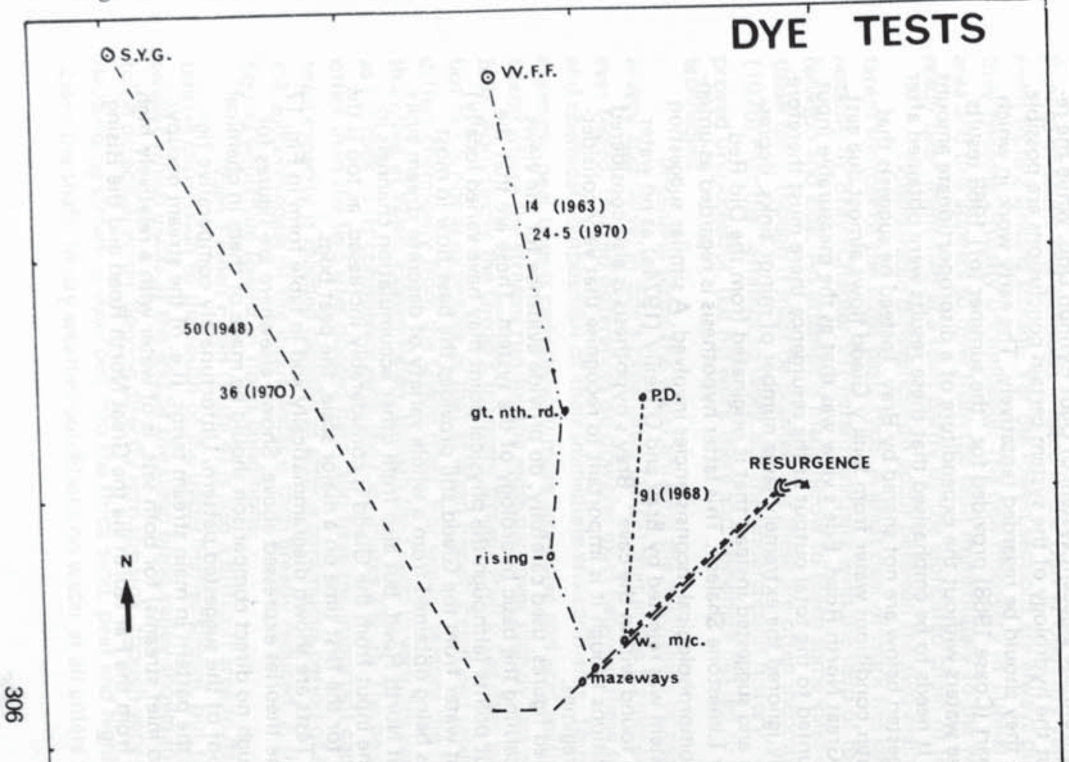
Another calcite formation which appears to be progressing actively are curtains, and several of them are seen as excellent examples in the Show Cave. However many of the massive flow formations found elsewhere appear to be undergoing relatively little development while in a few areas there is positive evidence of re-solution occurring. In other areas too there are examples of disintegration caused by mechanical collapse of passage roofs or walls, or by the infill of large debris. Newson suggests that apart from the straws, (plus in the writer's view curtains, helictites and quite extensive areas of mostly thin truncheon-like stalagmites) most existing formations represent different hydrological conditions which prevailed at an earlier stage of development.

Bray has written extensively (1969, 1971 and 1972) about the results achieved from Dan yr Ogof and subsequently (with O'Reilly 1974 a and b) from the adjacent system of Ogof Fynnon Ddu. While the results did not reveal as much as was hoped about the hydrology of the system certain conclusions are possible, though the writer would echo Bray's view that they should be regarded tentatively. The early work in which the writer and his students took a very active part (Coase 1968) provided for "the summer (of) 1968 results perhaps as reliable as will be obtained from cave waters without the expenditure of a disproportionate amount of time and effort" (Bray, Chapter VII herein). It needs to be emphasised that these results were obtained after a very dry period and that the conclusions suggested below are not shared by Bray. Instead he suggests that chemically at least, it is possible that in low water conditions water from Sink y Giedd flows almost due east to join with, or even provide, the water of the Great North Road. Ede's view was that as the measurable input of water via the two principal sinks never amounted to the total output at the resurgence there must therefore be another source of input water. He apparently ignored the extremely large number of minor sinks, depressions and percolation sources above the system and suggested instead that it originated from the Old Red Sandstone sources "via the 8 metre thick lower Limestone Shales". This latter hypothesis is regarded as untenable by the writer partly because of obvious geomorphological inconsistencies involved. A similar suggestion concerning the waters of Ogof Fynnon Ddu system was rejected by Bray and O'Reilly (1974a) as no water with the appropriately "low hardness had been found within the cave". Bray's hypothesis is also considered as inappropriate to the existing geological conditions though it is important to recognise that very considerable differences do prevail in different rainfall regimes.

Instead it is suggested that the published figures, used carefully, do provide evidence for the views frequently expressed by the writer (1967) concerning the basic hydrology of the system. These are that the two main sinks are the principal remaining input points (although the physical point may have varied locally) of the original consequent drainage system, that water from the Giedd still provides the base flow in most conditions with very considerable contributions being obtained from a whole variety of descrete stream sinks and percolation sources, notably from the Great North Road, but also from other accumulation channels including fault-lines. In wet weather conditions the input from the Giedd is considerably increased, as too is the input from all other sources including, possibly for the first time on a major scale, the peat bogs.

Selected results for the 1968 Summer Tests are shown diagrammatically and in table form in Fig. 17, a and b. and it is suggested that they support the theories expressed above. Shown elsewhere are figures for the wetter summer conditions of 1969 and though no direct comparison should be made of them in chemical terms, it is suggested that they offer further proof of the suggested pattern. Unfortunately comparative figures for the sinks in 1968 are not available, but the pattern in main stream terms, (I.e. of the stream occupying the main passage bed rather than referring to inlet streams) for both sets, is of water with a relatively high, and generally increasing total hardness, flowing from the Far North via the Great North Road and the Rising,

Fig. 18. Principal dye tests in the catchment area since 1948.



Routes only hypothetical but relative locations accurate.

Figures denote length of fastest flow-through times in hours.

Sink y Giedd to Resurgence

Two significant tests to resurgence, first 1948 (P.W. Harvey) 50 hours in moderate flood, second 1970 at start of moderate flood took 36 hours. No information on route available. Dye fluorescein, 35 and 36 ozs. respectively.

Waen Fignen Felen to Resurgence.

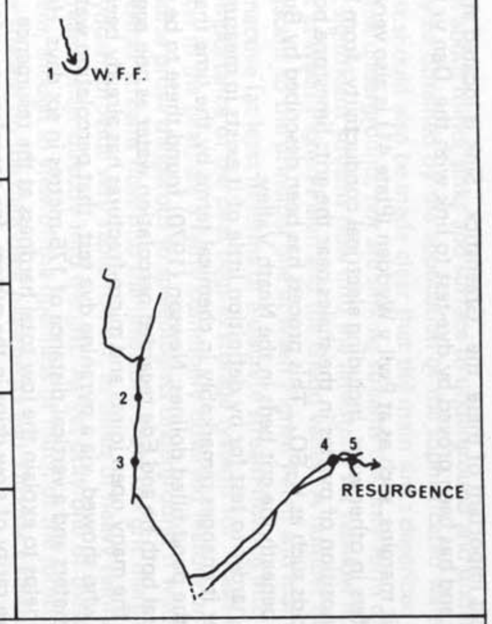
Two well recorded tests, 14 hours in heavy flood 1963 (Hunt and Jones) and 1970 (Coase) - full details of last in text.

Pwll Dwfn to Resurgence

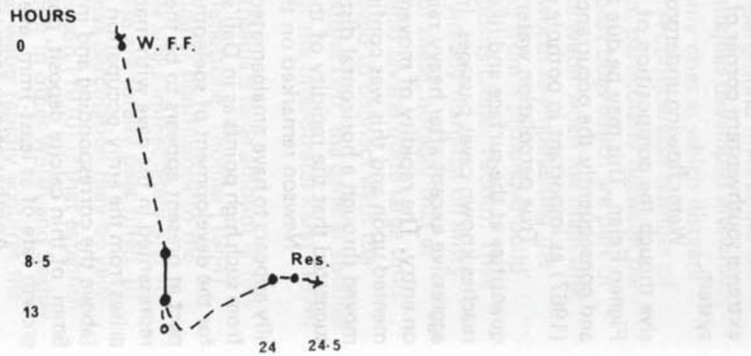
Several unsatisfactory tests, best Easter 1968 with fluorescein (Hall - Christopher 1968) took 91 hours.

Fig. 19. Summary of dye test from Easter 1970 dye test from Waen Fignen Felen.

Duration	
1. 0.00 hrs.	3 lbs. Fluorescein dye introduced to small stream flowing almost to lip of shaft.
2. 8.30 hrs.	Dye first encountered in Great North Road.
3. 11.00 hrs.	'Head' of dye passed halfway down Great North Road.
4. 24.00 hrs.	Seen in Lake 1, Show Cave (lake flowing briskly).
5. 24.30 hrs.	Seen at Resurgence.



N.B. Local tests have shown movement through the Rising to be comparatively rapid (40 mins. in average water conditions) - assumed that dye reached Rising after about 13.00 hours (± 2 hours). Thus:-



to reappear in the Mazeways Entrance Pool, and thence via the Washing Machine to the Resurgence. The readings along this route all appear chemically consistent. The water assumed to be flowing from Sink y Giedd is almost certainly seen first in Mazeways Two, although the Sump Passage in Mazeways One is the point from which its hardness figures are obtained and there they are substantially lower than in the Entrance Pool. These two pools have long been recognised as chemically distinct, just as two others, which are physically adjacent in Bakerloo Straight, show marked differences in turbidity and hardness. It seems clear that in the Lower Series of Dan yr Ogof, along the base of the syncline, there is a complex pattern of differing waters.

With regard to other results obtained Bray warns in his contribution against over-dependence upon pH readings and the pattern they reveal is quite inconclusive, although conductivity figures are more rewarding insofar as they again show considerable differences between the different sites in Mazeways. Dye-testing has also been an area where considerable efforts have been expended though misfortune and rather careless monitoring has reduced the value of the results. However, Fig. 18 summarises the principal significant tests made since the war, placing very heavy emphasis on those that have been thoroughly accepted, as opposed to those over which some doubt exists. In most though not all cases, the method of testing has been by use of fluorescein dye (Christopher 1968) Plate 27, and the proof accepted has been of positive visual sightings. Tests with activated charcoal markers have not been very effective, sometimes because floods have torn the markers away and partly because analysis of the markers have been inadequately performed. The only test with Pyranine Conc. (Ede 1972) was primarily conducted as a short distance timing exercise.

What is positively known from these tests is that water from Sink y Giedd, Waen Fignen Felen, Pwll Dwfn, Pwll y Wydden and an unnamed swallow hole draining a fairly extensive peat filled depression, on the Millstone Grit, to the south of Castell y Geifr (825161), enters the Dan yr Ogof caves and has been proved to resurge from them. In many cases the proof can only be related to the resurgence because of the flood conditions which prevailed and made the test possible, in other cases some visual observations were made inside the cave.

In both respects the dye tests of Easter 1970 were particularly valuable in providing reasonably comparable through-flow times for already proved sinks, for establishing the whereabouts of dye in the cave, and for obtaining rough estimates for its movement through a large vadose passage complex (Crabtree 1970). Water conditions were moderately high and it was the first occasion that a party had been in the further parts of Dan yr Ogof when water was known to be flowing into the main sink at Waen Fignen Felen. The through-flow time (sink to resurgence) proved to be 24.5 hours and immediately the last of the dye was through a further test was conducted from Sink y Giedd. This, in marginally wetter conditions, provided a proved link of 36 hours, though the point of entry to the known cave could not be observed as the low passage leading into the Third Lake had filled to the roof.

The rate of progress of the dyed water in the Waen Fignen Felen test are shown in Fig. 19 and are particularly significant in that they show the movement down the vadose streamway of the Great North Road to be relatively slow. Extrapolation from this and other and more local tests, suggests that the first of the dyed water would have entered the known parts of the cave approximately 5½-6 hours after entering the sink, taken a further 6-7 hours to reach the bottom of the Great North Road and clear the Rising Sump and then between 11 and 12 hours to the resurgence. The relationship of times and distances are shown in Fig. 18, from which it is clear that movement through the supposed phreatic zone, in the prevailing conditions, and in average straight line terms, is as rapid as through the vadose passage, while that from the sink to the cave is substantially faster. The further rider must be added that on the basis of this one highly averaged test alone, too much detail should not be inferred from the results though the general pattern is obviously accurate.

The comparative time for Sink y Giedd is tabulated below but all that can yet be given in times of average rates of flow is over the whole distance, i.e. the minimum straight line distance of 4.5 kilometres (between Sink y Giedd, the Mazeways Sump and Dan yr Ogof Resurgence), which yields a figure of 0.125 Kms/hour, very close to the rates of water flow in the other known parts of the system. Two other tests of these sites, (Harvey (1948) at Sink y Giedd and Coase, Waen Fignen Felen in 1968) yielded through-put times of 50 hours for the former in "moderate flood" and 14 hours for the latter in heavy flood. As well as indicating the variations that can occur in different water regimes these figures also indicate the need for a standardising of the descriptions adopted for flow conditions, preferably by accurate calibration of flow rates by automatic recorders.

Table 1 **Inferred relationship between dye tests from Waen Fignen Felen and Sink y Giedd, Easter 1970, and time, distance and altitude**

a. Time and distance

		From Waen Fignen Felen	From Sink y Giedd
Distance from sink[1] to resurgence	Kms.	3.5	4.7
Time taken for dye[2] to reach resurgence	Hrs.	24.5	36
Average rate of flow	Kms./Hr.	0.143	0.13

However the route from Waen Fignen Felen can be further sub-divided (on the basis of the information in Fig. 22) to yield approximations as:-

a. Rate of flow in unknown section Waen Fignen Felen to Far North		0.183
b. Rate of flow in mainly vadose section Far North to Rising.		0.128
c. Rate of flow in part vadose, part phreatic section (Rising to Resurgence)		0.130

on a similar though less proven basis, from Sink y Giedd as:-

a. Rate of flow in unknown section (Sink to Mazeways)	.135
b. Rate of flow in unknown section (Mazeways to Resurgence) presumed roughly as per Waen Fignen Felen water	.130

b. Approximate Altitude differences	W.F.F.		S.Y.G.
Altitude of Sink	448		438
Altitude of Resurgence		220.5	
Vertical difference	247.5		217.5

N.B. Water level at Rising is at 265 metres, and at Mazeways 227 metres.

Footnotes: [1] In straight line terms [2] To nearest half hour

Tests at the other three sites mentioned above have been even less satisfactory but the dye introduced into the sump at the bottom of Pwll Dwfn at the beginning of the underground Easter Camp 1968 was observed to be filling the lakes on the emergence of the camping party five days later (Coase 1968) and those tests for Pwll y Wydden and the Grit Sink proved positive links to the resurgence, but no times have been recorded. A further test in the Greenstick Sink at Waen Fignen Felen is known to have entered the Tawe during a very massive and sudden flood in 1967, but although a visual sighting was recorded, by Arculus and Coase, of dye in Dali's Delight sump shortly before the flood, some doubt is attached to this because subsequent visits to the, then newly discovered, sump have shown the water to be exceptionally clear and apparently green in colour.

Relatively few internal links have been proved though it is established that the water at the sump in the southern limit of the Great North Road does resurge at the Rising (taking about 30 minutes in moderate to low water conditions); that the small stream from Hangar Extension South runs into its northern counterpart; that a similar stream in Alfrebag Passage (Coase 1966) runs into the Lakes, probably into the Waterfall Chamber between Lake One and Three (Ford 1955, 1957), and that the stream in Red Chamber descends into Cauldron Chamber in the Show Cave. Other tests have been unsuccessful notably between the tight and immature sinks beneath the Rising and Dali's Delight and between the small streams at Shower Aven and in Gerard Platten Hall. Water at both pairs of sites has very similar chemical characteristics and all are developed at or adjacent to appropriately orientated joint planes.

Interesting observations concerning the cause of the rapid changes in the chemistry of the input waters between sink and entry to the cave were being made by Bray when rather abruptly the majority of his work was transferred to the adjoining and rather more accessible Ogof Fynnon Ddu system. More work has now been done therein on the relationship between levels of hardness and organic matter content in the streamway (Bray and O'Reilly 1974b) and particular emphasis is placed upon the generation of added aggressiveness within a cave by the oxidation of the water-borne organic matter. This hypothesis had been put forward by Bray in 1972 and the work in Ogof Fynnon Ddu appears to bear it out, though no attempt appears to have been made to measure the importance of the oxidation process relative to other more "conventional" solutional processes. Its relevance to the Dan yr Ogof System is considerable, especially as the geological environments and input waters are very similar. Similar changes in total and alkaline hardness and aggressiveness are also apparent, at least in the supposed Waen Fignen Felen streamway described above (Bray 1972 and Fig. 17 above). The total and alkaline hardness figures for the postulated Sink y Giedd waters are considerably lower but this is explicable in view of the lower initial aggressiveness and presumed much lower organic content of the waters from this site.

Other implications can also be drawn from the hardness figures relating to input waters derived from the large number of moderate sized streams which are presumed to enter from active sinks rather than as true percolation water. However these figures are not always comparable, for reasons already given, and until full sets of acceptably comprehensive figures are obtained for differing groundwater conditions the implications outlined below are best regarded as guides rather than firm statements of fact. In general it might be expected that water sinking in peaty or other ground with a high organic content will be aggressive and hard, while water sinking from more barren environments, or as a result of rapid run off is likely to be softer and less aggressive. From the figures published by Bray and Newson which relate to Dan yr Ogof it would be reasonable to assume that many sites in the synclinal passages including "Lavatory Dan", Shower Aven, Straw Chamber (all Dan yr Ogof One) and Platten Hall, Monk Hall, Cloud Chamber (in 'Two) come into the former category, while those in Pinnacle Chamber (Dan yr Ogof Three), Rottenstone Aven, Dali's Delight and the 100ft Cascade (in 'Two) are from the latter. It is also possible to point out that all of the former lie under the thick drift and occasionally peat covered dry valley which occupies much of the surface along the line of the Dan yr Ogof

Plate 49 . The bouldery drift cover of much of the catchment area.

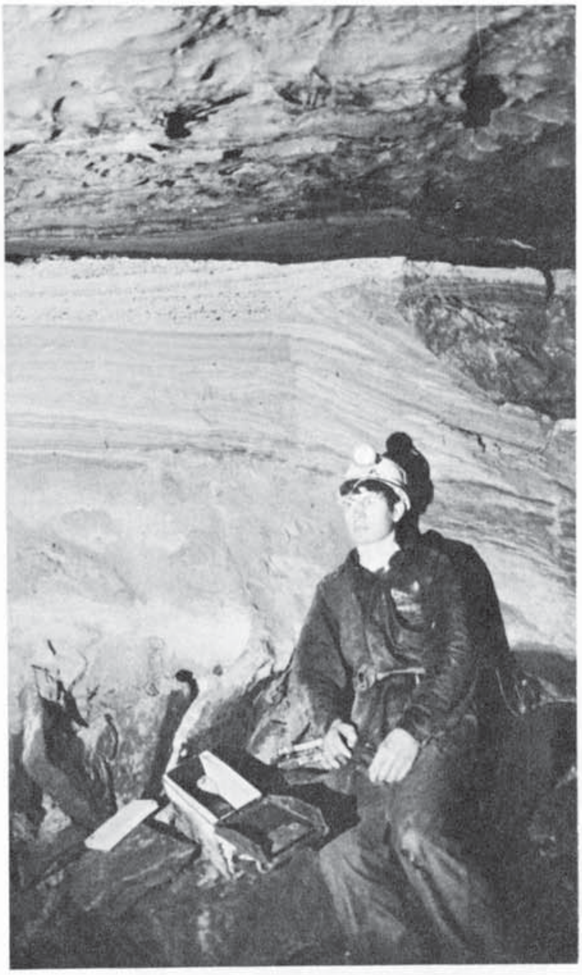


Plate 50 . Layered silts and sands in the Great North Road.

Plate 51 . Layered silts and sands on gravels, with the eroded face partly covered by later stalagmite.

Plate 52. (above) The dry valley south of Pwll Dwfn. Cribarth in the distance right of centre.

Plate 54. (left) The Nant-y-Gwared dry valley which crosses structures of the Cribarth Disturbance.

Plat e 53 (below) The gorge-like dry valley above Dan yr O gof.

Syncline, and that all but the last-named lie under rather more barren grit or solifluction cover. Certainly the existence of soil cover and "the presence of living organisms and vegetation" has been demonstrated in the laboratory by Groome and Ede (1972) to be of very great importance in increasing the hardness and aggressiveness of water entering the bedrock. However until much fuller tests are made such views should be regarded as premature and tentative and almost certainly many other factors are also influential.

Certainly also important in the underground solutional processes are the "conventional" sources of aggressiveness including carbonic acid, "strong" acids, including sulphuric acid from peat and shale sources (Burke 1967 and Stenner 1969). The importance of abrasion has already been mentioned and further emphasis is placed upon the nature of the caves' sediments below. Other possible processes or influences that almost certainly affect the erosiveness of the cave water include the relatively steep cave gradient, the very large amount of "aeration" and turbulence arising from the passage of water through the common, massive boulder chokes (which is what the entrance shaft of Waen Fignen Felen proves to be) and the very large number of significant but separate and distinctive water inputs points. These will undoubtedly create further turbulence at the point of entry to the main stream, but more significantly the mixing of such saturated solutions, leads to a further generation of CO_2 and "can result in a rejuvenation of aggressiveness by as much as 35%" (Picknett 1972). This process of "corrosion by mixing of karst waters" is believed by Bögli (1971) to be so important that "it may hardly be overstated" and certainly there are numerous examples throughout the main caves of the catchment area, of features that he has ascribed to this mode of initiation. One good example which has already been referred to exists in the show section of Tunnel Cave. This, the writer believes to be analogous to Bögli's "girlandengang" and certainly the consequent development of formations in the solution pockets seen there appears almost of textbook form. These features are well displayed in the postcards commercially available at the Show Cave.

Past water flow underground has undoubtedly undergone many local changes of route, level and direction and certainly anomalies, such as the Green Canal, exist and are hard to explain. However there is no evidence of major reversals of flow to judge from the evidence offered by existing flow or current markings, passage sections and gradient. Indeed the evidence of flow directions obtained from wall scalloping is very clear in most parts of the cave.

D. Cave Sediments

Frequent reference has been made throughout the preceding sections, to the range and character of sediments in the cave. Unfortunately little analytical work has pursued in this direction for the first few samplings and the relatively meaningless results that they provided, made it clear that a full-scale study covering a very large number of samples and a major commitment to laboratory analysis would be essential before results of real significance could be obtained. This aspect of the geomorphology of the system merits detailed study along the lines outlined by Ford (1974) and Bull (1975) although Newson (1970) did initiate some studies, mainly in connection with the influence of sediments on mechanical erosion in the cave. The results of this work, showing that abrasion was especially important in flood conditions, has already been discussed, but it is to be hoped that further studies will follow for there are few cave systems in the British Isles with as much variety or sheer volume of sediments as within the Dan yr Ogof catchment area. All that the writer can provide here is a very superficial description, but it is hoped that this will (again) provoke interest and hopefully initiate much more systematic and analytical investigation.

The turbidity of most of the waters in Dan yr Ogof is a marked feature with the most commonly encountered sediments being sands. These exist in almost all parts of the system but are outstanding in Dan yr Ogof Three where they are frequently found in well bedded deposits which may have originated through impounding perhaps by collapse and then deposition of the "settling-tank" nature described by Ford. (Plate 48) though others offer deltaic characteristics. In some locations calcite drip-pockets or "calcreted drip-pot formations" (Bull 1974) of a type very easily seen in the "Museum" of Davy Price's Hall, Tunnel Cave, are frequently found within the sands. Calcite flows are sometimes found on top of them (Plate 49), thereby implying that deposition occurred some considerable time ago. Wide variations also exist in particle size and mode of deposition, attention having been drawn at a very early stage (Coase 1967) to thin "loess-like" deposits of silt on boulders in Hangar Passage and its extensions.

In Mazeways One, Bakerloo Straight and the end and centre sections of the Show Cave (nearest the Lakes and above the lake at the Parting of the Ways) very large quantities of very pure, washed sands are usually deposited after most floods. Early tests proved the roundness of these sands long before the analyses performed by Newson for the cave management are still dismayed that the sands are unsuitable for concrete. The quantities are massive with several hundreds of tons having to be removed when the cave was re-opened in 1964 and each successive flood has introduced anything up to 50 tons into the commercialised sections (A. Price, personal communication 1975). Occasionally an alternative deposit of sludgy peat with very little sand occurs, usually after a flood which is the first for some time, the implication being that peat deposits are likely to be carried further through the cave in times of lower flow than are sands. However an alternative cause could be a very sudden, but brief "flash flood" which could carry a large amount of peat through the system via the Waen Fignen Felen route.

The deposits of coarse red sand or thin coatings of red clay which occur in many passages throughout the area are frequently overlaid by finer, light brown silt and sands, and it is hard to escape the conclusion that an early fill stage consisted of these coarser materials and was followed by a subsequent fill of lighter and smaller particles. These could be from different horizons within the same Devonian rocks and/or, as Ford

(1974) suggests, may result from minor changes in flow and depositional conditions which arise from differences in surface drainage. Clearly, careful plotting of the different types of deposit, coupled with an analysis of its contents, is likely to lead to an interesting and possibly significant pattern. So far no examples of what Bull (1974) describes as "Birdseye" structures have been observed.

In a few areas, notably near the present stream sink in Highway and in one or two points in the Great North Road streamway, some extremely sticky red clays are encountered which produce a very cloudy and colourful ochreous stain in the water after passing across them. In dry sites they ooze, plasticine-like, into a series of contoured terraces. Elsewhere clays are comparatively rare, although in parts of the Lower Series, particularly between the Abyss and Bakerloo Straight a dark coloured clay, peat, sand mixture forms the floor for considerable lengths of passage. In places it was initially very thixotropic, notably in the passage of that name, although constant traffic has fined out the sands.

Other clay deposits are found as part of massive boulder chokes, notably in Avalanche Corner, where it is hard to escape the conclusion, despite Ford's warning (1974) about solifluction materials, that this is glacially plugged material which has been forced into the system via a pothole open to the surface.

Limestone material derived from internal collapse, undercutting, etc. is widespread throughout the system and varies from enormous boulders weighing many tons in the Great North Road and Avalanche Corner to much smaller pebbles, gravels and cobbles found in almost all of the streamways. Other sites have been described extensively and the majority of the larger collapse or choked areas are evident on the cave survey.

The exogenetic materials introduced via the principal input points at Waen Fignen Felen and Sink y Giedd have been mentioned at considerable length and the nature of such deposits can also be gleaned from the many plates. In Tunnel Cave some similarities also exist and attention has already been drawn to the thick and relatively coarse sand deposits on the floor of Davy Price's Hall, (Plate 28), whose general characteristics are echoed by those of Square passage in D.Y.O. 'Three. A particularly good site to view and sample these deposits is on the "beach" at Lake One (non-existent in even minor flood conditions) where a very wide range of sizes and materials is available. Other notable areas are in Monk Hall, where several ledges contain what may be lag deposits of cobbles and gravels set in stiff red clay, as well as in the very photogenic area, known as Candlewax Passage, just before the Monk at the far end of the Grand Canyon.

Certainly the Dan yr Ogof systems contain evidence of several sequences of deposition of fluvioglacial sediments. The present stage clearly includes a great deal of material which is still being carried in to join with other endogenetically derived material being obtained as a result of present and past undercutting and collapse and abrasion. Many of the existing sediments are being re-worked but in many of the upper main passages, especially in Tunnel Cave, and in the '37 cave, but also in 'Two and 'Three, large amounts of sediments remain undisturbed except for the efforts of exploring cavers and with respect to these, it must be added that urgent taping is necessary.

E. Relationship with the Surface and Related Surface Features

Some observations concerning the relationship between the cave and the surface are also relevant, the more so as the subject of dolines and swallow holes as indicators of cave systems has long been a controversial one in South Wales and elsewhere, and as the character and origin of the main dry valleys is a matter of considerable interest but hitherto has barely been remarked upon.

a. Surface Depressions

The most detailed investigations on the solutional depressions have been carried out by the late T.M. Thomas and four of his works are particularly relevant. Two were published in 1954 and the others in 1963 and 1974, although references are also contained in other papers he produced on the area. Apart from brief references in early papers on Dan yr Ogof (Coase 1967) and Ogof Fynnon Ddu (O'Reilly et al 1969) the only other paper of significance relating to the topic in this area is that of Hartwell and Jones in 1964.

On the Carboniferous Limestone above Dan yr Ogof One and Two there is undoubtedly a close relationship between surface morphology and the cave passages. At its most obvious between the resurgence and just south of Pwll y Wydden Fach, (at 828150) there is clear evidence that both cave and solutional depressions are closely related to the Dan yr Ogof Syncline and many, though not all, of the latter can be directly related to underground boulder chokes or collapse areas (Fig. 4). The most obvious example is the very large and deep doline, known locally as the "Crater" (Plate 42) which has been proved by radio-location tests, to lie directly above the Long Crawl and the Platten Hall/Shower Aven 'chokes. Other correlations between surface depressions and underground 'chokes can be observed from Plan A with particular emphasis being apparent between parts of Dali's Delight and possibly A2 Chamber and Pwll y Wydden Fach.

The general conclusion reached by Hartwell and Jones after extensive field plotting on Pant Mawr and Mynydd Langattock, was that there was no significant increase in the number of, or obvious correlation in the pattern of, solution hollows over known caves in those areas. Thomas in the last paper on inter-stratal karst (1974) similarly concluded that Dan yr Ogof, as far as it was explored, did not lie under the Basal Grit and could not be directly responsible for the solution depressions thereon. In this he was misled by Weaver's 1973 paper for Fig. 1 and Plan A show that the cave does run under the Grit escarpment for some distance and the direct relationship implied in his earlier writings does exist. In fact the map published in his 1954b. paper shows a remarkably close relationship between the cave location and specific belts of large and medium sized swallow holes. The observation can be seen as particularly prophetic when it is borne in mind that only a small proportion of the caves had been discovered at the time when the paper was prepared, and the probable directions of further discoveries are certainly close to the writer's own views. The continuance of the northern parts of the belt in a north to north-northwesterly direction is appropriate to the known links to Waen Fignen Felen, and Tunnel Cave although then only recently discovered and not surveyed for some years, also closely coincides with another belt north of the Dan yr Ogof resurgence. Finally from this map, the marked assemblages of medium sized swallow holes around and in a belt to the south of Sink y Giedd is very significant.

In the same paper Thomas made some tentative calculations about "the maximum size of the caverns whose collapses have produced the larger swallow holes" and his conclusions were that to produce the large almost perfectly circular swallow holes the "initiating caverns must have been of greater width than the Main Chamber of Gaping Gill". This width of about 26 metres has not in fact been reached in the known cave but many of the passages are extremely wide and these widths are continuous, unlike the dimensions of a chamber which usually relate length quite closely to width. Obviously too, the observations made concerned chambers which had collapsed, and while many massive underground collapses and chokes are known, by their very nature none can be measured.

Elsewhere on the Basal Grit, Thomas in his 1974 paper, shows the greatest number of collapse dolines to lie where the cover is less than 30 metres thick above the Carboniferous Limestone though others are recognised where this thickness could exceed 100 metres. The larger examples are plotted on Plan A and reference has already been made to the appropriate photographs, (Plate 47). It is also possible to envisage hypothetical drainage routes between Sink y Giedd and the Dan yr Ogof Syncline by relating the pattern of these Grit depressions to the known fault lines and the known ends of the link. However in this early state of knowledge about the Giedd no firm suggestions can be made with any real authority.

To conclude, there is without any shadow of doubt, a close relationship between the location of many of the surface depressions and underground cave passages in the Dan yr Ogof catchment area.

b. Dry Valleys

During the Pleistocene it is clear that at certain periods water ran over the surface of the Carboniferous Limestone and cut a number of valleys which are now unoccupied by water even in the wettest conditions. These valleys may have been initiated at a time before the caves were sufficiently developed to take the increasing quantities of run-off water which typified certain stages in the Pleistocene, and re-occupied when excessive run-off in periods of glacial retreat produced the same effect. Alternatively they may have been initiated when solifluction deposits blocked entrances or when the soil and sub-soil were frozen. A further possibility is that they were direct drainage from glacial lakes or sub glacial streams but the orientation of the main dry valley, that from Waen Fignen Felen depression to the gorge above the Dan yr Ogof resurgence, known for convenience as the Pwll Dwfn Dry Valley, is suggestive of more normal fluvial development. (Plan A and Fig. 4).

Above, and until just south of, Pwll Dwfn, the valley is usually shallow and gentle sided (Plate 52) but as the two further photographs show (Plates 53, and 54) a little further to the south it becomes steeper and (from 835161) gorge-like. Near this point the valley is crossed by a major fault above which is a small cave with a spring and approximately at the line of the fault there is an area of collapsed boulders in its floor. Significantly these are at the southern end of two lines of surface depressions which continue for some hundreds of metres slightly east of north (and slightly west of Tunnel Cave).

From this point the dry valley turns abruptly south for 50-60 metres and then as rapidly east becoming a true gorge. The aerial photographs (Plates 1 and 52) suggest that this could be as a result of a surface stream entering and exploiting a major collapse depression of the scale of the Crater. The latter photograph also conveys this same impression for the area immediately above the resurgence and by the scree slope described elsewhere. However the gorge at these points is well wooded and the fore-shortening effect of the oblique angle may be misleading. Certainly the gradient increases markedly and the gorge eventually ends as a hanging valley with a major rock step down onto the quite extensive and somewhat puzzling scree slope.

There are several tributaries to this dry valley, one being evident to the north of Pwll Dwfn itself, but of more importance is the dry valley to the south which runs past the standing stones at Saeth Maen, before entering a similar gorge-type section above the Nant y Gwared farm (839155). The profile and plan of this valley are also seen respectively on Plan A and Fig. 4, and the gorge section is particularly interesting as it crosses the faults and folds of the Cribarth Disturbance at right angles, (Plate 54). Like the lower parts of the Dwll Dwfn Dry Valley it runs just south of east unlike the adjoining valley occupied by the small entrenched Nant y Gwared stream which runs almost due northeastwards along the line of the Garth Gwared Fault.

This dry valley, called for clarity the Saeth Maen Dry Valley, after the seven stones at 833154, is generally shallow and runs from the present watershed with the Nant y Ceiliog about 700 metres to the southwest, in a roughly northwesterly direction until it swings abruptly to the east and then just south of east through the gorge section which has already been referred to. Until this sudden change in orientation the valley closely follows the Dan'yr Ogof Syncline (and cave passages) although there is no indication that the valley ever continued towards the resurgence itself. There is also a close relationship between the lines of surface depressions already referred to, and the main line of the dry valley, but the former continue along the line of the cave and syncline and do not deviate to the east either. It is accepted that there is no evidence for the very early views held by the writer that the dry valley might be a relic of an earlier resurgence from the cave, possibly from the Upper Monk Hall area and it is also worth emphasising that the dry valley does not impinge on the sides of the Crater (834156).

The relevance of the nature of the Saeth Maen dry valley and its origin is made clear when it is recognised that it draws close to the Cribarth ridge at its southern end and terminates approximately above the Cribarth Passages in Dan yr Ogof Two. It has been suggested elsewhere that these may have developed from

Fig. 20. Tentative correlations between the development of the cave system and Middle to Late Pleistocene stages.

PERIOD	STAGE	Period in years before present	LOCAL NAME OR CHARACTER	CLIMATIC CONDITIONS	MAIN DEVELOPMENTS IN AREA	POSSIBLE EFFECTS ON CAVE DEVELOPMENT
POSTGLACIAL	PRESENT			Fluctuating but broadly Cool Temperate and wet	Continued downcutting. Peat deposits eroding.	Mainly misfit streams reworking fluvioglacial deposits. Increased organic content from peat - growth in aggressiveness.
	FLANDRIAN	5-8000 B.P.		Sub Boreal : Fluctuating temparatures	Slight marine transgression Peat and lake deposits - poss. drainage deviations Alluvium	Waen Fignen Felen depression occupied by peat bog. Possible effects on resurgence location. Considerable introduction of and reworking of deposits.
				Moderate to Warm Temperate	FINAL LOCALISED DRIFT & PERIGLACIAL DEPOSITS	Increased run-off from corrasive melt water. Fill stage?
PLEISTOCENE Late	DEVENSIAN (WURM)	10-12000 LATE Zone iii	Corrie Glaciations	iii. Sub-Artic → Final Cold Phase	iii. Final period of surface run-off on frozen sub-soil.	iii. Periglacial deposits (solifluction) Little solution. POSSIBLE CAPTURE OF UPPER HAFFES? Backcutting of Llynfell?
		Zone ii		ii. Boreal-Temperate → Warmer Interstadial	ii. Aggressive water - increased vegetation.	ii. Increased run-off from aggressive streams. Considerable cave development.
		Zone i		i. Arctic-Sub-Arctic → Fluctuating, poss. Interstadial	i. Periglacial conditions	i. Fluctuations between fill and aggressive water stages and surface stream flow.
		26000 MIDDLE	Paviland Interstadial	Boreal → poss. Sub.Arctic	Sea level fluctuations	Base level fluctuations and some rejuvenation
		50000 EARLY	Margam Glaciation	Arctic. Initially fluctuating with Interstadials.	NEWER DRIFT. Extensive glaciation from Beacons with considerable drift and morainic material. Downcutting of Tawe Valley.	Glacial and per-glacial conditions, Some plugging of caves & potholes & solifluction deposits. Little solution.
	IPSWICHIAN (EEMIAN)	75000	Minchin Hole Interglacial	Generally Warm Temperate but fluctuations - Cool Temp.-Boreal	Fall in sea level - major river rejuvenation especially including Haffes.	Tunnel Cave loses headwater? Rejuvenation - lower HAFFES CAPTURED? Aggressive water & corrasion. Caves well developed in basic form. Consid. run off, corrasive melt water & solifluction deposits. Introd'n of early cave fills.
	WOLSTONIAN (RISS/SAALE)	130000	Pencoed Glaciation	Arctic-sub Arctic	OLDER DRIFT. Extensive glaciation, sea level low. Downcutting of Tawe Valley.	Periglacial condits. surface drainage, drift deposits & solifluction active. Caves relatively quiescent, possib.plugged.
	HOXNIAN	150000	Gower Beach Interglacial	Temperate	Rejuvenation of main rivers, possibly Haffes begins to cut back more significantly.	Considerable Cave Development with downcutting commencing.
Middle	ANGLIAN (MINDEL)	240000	(Ante-Penultimate ? Glaciation on Continent)	Cold-sub-Arctic	No evidence of glaciation.	Abrasive sediments. Little cave development/solifluction deposits etc.
	CROMERIAN	310000	Interglacial	Temperate	Possible fluctuations in base level and rejuvenation	Presumed period of cave development
	BEESTONIAN (Gunz)	340 000	? (Early glaciation on continent)	Cold	No evidence of glaciation.	Presumed period of only minor cave development.

water sinking steeply from Cribarth and if this is the case then the origin of the dry valley would seem to be due to surface flow over the limestone when the sink was drift-filled or the sub-soil frozen. The likelihood of this being a fairly late occurrence is heightened by the steepness and northwesterly aspect of Cribarth which is likely to have encouraged the late survival of ice or snow patches.

Both dry valleys are floored with drift in their upper sections, (Plate 42) but that at Pwll Dwfn has numerous small but open jointed limestone fissures within and adjacent to it and in places, i.e. just above the resurgence at 834162 a small stream can sometimes be heard flowing beneath the drift. The Saeth Maen valley appears to be more thickly buried in drift and the characteristic interruption to its "course" are numerous, very steep sided, deep dolines. Some of these occasionally accept running water and several have bare rock exposures at their base, including one in the southwest with a small cliff and scree deposits. Both offer prospects for further investigation.

F. Evolution and Chronology of the Cave System

Any attempt to identify the stages in the development of the cave and to relate them to a denudation chronology can only be done with diffidence at this time for there are many more unknown than known variables. This reconstruction is therefore attempted with this point in mind and the hope that further evidence will become available to fill in the more obvious gaps.

Apart from the tentative dating of the initiation of the present course of the Tawe and the knowledge of the extensive rejuvenations of the Haffes and other tributaries within, respectively, the early and later stages of the Pleistocene, very little can be definitely stated about the evolution of the system. There is no indication of separate levels in the cave which can be related to distinct stages of valley down cutting, as has been shown in Yorkshire by Sweeting (1950) and Waltham (1974) and although a similar suggestion has been made for Ogof Fynnon Ddu by O'Reilly (1974) no detailed sections or altitudes have been published and such observations can only be regarded as preliminary. The fact also remains that in Dan yr Ogof there is no evidence from passage profiles, etc. to suggest that anything but local or minor fluctuations in levels exist and there are no distinctive levels which can be shown to relate to markedly different resurgence positions or altitudes.

The tentative outline attempted below (and summarised in the table, Fig. 20) is based on a number of sources including West (1968), Lewis (1970) and John and Ellis-Gruffydd (1970) with possible correlations to the caves' history added by the writer. Among the relatively obvious items of evidence used in support of the chronology outlined is the knowledge that there were a succession of ice advances, retreats, inter-stadial and inter-glacial periods. These were associated with climatic conditions ranging from the Warm Temperate in the Ipswichian Interglacial, through the Boreal and Sub-Arctic to Arctic. The latter prevailed in the main periods of ice advance, notably in the Wolstonian and in the early, and possibly also in the late, Devensian. Each of these climatic variations had its own associated characteristics and those which affected rate and character of run-off; the aggressiveness and organic content of the water; the amount of exogenetic materials carried underground; or those as in periglacial conditions, which may have totally inhibited movement of water underground; are all exceptionally important to this chronology.

These points have been elaborated by Warwick (1971) who particularly emphasised the effects of extreme cold in reducing vegetation cover and increasing scree formation and solifluction deposits. Possibly even more significant was the effect of greatly reducing the aggressiveness of water flowing underground, a situation that was reversed in interglacial, and, to a lesser degree, inter-stadial periods. Similarly in such warmer periods there would be, initially at least, considerable increases in the amount of meltwater flowing underground and carrying with it large quantities of outwash, drift and solifluction materials. Thus there would have been considerably increased corrasional as well as solutional effects. Furthermore Warwick stresses that "changes in sea level which accompanied the Pleistocene climatic changes" were almost certainly "the most important indirect effect of the Ice Ages". The evidence of the Dan yr Ogof system certainly confirms this view.

The following outline chronology is accompanied by a series of figures outlining surface and underground drainage developments but these, like Fig. 20 are very much open to modification especially in the earliest stages of the Pleistocene. (Figs. 21-23).

a) Initiation

In Brown's view (1960) the Tawe was initiated into its present course in one of the earliest interglacial periods of the Pleistocene and the probable pattern of drainage in the catchment area at this time is shown in Fig. 21. It is thought to have consisted of a fairly simple series of subparallel consequent streams flowing down-dip in a direction just west of south. Most, because of the lateness of the development process, are assumed to have occupied courses very close to those retained by their upper sections today but the Tawe itself was rapidly adapting to the fracture zone of the Cribarth Disturbance and took a more varied course.

Most of the consequents are thought to have entered the limestone at an early stage and initiated cave development, for their waters would have been aggressive and they may have carried underground considerable quantities of solifluction and other debris. A few streams may have continued their courses over the surface of the limestone, due perhaps to a blanketing of certain areas by solifluction and other deposits, however surface valley forms, such as those which persist today as dry valleys, are thought more likely to have developed relatively recently.

Underground the development at this stage is likely to have been one of numerous small phreatic tubes developing from the many diffuse input points. Percolation as well as discrete stream water would have been present from these earliest stages, but the latter supplies are considered likely to have been instru-

THE EVOLUTION OF THE DRAINAGE PATTERN

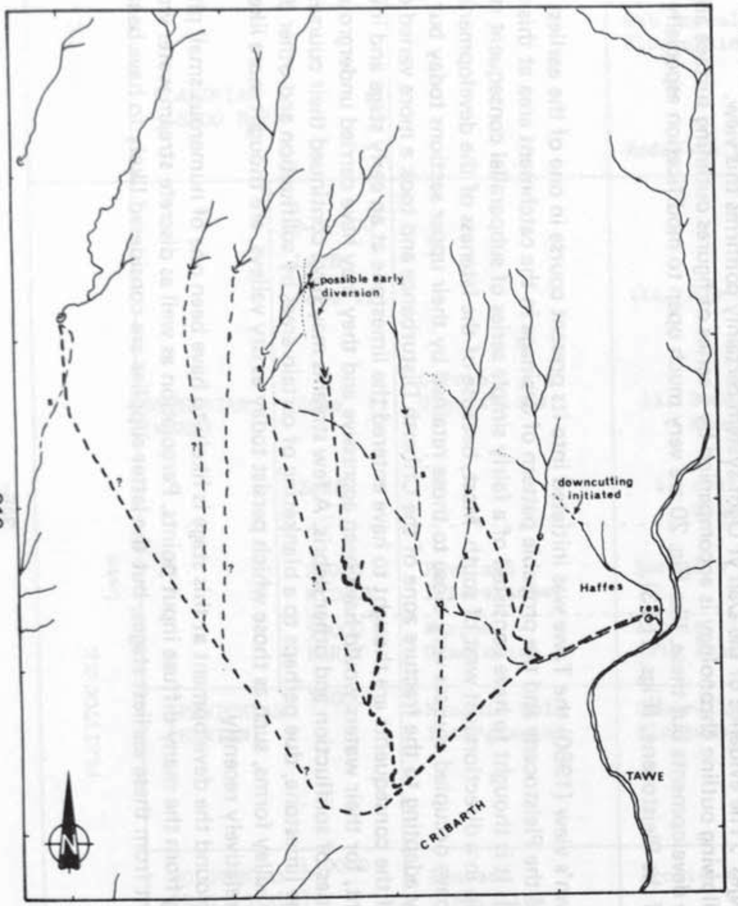


Fig. 21. Probable drainage pattern in the Early to Middle Pleistocene.

KEY

Underground:

Probable pattern.

" " " known route

" " " hypothetical route

Surface: Occasional surface drainage routes

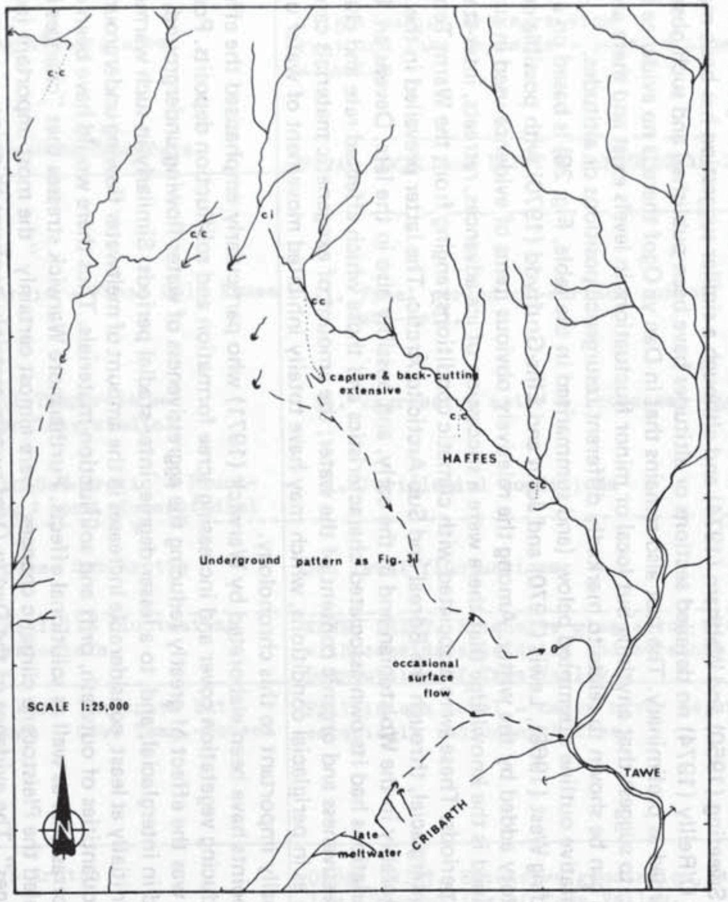


Fig. 22. Surface drainage in the Late Pleistocene.

c.i. River capture imminent

c.c " " complete

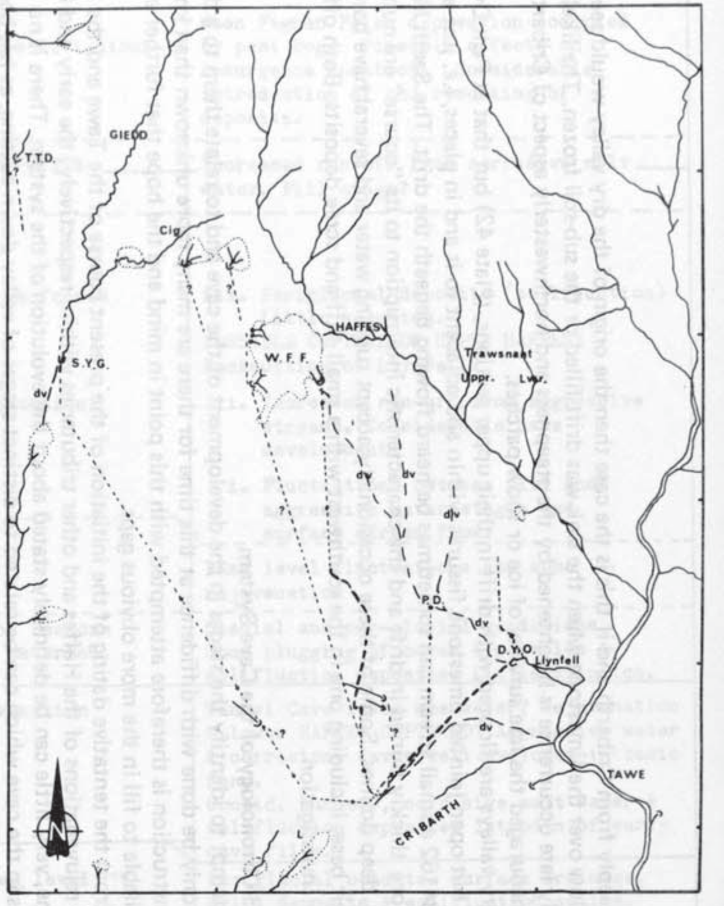


Fig. 23. The present drainage pattern.

KEY.

Underground:

Link unproved, route unknown.

" proved, " unknown.

" proved, " known.

Surface: dv Principal dry valleys.

see key Fig. I. for initials

mental in creating sizeable routeways quite rapidly, partly because of the aggressiveness of their waters, partly because of their abrasive load, but also because some rapidly adapted to major lines of weakness which coincided with the direction of dip. The basic framework of the cave pattern is believed to have developed in this earliest phase which is assumed to have preceded or ended with the Pencoed Advance.

b) Development

The chronology of development subsequent to the initiation is closely related to the succession of major ice advances, retreats and inter-glacial and inter-stadial stages. The relationship is best seen from Fig. 20, but can be summarised as two major glacial advances, the Pencoed or Older Glaciation of Riss/Wolstonian correlation and the Margam or Newer Glaciation of Wurm/Devensian age, divided by the important Minchin Hole or Eemian/Ipswichian Interglacial. Within the period it is suggested that the basic framework of the caves is considerably re-inforced and extended with, on the surface the continued down cutting of the Tawe valley, the rejuvenation of the Haffes and the subsequent beheading of most of the main input streams. The following post-glacial period is discussed separately below, though viewed objectively it could be regarded as sharing the characteristics of an inter-glacial stage.

The earliest sequence which was responsible for the further development of the basic framework of the system occurred during the Older or Pencoed Glaciation and the subsequent Minchin Hole Interglacial. The latter, with fairly high rainfall, and, at times, warm temperate conditions is regarded as being of particular importance. Subsequent developments associated with base level changes conspired to rob first Tunnel Cave and then much more recently the Waen Fignen Felen-Dan yr Ogof Three passages of their main stream, (Fig. 22). The latter shows far more subsequent development than most parts of the former and it is likely that it, and perhaps the upper parts of Dan yr Ogof One never developed the maturity of size and form that typify the further passages. It is probable too that the main sand-fill stage contributed greatly towards the development of the passages in the Great North Road and Far North. This being thought to have occurred at a very late stage which post-dated the truncation of Tunnel Cave and only just pre-dated the loss of the main stream from Waen Fignen Felen, (Fig. 23).

Thus the capture of the lower north bank tributaries of the Haffes, (the lower and upper Trawsnant streams), is seen as occurring possibly in the early aftermath of the Pencoed Glaciation, but certainly before the Margam ice advance. The capture of the upper headwaters could have arisen at the latter time, though it seems more probable that this could be related to the Paviland Interstadial or the minor ameliorations that occurred in the late Devensian.

So far however this account has not considered the possible chronology of the Cribarth Passages, and these, as has been implied above, could have had an important part to play, particularly in the development of the main Upper Series of 'Two. Attention has also been drawn above to the possible significance of the Saeth Maen dry valley and it is noteworthy that most of the speleothems in the relevant passages (Hangar Passage and its extensions, Cloud Chamber, Monk Hall and the Grand Canyon) are of an active and youthful form.

It is almost certain that water flowed into the system from the northern side of Cribarth and though any projected chronology has to be expressed tentatively, it seems likely that the major developments of these passages was fairly late. If the theory that these passages are totally attributable to Cribarth drainage proves correct, then it must have been associated with considerable quantities of very aggressive and possibly highly corrasive water. Alternatively these may have invaded a pre-existing passage and their contributions may have been short term and limited, first to a considerable inflow of aggressive water, and secondly to a considerable infill stage of solifluction and/or other fluvio-glacial materials. At a stage subsequent to this, collapse has occurred in several areas and it is this which makes assessment of the alternative hypotheses difficult.

Positive proof of an earlier contributor to these passages from an alternative source is likely to come only through the discovery of a major passage continuing westwards along the syncline, most likely through the first Hangar Passage boulder choke, (Plate 20). This the writer considers quite a strong probability, for the collapse in this area is extremely broad and the upper and more northerly parts bear little relation to the discovered route to the Extensions. If such a passage exists, however, further reservations have to be offered as to its source, for while it may be a high level upper series relating to the Giedd Series, it is considered quite likely that it will prove instead to be the other end of a massive, choked meander starting in A2 Chamber and representing drainage from Dali's Delight and the Upper Far Series of 'Two via the Abyss.

The possible chronology of these developments is difficult to establish though they are likely to be recent. Given the sequence as initially outlined it seems possible that the major period of development might have been the Paviland Inter-Stadial with subsequent further erosion followed by fill and collapse stages associated possibly with the late inter-stadials stages between the corrie glaciations. If however the passages do relate to the Giedd then their period of initiation and development is likely to be much earlier.

c) Post-Glacial Developments

These relate to the period dated variously as commencing between 10,000 and 12,000 years B.C. Thomas in his paper on limestone pavements (1970) makes a particularly good case for the former date, a view accepted by the writer as are Thomas's other views about the extent of glaciation in the later periods of the Pleistocene.

The main effect on surface and underground developments in the area was the resumption of "normal" karstic drainage after a period of fluctuating glacial and periglacial conditions. The aggressiveness of the waters is presumed to have risen with temperature improvements and again there would have been a considerable in-

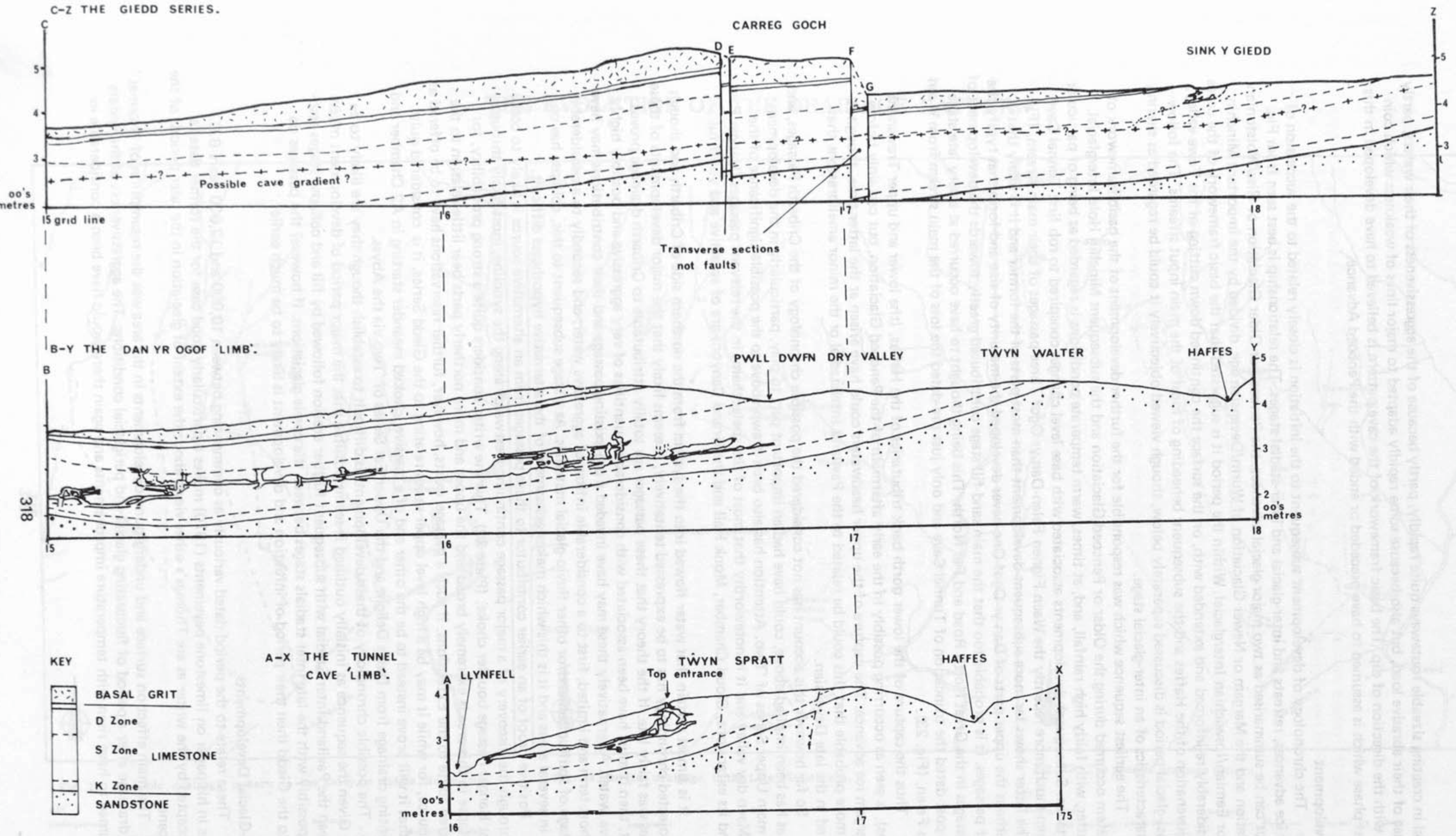


Fig. 24. Longitudinal profiles of the three main "input limbs" in relation to surface morphology and limestone lithology.

crease in the amount of exogenetic sediments carried underground. However only one of the main input systems was still functioning and the other main passages were either almost totally decapitated, as with Tunnel Cave, or else supplied by small pirate or misfit streams as in the case of Waen Fignen Felen-Dan yr Ogof Three. (Fig. 23).

The development of extensive peat deposits, about 5-8,000 B.P. in a number of the surface depressions was also significant in a number of ways, notably in the recently abandoned Waen Fignen Felen depression which Thomas (1959) regarded as a vast area of solutionally lowered Basal Grit and for which Jones, J.C. (1966) developed an elaborate evolutionary theory. While the peat is now eroding rapidly, the implications of this and similar deposits, are important to the current and recent phases of the caves development, for as well as increasing the organic material content of water flowing from the bog, it increased the waters initial aggressiveness and acidity. Furthermore by increasing the storage capacity at former stream input points it increased the probability of 'flash-floods' and these in turn have been shown to be of considerable importance in corrasional terms.

There will almost certainly have been other results, including the plugging of certain previously important input sites or possibly diversions of drainage, as for example in the Sink y Giedd area. No peats have been found underground which were interbedded with other deposits and which might therefore have provided reliable evidence for dating. However their non-existence (and the evidence of the superficiality of the existing peats) does provide an indication that their introduction is a late one which post-dates the introduction and deposition of other exogenetic sediments.

The small post-glacial rise in sea level, known as the Flandrian Transgression is thought to have had relatively little effect on the area or on the caves for it is believed that the valley floor had almost certainly been lowered considerably below the resurgence level prior to this. The difference in levels between Show Cave and River Cave which Weaver referred to in his thesis, being more explicable in terms of the much earlier development of the former at a time when the resurgence was located further to the northeast. The greater age certainly appears to be confirmed by the more massive calcite flows apparent in the Show Cave.

d) Summary

A brief summary of the above suggests:-

1. Initiation as a complex network of small phreatic tubes resulting from the sinking of at least three separate groups of streams.
2. Development by these streams, including enlargement by corrasion as well as by solution, basically on a down-dip pattern until obstacles caused deviation. (In the case of the streams sinking underground nearest to Cribarth this implied a straight-line distance of only a kilometre or so, but those to the west were several times this distance).
3. Fluctuations in quantities and characteristics of input water and associated sediments led to marked stages of growth and stand-still, to adaptations to lower base levels (see 4 below) and consequent vadose entrenchment, and to increasing amounts of bedding collapse.
4. Downcutting and river capture as a result of external base level changes and internal re-adaptations meant the loss of principal input waters, initially in the east, later in the centre and potentially to the west in the future.

At least three main input limbs can therefore be identified as a result of the underground drainage pattern and their long profiles are shown in Fig. 24. Their development and relationship to the Dan yr Ogof Syncline was however unequal and uneven. Thus:

(a). The Tunnel Cave limb, the eastern-most and shortest of the principal feeder systems and the one which first truncated, is relatively high in the bedding of the S_2 zone; is comparatively immature in form; shows little but short-distance fluctuations in gradient and relatively little sign of any distinctive levels associated with major changes in base level. Its level of entry to the syncline is considerably higher than the resurgence, but is, significantly, almost identical to the level at which the Far Series of 'Two enters it at the Abyss (257m. and 260m. respectively).

(b) The unit consisting of Dan yr Ogof Three and the Far Series of 'Two (and co-incident with the Fault-Aligned Unit already delineated), contains fairly extensive evidence of a large and complex series of high level tubes with many similarities to Tunnel Cave (one in fact being named after it) as well as massive vadose and phreatic passages. These are often closely associated with faulting, and corrasion as well as solution has played an important role. Its relationship with the main passages of the Syncline is an ambivalent one for though the gradient coincides very well with the Upper Near Series of 'Two there is little evidence to suggest that the actual link, via the Green Canal, is anything but a relatively late act of underground piracy. The more obvious link, via the Abyss, shows a very marked lack of concordance with the pre-existing lower series.

(c). The third limb is the almost totally unknown Giedd Series, though this may consist of several rather than just one, discrete series. These also enter from the north, possibly associated with such major fault lines as those adjacent to Disgwylfa and Carreg Goch. The one known characteristic of the unit is that its principal sink at Sink y Giedd is markedly different from the other existing major input points. It is near the southern limit of the Limestone and in the D_2 zone, whereas they are near the northern margin on S_2 beds. This may or may not be a point of great significance for there is evidence both on the surface and underground that the actual point of the sink may be relatively recent. More important is the fact that by the time that the system is re-encountered in the Syncline, it has 'graded' virtually to the bottom-most beds in the S_2 zone. Nothing can be positively asserted, as yet, about the existence of a significant upper series, for that known in the upper parts of the Syncline may be the result of earlier Giedd developments or be due to the much more local Cribarth or A2/Highway Links discussed above.

G. Conclusion

It is clear that foremost among the reasons for the development of the Dan yr Ogof caves to their present form is their favourable geological setting and the recent climatic history of the area in which they are located.

Geologically their relationship with neighbouring impermeable strata and the relatively gentle and consistent dip of the limestone, coupled with the intensive folding and faulting of the southwestern boundary of the catchment area all contribute to an extremely favourable location. On a more local scale the near coincidence of dip with the major directions of faulting and jointing and the controlling influence of the Dan yr Ogof Syncline on the main conduit passages are factors of major importance. The influence of faulting has been shown as extensive and profound and it is clear that the existence of parallel faults in the area has contributed considerably to the form and size of many of the passages as well as to their orientation.

Lithologically the almost complete containment of the known cave developments within the S_2 zone has been frequently emphasised. Equal emphasis has also been placed on the fact that most passages appear to be adapted to hydrological rather than to local lithological influences. It should not however be overlooked that passages in the lower and more active levels are closely related to the structure and lithology of their containing beds. There also appears to be a relationship between the complex network of early high level phreatic tubes and the approximate boundary between the upper and lower parts of the S_2 zone.

There is a marked variety in the form and development of the main north-south contributory passages compared to those of the syncline and the lack of adjustment between them is also very apparent. The contrast between the two known joint-aligned limbs is also considerable and when access is finally achieved to the third one, a unique opportunity should be available to study a major cave system with three major parallel branches each with many features in common, but each, for external reasons, at different stages of development. Even today the contrasts between the main limbs offers much valuable information to speleologists and geomorphologists and it is earnestly hoped that some at least of the possible lines of further study outlined above will be pursued now that the basic structural thesis is available. Particular benefits should emerge from more detailed hydro-geological studies and from work on sediments and on speleothems, especially if newly developed dating techniques can be applied to the latter. Hopefully these will provide fuller details to aid in the clarification of the chronology outlined, as too will a much more detailed analysis of the structure of the different limestone beds, particularly aimed at determining whether there are any significant relationships between micritic and sparry limestones and cavernous development (ref. Sweeting 1972).

The evolution of the caves and their development, for the most part within the framework of the Pleistocene period, is also of great significance for however ideal geological conditions might be, water is the essential agent in the process of cave initiation and development. In this part of Wales relief is comparatively high and climatic conditions are such that precipitation is, and has in the period under discussion, always been towards the upper limits prevailing. This and the succession of glacial advances, retreats and stands which were coupled with extensive periods of warmer, wet conditions have contributed to large quantities of water much of which has found its most favoured hydrological route to be a subterranean one.

The chemical characteristics of, and the organic and clastic materials transported by, the input waters have also played a very important role in the development of the caves to their present character and size. Although comparatively young the systems have developed a large and mature form because of the aggressiveness and abrasiveness of their waters coupled with their variety in both origin and flow rates. The latter, both in the short term, as floods, and in the long term as major fluctuations in quantities of precipitation and in run-off conditions arising from the varying climatic stages in the Pleistocene, have been particularly significant. The importance of the introduction of the clastic materials has already been stressed but it is also worthy of comment that Gams, showed that the largest Slovenian caves were found where input waters contained "pebbles and coarse debris". (Sweeting 1972). This fact coupled with high initial rates of aggressiveness and the subsequent undercutting and block breakdown, is held to be partly responsible for the massive size of the furthest passages in Dan yr Ogof and to a lesser Tunnel Cave.

Another aspect of the corrasiveness of the input waters also merits a brief mention for there has been considerable emphasis laid upon the clarity of flow markings almost everywhere except in Tunnel Cave. However this characteristic directly conflicts with Sweetings views (1972) that "scallops and flutes do not seem to occur if there is much sand, grit or mud in the cave waters, abrasion being destructive of solutional features". It is true that by the time that the sand reaches the final sections of Dan yr Ogof it is very considerably rounded (Newson 1970) but scallops are extensive throughout the system and this argument cannot apply everywhere.

The range, size and character of sediments passing through the system coupled with the speed of through-put times suggests that there is little impediment to fairly free flow. It equally implies that there is no deep phreatic development, a characteristic which is also confirmed by the lithological reconstructions shown on the sections. Indeed this, the relative flatness of dip and shallowness of the limestone combine to place the Dan yr Ogof caves very much into "the shallow karst cave" category with primarily horizontal development. In this respect it could be regarded as more akin to many American caves than to its geographical neighbours on Mendip or in Yorkshire (Miotke and Palmer 1974). However it is not realistic to attempt to classify the Dan yr Ogof system into one particular "type" of cave for like most major caves it combines a number of elements and is the result of a very wide range of influences. Despite its comparative youth it displays a considerable maturity of form because of the size of its catchment area and because of the volume, variety, aggressiveness and abrasiveness of its water sources. Its phreatic origins are clear in most areas but in the more developed north-south elements these are dominated by massive vadose developments except where minor deflections along the strike have led to phreatic characteristics on a major scale. Faulting and jointing have been of tremendous importance as an influence on the orientation of passages in all parts of the cave, though folding has guided the overall trend of the synclinal "drain".

The relationship between cave and surface features is also remarkably close and it is appropriate to end this part of the study with the observation that above and below ground this, and the immediately adjacent areas, are among the most developed and interesting karst areas in the British Isles.

A.C.C.

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Visual Aids

A series of film-strips and accompanying teaching note booklets on "Limestone Landforms" (in two parts), "Caving and potholing techniques", and "Caves: Origins, developments and formations" have been prepared by Alan Coase and published by Diana Wyllie Ltd., 3, Park Road, Baker Street, London, N.W.I. All contain photographs of the Dan yr Ogof caves and surrounding area, and part of the last-named deals with these caves as a specific case study.

b

APPENDIX B. SUMMARY OF PASSAGE ORIENTATIONS IN TUNNEL CAVE.

SECTOR°	DAVY PRICE'S HALL TO JUNCTION	CROSS PASSAGE AND CHRISTMAS GROTTO PASSAGE	WEST FORK	EAST FORK	GRAND TOTAL
270–279°	27	28	53	27	135
280–289	5	4	23	8	40
290–299	56	23	57	30	166
300–309	21	13	46	0	80
310–319	11	5	40	4	60
320–329	7	4	75	27	113
330–339	4	7	56	16	83
340–349	31	18	69	5	123
350–359	25	10	76	27	138
000–009	83	2	166	112	363
010–019	62	3	152	133	350
020–029	21	6	44	4	75
030–039	17	7	30	7	61
040–049	0	19	9	10	28
050–059	23	10	27	3	63
060–069	12	22	15	12	61
070–079	17	9	31	9	66
080–089	10	32	40	5	87
Total	422	222	1009	439	2092

APPENDIX A **PASSAGE ORIENTATIONS IN 10° SECTORS (T)**

DAN YR OGOF

Sectors °	River & Lakes	Tubes	Show	'37 Cave	Total DYO 1	Main Upper	Main Lower	Tubes	Mazeways 1 & 2	Total DYO 2 Near	Synclinal Total	Main Upper	Tubes	Total DYO 2 Far	Great North Road	Tubes & Pinnacle	Far North	Total DYO 3	Fault&Joint Guided Total	Grand Total
270–279°	36	94	21	12	163	103	25	9	47	184	347	87	47	134	36	32	7	75	209	556
280–289	0	67	18	0	.85	21	29	14	17	81	166	38	10	48	52	2	92	146	194	360
290–299	33	49	24	28	134	61	5	9	16	91	225	90	7	97	58	15	34	107	204	429
300–309	10	89	43	6	148	35	61	14	20	130	278	120	9	129	14	45	17	76	205	483
310–319	10	55	34	49	148	3	32	9	11	55	203	11	19	30	77	0	37	114	144	347
320–329	33	13	51	15	112	9	51	10	43	113	225	64	43	107	102	31	140	273	380	605
330–339	26	38	38	17	119	54	11	19	41	125	244	62	7	69	100	7	89	196	265	509
340–349	43	50	35	112	240	90	80	28	63	261	501	47	34	81	49	13	0	62	143	644
350–359	81	26	10	92	209	239	111	141	321	812	1021	300	16	316	168	96	95	359	675	1696
000–009	92	50	7	205	354	117	64	88	205	474	828	278	64	342	484	402	210	1096	1438	2266
010–019	5	128	62	58	253	75	45	27	473	620	873	370	4	374	125	93	143	361	735	1608
020–029	5	127	105	54	291	27	36	126	135	324	615	71	0	71	102	48	130	280	351	966
030–039	82	75	133	126	416	46	135	68	123	369	785	26	0	26	49	17	76	142	168	953
040–069	6	53	32	94	185	164	104	39	108	415	600	30	0	30	57	16	4	77	107	707
050–059	6	47	16	31	100	159	65	39	44	307	407	46	0	46	188	30	18	236	282	689
060–069	75	63	110	49	297	131	92	69	24	316	613	3	13	16	273	19	97	389	405	1018
070–079	16	70	12	61	159	146	109	46	66	367	526	30	13	43	0	17	21	38	81	607
080–089	37	42	40	26	145	24	78	35	121	258	403	67	3	70	8	0	25	33	103	506
	596	1136	791	835	3558	1501	1133	790	1878	5302	8860	1740	289	2029	1942	883	1235	4060	6089	14949

APPENDIX C. Table showing orientation of passages, by length and approximate percentage, in 30° sectors a. Dan yr Ogof and b. Tunnel Cave.

	a. Dan yr Ogof						b. Tunnel Cave		a. and b. Both Main Caves	
Sector°	Synclinal Unit		Fault Aligned Unit		Total		Total		Grand Total	
	1. Lengths	2. %	1. Lengths	2. %	1. Lengths	2. %	1. Lengths	2. %	1. Lengths	2. %
080–089 270–289	1000	11	450	6	1450	9	260	12½	1700	10
290–319	750	8	550	10	1300	8	300	14	1600	9½
320–349	1000	11	750	12½	1750	12	320	14½	2050	12
350–019	3000	32	2600	48	5600	37	850	42	6450	38
020–049	2000	21	600	11	2600	17	160	7½	2750	16
050–079	1550	16	750	12½	2300	15	190	9	2500	14½
TOTALS										
as shown	9300	99	5700	100	15000	98	2080	99½	17100	100
real	9303	100	5646	100	14949	100	2092	100	17041	100

Column 1. shows approximate length of passages in sector, in metres
2. shows approximate percentage of passage in sector.

VII

CAVE CHEMISTRY RESEARCH AND THE DAN-YR-OGOF SYSTEM

a. Introduction

Detailed cave chemistry research in South Wales began as an attempt to work out the underground history of the waters of the Dan-yr-Ogof cave system. For various reasons the attempt was not successful but it showed clearly some problems of fundamental importance to cave chemistry, and it may be reasonable to suggest that the early Dan-yr-Ogof work was more significant for where it led than for its own sake. New techniques and new ideas are available now and a detailed examination of the waters of the Dan-yr-Ogof system could well produce meaningful results. In the meantime an examination of some of the early results in the light of new ideas may be of interest: if the highly speculative discussion serves to stimulate a constructive re-examination of established theories it will have served its purpose.

b. Historical background

The present programme of cave chemistry research started as part of the activities of the Easter 1968 "camp-in" in the Dan-yr-Ogof system. Water samples were collected from sites within the cave and on the surface and were analysed in a makeshift laboratory within the Penwyllt Headquarters of the South Wales Caving Club. For this original study a limited number only of investigations was made (total hardness, calcium hardness, alkaline hardness, pH and electrical conductivity). The results were disappointing at the time as they showed little in terms of the cave system but they did indicate that the analytical techniques then common in cave chemistry left a great deal to be desired.

An improved method for the direct estimation of calcium and of magnesium in cave waters was worked out: it was used during the summer of 1968 and a start was made in the correlation of some of the various parameters of the waters. Perhaps the most significant result obtained was the demonstration of the totally different characteristics of the waters in the main sump of Mazeways and the entrance pool of Mazeways. Apart from this result it was clear that improved hardness estimation techniques alone were unlikely to give sufficient information about cave waters for their history to be worked out, and that some new experimental methods were needed (Bray, 1969).

During the summer of 1969 a method for the assessment of the limestone-attacking power (aggressiveness) of cave waters was added to the routine techniques available (Stenner, 1969). Most of the cave waters were only slightly aggressive and, apart from confirming earlier results, no new information in terms of the cave system was gained. In 1969 the project, which had been operated from a London comprehensive school, gained support and guidance under the Scientific Research in Schools scheme of The Royal Society. The author then realised that progress towards the original aim was not likely to be made until a great deal more was known about the basic chemical processes involved in the erosion of limestone in cave systems.

In 1970 poor weather and a reduced interest in the Dan-yr-Ogof system on the part of the cavers combined to make it impossible to go on with the Dan-yr-Ogof work and it was decided to carry out investigations on the processes of cave development and to gain information first from surface sites. By 1971 a most efficient field laboratory had become available at Penwyllt and, with equipment borrowed from the school, investigations were possible which were out of the question using the original makeshift laboratory facilities. Experimental work has shown the importance of water-borne organic matter in the limestone erosion processes taking place in cave streamways (Bray, 1972, 1975a; Bray and O'Reilly, 1974). The special needs of the Ogof Ffynnon Ddu system led to the development of a simplified method for studying extensive systems (O'Reilly and Bray, 1974) which has been modified to include a novel technique for the assessment of the aggressiveness of cave waters (Bray, 1976a). In addition some work on the effects of flooding in caves has been started (Bray, 1976b). Most of the results of this work have been derived from the Ogof Ffynnon Ddu system but the ideas have been applied to the Dan-yr-Ogof system in the discussion.

c. Results

Collected results are given in Table 1 and as most of these have not been published before, some qualification is needed.

All results from 1968 are from samples collected during prolonged periods of drought. The Easter 1968 results were obtained using methods now known to be of limited accuracy and they should not be used with values from later work although they are reasonably self-consistent: the derived values (magnesium and non-alkaline hardness) are likely to be very approximate. The summer 1968 results are perhaps as reliable as will be obtained from cave waters without the expenditure of a disproportionate amount of time and effort.

The summer of 1969 gave adverse weather conditions and values from a given sampling trip should not be compared with other results.

Units and terms are those customary in these papers and have been discussed (Bray and O'Reilly, 1974). In the early work the electrical conductivity values were corrected to an arbitary temperature of 15°C but a precision thermostat tank became available in 1971 and later results are from measurements at 25°C.

d. Discussion

As far as the limited accuracy will allow the Easter 1968 results indicate that the idea that relatively soft water enters the known cave and becomes progressively harder as it flows through the cave is not an

TABLE 1 COLLECTED RESULTS

SITE	Sampling trip	Total hardness (ppm $CaCO_3$)	Calcium hardness (ppm $CaCO_3$)	Magnesium hardness (ppm $CaCO_3$)	Alkaline hardness (ppm $CaCO_3$)	Non-alkaline hardness (ppm $CaCO_3$)	Aggressiveness (ppm $CaCO_3$)	pH	Sulphate (ppm SO_4^{2-})	Electrical conductivity (μmho per cm at 15°C)	Oxygen demand 4-hour (mg O_2 per litre)
EASTER 1968											
Sink y Giedd		12	10	2	7	5		6.8		38	
Waun-fignen-felen		3	2	1	-	-		4.2		43	
Pwll y Wydden		5	3	2	-	-		4.1		59	
Dan-yr-Ogof dry valley		92	89	3	76	16		7.9		146	
Dan-yr-Ogof resurgence		92	78	14	79	13		7.9		155	
Hospital Water Cave		113	100	13	96	17		7.9		183	
Great North Road (top)		107	96	11	88	19		7.8		170	
Great North Road (2nd Inlet)		99	93	6	87	12		8.1		158	
Pinnacle Chamber		74	64	10	58	16		7.8		127	
Highway Rising		105	91	14	90	15		8.5		162	
Rottenstone Aven		44	34	10	34	10		7.6		78	
Dali's Delight		56	54	2	44	12		7.5		106	
100ft. Cascade		54	52	2	45	11		7.8		99	
Monk Hall		127	115	12	110	17		8.0		190	
Washing Machine		90	86	4	78	12		7.7		152	
Gerrard Platten Hall		114	106	8	103	9		8.0		177	
Lake 3		96	80	16	82	14		7.8		157	
Cauldron Chamber		122	113	9	105	17		8.3		182	
SUMMER 1968											
Far North, Left Hand Series	b	119	108	11	109	10		8.0		181	
Far North, Right Hand Series	b	131	119	12	124	7		8.1		204	
Great North Road (top)	b	106	100	6	98	8		8.6		167	
Highway Rising	b	120	109	11	112	8		8.1		187	
Rottenstone Aven	b	52	47	5	45	7		8.0		99	
Dali's Delight	a	77	64	13	58	19		8.0		115	
100ft. Cascade	a	69	64	5	59	10		7.7		118	
100ft. Cascade	b	71	66	5	61	10		8.0		126	
Cloud Chamber	b	116	110	6	103	13		8.1		183	
Washing Machine	a	118	105	13	106	12		7.8		178	
Washing Machine	b	121	108	13	109	12		7.8		187	
Washing Machine	c	122	108	14	109	13		7.8		184	
Washing Machine	d	122	108	14	108	14		7.7		190	
Bakerloo Straight	c	120	108	12	109	11		7.8		188	
Mazeways, Entrance Pool	c	121	107	14	112	9		7.8		188	
Mazeways, Entrance Pool	d	121	107	14	109	12		7.8		190	
Mazeways, Main Sump	c	72	67	5	69	3		7.9		124	
Mazeways, Main Sump	d	72	68	4	65	7		7.5		123	
Crystal Pool	b	238	200	38	139	99		8.1		354	
Gerrard Platten Hall	b	123	118	5	114	9		8.1		191	
Gerrard Platten Hall	c	129	125	4	113	16		8.0		193	
Shower Aven	b	123	118	5	115	8		8.1		194	
Dan-yr-Ogof Resurgence	b	122	109	13	110	12	-1	8.0		190	
SUMMER 1969											
Hospital Water Cave	a	125	122	3						197	
Tunnel Cave , Entrance	a	156	150	6			-1	7.7		220	
Pwll y Wydden	b	3	2	1			+25	4.2		44	
Pwll y Cig	b	7	5	2			+14	4.8		27	
Giedd Stream	b	9	7	2			+10	5.4		21	
Confluence Giedd/Stream from Pwll y Cig	b	7	5	2			+14	5.2		21	
Waun-fignen-felen	b	5	3	2			+22	4.0		65	
Dan-yr-Ogof Resurgence	a	85	78	7						136	
Rottenstone Aven	d	46	41	5			+6	7.7		84	
100ft. Cascade	c	66	60	6			+3	7.9		111	
Washing Machine	c	111	99	12			-3	7.9		165	
Washing Machine	d	89	81	8			+2	7.8		142	
Mazeways, Entrance Pool	c	112	100	12			-1	7.9		151	
Mazeways, Main Sump	c	58	54	4			+3	8.1		95	
Gerrard Platten Hall	c	122	117	5			-10	8.4		171	
Shower Aven	d	104	99	5			0	7.9		157	
SUMMER 1971										25°C	
Waun-fignen-felen	a	14			-	-	+40	4.0	20	98	10.9
Pwll y Wydden	a	6			-	-	+27	4.0	13	62	3.8
Byfre Fechan	b	24			13	11	+8	-	13	77	1.3

appropriate model for the Dan-yr-Ogof system, and it seems likely that these results (together with later values) show the hardest waters to have reacted fairly completely with limestone before emerging into the cave. It is interesting to note that the waters from Rottenstone Aven, Dali's Delight and the 100ft. Cascade are softer than the general values. Some sites give low magnesium hardness waters but the non-alkaline hardness results (approximating to sulphate contents) are not reliable enough to be valuable.

Results from the summer of 1968 represent the state of the cave waters after a very dry period and, again, the waters from Rottenstone Aven, Dali's Delight and the 100ft Cascade are relatively soft. Static water from Crystal Pool provides the highest hardness values yet found in South Wales but the general hardness values of most of the other waters are similar to that shown by the Washing Machine water. The major point of interest is that the water in the Main Sump of Mazeways is much softer than that in the Entrance Pool of Mazeways and has lower magnesium and sulphate contents. Cave systems are dynamic systems from the chemical viewpoint and, to allow comparisons to be made between results from different sampling trips, it is necessary to use at least one "reference site". In this work the "Washing Machine" has been the reference site and it is interesting to note how constant the results are for very dry weather (summer 1968) and how wet weather is reflected (summer 1969).

Work in the summer of 1969 was hampered by changeable weather and this is reflected in the generally lower hardness values shown by water samples collected from the Dan-yr-Ogof system. The lower hardness of waters from Rottenstone Aven, the 100ft. Cascade and the Main Sump of Mazeways is confirmed. The values from Tunnel Cave show what could be the hardness level of percolation water in the area, but only more extensive studies will confirm this: the values are higher than the hardest flowing water sampled in Dan-yr-Ogof. The surface sites, sampled during rain, are interesting in that the relatively low aggressiveness of water entering the Sink y Giedd complex is indicated, as is the rather high pH and the somewhat greater hardness of the water at this sink compared with the other sinks.

No samples were available from within the Dan-yr-Ogof system during the summer of 1970 and surface site results only are given. The results from 1971 have been given before (Bray, 1972).

That the results themselves show all too little in terms of the cave system is clear but more recent work suggests lines along which the results might be used in a speculative manner. The author feels that speculation on the basis of experimental evidence is acceptable provided that it is recognised as speculation and used to stimulate new work. Unfortunately some of the once-accepted ideas of cave chemistry could have been little more than speculation unsupported by experimental fact, yet they gained a status comparable with Holy Writ.

Since the Dan-yr-Ogof study was halted as a separate aspect of the project, some work has been done on waters likely to enter the system. Samples have been collected from Waen Fignen Felen and from Pwll y Wydden under low water conditions (not drought) but no samples for detailed examination have been taken from Sink y Giedd under comparable conditions. Such work as has been done on Sink y Giedd water suggests that the chemical make-up is not dissimilar to that of the water in the Byfre Fechan stream as it leaves the slopes of Fan Gihyrich. The waters have been in contact with Old Red Sandstone debris and seem to have relatively low aggressiveness values suggesting similarly low organic matter contents. As far as the Sink y Giedd complex is concerned the eastern tributary, flowing from Pwll y Cig and apparently draining a peaty area, seems to have similar characteristics to the western tributary draining the area to the north. For the purposes of this article the data from the full analyses of water in the Byfre Fechan stream are used as substitutes for the values from Sink y Giedd. Some results are tabulated (Table 2).

SITE	Original total hardness (ppm $CaCO_3$)	Initial aggressiveness (ppm $CaCO_3$)	Contact hardness (ppm $CaCO_3$)	Oxygen Demand, 4-hour 27 C (mg O_2 per litre)	Latent aggressiveness (ppm $CaCO_3$)	Maximum "cave hardness" (ppm $CaCO_3$)
Byfre Fechan (substitute for Sink y Giedd)	24	+8	32	1.3	27	59
Pwll y Wydden	6	+27	33	3.8	80	113
Waun-fignen-felen	14	+40	54	10.9	229	283

TABLE 2. Comparison of sink waters.

The Byfre Fechan/Sink y Giedd results suggest that water would emerge into a cave system with a hardness value corresponding to the original hardness plus the initial aggressiveness i.e. 24 + 8 = 32ppm $CaCO_3$. However, work in the Ogof Ffynnon Ddu system has shown that a latent aggressiveness may be developed inside the cave system and that this latent aggressiveness is about 21ppm $CaCO_3$ for each 1mg per litre of oxygen demand lost from the water. The likely hardness in the cave of water from the Sink y Giedd source would thus be 32 + (1.35 x 21) = 59ppm $CaCO_3$ and, in the watercourse, such water would be expected to have a low oxygen demand, relatively low sulphate content (5 - 10ppm SO_4^{2-}) and very limited aggressiveness.

Water flowing into Pwll y Wydden from the Millstone Grit would have an expected hardness of 6 + 27 = 33ppm $CaCO_3$ to which might be added a latent aggressiveness of 3.8 x 21 or 80ppm $CaCO_3$ giving a hypothetical "cave hardness" of about 113ppm $CaCO_3$: water from such a source might be expected to have a sulphate content of rather more than 10 - 13ppm SO_4^{2-}.

The Waen Fignen Felen sink poses several problems not the least of which is where to collect the water samples as the major sink takes water quite rarely. The aggressiveness of the water is high (+40ppm $CaCO_3$) giving an anticipated initial contact hardness of the order of 14 + 40 = 54ppm $CaCO_3$ (although the 14ppm $CaCO_3$ total hardness value may be unusually high for this site).

However, the level of organic matter suggested by the 4-hour 27°C oxygen demand test is very high and it seems likely that some of this arises from inorganic sources (about 4mg per litre). The latent aggressiveness from the oxidation of the organic matter could be as high as 10.9 x 21 or 229ppm $CaCO_3$ thus giving a maximum "cave hardness" of 54 + 229 or about 283ppm $CaCO_3$ for the water from this source, although a value of about 200ppm $CaCO_3$ might be more appropriate. No flowing water of this hardness has been encountered in the Dan-yr-Ogof system. Water from this source would be expected to have a rather high sulphate content (about 20ppm SO_4^{2-}).

From a chemical point of view the relatively soft waters provided by certain sites (e.g. Rottenstone Aven, Dali's Delight, the 100ft. Cascade, Mazeways Main Sump) might arise either from sources akin to Sink y Giedd, in which case reaction would be fairly complete and oxygen demand low, or from other sources in which case reaction might be incomplete and the oxygen demand rather higher. These waters show low sulphate contents in general. The approximate location of Rottenstone Aven invites speculation that the water has entered the cave from Pwll y Wydden; in the absence of an unambiguous dye test there is no proof of this.

The puzzling feature of the results is that the sites along the Great North Road, heading toward Waen Fignen Felen, do not provide waters having high sulphate contents or high hardness values. This suggests that these waters might not originate from Waen Fignen Felen but rather from some source(s) akin to Pwll y Wydden. The sulphate content in flowing water in the cave does not reach a value much above 10 - 12ppm SO_4^{2-} until the Washing Machine and the value there is comparable to that at the Dan yr Ogof resurgence under similar conditions.

Dye tests under high water conditions have shown water from Sink y Giedd and from Waen Fignen Felen to emerge at the Dan-yr-Ogof resurgence and these results have suggested the assumed water flow pattern in which water from Sink y Giedd is shown to follow a different underground path from that flowing from Waen Fignen Felen. As the author understands the situation there is no separate flow of water in the cave which might correspond to water originating at Sink y Giedd and there is no major stream flowing in the Great North Road under low water conditions. It seems reasonable to consider a speculative alternative to the assumed water flow pattern.

On the moorland there is a line of collapse features (some of which are active sinks) heading approximately in a north-westerly direction from the head of the Dan-yr-Ogof dry valley, past Waen Fignen Felen and on towards the Sink y Giedd/Pwll y Cig complex. It seems possible to the author that these collapse features might mark the direction of a boulder-choked watercourse at a level different from that of the known cave. Under dry weather conditions, when the main sink of Sink y Giedd is dry, water from the Sink y Giedd/Pwll y Cig complex might flow along this watercourse joining water sinking at the numerous other minor sinks, and perhaps water from the Waen Fignen Felen area, to enter the known cave as a combined stream. Such an idea, however speculative, does explain why no major water flow is encountered in the cave showing the very low hardness expected of water from Sink y Giedd or the very high hardness and sulphate content expected of water from Waen Fignen Felen. Under flood conditions the so-called major points of engulfment become operative and the situation is likely to be very different with additional separate watercourses becoming filled with water. Detailed chemical investigations supported by careful dye tests monitored by fluorimetric studies might help to resolve some of the uncertainties posed by the Dan-yr-Ogof system.

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VIII

BIOSPELEOLOGY OF DAN YR OGOF

Abstract

Entry into the hitherto unexplored passages of Dan yr Ogof afforded the opportunity to obtain some idea of the distribution of animals, plants and bacteria in a cave system undisturbed by man. It was also possible to test a number of theories concerning the ecology of caves. Amongst these were the ideas that microbial populations of caves are intrinsically different from those of comparable, epigean habitats; that the cave ecosystem is an isolated one and that, in view of the total darkness, some unusual basis for the food and energy chains in caves must be sought.

The investigations showed that the bacterial populations of soils and water within the cave closely resembled those of comparable epigean habitats and that contrary to widely-held belief, populations of bacteria are present in the air of caves even in the absence of man. As both the investigations and exploration proceeded it became apparent that disturbance by man influenced the balance of all these populations.

Although some bacteria capable of growth in the absence of pre-formed organic material were present, the numbers were insufficient to provide a basis for food and energy chains. However, comparatively large and varied populations of heterotrophic bacteria existed throughout the cave system and investigations showed that sufficient organic material was carried into the caves by water action for the continued growth of the bacteria. The bacteria could themselves serve as food for some animals whilst their metabolic products would provide both food and vitamins.

a. Introduction

The idea that biological systems in caves must be intrinsically different from other freshwater and terrestrial systems is still widely discussed. Following the theory put forward by Dudich (1933) that "chemosynthesis" (implying chemolithotrophy) is the basis of subterranean food cycles, many writers have suggested that life in undisturbed caves could be based on energy sources other than solar energy.

It is well-known that there are bacteria which can derive their energy from inorganic substrates in dark chemical reactions. The bacteria involved in these reactions are known correctly as **chemolithotrophic** bacteria but are often referred to by the simpler term **autotrophic** bacteria. The activities of these bacteria have been suggested as a probable basis for the food and energy cycles in caves. However, the energy yields from the various reactions are relatively poor and only a limited number of species of bacteria are capable of chemolithotrophic growth. The great majority of bacteria are **chemo-organotrophic** (or heterotrophic) obtaining energy and food from the breakdown and transformation of preformed organic material. These reactions are efficient and the energy yields are good. A very wide range of organic substrates of both plant and animal origin can be used by the various groups of chemo-organic bacteria.

Entry into the new passages in Dan yr Ogof afforded the rare opportunity to study established communities within a cave where the influence of man was not already a major, but undefinable factor. It meant not merely the chance to collect individual animals for identification but the opportunity of gathering much-needed ecological information about established cave communities. By collecting information on (i) the identity of the animals present and their distribution in relation to micro-habitat and such factors as flooding; (ii) the natural populations of micro-organisms, particularly bacteria, in air, soil and water, it became possible to attempt some introductory analysis of food and energy resources within the system.

This account therefore, gives the results of ecological investigations which were aimed not only at identifying some of the members of the established populations in the undisturbed cave system but also at assessing possible food resources in such a cave. It also includes, for comparative purposes, information from caves frequented by man. The proximity of Ogof Ffynnon Ddu with its relatively easy access made it the obvious choice for comparison with Dan yr Ogof and some results from that system are included and discussed.

Obviously it would have been too great a task to consider all the habitats within the new passages. Consequently it was decided to concentrate primarily on aquatic habitats. The microbial populations of air and soil were of course investigated but not in such detail as those of the various bodies of water.

b. Bacterial Populations

It is convenient to discuss the bacterial analysis first. The methods used were all based on standard ones used by soil and water bacteriologists and for appropriate techniques, media, etc. reference can be made to Skerman (1959); Oxoid Manual of Culture Media; Burges (1958) and Collins (1964). The following notes summarize the method:-

(i) soil and water samples were collected in well-washed, sterilised glass containers and stored in cooled vacuum flasks for transport to the laboratory. Air samples were taken directly by exposing plates of nutrient media for standard lengths of time within the cave.

(ii) subculturing took place as soon as possible after the samples were collected to avoid the changes in populations known to occur when small samples of water or soil are stored.

(iii) to ensure reproducibility of results standard media were used and included: Thornton's agar; nutrient agar; McConkey agar; Czapek-Dox agar; Mannitol agar; Robertson's meat broth; Winogradsky's ammonium sulphate solution; Medium for Chlamydobacteria; Ferric ammonium citrate agar; Nitrate solution; Sulphur medium and a medium for Thiobacillus species.

(iv) incubation temperatures of 10°C and 18°C were used for bacterial and mycological cultures.

(v) identification of bacterial species followed the system given in Bergey's Manual of Determinative Bacteriology (Breed *et al*, 1957).

(i) Bacterial populations in the air

It has been argued by Molnar (1961) that the air of caves not visited by man is sterile except in the immediate vicinity of openings to the exterior. This theory is based on the idea that bacteria, fungal spores and pollen grains carried by air-currents become surrounded by moisture in the saturated air within the cave and thus precipitate out. Vandel (1965) elaborated on this, stating that when bacteria do occur in the air of caves, they have been introduced by man.

Investigations in the new passages in Dan yr Ogof cast doubt on both these ideas. A wide variety of bacteria was isolated by exposing plates of nutrient media to the air in a number of small side passages. The sites chosen were always in passages too small for access by cavers, leading off other passages known at that time to be unfrequented by exploring parties. The petri dishes containing the nutrient media were pushed in to arm's length before being opened. The media used were nutrient agar and Thornton's agar and each plate was exposed for 10 minutes.

The plates of media exposed in the undisturbed passages of Dan yr Ogof showed relatively sparse growth with counts between 20-50 colonies/plate after 7 days incubation at 18°C.

Table 1 lists the species isolated. Many of these are characteristic of soil; a point which suggests that at least some of the bacteria in the air are derived from disturbed soils within the cave, possibly disturbances due to floods. Another source of bacteria in the air is the spray produced by waterfalls and water drops falling from the roof which probably introduces into the air soil organisms carried in water. Air currents would be important in maintaining these populations in the air.

Some tests were made in Dan yr Ogof to investigate the effect of the passage of cavers through an area. Plates of nutrient agar and others of Thornton's agar were exposed in front of a party of cavers in a passage with the draught blowing out of the passage, towards the party. After 2½ hours a replicate set of plates were exposed before the party re-traversed the passage.

The plates exposed in front of the party showed the pattern of growth from undisturbed passages already described, that is relatively sparse growth (20-50 colonies/plate) with **Streptomyces** spp., **Nocardia** spp. and **Bacillus** spp. predominating. All the plates of nutrient agar and Thornton's agar opened 2½ hours after the cavers had passed through the passage showed very dense growth after 48 hours at 18°C. On these plates, the growth was dominated by micrococci and bacilli. Species of Gram-ve rods, mainly **Achromobacter** spp. and **Pseudomonas** spp. were common on the plates. It seems probable that these latter could have been derived from the water of The Lakes which have to be swum at the end of the Show Cave in Dan yr Ogof. The picture of the growth changed with continued incubation and after 7-10 days dome of the soil organisms, **Nocardia** and **Streptomyces** spp, had formed colonies.

These observations confirmed an earlier impression (Williams and Benson-Evans 1958) that visits by man (and other animals) augment existing populations in the air of caves through the introduction of organisms on body surfaces and on clothing, and also through the release of organisms from the disturbance of soil and water.

Table 1

Organisms identified from plates of nutrient agar and Thornton's agar after exposure to the air in previously unentered passages in Dan yr Ogof.

Bacillus species including:	**Bac. cereus**
	Bac. cereus var. mycoides
	Bac. subtilis
	Bac. pumilis
	Bac. sphaerophorus
Norcardia species including:	**N. corallina**
	N. alba
	N. citrea
Streptomyces species including:	**Strept. albus**
	Strept. longisporus
	Strept. griseolus
Various moulds including:	**Penicillium** spp.
	Aspergillus spp.
Two yeast species. (pigmented pink)	

(ii) Bacterial populations in soils

Table 2 summarises the bacterial genera represented in the various soil samples taken. Replicate samples were taken from all the sites at intervals during the year 1966/67. The table is presented in a form which gives an indication of the relative abundance of the different genera. Results from sites in Ogof Ffynnon Ddu are included for comparison.

It appears from these results that bacterial populations in cave soils do not differ essentially from those of other soils, (Alexander 1961). There appears to be a basic flora of organisms which is supplemented from time to time by bursts of activity associated with any disturbance which augments the organic content of the soil. Such disturbances often introduce at the same time different species of bacteria.

This was seen very clearly with the samples from the New Series in Dan yr Ogof. The samples taken in passages previously unentered showed the dominant aerobic microbial groups to be **Streptomyces, Nocardia** and soil **Corynebacteria.** Coccobacillary forms were always present although never in large numbers. There were relatively few Gram-ve rods although **Chromobacterium violaceum** was isolated from many samples. The few other Gram-ve species isolated belonged to the genera **Flavobacter** and **Achromobacter.** A variety of **Bacillus** spp. were isolated from each sample but rarely more than 2 or 3 colonies on any plate. Soils subjected to flooding gave the impression that Bacilli (possibly present in the soil as spores) were more abundant in them than in undisturbed soils. The numbers were however too small to be really significant. Species of **Clostridia** including **Cl. tetani** and **Cl. welchii** were isolated from the peaty soils brought in by flood water. Only a very few moulds were grown from the samples. It seems probable that many of the sporing organisms were brought in with flood debris in the spore form.

As the numbers of visits by cavers increased the populations of both the soil and the air of the cave changed. In the soil the numbers of species of **Corynebacteria, Nocardia** and **Streptomyces** remained relatively constant but the numbers of Gram-ve rods increased noticeably as did the numbers of Bacilli and moulds. The species of Bacilli which became dominant were **Bac. cereus, Bac. cereus var. mycoides** and **Bac. subtilis** whilst **Bac. circulans** and **Bac. pumilis** were isolated in larger numbers than previously.

Table 2

Bacteria isolated from soil samples from Dan yr Ogof and Ogof Ffynnon Ddu

Sites	**Characteristics**
Dan yr Ogof:	
1. *Long Crawl	Sand & gravel; never flooded
2. *Lower Series (Virgin Passage to Thixotropic Passage)	Dense water-logged mud containing peat; subject to flooding
3. *Go-Faster Passage	Peat; subject to flooding

At the time of sampling, site 1 had been traversed by cavers a number of times; sites 2 & 3 were remote from routes taken previously by cavers.

*Several sampling stations were used in each of these general locations.

Sites	**Characteristics**
Ogof Ffynnon Ddu:	
4. Cathedral Passage	Sand & gravel; rarely flooded
5. Traverse Passage	Sandy & clay; subject to flooding
6. Waterfall series	Sandy & clay; never flooded
7. Railton-Wild Series	Boulder clay; subject to flooding

All these sites are visited frequently by cavers.

Bacterial Genera	**Sites** 1.	2.	3.	4.	5.	6.	7.
Flavobacterium		p	p		c		c
Chromobacterium		p	p	p	p		p
Achromobacter	p	p	p	p	c		c
Micrococcus	p			p	p		
Bacillus	c	p	p	a	p	p	c
Clostridium	p	a	a	a	p	p	c
Corynebacterium		p	p	p	p		p
Nocardia	p	c	c	p	p		p
Streptomyces	p	c	a	c	c	p	p
not identified to generic level:							
Myxobacteria		c	c				
Gram-ve coccobacilli	p	p	c	c	c	p	c

Key: p = present in some or all samples in small numbers
c = common in some or all samples
a = abundant in most or all samples.

Bacterial populations in water

Table 3 summarises the bacterial genera isolated from the various water samples taken. It also gives some idea of the relative abundance of each genus in the different sites. The comparisons here with a range of sites in Ogof Ffynnon Ddu are interesting and important, consequently the results from both caves are given in one Table.

The sites have been classified into groups based on frequency of flooding and disturbance by man. On these bases the types of sites sampled were:-

1. Pools subject to flooding, rarely visited by man (at the time that the samples were taken).
   *Go Faster Passage
   *Pools in Lower Series (Virgin Passage to Bakerloo Straight).
2. Pools subject to flooding, frequently visited by man.
   Loopways
   Pluto's Passage
3. Pools fed by seepage only, rarely visited by man.
   Coral Pool
   *Gerrard Platten Hall
   *Top of Double Pots
   *Grand Canyon
4. Pools fed by seepage only, frequently visited by man.
   The Font
   Candlestick Pool
   Upper Column Passage
   Traverse Passage

(Sites in Dan yr Ogof are marked *)

In all cases several sampling stations were used in each of these general locations.

When the results from water samples from Dan yr Ogof are compared with the results obtained from similar samples from Ogof Ffynnon Ddu, it is surprising to find marked similarities between the bacterial populations of the various pools in the newly-entered passages in Dan yr Ogof and those of similar pools in Ogof Ffynnon Ddu. The range of genera, and indeed species, recovered from sites in Dan yr Ogof was very wide and comparable with the range one would expect from surface waters.

Table 3. Bacterial genera isolated from water in Dan yr Ogof and Ogof Ffynnon Ddu.

Sites	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii
coccobacilii:												
Gram + ve	a	a	p	p	p	p			c	c	c	c
Gram - ve	a	a	c	c	p	p	p	p	c	c	c	c
Spirochaetes			c	c								
Myxobacteria	c	c	c	p								
Caulobacteria			c	c						p	p	p
Chlamydobacteria			a	a	p	p			c	a	a	a
Nocardia	c	c	p	p		p	p		p		c	c
Streptomyces	a	p			p	c	c	p	p		p	p
Corynebacteria			p									
sporing rods:												
Clostridium	c	c	p	p	p	c	p	p	p	p	c	c
Bacilli	c	c	a	a	c	c	c	p	c	c	a	a
Sarcina									p			p
Micrococcus			p	p	p	p	p		a	p	a	a
Gram-ve rods:												
Chromobacterium	a	c	p	p	c	c	c	p	a	c	a	a
Achromobacter	p	p	a	a					p	p	c	c
Flavobacterium					p	p	p	p	c	p	c	c
coliforms:												
Aerobacter			p									
Escherichia			p	p								
Pseudomonads:												
Vibrio	p	p	p			p	p		p	p		
Pseudomonas	c	c	c	c	p	c	c	p	c	c	c	c
Spirillum	c	p	p	p								
N_2-fixing bacteria:												
Clostridium	c	p	c	c	p					p		
Azotobacter	c	p	c	c	c	c	c	p	c	c	c	c
Nitrifying bacteria:												
Nitrosomonas	c	c	p		c	c	c	p	p	c	c	p
Nitrosococcus	p				p	p	p		p	p		
Nitrobacter	c	c	p		c	c	p		c	c	c	p
Thiobacillus				c	c	c	p	p	p	c	c	p

Table 3.

Key:

Sites:	group 1.	i.	Go Faster Passage*
		ii.	Pools in Lower Series*
	group 2.	iii.	Loopways
		iv.	Pluto's Passage
	group 3.	v.	Coral Pool
		vi.	Gerrard Platten Hall*
		vii.	Top of Double Pots*
		viii.	Battleship Passage*
	group 4.	ix.	The Font
		x.	Candlestick Pool
		xi.	Upper Column Passage
		xii.	Traverse Passage

*indicates sites in Dan yr Ogof.

p = present in some or all samples in small numbers
c = common in some or all samples
a = abundant in most or all samples.

c. Animal populations of aquatic habitats

The considerable volume of work done on cave animals to date has been somewhat limited in its scope. Throughout the published work on cave animals one finds emphasis on the specialisation of troglobitic animals for the specialised environment of the cave, and the majority of serious studies on cave animals have had a morphological, descriptive emphasis. Relatively little attention has been given to the accidental inhabitants of caves, or indeed to many of the troglophilic animals. Consequently, a large body of descriptive material has been amassed and extensive references to this material can be found in Vandel (1965), Delamare-Deboutville (1960) and Cullingford (1962). Unfortunately, very few of these many studies have provided any ecological information.

For any ecological picture to have been built up in Dan yr Ogof information was required on:

(i) the animal species present (troglobitic and others) in different microhabitats within the cave
(ii) the distribution patterns of these animals
(iii) the relation of these distribution patterns to openings to the surface, drainage pattern and flooding.

As has been pointed out previously, it would have been impossible to consider all the habitats within Dan yr Ogof and thus, only the aquatic habitats were attempted. An advantage of this decision was that the aquatic animal populations are relatively limited and the majority of species found are fairly easily identified. The species actually found are listed in Table 4.

When the distributions of aquatic animals through the Dan yr Ogof systems were examined, some marked discontinuities were found. For example, the triclads **Dendrocoelum lacteum** and **Fonticola vitta** were found only in two areas of the New Series, Go-Faster Passage and the pools in the Lower Series. Both these areas are frequently flooded but are not the only parts of the cave subject to intermittent flooding. **Gammarus pulex** was found in the same two sites and also in the stream system upstream from Go-Faster Passage. After this initial work had finished, cavers exploring areas yet further upstream reported large numbers of **G. pulex** in pools adjacent to the stream (A. Coase and E.G. Inson, private communications). Larval stages of Trichoptera and Ephemeroptera were also found in areas known to flood.

Niphargus fontanus was found in appreciable numbers in the pools and the stream in Gerrard Platten Hall but so far has not been reported from any of the sites mentioned for **G. pulex. Asellus cavaticus** was abundant in shallow pools and shallow parts of the stream in Gerrard Platten Hall. Sparse populations of **A. cavaticus** were found in pools in the Lower Series and in Go-Faster Passage.

Table 4. Aquatic animals from Dan yr Ogof 1966 - 1967

Platyhelminthes		
Turbellaria:		**Fonticola vitta** (Duges)
		Dendrocoelum lacteum (Miller)
Arthropoda		
Crustacea:		
	Copepoda:	**Megacyclops viridis** (Jur.)
		Acanthocyclops vernalis (Fisch)
		Acanthocyclops viridis Jurdine
	Isopoda:	**Asellus cavaticus** Schiod.
	Amphipoda:	**Niphargus fontanus** Bate
		Niphargus aquilex Schiod
		Gammarus pulex (L)

(Table 4 continued)

Insecta (larval stages):		
	Ephemeroptera:	**Heptagenia lateralis** Curtis
	Trichoptera:	**Philopotamus montanus** Don
		Plectrocnemia geniculata McL.
		Stenophylax permistus McL.

d. Algal populations in water

Plant life in Dan yr Ogof as in other British caves is extremely limited. The main streams carry a few diatoms and desmids under normal flow conditions and after flooding the same species can be recovered from pools within the flood zone. A few unicellular green algae have been recovered from pools fed by seepage water. (Table 5).

Work reported from Hungary (Claus 1964; 1965; Kol 1966) has shown that a large number of algal species are capable of surviving for prolonged periods in caves. The authors of the papers cited also claimed that several algal species were capable of active growth in the dark zones of caves. Kol (1966) reported that a number of species of green and blue-green algae were capable of growth on inorganic media in the dark, utilizing "radiation of some type substituting for light". The type of radiation was not specified and the descriptions of the cells suggested that they became considerably modified during the experiments. A few of the individuals recovered from pools in Dan yr Ogof belonged to genera which Kol reported as capable of chemolithotrophic growth. However, there was no evidence here that these algae were growing and reproducing. Indeed, it proved very difficult, and sometimes impossible, to culture the individuals recovered. Any morphological changes seen in these cells were those associated with deterioration of the cells, none were comparable with those reported by Kol. The total impression is that the majority of algae represented survivors of populations carried in by water and unable to colonise the subterranean habitats.

Table 5. Algae from pools and streams in the new passages in Dan yr Ogof.

		Sites subject to flooding	Sites not known to flood at the time of this work (1967)
Chlorophyta:	Chlorococcales:	*Chlorella*	*Chlorella*
			Chlorococcus
	Volvocales		*Chlorogonium*
			Carteria
	Ulotrichales	*Ulothrix*	*Ulothrix*
		Hormidium	
	Conjugales	*Zygonema*	
Chlorophyta:	Conjugales (Desmids)		*Staurastrum*
Chrysophyta:	(Sub-division Bacillariophyceae)		
	Pennales	*Navicula*	*Navicula*
		Pinnularia	*Pinnularia*
		Cymbela	*Meridion*
		Synedra	*Stauroneis*
		Fragillaria	
		Diatoma	
Cyanophyta:	Chroococcales:		*Chroococcus*
			Synechococcus
			Aphanocapsa
	Hormogonales	*Phormidium*	
		Oscillatoria	
	Chamaesiphonales	*Chamaesiphon*	

e. Discussion

The observations and results described herein show that cave ecosystems cannot be discussed as though they existed in total isolation from other environments. It is true that, as a result of certain limitations, the numbers of species found in both aquatic and terrestrial habitats are very restricted compared with epigean situations. The relatively consistent low temperatures and high humidities can restrict colonization by birds and mammals but, by reducing the risks of desiccation or freezing, may offer some definite advantages to invertebrate groups.

It has been argued that as food supplies are limited in caves, colonisation is restricted and that many cave animals are constantly short of food. Vandel (1965) cites examples of these arguments. However, low temperatures are associated with low respiratory rates amongst cavernicolous animals (Fage 1962). Low temperatures are also responsible for slow metabolic rates in chemo-organotrophic bacteria. Consequently, at the temperatures of cave waters in Britain the rates of food and energy turnover will be slow so that, if food resources are indeed limited, their depletion or exhaustion will also be slow to occur.

Total darkness within caves has several important effects. The most obvious of these is that there can be no growth of photosynthetic plants or bacteria. Several theories have been put forward for alternative food and energy resources for cavernicolous animals; use of metabolic products of chemolithotrophic bacteria and algae, use of "fossil energy" in the form of hydrocarbon traces from limestone and organic material from external sources. These ideas are discussed in detail below.

Total darkness, however, has several other effects. It has a direct influence on the possibilities of colonization by many groups of animals. Thus, animals dependent on actively growing green plants and those normally hunting by sight will be absent from caves. A further limitation on animal colonization is imposed by the absence of the stimuli of either diurnal light variations or seasonal changes in day length. It is probable that the lack of diurnal stimuli can affect both vertebrate animals such as fish and also some invertebrate animals.

It is evident that connections with both terrestrial and aquatic surface habitats are important to cave ecosystems. They influence the food reserves available to animals in caves and also the distribution of these animals. Any consideration of troglobitic animals must therefore include the roles of accidental and intermittent inhabitants.

One of the most important points to emerge from the bacteriological work in Dan yr Ogof was that the microbial populations of the soils in that cave, and indeed in other caves, are quite comparable with soils outside caves. Thus the turnover of materials within soils in caves is likely to parallel that in soils of comparable types elsewhere. Cave soils contain varied bacterial populations dependent on soil type, (peaty, sandy etc.), soil conditions (water-logged, dry etc) and soil treatment. There appear to be basic populations in cave soils consisting of a variety of chemo-organotrophic Gram+ve and Gram-ve coccobacilli, and members of the genera **Nocardia, Streptomyces** and **Bacillus.** Nitrating and nitrifying bacteria, **Azobacter** spp., **Nitrosomonas europeae, Nitrobacter winogradsky** and **Clostridium** spp., including **Cl. pasterianum** can be found in small numbers from many soils and sediments in pools. The metabolic products of these organisms and materials from their breakdown of plant and animal materials are available in the soil itself and can also be carried into streams and pools to augment food and energy resources.

Obviously there is no systematic disturbance of cave soils comparable with cultivation of fields but flooding, disturbance due to boulder movements and visiting animals all cause variations in soil conditions which may be reflected in the microbial populations.

When soils are disturbed by flooding or other agencies their basic populations are augmented by a variety of chemo-organotrophic species. The numbers and varieties of **Streptomyces** spp. and **Bacillus** spp. increase considerably and in some peaty areas, such as Streptomyces Passage in Dan yr Ogof, dominate the microbial populations completely following times of flood. In other passages where rotting leaves and branches accumulate, the proportions of **Streptomyces** spp. and **Nocardia** spp. drop and those of Myxobacteria, especially **Cytophaga** spp. increase considerably.

To summarise, cave soils, like surface soils, have indigenous populations which, following any disturbance of the soil are augmented by a variety of transient species. The range of organisms isolated at different times and from different soils have features which have been discussed by many soil microbiologists (Clarke 1967; Conn 1948; Alexander 1961).

Caumartin (1961) explained the isolation of chemo-organotrophic bacteria from cave samples in terms of germination under laboratory conditions of spores and resting stages. This explanation is an unlikely one for the majority of Eubacteria, whilst for spore-bearing groups such as bacilli and **Streptomyces** there is evidence that at least some of the species present are growing actively in caves. In certain parts of Dan yr Ogof growths of **Streptomyces** spp. including **Strept. albus,** are abundant enough to form mycelial mats which can be seen with the naked eye. Caumartin frequently referred to the presence of **Actinomyces** in caves. These are **Actinomyces** as defined by Prevot (1961) and many of the species he referred to would be classed as **Streptomyces** using Bergey's Manual of Determinative Bacteriology (Breed et al. 1957). The abundant growth of these organisms is associated, in his opinion, exclusively with soils near cave entrances. The results from Dan yr Ogof and from other British and French caves refute this suggestion and replace it with the probability that members of the genera **Streptomyces, Nocardia, Arthrobacter** and **Coryne bacterium** represent a basic flora of cave soils, rather than the chemolithotrophic organisms so often postulated.

Undoubtedly chemolithotrophic organisms have considerable interest but it seems unlikely that they play more than a subsidiary role in the energy budgets of active caves such as those in South Wales. There is a sufficiently wide variety of chemo-organotrophic bacteria and sufficient detritus present in most habitats within caves on which to base the food and energy patterns of cave-dwelling animals.

Studies on the bacterial populations of the various water bodies in caves (Table 3) showed that even in pools not subjected to periodic flooding there is a diversity of chemo-organotrophic species. The studies also showed that chemolithotrophic bacteria are relatively scarce, both with regard to the numbers of different species present and the fraction that these species form of the total population.

In one of her papers concerned with food resources for **Niphargus** spp., Gounot (1960) discussed populations of 'heterotrophic' and 'autotrophic' bacteria isolated from silts in cave pools in France. She, too, noted the abundance of chemo-organotrophic organisms. Although Mlle. Gounot concluded that the activities of the chemolithotrophic bacteria appeared insufficient to support the **Niphargus** spp. in the pools under investigation, the presence of organic material and chemo-organotrophic bacteria was still referred to in terms of 'pollution'. The concept that any intrusive material constitutes pollution in caves is incidentally widespread and seems to be connected with attempts to explain the ecology of cavernicoles in terms of caves as isolated environments.

A very doubtful distinction has been made by Vandel (1965) between two types of bacterial populations in caves 'one exogenous and heterotrophic, the other endogenous and autotrophic'. The results from Dan yr Ogof and also from other caves in South Wales and in the Pyrenees certainly do not support this distinction. In the aquatic habitats as in the terrestrial ones there are floras of apparently endogenous bacteria containing chemo-organotrophic bacteria such as **Nocardia** and **Streptomyces** spp., several Gram-ve and Gram+ve cocco-bacillary forms, in addition to some chemolithotrophic bacteria. It is worth noting here that chemolithotrophic species such as **Nitrosomonas** and **Nitrobacter** spp. may themselves be exogenous and washed into the caves from surface soils. Cook and Young (unpublished theses) both reported these organisms from water percolating into caves.

Hawes (1939) made the suggestion that flooding was an important factor in cave environments, principally by disturbing the otherwise consistent, unvarying characters of the environment. Although he saw it mainly as a form of seasonal variation, Hawes also suggested that flooding was important in maintaining food supplies.

Before the significance of these bacterial populations in relation to the food chains of aquatic communities in caves can be discussed it is necessary to review the animals found in aquatic habitats in caves in relation to their known food requirements and distribution.

The two cavernicolous species typical of freshwater sites **Asellus cavaticus** and **Niphargus fontanus** are distributed irregularly throughout many British cave systems. **A. cavaticus** is also found in resurgences of cave streams. For example, on several occasions healthy specimens have been found living under stones in the River Llynfell some 150-200m. downstream from the mouth of Dan yr Ogof. Presumably, these are individuals washed out from the cave systems and unable to migrate back against the current. Similar situations are referred to by Minkley (1961).

Within the caves there is some apparent dissociation of the two species from each other with **A. cavaticus** frequently found in films of water too thin for **N. fontanus.** The latter occupies some pools not colonised by **A. cavaticus.** The dissociation is not complete and the two species occur together in some streams in Dan yr Ogof as they do in Ogof Ffynnon Ddu. The distribution patterns of the two species are complex and without further information it is difficult to define precisely the factors governing them. Direct observations indicate that the presence of clay or silt is essential for colonisation by **N. fontanus.**

There are reports of **N. fontanus** and other species of **Niphargus** eating clay (Vandel 1965), and it is noticeable that **N. fontanus** is absent from clean calcite slopes and from pools with beds of calcite crystals. An apparently wider range of sites can be colonised by **Asellus cavaticus** such as streams, pools and thin films of water with beds of either clean calcite or of clay, sand or gravel. Clay and silt cannot therefore be of the same importance in the diet of **A. cavaticus** as they are in that of **N. fontanus.**

There are few authoritative publications on the feeding mechanisms and food requirements of **N. fontanus** and **A. cavaticus.** Papers by Ginet (1964), Gounot (1960) and Husson (1962 & 1964) discussed the metabolism of **Niphargus virei** and other species of **Niphargus** found in continental Europe. Gounot (1964) has suggested that by eating clay or silt, **Niphargus** spp. are utilizing vitamins and other metabolic products secreted by bacteria. This limited view of the role of bacteria in relation to food resources for **Niphargus** ignores the size of the diverse populations of chemo-organotrophic bacteria found in the clays and silts and in the water. In fact these bacteria could contribute in two ways to the diet of **Niphargus** spp. through the breakdown of organic material to a form useful to the animals, and through the utilization of whole bacterial cells as food by the animals.

The investigations into the nature of the 'water-fungus' had shown that the calcite slopes and surfaces of rocks and pebbles in sites occupied by **A. cavaticus** generally have growths of filamentous Chlamydo-bacteria on them. This raised the possibility that growths of filamentous bacteria might be important in the diet of **A. cavaticus.** Examination of the gut contents of some **A. cavaticus** showed partially digested trichomes of filamentous bacteria similar to the Chlamydobacteria of the 'water-fungus'. A variety of unicellular non-filamentous bacteria were found in association with the Chlamydobacteria and the filamentous growth also entrapped plant debris. It remains to be shown, therefore, whether it is the Chlamydobacteria alone that are important as food for **A. cavaticus** or if a significant contribution is also made by the other bacteria and by plant debris.

Differences in their food requirements may explain the distribution of these two aquatic troglobites and the factors regulating the species and numbers of bacterial populations may indirectly regulate the animal populations.

From the points discussed here and on the basis of observations made in Dan yr Ogof and other caves, it is possible to suggest some links in the food chains involving the two British cavernicolous species, **A. cavaticus** and **N. fontanus,** and by considering the other aquatic animals present and the roles of the bacteria and algae in the pools it becomes possible to postulate a simple food web.

Three of the animal species regarded as accidental inhabitants of pools, **Gammarus pulex, Fonticola vitta** and **Dendrocoelum lacteum** are distributed widely in the Dan yr Ogof system. The pattern of their distribution is initially determined by the overall pattern of flooding in the system from surface streams. All three species can be found in surface streams known to enter the cave system.

Several cavernicolous species of triclads belonging to the genera **Fonticola** and **Dendrocoelum** have been described by Beauchamp (1919, 1949 & 1954) and by Gourbault (1965) from continental Europe. The persistence of the triclad populations in Dan yr Ogof however seems to be explicable in terms of continuous recruitment from surface streams through flooding and of the ability of triclads to survive for long periods with little or no food (Reynoldson 1966). There is no evidence at present for reproduction of triclad species in Dan yr Ogof.

The ecological significance of the recurrent triclad populations in Dan yr Ogof is difficult to estimate.

Fig. 25.

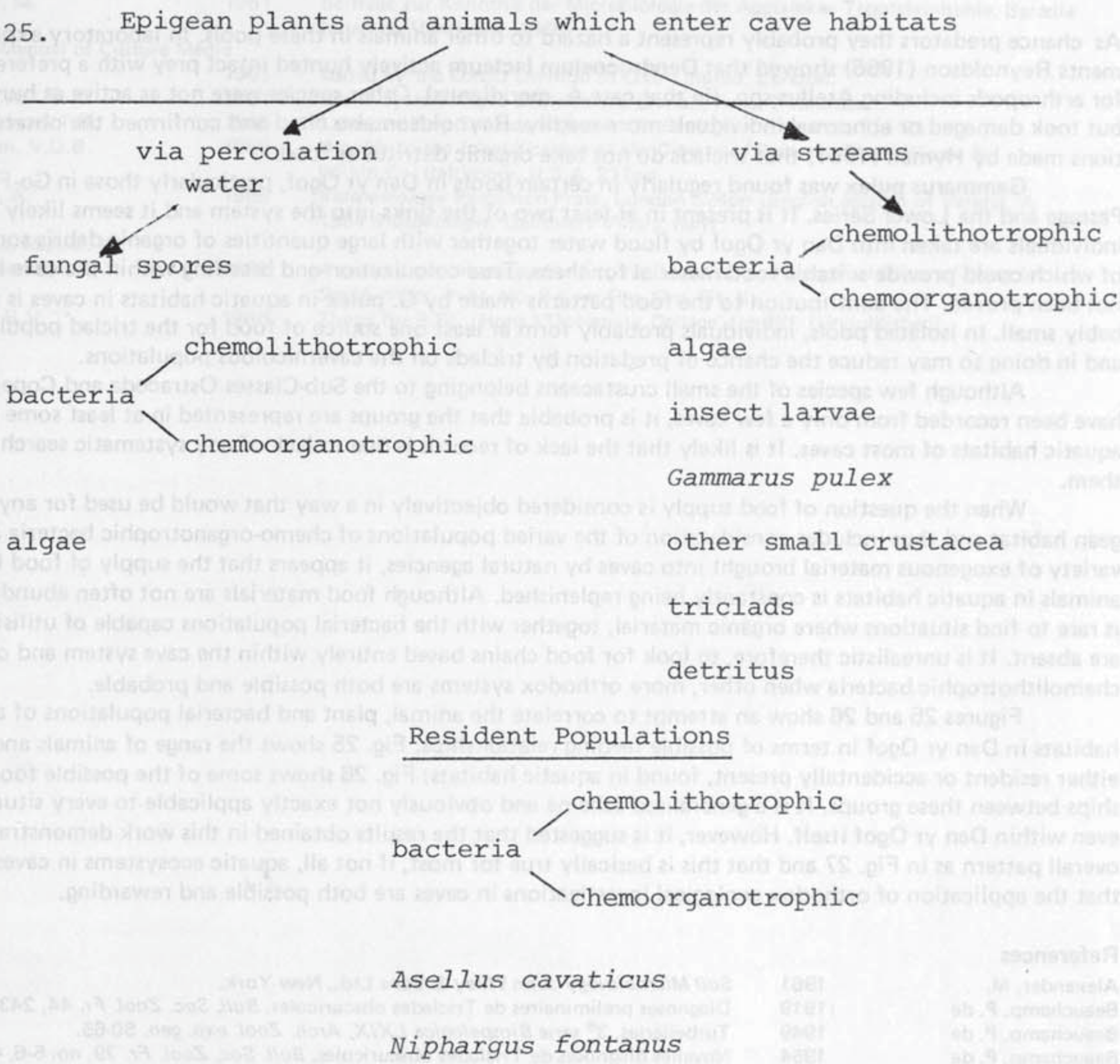
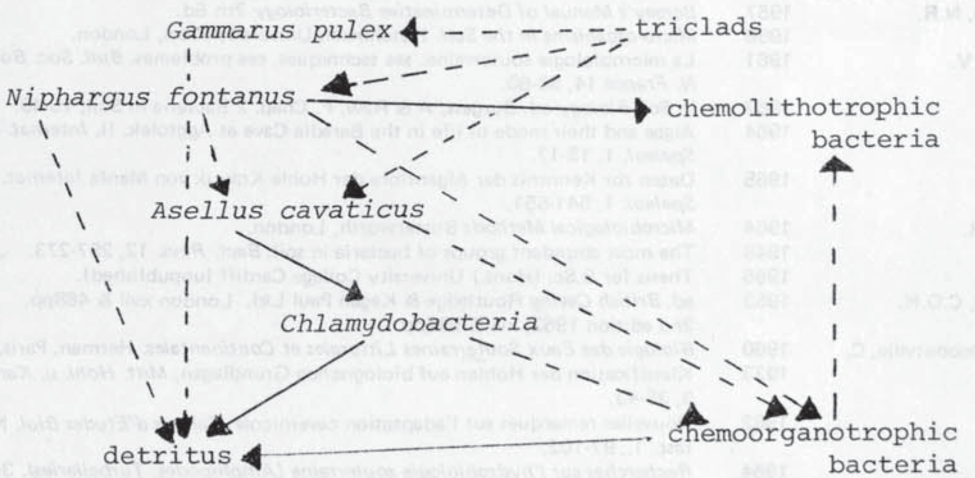
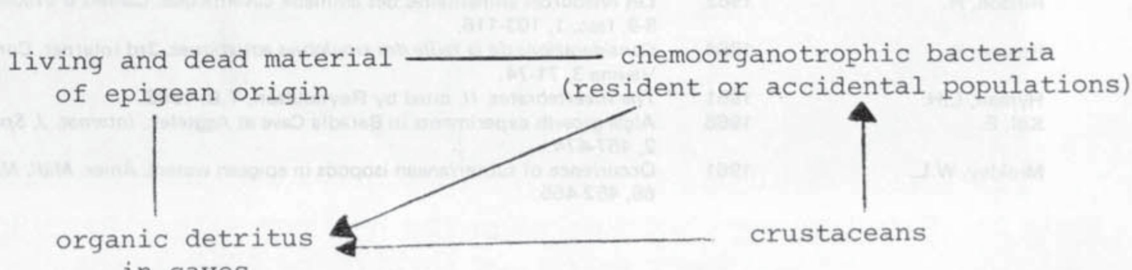


Fig. 26.



——— probable links with direct evidence
- - - - -possible links with only indirect evidence known from cave habitats.

Fig. 27



As chance predators they probably represent a hazard to other animals in these pools. In laboratory experiments Reynoldson (1966) showed that **Dendrocoelum lacteum** actively hunted intact prey with a preference for arthropods including **Asellus** spp. (in that case **A. meridianus**). Other species were not as active as hunters but took damaged or abnormal individuals more readily. Reynoldson also cited and confirmed the observations made by Hyman (1951) that triclads do not take organic detritus as food.

Gammarus pulex was found regularly in certain pools in Dan yr Ogof, particularly those in Go-Faster Passage and the Lower Series. It is present in at least two of the sinks into the system and it seems likely that individuals are taken into Dan yr Ogof by flood water together with large quantities of organic debris some of which could provide suitable food material for them. True colonization and breeding within the cave have not been proved. The contribution to the food patterns made by **G. pulex** in aquatic habitats in caves is probably small. In isolated pools, individuals probably form at least one source of food for the triclad populations and in doing so may reduce the chance of predation by triclads on the cavernicolous populations.

Although few species of the small crustaceans belonging to the Sub-Classes Ostracoda and Copepoda have been recorded from only a few caves, it is probable that the groups are represented in at least some of the aquatic habitats of most caves. It is likely that the lack of records is due to lack of any systematic search for them.

When the question of food supply is considered objectively in a way that would be used for any epigean habitat and thus includes consideration of the varied populations of chemo-organotrophic bacteria and the variety of exogenous material brought into caves by natural agencies, it appears that the supply of food for animals in aquatic habitats is constantly being replenished. Although food materials are not often abundant, it is rare to find situations where organic material, together with the bacterial populations capable of utilising it, are absent. It is unrealistic therefore, to look for food chains based entirely within the cave system and on chemolithotrophic bacteria when other, more orthodox systems are both possible and probable.

Figures 25 and 26 show an attempt to correlate the animal, plant and bacterial populations of aquatic habitats in Dan yr Ogof in terms of possible feeding relationships. Fig. 25 shows the range of animals and plants, either resident or accidentally present, found in aquatic habitats; Fig. 26 shows some of the possible food relationships between these groups. It is a generalised scheme and obviously not exactly applicable to every situation even within Dan yr Ogof itself. However, it is suggested that the results obtained in this work demonstrate an overall pattern as in Fig. 27 and that this is basically true for most, if not all, aquatic ecosystems in caves and that the application of orthodox ecological investigations in caves are both possible and rewarding.

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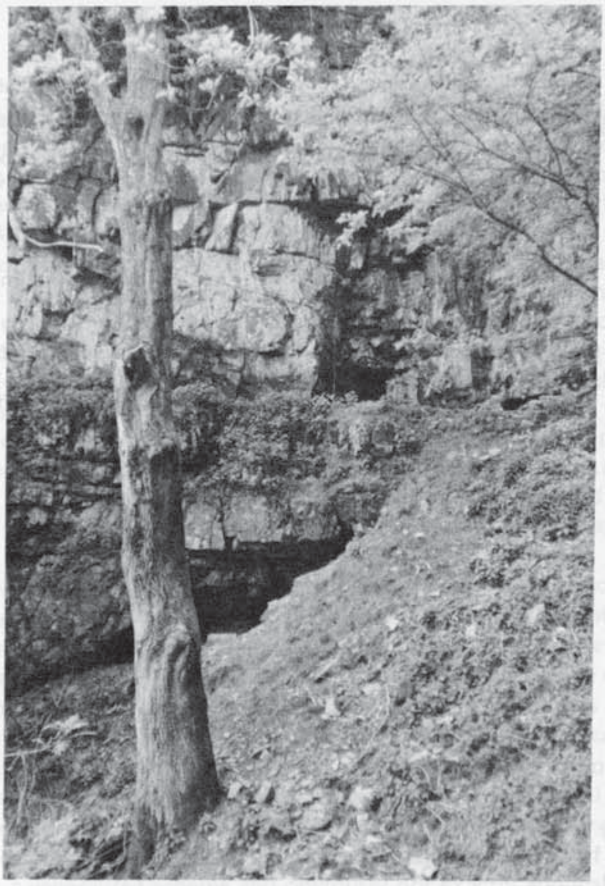

Plate 55. The entrance (on the ledge) to Ogof yr Esgyrn.

Plate 56. Eric Lawrence (of Wookey, on the left) and Arthur Price in the Gwyn Arms looking over the finds of the 1938-9 digs.

IX

THE ARCHAEOLOGY OF OGOF YR ESGYRN (THE BONE CAVE)

About 43m. above the mouth of the great cave of Dan-yr-Ogof is a group of small caves of which the largest is Ogof-yr-Esgyrn, once known as Yr Ogof (Plate 55). Thus the farm was known as "Dan-yr-Ogof", literally below the cave, and so later was the river cave itself. This group of small caves forms part of the old river levels before the Llynfell, a tributary of the Tawe, cut its present channel in the ravine below.

Ogof-yr-Esgyrn is a single chamber, about 18.3m. wide and 10.9m. deep entered by a low tunnel. People lived there nearly 3,000 years ago, not long after the first metal objects (of the alloy, bronze) were introduced into Wales and again during the early part of the Roman occupation and then towards the end of the Roman period. Not only did people live there in Roman times, but they also buried their dead in the cave and it is for this reason that the cave bears its present name.

The first known excavation were carried out in 1923 by a party of students from the University College of South Wales and Monmouthshire in conjunction with the National Museum of Wales, under the direction of Mr. R.H. D'Elboux. They dug several pits in the cave and found early and late Roman pottery, a ring of twisted silver, two bronze rings and an iron ring. Roman bone pins, a coin (a third brass of Constantinopolis), remains of hearths and fragmentary bones of a man, woman and child. Mixed with the relics were the bones of farm animals, some apparently split to get at the marrow.

No further excavations were done until 1938 (Plate 56) and from then until 1950 excavations were carried out over the whole of the cave by Mr. Edmund J. Mason of the Mendip Exploration Society, later the South Wales Caving Club, the largest and oldest caving club in South Wales and still very active in the area. Other experts who associated themselves with the work were Mr. (now Professor) W.F. Grimes, then of the National Museum of Wales and who was later associated with the Saxon Ship Burial Excavation at Sutton Hoo and the Mithras Temple Excavation in the City of London; Mrs. Audry Williams, then of Swansea Museum and Dr. Hubert Savory of the National Museum of Wales, all of whom did very active digging in the cave. In 1939, the excavation was visited during the British Speleological Association's Conference by many of the leading archaeologists in Britain and abroad.

The excavation was not easy. The floor was strewn with boulders, the earth was often muddy and unpleasant to handle and had to be dried out before it could be sieved. The stalagmite crust, which had to be broken in places sometimes involved many hours with sledge hammers and rock chisels. Sometimes large rocks several feet square, which had fallen from the roof in historic times, had to be raised with the help of teams from the South Wales Caving Club. At one point, the floor was covered by a rock so large that it had to be blasted. Underneath were two Roman coins, one with the remains of linen, too fragmentary for preservation, adhering to its underside — the remains of the bag in which the coins had been kept. The cave floor was excavated square yard by square yard, each with separate identification letters, so that the position of each object could be carefully recorded.

In one corner was a deep pocket of sand, the principal burial place in the cave. A human jaw, found at the base of the boulders which had been piled over it, gave an indiction of what was to follow. Skeleton after skeleton came from the pit. It was as much as carpenters could do to knock together the boxes in which to seal and carry them across the steep scree slope above the Show Cave approach. At that time there was no covered way to the entrance to the Show Cave, and it was difficult for four or more men handling a six foot container to keep their feet while they struggled in the loose scree, trying to avoid rolling boulders, down to the approach to the Show Cave. The date of the pit to Roman times was easily ascertained, as some of the skeletons had brooches of Roman date and the pit contained the first coin found in the 1938-1950 excavations, a sestertius of Trajan (97 A.D. — 115 A.D.).

Apparently, when the pit was full up, other burials were made at various places in the shallow soil covering the stalagmite floor and then covered with boulders. About 40 people, men, women and children were buried in the cave. Old burial places must have been subsequently lived on, since some bones had been charred by hearths. The ash from hearths covered practically the whole floor except where stalagmite slopes and bosses made both living and burial impossible. With the hearths were the fragments of pottery jars and dishes which had been broken and discarded. Here and there were found bone pins, bone needles and bronze awls which had been lost in the cracks in the rocks. Sometimes the people lost coins. Nine of them were found in various places and, with pottery, provided valuable dating material for the occupation.

Generally the objects were richer than one would expect from a community living in such a primitive dwelling. Indeed what was such a community doing with a seal box, a small locket-like container used for sealing when despatching messages, an object more likely to be found in villas, towns and military establishments. Were they an impoverished community who had seen better days? Were they in hiding? Or had some of the objects come their way as loot? It is quite common to find people in Roman times living in caves, but their goods are usually inferior to those found in Ogof-yr-Esgyrn.

To understand what kind of people lived in Ogof-yr-Esgyrn in Roman times, we must understand what is meant by the word "Roman" in this context. There were probably very few Romans in the true sense — people from Rome or indeed from Italy — during the Roman occupation in the British Isles. A Roman was a member of the Roman Empire, as the Empire was large, a Roman in the widest sense could be of any origin much in the same way as a member of the British Empire in its heyday could be of any colour and still be

British. The Roman army of the West was essentially Western European in origin – Spanish, Germanic, Gallic, etc. all using their native languages with Latin as a language common for army and administrative purposes. Beyond the military lines of defence, the policing of turbulent territories could be done by auxiliaries often made up of "native" troops, people who knew the country, much in the same way as is done today. Even more non-Roman in the strictest sense were the people of the towns and villages for these were the "local" people, the early Celtic settlers, in fact the early Welshmen. They were the people living here before the Roman Conquest during the Early Iron Age, the Ancient Britons of the old history books. Many of them were fine metal workers in bronze, iron and more precious metals. They farmed the land and could weave and dye cloth. The country was divided into petty kingdoms or tribal territories. In South Wales lived the Siluries. As the people came under Roman influence they became "Romanised". Some lived in cities, provided as a result of Roman policy. Well-to-do farmers lived in villas, which often also provided accommodation for his farm labourers. Administration continued to be in the hands of the old ruling class under "Romanised" conditions, subject to the policy of Roman organisation. The people were basically, therefore, the same as in the Early Iron age and as they were not true Romans in origin, we usually prefer to call them Romano-British. Some accepted "Romanisation" for such improvements as it gave to their way of life, others were more turbulent and did not accept it easily, as was the case in the Welsh mountains. The pottery and articles at Ogof-yr-Esgyrn indicate that the inhabitants were "Romanised" but how deep this went is difficult to judge.

The earliest people found, those of the Bronze Age, were not so numerous as those occupying the cave in Roman times, in fact very few pottery vessels are represented and no bones, as far as we know. Although the occupation by Bronze Age dwellers was probably only by a few people and of very short duration, they left some interesting articles behind, a gold bead, the only gold article found in the cave, a bronze "razor" (although it is not known whether such objects were really used for that purpose) and the blade of a bronze short sword or dirk, belonging to sometime between 1000 B.C. and 800 B.C., a double edged weapon which is part way between a dagger and a sword. The one found at Ogof-yr-Esgyrn was about 343mm. long. When the dirk was discovered, it was found that a rabbit had been burrowing in recent times and become impaled on or trapped by the point of the dirk and had died there. The weapon had proved lethal long after its original owner had lost it!

The Bronze Age people were the people living in the British Isles before the arrival of the Early Iron Age people. Just as the Early Iron Age people introduced the use of iron, the Bronze Age people brought with them the first organised knowledge of metallurgy in Britain, but iron was still unknown and although a few objects were made of copper most of the metal objects were made in bronze. Gold was often used for decorative purposes and farming was already known before the arrival of the first Bronze Age people. With them we associate the round burial mounds, so common on Salisbury Plain and stone circles such as Avebury and Stonehenge. To them probably belonged the Saithmaen, a group of stones on the Cribarth near Ogof-yr-Esgyrn, the stone circle below the Fan and several standing stones and certain other remains in the neighbourhood.

E.J.M.

This chapter is reprinted, with permission, from the Dan yr Ogof Cave Guide. A fuller account of the 1938-1950 Excavations is contained in "Archaeologica Cantabrica" 1968. Further work commenced in the Autumn of 1976 under the direction of Ted Mason and initial results were rewarding. Major efforts will re-commence from Easter 1977 and assistance will be welcomed.

X

FUTURE PLANS

It is hoped that this publication will act as a stimulant for further exploratory and scientific efforts in the Dan yr Ogof area. These may well prove or disprove some of the hypothesis herein but of much greater importance is the need for there to be a high degree of co-ordination of such activities and the recognition that without conservation and care much that we do now may impede the work of future generations of speleologists.

Many experts have expressed interest in Dan yr Ogof either actively or as "back-room boys" and it is hoped soon to launch a new programme of co-ordinated activities. The S.W.C.C. committee and the Dan yr Ogof directors support the concept and it is hoped that many cavers and scientists will support the ongoing programme. While the leader system operated by S.W.C.C. will still operate it is relevant to point out that there are many "guest leaders" drawn from other clubs. They have rights of access similar to those of S.W.C.C. leaders except that they are not permitted to lead other visiting clubs. However, it is hoped that the guest leaders and their own clubs will play an active role for Dan-yr-Ogof is not, as has sometimes been suggested, a "closed shop".

Plans include a detailed programme of exploration (with a careful log of progress being kept together with indications of further possibilities), surveying, hydrology, archaeology, bio-speleology, geology and geomorphology. Hopefully the results of these future explorations will make this Transactions look like a preliminary note, and will provide the material for many future publications.

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