UNIVERSITY OF BRISTOL

SPELAEOLOGICAL SOCIETY

SYMPOSIUM ON THE AGE OF THE CAVES OF NORTH-WEST CO.CLARE IRELAND

To be held in the Department of Geography on Saturday 12th December, 1964 at 2.30 p.m.

INTRODUCTION

South of Galway Bay Ireland lies a large area of limestone upland called the Burren. In the south of this area near the spa of Lisdoonvarna there are a considerable number of caves.

The society has been actively engaged in the exploration, survey and scientific investigation of these caves over a number of years. The question of the age of these caves has always been a particularly interesting one. The caves of the area are somewhat unusual in many respects and the solution to this problem may be of considerable importance to a complete appraisal of the geomorphology of this Karstic region.

SOME NOTES ON THE AGE OF THE CAVES OF N.W.CO.CLARE

by C.High

EARLIER IDEAS

It has been considered that in general the caves of N.W.Clare are a Post ~~part of~~ the last glacial age. This has been expressed by several members of the U.B.S.S. in proceedings (notably Ollier and Tratman 1956 and Perratt and Eaton 1960).

The arguments put forward may be summarised as -

1. The simplicity of the passage system and general apparent youthful appearance of the caves. Their shallowness and slight gradients.

2. Lack of frost shattering in the entrances and in the roofs of the shallow caves which are very near the surface.

3. Lack of drift blockage in the entrances.

4. Rate of solution data. Perratt 1960 has shown that according to the data then available the caves could have been formed in the last 20,000 years. (This calculation was for C3. cave only but would apply to the Callaun caves in general)

EXCEPTIONS

There are some caves or parts of caves that have been considered as being pre glacial in origin. Kilcorney caves and Fergus River cave are obvious examples as are some of the caves in the cliffs along the coast between Doolin and Fanore. Collingridge 1962 has concluded that parts of Poulnagollum are at least pre the Newer Drift. (72,000 years according to Zeuner).

Work done by the society in July 1964 has given rise to some newer ideas on the age of the caves in the area.

The work is of two kinds -

a) Morphological studies
b) Solution of limestone studies.

a) Morphology.

Summary of the work on the Cullaun caves.

I. The Cullaun valleys below the sinks are filled with large amounts of grey clay containing shale fragments. As far as can be ascertained by borings no shale occurs in the Cullaun valleys below the sinks (contrary to the map in Ollier and Tratman 1956)

II. There are notable gorge features in the valleys in the lowest sections. These must have been formed at a time when there was a considerable amount of surface drainage i.e. during peri glacial conditions of melt water and or perma frost.

III. The streams sink just below the shale edge. There is no stream coarse below the sinks but the valleys are partially blocked by infill. It is reasonable to argue that the streams must have gone underground before the infill was deposited. After the deposition of the infill it was easy for the streams to re-excavate an old sink without having to cut a new stream coarse in the valley.

IV. It is reasonable to ascribe a peri-glacial origin for the grey clay with shale fragments infill. The deposits are of a solifluction type and would require periglacial conditions of considerable lubrication and freeze thaw to produce them.

V. The lower gorge sections of the valleys must have been formed before the deposition of this solifluction infill because there is some of it in the floors of these gorges.

A suggested sequence for the drainage of the Cullaun valleys may be summarised as follows :-

a) Original Drainage pattern at least pre the Newer drift (probably pre the Glacial Period)

b) Newer drift deposited boulder clay on top of Poulacapple and elsewhere.

c) Peri glacial conditions at the end of the Newer drift surface streams deepened the cullaun valleys and probably formed the gorges.

d) The caves initiated between the end of the Newer drift and the beginning of the Scottish Readvance.

e) Scottish Readvance peri glacial period solifluction deposits of valley infill.

f) Return to warmer conditions surface drainage would have quickly re-excavated the old sinks and gone under ground leaving the lower sections of the Cullaun valleys dry and partly filled with solifluction deposits.

This suggests that the caves were formed between 72,000 and 20,000 years ago.

Solutional data does not correspond with this age but indicates a much younger age for the caves. However the data obtained this year is the most detailed yet available for the area and indicates that as yet the unknown factors and the inadequacies of the data are so great that no reliable conclusions can be drawn from it. Whilst the original figures for the rate of limestone solution obtained this year are completely different to the figures used by Perratt (1960) they give an age of a similar order but rather younger than those given in that paper. Also it has been shown that there are notable differences in the rate of solution between different caves in the Cullaun series. The major problem that has become obvious in the studies this year is the difficulty of assessing the importance of small seepages in their contribution to the total figures for calcium carbonate content of the stream water. Solutional data has not yet advanced sufficiently to enable it to be used for Geochronology.

COOLAGH RIVER CAVE

Immediately below the Coolagh River Cave entrance (Poldonough) there is a very large blockage of the valley by boulder clay. This gives a characteristic blind valley form. It seems most unlikely that the stream entering Coolagh River Cave could have cut through something of the order of 60 feet of Boulder Clay into a sink unless there was a pre-existing sink and underground drainage system into which it might have found its way. Boulder clay is exposed in the sides of the valley above the cave entrance as remanents of a once much larger infill. The situation at Poldonough south is somewhat similar

SOME POINTS BEARING ON THE AGE OF THE CLARE CAVES

By E.K.Tratman

A. Flora.

Soil cover from its flora will have a relatively high CO_2 content and water percolating through it will have a high CO_2 content and therefore high dissolving power.

Where there is shale cover and peat bogs a fair cover of trees is shown in peat cuttings. This cover continued sparsely till late Bronze Age times (c. 800 B.C.) at levels up to 600 ft. O.D. On Poulacapple a forest layer occurs up to 900 ft. O.D. and rests on "clay", presumably boulder clay. This forest layer can be dated from the objects found in it as existing as late as c. 1800 B.C. The layer is not very thick and may have been formed fairly rapidly. Deforestation seems to be of human origin and for Poulacapple took place during the early Bronze Age. It may be inferred that similar forest growth covered Slieve Elva up to 900 ft. O.D. and perhaps right over the summit.

The little evidence that there is suggests that on Poulacapple at least there was no thick soil cover before c. 2000 B.C. but this is an inference based solely on observations on Poulacapple.

For the bare limestone there are two opposed views :-

1. The vegetation cover is increasing.
2. The vegetation cover is decreasing.

Personally I favour (2) from detailed examinations of considerable areas. Dessication is progressive but is largely if not entirely man made (e.g. over grazing by beasts especially goats). It is probable that from at least 2000 B.C. and perhaps as early as 4000 B.C. that the limestone carried a substantial amount of vegetation much more than now though it is still considerable if the plants growing in grikes are considered.

Percolation water from the bare limestone does not seem to play an important part in cave formation in Co. Clare so vegetation cover is probably an unimportant factor. Temporary large flows do appear in caves and can only have been derived from percolation through cave limestone.

B. Sea Level

The changes can only be inferred because little if anything is known about them. By extrapolation from Britain sea levels can be assumed. However sea levels would not effect the Clare caves that we are considering except the Doolin system, unless the high level caves were formed very, very much earlier than is thought, sometime during the early middle Pleistocene when sea level might have been + 200 ft. and Doolin could not have formed.

The last glaciation (Wurm) in Britain had the lowest sea level (at - 150 ft. in Bristol Channel for example). It was not till the first maximum had passed that sea levels began to rise much. By 2000 B.C. they were about -10 ft. at Brean Down for example. A similar gradual rise can be postulated for Ireland after the maximum of the Irish 2nd glaciation correlated generally with Wurm 2.

C. Post-glacial Surface Erosion

The Aille River and its tributaries have cut deep narrow gorges in the shales. These gorges could not possibly have survived an actual glaciation. Besides there are glacial erratics along the edges of the gorges in places or near them. Exposed sections of shale do show some degree of disintegration in depth down to c.10 ft. This is presumably the result of frost action. ? permafrost conditions.

D. The Potholes Away From the Shale Edge

(1) Poulnagree. This may have glacial fill in it but if so is it stream borne or glacially borne ?

(2) Pollapooka. ? has glacial fill in it. Most of the material and that in adjacent hollows seems to be stream borne debris. ? temporary lakes under permafrost. In a branch of this depression is the choked mouth of a considerable cave. The roof is only just under the surface. There is a rudimentary valley system running into Pollapooka from N. descending from a summit area N. of Slieve Elva. If this was covered with shale it could have been the collecting ground for the original P. water. There is also a valley system of sorts running out of Pollapooka 1 and 2 to end on the steep slope down to the sea. The sides of P. 1 and 2 are breached well above their bottoms by these valleys.

(3) Poulnagollum. The passages of Upper Pg. run very close to the surface as they approach pot. Baker's Rift is unroofed some way back from the pot. (Only boulders block the roof opening). (This is NOT the opening Baker describes). U.Pg. main route is unroofed as soon as it gets within confines of pot. Considerable evidence of phreatic solution upwards in the pot. This runs up close to the surface. The amount of rock and mud in the pot is surprisingly small when it is examined in detail. One must also consider the substantial contribution by man to this infilling.

(4) Pollbeg. Pollardua. The latter is the top of an aven opening from a trough or dog valley in the limestone not far from Pg. the trough continues south and the next opening is Pollbeg. When this was open the stream route, a new route still developing, entered on the north with its roof about 15 ft. under the top of the limestone. The stream cascades down over a steeply sloping boulder ruckle and was visible. The dry valley continues about 100 yd. beyond Pollbeg.

(5) Poulelva. U.Pe. is unroofed as it enters pot. and there has been waterfall retreat. Round the top of the pot, especially at south end are many solutional features running up to a few feet from the surface. Their form indicates solution under phreatic conditions.

Parallel to the east side of the pot is a vertical rift. Its roof is close under the surface. It is quite wide at base. There are many vertical flutings down its walls. The total amount of fill in the pot is quite small. The mud slope on the south is largely a rock slope with a covering of mud. This applies also to north end.

(6) Hawthorn Swallet/Rising. The water rises temporarily in an extension of a closed depression with a massive fill. ? stream borne under permafrost conditions. The extension consists of two parallel joints about 2 ft. apart. The rock between has collapsed. The rift so formed contained only material from the collapse as can be seen from the material cleared out by the farmer. The cave roof where the water rises is only 8 ft. under the surface. This is about $\frac{1}{2}$ mile from source.

E. Swallets at shale edge

The extent of headward retreat and the size of the potholes is surprisingly large considering that these swallets must be of post-glacial origin. There are very many of them.

F. Potholes Within Shale Edge

Fisher Street. There is about 15 ft. of shale on the top of the limestone here. There is no more debris in floor than can be accounted for by simple collapse of shale into an existing cavity. There is no glacial borne debris.

G. Mud Fills

Several caves contain these. There may be remnants as yet unobserved in other caves. Some of these fillings are laminated and appear to be resorted boulder clay. In places they rest of coarse stream borne shale debris and the like. In general they are being removed and not deposited, at least in the accessible parts of the systems.

H. Poll-an-Ionian

The only cave in which glacially borne deposits can be seen to have been intruded into it by glacial action.

I. Caves at Sea Level

Pollsallagh and Poulcraveen. The latter still has a small stream issuing. Both are typical tall canyon passages of considerable size. Both are invaded by sea. They must belong to an older set of caves. They are quite isolated from existing known systems.

J. Water Supply

Present day water supply conditions, except under occasional floods, probably bear but little relationship to those when major parts of the systems were developing. Under periglacial conditions there would be for considerable periods each year diurnal floods (c.f. periglacial conditions today or even the rise and fall of rivers issuing from, for example, the Pyrennees). The daily flood could have been very substantial. It might have frequently equalled the 1961 flood when the surplus water not going through the Coolagh River Cave was of the order of 400 cu.ft./Sec assuming only rate of 10 ft./sec. flow. (The temporary river moved flattish stones along weighing at least 14 lbs.).

K. Closed Depressions

In the area considered there are several. A few are quite large. Some, such as the one related to Pollballiny and Thornbush Swallet rising have considerable deposits in them. Others only seem to have limestone boulders in them and a little soil derived from weathering. A noteable example of this type is on the col between the twin summits of Gleninagh Mt. This hollow must be postglacial in origin. It must be solutional in origin and represents a loss of at least 5 m. cu.ft. of limestone.

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Collingridge et al. 1962

Poulnagollum - Pouleva Caves.
Proc U.B.S.S. 1962 Vol.9 No.3.

THE AGE OF THE CLARE CAVES

B.R. Collingridge

The interstadial referred to in this selection of ideas is that which lay between the 2 main phases of the last glaciation. This ignores the brief and restricted phase of the Highland or Scottish Readvance and thus postulates only 2 possible periods for the formation of the Clare caves; either before or after the laying down of the Newer Drift.

The Criteria for judging the period of formation of the caves appears to to be as follows:-

A. Infilling

(i) If deposits are present in a cave and can be proved to have a glacial origin this is evidence of the formation of that cave at least before the last major advance of the ice.

(ii) If deposits of glacial origin are not present this fact alone need not preclude the earlier date of origin for the cave but the lack of such deposits is significant when one considers the relatively exposed position of some of the varved remnants on the shelves to the side of Polnagollum Main Streamway which will be covered by flood waters fairly frequently but still remain.

There is a possibility of confusion over the nature of deposits but generally the varved, immediately post glaciation deposits are markedly dissimilar to present day stream silt and boulder clay washed in from near a cave entrance.

B. The relation of the stream to the passage it occupies.

In a normal streamway the passage is an historical record of the occupying stream's or streams' character as evidenced by its or their erosive capacity.

'Typical' Canyon Passage

(i) Many of the Clare passages have a cross section of uniform width with a stream filling the passage floor and evidently in harmony with the passage long and cross sections. These can be called unicyclic - the stream flowing in the passage formed it.

(ii) Several of the passages lack this harmony between stream and cross section resulting in one or both of two variations.

Either the stream is eroding vertically where formerly it eroded laterally or v. versa. Or the passage plan reveals that the upper part of the passage meanders at a different wavelength to the lower part.

Both of these variations would appear to have been produced by
(a) A prolonged change in rainfall regime, or
(b) A new stream adapting an old passage, or
(c) A change in solubility resulting from a change in bed, or
(d) A change in catchment.

If (a) is the cause it will have affected all the caves of the area equally so evidently the unicyclic passages all developed within the present rainfall regime. However, some of the one cycle passages are quite considerable and it seems unlikely that they could have formed in a sufficiently short time to allow more than that one development since the last glacial advance.

Examples of (b) are known i.e. P.G. Low Road, Pol-an-Ionain.

It would appear that (c) can be largely disregarded as a cause, the beds of the limestone appear to be significant only at the start of a cave.

(d) can lead either to changes in a passage cross section or result in a small stream flowing in a passage out of proportion to its erosive capacity.

C. Periglacial collapse

For a considerable period this area underwent periglacial conditions and the probable effects of this can be seen clearly in some of the interstadially formed passages. Roof collapse on a massive scale with the admixture of much sticky clay is evident in Cottar's Gallery P.G. and in the entrance to Pol-an-Ionain for example. These passages and the others in which collapse has occurred are not the only ones near the surface however. It is a feature of the Clare caves that they are shallow. Thus it could reasonably be expected that collapse attributable to periglacial conditions would be apparent in most if not all of those caves which were of the same age as the two mentioned above. Relatively few caves exhibit this form of collapse.

Although this area lies to the north of the S. Irish End Moraine it was evidently never an ice centre, and so, as Charlesworth suggests, these uplands must have been among the first in Ireland to be free of ice, if in fact the crests were ever covered. So for a long time after the last main phase and perhaps again at the time of the Scottish Re-advance, N.W. Clare had a tundra climate with its attendant permafrost. Dury writing of permafrost in N. Canada states "In the belt of continuous permafrost, the sub-soil never thaws. Temperatures at 30 to 50 feet below the surface are below 23°F., and go as low as 10°F. in places". Dury gives no indication of the nature of the rock in which these observations were made unfortunately.

D. Surface evidence

There are few surface features which give any clear indications which will assist. Most of the caves start inside or at the Shale/Limestone boundary but some passages appear to have been formed when the Shale extended further out. These are principally the tributaries of Polnagollum which enter from the East e.g. Branch Passage Gallery, the surveyed end of which lies several hundred feet away from the present Shale edge and its stream is only a relatively insignificant trickle in a large passage. The three pot holes also stand clear of the shale edge.

A STUDY OF LIMESTONE SOLUTION: POULACAPPLE, CO. CLARE, EIRE.

Colin High.

It is increasingly obvious that geomorphology must involve a detailed study of the processes that are at work on the landscape, as a better understanding of these is essential to aproper interpretation of landforms. The investigation of erosional processes is complex. One of the most difficult problems is that of measuring the quantities of material which are being removed. As much of the material in limestone areas is being removed in solution, it is possible, by the application of simple chemical techniques, to measure the amount of limestone which is being eroded. The purpose of this account is to draw attention to some of these techniques and to describe how they were used in a small scale study in County Clare, Eire.

It is possible theoretically to measure the amount of solution taking place in a limestone area. This involves determining the calcium carbonate content of the water draining the area and the discharge of the streams, so that an estimate of the rate and amount of solution can be made as did Williams (1965) in the R. Fergus basin in Co. Clare. The study described here is of the solution in a very small area drained underground by a 1st. order stream.

As one of the most notable features of limestone areas is the tendency of drainage to go underground, many of the stream courses are not open to sub-aerial erosion. Thus, subterranean streams have eroded passages which are essentially the products of solution of the limestone. This comparative simplicity of process greatly facilitates a quantitative study.

Consider a small stream going underground and re-emerging at a rising small distance away. This may be considered as a model situation which is fairly typical of streams in the N.W. Co. Clare Karstic area. A good example is the Cullaun I stream which drains from the peat covered summit of Poulacapple Hill (907 ft.) on a basal geology of non-calcareous and impermeable Namurian shales. On the surface it has cut a small gorge into the shale on the flanks of the hill. Where the stream reaches the limestone underlying the shales it sinks in a small swallet and from this point it runs underground to re-emerge at Killeany. It is possible to enter and explore the stream passage for much of its length.

Measurements of Calcium Carbonate.

This study considers only erosion by solution. There is good evidence that mechanical erosion is of only minor importance in underground stream passages. In some places in the caves of the area false floors of insoluble chert bands remain at higher levels whilst solution has proceeded in the passage below. There is very little obvious bed or suspension load in the stream and most of the deposits in the cave are reddish-brown mud which is largely the insoluble remains of the limestone.

The technique for the determination of the calcium carbonate content of the water by titration with E.D.T.A. for calcium is adequately described in the literature (Smith and Mead 1962). This technique is simple and lends itself to the titration of a large number of samples under field conditions. 250 millilitres samples were collected in polythene bottles, excluding as much air as possible. Titrations were carried out on 100 ml within 36 hours of collection, leaving sufficient water for a further titration if required. The tables and graphs show the calcium carbonate contents of some samples collected at various places in Cullaun I cave, and from the stream on the surface.

Calcium Carbonate is the most important constituent of the dissolved load. The only other significant constituent of the limestone which is dissolved is magnesium carbonate. $MgCo_3$ is never more than 5% of the total disolved carbonates in this stream.

Discharge.

It is important to be able to determine the discharge of the stream in order to calculate the rate of erosion of the limestone. The best method of measuring the discharge of a small stream is by the use of a V notch weir. If the stream is ponded up and allowed to escape over the notch then it is possible to relate the depth of water over the apex of the V (H) to the discharge of the stream, using the equation,

$$Q = 2.5 \ H^{2.5}$$

where Q is the discharge in cubic feet per second, and H is in feet.

The building of weirs in underground passages can present difficulties and in consequence a chemical technique for determining the discharge was used in some instances. If a chemical of known concentration (in this case sodium chloride) is introduced into the stream at a known rate, then the ratio of the dilution of the chemical by the stream will be the same as the ratio of the rate of introduction of that chemical to the discharge of the stream. The salt concentration of the introduced solution and of the dilute sample from the stream can be determined by titration with silver nitrate down to concentrations of 50 ppm. This means that a discharge of up to 200 times the rate of introduction of the salt solution can be determined by this method. The formula for this calculation is

$$Q = r \times \frac{c_1}{c_2}$$

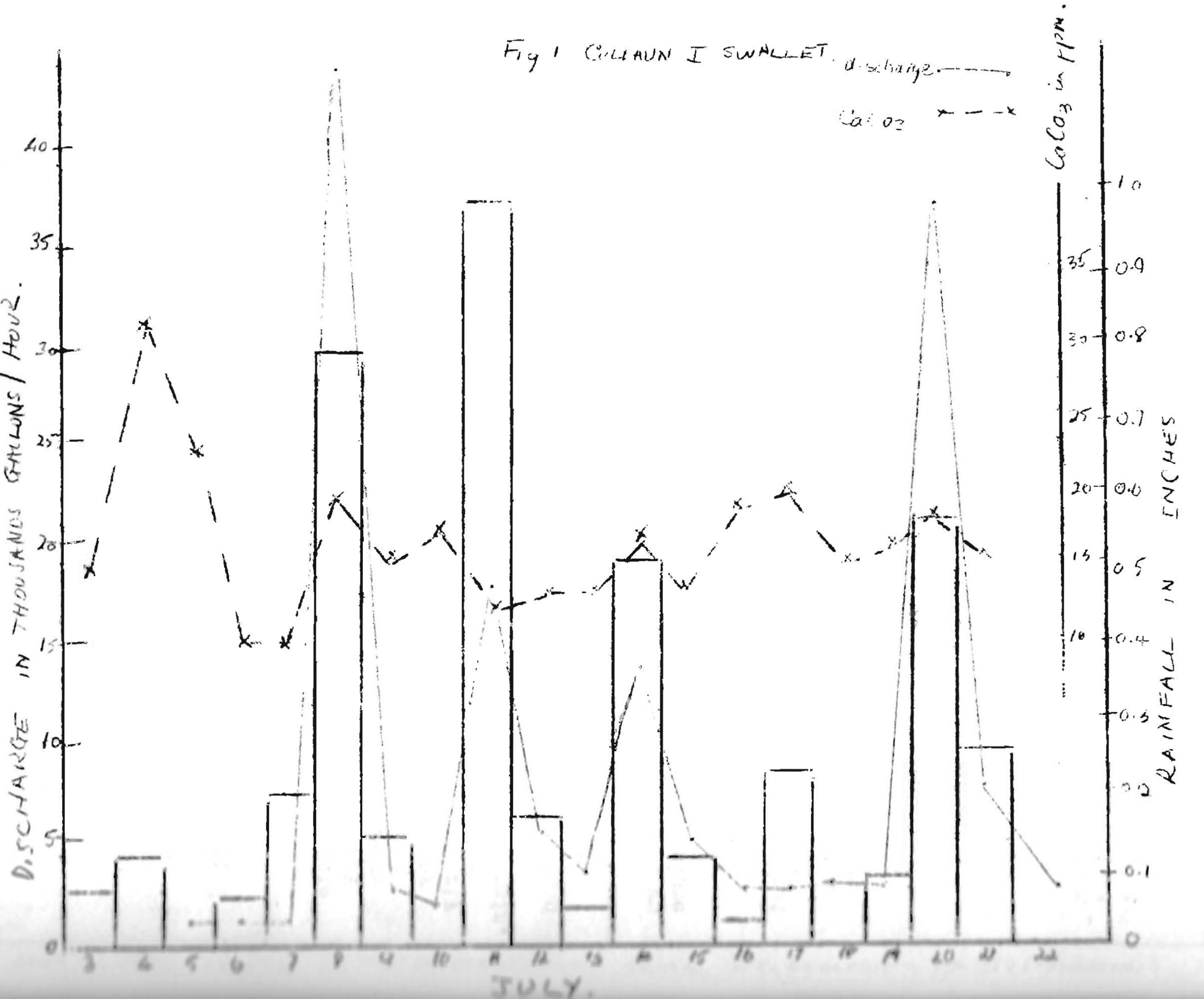

Fig 1 CILLIAUN I SWALLET.

51

where Q is the discharge of the stream, and r is the rate of introduction of the salt solution. c_1 and c_2 are the salt contents of the concentrated solution introduced and the diluted stream sample respectively.

Results

The stream entering Cullaun I swallet was sampled daily for 3 weeks and the calcium carbonate content as well as the discharge and the local rainfall are shown on fig I. It will be noted from this that there is a good correlation between increasing discharge and decreases in the calcium carbonate content of the stream. This accords with the work of Smith and Mead in the Mendips. The figures for the calcium carbonate content of the stream increase down the cave and the tributary streams contribute to the total. Fig 2 shows this progressive increase in the solution load down the cave. It is difficult to be sure to what extent the increase can be accounted for by additions from tributary streams, as these and more particularly seepages are invariably of a higher calcium carbonate content than the main stream. The origin of these waters is, in the main, by percolation through the soil and into fissures and joints. This means that the water will dissolve more carbon dioxide than a surface stream and hence will be more capable of solution. Thus, the waters in their slow passage from the surface may become very highly charged with calcium carbonate.

The discharge figures also show a progressive increase down the cave. It had been thought previously that the actual volume of water added by small seepages was not significant but discharge measurements by means of the salt solution method have shown that even when the individual volume of the seepages is so small that they can hardly be detected, their compound effect is considerable. That much of the water flowing past the end of the cave is from seepages which have entered by percolation through the soil and rock is important in making an assessment of the amount of solution by the stream.

The average calcium carbonate content for the swallet of Cullaun I stream is 15 ppm, while that for the end of the explorable part of the stream passage is 85 ppm. It could therefore be considered that the Calcium Carbonate increase was about 70 ppm. A calculation based on this and an average discharge of 100 litres per minute would indicate that the stream was dissolving at the rate of 7 grams of $CaCO_3$ per minute, As stated above, this does not take into consideration the considerable amount of calcium carbonate which is dissolved by the small seepages and tributary streams. The $CaCO_3$ content of the stream at the termination of the passage includes this addition; nonetheless these figures do show that solution is a

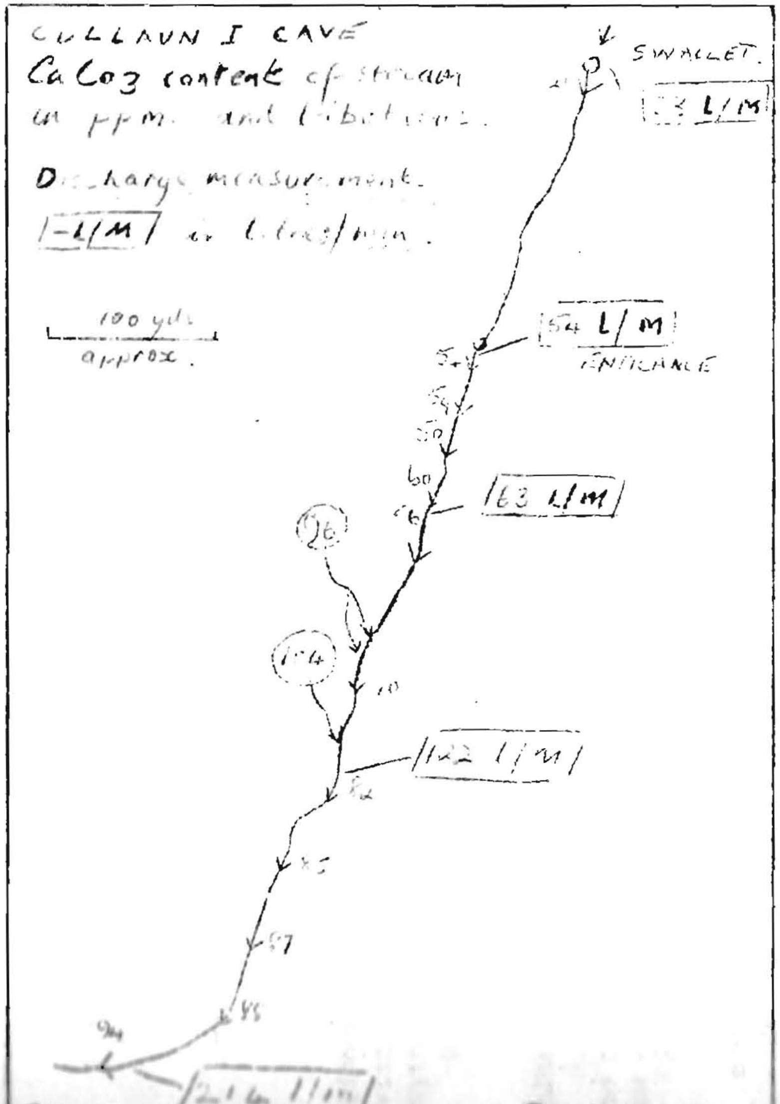

Fig. 2

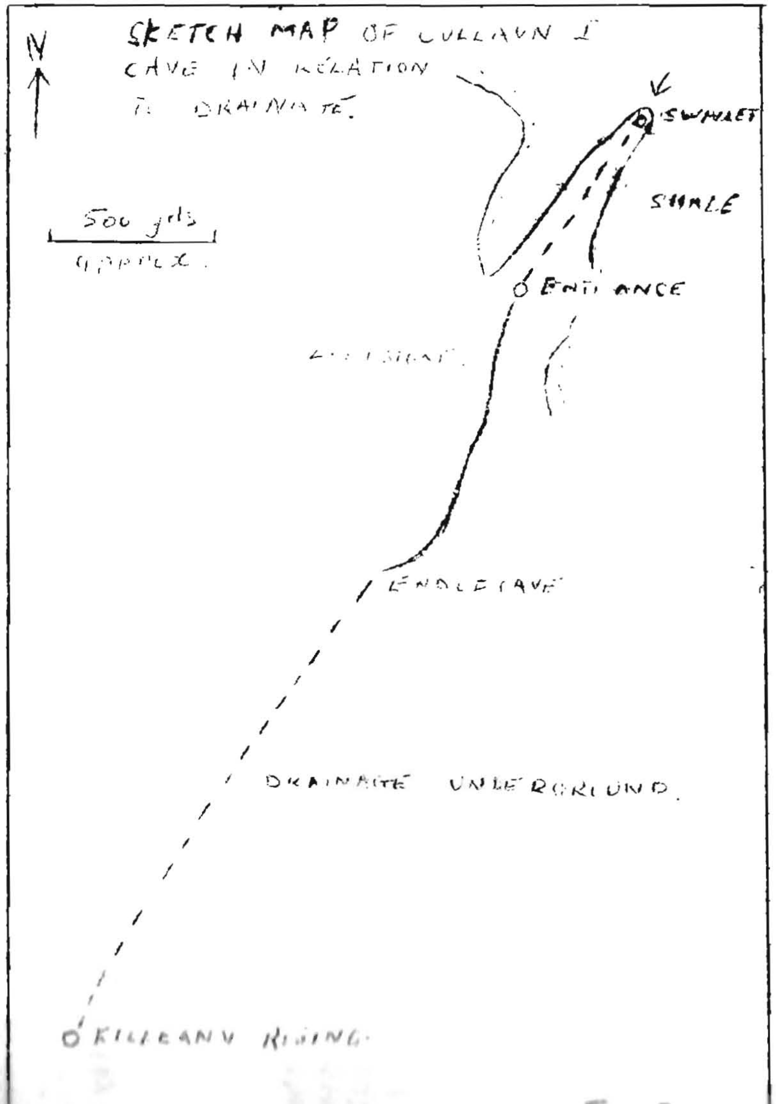

Fig 3.

FROM SURVEYS COURTESY OF THE UNIVERSITY OF BRISTOL SPELAEOLOGICAL SOCIETY very potent force in limestone areas.

This raises some interesting questions including the possiblity of calculating the age of cave passages in some cases by the rate of solution. Some writers have made attempts at this but, as yet, the amount of detailed data on the rate of solution is not sufficient for any accuracy to be obtained.

Conclusions.

It can be shown that solution seems to follow a reasonably logical pattern and that underground streams show a progressive increase both in the amount of dissolved load and in discharge. There is also a very good correlation between rainfall, discharge and calcium carbonate content. This variation of calcium content with discharge is important in considering the long term solution of the area for, unlike normal mechanical erosion, there is not such a simple increase of erosion with discharge and velocity. It is not clearly established when or under what conditions the most rapid solution takes place - much more detailed field and laboratory measurements of this are needed.

It should be possible by the use of chemical techniques to neutralise the solutional properties of the main stream and then determine the effect of the additions by small tributaries in increasing the calcium carbonate content of the stream. By such methods it may be possible to assess the solution rate of the stream alone and to determine how it varies seasonally, and under differing discharge and velocity conditions. Finally detailed solutional studies may solve the problem, raised by Corbel, of the rate of solutional development in contrasting climatic regimes.

Acknowledgements.

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