The Cullaun Series of Caves County Clare, Ireland

By Paul R. Acke

INTRODUCTION

About three miles to the north-north-east of the spa of Lisdoonvarna lies the mountain mass of Slieve Elva. The east side of this slopes down to a valley divided into northward and southward sloping parts. In the northern part is the surface river Caher. Near the south end of the southern part is the large, but partially intermittent, rising of Killeany. In the east side of Slieve Elva, starting to the north of the valley watershed and passing through that watershed on its way south, is the great cave system of Pollnagollum (Coleman and Dunnington, 1944). It may be likened to a great main drain receiving the waters of many tributaries.

On the opposite side of this double valley below Slieve Elva is the rounded ridge of Poulacapple Hill rising to 800 ft. The northern portion of the ridge consists of the bare limestone of The Burrens with its clint-like surface. The southern portion carries a covering of Upper Limestone Shales with glacial drift on top and peat over this : the one inch to one mile geological map (Clare, Sheets 114 and 123), shows a much indented outline for the shales on the west and to some extent on the south, with re-entrants of limestone and occasional inliers of the same rock.

The topographical map shows no cave systems save that there are several small streams marked as ending abruptly. The question therefore arose as to what caves there might be in the area. In 1951 preliminary investigations were made and one cave, Cullaun I, was discovered. The main work of the Society in that year, however, was the completion of the study of the Coolagh River system (Bendall and Pitts, 1953).

The results of 1951 were given careful consideration and it was decided to continue the investigation of the area in subsequent years. The objects of the work were :

1. To find out what caves existed in the area.
2. To determine their general form and characters.
3. To survey the pattern of the underground drainage and establish its relationship to the topography.
4. To make, if necessary, additions to the geological map of the area.

A brief account of the discoveries in 1951 and 1952 has already been published (Acke, 1953). The present paper includes the results of researches in 1953.

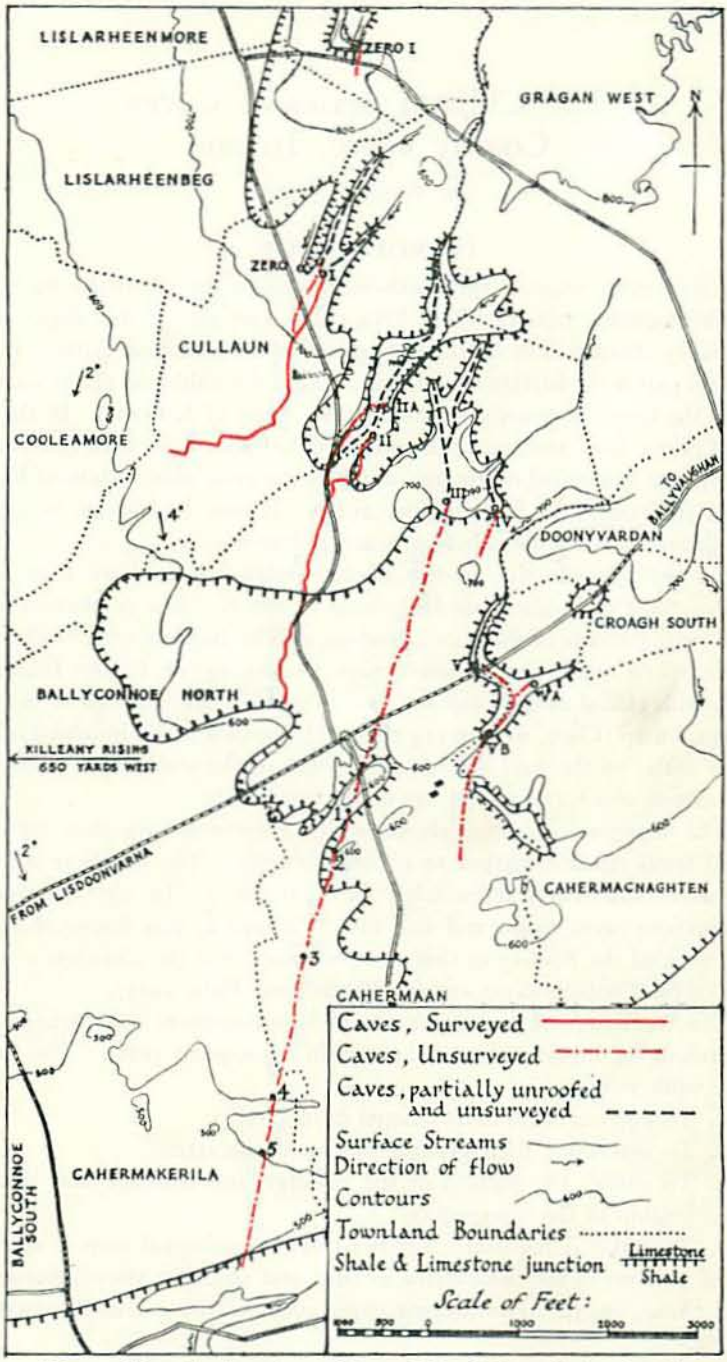


Fig. 1.—Map showing the positions of the Cullaun Series, based upon the Ordnance Survey by the permission of the Minister for Finance, Republic of Ireland.

The series has been named the Cullaun Series (*Fig.* 1) after the townland of Cullaun, in which lie the entrances to Cullaun Zero, I and II. In order to emphasize that the caves fall into a natural group it seemed desirable to have a single name instead of naming each cave after the townland in which its entrance lies. As no underground connexions have so far been discovered between the several members, the term "series" is used in contrast to the term "system".

The series is numbered from north-north-west to south-south-east, and is as follows:

Serial Number	*Other Name (if any)*	*Year of Discovery*	*Length in yards (approx.)*
Cullaun Zero I	Gaffers Gulch	1952	20
Cullaun Zero	. . . .	1953	—
Cullaun I	Teenagers	1951	1100
Cullaun II	The Bloody Guts	1952	1663
Cullaun III	The S.S. Cave	1952	2800
Cullaun IV	. . . .	1952	200
Cullaun V	. . . .	1953	1000 to date

SURVEY

In Cullaun I and Cullaun II the survey was made using a hand-bearing compass easily readable to one degree and a linen tape reinforced by metal wires. A line survey was plotted from the figures obtained. In the case of Cullaun I the survey by this method has only been carried down as far as the end of the first bedding plane passage beyond section 16 (*Fig.* 2). It is considered that these surveys rank for accuracy at between Cave Research Group grades 4 and 5, (Butcher, 1950). In two cases in Cullaun II (*Fig.* 3), loops were completed. One short one closed with an error of a foot. The other, involving 107 stations and a distance of 2346 ft., gave a closing error of 90 ft. or 1 : 23·5. If it is assumed that the errors are evenly distributed this would involve a displacement of 40 ft. for the junction of the Year Passage with the Main Passage and of 70 ft. for the far end of the cave; these displacements are of no great importance having regard to the objects stated above.

In the other caves and for the last 200 yards of Cullaun I the surveys were based on estimates of distance mainly by pacing, and on a number of compass bearings taken at various places. In the case of pacing, in two of the Cullaun series and in two cases in another series the estimates by pacing and other means were subsequently checked by survey with a tape. In each case the distance error was less than 3 per cent and the estimate was less than the actual distance given by the tape. Similarly the general direction of the cave by the method given has been checked on several occasions by the detailed survey and these results have tallied remarkably

well with the first, and it is considered that the surveys thus made are of Cave Research Group Grade 3.

In drawing out the plans of the caves (*Fig.* 2 and *Plate* 3), and denoting them on the map (*Fig.* 1), the great difference between the length of a cave and its width has necessitated an appreciable exaggeration of the width in order to show the passages at all clearly. For the same reason larger scales have been used for the cross-sections, which are drawn on ten times the scale of the plan. No longitudinal sections have been given because the dip of the strata is so slight, and the descent of the cave so gradual, that they would serve no useful purpose.

DESCRIPTION OF THE CAVES

Cullaun Zero I

This cave has been called Gaffers Gulch after a very garrulous old peat cutter encountered on the first visit to the hollow in which the cave lies. This hollow is shown on the map (*Fig.* 1) by the isolated 800-ft. contour inside the main contour of the same level in the northern part of the map. It occurs in an inlier of limestone entirely surrounded by Limestone Shales, only a few feet thick. The entrance is a pot, about 15 ft. deep, and partially subdivided. There is no surface valley or stream to the north, but two caves have become unroofed in places and can be examined. Both are of the vertical canyon type with much fluting on the walls, the horizontal projections between the flutes in places almost closing the passages which are generally about 10 ft. high and 15 in. wide. They unite at the south-east corner of the hollow and a canyon passage leads off and can be penetrated for 20 yards, but then becomes partly blocked by dripstone. There is no trace of a bedding plane type of passage in the roof, that is, no T shaped cross-section. The passage is about 10 ft. high. The lower parts of the walls and the floor show current markings and even in summer there is a small stream flowing in the passage. The direction of flow indicated by the current markings is to the south, the same direction as the present stream. The passage meanders and is, in fact, similar to considerable parts of the other caves of the series.

Cullaun Zero

This cave lies a little further south, at the southern edge of a re-entrant of the limestone and on the junction of the latter with the shales. There are several openings into a vertical canyon type passage with vertical flutings. The cave is about 1 ft. wide and from 6 to 8 ft. deep. A considerable stream may be heard at the bottom even in summer time. The passage is too narrow to be entered, but its characters are those of the rest of the series. Fluorescein tests have shown that its water does not flow into Cullaun I.

CULLAUN I (*Fig.* 2)

Here there is a shallow valley, not deep enough to be shown by the contours on the map (*Fig.* 1). The valley ends with a flat floor approximately at the line of the north–south road across the townland of Cullaun. Upstream from the entrance lie a confusing series of entrances into canyon type passages which repeatedly interconnect. Keeping to the most southerly series the small stream encountered on entry can be followed in its passages for several hundred yards up stream from the entrance shown in *Fig.* 2. There are numerous openings through the roof and the passage gradually diminishes in width and height till one must follow it on the surface to the point where a small surface stream first goes underground at the junction of the shales and limestone. Further to the north a branch of the valley appears to end, but this is really only a low col which forms a blind end to the valley running south and which contains the main stream, again in a canyon type passage. This is the stream that enters through the low bedding plane passage at section 8 (*Fig.* 2). The passage is not passable but can be examined through the numerous roof openings up to the point where the stream becomes completely open. It is interesting to note that between the col and the point where descent to the cave is made there are no openings through which one can enter the main streamway or hear the water in it.

The high canyon passage of the entrance is blocked with mud downstream. It is in fact an oxbow passage to the present active southerly stream passage down to which one must climb and follow for a few yards, when the canyon type passage comes in on the east with its floor about three feet above the level of the stream passage. From here down to just beyond section 5 the roof is formed by the same bed as shown in the sections 3, 4 and 5. The increase in height is due to the stream having cut its bed down. This part of the cave has clearly been formed along a joint in a plane vertical to the bedding but following the dip (*Plate* 1). The joint runs approximately from north–north-east to south–south-west. There is no evidence in this part of the cave for a pre-existing bedding plane type of passage before the canyon passage was formed.

At section 5 the stream originally went down a cross joint forming the widening of the cave at Cascade 1. The downstream wall is remarkably smooth, as is shown in *Plate* 1; upstream where the water has cut back the face there is a little vertical channelling. The whole forms a vertical feature very similar in many ways to those described by Davis (1930, p. 600) and Bretz (1942, pp. 685 and 722) as domepits. In the present case there can be no question of piracy of a high level stream by a lower one, such piracy being regarded as an essential feature in the formation of a domepit by Davis and Bretz. The absence of vertical channelling on the downstream

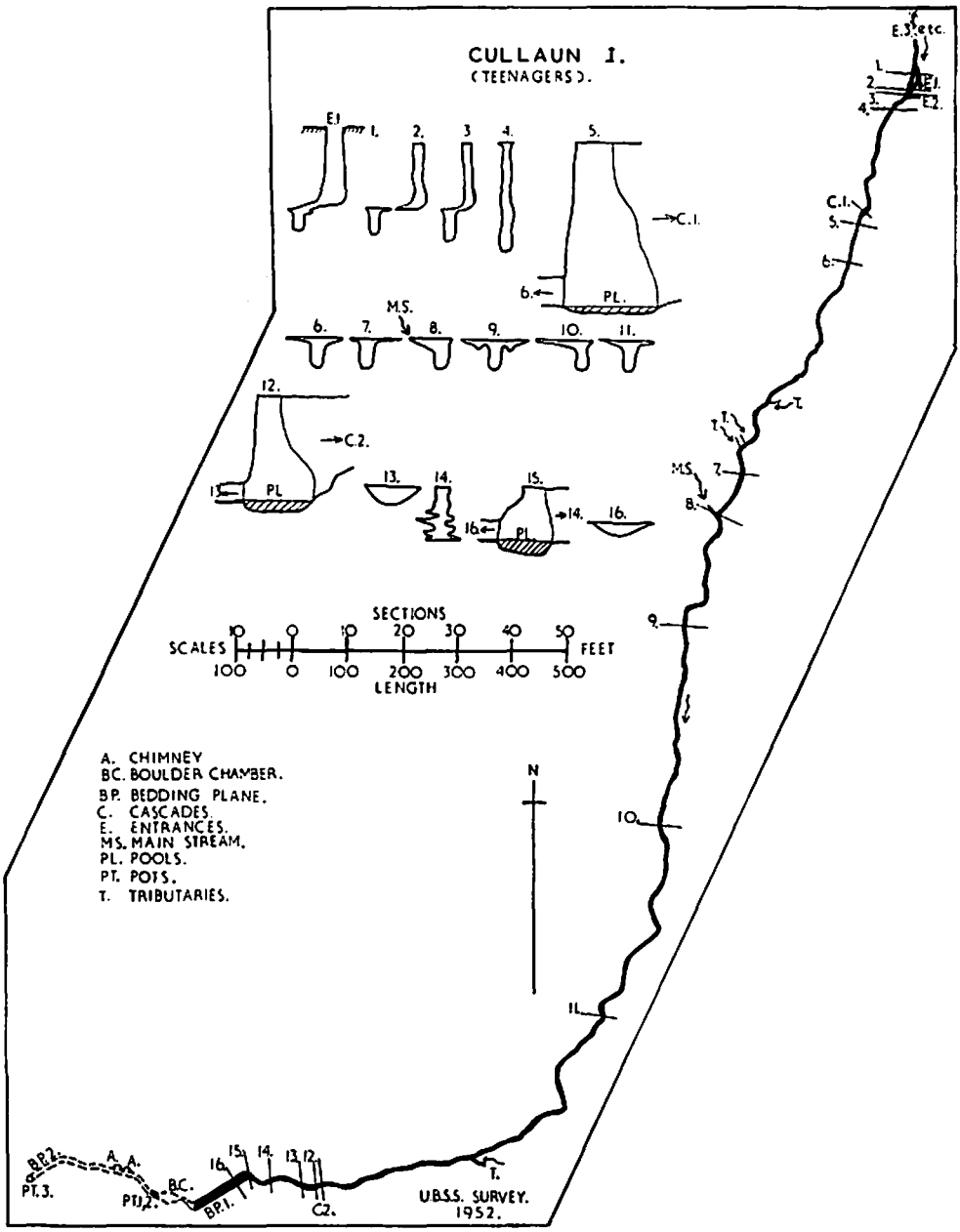


Fig. 2.—Plan and sections of Cullaun I. All sections have been drawn looking downstream.

face is also incompatible with their theory. Vertical features can develop in caves without any question of piracy and many examples in addition to the present one could be quoted to support this view. The smooth downstream face indicates rapid rather than slow flow.

The joint-determined canyon passage continues at a lower level and in diminished size for a short distance beyond the vertical feature just described before it is lost in the smooth roof of the next part. It can be seen in *Plate* 1 above the right side of the continuing passage. From section 5 to section 12 the character of the passage is remarkably uniform and differs materially from that above section 5. It is an incised meander trench cut in the floor of a bedding plane passage giving the typical T section. In the remarkably smooth roof can be seen occasionally smooth, low (2 in. at the most) projections, possibly the last remnants of an older spongework. One such projection is seen above the head of the figure in *Plate* 2, *A*. But there are current markings in the roof in places and on the whole of the walls and floor of the trench. All show flow downstream in the present flow direction. These markings are shown in *Plate* 2, *A*.

In this part of the cave a common variant is a small short oxbow near the roof, sometimes single and sometimes double as at section 9. The walls of these oxbows often do not reach the roof as is seen in *Plate* 2. These oxbows are current marked and clearly represent a post-bedding plane stage of cave formation, when rapidly moving water was using several channels before the present channel became dominant and capable of taking all the water. It is clear that although there was an initial stage of bedding plane passage formation this phase did not last very long and for most of the time the water was moving rapidly.

The main stream enters through openings in the roof of a low short bedding plane extension at section 8 of the main passage. (*See also* Cullaun II.)

Just before section 12 the stream has cut its bed down deeply. The roof remains the same bed from section 6 to 12 and so a vertical feature is formed, similar to that at Cascade 1 and by the same means. The height becomes 12 ft. for a short distance, after which the roof comes down several beds and the passage continues as a bedding plane, only 3 ft. high at section 13, but by section 14 the incised trench has been cut so deeply, with the roof remaining the same bed as at the exit from section 12, that the height is again 12 ft.

At section 14 another feature is prominent, namely the widely recessed walls and thin shelves with slip-off slopes.

At section 15 the roof again descends several beds in steps with well and smoothly rounded angles and the cave continues in a wide low bedding plane passage for 115 ft., the end of the Grade 4–5 survey. This bedding

plane passage is notable for the comparatively smooth lateral portions of the floor and the well-marked scalloping of the rest including the roof. The down draught encountered the whole length of the cave ceases here and "steaming up" is noticeable. Beyond, the pots 1 and 2 give a vertical descent of about 20 ft. and the final pot, 3, is estimated to be 15 ft. deep. The two chimneys, A, A, show an interesting stage of development of a vertical feature. The main stream passage being followed is very similar in form to the small oxbows described above. The north side of the passage does not reach the bedding plane roof and only forms a wall shutting the passage off from a narrow crack some 6 ft. deep. Upwards the south wall of the crack, which is obviously a joint partially opened, forms the south wall of the two chimneys. Small trickles of water descend each. After a short distance the active stream bed has been cut down to the level of the bottom of the crack. No signs were noted of any pre-existing upper level for the cave system as followed so far, nor could such a system have existed, unless a large syphon was formed here under considerable hydrostatic pressure, beyond the bedding plane (B.P.1 of *Fig.* 2). Such a syphon is most unlikely ever to have been formed here. It is to be noted that the terminal bedding plane passage (B.P.2 of *Fig.* 2) reverts in direction to that of the first one.

The whole of the cave beyond the first bedding plane passage is difficult to negotiate and it would appear that the passable part of the cave does not extend far beyond the point reached.

The change of direction towards the west of the lower parts of the cave tends to take the water down to the area of the Killeany Rising. In Cullaun II the direction is different and it seems as if an "underground watershed" lies between Cullauns I and II.

Down to the change in direction, the cave has generally followed the direction of dip, which beyond this seems to have had little influence unless there is an undetected local change of dip direction. If not, the change indicates an alteration of conditions during the initial stages of formation. It may be that the upper part of the cave was formed mainly under vadose conditions, perhaps intermittently phreatic, while the lower portions were initially formed under entirely phreatic conditions, although the water was moving fast for there is no evidence that the floor of the bedding plane passage was protected by sediment from further solution, but rather that it was the floor, and not the roof, that underwent solution.

CULLAUN II (*Plate* 3)

This cave bears the nickname "Bloody Guts" from one of the more highly coloured formations. The branch valley in which it occurs is the longest of the series and drains the largest catchment area. It runs approximately from north to south down to the cave entrance, where the floor

PLATE I

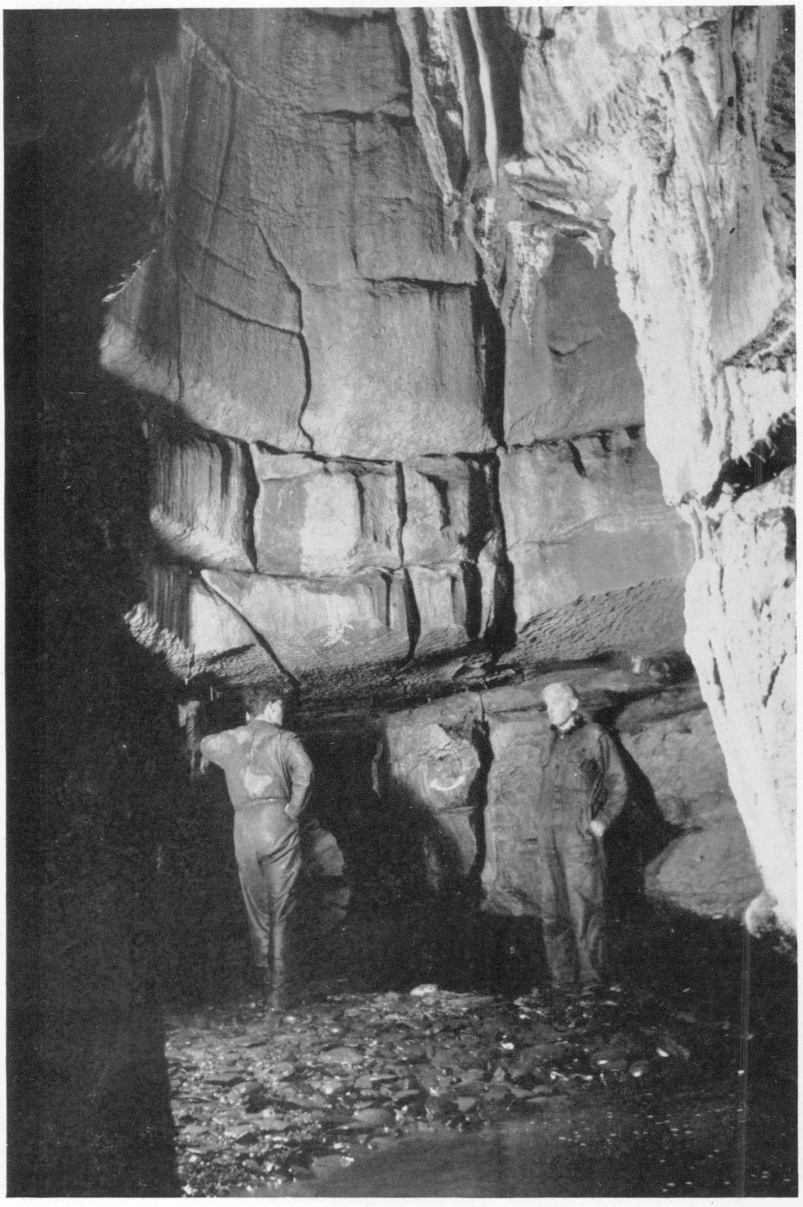


Photo: D. M. Thompson.

Cullaun I. Vertical feature, looking downstream at section 5. The walls are smooth. The continuing passage is seen to the right of the left-hand figure, and the continuation of the joint determined passage to the right of, and above, the continuing passage.

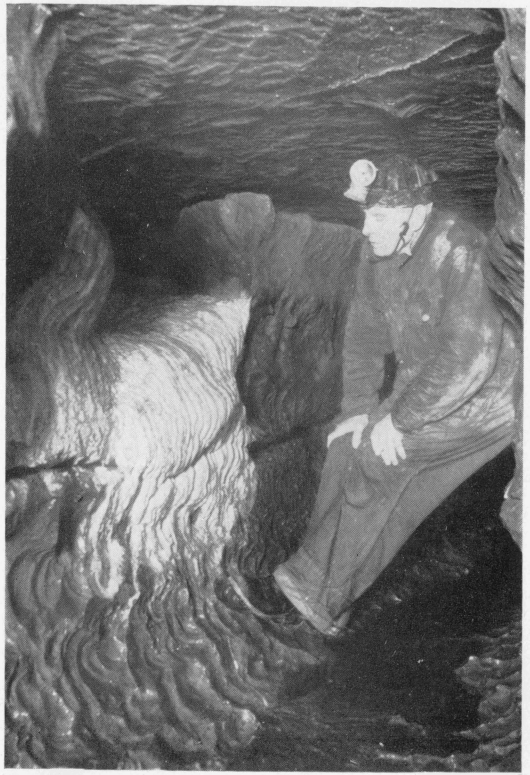


Photo: D. M. Thompson.

A.—Cullaun I. Typical view of the incised meander passage from section 6 to 11.

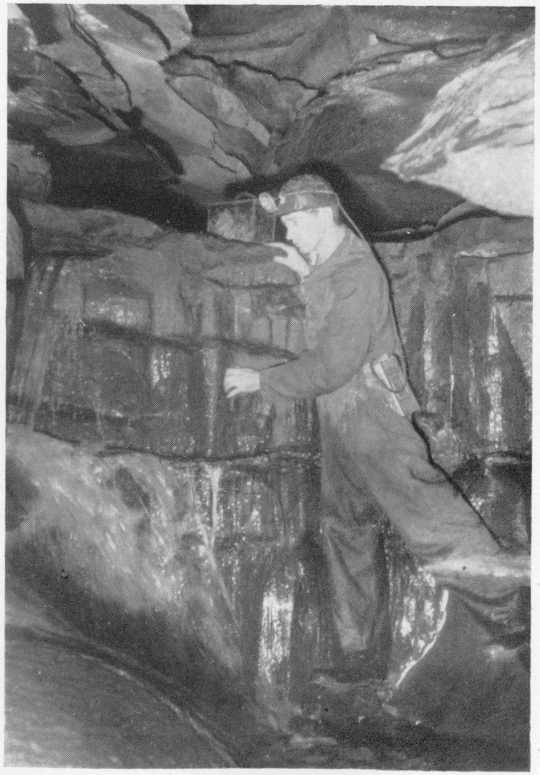


Photo: G. G. Fuller.

B.—Cullaun II. The descent to the pool at the entry of the main stream at section 6. One of the thin shelves is shown, and the water is entering by a very low bedding plane passage.

widens and flattens while the valley gradually turns to the west. The flat portion ends at the road past Cullaun Farm but the valley continues with a U form, lined on each side by numerous small sink holes, to end as a hanging valley over the main valley. Upstream from the cave entrance the valley floor is subdivided by several small ridges, and in the hollow on the upstream side of the first the main stream can be heard through openings in the rock. Upstream from the cave entrance to where the stream first goes underground there is an intricate series of passages extending for over half a mile. These passages comprise three sets, one on each side of the valley and one centrally in the floor, and each has three levels. The passages meander, cross each other and intercommunicate in a most complex pattern, with many connexions with the surface. Some passages are of the canyon type and others of the bedding plane type.

Immediately to the east of the entrance used by the Society is the margin of the Limestone Shales, which are capped by a thin layer of glacial drift. In 1952 a collapse took place just within this margin revealing several yards of a canyon type passage with vertically fluted sides present below the cover of shales. This is but one example of many in which it can be established that in this area canyon type passages exist under the shales. This suggests that surface streams which go underground when the limestone becomes exposed by denudation may utilize pre-existing passages. It shows also that the jointing of the limestone is in some cases of greater importance than the bedding in the determination of the formation of a cave.

Downstream from the entrance the cave (*Plate* 3), is a relatively high canyon type passage very similar to Cullaun I as far as Cascade 1, only on a slightly larger scale, and the similarity is continued right down to the terminal vertical feature, which in all its main aspects is a reproduction on a grander scale of the Cascade 1 zone of Cullaun I. The downstream roof of the vertical feature descends in a series of steps to water level.

The passage meanders in typical fashion, the roof being the same bed for long stretches, e.g., from sections 1 to 6 and 7 to 11. As it approaches the point of entry of the main stream the floor slope steepens and one enters a few yards of a low passage, with a number of thin, wide shelves with very sharp edges projecting from the walls, which leads to the lip of a 6-ft. drop into the pool below the entry of the main stream (*Plate* 3). Under normal conditions the stream enters from the west by two small openings in the roof of a bedding plane extension on one side of the passage (*Plate* 2, *A*), but under flood conditions at least eight openings are in use, extending several yards up and down stream from those normally in use. The present main active waterway ends in a low bedding plane passage with a number of small individual routes for the water. This is likely to be true also of Cullaun I, which has not yet been observed under flood conditions.

The canyon type passage has not ended at the entry of the main stream but has turned off sharply, only to return and cross the roof of the passage now occupied by the main stream. The meanders of the two passages, which are not physically divided, continue independently for some distance downstream until they gradually coincide. Comparison may be made with Gunman's Cave in the Pollnagollum system (Coleman and Dunnington, 1944). Minor trickles enter the passages all the way down. In each case, as in Cullaun I, the tributaries enter from bedding plane passages with incised floor trenches. The width of the bedding plane passage and the depth and width of the trench correspond to the size of the stream at present occupying it. In no case has there been observed any half-tube or other form of upward cutting or solution into the roof, which occasionally shows evidence of a poorly developed T section.

At section 9 the Year Passage enters. It always carries a small stream and during wet weather clearly carries a large one. The Year Passage leads back to the surface at a point close to the entrance used by the Society. It is essentially a bedding plane passage with an incised meander trench in the floor. It is interesting to note that a bedding plane passage at roof level connects with the main passage at section 8.

There are two vertical features in the Year Passage, at sections 3A and 5A. They resemble the domepit of Davis and Bretz in that they each have a stream in the bottom which could be regarded as a piratical stream, except for the fact that each upper opening also carries a stream. Here, then, is another form of vertical feature in caves.

Just before the 4-ft. drop into the pool at section 15 an oxbow passage goes off high up in the right side of the main passage only to end at an even higher level above the floor. The considerable enlargement of the cave at this point is due to the presence of an open cross joint running approximately 12° east of north. The exposed ends of the joint seen in section 15 are about a foot wide and filled with shattered rock looking rather like a badly built brick wall. There is no displacement of the beds on the sides of the joint so that it cannot be a fault.

There are many fine dripstone formations. There are long bands of stumpy helictites in their thousands growing on the rounded bulges of the passage walls. Stalagmite pillars grow up from these bulges and show an egg-shaped section with the longer axis along the length of the passage and the broader end facing upstream into the very pronounced air current. Their form is so consistent that it must be due either to the air current or to re-solution during flood conditions.

A number of chert layers occur in the lower portion of the cave. These layers are about 2 to 3 in. thick and are coated with a carbonaceous film probably derived from the peaty matter brought down by the stream. At

first each one in turn appears at floor level and then, as the floor slope is steeper than the dip slope, gradually comes to lie above the floor level and often forms bridges. These bridges, and the ledge remnants of them, are extremely dangerous as they give way without warning. Three layers are exposed at vertical intervals of about 3 ft. near the head of the terminal pitch. Where calcite veins appear in the roof and floor of the canyon passage and there is a bridge or ledge of chert it was often noted that the calcite vein was not interrupted by the chert layer but passed through it.

The pool just beyond the terminal pitch has a depth of 15 ft. just before the roof comes down to the water.

Cullaun III

This is in the next valley to Cullaun II. The valley is relatively narrow and deep and more juvenile in appearance than those already described. Beyond the cave entrance, however, the valley turns westwards and develops a wide flat floor, considerably wider than Cullaun II, with sink holes along both sides. It continues across the road (*Fig.* 1), south of Cullaun Farm and ends, like the others, as a hanging valley over the main valley. Its floor east of the road is far wider than those in any of the other valleys, but there are no entrances to the cave in this part, though there is one minor swallet with a small stream at the mouth of a branch off this flat portion. Upstream from the cave there is only one canyon type passage running under the centre of the valley floor. It appears that there is no complex system of passages upstream from the entrance as in Cullaun I and II.

Cullaun III is a difficult cave, as the first 1000 yards are so narrow that progress through most of it can only be made sideways, with several crawls in the actual stream past constrictions sometimes formed by dripstone formations. The cave is also dangerous as the effect of these constrictions is to cause flooding to the roof in certain places in the first 1000 yards. A few hours of heavy rain while a party was down the cave would trap them effectively for quite a long time. It takes over seven hours just to get down the cave and back so that careful regard must be paid to the weather conditions before entering.

This cave is the longest of the series so far explored. Almost its entire length is composed of a simple canyon type passage developed along a vertical joint running in the direction of dip. No major branches have been found. For the first 1300 yards the meanders follow a definite pattern, a series of gentle curves closely succeeding each other, and then there are several sharp bends. The cave is summarized in the table below. At section 5 the simple passage is broken up into three parts above each other, each part meandering separately but communicating with the others where it crosses them. Beyond this the passage becomes several feet wide and

comfortable to walk along. This widening, on the analogy of the other caves, suggests the entry of a large tributary, but one could not be found. Perhaps it enters through a low inaccessible bedding plane passage in the lowest of the three passages.

At section 8 just to the right of the main passage is a high tapering chimney about 25 ft. high and quite unclimbable. Down it, from what seems

CULLAUN III

Section	*Length in yards*	*Cumulative total in yards*	*Notes*
1. Canyon type passage 10–12 ft. high, 12–18 in. wide. Partly blocked by dripstone in places.	500	—	Awkward crawls in water. Necessary to move sideways whole length.
2. Small tributary on left. Bands of helictites on walls up to 100 yards at a time. Roof down to 8 ft. Floor cut down by stream and height gradually increases to 10–12 ft.	400	900	Passage is a little easier to traverse.
3. Tributary from right at barrier of blood-red stalagmite. Passage floods to depth of at least 8 ft.	200	1100	Passage a shade easier but still necessary to go sideways in places.
4. Stream cuts down into narrow gully in floor.	100	1200	Roof traverse for 30 ft.
5. Passage divides into three parts meandering separately above one another. Meanders close together and very tight. (1 in *Fig.* 1.)	150	1350	Take the topmost meander passage.
6. Passage 2–3 ft. wide. (2–4 in *Fig.* 1.)	400	1750	Easy walking. Climb up and down over wedges of rock fallen from the walls at end.
7. Floor slope slightly less than roof slope. Roof gradually comes down.	550	2300	
8. Tapering chimney on right with small stream. (5 in *Fig.* 1.)	200	2500	Dripstone formations begin in earnest.
9. Roof gradually descends to 8 ft. Smoothly current marked walls give way to wide knife-edged shelves on both sides of passage.	250	2750	Many dripstone curtains hang from edges of shelves.
10. Stream disappears into passage 18 in. high by 4 ft. wide, with markedly scalloped floor and walls. Oxbow above. Large pillar of limestone divides oxbow into right and left loops.	50	2800	Climb up a few feet into oxbow. This is 10 ft. wide. Long succession of rimstone pools and formations on walls. Roof drops to 3 ft. over 4 ft. of water. Way on blocked by grille of stalactite. No sound of running water.

to be quite a low and narrow passage at the top, falls a small stream. This is not large enough to be either the stream from Cullaun II or from IV. It is most likely the water from the small subsidiary swallet mentioned above.

Nowhere in the cave are there any tributaries comparable in size with the streams in Cullaun II or IV. This tends to confirm the line given by a series of compass bearings as being approximately correct and to be that shown in *Fig.* 1.

At the end of the cave there is no sign of flooding up as the pools and formations are clean and untouched by water flow. There is no evidence of the formations being redissolved.

Cullaun IV

A small valley with a V shaped section and juvenile in appearance runs south-west to the edge of the shales and then turns south. The stream goes underground to continue along a canyon type passage with surface access at numerous points, and finally disappears close to where the valley margin to the east approaches the shales again and a low col blocks the end of the valley. Before the stream went underground its valley used to continue south as Cullaun V valley. Only the low col a few feet in height and width separates the two parts of the valley. The cave can be followed for about 200 yards. Dry oxbow passages contain formations, but the active streamway goes into a bedding plane type of passage and the roof gradually descends till it is less than a foot high, with 6 in. of water on the floor.

Cullaun V

The stream of this juvenile valley comes in from the east about 50 yards from the entrance to Cullaun IV and then turns south, still flowing on shales. When it reaches an inlier of limestone, a hundred yards or so further down, it begins to go underground. At first the cave has a shallow U section, relatively wide for its depth, but soon the typical canyon type passage begins to take shape. One can examine it through the numerous roof openings. The stream finally goes underground where there is a blind end to the valley at the Lisdoonvarna–Ballyvaughan road (*Fig.* 1). The passage is just large enough to be followed. Eventually it links up with the stream from another valley, Cullaun VA and the passage now has a T section though at first the horizontal arm of the T is not very wide. At VB the two streams can be heard through another opening; this was the first entrance used to the system. Shortly before this opening the combined stream enters a bedding plane chamber with a much shattered roof. It runs down a bedding plane passage 20 ft. wide, but scarcely 6 in. high, in the floor of this chamber. Downstream from VB an old dry way can be followed. This soon picks up its own small stream. First the passage goes south-west

and then nearly due south for 500 yards where the little stream plunges down a vertical pitch to join a much larger stream that can be heard below. There was evidence in the mud of this upper way that someone had been in the cave before us, and subsequently it was learnt from the farmer that two men had been down the cave, it is thought not beyond the pitch, in 1951. Much remains to be done on this cave. Its location suggests that it may provide the linkage between Cullaun II, III, and IV if such linkage does exist.

The dry way was obviously the old course of the stream. Its floor is about 3 ft. above the floor of the bedding plane chamber and so the upstream portion of the floor has been deepened about 3 ft. since the water first started to go down the bedding plane passage.

SUMMARY AND CONCLUSIONS

The southern end of the Poulacapple ridge has a number of minor valleys. Each one has its own cave system and none of them communicate with each other as far as it has been possible to determine. There is, apparently, an " underground watershed " between Cullaun I and Cullaun II. Fluorescein tests on Cullaun III, although six pounds were used on the third occasion, failed to produce any observable results in either the Goulan River, the northern head of the Aille River coming down from the St. Brendans Well area, or in the other head draining in from the east as the sum of several different streams running on shale. It would seem, with the possible exception of Cullaun I, that none of the waters of this series comes to the surface in the neighbourhood. There must be a series of caves, perhaps eventually connected, underlying the surface drainage pattern. In the main they will be phreatic but parts of them may not be completely water-filled and vadose conditions may occur, if only intermittently. The waters in the systems must move fairly rapidly to their points of ultimate discharge as otherwise the caves that have so far been explored in this series would fill up from the bottom under wet conditions ; evidence of this has not been observed.

In Cullaun I a minor stream occupies the first part, of canyon passage form. The main stream, with its point of engulfment receding upstream all the time, has found a newer series to traverse and likewise Cullaun II in an even more marked manner, with the main water entering from a low bedding cave some way down the route followed in both cases. Each cave of the series seems, in its earlier part anyhow, to have been determined by a vertical joint running in the direction of dip. In Cullaun I and II there has been time for the streams to find new routes for part of the way. In Cullaun III and IV the present streams still occupy the only route, the canyon passage route, from the beginning of the cave.

Bretz (1942, p. 734) has stated that calcite is less soluble than limestone, as veins will stand out above a dissolving limestone surface. The contact between calcite vein and rock may, however, be more permeable than other surfaces so that water will seep through, dissolving a little limestone and leaving the calcite veins to fall out or disintegrate through lack of support. Evidence of this has been noted in Mendip on certain exposed rock faces and by D. T. Donovan (1949, p. 74). In the Cullaun series it has been repeatedly noticed that the line of a cave follows one or more well-marked calcite veins, particularly in the straighter parts.

The whole appearance of the series suggests comparative youth and it seems probable that the streams which at present occupy the caves are in fact the streams that made them. The surface valleys are presumably the result of the last ice age, and the question arises as to whether the caves of this series are entirely post-glacial in origin or not. There is certainly nothing to suggest that the surface features were very different from to-day when the caves were being formed. A post-glacial origin would go a long way towards explaining the absence of glacial drift filling, but this can also be accounted for in other ways. The exit points of the water may have become blocked in an early phase of glaciation and the caves filled up with water so that no drift could enter. Alternatively the freezing of the ground might have led to the caves becoming blocked with ice, with the same result. Both processes might have operated. On the other hand, it has been shown that canyon type, if not other types of passage occur in the limestone under shale cover, before it is exposed at the surface by denudation. It is possible that the shale may only have been stripped off the area which is now exposed limestone after the glaciation, by which time cave systems had already begun to develop under it.

All the caves show marked evidence of swiftly moving water in the explored parts. The roofs are smooth or in some parts clearly current marked.

In some places there is clear evidence of two stages in the formation of the cave: first, the formation of bedding plane passages, and second, the cutting down by streams into the floor of the bedding planes to form meanders or canyon type passages. The first phase may have occurred by solution by underground water with comparatively ill-defined circulation; the second marks the establishment of well-defined underground streams. The first stage is not always seen (for instance, Cullaun III), but could possibly have been destroyed during the second stage. It has not been observed in canyon type passages which exist in limestone under shale cover, for instance Cullaun Zero I and near Cullaun II, where the passages appear to have been formed along joints without a preliminary bedding plane stage. Although two stages of formation may often be traced, it

may be stressed that the development of the systems belongs to a single cycle, the division into two stages being the result of the normal evolution of the system and not an external factor such as a change in base level, though it is possible that climatic changes have been involved.

If this interpretation is correct, the area is an exception to the generalization made by Bretz (1942, p. 675) and implied in the two cycle hypothesis of Davis (1930), that most cave streams are misfits and that two stages of formation, an earlier under phreatic, and a later under vadose conditions, can generally be recognized in cave systems. It is true that the two stages probably occur in the development of any cave system, but the present investigation shows that they need not be sharply differentiated, or separated by a major geological change such as uplift of the area. The systems in County Clare seem to exemplify well the programme which may be followed by the earliest drainage in an area of nearly horizontal limestone. The caves are all shallow and largely related to surface features. It is possible, that after such an initial stage, the solution of deeper channels, in the phreatic zone, may continue for a long period. With a major lowering of the base-level at some future date these might come into operation as " two cycle " caves, while all traces of the systems here described would in due course be completely removed by denudation.

ACKNOWLEDGEMENTS

I would like to record my thanks to all those members of the Society who have taken part in the explorations and have assisted in other ways, and especially to the President, Professor E. K. Tratman, who has given much technical information and other help in the preparation of this paper. I would also like to thank Mr. and Mrs. O'Callaghan of the Castle Hotel, Ballynalacken, for their unfailing kindness in dealing with cave explorers coming and going at all sorts of times and in all sorts of clothes. Finally I wish to thank all those farmers who have let us roam freely over their land at all times.

REFERENCES

ACKE, P., 1953, " New Cave Discoveries in Ireland : Interim Report ", *Proc.* U.B.S.S., Vol. 6, No. 3, 246–7.

BENDALL, R. A., and PITTS, J. K., 1953, " The Coolagh River Cave ", *Proc.* U.B.S.S., Vol. 6, No. 3, 228–45.

BRETZ, J. H., 1942, " Vadose and Phreatic Features of Limestone Caverns ", *Jour. Geol.*, Vol. 50, 675–811.

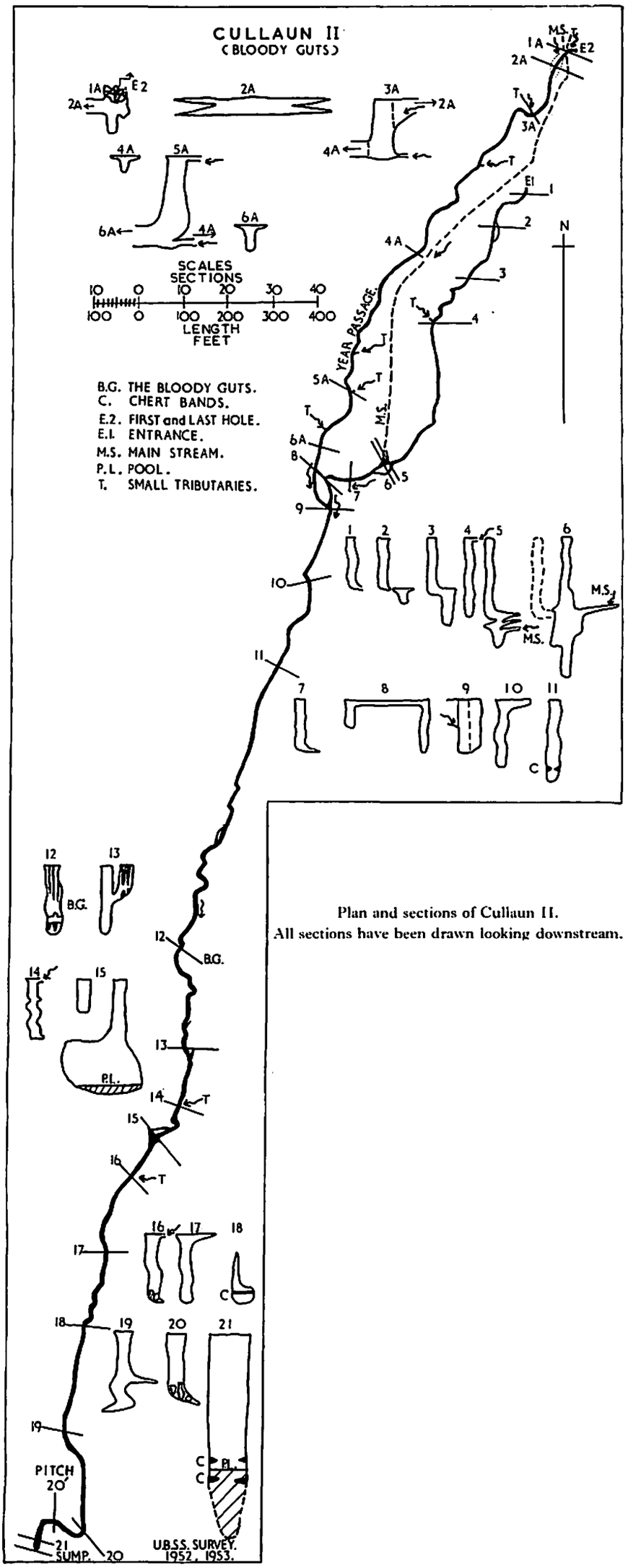
BUTCHER, A. L., 1950, " Cave Survey ", *Cave Research Group Publ.*, No. 3.

COLEMAN, J. C., and DUNNINGTON, N. J., 1944, " The Pollnagollum Cave, Co. Clare ", *Proc. Roy. Irish Acad.*, Sect. B., Vol. 50, 105–32 (Reprinted *Cave Science*, Vol. 1, No. 4, 100–120, 1948).

DAVIS, W. M., 1930, " Origin of Limestone Caverns ", *Bull. Geol. Soc. Amer.*, Vol. 41, 475–628.

DONOVAN, D. T., 1949, " The Geology of Rod's Pot, Burrington ", *Proc.* U.B.S.S., Vol. 6, No. 1, 72–5.

PLATE 3



Plan and sections of Cullaun II.
All sections have been drawn looking downstream.