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CAVE PASSAGES FORMED BY A NEWLY RECOGNISED TYPE OF MASS MOVEMENT: A GULL TEAR

by

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ABSTRACT

Sally's Rift is the most extensive landslip cave in the Great Oolite limestone of the Cotswolds. The cave was originally thought to be a simple rectilinear network, but new calculations show that it cannot have formed by mass movement in any single direction. A sequence of gulls leads almost directly into the hillside along an axis of mass movement spreading, whereby the rock masses on either side have moved in divergent directions – a *gull tear*.

INTRODUCTION

The mass movement cave Sally's Rift is located 4 km east of Bath, high on the eastern flank of the River Avon valley (Claverton Gorge) as it cuts through the Cotswold escarpment. The cave has been described in detail by Self (1986, 1995) and its relationship to other nearby landslip caves noted by Self and Boycott (2000). In brief, the geological setting is an overdeepened river valley in Lower to Middle Jurassic strata, including on the upper slopes the Fuller's Earth Formation (a predominantly mudstone sequence) which is capped by competent but fractured limestones of the Great Oolite Group. There is a regional dip to the southeast of about 2º.

The valley sides are steep with cambering of the Great Oolite limestone cap-rock in the direction of slope. This takes the form of largely lateral extension (sliding) of parts of the cap-rock strata by gravitational forces, resulting in the widening of joints in the limestone. Such open fissures are known as *gulls*. The boundary with the underlying mudstone formation provides the lower plane of sliding, while an upper sliding plane within the Great Oolite limestone sequence allows the surface beds to remain relatively undisturbed and form a roof. In this way, the gulls are protected from infill by material of surface origin, and so can be explored by cavers.

Despite the extensive landsliding that is present in the Claverton Gorge, accessible gull caves are not common. Very little bedrock is exposed, so the caves are found only where there has been quarrying for building stone.

THE CAVE

Sally's Rift is the most extensive cave in the Cotswolds, with a total length of 345 m (Figure 1). In plan, the cave appears to be a simple rectilinear network of gulls oriented according to the dominant jointing directions, 150º (±10º) and 65º (±5º). In the original report (Self, 1986) it was noted that the valley of the River Avon is closely aligned to the first of these jointing directions. Mass movement in the local direction of slope would open the 150º joints but could not possibly open the conjugate joint set. An explanation was offered: a few tens of metres beyond the northern limit of the known cave, the Avon valley makes an abrupt change

of direction to the north. If the cave formed as a result of movement in the direction of slope of this more northerly hillside, both joint sets would open.

An attempt was made to test this theory, by treating the length and orientation of each gull as a vector. The vector sum of all the gull passages on the cave survey might give an indication of the overall direction of mass movement. This method was acknowledged at the time to be a "crude device", but gave a calculated result of 272º (Self, 1986) – perfectly in accordance with the supposition that the cave was formed by mass movement associated with the hillside to the north.

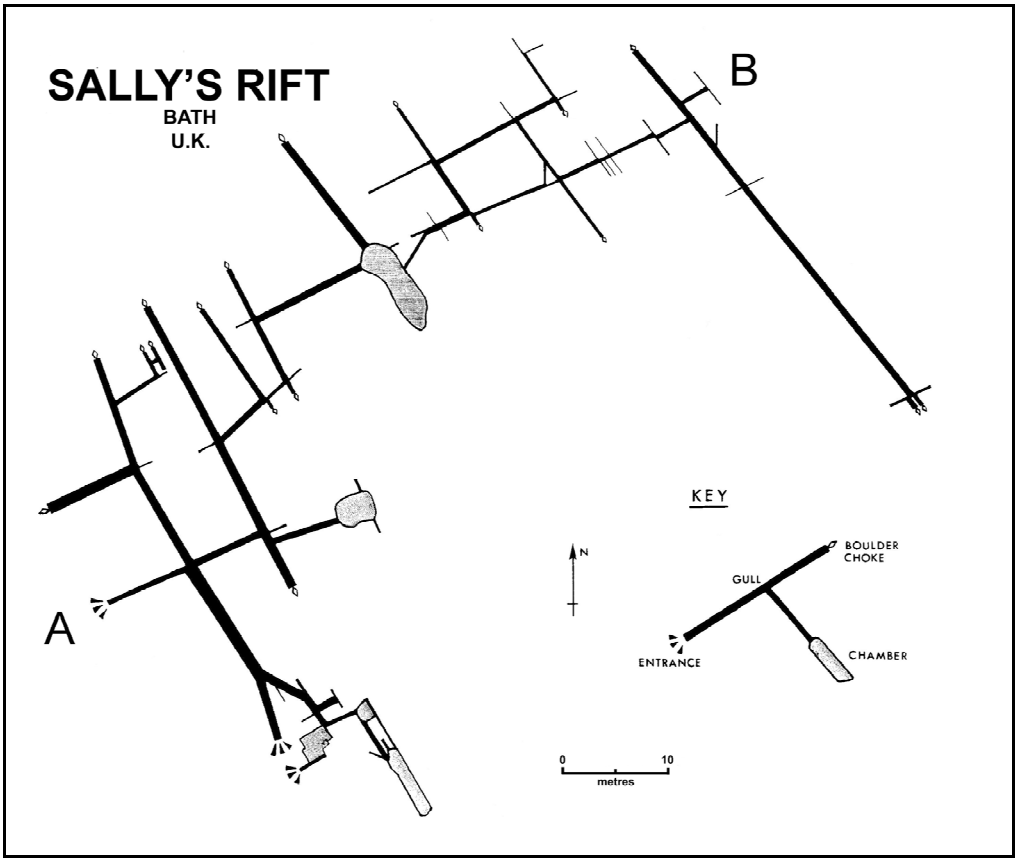

Figure 1. *Plan survey of Sally's Rift, showing gull tear A-B.*

A REAPPRAISAL OF THE CAVE

In recent years, the author has realised that the scientific basis of this "vector sum" methodology is unsound, even as an indicator. When cambering occurs on straight hillsides, each individual joint-bounded block moves by a different amount compared to its neighbours, but all movement is in the same direction. This is a fundamental principle of mass movement studies. If the direction of movement is oblique to the jointing, it is possible for more than one joint set to open.

In theory, it is possible to use vector sums to find the direction of movement if the **width** and orientation of every gull on a hillside is known. This is usually not possible in practice, since not all gulls are accessible for measurement. A fatal flaw in the original "vector sum" method is that there is no relationship between gull **length** and the direction of mass movement.

When more than one joint set opens, the width of the gulls in each set should depend on their orientation with respect to the direction of movement (Figure 2). In Sally's Rift, there is a major sequence of passages (A to B) developed on the 65º jointing direction. If mass movement was to the west as previously supposed, these gulls should be (on average) about half the width of those developed on the 150º jointing. This is not the case, as can be seen in Figure 1. There does not appear to be any difference in the frequency of fractures in the two joint sets, so some other explanation is needed.

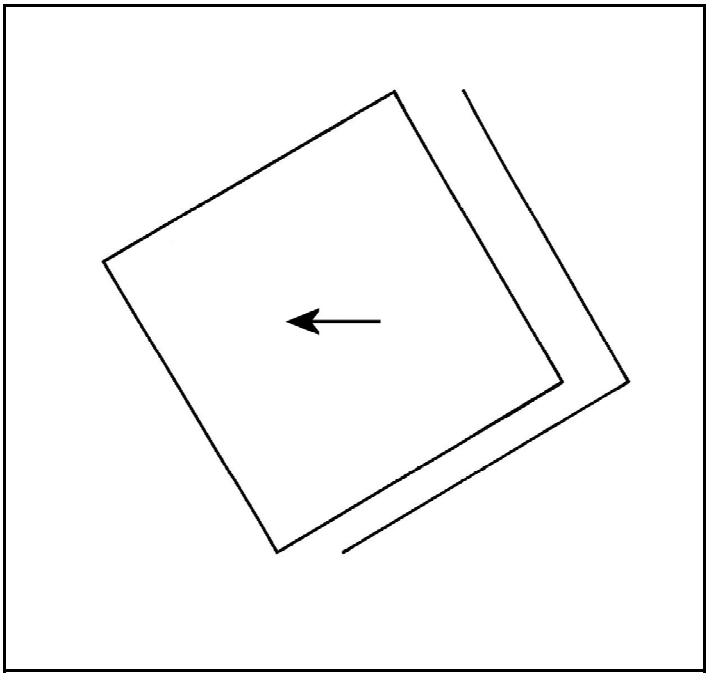

Figure 2. *The relationship between gull width and direction of movement.*

The author made a simplified plan of the jointing before mass movement occurred (Figure 3), so that the relative movement of individual blocks of rock could be calculated. The southern part of the cave was omitted, for clarity. The width of each gull is known from the original survey data and a direction of extension (270º) was assumed. Starting at point B, the cumulative movement of each block was calculated. This worked reasonably well at first, but anomalies soon began to appear. The amount of movement needed for a particular block to produce a gull of the correct width on one side would be incompatible with the amount needed on another. Closer to point A, the system broke down completely and it proved impossible to reproduce the pattern of the cave.

A direction of movement was needed that would affect the two joint sets more equally, so 285º was chosen. Using the same cave survey data and this new direction, a cave plan emerged with striking similarity to the northern and middle parts of Sally's Rift (Figure 4). However there are two major problems with this result. Firstly, as the pattern of blocks moves away from B a cumulative stagger develops at cross joints, which becomes very pronounced before A is reached. The only staggers in Sally's Rift are trivial and are due to original irregularities in the jointing, not to later mass movement. Secondly, 285º is an impossible direction for movement when the local direction of slope is about 240º, turning down-valley to 270º. To

prevent a buttressing effect by the strata to the north, the valley would need to turn much more than it actually does.

It should be borne in mind that we are considering the orientation of the valley in the past, at the time of mass movement. The available evidence indicates that the creation and overdeepening of the Claverton Gorge happened rapidly, when headward erosion allowed the River Avon to capture dip-slope streams that formerly flowed to the Thames (Self, 1995). This probably occurred during the late Anglian stage of the Quaternary. The cave was created by the massive landslipping that accompanied the formation of the Claverton Gorge. The valley today is simply a more mature version of that early Gorge, the orientation of each section fixed at the time of creation.

Figure 4 shows that the amount of widening seen in the 65º joint set cannot be obtained by movement of blocks in any single **available** direction. The solution is now apparent: the northern part of the cave has not moved in the same direction as the middle and southern parts. This has produced a camber spreading axis running into the hillside, which is the passage sequence A-B. This feature uses the same sliding planes within the rock sequence as other gulls, the only difference being that the rock masses on either side are moving in divergent directions. It is proposed to use the term *gull tear* for such a sequence of gulls.

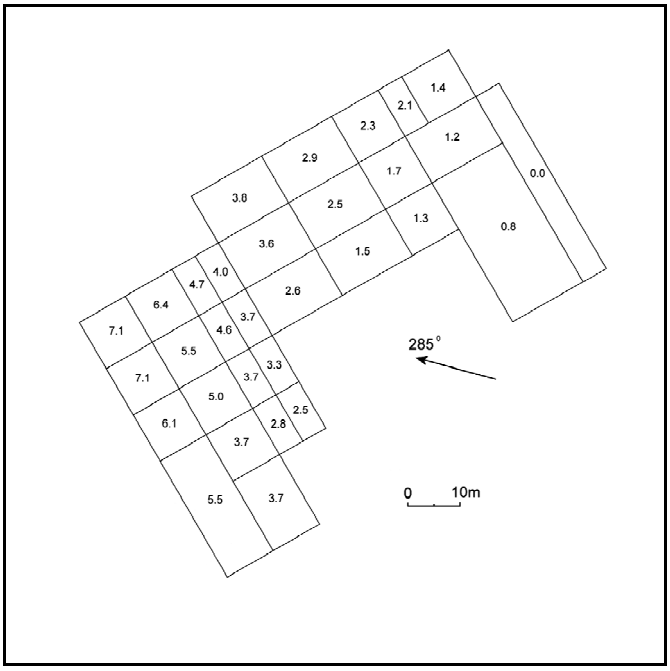

Figure 3. *Simplified plan of the joints in Sally's Rift before mass movement, southern part omitted for clarity. The figures refer to the required movement in metres of individual blocks.*

There is no reason to believe that B is the end point of this gull tear; it is simply the farthest point of contiguous access for cavers. However the passage width at B is much less than at A, so this may be taken as evidence that the camber spreading diminishes in effect as you go into the hillside. In the middle part of the route A-B, it can be seen that this gull tear is not a single sequence of 65º passages but involves the opening of parallel joints of this orientation. With basic trigonometry it is possible to prove that a divergence of only a few degrees is needed to produce the passages seen in Sally's Rift. Yet the valley abruptly changes direction by 30º. It would be reasonable to assume that there are other gull tears (unseen) in the strata immediately to the north. Within the cave, the northern ends of all the 150º passages end in boulder chokes which are roughly in alignment. The most likely explanation is that this is another gull tear, more divergent than A-B, where the cave roof and overlying strata has collapsed through to the surface.

This new interpretation of the evidence suggests that the mass movement seen in Sally's Rift **is** the result of gravitational sliding in the local direction of slope, but with an incremental change of orientation associated with the change of direction of the valley. The valley may turn abruptly, but underground the effect extends from the hinge line for at least 20-30 m to the gull tear A-B. The gull tear seen in the cave must therefore be part of a zone of lateral extension across this part of the hillside.

A small normal fault is marked on the British Geological Survey 6" field slip for this location. The fault (aligned 65º) was mapped across the plateau from the east, but is marked "inferred" on the valley side of the Claverton Gorge. Sally's Rift would appear to lie astride this fault, but this cannot be so. The gull tear A-B is definitely not a fault, since there are fit features along its course which prove that there has been no vertical displacement (see Self 1986, Plate 4). The thorn and scrub woodland of the Claverton Gorge is a difficult terrain for field mapping, so some small errors in both the location of the cave entrance and the fault can be assumed. The fault probably runs past the southern end of the cave, in the gap between Sally's Rift and the northern end of Gully Wood Cave no 4.

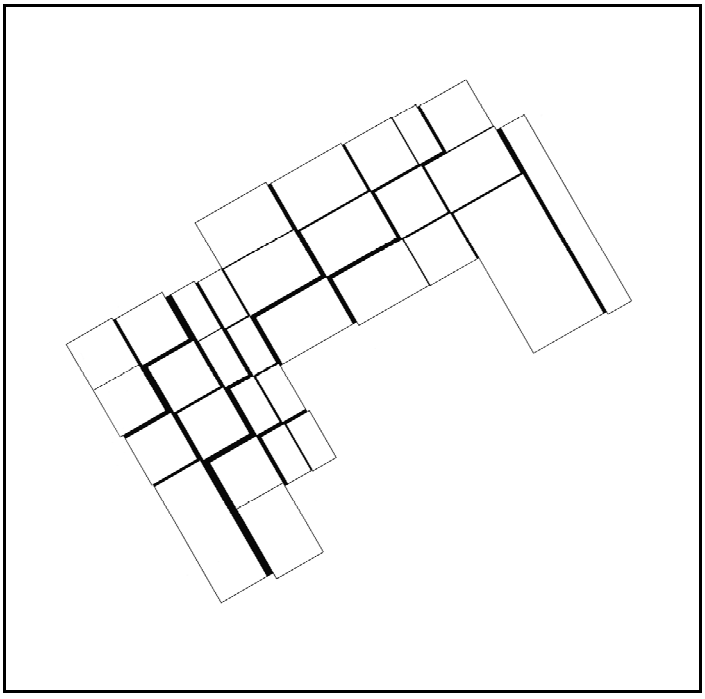

Figure 4. *A cave produced by mass movement in the 285º direction.*

DISCUSSION

Gulls are natural preexisting fractures in the bedrock that have opened as a result of lateral block movement under gravity in the local direction of slope. When mass movement is in only one direction, the widest gulls will form in the joint set whose orientation most closely corresponds with that of the local contours. Often the same structural controls also influence the surface topography, in which case the gulls will all run parallel to the contours. An example of this was reported by Hawkins and Privett (1981), who surveyed a building site on Blue Lias limestone near Radstock. They used orientation statistics to show "that the gulls run parallel to the contours with a very high degree of correlation".

When surveying cambered strata, engineering geologists are on the lookout for gulls in close alignment to the contours. To search for major gulls running directly into the hillside is

counterintuitive, but this study shows it is a real possibility when near a convex bend of a valley side. A small divergence in the direction of mass movement produces very substantial voids at depth, at least as wide as contour-aligned gulls. Of course, this makes it more likely that the surface beds will collapse; the geologist will note a small fault on his survey, not realising there may be other gull tears nearby hidden beneath intact surface strata.

The implication for the speleologist is also profound. The typical Cotswold cave is a single gull passage running sub-parallel to the contours. It is rare for there to be any significant side passages developed in the conjugate joint set and where this happens a link may be made into a parallel or *en echelon* contour-gull. A gull tear is a natural link to a whole series of parallel contour-gulls, as the example of Sally's Rift shows, allowing access much deeper into the hillside. So far, this is the only gull tear that has been identified, but surely there must be others.

ACKNOWLEDGMENTS

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