

## Notes on the Formation of the Yorkshire Caves and Pot-holes

BY E. SIMPSON.

The limestone district in which the caves and pot-holes of Yorkshire are situated has several features which give an illuminating insight into the primary cause of the origin of these underground phenomena. It is impossible in this brief paper to summarize more than the more important features of the tectonics of the area that bear upon the formation of the various chasms.

The hills of Craven rest upon a base of Silurian slates and grits, and upon their upturned edges is deposited the compact carboniferous limestone, which on the hills of Greygareth, Whernside, Ingleborough, and Penyghent reach a thickness of approximately 500 feet; above this is the Yoredale series, which is finally capped by the Millstone Grits. At the western extremity the limestone is cut off by the Dent and allied Faults, whilst a southern boundary is defined by the Craven Faults. It extends from Casterton Fell in the west, running roughly east through Ingleton, Austwick, and Stainforth, then to the south of Malham Tarn to Threshfield, when after crossing the river Wharfe at Linton Falls, it passes over Greenhow Hill to disappear finally a little below Pateley Bridge. This line of fracture—the North Craven Fault—is some forty miles in length and roughly defines the southern limits of the main Great Scar Limestone.

The South Craven Fault runs practically parallel to the Northern Fault from Ingleton to Austwick, then takes a sweep to the south-east, following the line of scars at Cave Ha, and forms the fine escarpment of Giggleswick Scars, where after crossing the River Ribble it takes another sweep to the south at the Roman Camp below High Hill. At this point it divides, the Middle Craven Fault following the course of Stockdale Beck to the north of Rye Loaf Hill, down to Malham, passing between the Cove and the village, then across Threshfield Moor, where it joins the North Craven Fault near Skirethornes. The South Craven Fault from High Hill runs south-east towards Bell Busk, but we are not here concerned with the area it embraces.

Owing to the dip of the strata (roughly  $5^{\circ}$ ), the limestone to the north and north-east is obscured by overlying rocks, and in consequence these boundaries cannot be clearly defined, but for our purpose the

northern boundary of the main Yorkshire Cave Area is a line drawn from Casterton Fell to Kettlewell. The area within these lines is that where the carboniferous limestone is exposed.

There are therefore three areas under consideration :—

1. That lying north of the Craven Faults, comprising in the main the area covered by the hills of Greygareth, Whernside, Ingleborough, Penyghent, and Fountains Fell.
2. That area situated between the Craven Faults.
3. The caves situated in isolated patches or outcrops of limestone lying outside the two above-mentioned areas.

#### SECTION I.

This section represents an area of approximately one hundred and fifty square miles, where the beds of strata lie nearly horizontal and are generally speaking practically undisturbed by the Craven and allied Faults. This district, the birthplace of rivers, is intersected by the deeply-cut valleys of Leck Beck, Kingsdale, Chapel-le-dale, Ribblesdale, and Wharfedale, which are cut through the limestone plateaux flanking the hills about 1200 feet above sea-level, the bottom portions of the dales exposing the underlying Silurian.

If we examine the western portion of this section it is interesting to note the manner in which the underground systems of drainage are grouped. They are not scattered haphazard over the flanks of the hills, but follow clearly-defined courses and are completely contained within themselves. However numerous the inlets in any given area, their waters ultimately unite, being collected in the lowest regions in what one might call a "Master Cave"; then the combined waters of that particular cave system issue at a given point.

The waters of the Three Pots of Casterton Fell, Bull Pot of the Witches (1), Hidden Pot, and Cow Pot (2), unite underground and issue at the west side of Easegill, whilst all the waters of the Leck Fell area apparently enter the Master Cave of Lost Johns to emerge at the same point as the Casterton Fell waters—Leck Beck Head (A). The Yordas Cave (6) with Bull Pot (7), Gingling and Rowten Pots (8) are joined by the Swinsto Cave (9) waters and issue at Keld Head in Kingsdale (B). In Chapel-le-dale there is no prominent "Master Cave" on the Whernside flank, though Gatekirk (20) and the river bed itself by the manner in which it acts on its underground journey to Gods Bridge (C) might be regarded as one. On Ingleborough there are no less than six of these entirely self-contained cave systems known at present, each with its individual Master Cave and issue. The flood waters which enter the now usually dry swallet, Rantry

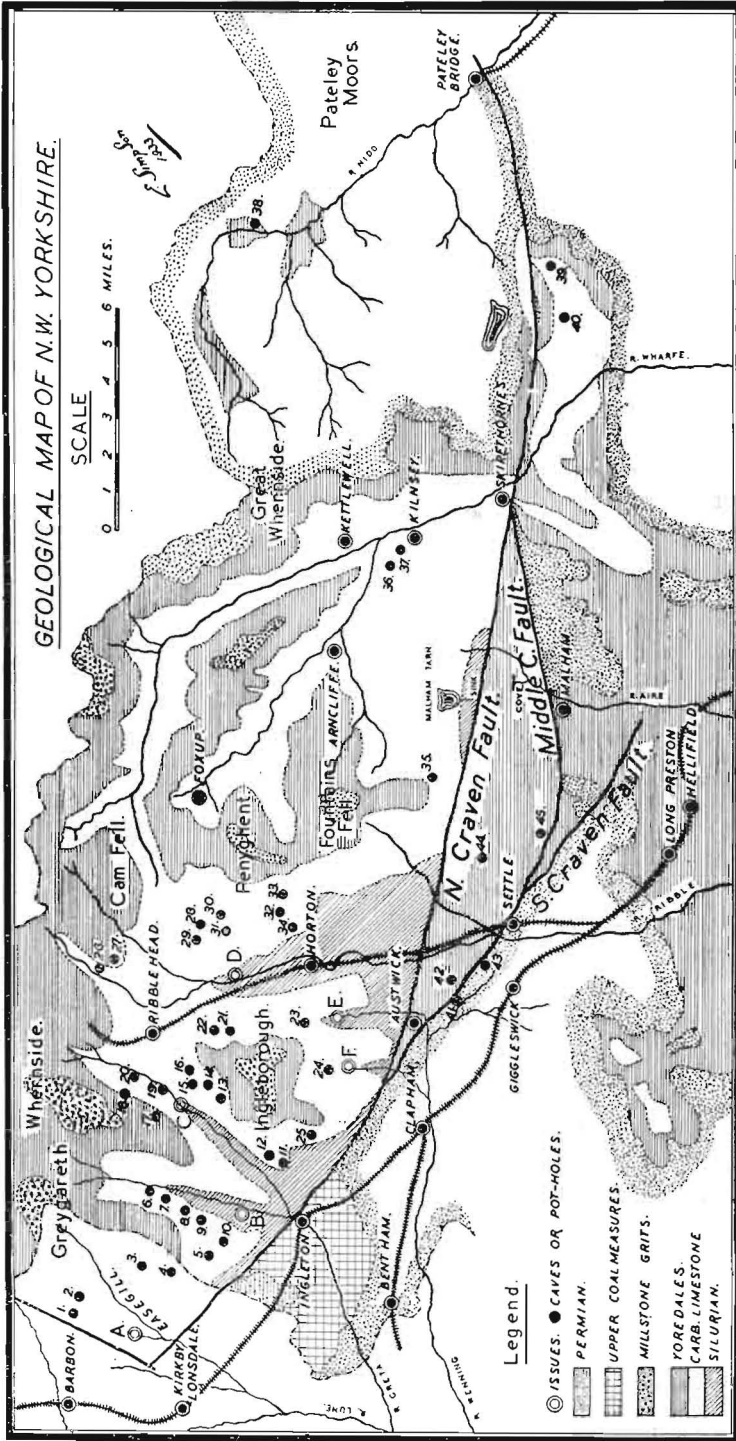
### Key to the Geological Map of N.W. Yorkshire.

#### ISSUES OR RISINGS.

- A. Leck Beck Head.
- B. Keld Head, Kingsdale.
- C. Gouls Bridge, Chapel-le-Dale.
- D. Turn Dub, Ribblesdale.
- E. Austwick Beck Head.
- F. Clapham Beck Head.

#### CAVES OR POT-HOLES.

- |                             |                                     |
|-----------------------------|-------------------------------------|
| 1. Bull Pot of the Witches. | 19. Weathercote Cave.               |
| 2. Cow Pot.                 | 20. Gatekirk Cave.                  |
| 3. Runibling Hole.          | 21. Alum Pot.                       |
| 4. Lost Johns Cave.         | 22. Washfold Caves.                 |
| 5. The Cavern, Ireby Fell.  | 23. Rift Pot, The Allotment.        |
| 6. Yordas Cave.             | 24. Gaping Ghyll Hole.              |
| 7. Bull Pot.                | 25. Long Kin West Hole, Newby Moss. |
| 8. Rowten Pot.              | 26. Capnut Cave.                    |
| 9. Swinsto Cave.            | 27. Cove Hole.                      |
| 10. Marble Steps Pot.       | 28. Calf Holes.                     |
| 11. Skirwith Cave.          | 29. Browgill Cave.                  |
| 12. White Scar Caverns.     | 30. Old Ing Cave.                   |
| 13. Meregill Holes.         | 31. High Birkwith Cave.             |
| 14. Sunset Hole.            | 32. Hull Pot.                       |
| 15. Hardrawkin Caves.       | 33. Hunt Pot.                       |
| 16. Douk Caves.             | 34. Sell Gill Hole.                 |
| 17. Bruntscar Cave.         | 35. Gingling Hole.                  |
| 18. Browside Cave.          | 36. Dowkerbottom Cave.              |
|                             | 37. Sleets Gill Cave.               |
|                             | 38. Goyden Pot.                     |
|                             | 39. Stump Cross Caverns.            |
|                             | 40. Hell Hole.                      |
|                             | 41. Cave Ha.                        |
|                             | 42. Kinsey Cave.                    |
|                             | 43. Kelcoe Cave.                    |
|                             | 44. Victoria Cave.                  |
|                             | 45. South Bank Hole.                |



Based on the Geological Survey map, with the sanction of the Controller, H. M. Stationery Office.

Hole, in Crina Bottom, emerge at Skirwith Cave (11). The White Scar Caverns (12) probably drain the whole of Lead Mines Moss together with portions of Dowlass Moss and the upper portion of Crina Bottom, and though at the surface there is only one stream entering a swallet in this area—Hard Gill—yet so far as exploration has been conducted in the White Scar Caverns there are over twenty strong tributary streams entering. Meregill Holes probably contain the Master Cave which collects all the drainage of the Southern Scales area, so that the waters from Douk Caves (16), Hardrawkin Caves (15), and Sunset Hole (14), after joining the Meregill waters underground, again join underground the main stream from Gatekirk Cave to issue finally at Gods Bridge. Alum Pot (21) waters issue, after being joined by those from the Washfold Caves (22) underground, at Turn Dub (D), and this series consists of the whole of the underground streams draining West Park Fell, Borrans Moor, and South House Moor. At Austwick Beck Head (E) the waters engulfed by the Allotment pot-holes (23), including also those of Nick Pot, reappear in daylight; all the streams sinking in the Gaping Ghyll area (24) issue at Clapham Beck Head (F).

It is to be noted that all the points of engulfment are situated on the limestone plateaux flanking the hills at approximately the 1200 to 1400 feet levels, whilst the points of debouchure are usually at or near the junction of the Silurian and the basement beds of the carboniferous limestone, so that the vertical height that they descend is some 500 feet, and their flow if measured in a straight line from the points of engulfment to the points of debouchure in any of the above areas is never less than one mile.

In Chapel-le-dale on the Whernside flank at Bruntscar Cave (17), Homeshaw Caves, Boggarts Holes, and Browside Cave (18); in Higher Ribblesdale, Capnut Cave (26), Cove Hole (27), Browgill Cave (29), and High Birkwith Cave (31); also in Wharfedale, Scoska Cave, Dowkerbottom (36); and Sleets Gill Cave (37) present another type of cave system, viz., one inlet and one outlet of the stream. On Penyghent there are also the Hull (32) and Hunt (33) Pots series, which are essentially of the first type group systems, but for our purpose in this respect we will deal purely with Ingleborough and the area to the west.

## SECTION 2.

This section represents the area situated between the Craven Faults where the strata dips sharply towards the Northern Fault. This area is interesting from an archæological standpoint, Cave Ha



"Gaping Ghyll Hole."

*Photo E. S.*



(41), Kinsey Cave (42), Kelcoe Cave (43) and the Victoria Cave (44) being some of several to yield important finds to excavators. None of the caves so far discovered is of any great extent, and they may be regarded as dead caves inasmuch as practically no water flows through them, and in some cases they contain masses of glacial clays. Only one pot-hole is so far known to exist in this section, South Bank Hole (45), having a total depth of 165 feet. Despite the contracted dimensions of these caves they are of vast importance, for they help to fix an approximate date for the formation of the Yorkshire caves and pot-holes. Despite the tilt of the strata towards the north, the caves are normal caves which, generally speaking, drain southwards against the dip. If they had been formed prior to the dislocation due to faulting they would have been tilted back with it. This does not occur, showing that their formation has taken place since that of the Craven Fault; also as some caverns contain large masses of laminated glacial clays, it is that evident they were at their highest point of development prior to the Glacial Epoch. South Bank Hole is a pot-hole where the various pitches, despite being situated in tilted strata, have all the characteristics of normal pot-holes as in Section 1.

The Malham area is included in this section. It presents many extremely interesting problems, e.g., the apparent crossing of the underground waters from Tarn Sink to Aire Head Springs, and those from Smelt Mill Sink to the Cove. These lines of drainage were conclusively proved by the Committee appointed by the Yorkshire Geological and Polytechnic Society in 1899, and it was also found that 19,800 gallons of water sinking at Smelt Mill (the only known surface sink communicating with the Cove) represented only 4 per cent of some half million gallons issuing at Malham Cove per day. The North Craven Fault possibly plays an important part in this increase of the volume of water, and is possibly the route by which the water from Gingleing Hole (35) on Fountains Fell might reach the Cove, though such communication has never been proved. In spite of the interesting hydrological problems to be found in the Malham area, there is only one cave, some 60 feet in length, which has been explored. This, Grey Gill Cave, is situated between Malham Cove and Gordale Scar.

### SECTION 3.

The caves within this section are in the main of similar type to those in Higher Ribblesdale, viz., one inlet and one outlet type, and will not be considered here.



The accepted theory of the primary cause of the Yorkshire caves and pot-holes is that of solution. As long ago as 1888, however, Mons. E. A. Martel pointed out the weakness of this theory, whilst in 1907, Messrs. C. A. Hill and H. Brodrick read a paper before the Yorkshire Geological Association, where they pointed out that the effects of fracturing during the formation of the Craven Faults upon the main mass of limestone to the north was probably the primary cause of the pot-holes and caves in north-west Yorkshire. The results of recent survey and exploration compel one to abandon the solution theory as the primary cause of the guiding forces directing underground flow, although it is admitted it plays along with erosion an important part in the secondary phase—the enlargement of the fractures and fissures once it has gained access underground. To make the solution theory effective, the first essential would be the ready circulation and flow from the point of engulfment of the surface stream to its point of debouchure. The theory of corrosion and erosion along the lines of joints could not in itself accomplish this task.

It is interesting to note that not only are all the deepest and most extensive pot-holes and cave systems situated in the vicinity of the Craven Fault, but they are also at the points where the greatest dislocation has taken place, nearly all lying between the valley of the Ribble and the western extremity of the limestone, where the Craven and Dent Faults meet.

The greatest earth movement is in the western section of the Craven Fault, and one is induced, from evidence *beneath* the surface, to believe that whilst the faults were in the course of formation there were innumerable minor fractures being formed in the more stable limestones to the north of the faults. In many cases it is probable that these fractures would result in the opening out of the joints in the carboniferous limestone, whilst on the other hand it is also evident that compensating forces crushed the rocks into fine breccia. It is already acknowledged by geologists that there are isolated cases where the Yorkshire pot-holes lie in the line of faults. Meregill Holes (13) is one, but it shows no vertical displacement; Alum Pot is another, crush breccia being a noticeable feature at the south end of that hole. Mr. H. Brodrick, as long ago as 1904, proved that Rift Pot (23) was a pure fissure, 300 feet deep, without any trace of water-action at its northern extremity; he also traced "slicken-sides" in this pot-hole. One could hardly wish for a more definite proof of this fracturing than in Burnetts Cavern (Bull Pot of the Witches), where the deep grooving of the wall is due to shearing, whilst the Craven Fault itself lies in very close proximity to this pot-hole.

The erosion of the crush breccia as a factor in the formation of pot-holes is illustrated in the case of Rumbling Hole (3); there the breccia is still to be seen extending to a depth of over 100 feet at both the north and south ends of the surface pot-hole. Respecting the formation of large chambers such as Gaping Ghyll (24), Yordas Cave (6) or Sell Gill Cave (34)—all these lie in lines of fault or fracture and it is apparent that they have been centres of great stresses coming from various directions, and in consequence the rock in the vicinity has been crushed in such a manner that when water did enter, the debris was easily washed away. The shattered walls at Gaping Ghyll, especially in the vicinity of the Telephone Corner, go far to prove this; also masses of crush breccia and shattered rock in the Second and Third Chamber at Marble Steps Pot (10). Nick Pot and Marble Pot lead to the same conclusion. Gable Pot, Tatham Wife Hole, Braithwaite Wife Hole (14) and Great Douk Pot-hole (16) probably owe their origin to the same causes.

Though in many cases these fractures descend through the whole thickness of the carboniferous limestone, as in the instance of Gaping Ghyll, Meregill Holes, Rift Pot, and Rumbling Hole, in the majority of cases they are not one continuous vertical fissure, but descend in steps through the strata. Here another important factor, responsible for the joining up step by step, fracture by fracture, is cave formation in the the Shale Beds.

These Shale Beds, which separate the various beds of limestone, do not appear to be uniform throughout any given area, and vary considerably in thickness; at Cow Pot (Shale Cavern), and Lost Johns (Shale Cavern) they reach a thickness of some 7 feet. At Rowten Pot (8) in Kingsdale (350 feet deep) there are ten shale beds each of which is in the vicinity of some important change in the configuration of the pot-hole. Bull Pot (7), 275 feet deep, lies half a mile to the north of Rowten Pot and has seven shale beds, all at important points.

Swinsto Cave (9), 395 feet deep, situated 700 yards south-west of Rowten Pot, owing to its long stretch of passage, offers an even more interesting illustration of the part that shale beds play in directing the underground flow of water. At the bottom of the first pitch (20 feet) we meet with the first bed, situated at roof level of the main passage, which runs for 360 yards, the roof throughout this distance being flat and unbroken. In this length of passage the height varies from 4 feet at the highest portions, and at its lowest it is only some few inches above the stream occupying the floor. These low sections are due to the undulations of the original shale bed and show where

in the hollows of that bed, the upper bed of limestone now forming the roof was deposited. We were able to trace six shale beds in Swinsto Cave and in four of them they form the flat roof level of the communicating passage which joins up the vertical fissures or fractures. The same thing happens in Yordas Cave, Marble Steps Pot, Hardrawkin Caves (15), Rift Pot (Long Kin East Section), Alum and Diccan Pots, Rumbling Hole, etc., etc.

As these shale beds are usually found at some important juncture in the course of these underground passages it is reasonable to surmise that they have played an important part in directing the course of subterranean flow. It is also reasonable to anticipate that whilst dislocations were taking place in the carboniferous limestone, similar dislocations were happening within the shale beds. Once the water had entered at the surface, it would be able to find its way downwards step by step to the basement beds of the limestone and so to the points of debouchure in the valleys. Such would be the primary action, and the secondary action of corrosion and erosion would then take place. In the case of the latter, except in cutting through the shale beds forming the bedding caves as compared with the primary action due to faulting, it is very slow and insignificant, for the bedding caves are usually very contracted and generally speaking form a very small percentage of the total length of the underground passages in Craven.

In many cases the vertical fissure forming the upper portions of the caverns show no water action, whilst, as already stated in the case of Rift Pot, there is no action by solution traceable in the northern section, and even after the water from the Long Kin East Cave has entered at the south end, the point of entrance being a shale bed 150 feet below the surface, the combined chemical and mechanical action or cutting back is comparatively small.