A large mineralized cavity in a tholeiite dike in Northumberland.

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Introduction.

TOWARDS the end of 1952 mining operations at West Sleekburn colliery, Bedlington, Northumberland, involved the driving of a drift through a 'whin' dike. In the process of doing so an unusual, large cavity was penetrated. When the cavity was first entered, by the manager and under-manager, it was found to be water-free but full of 'gas', which rendered them almost unconscious. Their exploration was therefore delayed until the gas was removed by pumping. Unfortunately no sample of the gas was collected, but it is thought to have been 'fire damp'. After examination the cavity repeatedly filled with gas, leading to a suspicion of a hidden extension to the cavity, under the roadway.

Mr. R. Beahey, in search of an explanation of the cavity, brought samples of the minerals to the Geology Department of King's College. The following is a record of the findings and results of the subsequent investigation.

Location and general description of the cavity.

The dike containing the cavity is one of the tholeiite dikes of the olivine-bearing Brunton type described by Holmes and Harwood.[1] It passes about a mile north of Bedlington and trends WNW.–ESE. (110–290°) and is normally about 30 feet thick, but in the vicinity of the cavity narrows to about 20 feet. The cavity is situated at lat. 55° 9′ 22″ N. and long. 1° 33′ 12″ W., and is found at a depth of about 100 fathoms, level with the Bensham coal seam.

The cavity is centrally placed in the dike. Its longest dimension, about 24 yards, is parallel to the dike walls. The other dimensions are variable. The maximum height is 12 feet and maximum width is 10

[1] A. Holmes and H. F. Harwood, The tholeiite dikes of the north of England. Min. Mag., 1929, vol. 22, pp. 1–52.

feet (figs. 1 and 2). The true length of the cavity is unknown, as the westerly portion disappears in a narrow sinuous passage, and the eastern end of the cavity was removed in driving the drift. It is also probable that there may be an extension downwards to the east which was covered when the cavity was broken into.

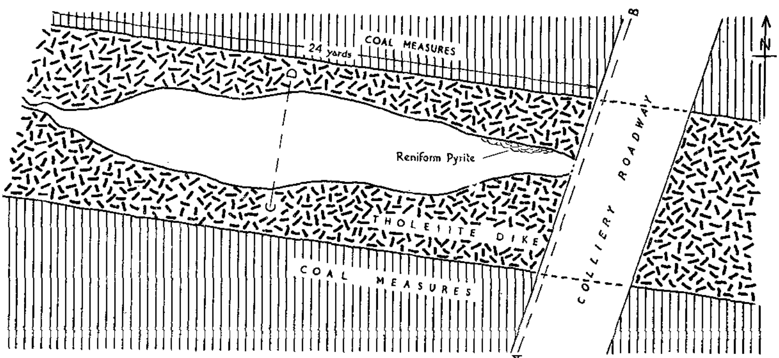

FIG. 1. Plan of cavity, showing relation of sections A-B and C-D in Figs. 2 and 3.

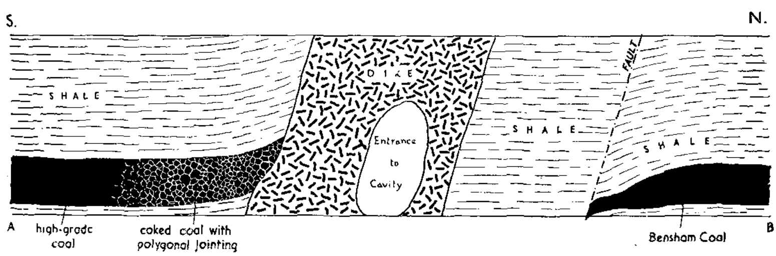

FIG. 2. Section A-B through cavity, as seen in roadway through the dike.

The coal on the northern margin of the dike is cut out by faulting, but on the southern margin it is hardly disturbed by the dike. It is, however, 'coked' for a distance of 10 feet and then passes abruptly into a high-grade coal in the manner described by Marshall.[1]

The minerals developed in the cavity are: pyrite, marcasite, ankeritic calcite, and a magnesium-rich ankerite. Generally their distribution is in three horizontal zones, as indicated in fig. 3.

[1] C. E. Marshall, The alteration of coal seams by the intrusion of some of the igneous dykes in the Northumberland and Durham coalfield. Trans. Inst. Mining Engineers, 1936, vol. 91, pp. 233–260.

Zone I.—The upper zone consists of a botryoidal development of pyrite and marcasite resting on a thin layer of carbonate. The sulphides tend towards a stalactitic development, especially at the top. The radial structure of the growth is obvious in a hand-specimen, and most of the surface shows an iridescence with blue and green tints. Platy, radial developments, characteristic of marcasite, are seen in certain parts of this zone. In one or two instances the marcasite growth has been sheathed with calcite and subsequently the marcasite has been removed, leaving the calcite in a form resembling platy baryte. In other places there is no development of the botryoidal material; instead a thin crust of pyrite rests on the carbonate layer. Sometimes the crust of pyrite is fractured and can be seen 'peeling', curling like dried orange skin, and simulating somewhat the leafy structures of zone II. About half-way down zone I is a shiny horizontal band 1–2 inches broad, lacking any trace of iridescence usually characteristic of the normal development.

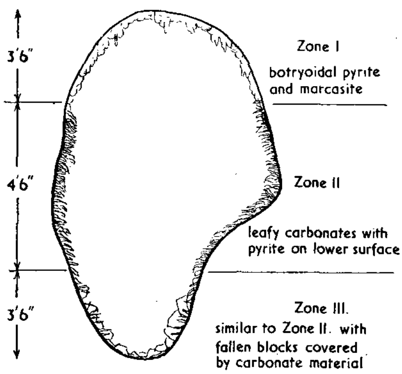

FIG. 3. Vertical section C-D (fig. 1) through cavity.

Zone II.—The middle zone has a well-defined boundary with zone I, but merges rather gradually downwards into zone III. This zone consists of a leafy development of the carbonate minerals standing out more or less horizontally from the walls. On the lower surface of the projections is a development of crystalline pyrite. Much of the material presents a brecciated appearance. Some of the material is very brittle, and breaks at the slightest touch.

Zone III.—The lower zone consists of similar material to zone II, together with fallen blocks of the dike, all coated with carbonate material. An unusual development occurs at the east end of the cavity on the northern wall. This consists of a massive growth of reniform pyrite covering an area of $10 \times 4\frac{1}{2}$ feet and merging to the west into the 'leafy' type of material. The south wall at this point has only a thin development of carbonate with very little sulphide material. The roof here bears small stalactites of carbonate. Carbonate stalactites are developed mainly in the eastern third of the cavity, the largest being about 2 feet in length. Down the walls of the cavity are several 'streams' of carbonate.

At the west end, the cavity has no visible termination as it passes into a tapering sinuous channel only a few inches in diameter. In the last accessible portion of the cavity, which is actually in zone II, are some remarkable stalactites of carbonate coated with botryoidal pyrite. Near the cavity, the dike is considerably altered to white trap impregnated with pyrite and veined with calcite and pyrite.

Determination of the minerals.

The iridescent surface of the sulphide material suggested the presence of copper or nickel, but this was not substantiated by qualitative analysis. X-ray powder photographs of the reniform material (taken from a central layer) indicated pure pyrite, while the botryoidal material proved to be a mixture of pyrite and marcasite.

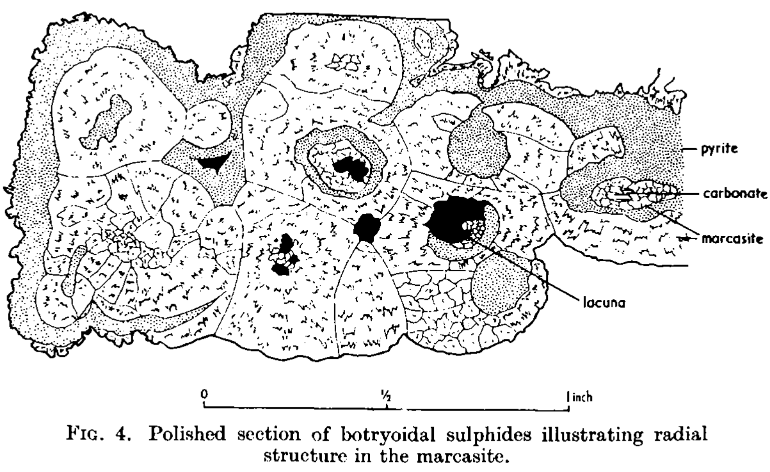

Fig. 4. Polished section of botryoidal sulphides illustrating radial structure in the marcasite.

The colour difference between marcasite and pyrite on freshly fractured surfaces was not regarded as a useful test,[1] since all the material had a fibrous, radial structure and material available for comparison was coarsely crystalline. The relation of the pyrite to marcasite was determined by the examination of polished surfaces under polarized light.

[1] F. A. Bannister, The distinction of pyrite and marcasite in nodular growths. Min. Mag., 1932, vol. 23, pp. 179-187.

In the botryoidal material the growth of the sulphides took place on a carbonate layer, commencing with pyrite, followed by oscillatory zoning of marcasite and pyrite, and terminating with a thin layer of marcasite. The actual structure of the marcasite as determined under crossed nicols is portrayed in fig. 4. The pyrite has a similar structure, but due to its isotropic nature is only seen on poorly polished surfaces.

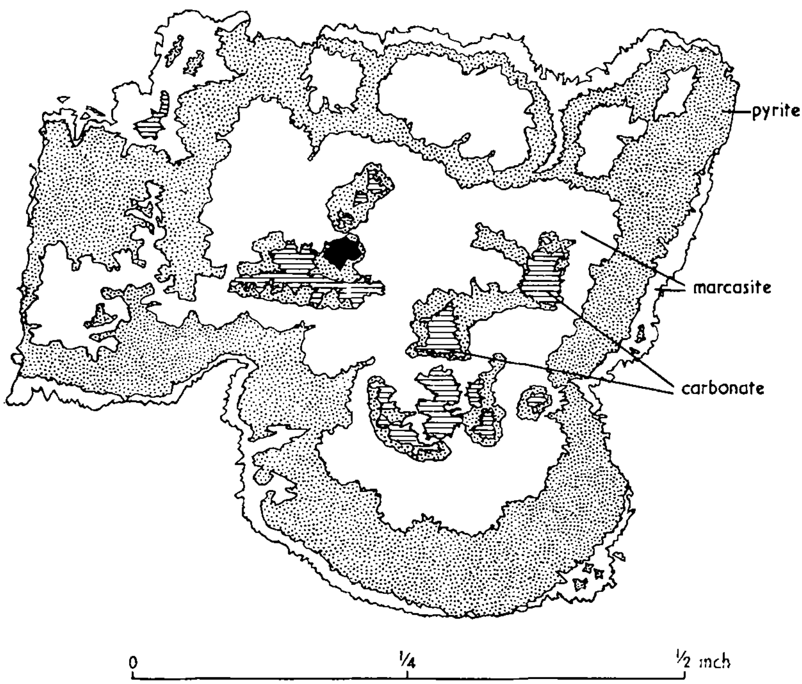

FIG. 5. Polished section of botryoidal sulphides.

The actual thickness of each layer is variable as represented in figs. 4 and 5. Polished sections of the reniform material showed that, although composed largely of pyrite, there are one or two thin layers of marcasite near the outside.

The 'leafy' material of zone II is composite in nature as is shown in the drawing of a thin section (fig. 6). Polished sections of the lower surface indicated that the sulphide is present mainly in the form of pyrite although some marcasite occurs. Above the pyrite layer is a fine-grained grey carbonate (A), then a thin discontinuous layer of pyrite, and finally a coarser-grained, pearly carbonate layer (B) which forms the upper surface. The last forms a downward projecting lip on the edge of the leafy material and is crystallized as nail-head spar in parallel growths. When treated with hydrogen peroxide and concentrated potassium hydroxide the grey carbonate was stained, whilst the pearly carbonate remained almost unchanged.

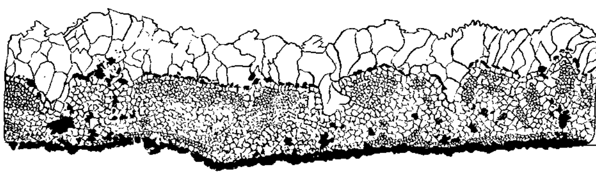

FIG. 6. Thin section of leafy development.

On analysis, the grey carbonate (A) (table I) was shown to be an ankerite close to dolomite in composition. Its refractive index ω 1·682 is in agreement with that shown on a graph plotting ordinary ray refractive index against composition for ankerites by Smythe and Dunham.[1] The pearly carbonate (B) has ω 1·665 identical with that of the stalactitic material. On analysis the stalactitic material was shown to be an ankeritic calcite.

TABLE I. Chemical analyses of carbonates (calculated to 100 %).

Grey carbonate (A) from 'leafy' development (analyst, B. A. O. R.).		Ankeritic calcite, stalactitic material (analyst, J. A. Smythe).	
$CaCO_3$	62·46	$CaCO_3$	97·19
$MgCO_3$	32·27	$MgCO_3$	0·93
$FeCO_3$	5·27	$FeCO_3$	1·50
$MnCO_3$	n.d.	$MnCO_3$	0·38

ORIGIN OF THE CAVITY.

In seeking the origin of the cavity the main characteristics of other similar cavities in dikes in Northumberland are important, so they are listed below. No record of cavities in dikes appears to have been made in the past by the mining industry, so it is highly probable that there

[1] J. A. Smythe and K. C. Dunham, Ankerites and chalybites in the northern Pennine orefield and the north-east coalfield. Min. Mag., 1947, vol. 28, pp. 53–73.

are many more that have been discovered and forgotten and so do not appear in the list.

1. Isabella shaft, Cowpen, $2\frac{1}{2}$ miles SE. of Bedlington.—Discovered in 1940 or 1941, at the level of the Plessey coal seam, within 100 yards of the shaft. Dimensions: 40 yards long × 10 feet high × 5 feet wide. Mineralization: calcite as 1-inch dog-tooth crystals.

2. Horton Grange colliery, $2\frac{1}{2}$ miles SE. of Bedlington.—Discovered in 1940 or 1941, at the level of the 5/4 seam. 30–40 yards × 9 feet × 4 feet. Calcite as white $\frac{1}{2}$-inch dog-tooth crystals.

3. West Cramlington colliery, 4 miles S. of Bedlington.—At the level of the Low Main coal. Length not measured but extending for many yards, height about 6 feet, width 4 inches. Dog-tooth calcite and possibly some pyrite.

4. Hartford colliery. 2 miles S. of Bedlington.—Discovered between 1920 and 1925. At the level of the Plessey coal seam. Calcite only.

5. Backworth colliery, 6 miles NE. of Newcastle-on-Tyne.—Discovered 1946, at the level of the Beaumont seam. 5 × 4 × 1 feet. No mineralization.

6. Prosperous colliery, 6 miles NE. of Newcastle-on-Tyne.—Discovered 1946. About the same size as no. 5. No mineralization.

In each case the longest dimension of the cavity is parallel to the trend of the dike and the height is greater than the width. All dimensions given are maximum values. The cavities listed here have not been examined by the author as they either occur in abandoned areas or have been removed by mining operations. These appear to be the only cavities of any size known in dikes, yet dikes have been tunnelled in many areas, as, for example, in work for the hydroelectric schemes in Scotland, without reports of any cavities.

The author suggests that the presence of coal is essential in the formation of these cavities and that they result from coal being caught up by the magma during intrusion and being subsequently gasified. It would be expected that the greatest dimension of such a cavity would be parallel to the walls of the dike. Faulting, as a mechanism in the formation of these cavities, can be discounted, as differing orientations of the cavities would surely be expected, and at Sleekburn there is no evidence to support this.

Age and order of mineralization.

The mineralization is thought to be unrelated to the actual formation of the cavity. The development of horizontal zones clearly indicates that water has been a controlling factor during deposition. It is thought that the junction of zones I and II represents the general high-water level during mineralization and that the minerals above this line developed in a gaseous environment. The bright line in zone I probably represents a fairly recent water level (before mining operations reduced the water table).

The leafy development in zone II probably represents growth of ankerite, crystallizing from the walls in a manner similar to formation of ice forming on the edges of a pond. This material is delicate and would have some support from the still water. Some of this material has collapsed and become cemented where it has fallen. The latest development has been the growth of the ankeritic calcite on the uppermost surfaces only, of the leafy development. This growth must have taken place in a water-free atmosphere as it develops an overhanging 'lip' to the leafy material. Accompanying this was the development of the calcite stalactites.

The alternate development of pyrite and marcasite in the botryoidal material suggests that there has been a series of oscillations from an alkaline to a weakly acidic environment, although these minerals may form together as is shown by the work of Allen et al.[1] The occurrence of the reniform material is puzzling. Its location may be governed by proximity to an inlet of solutions. It too, however, shows a change of environment near the end of its formation to more acid conditions.

Since all the minerals found in the cavity are very commonly developed in the Coal Measures, their occurrence in the cavity is not unexpected and suggests derivation from the surrounding strata.

Acknowledgements.—The author would like to express grateful appreciation to Mr. R. Beahey who originally notified him of the existence of the cavity; to the manager and under-manager of the West Sleekburn colliery for their help and willingness to allow visits to the cavity; and to numerous other people in the mining industry for information about the other cavities; to Dr. J. Shirley who accompanied the author on visits to the cavity and, together with other members of the departments of geology in Durham University, discussed the problem with him; to Dr. E. C. Ellwood for taking the X-ray photographs; and to Dr. J. A. Smythe for the ankeritic calcite analysis and for encouragement throughout the investigation.

Whilst all opinions expressed are those of the author, thanks are due to the Coal Board for permission to publish this communication.

[1] E. J. Allen et al., Amer. Journ. Sci., 1912, ser. 4, vol. 23, p. 169; 1914, ser. 4, vol. 28, p. 393.