Sideronatrite from mineralized cavities in the Rising Sun colliery, Backworth, Northumberland

By B. A. O. Randall, B.Sc., Ph.D., and J. M. Jones, M.Sc., Ph.D.

Department of Geology, University of Newcastle upon Tyne

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Summary. Two unusual cavities at a Northumberland colliery are described. Although apparently of tectonic origin they do not seem to be related to any major fault. Sideronatrite, not previously recorded in this country, is thought to result from the alteration of the marcasite and pyrite lining the cavities by underground saline waters. These waters are the source of the baryte and gypsum that are also found in the cavities and of the salt stalactites in the disused roadways of the colliery.

Two cavities were encountered in June 1960 during work in the Brockwell coal seam, 1220 ft below sea level, at the Rising Sun colliery, Northumberland; grid reference 431401/567640. They were brought to the authors' attention as a result of their inquiries into the presence of cavities within igneous dykes in the Northumberland coalfield. Through the courtesy of the National Coal Board the authors visited the Rising Sun colliery on 29 April 1965 and examined the cavities though work in that district of the mine had ceased.

The two cavities are close together but at slightly different levels. The lower, more easterly one is largely below the floor of the roadway while the upper is entirely above the level of the roof (see fig. 1).

The lower cavity, which is elongate north–south, is 36 ft in length with a maximum width of 6 ft 6 in. and height of 9 ft. It can be entered through a low passage or 'cundy', the top of which is only 1 ft 6 in. above the floor of the roadway. The roof of the cavity is flat and uniform, being formed by a bedding plane in sandstone, but the floor is uneven and is composed of fallen debris.

The main chamber contains two pools of water, a few feet deep, which are separated by a ridge of rock debris. The water in the pools was found to be at 24·5° C despite the fact that cold water from other workings in the pit was being pumped into the cavity. The high air temperature of 26° C probably results from the reduction of forced ventilation in the disused workings. It is, however, reported that when the cavity was first discovered a shallow stream of hot saline water flowed through it. This

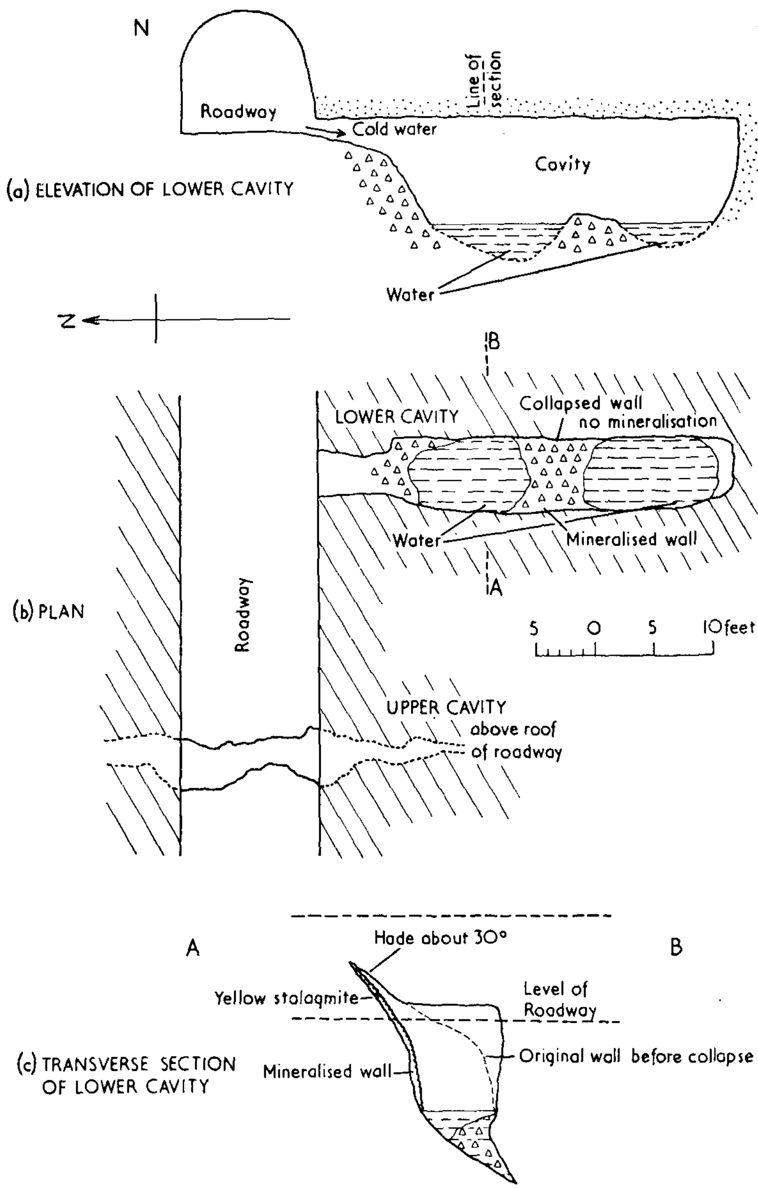


FIG. 1. Sketch illustrations of the Rising Sun cavities.

flow of water has now been upset by the colliery drainage but saline water is still pumped from the pit for barium extraction.

The walls of the cavity are almost vertical and appear to be controlled by the natural joint planes of the sandstone, although the western portion has an upward extension that hades to the east at about 30°. It is probable that all the walls and roof of the original cavity were mineralized but subsequent collapse of the roof and eastern wall has altered the shape of the cavity and exposed uncoated sediments.

The western wall is covered with botryoidal marcasite and pyrite, which in turn is coated with a thin (1 mm) coating of rust-red powdery material. The development of the botryoidal sulphides shows marked horizontal structures, as if its growth had been controlled by varying water levels (see fig. 2).

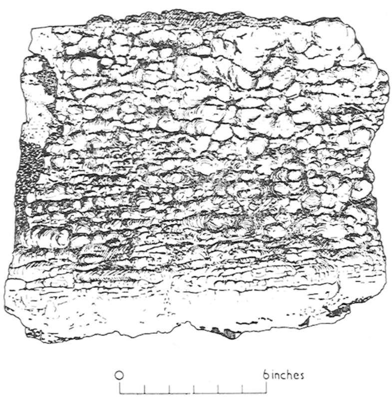
The upper cavity, which lies some six or seven yards to the west of the lower one, is irregular in shape and could only be penetrated for a short distance; the entry is from the roof of the roadway. It extends upwards about 12 ft and has an estimated length of 14 ft in a north–south direction, i.e. at right angles to the roadway. The width is extremely variable reaching a visible maximum of only 4 ft. Although previously there had been an accumulation of gas in the cavity it was relatively gas free at the time of the visit.

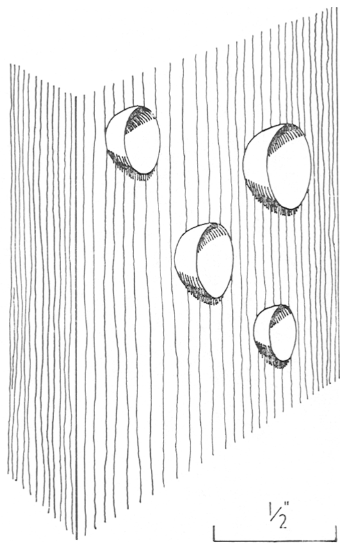
The upper cavity appears to be entirely lined with botryoidal sulphides, but in contrast to the lower cavity many of the growths are of a pendant nature. This is probably due to the more vertical attitude of the walls and similar pendants may well have formed part of the original roof lining in the lower cavity. The sulphides again show a marked horizontal structure but are much more 'yellow' than their counterparts in the lower chamber, although some have an extremely thin red veneer. In places the sulphides are coated by a fungoid-like growth of a yellow-orange mineral, later identified as sideronatrite.

Specimens collected from the cavity are mainly of brecciated sandy siltstone coated with sulphides. In addition, a few unmineralized fragments of shale and coal were found lying on the floor.

The cavity seems to be an expansion of a one-inch vein, which is visible in the roof and north wall of the roadway. Below the cavity in the south wall of the roadway there are a series of $\frac{1}{4}$–$\frac{1}{2}$ in. veins hading 20–30° E and in the coal seam, 8 ft below the cavity, there are a few minor faults with downthrows to the east of $\frac{1}{2}$ in. and 1 in.

The sulphides. The principal minerals in both cavities are marcasite and pyrite, the former predominating. These minerals form a skin on the walls of the cavities that is variable in thickness but rarely exceeds one inch, although some of the pendant growths of the upper cavity are more massive. The sulphides are botryoidal but have grown in such a manner that all the bulbous masses are aligned horizontally. When specimens of the sulphide layer are polished both radial and concentric growths are visible and it is seen that while most of the material is marcasite, pyrite is present as thin concentric layers within the main mass.





FIGS. 2 and 3: FIG. 2 (left). Drawing of botryoidal sulphides from lower cavity showing marked horizontal structure.
FIG. 3 (right). Hemispherical shells of halite on wooden pillar.

Some of the sulphide from the upper cavity has a dull tarnished surface while other material is covered by a thin red film. Unfortunately the latter was too thin to collect without excessive contamination. X-ray photographs of material scratched from the surface indicated only marcasite with a little gypsum.

Baryte. A thin deposit of rust-coloured material covers most of the sulphides of the lower cavity. An X-ray powder photograph of this material showed that baryte was the dominant material but gave no indication of the presence of any iron bearing mineral. At first sight this seems surprising but many strongly coloured rocks, such as the Penrith sandstone, may contain only 1 % of total iron as Fe_2O_3 (Waugh, 1965). Optical examination of this material confirmed the presence of baryte although much of it was almost opaque because of iron staining. Spectrographic analysis indicated the presence of many elements in addition to barium in particular strontium and sodium. It seems probable that the strontium is replacing barium in the baryte and that the sodium indicates the presence of a minute quantity of halite.

Sideronatrite is found in moderate quantity encrusting some of the sulphide in the upper cavity. It is lemon-yellow to orange in colour and occurs in composite masses of spherical shape up to $\frac{1}{10}$ in. in diameter. The individual crystals, which are about 1 mm in length, are prismatic and appear to be terminated by macrodomes. There is a dominant {010} cleavage and the two refractive indices (γ and β) measured on it are 1·584 and 1·526; γ is pale yellow, and β almost colourless. These properties agree well with those given by Larsen and Berman (1934).

The density of the mineral, which is insoluble in cold water, was determined by suspension in a graded density column used in conjunction with a goniometer (Jones, 1961) and was found to be 2·045. This figure is considerably less than the value usually quoted for this mineral, 2·15–2·35 (Palache *et al.*, 1951). X-ray powder photographs yield *d*-spacings that agree very closely with published data (Cesbron, 1964; Van Tassel, 1956).

When heated in water the sideronatrite broke down with the formation of a red-brown flocculant material that on X-ray examination proved to be natrojarosite.

Gypsum. A small fragile stalagmite ($\frac{1}{2}$ in.) of yellowish material found in the westerly upward extension of the lower cavity proved to be composed of gypsum. Small crystals of gypsum were also found adhering to the surface of some of the sulphides from the upper cavity.

Calcite. Small quantities of calcite were located between the sulphide layer and the wall material in the upper cavity. These appear to have been formed prior to the main sulphide mineralization.

Halite. All the specimens collected from the cavity were cleaned in cold water in the laboratory to remove pit dirt. Upon drying a thin encrustation of halite was visible on many of them, especially those composed mainly of sandstone, proving that the rocks in this vicinity have been impregnated by underground saline waters.

Large numbers of salt stalactites were seen in the disused roadway that leads to the cavity. Some of the more massive of these stalactites are up to $1\frac{1}{2}$ in. in diameter and cubic salt forms are visible on their attachment areas. Most, however, are only $\frac{1}{4}$ in. to $\frac{1}{2}$ in. in diameter even though they may be several feet in length, and on occasion extend from ceiling to floor. Nearly all the stalactites have a circular central cavity running their entire length such that the very narrow ones are virtually thin-walled tubes.

Salt, in the form of extremely thin-walled hemispherical shells, about the size of raindrops, was also found attached to the walls and timbers of the roadway (see fig. 3).

The origin of the cavity

The cavities described in this paper cannot really be compared either with those described by Randall and Jones (1966) in the dykes of the Northumberland Coalfield or with caves in carbonate rocks, which owe their origin to solution. Although it is considered that their formation must arise from tectonic movement they do not appear to be in any way related to a major fault. In the roadway section only small faults with throws of less than one inch are visible in the vicinity of the cavity but there are reports of minor faulting a little further east.

There are many indications of transcurrent fault movement in Northumberland (Robson, 1964), so that it is possible that the apparently minor faults near the cavity could have important lateral components, not visible because of the horizontal nature of the strata. If transcurrent movement can be visualized in this instance, then irregularities on the fault plane would permit the development of cavities.

The lower cavity is developed in a homogeneous fine-grained sandstone. In thin section it is seen to be a compact rock with a mosaic-like structure due to the secondary growth of quartz around the original sand grains. In addition the rock contains small areas rich in minute baryte crystals. The rock is both compact and competent and sufficiently strong to withstand the rock creep that at this depth would tend to fill the cavity; such movement is indicated by the buckled metal girders in the roadway. The wall-rock of the upper cavity was inaccessible but material collected from it did include sulphide coated brecciated mudstone and sandy shale.

The mineralization

Since the principal minerals of the cavity are pyrite and marcasite, both ubiquitous in the Coal Measures, it is thought most probable that they have been derived from the adjacent rocks and concentrated in the cavities by circulating ground-waters. There seems to be no need to propose any unusually high temperatures for this process. Cavities in the dykes of the coalfield also contain these minerals (Randall and Jones,

1966) and these too are ascribed to a low temperature transference of material. The marked horizontal structure developed in the sulphides of the Rising Sun cavities, which is absent in the deposits of the other cavities, suggests that there has been a frequently fluctuating water level.

It is tempting to try to equate the sulphide mineralization of these cavities with that of the Sleekburn Dyke cavity (Randall, 1953), which must be Tertiary or younger in age. However, such correlation seems untenable and it is felt that no estimate can be made as to the age of this mineralization.

The other minerals in the cavity have resulted from the alteration of the sulphides or from the underground saline waters. Sideronatrite, although well known in the iron deposits of Chile (Bandy, 1938; Van Tassel, 1956; Cesbron, 1964), has not been recorded previously in Britain. It has, however, been found in Belgian coal-mines both on wooden pit-props and as patches in sandstone (Van Tassel, 1956) and more recently in Israel (Sass, Nathan, and Nissenbaum, 1965). The more normal weathering product of iron sulphides is jarosite, which is recorded from many localities (Cosgrove and Hodson, 1963). It seems probable that the formation of sideronatrite, in this instance, is related to the saline nature of the underground waters (Anderson, 1945) and probably to the moderately high air temperatures (26° C and over) recorded in this part of the pit. The association of this mineral with the gypsum, baryte, and halite can hardly be fortuitous.

At one time the cavities and the roadway were flooded and the very rapid erosion of the iron work in the roadway leaves little doubt that this was saline water. The formation of the sulphates is probably due to the breakdown of the sulphides producing sulphuric acid, which then reacted with the material contained in the saline water to produce sideronatrite, baryte, and gypsum. The halite, which is found both as stalactites and as a general impregnation of the specimens, would be produced wherever there was evaporation of the saline water; certainly the hemispherical shells of salt found on the roadway walls and timbers were formed in this manner.

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