are thus supported by the analysis. An attempt was made to purify some of the finely ground feldspar in heavy solution but it proved to be impossible, the finest particles of powder still showing a network of the alteration products. The calculated amount of the impurity, 25%, did not seem unduly large in view of the abundance of the secondary bementite.

It is interesting to note that this occurrence adds one more mineral to the list of those common to Franklin Furnace and the manganese mines of Långban and Jakobsberg, Sweden. The hyalophane of the latter place is also a granular red feldspar associated with manganese epidote.

---

# MARCASITE INCLUSIONS IN FLUORITE FROM THE CENTRAL KENTUCKY BARITE-FLUORITE-CALCITE VEINS

William Drumm Johnston, Jr., *University of Cincinnati*

## Introduction

The occurrence of marcasite as inclusions in fluorite from the barite-fluorite-calcite veins of Central Kentucky is of genetic significance. These veins have been described by Miller[1], Fohs[2], and recently by Currier.[3] In the main, the veins have a north-south trend paralleling the axis of the Cincinnati anticline, altho departure from this general strike is not uncommon. The country rock is Ordovician limestone from the Camp Nelson formation, exposed on the crest of the Cincinnati anticline, to the top of the Trenton. There are several conspicuous fault zones in the central Kentucky region, and vein material is associated with all of them, usually however, occurring in tension fissures without vertical displacement as vein filling from a few inches to seven feet in width. Barite, fluorite, and calcite are the principal vein minerals, with minor amounts of galena and sphalerite, and oc-

[1]Miller, A. M.; The Lead and Zinc Bearing Rocks of Central Kentucky, *Ky. Geol. Survey, Bull.* **2**, (1905). Geology of Kentucky. *Ky. Geol. Survey, Series V, Bull.* **2**, (1919).

[2]Fohs, F. Julius; Fluorspar Deposits of Kentucky, *Ky. Geol. Surv., Bull.* 9, (1907); Barytes Deposits of Kentucky, *Ky. Geol. Surv., Series IV, Vol.* **1**, Part I, (1913).

[3]Currier, Louis Wade; Fluorspar Deposits of Kentucky, *Ky. Geol. Survey, Series* VI. *Vol.* **13**, (1923).

casionally smithsonite and celestite. The deposits are often banded. Great variation in mineral composition occurs along the strike of the veins. The limestone of the country rock is not replaced, consequently the vein walls are sharp.

## Purpose of the Present Paper

It has been customary to interpret the origin of the central Kentucky veins by analogy with the fluorite veins of western Kentucky and southern Illinois, as they have a similar mineralogic composition. It is natural that this analogy should extend so far as to lead to the general conclusion that the central Kentucky barite-fluorite-calcite veins are genetically identical with the fluorite-calcite-galena-sphalerite-quartz veins of western Kentucky and southern Illinois. Field evidence, however, does not justify an interpretation of hypogene[4] origin for these deposits. Rather, the absence of wall rock replacement, of associated dikes, and of quartz, and the occurring type of tension fissures in which the vein material is deposited point toward a parent solution of low acidity and low temperature. The occurrence of marcasite inclusions in fluorite will be noted as being in agreement with the field evidence for such conditions.

## The Occurence Of Marcasite

The accompanying sketch map (Fig. 1) shows the outcrop of a group of related veins exposed in the bluff of the Kentucky River. While the four mines are situated in a straight line, the continuity of the veins has not been established. In the Chinn mine, the minerals are calcite with occasional sphalerite, barite, and fluorite, while in the others barite and fluorite dominate, with some calcite and occasionally a small amount of galena and sphalerite.

Fluorite with marcasite inclusions was collected by the writer from the Fairchild and Twin Chimney mines. In all, some fifty specimens of fluorite containing marcasite rods were obtained. Those from the Fairchild mine were collected from the vein face, and those from the Twin Chimney mine were from both the mine and the mineral storage bin.

[4]Ransome's definition to denote *hot* ascending solutions is intended, see Ransome, F. L.; *Prof. Paper* 66, *U. S. Geological Survey*, pp. 169–170, (1909)

The marcasite is here, for convenience, described as (1) random inclusions in which the position of the rods bears no relation to crystallographic structure of the fluorite and (2) oriented inclusions in which the marcasite rods are arranged in definite relation to crystallographic faces (which may or may not be developed) in the fluorite.

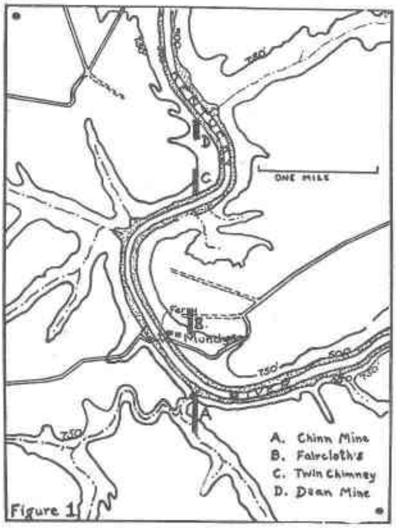


FIG. 1
Sketch map of the veins near Munday's Landing, Kentucky. The country rock is Ordovician limestone.

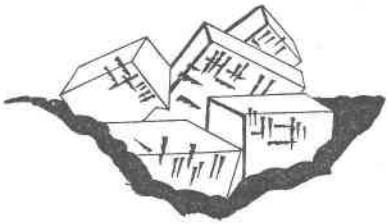

FIG. 2
Fluorite from the Twin Chimney mine, Mercer County, Kentucky. The marcasite is oriented normal to all cube faces.

## RANDOM MARCASITE

Fig. 3, *B*—is a fragment of fluorite with random marcasite rods from the Fairchild mine, Woodford County, Kentucky. It is typical of the greater number of specimens collected from both mines. The marcasite rods are not arranged in any definite crystallographic direction. The occurrence is significant only in as much as the marcasite is indicative of certain physical-chemical conditions existing at the time of its formation, i.e., the formation of the fluorite and of the veins.

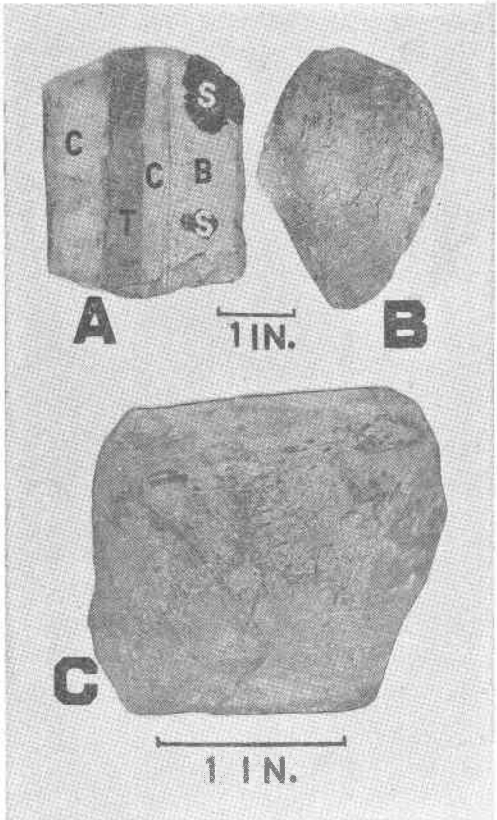


FIG. 3

A—Fragment from Calcite-barite-fluorite vein at Faircloth Mine, Woodford County, Kentucky. T, Tyrone Limestone; B, barite; C, Calcite; S, sphalerite. Fluorite occurs as selvage on the left between the limestone and the calcite, and in the barite.

B—Fluorite from Faircloth Mine with random inclusions of marcasite.

C—Fluorite from Twin Chimney Mine, Mercer County, Kentucky, with oriented inclusions of marcasite. The marcasite rods are arranged approximately perpendicular to the forms (011), (110), and (101).

PARAGENESIS. The work of Allen and Crenshaw[5] upon the formation of marcasite and pyrite is well known. They found that

[5]Allen, E. T., Crenshaw, S. L., and Johnston, John; The Mineral Sulfides of Iron, *Am. Jour. Sci.*, (4), **33,** pp. 169–236, (1912).

at a constant temperature, acidity favors the formation of marcasite, and non-acidity favors pyrite. At constant acidity, high temperature favors pyrite, and low temperature marcasite. The conditions, then, under which marcasite is formed are low temperatures and acidity; and conversely, high temperatures and non-acidity favor the formation of pyrite.

A recent scrutiny of the geological occurrence of marcasite by Newhouse[6] found no disagreement with their work.

As previously stated, there is little evidence for applying Bain's[7] magmatic interpretation of the Illinois fluorspar veins to those of central Kentucky. Additional negative evidence is furnished by the occurrence of the iron sulfides as inclusions in fluorite in the two regions.

Fig. 4, *A*—is a photograph of a cleavage fragment of fluorite containing pyrite inclusions from the Hillside Fluorspar mine, Hardin County, Illinois. Two points will serve to contrast the iron sulfide occurrences in the two regions.

In southern Illinois

(1) Pyrite occurs as inclusions in fluorite.
(2) There is much replacement of limestone by fluorite.

In central Kentucky

(1) Marcasite occurs as inclusions in fluorspar.
(2) There is no replacement of limestone by fluorite.

The replacement of limestone by fluorite can take place only in acid solutions; either the limestone is directly replaced by hydrofluoric acid or silicon fluoride is hydrolized and then replacement by hydrofluoric acid takes place. But as pyrite, which was not favored by acidity, is found, the controlling factor in the formation of southern Illinois fluorite was temperature.

In the Kentucky veins marcasite is found as inclusions in fluorite, and there is no appreciable replacement of the country rock by fluorite. This is indicative of the absence of hydrofluoric acid and of silicon fluoride, that is, of acid solutions. But here marcasite, which is favored by acidity, is formed. Hence low temperature was the controlling factor in the formation of the marcasite in the central Kentucky veins. It is obvious, then, that the difference

[6]Newhouse, W. H.; Paragenesis of Marcasite, *Economic Geology*, XX, pp. 54–66 (1925).

[7]Bain, H. F.; The Fluorspar Deposits of Southern Illinois, *U. S. Geol. Survey Bull.* **255,** (1905).

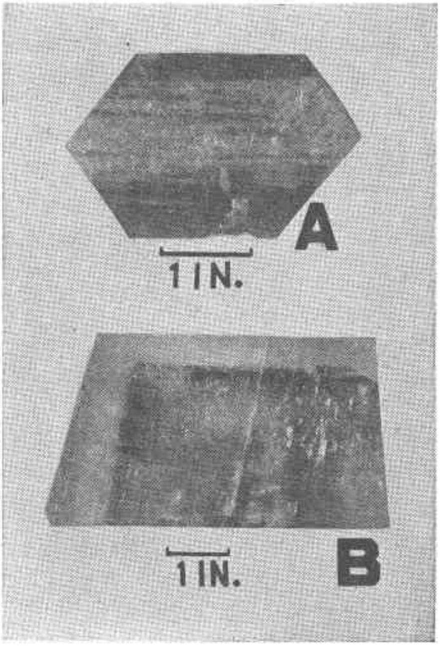


FIG. 4

A—Fluorite from Hillside Fluorspar Mine, Hardin County, Illinois, with inclusions of pyrite. The pyrite occurs in zones, paralleling one pair of cube faces.

B—Calcite from Roach's Crystal Cave, Joplin, Missouri, with oriented inclusions of marcasite. The marcasite rods are arranged perpendicular to crystal faces.

in temperature and the difference in acidity between the veins of central Kentucky and western Kentucky-southern Illinois region is marked and should it be found desirable to consider the central Kentucky veins as vein-dikes, surely they must be placed at considerably greater distance from the magma than those of western Kentucky and southern Illinois.

## ORIENTED MARCASITE

CENTRAL KENTUCKY. The Twin Chimney mine furnished all fluorite in which the marcasite rods were arranged with definite crystallographic orientation. Fig. 3, *C*—shows a cleavage fragment of fluorite in which the marcasite rods are arranged approximately perpendicular to the forms (011), (110), and (101). Specimens of this arrangement are the most common of the oriented group. Less common is the type shown in Fig. 2. Here the marcasite rods are arranged perpendicularly to all cube faces. The specimen is from a vug.

JOPLIN, MISSOURI. Merwin[8] has described calcite containing marcasite rods arranged normal to planes representing crystal faces. From the step-like interlocking of the rods at the intersection of two faces of the calcite, he concludes that the marcasite and calcite crystallized together. Fig. 4, *B*—of a specimen belonging to the University of Cincinnati shows a crystal of calcite with marcasite rods from Roach's Crystal Cove, Joplin, Missouri.

Oriented marcasite indicates one other condition at the time of vein filling. Locally, at least, the parent solutions were static.

SOUTHERN ILLINOIS. In Fig. 4, *A*—illustrates a cleavage fragment of fluorite with pyrite inclusions from the Hillside fluorspar mine, Hardin County, Illinois. The pyrite occurs in zones parallel to one pair of cube faces.

Recently, Steinmetz[9] has described oriented inclusions of chalcopyrite and pyrite in fluorite from Wölsenberg. The inclusions are arranged in a variety of small regular patterns, and are thought to have been deposited from hot solutions as gel on the fluorite. Contraction and dehydration of the gel with the subsequent burial of the sulfides by the growth of the fluorite crystal give rise to the regularly arranged inclusions.

## CONCLUSIONS

1. The occurrence of marcasite in the central Kentucky barite-fluorite-calcite veins is indicative of a low temperature of the parent solutions at the time of vein filling.
2. The inclusions of marcasite in fluorite in central Kentucky, and pyrite in fluorite in southern Illinois strongly suggest that the two deposits were deposited under different physical-chemical conditions, those in southern Illinois being more intense than those in central Kentucky.
3. Oriented marcasite inclusions in central Kentucky veins suggest a static parent solution.

[8]Merwin, H. E.; *Am. Jour. Sci.*, 4th ser., **38,** 355–359, (1914).
Steinmetz, H.; *Z. Kryst.*, Festband P. v. Groth, **58,** 330–339, (1923).