AN UNUSUAL ASYMMETRICALLY BANDED FISSURE VEIN

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Abstract

An asymmetrically banded fissure vein from Clausthal, Germany, is described and illustrated. The writer shows that the veins could not have developed by deposition from homogeneous dilute or concentrated solutions, from colloidal solutions by processes of replacement, or by reopening and filling. The unique features of the veins are explained on the basis of immiscible solution pairs which originated, before splitting, as the result of fractionation of an earlier concentrated mineral solution.

Introduction

The banding of minerals found in fissure veins was among the natural phenomena which first attracted the attention of geologists and mineralogists. Banding in veins is usually of a symmetrical character, that is, the structure of the vein from one wall to the center consists of bands of the same materials and order of arrangement as from the opposite wall to the center, although the corresponding bands may not all be of the same thickness or regularity. Bands of an asymmetrical character are uncommon unless a vein is reopened nearer one wall than the other. Replacement processes may occasionally be active in producing unequal banding, but the extent of the operation is probably rather limited. Asymmetrical banding produced by reopening of an earlier vein is usually easy to detect and the process of formation is clear and understandable.

Banding of the type described below appears to be very unusual if not a unique occurrence in known mineral deposits.

Description of the Veins

In 1926 while engaged in an investigation on the cause of banding in fissure veins based on the evidences available from a study of the vein specimens in the suites of ores in the Laboratory of Economic Geology at Cornell University,† the writer became particularly interested in a veined ore slab, Fig. 1, from the Rosenhof shaft at Clausthal, Germany. The specimen is about 12″×18″ in area and 4″ thick. It consists of a number of more or less parallel veins containing chiefly galena, siderite and quartz in their decreasing order of abundance, together with a very small amount of chalcopyrite and sphalerite.

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† This dissertation on a phase of filled-fissure veins is the third resulting from graduate study at Cornell University, 1925–1929.

The wall rock consists chiefly of fine-grained quartz and sericite of sedimentary origin. It has undergone fracturing and undoubtedly much alteration prior to the introduction of the vein-forming solutions. The vein systems are complex and their exact relationships are not always exhibited. However, many important features are clearly shown on the specimen although the veins do not always photograph as distinctly as one may desire.

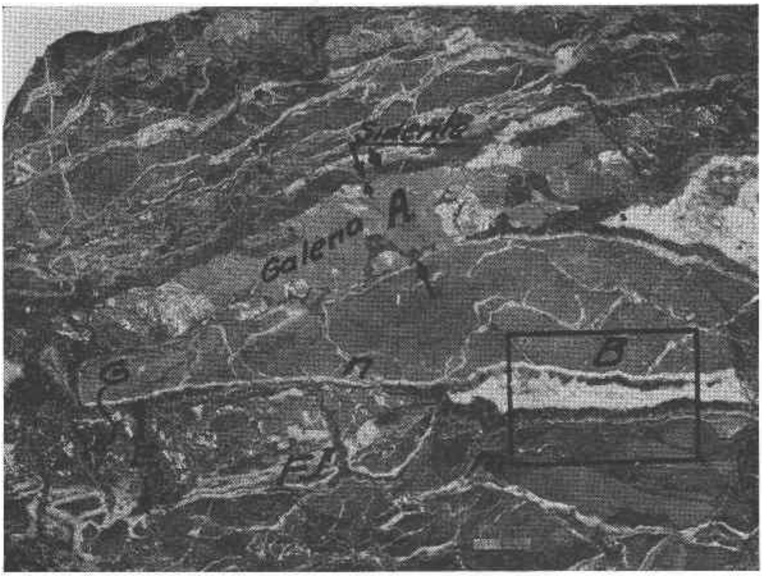

FIG. 1. Front view of ore slab from Rosenhof shaft, Clausthal, Germany, showing intricate system of veins. The larger ones, *A* and *E*, are the earlier while vein *B* is later and intersects vein *E* at *m-n*. The smaller veins are probably contemporaneous with *B* as they cut vein *E* at *F* and *G*. × = 0.30.

The first veins to develop appear to be those indicated at *A* and *E*, Fig. 1. These are branches of the same vein and they join at the left edge of the illustration. The sharply defined vein *B* intersects vein *E* along an irregular line *n–m* making an angle of about 45° with each other. The network of small veinlets appears to be later than *A* and *E* and probably are contemporaneous with vein *B* as shown at *F* and *G*, Fig. 1, where the small veins intersect the earlier ones. The earlier and larger veins contain predominantly galena and siderite while the later network of small veins consists chiefly of siderite and quartz, with a little galena.

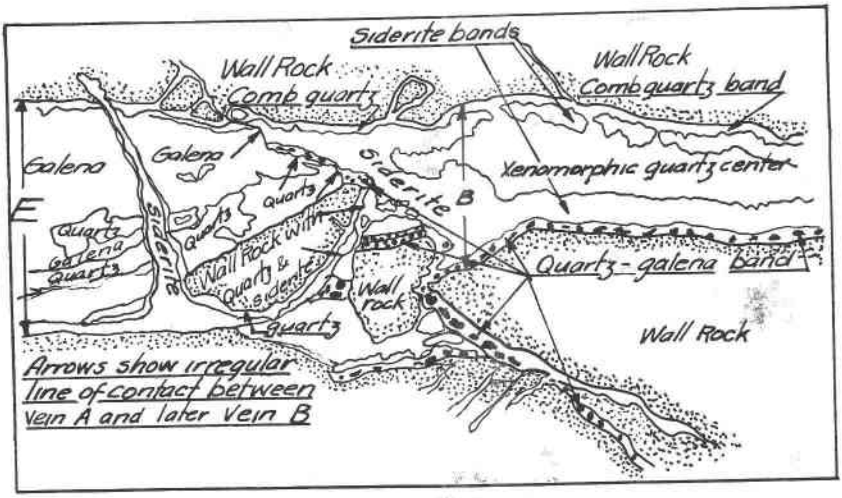

FIG. 2. Sketch of part of vein *B*, traced from polished surface of specimen, Fig. 1, showing the relationship of veins *E* and *B* together with the asymmetric banding of vein *B* and the small associated veins. About ½ natural size.

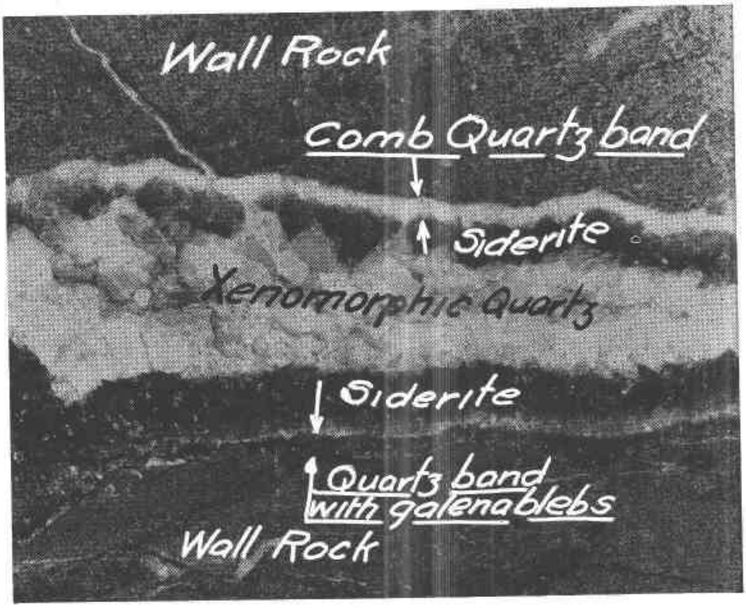

FIG. 3. An enlarged portion of vein *B*, Fig. 1, showing in more detail the relationship of the several bands producing the asymmetrical banding. × = 1.41.

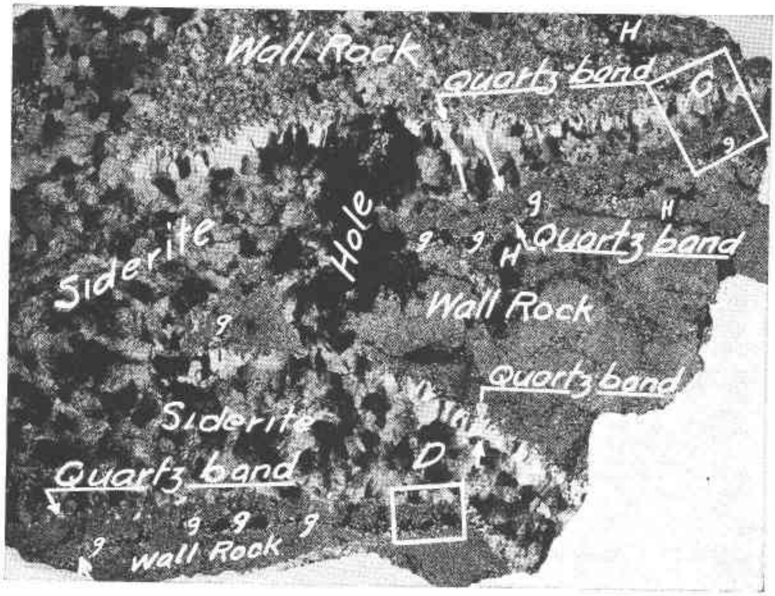

FIG. 4. Photomicrograph in crossed polarized light of a large thin section of two intersecting veins occurring on the back side of the specimen at right end of vein *B*, Fig. 1. Area *C* is shown enlarged in Fig. 5, and area *D* is shown enlarged in Fig. 6. *H* = holes. The dark areas indicated by *g* are galena blebs in the fine-grained quartz band. × = 2.

The initial deposition on the wall rock is usually a thin band of quartz followed by siderite and galena. The early deposition of quartz, a common feature in many veins, is probably due to the effect of the solid phase of quartz in the wallrock. Vein *B* and the associated smaller ones which are more or less parallel to the principal veins are the ones of particular interest owing to their marked asymmetrical banding shown in detail in the photomicrographs, Figs. 4, 5, and 6.

In the description of such complex vein systems and vein structures adequate photographic illustrations are of the utmost importance. In this instance a general view, less the irregular edges of the specimen, is shown in Fig. 1 and a detailed sketch of the most important part of the specimen traced from the polished surface on tracing paper appears in Fig. 2. The area outlined at *B* in Fig. 1 is reproduced to a larger scale in Fig. 3. The section for the photomicrograph shown in Fig. 4 was obtained from vein *B* on the opposite side of the specimen, Fig. 1, at the right. Areas *C* and *D* of Fig. 4 are reproduced on a larger scale in Figs. 5 and 6, respectively.

The unique feature of the later group of veins is the outstanding asymmetrical character of the banding and the mineralogical relationship of

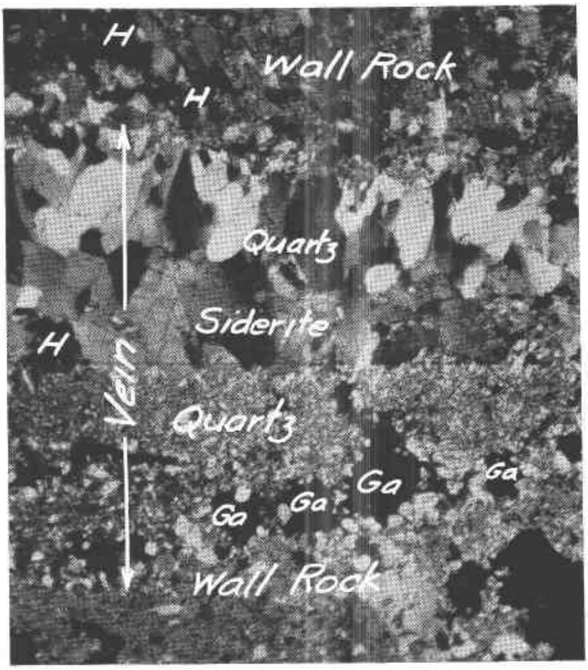

FIG. 5. Area *C* of Fig. 4 is shown in this illustration in crossed polarized light illustrating the texture and structure across a small vein. *H* = holes. *Ga* = galena. × = 11.8.

one band to another. Although the bands in contact with the walls consist largely of quartz, Fig. 5, nevertheless the structure, size and orientation of the constituent grains are entirely different in each. In addition to the quartz, the lower band contains a considerable amount of galena which occurs as blebs within the fine-grained, mostly xenomorphic quartz, while the quartz band in contact with the opposite wall consists entirely of comb quartz, the grains of which are oriented normal to the wall. The center of the smaller veins are filled with siderite. In the larger asymmetrically banded vein shown at *B* in Fig. 1, and on a larger scale in Fig. 3, the siderite occurs in bands following the first quartz bands and it is in turn followed by a central filling of xenomorphic quartz grains, the siderite bands being of unequal thickness, the larger band being at the bottom of the vein as shown in the illustrations. It will be observed that the siderite bands in vein *A* are unequal in width and are not continuous.

There are two features of the fine-grained quartz-galena band that are especially significant criteria concerning the origin of the banding. These are (1) the unequal and random development of an irregular comb

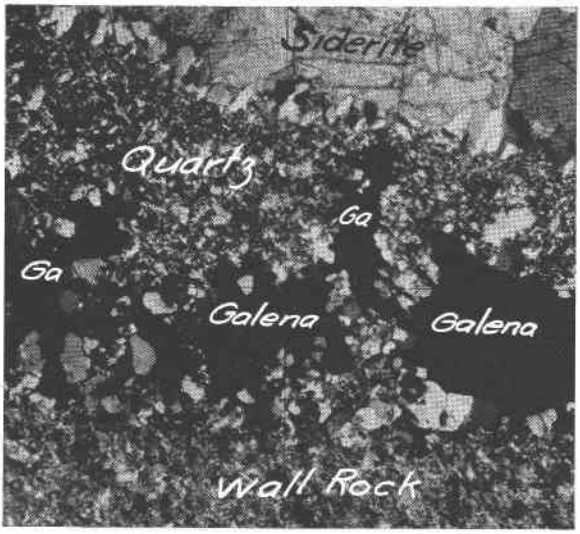

FIG. 6. Area *D* of Fig. 4 is shown in this illustration in crossed polarized light. The subhedral quartz grains projecting into the galena (*Ga*) are clearly shown. The illustration also exhibits the zenomorphic texture of the quartz in the quartz-galena bands as well as the rather feeble development of a quartz crust at the quartz-siderite contact. This crust is not always present between the quartz-galena band and the siderite. $\times = 22.3$.

structure projecting into and supporting the siderite, and (2) the development of an irregular and discontinuous comb quartz structure which projects into the galena blebs, Fig. 6.

A careful examination of the specimen does not show that a reopening occurred along any of the veins, especially those having non-symmetrical banding. In addition, a reopening and subsequent filling would fail to explain the present banding. If, for instance, the quartz-galena band were due to reopening, then, there should be a band of comb quartz adjacent to the quartz-galena band. On the other hand, a quartz-galena band is absent if the comb quartz band were due to a subsequent deposition in a later fracture. Moreover, comb quartz in a fissure-vein, filled by deposition from homogeneous solutions, should develop from both walls instead of from only the one. The constant occurrence of the quartz-galena band along a very irregular disconnected and branching arrangement of veins, Fig. 2, and always along the lower side of the vein is also inconsistent with a reopening and later filling as the cause of the non-symmetrical banding.

In the laboratory one may produce banding from a saturated aqueous solution by initiating the crystallization of compounds by reducing the temperature of the solution. If a saturated solution flows through a temperature-controlled chamber of deposition, a band will be produced along all of the walls in contact with the solution. If the heat is extracted uniformly from the walls, the bands will be uniform in character and thickness. If heat is extracted faster from one side, the deposition will then be the heaviest on that side. If heat were not extracted from any surface, crystallization would not occur and if heat were added at any place, the earlier crystals would possibly dissolve depending, however, on the nature of the existing crust and the character of the solution. In any case the direction of growth of the crystals would be toward the solution and away from the support of the bands, or in the opposite direction to the flow of heat.

Under the geological conditions attending the formation of veins it is very improbable that the wall on one side of a vein would be at a sufficiently different degree of temperature and pressure from that of the opposite wall to affect the character of the mineral crusts deposited from a homogeneous solution. If, therefore, the veins under consideration were deposited from a homogeneous solution the quartz bands should both be alike, and not so divergently opposite in character both texturally and mineralogically. One is therefore more or less forced to reject homogeneous solutions, either dilute or concentrated, as the source of the material which produced the mineral bands. Colloidal solutions would likewise deposit like bands on the opposite walls.

If one were to attempt to explain this unique banding on the basis of the replacement of previous mineral bands by later introduced minerals he would have the following relationships and phenomena to explain depending on the assumptions made concerning the initial conditions or starting phase:

1. Why did the replacing solutions attack one band preferentially to another of the same material?
2. Was the comb-quartz band or the quartz-galena band the earlier and why?
3. If the comb quartz is later, why are the grains oriented perpendicularly to the wall, as in a normal comb-quartz crust?
4. Why was the comb quartz or quartz-galena band (depending on the assumptions made) replaced instead of the siderite band when siderite is much more soluble than quartz?
5. Why are the blebs of galena moulded onto quartz grains which are normal to the contact between the quartz and the galena?
6. Why is there a partial, microscopic band of comb quartz between the quartz-galena band and the siderite?
7. If the quartz and galena did not crystallize essentially contemporaneously to produce the quartz-galena band, then which was earlier?
8. If galena is earlier, then why are the quartz grains, that are in contact with the

galena, larger and perpendicular to the contact with the galena while the rest of the quartz is of an equidimensional and fine-grained character?

9. If the galena is later, then the galena either filled vugs in the quartz or replaced residua of an earlier mineral surrounded by quartz, or selectively replaced the fine-grained quartz which was surrounded by relatively large quartz grains. Certain of these inquiries require an explanation if one attempts to account for the structure as a development resulting from selective replacement.

The writer has not been able to evolve a logical sequence of events to account for the structural, textural, and mineralogical relationships on the basis of replacement and has, therefore, discarded this theory as being inadequate to account for the asymmetrically banded veins.

In removing the specimen from the vein without marking its orientation, a very important datum has been lost and that is the vertical position of the specimen in the vein. The illustrations are oriented with the quartz-galena band at the bottom. If the specimen had been oriented otherwise than illustrated, within reasonable limits, the physico-chemical processes influenced by gravity will have been over-emphasized in the writer's tentative theory of origin for these veins. It is hoped that in the future the same or similar veins may become available to geologists and that special effort may be exerted to obtain all data vitally necessary in the solution of this geological riddle.

ORIGIN OF THE ASYMMETRICALLY BANDED VEINS

One may readily explain the origin of these non-symmetrical veins on the basis of the known properties of immiscible concentrated solutions. Liquids of this character are well known to metallurgists in the separation of slags and sulphide matts. In the process of separating metals, immiscible liquids consisting of certain compounds of the metals are sometimes used. It is not at all improbable that analogous processes occur in nature.

As the properties of immiscible solution pairs may so readily explain the features of these veins, the writer tentatively proposes a theory of origin involving crystallization from concentrated immiscible mineral solutions.

The solution pairs, in this instance, are indicated by the vein composition, consisting in one instance principally of quartz-galena and in the other of quartz-siderite. The former had a specific gravity of approximately 4.20 and the latter of 3.20, as obtained by measuring the areas of each principal constituent shown on photomicrographs by means of a planimeter. The principal phases and steps in the process of developing the veins appears to be essentially as follows:

1. The solution probably originated nearby as the result of fractionation of an earlier concentrated mineral solution. There are many possible phases, the earlier solution at a higher temperature may have been completely miscible. Lowering of the temperature of the solution, by being injected into the cooler fissures would be a sufficient change of condition for the mineral solution of correct composition to split into two immiscible pairs.

2. The immiscible solutions probably coursed through the fissures as a heterogeneous mass of globules of one liquid suspended in the other.

3. After coming to rest in the fissures, the heavier quartz-galena solution settled to the bottom of the veins where crystallization of the constituents subsequently occurred.

4. The quartz from the quartz-siderite band crystallized first and earlier than the quartz of the quartz-galena band, otherwise a prominent band of quartz would be projecting from the quartz-galena band into the siderite. The contact between the quartz-galena and quartz-siderite must have been a liquid interface until after most of the quartz of the quartz-siderite had crystallized forming the comb-quartz band. Crystallization rarely occurs at a liquid interface which is important in explaining the contact as it occurs between the siderite and the quartz-galena band, Figs. 5 and 6.

5. Before the siderite crystallized, the quartz of the quartz-galena band crystallized quickly as is indicated by the fine-grained texture of the quartz. If the siderite had solidified first, the small band of comb quartz would not project into the siderite. If the siderite had crystallized before the quartz-galena band the small quartz band would either be absent or point into the quartz-galena band.

6. The siderite was the last to crystallize from the quartz-siderite solution while the galena was the last to crystallize from the quartz-galena solution. Before the galena solidified the quartz remaining in the solution developed the small crusts which centripetally surrounded the residual portions of galena-rich solution and upon which the galena crystallized.

7. In the larger vein, Fig. 3, the siderite became sufficiently supersaturated to crystallize before the quartz had completely crystallized. The bands of the siderite almost completely cut off the liquid phase of the quartz from the solid phase. Complete crystallization of the siderite appears to have occurred at once leaving the residual quartz to fill the center of the vein. The xenomorphic texture of the quartz indicates a crystallization which occurred nearly simultaneously throughout the re-

maining solution. The banding in the large vein, *B*, is an example of rhythmic fractional crystallization.[1]

8. During the period of crystallization the solutions must have been at rest, otherwise the separation of the solutions and recrystallization of the minerals would not have produced such well-defined bands.

The theory of origin outlined above accounts for all phases of the veins observed. Neither homogeneous dilute or concentrated solutions, colloidal solutions, or processes of replacement offer a logical explanation for this unique banding.

Experimental work in economic geology and mineralogy does not appear to have attempted projects of the nature which would supply definite quantitative data of the type required to support or disprove a theory of origin for these veins based on immiscible concentrated solution pairs.

It appears desirable that more research be devoted to the behavior of concentrated mineral solutions to provide data that may apply to many of the economic mineral veins.

ACKNOWLEDGMENTS

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[1] Shaub, B. M., The cause of banding in fissure veins: *Am. Mineral.*, **19,** 398–399 (1934)