# AN UNUSUAL ASYMMETRICALLY BANDED FISSURE VEIN; A DISCUSSION[1]

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It is unfortunate that a theory of vein formation so in conflict with known facts of physical chemistry should be based on one small specimen, especially when the orientation of the specimen is not known, but must be assumed to be such as to accord with the theory. There is hardly a sentence in the interpretive part of the paper that is not open to question. In the following discussion no attempt is made to select all of the things that could be questioned; only those points are picked out that are answerable on general grounds, without reference to details of the specimen. Shaub makes an attempt at justification on the grounds that insufficient experimental work has been done to prove or disprove the operation of immiscible concentrated solution pairs. As a matter of fact, there is ample experimental evidence to indicate that such immiscible solutions do not exist at the temperatures under which such vein deposits form. The mineral assemblages give a reasonably accurate estimate of the temperatures of formation; at least, they indicate a temperature above which the solutions could not have been when crystallization began. Estimates range from 575° C. down.

According to Shaub's description of the vein under discussion, the material, if it crystallized in situ, would have had to consist almost entirely of $SiO_2$, FeO, PbS, and $CO_2$, because all the minerals are anhydrous and there are few voids that might have contained water left from the crystallizing solutions. Yet the temperature must have been quite low. This is indicated not only by the mineral assemblage ($FeCO_3$ and $SiO_2$ in solution at high temperature and pressure with little or no water present would produce iron silicate and not siderite and quartz), but also by the form of the quartz. The quartz, from its elongate prismatic form as shown in the photomicrographs, must be the low temperature form and was, therefore, formed below 575°, although it was, according to Shaub, the first mineral to crystallize.

If the layers suggested had separated as liquids there would have been three layers, because the "lower" layer of lead sulfide and silica would have formed two immiscible liquids. Moreover, the temperature required to keep these materials molten probably would have melted the wall rock, yet the photographs show no sign of melting adjacent to the veins.

It has been suggested by Farmin that carbon dioxide might aid in keeping such concentrated solutions (ore magmas) fluid at lower tempera-

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[1] Shaub, B. M., *Am. Mineral.*, **27**, 507–516 (1942).

tures, but recent experimental work done at the Geophysical Laboratory indicates that the effect of carbon dioxide is in the opposite direction, forcing silica out of solution, thus making the solution more dilute rather than more concentrated.

In a previous paper[2] Shaub cites observations by Newhouse in support of the view that some ore-forming solutions may have been concentrated. Newhouse did find some solutions in liquid inclusions that were relatively concentrated (15%±), but this concentration was of soluble salts such as NaCl, which says nothing of the concentration of $SiO_2$ or PbS in an ore-forming solution.

Greig[3] has shown that immiscibility almost certainly has no part in the formation of igneous rocks. It is even less likely that it plays a part in vein formation, because as the temperature decreases and the water content increases, immiscibility becomes less and less probable. The analogy of slags and mattes (p. 154) does not hold, not only because of differences in composition, but also because the temperatures cannot have been high enough.

Study of the pictures indicates that a straightforward interpretation on the basis of a homogeneous dilute solution, and replacement, can probably explain all the features, but to put forth a definite hypothesis merely from inspection of a few photographs is hardly justified.

The questions proposed on pages 513–514 are largely academic. A careful study of the specimen would be required to answer them specifically, but some of them become pointless at once if deposition from dilute solution is assumed rather than replacement (3, 5, 8). Question 4 is based on the assumption that $FeCO_3$ is "much more soluble" than quartz. That all depends upon the solution doing the dissolving. It is easy to prepare a solution in which quartz is much more soluble than $FeCO_3$, and similar solutions may well have a part in vein deposition.

Each step in the process of development as outlined by Shaub (pp. 515–516) is open to discussion:

(1) The development of immiscible liquids in silicate systems during cooling and crystallization can occur. However, in all systems containing compositions even remotely resembling magmas in which immiscibility occurs, it can be developed only at very high temperatures and from mixtures that approach 100% $SiO_2$, by the crystallization of silica.

(2) Having the liquids come in as a heterogeneous mixture of globules is obviously merely a convenient hypothetical mechanism for getting both of them into a small fissure simultaneously. Actually, if two such liquids had not separated at the higher temperatures obtaining before their intrusion, it is inconceivable that they would separate into perfect

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[2] Shaub, B. M., The cause of banding in fissure veins: *Am. Mineral.* **19,** 393–402 (1934).

[3] Greig, J. W., Immiscibility in silicate melts; *Am. Jour. Sci.*, **13** (5), 1–44 and 133–154 (1927).

layers on cooling and crystallization. The form of at least some of the globules would almost certainly be preserved.

(3) There is no evidence at all for gravity separation by settling of the liquid containing PbS, because the orientation of the specimen is assumed; it was not even known approximately.

(4) Crystallization may not begin at an interface between immiscible liquids in a crucible, because the melt cools from the sides and bottom but where the rate of cooling is uniform throughout a given volume, crystallization is more likely to begin at a discontinuity like an interface than within either liquid. This tendency is clearly shown in a photomicrograph by Greig[4] which shows crystals forming a ring at the interface around a globule, the center of which did not crystallize at all.

(4, 5, & 6) The order of crystallization is described so as to fit the theory, but there are inconsistencies (See 7).

(7) Separation of a *liquid phase* of quartz to crystallize alone in the middle of the vein is unthinkable. Even if water is concentrated along with it to keep it in solution (which possibility is not mentioned) there are two inconsistencies: In the first place, in (6) siderite, not quartz is said to be the last to crystallize. In the second place, the pictures (especially Fig. 5) show this last quartz to crystallize to be indistinguishable from that of the galena-quartz layer, which would hardly be expected if they crystallized at different times, presumably at different temperatures, and from solutions of quite different compositions.

Banding in the large vein is cited as an example of rhythmic fractional crystallization,[5] which is another process that cannot take place. When a cooling solution becomes saturated with respect to a solid phase and crystallization of that phase begins it continues to crystallize until it has all precipitated, or it becomes unstable, or there is a change of conditions that renders the solution unsaturated or just saturated again. Shaub does not recognize any of these factors, but assumes that a phase may crystallize for a time, then stop while another one crystallizes, then precipitate again, during continuous cooling of a stagnant solution. This is a convenient mechanism for producing banding, but it is hardly in accord with the way solutions are known to behave.

(8) Well defined bands are no evidence of solutions at rest. Much better defined bands than the ones pictured are formed in boilers and steam pipes through which dilute solutions are moving at high speeds and with much turbulence.

The evidence from the pictures, coupled with experimental data, indicates that such a vein could not have formed from "concentrated immiscible mineral solutions."

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[4] *Op. cit.*, Fig. 6*a*.

[5] Shaub, *op. cit.*, pp. 398–399.