THE CAUSE OF BANDING IN FISSURE VEINS

B. M. SHAUB, *Cornell University.*

Banding is a feature not uncommonly exhibited by deposits formed by the filling of fissures or other kinds of cavities. It may be due to alternating bands of different minerals of either metallic or non-metallic character, or in other cases it may be caused by successive deposits of the same mineral, the bands of which differ in purity, texture or degree of crystallinity. The bands may also vary in their regularity.

In this paper the several explanations of banding that have been suggested will be briefly outlined and some further causes of this phenomenon will be offered.

PREVIOUS VIEWS ON BANDING

Banding, particularly in fissure veins has been referred to by a number of writers,[1] but their explanations of its origin naturally differ somewhat.

Lindgren[2] states that "Precipitation from complex solutions in open spaces takes place in a certain orderly succession, and the deposits therefore assume a banded texture. . . ."

In a paper referring to the vein filling at Bendigo, Victoria, where quartz is found on ankerite, he remarked that: "It seems difficult to explain these relations by any other theory than that the cavity in the slate was first formed and that it remained open until the coating of ankerite had been deposited. At that time the character of the solutions changed and quartz was deposited."[3]

Whitehead,[4] also in discussing the veins at Cobalt, Ontario, writes: "The solutions, as shown by banding in the veins were changing in composition."

[1] Posepny, F., *Trans. Amer. Inst. Min. Engrs.*, vol. **23**, p. 197, 1894; Boydell, H. C., *Trans. Inst. Min. Met.*, London, vol. **34**, p. 196, 1924.

[2] Mineral Deposits, 4th ed., p. 168, **1933.**

[3] *Econ. Geol.*, vol. **15**, p. 314, 1920.

[4] *Econ. Geol.*, vol. **15**, p. 124, 1920.

Posepny,[5] observed that crustification was characteristic of cavity filling, and that the solutions were aqueous ones from which the minerals were deposited as crusts on the walls and around foreign objects in the cavities, such as fragments of wall rocks or earlier crusts, producing "crusted kernels" or a "cockade" structure.

"Differential crystallization" in concentrated solutions is the process assigned by Spurr[6] to explain the banding in some veins described in his book. He also refers to "pulsating crystallization" in fissure veins, but the exact manner in which either of these processes operates is not quite clear from the text. Fractional crystallization is scarcely more than mentioned.

The researches of Liesegang in connection with rhythmic precipitation,[7] caused by a reagent diffusing into a gel containing an active solute, and the application of this phenomenon to explain the banding in agates[8] has suggested its use to explain the banding in some ores.[9]

As noted by Lindgren,[10] "diffusing substances may meet and produce uniform or rhythmical replacements, a rhythmical banding . . . ," an explanation which he has applied to certain quartz-chalcedony bands in the ore deposits at Tintic, Utah.[11]

Knopf, in describing the banding of the wood-tin found in the Tertiary rhyolites of Nevada,[12] also suggests that it represents a diffusion effect.

Other causes mentioned are filling of fractures in a sheared vein,[13] and electro-kinetic deposition.[14]

So far as the concentration of the solutions is concerned, there seems to be a general opinion among most writers except Spurr, that they were of dilute character.[15]

[5] *Trans. Amer. Inst. Min. Engrs.*, vol. **23**, p. 197, 1894.

[6] The Ore Magmas, pp. 142, 524, 690, **1923**.

[7] Geologische Diffusionen, 1913: Review by A. Knopf, *Econ. Geol.*, vol. **8**, p. 812, 1913.

[8] Liesegang, Die Achate, 1915.

[9] Hatscheck, E. and Simon, A. L., *Trans. Inst. Min. and Met.*, London, vol. **21**, pp. 451–480, 1920; Watanabe, M., *Econ. Geol.*, vol. **19**, pp. 497–503, 1924.

[10] Mineral Deposits, 4th ed., p. 177, **1933**.

[11] *Econ. Geol.*, vol. **10**, p. 233, 1915.

[12] *Econ. Geol.*, vol. **11**, p. 652, 1916.

[13] Lindgren, Mineral Deposits, 4th ed., p. 173, **1933**.

[14] Van der Veen, R. W., Mineragraphy and Ore Deposition, p. 96, **1925**.

[15] Boydell, H. C., Operative Causes in Ore Deposition, *Trans. Inst. Min. and Met.*, London, **1927**, p. 36.

Boydell has divided the causes of banding into four groups as follows.[16]

1. Banding by incrustation in open spaces.
2. Banding following lines of shear and fracture.
3. Banding by replacement along shear planes, etc.
4. Banding by processes taking place in gels.

Boydell seems to place special emphasis on the last group, which hardly appears correct for the reason that there is little widespread evidence of colloform structures in fissure veins. A further objection to the acceptance of a general application of this phenomenon to banding in fissure veins is found in the delicate adjustment of concentrations[17] necessary between the incoming reagent and the solute in the gel in order to effect rhythmic deposition. Moreover, there must be the proper combination of reagent and solute to produce a metathetical reaction in the gel.

It seems to the writer that the classification of banded structures suggested by Boydell is incomplete, and he therefore proposes the following:

1. CRUSTIFICATION.
   a. Crystallization from changing solutions which carry essentially one mineral at a time.
   b. Fractional and rhythmic fractional crystallization from complex solutions of either dilute or concentrated character.
   c. Colloidal deposition with alternating colored bands.
   d. Colloidal deposits with bands of adsorbed colored minerals.
   e. Successive bands of the same mineral, having different textures.
   f. Bands of the same mineral of different colors.
   g. Crystalline bands (sometimes of the same mineral) alternating with bands of clay or other colloidal minerals.
   h. Inclusions of colloidal particles or other material forming streaks in the bands of crystalline material.
   i. A combination of two or more of the above.

2. REPLACEMENT.
   a. Along shear or fracture planes.
   b. Around fragments, in part a crustification.
   c. Along bands of clay or colloids.
   d. Along contacts of mineral crusts.

3. REOPENING AND FILLING WHICH MAY BE REPEATED.
   a. By processes under 1.
   b. By crystallization in a fissured non-banded vein, of a concentrated monomineral solution.

[16] *Trans. Inst. Min. and Met.*, London, vol. **34**, p. 196, 1924.

[17] Bradford, S. C., Adsorptive Stratification in Gels, *Jour. Biochem.*, vol. **10**, pp. 169, 196; vol. **11**, p. 14; vol. **14**, pp. 29 and 474.

CRUSTIFICATION

This structural feature is not uncommon in many filled fissure veins, or even other filled cavities, and has the characteristic appearance shown by Fig. 1. The relation of the bands to the surface from which mineral growth started may be clearly indicated by the lemniscate-like curves of the crusts (Fig. 1), and in addition in the illustration by the variation in size of the grains in the quartz bands.
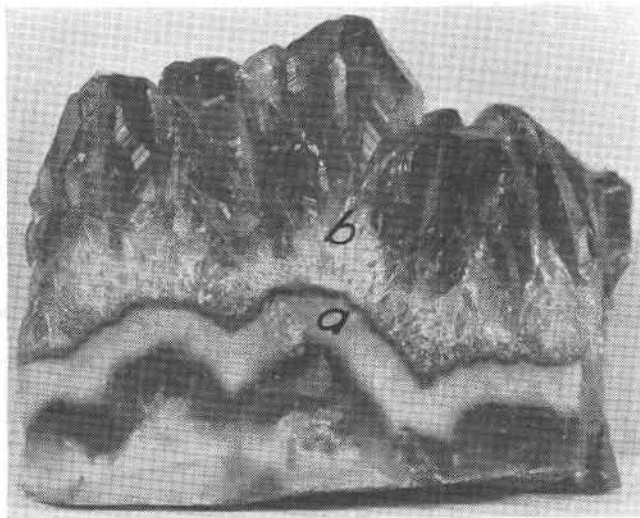

FIG. 1. Banding showing change from chalcedony
to amethystine quartz.

It is probably rare that successive mineral crusts are deposited in perfect parallelism for any appreciable distance, because of the initial irregularity of the surface of deposition, or uneven rate of growth of the crystals.

Those crystals or crystal groups that extend farthest into the vein solution are most likely to receive more material from it, owing to the fact that the solution adjacent to the crust is more stagnant, and contains a relatively lower concentration through the crystallization of the solute. For the same reason, projecting portions of the crust would grow faster than the main part, and so assist in increasing the convexity of the bands.
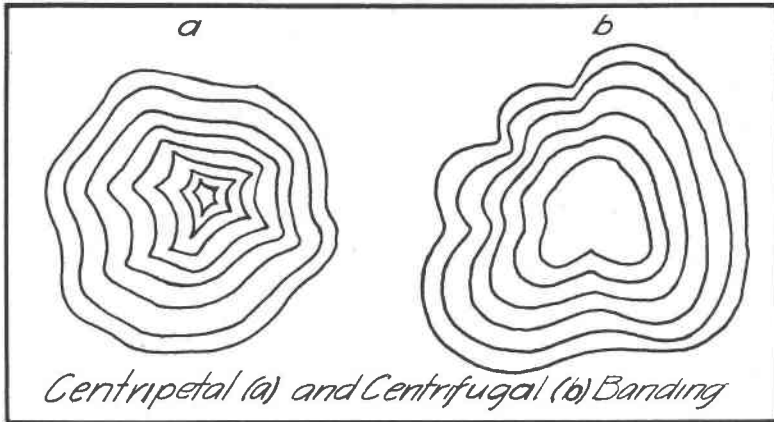
Fig. 2. Diagrammatic illustration of centripetal (*a*),
and centrifugal (*b*) types of banding.

Crust accumulating on the walls of a circular opening and growing toward the center develop the lemniscate-like bands shown in Fig. 2, *a*. This may be called *centripetal* banding. Should bands develop from a central point or axis and extend outward, it may be referred to as *centrifugal* banding (Fig. 2, *b*).

Individual bands or crusts may be started either by the accumulation of a layer of colloidal material (Fig. 1, *a*), or by the development of a band of very small closely packed crystals or grains indicating in either case a rapid rate of reprecipitation or crystallization from a supersaturated solution. As the degree of supersaturation diminishes or the rate of cooling decreases, the rate of growth of the crystals decreases.

Furthermore, with decreasing supersaturation, the osmotic pressure becomes less and the conditions are more favorable for the growth of larger crystals.[18]

The bands may thus be terminated by a comb of crystals which on the average are many times larger than those formed earlier (Fig. 1, *b*).

If the concentration or degree of supersaturation is subsequently sufficiently increased, a new band of small crystals will start and cover the larger ones since the osmotic pressure will then be increased sufficiently to permit the growth of smaller crystals in contact with the larger ones.

[18] Nernst, W., Theoretical Chemistry, p. 762, 1923. Translation by L. W. Cood.

FRACTIONAL AND RHYTHMIC FRACTIONAL CRYSTALLIZATION

Fractional crystallization is a common and important process in the industries for separating salts of various kinds from a common solution, and it seems not unreasonable to suppose that it might also operate in fissure veins.

Rhythmic fractional crystallization will depend upon the degree of supersaturation which the different substances in solution may reach before crystallization begins. The one first reaching the necessary degree of supersaturation will crystallize first, and will continue to be deposited until its degree of supersaturation in the solution becomes very low. Concordantly, the supersaturation of another compound will become sufficiently high to cause it to precipitate or crystallize on the crust of the first compound and thereby separate the solid or solution phases of the first. While the supersaturation of the second compound is being reduced by crystallization, the first may again reach a state of sufficient supersaturation to repeat the cycle and produce rhythmic banding.

It therefore seems possible that such a process may be operative in fissure veins, and account for the alternating bands of non-metallic minerals and sulphides which may be present in magmatic solutions.

Regarding the actual degree of saturation of these solutions we know comparatively little, although some studies by Newhouse on the composition of mineral solutions from liquid inclusions, has indicated that the concentration might be high,[19] and in any event a mineral would not be precipitated until the solution was saturated with respect to it.

It is also possible that more than two minerals may be involved in the process and when any mineral does not crystallize rapidly enough to isolate the solid and solution phases of the one earlier formed the two might crystallize simultaneously.

This process may continue until the solution is completely crystallized or deposition ceases for some other reason.

The width of the bands would probably depend principally on the physico-chemical nature of the substance and solution, the degree of supersaturation to which any of the substances may be raised, the rate of diffusion, and quantity of the solution.

Should there be quartz in both the solution and in the wall rock, the first mineral to crystallize would very likely be quartz since

[19] *Econ. Geol.*, vol. **27**, p. 419, 1932.

the solution cannot become more than slightly supersaturated because it is in contact with some of its solid phase. This initial crust of quartz is common in fissure veins, and Spurr[20] calls attention to its frequent occurrence. Rhythmic fractional crystallization as a cause of banding in filled fissures appears to be rarely mentioned, but it seems more reasonable than the assumption that the solutions following a fissure are constantly changing. In the case of banded veins like those of Clausthal where one finds repeated alternations of one non-metallic mineral with sulphides, changing solutions, as an explanation is hard to conceive.

COLLOFORM BANDING

The term colloform has been widely used by geologists,[21] to include a number of structures that have been usually attributed to colloidal deposition. Colloform structures when examined in thin section appear to be crystalline, or sub-crystalline (amorphous).

FIG. 3. Colloform bands of zinc sulphide, the bands colored probably by adsorbed iron compounds. Moresnet, Belgium.

[20] The Ore Magmas, vol. **II,** p. 677, 1923.
[21] Rogers, A. F., *Jour. Geol.*, vol. **25,** p. 518, 1917

The former is exhibited chiefly by carbonates, while the latter appears to be represented mainly by silicates and sulphides.

Since many of the bands observed in fissure veins, and which are ordinarily termed colloidal, consist of well crystallized minerals, one may question whether they represent colloidally deposited minerals which have subsequently crystallized, or whether they have actually originated by crystallization from molecular solution. Many of the carbonates show a colloform banding which is in reality caused by the feathery nature of the crystals.

The colloidally deposited zinc sulphide from Moresnet, Belgium (Fig. 3), shows a strikingly banded appearance, with alternating light and dark ribbons. This rhythmic coloration, in bands of uniform texture is probably caused by the adsorption of varying amounts of iron compounds. Discontinuous bands of galena and marcasite may be interbanded with the zinc sulphide. The lead sulphide was undoubtedly deposited from a molecular solution, which diffused through the colloidal zinc sulphide, the cubes of galena having replaced some of the sphalerite in the bands.

FIG. 4. Colloform bands of rhodonite (R) with sulphides, chalcopyrite (cp), sphalerite (sp) and pyrite (pr). Area beyond last continuous band shows portions of collapsed ones. Initial crust of quartz (q) on wall rock. Kapnik, Roumania.

Another interesting specimen, representing a portion of a banded vein from Kapnik, Roumania, is shown in Fig. 4. This shows alternating bands of colloidal and crystalline rhodonite, as well as galena, sphalerite, chalcopyrite and pyrite. The sulphides which have euhedral outlines, occur sparingly, and are probably contemporaneous. The rhodonite shows that the character of the material deposited changed from a colloidal to crystalline texture as precipitation progressed.

In seeking an explanation for colloform structure, it is suggested that the colloidal particles may have been thrown down from a supersaturated solution by rapid crystallization or condensation, and precipitated on the walls by a process of adsorption, or possibly in some cases by a difference of electrical potential[22] between the solution and the wall rock.

COLORATION BANDING

Minerals susceptible to the coloring effects of slight amounts of foreign material adsorbed or in solid solution; or more rarely minute inclusions, such as are noted in quartz, fluorite or tourmaline, may exhibit a well defined banded structure due to variations in the amount and character of the coloring agent.

BANDS OF IMPURITIES

Should the deposition of foreign matter which may have been included in the bands, become too great, it may separate the solid from the solution phase of the mineral, and cause the development of a second crust of the latter, when the active deposition of foreign matter ceases.

REPLACEMENT BANDING

Many irregularly banded veins, are undoubtedly the result of replacement along fractures[23] or shear planes in the vein material. These permit ready access of solutions, which replace the minerals along the fractures. Bands of clay and other colloidal minerals, or the boundary line between crusts may allow mineral solutions to diffuse through them and replace the bordering bands.

[22] Pictou, H., and Linder, S. E., The Electrical Connection of Certain Dissolved Substances; *Jour. Chem. Soc. Trans.*, vol. **71**, Pt. I, p. 568, 1897.

[23] For interesting cases of this see: Bornhardt, W., Gangverhältnisse des Siegerlands und seiner Umgebung; *Archiv. f. Lagerstattenforschung*, Heft. **8**, Pt. II, 1912.

Reopening and Filling

Fractures caused by the reopening of a vein which shows no original banding, may become filled with different minerals, thereby producing a banded appearance.

Summary

It is probable that the banding in some fissure veins is caused by filling of shear fractures in an originally unbanded vein, by replacement along the contact of two crusts, by the change in color of different crusts of the same mineral, or the operation of diffusion in gels as outlined by Liesegang. It is suggested, however, that in those veins which show a more or less regular crustification, particularly due to alternating bands of two different minerals, that the process of rhythmic fractional crystallization, as previously described, explains as well as any the mode of deposition of the individual bands. The process is in conformity with the laws of physical chemistry, and seems more logical than the assumption that the solutions rising in the fissure were constantly changing.

Attention is also called to the fact that in some veins there is a series of bands of the same mineral which show a change from colloidal or finely crystalline texture in the earliest deposited crust, to coarsely crystalline texture in the last. This change is thought to be due to a decrease in the degree of supersaturation of the solution, or decrease in rate of crystal growth due to cooling.