

Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen =
Bulletin suisse de minéralogie et pétrographie

Band: 12 (1932)

Heft: 1

Artikel: The Micro-texture and Paragenesis of Stromeyerite

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DOI: <https://doi.org/10.5169/seals-13326>

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The Micro-texture and Paragenesis of Stromeyerite

by *F. N. Guild* in Tucson, Arizona.

OUTLINE

The object of this paper is to summarize much of the work done in the writer's laboratories on the paragenesis of stromeyerite, and by means of tracings of photomicrographs to illustrate the most important textures that have been observed. In this connection the features of most interest perhaps are: The micro-texture of stromeyerite itself when pure or as formerly supposed when mixed with a slight excess of chalcocite; the derivation of stromeyerite from other minerals as argentiferous fahlerz by a breakdown of the complex fahlerz molecule, perhaps without the addition of new material; the building up of stromeyerite from such copper minerals as chalcocite or bornite by the introduction of some silver molecule; the breakdown of stromeyerite into chalcocite and native silver; and the intergrowths of stromeyerite with many of the associated minerals.

STROMEYERITE

Stromeyerite has not been mentioned very frequently in mineralogical literature, and when considered its paragenetic features and textural relations have not often been described in detail. When associated with argentite or chalcocite it is not easy to distinguish from those minerals in hand specimens, and even when pure it may be mistaken for chalcocite. Yet in the investigation of silver ores during the study of polished surfaces, stromeyerite is found to be of rather more frequent occurrence than was formerly suspected in megascopic examinations. It does not occur in large quantities but might be found in isolated areas in most any vein deposit of silver, lead or copper. In the latter case, that of copper deposits, it has been observed in very isolated fragments, in deposits not considered at all rich in silver. Its typical modes of occurrence have been summarized in the outline above and will be described in more detail in the present paper. In addition it has been found replacing quartz gangue, or else replacing ore minerals which in their turn have

replaced quartz gangue, where it apparently shows little relation, unless a large suite of specimens be investigated, to other sulphides.

According to HINTZE¹⁾ the first occurrence of this mineral to attract attention was that of Schlangenberg, Altai. This was first described by RENOVANTZ under the name of Silberglanz, later by HAUSMANN as Silberkupferglanz, while investigators from other localities used the terms "Argent et cuivre sulfuré", "argentiferous copper glance", and other similar names. It was analysed by STROMEYER in 1816 who obtained results very close to the theoretical composition. In 1832 it was given the name of stromeyerite by BEUDANT in honor of STROMEYER. Rhombic crystals were described by ROSE in 1833 in material from Silesia who considered it isomorphous with copper glance.

Stromeyerite has been described²⁾ as having either a smooth or ragged surface in polished sections. This observation probably has greater significance than the author at the time suspected. In 1917 the present writer³⁾ also observed the complicated surface in some specimens and attributed it to an excess of the chalcocite molecule which is harder than stromeyerite. It was found then that the irregular "ragged" surfaces sometimes presented the appearance of a definite and rather pleasing design resembling a mass of oleander leaves. (Fig. 1.) So far as the writer knows this texture has been observed only in one or perhaps two other cases. In 1931, RAMDOHR⁴⁾ described it in material from Guanacevi, Mexico, and made the startling discovery that it was found only in those samples that had been heated with sealing-wax in the process of preparation. All other samples gave on etching no evidence of the oleander-leaf texture. He further remarks that under oil immersion, and by use of the arc light, the transformation into the oleander-leaf texture could be easily observed; so that this structure seems to be developed by the action of the arc light as well as by heating with sealing-wax. This is thought to be a true transformation from the ordinary or rhombic phase of stromeyerite to some other phase not yet determined, similar, in fact, to the well known transformation of rhombic chalcocite

¹⁾ HINTZE, Handbuch der Mineralogie, I, p. 539.

²⁾ MURDOCH, Microscopical determination of the opaque minerals, p. 117, 1916.

³⁾ GUILD, A microscopic study of the silver ores and their associated minerals. Econ. Geol., Vol. XII, p. 310, 1917.

⁴⁾ SCHNEIDERHÖHN-RAMDOHR, Lehrbuch der Erzmikroskopie, II, p. 304, 1931.

to an isometric form at 91°. To quote further: — “Bei der Eigenart der Vorkommen — in vielen Fällen sind es lockere Zementationserze — wird man häufig die Präparate kochen müssen und so nur die GUILD'sche Form zu Gesicht bekommen, . . .” The present writer can state positively that the specimens he worked with in 1917 were heated (with Canada balsam) before the polished surfaces were inspected. This was not mentioned in the original paper as its significance was not appreciated at that time. This fact as well as further tests made on material from the same locality, Silver King, Arizona, in which unheated samples do not show the complicated structure and heated samples do, confirm the results of RAMDOHR's work. The oleander-leaf texture of some stromeyerite, therefore, seems to be due to the development of a higher temperature phase formed in heating the specimen in the process of preparation, and not (ordinarily at least) to an admixture of chalcocite as held originally by the present writer. Further results from Dr. RAMDOHR's laboratory as to more exact temperature determinations of the transformation point, will be awaited with interest.

The use of polarized light has rendered the investigation of this particular texture much more satisfactory than the former procedure of etching. Several specimens which under polarized light showed a granular texture of rather uniform, equidimensional particles, after two hours heating at a temperature near 100°, developed the oleander-leaf texture in a manner much more beautiful than we have ever obtained by etching. Both before and after heating the surface of the specimens was reasonably smooth and showed no appreciable design when ordinary light was employed.

In November 1931 somewhat later than RAMDOHR's work mentioned above, STEPHENS⁵⁾ showed that “Stromeyerite etched rapidly when exposed to the full beam of the arc light”. He further adds that “The etching, shown in fig. 4, resembles a wrinkled skum, but on close examination it showed a pattern suggestive of the intergrowth obtained by GUILD by etching stromeyerite with KCN”. (See Fig. 1, of the present article.) To quote still further: “A single large grain uniform under polarized light was observed after exposure to the light beam and found to have developed a fine granular, bladed, or interlocking structure”. In this particular case STEPHENS results seem to agree with those of SCHNEIDERHÖHN-RAMDOHR in that the inter-

⁵⁾ STEPHENS, Effect of light on polished surfaces of silver minerals. *Am. Mineral.*, vol. 16, p. 543, 1931.

growth-like etching is due to the action of the heat rays of the arc. Further etching by which a spotted effect is obtained is held to be due to light rays. The black dots are thought to be argentite and the mineral thus breaks down, or at least a part of it, to form argentite and chalcocite.

Stromeyerite in contact with chalcocite has a rather definite lavender grey shade and when polished for great relief is appreciably softer. These features together with its strong anisotropism are the most useful tests for the identification of the mineral. Its change of structure on heating should now be added to its characteristic tests. Chalcocite is somewhat sectile, though less so than stromeyerite, so that when associated with silver it has been mistaken for stromeyerite. Several specimens have been examined as stromeyerite that have proved from a microscopic study to be simply chalcocite frequently with native silver so finely divided as not to be seen with the naked eye. There is a tendency to consider those samples of chalcocite which for any reason respond to a test for silver as being stromeyerite.

STROMEYERITE AND CHALCOCITE

It has been shown above that the complicated oleander leaf texture brought out by etching the polished surfaces of stromeyerite or by heating, is due to some transformation or recrystallization induced by heat, and not necessarily to an admixture of chalcocite as first described by the writer in 1917. Nevertheless stromeyerite areas do pass into chalcocite areas and specimens have been observed in which the complicated texture appears on the borders of stromeyerite and the individual blades in the oleander-leaf texture project definitely into chalcocite areas. (Figs 3, 4 and 5.) This observation was what led the writer to advance his theory as to the cause of the texture.

The relations appearing in Figs 3, 4 and 5, would indicate a replacement; either chalcocite replaces stromeyerite or the reverse is true. It was formerly thought that stromeyerite was mainly an "enrichment" product of chalcocite in which case the silver mineral was held to be replacing chalcocite. It is true that stromeyerite, when accompanied with copper minerals as at Silver King, Arizona, appears in a long series of replacements in which it plays the same rôle as chalcocite, but in these cases it seems to replace bornite instead of chalcocite. This is illustrated in Fig. 12 where we have the series: chalcopyrite-bornite-stromeyerite-silver. Pyrite might be added to the

series as it is shown earlier than chalcopyrite in the specimen though not appearing in the drawing. It is now believed that the more characteristic reaction is that of stromeyerite to chalcocite so that the series mentioned above may be prolonged as follows: (pyrite)-chalcopyrite-bornite-stromeyerite-chalcocite-native silver. In support of this possibility we have the following arguments:

(1st) It has been repeatedly observed that when stromeyerite passes into chalcocite areas, there is a deposition in the latter mineral or around adjacent gangue or ore minerals, native silver as spots, wandering veinlets, as a sort of filligree work or as borders as illustrated in Figs 2 and 6. Here, then, it would seem that the stromeyerite has broken down into chalcocite and native silver, the excess of sulphur involved in this reaction escaping in some manner not indicated by microscopic work.

(2nd) The chalcocite as illustrated in Figs 3, 4 and 5 seems to show the orthorhombic cleavage by etching with KCN, thus indicating, as is held by many investigators, that it is the lower temperature phase of the chalcocite molecule and thus probably supergene and therefore later than stromeyerite. Moreover stromeyerite does not seem to be deposited under conditions that give rise to native silver and so might be considered as a deeper seated mineral perhaps hypogene.

(3d) In much of the material from the Silver King mine in Arizona, the stromeyerite appears in what might be interpreted as "residual grains" (Fig. 4) appearing in chalcocite areas with a reaction border between the two minerals sometimes showing the olean-der-leaf texture of Fig. 1. Thus it might be inferred that stromeyerite was first to form, perhaps as a hypogene mineral, later breaking down to chalcocite and other products, but leaving here and there uneffected patches. We must admit, however, that chalcocite areas that might be interpreted as "residual grains" are also found in stromeyerite areas, but we do believe that this texture is not so characteristic as the one just described.

STROMEYERITE AND SILVER

As indicated above stromeyerite is often associated with native silver. As an incipient breakdown of the double molecule, it may appear as microscopic spots evenly disseminated throughout the stromeyerite area or segregated into an intricate filligree pattern as illustrated in Fig. 2. In this case, however, the closely associated sul-

phide is chalcocite and not stromeyerite, as if the stromeyerite had broken down entirely into the simpler minerals. The silver may be segregated around quartz grains as illustrated in Fig. 6, form the cementing material in brecciated gangue minerals, or carried some distances into more definite veinlets. The ease with which silver salts break down into free silver is well known, so that we should expect to find native silver under a great variety of geologic conditions. STEPHENS ⁶⁾ suggests that free silver is ultimately formed in the light-etching of stromeyerite.

STROMEYERITE AND FAHLERZ (TETRAHEDRITE-TENNANTITE)

In Fig. 7 is shown stromeyerite exhibiting in relation to fahlerz the most typical replacement texture, namely, the crossing of one mineral by another in the form of definite veinlets. This seems to be a characteristic texture in the Silver King mine, Arizona. When this replacement is carried further residual grains of fahlerz are left behind in the stromeyerite areas as illustrated in Figs 3 and 4. The fahlerz here is in isolated grains and perhaps does not show the relationship as satisfactorily as in Fig. 8, where the "residual grains" are so abundant as to give a remote resemblance to the so-called graphic intergrowths. A really typical example of the pseudo-eutectic texture between stromeyerite and tennantite has recently been described by LINDGREN ⁷⁾ in material from Colquijira, Peru. A reproduction of this as a tracing of LINDGREN's half-tone is shown in Fig. 9. This is believed to be a replacement of tennantite by stromeyerite, the evidence being that the stromeyerite has convex surfaces with reference to tennantite and is therefore later. This texture is also associated with vein-like projections which is further confirmation of his views. All of the elements that make stromeyerite are present in argentiferous fahlerz so the explanation that it has been derived from the latter seems to be simple enough.

STROMEYERITE AND BORNITE

Stromeyerite may be found replacing bornite very much in the same manner that chalcocite does, i. e., as borders on isolated grains, as considerable areas constituting the groundmass or background of residual grains that have been more completely replaced, and as wandering veinlets following fractures or cleavage. These are all

⁶⁾ STEPHENS, M. M., op. cit., p. 544.

⁷⁾ LINDGREN, Pseudo-eutectic Textures. Econ. Geol., Vol. XXV, p. 1, 1930.

typical replacement structures. A veinlet of stromeyerite crossing both bornite and chalcopyrite is shown in Fig. 12, associated also with native silver. Pyrite, not shown in the tracing, was also present in the section and was replaced by the copper minerals thus showing the resemblance between stromeyerite and chalcocite.

In Fig. 10 is shown a rather crude graphic relation between bornite and stromeyerite. This texture is so intimately associated with others described above that it is held to be a replacement in which the stromeyerite is later than the bornite. The texture as illustrated in Fig. 11 (in this case stromeyerite and fahlerz) is, perhaps, such as might be produced by a continuation of the replacement shown in Fig. 10. Yet this is but a portion of the typical vein structure of Fig. 7. A section perpendicular to the surface shown in Fig. 11 might well show a texture like that of Fig. 10, in which the "spots" are but cross sections of channels elongated in the plane of section 11. In sections of this sort, diligent search, will nearly always bring out areas where the arrangement is more or less accidentally developed into a so-called graphic design.

STROMEYERITE AND CHALCOPYRITE

A definite relationship between these two minerals has been observed only in two cases. One is that mentioned above where a clear-cut veinlet crosses chalcopyrite as well as bornite and pyrite (Fig. 12). The other example was found in a specimen from Mt. Lyall, Tasmania. Here a veinlet of stromeyerite (Fig. 13) passes through chalcopyrite leaving, or at least, very nearly leaving, a residual patch of stromeyerite-chalcopyrite showing pseudo-eutectic texture. In Fig. 14, a complete detached grain showing this feature is illustrated. The magnification of Fig. 13 is rather too high to bring out the vein character of the stromeyerite, but this was necessitated in order to reveal the pseudo-eutectic design.

STROMEYERITE AND GALENA

This relationship has been observed by the writer in only one locality, that of the copper-silver minerals of the Silver King mine in Arizona. Frequently sections are found showing the pseudo-eutectic texture as illustrated in Fig. 15. This texture, perhaps, more closely resembles the true eutectic of many of the metallic alloys. A remarkable feature observed with reference to this texture is the habit of some areas to present euhedral boundaries as though the original surface was a section of an individual crystal that later

separated showing a structure as illustrated in Fig. 15. This seems to support the theory that such structures are the result of exsolution or segregation in the solid state. Chalcocite and galena show textures identical with that appearing in Fig. 15, and, in fact, it is often difficult to tell whether the mineral be stromeyerite or chalcocite on account of the fineness of the texture. Furthermore, considerable difficulty was experienced in identifying the galena in this intricate design. This was finally accomplished after long search by observing the characters of the white mineral when certain of those portions enlarged to areas of considerable size. This, also, is illustrated in Fig 15 where the triangular pits characteristic of galena can easily be seen.

STROMEYERITE AND ARGENTITE

A pseudo-eutectic texture identical to that appearing in Fig. 15, has also been observed at Silver King, Arizona, the minerals in the "intergrowth" being stromeyerite and argentite instead of galena. This seems to occur where the stromeyerite molecule (Ag_2S , Cu_2S) is associated with an excess of argentite or Ag_2S . This texture has also been described by SCHWARTZ and PARK⁸⁾ in material from Mt. Sopris, Colorado.

It seems to be suggested here, however, that the stromeyerite has replaced the galena in an original galena-argentite intergrowth.

Stromeyerite is now quite definitely considered as the double salt of copper and silver sulphides or $\text{Cu}_2\text{S}.\text{Ag}_2\text{S}$. The microscope would seem to show that the solubility of chalcocite or argentite in this molecule is not considerable and some of the earlier statements regarding the isomorphism of these molecules are probably incorrect. According to KALB and BENDIG⁹⁾ there are, in the system Ag-Cu-S, two compounds corresponding to the minerals stromeyerite ($\text{Ag}_2\text{S}.\text{Cu}_2\text{S}$) and Jalpaite ($3\text{Ag}_2\text{S}.\text{Cu}_2\text{S}$). It would be interesting to know how often results of this nature obtained from laboratory conditions correspond to the natural history of the molecules concerned. We are inclined to believe, however, that the correspondence is much closer than one might think when we consider the divergence of the conditions as to temperature, pressure and presence of water.

⁸⁾ SCHWARTZ and PARK, Pseudo-eutectic textures. *Econ. Geol.*, vol. XXV, p. 658, 1930.

⁹⁾ Quoted in W. EITEL, *Physikalisch-chemische Mineralogie und Petrologie*. Dresden and Leipzig, p. 95, 1925.

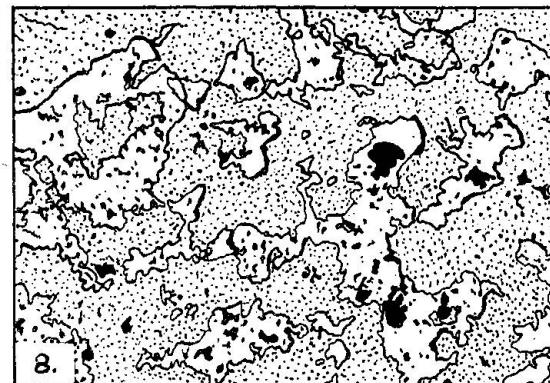
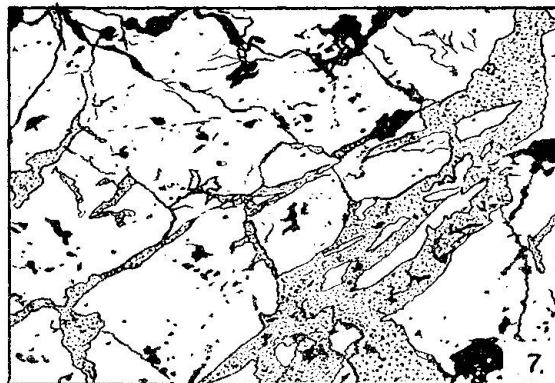
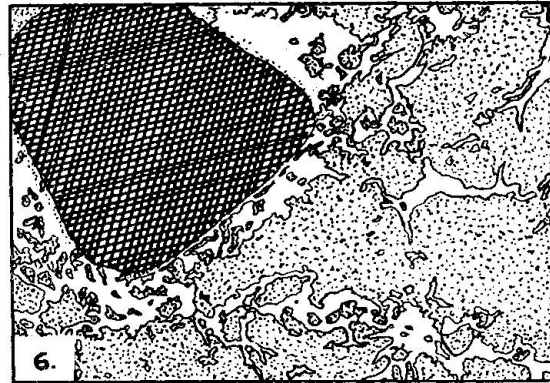
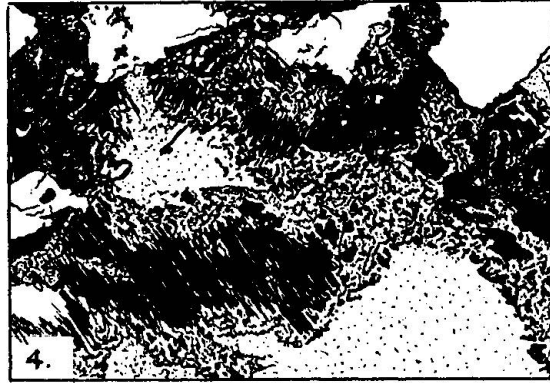
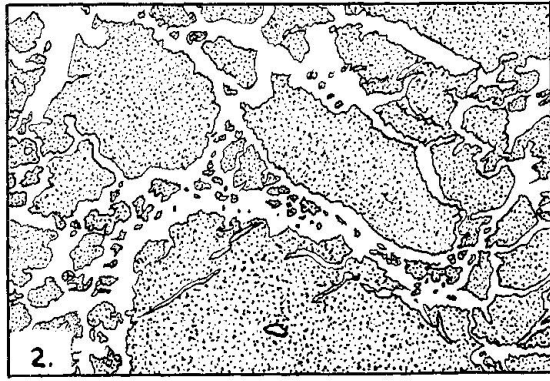
All of the illustrations accompanying this paper are tracings of photomicrographs. The photographs, with the exception of Fig. 9, were taken by means of a Leitz inverted metallographic microscope on Eastman panchromatic plates using the Wratten "M" ray filters.

University of Arizona. Tucson, Arizona. Feb. 1st, 1932.

Received: February 14th 1932.

DESCRIPTION OF ILLUSTRATIONS

- Fig. 1. Stromeayerite from Silver King, Arizona, showing complicated texture formerly thought to be due to an intergrowth with chalcocite. Now held to be caused by a readjustment of crystalline structure due to the heating in the process of preparation. Etched with KCN solution. The same texture may be brought out by polarized light. $\times 130$.
- Fig. 2. Chalcocite (dotted) and native silver (white) from Silver King, Arizona. This texture frequently results from a breakdown of stromeayerite ($\text{Ag}_2\text{S} \cdot \text{Cu}_2\text{S}$). $\times 295$.
- Fig. 3. Stromeayerite (dotted), fahlerz (white) and chalcocite (black), from Silver King, Arizona. Etched with KCN solution. A smooth area of stromeayerite with complicated texture grading of towards chalcocite. Stromeayerite is held to be breaking down to chalcocite. The silver necessarily formed in the reaction does not appear in the illustration. About $\times 200$.
- Fig. 4. Stromeayerite (dotted), fahlerz (white) and chalcocite (black) from Silver King, Arizona, showing the residual nature of one of the stromeayerite areas replaced by chalcocite. The borders show the complicated texture of stromeayerite. Etched with KCN solution. About $\times 100$.
- Fig. 5. Another tracing of stromeayerite from Silver King, Arizona, showing its probable alteration to chalcocite with borders of the complicated texture. Etched with KCN. $\times 384$.
- Fig. 6. Chalcocite (dotted), native silver (white) and quartz (dark) from Silver King, Arizona. This specimen shows the breakdown products of stromeayerite with a segregation of the resulting silver around quartz grains and throughout the chalcocite areas. $\times 295$.
- Fig. 7. Stromeayerite (dotted) replacing fahlerz (white) in veinlets. Silver King, Arizona. $\times 76$.
- Fig. 8. Stromeayerite (dotted) showing a further replacement of fahlerz (white). The vein structure has disappeared leaving many residual grains of fahlerz. Silver King, Arizona. $\times 76$.



- Fig. 9. Stromeyerite (dotted) replacing tennantite (white) from Colquijirca, Peru. Here is shown these two minerals in pseudo-eutectic texture. $\times 446$. After LINDGREN, *Econ. Geol.*, vol. XXV, p. 4, Fig. 4, 1930.
- Fig. 10. Stromeyerite (dotted) and bornite (white) in what might possibly be termed a crude graphic arrangement. The stromeyerite is believed to be replacing bornite. Silver King, Arizona. $\times 80$.
- Fig. 11. Stromeyerite (dotted) replacing fahlerz (white), Silver King, Arizona. This is introduced here to show how another section cut from right to left perpendicular to the surface might reveal quite a different texture, perhaps one like Fig. 10. About $\times 150$.
- Fig. 12. Stromeyerite (dotted) crossing chalcopyrite (broken lines) and bornite (lined), from Silver King, Arizona. Silver (white) is probably still later. $\times 297$.
- Fig. 13. Stromeyerite (dotted) replacing chalcopyrite (white) leaving, or nearly leaving, an isolated area showing pseudo-eutectic texture. Mt. Lyell, Tasmania. $\times 356$.
- Fig. 14. Stromeyerite (dotted) and chalcopyrite (white). This shows another portion of the section illustrated in Fig. 13. Here the "residual" area showing the pseudo-eutectic texture is isolated in the stromeyerite, while in Fig. 13 it appears as a part of the stromeyerite vein. Silver King, Arizona. $\times 356$.
- Fig. 15. Stromeyerite (dotted) and galena (white) in pseudo-eutectic design. This shows how the galena areas may enlarge sufficiently to show the characteristic triangular pits. The galena was finally identified in this manner. Silver King, Arizona. $\times 804$.
- Fig. 16. The Same as Fig. 15 but showing coarser texture. Silver King, Arizona. $\times 804$.

