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MYRMEKITIC TEXTURES OF GALENA IN BORNITE FROM THE COPPER DEPOSITS IN LOWER SILESIA

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A b s t r a c t. Myrmekitic textures of galena in bornite have been ascertained. The investigations performed suggest that they originated at low temperatures, with the two minerals crystallizing simultaneously and intergrowing in the course of that process. The textures in question owe their origin to the evolution of mineralizing solutions from copper- and iron-bearing to lead-bearing. When the content of Cu and Fe decreased and that of Pb simultaneously increased, submicroscopic inclusions of galena in bornite were formed. The formation of myrmekitic intergrowth bornite + + galena followed. Coarse grains of galena crystallized when the Pb content was rapidly increasing.

In ore veins of the copper deposits in the Fore-Sudetic Monocline, myrmekitic textures of galena in bornite have been encountered. Similar, though not identical, myrmekitic textures have been reported in literature; they are bornite in galena, chalcopyrite in galena, clausthalite in chalcocite, galena in chalcocite (Ramdohr 1969).

M i c r o s c o p i c e x a m i n a t i o n s. The bornite under study is untypical. It resembles in colour orange bornite, whereas its chemical composition is similar to that of bornite from Chile (Sillitoe, Clark 1969). It contains 2.2% more Fe, 1.5% more S and 4.5% less Cu than theoretical bornite. Moreover, electron microprobe analyses have revealed the presence of 0.16% Pb. The bornite in question occurs in paragenesis with chalcocite, chalcopyrite, uncommonly with digenite. Myrmekitic textures always appear in bornite at a certain distance from Cu_5FeS_4 intergrowths with other copper minerals. Larger galena grains present in bornite are usually surrounded with a myrmekitic "halo" (Kucha, Salamon 1972).

E l e c t r o n m i c r o p r o b e i n v e s t i g a t i o n s. The investigations were carried out in microarea shown on Photograph 1*a*. The results of qualitative and semi-quantitative analyses are presented, respectively, on Photographs 1*b*—1*f* and in Figure 1. The content of Cu and Fe in

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bornite is variable. Greater variations in the concentration of these elements may be correlated with myrmekitic forms of galena visible under the microscope whereas smaller changes are related to submicroscopic secretions of the type discussed. Microprobe traces for Pb (Fig. 1), Cu and Fe across bornite point to the presence of submicroscopic myrmekitic textures of galena. The Pb content in bornite at a distance of 0.6 mm from the myrmekitic zone is 0.16 wt. %.

In the course of quantitative analyses, several, admixtures have been recorded both in galena and bornite (Tab. 1). These admixtures are essential for explanation of the genesis of myrmekitic textures bornite + galena.

X-ray investigations. Considering the substantial amount of admixtures in galena as well as the decreased Pb content (Tab. 1) compared with the stoichiometric composition of PbS (86.6% Pb, 13.4% S), this mineral was subjected to X-ray examinations. X-ray powder patterns were taken using Fe-filtered CoK$_{\alpha}$ radiation. Interplanar spacings of the investigated mineral correspond to the standard data for galena. A slight difference has been

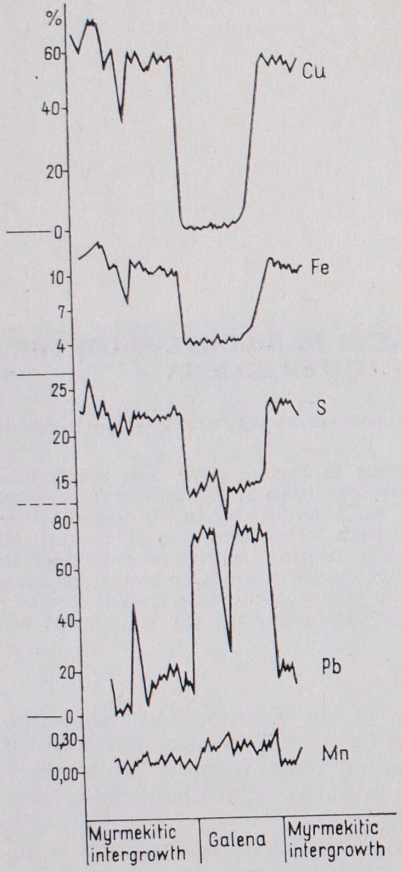

Fig. 1. Change of Cu, Fe, S, Pb and Mn content along the line crossing the galena grain and myrmekit galena in bornite. The investigations were carried out along the I—II line shown in the Photograph 1a

Table 1

Chemical composition of galena and bornite (weight %)

Galena		Bornite	
Pb	84,57	Cu	58,81
S	14,40	S	27,04
As	0,40	Fe	13,45
Cu	1,11	Pb	0,16
Fe	0,31	Mn	0,04
Mn	0,29	As	0,00
Total	101,08	Total	99,50

noted in the dimensions of the unit cell $a_0 = 5.946 \pm 0.005$ Å when compared with the data of Micheev (1957): $a_0 = 5.924 \pm 0.003$ Å.

As appears from the X-ray examinations, the investigated mineral is galena, despite some anomalies in the chemical composition. The recorded high Cu content is presumably due to the occurrence of submicroscopic myrmekitic textures galena + bornite.

The origin of myrmekitic textures. The Mn content in galena is about 7 times higher than in bornite (Tab. 1). Moreover, certain amounts of Cu and Fe are present in PbS. It is relatively easy to account for these facts assuming that manganese occurs in galena in the form of an isomorphic admixture of MnS. It is evident from the thermodynamic data (Garrels, Christ 1965) that the stability field of MnS is very small (Fig. 2). The presence of Mn in PbS suggests that MnS and PbS crystallized in the stability field of alabandite. The stability field of MnS also comprises partly that of Cu_5FeS_4. The ratio of the part of the stability field of PbS comprised in the stability field of MnS to the analogously limited stability field of Cu_5FeS_4 is about 7 : 1 (Fig. 2). There is here then an important consistency between the theoretical data (Garrels, Christ 1965) and the natural processes.

It appears from the above considerations that the process of formation of myrmekitic intergrowth bornite + galena occurred presumably close to the point with the following parameters: pH = 8.5, Eh = −0.4.

Studies of the parageneses, textures and structures of sulphide minerals making up ore veins in the copper deposits in Lower Silesia indicate that they originated at a temperature not higher than 100°C. This fact, as well as the character of the admixtures in galena and bornite suggest that myrmekitic textures bornite + galena formed, according to Ramdohr's classification (1969), by "simultaneous formation of the intergrowth of the components in an independent process".

The large galena grain (Phot. 1) seems to be somewhat later than the myrmekitic textures bornite + galena.

Microscopic examinations have shown that the minerals in the discussed paragenesis crystallized in the following order: chalcopyrite, bornite, myrmekite (bornite + galena) and galena. The textures under study owe their origin to the evolution of mineralizing solutions from Fe-Cu--bearing, with the Fe and Cu content decreasing, to Pb-bearing. In the initial stage bornite and a small amount of chalcopyrite formed; then bornite appeard. An increase in the

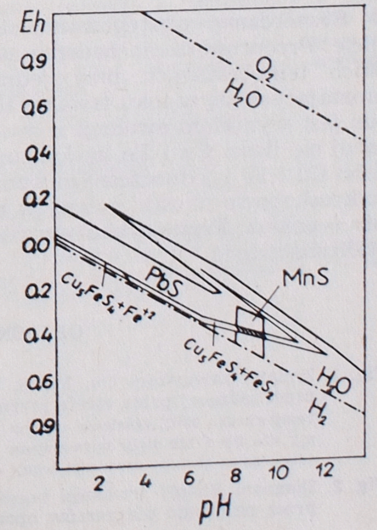

Fig. 2. Eh-pH diagram of the stability of bornite, galena and alabandite in water constructed by overlapping of diagrams for Cu, Pb, Mn

Temperature 25°C, total pressure 1 atm, total dissolved sulphure $\Sigma S = 10^{-4}$. For Pb and Mn $P_{CO_2} = 10^{-4}$ were taken. Doted line-stability field of H_2O (after Garrels, Christ 1965)

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Pb content in the solution manifested itself presumably in submicroscopic myrmekitic textures of galena in bornite. A period of Pb domination in the solution followed. Crystallization of galena was proceded by a gradually enlarging halo of myrmekitic textures bornite + galena. The last to form was galena with an increased Cu content (Tab. 1).

Since similar textures have not been mentioned yet in literature, it may be inferred that this is the first report of myrmekitic textures bornite + galena.

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STRUKTURY MYRMEKITOWE GALENY W BORNICIE ZE ZŁÓŻ MIEDZI NA DOLNYM ŚLĄSKU

Streszczenie

Stwierdzono występowanie struktur myrmekitowych galeny w bornicie. Przeprowadzone badania sugerują, że struktury te powstały w niskich temperaturach przy jednoczesnej krystalizacji obu minerałów, zrastających się w toku trwania tego procesu. Powstanie opisanych struktur jest wynikiem ewolucji roztworów mineralizujących, przy zmniejszającej się ilości Cu i Fe, w kierunku ołowionośnych. Przy spadku zawartości Cu i Fe i jednoczesnym wzroście koncentracji Pb pojawiały się submikroskopowe wrostki galeny w bornicie. Później powstał myrmekit bornit + galena. Przy szybko wzrastającej ilości Pb tworzyła się grubokrystaliczna galena.

OBJAŚNIENIA FIGUR

Fig. 1. Zmiana zawartości Cu, Fe, S, Pb i Mn wzdłuż linii I—II na fotografii 1*a* przechodzącej przez strefę myrmekitową bornit + galena oraz galenę
Temperatura 25°C, ciśnienie ogólne 1 atm, suma rozpuszczonej siarki $\Sigma S = 10^{-4}$. Diagramy dla Pb i Mn były opracowane przy uwzględnieniu $P_{CO_2} = 10^{-4}$. Linią przerywaną zaznaczono granice trwałości wody (według Garrelsa i Christa 1965)

Fig. 2. Diagram Eh-pH trwałości bornitu, galeny i alabandynu w wodzie uzyskany przez nałożenie diagramów opracowanych oddzielnie dla Cu, Pb, Mn

OBJAŚNIENIE FOTOGRAFII

Fot. 1. Struktury myrmekitowe galeny w bornicie
a) obraz elektronowy absorpcyjny; odcinek I—II oznacza profil, wzdłuż którego dokonano badań koncentracji pierwiastków (por. fig. 1); cyfrą 2 oznaczono punkt analizy ilościowej, *b*) rozmieszczenie Pb, *c*) rozmieszczenie S, *d*) rozmieszczenie As, *e*) rozmieszczenie Fe, *f*) rozmieszczenie Cu. Wielkość 100 × 100 μm.

Хенрик КУХА, Витольд САЛЯМОН

МИРМЕКИТОВЫЕ СТРУКТУРЫ ГАЛЕНИТА В БОРНИТЕ НА МЕДНОМ МЕСТОРОЖДЕНИИ В НИЖНЕЙ СИЛЕЗИИ

Резюме

Наблюдались мирмекитовые структуры галенита в борните. Проведенные исследования показывают, что эти структуры образовались при низких температурах путем одновременной кристаллизации обоих минералов и их срастания во время этого процесса. Возникание описанных структур было обусловлено изменениями состава рудообразующих растворов, в которых уменьшалось содержание меди и железа с повышением количества свинца. В таких условиях возникали субмикроскопические вростки галенита в борните. Позже образовался мирмекит борнит + галенит. При ускоренном возрастании содержания свинца возникал крупнокристаллический галенит.

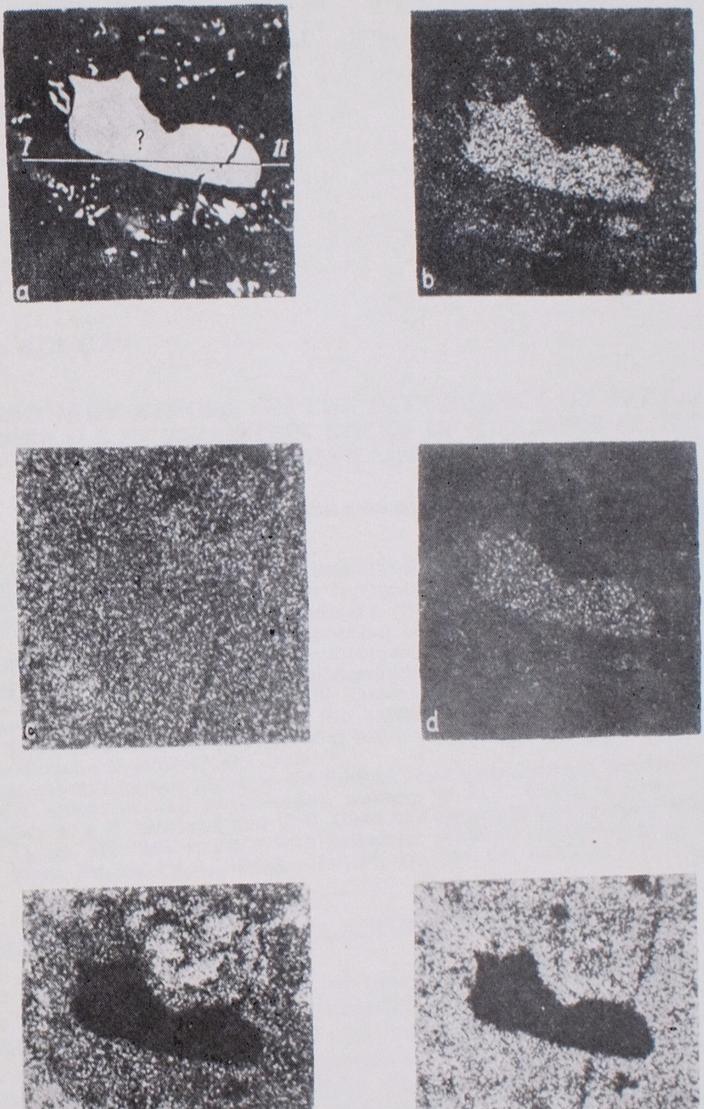
ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Изменение содержания Cu, Fe, S, Pb и Mn по линии I—II на фото 1*a*, проходящей через мирмекитовую зону борнит + галенит и галенит

Фиг. 2. Диаграмма Eh-pH устойчивости борнита, галенита и алабандинта в воде, полученная путем наложения диаграмм, составленных отдельно для Cu, Pb, Mn
Температура 25°C, общее давление 1 атм, сумма растворенной серы $\Sigma S = 10^{-4}$. Диаграммы для Pb и Mn были составлены при условии $P_{CO_2} = 10^{-4}$. Штриховой линией оконтурена область устойчивости воды (по Гаррелсу и Кристу 1965)

ОБЪЯСНЕНИЯ К ФОТОСНИМКАМ

Фото 1. Мирмекитовые структуры галенита в борните
a — образ электронного поглощения; участок I—II показывает профиль, по которому определялась концентрация элементов (см. Фиг. 1); цифрой 2 отмечена точка количественного анализа, *b* — распределение Pb, *c* — распределение S, *d* — распределение As, *e* — распределение Fe, *f* — распределение Cu; величина 100 × 100 μм



Phot. 1. Myrmekitic textures of galena in bornite

a) absorbed electron image; scan along the I—II line — see Figure 1, quantitative analysis were made in point 2, *b*) distribution of Pb, *c*) distribution of S, *d*) distribution of As, *e*) distribution of Fe, *f*) distribution of Cu. Microarea 100 × 100 μm

Henryk KUCHA, Witold SALAMON — Myrmekitic textures of galena in bornite from the copper deposits in Lower Silesia