

SBORNÍK NÁRODNÍHO MUZEA V PRAZE

ACTA MUSEI NATIONALIS PRAGAE

Volumen XXVII B (1971), No. 5

REDAKTOR JIŘÍ KOUŘIMSKÝ

FRANTIŠEK NOVAK

FERROAN ALABANDITE FROM HYDROTHERMAL VEINS

AT CHVALETICE, EASTERN BOHEMIA

Abstract

Prvý makroskopický výskyt železnatého alabandinu je popsán z 2. patra východní části pyritového a manganového dolu Chvaletice, východní Čechy, ČSSR. Vyskytuje se jako vzácný minerál na hydrotermálních žilách, které pronikají algonkickým metamorfovaným horizontem manganových rud. Je provázen manganatým cummingtonitem, křemenem, pyrhotinem, sfaleritem, pyritem, neotokitem a rodochrozitem. Tvoří agregáty dosahující v průměru až 6 cm. Na čerstvém lomu je ocelově šedočerný. Lesk má kovový, vryp šedočerný až černý. Štěpnost je dokonalá podle (100). Hustota $h = 4,101$, $h_{vyz.} = 4,120$, $a_o = 5,1985 \text{ \AA}$. Je středně magnetický. V odraženém světle je šedobílý, izotropní s nápadnou štěpností připomínající galenit. Mikrotvrdość = 218 kg/mm^2 . Leptací zkoušky pozitivní s HNO_3 , HCl , H_2O_2 , negativní s KOH , FeCl_3 , KCN a HgCl_2 . Velmi snadno se rozkládá v HCl . Chemické analýze (51,87 % Mn, 10,86 % Fe, 36,89 % S, 0,18 % nerozp. zbytek, 99,80 % celkem) odpovídá krystalochemický vzorec $(\text{Mn}_{0,82}\text{Fe}_{0,17})_{0,99}\text{S}_{1,00}$. Elektronová mikrosonda udala 52,1 % Mn, 10,4 % Fe a 33,8 % S. Jsou uvedeny a diskutovány křivky GTA a DTA.

Introduction

The first occurrence of natural ferroan alabandite of macroscopic size was found in the pyrite-manganese ore deposit at Chvaletice-East, Bohemia. Until then, it occurred only in microscopic quantities, mostly insufficient to enable complex mineralogical research.

Iron-rich alabandite was first described from Bühl near Kassel, Germany (P. RAMDOHR, 1952). It occurs here as a rare accessory mineral in basalt, in association with native iron. Later, P. RAMDOHR (1957)

described yet another natural occurrence of this mineral, i. e. from Fohlberg near Oberschaffhausen (Germany), where it formed rare inclusions in pyrrhotite in phonolite. Ramdohr described this iron-rich alabandite as ferroalabandite („Eisenalabandin“), calling it a remarkable, natural, high-temperature mixed crystal (Mn,Fe)S.

Lately, the application of electron microprobe has made it possible to identify minor inclusions of iron-rich alabandite also in some meteorites (K. DAWSON and I. A. MAXWELL, 1960; K. KEIL and K. FREDERIKSSON, 1963; K. KEIL and CH. A. ANDERSEN, 1965).

In the area of the Železné hory Mts. pyrite-manganese deposits, Eastern Bohemia, black alabandite, was found to occur in the locality of Litošice (8 km south-east of Chvaletice), as described by L. ŽÁK and J. NOVOTNÝ (1954). It was in several ore samples in the form of finely grained aggregates (maximum size 5 mm), in association with graphite, pyrite, pyrrhotite, chalcopyrite, rhodonite, quartz and carbonate. This black alabandite from Litošice is probably identical with the ferroan alabandite from Chvaletice, which is the subject of this study. Later, L. ŽÁK (1956) described yet another Litošice alabandite of a younger generation, a nicely coloured grassy green variety, occurring in rhodochrosite veins together with opal, neotokite, chalcedony, pyrite, ankerite and quartz. Specimen of Chvaletice ferroan alabandite is deposited in the collection of the Department of Mineralogy, National Museum, Prague.

Occurrence and paragenesis

The ferroan alabandite was found on the 2nd level of the pyrite and manganese quarry Chvaletice-East. It occurs here in irregular, in places lenticular, hydrothermal veins which penetrate the metamorphic parts of the Algonkian manganese horizon. This, originally carbonate manganese horizon, has been metamorphed in these parts to silicate hornfels.

Ferroan alabandite samples also contain manganoan cummingtonite, pyrrhotite, sphalerite, quartz, neotokite and rhodochrosite. Ferroan alabandite, pyrite and quartz predominate over the distinctly subordinate neotokite and rhodochrosite. The occurrence of other minerals can be described as rare-to-accessory.

The ferroan alabandite forms medium-to-coarse grained irregular aggregates of up to 6 cm in diameter. It is liable to quick weathering on its surface and becomes coated by brownish-black to greyish-black earthy film.

The pyrite forms fine-to-medium grained aggregates and is closely associated with ferroan alabandite. It also forms fine veinlets and irregular network in the ferroan alabandite accumulations.

The pyrrhotite and sphalerite occur only as accessories forming inclusions in the ferroan alabandite.

The quartz, which forms hypidiomorphic crystals of up to 2 cm size, is greyish-white, in places coloured reddish-brown by fine coatings of neotokite.

The manganocummingtonite is comparatively rare and probably belongs to the oldest minerals. It forms fine, fibrous, by pressure contorted, aggregates of greyish-white colour. Its identity was confirmed by X-ray analysis.

The neotokite is black to brownish-black with a pitchy lustre, in thin coatings reddish-brown. It fills fine fissures and intergranular spaces in the ferroan alabandite, quartz and pyrite.

The rhodrosite is light pink and is fine grained. It forms thin, from 1 to 2 mm thick veins and is the youngest mineral. Apart from this vein variety, rhodochrosite is represented here by another, greyish-white, earthy-to-powdery variety. The size of the grains ranges about $1\text{ m}\mu$. The following main lines were established by means of an X-ray powder method (Guinier de Wolff camera, *Cu*-radiation): 3.64 (9), 2.83 (10), 2.16 (8), 1.76 (8), 1.75 (9), 1.52 \AA (9). It is probably of supergene origin.

Physical properties

On a fresh fracture, the ferroan alabandite from Chvaletice is steely greyish black. It distinctly differs from the alabandite of a younger generation from the near by Litošice, which is of a nicely grassy green colour (L. ŽÁK, 1956). The fracture is uneven, the streak greyish black, with metallic lustre. It is opaque, macroscopically similar to the ferroan variety of sphalerite. It is characterized by perfect cleavage along (100) , in which property it remarkably resembles galena.

The density (4.101), as determined by means of a pycnometer at the temperature of 20°C , closely approaches the calculated value of 4.120. CH. PALACHE et al. (1946) have reported for alabandite the density of 4.031 to 4.040 [$n_{calc.} = 4.050$]. According to this comparison, the ferroan alabandite has a higher density than the ordinary alabandite.

The ferroan alabandite from Chvaletice is medium magnetic. On the electromagnet (type Cook), it separates well within a comparatively narrow range of low intensity, about 0.2 A, which is between 1500 and 1800 Oe in the electromagnetic field.

Ore microscopy

In reflected light, ferroan alabandite is greyish white, of a similar colour as tetrahedrite. Compared with sphalerite, it is distinctly lighter. It can be easily polished. It shows very perfect cleavage along (100) . Triangular shaped chippings are abundant. It is isotropic in crossed nicols. Reddish brown inner reflexes are rare. The aggregates are composed of allotriomorphic grains of a maximum size of 8 mm. Etching tests: HNO_3 (1:1) and HCl (1:1) strongly positive with plentiful bubbles of escaping H_2S , and it leaves a greyish black spot; H_2O_2 (30 per cent) is also positive, with escaping gas bubbles and a resulting greyish black spot, but less intensive than with the HNO_3 and HCl ; KOH (40 per cent) is negative (pyrrhotite inclusions become covered by iridescent coating); FeCl_3 (20 per cent), KCN and HgCl_2 are also negative.

The microhardness measurements were carried out on the Hanemann, microdurometer type D 32, at a pressure of 15.2 g (the measurements were made by Dr. A. Blüml).

	Range	Average	Remark
Ferroan alabandite, Chvaletice	205—232	218	kg/mm ²
Alabandite (S. H. U. BOWIE and K. TAYLOR, 1958)	240—266	251	kg/mm ²
Alabandite (G. TOUBEAU, 1962)		179	pressure 15—25 g

In comparison with the values for standard alabandite, the microhardness of the Chvaletice ferroan alabandite appears to be somewhat lower.

Pyrrhotite and sphalerite in the ferroan alabandite occur in the form of fine inclusions. Pyrrhotite inclusions are quite abundant, in some places their size ranging from 0.01 to 0.42 mm. They form fine laths, but also elongated and isolated inclusions, some of which show a tendency to idiomorphic development (laths and pseudohexagonal cross sections). Their distribution is very irregular, in places they are almost absent, elsewhere amounting to up 3 per cent. The orientation of pyrrhotite inclusions in two directions and their crossing can be also sporadically observed. Sphalerite is much rarer than pyrrhotite. Pyrrhotite and sphalerite always occur only in the form of inclusions in the ferroan alabandite. Their genetic interpretation is not clear and is difficult to make.

Spectrographic analysis

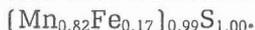
A spectrographic analysis (spectrograph Zeiss Q 24, analyst O. Paukner):

Per cent	Elements
XO.O	Fe, Mn
X.O	—
O.X	Si
O.OX	Al, Ca, Zn
< O.OX	Cd, Cu, Mg, Mo, Ni, Ti

Besides Mn and Fe, the majority of the other detected elements are apparently present only as minor admixtures of quartz, manganese silicates, sphalerite, pyrrhotite, etc. In alabandite structure a part of Ca can be bound isomorphically because this mineral is isostructural with oldhamite CaS. In green alabandite from the near-by Litošice, L. ŽÁK (1956) found gallium and germanium as characteristic microelements. These microelements were not found in the ferroan alabandite from Chvaletice.

Chemical composition

The results of a chemical analysis of the ferroan alabandite from Chvaletice are given in Table 1 [No. 5]. On the basis of these the following crystallochemical formula was calculated:



The minor insoluble residue is predominantly composed of quartz and pyrite. The mineral very easily decomposes in HCl and releases plentiful bubbles of H₂S. This is a good diagnostic feature distinguishing it from other similar minerals.

Table 1. Chemical analyses of alabandite, ferroan alabandite and ferroalabandite

	1	2	3	4	5	6	7	8
Mn	63.14	62.09	59.67	61.45	51.87	45.8	32.4	31.41
Fe		0.55	1.09	2.70	10.86	11.7	15.2	31.93
Mg			3.37			2.15	10.0	
Ca						0.20	0.1	
Zn				0.57				
Cu				0.39				
Cr							0.55	
SiO ₂		1.32						
Insol.					0.18			
S	36.86	35.80	36.35	34.52	36.89	37.4	41.4	36.66
Total	100.00	99.78	99.48	99.76	99.80	97.80	99.0	100.00

- 1 — Calculated composition of MnS
- 2 — Alabandite from the sedimentary manganese ore north of Varna, Bulgaria, L. VASILEV (1969)
- 3 — Alabandite from Dastakerskoye ore deposit, Arm. SSR, analyst Dekhtrikyan, K. A. KARAMYAN (1957)
- 4 — Alabandite from the Karolin mine, Sâcâramb, Roumania, S. KOCH — E. DONÁTH (1950)
- 5 — Ferroan alabandite from Chvaletice, Eastern Bohemia, Czechoslovakia, analyst Vl. Hartman, this paper
- 6 — „Ferroalabandite“ (= ferroan alabandite) from the Jahj deh Kot Lalu enstatite chondrite, K. KEIL — CH. A. ANDERSEN (1965)
- 7 — Ferromagnesian alabandite from Norton County achondrite, K. KEIL — K. FREDERIKSSON (1963)
- 8 — Calculated composition of ferroalabandite with MnS:FeS ratio 1:1.

Table 1 summarizes the results of new chemical analyses of alabandite, ferroan alabandite and ferroalabandite. The highest iron content (2.70 per cent), so far detected, was established in the Roumanian alabandite from Sâcâramb (S. KOCH and E. DONÁTH, 1950). According to the results of old chemical analyses, as summarized by C. DOELTER (1926), alabandite contains either no iron or only traces of it. Natural ferroalabandite has not been chemically analyzed so far. The highest iron, P. RAMDOHR (1952, 1957) assumes, is contained in the ferroalabandite

found at Bühl, near Kassel (Germany), in which the content of the isomorphically substituting components, MnS and FeS, approaches the ratio of 1:1 (the theoretical composition of this member is apparent from Table 1., No. 8). The only data available for comparison are those of alabandite from meteorites, as obtained by an electron microprobe analysis (Table 1, No. 6 and 7). The nearest to the Chvaletice ferroan alabandite, as far as its iron content is concerned (11.7 per cent), is the alabandite found in achondrite from Norton County (K. KEIL and K. FREDERIKSSON, 1963).

Electron microprobe analysis

The electron microprobe analysis of ferroan alabandite was carried out with an electronprobe microanalyser Geoscan II Cambridge in the laboratory VZUP Dobříš (analyst Ing. Václavíková). Electron microprobe analysis gave 52.1 per cent Mn, 10.4 per cent Fe and 33.78 per cent S (average of three separate measurements of the first approximation). The results obtained are in good agreement with the chemical analysis. The linear scan 50 μm long shows that the iron content varies little ± 0.7 per cent approximately.

X-ray powder study

According to R. W. G. WYCKOFF (1921), alabandite is cubic, with a crystal structure of NaCl type, space group O_h^5 - Fm3m and Z 4. Its structure resembles galena, not sphalerite, as originally supposed. Ferroan alabandite is structurally identical with alabandite, but is characterized by a lower lattice dimension (Table 3). The ferroan member of the MnS-FeS cubic isomorphous series, with predominating FeS, has not been so far found in natural state.

The X-ray powder data for the ferroan alabandite from Chvaletice are given in Table 2. The d -values, as established, are in good agreement with

Table 2. X-ray powder diffraction data of ferroan alabandite from Chvaletice
[X-ray diffractometer, Cu-radiation, intern. standard SiO₂]

I	$d_{(\text{meas.})}$	$d_{(\text{calc.})}$	hkl
10	3.000	3.001	111
100	2.600	2.599	200
45	1.839	1.838	220
10	1.500	1.5007	222
10	1.300	1.2995	400
20	1.162	1.162	420

$$a_0 = 5.1985 \text{ \AA}$$

the table values for alabandite (L. G. BERRY and R. M. THOMPSON, 1962), but they are somewhat lower. The comparison of the a_0 value for the ferroan alabandite from Chvaletice with the alabandite and ferroan

Table 3. Lattice constants of synthetic α -MnS, alabandite, ferroan alabandite and ferroalabandite

	Locality	a_0 (\AA)	Authors
Alabandite	Sâcâramb, Roumania	5.225	R. W. G. WYCKOFF (1921)
Synthetic α — MnS		5.223 _s	H. E. SWANSON et al. (1955)
		5.223	H. SCHNAASE (1933)
		5.222	F. MEHMED-H. HERALDSEN (1938)
Alabandite (green)	Litošice, Eastern Bohemia	5.220	This paper
α -Mns		5.219	F. A. KRÖGER (1939)
Alabandite (green)	Litošice, Eastern Bohemia	5.216	L. ŽÁK (1956)
Alabandite (metacolloidal)	Varna, Bulgaria	5.209	L. VASILEV (1969)
Alabandite	Sâcâramb, Roumania	5.208	V. I. MIKHEYEV (1957)
Alabandite	Ruen, Bulgaria	5.202*	S. MINKOV (1969)
Ferroan alabandite	Chvaletice, Eastern Bohemia	5.198 _s	This paper
Ferroan alabandite (from meteorite)	Abee, Alberta, Canada	5.164*	K. DAWSON-I. A. MAXWELL (1960)
Ferroalabandite	Bühl, near Kassel, Germany	5.15	P. RAMDOHR (1952)

* Calculated by author from the X-ray powder data presented in the paper cited.

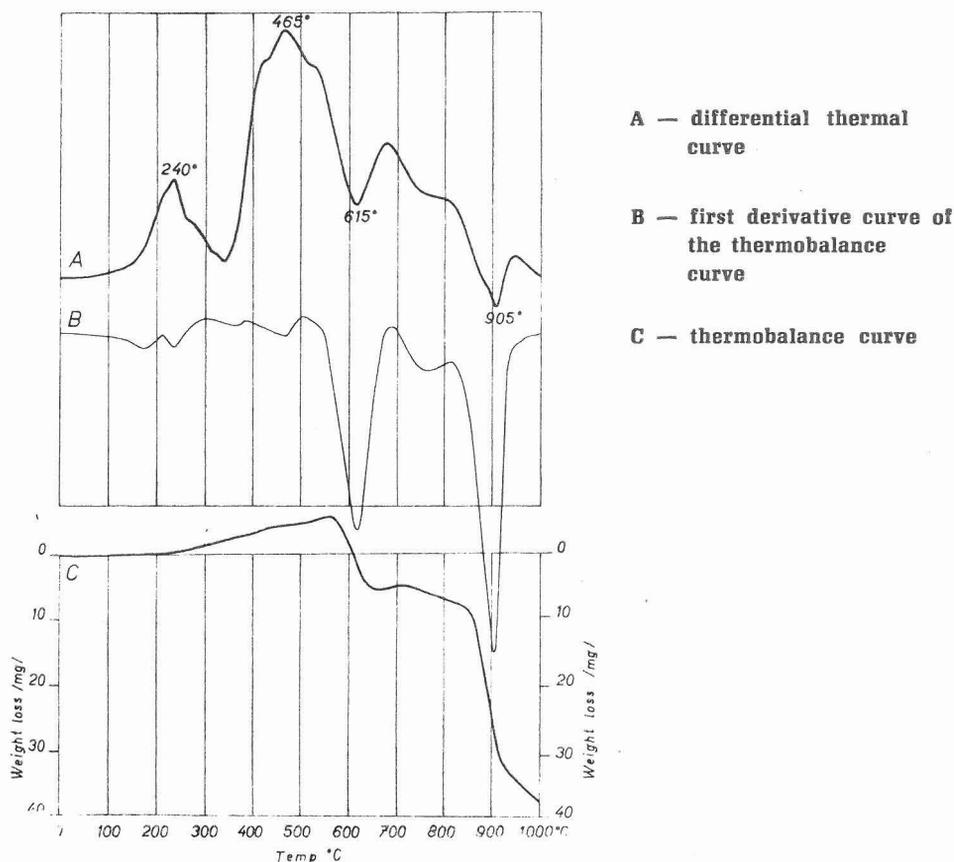
alabandite and ferroalabandite lattice constants, as obtained from literature, is recorded in Table 3. According to it, the lattice constant for pure alabandite and the synthetic α -MnS ranges at about 5.22 \AA . The iron content in the alabandite structure reduces the a_0 value down to 5.15 \AA , which is so far the lowest known value for ferroalabandite from Bühl near Kassel (P. RAMDOHR, 1957). Ramdohr assumes the ferroalabandite from Bühl to be a mixed crystal with the $MnS : FeS$ ratio of 1 : 1. The cubic structure of MnS can accept up to 60 per cent FeS at very high temperatures (ZEN-ISHI-SIBATA, 1928; in P. RAMDOHR, 1957). The content of 10.8 per cent Fe in the Chvaletice ferroan alabandite reduces the a_0 by 0.024 \AA , in comparison with pure α -MnS. Assuming that this lowering of a_0 , in dependence on the increasing Fe content, is a linear function, with a threefold Fe content approximately corresponding to

the $MnS:FeS$ ratio of 1:1, the calculated a_0 is 5.15 \AA . If the FeS content in the alabandite lattice really proves to be directly dependent on the temperature during which it originated, it will be possible to use this relationship as a geological thermometer, in a similar way as with sphalerite.

Thermal analysis

The thermic investigation of the ferroan alabandite from Chvaletice was carried out on the Orion type Derivatograph (Budapest). The thermic curves are shown in Figure 1.

Fig. 1 Thermal data for ferroan alabandite from Chvaletice



The DTA curve shows two exothermic reactions, the first of which is weaker, with a peak at 240°C , and the second is strong, with a peak at 465°C . These exothermic reactions correspond with the progressive oxidation of (Mn, Fe) S. Two endothermic reactions follow after the com-

pleted oxidation. The first is weaker, with its maximum at 615°C, and the second is stronger, with its maximum at 905°C.

L. ŽÁK (1956) has been lately engaged in the research of the thermic decomposition of the Sâcâramb and Litošice alabandites and of the synthetic α -MnS. According to this author, the first exothermal reaction (peak at 230°C synthetic MnS; 260°C — Sâcâramb alabandite) represent the oxidation of the MnS part to MnO and MnSO₄, or a transitional phase of the oxidation of MnS. The second exothermal reaction (peak at 315°C for synthetic MnS and at 340°C for natural alabandites), according to Žák, probably pertains to the oxidation of MnO or MnS to the tetragonal Mn₂O₃. During this reaction, MnSO₄ can be partly formed to the detriment of the oxidation of MnS. The third exothermal reaction (with its peak at 410°C for synthetic MnS and between 420°C and 440°C for natural alabandites), according to Žák, can be interpreted as the oxidation of MnS to MnSO₄. With the ferroan alabandite under study, the second and the third exothermal reactions have joined to form one wide peak, probably composed of three not distinctly separated exothermic effects, one closely following the other. The gradual oxidation, in this case, has been influenced by the increased iron content.

The endothermal peak (610°C with synthetic MnS, 610—620°C with natural alabandite), according to Žák, was caused by the transition of the tetragonal Mn₂O₃ to Mn₃O₄. Žák did not discuss the second endothermic reaction, because he studied the thermic behaviour of the samples to only 800°C. This could probably be best explained by the decomposition of the sulphates that had formed.

The final product of the thermic analysis was identified by X-ray analysis as tetragonal Mn₃O₄ (Guinier de Wolff camera, Cu-radiation). No iron oxides were found.

The GTA curve at first rises from 240°C to about 560°C, representing thus the gradual oxidation of MnS (2 per cent weight increase). This is further followed by a distinct loss in weight, 3,7 per cent, corresponding with the first endothermic reaction on the DTA curve. Finally, within the range of 810°C to 920°C this is followed by a very steep loss in weight (9 per cent), which corresponds with the second endothermic reaction.

Mineralization and succession

The minerogenetic relation of the area of the Železné hory Mts. pyrite and manganese deposits is being systematically investigated by L. Žák. According to him (L. ŽÁK, 1965), four main minerogenetic units can be distinguished here:

1. sedimentary,
2. metamorphic,
3. higher-temperature hydrothermal,
4. lower-temperature hydrothermal.

The sedimentary unit is composed of graphitic shales with pyrite and includes a formation of fine-grained ferrorhodochrosite. Apatite is the most abundant of the other accessory minerals. The metamorphic unit is

characterized by manganese silicates (spessartite, rhodonite, tephroite, manganoo cummingtonite), and it originated from the hydrothermal and kinetic metamorphosis after the intrusion of younger basic eruptive rocks and of the Chvaletice granite with its associated dykes. The higher temperature hydrothermal unit is characterized by the main generation of vein quartz, sulphides (arsenopyrite, pyrite, pyrrhotite, sphalerite, black alabandite), kutnohorite, apatite and other minerals. The lower temperature hydrothermal unit is characterized by vein rhodochrosite, and of the other minerals, by green alabandite, helvite, cronstedtite, neotokite-hisingerite, pyrite, rock crystal, opal, etc. The last two mentioned units show many features in common with the alpine paragenesis, which is especially apparent with the lower temperature hydrothermal unit.

In the sense of the Žák's division, the minerogenetic development of the Železné hory Mts. pyrite and manganese deposits, the ferroan alabandite, under study, belongs to the early stages of the third, higher temperature hydrothermal unit. It is probably identical with the older generation of black alabandite, which, according to Žák, is one of the characteristic minerals of this unit.

On the ground of macro- and microscopic observations, roughly the following succession can be determined in the samples containing ferroan alabandite: hornfels fragments → manganese cummingtonite → quartz → pyrrhotite, sphalerite, ferroan alabandite → pyrite I → neotokite → rhodochrosite (pink) → pyrite II → rhodochrosite, white (supergene?). A similar succession was presented by L. ŽÁK (1956) for the black alabandite from Litošice: graphite, pyrite → garnet, rhodonite → apatite (?) → quartz → pyrite II → alabandite → pyrrhotite → neotokite → pyrite III.

To summarize, we can conclude that the ferroan alabandite from Chvaletice formed as one of the highest temperature minerals of the hydrothermal vein association, which shows a direct material continuity with the processes of the Algonkian pyrite and manganese deposit mobilization.

The world-wide occurrences of ferroan alabandite and ferroalabandite

The occurrences of ferroan alabandite and ferroalabandite, so far known, can be divided into several groups:

I — meteorites

1 — achondrite

The ferro-magnesian alabandite from Norton County achondrites, as described by K. KEIL and K. FREDERIKSSON (1963). It forms accessory grains (maximum size 1 mm) associated with native copper, titanite, troilite and nickel iron.

2 — chondrites

Ferroan alabandite was found as one single grain in a kamacite-taenite zone of a stone meteorite which fell near Abee, Alberta, Canada (K. DAWSON and I. A. MAXWELL, 1960). It occurs in association with

oldhamite, taenite, orthopyroxene and troilite. Later, K. KEIL and CH. A. ANDERSEN (1965) found ferroalabandite in an enstatite chondrite from Jajh deh Kot Lalu. It forms segregated lamellae and cigar shaped bodies in troilite, in association with enstatite, pigeonite, oligoclase, kamacite, troilite, oldhamite, daubréelite, schreibersite, graphite and sinoite.

II — natural occurrences

3 — enclosures in eruptive rocks

The ferroalabandite from Bühl near Kassel, first described by P. RAMDOHR (1952), belongs to this group. It forms inclusions in native iron in basalt, in association with pyrrhotite, ilmenite, hematite, magnetite and cohenite. According to Ramdohr's assumption, this association formed as „natürliches Verhüttungsprodukt“ in those places, where basalt, contained in a strong reductive medium on the contact of coal seams, reduced enclosures of oxidic iron ores.

The ferroalabandite from Fohlberg near Oberschaffhausen, Germany, forms inclusions in pyrrhotite, which, together with other sulphidic minerals, occur in the form of enclosures in phonolite (P. RAMDOHR, 1957). Associated with it are: chalcopyrite, valleriite (?), sphalerite, rutile, ilmenite, pyroxene, wollastonite, sanidine, apatite, plagioclase, melanite and sphene. According to Ramdohr, they are probably ore veins with pyrite, chalcopyrite, sphalerite and Mn-calcite, enclosed and metamorphosed on contact with phonolite.

4 — hydrothermal veins

The ferroalabandite from Chvaletice, which is being described here, belongs to this group.

Reports of several more alabandite occurrences are known to exist in the literature, of which, although they resemble in their genetic conditions the described alabandite, no analytic data were presented. So e.g., H. HUTTENLOCHER (1936) described a dark alabandite from Swiss Alps. The compact alabandite aggregates occur here in association with pyrrhotite, sphalerite and rare stannite and galena in quartz-carbonate vein filling. The character of these veins and the presence of rhodonite indicate according to Huttenlocher's opinion, that they had been affected by alpine dynamic metamorphosis. According to A. G. BETEKHTIN (1940), alabandite also occurs in the Chiaturi manganese deposit (Gruzian SSR), in metamorphic ores on the contact of the ore-bearing bed with basalt. Finally, a mention must be made of the alabandite occurring in the manganese deposit in Devonian carbonate rocks at Serre d'Azet at Haute Pyrenees (France), as described by A. LACROIX (1900, in D. F. HEWETT and O. N. ROVE, 1930). In this deposit, alabandite is mixed with rhodochrosite in association with rhodonite, friedelite, quartz and the rare tephroite and huebnerite.

A survey of alabandite occurrences, their description and genesis was the subject of a study by D. F. HEWETT and O. N. ROVE (1930). P. RAMDOHR (1960) introduced in his book the more recent occurrences of this mineral. The majority of alabandite occurrences are bound to low tempe-

rature (epithermal) hydrothermal veins, where they occur in association with common sulphides, Ag-ores and more and less rarely, with Ag-Au tellurides (Roumania) and Sn-minerals (Bolivia). Lately, alabandite has been also found in the medium-to high temperature Cu-Mo deposit at Dastakerskoye, in the Armenian SSR (K. A. KARAMYAN, 1957) and in the cassiterite sulphidic deposits in the Yuzhnoe Primorie Province, USSR (V. P. POLOKHOV, 1959). Occurrences of alabandite of sedimentary origin in Bulgaria are rare (L. VASILEV, 1969; S. MNKOV, 1969). Mineral associations of the known alabandite deposits, according to the literature cited above, are summarized in Tab. 4.

Suggestion of nomenclature

It has been demonstrated that up to 60 per cent of FeS can be bound in the structure of the cubic α -MnS. Natural alabandite with the $MnS:FeS$ ratio of about 1:1, was denominated by P. RAMDOHR (1952, 1957) as *f e r r o a l a b a n d i t e*. The author recommends to use this name only for the members which have the MnS/FeS ratio of 1:1 and for those that are richer in FeS. For the members of this isomorphous series, the FeS per cent of which is lower, the author proposes the name *f e r r o a n a l a b a n d i t e*.

Acknowledgements

The author wishes to express his appreciation to Messrs Vl. Hartman, O. Paukner, Dr. J. Ševců and J. Zelený, all from the Institute of Mineral Raw Materials in Kutná Hora, for their carrying out the necessary analyses and to Dr. A. Blüml, from the Geochemical Laboratory at Příbram, for his microhardness determinations.

Finally, the author is also deeply indebted to Associate Professor Dr. F. Čech, from the Department of Mineralogy, Charles University in Prague and to Dr. Karel Tuček from the Department of Mineralogy of National Museum in Prague, for the critical reading of the manuscript and many valuable comments.

Ústav nerostných surovin, Kutná Hora

Translated by J. Horák

Table 4. Minerals associated with alabandite of various world deposits

	SPHALERITE	GALENA	CHALCOPYRITE	ARSENOPYRITE	PYRITE	PYRRHOTITE	MARCASITE	TETRAHEDRITE	BOURNONITE	Ag-SULPHOSALTS	STIBNITE	STANNITE	CASSITERITE	QUARTZ	CALCITE	RHODOCHROSITE	DOLOMITE	ANKERITE	SIDERITE	BARITE	RHODONITE	TEPHROITE	GARNET	
<i>Bisbee, Arizona, USA</i>	■	■																						
<i>Harshaw district, Arizona, USA</i>	■		■																					
<i>Tombstone district, Arizona, USA</i>	■																						■	
<i>Mineral County, Colorado, USA</i>	■		■																					Chlorite
<i>Summit County, Colorado, USA</i>	■																							
<i>Jefferson County, Montana, USA</i>	■								■															
<i>Schellbourne, Nevada, USA</i>	■		■																					
<i>Chiricahua Mts., New Mexico, USA</i>	■	■						■																
<i>Mina Preciosa, Pueblo, Mexico</i>	■								■															
<i>Potosi, Bolivia</i>	■											■												Andorite, Zinckenite, Stromeyerite
<i>Mutsu mine, Aomori, Japan</i>	■																							
<i>Dastakerskoye deposit, Armenia, USSR</i>	■																							Manganocalcite, Enargite, Melnikovite - Pyrite
<i>Yuzhnoe Primorie Province USSR</i>	■																		■					
<i>Adervielle, France</i>	■													■										Friedelite, Huebnerite
<i>Pattipki, Finland</i>	■																							
<i>Sâcâramb / Nagyág /, Roumania</i>	■																							Telluride Ag, Au, Pb, Bismuth native
<i>Kapnic, Roumania</i>	■																							Fluorite
<i>Dobrevo, Serbia, Yugoslavia</i>	■																							Magnetite
<i>Varna, Bulgaria</i>	■																							Ag-minerals
<i>Osogovskoye deposit, Ruen, Bulgaria</i>	■																							
<i>Amsteger power-station, Alps, Switzerland</i>	■																							Carbonatic gangue, Amphibol

REFERENCES

- BERRY L. G. — THOMPSON R. M. (1962): X-ray powder data for ore minerals: The Peacock atlas. — Geol. Soc. Amer., Mem. **85**, New York.
- BETEKHTIN A. G. (1940): The minerals of USSR. — Izd. AN SSSR, **2**, 192 (in Russian).
- BOWIE S. H. U. — TAYLOR K. (1958): A system of ore mineral identification. II Atom. Energ. Confer., A/Conf. 15/P/42, Genova.
- DAWSON K. — MAXWELL I. A. (1960): A description of the meteorite which fell near Abee, Alberta Canada. — Geochim. Cosmochim. Acta, **21**, 127—144.
- DOELTER C. (1926): Handbuch der Mineralchemie. — Vol. **3**, 485, Dresden — Leipzig.
- HEWETT D. F. — ROVE O. N. (1930): Occurrence and relations of alabandite. — Econ. Geol., **25**, 36—56.
- HÜTTENLOCHER H. (1936): Zur Mangan-Zinn-Silber-Lagerstätte aus dem Wasserstollen des Amsteger Kraftwerkes. — Schweiz. Min. Petr. Mitt., **16**, 406 — 408.
- KARAMYAN K. A. (1957): Alabandite from Dastakerskoye coppermolybdenum ore deposit. — Izv. AN Arm. SSR, ser. geol., geograf., **10**, 115 — 120 (in Russian).
- KEIL K. — FREDERIKSSON K. (1963): Electron microprobe analysis of some rare minerals in the Norton County achondrite. — Geochim. Cosmochim. Acta, **27**, 939 — 947.
- KEIL K. — ANDERSEN CH. A. (1965): Electron microprobe study of the Jajh deh Kot Lahu enstatite chondrite. — Ibidem, **29**, 621 — 632.
- KOCH S. — DONÁTH E. (1950): Data relating to the alabandite deposits in Săcărâmb (Nagyág, Roumania) and to those of hauerite in Kalinka (Czechoslovakia). — Acta Univ. Szeged., Acta min. petr., **4**, 42 — 46 (in Hungarian).
- KROGER F. A. (1939): Formation of solid solutions in the system zincsulfide — manganese sulfide. — Z. Krist., **A 100**, 543 — 545.
- MEHMED F. — HARALDSEN H. (1938): Das magnetische Verhalten der allotropen Modifikationen des Mangan (II)—Sulfides. — Z. anorg. Chem., **235**, 193 — 200.
- MIKHEYEV V. I. (1957): Tabeles for the X-ray determination of minerals. — Moscow (in Russian).
- MINKOV S. (1969): Alabandite from Osogovskoye zinc-lead ore deposit Ruen. — Izv. Geol. in-t. Ser. rudni i nerudni polezni iskop., **18**, 115 — 118 (in Bulgarian).
- PALACHE CH. — BERMAN H. — FRONDEL C. (1946): The system of Mineralogy of J. D. Dana and E. S. Dana. — 7th Edit., Vol. **1**, New York — London.
- POLOCHOV V. P. (1959): Alabandite and the others minerals of manganese from the cassiterite-sulfidic ore deposit in the South Primorie. — Izv. vysš. učeb. zaved., Geol. razvedka, No. **7**, 80 — 88 (in Russian).
- RAMDOHR P. (1952): Neue Beobachtungen am Bühleisen. — Sitz.-Ber. Berliner Akad. Wiss., math.-naturwiss. Kl., **9** — 24.
- RAMDOHR P. (1957): Eisenalabandin, ein merkwürdiger natürlicher Hoch-temperatur-Mischkristall. — Neus Jb. Mineral. Abh., **91**. Festband Schneiderhöhn, 89 — 93.
- RAMDOHR P. (1960): Die Erzminerale und ihre Verwachsungen. — 3. Auflage, Akad.-Verlag Berlin.
- SCHNAASE H. (1933): Kristallstruktur der Mangano-sulfide und ihrer Mischkristalle mit Zinksulfid und Cadmium-sulfid. — Z. Phys. Chem., **B 20**, 89 — 117.
- STRUNZ H. — TENNYSON CH. (1966): Mineralogische Tabellen. — Leipzig.
- SWANSON H. E. — FUYAT R. K. — UGRINIC G. M. (1955): Standard X-ray diffraction powder patterns. United States Department of Commerce, National Bureau of Standards NBS Circular, Vol. **4**, 11 — 12.
- TOUBEAU G. (1962): Mesure de la microdureté Vickers des minéraux opaques et son intérêt en minéralogie. — Bull. Soc. Belge geol. pal. hydrogeol., **V 71**, Fasc. 2.
- VASILEV L. (1969): Alabandite in the sedimentary rock of the manganese ore deposit northly of Varna. — Izv. Geol. in-t. Ser. rudni i nerudni polezni iskop., **18**, 103 — 114 (in Bulgarian).
- WYCKOF R. W. G. (1921): The crystal structure of alabandite. — Amer. J. Sci., **2**, 239.

- ŽÁK L. — NOVOTNÝ J. (1954): Preliminary report concerning the occurrence of alabandite from Litošice in the Železné hory Mts. — Věst. ÚÚG, **29**, 223 — 224 (in Czech).
- ŽÁK L. (1956): Alabandite from Litošice in the Železné hory Mts. (East Bohemia). — Rozpr. ČSAV, **66**, 49 — 78 (in Czech).
- ŽÁK L. (1956): Contribution to the thermal study of MnS. — Min. Sbor. Lvov. geol. obšč., No. **10**, 212 — 227 (in Russian).
- ŽÁK L. (1965): Minerogenetic units of the north-west part of Železné hory Mts. — Čas. min. geol., **10**, 495 (in Czech).

SBORNÍK NÁRODNÍHO MUZEA V PRAZE — ACTA MUSEI NATIONALIS PRAGAE

Volumen XXVII B (1971), No. 5

Redaktor: Dr. JIŘÍ KOUŘIMSKÝ, CSc.

Cena 8,50 Kčs