ON SOME EXSOLVED MINERALS IN GALENA

S. KARUP-MØLLER *

Abstract

Two new sulphides mineral "A" ($Ag_2Cu_3Bi_6Pb_9S_{20.5}$) and mineral "B" ($Bi_2Cu_4Fe_5Pb_6S_{18.5}$) are present as exsolution minerals in galena from different deposits. Their fine grain size prevent a complete mineralogical study and no new mineral names have been proposed. The present study shows that bismuth and/or silver-bearing galena cannot dissolve more than 0.5 percent copper at room temperature. At temperatures above 215°C and possibly as high as 400°C no more than an estimated 1 percent copper can dissolve in the galena structure. Therefore no solid solution series, similar to that between PbS and $AgBiS_2$, appears to be present between PbS and $CuBiS_2$.

Introduction

Galena from Ivigtut, Greenland, Bjőrkåsen, Norway and Gladhammar, Sweden, associated with sulphides composed of two or more of the elements bismuth, lead, silver and copper, have been found to contain minerals formed as a result of exsolution. The composition of these exsolved products was determined by the microprobe analyser** and two of them have not previously been described. Their fine grain size did not permit a complete mineralogical study and no new mineral names have been proposed. They have been described below as mineral "A" and mineral "B".

The conditions under which silver and bismuth dissolve in the galena structure are known from the description of natural occurrences (Ramdohr 1938, and others) and more recently, from the result of experimental studies (Van Hook 1960, Craig 1967, and others). All of the exsolution minerals from galena described below contain copper. The study of these and their host, has revealed some information on the ability of copper to dissolve in bismuth and sometimes also silver-bearing galenas.

Galenas from the Cryolite Deposit at Ivigtut, S.W. Greenland

Galena accompanied by several additional sulphides have been found in the cryolite deposit of Greenland below the siderite-cryolite zone

* Universitetets Mineralogisk-Geologiske Instituter Østervoldgade 5-7, København K. Denmark.

** Determinations were carried out on an ARL, model EMX microprobe. Standards used during the present investigation were native elements for copper, silver, and bismuth, galena for lead and sulphur, and pyrite for iron. The data were processed using a program written by Rucklidge (1967).

described by Pauly (1960). Three of these sulphides, berryite, gustavite and phase X have been described by Karup-Møller (1966, 1970). Galena when closely associated with berryite contains rare exsolution lamellae of a mineral, which is designated as mineral "A" (Fig. 1).

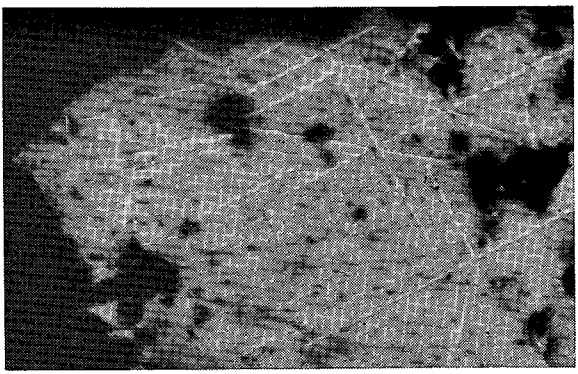

FIG. 1. Exsolution lamellae of mineral "A" in galena from the cryolite deposit at Ivigtut, S.W. Greenland. (210 ×, partly crossed nicols, oil imm.).

The microprobe analyses (Table 1) agree best with the formula: $Ag_2Cu_3Bi_6Pb_9S_{20.5}$. The sulphide is distinctly bireflecting with reflection colours ranging from white to grey white. It is strongly anisotropic but the colours could not be determined due to its fine grain size. Both bireflectance and anisotropy are strongly accentuated in oil. The reflectivity has visually been estimated to be similar to that of galena when the mineral is in its brightest position. Polishing hardness is higher than that of galena.

Microprobe analyses on the galena host grain showed, that this contains approximately 3.5 percent Ag and 0.5 percent Cu.

TABLE 1. MINERAL "A": MICROPROBE ANALYSES

	Wt.%	Mol.%	Wt.%	Mol.%	Wt.%	Mol.%
Pb	40.1	20.1	40.4	21.0	42.4	21.3
Bi	29.6	14.7	30.4	15.7	27.8	13.9
Ag	5.6	5.4	5.5	5.5	5.2	5.0
Cu	4.5	7.4	3.1	5.3	4.4	7.2
S	16.2	52.5	15.6	52.5	16.2	52.6
Total	96.0	99.9	95.0	100.0	96.0	100.0

Galena associated with matildite and aikinite has been found elsewhere in the cryolite deposit. Galena is the dominant of the three sulphides and contains irregularly shaped inclusions of small aikinite grains. Larger grains of aikinite have developed irregular mutual boundaries with galena, suggesting the two minerals formed penecontemporaneously. An estimated 15 percent by volume of matildite has exsolved from galena and occurs as well rounded to irregularly shaped blebs in random orientation. Microprobe analyses indicate that the copper content of the galena and matildite is less than 0.3 percent and the silver content in aikinite less than 0.4 percent.

Galena from Björkåsen, Norway

Bismuth and silver-bearing galena from Björkåsen and other localities in Norway, containing a lamellar exsolution mineral, have been described by Oftedal (1941, 42). He considered the lamellar mineral to be bismuth-rich, because of a higher content of bismuth (1.3-1.7%) than silver (0.2%) in the galena host. Galena with more bismuth than silver has been described by Ontoev *et al.* (1960). This galena contained a lamellar exsolution mineral, considered to be beegerite*.

A mineralogical study of a specimen from Björkåsen show the major sulphides present to be galena, cosalite, pyrite, pyrrhotite, chalcopyrite and minor native bismuth. They occur disseminated through coarse grained, translucent quartz.

A lamellar mineral has exsolved from the galena and is described below as mineral "B". Microprobe analyses on the galena host for this mineral gave a bismuth content of 0.5 to 1.8 percent but copper and silver values of less than 0.3 percent.

About 25 lamellae of mineral "B" have been observed in four polished sections. In general the lamellae are regularly shaped (Fig. 2) but occasional irregular laths are observed, a feature which may be due to an almost parallel orientation of the polished surface to the lamellae.

These microprobe analyses (Table 2) agree best with the following formula : $Bi_2Cu_4Fe_5Pb_6S_{18.5}$. The mineral is distinctly bireflecting and strongly anisotropic in both air and oil. Reflection colours are olive grey and the anisotropy colours, white to black. The reflectivity is considerably less than that of galena, while the polishing hardness is higher.

* No complete mineralogical study on a natural phase with the composition $Pb_6Bi_2S_9$ supposed to be that of beegerite has been described in the literature.

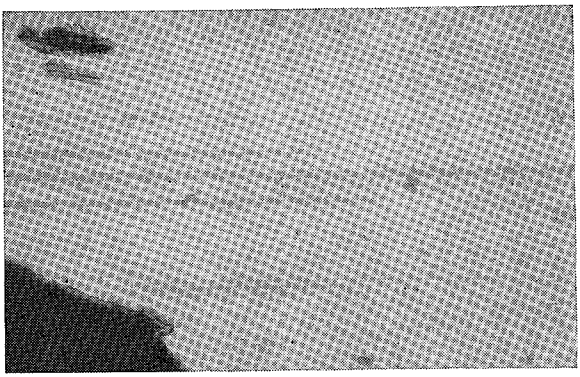

FIG. 2. Exsolution lamellae of mineral "B" in galena from Björkåsen, Norway. (325 ×, one nicol, oil imm.).

GALENA FROM GLADHAMMAR, SWEDEN

A number of sulphides (gladite, hammarite, etc.) with compositions lying on the Bi_2Si_3–$PbBiCuS_3$ join are known from the sulphide deposit at Gladhammer in Sweden (Johannson 1924 and Welin 1966). A galena-rich specimen from this deposit has been studied. Several well defined galena cubes up to half a centimeter in size were polished and found to have a distinct {111} cleavage in addition to the much more prominent cleavage parallel to {100}. Fine exsolution lamellae of aikinite (identified by the microprobe analyser) lie parallel to the {111} cleavage direction. Microprobe analyses on the galena host indicate a bismuth content of 0.5 to 1.0 percent but failed to detect any content of copper or silver. This relationship between bismuth-bearing galena and octahedral cleavage confirms the similar observations made on galena by Oftedal (1941, 42).

TABLE 2. MINERAL "B": MICROPROBE ANALYSES

	Wt.%	Mol.%	Wt.%	Mol.%	Wt.%	Mol.%
Pb	43.3	16.7	43.8	16.6	44.7	17.1
Bi	14.8	5.7	13.7	5.3	14.3	5.4
Fe	10.0	14.3	10.7	15.1	10.6	15.2
Cu	9.6	12.1	9.1	11.3	9.1	11.3
S	20.5	51.2	21.1	51.8	20.7	51.1
Total	98.2	100.0	98.4	100.1	99.4	100.1

Discussion

Of the copper-bearing minerals exsolved from galena and described above two have not previously been recorded. The galena hosts for the exsolved minerals contain very little copper (less than ½ percent) but greater amounts of bismuth and sometimes also silver. The low copper content of the galena containing the copper-bearing exsolution minerals excludes the possibility that any significant amount of Cu^+ can substitute for Ag^+ in silver and/or bismuth-bearing galena at room temperature.

The situation does not appear to be much different at elevated temperatures. Galena associated with aikinite and berryite from the cryolite deposit at Ivigtut in Greenland contains exsolved matildite and the temperature of formation must therefore have been above 215°C (Craig 1967). This galena was found in the siderite-cryolite ore which, according to Pauly (1960) began to crystallize at temperatures between 500 and 600°C. The temperature at which the galenas crystallized is estimated to lie somewhere between 250 and 400°C. The galena variety containing aikinite, dissolved less than 0.3 percent copper and that associated with berryite and containing exsolution lamellae of mineral "A" dissolved an estimated 1 percent copper. The galena from Bjőrkåsen in Norway dissolved less than 0.3 percent copper and that from Gladhammar in Sweden dissolved an estimated 0.3 percent copper, although the mineral from the two localities is associated with various bismuth and copper-bearing sulphides. The low copper content of the investigated galenas and the penecontemporaneous crystallization of these with copper and bismuth-bearing minerals such as berryite and aikinite appear to exclude the existence of a solid solution series between PbS and $CuBiS_2$, similar to that which exists between $AgBiS_2$ and PbS at temperatures above 215°C.

Acknowledgments

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