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THE SECOND OCCURRENCE OF ARDAITE: GRUVÅSEN, BERGSLAGEN, SWEDEN

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ABSTRACT

The second occurrence of ardaite is reported from the Gruvåsen Pb–Zn–Cu–Ag deposit, western Bergslagen, central Sweden. The average composition is Pb 57.94, Fe 0.31, Sb 21.44, S 15.44, Cl 4.39, total 99.52 wt. %, leading to an ideal formula $(Pb,Fe)_{20}Sb_{12}S_{34}Cl_8$. The mineral occurs as small inclusions in galena and was probably formed by a reaction of halogen-rich solutions with remobilized Sb-bearing galena.

Keywords: ardaite, chlorine-sulfosalts, Bergslagen, Sweden.

SOMMAIRE

On signale une deuxième trouvaille d'ardaïte, cette fois dans le gisement Pb–Zn–Cu–Ag de Gruvåsen (Bergslagen occidental, Suède centrale). La composition moyenne, Pb 57.94, Fe 0.31, Sb 21.44, S 15.44, Cl 4.39, total 99.52% (en poids), répond à la formule idéalisée $(Pb,Fe)_{20}Sb_{12}S_{34}Cl_8$. L'ardaïte, qui se présente en petites inclusions dans la galène, serait le produit d'une réaction entre solutions riches en halogènes et galène stibifère remobilisée.

(Traduit par la Rédaction)

Mots-clés: ardaïte, sulfosel chloruré, Bergslagen, Suède.

INTRODUCTION

Pb–Sb chlorosulfosalts have recently been identified as minerals (Moëlo 1978, Breskovska *et al.* 1978, 1979, 1980, Cervelle *et al.* 1979), and have been studied as synthetic compounds (Moëlo 1979, Bortnikov *et al.* 1979). It has been established that chlorine is an essential compound of dadsonite (Moëlo 1979). One of the Cl-bearing Pb–Sb sulfosalts discovered in the Madyarovo polymetallic deposit (Bulgaria), previously described as "chlorine falkmanite" (Breskovska *et al.* 1979), has been recognized as a separate mineral species and named *ardaite* (Breskovska *et al.* 1981). Investigations within the framework of a current petrological and metallogenetic project in the Hällefors area of central Sweden led to the discovery of ardaite in the Gruvåsen deposit, a small Pb–Zn–Cu–Ag occurrence in western Bergslagen, a Precambrian metallogenic province.

OCCURRENCE

The Gruvåsen deposit is located about 12 km east of Filipstad in the Saxå syncline, which involves slates, greywackes, greenstones, dolomites and limestones; the deposit is surrounded by leptites (metamorphosed volcanic rocks of rhyolitic composition). Mineralization occurs in the dolomites (Fig. 1); these are flanked by sterile limestones, suggesting that the carbonates form a local anticline (Magnusson 1925). The anticline is truncated to the south by postorogenic granites (1665 *Ma*: Welin *et al.* 1977).

The polymetallic ores of the Gruvåsen deposit were excavated from eight small mines (shafts) during the sixteenth and seventeenth centuries; more recent exploitation took place from 1906 to 1917, and numerous pits and dumps from this operation are still in evidence. The mineralization has been described in some detail in connection with the occurrence of a number of rare Co and Ni minerals (Zakrzewski *et al.* 1980). The chlorine-sulfosalt *ardaite* occurs in specimens from the Dressfall mine in the southern part of the Gruvåsen deposit (Fig. 1).

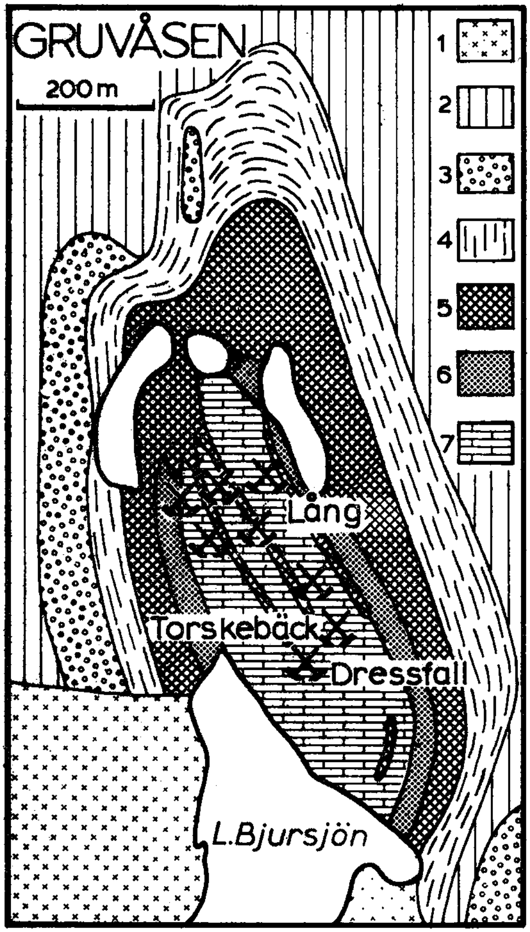

FIG. 1. Geological map of Gruvåsen (after Magnusson 1925) showing the location of mines. (1) Postorogenic granite, (2) slate, (3) spilitic greenstone, (4) greywacke, (5) massive greenstone, (6) limestone, (7) dolomite.

MINERALOGY

Ardaite occurs as small inclusions in galena, usually as rounded grains (maximum dimensions 50 x 50 μm) and, more rarely, as elongate grains. Other minerals in the assemblage are sphalerite, pyrrhotite, chalcopyrite, magnetite, scheelite, pyrargyrite, native silver, native antimony, stannite, arsenopyrite, nisbite and graphite.

In reflected light, ardaite is bluish green, with a reflectance (R = 30–35% at 546 nm) distinctly lower than that of galena, a distinct reflection pleochroism and strong anisotropy. The polishing hardness is somewhat higher than for galena. In contrast to pyrargyrite, ardaite has a higher reflectance and no internal reflections.

The small grain-size prohibits the extraction of powder for X-ray-diffraction patterns; the identification of the mineral is thus based on chemical composition only. Seventeen electron-microprobe analyses have been carried out on six grains with a Cambridge Instruments Microscan 9 with accelerating potentials of 15 and 20 kV, using PbS (Pb $L\alpha$ and S $K\alpha$), FeS (Fe $K\alpha$), Sb_2S_3 (Sb $L\alpha$ and S $K\alpha$) and NaCl (Cl $K\alpha$) as standards. Apparent concentrations were ZAF-corrected with the Microscan 9 online ZAF program. The composition of the Gruvåsen ardaite is given in Table 1, as are the results of Breskovska *et al.* (1981) for comparison.

Some grains contain no Fe, others up to 1.65 wt. %; the Pb and Fe contents show an antipathetic substitutional relation, indicating that these elements occupy the same position in the structure. Bromine was sought but is not present in measurable quantities. Calculation on the basis of Pb + Fe + Sb = 32 yields an empirical formula for the Gruvåsen ardaite of $(Pb,Fe)_{20}Sb_{12}S_{33}Cl_9$; balancing the valences, however, requires an adjustment of this result to an ideal formula of $(Pb,Fe)_{20}Sb_{12}S_{34}Cl_8$. This adjustment amounts to a difference of about 0.2 wt. % S and 0.35 wt. % Cl in the analysis (Table 1), which is within the analytical error for these elements.

TABLE 1. ELECTRON-MICROPROBE ANALYSES OF ARDAITE

Gruvåsen, Bergslagen, Sweden (this paper)

	Mean value and range of 17 analyses (wt.%)		Number of atoms with (Pb+Fe+Sb) = 32	$Pb_{20}Sb_{12}S_{34}Cl_8$ (weight %)
Pb	57.94	(55.25-58.55)	19.40 } 32	59.37
Fe	0.31	(0.1 - 1.65)	0.38 } 32	-
Sb	21.44	(21.2 -21.55)	12.21 } 32	20.94
S	15.44	(15.3 -15.6)	33.42	15.62
Cl	4.39	(4.25- 4.55)	8.59	4.06
Tot.	99.52	(97.8 -100.15)		99.99

Madyarovo, Rhodope Mountains, Bulgaria (Breskovska et al. 1981)

	Mean value and range of 6 analyses (wt.%)		Number of atoms with (Pb+Ag+Sb) = 32	$Pb_{19}Sb_{13}S_{35}Cl_7$ (weight %)
Pb	56.50	(54.72-57.82)	19.06 } 32	57.14
Ag	0.04	(0.00- 0.16)	0.03 } 32	-
Sb	22.48	(21.10-24.40)	12.91 } 32	22.97
S	15.56	(14.93-16.78)	33.96	16.29
Cl	3.78	(3.02- 4.16)	7.46	3.60
Tot.	98.36	(97.98-99.52)		100.00

Breskovska *et al.* (1981) observed a variation in the composition of the Bulgarian ardaite in the range of $Pb_{20-18}Sb_{12-14}S_{34-36}Cl_{8-6}$, with an ideal formula of $Pb_{19}Sb_{13}S_{35}Cl_7$ (Table 1); the Gruvåsen material has a high Pb and low Sb composition in this range.

Origin

Moëlo (1979) assumed that the formation of chlorine-sulfosalts is the result of a reaction in a nearly closed system between lead–antimony ore and highly chlorinated solutions that may be present during the late stages of mineralization. For the Långban ores, which are situated close to Gruvåsen, Boström *et al.* (1979) proposed an exhalative sedimentary origin in which the brine environment saturated the primitive sulfide deposits with halogens. Subsequent folding and metamorphic events caused recrystallization of the ores and mobilization of halogen- and sulfide-rich materials; these intruded the Fe and Mn ores, causing the formation of oxyhalogen compounds and veins of various reduced minerals. Such oxyhalogen compounds (hematophanite, blixite, mendipite, nadorite, perite, sundiusite) have been described (Moore 1970, Dunn & Rouse 1980) from several deposits in the Bergslagen province: Långban, Jakobsberg, Harstigen.

The formation of minor amounts of Sb-bearing minerals in the Gruvåsen ores is attributed to remobilization of pre-existing sulfides of volcanosedimentary origin, probably by hydrothermal solutions associated with the Filipstad granite, which is postorogenic in relation to the Svecofennian folding. Galena from the Dressfall mine in the Gruvåsen field contains up to 0.1 wt. % Sb and 0.1 wt. % Ag, but in assemblages containing Sb and Ag minerals (pyrargyrite, native silver and antimony, nisbite) both Sb and Ag contents of galena are below the detection limit (0.02 wt. %). This suggests that the Sb and Ag minerals were formed at the expense of trace elements liberated from galena during the remobilization. The ardaite was probably formed by a similar reaction of halogen-rich solutions with remobilized Sb-bearing galena.

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