

SVERIGES GEOLOGISKA UNDERSÖKNING

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NILS SUNDIUS, ALEXANDER PARWEL
AND BENITA RAJANDI

THE MINERALS OF THE SILVER MINES
OF HÄLLEFORS



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CONTENTS

	Page
Abstract	4
Introduction	5
The Eastern silver mine	6
Knebelite	9
Grünerite	9
Garnet	9
Biotite	10
Pyrosmalithe	10
Magnetite	10
Cassiterite	10
Graphite	12
Pyrrhotite	12
Arsenopyrite	12
Sphalerite	12
Chaleopyrite	12
Galena	13
Carbonate	13
The Western mines	14
The zinc-ores	16
Amesite	16
Boulangerite	18
Discussion	18
Acknowledgements	20
References	20

ABSTRACT

A renewed study of the silver mines of Hällefors has revealed that the lead ore once mined was surprisingly high in SnO_2 . Cassiterite is also present in considerable amounts in the dark ore-bearing carbonate rock in the Eastern silver mine. Besides the Grängesberg apatite ore this is the greatest supply of tin known in Sweden. The carbonate in the black ore bearing stone in the Eastern mine is an oligonite with more than 60 per cent MnCO_3 and about 21 per cent FeCO_3 . The rock seems to be the most Mn-rich carbonate stone in Sweden. Besides the common sulphides, boulangerite occurred in in considerable amounts and other minerals include pyrosmalithe and amesite.

INTRODUCTION

The silver mines are situated about 8 km north of Hällefors village and about 210 km WNW of Stockholm. The mines are of two kinds. In the middle and western fields — hereafter called the western mines — sulphide minerals are found along fissures in a hard, dark hälleflinta which shows no or only slight changes. In the eastern field the ore occurred in a peculiar black rock, previously called skarn but in reality a carbonate stone rich in magnetite and pyrrhotite (fig. 1—4).

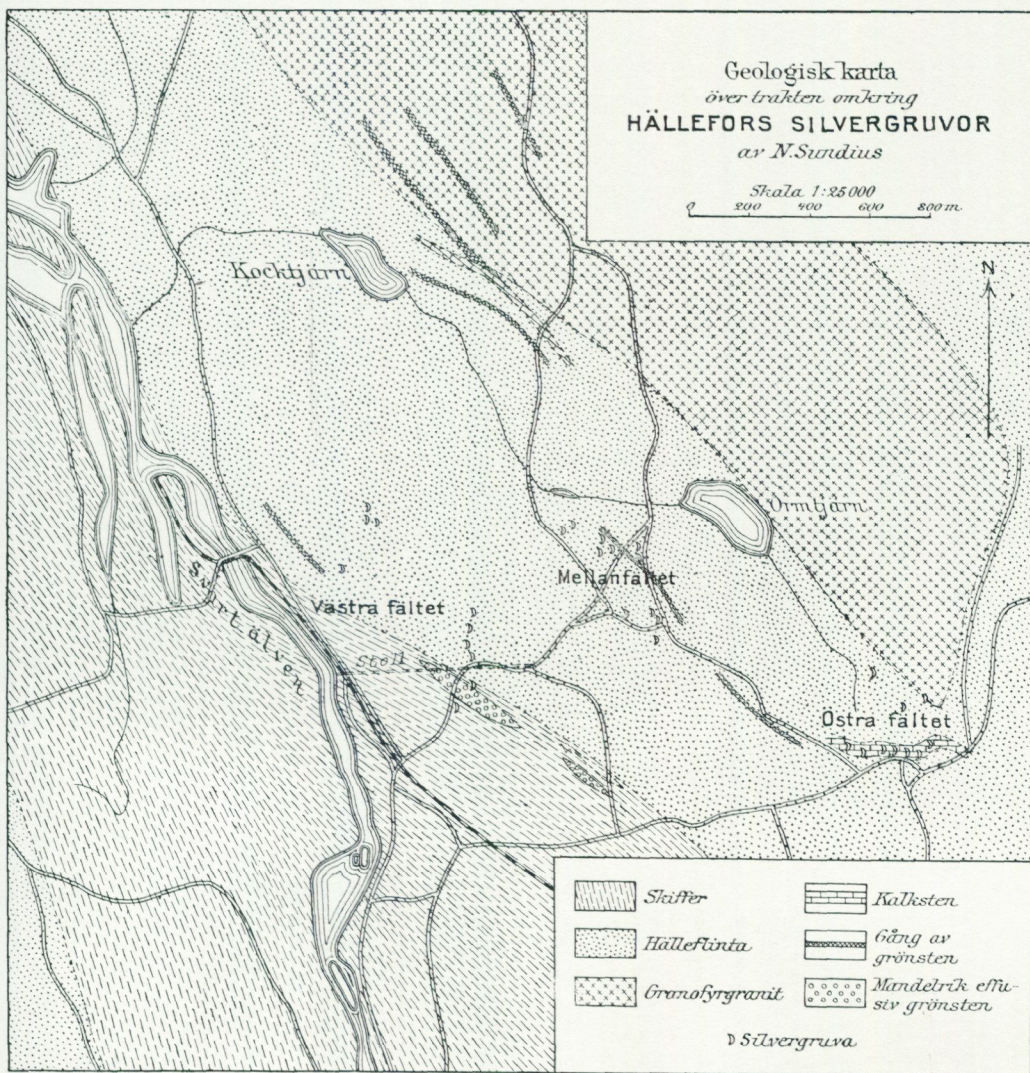


Fig. 1. The silver mines of Hällefors. Skiffer = schist, Kalksten = limestone, Hälleflinta = hällflint, Gång av grönsten = dike of greenstone, Granofygranit = granophyric granite, Mandelrik effusiv grönsten = amygdaloid effusive greenstone, Silvergruva = silver mine.

The first mining was performed in the eastern silver mine where during the years 1635—1726 ten small mines were in operation, partly united to one open pit. The first of the western mines, S:t Eriksgruvan, was discovered in 1668. Mining continued in the western mines until 1896. The Jan Olofs and Alfrida mines in the eastern field were opened in the 1880's.²⁾

No figures are available about the production from the eastern mine but it must have been considerable. For the years 1878—1896 it is reported that 4.493 tons of graded ore were produced from the western mines. The production of silver in the years 1639—1852 was 15 tons and of lead in the years 1843—1874 36.8 tons. Two analyses of average samples of ore produced in 1892, from the "western and eastern mines" are reported below. The eastern mines may here refer to the eastern members of the fissure ores.

The western mines		The eastern mines
PbO	38.90	31.65
Zn	12.76	3.48
Fe ₂ O ₂	9.98	—
Al ₂ O ₃	0.31	—
MnO	0.31	7.25
Cu	Tr.	Tr.
Sb	0.285	—
Ag	0.156	0.098

According to these figures the content of Ag was higher in the westernmost ores.

The geological and to some extent the mineralogical relations of the silver mines of Hällefors have been described (in Swedish) by N. Sundius (1923). The reason for a reexamination of the mines is the discovery of cassiterite in the black carbonate rock in the eastern mine. A sample of the rock was originally examined spectrographically for Ba but while negative as regards this element a surprisingly high content of SnO₂ (1.1 %) was found.

The eastern Silver mine

The mine consists of a complex of openings about 150 m long and 20—30 m wide that for the most part are united by the workings. The strike is WNW—ESE. In the continuation to the WNW two smaller mines, the Alfrida and the Jan Olovs mines were later opened. The eastern mine is situated in the black carbonate rock mentioned above. This rock forms a zone about 60 m in width and is known to 95 m depth where its breadth has diminished to 5 m. The black rock is not quite homogeneous but contains isolated lumps of a dense yellow grey carbonate stone that represent less completely changed parts of the original limestone. The black rock lies in a limestone and has been formed through

²⁾ A more detailed history of the mines is found in F. Tegengren (1924).

metasomatic changes of the limestone along a zone parallel to its strike. Whether the black rock continues to the Alfrida and Jan Olofs mines is uncertain as its real dimensions are not well known. Dikes of a white and very pure fine grained limestone are reported and can be seen in the eastern mine as walls between smaller openings. They are the youngest rocks.

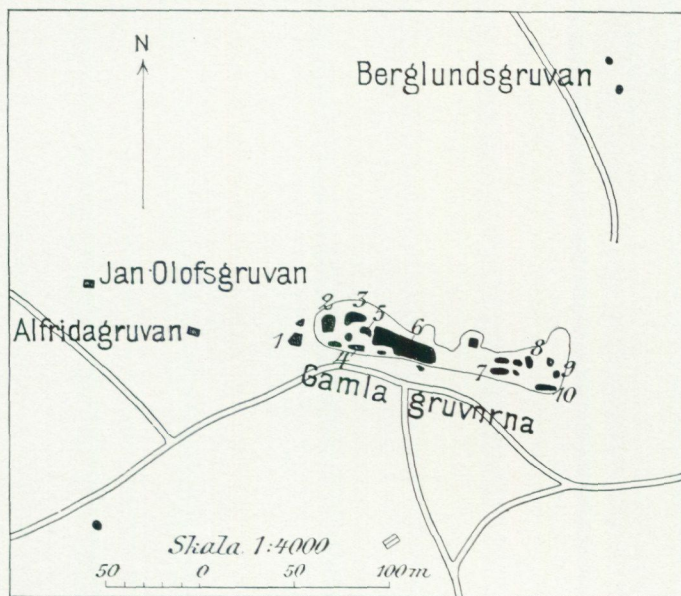


Fig. 2. Map of the Eastern silver mine.

The black rock has a peculiar consistency. To the naked eye it appears medium grained with a high lustre on the cleavage faces of the carbonate. The content of silicates is generally low but locally it is a skarn. The black colour is caused by abundant magnetite, partly distributed as fine grains in the carbonate but for the most part forming a network between the carbonate individuals. Magnetite occurs together with pyrrhotite. The latter is distributed in a similar way and may occur in rather large amount.

An analysis by G. Assarsson of the yellowish grey relics in the black rock gave the following result.

Undiss. in HCl	11.77 %	CO ₂	37.64 %
Fe ₂ O ₃	1.82 "	S	—
FeO	7.83 "	CuO	0.10 "
MnO	5.94 "	ZnO	Tr
MgO	7.48 "	PbO	—
CaO	27.56 "		<hr/>
			100.14 "

A spectrographic test of a similar rock showed only traces of Sn. The rock is a dolomitic limestone rich in Mn- and Fe-carbonate. The silicates in it are colourless grünerite and green actinolite. Two analyses have been published by Sundius (1923).

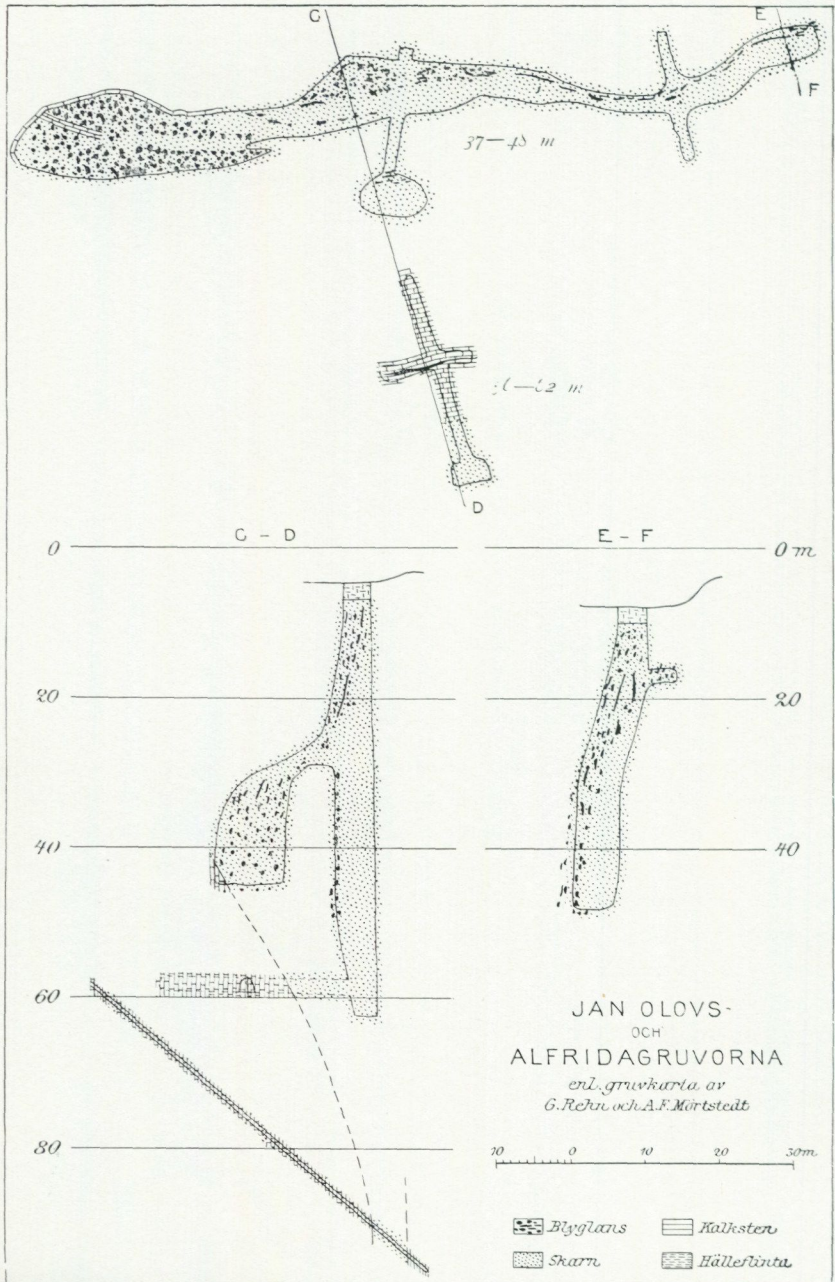


Fig. 3. Horizontal and vertical sections through the Eastern silver mine of Hällefors.

An analysis by G. Assarsson of a specimen of the black rock is referred to below. Before the analysis most of the magnetite, about 20 % of the rock, had been separated out with a magnet.

Undiss. in HCl	27.73	CO ₂	26.12
Fe ₂ O ₃	2.20	S	0.80
FeO	11.04	ZnO	Tr
MnO	26.02	PbO	1.33
MgO	2.95		<hr/>
CaO	1.81		100.32 ¹⁾

¹⁾ Herein 0.20 SiO₂ and 0.12 Al₂O₃ dissolved in HCl.

A spectrographical test of the trace elements made on material from two other specimens gave the following result.

SnO ₂	—	1.1	%	Mo	—	0.001	%
PbO	—	0.9	"	W	—	0	"
ZnO	—	1.2	"	Sb	—	Tr.	"
Ag	—	0.01	"	Bi	}	0.001	"
TiO ₂	—	0.013	"	Cr			
Cu	—	0.01	"	Co	}	0.001	"

But the relations vary. The average for a large number of samples was as follows.

SnO ₂	0.06	%
PbO	0.9	"
ZnO	2.0	"
Ag ₂ O	0.01	"
CuO	0.017	"

The following minerals have been found in the black carbonate rock.

KNEBELITE. Colourless small grains generally assembled in aggregates. $2V_{\alpha}$ about 52—55°. The knebelite is often changed to grünerite, more seldom to a brown red serpentine.

GRÜNERITE. Generally the amphibole is colourless and developed as fine needles or clusters of needles. It may originate by alteration of knebelite. A reddish amphibol can also occur as larger homogeneous grains. This is also a grünerite but somewhat richer in FeO and MnO. This amphibole may be primary. The refraction of γ is about 1.661 in the white and 1.665 in the red. A spectrographic test on isolated red amphibole gave Pb-traces, Sn—0.1, Bi-traces, Ag—0.001, Zn—0.1—1.0, Ga—0.01, Sr—0.001. Of interest is the high Zn-content. Further tests for SnO₂ on material from two specimens showed 0.16 and 0.4 %. The material was carefully examined under a microscope and found to be free of cassiterite. The Sn is, therefore, present in amphibole. No earlier instance of an Sn-bearing amphibole is known to the writers.

GARNET. It forms rounded red grains about 0.2—0.6 mm in diameter, often with crystal faces. Under the microscope they often show a weak double refraction.

The garnet is partly altered to dense colourless masses, probably mica. Unusually large crystals from a nodule of garnet, gave the following values:

SiO ₂	36.42	6.070	} 6.096	Spec.gravity	4.081
TiO ₂	0.21	26			
Al ₂ O ₃	18.45	1.809	} 2.034		
Fe ₂ O ₃	3.60	225			
FeO	8.04	1.117	} 6.021		
MnO	29.97	4.221			
MgO	0.58	145			
CaO	3.01	538			
	<u>100.28</u>				

From this the garnet contains about 69.7 per cent spessartine, 9.1 % andradite, 18.5 almandine and about 2 per cent pyrope.

Two samples — the first of them from the same garnet nodule that had been analysed — were tested for Sn and gave SnO₂ = 0.04 and 0.23 %. As the grain of the garnet is rather coarse the absence of cassiterite in the analysed material could be controlled the tin therefore enters in the garnet. Tin-bearing garnets have been reported by several authors. V. Dadák and F. Novák (1965) describe an andradite from the Plavno mine, Bohemia with 1.07 % SnO₂ and refer to analyses by M. Saksela from Pitkäranta with 0.32—1.44 per cent and older authors who found 0.0103 to 0.13 per cent in grossular-andradite from different localities.

BIOTITE. Mica in the form of light green biotite is common but its amount is restricted. It is often changed to a deep green chlorite.

PYROSMALITHE H₇(FeMn)₅Si₄O₁₆Cl. This rare mineral has only been found in the garnet nodule named above. It forms a dark green-brown mass between the garnet crystals. It is uniaxial, optically negative and has one cleavage at right angle to the opt. axis. Refraction and double refraction are rather strong. An X-ray film showed the reflexions typical for the relevant mineral. Pyrosmalithe is earlier known from Nordmarken and Dannemora. A related mineral, ekmanite, containing more MgO and OH instead of Cl has been found in the skarn from the Brunsjö mine about 18 km south of Hällefors (Sundius 1923, p. 305). The mode of occurrence of the pyrosmalithe suggests it was formed during a late stage of the mineralization.

MAGNETITE forms about 20 to 25 % of the whole rock. A spectrographic test on carefully selected material showed 0.58 % MnO and 0.025 % SnO₂.

The **CASSITERITE** is always developed as small grains with a diameter of about 0.1 mm or less, rarely somewhat larger. The small dimensions of the grains and the generally few number of them in the slides make it easy to overlook them. When the analysis of the rock is made with HCl-extraction the cassiterite remains in the undissolved part and will not be found if not specially searched for. The grains are dark brown, in thin slides yellow-brown, with a colourless outer zone of varying width. Sometimes they show a quadratic outline. Cassiterite seems to be present everywhere in the black carbonate rock but its distribution is irregular. In



Fig. 4. Accumulation of cassiterite grains in the black carbonate stone seen in a slide. 12x. Grey = cassiterite, black = magnetite, white = carbonate.

five of six thin slides only a few grains were found but in the sixth they are more numerous and also a rich assemblage of grains was present (fig. 4). A test on material from two specimens gave 1.7 % SnO_2 and further tests on isolated samples gave 0.04–0.65 %. As named in the introduction a mean sample from a great number of specimens gave 0.06 % SnO_2 and this seems to be a reasonable figure for the whole rock.

A spectrographic analysis of the cassiterite showed Pb—0.07, Be—traces, Sb—0.01, W—0.12, Ag—0.003 to 0.01, Mo—0.001, Zn—0.01, Ti—0.13, Fe—0.25, Mn—0.05.

Cassiterite was long known in Sweden only as isolated crystals in pegmatites (Utö, Finnbo, Varuträsk). The presence of Sn was discovered spectrographically by S. Landegren (1943) in the iron ore at Grängesberg. He accepts about 0.02 to 0.04 % as a mean value for the ores and supposes the Sn to be in the form of cassiterite. The analyses from the silver mines at Hällefors show that we have had a significant amount of tin in the ores, and in the ore bearing black carbonate rock in the eastern mine the metal is still found. In Norway F. M. Vokes (1960 and 1963) has described cassiterite from a pyritic lead-zinc ore at Bleikvassli south of Mo i Rana. The mode of occurrence of SnO_2 seems to be rather similar to that in the eastern

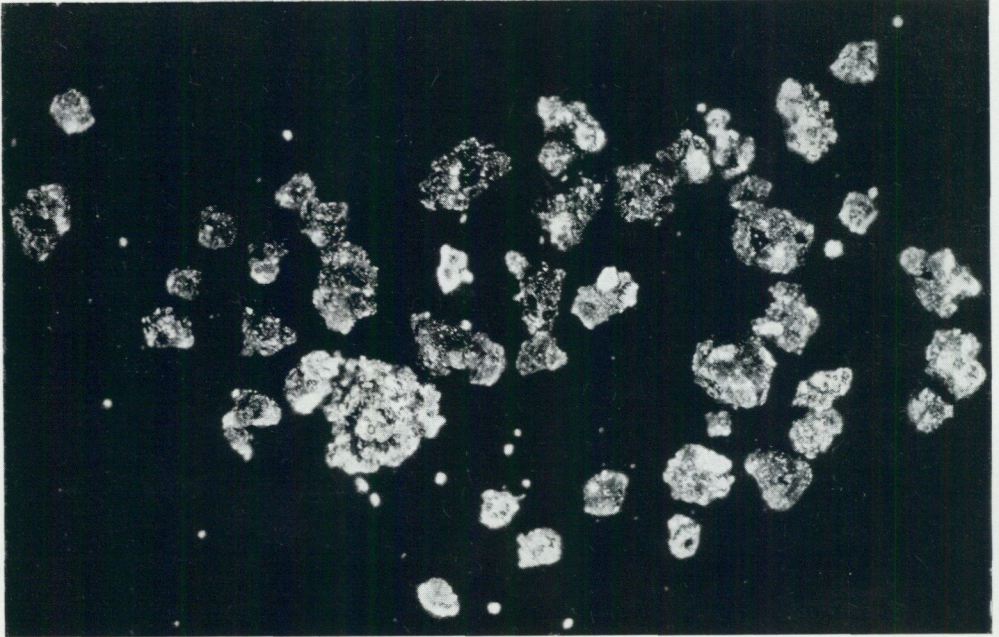


Fig. 5. Cassiterite grains isolated from the black carbonate stone. 27x.

silver mine at Hällefors. As a fair average for the SnO_2 -content in the ore he gives 0.04 per cent. Further references are given by him to similar occurrences in British Columbia and New Brunswick.

GRAPHITE has been observed in powders of the black rock but its amount is insignificant.

PYRRHOTITE is a common constituent of the black carbonate rock but its amount is smaller than that of magnetite. It has the same mode of distribution as the latter. PYRITE is sparse.

ARSENOPYRITE is common and rather abundant. It forms well developed crystals in the garnet-nodule described, otherwise the grains are anhedral. A spectrographic test of selected material gave $\text{Ag} = 0.03$ and $\text{SnO}_2 = 0.5\%$.

SPHALERITE is also a common mineral in the rock and its amount is greater than that of arsenopyrite but less than that of pyrrhotite. It has an irregular distribution. In two out of six slides ZnS is rather abundant. It partly forms small grains in the magnetite-pyrrhotite aggregates, partly occurs as larger spots enclosing silicates and other ore minerals. No spectrographic test could be made on sphalerite on account of the difficulty of separating it out.

CHALCOPYRITE. Small amounts of Cu are reported in the analyses and in spectrographic tests of the black carbonate rock. They may arise from chalcopyrite but this sulphide is seldom seen in the specimens. The content of Cu is therefore subordinate.

Carbonate, Hällefors
 $a = 4.77$, $c = 15.40$

TABLE I
 Oligonite, Hungary
 $a = 4.713$, $c = 15.45$, $a_{rh} = 5.831$

	d in Å	I	d in Å	I
$10\bar{1}1$	4.10	1		
$10\bar{1}2$	3.61	5	3.603	6
$10\bar{1}4$	2.823	10	2.798	10
0006	2.590	2	2.568	1
$11\bar{2}0$	2.366	5	2.345	7
$11\bar{2}3$	2.151	7	2.138	8
$20\bar{2}2$	1.981	6	1.961	8
$02\bar{2}4$	1.814	3	1.802	5
$11\bar{2}6$	1.751	8—9	1.741	10
$21\bar{3}1$	1.543	2	1.532	3
$12\bar{3}2$	1.520	4	1.513	6
$21\bar{3}4$	1.440	3	1.433	6
$20\bar{2}8$	1.410	2	1.430	4
$12\bar{3}5$; $11\bar{2}9$	1.395	2	1.384	4
$30\bar{3}0$	1.368	4	1.360	7
$0 \cdot 0 \cdot 0 \cdot 12$	1.297	3	1.288	5
$12\bar{3}7$	1.274	1	1.266	2
$0 \cdot 2 \cdot \bar{2} \cdot 10$	1.241	2	1.232	5
$30\bar{3}6$; $12\bar{3}8$	1.2128	3	1.205	6
$22\bar{4}0$	1.1867		1.1791	3

The western mines

The ore was here deposited in fissures with a NNE—SSW or N—S trend and about perpendicular to the strike of the hälleflint layers or at a high angle with them. The hälleflinta of the host rock has not generally been altered and, when some change is seen, dense grey yellow masses and veinlets of sericite and calcite are developed. Both ore and hälleflinta are sometimes cut by a calcitic white limestone that can contain sparse ore minerals. This limestone also belongs to the last phase of the mineralization and is equivalent to the calcite dykes in the eastern mine. The characteristic gangue minerals in the ores were quartz and subordinate calcite. Quartz crystals have generally lined the walls of fissures and one often finds veins of barren quartz. In veins of this kind crystals of calcite, apophyllite, fluorspar and pyrrhotite have been observed. On the other hand no skarn was formed during the deposition of the ores. Sparse grains of garnet, and in rare cases a small amount grünerite, are the only traces of silicates.

From the mining relations the ore occurred as veinfillings without the minerals showing any symmetrical distribution. The ore formed veins locally up to 20—30

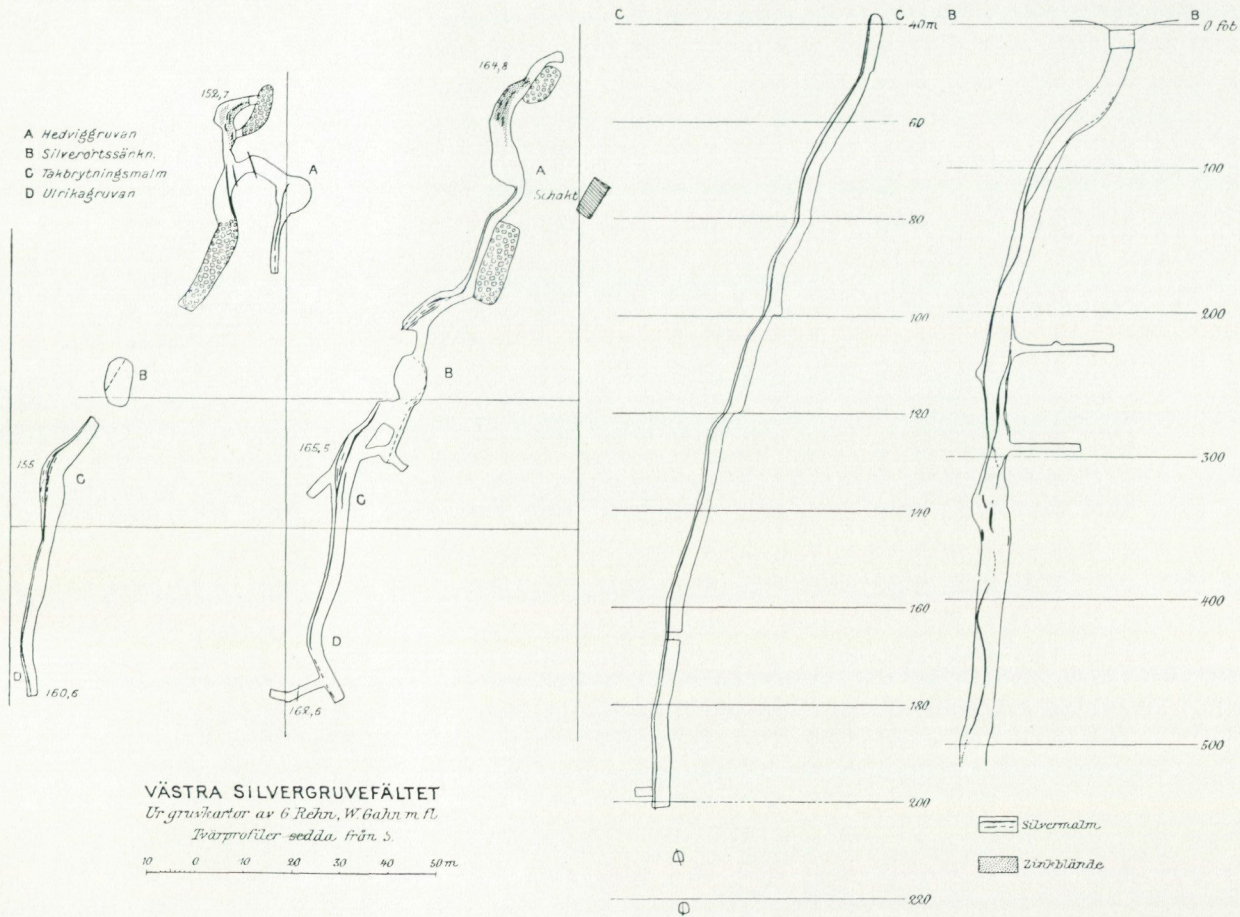


Fig. 6. Horizontal and vertical sections through mines in the Western mining field of Hallerfors.

cm in thickness and in some cases persisting to a depth of 147—200 m. The ore minerals were galena and sphalerite and seem to have been present as separate bodies. Chalcopyrite was sparse and pyrite subordinate. Arsenopyrite seems to have been common and boulangerite occurred. The latter two minerals, together with quartz, are also present in specimens from the Jan Olovs mine. The presence of quartz makes it unprobably that the ore here is to be regarded as an easterly type deposited in a carbonate rock.

The content of Ag in the galena ore is said to have been highest in the western-most mines.

Cassiterite is present in all specimens of galena ore tested. In four specimens from different mines the content of SnO_2 was 0.01 to 0.025 % but in a fifth it was found to be 1.7 %. The distribution of the cassiterite was irregular here also.

THE ZINC-ORES. In the Eastern mine sphalerite is common as small accumulations in the black carbonate stone. Its mode of occurrence indicates that it is a late crystallisation product. It is not known if larger, homogeneous accumulations of sphalerite occurred as the mine was in operation at an early date. In the Western mines ZnS was rather well differentiated from the galena and formed separate bodies. Probably this is due to the late crystallisation of the sphalerite. Besides compact ores, sphalerite is also found in thin fissures in the wall-rock that are bordered with quartz crystals and contain ZnS in their interior. The sphalerite is here relatively coarse-grained. In the ore bodies it seems to have been of a fine grain.

Two specimens were at our disposal. One may originate from a small fissure in the western field. The sphalerite here is of medium grain size and when dissolved in acids left only a quartz residue. The other specimen is fine grained and contains scattered light green crystals visible to the naked eye. Whether this specimen originates from one of the Western ores or from the Eastern mine is not known. The locality given on the label is "Silvergruvan, Hällefors". A spectrographic test for Sn on the ore showed only 0.001 %. A similar test on arsenopyrite from the Zn-ore showed 0.003 % Sn. The arsenopyrite contains only 0.01 % Ag. It is of interest that Sn has faithfully followed the galena ores but is practically absent in the zinc ore. When the Zn-ore was dissolved with HCl a rather large residue of arsenopyrite and a light green mineral remained behind. The latter has been shown to be the rare mineral AMESITE, a Mg-chlorite. The mineral occurs as tabular or thick prismatic crystals, hexagonal in outline and about one or a few millimetres in diameter. No grains of quartz were seen in the residue and this favours the assumption that the specimen originates from the Eastern mine.

Amesite has previously only been reported from Chester, Massachusetts and from the Saranovskoye chromite deposit in the northern Urals. The amesite from the silver mines i Hällefors is rather similar to both these but is purer in FeO. Amesite has also been produced artificially at 500° and 10 000 Psi H_2O by Nelson and Ray (1958).

CHEMICAL ANALYSES OF AMESITES

	Chester	Hällefors	
		Mol %	
SiO ₂	20.95	34.74	29.47
Al ₂ O ₃	35.21	15.80	7.89
FeO	8.28	3.15	2.22
MnO	tr	0.13	0.09
MgO	22.88	32.81	41.75
CaO	0.58	tr	
H ₂ O	13.02	13.13	18.58
	100.92	99.76	100.00

$D = 2.77$, $\alpha = \beta = 1.597$, $\gamma = 1.612$. $D = 2.65$ (± 0.02), $\alpha = 1.578$

Chester. Amesite anal. by F. V. Shannon, 1921, at J. V. Gruner (1944).

Hällefors. Amesite, anal. by A. Parwel, Swedish Museum of Natural History, Section for Mineralogy, Stockholm, 1966.

From this the molecular proportions of the Hällefors amesite are 3.74 SiO₂, Al₂O₃, 5.59 (MgFeMn)O, 2.36 H₂O.

TABLE II
X-RAY POWDER DATA FOR AMESITES

Chester a = 5.298, b = 9.177, c = 13.95		Hällefors		Artificial	
d in Å	I	d in Å	I	d in Å	I
		13.7	8		
6.93	8	7.0	10	7.08	100
4.529	1	4.680	10	4.62	80
		4.085	7	3.97	20
3.469	10	3.580	10	3.55	100
2.733	1	2.826	8	2.65	80
2.605	2	2.5675	6	2.59	60
2.467	6	2.5175	9	2.505	60
2.315	3	2.43	8	2.396	80
		2.3675	5		
		2.253	6	2.270	20
1.995	1	1.993	9	2.013	60
1.920	7			1.942	20
		1.8775	5	1.886	20
		1.8205	5		
		1.731	1	1.745	20
1.685	1			1.704	20
		1.6605	1	1.664	60
				1.617	40
1.596	3	1.5645	7	1.564	20
1.529	5	1.53	9	1.540	100
1.494	1	1.499	5	1.504	40
1.456	4	1.4565	1		
1.398	4	1.419	1	1.414	1
1.339	4	1.3635	7		
		1.34	5	1.326	
1.301	3	1.294	4	1.294	20
				1.130	5
				1.005	20
				0.995	20

BOULANGERITE. This mineral is known from Jan Olofs mine and Samuels mine in the Western field. At least, in the former mine its quantity was large. The boulangerite is mixed with arsenopyrite and quartz. The mineral was called boulangerite by Törnebohm but according to an analysis of R. Mauzelius it should be menighinite. The analysis is shown below:

Pb = 62.45	AG = tr
Cu = 1.21	S = 17.47
Fe = 0.07	Undis = 0.05
Sb = 18.94	100.19

According to an X-ray film the d-values correspond to those of boulangerite. A spectrographical test on pure separated material from Jan Olofs mine showed 0.2 % SnO_2 . Another powder from Samuels mine contained 0.02 % SnO_2 .

Discussion

The mineral composition of the ores and the black carbonate stone in the silver mines of Hällefors excludes the possibility of a sedimentary origin for the ore substances. The mineralization must be the result of metasomatic processes and the substances deposited may have arisen from hydrothermal solutions given off by some magma. Only 300 to 400 m to the north of the mines we have an intrusive body of a granophyric granite, the Silverknuts granite and the opinion has been set forth that the ore solutions originate from it. On the other hand this granite is extremely albitic and only at its northernmost end has potash feldspar been observed in it. Furthermore it is a general rule in the whole Grythytte district that Mn is restricted to the potashbearing hälleflintas and this holds good also for the silver mines of Hällefors. Another theory is that the ore forming solutions came from the magma from which the volcanic hälleflintas originated. In this case the ore formation took place at the close of the lava extrusions or on folding of the layers. As thin veins of ZnS have been observed in the bottom layers of the overlying slate, the ore formation had not occurred before the close of the volcanic activity. Previous authors have suggested that the lead ore belonged to a later epoch than the other minerals. This is not probable because of the widesprad distribution of galena in the black carbonate rock and on account of the similar contents of SnO_2 in the ores and the orebearing carbonate rock.

The ore-forming solutions first penetrated the carbonate layer along the zone of the dark carbonate rock and deposited here practically all their content of Mn-Fe-oxides, FeS and part of the other sulphides. If SiO_2 was present it entered the silicates of the carbonate rock. The rest of the solutions continued along fissures in the neighbouring hälleflintas and deposited the remaining sulphides and the small amount of silicate. In all these solutions Sn was present, probably in the form of colloidal SnO_2 .

The tin is not merely restricted to cassiterite. In the grünerite of the black carbonate stone 0.1 % SnO_2 was found spectrometrically. Here also 0.1—1 % Zn was found. Two selected materials of garnet contained 0.04 and 0.23 % SnO_2 . In magnetite and arsenopyrite 0.025 and 0.5 % SnO_2 were found. The content of Sn is very low, 0.001 %, only in the zink ore this may depend on the late crystallization of ZnS.

No minerals for determining the temperature of mineralization are available. The amesite (Mg-chlorite) and the pyrosmalithe are low temperature minerals but they belong to the close of the mineralization.

Of the sulphides, galena and sphalerite have been the most abundant. But arsenopyrite has played a great rôle and in the black carbonate stone pyrrhotite is abundant. The Sb-sulpho-mineral boulangerite occurred in significant amounts. Chalcopyrite was common but in small amounts.

In general the mineralization proceeded as follows. The original solution must have been alkaline or neutral and contained the metals Pb, Zn, Ag, As, Sb and part of Fe as colloids in the form of sulphides in order that they should be held in solution. The quantity of sulphur was not sufficient to form sulphides for the whole content of metals. Sn was in the form of $\text{SnO}_2 \times \text{H}_2\text{O}$ and all the Mn and the greater part of the Fe may have been present as hydroxyls. SiO_2 was present but its amount was relatively small.

When this solution came in contact with the limestone the relations changed. The flow may have been slower and cooling took place. This reduced the solubility and reactions with the limestone began. Part of the sulphides crystallized and practically all the iron sulphide as pyrrhotite. The SiO_2 present in the solution formed Fe- and Mn-rich skarn silicates and in the limestone existing tremolite was changed to similar silicates. Hydroxides of Fe and Mn reacted with CaCO_3 and formed iron and manganoan carbonate. Part of the Fe changed to Fe_3O_4 . As the newly formed dark rock was a carbonate it took CO_2 from the limestone and only a part of the CO_2 was set free. The surplus CaO may have been dissolved as $\text{Ca}(\text{OH})_2$ together with the released CaCO_3 forming together with CO_2 in the environs of the ore-bearing zone limestones of very pure CaCO_3 -composition now occurring as dykes in the neighbouring rock and also in the ore-bearing zone. However part of the $\text{Ca}(\text{OH})_2$ was transported further by the solutions that contained the remaining Pb-, Zn-, Cu-As-Sb-sulphides. This solution migrated further in the fissures in the hällflinta and on cooling deposited the western ores. On account of the content of $\text{Ca}(\text{OH})_2$ silica was dissolved from the hällflinta and was later on cooling deposited as a coating of quartz crystals on the fissures characteristic of the Western field. $\text{Ca}(\text{OH})_2$ united with CO_2 in the hällflintas and formed the white and pure limestone dikes with sparse ore minerals that represent the last phase of the ore-forming processes.

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