Canadian Mineralogist
Vol. 18, pp. 165-171 (1980)

COBALT MINERALS IN THE HÄLLEFORS AREA, BERGSLAGEN, SWEDEN: NEW OCCURRENCES OF COSTIBITE, PARACOSTIBITE, NISBITE AND COBALTIAN ULLMANNITE

M.A. ZAKRZEWSKI, E.A.J. BURKE AND H.W. NUGTEREN*
Institute of Earth Sciences, Free University, De Boelelaan 1085, 1801 HV Amsterdam, The Netherlands

Abstract

Costibite, paracostibite, nisbite and cobaltian ullmannite are found associated for the first time in the small Gruvåsen and Getön Pb–Zn–Cu–Ag deposits, western Bergslagen, central Sweden. A review of the Co minerals in the Bergslagen province is given. They were probably formed by remobilization of cobalt from older sulfides by hydrothermal solutions during emplacement of late orogenic or postorogenic granites.

Keywords: costibite, paracostibite, nisbite, cobaltian ullmannite, cobalt ores, electron-microprobe analysis, Bergslagen, Sweden.

Sommaire

A Gruvåsen et Geton, deux petits gisements de Pb–Zn–Cu–Ag situés dans le Bergslagen occidental (Suède centrale), on trouve pour la première fois l'association costibite, paracostibite, nisbite et ullmannite cobaltifère. Après réexamen des minéraux de cobalt du Bergslagen, nous proposons comme mécanisme génétique une remobilisation hydrothermale du Co de sulfures anciens pendant la mise en place de granites tardifs, voire post-orogéniques.

(Traduit par la Rédaction)

Mots-clés: costibite, paracostibite, nisbite, ullmannite cobaltifère, minerai de cobalt, analyse à la microsonde, Bergslagen, Suède.

Introduction

Investigations within the framework of a current project on the petrology and ore geology of the Hällefors area of central Sweden (Fig. 1) led to the discovery of the minerals costibite, paracostibite and nisbite in the Gruvåsen and Getön deposits, and of cobaltian ullmannite in the Getön deposit. These two mines are small Pb–Zn–Cu–Ag occurrences in western Bergslagen, a Precambrian metallogenic province. Bergslagen is well known for its more than 2,000 iron deposits and more than 200 base-metal deposits, predominantly of the polymetallic Ag–Pb–Zn(–Cu) type. The Falun, Sala, Garpenberg and Kaveltorp mines are representative of these sulfide deposits. Practically all ore deposits are connected with folded, metamorphosed volcanic rocks of rhyolitic composition (in Sweden called *hälleflintas* where finely crystalline, and *leptites* where more coarse grained). These rocks and the associated metasedimentary units were intruded and surrounded by granites of at least two generations during the 1800–2000 *Ma* Svecofennian folding. The geology of the Bergslagen province has been summarized by Magnusson (1970) and Grip (1978).

Cobalt ores were mined in this region as a by-product of the copper ores. Between 1807 and 1905 about 310 metric tons of metallic Co were extracted from seven mines (Fig. 1): the Gladhammar mine produced 89.6% of the total, Vena 8.7% and Tunaberg 1.3%; 0.4% came from the Håkansboda, Åtvidaberg, Los and Riddarhyttan mines (Tegengren 1924). Minor amounts of Co minerals were also found in several other polymetallic ore deposits.

Cobaltite is the main source of Co in all the mines mentioned above; it also occurs in small quantities in the Utö, Brodd and Ingelsby mines. "Smaltite–chloanthite" (= skutterudite) is described from Vena and Los, but Welin (1965) showed that the museum specimens from Los consist of cobaltite. Linnaeite is noted in Gladhammar, where it occurs with cobaltite, carrollite and bravoite, and in Riddarhyttan with cobaltite, skutterudite and several cerium minerals. Glaucodot is known from Håkansboda in large, perfect crystals that occur with cobaltite in Cu–Zn–Pb ores. Co-bearing arsenopyrite (7.9 wt. % Co) has been described from the Los mine (Welin 1965). Safflorite occurs in Tunaberg.

In connection with the presence of nisbite in

*Present address: U.N.D.P., B.P. 836, Yaoundé, Cameroun.

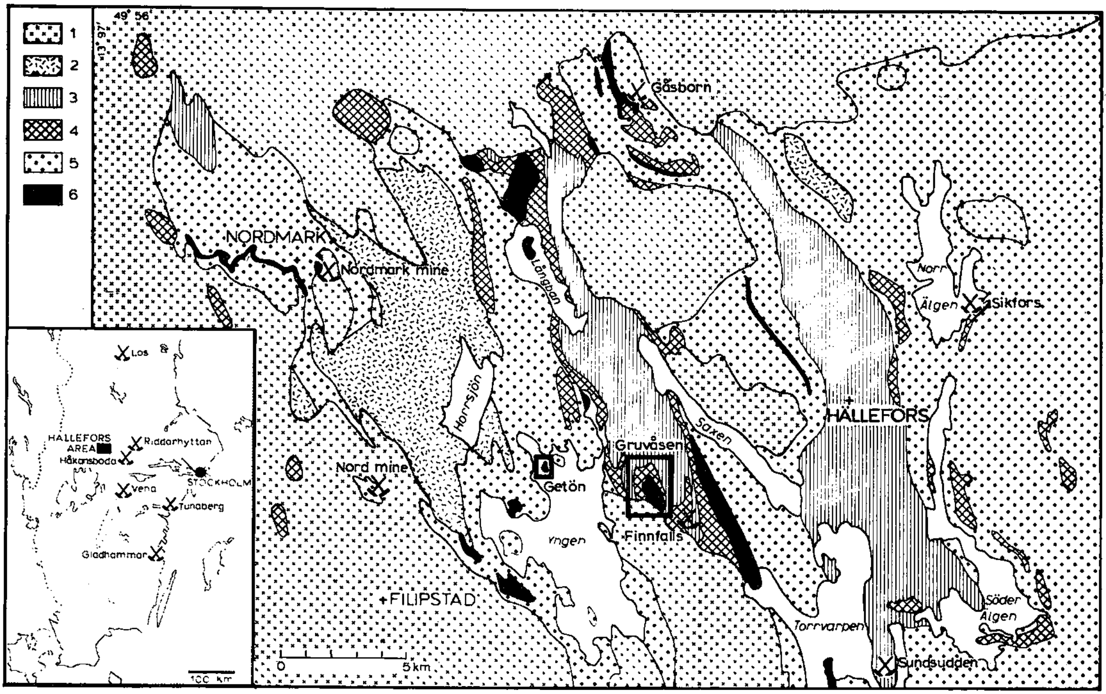


FIG. 1. Geological map of the Hällefors area, simplified after Magnusson (1925) and Sundius (1923), with location of examples of cobalt mineralization. Inset shows the location of cobalt-bearing deposits in central Sweden and situation of the Hällefors area. (1) Late orogenic and postorogenic granites, (2) Svecofennian synorogenic granites, (3) slates and greywackes, (4) greenstones, (5) leptites and hälleflintas, (6) limestones and dolomites.

the Hällefors area, it is interesting to note the Ni minerals of central Sweden. Breithauptite was found in Tunaberg (Ödman 1933) with rammelsbergite, nickeline, pentlandite, cobaltite and safflorite, in the Svärdsjö Zn–Pb–Cu mine with Ag, Bi and Mo minerals, and in Kaveltorp in Cu–Pb–Zn ores with Bi, Mo, Ag, Au and As minerals. Gersdorffite occurs in the Los mine, and nickeline in Sala. Pentlandite is the common mineral in Ni mines, where it occurs with pyrrhotite and chalcopyrite.

Co MINERALIZATIONS IN THE HÄLLEFORS AREA

The discovery of the CoSbS phases in the Getön and Gruvåsen mines started a search for Co minerals in about 80 other base-metal deposits in the Hällefors area. Cobalt minerals were found in only six deposits, in addition to two other localities (Nordmark and Gåsborn) described by Magnusson (1925). Their locations are marked on the geological map (Fig. 1). All these Co mineralizations are small and without any economic value, but they constitute an important phenomenon in discussions of genesis in the Bergslagen district. Table 1 presents a summary of the ore-mineral parageneses of these deposits.

The Getön mine (Fig. 2) is situated on a small island 8 km east of Filipstad in the western flank of the Saxå syncline. A magnetite-bearing skarn was developed between the dolomite and leptite units that form the border of a central limestone dome. The sulfides either occur in the magnetite ore or form separate bodies. A cordierite–gedrite quartzite accompanies the magnetite and sulfide ores in the northern part of the island. This ore-bearing quartzite, which also occurs in other Bergslagen sulfide deposits, can be compared with a similar unit in the Falun mine. Production started in 1740, initially for iron and later for Cu, Pb and Ag. During short periods of activity before 1918, about 50,000 tons of magnetite ore were extracted, along with ores containing 650 tons of Pb, 50 tons of Cu and 400 kg of Ag. As the dumps from the last period of production are relatively rich in sphalerite, it is probable that 300–600 tons of Zn were also present in the sulfidic ores.

The Gruvåsen deposit (Fig. 3) is located about 4 km east of Getön in the Saxå syncline, which involves slates, greywackes, greenstones, dolomites and limestones surrounded by leptites. The mineralization occurs in the dolomites flanked by sterile limestones, suggesting that the carbonates form a local anticline (Magnusson 1925). The anticline is truncated to the south by post-Svecofennian granites (1700 *Ma*: Welin *et al.* 1977). Ore was excavated from seven mines during the sixteenth and seventeenth centuries; more recent exploitation took place from 1906 to 1917, and numerous pits and dumps are still in evidence from this operation. The estimated production was about 500 tons of Pb:Zn:Cu in the proportion 11:9:1. The richest deposit was the Lång mine in the central part of the carbonate dome. Judging by the location of the dumps, it is assumed that the central storage point of the ores was close to the northern shaft, the Kung Karla mine. There are two types of ore: (1) massive sphalerite with pyrrhotite, chalcopyrite and galena and (2) light-colored diopside skarn with rich disseminations of chalcopyrite, molybdenite and native bismuth.

The Finnfalls mine is a small excavation 2 km south of Gruvåsen. About 250 tons of Cu ore were produced, of two types: (1) rich disseminations of pyrrhotite and chalcopyrite in greenstone and (2) disseminations with native bismuth, molybdenite and chalcopyrite, mineralogically very similar to the Gruvåsen mine (Table 1). The trace-element contents of galena and sphalerite from both localities are also very similar.

The Nord iron mine occurs in the Finnshytteberg field, 4 km north of Filipstad. The iron ores occur in skarns and leptite rocks surrounded by the Filipstad granite. According to Magnusson (1925) the ore consists of magnetite with accessory pyrrhotite and pyrite; the most interesting feature, however, is the occurrence of native bismuth. The latter mineral was found in samples from the dumps, as microscopic inclusions in a Co mineralization containing cobaltite, cobaltian pyrite, linnaeite–corrollite and clinosafflorite (Burke & Zakrzewski *in prep.*).

In the Nordmark mine sulfides occur as disseminations in the Mn-bearing carbonate dome associated with the main magnetite skarn ores. The ore minerals, as described by Magnusson (1925), are listed in Table 1.

In the Gåsborn mine a small cobaltite and bismuthinite mineralization was noticed by Magnusson (1925) in the magnetite ores of the Anders Pers shaft. In Sundsudden, a small manganese mine, disseminated cobaltite was discovered by S. Maesschalck (pers. comm. 1979). The geology of the Sikfors mine resembles that of the Finnfalls mine. Cobaltite and skutterudite are associated with pyrite, pyrrhotite and chalcopyrite, which occur together with quartz, chlorite and calcite in greenstone and in fine-grained leptite.

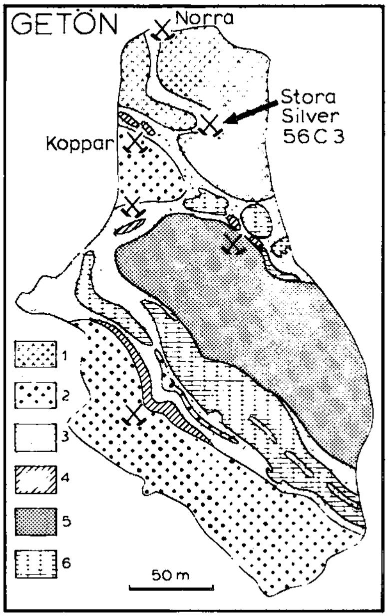
TABLE 1. ORE MINERAL ASSEMBLAGES IN CO-BEARING MINERALIZATION, HÄLLEFORS AREA

Mineral	1	2	3	4	5	6	7	8	9	10	11
Gold							+				
Silver	+	+	+				+				
Allargentum	+										
Bismuth	+	+			+	+		+		+	
Antimony				+							
Galena	+	+	+	+	+		+				+
Selenian galena	+					+					
Sphalerite	+	+	+	+	+	+	+	+		+	+
Wurtzite							+				
Troilite	+	+									
Pyrrhotite	+	+	+	+	+	+	+	+	+	+	+
Pyrite		+		+	+		+	+		+	+
Marcasite	+	+						+			+
Mackinawite	+				+	+					
Cubanite	+	+			+	+					
Chalcopyrite	+	+	+	+	+	+	+	+	+	+	+
Covellite	+	+								+	
Stannite	+	+	+								
Acanthite	+	+					+				
Hessite	+					+					
Tetradymite							+				
Bismuthinite	+				+		+		+	+	
Molybdenite	+	+		+	+	+	+	+		+	
Arsenopyrite		+	+		+		+	+		+	
Gudmundite		+									
Cobaltite	+					+	+	+	+	+	+
Gersdorffite				+							
Costibite	+			+							
Paracostibite	+			+							
Cobaltian ullmannite				+							
Nisbite			+	+							
Breithauptite		+									
Nickeline							+				
Skutterudite										+	
Safflorite							+	+			
Tetrahedrite		+									
Pyrargyrite	+	+	+								
Pb-Sb-sulfosalt			+								
Bi-sulfosalt	+										
Cosalite							+				
Galenobismutite							+				
Magnetite		+	+	+	+		+	+	+	+	
Hematite		+			+			+			
Ilmenite	+	+		+					+	+	+
Rutile	+										+
Goethite	+	+	+					+		+	
Cassiterite	+	+									
Scheelite			+				+				

1. Gruvåsen, Lång mine (spec. 12f); 2. Gruvåsen, Torskebäck mine; 3. Gruvåsen, Dresfall mine; 4. Getön, Stora Silver mine (spec. 56C3); 5. Getön, Koppar + Norra mine; 6. Finnfalls; 7. Nordmark (Magnusson, 1925); 8. Nord mine; 9. Gåsborn (Magnusson, 1925); 10. Sikfors; 11. Sundsudden (S. Maesschalck, pers. comm.).

Description of (Co,Ni)–Sb–S Phases

Costibite has previously been described from Broken Hill, New South Wales, Australia (Cabri *et al.* 1970b), paracostibite from the Red Lake area, Ontario (Cabri *et al.* 1970c) and from the Guangdong province, China (Anonymous 1976), nisbite also from the Red Lake area (Cabri *et al.* 1970c) and from the Festivalnoe Cu–Sn mine in the Magadan district,



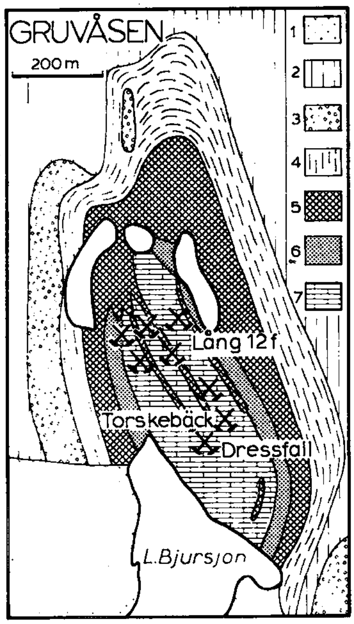


FIG. 2. Geological map of Getön island (after Magnusson 1925) and location of mines. (1) Cordierite–gedrite quartzite, (2) leptite, (3) skarn, (4) iron ore, (5) limestone, (6) dolomite.

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

U.S.S.R. (Kachalovskaya & Kukoev 1973), and cobaltian ullmannite from Broken Hill (Cabri *et al.* 1970a) and from Espeland, Norway (Naik *et al.* 1976). The present study reports the first occurrence in which the four minerals are found together.

The small grain-size and the fine intergrowths shown by these minerals prohibited the extraction of powder for X-ray-diffraction patterns; thus, the identification of the (Co,Ni)–Sb–S phases is based on electron-microprobe analyses (Table 2) and on the comparison of their optical properties with those described by Cabri *et al.* (1970a, b, c). Electron-microprobe analyses were performed with a Cambridge Instruments Geoscan (equipped with a LINK energy-dispersive system) and Microscan 9. Natural and synthetic compounds were used as standards. Apparent concentrations were ZAF-corrected with a modified Springer (1967) program and with the Microscan 9 on-line ZAF program.

TABLE 2. ELECTRON-MICROPROBE ANALYSES OF Co- AND Ni-MINERALS FROM THE HÄLLEFORS AREA

Spec.	Mineral	Co	Ni	Fe	Sb	As	S	Total
37A	Cobaltite	31.2	1.2	2.4	-	47.7	19.3	101.8
622E	Cobaltite	27.7	4.2	2.5	-	44.8	19.2	98.4
12J5	Nisbite	-	17.9	-	74.2	-	-	92.1*
37A	Skutterudite	18.6	0.9	1.1	-	77.9	-	98.5
56C3	Cobaltian ullmannite	11.0	14.4	2.3	52.7	-	15.7	99.3**
56C3	Costibite	25.6	2.4	0.8	56.8	0.3	14.7	100.6
12f	Costibite	24.2	2.3	2.0	55.0	0.3	15.0	98.8
12f	Costibite	25.6	1.8	0.6	56.6	0.3	14.4	99.3
12f	Costibite	25.9	1.6	0.3	56.1	0.4	14.6	98.9
12f	Paracostibite	23.2	3.1	1.5	56.1	0.2	14.5	98.6

* semi-quantitative analysis; low total due to small grain size
** includes 3.2 wt. % Pb from adjacent galena
analyses are reported in weight %.
37A - Sikfors; 622E - Sundsudden; 12J5 - Gruvåsen, Dressfalls mine; 56C3 - Getön, Stora Silver mine; 12f - Gruvåsen, Lång mine.

In the Gruvåsen deposit, intergrowths of costibite and paracostibite (Figs. 4A and 4B) attain maximum dimensions of 40 x 40 μm, and always occur on the contacts between chalcopyrite and native bismuth (see Table 1 for a summary of the mineral assemblage). The compositions of both minerals are identical; electron-microprobe traverses across the intergrowths failed to show any differences. It is easy to recognize the minerals optically because of their intergrowths. In oil immersion costibite shows a very weak reflection-pleochroism, grey-white with a bluish tint to grey-white with a brownish tint. The anisotropy is distinct, somewhat stronger than for chalcopyrite, with reddishbrown and dark-grey polarization colors (with exactly crossed nicols), or orange and bluish colors (nicols slightly uncrossed). In contrast, paracostibite has a somewhat higher reflectance and a more distinct reflection-pleochroism, grey-white with a slight bluish tint (in this position almost the same as costibite) to grey-white with a pinkish tint (distinctly lighter than costibite). The anisotropy is distinct, somewhat stronger than for costibite, with the same polarization colors but with more pronounced tints. Cobaltite (Fig. 4A) has a distinctly higher reflectance; costibite and paracostibite have a more bluish color in comparison. The anisotropy of costibite is weaker than that of cobaltite, but paracostibite is more anisotropic than cobaltite. The polishing hardnesses of costibite and paracostibite are similar, higher than for chalcopyrite and lower than for cobaltite. The replacement of paracostibite by costibite (Fig. 4) is in agreement with the suggestion by Cabri *et al.* (1970b) that costibite is the lower temperature polymorph.

Nisbite occurs as small grains (maximum diameter 4 μm) at the contacts between galena and pyrrhotite grains. The mineral is white, shows a reflectance higher than all other phases except native bismuth, and has a very weak reflection-pleochroism and anisotropy, much weaker than for costibite. The polishing hardness is higher than for pyrrhotite. The occurrence of nisbite with pyrrhotite is also characteristic of the Red Lake (Cabri *et al.* 1970c) and Festivalnoe (Materikov 1977) deposits, in which it is further associated with chalcopyrite, galena, arsenopyrite, tetrahedrite and breithauptite. Ullmannite and native bismuth are also present in the Festivalnoe mine (Kachalovskaya & Kukoev 1973).

The identification of the (Co,Ni)–Sb–S phases in the Getön deposit is more difficult because of the much smaller grain-size (Fig. 4C). Costibite, paracostibite, cobaltian ullmannite and gersdorffite occur as small inclusions in galena. The optical properties of the CoSbS phases are the same as in the Gruvåsen deposit. Cobaltian ullmannite, with Co/(Co + Ni) = 43.2 (Table 2), is grey, without pinkish or bluish tints, and isotropic; the reflectance is slightly higher than for costibite, but lower than for paracostibite, in agreement with the data given by Cabri *et al.* (1970b). A small grain of gersdorffite (2 μm) is white and isotropic, with a reflectance slightly higher than for paracostibite and cobaltian ullmannite. The cobaltian ullmannite grains contain small specks (1 μm) of a white, weakly anisotropic mineral with a much higher reflect-

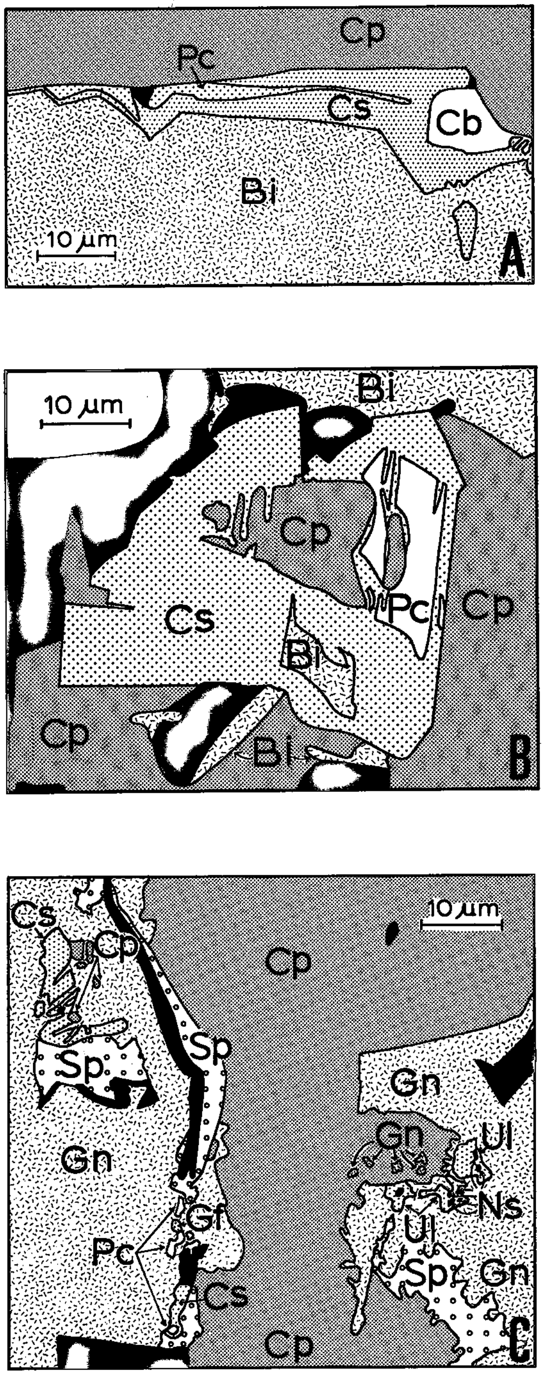


FIG. 4. Textural relations of Co and Ni minerals from Gruvåsen (A, B: spec. 12f), and Getön (C: spec. 56C3). Drawings after microphotographs. Abbreviations: Bi native bismuth, Cb cobaltite, Cs costibite, Gn galena, Gf gersdorffite, Ns nisbite, Pc paracostibite, Sp sphalerite, Ul cobaltian ullmannite; black is gangue.

ance; it was determined as nisbite with the help of electron-microprobe traverses across the grains.

The Occurrence of Co Minerals in Bergslagen

Field investigations and microscopic data indicate the occurrence of two types of sulfide mineralization in the polymetallic ores of western Bergslagen. The older pyrrhotite–pyrite–galena–sphalerite–chalcopyrite–arsenopyrite mineralization may be regarded as belonging to the "Falun type", according to the classification of Magnusson (1970). The younger molybdenite–native bismuth–chalcopyrite(–stannite) mineralization may be compared with the "Yxsjöberg-Hörken type" of Magnusson (1970).

Discussion of the genesis of the Falun-type mineralization is strongly influenced by the proposal of magnesium metasomatism developed by Geijer (1917, 1964) and Magnusson (1925, 1970). According to this theory, the ore deposits are introduced into the leptite complex by solutions driven from the synkinematic older granites. These solutions would also be responsible for the formation of the cordierite–gedrite-bearing quartzite that frequently accompanies the sulfides. Koark (1962) suggested that the ores were formed syngenetically, together with the volcano-sedimentary rocks, their source being volcanic exhalations or solutions. In this case, the cordierite–gedrite rocks would be the result of metamorphism of these volcano-sedimentary deposits in a later stage. The Yxsjöberg-Hörken type of mineralization is apparently related to the late orogenic Svecofennian palingenetic granites and pegmatites (Magnusson 1970, Hübner 1971, Ohlsson 1979). The ore minerals are molybdenite, scheelite, chalcopyrite, native bismuth, sometimes with bornite, sphalerite, allanite and fluorite. At Gruvåsen, the CoSbS minerals were formed in this type of mineralization.

Microscopic observations show that the occurrence of CoSbS phases is restricted to the contacts between chalcopyrite and native bismuth (Figs. 4A,B); in the Getön examples, they occur only at the contacts of galena with chalcopyrite (Fig. 4C). Microprobe analyses of native bismuth from Gruvåsen show an Sb content of 0.3 wt. % in occurrences devoid of Sb minerals, but under the detection limit (0.02 wt. %) if Sb minerals are present. Similarly, in polished sections from Getön containing CoSbS phases and native antimony, the Sb content of galena is below the detection limit, whereas in other sections galena contains 0.02–0.13 wt. % Sb. These observations suggest that costibite and paracostibite derived their Sb content from native bismuth or galena. The Co was probably derived from chalcopyrite. The well-known preference of cobalt for chalcopyrite and pyrite, and that of nickel for pyrrhotite (Cambel & Jarkovský 1969), are demonstrated by the presence of the Co phases at contacts with chalcopyrite, and by the presence of nisbite at pyrrhotite contacts, respectively.

The relative rarity of costibite and paracostibite compared with cobaltite is due to two factors: (1) a relatively low concentration of Co, leading to a general paucity of Co minerals, and (2) the relatively high concentration of As. In most Bergslagen Co deposits cobaltite was the only Co mineral to form, provided that the Co atoms did not stay trapped in pyrite or chalcopyrite. The Sb-bearing phases could only crystallize if no more As was available.

The many Mo–W and Bi mineralizations in Bergslagen frequently occur in a spatial relationship with the late orogenic granite, but only in a few deposits is Co present in this paragenesis, suggesting that the granite could not have been the source of this metal. The distribution of Co minerals in the Hällefors area indicates two other possibilities: (1) remobilization of cobalt from other sulfides of the older Falun type and (2) remobilization of cobalt from greenstones. In both cases cobalt would have been leached from chalcopyrite or pyrite, probably by hydrothermal solutions associated with the late orogenic or postorogenic granites.

Acknowledgements

Boliden Metall AB kindly gave access to their material from the Bergslagen area. Professor Oen Ing Soen (University of Amsterdam) and Dr. U. Wiklander (Geological Survey of Sweden) are thanked for the helpful discussions and for the specimens. Electron-microprobe facilities were provided by the Free University and the WACOM, a working group for analytical geochemistry subsidized by the Netherlands Organization for the Advancement of Pure Research (ZWO). Dr. C. Kieft (WACOM) carried out some of the analyses.

References

Anonymous (1976): The crystal structure of paracostibite. *Sci. Geol. Sinica* **1976**, 227-234 (in Chinese with English abstr.).

Cabri, L.J., Harris, D.C., Stewart, J.M. & Rowland, J.F. (1970a): Willyamite redefined. *Proc. Aust. Inst. Mining Metall.* **233**, 95-100.

———, ———, ——— & ——— (1970b): Costibite (CoSbS), a new mineral from Broken Hill, N.S.W., Australia. *Amer. Mineral.* **55**, 10-17.

———, ———, ——— & ——— (1970c): Paracostibite (CoSbS) and nisbite ($NiSb_2$), new minerals from the Red Lake area, Ontario, Canada. *Can. Mineral.* **10**, 232-246.

CAMBEL, B. & JARKOVSKÝ, J. (1969): *Geochemistry of Pyrrhotite of Various Genetic Types.* Komenský Univ., Bratislava.

GEIJER, P. (1917): Falutraktens berggrund och malmfyndigheter. *Sver. Geol. Unders. Ser. C* **275**.

——— (1964): On the origin of the Falun type of sulfide mineralization. *Geol. Fören. Stockholm Förh.* **86**, 3-27.

GRIP, E. (1978): Central Sweden (Bergslagen). *In* Mineral Deposits of Europe. 1. Northwest Europe (S.H.U. Bowie, A. Kvalheim & H.W. Haslam, eds.). Inst. Mining Metall., London.

HÜBNER, H. (1971): Molybdenum and tungsten occurrences in Sweden. *Sver. Geol. Unders. Ser. Ca* **46**.

KACHALOVSKAYA, V.M. & KUKOEV, V.A. (1973): The first finding of nisbite in the U.S.S.R. *In* Investigations on Ore Mineralogy (M.S. Bezsmertnaya, ed.). Nauka, Moscow (in Russ.).

KOARK, H.J. (1962): Zur Alterstellung und Entstehung der Sulfiderze vom Typus Falun. *Geol. Rundsch.* **52**, 123-146.

MAGNUSSON, N.H. (1925): Berggrunden inom de centrala delarna av Filipstads Bergslag. Persbergs Malmtrakts malmfyndigheter. *Kungl. Kommerkollegium & Sver. Geol. Unders. Beskr. över mineralfyndigheter* **2**, 1-231, 459-464.

——— (1970): The origin of the iron ores in central Sweden and the history of their alterations. *Sver. Geol. Unders. Ser. C* **643**.

MATERIKOV, M.P. (1977): The Festivalnoe deposit. *In* Ore Deposits of the U.S.S.R. III (V.I. Smirnov, ed.). Pitman, New York.

NAIK, M.S., GRIFFIN, W.L. & CABRI, L.J. (1976): (Co,Ni)SbS phases and argentian boulangerite in galena from Espeland, Norway. *Norsk Geol. Tidsskr.* **56**, 449-454.

ÖDMAN, O. (1933): Erzmikroskopische Untersuchung der Sulfiderze von Kaveltorp in Mittelschweden. *Geol. Fören. Stockholm Förh.* **55**, 563-611.

OHLSSON, L.-G. (1979): Tungsten occurrences in central Sweden. *Econ. Geol.* **74**, 1012-1034.

SPRINGER, G. (1967): Die Berechnung von Korrekturen für die quantitative Elektronenstrahl-Mikroanalyse. *Fortschr. Mineral.* **45**, 103-124.

SUNDIUS, N. (1923): Grythyttefältets geologi. *Sver. Geol. Unders. Ser. C* **312**.

TEGENGREN, F.R. (1924): Sveriges ädlare malmer och bergverk *Sver. Geol. Unders. Ser. Ca* **17**.

WELIN, E. (1965): Two occurrences of uranium in Sweden. The Los cobalt deposit and the iron ores of the Västervik area. *Geol. Fören. Stockholm Förh.* **87**, 492-508.

———, GORBATSCHEV, R. & LUNDEGÅRDH, P.H. (1977): Rb–Sr dating of rocks in the Värmland granite group in Sweden. *Geol. Fören. Stockholm Förh.* **99**, 363-367.

Received December 1979, revised manuscript accepted February 1980.