SVERIGES GEOLOGISKA UNDERSÖKNING

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RUDYARD FRIETSCH

BRIEF OUTLINE OF THE METALLIC MINERAL RESOURCES OF SWEDEN

STOCKHOLM 1975

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Errata

p. 57, line 17: 300—400 g/t U in the ”kolm”, shall be
3000—4000 g/t U in the ”kolm”,

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ABSTRACT

This paper presents a brief outline of the mineral resources of Sweden. Only the metallic mineral deposits are reviewed. They are grouped according to 1. composition (main element or elements), 2. geographical distribution and 3. mode of occurrence and mineralogical composition. The genesis of each ore type is briefly discussed. In addition there is given a short review of the discovery and the mining history of the Swedish ores.

INTRODUCTION

The ore deposits of Sweden are found in a number of geographical regions which are distinctly separated from each other. The historically oldest and formerly most important district is situated in Central Sweden (Fig. 1). Here are found iron ores and base metal sulphide ores. In the north lies the iron ore district of Norrbotten, also containing some copper deposits. In between Norrbotten and Central Sweden is the Skellefte district containing base metal sulphide ores. All these ore districts are lying in Precambrian rocks. Also within the Precambrian are further scattered occurrences of ores with base metals, titanium, manganese, tungsten etc. Younger than the Precambrian are the base metal sulphide ores in the Caledonian mountains. Deposits of lead ore occur at the eastern margin of the Caledonides, in the Eocambrian and partly in the Cambrian. Further west, in the allochthonous and metamorphic rocks of the Caledonides occur metal sulphides ores in the Cambro-Silurian. In the Precambrian in Southern and Central Sweden occur vein-deposits with lead-silver or manganese-oxides which are related to faulting of Post-Silurian, possibly Permian age. The youngest ores in Sweden are the Jurassic iron ores in Scania in Southern Sweden.

The purpose of this paper is to give a short review of the mineral resources of Sweden. Only the metallic mineral deposits will be dealth with. As the basic aim is to describe the different ore types, details about single deposits are given only occasionally. The ores are grouped after: 1. composition according to the main metals that enter the ore, 2. geographical distribution, divided in three regions: Southern, Central and Northern Sweden and 3. mode of occurrence (e.g. vein, impregnation, massive ore) and mineralogical composition.

ORE DEPOSITS
IN SWEDEN
R. Frietsch 1975
15°E
0
100
200
300 Km
Kopparåsen
Rautasjaure
Sjangeli
Kiirunavaara
Unna Järta
Tjavelk
Leveäniemi
Kaunisvaara
Svappa-
vaara
Mas-
ugnsbyn
Akka-
vare
Malmberget
Nautanen
Aitik
Alkavare
Lanjek
Ultevis
Porjus
Ruotivare
Jervas
Kallak
Nasafjäll
Essmitjåkko
Majva
Lais-
vall
Arjeplog
Radnejaure
Jerfojaure
Laver
LULEÅ
Tjåter
Gaisa
Storbodsund
Adak
Lainijaur
Remdalen
Rävliden
Boliden
Stekenjokk
Ankarvattnet
Kristineberg
Jormlien
C Lejarklumpen
SKELLEFTEÅ
Björkvattnet
C Ruotats
Lövstrand
Åkerlandet
Bellviksberg
Olden
Kittlahäll
Bjelke
Fröå
ÖSTERSUND
Förnätra
Ulvön
Ljusnedal
Kväcklinge
Vassbo
Norr-
botten
Caledonides
NORTHERN SWE-
DEN
Skellefte
district
CENTRAL
SWEDEN
SOUTHERN
SWEDEN

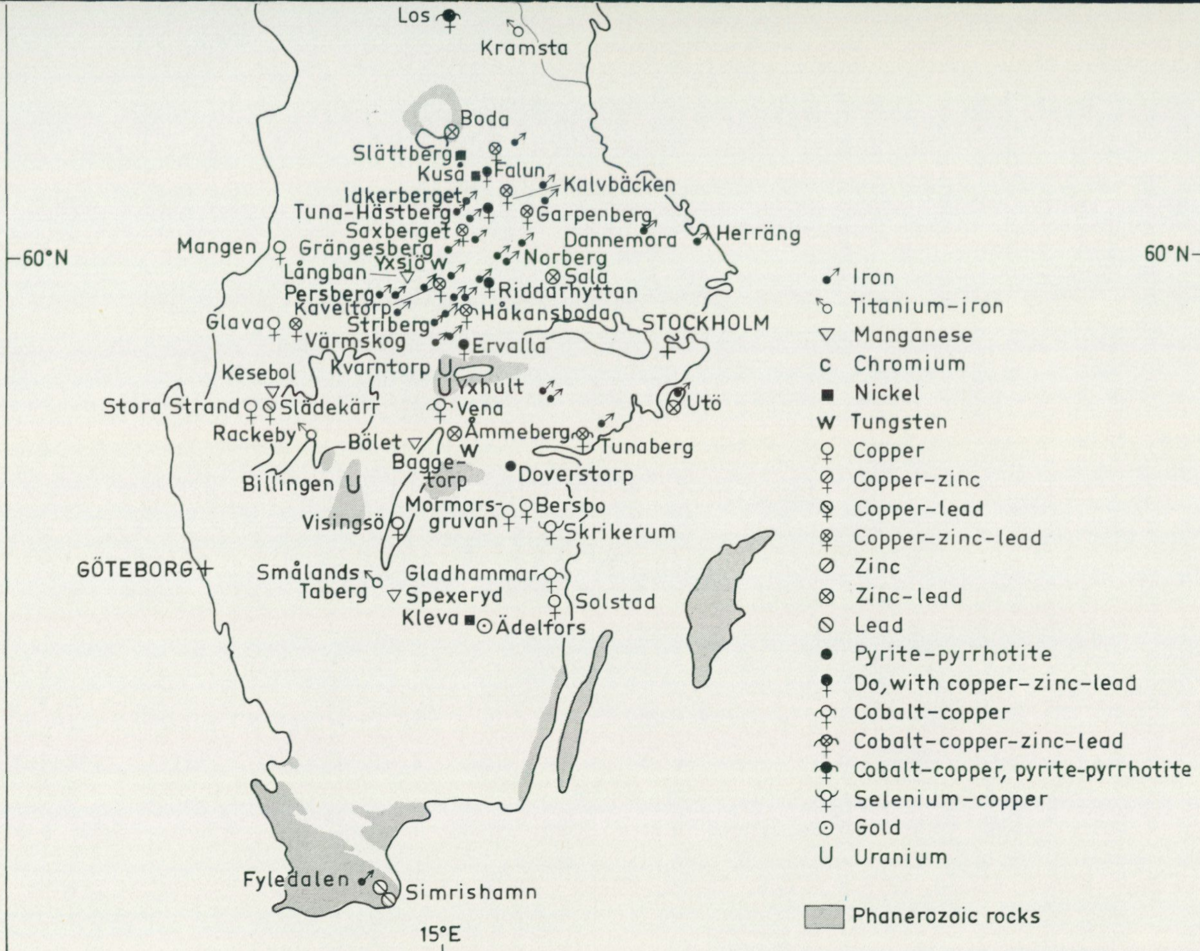

Fig. 1. Map showing the site of some of the ore deposits in Sweden.

IMPORTANCE OF SWEDISH METAL AND MINING INDUSTRY

The mineral industry of Sweden has a long history and has been of great importance to the country and its economy. Even if Sweden sometimes is considered as rich in mineral deposits, the range of mineral commodities produced is relatively limited. The main production in 1972 comprised the following mineral commodities in order of decreasing value: iron, copper, zinc, lead, silver, gold, pyrite and tungsten. Further there was a production of arsenic, selenium, bismuth and uranium. 53 mines were operative, of these 30 extracted iron ore. Sweden has a sufficient production of iron, lead, zinc, gold, silver, arsenic, selenium and pyrite but on the other hand it lacks many mineral commodities and has to import them. In particular Sweden is a major producer of special steel but has to import the necessary ferro-alloys. The consumption of these is rather important, as can be seen from Table 1. The trade balance of Swedish mineral production is shown in Table 2.

TABLE 1. Consumption of ferro-alloys in Sweden 1968

	Million kronor	Tons
Nickel	275	24 300
Chromium	100	54 000
Molybdenum	60	3 200
Manganese	45	40 000
Tungsten	40	1 400
Titanium	8	600
Vanadium	8	400
Other	37.7	24 200
Gross total	570.7	148 200

Reference: SJM-bulletin 1972, No. 4, p. 13–20.

TABLE 2. Exports and imports of mineral commodities in 1973

	Exports		Imports	
	Million kronor	%	Million kronor	%
Iron ore and concentrate	1 543	2.9	–	–
Commercial iron and steel	4 194	7.9	2 899	6.3
Other metals and metal products	2 879	5.4	1 628	3.5
Total exports-imports	54 000	100	46 300	100

Sweden has about 0.2 % of the population of the world, consumes 1.1 % of the petroleum produced in the world and 1.3 % of the electric energy produced in the world. The share of Sweden in the international trade is about 2 %. The importance of the Swedish mining industry is shown by the fact that Sweden stands for 0.7 % of the pig iron industry of the world, 1 % of the steel production of the world and 5 % of the iron ore production of the world. The share of the metal and mining industries of the total industrial production in Sweden is about 2—3 %. In 1970 these industries employed about 14 000 persons at a total of 80 enterprises, which means that about 1.6 % of the employees in Sweden were at the mining industry. The sales value of the production from the metal and mining industries was in 1970 1 440 million kronor. The export of mineral commodities, which was about 80 per cent of the domestical production, valued 1 470 million kronor. Of the export value about 85 per cent was due to iron ore and about 10 per cent due to non-ferrous ore. The export value of products from the metal and mining industries was in 1970 about 4 per cent of the total export value of Sweden. The iron and steel factories employed in 1970 56 000 persons and the sales value amounted to 3 600 million kronor. In 1970 was produced 3.9 million tons saleable iron. The import was 1.7 million tons and the export 1.4 million tons, viz. the domestical market was 4.2 million tons. The total extraction of non-ferrous metal ores amounted in 1972 to 927 000 tons of concentrates of different kinds representing a total sales value of 349 million kronor.

The reserves and annual production of different ores and metals are shown in Tables 3 and 4.

TABLE 3. Reserves and production of the main ore types in Sweden (million tons)

	Reserves ore	Reserves metal Fe	Production 1972 ore
IRON ORE			
Central Sweden			
Apatite iron ore	282	130	3.7
Quartz-banded iron ore	288	98	2.3
Skarn iron ore with less than 1 per cent manganese	42	17	1.1
Skarn iron ore with more than 1 per cent manganese	252	94	1.1
Iron ores in the exploration stage	112	34	
Total	976	373	8.2
Northern Sweden			
Apatite iron ore	3 410	1 760	30.7
Skarn iron ore	502	184	
Quartz-banded iron ore	120	39	
Total	4 032	1 983	30.7
Sweden total	~ 5 000	~ 2 350	38.9
TITANIFEROUS IRON ORE			
Central Sweden	150	45	
Northern Sweden	96	30	
Total	~ 250	~ 75	

TABLE 3, continued

BASE METAL ORE

	Reserves ore	Reserves metal Cu	Zn	Pb	Cu+Zn+Pb	Production 1972 ore
Lead ore						
Caledonides, eastern part	50			2.0	2.0	1.4
Copper-zinc-lead ore						
Central Sweden	20	0.1	0.8	0.4	1.3	1.3
Skellefte district	100	0.8	2.3	0.2	3.3	2.5
Caledonides, inner (western) part	25	0.38	0.8	0.08	1.26	
Copper ore						
Aitik	150	0.75			0.75	4.0
Sweden total	~ 345	2.03	3.9	2.68	~ 8.6	9.2

References: Bergshantering (1972), Grip & Frietsch (1973), Magnusson (1973).

TABLE 4. Production 1972 of some metals in Sweden

SALEABLE IRON	Million tons
Pig iron	2.36
Crude steel	5.25
BASE METAL CONCENTRATES	Tons
Pyrite	486 000
Copper	129 000
Zinc	203 466
Silver-lead	108 038
BASE METALS	Tons
Copper	30 619
Lead	75 841
Zinc	113 728
Gold	1.8
Silver	132

Reference: Bergshantering (1972).

DISCOVERY AND MINING HISTORY OF THE SWEDISH ORE DEPOSITS

The mining activity of Sweden has old traditions. It started in the central and southern parts of the country. Here the mining of the limonitic bog and lake ores begun as early as about 500—200 B.C. These ores, which are of post-glacial origin, are mainly found in Småland in Southern Sweden and in Dalarna and Värmland in Central Sweden. In the Middle Ages the use of ”rock ore” started in Central Sweden and until about hundred years ago the ores of these regions accounted for practically the whole mineral production of the country. The mining of copper ores began in about the 12th century and of iron ores in 14th century. The metal industry developed around the numerous iron and sulphide ore mines especially in Northern Västmanland and surrounding provinces. This area is called Bergslagen (The mining district) and royal charters were given as early as the 13th and 14th centuries to regulate the activity of the mining and metallurgical workings. The sulphide mines of Sala and Falun are famous, the production was of great value to the state and the mines represented real treasures. By modern standards, however, the production was small. The Sala silver-(lead)-mine was of great importance in the 16th century. The silver production 1506—1600 amounted to 238 tons, the main production being before 1570. The Falu mine or Stora Kopparberget (the Great Copper Mine) was an even more valuable deposit to the Swedish crown. During its heyday in the 17th century the mine had a yearly production of about 3 000 tons of copper, which at that time represented two-thirds of the copper production of the world.

During the 15th and 16th centuries mining outside Central Sweden was only on a very small scale, such as at the silver-(lead) deposits in SE Scania, South Sweden, which at the time belonged to Denmark. With the establishment in 1630 of the Bergskollegium the search for new ore deposits was encouraged. A staff of government prospectors was established. In addition the Bergskollegium improved the administration of the mining activity and gave it technical advice and aid. Due to the increased prospecting activity many new ore deposits were discovered both in inhabited areas and in virgin territory: in 1635 the Nasafjäll silver-(lead) deposit in the inner part of the Caledonian mountains, in 1644 the Svappavaara copper ore, in 1657 the Kvikkjokk silver-(lead) ores and in 1697 the Sjangeli copper ore. None of these deposits were, however, economic. In 1644 the iron ore at Masungsbyn was discovered, the first of all of the iron deposits in the north. A blast furnace was erected here a few years later and was the most northerly blast furnace of its kind in the world.

Sweden has occupied a prominent position as an iron ore producer over a long period. In the 15th century, or possibly even earlier, the original crude furnaces were replaced by blast furnaces. The pig iron ore production at the later half of the 17th century was about 40 000 tons. In 1740 the production of iron ore was 150 000 tons and that of pig iron 65 000 tons, which means that Sweden accounted for 38 % of the world's iron production and for 40 % of the world's pig iron production. At the end of the 18th century Swedens part of the world's production diminished rapidly. Thus in 1800 Sweden accounted for 12 % of the world's iron ore production and for 13 % of the world's pig iron production. In 1820 these figures only amounted to 7.5 % and 8.3 %. One serious reason for the lack in expansion was that the Swedish iron industry was based on charcoal and lacked fossil fuels.

The vast iron ore deposits at Kiruna and Malmberget (Gällivare) have been known since the latter part of the 17th century. The first systematic search for iron ores in this part of the country was made at the end of the 19th century when several deposits were found. Most of the iron ore deposits in Northern Sweden were, however, discovered during and immediately after the First World War. A small number of iron deposits, some of which are rather large, have been found since 1940, mainly with the aid of geophysical methods.

In older times the iron ores were only used for the domestic iron industry; exportation did not occur until after 1865, when relatively small quantities were exported to England and Germany. The invention of the basic steel-making processes, however, changed the situation drastically, as this enabled the large phosphorus-bearing iron ores in Northern and Central Sweden to be exploited. The mining at Grängesberg and Malmberget started in 1888 and at Kiruna 1898. A large part of this ore type is now exported; only a minor part is used for domestical purposes.

At the end of the First World War there was a shortage of pyrite ore and ores with base metals in Sweden. A prospecting campaign was therefore started by the Geological Survey of Sweden and by private enterprises. This exploration was directed mainly towards sulphide ores in the inner part of the Caledonian mountains. Efforts were concentrated within the county of Västerbotten but no economic deposits were discovered. Renewed work in this area since the beginning of the 1960s has resulted in the discovery of a large sulphide ore (Stekenjokk) which in near future will be put into production. At the time of the First World War the Geological Survey and the Boliden Company started prospecting for sulphide ores in the Skellefte district. This resulted in the discovery of several valuable deposits. The first discovered was Kristineberg in 1918 and the first to be put in production was Boliden at 1925; the mine now being exhausted.

During the 1930s the Boliden Company performed an extensive exploration campaign in the outer part of the Caledonian mountains. In the eastern border there were already known to be some lean silver-(lead) ores. The exploration resulted in the discovery of a vast impregnation of lead in the Eocambrian and Cambrian sandstones and a new ore province appeared. The mining of the Laisvall lead ore started at 1942.

In the 1930s prospecting extended into Norrbotten county and in 1932 the first indication of the Aitik copper deposit was found. The ore has been mined since 1968 and is the biggest single copper mine in Sweden.

Mining activities in Sweden are performed by a restricted number of companies. In Northern Sweden LKAB (Luossavaara-Kiirunavaara AB) produces the greatest part of Swedish iron from the mines Kiirunavaara, Malmberget and Leväniemi. In Central Sweden the main producer of iron ore is Gränges Stål which mines Grängesberg and Stråssa. The third largest mining enterprise is Stora Kopparbergs Bergslags AB (Stora) which exploits the Grängesberg, Blötberget, Håksberget, Ickorrbotten, Källbotten, Risberg, Dannemora and Ramhäll deposits.

Other iron ore producers are Uddeholms AB, Ställbergs Grufve AB, Stripa Gruv AB, Bastkärns Gruf AB and Idkerbergets Gruf AB. All companies mentioned are private except LKAB which is state-owned.

The number of companies mining sulphide ores is rather small. The ores in Central Sweden are mined by Boliden AB, Stora Kopparbergs Bergslag AB, Vieille Montagne and AB Statsgruvor (state-owned). The last mentioned company also mines the Yxsjöberg tungsten deposit. The sulphides ores in the Skellefte district, the Aitik mine and the Stekenjokk mine are exploited by Boliden AB.

Prospecting activities are performed by a few enterprises. The Geological Survey is the biggest prospecting agency and searches for a range metals mainly in Northern Sweden, although ferro-alloy metals and uranium are being explored for over the whole country. The Boliden AB searches for base metal sulphide ores in Northern and Central Sweden. Stora Kopparbergs Bergslags AB prospects in Central Sweden after both iron and base metal ores.

References: Carlberg (1879), Eriksson (1960), Geijer & Magnusson (1952 b), P. Ljunggren (1953), Tegengren (1912), (1924).

DESCRIPTION OF THE ORES

IRON ORES

Non-titaniferous iron ores occur in the Jurassic of Scania and in the Precambrian of both Central and Northern Sweden. The Precambrian ores comprise quartz-banded iron ores, skarn iron ores and apatite iron ores; all types are represented in both regions. Only in Central Sweden the quartz-banded iron ores and the skarn iron ores have been mined. Due to their low content of phosphorus and sulphur these ores were the main source of Swedish iron until the end of the last century when the basic steel-making processes made it possible to utilize apatite-rich ores. It is the apatite ore type which nowadays constitutes the bulk of Sweden's iron ore resources and provides the principal part of the country's iron ore production (Table 3). The greatest deposits are in Northern Sweden.

Reference: Frietsch (1975).

SOUTHERN SWEDEN

BEDDED CHAMOSITE-LIMONITE-SIDERITE ORES

In Fyledalen in SE Scania there occurs between the Silurian and the Cretaceous a tilted series of sediments of middle or more probably upper Jurassic age (Dogger or Malm). In arenaceous members of these series occur sedimentary iron ores of two chemically and structurally different types. The most common is an oolitic, stratified ore with chamosite and limonite and varying amounts of siderite and hematite. The other type is a massive siderite without any oolitic texture. The iron-bearing beds are narrow and the iron content is lean, in the richer part rising to 35 per cent, and thus of no economic interest. The content of phosphorus reaches at maximum 0.7 per cent. These ores are similar to the Jurassic Minette ores found in Western Europe and elsewhere in the world.

References: Brotzen (1962), Hadding (1933), Magnusson et al. (1960), Palmqvist (1935).

CENTRAL SWEDEN

The iron ores of Central Sweden occur in a great numbers of deposits. The ores belong to a metamorphic volcanic-sedimentary complex of Svecofennian age. The complex begins with a sequence of acid volcanics with intercalations of limestone-dolomite and clastic sediments. The volcanics are called hälleflintas, leptites or leptite-gneisses depending on the degree of metamorphism. Best preserved are the hälleflintas which mainly are found in the west. These volcanics vary from extremly sodic to potassic types, intermediate types are rather scarce. The sodic volcanics are quite dominating. The acid volcanics are in the central and eastern part followed by dacitic and andesitic rocks. This volcanic sequence is overlain by detrital sediments, with greywackes, slates and quartzites. In these sediments occur intercalations of greenstones.

The supracrustal rocks were folded in connection with the intrusion of the oldest group of Svecofennian granites, a differentiated series of concordant intrusions of which the first members are gabbros and diorites. The granitoids caused thermal metamorphism in the volcanic-sedimentary complex. The hälleflintas were altered into leptites and the intercalated limestone-dolomites recrystallized under internal reactions giving rise to skarn minerals such as andradite, diopside and tremolite. Furthermore the supracrustal rocks were subject to widespread metasomatic alteration which resulted in considerable chemical and mineralogical changes. The main element added was magnesium. By this "magnesia-metasomatism" the leptites were changed into mica schists and "quartzites" characterized by minerals rich in magnesium and ferrous iron (i.a. cordierite, almandite and anthophyllite). The limestones-dolomites were altered and contain tremolite, diopside, humite and serpentine.

After a non-orogenic period marked by the intrusion of basic dikes there occurred a migmatization of the supracrustal rocks in connection with the intrusion of the late Svecofennian granites. These cross-cut the structures and were accompanied with large amounts of pegmatite. The age of the pegmatites is about 1 800 m.y.

The iron ores all occur in the lower, volcanic section of the volcanic-sedimentary complex. Of the different ore types the reserves of the apatite iron ores are most important, being followed by the quartz-banded iron ores and the skarn and limestone ores (Table 3). The skarn and limestone ores are divided into a non-manganiferous and a manganiferous type, the limit being put at 1 % Mn. The manganese is sited in the gangue and the content reaches 10 % in the manganiferous type. The manganiferous type occurs in the potassic volcanics and the non-manganiferous type mostly in the sodic volcanics. All ore types form long and narrow bodies which are concordant with the enclosing volcanic rocks. Due to the later folding the form of the ores is sometimes rather complicated.

References: Geijer & Magnusson (1944), (1952 a), (1952 b), Magnusson (1960), (1970), (1973).

APATITE IRON ORES (KIRUNA TYPE)

The apatite iron ores occur in a few deposits (Grängesberg, Blötberget, Fredmundberget, Lekomberget and Idkerberget) of which the largest is Grängesberg. The average content of iron varies between 45 and 63 % and the average content of phosphorus between 0.5 and 1.3 %. The content of sulphur and manganese is low. The ores form lens-shaped, compact bodies conformable with the bedding in the leptites. The ores have an intrusive appearance against the leptites, and are considered to be late intrusions belonging to the same magmatism as the volcanics in which they occur. It has been argued solely on geochemical grounds that the ores are sediments which were later mobilized by palingenetic processes. Furthermore the leptites contain impregnations with skarn minerals (biotite, chlorite, actinolite and hornblende), magnetite and apatite which are connected with the formation of the ore-bodies. These impregnations represent more gas-rich parts of the ore magma. The apatite iron ores in Central Sweden have the same principal features as those in Northern Sweden but are somewhat different in details. In Central Sweden they have a more complex mineralogical composition with a greater variety of skarn minerals and contain more ore impregnations than the analogous ores in the north. In the latter breccia-like networks (”ore-breccias”) are more common.

The ore minerals in the apatite iron ores of Central Sweden are magnetite and hematite. In connection with the intrusion of the late Svecofennian pegmatites the hematite in the Grängesberg ore has been altered to magnetite. The ore minerals are accompanied by apatite and small amounts of quartz and skarn minerals, predominantly actinolite. The skarn occurs evenly distributed or forms veins in the leptite. The latter, termed ”skarn-breccias” are rich in actinolite, hornblende, garnet and biotite together with magnetite, apatite, sphene and allanite.

References: Björkstedt (1972), Geijer (1931 b), Johansson (1911 a), Landergren (1943), (1948), Looström (1939), Magnusson (1938).

SILICEOUS HEMATITE IMPREGNATIONS

At Ormberget and Lomberget, near the Grängesberg ore, there occur hematite impregnations which are rich in quartz, feldspar, muscovite and biotite but poor in apatite. The content of phosphorus is less than 0.2 %. These impregnations possibly represent a late metasomatic phase in the same process that gave the apatite-rich ores. The formation of the impregnations took place under relatively low temperatures and pressures. Occasionally the impregnations grade into bodies of "normal" apatite iron ore. At Risberget there occurs an ore type which is transitionary between the apatite iron ores and the hematite impregnations. The Risberget ore is a magnetite-hematite impregnation in a leptite and is thus rich in quartz, biotite and feldspar. The amount of apatite is relatively high; the content of phosphorus is on an average 0.7 %.

Reference: Magnusson (1938).

QUARTZ-BANDED IRON ORES

The quartz-banded iron ores of Central Sweden are characterized by a regular alternation of thin layers of hematite and/or magnetite and quartz. Magnetite which usually has been formed from hematite indicates a higher degree of metamorphism. The iron content varies between 30 and 50 %. Phosphorus is in most cases between 0.007 and 0.03 % and manganese usually lower than 0.2 %. The content of SiO_2 is around 18—28 %. Besides the iron oxides and quartz the ores contain small amounts of skarn silicates such as andradite, diopside and tremolite. If the ore is mixed with leptite material epidote and hornblende may belong to the skarn association.

The quartz-banded iron ores, which occur as lens-formed bodies following the structures in the leptites, are considered to be sedimentary. The source of the iron and silica must be sought in volcanic emanations connected with the formation of the volcanic-sedimentary complex. The original iron mineral is believed to have been hematite or in part limonite. The skarn silicates mentioned above are formed through internal reactions caused by the intrusion of the older Svecofennian granites. Later, in connection with the magnesia-metasomatic alterations, there was formed a skarn rich in magnesium. Furthermore there was a sulphide formation and the quartz-banded ores are therefore sometimes impregnated with sulphides. The content of sulphur is mostly in the range 0.001—0.1 %.

Typical deposits include Norberg, Riddarhyttan, Striberg, Stripa and Stråssa.

References: Geijer (1923), (1927 b), (1936), (1938), (1957), Hjelmqvist (1942), Lindroth (1916), Magnusson (1965 a).

SKARN AND LIMESTONE IRON ORES

Non-manganiferous type

The skarn and limestone ores poor in manganese (with less than 1 % Mn) are also low in phosphorus and sulphur. The content of SiO_2 varies between 10 and 20 %. The ore mineral is magnetite. In addition there occur skarn silicates and carbonates. The magnetite and skarn silicates are irregularly distributed or occur in a regular stratification. The skarn silicates are either 1. rich in $Ca\text{-}Fe^{3+}$ or Ca-Mg (andradite, diopside-hedenbergite and actinolite) and appearing in connection with limestones-dolomites or 2. rich in Mg (anthophyllite-gedrite, cummingtonite, talc, forsterite, humite minerals and serpentine). The Mg-rich skarns are younger than the Ca-rich skarns.

The limestone ores have little or no skarn and consist of magnetite and limestone-dolomite. The content of SiO_2 is lower than 10 %. This ore type shows a distinct stratification and is thus considered to be of sedimentary origin.

The origin of the skarn iron ores poor in manganese is unclear. These ores might be either sedimentary deposits later affected by the regional metamorphism connected with the older Svecofennian granites or true pyrometasomatic deposits. In some cases it is evident that the ores are sediments where the skarn is formed by internal reactions and has been later reworked by the magnesia-metasomatism giving rise to Mg-rich skarns. Indications that the skarn ores might have been sediments originally are the transitions between the quartz-banded ores and skarn ores and between skarn ores and limestone ores. Evidence for an origin by replacement is in some deposits given by the presence of B- and F-bearing minerals (ludwigite, fluoborite and humite).

Typical skarn iron ore deposits include Dalkarlsberg, Finnmossen, Nordmark, Nyberg, Nyäng, Persberg and Sirsjöberg. Limestone ore deposits include Persberg, N. Klampåsgruvan and Sköttgruvan.

References: Bergström (1959), Geijer (1921), (1923), (1927 a), (1959), (1961 a), (1963), Landergren (1931), Lindroth (1926), Magnusson (1925), (1928), (1929), (1936 a), (1940 a), Petersson (1896), Pilava-Podgurski (1956), Sjögren (1911 b), Törnebohm (1875).

Manganiferous type

The manganiferous iron ores (with more than 1 % Mn) of Central Sweden are mostly developed as limestone ores. The content of phosphorus is less than 0.1 % and the content of sulphur is relatively high, in several deposits higher than 0.2 %. The ores are stratified and built up of magnetite and skarn silicates rich in manganese (spessartite, dannemorite, knebelite, manganiferous fayalite and in some cases rhodonite). The content of manganese is mostly varying between 2 and 5 %, and is highest at the Hilläng ore with 8—10 %. The content of iron is between 35 and 50 %. The ores are considered to be sedimentary and the skarn is a product of internal reactions caused by increased metamorphism.

Typical deposits include Basttjärn, Dannemora, Hilläng, Klackberg, Kolningsberg, Ställberg and Tuna-Hästberg.

Skarn bodies where knebelite is the dominating mineral are called eulysites. The largest deposits are at Tunaberg (Stora Utterviks hage and Strömshult). There occurs knebelite, spessartine and manganese-rich diopside together with subordinate amounts of dannemorite, iron-anthophyllite and almandine. The manganese content varies between 6 and 12 % and the iron content between 24 and 33 %. The content of phosphorus is about 0.2 %.

References: Geijer (1925 b), Lindroth (1916), Palmgren (1921).

SOFT GOETHITE-MARTITE-SIDERITE ORES

Some of the occurrences of iron ore in Central Sweden have been affected by a pre-glacial weathering which locally can go down to relatively great depths. The weathering is due to surface waters percolating downwards in zones of tectonic disturbance. The iron ores most usually affected are the limestone and skarn types. In some cases the weathering was reducing giving siderite and in other cases oxidizing giving limonite (goethite) and martite. The limonite or at least most of it originated from the oxidation of secondary siderite. In the Taberg ore the magnetite (and hematite) was directly transformed into goethite; siderite was not an intermediate mineral. The wall rock was also affected by this pre-glacial weathering, developing minerals such as kaolinite, opal and calcedony. In the Norberg mine there was differential weathering; the non-ore minerals were selectively dissolved, leaving behind an ore enriched in (unaltered) hematite.

References: Geijer (1936), Geijer & Magnusson (1926), P. Ljunggren (1958 a).

NORTHERN SWEDEN

The non-titaniferous iron ores in Northern Sweden occur in the county of Norrbotten, and most of them lie in a wide zone going roughly E—W on both sides of Kiruna. Four different types can be distinguished: 1. apatite iron ores, 2. siliceous hematite impregnations associated with the former, 3. skarn iron ores and 4. quartz-banded iron ores. Only the apatite ore type is mined. These ores are quantitively the most important (Table 3). An outstanding feature in this type is that the deposits are throughout relatively large. The two biggest deposits are Kiirunavaara, with about 1 800 million tons of ore, and Malmberget with about 660 million tons of ore. These two deposits and some smaller deposits near Kiruna and the Leveäniemi deposit produced a total of 30.7 millions tons of ore in 1972. The siliceous hematite ores associated with the apatite iron ores form quite unimportant deposits. The skarn iron ores, which occur in a great number of deposits, are mostly rather small but form together an important ore reserve. The quartz-banded iron ores are of small size.

All the different types of iron ore occur within supracrustals of Svecofennian-Karelian age. The supracrustals can be divided into four units (Table 5). Oldest is the greenstone group built up of greenstones and porphyrites. To the north of Kiruna the greenstones are underlain by a granite which has an age of about 2 800 m.y. In the greenstone group occur, in the stratigraphic higher parts, intercalations of tuffs, tuffites, phyllites, graphite-bearing schists, limestones-dolomites, marls and cherts. The skarn iron ores and quartz-banded iron ores occur in connection with these sediments. The greenstone group is overlain by mica-schists and conglomerates of moderate thickness. Younger than these rocks is the porphyry group which is mainly occurring in the western part of the iron-bearing area. The group consists of acid to intermediate volcanics which in many cases occur as porphyries. The age of these rocks is 1 605—1 635 m. y. It is within this unit that the apatite iron ores and the siliceous hematite impregnations occur. The youngest supracrustal unit is a quartzite group of restricted extent.

TABLE 5. Stratigraphic scheme for the northern part of the Norrbotten county

Age (m. y.)	Supracrustal rocks	Intrusive rocks	Iron ores
1 540		**Granite group:** granite ("Lina granite") with pegmatite and aplite	
	Quartzite group: quartzitic sandstone with conglomerate and phyllite		
1 605 −1 635	**Porphyry group:** acid and intermediate volcanic rocks with intercalations of basic volcanic rocks		Apatite iron ores and siliceous hematite impregnations
1 880		**Granodiorite group:** granodiorite with diorite and gabbro	
	Schist-conglomerate group: mica-schist, with intercalations of biotite-rich quartzite, and conglomerates		
	Greenstone group: basic volcanic rocks with intercalations of detrital and chemical sediments		Skarn iron ores and quartz-banded iron ores
2 800		Granite north of Kiruna	

The igneous rocks are of two different ages. The older group is a differentiated series with gabbro, diorite and granite which have been dated to around 1 880 m.y. These rocks intrude the greenstone group and the schist-conglomerate group in which they follow the tectonical structures.

These intrusives and all supracrustals, including the rocks of the porphyry group, are cut by a series of younger granites with pegmatites and aplites. Most common is the so-called Lina granite. The age is about 1 540 m.y. The formation of these granites was followed by intense migmatization.

References: Frietsch (1963), (1973 a), (1975).

APATITE IRON ORES (KIRUNA TYPE)

The apatite iron ores consist of magnetite and hematite together with varying amounts of apatite. In many deposits the content of phosphorus is on an average about 1 %. Some deposits are, however, very low in phosphorus. The apatite, which is a fluorine-apatite, occurs evenly distributed or as a distinct layering. Other minerals are tremolite-actinolite, diopside and in some deposits calcite. The content of titanium is less than 1 % and the contents of manganese and sulphur are less than 0.1 %.

The ore form elongated, tabular bodies mainly concordant with the strike of the enclosing rocks which are acid or intermediate volcanics of the porphyry group. A part of the ore occurs as veinlets forming an irregular network (so-called ”ore-breccia”) in the host rock.

The apatite iron ores originated by a magmatic differentiation in which volatiles played an important role. While the main part of the magma crystallized the ore remained in solution and was injected as a late, separate phase. This explanation has, however, its opponents and sedimentary (mostly exhalative-hydrothermal) theories have been postulated to explain the origin of these ores.

Typical representatives include Kiirunavaara, Luossavaara, Tuolluvaara, Mertainen, Gruvberget, Leveäniemi and Malmberget.

Apatite-rich ores, with between 2 and 5 % phosphorus, occur in a few deposits in the vicinity of Kiruna (Rektorn, Hauki, Nukutus, Henry and Lappmalmen) and SW of Kiruna (Pattok). They differ from the normal apatite iron ores not only in their apatite content but also in that hematite is the main ore mineral, magnetite being absent or subordinate. Other minerals that occur in the ore are quartz and carbonate (calcite and ankerite) with a little tourmaline, muscovite and albite. The content of barium (as barite) is relatively high. These ores were formed by a similar magmatic activity as the other apatite iron ores but at a lower temperature and with a higher content of volatiles.

In the apatite iron ores magnetite is the primary iron oxide from wich hematite has been formed by oxidation. This is due to metasomatic processes occurring as a late phase in the magmatic activity that gave the ore. These processes also affected the wall rock with the new-formation of quartz and sericite, sometimes also calcite and chlorite. Minor amounts of tourmaline, fluorite, barite and allanite belong to the paragenesis.

The Kiruna type of ore is not a common one in the world. Deposits of apatite iron ore outside Northern and Central Sweden are found in the Precambrian of SE Missouri, USA, and in the Cordilliera around the Pacific Ocean in Nevada, USA; Mexico and Chile. The age of the Cordillieran ores is late Mesozoic or Tertiary.

References: Frietsch (1966), (1967 b), (1973 b), (1974 a), (1974 b), (1975), Geijer (1910), (1912), (1920), (1930 a), (1931 b), (1935), (1950), (1960), (1967), Geijer & Ödman (1974), S. Ljunggren (1960), Lundbohm (1911), Parák (1973), (1975).

SILICEOUS HEMATITE IMPREGNATIONS

Near Kiruna and to the southwest of the town there are some economically unimportant apatite-free, siliceous hematite ores that replace acid volcanics. These ores were presumably formed by hydrothermal activity at a late stage in the same magmatic differentiation that gave rise to the apatite iron ores, that is to say, at a lower temperature and with a higher content of volatiles. The wall rock is metasomatically altered with the formation of quartz, sericite, calcite and chlorite. In some respects these ores are similar to the impregnations of the Lomberg-Ormberg ore type in Central Sweden (p. 16).

Reference: Frietsch (1967 b).

QUARTZ-BANDED IRON ORES

The quartz-banded iron ores in the northern part of the Norrbotten county are chemically precipitated quartzites in which magnetite and skarn minerals occur as layers. The ores are lean, the iron content mostly not exceeding 20 %. The ore bodies are thin but have relatively large extension parallel to bedding. They often contain small amounts of pyrite and pyrrhotite and the content of sulphur may be more than 1 %. The content of phosphorus is less than 0.1 %. The content of manganese is low but rises occasionally to 1 or 2 %. The skarn minerals are rich in Fe^{2+}-Mg. The most common are hornblende, grünerite-cummingtonite, clino-enstatite, hedenbergite and almandine. Occasionally a manganiferous fayalite is found.

These ores have the same mode of occurrence as the skarn iron ores and occur as lens-shaped bodies concordant with the strike of the enclosing greenstones and their sediments, which often are limestones-dolomites. The quartz-banded ores are chemical sediments which precipitated in the final stage of the basic volcanism giving the greenstones. In the Käymäjärvi deposit there are found relict granules of greenalite or some other iron silicate.

Representatives include Tornefors, Marjarova and Käymäjärvi.

The quartz-banded iron ores in the southern part of the Norrbotten county differ somewhat from those in the northern part. They are associated with acid volcanics and not basic ones. The immediate wall rock is made up of mica-schists or quartzites. The skarn minerals are Ca-Mg-rich (tremolite, diopside, garnet and epidote). The ores are free from iron sulphides. The ore mineral is magnetite but in some deposits also partly hematite. In some deposits the manganese content (in skarn silicates) is relatively high, rising to 7 %. These ores are in many respects similar to the quartz-banded ores in Central Sweden. Examples of this ore type are found at Peltovaara, Kallak and Arjeplog.

References: Folcker (1974), Frietsch (1970), Geijer (1925 a).

SKARN IRON ORES

The skarn iron ores occur in the upper, more varied part of the greenstone group in connection with the chemical and detrital sediments. In many deposits the ores are associated with or at the same stratigraphic level as limestones-dolomites. The ores form lenses concordant with the strike of the host rocks. The ore mineral is magnetite, occasionally with hematite. Small amounts of pyrite, pyrrhotite and chalcopyrite are always present. The content of sulphur is mostly higher than 1 %. The content of phosphorus in the form of a fluorine-chlorine-bearing apatite, is in most deposits lower than 0.1 %, but in some deposits it rises to several per cent. The content of manganese is low. The ore is followed by large amounts of skarn silicates rich in Ca-Mg or Mg such as tremolite-actinolite, diopside, phlogopite and serpentine. An interlayering of magnetite with skarn minerals and sometimes calcite is a rather common feature.

Representatives of the skarn ores include Vieto, Tjavelk, Sautusvaara, Tervaskoski, Masugnsbyn and Kaunisvaara.

The skarn iron ores were once considered to be pyrometasomatic, the iron emanating from the older intrusive group. A sedimentary origin seems however more justified. The skarn iron ores and the quartz-banded iron ores occur not only in the same stratigraphic position but are sometimes intermingled. The magnetite in the skarn iron ores and in the quartz-banded iron ores has a similar trace element distribution with relatively high content of magnesium and chromium. There is geological evidence that the skarn iron ores at least in part are older than the older intrusive group. The skarn iron ores are thus considered to be iron-silica-carbonate-rich sediments which by later metamorphic processes have aquired the present mineralogical composition. The skarn-layering in the skarn ores is probably a relict sedimentary texture.

References: Frietsch (1967 a), (1970), (1973 a), (1975), Geijer (1918 b), (1929), (1931 a), Lindroos (1974), Lundberg (1967).

SOFT HEMATITE ORES

A pre-glacial weathering affecting the ore and wall rock is known from a few deposits of iron ore in Northern Sweden; namely the apatite iron ores at Kiirunavaara and Gruvberget, Svappavaara and the skarn iron ores at Laukkujärvi and Vathanvaara. In some places the weathering goes down to depths of several hundred metres. By this process magnetite is altered to hematite. At Gruvberget the weathering attacked a hematite ore and leached the non-ore minerals leaving behind only the hematite. In the same deposit the leptitic wall rock was altered to a clay rich in kaolinite and quartz.

References: Frietsch (1960), Geijer (1910), (1924), Geijer & Magnusson (1926).

TITANIFEROUS IRON ORES

MAGNETITE-ILMENITE ORES (TABERG TYPE)

In Sweden there are only a few deposits of titaniferous iron ore. The content of titanium and vanadium in these is low. None of the deposits is mined at the moment. The ores are associated with basic, or less commonly with ultrabasic, intrusions, the ages of which range from Svecofennian to Jotnian. In the Ruotivare deposits, which lies in the Caledonides, the host rock is possibly of Cambro-Silurian age but may be Precambrian. The ore minerals are magnetite and ilmenite, mostly in a complicated intergrowth, although in Ruotivare there occur considerable amounts of free ilmenite. The mineralogical composition of the ore in the different deposits is shown in Table 6. All these ores are formed by magmatic differentiation. Counterparts outside Sweden are common and large deposits occur in Canada, USA and USSR.

The total reserves are about 250 million tons of ore. Smålands Taberg contains 150, Ruotivare 50, Kramsta 20, Ulvön 20 and Jerfojaure 6 million tons.

References: Frietsch (1975), Geijer (1930 b), Grip & Frietsch (1973), Hjelmqvist (1950), Lundegårdh (1957), (1967), Mogensen (1946), Tegengren (1911).

TABLE 6. Titaniferous iron ores in Sweden

Locality	Host rock (age)	Mineralogical composition	% Fe	% TiO_2	% V
		Southern Sweden			
Smålands Taberg	Hyperite	Magnetite, olivine, labradorite, amphibole, apatite	28−32	5−10	0.12−0.17
Rackeby	Norite		10	2−3	
		Central Sweden			
Kramsta	Gabbro (Svecofennian)	Andesine, clinopyroxene, apatite, magnetite	15−30	5−6	0.1 −0.3
		Northern Sweden			
Ulvön	Diabase (Jotnian, 1245 m.y.)	Labradorite, olivine, clinopyroxene, magnetite, ulvöite	25	8	0.2
Ruotivare	Anortosite (Precambrian-Caledonian?)	Magnetite, ilmenite, spinel, corundum, högbomite, plagioclase	40	10	0.18
Akkavare	Gabbro (Svecofennian)	Magnetite, ilmenite, andesine-labradorite, enstatite-hyperstene, hornblende	18.5	4.5	
Jerfojaure	Gabbro (Svecofennian)	Magnetite, ilmenite, plagioclase, biotite, amphibole, chlorite	15−20	5−7	

MANGANESE ORES

The manganese ores in Sweden are of two types: 1. bedded deposits of exhalative-sedimentary origin in volcanic-sedimentary rocks (in Central and Northern Sweden) and 2. hydrothermal fissure fillings in fault zones in intrusive and supracrustal rocks (in Southern Sweden). There is no production of manganese ore in Sweden at the present time.

SOUTHERN SWEDEN

FISSURE VEINS WITH Mn-OXIDES

In Southern Sweden occur fissure fillings of manganese ores in connection with fault and crush zones. The Bölet and Spexeryd deposits occur in the fault systems which border the Lake Vättern depression on the west and east side respectively. Although the rocks affected are mainly granites of post-orogenic Svecofennian age (1 750—1 700 m.y.) the zones themselves may be younger than Permian. The ores contain mainly manganite, braunite and pyrolusite. The gangue is made up of barite, calcite, quartz and fluorite. Counterparts to this type of mineralization outside Sweden can be found at Schwarzwald, Thüringer Wald and Harz in Germany.

At Bölet the ore minerals are manganite and pyrolusite which form a matrix between fragments of host rock (granite and gneisses) in a breccia or occur as druses in the wall rock of the veins. The manganese minerals are accompanied by calcite, quartz, barite and fluorite. The content of barite is often high. The average content of manganese of the ore is about 15 %. The width of the mineralization is on an average 1.5 m.

At Spexeryd there is a breccia with fragments of a granite and in part a mylonite. The breccia which has a width at maximum of 10 m, contains braunite, manganite and pyrolusite. The gangue is made up of calcite, some quartz, chalcedony and barite. The content of manganese is on an average about 15 %.

In SW Sweden, in Dalsland occur several small manganese-iron mineralizations in N—S orientated crush zones and breccias. These zones cut the supracrustal rocks of the Åmål formation, the Åmål-Kroppefjäll granites and the supracrustal rocks of the Dalsland group. The age of the latter, youngest unit is about 1 000—1 250 m.y. The ore minerals are hausmannite, manganite, hematite, rhodonite, manganspar and spessartine. The gangue is made up of quartz, calcite, chlorite, barite and occasionally fluorite. In the Kesebol ore, the only deposit of importance, a hausmannite ore with 28 % Mn and a garnet-rhodonite-manganese spar ore with 15 % Mn have been mined. In the foot wall of the Kesebol deposit there is a massive hematite ore. Between this and the manganese ore occurs a beryllium-bearing jacobsite and as secondary minerals bementite, psilomelane and serpentine.

References: Geijer (1961 b), P. Ljunggren (1958 b).

CENTRAL SWEDEN

BEDDED Mn-OXIDE-SILICATE ORES (LÅNGBAN TYPE)

This ore type is mostly associated with iron oxides, often primary jaspilitic hematite ores which due to later metamorphism have been changed to magnetite. Between the manganese oxides and the iron oxides there are lateral transitions.

The bedded deposits of manganese ores are built up of oxides and silicates rich in manganese. Most common among the oxides are braunite and hausmannite, the latter usually formed from braunite by metamorphism. The most common manganese silicates are spessartine, rhodonite and richterite. The ores show often a complex mineralogy with a great number of different minerals. The geochemical features are also complex. There are usually relatively high contents of barium, lead and antimony in the ores.

The bedded character of the ores and the surrounding volcanic-sedimentary rocks point to a hydrothermal-exhalative-sedimentary origin of this ore type.

The main deposit with manganese oxides in Central Sweden is Långban. The ore occurs in limestones-dolomites of the volcanic-sedimentary complex (cf. p. 14). In Långban the manganese ores with braunite and hausmannite are associated with iron ores with hematite and magnetite. Both ore types occur near each other side by side. The content of iron in the manganese ores and the content of manganese in the iron ores is low, less than 2 %. Originally the iron ores were built up of hematite and ferruginous quartz but due to increased metamorphism the ores have changed into magnetite, mainly in the outer masses of the ore bodies, partly against the surrounding dolomite. The magnetite is followed by skarn minerals as andradite, diopside, tremolite and serpentine. The magnetite and the skarn minerals are later alteration and reaction products.

In the manganese ores braunite is in the central part and hausmannite in the outer part, indicating in similarity with the iron ores, that hausmannite is formed from braunite. The more oxidized mineral lies in both types at the outer part. Sometimes hausmannite is the only manganese mineral. This is especially the case where the ore is intimately mixed with the dolomite. Other oxides found in small amounts are jacobsite, mangano-magnetite, magnesioferrite and plumboferrite.

The main skarn minerals are schefferite and rhodonite. Subordinate are richterite, spessartine, tephroite and manganophyll. In the manganese ores there are a great number of minerals rich in lead (silicates), arsenic (arseniates) and antimony (antimoniates). There occur also minerals containing beryllium (silicates and oxides), barium, titanium, vanadium, boron, phosphorus, chlorine and fluorine. Furthermore there are sulphides, as pyrite, chalcopyrite, galena and sphalerite, present. The Långban ores are unusually rich in minerals. There are about 190 distinct species of which at least 50 are peculiar for the deposit.

The Långban ores are considered to have been formed by precipitation in the dolomite near the surface as thermal products. Both the iron and the manganese was followed by a precipitation of silica, forming the original ore. The hausmannite has originated in part from manganese carbonate which locally still occurs as an essential mineral in the manganese ores. The original material for the iron is considered to have been Fe_2O_3 and for manganese Mn_2O_3 and $MnCO_3$. Possibly Fe_2O_3 and Mn_2O_3 have been precipitated as hydrates.

The high content of lead, arsenic and antimony in the manganese ores are due to metasomatic solutions acting on the ores. As the precipitation was near the surface there was sufficient oxygene present to enable the formation of oxides of these elements.

The deposits Pajsberg, Harstigen, Sjögruvan and Jakobsberg are similar to Långban but of smaller size. In the Nordmark deposit there occur manganese oxide ores which differ from the above described as lead minerals are missing and manganese silicates are rare. The main ore mineral in Nordmark is hausmannite. Manganosite, rhodocrosite, pyrocroite and calcite are also found. Together with the hausmannite occur barite, manganostibite and adelite.

At Slöjdartorp, Nyberget, there occurs a manganese ore that differs somewhat from the Långban type. The ore, which is associated with manganese-poor jaspilite iron ores, partly with lateral transitions, is bedded with layers of jacobsite, braunite, hematite and Mn-rich silicates (urbanite, rhodonite, spessartine, dannemorite, richterite, manganophyll and piemontite). The content of manganese is between 16 and 34 %. There is an other ore type which is built up of bed-like or lens-shaped hematite-spessartine layers partly with rhodonite and urbanite. The content of manganese is between 12 and 18 %. Furthermore there occur segregations and veins of manganese silicates together with braunite, hematite, jacobsite, barite, quartz and feldspars, which are due to chemical rearrangement and regional metamorphism. Connected with this process is a sulphide formation giving pyrite, some chalcopyrite and traces of sphalerite.

The Långban ore type seems to be rare in the world. Similar counterparts outside Sweden are found in Paleozoic sediments in the Southern Ural mountains and in the Atasu district in Central Kazakhstan where the greatest deposit are Karadzhal and Dzhumart. The zinc ore at Franklin Furnace, New Jersey, USA, shows certain similarities, especially the rather complex composition with silicates of manganese and lead.

References: Koark (1970), Magnusson (1924), (1929), (1930), Moore & Wickman (1971), Petersson (1896), Sjögren (1911 a).

NORTHERN SWEDEN

BEDDED Mn-OXIDE-SILICATE ORES (LÅNGBAN TYPE)

At Ultevis there is a lean manganese mineralization in volcanics which are considered as equivalents to the Arvidsjaur porphyries and Kiruna porphyries. In the volcanics, which mostly are of acid composition, occur layers of tuffites, quartzites, limestones and greenstone lavas. In the tuffitic sediments there are bedded ores with layers of hollandite, bixbyite, braunite and hematite together with viridine, spessartine and piemondite. Furthermore there occur layers of hematite, and in cases jaspilite, which are manganese-free. In the manganese oxides ores there is a concentration of barium and lead. All these features make the Ultevis ores resemble the Långban ores. The Ultevis ores are considered as syngenetic, chemical sediments which were formed in connection with the formation of the surrounding tuffites. The metal content of the ores was in part derived through leaching by carbonated water from the surrounding rocks and in part of direct volcanic origin and due to volcanic emanations.

The greater part of the Ultevis mineralization is, however, epigenetic. The manganese minerals occur as breccias, metasomatic replacements or as pegmatitic veins, all formed by mobilization processes in connection with granite intrusions. The primary sedimentary material has been brought into solution by means of hydrothermal emanations. In close connection with the epigenetic manganese mineralization occurs a mineralization with hematite, also being mobilized.

Furthermore the granite intrusions caused an addition of molybdenum and tungsten occurring as a weak mineralization of molybdo-scheelite.

At Porjus occur narrow zones of spessartine and rhodonite in a microcline gneiss which possibly is a metamorphosed volcanic rock. The gneiss is veined by granites and pegmatites. Other constituents in the manganese-mineralization are quartz, magnetite, allanite and fluorite. Also small amounts of hausmannite are encountered. The average content of manganese in the mineralization is 15.7 %. Most likely the deposit is, like the bedded ores at Ultevis, of syngenetic origin.

References: Geijer (1919), Ödman (1947), (1950).

COPPER-ZINC-LEAD ORES

In Sweden there are three geographical regions where complex sulphide ores with pyrite, pyrrhotite, chalcopyrite, sphalerite and galena occur, namely: 1. Central Sweden, 2. the Skellefte district and 3. the inner (western) part of the Caledonides. The ores occur either as compact bodies or impregnations.

The ores in the different regions differ from each other in age, appearance and geochemical features. The ores in Central Sweden and the Skellefte district are found in Precambrian rocks, mostly acid volcanics. The ores in the Caledonides occur in sediments and basic volcanics of Cambro-Silurian age. The metasomatic alterations of the wall rock that accompanied the ore-formation in Central Sweden involved an enrichment in magnesium and ferrous iron and in the Skellefte district and in the Caledonides involved a new-formation of sericite and chlorite. The ores in the Skellefte district and the Caledonides are mostly pyrite-dominated with additional amounts of pyrrhotite, chalcopyrite, sphalerite and galena, whereas the ores in Central Sweden mostly are made up of mixtures of these sulphides. The ores in the Skellefte district are relatively enriched in gold and arsenic compared those in the Caledonides (Fig. 2 and Table 7), the content of the other elements copper, zinc, lead and silver being rather similar. As only a little analytical data for the ores in Central Sweden is available no comparisons can be made in this respect.

Only the deposits in the Skellefte district and Central Sweden are mined at the moment (Table 3).

The sulphide ores of the Skellefte district and the Caledonides show similarities to some pyritic ore deposits of igneous derivation outside Sweden. Counterparts include Lökken and Sulitelma, Norway, which are the direct continuation of the ores in the Caledonides. Other similar deposits are Rio Tinto, Spain; Maidanpek, Jugoslavia; Beshi and Hitachi, Japan and United Verde, Arizona. The sulphide ores in Central Sweden are with their magnesium-rich wall rock alteration of rather odd character. Similar ores are found in the Orijärvi district, SW Finland.

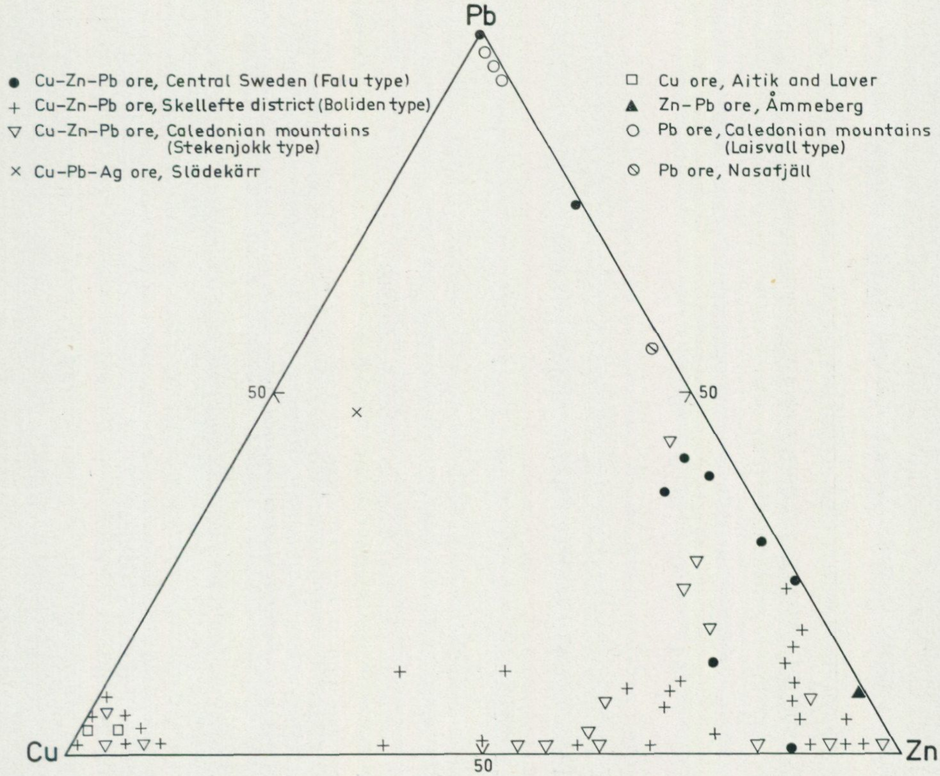

Fig. 2. Distribution of Cu, Zn and Pb in some types of sulphide ore in Sweden.

TABLE 7. Analyses of some of the sulphide ores in Sweden

	% Cu	% Zn	% Pb	% S	Ag g/t	Au g/t	Ag g/t / % Pb	Au g/t / % Cu	100×Au g/t / (%Cu+%Zn+%Pb)
COPPER-ZINK-LEAD ORES, massive bodies or disseminations									
Central Sweden (Falu type)									
Falun		4	1.5	30					
Falun, Cu-ore	2−4			32−42	(13−24)	(2−4)			
Kalvbäcken, Zn-ore	0.1	28.1	8.4	28	200		24		
Ö. Silvberg, FeS_2-ore	0.9	5.6	1.2		45		38		
Ö. Silvberg, Zn-ore		22.5	2.9		70		24		
Garpenberg	0.4	3.9	3.0		94	1	31	2.5	13.5
N. Garpenberg	0.07	1.2	2.9		187	0.2	64	3	4.8
Ryllshyttan		42.8	1.5	26					
Saxberget	1	←23→			200	1−2			
Saxberget	0.9	4.5	3						
Ljusnarsberg	0.5	8.5	5.5						
Sala							800−1000		
Håksboda	1				30	2			200
Hällefors	tr.	12.8	38.9		1560		40		
Skellefte district (Boliden type)									
Adak	1.9								
Karlsson	4.5								
Lindsköld	1.7								
Brännmyran	1.7								
Rudtjebäcken	0.8	3.0	0.1	35					
Kristineberg	1.0	2.4	0.3	27	23	0.9	77	0.9	24.3
Kimheden	1.2	0.1		21	6	0.3		0.3	23.1
N. Brattmyrhögen				33					

TABLE 7, continued

	% Cu	% Zn	% Pb	% S	Ag g/t	Au g/t	Ag g/t / % Pb	Au g/t / % Cu	100×Au g/t / (%Cu+%Zn+%Pb)	% As
					Skellefte district, continued					
Rävlidmyran	1.2	3.7	0.5	20	55	0.9	110	0.8	16.7	
Rävliden, Cu-ore	1.9	3.1		22	67	0.6		0.3	12.0	
Rävliden, Zn-ore	0.4	8.4	1.7	20	193	0.2	114	0.5	1.9	
Rakkejaur	0.3	2.3		27	45	1		3.3	38.5	1.6
Näsliden A	1.1	3	0.3	29	35	1.3	117	1.2	29.5	1.3
Näsliden B	0.6	1.7	0.2	26						
Inre Sjömalmen	0.5	2.2		31						
Elvaberget	0.6	1.9		32						
W. Maurliden	0.2	2.7	0.3	36	44	0.7	147	3.5	21.9	
E. Maurliden	0.8	0.5		33	16	0.8		1	61.5	
Bjurfors	2.6			27						
Bjurliden	0.1	3.7	0.2		40	0.2	200	2	5.0	
E. Bjurträsk	0.3	6.6		34						
Svansele	0.3	0.3		36						
Udden	0.5	4.8	0.3	27	38	0.8	127	1.6	14.3	
Åsen	1.7	1.9	0.5	23	64	1.0	128	0.6	24.4	
W. Renström	0.9	11.7	2.0	28	184	3.9	92	4.3	26.7	0.3
Kankberg	0.3	2.9	0.4	37	45	2.4	112	8	66.7	0.8
Bastuheden	1–1.2			5–6						
W. Åkulla	1			34						
Boliden	1.4	0.9	0.3	25	50	15.5	166	11	596.1	6.8
Långsele	0.4	4.3	0.3	35	25	0.8	83	2	16.0	0.4
Långdal	0.1	5.9	1.8	12	154	1.9	86	19	24.4	
Average all ores	0.8	2.3	0.2	30	39	1.5	195	1.9	45.5	0.8

TABLE 7, continued

	% Cu	% Zn	% Pb	% S	Ag g/t	Au g/t	Ag g/t / % Pb	Au g/t / % Cu	100×Au g/t / (%Cu+%Zn+%Pb)
Caledonides, inner (western) part (Stekenjokk type)									
Essmitjåkko	2	19	16		100	1	6	0.5	2.7
Rikarbäcken	0.8	4.3	1.1	35	43	0.2	39	0.3	3.2
W. Storbäcksdalen	1.2	6.3	2.4	16	49	0.5	20	0.4	5.1
Tjåter	1.0	4.8	1.9	13	49	0.5	26	0.5	6.5
Gaisar	0.8			30					
Daningen	2			30					
Remdalen	1.5	2.5		25					
Stekenjokk	1.5	3.0	0.3	20	53	0.3	177	0.2	6.3
Levi	1.2	1.6	<0.1	16	20	<0.1			
Tjokkola	1.1	1.9		6					
Ankarvattnet, FeS-ore	0.6	8	0.1		<5	<0.1			
Ankarvattnet, FeS_2-ore	0.6	7	0.9		45	0.5	50	0.8	5.9
Ankarvattnet, total	0.5	5.5	0.4	18	17	0.2	42	0.4	3.1
Jormlien	1	16–20		30					
Fröå	1–1.5	>1.5							
Average 13 deposits	1.3	3.2	0.3	20	44	0.2	147	0.2	4.2
COPPER-LEAD-SILVER ORES, fissure veins									
Southern Sweden									
Slädekärr	0.85	0.24	0.96		170		177		
COPPER ORES, fissure veins									
Northern Sweden									
E. Liikavaara	0.6				6	0.1		0.2	15.9
Aitik	0.4			1.5	5	0.3		0.8	75.0
Laver	1.5				36	0.2		0.1	13.2
Nautanen	4.4				57	tr.			

TABLE 7, continued

	% Cu	% Zn	% Pb	% S	Ag g/t	Au g/t	Ag g/t / % Pb	Au g/t / % Cu	100×Au g/t / (%Cu+%Zn+%Pb)
ZINC-LEAD ORES, layered disseminations									
Central Sweden									
Åmmeberg, Zn-ore		38.5	3.3		58		17		
Åmmeberg, average		10.5	1.4						
LEAD ORES, stratabound fissure veins and disseminations									
Caledonides, eastern part (Laisvall type)									
Vassbo		0.3	5.7		18		3		
Bellviksberg		0.3	5.0		21		4		
Lövstrand			2.4						
Majva		0.1	5.1		110		22		
Average all ores	<0.01	0.3	3.8		11		3		
LEAD ORES, fissure veins									
Southern Sweden									
Simrishamn							0.7		
Central Sweden									
Boda			16		150		9		
Northern Sweden									
Kväcklinge	0.1		18.5		933	1	51	10	5.4
Olden							9		
Nasafjäll		1.2	1.5		30		20		
Kvikkjokk							30		
Lanjek							16		
Alkavare							16		

References: Grip & Frietsch (1973), Magnusson (1960), Tegengren (1924).

CENTRAL SWEDEN

MASSIVE ORES — DISSEMINATIONS OF Fe-Cu-Zn-Pb-SULPHIDES (FALU TYPE)

There is a great number of sulphide ores with copper, lead and zinc in Central Sweden. Most of them are rather small. The ores are connected with the magnesia-metasomatism that altered the hälleflintas-leptites and the limestones in the volcanic-sedimentary complex in Central Sweden (cf. p. 14). The alterations and the ore-formation are believed to have been casused by solutions during the folding of the volcanic complex and the intrusion of the older group of Svecofennian granitoids. The leptites were changed into mica-schists and ”quartzites”. These rock are rich in minerals such as cordierite, almandine, andalusite, gedrite, anthophyllite and cummingtonite. The limestones were altered more or less into dolomites or into skarns with tremolite-diopside, anthophyllite, cummingtonite, humite minerals, forsterite, serpentine and talc. The dolomites were sometimes changed into ophicalcite with serpentine pseudomorphos after humite minerals and forsterite. In many localities the quartz-banded iron ores of Central Sweden have been affected by the sulphide-bearing solutions and the iron ores consequently intermingled with sulphide minerals and skarn minerals.

The sulphide ores formed where the tectonic and chemical conditions were suitable. Favourable rocks are limestones and silicate rocks bordering the limestones. The ores occur in the limestones, the ”quartzites” and in fissures or along faults. The sulphides are often localized along thrust planes, fold axes and zones of schistosity, especially in areas with limestones. In part the ore minerals occur in ”sköls” of biotite, chlorite and talc together with anthophyllite, gedrite, cummingtonite, hornblende, almandine and cordierite. These ”sköls”, which often are branching and forming a network, are considered to have been channelways for the ore forming solutions. This epigenetic explanation has its opponents and it has been proposed that the ores are syngenetic in the leptites and that the ore-formation is due to exhalative-sedimentary processes.

The main ore minerals in the sulphide ores of Central Sweden are pyrite, pyrrhotite, chalcopyrite, sphalerite and galena. Of these minerals either one or several form the ore or they can be mixed in complex ores. The minerals occur in concentrations varying from weak disseminations to massive ores. Impregnations of chalcopyrite in the ”quartzites” are the most common among the disseminated ores and are characteristic for the Falu type of ore. The compact ores are made up of galena together with sphalerite or of pyrite. Along shear zones there occur compact ores which contain rounded pieces of the wall rock. These ”pebbles ores” are formed when tectonic movements have been active.

Other ore minerals found locally and mostly only in small amounts are bornite, chalcocite, cubanite, vallerite, arsenopyrite, molybdenite, gold and selenium-lead-bismuth minerals (Falu mine), cobaltite (Riddarhyttan mine), native silver with antimony and mercury minerals (Sala mine), dyscrasite, pyrargyrite and silver-bearing tennantite-tetrahedrite (Garpenberg mine).

On the basis of the character of wall rock two different types of ore can be discerned. There are lateral transitions between these and often both occur in the same deposit.

The first type is bound to the limestones-dolomites and related skarns. In this group the ore minerals are mostly galena and sphalerite. The galena is often silver-bearing. Representatives are Sala, Kaveltorp, Lövåsen, Ryllshyttan and Skyttgruvan. There are also exceptions from the rule that galena-sphalerite occur in limestones-dolomites and skarns, for example at Garpenberg, where these minerals mainly occur in the ”quartzites” and mica-schists, and only to a minor degree in dolomites.

The second ore type occurs in the volcanics (leptites) which in the neighbourhood of the ores are altered into ”quartzites” with cordierite, anthopyllite, gedrite, cummingtonite, andalusite, almandine and biotite. Farther away from the ores the leptites are altered into mica-schists with cordierite and andalusite. In these rocks occur mainly chalcopyrite ores, but ores with pyrite, sphalerite and galena are also found. Representatives for this ore type are among others Falun, Garpenberg, Riddarhyttan, Öster-Silvberg, Näverberg and Tomtebo.

References: Du Rietz (1968), Geijer (1917), (1923), (1924), (1958), (1962), (1964), (1965), Hübner (1966), Koark (1962), Landergren (1931), Magnusson (1936 b), (1940 b), (1948), (1960), Pilava-Podgurski (1957), Santesson (1889), Sjögren (1911 c), Sundius et al. (1966 a), (1966 b), (1967), Ödman (1933).

NORTHERN SWEDEN

MASSIVE ORES — DISSEMINATIONS OF Fe-SULPHIDES WITH Cu-Zn-Pb IN THE SKELLEFTE DISTRICT (BOLIDEN TYPE)

The Skellefte district contains a considerable number of sulphide deposits. 15 mines are operating and five ore bodies have been mined out.

The stratigraphy of rocks in the Skellefte district is shown in Table 8.

TABLE 8. Stratigraphy of the rocks in the Skellefte district

Age m.y.	Supracrustal rocks	Intrusive rocks	Processes
1 625		Sorsele granite	
1 725	Conglomerate and volcanics		
1 785		Revsund granite	Folding. Migmatization. Formation of sulphide ore
	Schists and basic volcanics Unconformity with ”border zone”		
1 880		Jörn granite	Folding, formation of diapires
	Acid-intermediate volcanics with sediments		

The oldest rocks are quartz-porphyries, quartz-keratophyres, keratophyres, their pyroclastic products and other sedimentary intercalations. In connection with the intrusion of the Jörn granite, which is a differentiated series whose first members are gabbros and diorites, the volcanics were folded and diapiric structures were formed. These cupolas are of great importance for emplacement of the sulphide ores. Then followed a denudation of the rocks giving the "border zone" with weathering breccias, conglomerates and limestones. At the same time there occurred eruption of basic volcanics. This period of denudation and volcanism was followed by a period of sedimentation of schists. The basic volcanism continued during the sedimentation. The rocks were then folded and migmatized, the end result of which was the formation of the Revsund granite.

The sulphide ores in the Skellefte district are epigenetic and their formation was accompanied by metasomatic alterations of the wall rock. The main ore minerals are pyrite, pyrrhotite, chalcopyrite and sphalerite together with galena in varying amounts. Arsenopyrite is occurring in many deposits.

The ores are found in the "border zone" or in the immediate proximity to that, in the lower, acid volcanics or in the above lying schists. The coarse sediments of the "border zone" acted as a suitable channel for the transportation of the ore forming solutions. The above lying schists and basic volcanics acted as "cap rocks" and the ore-forming solutions were stopped against these.

The most common metasomatic alteration product of the wall rock are sericite quartzites and chlorite quartzites which have been formed from acid or intermediary volcanics or sediments. In part there are also pure sericite or chlorite schists. Furthermore occur minerals indicating a higher temperature of formation such as garnet, cordierite, andalusite, staurolite and spinel, locally also tourmaline. Where the wall rock is lime-rich there were formed skarn minerals (tremolite-actinolite, hornblende, diopside and epidote). The alteration rocks form aureoles around the ores, but are also known to occur outside the ores, often connecting different deposits.

The deposits can be divided into: 1. compact ores, 2. disseminations connected with the compact ores and 3. breccia ores and disseminations indepedent to compact ores.

The most common mode of occurrence is as compact ore bodies. These are built up of pyrite and subordinate pyrrhotite, chalcopyrite and sphalerite in varying amounts. The economic value of the ores lies mostly in the content of chalcopyrite and sphalerite. The copper and zinc ores occur in separate ore bodies within the same deposit or as different parts in the same ore body. Connected with sphalerite is galena, always being the subordinate of these two minerals. Arsenopyrite is a common constituent and occurs mixed with the other ore minerals or as separate, massive ores and veins. Associated with the galena are antimony minerals (Cu-Sb-S- or Pb-Sb-S-minerals). In the Boliden mine bismuth, tellurium and selenium minerals occur. Precious metals occur in some ores in concentrations of conspicous economic importance. Gold is found in several deposits, mostly in connection with the arsenopyrite ores. Silver is preferentially concentrated to ores richer in lead, especially in such ores which contain antimony minerals. The grades of the main metals are given in Table 7.

The compact ore type occurs as disc- or lens-formed bodies which are more or less elongated in the direction of lineation and fold axes.

Representatives of the massive ore type include Boliden, Rävliden and Kristineberg. The ore at Boliden, which was in operation from 1924 to 1967 when it was exhausted, is the most complex of the ores in the Skellefte area. The mine yielded 8.3 millions tons of ore giving 118 000 tons of copper, 566 000 tons of arsenic, 128 tons of gold, 411 tons of silver and smaller amounts of other elements as selenium and tellurium. The ore contained on average 1.4 % Cu, 0.9 % Zn, 0.3 % Pb, 25 % S, 15.5 g/t Au and 50 g/t Ag. There are three types of ore, indicated in the order of formation: 1. arsenopyrite ore, 2. lamprophyre ore with quartz, tourmaline and sulphides and 3. pyrite ore. The wall rock is rather intensely chloritized and sericitized by hydrothermal solutions which preceeded the introduction of the ore. The arsenopyrite ore was formed at a relatively high temperature. The second ore type is connected with the intrusion of lamprophyres. These were followed by solutions giving quartz, tourmaline and elements as bismuth, tellurium, selenium, gold and silver. The mineral association in this ore type is rather complex and there occur many rare ore minerals. The third stage in the ore formation at Boliden is the pyrite ore with chalcopyrite, pyrrhotite and quartz.

In several deposits the compact sulphide ore bodies are associated with disseminations of sulphides in the altered wall rock. Many of these contain chalcopyrite, sphalerite, galena and precious metals in such amounts that the mineralizations are economic to mine.

In the third type of ore in the Skellefte district the sulphides occur as breccias or impregnations with no direct connection with massive pyrite ore bodies. This ore type occurs in the Adak area which has a cupola structure. The alteration of the wall rock is different from the above mentioned, here occur "ore quartzites" rich in cordierite and cummingtonite. Other new minerals are almandine, chlorite, biotite, muscovite and andalusite. The most common ore minerals are chalcopyrite and pyrrhotite, which often are accompanied by arsenopyrite. Pyrite occurs only occasionally. This ore type is represented by the Adak and Karlsson ores. In addition there are lens-formed ore bodies in the Adak area, namely Lindsköld, Brännmyran and Rudtjebäcken. The Rudtjebäcken ore is pyritic and similar to the compact ore type in the other parts of the Skellefte district. In the Lindsköld mine there occurs a low temperature mineralization phase with calcite filled veins with sphalerite and small amounts of native arsenic, native silver, dyscrasite, proustite, tetrahedrite and Co-Ni-arsenides. Besides calcite the gangue is made up of quartz and zeolites.

Most of the important sulphide ores in the Skellefte district are considered to be genetically related to the Revsund granite and its formation. Possibly the ores represent secondary concentrations of the original metal content of the sedimentary rocks in the Skellefte district, in the first hand the black schists. The metals were driven out in connection with the granitization and the formation of the Revsund granite. The Adak ores are genetically related to the formation of the Adak and Sorsele granites which are younger than the Revsund granite. According to other views the ores in the Skellefte district are stratabound and of submarine-volcanic origin. The ore formation followed by later deformation and remobilization of the ore material through tectonic and metamorphic processes.

References: Bergenfelt (1953), du Rietz (1953), Gavelin (1939), (1942), (1943), (1945), (1948), (1952), (1953), (1954), (1955), Gavelin & Gabrielsson (1947), Grip (1948 a), (1948 b), (1951 a), (1951 b), Grip et al. (1960), Grip & Frietsch (1973), Grip & Wirstam (1970), Grip & Ödman (1942), (1944), Hübner (1967), Ljung (1974), Nilsson (1968), Rickard & Zweifel (1975), Ödman (1939), (1941).

MASSIVE ORES — DISSEMINATIONS OF Fe-SULPHIDES WITH Cu-Zn-Pb IN THE INNER (WESTERN) PART OF THE CALEDONIDES (STEKENJOKK TYPE)

In the inner (western) part of the Caledonides occur several sulphide deposits. The orogenic belt has a N—S extension and is made up of nappes of late Precambrian and Cambro-Silurian rocks which dip gently westwards. The rocks are dominantly sedimentary. Volcanics are probably absent in the older rocks but in the Ordovician rocks occur volcanics with agglomerates and tuffs of varying degree of basicity. In the inner (western) part of the mountains occur minor bodies and massifs of ultrabasic, gabbroic and granitic intrusive rocks. At the eastern margin of the mountain range the rocks are in undisturbed position. In this part occur rocks from Eocambrian to Ordovician, lying on a Precambrian basement. Over these lie the nappes of which the Seve-Köli Nappe complex forms a major unit. It is formed by highgrade, metamorphic rocks (Seve) in the east with mica-schists, gneisses and amphibolites. The upper Köli part of the complex is built up of lowgrade, metamorphic rocks as phyllites, quartzites and limestones.

The greatest part of the ores occur in the Köli meta-sediments and meta-volcanics, partly of Ordovician but partly also of Silurian age. The host rocks are greenschists, amphibolites, phyllites and mica-schists. The greatest deposit, Stekenjokk, occurs in a pile dominated by quartz-keratophyre, generally altered and rich in sericite and chlorite. The ores are remarkedly stratiform but might occur at several levels within one stratigraphic unit. The geometry of the ore bodies is mainly controlled by tectonic structures and they are strongly elongated, parallel to lineations and fold axes. Massive ore bodies are the most common; disseminated ores are less common. The ore minerals are pyrite and pyrrhotite with varying amounts of chalcopyrite, sphalerite and galena. The Stekenjokk deposit contains more than 15 million tons of ore. It is partly a massive pyrite ore with sphalerite and chalcopyrite. In lesser amounts occur pyrrhotite, galena, arsenopyrite, argentite, bornite, bournonite, tetrahedrite-tennantite and cubanite. In addition, large volumes of disseminations occur in sericite quartzite and graphite schist adjacent to the massive ores. The impregnations contain pyrite and chalcopyrite with smaller amounts of pyrrhotite, sphalerite, cubanite and arsenopyrite.

The 13 greatest deposits of the inner Caledonian belt contain together 25 million tons of ore with an average of 1.3 % Cu, 3.2 % Zn, 0.3 % Pb, 20 % S, 0.2 g/t Au and 44 g/t Ag.

There are some deposits which have a composition somewhat different from that described above. Thus Essmitjåkko is a sphalerite-galena-rich ore, low in Fe-sulphides and with relatively high contents of copper, silver and gold (cf. Table 7). The Jormlien deposit is made up of pyrrhotite, sphalerite and chalcopyrite with 1 % Cu and 16—20 % Zn. The Ankarvattnet deposit is partly made up of pyrrhotite and partly of pyrite. In both occur small amounts of sphalerite, and in the pyrite ore also a little galena.

The ores of the Stekenjokk type are considered to be of volcanic-sedimentary origin. During the Caledonian orogeny the ore material was mobilized, reworked, and concentrated, the new geometry being influenced by the major fold phases.

All the described sulphide ore bodies lie in the Köli rocks in the northern part of the Caledonides. Further to the south in Jämtland and Härjedalen there occur within the Seve part a few sulphide deposits. The host rock is mostly a quartzite-gneiss with silicate skarn (epidote, hornblende and garnet) and limestone intercalations. The ores, which form long zones of impregnation, are built up of pyrite, chalcopyrite, sphalerite and some bornite and pyrrhotite. Representatives are Bjelke, Fröå and Ljusnedal. In Ljusnedal the sulphide mineralization is connected with an epidote-bearing magnetite ore.

References: Grip & Frietsch (1973), Helfrich (1967), (1969), Juve (1974), Zachrisson (1971).

COPPER-LEAD-SILVER ORES

This ore type, which occurs in Dalsland and SW Värmland, is of hydrothermal origin and is made up of quartz veins with copper sulphides, silver-bearing galena, tetrahedrite and in part native silver. The gangue contains calcite, barite and fluorite. The veins are related to fault zones and are younger than or connected with the folding of the Dalsland group (about 1 000—1 250 m.y. old). This group is cut by the Bohus granite (aboute 930 m.y. old) and the formation of the ore could possibly be related to this granite.

These vein deposits belong to a type of ore which is widespread throughout the world, although in most cases containing sphalerite as an essential mineral. Examples include Erzgebirge around Freiberg, Germany and Sadon, Altai, W. Mongolia.

SOUTHERN SWEDEN

FISSURE VEINS WITH Cu-Pb-SULPHIDES AND SILVER

In Dalsland, near the western shore of Lake Vänern, there are small deposits (Slädekärr and Vassvik) of sulphide-bearing quartz veins. They occur in E—W striking fissures in the sedimentary rocks of the Dalsland group and the surrounding intrusives. The veins occur in crush zones formed in connection with the folding of the Dalsland group. The width of the veins is usually 1 to 2 m. The ore minerals are galena, chalcopyrite, bornite, chalcocite, pyrite and tetrahedrite-tennantite. Furthermore there occur native silver, proustite, molybdenite and magnetite. The veins can be divided into the following types: 1. veins with pyrite, chalcopyrite and galena, 2. veins with bornite and 3. veins with tetrahedrite-tennantite. The galena contains 1 200—22 000 g/t Ag and the tetrahedrite 6 000—8 000 g/t Ag. The gangue is made up of quartz with subordinate amounts of carbonate (calcite, siderite and ankerite) and chlorite, sometimes also barite, fluorite and albite.

In the proximity of the Kesebol manganese ore (p. 25) there is a copper mineralization with chalcocite, bornite and chalcopyrite. The copper ore passes partly into the manganese ore and is accompanied by quartz, magnetite and hematite. Furthermore there occur barite, fluorite, silver-bearing tetrahedrite, bementite and galena.

In SW Värmland, NW of Lake Vänern, there are sulphide-bearing quartz veins which possibly are related to the above mentioned type. The Värmskog veins, which have a E—W extension, are built up of chlorite, sericite, epidote and quartz. The wall rock are gneisses, possibly of Pre-Svecofennian age which in connection with the formation of the veins have been hydrothermally altered. The feldspar has been changed to sericite and the biotite has been bleached. The outer parts of the veins are rich in chlorite; this is succeeded inwards by sericite and epidote veined by quartz and, in the middle of the veins, by quartz with the gangue and ore minerals. Two types of veins occur: 1. silver veins with silver-bearing galena, sphalerite, chalcopyrite and locally a silver-bearing tetrahedrite and 2. copper veins with chalcocite, bornite and chalcopyrite. Additional minerals found in the veins include hematite, pyrite, ilmenite, linneite, millerite, native gold and sphalerite. The gangue consists of calcite, fluorite, ironspar and barite. The width of the veins is less than 2 m.

At Glava there occur quartz veins 0.4—0.6 m wide which differ somewhat in mineralogical composition from the above as galena and tetrahedrite are missing and the silver occurs in other minerals (tellurides and selenides). The main ore minerals are bornite and chalcocite, with subsidiary chalcopyrite, pyrite and hematite. Minor constituents include tellurides of gold, copper and silver plus lead; selenides with lead, bismuth, copper and silver, native gold, native silver and native bismuth. The gangue contains barite and calcite. The veins have metasomatically altered the wall rock with the formation of epidote and chlorite.

A rather similar copper mineralization to those mentioned above occurs in the great mylonite zone which separates the veined gneisses of SW Värmland from the central gneisses of Värmland. At Mangen, Bortan and Treskog impregnations of quartz with chalcopyrite and bornite occur in crushed and schistose rocks.

References: Jongejan & Westerveld (1949), Magnusson (1973), Tegengren (1924).

SELENIUM ORE

SOUTHERN SWEDEN

FISSURE VEINS WITH Cu-SULPHIDES AND Cu-Ag-SELENIDES

At the Skrikerum mine there are supracrustal rocks bordered or surrounded by Småland granites (about 1 700—1 750 m.y. old). The ore which has been mined for copper and selenium minerals occurs in amphibolites which are cut by aplite schlieren. In a fracture zone in the amphibolites occur calcite veins which contain berzelianite, eucarite and crookesite and further also chalcopyrite and bornite. The main copper mineralization at Skrikerum was apparently in tectonized and altered parts of the amphibolites. The alteration meant replacement of the amphibole by hisingerite and chlorite and deposition of quartz and calcite together with small amounts of pyrite. Furthermore there occur thucolite and other secondary uranium minerals. The mineralization is regarded to have been formed by the intrusion of the Småland granites.

Similar fissure veins of hydrothermal origin are outside Sweden found at Harz, Germany; Sierro de Umango, Argentina; Sierra de Guanajuato, Mexico and Pacajake, Bolivia.

References: Tegengren (1924), Welin (1966 b).

COPPER-COBALT ORES

There are three different types of copper-cobalt ores in Sweden, namely: 1. layered disseminations, 2. fissure veins and 3. disseminations of metasomatic origin belonging to the Falu type of ore.

The copper-cobalt ores occurring as layered disseminations are made up of copper-sulphides, cobalt-sulphides and -arsenides. In addition bismuth occurs as sulphides or lead-bismuth-sulphides. These bedlike impregnations form narrow zones but are of considerable length. They occur in Southern Sweden at Lake Vättern and east of the northern end of the same lake. The ores are similar in mode of occurrence to the ore at Åmmeberg (cf. p. 48) and are considered either to have been formed by metasomatic replacement (epigenetic) or to be volcanic-sedimentary (syngenetic).

The only representative of the copper-cobalt ores in fissure fillings is the Los deposit where calcite-quartz veins contain copper-sulphides, nickel-arsenides and -sulphides, cobalt-arsenides and -sulphides together with native bismuth and bismuth-sulphides. The ore is of hydrothermal origin and belongs to the common cobalt-nickel-arsenide association of the "Cobalt" type.

SOUTHERN SWEDEN

LAYERED DISSEMINATIONS WITH Cu-Co-SULPHIDES AND Co-ARSENIDES

The Gladhammar ore lies in the Västervik quartzite (more than 1 950 m.y. old) which is surrounded by granites. In this quartzite occur long and narrow zones of skarn-like rocks which follow the bedding in the quartzite. The skarn is built up of chlorite, hornblende and biotite together with quartz and some calcite. In these zones and in apophyses there are impregnations of magnetite, hematite, pyrite, chalcopyrite, bornite, linneite and cobaltite. In addition there are subordinate amounts of sphalerite, galena, molybdenite and lillianite ($Pb_3Bi_2S_6$). In the area occur also magnetite-hematite ores which are older and thus impregnated with the sulphides. The sulphides have been mined for copper and cobalt. At the 1870s an ore with 6 % Co was mined.

At Tunaberg occur bedlike layers of sphalerite, galena and pyrrhotite in a leptite and of copper-sulphides, cobalt-arsenides and -sulphides in a skarn-bearing limestone. The rocks belong to the volcanic-sedimentary complex in Central Sweden (p. 14). The limestone which is surrounded by granites and pegmatites is rich in a skarn of salite together with basic plagioclase, zoisite, scapolite, allanite and sphene. In the limestone occur lens-formed impregnation zones with chalcopyrite, cobaltite and small amounts of safflorite. The richer parts of these impregnations contain about 2 % Co.

The Vena ore is made up of long narrow zones of sulphide impregnations in leptites, leptite gneisses and amphibolites which are intercalated in these rocks. The rocks are cut by granite and pegmatite veins. The ore minerals are (in order of abundance) pyrrhotite, pyrite, chalcopyrite, cobaltite, sphalerite, arsenopyrite, kobellit, galena, speisscobalt and bismuthinite. Locally the leptite near the ore is altered to a cordierite-bearing "quartzite" or to a biotite- or chlorite-rich rock which in part is cordierite-bearing. The ore minerals are accompanied by tourmaline, amphibole, sphene, zoisite and sometimes also cordierite. The ore contains about 0.2—0.5 % Co and somewhat higher contents of copper. The formation of the ore is considered to be due to the younger pegmatite veins.

The mineralogical composition of the Tunaberg and Vena ores is rather similar to that found in contact-metasomatic magnetite-skarn deposits where cobaltite occurs adjacent to the iron ore as in Dashkesan, Azerbaidzhan, USSR.

References: Geijer (1924), Johansson (1910), Magnusson (1973), Tegengren (1924).

CENTRAL SWEDEN

FISSURE VEINS WITH Cu-Co-Ni-Bi-SULPHIDES AND U-OXIDES

In the Los area occur amphibolites, partly gabbroic, which are metamorphosed greenstones. These rocks, which are contemporaneous with the Svecofennian supracrustal rocks in other parts of Central Sweden, are partly schistose and albitized. In connection with this process there were formed weak impregnations with pyrrhotite, pyrite, chalcopyrite and smaltite. Economically more important are narrow fissures filled with calcite and quartz, small amounts of hornblende, barite, fluorite and tourmaline. In these veins, which formerly were mined, occur cobaltite, gersdorffite, pyrrhotite, chalcopyrite, pitchblende, pyrite, arsenopyrite, bismuthinite, native bismuth and marcasite. Furthermore there are found chalcocite, sphalerite, galena, tennantite-tetrahedrite and nickelin. The mineralization contains 0.12 % Co, 0.11 % Ni, 2.79 % Cu, 65 g/t Ag and 0.5 g/t Au. The age of the mineralization is estimated to about 1 690 m.y. which is contemporaneous with the post-orogenic Dala granites (Sub-Jotnian) in the Los area. The mineralization is of hydrothermal origin and similar to those occuring at Erzgebirge, Germany; Great Bear Lake, Canada and Shinkolobwe, Zaire.

References: Grip (1961), Lundqvist (1968), Welin (1966 a).

DISSEMINATIONS WITH Fe-Cu-Zn-Pb-SULPHIDES and Co-SULPHIDES

At Håkansboda occurs an ore of the Falu type (p. 34). There are disseminations of sulphides partly in a dolomite and partly in a leptite metasomatically altered to a ”quartzite”. The ore minerals are chalcopyrite, pyrite, pyrrhotite, sphalerite and galena. In addition occur arsenopyrite, glaucodote, cobaltite and native bismuth. The ore has been mined for copper and contained about 1 % Cu, 2 g/t Au and 30 g/t Ag.

References: Magnusson (1973), Tegengren (1924).

COPPER ORES

In Sweden there occur copper deposits in: 1. veins and impregnations which are of magmatic origin and 2. sediments where the origin of the ores is uncertain, either syngenetic or epigenetic.

SOUTHERN SWEDEN

FISSURE VEINS AND DISSEMINATIONS WITH Fe-Cu-SULPHIDES

The copper ores which occur in Southern Sweden as fissure fillings, are built up of pyrite and pyrrhotite together with copper-sulphides (mostly chalcopyrite) which represent the economic value of the deposit.

Around Åtvidaberg in Östergötland occur long and narrow pyrite-chalcopyrite impregnations in mica- and quartz-rich zones in a gneissic granite of early Svecofennian age. Furthermore there are quite small ores of copper in amphibolites and leptites which are intruded by the same granite. In the mineralized zones of the granite which follow the schistosity and the borders of the granites, occur biotite and quartz, some garnet and amphibole and small amounts of tourmaline and fluorite. In the Mormorsgruvan mine, the most valuable deposit in the Åtvidaberg area, the ore is built up of chalcopyrite, pyrite and some bornite. Occasionally arsenopyrite is observed. The ore contains rounded pebbles of quartz and a quartz-biotite schist which indicates that deformation occurred during the formation of the ore. The metasomatic alteration which produced the ore is younger than the older granites. The ore forming process is considered either to be related to late solutions from the same granite magma in which the mineralization occurs, or, according to other opinions, to be related to tourmaline-bearing pegmatites and quartz veins of late Svecofennian age.

The Bersbo mine, also in the Åtvidaberg area, is in some respects similar to the above described deposit, but in other respects similar to the sulphide ores of the Falu type in Central Sweden. The ore at Bersbo occurs as impregnations or massive bodies in leptites, which in the ore-bearing parts are altered to biotite- or chlorite-rich rocks, quartzitic rocks and to mica-schists. In these rocks occur minerals such as andalusite, fibrolite, cordierite and gahnite. The ore minerals are pyrrhotite, magnetite, pyrite and chalcopyrite and sometimes a little sphalerite.

The Solstad mine lies in the Västervik quartzite (older than 1 950 m.y.). The rock is cut by fissures filled with chlorite, biotite and amphibole in which, or around them, occur chalcopyrite with subordinate amounts of pyrite and pyrrhotite.

References: Geijer (1924), Sundius (1921), Welin (1966 b).

BEDDED DISSEMINATIONS WITH Cu-SULPHIDES

At Stora Strand in Dalsland there is a copper mineralization in a phyllitic mica-chlorite-schist in the Dalsland group (about 1 000—1 250 m.y. old). The schist which contains up to 1 % Cu has a maximum width of 1 metre. The horizon can be followed for about 20 km. The copper schist has a high content of sodium (3—4 %) present in finely dispersed albite. The albite forms often segregations together with quartz and some brownspar (Ca-Mg-Fe-Mn carbonate), chlorite, chalcopyrite and fluorite. Bornite and galena occur rarely. The chalcopyrite impregnation occurs as small streaks or as a fine matrix in the schists. The copper mineralization is considered either to be a syngenetic, sedimentary deposit formed simultaneously with the host rock by interaction between the metal ions in the sea water and sulphur bacterias, or to be an epigenetic deposit formed by hydrothermal infiltration into the host rock. The latter opinion is supported by the high content of sodium, a feature not usual in a normal sediment. The deposit at Stora Strand has many features in common with the Mansfield ores ("Kupferschiefer") in Germany.

On the island Visingsö there is found a sandstone with a mineralization with pyrite, chalcocite, chalcopyrite, covellite and secondary minerals as limonite, malachite and azurite formed by weathering. The ore minerals occur as concretions together with calcite and replace the groundmass of the sandstone more or less completely. Pyrite is the oldest ore mineral and its formation was a process without any direct connection with the formation of the copper ore. The sandstone belongs to the so-called Visingsö formation, a sedimentary series of rocks mainly distributed around the Lake Vättern basin. The formation is younger than the Late Precambrian Jotnian sandstone series and older than the Cambrian, and thus belongs to the Eocambrian. The ore deposit at Visingsö is in part similar to the "Red bed" deposits in Western USA, Central Europe and the Urals, which are usually considered to have been formed as concentrations by precipitation from percolating meteoric waters. According to other opinions the ores are epigenetic and formed hydrothermally in the epi-tele-termal interval. Certain features of the Visingsö mineralization indicate a formation by ascending, low-hydrothermal solutions.

References: Brotzen (1941), Johansson (1909), Ödman (1942).

NORTHERN SWEDEN

FISSURE VEINS WITH Cu-SULPHIDES

In the county of Norrbotten occur at many places copper mineralizations but these are mostly too lean to be workable. The mineralizations follow in many cases the same stratigraphic horizon as the skarn iron ores and the quartz-banded iron ores, i.e. they occur in the upper part of the greenstone group (cf. p. 19). In part the copper mineralizations occur in acid volcanics and follow rigid tectonic structures as fissure lines, breccias and faults. In the faults there are veins with quartz and sometimes calcite and barite. The copper minerals are chalcopyrite together with bornite and chalcocite. Other ore minerals are pyrite, scheelite and in cases also gold. Zeolites are relatively common in the mineralizations. Another ore type occurs in tectonic dislocations. This type is rich in albite with varying amounts of quartz and carbonate (calcite or ankerite). In these alterations occur small amounts of pyrite and chalcopyrite and sometimes bornite and magnetite.

The only copper deposit of importance in Norrbotten is Aitik, SE of Gällivare (Malmberget). The host rock is made up of highly metamorphosed sediments of different kinds, mainly meta-arenites and skarn-gneisses which are metamorphosed to mica-schists. The sediments have been metasomatically altered with the formation of sericite, tourmaline, scapolite and skarn minerals such as biotite, diopside, chlorite and garnet. The emplacement of the copper mineralization is tectonically controlled. The ore minerals occur as veins or disseminations. There are no sharp borders between the host rock and the mineralization. The main ore minerals are pyrite and chalcopyrite with subsidiary magnetite, pyrrhotite and occasional bornite, chalcocite, arsenopyrite, tennatite-tetrahedrite, sphalerite, galena, molybdenite and hematite with ilmenite. The ore minerals are accompanied by quartz, calcite, tourmaline and flourite. The outcrop of the mineralization has a surface area of about 220 000 m^2 counted with a cut-off grade of 0.4 % Cu and an average grade of 0.5 % Cu. The upper part of the mineralization, which is better known, contains on average 0.4 % Cu (cut-off grade 0.37 % Cu), 1.5 % S, 0.3 g/t Au and 5 g/t Ag. To a depth of 300 m the reserves are about 150 million tons of ore.

In Nautanen, N of Aitik, there occur in mica-schists and meta-sediments zones which have been altered metasomatically. This resulted in the formation of scapolite, tourmaline, hornblende, garnet, epidote, pyroxene, apatite, calcite, desmine and chabazite. In these zones there occur different types of mineralizations: 1. impregnations of chalcopyrite and magnetite, 2. quartz veins, often tourmaline-bearing, with chalcopyrite, bornite, pyrite and malachite and 3. quartz veins with calcite containing chalcocite, desmine and chabazite and sometimes native gold.

In the Svappavaara area, east of Kiruna, there are sulphide mineralizations which are genetically related to scapolitized rocks. Representatives are Gruvberget and Särkivaara. At Gruvberget there occurs a copper mineralization in a scapolitized leptite. Primary copper minerals are chalcopyrite and bornite from which secondary chalcocite, covellite, malachite and azurite formed by weathering. In very minor amounts occur pyrite, arsenopyrite, erythrite, molybdenite, gold and native copper. The mineralization occurs in schlieren and joints which besides scapolite contain amphibole, zeolites (stilbite and chabazite) and calcite. At Särkivaara there is a narrow zone in basic tuffites with diopside, epidote, chabazite, calcite, biotite and garnet. The ore minerals are pyrite, chalcopyrite and molybdenite.

In Sjangeli there occur in bedded amphibolites and associated sediments, veins and impregnations of copper minerals. The mineralization is bound to zones of schistosity, fracturing and brecciation. The ore minerals are bornite, chalcocite, magnetite and in small amounts chalcopyrite, pyrite and hematite. Secondary copper minerals are malachite and azurite. The ore minerals are accompanied by epidote, quartz, calcite and amphibole. The mineralization is genetically connected to the Vassijaure granite which cuts the amphibolites and sediments. Evidence for the epigenetic origin of the ore is that, quartz veins which are related to the mineralization, increase in number towards the granite. In addition the formation of epidote in the rocks seems related to the granite.

The Laver mine occurs in Southern Norrbotten in the so-called Arvidsjaur porphyries. The main rock is a liparite with a subordinate banded tuffite. The ore occurs partly at the contact between these rocks and is related to faulting. The quantity mined out (the mine is shut down) was 1.5 million tons of ore with 1.5 % Cu, 0.2 g/ton Au and 36 g/ton Ag. Several different ore types can be distinguished. There is a breccia type built up of veinlets of chalcopyrite and pyrrhotite in the liparite. The ore minerals are accompanied by skarn minerals, mainly chlorite and biotite, but also magnetite, sericite, garnet, epidote, gahnite, tourmaline, quartz and plagioclase. In the contact between the liparite and tuffite occur ore veins which consist mainly of quartz with chalcopyrite and pyrrhotite; the subsidiary ore minerals being sphalerite, arsenopyrite and molybdenite. The veins sometimes form horse-tail structures. In a fault which cuts both the ore types occurs a mineralization similar to that in the veins, but accompanied by a late Co-Ag-Ni-mineralization in a crush zone. This late mineralization contains native silver, argentite, pyrargyrite, Co-Ni-arsenides, tetrahedrite and chalcopyrite. The gangue is made up of calcite, apophyllite and zeolites.

The formation of the ore at Laver is connected with fault fissures and the intrusion of dikes of greenstone and granite porphyry. The ore formation is younger than the Arvidsjaur granite and most likely connected with the Lina granite (p. 20). The ore solutions and the greenstone-granite porphyry magma seem to be differentiation products from a common origin.

In the Radnejaure area, 20 km E of Arjeplog, occur basic to acid lavas with sedimentary derivatives. These rocks are surrounded by younger granites. In the area occur several epigenetic copper mineralizations which mostly are located in zones where the wall rock has been tectonically brecciated. Some of the mineralizations are connected with post-granitic faulting. The wall rock is chloritized and sericitized and in part there are new-formed garnet and scapolite. The ore, which is of hydrothermal origin, is possibly connected with the granite emplacment and regional metamorphism. The most common ore mineral associations are: 1. chalcopyrite and pyrite with some sphalerite and molybdenite and 2. chalcopyrite and bornite with some chalcocite.

In the biggest deposit in the Radnejaur area, Lulepotten, occur copper impregnations in schistose, intermediate volcanics and sediments. The mineralizations follow the schistosity in the host rocks and partly occur as fissure fillings in a granite. The main ore minerals are chalcopyrite and bornite together with minor amounts of chalcocite, hematite and pyrite. The gangue is made up of quartz, some carbonate and occasionally a little tourmaline and fluorite. The ore reserves are 4.2 million tons with 1 % Cu.

There are some other smaller deposits in the Radnejaur area (Ballek, Soggovare and Nimtekjaure) which lie in basic volcanics and are made up of chalcopyrite and pyrite together with a little sphalerite. In Nimtekjaure traces of bornite, molybdenite, native copper and arsenopyrite have been observed. The ore veins are often quartz-bearing.

References: Du Rietz (1945), Frietsch (1966), Geijer (1918 a), (1924), Grip & Frietsch (1973), Padget (1959), (1966), Zweifel (1972), Ödman (1943), (1945).

ZINC-LEAD ORES

CENTRAL SWEDEN

LAYERED DISSEMINATIONS WITH Zn-Pb-Fe-SULPHIDES (ÅMMEBERG TYPE)

In Central Sweden occur several deposits of bedded zinc-lead ores which may be either syngenetic or epigenetic.

The rocks of Central Sweden were migmatized over large areas about 1 800 m.y. ago in connection with the intrusion of the younger Svecofennian granites (p. 14). The rocks were changed into veined gneisses interwoven with granites and pegmatites. In the central part of the Sörmland region there occur sulphide mineralizations with: 1. zinc plus lead and 2. cobalt plus copper (cf. p. 41). which are located in the outer parts of the veined gneisses, against the leptites. Åmmeberg is the only zinc-lead deposit of importance in this region. Here the sulphide ores with sphalerite and galena occur as long and narrow layer-like beds in a relatively narrow unit of grey, banded leptites which contain intercalations of limestone and greenstone. The grey leptites are bordered to the south by veined gneisses and to the north by a red leptite rich in potassium. In the grey leptites are skarn layers with diopside, garnet, hornblende and tremolite-actinolite and near the veined gneisses also wollastonite and vesuvianite. The sulphide minerals sphalerite and galena occur as disseminated thin bands in the leptites, often in the same layers as the skarn minerals. Native silver, chalcopyrite, tetrahedrite, pyrrhotite, pyrite and arsenopyrite occur sparsely. In the leptites at the contact against the veined gneisses occurs a calcareous layer impregnated with pyrrhotite. The richest ores contain 40—50 % Zn. The ore mined contains about 10—14 % Zn and 1—3 % Pb.

The origin of the Åmmeberg ores is uncertain. In part they are considered to be epigenetic; a result of the migmatization. The ore-forming and skarn-forming solutions would have emanated in connection with the palingenetic processes. According to other views the ores are considered to be older than the palingenetic processes and consequently syngenetic. They may be submarine emanations formed by hydrothermal solutions.

In a similar regional geologic position to the Åmmeberg deposit occur other sulphide ores such as Vena, Doverstorp, Tunaberg and Utö. All deposits are lying at the southern border of the volcanic-sedimentary complex of Central Sweden with a migmatic border in the south. In part they occur within the migmatites. These ores show features in common with the Åmmeberg ore, especially their occurrence as long and narrow, bedded impregnations. The mineral composition is, however, often different with iron sulphides as the dominating minerals. Furthermore there are banded iron sulphide ores at Dylta and Ervalla, but they occur at the northern border of the same lobe of the volcanic-sedimentary complex.

The ores at Vena and Tunaberg have already been described in connection with the copper-cobalt ores (p. 42).

At Utö occur long narrow zones with impregnations of sphalerite and galena in a layered series of hälleflintas with intercalations of limestone and banded hematite-magnetite ores of the same type as in Central Sweden. The limestones have been altered by granitic solutions to skarns with diopside, tremolite and scapolite. In the iron ores there is a new generation of biotite, chlorite and hornblende. The sulphides which occur in the hälleflintas, skarns and iron ores, are sphalerite, galena and pyrrhotite. In the iron ores there are some bornite, chalcocite and native silver. As at Åmmeberg the migmatite front has stopped against limestone.

The formation of the ore at Utö might be similar to that for the ore at Åmmeberg. The Utö ore occurs at the border of a migmatite front and in connection with limestones in volcanics. Here also an epigenetic or syngenetic origin is possible.

At Doverstorp there occur in the leptites several long and narrow zones of sulphide impregnations. The leptites are altered; this has given rise to new minerals such as quartz, cordierite, mica and small amounts of sillimanite and andalusite. The ore minerals, which form veinlets or, more rarely, impregnations, are pyrrhotite with subordinate pyrite and occasionally chalcopyrite, sphalerite and galena.

At Dylta and Ervalla there are impregnations of pyrrhotite and pyrite in a grey, gneissose leptite which has been metasomatically altered into a ”quartzite” in connection with the formation of the ore minerals. In the Ervalla ore are found subordinate amounts of chalcopyrite, sphalerite and galena. The ore is connected with a limestone and a skarn rich in pyroxene, garnet, vesuvian and epidote.

References: Geijer (1924), Henriques (1964), Johansson (1911 b), Pilava-Podgurski (1956).

LEAD ORES

There are two main types of lead ore in Sweden. One ore type is formed by hydrothermal solutions and is made up of quartz- and calcite-filled fissures and veins in Paleozoic sediments. The main ore mineral is a silver-bearing galena which often is followed by minor amounts of sphalerite. These mineralizations are in many cases linked with faults of Post-Silurian (Permian?) age. In the Precambrian in Northern Sweden occur similar veins and fissure fillings. This is a common ore type found at many places in the world. Counterparts outside Sweden are among others the ores at Freiberg and Schwarzwald, Germany; Pribram, Czechoslovakia; the Alps and Altai, Western Mongolia. The other ore type is made up of stratabound impregnations and veins of galena and minor amounts of sphalerite in Eocambrian to Cambrian sandstones at the eastern border of the Caledonian mountains. The galena is here poor in silver.

SOUTHERN SWEDEN

FISSURE VEINS WITH Pb-SULPHIDES

Around Simrishamn in SE Scania occur mineralizations of galena in fissures and breccias in a Cambrian sandstone. They are connected with faults and tectonic lines that cut the Cambro-Silurian rocks of the area. The age of the dislocations is most probably Post-Silurian (Permian?). The gangue of the fissure fillings and veins is made up of quartz, calcite and fluorite. The ore minerals are galena with subordinate sphalerite, chalcopyrite and pyrite. The content of silver is low, only 0.7 g/t Ag for each per cent of lead (cf. Table 7). Representatives of this ore type include Gladsax, Onslunda and Brantevik. The deposits have been mined for silver as early as in the 16th century. In recent time there has been a mining for fluorite in Onslunda and Gladsax. Here fluorite dominates over quartz and calcite in the gangue.

References: Grip & Frietsch (1973), Lundegårdh (1971), Magnusson (1973), Tegengren (1924).

CENTRAL SWEDEN

FISSURE VEINS WITH Pb-SULPHIDES

At Boda and Sollerön in Dalecarlia sulphides occur in narrow fissures or disseminations with calcite, and some barite and fluorite in an Ordovician limestone. These mineralizations are related to faulting. The ore minerals are galena, sphalerite and some pyrite and pyrrhotite. The ore mined at Boda contained 16 % Pb and 150 g/ton Ag. The faults that gave the fissures are most probably of Post-Silurian (Permian?) age.

References: Magnusson (1973), Tegengren (1924), Welin (1959).

NORTHERN SWEDEN

STRATABOUND FISSURE VEINS AND IMPREGNATIONS WITH Pb-Zn-SULPHIDES IN THE EASTERN PART OF THE CALEDONIDES (LAISVALL TYPE)

In the outer, eastern edge of the Caledonides, in sandstones and quartzites of Eocambrian or Cambrian age, occur impregnations and fissure fillings with sulphides. Galena is the dominating ore mineral, but sphalerite is often present and is sometimes more abundant than galena. Pyrite and chalcopyrite are less common. The sulphides are accompanied by barite, fluorite and calcite. Sericite is a common alteration product in the wall rock. Depending on the grade of diagenesis the sulphides either replace the matrix in a sandstone or occur as fissures fillings in a quartzite. Associated shales in these rocks are not usually mineralized. The sulphide mineralization is mostly stratabound but cuts locally the sedimentary structures.

Along the border of the Caledonides there occur several lead deposits of this type; namely (from the south to the north) Vassbo, Bellviksberg, Lövstrand, Laisvall, Majva, Gautojaure and Rautasjaure. The largest individual ore is Laisvall which contains (including parts mined out) about 60 million tons of ore with 4 % Pb. The ores of the Laisvall type contain 2.4—5.7 % Pb, 0.1—0.3 % Zn and 10—20 g/t Ag, or on average 3.8 % Pb, 0.3 % Zn, less than 0.01 % Cu, 13 % S, less than 0.1 g/t Au and 11 g/t Ag.

The identical mineral association in the different deposits and the occurrence of the ores in host rocks of different age from Eocambrian to Cambrian excludes a syngenetic mode of formation for the Laisvall type of ore. The ore formation is controlled by sedimentary features and tectonic structures. An important clue to the mode of formation is that hydrothermal ore solutions have affected sandstones between impounding layers of shale. The ores are related to faulting and crushing; in some deposits there is a striking similarity between the distribution of the ore and the fissures in the host rock. The ore solutions have probably come from the inner part of the Caledonides where palingenetic processes have been active. The solutions are thus thought to have moved laterally through hundreds of kilometres of rocks. At least a part of the lead has its origin in the overlying Cambrian shales which have been leached by the solutions. According to other hypotheses the mineralizing solutions came directly through the underlying Precambrian basement and are related to a fracturing in it. Studies of fluid-inclusions indicate that the ore-forming solutions were hot, strongly saline brines.

The Laisvall type of ore has many features in common with the "Alpine-" and "Missisippi-Valley"-type of lead-zinc ore which is found in the Tri-State district, USA; Gorny Slask, Poland and Karatau, Central Kazakhstan. This ore type is stratabound and confined to particular horizons on a large scale but is usually discordant on a small scale. The host rock is in many cases limestones-dolomites, and not sandstones as in the Laisvall type.

References: Gee (1972), Grip (1948 a), (1954), (1960), (1967), Grip et al. (1960), Roedder (1968), Tegengren (1962).

FISSURE VEINS WITH Pb-Zn-SULPHIDES (NASAFJÄLL TYPE)

In the inner, western part of the Caledonides, adjacent to windows where the Cambro-Silurian rocks have been eroded and the Precambrian basement is exposed, galena-bearing fissure fillings and veins are found. They lie near the Pre-Eocambrian peneplane and occur in the underlying Precambrian rocks or in the above lying sediments. In addition there are some deposits in the Precambrian which lie far away from the Caledonides. The veins are built up of quartz and occasionally calcite. The ore minerals are sphalerite, galena and some chalcopyrite and in the deposits in the Caledonides also pyrrhotite, boulangerite, arsenopyrite and pyrite. These minerals indicate a somewhat higher temperature of formation than in the Laisvall type. The sphalerite in the vein type is richer in iron than that in the Laisvall type of ore. Furthermore the silver/lead ratio is higher in the vein deposits than in the Laisvall type of ore (Table 7).

At Åkerlandet a veined gneiss is cut by a breccia zone which is filled with calcite, small amounts of fluorite, sphalerite and occasionally also galena. At Kväcklinge there is a deposit of the same type. In a grey gneiss occur veins of quartz and calcite containing silver-bearing galena, sphalerite, pyrite and some chalcopyrite and native silver. An analysis shows 18.5 % Pb, 0.1 % Cu, 1 g/t Au and 933 g/t Ag. Both occurrences lie in Precambrian rocks.

At Olden in Jämtland there are quartz veins in a Precambrian granite and a Silurian shale which contain galena, sphalerite and some chalcopyrite, pyrite and fluorite. The content of silver in the galena is 775 g/t.

The Nasafjäll deposit occurs in Eocambrian or Cambrian sediments made up of quartzites and schists. The sediments lie on top of a Precambrian granite and above the sediments there is a nappe of a similar granite. During the overthrusting the sediments were deformed and chemically altered. Veins in the sediments contain quartz and small amounts of calcite. In the veins there are druses and cavity fillings with sphalerite, pyrrhotite and galena, sometimes also antimonite and boulangerite and a little pyrite, arsenopyrite and chalcopyrite. The galena contains about 0.15 % Ag. The deposit which formerly was mined gave 1.6 million tons of ore with 1.5 % Pb, 1.2 % Zn, 3.3 % pyrrhotite and 30 g/t Ag.

In the Kvikkjokk mountains occur several deposits similar to the mineralization at Nasafjäll. The host rocks are Cambro-Silurian schists with intercalations of limestone and amphibolite. The quartz veins contain a silver-bearing galena together with pyrrhotite, chalcopyrite and small amounts of arsenopyrite and boulangerite. Representatives are Silpatjåkko, Alkavara, Lanjek and Juonkatjåkko. The galena in Silpatjåkko contains about 0.2 % Ag. Further to the north at Unna Järta occurs a similar vein deposit.

References: Tegengren (1924), Zenzén (1927).

GOLD ORE

SOUTHERN SWEDEN

FISSURE VEINS WITH Fe-SULPHIDES AND GOLD

The only mineral deposit in Sweden that has been mined solely for gold is Ädelfors. Narrow quartz veins, 0.3—0.4 m wide, occur in mica- and hornblende-schists and partly in amphibolites and hälleflintas (belonging to the Vetlanda group which at minimum is about 1 700—1 750 m. y. old). The quartz in the gangue is accompanied by calcite, feldspar, garnet, epidote, amphibole and wollastonite. The main ore mineral is pyrite. In addition there are subordinate amounts of pyrrhotite, chalcopyrite, bornite and sometimes arsenopyrite. The gold is bound to the pyrite (with 600—1 000 g/t Au) and to a minor extent to the pyrrhotite (with 30—40 g/t Au).

The formation of this mineralization is hydrothermal and of the hypothermal stage. Counterparts outside Sweden are many, among others Mother Lode, California; Bendigo, Australia; Kolar, India; Kozkar and Berezovsk, Ural.

Reference: Tegengren (1924).

CHROMIUM ORES

NORTHERN SWEDEN

SEGREGATIONS WITH Fe-Cr-OXIDES

In the Caledonian mountains, at the border between the low-metamorphic Köli-nappes and the high-metamorphic Seve-nappes (cf. p. 38), there occur abundant massifs of olivinites which are altered to serpentinites. These ultrabasites contain chromite as irregular veinlets, segregations and layers, which mostly follow the structure of the rocks. The size of the concentrations of chromite is too small to be economical. The width is mostly less than 5 dm and often less than 1 dm. Such mineralizations are found at Ruotats, Lejarklumpen and Junsterklumpen. Ore formerly mined from Lejagruvan and Röfjällgruvan contained 19 % Cr. The content of Cr_2O_3 varies between 31 and 49 %. These segregations show features which are typical for the "Alpine-" type of intrusions of chromite ore as compared with the chromite ore in layered intrusions, and have their largest known counterparts in Turkey, the Ural mountains and the Philippines.

References: Du Rietz (1956), Tegengren (1924).

NICKEL ORES

The nickel deposits of Sweden are, with the exception of Lainijaur and Slättberg, similar to each other and consist of concentrations of pentlandite-bearing pyrrhotite in gabbroic rocks. The ore is formed by magmatic differentiation. Other ore minerals are chalcopyrite and pyrite. All deposits occur in the Precambrian. The same ore type is found in many places in the world, the biggest representatives occur in Canada and the Soviet Union. Very lean disseminations with Ni-sulphides occur in the ultrabasites in the Caledonides.

At the moment there is no production of nickel ore in Sweden.

SOUTHERN SWEDEN

SEGREGATIONS WITH Fe-Ni-SULPHIDES

At Kleva irregular, schlieren-formed ore bodies of pyrrhotite with pentlandite, some chalcopyrite and pyrite occur in the central part of a gabbro massif. In the richer parts the ore contains 2—3 % Ni, 0.1 % Co and 0.25—0.50 % Cu.

References: Grip (1961), Magnusson (1973), Tegengren (1924).

CENTRAL SWEDEN

SEGREGATIONS WITH Fe-Ni-SULPHIDES

At Kuså occurs a gabbro which in parts is pyroxenitic and hornblenditic. The ore is an impregnation of pyrrhotite and chalcopyrite in a hornblendite which is veined by zones of microcline, albite, calcite and chlorite. There are parts rich in pyrrhotite and parts rich in chalcopyrite. The other ore minerals are pentlandite and bravoite, the latter being an alteration product of pentlandite. Furthermore there occur some magnetite, cobaltite and a linneite-like mineral. The ore contains 1—2 % Ni, somewhat less than 1 % Cu and up to 0.2 % Co.

The Slättberg ore occurs in a diabase which has been metasomatically altered with the formation of chlorite, epidote, hornblende and quartz. The ore is built up of pyrrhotite and some pyrite, chalcopyrite, magnetite and hematite. In the pyrrhotite there are pentlandite and bravoite. Together with chalcopyrite occur linneite and millerite.

References: Grip (1961), Magnusson (1973), Tegengren (1924).

NORTHERN SWEDEN

SEGREGATIONS WITH Fe-Ni-SULPHIDES

The Förnätra deposit occurs in a diorite-gabbro and is made up of pyrrhotite and chalcopyrite together with hornblende. The ore contains 1 % Cu, 0.5 % Ni and 19 % S.

The nickel ore at Lainijaur occurs in the outer zone of a gabbro massif and also in part in the surrounding schist which belong to the supracrustal rocks of the Skellefte district (cf. p. 35). The ore is made up of pyrrhotite with pentlandite as impregnations or veins. The main ore type is a compact, rather coarse pentlandite-pyrrhotite ore with some chalcopyrite and arsenic-nickel minerals.

This ore type, which brecciates both the gabbro and the schists, contains 0.4 % Cu, 2.6 % Ni, 0.03 % Co, 0.1 % As and 32 % S. In addition there is a nickel-arsenic ore which brecciates the pentlandite-pyrrhotite ore and is thus later than this. The nickel-arsenic ore is characterized by a complex composition with a great number of Ni-Co-As-S minerals. Common minerals are cobaltite, arsenopyrite, niccolite and maucherite. Occasionally occur smaltite, chloanite, rammelsbergite and löllingite. To the association belong also magnetite and ilmenite. Furthermore there are small amounts of pyrrhotite, pentlandite, pyrite, bornite, sphalerite, galena, vallerite, molybdenite and scheelite. The nickel-arsenic ore, which on average contains 1.9 % Cu, 10.1 % Ni, 1.1 % Co, 18.5 % As and 16 % S, belongs to the same magmatic differentiation as the pentlandite-pyrrhotite ore, but is possibly formed under more pronounced hydrothermal conditions than the pentlandite-pyrrhotite ore.

The nickel-bearing intrusives in the Norrbotten county belong to the younger Sorsele granite series (about 1 625 m.y. old) and the older series of intrusives (cf. p. 20). The only deposit worth mentioning is Storbodssund which lies in a gabbro belonging to the Sorsele granite series. The ore forms a very small disc of about 3 000 tons with 0.6 % Cu, 2.3 % Ni and 21 % S. The ore minerals are pyrrhotite with pentlandite, chalcopyrite, pyrite and magnetite.

References: Grip (1961), Grip & Frietsch (1973).

DISSEMINATIONS WITH Ni-SULPHIDES

The chrome-bearing peridotites in the Caledonides (p. 53) contain also small amounts of nickel and cobalt. The content of nickel is rather constant averaging a little above 0.2 %, the content of cobalt being about 0.02 %. The nickel is bound partly to magnesium silicates, partly to nickel and iron sulphides and to a small degree to chromite and magnetite. The content of sulphides increases with the serpentinization of the peridotite. The most common sulphides are pentlandite, heazlewoodite and nickel-bearing pyrite. Furthermore bravoite, pyrrhotite, marcasite, chalcopyrite and awaruite are found. The sulphides are disseminated.

Reference: Du Rietz (1956).

TUNGSTEN-MOLYBDENUM ORES

CENTRAL SWEDEN

DISSEMINATIONS WITH W-OXIDES AND Mo-SULPHIDE (YXSJÖ — HÖRKEN TYPE)

There are a few tungsten-molybdenum ores in Central Sweden. The deposits are related to the late Svecofennian granites and related palingenetic processes which occurred about 1 800 m.y. ago. The granites themselves contain economically unimportant quartz veins and pegmatites which are molybdenite-impregnated. North of Hörken lies Uddgruvan which is a quartz pegmatite with molybdenite. The content of MoS_2 is about 2 %. Mineralizations of molybdenite occur at Bispbergsklack (in Dalarna) in pegmatite veins or quartz veins and at Algruvan (near Västerås) in feldspar concentrations in a granite.

Economically more interesting are the contact-metasomatic tungsten-molybdenum ores at Hörken and Yxsjö (Yxsjöberg). Here occur leptites with intercalations of limestone-dolomite and quartz-banded iron ore. Through the intrusion of the late Svecofennian granites and pegmatites the limestones-dolomites have been changed and are rich in pegmatitic material with quartz, microcline and albite. New minerals in the limestone-dolomite are hedenbergite, grossularite, potash-iron-rich amphibole and minor amounts of epidote, biotite and chlorite. At Yxsjö there is about 5 % fluorite.

The content of tungsten in the form of scheelite is 0.3—0.4 % WO_3 at Yxsjö and 0.08 % WO_3 at Hörken. At both deposits there occurs molybdenite, more abundantly at Hörken where the content is 0.1—0.2 % MoS_2, and only sporadically at Yxsjö. Sulphides occur in the ores; mainly pyrrhotite with some chalcopyrite and pyrite. At Yxsjö there are also small amounts of magnetite, apatite, sphene, bismuthinite and native bismuth.

At Baggetorp there is a quartz-aplite which cuts a schlieren-gneiss. The aplite contains wolframite and subordinate molybdenite together with sulphides such as pyrite and chalcopyrite. The mode of formation of this ore is similar to that of the Hörken-Yxsjö ores, but the formation occurred under more pegmatitic conditions. The age of the mineralization at Baggetorp is uncertain but could be connected with the intrusion of the Småland granites (1 700—1 750 m. y. ago) or the late Svecofennian migmatization (1 800 m.y. ago).

Deposits of the Yxsjö-Hörken type are not uncommon in the world. Rather similar contact-metasomatic scheelite ores are found in western USA, Mexico, northeastern Brazil and Korea.

References: Hübner (1971), Lindroth (1922), Magnusson (1940 b).

URANIUM ORES

There are in Sweden several types of uranium mineralizations: 1. uranium oxides in iron oxide placer deposits, 2. uranium oxides in fissure veins in iron ores, 3. uranium oxides in alum shales and 4. uranium-bearing apatite in arenaceous sediments.

SOUTHERN SWEDEN

BEDDED IRON ORES WITH U-OXIDES

In the quartzitic sediments at Västervik, which have an age of about 2 000 m.y., there are small occurrences of iron ore which consist of thin layers of magnetite, hematite, ilmenite and occasionally uraninite alternating with equally thin beds of quartz, biotite and small amounts of apatite, epidote, monazite and locally also rutile, zircon and garnet. The quartzites have been strongly folded and metamorphosed at the time of the intrusion of the Småland granites (about 1 745 m.y. ago). One hypothesis is that the iron ores were depositions of limonite in sandy sediments. An alternative hypothesis is that both the iron and uranium minerals were detrital, the uraninite and monazite being syngenetic in mechanical accumulated black sands.

References: Geijer & Magnusson (1944), Uytenbogaardt (1960), Welin (1966 a), (1966 b).

CENTRAL SWEDEN

ALUM SHALES WITH U-OXIDES

In the Lower Paleozoic rocks around the Lakes Vänern and Vättern occur black shales which are uranium-bearing, especially at Kvarntorp, Yxhult and Billingen. The reserves are very large. In these areas the Middle Cambrian and Upper Cambrian are developed as alum shales with bituminous limestone. The Upper Cambrian shale at Ranstad, Billingen has a relatively high content of uranium, about 300 g/t U. The uranium content is highest (300—400 g/t U) in the ”kolm”, a kind of coal matter rich in ashy materials. The major part of the uranium is present as amorphous uranium oxide and is to a lesser degree bound to phosphorite and organic materials. The uranium has been precipitated in the shale by reduction processes.

At present the investigations are made of the economics of producing uranium on a commercial scale from the Ranstad deposit in the Billingen shale. 1967—1972 there has been a small scale operation with a yearly production of 120 tons of uranium.

References: Armands (1972 b), Dahlman & Eklund (1953).

FISSURE VEINS WITH U-OXIDES

In the iron ores of Central Sweden occur occasional impregnations of uraninite. Fissure fillings occur in the quartz-banded iron ores of Stripa and Blanka in Västmanland. The pitchblende-filled veins are younger than the time of folding of the iron ores and the intrusion of the late Svecofennian granites. The age of the mineralization is about 1 585 m.y. The gangue consists of chlorite, quartz and calcite. Other ore minerals besides pitchblende are hematite, pyrite, chalcopyrite, galena and bornite.

There are also uranium mineralizations in several skarn iron ores in Uppland. The uranium mineralization which was formed during the late Svecofennian palingenesis about 1 785 m.y ago, was precipitated in the iron ores by an oxidation-reduction process. Another mineralization occurred in the bedrock of the ores. It is built up of pitchblende, hematite and some simple sulphides in a gangue of chlorite, calcite and quartz. Furthermore there was formed a quartz breccia with pitchblende and minor amounts of bornite, chalcopyrite, galena and hematite. These mineralizations are related to deformation in connection with the emplacement of the Gothian granites about 1 585 m.y. ago.

The mineralization at Los with Cu-Co-Ni-Bi-sulphides and pitchblende in fissure veins has already been described (p. 43).

In the Håkantorp skarn iron ore in Närke, there are uraninite disseminations along shear zones. The uraninite is formed through reduction of acid uranium-bearing solutions by the skarn ores. The mineralization is connected with the palingenesis of late Svecofennian age about 1 800 m.y. ago.

References: Welin (1961), (1964 a), (1964 b), (1966 a), (1966 b).

NORTHERN SWEDEN

URANIUM-BEARING APATITE IN SANDSTONE-SILTSTONE

In the region of Tåsjön, NW Ångermanland, at the eastern border of the Caledonides, occur calcareous sandstones-siltstones of Lower Ordovician age which contain a marked concentration of uranium. This sedimentary unit is found in all Lower Paleozoic sequences above the Cambrian alum shales in Sweden but at Tåsjö it is unusually thick. The majority of the uranium at Tåsjön is bound to a carbonate-fluor-apatite of marine origine. The content of uranium in the sediment is about 200—500 g/t U. The parts of the sedimentary rock which are rich in uranium contain glauconite (in part altered to siderite), calcite, dolomite and quartz. The uranium is considered syngenetic with the deposition of the sediment and the formation of the apatite. The apatite was precipitated where upwelling currents with relatively cold, phosphate-rich water met warmer water with a higher pH. The concentration of uranium has been related to erosion of the underlying Cambrian shales.

References: Andersson (1971), Armands (1970), (1972 a), Gee (1972).

DISSEMINATIONS WITH U-OXIDE AND Cu-Zn-Pb-Fe-SULPHIDES

At Kopparåsen occur basic volcanics, largely builts up as tuffs and tuffites with sediments which belong to the greenstone group in Norrbotten (cf. p. 19). In banded tuffs, graphite schists and cherts occur narrow zones with impregnations of uraninite, magnetite and sulphides such as pyrite, pyrrhotite, chalcopyrite, bornite, galena, sphalerite, gersdorfite, arsenopyrite and molybdenite. The mineralization is considered to be of volcanic-sedimentary origin.

Reference: Adamek (1975).

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REFERENCES

GFF = Geologiska Föreningens i Stockholm Förhandlingar
SGU = Sveriges geologiska undersökning

ADAMEK, P. M., 1975: Geology and mineralogy of the Kopparåsen uraninite-sulphide mineralization, Norrbotten county, Sweden. — SGU C 712.

ANDERSSON, A., 1971: Petrographic and chemical study of the Lower Ordovician uranium-bearing sedimentary unit at Tåsjö Lake. — GFF 93, 117—135.

ARMANDS, G., 1970: A uranium-bearing layer from the Lower Ordovician, Sweden. — GFF 92, 481—490.

— 1972 a: Caledonian geology and uranium-bearing strata in the Tåsjö Lake Area, Sweden. GFF 94, 321—345.

— 1972 b: Geochemical studies of uranium, molybdenum and vanadium in a Swedish alum shale. — Acta Universitatis Stockholmiensis XXVII:1.

BERGENFELT, S., 1953: Om förekomsten av selen i Skelleftefältets sulfidmalmer. — GFF 75, 327—359.

BERGSHANTERING, 1972: Sveriges officiella statistik. — Statistiska Centralbyrån. Stockholm.

BERGSTRÖM, L., 1959: Geologiska studier i Lövsvedsgruvan, Folkärna socken, Dalarna. — GFF 81, 641—669.

BJÖRKSTEDT, K-A., 1972: Investigation to determine the content of tin and other trace elements in Grängesberg ore. — GFF 94, 165—192.

BROTZEN, F., 1941: Några bidrag till visingsöformationens stratigrafi och tektonik. — GFF 63, 245—261.

— 1962: Mesozoiska avlagringar. *In:* Beskrivning till karta över Sveriges berggrund. — SGU Ba 16.

CARLBERG, J. O., 1879: Historiskt sammandrag om svenska bergverkens uppkomst och utveckling samt grufvelagstiftningen. — K. L. Beckman, Stockholm.

DAHLMAN, B., & EKLUND, J., 1953: Sveriges uranförande skiffrar. — SGU. Library archive.

DU RIETZ, T., 1945: The alteration of the rocks in the copper deposit at Laver in N. Sweden. — SGU C 467.

— 1953: Geology and ores of the Kristineberg deposit, Vesterbotten, Sweden. — SGU C 524.

— 1956: The content of chromium and nickel in the Caledonian ultrabasic rocks of Sweden. — GFF 78, 233—300.

— 1968: Huvuddragen av Garpenbergstraktens bergbyggnad. — SGU C 631.

ERIKSSON, G., 1960: Der Bergbau, die Eisen- und Stahlindustrie im Norden. — Geographische Rundschau 12, 233—243.

FOLCKER, G., 1974: Urbergsstratigrafisk studie över Vittangivaara, Norrbottens län. — SGU C 697.

FRIETSCH, R., 1960: En zon av kaolinlera och vittrad blodsten vid Svappavaara, Norrbotten. — SGU C 572.

— 1963: Järnmalmsförekomster inom Norrbottens län. — SGU C 592.

— 1966: Berggrund och malmer i Svappavaarafältet, norra Sverige. — SGU C 604.

— 1967 a: On the relative age of the skarn iron ores and the Haparanda granite series in the County of Norrbotten, Northern Sweden. — GFF 89, 116—118.

— 1967 b: The relationship between magnetite and hematite in the iron ores of the Kiruna type and some other types. — SGU C 625.

— 1970: Trace elements in magnetite and hematite mainly from Northern Sweden. — SGU C 646.

— 1973 a: Precambrian iron ores of sedimentary origin in Sweden. Unesco 1973. Genesis of Precambrian iron and manganese deposits. Proc. Kiev Symp. 1970 (Earth sciences, 9).

— 1973 b: The origin of the Kiruna iron ores. — GFF 95, 375—380.

— 1974 a: The occurrence and composition of apatite with special reference to ores and rocks in Northern Sweden. — SGU C 694.

— 1974 b: The Ekströmsberg iron ore deposit, Northern Sweden. — SGU C 708.

Frietsch, R., 1975: The iron ore deposits in Sweden. Explanations to the International map of the iron ore deposits of Europe. — Geologische Bundesanstalt. Hannover. (In press).

Gavelin, S., 1939: Geology and ores of the Malånäs district. — SGU C 424.

— 1942: Relations between ore deposition and structure in the Skellefte district. — SGU C 443.

— 1943: On the distribution of metals at Rävliden, N. Sweden, and in some other copper-zinc ores. — SGU C 454.

— 1945: Arsenic-cobalt-nickel-silver veins in the Lindsköld copper mine, N. Sweden. — SGU C 469.

— 1948: Adakområdet. — SGU C 490.

— 1952: Lime metasomatism and metamorphic differentiation in the Adak area. — SGU C 521.

— 1953: Die Beziehungen zwischen Sulfidvererzung und Granitbildung im Skelleftefeld, Nordschweden. — Geol. Rundschau 42.

— 1954: A telluride assemblage in the Rudtjebäcken pyrite ore, Västerbotten, northern Sweden. — SGU C 536.

— 1955: Sulphide mineralization in the Skellefte district, northern Sweden, and its relation to regional granitization. — Econ. Geol. 50.

Gavelin, S., & Gabrielson, O., 1947: Spectrochemical investigations of sulphide minerals from the ores of the Skellefte district. — SGU C 491.

Gee, D., 1972: The regional geological context of the Tåsjö uranium project, Caledonian front, Central Sweden. — SGU C 671.

Geijer, P., 1910: Igneous rocks and iron ores of Kiirunavaara, Luossavaara and Tuolluvaara. — Scientific and practical researches in Lapland arranged by Luossavaara-Kiirunavaara Aktiebolag, Stockholm.

— 1912: Studies on the geology of the iron ores of Lappland. — GFF 34, 727—789.

— 1917: Falutraktens berggrund och malmfyndigheter. — SGU C 275.

— 1918 a: Nautanenområdet. — SGU C 283.

— 1918 b: Det grafit- och järnmalmsförande området vid Vittangi. — SGU C 284.

— 1919: En manganförekomst vid Porjus. — SGU C 287.

— 1920: Tuolluvaara malmfälts geologi. — SGU C 296.

— 1921: The cerium minerals of Bastnäs at Riddarhyttan. — SGU C 304.

— 1923: Riddarhytte malmfält. — Beskrivning av mineralfyndigheter nr 1, Kungl. Kommerskollegium, Stockholm.

— 1924: Some Swedish occurrences of bornite and chalcocite. — SGU C 321.

— 1925 a: Eulysitic iron ores in Northern Sweden. — SGU C 324.

— 1925 b: Om några skiktade mangansilikatmalmer i Bergslagen. — SGU C 326.

— 1927 a: Some mineral associations from the Norberg district. — SGU C 343.

— 1927 b: Stråssa och Blanka järnmalmsfält. Geologisk beskrivning. — SGU Ca 20.

— 1929: Masungsbyfältens geologi. — SGU C 351.

— 1930 a: Gällivare malmfält. Geologisk beskrivning. — SGU Ca 22.

— 1930 b: On the iron-rich norite of Akkavare (Sjaunja). — GFF 52, 391—397.

— 1931 a: Berggrunden inom malmtrakten Kiruna-Gällivare-Pajala. — SGU C 366.

— 1931 b: The iron ores of the Kiruna type. Geographical distribution, geological characters and origin. — SGU C 367.

— 1935: Die nordschwedischen Eisenerze und verwandte Lagerstätten als Beispiele eruptiver Spaltungsprozesse. — Geol. Rundschau 26, 351—366.

— 1936: Norbergs berggrund och malmfyndigheter. — SGU Ca 24.

— 1938: Stripa odalfälts geologi. — SGU Ca 28.

— 1950: The Rektor ore body at Kiruna. — SGU C 514.

— 1957: Die Herkunft der quarzgebänderten Eisenerze: Eine Übersicht der Problemlage. — N.Jb. Min. u.s.w., Abh. 92 (Schneiderhöhn-Festband).

— 1958: Galena in pyrometasomatic deposits. — Econ. Geol. 53, 210—214.

— 1959: Några aspekter på skarnmalmsproblemen i Bergslagen. — GFF 81, 514—534.

— 1960: The Kiruna iron ores: *In:* Archean geology of Västerbotten and Norrbotten, Northern Sweden. — XXI Int. Geol. Congr. Norden. Guide to Excursions Nos A 32 and C 26. SGU. P. 34—38.

— 1961 a: The distribution of halogens in skarn amphiboles in Central Sweden. — Arkiv Min. Geol., Stockholm, 2, no. 36, 481—504.

— 1961 b: The manganese, iron and copper mineralization at Kesebol, Dalsland, Southwestern Sweden. — Bull. Geol. Inst. Uppsala XL, 37—49.

GEIJER, P., 1962: On the association of magnesium and sulphide ores in metasomatic mineralization. — Arkiv Min. Geol., Stockholm, 3, no. 8, 153—164.
— 1963: The geological significance of the cerium mineral occurrences of the Bastnäs type in Central Sweden. — Arkiv Min. Geol., Stockholm, 3, no. 2.
— 1964: On the origin of the Falu type of sulfide mineralization. — GFF 86, 3—27.
— 1965: Types of sulfide ore and associated wall rock alteration in the Öster-Silvberg district, Central Sweden. — SGU C 603.
— 1967: Internal features of the apatite-bearing magnetite ores. — SGU C 624.

GEIJER, P., & MAGNUSSON, N. H., 1926: Mullmalmer i svenska järngruvor. — SGU C 338.
— 1944: De mellansvenska järnmalmernas geologi. — SGU Ca 35.
— 1952 a: Geological history of the iron ores of Central Sweden. — XVIII Int. Geol. Congr., Great Britain. Rep., Pt. XIII, 84—89.
— 1952 b: The iron ores of Sweden. *In:* Symposium sur le gisements de fer du monde. — XIX Congrès Géologique International. Alger. P. 477—499.

GEIJER, P., & ÖDMAN, O. H., 1974: The emplacement of the Kiruna iron ores and related deposits. — SGU C 700.

GRIP, E., 1948 a: Lead and zinc deposits in northern Sweden. — XVIII Int. Geol. Congr. Proceedings. Pt. VII.
— 1948 b: On the occurrence of mercury in Boliden and in some other sulphide deposits in northern Sweden. — SGU C 499.
— 1951: a: Geology of the sulphide deposits at Mensträsk and a comparison with other deposits in the Skellefte district. — SGU C 515.
— 1951 b: Tungsten and molybdenum in sulphide ores in northern Sweden. — GFF 73, 455—472.
— 1954: Blymalmen vid Laisvall, dess geologi och en jämförelse med några utländska förekomster. — GFF 76, 357—380.
— 1960: The lead deposits of the eastern border of the Caledonides in Sweden. — Int. Geol. Congr. XXI Session, Norden. Pt. XVI, 149—159.
— 1961: Geology of the nickel deposit at Lainijaur in northern Sweden. — SGU C 577.
— 1967: On the genesis of the lead ores of the eastern border of the Caledonides in Scandinavia. — Econ. Geol. Monograph 3, 208—218.

GRIP, E., & FRIETSCH, R., 1973: Malm i Sverige 2, Norra Sverige. — Almqvist & Wiksell, Stockholm.

GRIP, E., QUENSEL, P., GEIJER, P., & LJUNGGREN, S., 1960: The Skellefte district and the Laisvall area. *In:* Sulphide and iron ores of Västerbotten and Lappland, northern Sweden. — XXI Int. Geol. Congr. Norden. Guide to Excursions Nos A 27 and C 22. SGU. P. 3—14.

GRIP, E., & WIRSTAM, Å., 1970: The Boliden sulphide deposit. — SGU C 651.

GRIP, E., & ÖDMAN, O. H., 1942: The telluride-bearing andalusite-sericite rocks of Mångfallberget at Boliden, N. Sweden. — SGU C 447.
— 1944: On thucholite and natural gas from Boliden. — SGU C 464.

HADDING, A., 1933: Den järnmalmsförande lagerserien i sydöstra Skåne. — SGU C 376.

HELFRICH, H. K., 1967: Ein Beitrag zur Geologie des Åregebietes aus dem zentralen Teil der schwedischen Kaledoniden. — SGU C 612.
— 1969: Undersökning av malmtyper, strukturtyper och sammanväxningsstrukturer inom Stekenjokkmalmen. — SGU C 645.

HENRIQUES, Å., 1964: Geology and ores of the Åmmeberg District (Zinkgruvan) Sweden. — Arkiv. Min. Geol., Stockholm, 4 no. 1.

HJELMQVIST, S., 1942: Stribergs malmfält. Geologisk beskrivning. — SGU C 449.
— 1950: The titaniferous iron-ore deposit of Taberg in the south of Sweden. — SGU C 512.

HÜBNER, H., 1966: Die Geologie der Sulfiderzlagerstätte Kalvbäcken, Mittelschweden. — SGU C 615.
— 1967: Klüftung und Vererzung in Grubengebiet Adak, Nordschweden. — SGU C 628.
— 1971: Molybdenum and tungsten occurrences in Sweden. — SGU Ca 46.

JOHANSSON, H. E., 1909: Om kopparmalmsförekomsterna vid Stora Strand. — SGU C 214.
— 1910: Om Tunabergs kopparmalmsfält. — SGU C 221.
— 1911 a: Die Eisenerzführende Formation in der Gegend von Grängesberg. — GFF 32, 239—410.
— 1911 b: The Åmmeberg zinc ore field. — GFF 32, 1051—1078.

JONGEJAN, A., & WESTERVELD, J., 1949: A few data on the copper ore deposits near Värmskog in Värmland, Sweden. — GFF 71, 577—594.

JUVE, G., 1974: Ore mineralogy and ore types of the Stekenjokk deposit, central Scandinavian Caledonides, Sweden. – SGU C 706.

KOARK, H. J., 1962: Zur Alterstellung und Entstehung der Sulphiderze von Typus Falun. – Geol. Rundschau 52, 123–145.

– 1970: Zur Geologie des neuendeckten Jakobsit-Braunit-Hämatit-Mangansilikat-Lagers Slöjdartorp im Nybergetfelde in Zentralschweden. – GFF 92, 388–401.

LANDERGREN, S., 1931: Några iakttagelser över malmerna i Saxbergets gruvor. – GFF 53, 321–328.

– 1943: Geokemiska studier över Grängesbergsfältets järnmalmer. (Geochemical studies of the iron ores in the Grängesberg area). – Ingenjörsvetenskapsakademien, Proc. 172. Stockholm.

– 1948: On the geochemistry of Swedish iron ores and associated rocks. A study in iron ore formation. – SGU C 496.

LINDROOS, H., 1974: The stratigraphy of the Kaunisvaara iron ore district, Northern Sweden. – SGU C 695.

LINDROTH, G. T., 1916: Geologiska och petrografiska studier inom den järnmalmsförande formationen omkring Ramhäll. – SGU C 266.

– 1922: Studier över Yxsjöfältets geologi och petrografi. – GFF 44, 19–123.

– 1926: Bidrag till frågan om kalk-skarnjärnmalmernas genesis. – GFF 48, 357–409.

LJUNG, S., 1974: Adak-, Lindsköld- och Brännmyrangruvorna inom Adak-fältet. Petrografi och malmer. – SGU C 701.

LJUNGGREN, P., 1953: Some data concerning the formation of manganiferous and ferriferous bog ores. – GFF 75, 277–297.

– 1958 a: The soft iron ores of Vermlands Taberg. – GFF 80, 59–70.

– 1958 b: Origin of the manganese ore deposit of Bölet, southern Sweden. – Kungl. Fysiografiska Sällsk. Lund Förh., 28, no. 10.

LJUNGGREN, S., 1960: Geology of the Gällivare iron ore field. *In:* Sulphide and iron ores of Västerbotten and Lappland, Northern Sweden. – XXI Int. Geol. Congr. Norden. Guide to Excursions Nos A 27 and C 22. SGU. P. 39–45.

LOOSTRÖM, R., 1939: Lönnfallet, southernmost part of the Export field at Grängesberg. – – SGU C 428.

LUNDBERG, B., 1967: The Stora Sahavaara iron ore deposit, Kaunisvaara, Northern Sweden. – SGU C 620.

LUNDBOHM, HJ., 1911: Sketch of the geology of the Kiruna district. – GFF 32, 751–788.

LUNDEGÅRDH, P. H., 1957: The titaniferous ore-bearing gabbro of Helsingland, Central Sweden. – SGU C 549.

– 1967: Berggrunden i Gävleborgs län. – SGU Ba 22.

– 1971: Nyttosten i Sverige. – Almqvist & Wiksell, Stockholm.

LUNDQVIST, TH., 1968: Precambrian geology of the Los-Hamra region, Central Sweden. – SGU Ba 23.

MAGNUSSON, N. H., 1924: Långbansmineralen från geologisk synpunkt. – GFF 46, 284–300.

– 1925: Persbergs malmtrakt och berggrunden i de centrala delarna av Filipstads bergslag. – Beskrivning av mineralfyndigheter nr 2, Kungl. Kommerskollegium. Stockholm.

– 1928: En skarnmineralassociation från Lindbomsgruvorna i Filipstads bergslag. – Fennia 50. Helsingfors.

– 1929: Nordmarks malmtrakt. Geologisk beskrivning. – SGU Ca 13.

– 1930: Långbans malmtrakt. Geologisk beskrivning. – SGU Ca 23.

– 1936 a: Berggrunden inom Kantorps malmtrakt. – SGU C 401.

– 1936 b: The evolution of the lower Archean Rocks in Central Sweden and their iron, manganese and sulphide ores. – Quaterly Journ. Geol. Soc. London. XCII, 332–358.

– 1938: Neue Untersuchungen innerhalb des Grängesberg feldes. – SGU C 418.

– 1940 a: Herrängsfältet och dess malmer. – SGU C 431.

– 1940 b: Ljusnarsbergs malmtrakt. Berggrund och malmfyndigheter. – SGU Ca 30.

– 1948: Zinc and lead deposits of Central Sweden. – XVIII Int. Geol. Congr. Great Britain. Rep. Pt. VII.

– 1960: Iron and sulphides ores of Central Sweden. – XXI Int. Geol. Congr. Norden. Guide to Excursions Nos A 26 and C 21. SGU.

– 1965 a: Vorkommen und Genese itabiritischer Eisenerze in Schweden etc. – Schriften der Gesellschaft Deutscher Metalhütten und Bergleute.

– 1965 b: Die mittelschwedischen Eisenerze und ihre Skarnmineralien. – Fortschr. Mineralogie. Stuttgart.

MAGNUSSON, N. H., 1970: The origin of the iron ores in Central Sweden and the history of their alterations. – SGU C 643.
– 1973: Malm i Sverige 1, mellersta och södra Sverige. – Almqvist & Wiksell, Stockholm.
MAGNUSSON, N. H., THORSLUND, P., BROTZEN, F., ASKLUND, B., & KULLING, O., 1960: Description to accompany the map of the Pre-quaternary rocks of Sweden. – SGU Ba 16.
MOGENSEN, F., 1946: A ferro-ortho-titanite from Södra Ulvön. – GFF 68, 578–588.
MOORE, P. B., & WICKMAN, F. E., 1971: The Flink collection of unknown Långban minerals: A progress report. – GFF 93, 289–301.
NILSSON, C. A., 1968: Wall rock alteration at the Boliden deposit, Sweden. – Econ. Geol. 63, 472–494.
PADGET, P., 1959: Leucodiabase and associated rocks in the Karelidic zone of Fennoscandia. – GFF 81, 316–332.
– 1966: The geology and mineralization of the Radnejaure area. – SGU C 609.
PALMGREN, J., 1921: Die Eulysite von Södermanland. – Bull. Geol. Inst. Uppsala, XVII.
PALMQVIST, S., 1935: Geochemical studies on the iron-bearing Liassic series in Southern Sweden. – Medd. Lunds geol. mineral. Inst., 60.
PARÁK, T., 1973: Kirunamalmernas bildning. – Tryckericentralen, Luleå.
– 1975: The origin of the Kiruna iron ores. – SGU C 709.
PETERSSON, W., 1896: Geologisk beskrifning öfver Nordmarks odalfält. – SGU C 162.
PILAVA-PODGURSKI, N., 1956: Nya geologiska undersökningar vid Utö järnmalmsfält. – SGU C 541.
– 1957: Lövås gruva. – GFF 79, 179–194.
RICKARD, D. T., & ZWEIFEL, H., 1975: Genesis of Precambrian sulfide ores, Skellefte district, Sweden. – Econ. Geol. 70, 255–274.
ROEDDER, E., 1968: Environment of deposition of the disseminated lead ores at Laisvall, Sweden, as indicated by fluid inclusions. – XXIII. Int. Geol. Congr., Prag, 3, 389–401.
SANTESSON, B., 1889: Beskrifning till karta öfver berggrunden inom malmförande trakterna i norra delen af Örebro län. II. Geognostiska kartor och beskrifningar öfver de viktigare grufvefälten. – SGU Bb 4.
SJÖGREN, H., 1911 a: The Långban mines. – GFF 32, 1295–1325.
– 1911 b: The Persberg mines. – GFF 32, 1327–1361.
– 1911 c: The Sala mine. – GFF 32, 1363–1396.
SUNDIUS, N., 1921: Åtvidabergstraktens geologi och malmfyndigheter. – SGU C 306.
SUNDIUS, N., PARWEL, A., & RAJANDI, B., 1966 a: The minerals of the silver mines of Hällefors. – SGU C 614.
– 1966 b: Undersökning angående tenn i mellansvenska sulfidmalmer. – GFF 88, 410–411.
– 1967: Carbonates from Väster-Silvberg. – Arkiv Min. Geol., Stockholm, 3, no. 19.
TEGENGREN, F. R., 1911: Järnmalms- och magnesitförekomsterna inom Kvikkjokks kapellag. – SGU C 230.
– 1912: Järnmalmstillgångarna i mellersta och södra Sverige. – SGU Ca 8.
– 1924: Sveriges ädlare malmer och bergverk. – SGU Ca 17.
– 1962: Vassbo blymalmsförekomst i Idre och dess geologiska inramning. – SGU C 586.
TÖRNEBOHM, A. E., 1875: Geognostisk beskrifning öfver Persbergets grufvefält. – SGU C 14.
UYTENBOGAARDT, W., 1960: Uranium mineralization in the Västervik area. – XXI Int. Geol. Congr. Norden. Proc. Pt. XV.
WELIN, E., 1959: Till kännedom om sulfidmalmerna och de zonerade zinkbländena i Boda och Solleröns kommuner, Kopparbergs län. – GFF 81, 495–513.
– 1961: Uranium mineralization in a skarn iron ore at Håkantorp, County of Örebro, Sweden. – GFF 83, 129–143.
– 1964 a: Uranium disseminations and vein fiilings in iron ores of Northern Uppland, Central Sweden. – GFF 86, 51–82.
– 1964 b: Pitchblende-bearing vein fillings in the Stripa and Blanka iron ores. – GFF 86, 257–270.
– 1966 a: Two occurrences of uranium in Sweden – the Los cobalt deposit and the iron ores of the Västervik area. – GFF 87, 492–508.
– 1966 b: Uranium mineralizations and the age relationships in the Precambrian bedrocks of central and south-eastern Sweden. – GFF 88, 34–67.
ZACHRISSON, E., 1971: The structural setting of the Stekenjokk ore bodies, Central Swedish Caledonides. – Econ. Geol. 66, 641–652.
ZENZÉN, N., 1927: Bidrag till kännedom om de geologiska förhållandena vid Nasafjälls gruvfält. – GFF 49, 351–396.

ZWEIFEL, H., 1972: Geology of the Aitik copper deposit. — XXIV Int. Geol. Congr. Montreal. Sect. 4, 463—473.
ÖDMAN, O., 1933: Erzmikroskopische Untersuchung der Sulfiderze von Kaveltorp in Mittelschweden. — GFF 55, 563—611.
— 1939: The gold-copper-arsenic ore at Holmtjärn, Skellefte District. — GFF 61, 91—111.
— 1941: Geology and ores of the Boliden Deposit, Sweden. — SGU C 438.
— 1942: Copper ores of the "Red bed" type from Visingsö. — SGU C 444.
— 1943: Geology of the copper deposit at Laver. — SGU C 452.
— 1945: A Ni-Co-mineralization in the Laver copper mine. — SGU C 470.
— 1947: Manganese mineralization in the Ultevis district, Jokkmokk. Part I, Geology. — SGU C 516.
— 1950: D:o. Part II, Mineralogical notes. — SGU C 516.

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