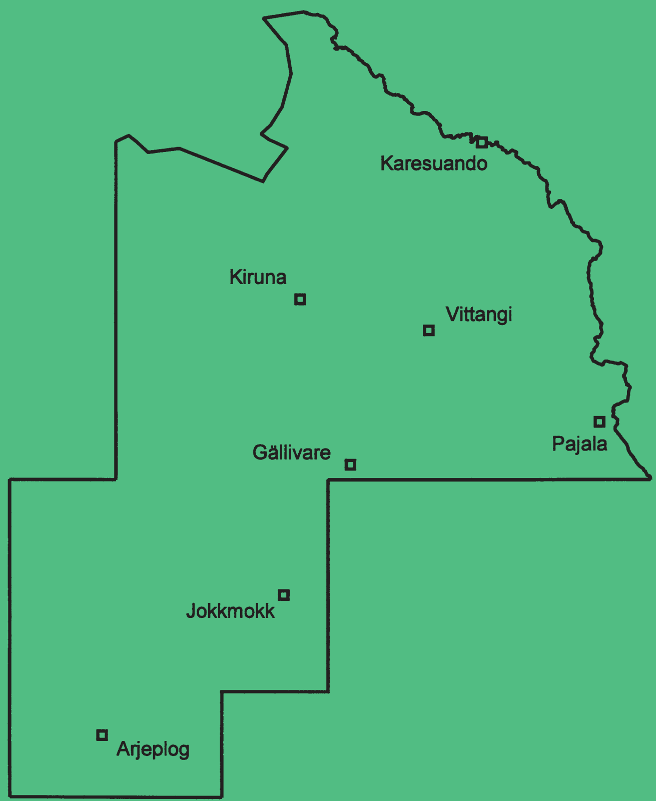
Rapporter och meddelanden nr 92

The Iron Ore Inventory Programme 1963–1972 in Norrbotten County



Rudyard Frietsch

SGU
Sveriges Geologiska Undersökning

Uppsala 1997

Rapporter och meddelanden nr 92

The Iron Ore Inventory Programme 1963–1972 in Norrbotten County

Rudyard Frietsch

SGU
Sveriges Geologiska Undersökning

1997

ISSN 0349-2176
ISBN 91-7158-557-5

Layout: Agneta Ek, SGU
Tryck: Gotab, Stockholm 1997

CONTENTS

ABSTRACT

In 1963 the Swedish government decided to initiate a regional investigation into the iron ore resources of Norrbotten County, in the far north of the country. The task was intended to take 10 years at an estimated cost of 40 million Swedish kronor (SEK). Non-ferrous deposits were also to be assessed at the same time. The assignment to perform the investigation was given to the Geological Survey of Sweden (SGU). In 1963 a law was passed prohibiting private companies and persons from prospecting within the designated area during the same period.

The inventory programme comprised 23 map sheets covering 50x50 km, of which the more important ones were to be covered by geological and geophysical mapping, the latter based mainly on airborne, low altitude magnetometric measurements. About 100,000 metres of diamond drilling were also made.

Seventy-five mineralizations were investigated. The total reserves in the major deposits were estimated to about 1,123 million tonnes (Mt) of ore. Approximately 275 Mt were found in 14 newly discovered deposits. At seven new discoveries, mining rights were registered by the State. The largest new deposits were the Jokkmokk ores (ca. 100 Mt), Pattok (ca. 68 Mt), Tjårrojåkka (ca. 55 Mt) and Puoltsa (ca. 32 Mt). The ores of the Kaunisvaara belt were upgraded from ca. 90 Mt to ca. 180 Mt. The Sautusvaara ore field, previously regarded as insignificant, now revealed reserves of 55 Mt. The inventory resulted in the discovery of several copper mineralizations adjacent to the iron mineralizations, e.g. in the Tjårrojåkka deposit. Simultaneously, but outside the scope of the programme, a number of minor mineralizations of base metals, graphite and uranium were investigated.

The iron ore inventory programme increased the knowledge of the various ore types and their environments, which has greatly enhanced the understanding of their metallogeny and also facilitating further prospecting.

INTRODUCTION

Since the early 1950's until the mid-1980's, the State took an active part in the mineral exploration of northern Sweden. Some was undertaken in the early 1950's during a regional mapping of Norrbotten County. The first large-scale prospecting investigation in the County was made in 1957–63 by the Geological Survey of Sweden (SGU) on a few previously known mineralizations in the Svappavaara region, SE of Kiruna township. This work, necessitated by an increased demand for iron ore by the Luossavaara– Kiirunavaara Company (LKAB), was conducted with the agreement of the Board of Trade and the company was given an option for the region.

In 1963 the Government decided to conduct a general examination of the iron ore mineralizations of Norrbotten County. This general survey was planned to improve the knowledge of already known mineralizations and to discover new ones. New finds of other metals were also to be investigated. The guidelines for the Iron Ore Inventory Programme (IOIP) are set out in the report ”Malmen i Norrbotten, Statens Offentliga Utredningar 1963:36” (The Ores of Norrbotten, Public Inquiries 1963:36). The assignment to undertake the programme was given to the SGU, for which purpose the agency established a regional office in Kiruna.

The area of investigation was limited to the northern and western part of Norrbotten, excluding the mountain region with the Caledonides (Fig. 1). The area covered 23 topographic map sheets, each covering 50x50 km. The investigation proceeded until 1973, costing some 40.5 million SEK. Annual expenditure varied between 1.4 and 5.4 million SEK.

The work was based on detailed airborne measurements made from an altitude of 30 metres with a line spacing of 200 m. These regional airborne measurements by SGU started as early as 1960 in the Kiruna area. In 1961 and 1962, four map sheets were covered. Since 1967, airborne measuring has been combined with radiometric methods. The latter have been confined to the remaining southern part of the area, mainly maps sheets 27J to 25N (partly outside the area delineated by the IOIP). Subsequent work involved regional and detailed geological mapping, geophysical ground measurements (magnetic, gravimetric, Slingram and Self-potential) plus about 100,000 m of diamond drilling. On many map sheets, regional geological mapping was done, which greatly improved the understanding of the environment in which the ores were formed.

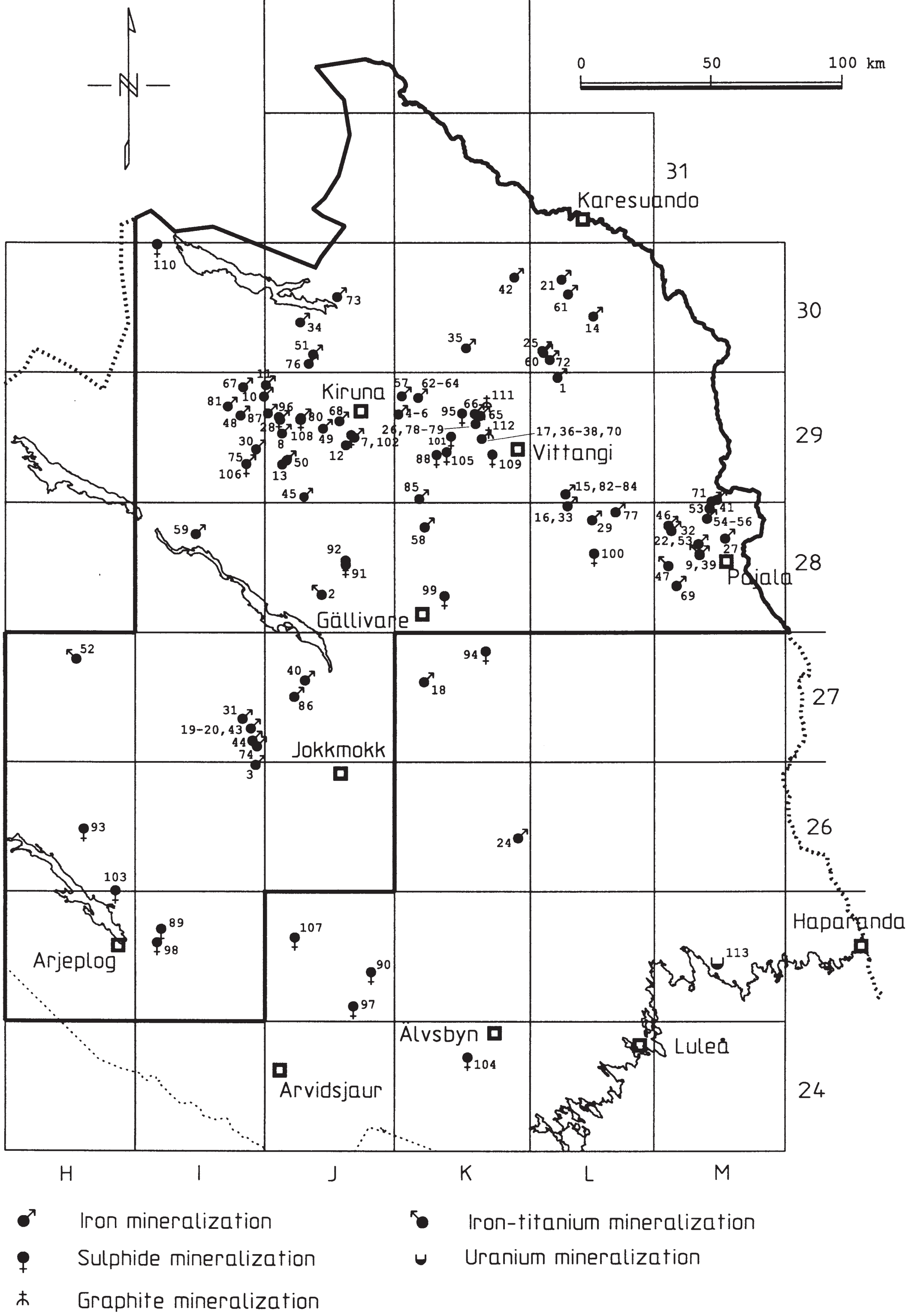


Fig. 1. Map showing the region covered by the Iron Ore Inventory Programme 1963–1972 (heavy solid line) and the location of some of the investigated deposits. The numbers refer to deposits listed in Table 6. Previously known and recently investigated iron and sulphide ores (e.g. Kiirunavaara, Aitik, Pahtohavare) are not shown.

With the intention that larger non-magnetic iron ores should not be overlooked, regional gravimetric measurements covering entire map sheets were made, leading to several such finds.

Although it had been planned that the inventory should conclude with a descriptive compilation of all investigated deposits, this could not be accomplished because of the state budget after finished field work did not allow for further work on a compilation of the entire IOIP. The present report is a belated attempt to fulfil the assignment in this respect, though it has been hampered by the following circumstances. Regarding most deposits there exist rather brief, more or less technical reports presenting such data as extent, tonnage and grade of the mineralizations. In most instances, no detailed geological investigation of the nature of the ores and host rocks was made. Moreover, as SGU has suffered a succession of organizational upheavals since 1973, some of the primary material, such as drill loggings, reports, geological and geophysical maps, no longer exists. The quality and amount of data presented here have been profoundly affected by these circumstances. They could perhaps be improved on, but would require a considerable amount of complementary work. Consequently, the quality of the underlying reports has affected the descriptions of the various deposits.

Results and data from later prospecting work (i.e. after 1973) on the mineralizations investigated during the IOIP are largely disregarded in the present compilation. However, when describing the general features of the various ore types, the results of more recent geological investigations and results have been taken into account.

In connection with the IOIP, the Government laid down specific legislative guidelines to create conditions for mining work that would be advantageous for the public sector. In order to ensure that all new mineral finds by the IOIP should become public property, an ad hoc law was passed, giving the State the exclusive right to stake claims throughout Norrbotten. This restrictive law remained in force until 31st December 1972. The legislation forbade all other prospecting work during that period. However, the Boliden Company was granted an exemption for an area within the County but lying outside the purview of the IOIP. The exemption also covered the IOIP area south and west of the Piteå river.

DISCOVERY OF THE MINERALIZATIONS IN NORRBOTTEN COUNTY

Norrbotten County has several hundred of mineral deposits, most of which were discovered at various times during prospecting by the State, private individuals and private companies.

17th century. Early finds were silver-lead ores within the Caledonides (Nasafjäll in 1635, Silpatjåkko in 1657, Lanjek in the 1680’s and Alkavare in 1691) and copper ores in the north of the county (Svappavaara in 1654, Raggisvaara–Yli Pårro in 1683, Sjangeli in 1696; Maunuvaara and Pahtavaara, both during the 17th century; Pahtavaara before 1690). Some iron ores were also found during this period (the southern part of Masugnsbyn in 1644, and Gruvberget, Svappavaara in 1654). Several of these finds can be credited to the ”*Bergskollegium*” (the Crown Mining Authority), established in 1630, which sent prospectors to this part of Sweden.

18th century. During the 18th century a number of copper mineralizations were found between Kiruna and Svappavaara: Särkivaara in 1714; Huornats, Kurravaara and Kovo, all in 1747; Harrivaara in 1749, Särkivaara in 1756 (1714) and Patnakieli in 1736 (1751). The large iron ore deposits have been known since the late 17th century; written documentation exists concerning Luossavaara (1690), Malmberget (Gällivare, 1704) and Haukivaara (1759). The titaniferous ore Ruoutevare (Routevare, Ruotivare) has also been known since the 18th century.

19th century. The 19th century, especially the latter half, was characterized by greatly intensified prospecting work and regional investigations of the geology and ore deposits in northern Norrbotten. The new finds were mainly iron ores: Ekströmsberg (written documentation) in 1818, Ristjäln in 1830, Leppäkoski in 1840, Killingelinka in 1872, and Nokutus in 1888. When the question was raised of building a railway from Gällivare to Kiruna and over to the Norwegian coast at Narvik, several private expeditions were sent out in 1895–98 to search for mineral deposits along the route of the projected railway. Chief participants were the owners of LKAB and Svappavaara Malmfält AB. As a result of their efforts a large number of iron ore deposits were found: Ekströmsberg in 1895 (rediscovered); Sautusvaara in 1896; Leveäniemi, Mertainen, Painirova, Salmivaara, Tuolluvaara, Altavaara, Nakerivaara, Tjavelk, all in 1897; Alpha, Laukujärvi, Ylipääsnjaska, Rakkurijoki, Tuollujärvi, Rakkurijärvi, Syväjärvi, Ainasjärvi, all in 1898; and Toppi in 1899. In addition, the titaniferous Akkavaara (Melko) ore was discovered during the 1890's.

New discoveries of other ores were sparse during the 19th century. Examples are Porjusvare manganese ore in 1862, Kopparåsen (Kuokel) zinc–copper ore at the turn of the century**,** Nautanen copper ore in 1898, and in the Caledonides the lead ores Lauteråive 1889 and Svangeråive during the 1890's.

Turn of the century. Shortly after the turn of the century, several more iron mineralizations were discovered: Njuotjamavaara in 1903; Keskinen Käyrävaara and Tansari, both in 1904 as were the graphite deposits of the Vittangi region: Jälketkurkkio in 1898, Äijärova in 1899, Nunasvaara and Kuusi Nunasvaara both in 1910, and Ylisuannonmaa in 1912.

The period spanning the close of the 19th century and the early 20th is characterized by numerous regional surveys of the geology and the ore deposits in the County, especially its northern parts. As early as 1804, S.G. Hermelin was the first to attempt a survey of the mineralizations. In 1875 a governmental commission led by the SGU visited northern Norrbotten. Their findings were published in 1877, comprising a detailed description of the region's geology and a number of iron and copper deposits. During the period 1889–1910, many important contributions were made to the knowledge of Norrbotten's geology. The mode of occurrence of the apatite iron ores and apatite was accorded great importance. From 1889 to 1897, state prospecting of the Gällivare and Kiirunavaara–Luossavaara iron ores was undertaken. The results were published by SGU in 1890, 1892 and 1898. Of importance to the investigation of the ore deposits in the Kiruna and Svappavaara areas were the ore-prospecting expeditions sent out in 1899 under SGU auspices. Their findings were published in 1900.

20th century. In 1905–1910 a thorough investigation of the geology and ores of the Kiruna area was made under the leadership of Hj. Lundbohm. At the same time the Gällivare ore was investigated. The results were published in 1910 and in 1915.

In 1913 a governmental commission was ordered to ascertain how the iron ore deposits owned by the Crown in Norrbotten could be exploited. The commission published their considerations in a report in 1923. In 1916 the commission formulated proposals concerning the investigation of certain ore prospects. However, only at the Mertainen ore were investigations actually carried out.

During the 1910's and 1920's a number of iron ore finds were made by the AB Nordsvenska Malmfält company: Vathanvaara in 1901, Vieto in 1914, the northern part of Masugnsbyn in 1915–1916, Nunasjärvenmaa in 1916, the Kaunisvaara ores (Stora Sahavaara, Tapuli and Palotieva) in 1918; Pellivuoma and Marjarova (Marjajärvi) both in 1919, the Lannavaara ores (Kevus, Sattavara and Teltaja) in 1920–21, Sautusvaara in 1921, and Erkheikki in the early 1920's.

During the 1910's and 1920's the SGU conducted practical-geological work in the Kiruna, Gällivare and Pajala areas. The prospecting comprised the Nautanen copper ore, the Vittangi iron ores and graphite deposits, all in 1918; the Tuolluvaara iron ore and the Porjusvare manganese ore in 1919, the Masugnsbyn iron ore in 1929 and the Gällivare iron ore in 1930. As a result of these works, SGU published the first modern survey of the rocks in the ore-bearing region of Kiruna–Gällivare–Pajala.

At the end of the 1920' when the inland railway line was extended south from Jokkmokk, SGU made practical-geological investigations in the Jokkmokk area. The results, published in 1931, comprise descriptions of the regional geology and deposits of ore and industrial minerals.

Around 1930 the Boliden company started extensive prospecting operations in the southern and northern parts of the Precambrian rocks of the county, as well as within the Caledonides and the Caledonian Front. In the Precambrian rocks, copper mineralizations were discovered in 1930 at Laver and in 1932 at Aitik. The regional prospecting operations resulted in the late 1930's in the discovery of a new ore province in the Caledonian Front with abundant lead–zinc mineralizations. Laisvall was discovered in 1938**.**

In 1940, SGU restarted prospecting in Norrbotten. This time, large investigations were concentrated on manganese and the Ultevis ore was discovered in 1943. SGU began regional geological mapping of the County, including the Caledonides, in 1945. This involved investigation of the bedrock, the ores and the mineral deposits. In the late 1940's, Johnson AB and Boliden AB companies initiated extensive prospecting work which, for the first time, included airborne measurement. During the late 1940's, several iron ore finds had been made: by SGU at Kallak (1947), Luppovare (1948) and Peräjävare, Tornefors and Renhagen (1949); by Boliden AB at Ruutijärvi (1949), and by Johnson AB at Harrejaure and Pattovare. In 1949 the graphite deposit at Meraslinka was discovered by SGU.

The 1950's were dominated by new iron ore finds. The regional mapping by SGU revealed the Hejka and Rebak iron ore deposits in the Arjeplog area. In 1950, SGU also found the copper mineralization at Laukujärvi and in 1953 the molybdenum mineralizations at Härkevaara. In the late 1950's, Johnson AB discovered the Tjåorika, Tjärro, Karhujärvi, Suksivuoma and Venetvuoma iron mineralizations. In 1955–57, Boliden AB found the Tervaskoski iron ore and in 1957 the Jerfojaure titaniferous ore.

State prospecting work in Norrbotten was intensified in the late 1950's. When LKAB received a government assignment to investigate the so-called 'option area', SGU conducted extensive investigations in 1957–64 of the iron mineralizations of the Svappavaara district (Gruvberget, Leveäniemi, Tansari, Painirova and Mertainen). SGU investigated the Stora Sahavaara iron ore in 1960-64, on behalf of LKAB. From 1959, regional aeromagnetic measurements led to the discovery of Parkijaure and Akkihaure (both in late 1950's); Puoltsa, Årosjåkk, Eustilljåkk, Suolojokk (all in 1960), Peräjävuoma (titaniferous ore, in 1961) and Leppäjoki (in 1962).

In 1963, SGU was allocated funds to make an inventory of the Norrbotten iron ore reserves, for the purpose of improving the knowledge of all previously known iron deposits and exposing new ones. In addition to iron ore, the inventory was to concern itself with other useful minerals. The prospecting work covered the northern and western part of the County. This work, and especially the airborne measurements, revealed a number of iron mineralizations: Tjårrojåkka, Pattok, Pirttivuopio, Gäddmyr and Vistas (all in 1963), Satisjaure (in 1965), Ahmavuoma, Nalmoinen, and Palovaara (all in 1968), Ruutijärvi (blind ore body, in 1969), and Åkosjägge (late 1960's).

Since the mid-1950's LKAB has been prospecting in the Kiruna and Gällivare areas. Adjacent to Kiirunavaara the Henry iron ore was discovered in 1958, and the Haukivaara and Lappmalmen iron ores in 1960.

During the 1950's and 1960's, SGU found a number of sulphide ores: the copper ores Lulepotten in 1960; Nimtek and Ballek both in 1961; Singis in 1964; Äijäjärvi in 1965; Vieto, Rakkurijärvi, Benbrytefors, Stavträsk, all in 1967; the zinc ore Ljusträsk in 1967; the copper ore Ainasjärvi; the zinc ores Vargisträsk and Tjärrovare, the tungsten ores Kårsovare and Ardnajokk, the molybdenum ores Norrpuoda, Haukok and Björntjärn, all in 1968; the copper ore Jårbojåkk in 1969; the copper ores Tjårrojåkka in 1971, Luspevaratj, and Iekelvare; the molydenum ores Skarjaviken and Munka, both in 1971, and Åggojaure in 1972; the copper ores Kivijänkkä, Sjaunja, and Holmajärvi, all in 1974; and the copper ore Kiskamavaara in 1975.

While prospecting the state mine district of Kiruna LKAB found the Viscaria copper ore in 1973. In the same area the copper–gold occurrence was found at Pahtohavare by the State Mining Property Commission (NSG) in 1988 and later put into production by the Outokumpu OY company.

AB Atomenergi found uranium mineralizations during the 1960's at Masugnsbyn and Kopparåsen. Since 1968, when SGU started uranium prospecting, several uranium deposits have been found: Akkapakte, Pålänge, Ultevis, and Pleutajåkk, all in 1969; Plättik in 1970; Grutaure, Labbas, Manak, Harrejokk and Kvarnån, all in 1971; Björklund, Kikkejaur and Rebraur, all in 1972; Rävaberget in 1973 and Gervåive in 1974.

MODE OF DESCRIPTION

The aim of the IOIP was to make a survey of the iron mineralizations in Norrbotten County, as concerns both the reserves and the geological features of the various ore types. In addition, occurrences of other elements were to be considered.

Each deposit investigated in the IOIP is described in the present work according to the following scheme:

Site: Map sheet:
Discovery:
Geophysical features:
Structural features:
Geological structures:
Mineralization:
Reserves:
Host rock:
Reference:

In a number of deposits some of the entries could not be filled in for lack of data.

It should be emphasized that the investigation of the geology of the various deposits is of varying quality and contains varying quantities of data. In many cases the geological records have to be considered only as basic facts. Only a few deposits have been investigated to such an extent that a complete description can be given.

The mineralizations belong to different types of ore and are described accordingly. The investigated iron ore types are:

(a) apatite iron ores of the Porphyry Group,
(b) skarn iron ores of the Greenstone Group,
(c) quartz-banded iron ores of the Greenstone Group,
(d) quartz-banded iron ores of the Porphyry Group,
(e) metasomatic iron ores and sulphide ores associated with scapolitization–albitization–tourmalinization of the Greenstone Group and of the Porphyry Group,
(f) magmatic-tectonic iron ores,
(g) titaniferous ores.

The deposits investigated are listed in Table 1. The content of different elements and the estimated reserves are shown in Table 2. Figs. 1–5 show the sites of the main occurrences.

Some non-ferrous deposits are described only briefly as they were discovered and investigated at the time of the IOIP. These are graphite and uranium in the Greenstone Group, and magmatic sulphide ores in southwestern Norrbotten.

GEOLOGICAL SETTING

The investigated mineralizations occur in Palaeoproterozoic, 1.9–2.5 Ga old, metavolcanic and metasedimentary rocks. Plutonic rocks cover large areas surrounding the supracrustal rocks which form irregular, elongated belts, mostly with a NNE or a NW extension. The grade of metamorphism is intermediate, being mostly within the amphibolite facies.

The Greenstone Group contains mafic volcanic and sedimentary rocks which rest on a ca. 2.8 Ga Archaean granite–gneiss basement (Welin et al., 1971; Skiöld, 1979). The volcanic rocks consist of basalts and subordinate andesites and ultramafic rocks. At high stratigraphic levels they contain sedimentary intercalations of tuffs–tuffites, phyllites, graphite-bearing schists, and calcite–dolomite marbles. U/Pb radiometric dating of the greenstones yields ages between 2.0 and 2.5 Ga (Skiöld and Cliff, 1984; Krill et al., 1985; Skiöld, 1986). Pb-Pb and Sm-Nd determinations of metasedimentary rocks and tholeiitic basalts along the Gulf of Bothnia bay give an age of 2.1–2.3 Ga (Huhma et al., 1990; Öhlander et al., 1992).

Skarn iron ores, some quartz-banded iron ores and some metasomatic iron and sulphide ores occur in the rocks of the Greenstone Group. At Pålänge there is a uranium mineralization.

The Svecofennian Porphyry Group, overlying the Greenstone Group, comprises terrestrial and marine metavolcanic rocks of intermediate to felsic composition. U/Pb determinations yield ages of 1.88–1.91 Ga (Skiöld and Cliff, 1984; Skiöld, 1987; Welin, 1987). The volcanic rocks were genetically linked with differentiated plutons, 1.86–1.89 Ga old, and later affected by a granitic pluton, 1.77–1.83 Ga old (Skiöld, 1987; Tuisku, 1993).

The Porphyry Group comprises apatite iron ores of the Kiruna type and quartz-banded iron ores. In various metavolcanic and metasedimentary rocks, probably of Svecofennian age, there are base metal ores. The 1.86–1.89 Ga old Svecofennian mafic intrusions contain titaniferous iron ores and nickel sulphide ores.

Of unknown age but probably relatively young are some iron and base metal-gold ores formed in connection with sodium–chlorine-rich metasomatic processes affecting rocks of the Greenstone and Porphyry Groups.

DEPOSITS INVESTIGATED

APATITE IRON ORES (OF KIRUNA TYPE) OF THE PORPHYRY GROUP

GENERAL FEATURES

The deposits of the Kiruna iron ore type with magnetite–haematite–apatite and additional amounts of calcite, actinolite and diopside occur in rocks of the Porphyry Group in the northern parts of Norrbotten County (Frietsch, 1980).

The ore is characterized by a F-apatite with small amounts of Cl and OH (Frietsch, 1974a, 1978). The P content varies from low to high (<2% P), while the contents of Ti (in sphene or occasionally in ilmenite) and S (mostly in pyrite) are low (<0.1%). The ore forms tabular bodies with associated breccias and behaves as an intrusive rock. The form of emplacement depends on the vertical level of the ore magma (subsurface intrusion to surface extrusion). Hydrothermal alterations (silicification–sericitization with minor addition of CO_2 , Ba, B and F) occur only locally.

The rocks of the Porphyry group are calc-alkaline, or weakly alkaline, rhyodacites and trachytes (Frietsch and Perdahl, 1989; Perdahl and Frietsch, 1993) which according to U/Pb determinations are 1.88–1.91 Ga old (Skiöld and Cliff, 1984; Skiöld, 1987; Welin, 1987).

According to Cliff et al. (1990) the Kiirunavaara ore was emplaced in the period between 1.88 and 1.90 Ga. U/Pb dating of sphene indicates that the Luossavaara ore is 1.89 Ga old (Cliff et al., 1990). The ore formation is related to fault zones in a rifting environment, close to the border of the Archaean basement (Frietsch, 1984, 1991). It originated by magmatic differentiation as a late phase in the volcanism, forming sub-surface injections or surface flows (Frietsch, 1988). While the main part of the magma crystallized, the ore remained in solution and was injected as a late, separate phase (Geijer, 1931; Frietsch 1973a, 1984; Geijer and Ödman, 1974). Apatite lowered the melting point of the magma and the ore–apatite system behaved intrusively. From the intrusion to the extrusion level, the following ore varieties formed in the Kiruna area:

1) main magnetite–haematite ores with moderate P content (<1% P, e.g. Kiirunavaara),
2) P-rich magnetite–haematite ores (>1% P, e.g. Rektorn) and
3) P-free (Hauki) haematite ores.

The latter ore type is a hydrothermal phase with silicification and sericitization of the host volcanic rocks. In many of the magnetite–haematite ores, the transformation of magnetite (which is the primary ore mineral) to martite and haematite is associated with metasomatism causing sericite–quartz–alteration (Frietsch, 1967).

Ekströmsberg

Site: 30 km WSW of Kiruna **Map sheet:** 29 J/5b

Discovery: In the Ekströmsberg area there are several iron mineralizations of the Kiruna type, varying in type from massive bodies, breccias to impregnations. From north to south the following mineralizations are found: Njakak, Kajpak, Ekströmsberg, Piedjastjåkko, Skåukem (Skuokimjokk), Tjåurekah (Tjåorika), Renhagen and Harrejaur. All deposits, except Tjåurekah and Harrejaur which belong to Nordstjernan AB, were investigated by SGU during the IOIP.

The Ekströmsberg deposit has been known since the early 19th century (written documentation in 1818), since when it has been investigated on different occasions, mainly around the turn of the century. Rediscovered in 1895. In 1950 SGU conducted magnetic measurements, diamond drilling (13 holes totalling 1971.2 m) and bedrock mapping. In 1961–62 magnetic and gravimetric measurements. In 1965–67 bedrock mapping; in 1965–69, diamond drilling (48 holes totalling 7539.58 m).

Structural features: The mineralization is transected by a NE–SW striking fault. The main part of the ore is found north of that and probably represents a deeper part of the mineralization.

Mineralization: The ore-bearing area is about 1500 m long and contains magnetite, martite and haematite mineralizations, which strike NW and dip vertically or steeply toward the SW. The width of the ore-bearing area is 150–160 m; in the southern part, 30–40 m. The largest single mineralization is a ca. 50 m wide magnetite lens. Martite is found in the northern part between magnetite and haematite. Both haematite and martite are formed by oxidation of magnetite. An up to 40 m wide tremolite–actinolite skarn, with some magnetite and apatite, occurs in the northern part. Apatite is omnipresent, mostly as layers. In the southern part there are intercalations of magnetite–martite–haematite–layered quartzites, probably formed by metasomatic (hydrothermal) processes. The host rock contains narrow veins of secondary minerals, mainly quartz and sericite, and some calcite, zircon, orthite, tourmaline and fluorite. The mineralizations contain 55–63% Fe, 0.8–1.5% P, 0.01–0.03% S, 0.03–0.29% Ti and 0.04–0.06% V.

Reserves: The total area of the mineralizations covers 45,725 m^2. Down to a depth of 230–250 m below the surface the deposit contains 19.1 million tonnes of magnetite ore with an average of 55.0% Fe and 1.3% P, 7.9 million tonnes martite ore with an average of 57.6% Fe and 1.3% P, and 10.0 million tonnes haematite ore with an average of 56.3% Fe and 1.35% P; in total, 37 million tonnes of ore with an average of 55.9% Fe and 1.3% P.

Host rock: Felsic volcanic rocks. Quartz-bearing porphyry with quartz, microcline, albite, small amounts of magnetite with phenocrysts of perthitic microcline. Locally the porphyry is metasomatically altered with formation of quartz and sericite. Subordinate are intercalations of trachyandesite with phenocrysts of albite in a biotite-rich matrix with some magnetite and chlorite. As the magnetite content increases, the rock grades locally into a magnetite-rich trachyandesite.

References: Frietsch, 1974b; Frietsch et al., 1974.

Eustilljåkk

Site: 37 km WNW of Kiruna. **Map sheet :** 29J/8a–9a.

Discovery: New discovery in 1960 by airborne magnetic measurement by SGU. In 1969, magnetic and gravimetric measurements.

Geophysical features: Magnetic anomaly ca. 1 km long, extending NNE. Toward the east are several smaller magnetic anomalies extending NW–SE.

Mineralization: Geological mapping shows 50–100 m wide mineralization of magnetite in a network ('breccia') , less commonly as impregnation or as amygdules. The richer part of the breccia is ca. 50 m wide and ca. 500–600 m long. The mineralization contains <45% Fe, 0.001–1.2% P and 0.01% S. In the southern part there is an additional lens, 100 m long and 10 m wide, of rich ore. In the southern part a tremolite–actinolite skarn forms up to 0.5 m wide veins or schlieren. Epidote is locally abundant.

Reserves: Rich breccia with 30–45% Fe covers about 25 000 m^2. A rough estimate gives about 5 million tonnes of ore.

Host rock: Felsic volcanic rocks with quartz, microcline and some albite which contains microperthitic feldspar phenocrysts. The felsic volcanic rocks are bordered to the west by mafic volcanic rocks, which are locally scapolite-altered, and to the east by intermediate–composition volcanic rocks. To the north, granites and syenites with perthitic feldspar occur. The granite is veined by calcite, amphibole, epidote and fluorite.

References: Grip and Frietsch, 1973; Lindroos: Unpublished report with map, SGU.

Gäddmyr

Site: 15 km SSW of Kiruna **Map sheet:** 29J/4g

Discovery: New discovery in 1963 by airborne magnetic measurement by SGU. Magnetic measurements in 1964, gravimetric measurements in 1969, and Slingram measurements in 1980; in 1980, diamond drilling (1 hole of 57.0 m).

Geophysical features: Magnetic anomaly extending ENE with a length of 60 m and 12–15 m wide. Extreme high magnetometric values with strong remanent magnetization.

Mineralization: The mineralization does not outcrop. The drill hole and geophysics indicate a surface-near, magnetite–haematite body which is extended roughly ENE, ca. 60 m long, 12–15 m wide and with a depth of 50 m. Near the surface, magnetite dominates over haematite; at deeper levels the converse is found. Both minerals occur in each other as spots and irregular schlieren of cm-size. Small cavities filled with magnetite or haematite are common in the host rock. Apatite is omnipresent as impregnation or mm-wide schlieren.

Reserves: Geophysical estimate shows an outcropping area of about 700 m^2 and a depth of 50 m, which gives ca. 214,000 tonnes of ore with 67–69% Fe. According to these calculations the ore contains 61,000 tonnes of magnetite and 142,500 tonnes of haematite.

Host rock: Trachyandesite with cm-large feldspar phenocrysts. Contains breccias and impregnations of magnetite, haematite and some apatite.

Reference: Johansson, 1981.

Hotnjos

Site: 35 km WSW of Kiruna **Map sheet:** 29J/2b–3b

Discovery: Magnetic and gravimetric measurements and detailed geologic mapping by SGU in 1971.

Geophysical features: Magnetic anomaly, striking approximately E–W, 2 km long and 100–200 m wide. Encloses smaller areas with >8 000 γ. The deposit lies about 3 km S of the Tjåorekah (Tjåorika) iron mineralization and about 3 km SW of the Renhagen iron mineralization, and is probably related to the latter.

Host rock: No outcrops. On the Hotnjos hillock there are outcrops of a greenstone which locally is porphyritic, rich in epidote and scapolite-altered. The rock is veined by a red aplite granite and quartz–pegmatite veins. An E–W fault occurs immediately south of the anomaly.

References: Offerberg, 1967; Lindroos, 1971: Geological field map, SGU.

Luppovare (Luopovare, Ailatis)

Site: 47 km WSW of Kiruna **Map sheet:** 29I/3j–2j

Discovery: At Luopovare, on top of the Luppovare hill, martite ore has long been known. In 1948, discovered and investigated by SGU by geological mapping and magnetic measurement. Luppovare is a magnetite mineralization 5 km W of Luopovare and in 1970 was magnetically and gravimetrically measured by SGU.

Mineralization: At Luppovare there at three localities ENE-striking, 10–20 m wide breccia zones. The largest, about 20 m wide and at least 80 m long, consist of a poor breccia with metre-wide layers of haematite. Haematite forms bodies or veins which cut the porphyry into angular pieces up to 10 cm long. Magnetite is sparse; probably most of the haematite is formed from magnetite. The gangue consists of quartz, fluorite, locally tremolite and sphene. Both the ore bodies and the breccia are schistose and run parallel with metabasite dikes.

Single analysis of the haematite gave 63.6% Fe, 0.16% P, 0.015% S, and of a quartz-bearing magnetite 50.1% Fe, 0.015% P and 0.007% S.

Host rock: K-rich, quartz-bearing, porphyritic rhyolite (74.9% SiO_2, 6.8% K_2O, 3.16% Na_2O), locally sericitized-altered and fluorite-bearing. The rhyolite is cut by NNW-striking, up to 10 m wide metabasite dikes. Locally the haematite bodies and breccia show a schistosity parallel with the metabasite dikes.

Reference: Ros, 1971.

Nakerivaara

Site: 52 km NW of Kiruna **Map sheet:** 30J/4c

Discovery: Found in 1897. Magnetic measurement in 1958 by SGU; gravimetric measurement, 1967; diamond drilling, 1959 (3 holes totalling 525.78 m) and in 1964 (5 holes totalling 866.75 m).

Geophysical features: 1.8 km long magnetic anomaly.

Mineralization: The ore-bearing zone strikes NNW–SEE, dips vertically and is c. 1500 m long and 100 m wide in the north and 20 m wide in the south. The zone consists of a lean magnetite breccia, which toward the south is somewhat haematite-altered. To the paragenesis belong apatite, tremolite–actinolite and biotite.

Reserves: The northern, more investigated part, has according to Stacey (1966) a surface covering c. 26,000 m^2 and contains to a depth of 200 m 12.7 million tonnes of ore with an average of 31% Fe, 0.3% P, 0.028% S and 0.12% Ti. According to Danielsson and Cornwell (1977) the ore covers 13,900 m^2 and contains down to 200 m below the surface 7.5 million tonnes of ore of which 1.8 million tonnes are rich ore with an average of 39.3% Fe and 0.32% P.

Host rock: Fine- to medium-grained, often schistose, dioritic rock (amphibolite) which consists of oligoclase, amphibole (tremolite–actinolite and hornblende) and some biotite and diopside. Represents an intrusive or a metamorphosed volcanic rock. Analyses show 48–54% SiO_2, 2–5% Na_2O and 1.1–3.3% K_2O. Untypical of the Kiruna type of ore. The diorite and the breccia are veined by syenite and granite.

References: Frietsch, 1960; Stacey, 1966; Grip and Frietsch, 1973; Danielsson and Cornwell, 1977.

Pattok

Site: 39 km SW of Kiruna **Map sheet:** 29J/0d

Discovery: New discovery in 1960 by SGU by airborne magnetic measurement; in 1963–65, gravimetric and magnetic measurements; in 1967–70, diamond drilling (23 holes totalling 5164.27 m). The occurrence is the northwestern, and larger, part of the Pattovare magnetite mineralization discovered in 1951 by the Johnson AB company.

Geological structures: The Pattok ore and associated breccia form a 1 km long zone striking NNW. The dip of the mineralization is vertical in the northern part and steeply west in the southern part. Two faults have dislocated the mineralization. The fault in the middle part strikes E–W and dips steeply S. The displacement is 50 m and resulted in a subsidence of the northern block. The fault in the southern part strikes NNE and has dislocated the southern part upwards.

Mineralization: The mineralization consists of a 1000 m long and up to 90 m wide lens-formed haematite body. In the south–eastern part there is, probably separated from the haematite, the minor Pattovare magnetite body of only some hundred metres length. The northwestern haematitic part consists of three ore types: 1) chlorite-bearing haematite ore, 2) massive haematite ore, and 3) P-rich massive haematite ore with >2.5% P. The chlorite-rich ore, which is found in the northern end of the mineralization and in the southern part west of the massive ore, contains bands of chlorite and quartz. In the massive haematite, apatite is irregularly distributed. In the P-rich parts, apatite forms mm-wide, parallel layers, which are cut by narrow haematite-apatite veins. The gangue in massive ore consists of calcite, goethite, chlorite, biotite and quartz. In the massive ore there are numerous cavities, 1–5 mm long, occasionally larger, making up 10–20 volume% of the ore. Haematite is formed by martitization of magnetite. Martite is found mainly in the southern part bordering the magnetite. The degree of martitization varies, however, the border to the haematite ore being sharp.

The ore breccia that surrounds both sides of the middle and southern parts of the massive ore, occurring partly within the ore, consists of haematite and apatite in parallel veins; associated are tourmaline, calcite and quartz. The host rock trachyandesite is veined by coarse schlieren of scapolite, chlorite and quartz. Locally the breccia is rich in apatite; in the middle part of the deposits are up to 10 m long sections with more than 30 volume% apatite. There is also a breccia rich in apatite and calcite in the southern part of the ore deposit.

Reserves: The ore covers an area of 72,000 m^2 and contains, down to a depth of about 250 m, 68 million tonnes of ore with an average of 45.1% Fe and 1.99% P. The Pattovare magnetite ore body, which belongs to the Johnson AB company, covers an area of 4000 m^2 and contains on average 40% Fe, 3% P and 0.02% S.

Host rock: The host rock is mostly metasomatically altered. The main host rock is a trachyandesite with sericitized plagioclase phenocrysts in a matrix of albite, sericite, biotite and iron oxide; locally, chlorite and scapolite are abundant. Accessories are microcline, baryte, tourmaline and goethite, rarely apatite, fluorite and sphene. Secondary veins, amygdules and aggregates of quartz associated with calcite, iron oxides and baryte are common.

In the middle part of the deposit there is a 7 m wide dike or lava bed of a quartz-bearing porphyry which, in a matrix of quartz, some scapolite, sericite and opaque minerals, contains sericitized feldspar phenocrysts. In the southern part of the deposit is a 6 m wide dike of trachyandesite with albite, chlorite and opaque minerals, which is cut by haematite–apatite veins. In the southern part of the occurrence there are also up to 10–15 m wide, discordant dikes of a scapolitized and chloritized mafic rock cutting the syenite porphyry and the ore.

Towards the SW there is an andesitic greenstone which is the predominant rock of the region. It is scapolitized, with numerous calcite veins, secondary albite, amphibole and biotite. Some altered parts are almost free from dark minerals, while others consist solely of coarse amphibole and scapolite.

References: Ambros et al., 1973; Grip and Frietsch, 1973.

Renhagen

Site: 33 km WSW of Kiruna **Map sheet:** 29J/3b

Discovery: By SGU in 1949 as an outcropping mineralization. In 1951, SGU made magnetic measurements; in 1962–63, magnetic and gravimetric measurements, geological mapping in 1964; in 1969, diamond drilling (5 holes totalling 891.11 m). Mining rights in 1952.

Geophysical features: A 1500 m long and 300 m wide area with magnetic anomalies which form a pointed fold open towards SE.

Geological structures: The mineralization forms a synclinal fold with steep dipping limbs which in the main are parallel with the NNW striking schistosity of the host rock.

Mineralization: Magnetite forms an ore breccia which is locally rich in magnetite. Near the surface, martitization is encountered. The richest part of the mineralization occurs in the northern limb as an approx. 700 m long and 5–40 m wide zone, dipping 80–85°S. In the fold crest the ore zone has a vertical dip and in the southern limb the dip is 75–85°N. In the eastern part of the deposit, in connection with the ore breccia, there is a skarn with actinolite, some quartz, calcite, biotite, chlorite, and sphene. Locally the breccia passes gradually into ore-bearing skarn. The skarn zones are 1–4 m wide. Locally the ore veins occur at an oblique angle towards the schistosity. Here the magnetite is coarse-grained and associated with calcite, quartz and iron sulphides, indicating an origin by secondary mobilization.

Reserves: In the ore-bearing northern zone the richer breccia contains >35% Fe and the poorer breccia 20–35% Fe. The richer breccia covers 7900 m^2 and contains to a depth of 170–185 m, 4.8 million tonnes of ore with an average of 41.7% Fe and 0.13% P. The poor breccia covers 11,150 m^2 and contains 6.5 million tonnes of ore with an average of 27.8% Fe and 0.31% P. Altogether there are 11.3 million tonnes of ore with an average of 33.7% Fe, 0.23% P and 0.03% S.

Host rock: Dark grey, often schistose trachyandesite. Lath-formed, sericite-altered and crushed phenocrysts of plagioclase and microperthite. The matrix is rich in biotite, and varying, usually small amounts of quartz, microcline, chlorite, epidote and sericite. Accessories are apatite, sphene, calcite, and fluorite, the latter two minerals in veins. Locally scapolite alteration is found. The trachyandesite contains varying amounts of magnetite as veins, amygdules and powdering. The amygdules, 1–20 mm long, contain in addition biotite, chlorite and calcite. In the ore veins amphibole, biotite, calcite and apatite are found. Locally the trachyandesite is intersected by up to some metres wide dikes of a grey-green, non-schistose metabasite, mostly parallel with the mineralization.

References: Lindroos and Mannström, 1971; Grip and Frietsch, 1973

Satisjaure

Site: 92 km WNW of Gällivare **Map sheet:** 28I/7e

Discovery: New discovery in 1965 by SGU by airborne magnetic measurement; in 1969, magnetic and gravimetric measurements; in 1970, geologic mapping.

Geophysical features: S of Lake Satisjaure there is a 1 km long and 200–300 m wide magnetic anomaly striking N30°E. Further to the S there are some scattered weak magnetic anomalies.

Mineralization: Within the magnetic anomaly, outcrops are found only in the northernmost part, along the shore of Lake Satisjaure (Satihaure, Satisjärvi). Here an up to 50–60 m wide magnetite breccia zone occurs in felsic volcanic rocks. The magnetite forms bodies and veins up to 30 m wide. Richer parts contain 39.6% Fe, 0.004% P and 0.01% S. The main part is poorer and contains 15–25% Fe. Magnetite also occurs as a fine-grained impregnation. In richer parts of the breccia the host rock is granite-altered.

In view of the mode of emplacement of the ore and the type of host rock, the deposit probably belongs to the Kiruna ore type, even though the phosphorus content is low.

Reserves: The surface covered by the magnetic anomaly exceeding 16,000 γ is about 50,000 m^2. Geophysical estimates indicate reserves of about 10 million tonnes of ore down to a depth of 100 m.

Host rock: Red, felsic volcanic rock which in a quartz–microcline matrix contains plagioclase phenocrysts. Near the mineralization the host rock is dense, aplite-like and contains vugs and veins of quartz. In addition there are fissure-fillings with chlorite, epidote, calcite and fluorite. Towards east the rock is banded and tuffitic. In the same area there are 2–10 m wide dikes of metabasite with cm-long scapolite laths (altered feldspar) in a matrix of scapolite, amphibole, subordinate chlorite, epidote, calcite, sphene, quartz and microcline.

Reference: Grip and Frietsch, 1973.

Tjårrojåkka

Site: 50 km WSW of Kiruna **Map sheet:** 29I/2–3i

Discovery: New discovery in 1963 by SGU by airborne magnetic measurements; in 1965–66, magnetic and gravimetric measurements; in 1965–69, electromagnetic and IP measurements; in 1967–70, diamond drilling (35 holes totalling 11119.61 m); in 1980–1981, mineral right claim.

Geological structures: The bedrock is built up of ignimbrites (welded tuffs), tuffs, tuffites, felsic to intermediate volcanic rocks, and intercalations of marble, all alternating and rapidly deposited. The rocks probably form a steep-standing structure. The ore occurs between felsic volcanic rocks with intercalations of intermediate to mafic volcanic rocks in the north, and mafic volcanic rocks in the south. Mafic dike rocks and pegmatites intersect the volcanic rocks and the ore. The metabasites are involved in the folding and occur in boudinage structures and are thus older than the folding.

South of the ore there is a granite–diorite which intrudes the volcanic rocks and the iron ore. A strong albitization is encountered, probably connected with the granite.

Later the area has been affected by strong tectonization associated with skarnification, brecciation and faulting of ore and volcanic rocks. Broad zones contain angular fragments of volcanic rocks, granite and iron ore. The matrix is composed of chlorite, tremolite, diopside and biotite. In connection with the tectonization, or probably of even younger age, is a regional metasomatic event that gave the volcanic rocks a strong reddish colour, caused by haematite pigmentation of albite and alteration of biotite to chlorite. In addition, epidote and sericite were formed. In connection with the latest tectonization, magnetite has been martitized.

Host rocks and ore are strongly faulted. In a regional context the Tjårrojåkka ore occurs in an E–W striking fault system.

Mineralization: Magnetite occurs as bodies and breccias in an irregularly distributed pattern. Only a minor part of the mineralization reaches the surface in the central part of the deposit along a length of 100 m. The rest of the mineralization, which has a total length of about 600 m, is covered by host rocks. It has been deformed by both faulting and folding. The upper parts of the mineralization are delineated by a NE–SW fault which dips 40°SE. The structure of the mineralization can be characterized as a NE–SW oriented, long and narrow inverted keel.

The rich ore occurs in the inner, more central parts and the breccia ore in the outer, more peripheral parts. The largest part of the breccia ore occurs SE of the rich ore. The breccia consists of magnetite veins in the host rock; in addition, magnetite is found as impregnation, vugs and amygdule fillings, the varieties showing all gradations. Both rich ore and breccia ore associated with skarn, mainly tremolite–actinolite, chlorite, diopside, and also epidote. In the rich ore there is mainly tremolite–actinolite as a fissure filling. Apatite appears as impregnation or as schlieren, often associated with calcite, locally also with tremolite and chlorite. Chalcopyrite and traces of pyrite occur irregularly, mostly as fissure fillings. In the ore breccia the host rock is often metasomatically altered to scapolite, sericite and red-coloured feldspar.

Reserves: By analytic definition the mineralization is divided into (1) rich ore with >52% Fe, and (2) breccia ore with 20–52% Fe. The outcropping surface of the mineralization is 3921 m^2 (2476 m^2 rich ore and 1445 m^2 breccia ore). About 300 m below exposure, the mineralization covers 50,000 m^2 (30,000 m^2 rich ore and 20,000 m^2 breccia ore). Frequency diagrams show that the rich ore contains >58% Fe. Down to a depth of 350 m there are 35.4 million tonnes of rich ore with an average of 62.2% Fe and 0.77% P; 17.3 million tonnes of breccia ore with an average of 30.9% Fe and 0.78% P; altogether 52.6 million tonnes with an average of 51.5% Fe and 0.77% P. Both types are similar in average P content. <0.1% P and >1.8% P contents are rare.

Associated with the iron ore is a copper mineralization which is too small and of too low grade to be of economic interest. On the whole the breccia ore has higher sulphur and copper contents (0.13–0.22% S and 0.05–0.9% Cu) than the rich ore (0.07% S and 0.03% Cu). There is an adjacent, separate copper mineralization (p. 00).

Host rock: Banded ignimbrites with fluidal textures contain quartz amygdules and quartz–feldspar phenocrysts. Tuffites form gradations to the ignimbrites with larger amounts of biotite and scapolite; they occur partly as interlayers. The mafic-intermediate volcanic rocks have an andesitic to dacitic composition. All rocks are more or less altered to secondary minerals, especially scapolite. Small amounts of ore mineral such as magnetite, haematite, molybdenite, pyrite and chalcopyrite, are associated, mainly in the tuffites. In all rock members, potassium (mostly >6% K_2O) dominates over sodium (mostly <3% Na_2O). Only the ignimbrite (with 8.6% Na_2O and 0.8% K_2O) and an albitite which consists of albite, quartz, amphibole, chlorite, and epidote, show sodium dominance.

References: Rönnbäck and Ros, 1971a; Ros and Rönnbäck, 1979; Grip and Frietsch, 1973; Quezada and Ros, 1975.

Vistas

Site: 50 km W of Kiruna **Map sheet:** 29I/7h

Discovery: In 1963 by SGU by airborne magnetic measurement; magnetic and gravimetric measurements in 1967; geological mapping in 1970.

Geophysical features: Two NW–SE striking, about 500 m long magnetic anomalies.

Mineralization: In the southern part of both anomalies, magnetite occurs mainly as an impregnation, but also as up to 10 cm thick layers and schlieren following the schistosity. The schlieren contain coarse-grained amphibole. The mineralization in the western anomaly consists of a lean magnetite impregnation in phyllite-like volcanic rocks. A chemical analysis of the eastern parallel showed 15.7% Fe, 0.02% S and 0.20% P.

Host rock: Weakly schistose, fine-grained felsic volcanic rocks which are in part strongly schistose and biotite-rich. Locally there are varieties with K-feldspar phenocrysts in a matrix of amphibole and biotite. The felsic volcanic rocks are surrounded by mafic volcanic rocks, perthite granites and perthite syenites with up to 5 mm large feldspar phenocrysts.

Reference: Detailed geological mapping in 1970, SGU.

Ylipääsnjaska

Site: 20 km SW of Svappavaara **Map sheet:** 29K/0b

Discovery: Found in 1898, diamond drilling was undertaken somewhat later. Magnetic and gravimetric measurements made by SGU in 1971.

Mineralization: Apatite-bearing magnetite mineralization.

Host rock: Grey, biotite-rich metatrachyte.

References: Petersson, 1900; Eriksson and Hallgren, 1975.

SUMMARY

Most of the investigated deposits fit into the general features for the Kiruna iron ore type, though certain specific features are present.

The Pattok deposit is the only high-P iron mineralization of the Kiruna type outside the Kiruna area and is in this respect similar to the high-P deposits east of Luossavaara at Kiruna, such as Rektorn and Henry. However, the ore breccia of the Pattok deposit distinguishes it from the other high-P Kiruna ores.

The Ekströmsberg deposit differs from other deposits of the Kiruna ore type by the absence of ore breccia, typical in other Kiruna iron ores with an intermediate P-content. The felsic volcanic rocks are locally strongly sericitized. The haematite–magnetite–quartzites, sericite–quartz alterations of the quartz-bearing porphyry, and the secondary veins with quartz, sericite, some zircon, orthite, tourmaline, and fluorite, indicate a metasomatic provenance. In this respect Ekströmsberg is more similar to the hydrothermal (Hauki) haematite ores at Kiruna.

Influence of metasomatic processes is also evident in some of the other deposits investigated. In the Ekströmsberg, Pattok, Renhagen and Tjårrojåkka mineralizations the host rocks are sericite-altered, which is locally strong as at Ekströmsberg. In these deposits there are secondary veins of quartz, sericite and some calcite, zircon, orthite, tourmaline and fluorite. In addition fluorite occurs in Satisjaure and Eustilljåkk.

Scapolite seems to be rather common in the host rocks, often associated with quartz, chlorite, calcite, and small amounts of microcline, baryte, fluorite and sphene, as in Pattok, Renhagen, Satisjaure and Tjårrojåkka. Scapolitization is strong at Tjårrojåkka where the ore and the host rocks are scapolite–sericite–feldspar-altered. To make a genetic distinction between sericitization and scapolitization in these deposits would require further mapping. That scapolite is formed at least partly by a late process is shown by the scapolitization of the metabasite dikes at Eustilljåkk postdating the ore.

SKARN IRON ORES OF THE GREENSTONE GROUP

GENERAL FEATURES

The mafic volcanic rocks of the Greenstone group which are 2.0–2.5 Ga old (Skiöld and Cliff, 1984; Skiöld, 1986) contain, in sedimentary intercalations at high stratigraphic levels, both skarn iron ores and quartz–banded iron ores. The host rocks are marbles, marls and cherts associated with tuffs–tuffites, phyllites, and graphite–bearing schists. Occasionally, as at Vieto, west of Kiruna, skarn iron ore occurs within mafic volcanic rocks proper. The skarn iron ores and quartz-banded iron ores are of volcano-sedimentary (exhalative) origin as shown by the strata-bound appearance and the banded character (Frietsch, 1973b, 1977, 1980). The skarn silicates are formed by regional metamorphism with internal reactions between the chemical precipitates of iron, calcium, magnesium and silica.

The skarn iron ores are composed of magnetite (often Mg-bearing; Frietsch, 1985b), Ca-Mg silicates (tremolite–actinolite, diopside and less commonly hornblende) and Mg–silicates (phlogopite-biotite, serpentine and less commonly olivine, chlorite, talc and chondrodite). The skarn silicates are either evenly distributed in the ore or form separate masses or layers. A rather common feature is an interlayering of magnetite and skarn minerals, and sometimes also of calcite. Typically, small amounts of pyrite and pyrrhotite are associated. Occasionally accessory amounts of chalcopyrite are found. The content of sulphur is mostly greater than 1%. The content of phosphorus (in apatite) is mainly less than 0.2%, but can in some deposits rise to several per cent.

It should be noted that as iron grades in the analyses given below are mostly not corrected for iron bound to silicates, the iron grade bound to magnetite is somewhat lower.

Altavaara area

Site: 15 km ENE of Kiruna **Map sheet:** 29K/6a

Discovery: Magnetic anomaly investigated in 1897 by trenching and diamond drilling. There are no outcrops in the area. Diamond drilling in the early 1900's (4 holes totalling 34.85 m) and in 1916–17 (5 holes totalling 503 m). In 1958 two magnetic anomalies were found by SGU by airborne measurement south and east of the larger, original anomaly. SGU made magnetic measurements in 1961, and gravimetric measurements in 1962. In 1964, diamond drilling (4 holes totalling 747 m, of which one hole was placed in the northern mineralization, two holes in the southern mineralization and one in the eastern mineralization).

Geological features: There are three separate mineralizations. The deposits Altavaara Norra and Altavaara Södra belong to a 2 km long, N–S striking zone, while Altavaara Östra lies in a separate zone about 1 km east of Altavaara Norra. The rock sequence and the mineralizations dip steeply towards the west.

Altavaara Norra

Mineralization: The 100 m wide and 500 m long ore-bearing area hosts magnetite mineralizations in mafic volcanic rocks. The magnetite-rich zones which are mainly <10 m wide contain feldspar, scapolite and amphibole, and also some apatite, pyrite, pyrrhotite and occasionally chalcopyrite. There are no distinct ore borders; the ore-bearing parts are delineated by chemical analyses. The mineralization contains 0.13–0.80% S and mostly 0.02–0.07% P; however, in the northeastern and middle parts there are sections rich in apatite (0.62% P and 0.45% P).

Reserves: Over an area of 7500 m^2 and to depth of 100 m there are 2.2 million tonnes of ore with 20–25% Fe, with an average of 22.5% Fe, 0.43% P and 0.22% S; over an area of 16,500 m^2 there are 4.9 million tonnes of ore with >25% Fe, with an average of 27.3% Fe, 0.35% P and 0.46% S; in total 24,000 m^2 with 7.1 million tonnes of ore, with an average of 25.8% Fe, 0.37% P and 0.38% S.

Host rock: Varying lithologies. Predominantly amphibolitic, mafic volcanic rock (andesite) with oligoclase, hornblende, biotite and scapolite, and small amounts of epidote, sphene, apatite and chlorite. Contains occasional porphyroblasts of feldspar and amphibole. Interlayered are biotite schists, scapolite–biotite schists, and scapolite schists. Within the ore zone, the metamorphic alteration increases, forming gneisses partly rich in hornblende. In addition there are fine-grained, amphibole-bearing schists which probably are dike rocks. Aplites of granitic composition occur as dikes and form hybrids with the other rocks. All rocks except the aplite are scapolite-altered.

Altavaara Södra

Mineralization: Ca. 1 km long and up to 50 m wide magnetite-bearing zone. Magnetite occurs as schlieren and lumps, sometimes brecciating the host rock. Paragenesis as in Altavaara Norra, but poor in sulphides. Quartz veins with tourmaline and microcline are locally rather common.

Reserves: 0.1 million tonnes of ore with 20% Fe, <0.1% P and <0.1% S.

Host rock: Amphibole gneisses and plagioclase–microcline–quartz–biotite–muscovite schists passing into microcline–quartz–muscovite schists. Tourmaline is common. The ore zone and host rock contain scapolite–biotite-rich rocks.

Altavaara Östra

Mineralization: Up to 30 m wide mineralizations with magnetite as veins (<0.5 m wide), lumps and impregnations associated with quartz, garnet and amphibole in garnet gneisses.

Reserves: 0.1 million tonnes of ore with 25% Fe, <1% P and <0.1% S.

Host rock: Garnet gneisses rich in microcline, quartz, muscovite and biotite. Garnet mainly at the border of the magnetite–quartz veins. Passes outwards into red-grey gneiss.

References: Eriksson and Espersen, 1965; Grip and Frietsch, 1973.

Erkheikki (Juhonpieti)

Site: 10 km W of Pajala. **Map sheet:** 28M/5d

Discovery: In the early 1920's, discovered by the Nordsvenska Malmfält company. Mine claim Juhonpieti in 1922. In 1965–66, magnetic and gravimetric measurements by SGU; electric measurements in 1971; in 1969–70, diamond drilling (6 holes totalling 1171.04 m).

Geological features: The rocks within the area show a complex pattern due to strong faulting and mafic intrusions.

Mineralization: NW–SE striking magnetite mineralization with around 35% Fe in a 600–700 m long and up to 30 m wide zone, dipping SE. 350 m to the S there is another parallel ore zone, ca. 150 m long, locally rich in iron with up to 50% Fe. Magnetite is associated with serpentine, phlogopite, chlorite, and some pyrite and pyrrhotite. Small skarn zones outside the mineralization consist of tremolite and diopside. In one drill hole outside the main mineralization, is a narrow ore horizon rich in olivine.

Adjacent to the skarn iron ore, there is a magnetite–grunerite–hornblende-banded quartzite.

Reserves: Down to 150 m below the surface, 3.4 million tonnes ore with 32.5% Fe, 2.1% S, 0.076% P and 0.07% Cu.

Host rocks: A southern continuation of the rocks in the Kaunisvaara ore belt with mafic volcanic rocks, phyllites, graphite-bearing schists and quartzites. Stratigraphically below the mineralization, there are metagabbroic, mafic lavas. Above the mineralization there are stratified phyllites, graphite-bearing phyllites and quartzites.

References: Rönnbäck and Ros, 1971b; Grip and Frietsch, 1973.

Eustillako

Site: 37 km W of Kiruna **Map sheet:** 29I/7j–8j

Discovery: In 1965, by magnetic and gravimetric measurements made by SGU.

Geophysical features: A magnetic N–S winding anomaly, about 3 km long and 200 m wide, partly above 4000 γ and small areas with 8000 γ.

Mineralization: No outcrops, but possibly bound to magnetite-rich layers.

Host rock: Mafic volcanic rocks; according to Offerberg (1967), andesitic to basaltic greenstones. Uncertain provenance.

Reference: Offerberg, 1967.

Kaddevare

Site: 25 km S of Gällivare **Map sheet:** 27K/6c

Discovery: New discovery. In 1971, magnetic and gravimetric measurements; in 1972, diamond drilling (one hole, 189.61 m).

Mineralization: 26 m ore with 42.3% Fe, 0.19% P and 1.39% S. In addition there are low-grade copper sections (<0.2% Cu). Provenance uncertain. Probably related to the skarn iron ores.

Kallojärvi

Site: 20 km NNE of Lannavaara **Map sheet:** 30L/7d

Discovery: New discovery by airborne magnetic measurements in 1960 by SGU; in 1968-69, magnetic and gravimetric measurements.

Geophysical features: According to Ambros (1980) the magnetic anomalies N and SV of Sautusjärvi and under Lake Kallojärvi are too weak to be of interest for further investigations.

Geological features: In an outcrop N of Sautusjärvi there is a 0.5 m wide skarn-bearing magnetite mineralization hosted by banded, mafic sedimentary rocks and amphibolites.

Mineralization: Parallel with the magnetite layers are layers of quartz and calcite. Perpendicular to the layering there is a green silicate. The mineralization contains ca. 35% Fe, 0.08% P and 0.005% S.

Reference: Ambros, 1980.

Kaunisvaara area

Site: NNW–N of Pajala **Map sheet:** 28M/8-9e–29M/0e

Common features: The Kaunisvaara iron mineralizations occur NNW–N of Pajala village in a 20 km long, NNE-striking belt. Most part of the mineralizations lie on map sheet 28 M Pajala, and on the northern end of map sheet 29M Huuki. From north to south the deposits Palotieva, Tapuli (Tapulivuoma), Ruutijärvi, Stora Sahavaara, Södra Sahavaara, Östra Sahavaara, Suksivuoma and Karhujärvi occur. Of these, Suksivuoma and Karhujärvi belong to the Johnson AB company, Ruutijärvi (in part) to the Boliden AB company, the other to the Crown.

Discovery: The Kaunisvaara ores Stora Sahavaara, Tapuli and Palotieva were discovered magnetically in 1918 and later investigated by diamond drilling and trenching by the AB Nordsvenska Malmfält company. At the end of the 1940's part of the Ruutivaara deposit was found by Boliden AB company by airborne magnetic measurement. The Karhujärvi and Suksivuoma mineralizations were discovered in 1958 by Rederi AB Nordstjernan with airborne magnetic measurements. Karhujärvi was drilled by 5 holes and mineral rights were given in 1962. Suksivuoma was drilled with two holes and mining rights were provided in 1963.

The investigations during the IOIP made by SGU of the publicly owned mining rights started in 1960 and continued until 1969. Certain works at Stora Sahavaara were financed by LKAB. The Stora Sahavaara mineralization was measured in 1960 by magnetometer and gravimeter. In 1961-64, diamond drilling (39 holes totalling 8695 m). In 1960, LKAB deepened an older shaft at Stora Sahavaara (*Tanners sänke*) for milling tests which were made in 1960–62. The rest of the publicly owned deposits (Södra Sahavaara, Tapuli, Palotieva, and Ruutijärvi blind ore) were measured in 1963–65 by magnetometer and gravimeter. Södra Sahavaara was diamond drilled in 1964-65 (13 holes totalling 2627 m). At Tapuli, diamond drilling was carried out in 1965–69 (26 holes totalling 6101 m). Palotieva was diamond drilled in 1969 with one hole of 208 m. The Ruutijärvi blind ore was drilled in 1969 with one hole of 426 m. Since 1960, within the mining rights owned by the Crown and Kaunisvaara *statsgruvefält*, 82 holes have been drilled, totalling 18,998 m. In 1969 a hole was drilled in a gravimetric anomaly S of Karhujärvi. Only narrow horizons of iron ore were found.

Geological structures: The Kaunisvaara iron mineralizations have a common geological appearance and are of similar type. The ores lie in the upper part of the rocks of the Greenstone Group at somewhat different stratigraphic levels in a sedimentary sequence. The rocks are concordant, striking NNE with a moderate dip to the NW.

The lowest unit of the Greenstone Group comprises layered tuffs and tuffites rich in agglomerates. The rocks consist of amphibole, quartz, plagioclase, chlorite and magnetite. The latter sometimes occurs in more significant amounts. Scapolite is also present (Lindroos, 1974). The agglomerates are 2–10 m thick and contain <3 cm long fragments.

The tuffs–tuffites are overlain by an up to 800 m thick unit of phyllite. The upper part consists of a 200 m thick graphite–phyllite which contains 6–8% C and small amounts of pyrite and pyrrhotite. The phyllite and graphite–phyllite pass gradually into each other. Interlayered in the graphite–phyllite are 1–25 m thick layers of a scapolite-rich marl, which is locally banded and consists of quartz, scapolite, diopside, tremolite, and small amounts biotite, muscovite, sphene, pyrite and pyrrhotite.

The overlying ore-bearing formation is between 90 and 330 m thick and consists of dolomite marble, skarn and magnetite. The marble is the lowest unit, overlain by skarn and ore. The marble is up to 110 m thick (at Tapuli) and the skarn up to 150 m thick. The marble–skarn unit is mainly not present at Stora Sahavaara. A thinner (< 30 m) marble horizon is present in the phyllite at Östra Sahavaara. The marble contains small amounts of calcite, skarn, iron sulphides and magnetite. The contact between marble and massive skarn is gradational.

The ore-bearing formation is overlain by quartzites and quartzitic phyllites, which toward the west are gneissose and granitized. The quartzite consists of quartz, subordinate biotite, feldspar, muscovite, zoisite and some magnetite. The phyllite consists of quartz, feldspar, amphibole, chlorite and scapolite. To the west, there are biotite gneisses.

The iron mineralizations are associated with dolomite–calcite marble and appear at three different stratigraphic horizons. The Stora Sahavaara ore lies at the contact between a quartzite to the west and a graphite–phyllite to the east. To the south the continuation consists of a skarn zone. Södra Sahavaara lies in a phyllite 150 m east of this contact. Some tens of metres to the east there is a smaller ore lens, the 'Parallel ore'.

All rocks are cut by mafic dikes up to 15 m thick, striking in NW–NNW directions. A granitization partly overprints the dikes.

Mineralization: The iron mineralization occurs in the upper part of the marble and is often overlain by skarn. The ore mineral is magnetite, which contains small amounts of magnesium (cf. Frietsch, 1985b; in Stora Sahavaara, 2.6% MgO = 1.5% Mg^{2+}). Small amounts of pyrrhotite and pyrite are associated. A high pyrite content equals a lower S content, and greater grain size of magnetite. This is probably due to metamorphic recrystallization. In Stora Sahavaara, pyrrhotite changes mainly to pyrite. The Östra Sahavaara and Tapuli mineralizations are sulphide-poor (around 0.2% S). The Södra Sahavaara mineralization contains 0.8% S and the other deposits contain higher grades (2.2–2.5% S). The copper content is low (<0.1% Cu), likewise the content of phosphorus (<0.1% P).

The skarn occurs disseminated in the ore or as layers–masses adjacent to the ore. The ore is often skarn-banded. Diopside–tremolite occur as separate masses, whereas in the ore, serpentine and subordinate phlogopite are common. There is a tendency for tremolite to have been formed from diopside. In Stora Sahavaara the composition of diopside is $Ca(MgO_{0.90\text{-}0.92}FeO_{0.08\text{-}0.10})Si_2O_6$ and of tremolite, $Ca_2(MgO_{0.96}\ FeO_{0.04})_5Si_8\ O_{22}(OH)_2$. In Tapuli, both minerals occur, interlayered, and a banded skarn is typical. Olivine is found as remnants in serpentine, indicating that serpentine has been formed from olivine. Phlogopite occurs abundantly toward the foot wall. Mg serpentine and phlogopite (5.57 Mg^{2+} and 0.25 $Fe^{2+)}$ occur in Stora Sahavaara. Antigorite ($H_4Mg_3Si_2O_9$) is present in Tapuli. In Stora Sahavaara the ore contains graphite (0.6–0.8% C), mostly as a fine powdering in serpentine and associated with iron sulphides.

Reserves: The mineralizations of the Kaunisvaara contain altogether about 180 million tonnes of iron ore.

References: Lundberg and Werner, 1965; Lundberg, 1967; Lindros 1971; Grip and Frietsch, 1973.

Palotieva

Site: 23 km NNW of Pajala **Map sheet:** 29M/0e

Discovery: In 1963–65, magnetic and gravimetric measurements by SGU; in 1969, diamond drilling (one hole, 208 m).

Structural features: The ore is cut by a NW–SE fault.

Mineralization: An approx. 300 m long and 60 m wide zone striking ENE and dipping 65°NW which contains magnetite with some pyrite, pyrrhotite and chalcopyrite.

Reserves: On a surface covering 12,000 m^2 and to a depth of 200 m, the deposit contains 8.1 million tonnes of ore, with 27.4% Fe, 0.06% P and 2.5% S. The mineralization contains a one metre section with 5.3% Cu.

Host rock: Skarn and mafic tuffite.

Reference: Lindroos et al., 1972b; Padget, 1977.

Ruutijärvi blind ore

Site: 20 km NNW of Pajala **Map sheet:** 28M/2e

Discovery: New discovery by SGU by airborne magnetic measurement in 1968. Indicated as a deep-seated ore south of the ore discovered in 1949 by Boliden AB. In 1963–65 magnetic and gravimetric measurements; in 1969–71, diamond drilling (3 holes totalling 1125.1 m). Mining right Kokkovuoma was accepted in 1972.

Geophysical features: Occurs between the Stora Sahavaara and Tapuli deposits, as a blind ore-body, not outcropping. 300 m to the north is the outcropping ore Northern Ruutijärvi, discovered by Boliden AB.

Structural features: The ore is cut at a depth of 190 m below ground level by a N–S fault, dipping gently towards the east. The tectonic conditions are complicated; the 100 m thick ore pinches out over a short distance.

Mineralization: Skarn-banded magnetite in a 100 m wide and 200 m long lens delineated on both sides by faults. Strikes N–S and dips 40-45°W. A relatively gently dipping fault cuts the top of the ore at a depth of ca. 190 m below ground level. Important dislocations have occurred along this fault and the adjacent rocks are fractured.

There are two types of skarn. Serpentine, occasionally rich in mica, occurs in the ore proper. Usually there is a banding between serpentine and magnetite. The other skarn type with tremolite–diopside occurs mainly outside the ore, but also in the latter, in the dolomite marble and in the phyllite of the hanging wall.

Reserves: The occurrence covers 20,000 m^2 and contains, to a depth of 190–320 m 8.3 million tonnes of ore with an average of 40.9% Fe, 0.08% P, 2.2% S, 0.01–0.10% Cu and 0.5–2.0% CO_2. The sulphur content decreases towards the fault.

Host rock: The rock sequence is the same as at Tapuli. Counting from the foot wall, there are banded graphite–phyllite with scapolite–amphibole–fels (marl); skarn-ore-bearing graphite–phyllite and skarn-bearing marble; 100 m ore with skarn-banding; 50 m marble with skarn horizons; phyllitic–quartzitic sedimentary rocks. The rock sequence is intersected by 0.2–2.5 m wide, steep dikes of a scapolitized metabasite.

References: Lindroos and Johansson, 1972; Grip and Frietsch, 1973.

Sahavaara Stora

Site: 16 km NNW of Pajala **Map sheet:** 28M/8e

Discovery: In 1961–64, diamond drilling (39 holes totalling 8,695 m).

Geophysical features: Weak folding of small amplitude gives variation in the dip 50–70°. In the northern part the dolomite marble is dislocated 120 m to the east by a NW–SE fault.

Mineralization: Stora Sahavaara, which is the largest skarn iron ore in northern Sweden, has a length of about 1300 m and a width varying between 10 and 90 m, on average 40 m. Skarn and marble are quite subordinate, compared with ore. The skarn occurs as separate masses, disseminated in the ore, or as a layering together with magnetite. Two types of skarn are present: 1) diopside–tremolite, and 2) serpentine–phlogopite, partly with remnants of olivine. The magnetite is magnesium-bearing with about 1.5% Mg. The ore contains 0.6–0.8% graphite as a fine dusting in serpentine, often connected with sulphide-bearing parts. The ore contains, on average, 2.5% S, bound to pyrite and pyrrhotite. The content of pyrite increases toward the northern end of the ore belt. Chalcopyrite is an accessory component.

Reserves: Covering an area of 53,820 m^2 and down to 435 m, the reserves are 82 million tonnes of ore, with an average of 41% Fe, 0.07% P, 2.5% S, and 0.08% Cu.

Host rock: The mineralization is underlain by graphite-bearing schist and marl, and overlain by quartzite.

References: Lundberg and Werner, 1965; Lundberg, 1967; Grip and Frietsch, 1973; Lindroos 1974.

Sahavaara Södra

Site: 18 km NNW of Pajala **Map sheet:** 28M/8e

Discovery: Found in 1918. In 1918-20, magnetic measurements and diamond drilling (4 holes); in 1963–65, magnetic and gravimetric measurements made by SGU; in 1964–65, diamond drilling (13 holes totalling 2627 m).

Mineralization: Skarn–magnetite mineralization with a high content of iron sulphides. Strikes NE–SW and dips 50–65°W. The skarn is of two types: serpentine–phlogopite in more massive ore, and diopside–tremolite with minor amounts of magnetite. The deposit is similar to the Sahavaara Stora mineralization. At the northern end, pyrrhotite dominates and at the southern end, pyrite. East of the northern end of the main mineralization there is a minor mineralization which passes into a dolomite.

Reserves: The main mineralization is 1000 m long and 10–20 m wide, covering a surface of 18,100 m^2. The minor parallel is 300 m long and 2–6 m wide, covering 1600 m^2. Covering a surface of 19,700 m^2 and to a depth of 260 m, the deposit contains 19.6 million tonnes (of which 1.6 million tonnes in the parallel lens) of ore with 32.1% Fe, 0.04% P, 0.8% S and 0.05% Cu.

Host rock: Phyllite which occurs between greenstones in the east and quartzites in the west. The phyllite is rich in bands of biotite and quartz. Scapolite is common as cm-long porphyryblasts. The underlying unit, ca. 40–100 m thick, consists of scapolite-bearing graphite–phyllite and skarn–scapolite rock with scapolite, tremolite and diopside.

East of Södra Sahavaara there is a magnetic anomaly. One drillhole showed a fine-grained to coarse, massive greenstone.

References: Lundberg and Werner, 1965; Grip and Frietsch, 1973.

Sahavaara Östra

Site: 16 km NNW of Pajala **Map sheet:** 28M/6e

Discovery: In l964, magnetic and gravimetric measurements and diamond drilling (one hole 268 m) by SGU.

Mineralization: Magnetite with pyrite and pyrrhotite in skarn with serpentine, phlogopite, diopside and tremolite–actinolite.

Reserves: Covering a surface of 5000 m^2 and down a depth of 100 m, the deposit contains 2 million tonnes with an average of 40.5% Fe, 0.014% P, 0.2% S and 0.03% Cu.

Host rock: Marble and phyllite.

References: Lundberg and Werner, 1965; Grip and Frietsch, 1973.

Tapuli (Tapulivuoma)

Site: 22 km NNW of Pajala **Map sheet:** 29M/0e

Discovery: In 1963–65 by SGU by magnetic and gravimetric measurements; in 1965–69, diamond drilling (25 holes totalling 6074 m).

Structural features: The ore lens is cut by a fault. The ore increases in thickness in its central part. There is a concentration in a fold-like structure with the axis dipping 60°NW.

Mineralization: Magnetite with pyrite and pyrrhotite in a skarn of scapolite, serpentine, talc, chrysotile and phlogopite. Banded, massive ore with a 'breccia' containing fragments and lumps of the host rock in an ore-rich matrix. There are gradational contacts between breccia and banded ore.

Reserves: The mineralization has a length of ca. 2500 m and a width in the middle of the deposit of 180 m, in the north 10–20 m and in the south 70 m. Covering a surface of 110,000 m^2 and down to 300 m, the deposit contains 60.3 million tonnes of ore with an average of 29.3% Fe, 0.07% P, 0.18% S and <0.01% Cu. If only richer ore is considered, there are 17 million tonnes with an average of 39.6% Fe.

Host rock: Skarn and dolomite marble.

References: Lindroos et al., 1972b; Grip and Frietsch, 1973; Padget, 1977.

Käryjärvi

Site: 9 km N of Pajala **Map sheet:** 28M/7f

Discovery: New discovery by SGU by airborne measurement in 1960; magnetic and gravimetric measurements in 1967; in 1971, diamond drilling (one hole, 168.10 m).

Geophysical features: 1 km long, NE-striking magnetic anomaly which, from the air, gives 96,000 γ.

Mineralization: Poor magnetite and haematite mineralization in greenstone in breccias and veins with epidote, calcite, quartz, pyrite and pyrrhotite. Contains about 10% Fe and 0.05–0.08% P.

Host rock: Mafic porphyritic volcanic rocks and pelitic schists. The volcanic rocks, which consist of amphibole, plagioclase and scapolite, are partly strongly fractured and metasomatically altered.

Reference: Padget and Lindroos, 1971.

Laukujärvi

Site: 30 km WSW of Kiruna **Map sheet:** 29J/6b

Discovery: Found in 1898. Around the turn of century investigations by trenching; in 1951–53 and in 1963, measured magnetically by SGU, in 1963 gravimetrically; in 1968–69, diamond drilling (5 holes totalling 1057.10 m).

Geophysical features: Aeromagnetic anomaly, ca. 800 m long and 200 m wide, striking NNW–SSE and dipping steeply to the west.

Geological structure: The ore zone strikes NW–SE, dipping steeply to the SW.

Mineralization: Six separate magnetite mineralizations up to 20 m wide in a 900 m long and up to 200 m wide zone, occurring in a banded, small-folded marble associated with an up to 35 m thick diopside skarn. The northern mineralizations occur in an andesitic to basaltic greenstone. In the SE part the magnetite is martitized. The sulphur content is 1–4% S, locally in the NW part <0.01% S. The phosphorus content is <0.01% P.

Reserves: In three ore lenses, covering together 10,000 m^2 and down to 100 m below the surface, there are 3.7 million tonnes of ore with 33.46% Fe.

Host rock: Andesitic to basaltic greenstone, somewhat scapolitized, with intercalations of tuffites and marble. Towards the SW, a porphyrite, towards the NE, felsic volcanic rocks.

Reference: Damberg et al., 1974a.

Leppäjoki

Site: 10 km WSW of Junosuando **Map sheet:** 28L/8f

Discovery: New discovery by SGU by airborne magnetic measurements in 1962. Magnetic and gravimetric measurements in 1964–65 and in 1968; in 1971, diamond drilling (one hole, 221.14 m).

Geophysical features: A 250 m long and 50 m wide magnetic anomaly extended E–W. Some hundreds of metres to the SE there is another anomaly, extended NNW with a length of 300 m. Both anomalies are caused by remnants of rocks of the Greenstone Group lying in granite (cf. Padget 1970).

Geological features: Along the NE border there is a fault. Immediately N of the NW ore-body, the hanging wall is a biotite-rich tuffite with layers or schlieren of skarn with some magnetite or haematite. The lower part of tuffite is homogeneous, with no stratification.

Mineralization: Two parallel, about 250 m long layers of skarn iron ore, dipping steeply to the north. The southern one is ca. 35 m wide and the northern one, ca. 5–8 m wide. Magnetite occurs as fine-grained impregnation in skarn, often as a banding. The skarn consists of amphibole, chlorite, quartz and calcite and in some parts also mica. Pyrrhotite and pyrite occur as impregnation and vein filling in the ore. The northern body contains 40.8% Fe, 0.03% P and 0.8% S; the southern ore body, 32.8% Fe, 0.04% P and 0.9% S. The copper content is 0.04% Cu.

Reserves: Covering a surface of 6650 m^2 and down to a depth of 250 m, the occurrence contains c. 6 million tonnes, with 32.0% Fe.

Host rock: Stratified tuffite with cm-thick layers of skarn, magnetite and haematite which are remnants of the Greenstone Group surrounded and intersected by a microcline granite. Ore and granite are cut by narrow metabasite dikes.

Reference: Lindroos, 1971, 1979.

Masugnsbyn area

Site: 90 km ESE of Kiruna **Map sheet:** 28L/9d–29L/0d

Discovery: In 1644. Mined until beginning of 19th century. In 1915–16, AB Nordsvenska Malmfält discovered the northern part. Diamond drilling (17 holes) was carried out around the 1920's. In 1929, geological investigations by SGU; in 1965, SGU made magnetic and gravimetric measurements; in 1967–70, diamond drilling (33 holes totalling 5488.25 m).

Geological structures: The Masugnsbyn iron mineralizations occur in an about 8 km long belt striking mainly N–S, though towards the north it turns west. The belt comprises, from S towards N, the deposits Junosuando, Vähävaara, Välivaara, Vuoma, Isovaara and Nya Isovaara. Of these only the first two are of any importance. Only Junosuando and Nya Isovaara are typical skarn iron ores. The rest of the mineralizations are treated under the section with quartz-banded iron ores (cf. p. 00, Masugnsbyn area).

The deposits lie in a synform which is partly surrounded and intruded by younger granites (perthite granite and Lina granite). The mineralizations form a horizon between the (Veikkavaara) Greenstone Group and younger metasedimentary rocks of the Pahakurkkio Group. The dip in the sequence is moderately toward the west. In the northern end the dip is toward the south. In the southern and middle parts of the belt (Junosuando and Vähävaara) the ore is associated with skarn; from Välivaara and northwards due to recrystallization the ore also lies in skarn, but partly also within banded metasedimentary rocks. Faults younger than the granites strike mainly NW and NNW, and are found at the northern part of Välivaara and Isovaara, and also at the southern part of Junosuando.

Mineralization: Magnetite associated with skarn. The skarn is made up of four different types: 1) tremolite–actinolite–diopside–(augite), 2) biotite–(phlogopite), 3) serpentine, and 4) carbonate. There are no sharp borders between the varieties, and they are often interlayered. The tremolite skarn is most common and contains pyrrhotite, pyrite and magnetite as accessories. The mica-rich skarn is closely associated with the ore. The mica consists mainly of phlogopite, more rarely of biotite. Associated are muscovite, chlorite and serpentine. The serpentine skarn is the latest formed of the different types, occurring as fissure filling in pyroxene or chondrodite, or as masses in the richer part of the ore. The ore cuts serpentine veins. Chondrodite is mostly associated with magnetite and often with carbonate (calcite–dolomite). The carbonate-rich skarn is found in the southern part of the ore belt; calcite is associated with tremolite, diopside, phlogopite and some serpentine. The ore occasionally contains calcite and fluorite. The sulphides are late; in particular pyrrhotite forms veins in the ore. Pyrite is probably older than pyrrhotite. Small amounts of chalcopyrite occur, mainly associated with pyrrhotite.

Reserves: Important ores are found in the Junosuando field, and to a lesser extent in the Vähävaara field. Magnetite is irregularly distributed in the skarn. To connect ore-bearing parts in drill-profiles is often difficult, even in adjacent holes. Magnetite–skarn-banded ore is common, conform with the strike. Rich ore is commonly veined by serpentine and contains different skarn minerals. The iron content is on average 30% Fe, more rarely up to 40% Fe. Even higher contents (up to 50% Fe) are found locally, as in the foot wall against the perthite granite, probably due to secondary concentration–mobilization of magnetite.

Host rock: Most of the mineralizations lie in the metasedimentary rocks of the Pahakurkkio group. Towards the east there are, especially at the northern end, mafic lavas of the Greenstone Group, which, however, are replaced by granite. The metasedimentary rocks of the Pahakurkkio Group are mainly fine-grained, schistose quartz–biotite–feldspar rocks. The ore horizon is separated from the Pahakurkkio sedimentary rocks by a 5–80 m thick layer of greenschist and fine-grained, recrystallized and scapolite-altered greenstone. Close to the ore the greenstone is skarn-altered with augite and tremolite.

In the southern part of the belt there is a dolomite marble with 30% CaO and 20% MgO, containing layers of quartz, magnetite, tremolite, pyrrhotite, pyrite and graphite. South of the ore belt are two narrow horizons of graphite schists which contain up to 18% C and rich in pyrrhotite, pyrite and small amounts of chalcopyrite. One horizon is found east of the northern end the Junosuando ore, and the other west of the Vähävaara ore. A large part of the latter graphite–schists contains more than 20% S. Mafic rocks, mainly dolerites, are common in the northern part of the ore belt.

References: Witschard, 1972; Grip and Frietsch, 1973.

Junosuando (Masugnsbyn)

Site: 90 km ESE of Kiruna **Map sheet:** 28L/9d

Discovery: See above. Diamond drilling (28 holes totalling 4926.97 m).

Geological features: In the southern part there is a thick dolomite marble forming the hanging wall. The skarn-ore zone is probably limited towards the south by a fault. In the southern part mylonites occur. The skarn is limited towards west by a 5–80 m thick greenschist. In the northern part narrow layers of quartzite replace the greenschist, i.e. between the skarn-ore zone and the feldspar-rich schists. Further towards west the sedimentary rocks of the Pahakurkkio Group occur. The skarn is partly carbonate-bearing, containing layers of actinolite–tremolite–augite and biotite–(phlogopite). Serpentine is less common. The foot wall is a perthite granite; closest to the ore there is an albite granite. The hanging wall consists of graphite-bearing schists.

Mineralization: The Junosuando deposit is 3 km long and has a maximum width of 100 m. In the middle part the ore is narrow. The strike is N–S, the dip vertical or steeply westward.

A large part of the ore horizon is built up of a skarn composed of three different mineral assemblages which gradually pass into each other: 1) tremolite–actinolite–diopside, 2) biotite–(phlogopite), and 3) serpentine. Marble is partly preserved. The first skarn type is most common and contains pyrite, pyrrhotite and magnetite as accessories. The biotite–(phlogopite) skarn is directly associated with the ore. The serpentine skarn consists of serpentine and chlorite which in part is altered to sericite. The richer part of the ore is often associated with serpentine skarn. The ore contains diopside, tremolite–actinolite, some serpentine, chondrodite, and partly calcite and fluorite. Pyrite, pyrrhotite and accessory amounts of chalcopyrite belong to the association. The sulphur content of the Junosuando ore varies between 1 and 3% S.

Reserves: On an outcropping surface of 137,500 m^2 and down to 150 m below the surface the deposit contains 59.8 million tonnes of ore with an average of 30% Fe, 1.9% S, 0.024% P, 1.3% F and 0.08% Cu.

References: Witschard, 1972; Grip and Frietsch 1973.

Pellivuoma

Site: 24 km WNW of Pajala **Map sheet:** 28M/7b–8b

Discovery: Discovered in 1919 by Nordsvenska Malmfält company. Two concessions were provided in 1921, and became *Statsgruvefält* in 1929. In 1963–66, SGU made magnetic and gravimetric measurements; in 1969–71, diamond drilling (13 holes totalling 2493.59 m). Mining rights Pellivuoma was provided in 1974.

Geophysical features: A magnetically disturbed area ca. 900 m long and ca. 400 m wide, extending WNW–ESE. Three stronger anomalies, two in the southern part striking NNW, and one in the eastern part striking NW. Sharp borders towards N, NW and NE with low magnetic areas, slowly decreasing towards the S.

Mineralization: Steeply towards SW dipping ore zones with magnetite, marble and skarn which vary in width and composition. In the skarn and the ore zones, fine-grained, quartzitic rocks are found. The ore zones contain magnetite, tremolite–actinolite, diopside and serpentine, the latter with remnants of olivine. Near the host rock granite, garnet, chlorite and phlogopite are encountered, rarely also chondrodite. The magnetite contains small lamellae of ilmenite. The content of magnesium in magnetite varies between 0.1 and 0.2% Mg , but occasionally reaches 1.8% Mg, especially in those parts where serpentine is encountered. Associated are pyrrhotite, pyrite and small amounts of chalcopyrite. The ore contains on average 0.58% S. In two ore bodies outside the main ore zone, the S content is higher. The copper content is <0.1% Cu.

Reserves: The outcropping area is geophysically calculated to 84,000 m^2. Down to a depth of c. 200 m the deposit contains 43.5 million tonnes of ore with 32.7% Fe, 0.04% P and 0.58% S.

Host rock: In the eastern part there is a thick dolomite marble (20.2–28.2% CaO and 12.5–20.1% MgO) which is rich in tremolite, serpentine, phlogopite and partly iron sulphides. Further eastward there is a narrrow 3 m wide graphite phyllite. Here metabasite dikes occur. Toward N and NE there is a coarse granite. The contact dips 50–60°S and is mica- and chlorite-altered. The granite contains epidote and garnet.

References: Rönnbäck and Ros, 1971b; Grip and Frietsch, 1973; Rova, 1974; Ros et al., 1980.

Rensjön area

Toppi–Njuotjama–(Njuotjamavaara)–Rensjön

Site: 27 km NW of Kiruna **Map sheet:** 30J/0d–1d

Discovery: Toppi, and probably also adjacent deposits, were discovered in 1899. Njuotjama was discovered in 1903. In 1968, SGU made magnetic and gravimetric measurements. In 1970–71, Toppi was diamond drilled (4 holes totalling 550.70 m).

Geological structures: The deposits lie in a N–S striking belt in the rocks of the Greenstone Group. Toppi and Njuotjama lie in the same NNE-striking, about 5 km long belt which at its southern end is openly folded. The belt contains several from each other separated magnetic anomalies. The belt is probably split by faults in different directions. The deposits Njuotjama and Rensjön consist of NNE-striking ore bodies. The magnetic anomalies are narrow and short. There are no geological data, but these deposits are probably of the same type as Toppi. Rensjön is a small anomaly separated from this belt.

About 1.5 km SW of Toppi there is a gravimetric anomaly in combination with weak magnetic anomalies. A bore hole in 1971 showed a concentration of diopside–serpentine-skarn in biotite- and scapolite-altered greenstone and gabbrodiabase.

Mineralization: Toppi forms a NNE-extended, 600 m long and 30 m wide ore lens, dipping 70°E. The ore is composed of a calcareous magnetite mineralization with skarn of phlogopite, serpentine, chlorite, either as banding or as patches. In the ore there are, locally, narrow intercalations of calcareous sedimentary rocks, totally skarn-altered with diopside, chlorite, phlogopite and calcite. Locally some graphite and apatite is found. Small amounts of pyrite, locally also pyrrhotite and traces of chalcopyrite, are common. In the northern part of the ore near the foot wall there is a chemically precipitated quartzite.

Reserves: On an outcropping area covering approximately 10,000 m^2 and down to 200 m there are 7.8 million tonnes ore with an average of 40.8% Fe, 0.04% P and 1.91% S.

Host rock: The hanging wall toward the east consists of mafic albite–tremolite–biotite-bearing volcanic rocks forming gabbrodiabases with intercalations of greenstone. The gabbrodiabase is cut locally by narrow syenite veins. The foot wall toward the west consists of marble and phyllite, rich in mica and calcite, also talc and serpentine. The sedimentary rocks are intersected by crush zones. Further toward the west there are mafic volcanic rocks.

Reference: Frietsch, 1979a.

Salmivaara

Site: 33 km NNE of Gällivare **Map sheet:** 28K/8c

Discovery: Found in 1897. In 1904, diamond drilling; magnetic and electrical measurements by SGU in 1940 and in 1967–71 magnetic and gravimetric measurements. *Statsgruvefält* in 1910. In 1940–41 diamond drilling (8 holes), in 1970–71 (3 holes and one older hole made deeper). Altogether 1818.3 m have been drilled.

Geological features: Steeply dipping ore disks and lenses which with associated skarn, marble, mica schist and biotite–gneiss form a steep arc-formed structure open toward the north. The sequence is surrounded by granite.

Mineralization: Skarn-banded magnetite with pyrite, pyrrhotite and some chalcopyrite. The mineralization is rich in skarn, either as masses or intermingled with magnetite. There are minor marble lenses within the skarn zone. Two types of skarn are encountered: 1) diopside–amphibole skarn, which dominates, and 2) olivine–serpentine skarn. The amphibole contains remnants of diopside. Associated are mica (biotite–muscovite–phlogopite), epidote, chlorite, plagioclase, quartz, calcite, sphene, pyrite and pyrrhotite. The sulphides occur as impregnations, lumps or vein fillings. The olivine–serpentine skarn is associated with more massive magnetite. The skarn is mica-alterated, and a typical association is olivine–serpentine–mica–magnetite. The olivine with the composition $(Mg_{1.6}\ Fe_{0.4})SiO_4$ occurs as crushed crystals surrounded by serpentine and magnetite. The mica is mainly muscovite, rarely phlogopite. Garnet-bearing skarn (grossularite) occurs in small amounts.

Reserves: The ore lenses are 10–75 m wide and c. 100 m long. The richest ore is found in the western limb and in the crest of the arched structure. The outcropping area covers 37,500 m^2, of which 35,000 m^2 are in the western limb. Down to a depth of 120 m there are 16 million tonnes of ore with 33.5% Fe, 0.03% P, 3.6% S and 0.1% Cu. Locally the ore is S-rich with > 5% S and Cu-bearing with 0.2–0.8% Cu.

Host rock: Mica schist and biotite gneiss with biotite, plagioclase, quartz and amphibole, the latter forms partly >50 volume%. 0.3–2.5 m wide dikes of a biotite–amphibole-rich, scapolitized porhyritic metabasite have intruded along the schistosity in the mica schist and gneiss, and the banded structure in skarn and ore. The whole series is surrounded by Lina granite which intersects skarn and iron ore.

References: Lindroos et al., 1972a; Grip and Frietsch, 1973.

Sattavaara

Site: 76 km ENE of Kiruna, 8 km SSE of Lannavaara **Map sheet:** 30L/1b

Discovery: Kevus, Teltaja and Sattavaara were in discovered in 1920-21 by AB Nordsvenska Malmfält company. In 1967–68, SGU made magnetic and gravimetric measurements, and at Sattavaara in 1971, Slingram measurements. Kevus and Teltaja were drilled in 1971. At Sattavaara, extensive trenching and detailed geologic mapping was undertaken in 1970–71.

Mineralization: Skarn iron ore rich in chert and Fe^{2+}–Mn silicates which, together with magnetite, form narrow bands and layers. The mineralization differs from other skarn iron ores due to the content of manganese-bearing silicates. Clinopyroxene, biotite, garnet and hornblende are common minerals. Most of the silicates are Ba-bearing, the highest contents is found in microcline. Scapolite occurs in a diopside–amphibolite. A set of samples contains 33.0% Fe, 4% Mn and 0.35% Cu.

Host rock: Mafic metatuffites, metasedimentary rocks and calcite–dolomite marble**.**

References: Ambros and Nylund, 1977; Frietsch, 1985a.

Sautusjärvi

Site: 20 km NE of Lannavaara **Map sheet:** 30L/6d

Discovery: In 1896. No outcrops. By SGU in 1972, diamond drilling (one hole, 249.25 m).

Geophysical features: 600 m long in NNW-striking magnetic anomaly.

Geological features: Constitutes the northern continuation of the Paljasjärvi deposit, owned by Nordstiernan Company AB.

Mineralization: 10 m wide skarn-bearing magnetite mineralization with some pyrrhotite, pyrite and traces of chalcopyrite. Contains 30–40% Fe, 0.02–0.04% P, 0.02–0.09% S and 00.2–0.06% Mn.

Host rock: Banded-layered, mafic sedimentary rocks with alternating feldspar–amphibole-rich and mica-rich layers. Cut by a non-schistose albitite which contains remnants of the mafic sedimentary rocks.

Reference: Ambros, 1980.

Sautusvaara area

Site: 25 km ENE of Kiruna **Map sheet:** 29K/7c–b

Discovery: In 1896 magnetically discovered by AB Nordsvenska Malmfält company. In 1929 claimed as *Statsgruvefält*. The mineralization forms a more than 2 km long belt, cut by faults, and divided into two main ore bodies, Södra and Norra Sautusvaara. Norra Sautusvaara lies 500 m WNW of the northern end of Södra Sautusvaara. In 1961–62 SGU made magnetic measurements. At Södra Sahavaara in 1963–67, diamond drilling (49 holes totalling 10 517.23 m) and at Sautusvaara Norra in 1965–67, diamond drilling (25 holes totalling 4 774.37 m).

Sautusvaara Norra

Geological structures: The ore lies in the same stratigraphic position as Södra Sautusvaara. By faulting Norra Sautusvaara forms a pyramid with its apex downwards. Toward the west and south the ore is delimited by vertical faults, whereas the NW–SE limit is the interface against the underlying metasedimentary rocks, dipping 60°SW.

Mineralization: Banded skarn iron ore predominates, but is more recrystallized than in Södra Sautusvaara, resulting in a higher iron content and a lower content of sulphur. Along fracture zones there is a superficial weathering in the ore down to a depth of 170 m.

Reserves: The surface area covers 33,800 m^2 and the ore is known to a depth of 225 m where it practically pinches out. Contains 13.3 million tonnes of ore with an average of 42.1% Fe, 0.074% P and 0.48% S.

Host rock: The mineralization is underlain by sedimentary rocks, where scapolite-rich rocks and scapolite felses are common. Toward the west and south porphyrites occur. The conglomerate adjacent to the Södra Sautusvaara ore in the hanging wall is not found here. The rocks adjacent to the faults are strongly fractured.

References: Hallgren, 1970; Grip and Frietsch, 1973; Eriksson and Hallgren, 1975.

Sautusvaara Södra

Geological features: Södra Sautusvaara forms a 1100 m long body striking N30°W, split by faults. The width is ca. 130 m in the northern part and in the southern part, between 30 and 50 m. The middle part is dislocated 110 m toward the east by E–W, N–S, NW–SE and NNE–SSW faults. In the northern part, at the surface, the ore has a vertical dip, whereas ca. 100 m below surface the dip is 60–65°W. In the southern part the ore dips steeply toward the west. The deeper the ore is, the narrower it becomes being only 25 m in the northern part, 300 m below the surface.

Mineralization: Layered and banded skarn iron ore in which magnetite occurs, associated with diopside–(hedenbergite), tremolite, and minor biotite and chlorite. A rhythmic layering in which 2–5 mm thick magnetite layers alternate with skarn bands of varying thickness. The layering is occasionally folded. In the banded ore the iron content reaches 35%. By increased recrystallization secondary, partly discordant, veins of magnetite appear and the iron content increases. The veins have obliterated the banding. A magnetite with only diffuse skarn layers contains 50–55% Fe. Calcite occurs in varying amounts. Small amounts of apatite are common. The ore contains pyrite, pyrrhotite and some chalcopyrite.

In the northern part of the deposit, soft ore is found in connection with zones of crushing and faulting, formed by superficial weathering, down to a depth of some tens of metres.

Reserves: The outcropping area is 53,000 m^2 of which the northern part covers 28,900 m^2. To a depth of 235 m there are 42.1 million tonnes of ore with an average of 37.2% Fe, 0.066% P, 1.82% S, 0.05% MnO and 0.15% Ti. The southern part of the deposit contain less iron (25.7% Fe) but more sulphur (2.93% S) and phosphorus (0.122% P).

Host rock: East of the ore, in the foot wall, phyllitic sedimentary rocks with intercalations of mafic volcanic rocks occur. Locally the sedimentary rocks are graphite-bearing and contain some marble- and skarn-horizons. Scapolite alteration is common; locally there are also scapolite–skarn felses with a diffuse banding and consisting of scapolite, diopside, and tremolite. West of the ore, in hanging wall, there is an albite porphyrite, and a conglomerate which in a magnetite–skarn matrix contains fragments of varying size and composition (felsic to intermediate volcanic rocks, magnetite-rich trachyandesites, amphibolites and magnetite).

The whole series and the ore are cut by dikes of scapolite-altered porphyrite. The metabasite is cut by a red, phenocryst-bearing granite.

References: Grip and Frietsch, 1973; Eriksson and Hallgren, 1975; Hallgren, 1966, 1970.

Staggotjåkka

Site: 40 km WNW of Kiruna **Map sheet:** 29I/8i-9i

Discovery: New discovery in 1963 by aeromagnetic measurement by SGU; magnetic and gravimetric measurements in 1966.

Geophysical features: A 2 km long and 300–400 m wide magnetic anomaly extending NNE–SSW. West of the area along Vallasjoki there is another 1 km long and 200 m wide anomaly striking in WNW–ESE. Both anomalies are covered by Caledonian rocks, only the northern part of the first anomaly is uncovered.

Mineralization: Probably magnetite–skarn mineralization in a greenstone–marble association.

Host rock: Fine–medium grained greenstone which becomes gabbroid toward the NW. Contains intercalations of a locally banded marble, up to some hundred metres wide (probably by repeated folding), striking NNE and dipping 60–70°W. Near the Caledonian Front, and further to the north, there is an intensely folded, somewhat magnetic skarn with talc, serpentine, amphibole and some asbestos. The sequence is veined by a red, fine-grained, amphibole-bearing aplite forming hybridic rocks with the greenstone.

References: Lindroos, 1970: detailed geologic map, SGU.

Suolojåkk

Site: 8 km SW of Kiruna **Map sheet:** 29J/6f

Discovery: New discovery by SGU by aeromagnetic measurement in 1960. No outcrops. In 1964 and in 1969 diamond drilling by SGU (3 holes totalling 186.88 m).

Geophysical features: A narrow, 1400 m long magnetic anomaly striking N–S. Probably dipping steeply toward the west.

Mineralization: Three separate magnetite mineralizations 5–10 m wide. Magnetite occurs in greenstone as schlieren and aggregates associated with talc, serpentine and small amounts of pyrite. Locally calcite-filled vugs occur. The ore-bearing parts contain somewhat more than 25% Fe, mostly < 0.005% P (locally up to 0.2% P), 0.01–0.37% S and less than 0.01% Cu.

Reserves: The mineralization covers an area of 20,000 m^2 and contains to a depth of 100 m reserves of about 6 million tonnes of ore.

Host rock: The area is covered by rocks of the Greenstone Group, mainly spilitic and pillow-bearing basalts, tuff–tuffites and porphyrites (lavas and dikes).

Reference: Damberg and Nylund, 1973b.

Suorsapakka (Suorsa)

Site: 18 km WSW of Pajala **Map:** 28M/2–4 b-e

Discovery: Magnetic and gravimetric measurements by SGU in 1966–67.

Geophysical features: Characterized by highly magnetic anomalies and rather homogeneous gravity anomalies with moderate gradients. Three separate anomalies extending in NE occur. The central part of the structure is dominated by magnetite-bearing rocks of intermediate to mafic composition. In the south-eastern part, intermediate to felsic volcanic rocks and schist are indicated. To the east the structure terminates towards a prominent N–S striking fault with a large vertical throw downwards on the western side.

Mineralization: See above. There is a vertical, dike-like magnetite about 60 cm wide on the Suorsapakka hill in 'thermally' altered rocks.

Host rock: Probably belonging to the Greenstone Group.

Reference: Padget and Henkel, 1977.

Tjavelk

Site: 46 km NNW of Kiruna **Map sheet:** 30J/5f-6f

Discovery: Found in 1897. In the 1950's the Boliden AB company conducted magnetic and electric measurements and diamond drilling (6 holes). In 1968–70, SGU made magnetic, gravimetric and electric measurements; in 1969 diamond drilling (3 holes totalling 480.36 m).

Geophysical features: 4 km long, ENE–WSW magnetic anomaly. There is a strong (>32,000 γ) 900 m long magnetic anomaly S of Lake Kojijärvi. Small scattered anomalies are found SE of the lake.

Geological structures: The ore lies in an ENE–WSW belt of calcareous sedimentary rocks with intercalations of graphite schists, forming the northern continuation of the Kiruna greenstones. South of the ore, mica-rich sedimentary rocks occur and north of the ore, bedded sedimentary rocks are found. There are several faults, partly following the ore, partly striking NE–SW. The rocks dip 65°N. The ore-bearing sedimentary rocks are bordered towards north by a biotite- and scapolite-altered gabbro which partly veins and intrudes the sequence. The mica schists in the foot wall are intersected by narrow porphyrite dikes.

Mineralization: The mineralization forms a lens-shaped body, 600 m long and 15 m on average, 35 m thick at most, striking ENE and dipping 65°N. The ore is associated with impregnations or some metres wide masses of skarn composed of chlorite, phlogopite and serpentine, less usually diopside and actinolite. In the ore and skarn is are some pyrrhotite and chalcopyrite, whereas pyrite is not present. The ore contains small amounts of apatite, on average 1.2% P, which is exceptionally high for a skarn iron ore. In connection with pyrrhotite, there is cobalt pentlandite ($Fe_{0.20}Co_{0.12}Ni_{0.21}S_{0.47}$); Tjavelk is the only skarn iron ore in Norrbotten which contains pentlandite. The mode of formation is unclear, though, the nickel-bearing pyrrhotite which occurs in the sedimentary rocks in the hanging wall may be related to the adjacent gabbro.

Reserves: On a surface covering approximately 9000 m^2 and down to a depth of 200 m, there is a reserve of 6.8 million tonnes ore, with an average of 38.6% Fe, 1.20% P, 3.56% S and 0.12% Cu. Boliden AB's investigations show that the sulphides occur in calcareous parts of the ore. The sulphides partly follow faults and fractures. Chalcopyrite occurs in connection with leucodiabases and greenstone dikes.

Host rock: North of the ore in the hanging wall there are biotite-banded, quartz-bearing metasedimentary rocks which partly are scapolite-altered and contain up to 0.5 m wide parts of scapolite– skarn–mica. Discordant skarn-rich fissures with pyrite and chalcopyrite occur. In the sediments there is a narrow intercalation of a tuffite with veins and schlieren of pyrite, pyrrhotite and some chalcopyrite. Close to the ore there is a 5 m wide mica–magnetite-rich skarn. South of the ore the mica schist in the foot wall is scapolitized and rich in skarn–schlieren.

Reference: Frietsch, 1979b.

Vieto

Site: 22 km WSW of Kiruna **Map sheet:** 29J/6c

Discovery: Found in 1914 by the AB Nordsvenska Malmfält company. Four diamond holes and trenches were made and a mining rights was accepted. In 1929 the deposit was incorporated in Ekströmsberg *statsgruvefält*. In 1951–53, SGU made magnetic measurements; in 1963 magnetometric and gravimetric measurements; in 1967–69, diamond drilling (25 holes totalling 4610 m).

By drilling, a new discovery of copper mineralization was made in 1967 in the eastern part of the ore. Slingram measurements in 1968, later followed by IP and resistivity measurements; in 1969–71, diamond drilling (9 holes totalling 1220 m).

Mineralization: The iron mineralization consists of three separate skarn iron ore bodies in a partly marble-bearing horizon conformly occurring in mafic metavolcanic rocks and associated sedimentary rocks. The ore lies in the southern part of a larger greenstone area quite close to the contact with felsic volcanic rocks. To the east the ore area is delimited by an intrusion of perthite syenite, following a large N–S fault. To the west the area is delimited by a younger granite.

The ore horizon strikes largely WSW–ENE with a bend towards north furthest east. The ore dips 45– 75°N below the greenstones, and apparently forms a synform open towards north. Whether the felsic volcanic rocks are older than the ore is uncertain; they may possibly be intrusive.

A number of faults intersect the area. Most important is a N–S fault, just east of the ore, along Atjejåkk. Between the middle and eastern ore bodies there is a WNW–ESE fault by which the NE block has been moved ESE.

The ore–skarn horizon has a width of 20–70 m. Between ore and skarn there all gradations. The ore consists of magnetite and varying amounts of silicates, sulphides and calcite. Tremolite is most common; less common are talc, chlinochlore, phlogopite, occasionally epidote. The ore is often skarn-banded. In the western ore body there are quartz-bearing parts which probably represent a primary banding. Small amounts of pyrite and pyrrhotite are common. As accessories, chalcopyrite and sphalerite occur. The skarn masses, which alternate with mica schist sedimentary rocks, consist of tremolite, biotite–phlogopite, and chlorite, and are often calcareous.

Reserves: The outcropping area is 24,600 m^2. Down to a depth 150 m there are 14 million tonnes of ore with an average of 42.3% Fe, 0.13% P and 1.77% S, and 1.65 million tonnes with an average of 24.3% Fe, 0.20% P and 1.08% S, in total 15.65 million tonnes of ore with an average 40.4% Fe, 0.14% P and 1.70% S.

Host rock: In the foot wall fine-medium-grained, often magnetite-rich diabases occur. The hanging wall is dominated by fine-grained, effusive greenstones interlayered with conform diabases. Close to the middle ore-body there are lapilli tuffs, graphite-bearing mica schists and mica-quartzites. The sequence forms a synform cut by dikes of felsic porphyry and hornblende-bearing oligoclase porphyrite, the latter probably related to the diabases. Around the middle and western ore bodies there are dikes of granite, quartz and rarely granite porphyries.

Reference: Eriksson et al., 1979.

Vittangi area

Site: 10–20 km NW of Vittangi **Map sheet:** 29K/6g–3h

Discovery: Around the turn of the century. In 1918, compilation by SGU (Geijer, 1918) of the geology of iron ore and graphite deposits. In 1964–68, magnetic, gravimetric, Slingram and IP measurements by SGU.

Geological structures: The area consists of metasedimentary rocks and mafic metavolcanic rocks of the Greenstone Group which, due to folding and faulting, form a complicated pattern (Eriksson and Hallgren, 1975; Martinsson, 1993). The Lower Greenstone formation comprises mafic volcanic rocks and ultramafic dikes. In the contact with the overlying Lower Sedimentary formation, there are mafic and ultramafic sills. The Lower Sedimentary formation consists of quartz–biotite-rich schists with andalusite, sillimanite and cordierite.

There are several separate deposits of skarn iron ore in metasedimentary rocks in the upper part of the rocks of the Greenstone Group. The area has been subject to folding, resulting in NE–SW directed structures. The ores occur in NE–SW extended synforms with the metasedimentary rocks and mineralizations lying in limbs about 5 km from each other. In the NW limb there are, from NE to SW, the iron mineralizations Sorvivuoma, Sorvijärvi, Vathanvaara, Mänty Vathanvaara, Kivijärvi and Tervaskoski, the latter belonging to the Boliden AB company and not investigated by the IOIP. In a limb toward the SE there are, from NE to SW, the Nälkäjärvet, Kuusi Nunasvaara, Svanbolandet, Nunasjärvenmaa and Jänkkä mineralizations. In a third limb further southeast there are, from NE to SW, the Venetvuoma, Ylisuannonmaa and Haren mineralizations. The structures have been affected by faults, mainly in NW and WNW directions.

The stratigraphical sequence is: (lowest) mafic volcanic rocks; quartz–biotite-rich schists with andalusite, sillimanite and cordierite; graphite-bearing schists; amphibolites with graphite-bearing schists and biotite-rich schists; iron ore-bearing unit with marbles, ultramafic volcanic rocks, quartz–biotite schists, skarn iron ores and magnetite-bearing quartzites; basaltic volcanic rocks; graphite-bearing schists and scapolite–amphibole-pyroxene-bearing schists (marls). 1.87–1.89 Ga old granodiorites intersect the whole sequence, which is also intruded, except for the members above the iron ore-bearing formation, by diabases up to some hundred metres wide.

Mineralization: The mineralizations consist of magnetite associated with tremolite–actinolite and diopside. Other minerals are calcite, chlorite, serpentine and talc. A layered–banded structure is common. In Kuusi Nunasvaara and Mänty Vathanvaara the layering consists of calcite, in the first-mentioned deposit also garnet. Quartz occurs as bands in Nunasjärvenmaa. Pyrite and pyrrhotite are common. In Svanbolandet, Nunasjärvenmaa, Kuusi Nunasvaara, Kivijärvi, Mänty Vathanvaara, Sorvijärvi, Sorvivuoma and Vathanvaara, the ore is locally loose and earthy due to superficial weathering:

Reserves: 72.98 million tonnes of iron ore for all deposits in the area. The figures are based on preliminary calculations made in 1980, but cannot at present be verified.

References: Geijer, 1918; Grip and Frietsch, 1973; Eriksson and Hallgren, 1975; Lilljequist, 1981; Martinsson, 1993.

Jänkkä

Site: 14 km W of Vittangi **Map sheet:** 29K/4g

Discovery: In 1965–68, SGU made magnetic and Slingram measurements; in 1971, diamond drilling (one hole, 161.46 m; in 1978, other drill holes for sulphide mineralizations).

Mineralization: Magnetite and tremolite–actinolite in up to 10 m wide layers with 30–50% Fe. A magnetite-banded skarn with decimetre- to metre-wide magnetite layers which often are tectonized. In the magnetite-rich layers, pyrite, some pyrrhotite and traces of chalcopyrite as impregnation or fissure filling.

Reserves: 3.5 million tonnes of ore with 36.3% Fe (30–55% Fe), 0.02% P (0.005–0.05% P), 2.14% S (0.5–3% S) and 0.1–0.2% Cu.

Host rock: Banded–layered tuff–tuffites which are altered, scapolite-spotted and contain iron sulphides. In addition there are mafic volcanic rocks which are metamorphosed into fine- to medium-grained amphibolites, skarn-altered and rich in quartz veins and feldspar-filled vugs. The coarser forms resemble metadiabases. The lava beds are interlayered by tuffs–tuffites with scapolitization at the contacts. The rock sequence is intersected by fine-grained metabasite dikes and a granodiorite, probably 1.89–1.87 Ga old.

Reference: Danielsson and Johansson, 1979.

Kivijärvi

Site: 18 km WNW of Vittangi **Map sheet:** 29K/5g

Discovery: Geological detail mapping.

Mineralization: Epidote-bearing, loose magnetite ore with skarn, partly banded. In fissures, sulphides, predominantly pyrite, but also some chalcopyrite. The ore is associated with a sulphide-bearing scapolite–diopside skarn.

Host rock: A sequence that consists of mafic schist; layered, partly porphyritic amphibolite, grey-white marble, mica schist and quartzite rich in sulphides. On the NW side are skarn–scapolite rock, dense quartzite and mica-rich sediment. To the west, basaltic greenstone. The sequence is cut by dikes of metabasite and pegmatite.

References: Geijer, 1918; Eriksson, 1969; Eriksson and Hallgren, 1975.

Kuusi Nunasvaara

Site: 12 km NW of Vittangi **Map sheet:** 29K/5h

Discovery: In 1972, diamond drilling (2 holes totalling 534.10 m).

Mineralization: Up to 10–15 m wide layers of skarn-layered magnetite with 20–40% Fe, 0.02–0.1% P, 1–2% S and 0.05–0.1% Cu. The ore-bearing horizon is about 3 km long. Skarn as separate bodies, mostly tremolite–actinolite, rarely phlogopite and garnet. Secondary calcite veins. Pyrite and pyrrhotite, mostly in the magnetite- or calcite-rich parts.

Reserves: 23.72 million tonnes of ore with an average of 30.5% Fe, 0.068% P and 1.56% S.

Host rock: Alternation between banded–layered amphibole-bearing sedimentary rocks and biotite-rich amphibolites. Layers and spots of scapolite are common. In addition there is a skarn-bearing marble with amphibole and phlogopite, which is locally chalcopyrite-bearing with 0.1–0.5% Cu and 1.5–4.0% S. Chalcopyrite also occurs in the sedimentary rocks. The sequence is cut by metabasite dikes.

References: Frietsch, 1957; Grip and Frietsch, 1973.

Mänty Vathanvaara

Site: 18 km NW of Vittangi **Map sheet:** 29K/6g

Discovery: In 1971, diamond drilling (two holes totalling 534.10 m).

Geological structures: Crushing and weathering less common than in Vathanvaara.

Mineralization: Skarn-layered magnetite with impregnations of pyrite and pyrrhotite. Locally calcite occurs as bands and secondary schlieren. The skarn which consists of tremolite–actinolite, less commonly also hornblende, forms partly separate layers. Garnet occurs in cm-wide layers. Mineralization in sedimentary rocks and associated with marble.

Reserves: 10.73 million tonnes of ore with an average of 31.3% Fe, 0.057% P and 2.46% S. Contains 25–40% Fe, 0.05–0.2% P, 1.5–4% S, 0.05–0.1% Cu, 1–10% CO_2.

Host rock: Layered–bedded metasedimentary rocks, partly graphite-bearing. Scapolite-spotted schists are subordinate. Locally marble, often skarn-bearing, and even-grained feldspar–epidote-rich alteration rocks occur. The sequence is cut by dikes of porphyritic metadiabase with epidote-altered phenocrysts.

References: Grip and Frietsch, 1973; Eriksson and Hallgren, 1975.

Nunasjärvenmaa

Site: 14 km WNW of Vittangi **Map sheet:** 29K/4g

Discovery: Found in 1916 by AB Nordsvenska Malmfält company. In 1972, SGU conducted diamond drilling (2 holes totalling 486.61 m).

Geophysical features: Magnetic anomalies striking NNE–SSW.

Mineralization: Skarn–quartz-banded magnetite, rich in calcite as schlieren and layers. The ore contains small amounts of pyrite, pyrrhotite and locally chalcopyrite. Partly crushed and weathered.

Reserves: Covering an area of 7500 m^2 and to a depth of 100 m, the deposit contains 2.25 million tonnes of ore with an average of 30.9% Fe, 0.045% P and 0.76% S. Contains 25–50% Fe, 0.02–0.2% P , 0.2–3% S, 0.07–0.8% Cu. Also up to 0.6% Cu in the sedimentary rocks.

Host rock: Fine-layered–banded phyllite, locally graphite-bearing and with iron sulphides. Contains cm-wide magnetite layers, skarn layers and scapolite-spotted layers which grade into scapolite–quartzites. Alternation with biotite-rich, scapolite–spotted amphibolites and skarn-banded calcareous rocks. Dikes of a red, fine-grained to coarse granite.

References: Frietsch, 1957; Grip and Frietsch, 1973; Eriksson and Hallgren, 1975.

Nälkäjärvet (Nälkävuoma and Nälkäjärvi)

Site: 14 km WNW of Vittangi **Map sheet:** 29K/5g

Mineralization: Comprises the two deposits Nälkävuoma and Nälkäjärvi. Skarn iron ore, similar to other occurrences in the Vittangi area. In Nälkäjärvi, magnetite, amphibole and skarn occur in a banding. Nälkävuoma is a very minor deposit with 1–2 cm wide layers of magnetite, diopside and garnet.

Host rock: Diopside–plagioclase-bearing sedimentary rocks.

References: Geijer, 1918; Danielsson et al., 1980.

Sorvijärvi

Site: 20 km NW of Vittangi **Map sheet:** 29K/6g

Discovery: In 1971–72. In 1971, diamond drilling (3 holes totalling 464.25 m).

Mineralization: Weathered and crushed sulphide-bearing magnetite ore with calcite veins.

Reserves: 0.0073 million tonnes with 34.5% Fe, 0.060% P and 1.16%S. Contains 20–35% Fe, 0.05–0.2% P, 0.4–3% S, and 0.03–0.09% Cu.

Host rock: Skarn–scapolite–fels rich in secondary calcite veins. Phyllite with scapolite-rich layers. Dikes of epidote-altered, scapolitized mafic rock (greenstone).

Reference: Grip and Frietsch, 1973.

Sorvivuoma

Site: 21 km NW of Vittangi **Map sheet:** 29K/6g

Discovery: In 1972, diamond drilling (2 holes totalling 311.08 m).

Mineralization: Skarn-banded ore, rich in calcite-filled veins. Skarn in spots and schlieren. Locally weathered. Small amounts of iron sulphides. 35–45% Fe, 0.05–0.10% P, 0.03–0.9% S, <0.01% Cu and 0.2–0.5% CO_2.

Reserves: 4.29 million tonnes with 39.7% Fe, 0.09% P and 0.31% S.

Host rock: Locally the rocks are (superficially) weathered. Banded–layered metasedimentary rocks, locally partly with thin layers of magnetite and skarn. The rocks are occasionally scapolite-spotted and altered, gradually passing into scapolite–biotite–fels with remnants of banding. Scapolite–calcite veins with some pyrite. Skarn-bearing marble.

The sequence is intersected by a scapolite–epidote-altered mafite. The ore is intersected by a dense red granite containing hornblende-filled fissures.

References: Grip and Frietsch, 1973; Eriksson and Hallgren, 1975.

Svanbolandet

Site: 15 km WNW of Vittangi **Map sheet:** 29K/5g

Discovery: In 1972, diamond drilling (1 hole, 214.31 m).

Mineralization: Three different magnetic anomalies. Skarn and magnetite layers in mica schist. In addition, layers of skarn-banded jaspilitic quartzite. Magnetite also occurs as impregnation in the metasedimentary rocks. Sporadically pyrite- and chalcopyrite-bearing. Contains 15–25% Fe, 0.07–0.1% P, 0.7–1.2% S, 0.05–0.1% Cu.

Reserves: 0.49 million tonnes with 24.7% Fe, 0.097% P and 0.63% S. Mostly <0.1% Cu, occasionally <0.3% Cu.

Host rock: Mica schist, partly layered, pyrite–chalcopyrite-bearing. Up to metre-wide granite veins with granitization of the mica schist occurring as nebulitic remnants. Dikes of a fine- to middle-grained, weakly schistose metabasite.

Reference: Danielsson et al., 1980.

Vathanvaara

Site: 20 km WNW of Vittangi **Map sheet:** 29K/6g

Discovery: Found in 1901. In 1971, by SGU diamond drilling (11 drill holes totalling 1658.30 m).

Geological structures: The ore and the host rocks are locally strongly fractured and (superficially) kaolin-weathered to a depth of at least 100 m.

Mineralization: Magnetite with amphibole–skarn in masses or as banding, locally with calcite veins. Partly, a dark serpentine-bearing ore. To a small extent haematite-bearing. Rich in pyrite and pyrrhotite, occasionally forming up to 10 m wide veins with sharp borders against the hosting sedimentary rocks which occur partly as remnants in the sulphides. Small amounts of chalcopyrite occur sporadically.

Reserves: 28.03 million tonnes of ore with on average of 39.4% Fe, 0.049% P and 2.91% S. Contains 35–50% Fe, 0.04–0.1% P, 0.6–4.0% S (locally up to 10% S), 0.03–0.04% Cu (locally 0.1–0.3% Cu) and 0.3–0.5% CO_2.

Host rock: Layered graphite-bearing biotite schist with pyrite, pyrrhotite and rarely chalcopyrite. Subordinate is a scapolite-bearing quartzite with magnetite impregnations. The sequence is cut by porphyritic, scapolitized and epidote-altered metabasites. Albite-rich rocks, probably metasomatic alteration products, are relatively common.

References: Frietsch, 1957; Grip and Frietsch, 1973; Eriksson and Hallgren, 1975; Norberg, 1978.

Årosjåkk

Site: 35 km W of Kiruna **Map sheet:** 29J/6a

Discovery: New discovery by SGU in 1960 by aerial measurement. In 1963, magnetic and gravimetric measurements; in 1969, diamond drilling (3 holes totalling 479.37 m). Mining rights in 1973.

Geophysical features: Magnetic anomaly 500 m long, 100 m wide and striking N–S.

Geological features: The mineralization forms a 250 m long and 50–60 m wide lens striking NNW–SSE and dipping 60°W. West of the ore is a gneiss–granite which is cut by mafic dikes and pegmatites.

Mineralization: Magnetite rich in skarn, consisting of serpentine, subordinate amphibole and talc. Pyrite occurs in small amounts, locally some chalcopyrite and sometimes pyrrhotite. The ore forms schlieren, lumps and aggregates in the host rock greenstone. The contact with the sedimentary rocks in the foot wall is relatively sharp, whereas the ore towards the hanging wall decreases successively.

Reserves: Ore defined as >10 m wide and with a grade >20% Fe. Down to a depth of 125 m there are 2.7 million tonnes of ore with an average of 28.3% Fe, 0.018% P and 0.11% S.

Host rock: Fine-grained mafic volcanic rocks and gabbroid greenstones, all probably belonging to the Paittasjärvi greenstones. The foot wall of the ore consists of a fine-grained, banded, tuffitic sediment.

Reference: Damberg et al., 1974b.

SUMMARY

The investigated deposits are typical of the skarn iron ores of Norrbotten. Magnetite is associated with separate layers or intermingled skarn of tremolite–actinolite, diopside, less commonly biotite and chlorite. In rather many deposits serpentine and minor phlogopite are closely associated with massive ore. In some deposits serpentine contains remnants of olivine. The difference in genesis between the two skarn types, i.e. the Ca–Mg-skarn and the Mg–skarn, is not known, but is probably a primary feature reflecting differences in the precipitating ore solutions.

The skarn iron ores are closely related to the quartz-banded iron ores, mainly in the Masugnsbyn belt, but also at Erkheikki where minor layers of this ore type occur. These ores are characterized by Fe^{2+}-silicates such as grunerite. The presence of this ore type, with gradations to the quartz-bearing iron ores of the Greenstone Group, indicates a precipitation under more reducing conditions.

The host rocks are metasedimentary rocks or less commonly, as at Vieto and the northern part of Laukujärvi, mafic volcanic rocks of the Greenstone group. The apatite content is low, with a few exceptions as at Tjavelk. Chondrodite occurs in the Masugnsbyn mineralization. The rock sequence is intersected in most places by metabasites.

Scapolitization is common in the host rocks of the skarn iron ores. The metasedimentary rocks and mafic metavolcanic rocks are often scapolite-spotted and the feldspar is scapolite-altered. Scapolite-dominated rocks such as scapolite–biotite schists and biotite–schist are typical. A specific type of rock is a scapolite–skarn fels composed of scapolite, diopside, tremolite, quartz, small amounts of biotite, muscovite, sphene, pyrite and pyrrhotite. It is often banded and represents an altered marl. It should be emphasized that scapolite is not found in the ore itself, the Norra Altavaara and Tapuli mineralizations being exceptions.

The formation of scapolite is a late metasomatic process indicated by the presence of scapolite in metabasite dikes in the ore and the host rocks, i.e. the scapolitization is later than the intrusions. In the amphibole gneisses and mica schists at the Altavaara Södra mineralization tourmaline is common, probably belonging to the same alteration process. Here the only rocks that are not scapolitized are the young aplites and granites.

A typical feature of the skarn iron ores is the omnipresence of small amounts of pyrite and pyrrhotite, and in some deposits minor amounts of chalcopyrite. In the mafic volcanic rocks and sedimentary rocks there are also mineralizations of chalcopyrite with small amounts of pyrrhotite and pyrite, and in some cases also magnetite (as in the Viscaria copper deposit NW of Kiruna). There is thus a paragenetic connection between the iron and the sulphide mineralizations in the Greenstone Group.

The content of sulphur in the skarn iron ores is mostly around 1–2% S. Locally, contents amounting to 5% S or occasionally up to 10% S are encountered. The variations in the content within single deposits are relatively great, showing rapid changes within short distances. The highest average content (3.6% S) occurs in the Salmivaara and the Tjavelk deposits. Deposits with a low average content of sulphur are rare. The Tapuli ore, which is part of the Kaunisvaara ore belt, has an average content of 0.18% S. Pyrite and pyrrhotite occur mostly in close association with each other but the relative proportion varies from deposit to deposit and also within one and the same ore body. For example there are rapid variations between the two sulphides in the Sautusvaara ore; up to 7.8% FeS_2 vs. 12.2% FeS have been found in different parts of the ore (Hallgren, 1970). In a few deposits one of the sulphides is predominant; the Tjavelk ore contains a high content (8.8%) of pyrrhotite, whereas pyrite is scarcely present.

The internal relationship between pyrite and pyrrhotite in the skarn iron ores of Norrbotten is poorly known. The complexity in the distribution of pyrite–pyrrhotite and the variations in the sulphur content in the different deposits are probably primary features, established at the time of the ore's deposition. However, in some deposits the sulphur content has decreased locally due to later metamorphic processes causing ore recrystallization and simultaneous mobilization of the sulphur, as in Kaunisvaara ore belt. The different ore bodies have been deformed by tectonization, and are locally, tectonically brecciated, especially against the wall rock (Lindroos, 1974). Due to recrystallization, the magnetite in the breccias is often more coarse–grained and the iron grade higher than in the non-brecciated parts. The effect of mobilization and recrystallization of the ore is obvious in the Tapuli deposit. The sulphur content of this deposit is the lowest (0.2% S) of the Kaunisvaara horizon. Even if most of the sulphides have been driven out in

connection with tectonization, there are still parts rich in sulphur. An example of a clear relationship between increase in grain size, increase in iron content and decrease in sulphur content, is encountered in the Sautusvaara deposit. The main part of the ore has a grain size of 0.01–0.5 mm and contains 37% Fe and 1.8% S, whereas the northern continuation has a grain size of 0.1–1.5 mm and contains 42% Fe and 0.5% S (Hallgren, 1970). The northern part of the ore has been subjected to redistribution and recrystallization, possibly in connection with folding and faulting, thus causing the differences in chemistry and grain size. The relative amounts of pyrite and pyrrhotite seem not to have changed, however.

The above indicates that some of the skarn iron ores of Norrbotten have undergone local changes in their sulphur content in connection with tectonization. However, it is probable that the sulphur content of most ores is still as it was at the time of their deposition.

The high content of sulphur during the precipitation of the skarn iron ores has caused the formation of magnetite as the only iron oxide mineral. The high sulphur fugacity prohibited formation of haematite.

QUARTZ-BANDED IRON ORES OF THE GREENSTONE GROUP

GENERAL FEATURES

The quartz-banded iron ores, which occur in the Greenstone Group in a rock association similar in composition and stratigraphic position to the skarn iron ores, consist of quartzites with magnetite and Fe^{2+}–Mg–(Mn) silicates, mostly forming distinct layers. Common silicates are hornblende, grunerite, clinoenstatite, hedenbergite and almandine. The manganese content is low, but in some deposits reaches 1–2% Mn. Ca–Mg silicates of the same type as in the skarn iron ores are subordinate or not present. Small amounts of pyrite and pyrrhotite are typical; the sulphur content can reach a few per cent. The phosphorus content is less than 0.1% P.

Marjarova (Marjajärvi)

Site: 22 km WNW of Pajala **Map sheet:** 28M/7b

Discovery: In 1919, discovered by the Nordsvenska Malmfält company. In 1964, SGU made magnetic and gravimetric measurements; in 1968–70, diamond drilling (9 holes totalling 1709.56 m).

Geological structures: A ca. 1 km long and 10–20 m wide, partly folded belt of a magnetite- and skarn-layered quartzite which contains minor pyrrhotite, pyrite and accessory chalcopyrite. Pyrrhotite dominates over pyrite. The ore zone extends NW–SE. At its northern end, the zone bends toward the SW.

Mineralization: Skarn with magnetite alternating with layers of a fine-grained quartzite. The skarn minerals are cummingtonite–grunerite, hornblende and hedenbergite, and in the magnetite-rich layers, also biotite. Fayalite is found in the SE part of the deposit. Towards NE the mineralization is richer in quartzite-layers. The iron content of the mineralization is around 20% Fe. There are up to 20 m wide layers containing up to 45% Fe, on average 32% Fe. The mineralization contains <0.05% P and 1–5% S, in part up to 7% S. The copper content is <0.1% Cu.

Reserves: Covers an area of 10,000 m^2 and down to a depth of 100 m, the ore reserves are approximately 3 million tonnes.

Host rock: Toward the SW, bordered by a coarse granite. Toward the NW, there are garnet-bearing, mica-rich, stratified sedimentary rocks which grade into magnetite–banded skarn-rich rocks. NE of the ore zone a phyllite with quartzitic layers which grades into a wide graphite–phyllite (in a drillhole more than 150 m). The graphite content is low, but that of pyrrhotite is high. North of the ore zone, marble is encountered.

References: Rönnbäck and Ros, 1971b; Grip and Frietsch, 1973.

Masugnsbyn area

The general features of the Masugnsbyn ore belt are described in connection with the skarn iron ores, cf. p. 00. The quartz-banded mineralizations are narrow and with low iron contents. Magnetite-skarn-layered quartzites are associated here with skarn iron ores. In the quartzites, locally rich in pyrrhotite, the skarn minerals are almandine, cummingtonite–grunerite and clinoenstatite–hypersthene.

Isovaara

Site: 6 km NNW of Masugnsbyn **Map sheet:** 29L/0d

Discovery: In 1969, diamond drilling by SGU (one drill hole, 90.95 m).

Geological structures: The Isovaara mineralization which is situated in the northern part of the Masugnsby iron ore field, strikes WNW–ESE and is about 1 km long. The whole sequence is cut by a granite.

Mineralization: Magnetite in granite-altered skarn and partly interlayered with quartzite, schist and skarn. The skarn consists of tremolite–actinolite, diopside, talc and phlogopite. In the skarn there are minor intercalations of light-grey quartz–feldspar quartzites ('chert'). Pyrite–pyrrhotite and accessory amounts of chalcopyrite occur as stringers, disseminations and scattered grains.

Host rock: Towards the south the ore is bordered by a pyrite–pyrrhotite-bearing greenstone which passes into a banded skarn with quartz, diopside, tremolite–actinolite and in part, scapolite and epidote.

References: Lundbohm and Wallin, 1918; Witschard, 1972.

Vuoma

Site: 11 km N of Masugnsbyn **Map sheet:** 29L/0d

Discovery: In 1969, diamond drilling (1 hole, 144.11 m).

Geological structures: Northernmost mineralization in the Masugnsby ore belt. No skarn is present; magnetite occurs in well-stratified, fine-grained metasedimentary rocks. In a biotite schist is a magnetite-layer, some metres thick.

Host rock: Quartz-rich metasedimentary rocks, biotite schists and greenschists.

References: Lundbohm and Wallin, 1918; Witschard, 1972.

Vähävaara

Site: 5 km N of Masugnsbyn **Map sheet:** 29L/0d

Discovery: In 1968 and 1970, diamond drilling (4 holes totalling 630.87m).

Reserves: 400 m long mineralization, striking N–S and dipping vertically or steeply towards WNW. On a surface of 9350 m^2, down to 150 m, the deposit contains 3.08 million tonnes of ore with an average of 28.8% Fe, 0.048% P and 2.7% S.

References: Geijer, 1924; Ödman, 1957; Frietsch, 1962; Witschard, 1972; Grip and Frietsch, 1973.

Välivaara

Site: 8 km N of Masugnsbyn **Map sheet:** 29L/0d

Discovery: In 1969–70, diamond drilling (2 holes totalling 243.05 m).

Mineralization: Magnetite concentrations mostly in skarn, but also in banded, fine-grained, quartz-rich metasedimentary rocks.

Host rock: Well-stratified metasedimentary rocks with subordinate greenschists. Narrow calcite layers are found in feldspar-rich schists in the northernmost part.

Reference: Witschard, 1972.

Tornefors (Junosuando)

Site: 110 km ESE of Kiruna **Map sheet:** 28L/9h

Discovery: Found by SGU in 1949 by magnetic measurement in the village of Junosuando. In 1949, diamond drilling (6 holes totalling 808.15 m). In 1966, gravimetric measurements; in 1970, diamond drilling (2 holes totalling 316.25 m).

Geological structures: The mineralization forms a 700 m long and up to 120 m wide layer, extending in N–S, gently winding and in the southern part dislocated by two minor faults. At the northern end the dip is 50–60°E, and in the southern part (south of the faults) steeper, c. 80°E.

Mineralization: Magnetite occurs as bands or schlieren alternating with skarn and a dense quartzite. The quartzite layers are mostly narrow, occasionally up to 30 m wide. The skarn minerals are actinolite–tremolite and diopside, locally associated with small amounts of calcite. In the western part of the zone, serpentine predominates. Locally, pyrite, pyrrhotite and some schlieren of chalcopyrite occur. The mineralization contains around 20% Fe (in sections some metres wide >50% Fe), 0.005–0.027% P, and 1–3% S (rarely up to 5% S).

Reserves: The outcropping areas is ca. 8 000 m^2. Down to 100 m depth there are around 2.6 million tonnes ore containing approximately 20% Fe.

Host rock: West of the mineralization there is a strongly schistose, biotite-rich, agglomeratic greenstone. Locally there are tuffs and tuffites, with graded bedding showing upwards toward the east. Immediately west of the mineralization is a 10 m wide marble with magnetite, phlogopite and some serpentine. East of the mineralization there is a biotite–schistose greenstone with intercalations of a pyrrhotite-bearing graphite–schist.

The ore-bearing zone is intersected by up to 10 m thick dikes of diabase and uralite porphyrite.

Reference: Damberg et al., 1974c.

SUMMARY

All deposits fit the description given at the beginning of the paragraph. The quartz-bearing ores of the Greenstone Group are similar in most respects to the skarn iron ores. The main difference is the association of the quartz-bearing ores with quartzites which represent metamorphosed cherts. Among the investigated deposits Marjarova is the only one that contains manganese, present here as fayalite.

QUARTZ-BANDED IRON ORES OF THE PORPHYRY GROUP

GENERAL FEATURES

In the intermediate-felsic volcanic rocks of the ca. 1.9 Ga old Porphyry Group in the region W and NW of Jokkmokk and SW of Malmberget, there are quartz-banded iron ores of volcanogenic origin (Frietsch, 1980). The iron mineralizations occur in a 4–5 km wide, N–S to NNE–SSW-striking belt of supracrustal rocks, starting from Laddenjaure in the S over Parkijaure, Kallak, Råvvauratjape, Åkåsvare to Pakkojokk in the N. The deposits are, from S to N, Akkihaure, Tjårovarats, Södra Parkijaure, Parkijaure, Södra Kallak, Kallak, Maivesvare, Åkosjegge and Pakko.

Kallak was investigated by SGU in 1947–48. In the late 1950's, airborne magnetic measurements were made by SGU from Kallak to Laddonjaure. Somewhat later ground magnetic measurements were made at the mineralizations from Parkijaure and 5 km southwards. Magnetic and gravimetric measurements were made in 1968–70 in the Kallak–Laddonjaure area and in 1969 at Åkosjegge.

The host rocks of the mineralizations are felsic to intermediate composition volcanic rocks and metasedimentary rocks, metamorphosed into banded gneisses. They contain up to kilometre-long intercalations of skarn. In conncection with these the iron mineralizations occur, consisting mostly of magnetite but partly also of haematite. The gneisses consist of quartz , feldspar (microcline–plagioclase) and varying amounts of skarn minerals, mainly hedenbergite, hornblende, garnet, epidote and serpentine with remnants of hornblende. In addition, garnet-bearing biotite gneisses are found. The gneisses occur in a synform which is folded and disturbed by numerous faults.

The gneisses contain layers and intrusive bodies of mafic porphyrites, partly concordant with the gneiss structure, but partly cutting it. The gneisses are surrounded and intruded by augen-bearing gneiss granites. The youngest rock is a red microcline granite.

Jokkmokk area

Akkihaure

Site: 33 km W of Jokkmokk **Map sheet:** 26I/9j

Discovery: By SGU in the late 1950's by airborne magnetic measurement. Magnetic and gravimetric measurements by SGU in 1960–70; diamond drilling in 1970–72 (one drill hole, 222 m).

Structural features: The ore-bearing zone strikes N–S and forms a steep-standing, isoclinal fold open toward the N.

Mineralization: The ore-bearing area is c. 650 m long and c. 50–60 m wide. The largest ore zone, up to 30 m wide, lies in the western limb of the fold.

Reserves: Geophysical calculations show that down to a depth of 175 m the deposit contains 12 million tonnes of ore (gravimetry) or 13 million tonnes of ore (magnetometry).

Host rock: Amphibole–biotite–feldspar gneisses, surrounded by younger granite.

Reference: Johansson, 1980.

Kallak (Björkholmen)

Site: 37 km WNW of Jokkmokk. **Map sheet:** 27I/2j

Discovery: In 1947–48 by SGU.

Structural features: The ore lies in a basin-shaped structure with the crest in the north and open toward the south.

Mineralization: The mineralization forms a 1 km long, up to 300 m wide zone, known to a depth of 250 m. There are no sharp borders toward the host rock gneisses. Magnetite and haematite occur interlayered with quartz, feldspar and small amounts of hornblende, diopside, more rarely chlorite. Magnetite dominates, however; in the south, haematite is present up to 30 volume%. The haematite forms discrete grains or is a martitization product of magnetite. Skarn, mainly garnet and epidote, rarely scheelite, forms up to metre-wide layers between ore and gneiss.

Reserves: The mineralization covers an area of 97,000 m^2. The average grade is 35–38% Fe, 0.04% P, 0.4% Mn, 0.06% Ti and 38–39% SiO_2 . Geophysical calculations give an ore reserve of 92 million tonnes (gravimetry) and 73 million tonnes (magnetometry; 104 million tonnes if corrected for a haematite content of 30 volume%). Down to 90 m there are 50 million tonnes of ore with 35–42% Fe, 0.04% P, 0.6% and 0.4% Mn.

Host rock: Felsic, partly biotite-bearing gneisses and intermediate composition, biotite–amphibole–skarn-bearing gneisses.

References: Erikson and Ödman, 1948; Grip and Frietsch, 1973; Johansson, 1980.

Kallak Södra

Site: 37 km NW of Jokkmokk, 1 km SSW of Kallak **Map sheet:** 27I/1j

Discovery: Diamond drilling in 1970-72 (2 holes totalling 293 m).

Structural features: The mineralizations Södra Kallak and Parkijaure, which lie 1 km toward S of Kallak, are part of the same ore horizon as Kallak and lie at the end of a 2 km long keel-formed structure, with Södra Kallak in the northern part dipping toward the south, and Parkijaure at the bend of the structure. Södra Kallak is isoclinally folded with the ore in an anticlinal position. There are two mineralized horizons of the which the northern is the more important. The plunge is to the south.

Mineralization: Magnetite occurs as grains or aggregates elongated parallel with bands of quartz and subordinate feldspar. Associated are amphibole, biotite, and less commonly pyroxene, serpentine and carbonate. The magnetite is martitized; in addition haematite is found as single grains.

Reserves: In the northern, richer part, the mineralization contains around 30% Fe, 0.04–0.06% P, 0.1–0.2% Mn and 40–50% SiO_2 .The southern part contains 0.2–0.7% Mn. According to geophysical calculations the ore reserves are 29 million tonnes (gravimetry) or 16 million tonnes (magnetometry; if corrected for a content of 30% haematite, 23 million tonnes).

Host rocks: Felsic to intermediate composition gneisses which contain skarn with pyroxene, hornblende, serpentine and locally garnet. Cut by gneissose porphyrite, granite and pegmatite. The porphyrite forms syn-post-tectonic veins.

Reference: Johansson, 1980.

Maivesvare

Site: 44 km WNW of Jokkmokk **Map sheet:** 27I/3i

Geological structure: The ore zone and surrounding gneisses lie in an antiform open toward the N and folded with an axis 60–70°E. In the southernmost end the ore forms a fold enclosing the gneiss.

Mineralization: Along Lake Skalka there is a 10 m wide ore layer, gently folded, striking NNW and with sharp borders conformable with the gneiss. The ore horizon can be followed along a length of 800 m. Magnetite ore with c. 32% Fe predominates. Subordinate is skarn-bearing haematite ore with 37% Fe, mostly along N–S and NE–SW faults. The mineralization contains 0.16–0.23 Mn, 0.03–0.8% P and <0.02% S.

Host rock: Quartz–biotite gneiss and amphibole-bearing gneiss. Cut by dikes of amphibolites, altered to chlorite schists, and pegmatite–aplite veins. Toward the west, there are augen-bearing granites.

References: Persson, 1974; Johansson, 1980.

Pakko

Site: 10 km WSW of Porjus, 38 km NNW of Jokkmokk **Map sheet:** 27J/6d

Geological structure: The ore zone strikes N30°E.

Mineralization: A 120–130 m long and 10 m wide zone of banded, folded and distorted haematite–magnetite mineralization with around 20% Fe. It is migmatized and veined by pegmatites.

Host rock: Migmatized supracrustal gneisses, mainly felsic.

Reference: Persson, 1974.

Parkijaure

Site: 37 km WNW of Jokkmokk **Map sheet:** 27I/2j

Discovery: By SGU in the late 1950's by airborne magnetic measurement.

Geophysical features: A magnetic zone ca. 750 m long and 150 m wide.

Mineralization: cf. Kallak Södra. The magnetite-bearing parts contain 38–39% Fe.

Reserves: Based on geophysical calculations the mineralization contains 23 million tonnes of ore.

Reference: Johansson, 1980.

Parkijaure Södra

Site: 37 km WNW of Jokkmokk**,** 1 km S of Parkijaure **Map sheet:** 27I/1j

Discovery: No outcrops. In 1970–72, diamond drilling (one hole, totalling 238 m).

Structural features: In analogy with the structural conditions at Tjårovaratjs area further to the ESE, it is probable that the structures at Södra Parkijaure form N–S isoclinal folds with gently south dipping axes.

Mineralization: The mineralized horizon, up to 20 m wide, is made up of a quartz–amphibole-layered magnetite and a magnetite-bearing gneiss with quartz, plagioclase and some biotite. Associated is a pyroxene–garnet skarn.

Reserves: 5 million tonnes (gravimetric) and 11 million tonnes (magnetic), calculated to a depth of 165 m. If calculated to 100 m depth the reserves are 6 million tonnes.

Reference: Johansson, 1980.

Tjårovarats

Site: 33 km WNW of Jokkmokk **Map sheet:** 27I/1j

Geophysical features: The magnetic anomalies indicate a continuation of Akkihaure in the south.

Geological structure: From Parkijaure in the south towards SSW a narrow iron ore-bearing horizon in a fold open toward the SSW. The ore-bearing horizon follows the fold structure with the axis toward the SSW. The area is cut by faults and fracture zones, mainly striking NNW.

Mineralization: About 6–10 m wide magnetite–microcline–pyroxene-banded mineralization containing 20–30% Fe, 0.01–0.03% P, < 0.01% S and 0.13% Mn.

Host rock: Felsic gneiss. Pegmatites and granites cut both ore and gneiss.

Reference: Johansson, 1980

Åkosjägge

Site: 34 km NW of Jokkmokk, 17 km SW of Porjus **Map sheet:** 27J/4-5c

Discovery: New discovery by SGU in the late 1960's. Diamond drilling (2 holes in total 47 m).

Geological structure: Ca. 1.5 km long and 500 m wide, ENE striking zone with magnetite-skarn layers. Almost completely soil covered.

Mineralization: Small-folded quartz–feldspar-layered magnetite consisting of magnetite, quartz, plagioclase, amphibole, and some biotite. Locally microcline and pyroxene are present. The iron content is around 30% Fe.

Reserves: According to geophysical calculations the depth of the mineralization is about 200 m and the ore reserves are 75 million tonnes (gravimetric) and 74 million tonnes (magnetic).

Host rock: Intermediate composition gneisses.

Reference: Johansson, 1980.

SUMMARY

The quartz-banded magnetite–(haematite) ores within the rocks of the Porphyry Group are fairly homogeneous in composition and mode of formation. They have a volcanogenic origin. Of interest is their relatively high content of manganese (<0.5% Mn). The mineralization and their volcano-sedimentary host rocks have undergone medium-grade metamorphosis, and the associated skarn minerals were formed by internal thermal reactions. In many respects (magnetite–haematite layering, felsic–intermediate composition of host rocks volcanics, low phosphorus and sulphur contents, and relatively high manganese content) these ores are similar to the quartz-banded ores of Central Sweden.

EPIGENETIC, METASOMATIC ORES ASSOCIATED WITH SCAPOLITE–(ALBITE–TOURMALINE)

GENERAL FEATURES

Epigenetic mineralizations associated with scapolitization represent a specific type of metasomatic ore formation bearing no relationship to other ore types in Norrbotten. Both iron mineralizations and sulphide mineralizations are encountered (Frietsch et al., 1997).

Northern Sweden is one of the largest scapolite-bearing Precambrian terrains in the world. Albitization, and to a lesser extent carbonitization and phyllic alteration, are connected with the process. In some cases tourmaline is associated with scapolite, but also occurs separately.

A number of epigenetic Cu–(Au) and Fe deposits show a spatial and genetic relationship to this type of alteration, mainly scapolitization and albitization. The main metal deposits are in mafic volcanic rocks and sedimentary rocks of the Greenstone Group and in intermediate composition volcanic and volcaniclastic rocks of the Porphyry Group.

Scapolite and, probably also tourmaline, were formed by a complex, multistage process. The source of the components in scapolite may have been evaporitic sequences or high salinity brines in rift basins in mafic volcanic rocks. During low to medium-grade (low P) regional metamorphism, the components that formed scapolite and tourmaline were mobilized and transported to their present positions. Fault zones with fractures and breccias channelled the fluids, resulting in locally developed intense alterations. Evidence of the hydrothermal nature of the alteration is the presence of albitization and carbonatization, and small amounts of fluorite, baryte, zeolites, and manganese minerals. The latter minerals are present mainly in the ore deposits of the Porphyry Group.

The iron ore Pirttivuopio differs from the other deposits in this group. The alteration gave mainly albite, scapolite and tourmaline not being present.

IRON ORES

Lannavaara area

Site: 76 km ENE of Kiruna **Map sheet:** 29L/9c 30L/0b–1b

Discovery: The Lannavaara iron ores Kevus, Teltaja and Sattavaara (the latter is a skarn iron ore, cf. p. 00) were discovered in 1920–1921 by AB Nordsvenska Malmfält company. In 1967–68, SGU made magnetic and gravimetric measurements, and in 1971 Slingram measurements at Sattavaara. Kevus and Teltaja were drilled in 1971. At Sattavaara, extensive trenching and detailed geologic mapping were conducted in 1970–71.

Structural features: Geophysical maps show that the area is heavily faulted.

Mineralization: Kevus and Teltaja contain magnetite–haematite in massive bodies, veins or impregnations in trachyandesites and trachytes (albite–microcline–quartz rocks). Associated with the mineralizations is a hydrothermal alteration forming scapolite, tourmaline, fluorite, analcime and baryte. The magnetite–haematite mineralization was mobilized, giving it its intrusive mode of occurrence.

Kevus is a magnetite–(pyrrhotite–pyrite) deposit. Teltaja is a magnetite–haematite deposit rich in quartz. Both mineralizations are associated with small amounts of pyrite and pyrrhotite. A relatively high content of manganese (< 0.4% Mn) belongs to the association. The mineralizations are accompanied mainly by biotite, diopside, hornblende, tremolite, calcite, scapolite, and rarely also tourmaline. In places, the wall rock is largely replaced by scapolite and hornblende.

Reserves: Together, Kevus and Teltaja contain 82 million tonnes of iron ore.

Host rock: Trachyandesites and trachytes of uncertain lithostratigraphic position, belonging either to the Porphyry Group or the Greenstone Group. Sulphur isotopic compositions of the sulphides in the mineralizations ($\delta^{34}S$=–1.8 to +31.2 ‰) show affinity to sulphides of the skarn iron ores and quartz-banded iron ores of the Greenstone Group. This, however, only indicates an inheritance of the sulphur in these rocks, and not an association with a specific host rock.

References: Frietsch 1985a; Frietsch et al., 1995.

Ahmavuoma

Site: 76 km ENE of Kiruna **Map sheet:** 29L/9c

Discovery: New discovery by aeromagnetic measurements in the late 1960´s by SGU.

Geophysical features: The magnetic anomalies indicate a southern continuation of the Kevus and Tapuli occurrences. However, the deposit was never drilled during the IOIP.

Mineralization: No outcrops. Later drillings indicated a Fe-Cu-(Au-Co) mineralization as veins and breccia in andesitic volcanic rocks associated with a biotite–scapolite–microcline alteration. The deposit belongs, even if poorly known, probably to the same ore type as Kevus and Teltaja. There are up 10 m wide pyrite-rich layers with 10–25% S.

References: Lehto, 1983; Virkkunen, 1985; Lehto, 1987; Niiniskorpi, 1990; Martinsson, 1994.

Kevus

Site: 76 km ENE of Kiruna, 5 km SSE of Lannavaara **Map sheet:** 30L/1b

Discovery: In 1967, magnetometric and gravimetric work by SGU; in 1971, diamond drilling (4 holes totalling 1077.56 m).

Mineralization: Ca. 600 m long and 100 m wide, strikes N–S and dips 80–85°W. Massive bodies and veins of skarn- and sulphide-bearing magnetite. The veins vary in width from mm- to cm-scale and appear as a network forming an 'intrusive' breccia. Magnetite also occurs as an even impregnation in the trachyte. The gangue consists of diopside, scapolite and hornblende. Biotite, calcite, tremolite and chlorite are less abundant. A minor content of manganese (<0.5% Mn) belongs to the association. Small amounts of tourmaline, fluorite and analcime are present. In places, the wall rock is largely replaced by scapolite and hornblende. The trachyte is locally rich in an even impregnation of tourmaline.

Reserves: Based on chemical analyses, the mineralization divides into 1) rich ore with >30% Fe, and 2) lean ore with 20–30% Fe. Two zones, up to 20 m wide, of rich ore are surrounded by lean ore. The rich ore covers an area of 11,000 m^2 and contains to a depth of 200 m, 9.4 million tonnes of ore with an average of 39.5% Fe, 0.01–0.09% P (occasionally up to 0.2% P), 1–2% S, 0.2–0.5% Mn and <0.1% Cu. The lean ore covers an area 41,600 m^2 and contains 29.4 million tonnes of ore with an average of 24.3% Fe, the contents of other elements are as in the rich ore. In total there are 38.8 million tonnes of ore with an average content of 28% Fe.

Host rock: Trachytes and trachyandesites, cf. above the Lannavaara area.

References: Ambros and Nylund, 1976; Grip and Frietsch, 1973; Danielsson, 1982; Frietsch, 1985a.

Teltaja

Site: 76 km ENE of Kiruna, 9 km SSE of Lannavaara **Map sheet:** 30L/0b

Discovery: By SGU in 1967–68 by magnetic and gravimetric measurement. In 1971, diamond drilling (7 holes totalling 1704 m).

Geophysical features: About 1 km long magnetic anomaly striking NNW–SSE and dipping steeply toward the west.

Geological structures: Two separate mineralizations, dislocated by an ENE–WSW fault.

Mineralization: Though the Teltaja deposit is in some respects similar to Kevus, it is a magnetite–haematite mineralization rich in quartz but is almost totally devoid of sulphides. The mineralization shows epigenetic traits with the ore brecciating and veining the wall rock. Associated are microcline, quartz, albite, scapolite, tourmaline, fluorite, analcime and small amounts of pyrite and pyrrhotite.

The southern mineralization is 20 m wide and contains 33–39% Fe, 0.01–0.13% P and 0.04–4.5% S. The northern mineralization is about 70 m wide and contains 47% Fe and 0.04–0.28% P; there is no sulphur or manganese.

Reserves: The magnetometric map shows that the surface of the southern mineralization covers 13,000 m^2 and of the northern one, 9000 m^2. The gravimetric mass excess is 17.5 million tonnes of iron which with an average of 41% Fe, means an ore reserve of 43 million tonnes.

Host rock: Trachyte (albite–microcline–quartz rock) as at Kevus, but differing by being partly fragment-bearing. Contains an intercalation of graphite-bearing schist in which the sulphides have similar high $d^{34}S$ values as the sulphides in the graphite-bearing schist in Stora Sahavaara skarn iron ore.

References: Ambros, 1970; Ambros and Nylund, 1971; Grip and Frietsch, 1973; Danielsson, 1982; Frietsch, 1985a.

Pirttivuopio

Site: 45 km W of Kiruna **Map sheet:** 29I/6i

Discovery: New discovery in 1963 by SGU by airborne magnetic measurements; magnetic and gravimetric measurements in 1967; in 1968–69, diamond drilling (2 holes totalling 304.82 m).

Mineralization: Several NNW–SSE extending, towards 80°W dipping magnetite mineralizations up to 15 m wide and approx. 350 m long. The magnetite occurs as even impregnation, schlieren, uneven pods and aggregates, and in irregular fractures in a 'breccia'-like pattern. The magnetite is associated with albite, minor amounts of amphibole, quartz, biotite, and accessory apatite.

Reserves: The mineralizations contain 16–25% Fe, 0.24–1.0% P, <0.2% S, 47–50% SiO_2 and 0.4–2.2% CO_2. A mineralized zone 100 m long, 40 m wide (all mineralizations together) and 100 m deep, gives a reserve of 1.2 million tonnes of ore.

Host rock: Greenstone composed of albite, hornblende and subordinate biotite and magnetite. Locally schistose and containing cm-wide veins and vugs with quartz, feldspar and amphibole, sometimes also calcite. In the greenstone there are up 20 m wide dikes or intercalations of porphyrite. An effusive character of the greenstone is supported by the presence of quartz-filled amygdules and numerous sedimentary intercalations. Up to 10 m wide bodies of a green-red, patchy, dense, albite-rich rock are common, cut by amphibole veins and strongly fractured. This albite-rock has probably a metasomatic origin.

Reference: Damberg and Nylund, 1973a.

SUMMARY

The presence of scapolite and small amounts of tourmaline, fluorite and analcime in the Kevus and Teltaja iron deposits indicate formation by hydrothermal,metasomatic processes with fluids rich in volatile components. The deposits have probably a volcanic–exhalative origin, being formed in connection with a silica–intermediate volcanism (Frietsch, 1985a). In the Kevus and Teltaja deposits the main ore mineral phase was magnetite–(haematite). This was later mobilized, giving the ore its intrusive mode of occurrence. The Ahmavuoma deposit differs from these, having a more complex ore mineralogy with iron oxides and copper–cobalt sulphides. In the Pirttivuopio deposit, magnetite is mainly associated with albite.

SULPHIDE ORES

In the Greenstone Group

Relatively common in the metasedimentary rocks of the Greenstone Group are small amounts of pyrrhotite and pyrite as disseminations or fine layerings. Occasionally chalcopyrite is associated in economic or subeconomic amounts. In the Viscaria copper mineralization, NW of Kiruna, chalcopyrite is present as a fine banding, even as impregnation and veinlets. The highest concentrations are found in marbles and graphite schists. Sphalerite is also present as disseminations and fracture fillings.

Scapolitization is wide spread in rocks of the Greenstone Group. The ore-forming effect of this process is rather restricted, however, and locally only small amounts of pyrite and pyrrhotite and traces of chalcopyrite were produced. Scapolitization is common in the host rocks of the skarn iron ores (cf. p. 00). It should be emphasized that scapolite is only exceptionally found in the ore itself, as in Norra Altavaara and Tapuli.

In some localities, however, scapolitization has given rise to copper–(gold) deposits. In the epigenetic Pahtohavare Cu–(Au) (chalcopyrite–pyrite–pyrrhotite–magnetite±native gold) deposit, SSW of Kiirunavaara and about 10 km S of the Viscaria deposit, the association with scapolitization is prominent (Martinsson, 1992, 1993; Martinsson and Söderholm, 1994; Martinsson, 1995). The deposit is hosted by albite-rich rocks (albite felsites) such as strata-bound to discordant zones in tuffite, black schist, and mafic sills. The ore is tectonically and stratigraphically controlled and occurs in stratabound to discordant alteration zones. The ore is related to late fracturing with quartz-rich impregnations, breccias and vein fillings. The most conspicuous feature is the strong alteration with formation of albite, scapolite and biotite, and the loss of graphite in the altered black schists.

In the Greenstone Group there are other epigenetic, hydrothermal copper deposits of the same type as Pahtohavare, such as at Pahtavaara, NE of Kiruna, and Jälketkurkkio, E of Kiruna (Martinsson, 1994). The deposits described below probably belong to the same ore type.

Ainasjärvi

Site: 10 km W of Svappavaara **Map sheet:** 29K/3d

Discovery: Boulders of magnetite and haematite mineralization found in 1898; magnetic measurement in 1898 and in 1940; diamond drilling in 1941–43; chalcopyrite boulders found in the mid-1950's. In the late 1960's, geochemical and geophysical investigations by SGU; diamond drilling in 1966–70 (7 holes), in 1977 (4 holes) and in 1979 (17 drill holes).

Structural features: The area is intensely faulted, with several fault systems of which the main one strikes NNE.

Mineralization: Breccia-like, lean iron mineralizations occur between Lake Mustalombolo and Lake Ainasjärvi. Magnetite, haematite, quartz and biotite, and some tourmaline and sphene, form the matrix of a breccia with fragments of quartzites, and to a small extent, quartz-bearing porphyries, albite porphyrites and albitophyres (probably all rocks formed by albitization–silicification). The wall rock is an albite porphyrite with intercalations of albitophyre which is locally sericite-altered. The breccia is of tectonic origin and the mineralization is metasomatically formed. The quartzite in the fragments is an altered felsic volcanic rock. In addition there is chalcopyrite in calcite veins in the strongly fractured bedrocks.

Host rock: Mainly felsic volcanic rocks (porphyries and porphyrites) of the Porphyry Group. Toward the SE there are tuffs, tuffites and marbles of the Greenstone Group. The tuffs–tuffites are locally scapolite-bearing. Most of the rocks are strongly fractured and contain rock fragments.

References: Frietsch, 1966; Eriksson and Hallgren, 1975; Person et al., 1981a.

Fjällåsen copper

Site: 35 km NW of Gällivare, 60 km S of Kiruna **Map sheet:** 28J/8g

Discovery: A partly new discovery in connection with geological mapping in 1968–70; magnetic and gravimetric measurements by SGU in 1967–70.

Mineralization: Epigenetic veins of lean copper mineralization with chalcopyrite, bornite, chalcocite, malachite, and azurite.

Host rock: Tuffite, amphibole schist, marble, greenstone, and skarn.

Reference: Gerdin et al., 1980.

Fjällåsen gold

Site: 35 km NW of Gällivare, 60 km S of Kiruna **Map sheet:** 28J/5g

Discovery: A partly new discovery in connection with geological mapping in 1968–70. Magnetic and gravimetric measurements by SGU in 1967–70. Probably connected with Fjällåsen copper mineralization

Mineralization: Epigenetic veins with bornite, digenite, and chalcopyrite in a variety of rocks, inclusive porphyrites. Contains 2.4 ppm Au. Tourmaline belongs the association.

Reference: Carlsson, 1982.

Oriasvaara

Site: 5 km S of Sattavaara **Map sheet:** 28L/6f

Discovery: By SGU by Slingram measurements in 1965.

Mineralization: Two mineralized horizons in greenstone and quartzite with impregnations and schlieren of pyrite, pyrrhotite, chalcopyrite and traces of bornite. Contains 0.01–1.25% Cu within an area of 10,000 m^2. Individual analyses show 0.2–0.5 g ppm Au and 0.1–15 ppm Ag. Locally, chalcopyrite impregnations occur in skarn-altered marble.

Host rock: Greenstone, quartzite and marble.

References: Padget, 1970; Carlson, 1982.

Rakkurijärvi

Site: 10 km S of Kiruna **Map sheet:** 29J/5g

Discovery: In 1968, magnetic, Slingram and IP measurements by SGU.

Mineralization: C. 1000 m long mineralization of magnetite with pyrite and chalcopyrite, extending NE–SW and dipping steeply SE. Contains around 25–35% Fe, 0.05% P (locally up to 0.4% P) and 1% S.

Reserves: 6 million tonnes of iron ore.

Host rock: Porphyrites, porphyries and greenstones, cut by syenite dikes. Copper mineralization in porphyries, greenstone and conglomerate; iron mineralization in skarn, porphyrite and greenstone.

Reference: Grip & Frietsch, 1973; Lilljequist & Johansson, 1979.

Särkivaara

Site: 5 km NW of Svappavaara **Map sheet:** 29K/3d

Discovery: In 1714. Investigated in 1942 and 1963 by geophysical measurements, and by diamond drilling in 1963–64 (2 holes).

Structural features: Adjacent to a ENE–WSW fault.

Mineralization: 2 m wide mineralization with pyrite, some chalcopyrite and molybdenite. Strikes NE–SW and dips 50°SE.

Host rock: Scapolite–fels intersected by 1–2 cm wide veins of epidote–chabazite-bearing pyroxene skarn. The sulphides are mainly associated with chabazite.

Reference: Eriksson and Hallgren, 1975.

Vieto

Site: 22 km WSW of Kiruna **Map sheet:** 29J/6c

General features: Cf. Vieto skarn iron ore (p. 00).

Discovery: By drilling, discovery of copper mineralizaton in 1967 in the eastern part of the iron ore. Slingram measurements in 1968, later followed by IP and resistivity measurements. In 1969–71, diamond drilling (9 holes totalling 1 220 m).

Mineralization: A 20 m wide low-grade, epigenetic chalcopyrite mineralization in quartz–calcite–chlorite-filled veins and in biotite–amphibole alteration in the hanging wall of the iron ore, in part conformable with that. To the paragenesis belong pyrite, sphalerite and molybdenite. The sulphide mineralization is associated with veins of amphibole, biotite, calcite and tourmaline, and probably later than the iron ore.

Reference: Eriksson et al., 1979.

Äijäjärvi Östra

Site: 15 km ENE of Svappavaara, 14 km W of Vittangi **Map sheet:** 29K/3h

Discovery: New discovery by SGU in 1965, followed by Slingram, self-potential, magnetic and gravimetric measurements; diamond drilling in 1967–69. Mining rights in 1972.

Mineralization: Several sulphide mineralizations of which the middle one is the largest and best investigated. Chalcopyrite, pyrite, pyrrhotite and some magnetite. Locally also some galena and sphalerite. The pyrite contains 0.14% Co.

Reserves: Estimated to more than 0.1 million tonnes with an average of 1% Cu (calculated on a cut-off 0.70% Cu). Other estimates give 0.136 million tonnes in schist–tuffite and 0.450 million tonnes in metamarls.

Host rock: Mafic schists and metamarls (scapolite-rich schists) which are intersected and surrounded by granite.

References: Nilsson, 1971; Eriksson and Hallgren, 1975; Lilljequist, 1981.

SUMMARY

The Ainasjärvi, Särkivaara and Östra Äijäjärvi sulphide mineralizations are formed by metasomatic alterations which caused alteration of the rocks of the Greenstone Group. A prerequisite seems to be proximity to fault and fracture zones.

In the Porphyry Group

SE of Malmberget in the Porphyry Group there are several hydrothermal Cu–(Au) mineralizations, of which Aitik and Nautanen are the most important. Disseminations and stringers of chalcopyrite, bornite, chalcocite, magnetite and pyrite occur in volcanic, pyroclastic and minor epiclastic rocks which are metasomatically altered with sericitization, scapolitization and tourmalinization (Frietsch, 1985a; Zweifel, 1976; Drake, 1992). A relationship to fault-fracture structures is a typical feature. In principle the ore forming process is the same as for the metasomatic copper ores in the Greenstone Group.

During the IOIP, other copper mineralizations of this type were discovered in rocks of the Porphyry Group. They occur as impregnations and veinlets, often accompanied by metasomatic alterations forming scapolite and tourmaline.

Kiskamavaara

Site: 24 km E of Svappavaara **Map sheet:** 29K/6f

Discovery: New discovery by SGU in 1966 as a geochemical anomaly; magnetic and Slingram measurements in 1967; copper mineralization found by SGU in 1975; diamond drilling 1972–78 by SGU (43 holes totalling 1 080 m.)

Mineralization: Impregnation and fissure fillings with cobalt-bearing pyrite, chalcopyrite, magnetite, haematite and minor amounts of bornite and molybdenite. Often associated with secondary calcite.

Reserves: 3.4 million tonnes of copper ore. Down to 100 m with an outcropping surface of 8080 m^2 there are 2.1 million tonnes with 0.54% Cu and 0.1% Co, alternatively with a surface of 24,000 m^2, 6.3 million tonnes with 0.37% Cu and 0.06% Co.

Host rock: Rhyolites and felsic tuffs, intermediate tuffites and mafic metavolcanic rocks, which are strongly tectonized, sericitized and locally albite-altered.

References: Eriksson and Hallgren, 1975; Persson, 1980, 1981, 1982; Persson et al., 1981b; Lilljequist, 1981.

Paurankilantto

Site: 10 km N of Svappavaara **Map sheet:** 29K/5e

Discovery: Magnetic and Slingram measurements by SGU in 1971, followed by diamond drilling.

Geological features: A NE–SW striking zone of albite-altered rocks, heavily faulted and fractured, with the formation of mylonites, fracture–breccias and cataclastic gneisses.

Mineralization: In the southern part of the zone there are altered porphyries, albitites, graphite–schists and tuffites which are brecciated by pyrrhotite and some chalcopyrite. In the northern part of the zone, sulphides occur in a calcite-cemented, limonite-weathered breccia with fragments of albitite.

References: Eriksson and Hallgren, 1975; Person et al., 1981a.

Tjårrojåkka

Site: 50 km WSW of Kiruna **Map sheet:** 29I/2i

Discovery: In 1970, found by SGU; in 1970–75, diamond drilling (62 holes totalling 14,678.44 m).

Geological features: Around the Tjårrojåkka apatite iron ore (cf. p. 00) there are several copper mineralizations which, however, are mostly without economic interest. The present investigated copper mineralization lies 400 m west of the iron mineralization in intermediate volcanic rocks and tuffites which dip 70–80°NNW. The provenance of the copper ore is unclear. The relationship to the nearby apatite iron ore is unknown. The breccia of the apatite iron ore is metasomatically altered, with formation of scapolite, sericite and feldspar and the copper mineralization is probably related to this process. Fault-fracture zones played important role for the transport of the fluids.

Mineralization: The copper mineralization which occurs as an impregnation in specific tuffitic layers consists of chalcopyrite, magnetite, bornite, pyrite and small amounts of haematite, chalcocite, covellite, and traces of gold. The magnetite is partly martitized. Later tectonic activation has mobilized the ore minerals, concentrating them into fissures. This concerns mainly chalcopyrite, magnetite–haematite, pyrite and bornite.

Reserves: The mineralization extends ENE–WSW, is 650 m long and 10–60 m wide. With a cut-off grade of 0.2% Cu, the area at the surface covers 21,000 m^2. A cut-off grade of 0.4% Cu and a depth of 200 m gives 3,23 million tonnes of ore with 0.87% Cu. If the intervening parts with lower grades are included, the tonnage increases to 5,58 million, with 0.68% Cu. A cut-off grade of 0.2% Cu gives 13,08 million tonnes ore with 0.43% Cu.

Host rock: Intermediate volcanic rocks, tuffite and felsic volcanic rocks which are folded and tectonized. Tectonized and altered metabasites are common.

References: Ros, 1970, 1971, 1979; Ekström, 1978.

SUMMARY

The sulphide occurrences are associated with tectonic zones (fractures and faults). Albitization and metasomatic alteration have played an important role.

MAGMATIC–TECTONIC IRON ORES

GENERAL FEATURES

Iron ores of varying type and age, magmatically and partly tectonically related.

Nalmoinen

Site: 19 km WSW of Övre Soppero **Map sheet:** 30K/1f

Discovery: New discovery by airborne measurement in 1967 by SGU; in 1968, magnetic and gravimetric measurements.

Geophysical features: Magnetic anomaly, 750 m long and narrow, extending NNW. In addition, there are E–W-striking magnetic anomalies.

Structural features: The mineralization is tectonically emplaced along NW-striking tectonic zones.

Geological structures: No outcrops have been found. In the southern end of the anomaly there are a few boulders of a thin-banded magnetite mineralization containing feldspar, quartz , pyrite and some chalcopyrite.

Mineralization: Probably similar to Palovaara, cf. below.

Host rock: The deposit is situated on the eastern slope of the hillock Karittinenvaara in Archaean quartz–biotite–feldspar gneisses which strike N20–30°E and dip 20–40°E.

Reference: Cf. Palovaara.

Palovaara

Site: 20 km N Övre Soppero **Map sheet:** 30K/7j

Discovery: New discovery by airborne measurement by SGU in 1967; magnetic and gravimetric measurements in 1968; detailed magnetic mapping in 1969; in 1972 diamond drilling (one hole of 154.33 m).

Geophysical features: A magnetic anomaly area 900–1000 m long and extending NNW. The strongest anomalies follow NNW and N–S directions, and represent two different fault systems.

Geological structures: The deposit lies in an area covered by Archaean gneisses, about 2 km west of the Tjärro quartzite which forms the border against the Proterozic rocks to the east. The supracrustal rocks consist mainly of mafic volcanic rocks and sedimentary rocks. The mineralization is tectonically emplaced along fracture zones in a NNW–NW direction. To the east is the Rautukursu tectonic zone striking WNW and cutting the mineralization.

Mineralization: Up to 5 cm wide veins of magnetite and quartz, usually zoned, with magnetite towards the border and quartz in the centre. Later tectonization has mobilized the veins. Locally the granitic host rock has been brecciated by magnetite with up to 0.5 cm large, intensely red-coloured angular granite fragments in a magnetite matrix. Veins of pyrite cut the granite. The greenstone fragments within the granite also contain magnetite veins.

The drill hole contained 5 m ore with 7.7% Fe, 0.055% P and 0.76% S.

Host rock: Grey, fine-grained, non-deformed, homogeneous granite, cutting the supracrustal rocks. The colour changes from grey to red towards the ore. Near the ore it has a 'flamy' appearance and contains irregular white phenocrysts. The granite contains schlieren of dark minerals, mainly remnants of an amphibolite. East of the granite there is a greenstone grading into a gabbroid rock.

Reference: Hallgren, 1972.

Puoltsa

Site: 15 km WSW of Kiruna **Map sheet:** 29J/5e

Discovery: New discovery by SGU by airborne magnetic measurement in 1960; magnetic and gravimetric measurements in 1961; in 1963–67, diamond drilling (46 holes totalling 9740 m).

Geophysical features: Geophysical measurements showed that the ore in the central part lies in a synformal structure striking E–W . Reinterpretation after drilling shows that the rocks strike NNE, and lie in complex synform with the fold axis 35°NE.

Geological structures: Iron ore and skarn are interlayered in andesitic greenstone and rhyolite which are cut by dikes of metabasite and granite. A number of faults and fracture zones strike N–S, NW–SE and E–W. North of the area there is large fault zone striking WNW.

Mineralization: Magnetite and skarn are associated. Ore is defined as >20% Fe. The skarn consists of diopside, tremolite, hornblende, and locally also olivine and serpentine. Most common is a diopside–tremolite skarn, usually as impregnation in massive ore, in richer ore as aggregates. Smaller parts of the ore show skarn layering and locally also calcite layering. The magnetite ore contains inclusions of skarn, in particular olivine–serpentine and some phlogopite (biotite). The magnetite is magnesia-bearing, with 0.3–1.5% Mg. The serpentine contains remnants of olivine, diopside, and tremolite. Diopside is altered into tremolite. The skarn rich in tremolite–hornblende contains scapolite, as banding and patches, and small amounts of calcite.

Reserves: The ore-bearing area covers 160,000 m^2. 32 000 m^2 are covered by a greater single ore body in the west. Down to 200 m depth there are 31.5 million tonnes of ore with an average of 34.3% Fe, 0.037% P (large parts <0.005% P) and 0.019% S.

Host rock: Scapolite-altered greenstone consisting of andesites to trachyandesites, the latter in part rich in magnetite. The better preserved parts contain, in a feldspar–biotite–hornblende matrix, laths of a somewhat sericite-altered plagioclase. The rocks are intersected by veins and schlieren of hornblende and magnetite. The border between ore skarn and host rock is mostly sharp; where the greenstone is hornblende-altered, the border is diffuse. The rocks are locally strongly scapolite-altered and contain biotite, actinolite, epidote, carbonate, sphene, apatite and chlorite.

A subordinate rhyolite is interlayered with ore–skarn and greenstone. The border between ore–skarn and rhyolite is mostly sharp. The rhyolite is cut by dikes of scapolite-altered metabasite and perthite granite.

References: Hallgren et al., 1973; Martin, 1980.

Saivo

Site: 18 km ENE of Kiruna **Map sheet:** 29K/8a

Discovery: By SGU by regional bedrock mapping in 1962; magnetic and gravimetric measurements in 1967–68; detailed geological mapping in 1970–71.

Mineralization: In a syenite, a 250 m long and 50–60 m wide and E–W-striking skarn zone resembling a fissure-filling. In an associated gabbro and in the syenite are narrow veins of skarn. The skarn contains sharp-wedged fragments of the syenite in a breccia-like formation. The main skarn body consists of diopside (with up to 50 cm long crystals), magnetite, sphene, ankerite and plagioclase. At the contact between skarn and syenite there are up to 5–6 m wide bodies of magnetite which contain up to 10–20 cm long crystals. The magnetite, which is associated with diopside, amphibole and sphene, contains up to 3% Ti. The order of formation is gabbro – syenite – skarn – magnetite.

Host rock: In a gabbro intrusion there is a perthite syenite which partly is of granitic composition and here porphyritic. The syenite consists of albite–oligoclase, perthitic microcline and subordinate diopside, tremolite–actinolite, quartz, epidote, magnetite and sphene. The syenite and gabbro pass into each other gradually. The syenite contains irregular, schlieren-like remnants of the gabbro which are mostly scapolitized.

References: Frietsch, 1970, 1980; Eriksson and Hallgren, 1975; Lehto, 1975.

SUMMARY

The deposits form a rather incoherent group. The Nalmoinen and Palovaara deposits are clearly intrusive and are without doubt related to tectonic zones at the edge of the Archaean craton. The absolute age of the mineralization is unknown. In Palovaara the magnetite is younger than the host rock granite, which is probably Archaean.

The origin of the Puoltsa deposit is enigmatic. The abundance of skarn, its composition and the relatively high content of magnesium in the magnetite show similarity to the skarn iron ores. However, the low sulphur content and the felsic to intermediate-composition volcanic host rocks are untypical for the skarn iron ores. Magnetite and skarn have an intrusive mode of replacement which points to a Kiruna type of ore. The low phosphorus content does not indicate an iron ore of the Kiruna type, even though there are many examples of a low P-content in this ore type. The deposit lies close to large faults. Consequently, a magmatic origin is therefore advocated.

The Saivo deposit is of unique character and most likely represents a magma intrusion with a pegmatitic rest of Ti–magnetite–amphibole.

TITANIFEROUS ORES

GENERAL FEATURES

Titaniferous ores in mafic to ultramafic intrusive rocks of different age.

Akkavare (Melko)

Site: 40 km WNW of Gällivare **Map sheet:** 28J/2e

Discovery: Older investigations probably in the late 1890's. The Stora Kopparbergs Bergslags AB carried out magnetic measurements and diamond drilling in 1957–58 (14 holes totalling 480.24 m). SGU made airborne magnetic measurements in 1965 and in 1968 magnetic, gravimetric and Slingram measurements over the part belonging to Bergverks Freja AB.

Structural features: In the northern part of the intrusion there is a fault striking N10°W and dipping 60–65°E. The northern block has moved toward the north and is down-faulted.

Geological features: A 5.8 km long intrusion striking NNE, 0.6 km wide in the southern part and 1.2 km wide in the northern part. The bottom of the gabbro is 160–230 m below the surface, increasing towards north to 430 m.

Mineralization: Concentrations of magnetite with lamellae of ilmenite. Associated with pyroxene, hercynite, some pyrrhotite and traces of pyrite and chalcopyrite. The content of sulphides increases with the ore grade. The richer mineralizations occur in the northern part. The mineralizations are up to some dm wide and up to 50 m long. In the northern part, a 27 m wide mineralization with 25.9% Fe and 4.3% Ti and a 16 m wide mineralization with 24.6% Fe and 3.5% Ti. The average content is 21.4% Fe and 3.3% Ti. The magnetite contains 0.2–0.3% V and the pyrrhotite, 0.3–1.1% Co.

Host rock: A noritic gabbro with a diffuse layering dipping gently SE, probably belonging to the older Proterozoic intrusive rocks. The gabbro consists of andesine–labradorite, enstatite–hyperstene, uralitic hornblende, small amounts of biotite, chlorite, hercynite and apatite (up to 9.7 volume%). The gabbro is bordered by a granite and intersected by pegmatite veins.

References: Frietsch, 1969; Ambros and Henkel, 1973; Grip and Frietsch, 1973.

Pajala Södra

Site: 1 km S of Pajala **Map sheet:** 28M/5f

Discovery: Magnetic and gravimetric measurements by SGU in 1965; in 1967, one borehole, of 145.50 m.

Geophysical features: N–S striking magnetic anomaly, to the north curving E–W (by faulting?).

Mineralization: Altered gabbro or diorite with magnetite.

Reference: Cornwell, 1967.

Peräjävuoma

Site: 20 km WSW of Pajala **Map sheet:** 28M/5b

Discovery: New discovery in 1961 by airborne measurements by SGU. Magnetic and gravimetric measurements in 1965–67 by SGU; in 1970 diamond drilling (2 holes totalling 263.72 m).

Geophysical features: Two weak, adjacent, 1 km long magnetic anomalies, the northern one striking E–W, and with a width of up to 300 m, the other striking ENE and a width of up to 100 m.

Mineralization: Sparse mineralization of magnetite and ilmenite, small amounts of pyrite and haematite. Analyses of the southern anomaly show 7.1–13.5% Fe, 1.55–2.14% Ti. The magnetite concentrate contains 0.42% Ti and 0.23% V.

Host rock: Coarse, scapolitized meta–gabbro consisting of andesine, amphibole, biotite and pyroxene. Apatite is a common minor constituent, analyses show 0.60–2.72% P. The gabbro is surrounded by a coarse-grained granite.

Reference: Rönnbäck and Ros, 1971b.

Ruoutevare (Routevare, Ruotivare)

Site: 15 km NV Kvikkjokk **Map sheet:** 27H/7–8f

Discovery: Known since the 18th century. Geological mapping in 1910 and in 1970. SGU carried out magnetic and gravimetric measurements and diamond drilling in 1971–73 (32 holes totalling 6233 m).

Geological structures: The ore occurs in a mafic intrusion within the Seve Nappes of the Caledonian mountain range.

The ore-bearing area is c. 1500 m long and up to 200 m wide. The ore lenses strike NW and dip gently towards SW. There are probably two lenses lying one above the other. The ore outcrops in the eastern part. The largest ore body, which outcrops in the central part of the deposit, is an approximately 1000 m long and 20–150 m thick lens which dips 15°WNW. A smaller ore body, about 600 m long, 350 m wide and 40–110 m thick, is present in the SE part, where it forms the so-called 'wall of Hermeline'. The dip is 25°WSW, probably under the larger ore body. The massive ore is surrounded by a breccia in which the ore forms veins, lenses and lumps in the host rock anorthosite. The ore forms apophyses from the main ore bodies or also separately. The ore encloses anorthosite fragments several metres in length.

Mineralization: The ore consists of magnetite, ilmenite, spinel, and small amounts of pyrrhotite, chalcopyrite and pentlandite. Locally, corundum and högbomite are found. Limonite occurs in the upper part of the ore. The silicates in the ore are plagioclase, olivine, pyroxene and garnet. The ore is often tectonically affected and there are gradations between massive ore, schistose ore and columnar ore. Ilmenite has been mobilized by the tectonization and the magnetite–ilmenite relationship has changed. In the least affected parts the ore is coarse to middle grained with < 2 cm long grains of magnetite and ilmenite, and 0.5 cm long grains of spinel. In the tectonized parts there are recrystallized lenses of striped and flattened ilmenite.

Reserves: The ore defined as >15% Fe has an outcropping area of 387,000 m^2. The average thickness is 75 m. The reserves are 116 million tonnes of ore, with an average of 38.2% Fe, 5.6% Ti and 0.17% V.

Host rock: Anorthosite locally grading into gabbro. The anorthosite consists of saussuritized plagioclase, uralitic pyroxene, partly chlorite-altered garnet and biotite. Ore and anorthosite are cut by greenstone dikes at an oblique angle to the schistosity.

References: Tegengren, 1910; Nyström, 1970; Nyström et al., 1975.

SUMMARY

The deposits are typical Ti-bearing magnetite ores in mafic to ultramafic intrusions. They probably all belong to the older Svecofennian intrusions. The Ruoutevare ore occurs within Caledonian rocks but is probably of Precambrian age.

OTHER (NON-FERROUS) DEPOSITS DISCOVERED AND INVESTIGATED IN NORRBOTTEN COUNTY DURING THE IRON ORE INVENTORY PROGRAMME

The main aim of the Iron Ore Inventory Programme was to make a survey of the iron ore occurrences of the Norrbotten County. However, a number of mineralizations of other metals were investigated simultaneously (Table 4). A short description is given in the present report. Most of the occurrences comprise epithermal, magmatic base metal deposits mainly in supracrustal rocks associated with the Porphyry Group. In addition graphite and uraninite in rocks of the Greenstone Group are dealt with.

MAGMATIC SULPHIDE ORES IN SOUTHWESTERN NORRBOTTEN

In the southwestern part of the Norrbotten County, between Malmberget and Arvidsjaur, there is in the felsic–mafic volcanic rocks and associated sedimentary rocks of the Porphyry Group a metallogenetic province with about 40 minor Cu–Zn-Pb-(Ag) deposits. The copper minerals are chalcopyrite, bornite, covellite and chalcocite. Commonly present are sphalerite, galena, pyrrhotite, pyrite and magnetite. The gangue is made up of quartz, chlorite, calcite, biotite and feldspar. Locally fluorite, garnet, tourmaline, scapolite and gahnite belong to the association.

The host rocks are mostly felsic, partly tuffitic volcanic rocks. Other host rocks are intermediate-mafic volcanic rocks, metasedimentary gneisses with pelites, quartzites and sericite-rich rocks. Locally cordierite–garnet–sillimanite–amphibole–mica–gahnite-bearing gneisses and anthophyllite–hornblende–sillimanite–andalusite–cordierite– garnet gneisses are present.

The mineralizations occur discordantly, as breccias and vein fillings, and in shear and crush zones. The Iekelvare mineralization occurs in different rocks (granite, diorite and volcanite), indicating the epigenetic nature of the ore. Quite a number of the mineralizations are related to major fault zones, striking mainly NE–SW, NNE–SSW and E–W. In some deposits there are metasomatic alterations such as sericitization.

Many of the deposits were investigated geophysically and diamond drilled at the same time as the IOIP: Ballek Norra, 16 km ENE of Arjeplog; Ljusträsk (Gåbdejaure Östra), 4 km SSW of Ljusträsk; Iekelvare, 25 km WNW of Jokkmokk; Jårbojoki, 13 km SE of Aitik; Lullepotten, 14 km ENE of Arjeplog which is the largest of the sulphide deposits in southern Norrbotten, containing 4.2 million tonnes of ore with c. 1% Cu; and Vargisträsk.

The deposits are of magmatic origin, formed by near-surface solutions. The $\delta^{34}S$ values of the sulphides are around zero per mil, indicating a magmatic origin of the sulphur (Frietsch et al., 1995). The galenas have mainly a homogeneous lead isotopic composition and lie in a range similar to that of the sulphide deposits associated with the Central Finnish batholith (Vaasjoki, 1981) and of the North-Central Skellefte district (Billström et al., 1997), indicating that these terrains formed a single crustal unit at the time of ore deposition.

Non-metallic mineralizations in the Greenstone Group

Graphite

The rocks of the Greenstone Group of the Vittangi area contain numerous occurrences of graphite-bearing schist. The Maltosrova deposit, 20 km W of Vittangi, was measured electrically by SGU in 1966–67. A 6 m wide and 800 m long graphite schist containing more than 40% C was indicated. There are other graphite schists of economic interest 4 km NE and 4 km N of Maltosrova. The Nunasvaara graphite deposit within the Vittangi area was also investigated during the 1960's.

Uranium

By airborne radiometric measurements, made in 1969 by SGU, the Pålänge phosphorite, 40 km NE of Luleå, was found in a sequence of 2.1–2.3 Ga rocks of the Greenstone Group, consisting of metasedimentary rocks and mafic volcanic rocks covering the coast of Kalix and eastwards into Finland. The phosphorite, which consists of apatite, pyrite, pyrrhotite, graphite, quartz, phlogopite and accessory uraninite and rutile, was investigated for uranium. Apatite occurs as layers and fragments in a breccia which has been deformed and mobilized by metamorphism. Analyses show around 0.03% U and the reserves to a depth of 100 m are 1800 tonnes U and 120,000 tonnes P_2O_5 (Gustafsson, 1979; Frietsch and Perdahl, 1995).

The Kopparåsen (Kuokel) uranium deposit, in a window in the Caledonides, contains a complex sulphide–uranium mineralization in rocks of the Greenstone Group. The zinc–lead–copper sulphides are syngenetic in the metasedimentary rocks, whereas the uranium occurs in epigenetic quartz veins.

SUMMARY OF RESULTS OBTAINED BY THE IRON ORE INVENTORY PROGRAMME

Iron ore types

The work of the Iron Ore Inventory Programme was intended to compile a survey of the iron mineralizations in the Norrbotten County, as concerns their existence, the reserves, and the geological features of the various ore types. The mineralizations investigated by the Programme are shown in Table 1.

The investigated iron ore types are:

(a) apatite iron ores of the Porphyry Group,
(b) skarn iron ores of the Greenstone Group,
(c) quartz-banded iron ores of the Greenstone Group,
(d) quartz-banded iron ores of the Porphyry Group,
(e) epigenetic, metasomatic ores associated with scapolite–albite–tourmaline:
1) iron ores, 2) sulphide ores in the Greenstone Group, and 3) sulphide ores in the Porphyry Group,
(f) magmatic–tectonic iron ores, and
(g) titaniferous ores.

Of these types (e) and (f) have not been described previously.

Non-iron mineralizations, investigated simultaneously with the iron ores, are graphite and uraninite of the Greenstone Group, and magmatic base metal sulphide ores in the Porphyry Group of southwestern Norrbotten (Table 4).

Resources of iron ore

75 iron mineralizations were investigated, of which 22 are new discoveries (Tables 1 and 5). In all the deposits investigated (previously known and newly discovered) 1122.7 million tonnes of iron ore were found (Tables 2 and 3). Only major deposits are included; no figures are given for minor mineralizations. 14 major new discoveries contain 294.4 million tonnes of ore. For seven newly discovered deposits, mining rights were taken out in the name of the Crown.

The reserves in the investigated deposits are:

(a) apatite iron ores of the Porphyry Group in 31 deposits comprising about 200 million tonnes of ore, of which 6 are new discoveries with about 139 million tonnes;
(b) skarn iron ores of the Greenstone Group in 32 deposits comprising about 500 million tonnes of ore, of which 5 are new discoveries with about 26 million tonnes;
(c) quartz-banded iron ores of the Greenstone Group in 3 deposits comprising about 9 million tonnes of ore;
(d) quartz-banded iron ores in the Porphyry Group in 6 deposits comprising about 190 million tonnes of ore, of which 2 are new discoveries with about 100 million tonnes;
(e) epigenetic, metasomatic iron ores associated with scapolite, albite and tourmaline in 2 new discoveries comprising about 83 million tonnes;
(f) magmatic–tectonic iron ore in one new discovery with about 32 million tonnes of ore, and
(g) titaniferous ore in one deposit of about 116 million tonnes of ore.

The largest new discoveries are: 1) about 100 million tonnes of quartz-banded iron ores in the Jokkmokk area, 2) about 68 million tonnes in the Pattok apatite iron ore of the Porphyry Group, 3) about 55 million tonnes in the Tjårrojåkka apatite iron ore of the Porphyry Group, and 4) about 32 million tonnes of iron ore in Puoltsa of magmatic-tectonic origin.

Resources of non-ferrous metals

The exploration also resulted in the discovery of some copper mineralizations adjacent to iron mineralizations such as Tjårrojåkka and Vieto. Of these only Tjårrojåkka is of importance. The deposit, which is probably associated with hydrothermal alterations of the Porphyry Group, contains 3.2 million tonnes of 0.87% Cu ore.

Simultaneous with work of the Iron Ore Inventory Programme some sulphide ore deposits were discovered: 1) Äijäjärvi with 0.1 million tonnes of 1% Cu ore, associated with scapolite in the rocks of the Greenstone Group; 2) Kiskamavaara with 2.1 million tonnes of ore with 0.5% Cu and 0.1% Co, associated with scapolitized-albitized rocks of the Porphyry Group, and 3) Lulepotten with 4.2 million tonnes of 1% Cu ore, formed by epigenetic, volcanogenic processes in the rocks of the Porphyry Group.

New knowledge of ore petrology and genesis

The Iron Ore Inventory Programme greatly improved the knowledge of the size, quantity and quality of the mineralizations of iron and certain other metals in Norrbotten County. The knowledge of the metallogenetic features was also enhanced. During the Programme an immense amount of geological, geophysical and diamond drilling data was collected. Older knowledge of the geology and ore formation had to be revised. New and improved knowledge of the bedrock geology was obtained by 1) geological mapping on a scale of 1:50,000 of large parts of the region, covering many map sheets; 2) airborne, low-altitude geophysical measurements which supplied the 'backbone' for the geological maps; and 3) detailed geological and geophysical mapping of the ore-bearing belts and individual deposits, such as Kaunisvaara, Svappavaara, Vittangi, Masugnsbyn, Ekströmsberg and Tjårrojåkka. These works form the basis for the present understanding of the metallogenesis of the ore-bearing areas in Norrbotten. This knowledge facilitated the discovery of new mineralizations made during the last decade.

ACKNOWLEDGEMENTS

I am grateful to Leif Björk, Bo Gustafsson and Arne Sundberg at the Geological Survey of Sweden for their help to make the present report possible. Without their support the report would not have been possible to carry out. In particular I thank Bo Gustasson for the compilation of the maps. Max Brant has kindly corrected the English manuscript.

REFERENCES

SGU = Sveriges Geologiska Undersökning; Geological Survey of Sweden

Ambros, M., 1980: Beskrivning till berggrundsbladen Lannavaara NV, NO, SV, SO. – SGU Af 25–30.

Ambros, M. & Henkel, H., 1973: Titanjärnmalmsfyndigheten Akkavare (Melko), kartbladet 28J Fjällåsen. – SGU BRAP 00696. 12 pp.

Ambros, M. & Nylund, B., 1977: Lannavaarafälten. Resultat av SGU:s undersökning 1967–1971. – Malmbyrån, SGU. 75 pp.

Ambros, M., Nylund, B. & Mannström, B., 1973: Pattok järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1963–72. – Malmbyrån, SGU. 44 pp.

Billström, K., Frietsch, R. & Perdahl, J.-A., 1997: Lead isotopic compositions of galena in Paleoproterozoic mineralizations in northern Sweden and their bearing on local crustal evolution. – Prec. Research 81, 83–99.

Carlsson, L., 1982: Guld i Norrbotten. Del 2. – Berggrundsbyrån, SGU. BRAP 82040. Bilaga 42.

Cliff, R.A., Rickard, D. & Blake, K., 1990: Isotope systematics of the Kiruna magnetite ores. Part 1. Age of the Ore. – Economic Geology 85, 1770–1776.

Cornwell, J.D., 1967: Pajala Syd. Report. – Malmbyrån, SGU. 4 pp.

Damberg, K. & Nylund, B., 1973a: Pirttivuopio järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1968–69. – Malmbyrån, SGU. 13 pp.

Damberg,K. & Nylund, B., 1973b: Suolojåkk järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar 1964–69. – SGU Malmbyrån, 14 pp.

Damberg, K., Oldeberg, H. & Nylund, B., 1974a: Laukkujärvi järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1963-69. – Malmbyrån, SGU. 19 pp.

Damberg, K., Oldeberg, H. & Nylund, B., 1974b: Årosjåkk järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1963–69. – SGU, Malmbyrån.19 pp.

Damberg, K., Nylund, B. & Mannström, B., 1974c: Tornefors järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1949, 1966, 1970. – Malmbyrån, SGU. 23 pp.

Danielssson, S. & Cornwell, J., 1977: Nakerivaara järnmalmsfyndighet. – Malmbyrån, SGU. BRAP 77501. 28 pp.

Danielssson, S., 1982: Undersökning av kobolt i pyritiska järnmalmer i norra Norrbotten. Report February 1982. – Berggrundsbyrån, SGU. BRAP 82015. 10 pp.

Danielsson, S. & Johansson, L. 1979: Resultat av geologiska, geofysiska och geokemiska arbeten samt borrning. – Malmbyrån, SGU. BRAP 79011.

Danielsson, S., Johansson, L. & Magnusson, J., 1980: Nunasvaaraområdet. Sammanställning av sulfidmalmsuppslag och utförda prospekteringsarbeten. – Berggrundsbyån, SGU. BRAP 80054. 18 pp.

Drake, B., 1992: Aitik copper mine. Geologi, 19–23.

Ekström, M.,1978: Mineralogisk karakteristik av kopparmineraliseringen vid Tjårrojåkka. – Berggrundsbyrån, SGU. BRAP 78002, 13 pp.

Eriksson, B., 1969: Berggrunden inom centrala Vittangifältet, stratigrafi och tektonik. – Lic. work, Stockholms Universitet. 75 pp.

Eriksson, B. & Espersen, J., 1965: Altavaara järnmalmsfyndighet. Rapport rörande SGU:s arbeten under åren 1961–1964. – Malmbyrån, SGU. 15 pp.

Eriksson, B. & Hallgren, U., 1975: Beskrivning till berggrundskartbladen Vittangi NV, NO, SV, SO. – SGU Af 13–16.

Eriksson, T. & Ödman, O.H., 1948: Järnmalmen vid Björkholmen i Jokkmokks socken. – Berggrundsbyrån, SGU. 13 pp.

Eriksson, B., Frietsch, R., Nylund, B. & Johansson, K., 1979: Vieto järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar. – Berggrundsbyrån - geofysiska byrån, SGU. BRAP 79508. 35 pp.

Frietsch, R., 1957: Järnmalmsförekomster inom Norrbottens län. – SGU. 34 pp.

Frietsch, R., 1960: PM rörande borrningarna på Nakerivaara. – SGU Report. 1 pp.

Frietsch, R., 1967: The relationship between magnetite and haematite in the iron ores of the Kiruna type and some other iron-ore types. – SGU C 625.
Frietsch, R., 1969: P.M. rörande titanjärnmalmen Melko (Akkavare). – SGU BRAP 00693.
Frietsch, R., 1970: Trace elements in magnetite and haematite in the iron ores of the Kiruna type and some other ore types. – SGU C 646.
Frietsch, R., 1973a: The origin of the Kiruna iron ores. – Geol. Fören. Förh. Stockholm 95, 375–380.
Frietsch, R., 1973b: Precambrian iron ores of sedimentary origin. In Genesis of Precambrian iron and manganese deposits. Proc. Kiev Symp. 1970. – UNESCO. Pp. 77-83.
Frietsch, R., 1974a: The occurrence and composition of apatite with special reference to iron ores and rocks in northern Sweden. – SGU C 694.
Frietsch, R., 1974b: The Ekströmsberg ore deposit, northern Sweden. – SGU C 708.
Frietsch, R., Nylund, B. & Oldeberg, H., 1974: Ekströmsbergs malmfyndighet. Rapport rörande SGU:s undersökningar 1961–1969. – SGU, Malmbyrån. 93 pp.
Frietsch, R., 1977: The iron ore deposits in Sweden. *In* A. Zitzman (ed.). The Iron Ore Deposits of Europe and Adjacent Areas. Explanatory note to the International map of iron ore deposits of Europe. – Bundesanstalt für Geowissenschaften und Rohstoffe, vol. 1, 279–293.
Frietsch, R., 1978: On the magmatic origin of the iron ores of the Kiruna type. – Econ. Geol. 73, 478–485.
Frietsch, R., 1979a: Järnmalmsfyndigheterna Toppi, Njuotjama and Rensjön. – Report, Berggrundsbyrån, SGU.
Frietsch, R., 1979b: Järnmalmsfyndigheten Tjavelk. – Berggrundsbyrån, SGU. BRAP 79507. 9 pp.
Frietsch, R., 1980: Volcanism and iron ores in the Precambrian of Sweden. In: Metallogeny of the Baltic Shield. Proc. symposium 1978, Helsinki. – Geol. Surv. Finland Bull. 307, 25–37.
Frietsch, R., 1984: Petrochemistry of the iron ore-bearing metavolcanics in Norrbotten county, northern Sweden. – SGU C 802.
Frietsch, R., 1985a: The Lannavaara iron ores Northern Sweden. – SGU C 807.
Frietsch, R., 1985b: Formation of Mg-bearing magnetite and serpentine in skarn iron ores in Northern Sweden. – Geol. Fören. Stockholm Förh. 106, 219–230.
Frietsch, R., 1991: New ore types in the northern part of the Fennoscandian shield. – Geol. Fören. Stockholm Förh. 113, 46–48.
Frietsch, R . & Perdahl, J-A., 1989: Geochemical features of Early Proterozoic volcanites in the Aitik sulphide ore and some other sulphide and iron ores in Norrbotten, northern Sweden. – Research Report TULEA 1989:25. Luleå University of Technology. 63 pp.
Frietsch, R. & Perdahl, J-A., 1995: Rare elements in apatite and magnetite in Kiruna-type iron ores and some other iron types. – Ore Geology Reviews 9, 489–510.
Frietsch, R., Nylund, B. & Oldeberg, H. 1974: Ekströmsbergs malmfyndighet. Rapport rörande SGU:s undersökningar 1961–1969. – Malmbyrån, SGU. 93 pp.
Frietsch, R., Billström, K. & Perdahl, J., 1995: Sulphur in Lower Proterozoic iron and sulphide ores in northern Norrbotten. – Mineral. Deposita 30, 275–284.
Frietsch, R., Tuisku, P., Martinsson, O. & Perdahl., J-A., 1997: Early Proterozoic Cu-(Au) and Fe ore deposits associated with regional Na-Cl metasomatism in northern Fennoscandia. – Ore Geology Reviews 12, 1–34.
Geijer, P., 1918: Det grafit- och järnmalmsförande området vid Vittangi. – SGU C 284.
Geijer, P., 1924: Some Swedish occurrences of bornite and chalcocite. – SGU C 321, 15–20.
Geijer, P., 1931: The iron ores of the Kiruna type. Geographical distribution, geological character and origin. – SGU C 367.
Geijer, P., and Ödman, O.H., 1974: The emplacement of the Kiruna iron ores and related deposits. – SGU C 700.
Gerdin, P., Johansson, L. & Magnusson, J., 1980: Resultat av utförda prospekteringsarbeten. – Berggrundsbyrån, SGU. BRAP 80010. 16 pp.
Grip, E. & Frietsch, R., 1973: Malm i Sverige 2. – Almqvist and Wiksell, Stockholm.
Gustafsson, B., 1979: Uranuppslag inom Norrbotten och Västerbotten. – Swedish Geological Survey, berggrundsbyrån, BRAP, 79056. 17 pp.
Hallgren, U., 1970: Sautusvaara järnmalmsfyndighet. – Malmbyrån, SGU. 110 pp.

Hallgren, U., 1972: Borrprotokoll Palovaara 72001. – SGU.

Hallgren, U., Nylund, B. & Eriksson, B., 1973: Puoltsa järnmalmsfyndighet. Rapport rörande SG:s undersökningar under åren 1961–1967. – Malmbyrån, SGU. 44 pp.

Huhma, H., Cliff, A.R., Perttunen, V. & Sakko, M., 1990: Sm-Nd and Pb isotopic study of mafic rocks associated with Early Proterozoic continental rifting: the Peräpohja schist belt in northern Finland. – Contributions to Mineralogy and Petrology 104, 369–379.

Johansson, L., 1980: Jokkmokksområdets järnmalmer. Geofysisk tolkning med malmberäkning. – Geofysiska byrån, SGU. FM 8012. 14 pp.

Johansson, L., 1981: Gäddmyr. – SGU geofysikrapport. FM 8109

Krill, A.G., Bergh, S., Lindahl, I., Mearns, E.W., Often, M., Olerud, S., Olsen, O., Sandstad, J.S., Siedlecka, A. & Solli, A., 1985: Rb-Sr, U-Pb and Sm-Nd isotopic dates from Precambrian rocks of Finnmark. – Norges Geol. Undersökn. Bull. 403, 37–54.

Lehto, T., 1975: Järnmalmsfyndigheten Saivo, Norrbotten, norra Sverige. – Pro gradu thesis, Åbo Akademi. 57 pp.

Lehto, T., 1983: Ahmavuoma. LKAB prospektering. – Rapport K 85-4. 12 pp.

Lehto, T., 1987: Ahmavuoma. – Årsrapport 1986. LKAB prospektering. Rapport K 87-11. 9 pp.

Lilljequist, R., 1981: Sammanfattning av utförda prospekteringsarbeten 1975–80 (i Vittangifältet) samt synpunkter på områdets malmpotential. – SGU. 21 pp.

Lilljequist, R. & Johansson, L., 1979: Mineraliseringarna vid Rakkurijärvi. SGU BRAP 79055.

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

Lindroos, H., 1979: Leppäjoki järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1969–1972. – Malmbyrån, SGU. BRAP 79505. 5 pp.

Lindroos, H. & Johansson, K.I., 1972: Ruutijärvi järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1963–1971. – Malmbyrån, SGU. 19 pp.

Lindroos, H. & Mannström, B., 1971: Renhagen järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1962–1969. –Malmbyrån, SGU. 24 pp.

Lindroos, H., Nylund, B. & Eriksson, L., 1972a: Salmivaara järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1967–1971. – Malmbyrån, SGU. 35 pp.

Lindroos, H., Nylund, B. & Johansson, K., 1972b: Tapuli och Palotieva järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1963–1969. – SGU BRAP 00764. 36 pp.

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

Lundberg, B. & Werner, S., 1965: Stora Sahavaara järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1960–64. SGU. 53 pp.

Lundbohm, H. & Wallin, G., 1918: PM angående Svenska Emissionsbolagets malmfyndigheter i Lappland. – SGU. 3 pp.

Martin, J., 1980: Mineralogisch-lagerstättenkundliche Untersuchungen an Bornkernen aus der Eisenerzlagerstätte Puoltsa bei Kiruna/Nordschweden. Diplomarbeit. – Institut für Mineralogie und Lagerstättenlehre an der Rheinisch Westfälischen Technischen Hochschule Aachen. 48 pp.

Martinsson, O., 1992: Greenstone hosted Cu-Au ores. The Viscaria and Pahtohavare sulfide deposits and the stratigraphy of the Kiruna greenstones. Research Programme Ore Geology Related to Prospecting. – NUTEK Report. Project No. 88-05116P. Department of Economic Geology. Luleå University of Technology. 79 pp.

Martinsson, O., 1993: Greenstone and porphyry hosted ore deposits in northern Norrbotten. NUTEK Project No. 92-00752P. 71 pp.

Martinsson, O., 1994: Greenstone and porphyry hosted ore deposits in northern Norrbotten. NUTEK Project No. 92-00752P. 31 pp.

Martinsson, O., 1995: Greenstone and porphyry hosted ore deposits in northern Norrbotten. NUTEK Project No. 92-00752-3. 58 pp.

Martinsson, O. & Söderholm, K., 1994: The greenstone hosted Pahtohavare Cu-Au deposit at Kiruna, northern Sweden. – Abstract. 21:a Nordiska Vintermötet, 10–13 January Luleå 1994. p. 137.

Niiniskorpi, V., 1990: Svavelrika förekomster i norra Norrbotten. – SGAB BRAP 90027. 9 pp.

Nilsson, G., 1971: Östra Äijäjärvi. Malmberäkning över kopparmineraliseringen. – Malmbyrån, SGU. 12 pp.

Norberg, A., 1978: Vathanvaara kaolin- och järnmalmsfyndighet.Geofysisk undersökning av kaolin och järnmalmsfyndigheten vid Vathanvaara. – SGU, BRAP 78505. 18 pp

Nyström, J.O., 1970: En strukturundersökning av titanjärnmalmen i Ruotevare. Report. – Malmbyrån, SGU. 56 pp.

Nyström, J.O., Nylund, B. & Mannström, B., 1975: Titanjärnmalmen i Routevare. Orienterande malmberäkning. – Berggrundsbyrån, SGU. 39 pp.

Ödman, O.H., 1957: Beskrivning till berggrundskarta över urberget i Norrbottens län. – SGU Ca 41. 120 pp.

Offerberg, J., 1967: Beskrivning till berggrundskartbladen Kiruna NV, NO, SV, SO. – SGU Af 1–4.

Öhlander, B., Lager, I., Loberg, B.E.H. & Schöberg, H., 1992: Stratigraphical position and Pb-Pb age of Lower Proterozic carbonater ocks from the Kalix Greenstone Belt, northern Sweden. – Geol. Fören. Stockholm Förh. 114, 317–322.

Quezada, R. & Ros, F., 1975: Malmberäkning av Tjårrojåkka järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar 1967–71. – SGU, BRAP 82569. 10 pp.

Padget, P., 1970: Beskrivning till berggrundskartan Tärendö NV, SO, SV, SO. – SGU Af 5–8.

Padget, P., 1977: Berggrundsgeologiska, flygmagnetiska och gravimetriska kartbladen Pajala NV, SO, SV, SO. – SGU Af 21–28.

Padget, P. & Lindroos, H., 1971: Rapport över borrningsresultat från objektet Käryjärvi. – Malmbyrån, SGU. 2 pp.

Persson, G., 1974: Järnmalmsfyndigheter väster om Jokkmokk. – Malmbyrån, SGU.

Persson, G., 1980: Kiskamavaara koppar-koboltfyndighet. – Berggrundsbyrån, SGU, BRAP 80524. 25 pp.

Persson, G., 1981: Kobolt-kopparfyndigheten vid Kiskamavaara. Berggrundsbyrån, SGU, BRAP 81552. Del 1+2. 18 pp.

Persson, G., 1982: Kiskamavaara. Tonnageberäkning på koppar och kobolt. – Berggrundsbyrån, SGU. BRAP 82509. 15 pp.

Persson, G., Lilljeqvist, R., Johansson, L., Gerdin, P. & Fajers, G., 1981a: Ainasjärvi. Resultat av geokemiska och geofysiska undersökningar samt blockletning och borrningsarbeten. – Berggrundsbyrån, SGU. 27 pp.

Persson, G., Johansson, L. & Gerdin, P., 1981b: Kiskamaa-Talvimaa. Resultat av utförda prospekteringsarbeten. – Berggrundsbyrån, SGU, BRAP 81020. 32 pp.

Petterson,W., 1900: Underdånig berättelse om en undersökning af mindre kända malmfyndigheter inom Jukkasjärvi malmtrakt och dess omgifningar. – SGU C 183.

Ros, F., 1970: Tjårråjåkka kopparmalmsfyndighet. BRAP 82567. – Berggrundsbyrån, SGU.

Ros, F., 1971: Järnmineraliseringen Luppovare (Luopovare) vid Ailatis. – Berggrundsbyrån, SGU. BRAP 82566, 2 p.

Ros, F., 1979: Tjårrojåkka kopparmalmsfyndighet. Prospekteringsrapport. – Berggrundsbyrån, SGU.

Ros, F., and Rönnbäck, L., 1979: PM rörande malmobjektet Tjårrojåkka. – SGU, BRAP 82570. 2 pp.

Ros, F., Nylund, B. & Oldeberg, H., 1980: Pellivuoma järnmalmsfyndighet. Rapport rörande resultaten av SGU:s undersökningar under åren 1964-1971. – Malmbyrån, SGU. 20 pp.

Rova, H., 1974: Utmålsprotokoll för Pellivuoma i Pajala kommun, Norrbottens län. – SGU. 11 p..

Rönnbäck, L. & Ros, F., 1971a: PM rörande malmobjektet Tjårrojåkka. – SGU, Malmbyrån.

Rönnbäck, L. & Ros, F., 1971b: PM rörande malmobjekten Peräjävuoma, Erkheikki and Marjarova. – SGU, Malmbyrån.

Skiöld, T., 1979: Zircon ages from an Archean gneiss province in northern Sweden. – Geol. Fören. Förh. Stockholm 101, 169–171.

Skiöld, T., 1986: On the age of the Kiruna greenstones, northern Sweden. – Precambrian Res. 32, 35–44.

Skiöld, T., 1987: Aspects of Proterozoic geochronology of northern Sweden. – Precambrian Res. 35, 161–167.

Skiöld, T. & Cliff, R.A., 1984: Sm-Nd and U-Pb dating of Early Proterozoic mafic-felsic volcanism in northernmost Sweden. – Precambrian Res. 26, 1–13.

Stacey, P.F., 1966: The Nakerivaara deposit. A preliminary report. – SGU.

Tegengren, F., 1910: Järnmalms- och magnesitförekomsterna inom Kvikkjokks kapellag. – SGU C 230, 134 pp.

Tuisku, P., 1993: Relation of convergent deformation, granite emplacement and low-P metamorphism, the North Bothnia Schist Belt and the Merikoski Granite, Finland. Geological Association of Canada and Mineralogical Association of Canada. – Program with Abstracts, 18: A105.

Vaasjoki, M., 1981: The lead isotopic composition of some Finnish galenas. – Geol. Survey Finland Bull. 316. 30 pp.

Welin, E., 1987: The depositional evolution of the Svecofennian supracrustal sequence in Finland and Sweden. – Precambrian Res. 35, 95–113.

Welin, E., Christiansson, K. & Nilsson, Ö., 1971: Rb-Sr radiometric ages of extrusive and intrusive rocks in northern Sweden, 1. – SGU C 666.

Virkkunen, R., 1985: Ahmavuoma. – LKAB prospektering. Rapport K 85-4. 12 p.

Witschard, F., 1972: Masugnsbyn iron ore. Rapport rörande resultaten av SGU:s undersökningar under åren 1965–1970. – SGU Malmbyrån, 56 pp.

Zweifel, H., 1976: Aitik - geological documentation of a disseminated copper deposit. – SGU C 720.

Table 1. Geophysical works and drillings made on mineralizations on different map sheets in Norrbotten County during the Iron Ore Inventory Programme, 1963-1972. M = magnetic, G = gravimetric, S = Slingram and P = IP measurements. (*** = not covered by the Programme, but investigated simoultaneously).

Deposit	***Ore type***	***Geophysics***	***Drillings***	***Remarks***
	30I Abisko			
(***Kopparåsen	uranium)			
	30 J Rensjön			
Nakerivaara	apatite iron ore	1958, 1967	1959, 1964	M G
Rensjön area				
Njuotjama-Rensjön-Toppi	skarn iron ore	1968	1970-71	M G
Tjavelk	skarn iron ore copper ore	1967	1968-69	M G S P New discovery. Mining rights 1973
	30 K Soppero			
Nalmoinen	magmatic-tectonic iron ore	1967		M G New discovery
Palovaara	magmatic-tectonic iron ore	1967	1972	M G New discovery
	30 L Lannavaara			
Kallojärvi	skarn iron ore	1968-69		M G New discovery
Lannavaara area				
Kevus	metasomatic iron ore	1967-68	1971	M G
Teltaja	metasomatic iron ore	1967-68	1971	M G
Sattavaara	skarn iron ore	1967-68, 1971		M G S
Sautusjärvi	skarn iron ore		1972	
	29 I Kebnekaise			
Eustillako	unknown iron ore type	1965		M G
Kaitumjaure	copper ore	1965		S
Luppovare	apatite iron ore	1970		M G
Pirttivuopio	metasomatic iron ore	1967	1968-69	M G S IP New discovery
Staggotjåkka	skarn iron ore	1966		M G New discovery
Tjårrojåkka	apatite iron ore metasomatic copper ore	1964-69	1969-70	M G S P New discovery. Mining rights 1980-81
Vistas	apatite iron ore	1967		M G
	29 J Kiruna			
Aptasjärvi		1964		M G
Ekströmsberg	apatite iron ore	1961-62	1968-69	M G
Eustilljåkk	apatite iron ore	1960 1964		M G New discovery
Gäddmyr	apatite iron ore	1963, 1964, 1969		M G New discovery
Hotnjos	apatite iron ore	1971		M G
Kuosatjvare (Kuosasj)	apatite iron ore	1968		M G
Laukujärvi	skarn iron ore	1963	1968-69	M G S P
Pattok	apatite iron ore	1963	1969-70	M G New discovery Mining rights 1973
Puoltsa	magmatic-tectonic iron ore	1961	1963-67	M G New discovery. Mining rights 1971
Rakkurijärvi	copper and iron ore	1968	1969-70	M S P
Renhagen	apatite iron ore	1951, 1962-63	1969	M Mining rights 1952
Sakkaravaara	copper ore	1968-69		M S
Vieto	skarn iron ore	1963-65, 1968	1969-70	M G S P

Vieto	metasomatic copper ore			M S G P New discovery

Deposit	***Ore type***	***Geophysics***	***Drillings***	***Remarks***
Årosjåkk	skarn iron ore	1963	1968-69	M G New discovery. Mining rights 1973
	<u>29 K Vittangi</u>			
Ainasjärvi	metasomatic copper ore		1969-70	New discovery
Altavaara	skarn iron ore	1961-62	1964	M G
Kiskamavaara	metasomatic copper ore	1967	1972-78	M S New discovery
Maltosrova	graphite	1966-67		S
Pauranki	metasomatic copper ore	1971		M S
Saivo	metasomatic skarn with magnetite	1967-68		M G
Sautusvaara	skarn iron ore	1961-62	1963-67	M G Partly new discovery. Mining rights 1973
Särkirova	molybdenum skarn	1963	1963-64	
Vittangi area	skarn iron ore	1964-68	1971-72	M G S P
Jänkkä	skarn iron ore	1965-68	1971 (later 1978)	M Sl
Kuusi Nunasvaara	skarn iron ore	1964-68		
Kivijärvi	skarn iron ore	1964-68		
Mänty Vathanvaara	skarn iron ore	1964-68		
Nunasjärvenmaa	skarn iron ore	1964-68		
Sorvijärvi	skarn iron ore	1964-68		
Sorvivuoma	skarn iron ore	1964-68		
Svanobolandet	skarn iron ore	1964-68		
Vathanvaara	skarn iron ore	1966		M G
Ylipääsnjaska	apatite iron ore	1971		M G
Äijäjärvi Östra	metasomatic copper ore	1965-69	1967-69	New discovery Mining rights 1972
	<u>29 L Lainio</u>			
Ahmavuoma	metasomatic iron ore	1968		M G New discovery
Kivijänkkä	skarn iron ore	1970-71		M S
Masugnsbyn area				
Isovaara Nya	skarn iron ore	1964-65	1967-70	M G
Isovaara	quartz-banded iron ore	1964-65	1967-70	M G
Vuoma	quartz-banded iron ore	1964-65	1967-70	M G
Vähävaara	quartz-banded iron ore	1964-65	1967-70	M G
Välivaara	quartz-banded iron ore	1964-65	1967-70	M G
	<u>28 I St. Sjöfallet</u>			
Satisjaure	apatite iron ore	1965, 1969		M G New discovery
	<u>28 J Fjällåsen</u>			
Akkavare	titaniferous ore	1968		M G S by SGU, drilled by STORA
Fjällåsen	copper ore	1967-70		M G Partly new discovery
	<u>28 K Gällivare</u>			
Salmivaara	skarn iron ore	1967-71	1970-71	M G
	<u>28 L Tärendö</u>			
Leppäjoki	skarn iron ore	1964-65, 1968	1971	M G New discovery
Oriasvaara	metasomatic copper ore	1965		S
Masugnsbyn	skarn iron ore	1964-65	1967-70	M G
Tornefors	iron ore	(1949) 1966	1970	(M) G
	<u>28 M Pajala</u>			

Deposit	Ore type	Geophysics	Drillings	Remarks
Erkheikki	skarn iron ore	1965-66, 1971	1969-70	M G S
Kallojärvi	skarn iron ore			M
Kaunisvaara area	skarn iron ore	1963-65		M G
Karhujärvi	skarn iron ore	1963-65	1969	M G
Palotieva	skarn iron ore	1963-65	1969	M G
Ruutijärvi	skarn iron ore	1963-65	1969-1971	M G New discovery Mining rights Kokkovuoma 1972
Sahavaara Stora	skarn iron ore	1960	1961-64	M G
Sahavaara Södra	skarn iron ore	1964-65	1966-67	M G
Sahavaara Östra	skarn iron ore		1964	M G
Tapuli	skarn iron ore	1963-65	1965-69	M G
Käryjärvi	skarn iron ore	1965, 1967	1971	M G New discovery
Laukujärvi	skarn iron ore	1951-53, 1963	1968-69	M G
Marjarova (Marjajärvi)	quartz-banded iron ore	1964	1969-70	M G
Pajala Södra	titaniferous ore	1965		M G
Palotieva	skarn iron ore		1968-69	
Pellivuoma	skarn iron ore	1963-66	1969-71	M G Mining rights 1974
Peräjävuoma	titaniferous ore	1965	1970	M G New discovery
Suorsapakka	skarn iron ore	1963-65		M G
	<u>27 H Kvikkjokk</u>			
Ruoutevare	titaniferous ore	1969-70	1971-73	M G
	<u>27 I Tjåmotis</u>			
Jokkmokk area				
Akkihaure	quartz-banded iron ore	1969		M S P
Iekelvare	copper–zinc–lead ore	1972	1974-77	
Kallak (Björkholmen)	quartz-banded iron ore	1968-70		M G S
Kallak Södra	quartz-banded iron ore	1968-70		
Maivesvaara	quartz-banded iron ore	1968-70		
Parkijaure	quartz-banded iron ore	1968-70		New discovery
Parkijaure Södra	quartz-banded iron ore	1968-70		
Tjårovarats	quartz-banded iron ore	1968-70		
	<u>27 J Porjus</u>			
Pakko	quartz-banded iron ore	1968-70		
Åkosjägge	quartz-banded iron ore	1968-69		M G New discovery
	<u>27 K Nattavaara</u>			
Jårbojoki	copper ore	1965, 1970-1971		M S P
Kaddevare	unknown iron ore type	1971		M G New discovery
	<u>26 I Luvos</u>			
Akkihaure	quartz-banded iron ore	1960-70	1970-72	M G
	<u>25 I Stensund</u>			
(***Ballek	copper ore)	1960-62, 1971, 1975	1961-63	New discovery
(***Lulepotten	copper ore)			
	<u>25 J Moskosel</u>			
(***Benbrytefors	copper ore)			
(***Gåbdejaure Östra, Ljusträsk)	copper ore)	1965-66	1966, 1977-79	M S New discovery
(***Vargisträsk	zinc–copper ore)			
	<u>25 M Kalix</u>			
(***Pålänge	uranium ore)			

	24K Älvsbyn
(***Stavträsk	copper ore)

Table 2. Reserves and compositions of major mineralizations in Norrbotten County investigated during the Iron Ore Inventory Programme 1963-1972. *= new discovery. Minor or uncompletely known deposits are not included.

Deposit	Surface area 1000 m^2	Known depth in metres	Reserves 10^6 tonnes	% Fe	% P	% S	Other elements
			Apatite iron ore				
Ekströmsberg	46	250	37	55.9	1.3	0.01-0.03	0.03-0.29% Ti, 0.05% V
Eustilljåkk *	25	100	5	30-45	0.01-1.2	0.01	0.25% V
Gäddmyr *	0.7	50	0.2	67-69			
Nakerivaara	26	200	12.7	31	0.3	0.028	0.12 % Ti
Pattok*	72	250	68	45.1	2.0	0.01	
Renhagen	19.1	175	11.3	33.7	0.23	0.03	
Satisjaure*	50	100	10	20-40	0.004	0.01	
Tjårrojåkka*	<50	350	52.6	51.5	0.77	0.13-0.22	0.03-0.09% Cu
Σ all deposits			197.1				
Σ new discoveries			139.0				
			Skarn iron ore				
Altavaara area							
Altavaara Norra	24		7.1	25.8	0.37	0.38	
Altavaara Södra			0.1	20	<0.1	<0.1	
Altavaara Östra			0.1	25	<1	<0.1	
Erkheikki		150	3.4	32.5	0.076	2.1	0.07% Cu
Kaunisvaara area							
Palotieva	12	200	8.1	27.4	0.06	2.4	<0.1% Cu
Ruutijärvi blind ore	20	190-320	8.3	40.9	0.08	2.2	0.01-0.1% Cu
Sahavaara Stora	53.8	435	82	41	0.07	2.5	0.08% Cu
Sahavaara Södra	19.7	260	19.6	32.1	0.04	0.8	0.05% Cu
Sahavaara Östra	5	100	2	40.5	0.014	0.2	0.03% Cu
Tapuli	110	300	60.3	29.3	0.07	0.18	<0.01% Cu
Laukujärvi	10	100	3.7	33.5	<0.01	1-4	
Leppäjoki*	6	250	6	32	0.03	0.8-0.9	0.04% Cu
Masugnsbyn area							
Junosuando	137.5	150	59.8	30	0.024	1.9	0.4-1.3% Mn, 0.08% Cu
Pellivuoma	84	200	43.5	32.7	0.04	0.58	
Ruutijärvi blind ore*	20	150	10	40.9	0.12	2.1	0.05-0.1% Cu
Salmivaara	37.5	120	16	33.5	0.03	3.6	0.2-0.8% Cu
Sautusvaara area							
Sautusvaara Norra	33.8	225	13.3	42.1	0.074	0.48	
Sautusvaara Södra	53	235	42.1	37.2	0.066	1.82	
Suolojåkk*	20	100	6	20-30	0.01	0.01-0.37	
Tjavelk	9	100	6.8	38.6	1.2	3.56	0.12% Cu
Rensjön area							
Toppi	10	200	7.8	40.8	0.040	1.91	
Vieto	24.6	150	15.7	40.4	0.14	1.70	
Vittangi area							
Jänkkä			3.5	36.3	0.02	2.14	0.1-0.2% Cu
Kuusi	10	100	23.7	30.5	0.068	1.56	
Nunasvaara							
Mänty	5	100	10.7	31.3	0.057	2.46	
Vathanvaara							
Nunasjärvenmaa	2.3	100	2.3	30.9	0.045	0.76	

Tab. 2 cont.

Deposit	Surface area 1000 m^2	Known depth in metres	Reser-ves 10^6 tonnes	% Fe	% P	% S	% Mn	% Ti	Other elements
			Skarn iron ore (cont.)						
Sorvivuoma			4.3	39.7	0.09	0.31			
Svanbolandet		100	0.5	24.7	0.097	0.6			
Vathanvaara	18	100	28.0	39.4	0.049	2.91			
Årosjåkk*	7	150	2.7	28	0.01	0.1			
∑ all deposits			498.6						
∑ new discoveries			25.90						
			Quartz-banded iron ore						
			In the Greenstone Group						
Marjarova	10		3	25-45	<0.1	1.5-5			
Masugnbyn area									
Vähävaara	9.350	150	3.1	28.8	0.048	2.7			
Tornefors	8	100	2.6	20					
0.005-0.027	1-3								
∑ all deposits			8.7						
			In the Porphyry Group						
Jokkmokk area									
Akkihaure			12						
Kallak	97	90	50	35-42	0.04	0.6			0.4% Mn, 0.06% Ti
Kallak Södra			23		0.04-0.06				0.1-0.2% Mn
Parkijaure*		100	23	38-39					
Parkijaure S.			6						
Åkosjägge*		200	75	30					
∑ all deposits			189.0						
∑ new discoveries			98						
			Metasomatic iron ore						
Lannavaara									
Kevus	52.6	200	38.8	28	0.01-0.09	1-2			0.2-0.5% Mn, 0.1% Cu
Teltaja	22		43	41	0.01-0.13	0.04-(4.5)			
Pirttivuopio*			1.2	16-25	0.24-1.01	<0.2			
∑ all deposits			83.0						
∑ new discovery			1.2						
			Magmatic–tectonic iron ore						
Poultsa	160	200	31.5	34.3	0.037	0.019			
∑ new discovery			31.5						
			Titaniferous ore						
Ruoutevare	387		116	38.2					5.6% Ti, 0.17% V
			Gross total						
∑ all deposits			1122.7						
∑ all new discoveries			294.40						

Table 3. Reserves in iron mineralizations in Norrbotten County resulting from the Iron Ore Inventory Programme, 1963-1972.

Ore type	Number of deposits investigated	Reserves 10^6 tonnes in major deposits	Number of new discoveries	Reserves 10^6 tonnes in major new discoveries
Apatite iron ore	31	197.1	6	139.0
Skarn iron ore, Greenstone Group	32	498.6	5	25.9
Quartz-banded iron ore, Green-stone Group	3	8.7		
Quartz-banded iron ore, Porphyry Group	6	189.0	2	98.0
Metasomatic iron ore	3	83.0		
Magmatic–tectonic iron ore	1	31.5	1	31.5
Titaniferous ores	1	116.0		
Gross total	75	1122.7	14	294.4

Table 4. Other (non-iron) deposits discovered and investigated in Norrbotten County during the Iron Ore Inventory Programme, 1963–1972.

Name of deposit	Map sheet	Metal
Stavträsk	24 K	Copper
Lullepotten	25 I	Copper
Ballek	25 I	Copper
Vargisträsk	25 J	Zinc–copper
Ljusträsk	25 J	Copper
Benbrytefors	25 J	Copper
Pålänge	25 M	Uranium
Ö. Skogsträsk	25 M	Nickel
Skomerjaure	26 H	Copper
Norrpouda	26 H	Molybdenum
Haukok	26 H	Molybdenum
Jårbojoki	27 K	Copper
Kopparåsen	30 I	Uranium

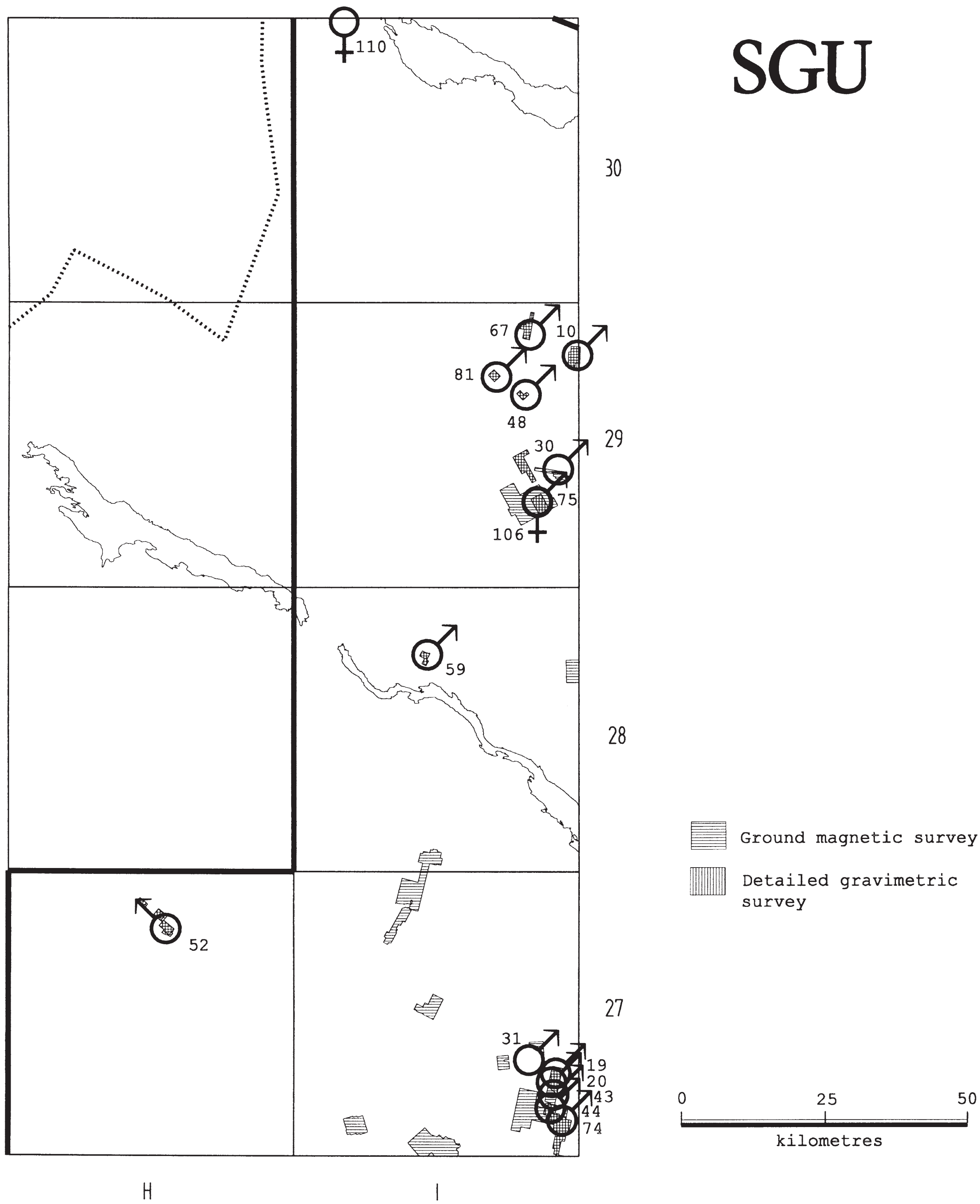
Table 5. New discoveries of iron ores during the Iron Ore Inventory Programme, 1963–72, totalling 21 deposits.

Apatite iron ore	Skarn iron ore	Quartz-banded iron ore	Metasomatic iron ore	Magmatic–tectonic iron ore	Titaniferous iron ore
Eustilljåkk	Kaddevare	Parkijaure	Ahmavuoma	Nalmoinen	Peräjävuoma
Gäddmyr	Kallojärvi	Åkosjägge	Pirttivuopio	Palovaara	
Pattok	Käryjärvi			Puoltsa	
Satisjaure	Leppäjoki				
Tjårrojåkka	Ruutijärvi blind ore				
	Staggotjåkka				
	Suolojåkk				
	Årosjåkk				

Table 6. Deposits shown in Figs. 1–5.
*Not included in the Programme but investigated simultaneously.

Nr	Prospect name	District	Map	Sq	N coordinate	E coordinate
	IRON OXIDES					
1	Ahmavuoma	Kiruna	29L	9c	7548000	1763000
2	Akkavare	Gällivare	28J	2e	7464600	1671000
3	Akkihaure	Jokkmokk	26I	9j	7399400	1646300
4	Altavaara Norra	Kiruna	29K	6a	7533800	1701350
5	Altavaara Södra	Kiruna	29K	6a	7532500	1701300
6	Altavaara Östra	Kiruna	29K	6a	7533800	1702550
7	Rakkujärvi Fe	Kiruna	29J	5g	7525950	1683250
8	Ekströmsberg	Gällivare	29J	5b	7527000	1656900
9	Erkheikki	Pajala	28M	5d	7479900	1817350
10	Eustillako	Kiruna	29I	8j	7540700	1649900
11	Eustilljokk	Kiruna	29J	8a	7544900	1650300
12	Gäddmyr	Gällivare	29J	4g	7522200	1680900
13	Hotnjos	Gällivare	29J	2b	7514700	1656300
14	Härkmyran*	Kiruna	30L	4f	7571900	1776700
15	Isovaara	Kiruna	29L	0d	7503200	1765600
16	Junosuando	Pajala	28L	9d	7498600	1766800
17	Jänkkä	Kiruna	29K	4g	7521100	1733020
18	Kaddevare	Gällivare	27K	6c	7406200	1711200
19	Kallak	Jokkmokk	27I	2j	7414500	1646000
20	Kallak Södra	Jokkmokk	27I	2j	7413000	1645500
21	Kallojärvi	Kiruna	30L	7d	7586000	1764700
22	Karhujärvi	Pajala	28M	6d	7484000	1817100
23	Kaunisvaara	Pajala	28M	9d	7497000	1816500
24	Kesajärv	Överkalix	26L	4j	7370700	1747700
25	Kevus	Kiruna	30L	1b	7558350	1757200
26	Kivijärvi	Kiruna	29K	5g	7529100	1731750
27	Käryjärvi	Pajala	28M	7f	7486000	1827000
28	Laukujärvi	Kiruna	29J	6b	7532580	1655400
29	Leppäjoki	Pajala	28L	8f	7493250	1776200
30	Luppovare	Gällivare	29I	3j	7520050	1646100
31	Maivesvaara	Jokkmokk	27I	3i	7416800	1641300
32	Marjarova	Pajala	28M	7b	7489000	1806750
33	Masugnsbyn	Kiruna	28L	9d	7497500	1767000
34	Nakerivaara	Kiruna	30J	4c	7574500	1661300
35	Nalmoinen	Kiruna	30K	1f	7559300	1727650
36	Nunasjärvenmaa	Kiruna	29K	4g	7524500	1734300
37	Nunasvaara Kuusi	Kiruna	29K	5h	7527600	1736500
38	Nälkäjärvet	Kiruna	29K	5g	7526900	1734300
39	Pajala Södra	Pajala	28M	5d	7479550	1817350
40	Pakko	Jokkmokk	27J	6d	7431500	1665600
41	Palotieva	Pajala	29M	0e	7500950	1823900
42	Palovaara	Gällivare	28L	0e	7452500	1772000
43	Parkijaure	Jokkmokk	27I	2j	7411800	1645700
44	Parkijaure Södra	Jokkmokk	27I	1j	7408300	1645400
45	Pattok	Gällivare	29J	0d	7502200	1665000
46	Pellivuoma	Pajala	28M	8b	7490850	1805750
47	Peräjävuoma	Pajala	28M	5b	7475500	1805500
48	Pirttivuopio	Kiruna	29I	6i	7533600	1640600
49	Puoltsa	Kiruna	29J	5e	7528800	1672300
50	Renhagen	Gällivare	29J	3b	7516400	1659100
51	Rensjön	Kiruna	30J	1d	7558500	1667800
52	Ruotevare	Jokkmokk	26J	7f	7388500	1679000
53	Ruutijärvi	Pajala	28M	9e	7497700	1821300
54	Sahavaara Stora	Pajala	28M	8e	7494700	1820800
55	Sahavaara Södra	Pajala	28M	8e	7493900	1820400

56	Sahavaara Östra	Pajala	28M	8e	7493200	1821250
57	Saivo	Gällivare	29J	1j	7508200	1698800
58	Salmivaara	Gällivare	28K	8c	7490500	1711750
59	Satisjaure	Gällivare	28I	7e	7487900	1623400
60	Sattavaara	Kiruna	30L	1b	7556800	1758000
61	Sautusjärvi	Kiruna	30L	6d	7580400	1767200
62	Sautusvaara	Kiruna	29K	8b	7540300	1709200
63	Sautusvaara Norra	Kiruna	29K	8b	7540800	1708600
64	Sautusvaara Södra	Kiruna	29K	7b	7539800	1710100
65	Sorvijärvi	Kiruna	29K	6g	7533600	1731700
66	Sorvivuoma	Kiruna	29K	6g	7534300	1730700
67	Staggotjåkka	Kiruna	29I	8i	7544300	1641600
68	Suolojokk	Kiruna	29J	6f	7531400	1678600
69	Suorsapakka	Pajala	28M	3b	7467800	1808700
70	Svanbolandet	Kiruna	29K	4g	7524300	1733750
71	Tapuli	Pajala	29M	0e	7500600	1822200
72	Teltaja	Kiruna	30L	0b	7555000	1759800
73	Tjavelk	Kiruna	30J	5f	7579400	1678000
74	Tjårovarats	Jokkmokk	27I	1j	7406000	1647000
75	Tjårrojåkka	Gällivare	29I	2i	7515000	1642800
76	Toppi	Kiruna	30J	0d	7554600	1667500
77	Tornefors	Pajala	28L	9h	7496400	1785075
78	Vathanvaara	Kiruna	29K	6g	7532250	1730500
79	Vathanvaara Mänty	Kiruna	29K	6g	7530100	1731100
80	Vieto	Kiruna	29J	6c	7532500	1664000
81	Vistas	Kiruna	29I	7h	7536900	1635500
82	Vuoma	Kiruna	29L	0d	7503300	1765900
83	Vähävaara	Gällivare	27K	9j	7448000	1749000
84	Välivaara	Kiruna	29L	0d	7502400	1766500
85	Ylipääsnjaska	Gällivare	29K	0b	7501050	1708950
86	Åkosjägge	Jokkmokk	27J	5c	7425100	1661350
87	Årosjokk	Kiruna	29J	6a	7534500	1651000
	SULPHIDES					
88	Ainasjärvi	Kiruna	29K	3d	7518400	1716250
89	Ballek*	Arjeplog	25I	7c	7335700	1610800
90	Benbrytefors*	Arvidsjaur	25J	3i	7318900	1690850
91	Fjällåsen Au	Gällivare	28J	5g	7475800	1681030
92	Fjällåsen Cu	Gällivare	28J	5g	7478000	1681000
93	Haukok*	Arjeplog	26H	4g	7371800	1581800
94	Jårbojoki*	Gällivare	27K	8g	7442800	1735200
95	Kiskamavaara	Kiruna	29K	6f	7534300	1725850
96	Laukujärvi	Kiruna	29J	6b	7532300	1655900
97	Ljusträsk*	Arvidsjaur	25J	1g	7305950	1684350
98	Lulepotten*	Arjeplog	25I	6b	7330700	1608700
99	Nautanen	Gällivare	28K	2d	7464300	1719200
100	Oriasvaara	Pajala	28L	6f	7480300	1777050
101	Paurankilantto	Kiruna	29K	5e	7525500	1721700
102	Rakkurijärvi Cu	Kiruna	29J	5g	7526500	1682300
103	Skomerjaure*	Arjeplog	26H	0i	7350400	1592300
104	Stavsträsk*	Älvsbyn	24K	7f	7286100	1728250
105	Särkivaara	Kiruna	29K	3d	7519400	1719900
106	Tjårrojokka	Gällivare	29I	2i	7515000	1642800
107	Vargisträsk*	Arvidsjaur	25J	6c	7332350	1661450
108	Vieto	Kiruna	29J	6c	7532500	1664000
109	Äijäjärvi Östra	Kiruna	29K	3h	7518500	1737900
110	Kopparåsen*	Kiruna	30I	9b	7599700	1608700
	OTHER					
111	Maltosrova C	Kiruna	29K	7h	7536650	1735250
112	Nunasvaara C*	Kiruna	29K	4h	7523800	1736050
113	Pålänge U*	Kalix	25M	4e	7322000	1824000



SGU

Fig. 2. Map sheets 27–30 H–I with areas of geophysical measurements and sites of mineralizations. Legend see Fig. 1, p. 7.

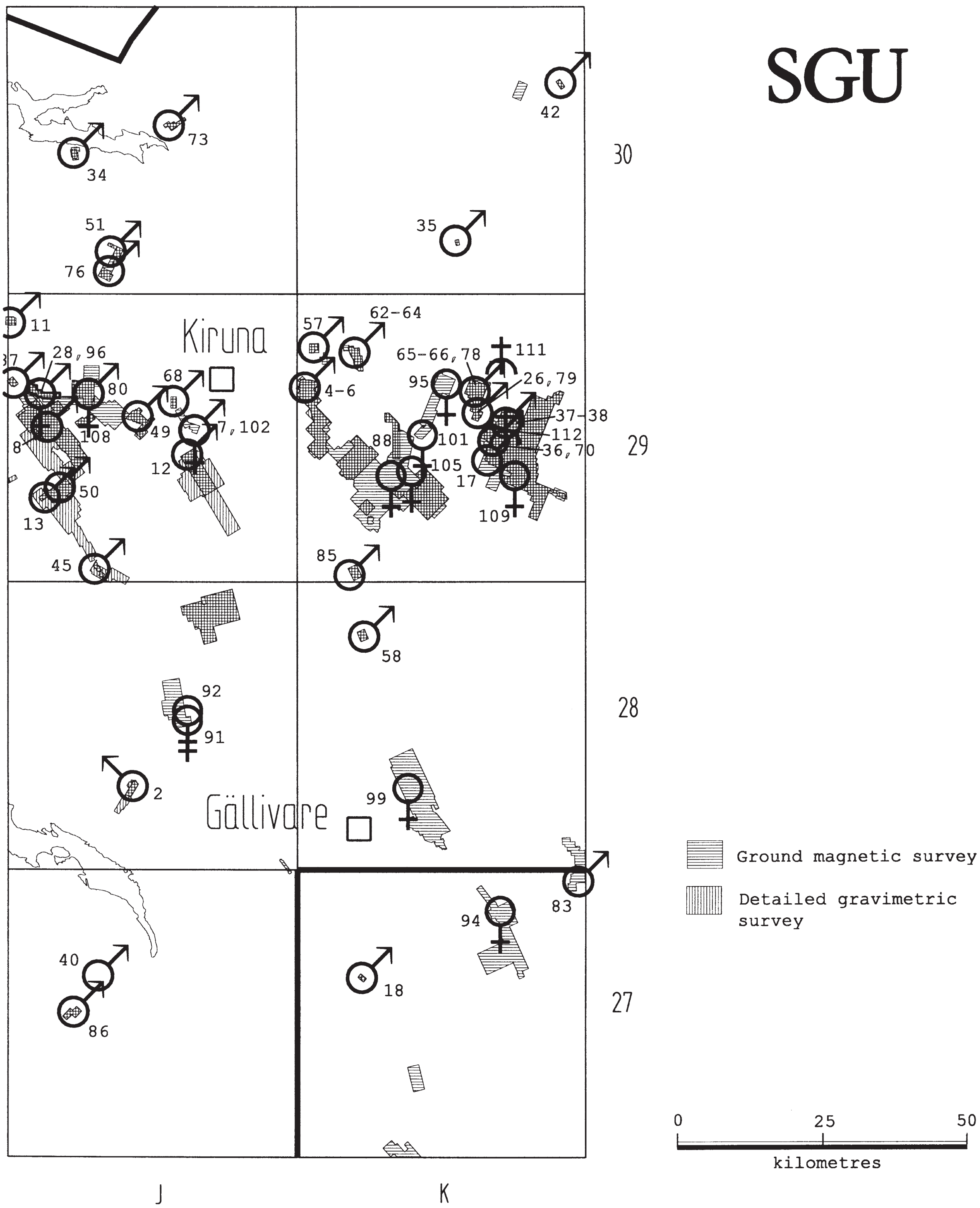


Fig. 3. Map sheets 27–30 J–K with areas of geophysical measurements and sites of mineralizations. Legend see Fig. 1, p. 7.

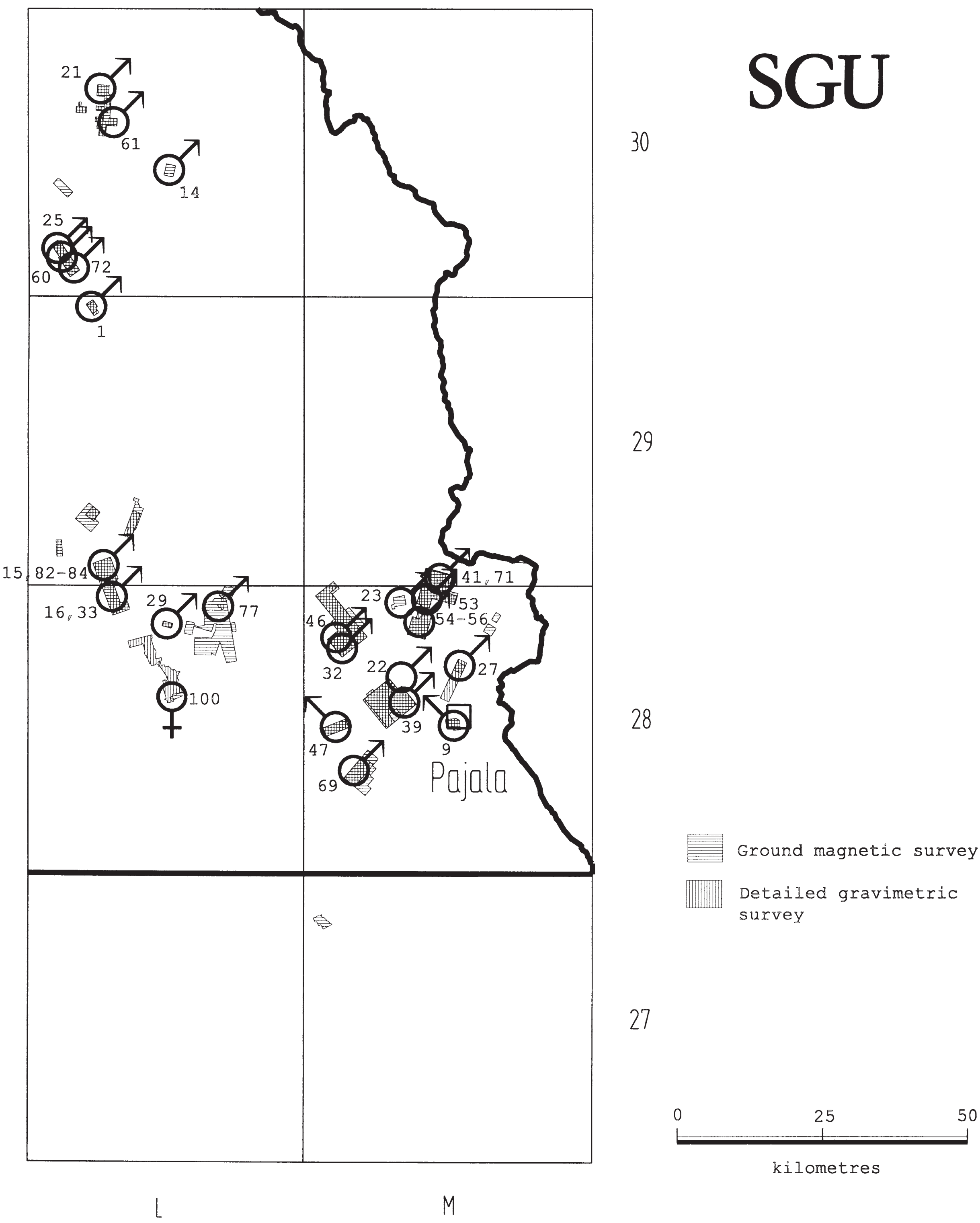


Fig. 4. Map sheets 27–30 L–M with areas of geophysical measurements and sites of mineralizations. Legend see Fig. 1, p. 7.

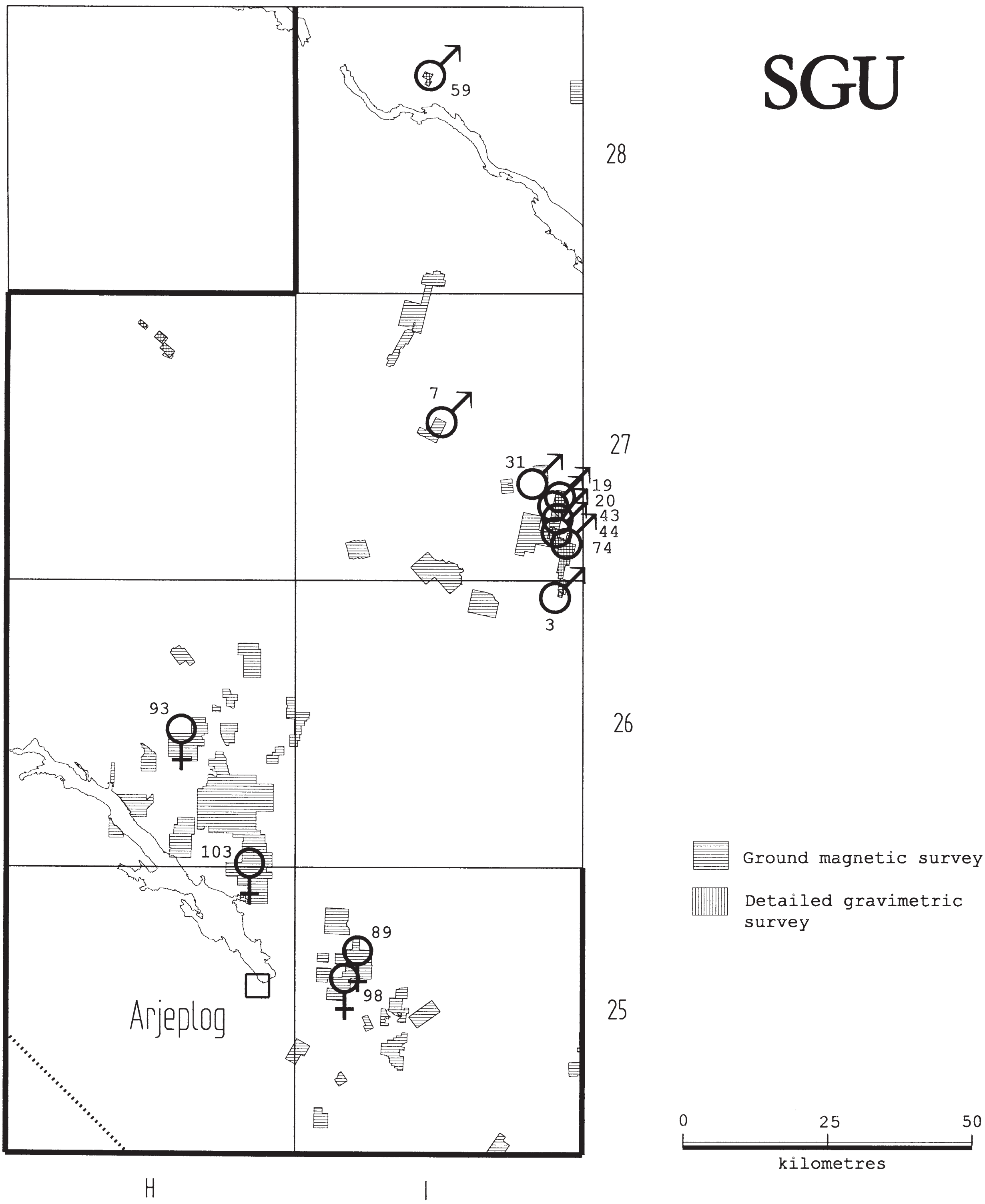


Fig. 5. Map sheets 25–28 H–I with areas of geophysical measurements and sites of mineralizations. Legend see Fig. 1, p. 7.

I SGUs serie Rapporter och meddelanden har hittills utgivits:

* 1. Utredning rörande det svenska jordbrukets kalkförsörjning 1–2. 1931.
* 2. **Sahlström, K.E.** Sveriges lodade sjöar. 1945.
* 3. **Ödman, O.H.** Rapport över manganmalmsletningen i Jokkmokks socken 1940–48.
4. **Stålhös, G**. Bidrag till kännedomen om den radioaktiva strålningens fördelning inom den svenska berggrunden. 1959.
5. **Johansson, H.G. och Ericsson, B.** Grusutredningen -74. Översiktlig inventering av sand- och grusförekomster – Försöksverksamhet. 1976.
* 6. **Knutsson, G., m.fl.** Grustillgångarna i Östersundsområdet. Del 1 inventering. 1976.
* 7. **Ericsson, B.** Svallgrustillgångar längs Kilsbergen, Örebro län. 1977.
8. **Gustafsson, O. och De Geer, J.** Skånes större grundvattentillgångar. 1977.
9. **Knutsson, G. och Fagerlind, T.** Grundvattentillgångar i Sverige. 1977.
10. **Modig, S., Knutsson, G., Nordberg. L. och Persson, G.** Särtryck ur Ymer 1978 – Bebyggelsen och vattnet. 1978.
11. **Guy-Ohlson, D.** Jurassic biostratigraphy of three borings in NW Scania. (A brief palynological report.) 1978.
12. **Gustafsson, O., Andersson, J.-E. och De Geer, J.** Sammanställning av hydrogeologiska data från Kristianstadsslätten. 1979.
13. **Hörnsten, Å.** Sand och övriga jordarter i Öresund. Maringeologiska kartor över Öresund. 1979.
* 14. Hydrogeologi vid SGU. Särutgåva av Vannet i Norden. 1979.
15. **Knutsson, G., Lindén, A. och Rudmark, L.** Grus- och moräntillgångar i Nybroregionen. 1979.
16. **Wilson, M.R. och Sundin, N.O.** Isotopic age determinations on rocks and minerals from Sweden. 1960-1978.
17. **Karlqvist, L. och Qvarfort, U.** Modell för simulering av utbytesförlopp i ett sand-bentonitskikt. 1980.
18. **Karlqvist, L. och Qvarfort, U.** Gruvhanteringens inverkan på Bersboområdet, Åtvidabergs kommun. 1980.
19. **Wilson, M.R. and Åkerblom, G.** Uranium enriched granites in Sweden. 1980.
* 20. **Cato, I och Engdahl, M.** Beskrivning till temakartor utvisande var särskild uppmärksamhet av stabilitetsförhållanden erfordras inom vissa bebyggda eller detaljplanerade områden med lerjord. 1982.
21. **Olsson, T.** Ground-water-level fluctuations as a measure of the effective porosity and ground-water recharge. 1980.
22. **Bergström, J. och Shaikh, N.A.** Malmer, industriella mineral och bergarter i Kristianstads län. Projekt i länsplanering 1980. 1980.
23. **Lilja, A.** Störning av berggrundens temperaturförhållanden vid hammarborrning. 1981.
24. **Agrell, H.** Gotska Sandöns kvartärgeologi. (Summary: The Quaternary geology of the island of Gotska Sandön in the Baltic.) 1981.
25. **Laufeld, S. (Ed.).** Proceedings of Project Ecostratigraphy Plenary Meeting, Gotland, 1981. 1981.
26. **Fredén, C., m.fl.** Tuveskredet, 1977-11-30. Geologiska undersökningar. Särtryck av SGI Rapp. 11 B. 1981.
27. SWIM 81. Intruded and relict groundwater of marine origin. Proceedings of Seventh Salt Water Intrusion Meeting, Uppsala, Sweden, 14–17 September 1981. 1981.
28. **Aastrup, M., Aneblom, T., Henriksson, B. och Persson, G.** PMK-grundvatten. Lägesrapport mars 1982. 1982.
29. Energigeologi. Exempel på verksamhet inom energisektorn vid SGU. April 1982.
30. **Åkerblom, G. and Wilson, C.** Radon – geological aspects of an environmental problem. 1982.
31. **Bergström, J. och Shaikh, N.A.** Malmer, industriella mineral och bergarter i Malmöhus län. 1982.
32. **Ericsson, B. och Grånäs, K.** SGU:s grusdataarkiv. 1983.

33. **Sivhed, U.** Upper Cretaceous Ostracodes from the Malen Limestone quarry and the river Stensån, southern Sweden. 1983.
34. Berggrundsgeokemi som prospekteringsmetod i Sveriges urberg. Föredrag och inlägg från ett symposium i Uppsala den 17–18 mars 1983 anordnat av Sveriges geologiska undersökning och Svenska Gruvföreningen. O. Selinus (Red.). 1983.
35. Vanadin. 1984.
37. **Andersson, M. och Ohlsson, S.-Å.** Geokemisk kartering. 1984.
38. **Lundqvist, Th.** Färg- och teckenschema för SGU:s berggrundskartering. 1984.
39. **Lindewald, H.** Salt grundvatten i Sverige. 1985.
40. **Guy-Ohlson, D. and Malmquist, E.** Lower Jurassic biostratigraphy of the Oppegård Bore No. 1, NW Scania, Sweden. 1985.
41. **Andersson, M.** Geokemisk kartering. Tungmineralanrikad morän. Kartbladen 15–16, C–D och 16–17, G. 1985.
42. **Ressar, H. och Ohlsson, S.-Å.** Geokemisk kartering. Bäcktorv. Bilaga: Beskrivning av de fjorton spårelementens exogena geokemiska kretslopp av John Ek. 1985.
43. Grundvattennätet. Svenskt vattenarkiv. 1985.
44. Grundvattenkvalitet. Svenskt vattenarkiv. 1985.
45. **Shaikh, N.A., Samuelsson, L., Sundberg, A. och Wik, N.-G.** Malmer, industriella mineral och bergarter i Älvsborgs län. 1986.
46. **Fredén, C.** Quaternary marine shell deposits in the region of Uddevalla and Lake Vänern. 1986.
47. **Ahlberg, O.** Den svenska kontinentalsockelns berggrund. 1986.
48. **Ressar, H., Ohlsson, S-.Å. och Ekelund, L.** Geokemiska kartan. Tungmetaller i Bäcktorv. Översiktskartbladen Kalmar, Oskarshamn, Sundsvall och Vilhelmina. 1986.
49. **Ressar, H., Ohlsson, S.-Å. och Ekelund, L.** Geokemiska kartan. Tungmetaller i Bäcktorv. Översiktskartbladen Malmö och Sundsvall. 1987.
50. **Shaikh, N.A., Persson, L., Sundberg, A. och Wik, N-.G.** Malmer, industriella mineral och bergarter i Jönköpings län. 1989.
51. **Ressar, H., Ekelund, L. och Ohlsson, S.-Å.** Biogeokemiska kartan. Tungmetaller i Bäckvattenväxter. Översiktsbladen Göteborg och Borås. 1988.
52. **Gustafsson, O., Jonasson, S.A. och Andersson, C.** Grundvattenundersökningar på Kristianstadsslätten 1976–1987. 1988.
53. **Andersson, M.** Markgeokemiska kartan 18–22, G–I. 1988.
54. **Shaikh, N.A., Karis, L., Kumpulainen, R., Sundberg, A. och Wik, N.-G**. Kalksten och dolomit i Sverige. Del 1. Norra Sverige. 1989.
55. **Shaikh, N.A., Karis, L., Snäll, S., Sundberg, A., och N.-G. Wik.** Kalksten och dolomit i Sverige. Del 2. Mellersta Sverige. 1989.
56. **Shaikh, N.A., Bruun, Å., Karis, L., Kjellström, G., Sivhed, U., Sundberg, A. och Wik, N.-G.** Kalksten och dolomit i Sverige. Del 3. Södra Sverige. 1990.
57. **Modig, H., Miller, U. och Robertsson, A.-M.** Karbonat i jord. Del 4. Försurning i äldre sedimentlagerföljder med anknytning till och i jämförelse med nutid. 1990.
59. **Andersson, M.** Markgeokemiska kartan 16–18., G–I. 1989.
60. **Ressar, H., Ekelund, L. och Ohlsson, S.-Å.** Biogeokemiska kartan 14–16, G–H. Tungmetaller i bäckvattenväxter. 1990.
61. **Kornfält, K.-A., Samuelsson, L., Sundberg, A., Wik, N-.G. och Wikman, H.** Malmer, industriella mineral och bergarter i Kronobergs län. 1990.
62. **Andersson, M.** Markgeokemiska kartan 18–21, H–J. 1990.
63. **Ressar, H., Ekelund, L. och Ohlsson, S.-Å.** Biogeokemiska kartan 8–10, A–D. Tungmetaller i bäckvattenväxter. 1990.
64. **Cato, I.** Sedimentundersökningar i Brofjorden särskilt Trommekilen 1989, samt förändringar efter 1972 och 1984. 1990.
65. **Bruun, Å., Kornfält, K.-A., Sundberg, A., Wik, N.-G., Wikman, H. och Wikström, A.** Malmer, industriella mineral och bergarter i Kalmar län. 1991.
66. **Frietsch, R., Sundberg, A. och Wik, N.-G.** Register över svenska fyndigheter av malmmineral och industriella mineral och bergarter. 1991.
67. **Robertsson, A.-M.** Strandförskjutningar i Eskilstunatrakten för ca 9000 till 4000 år sedan. 1991.

68. **Ressar, H., Ekelund, L. och Ohlsson, S.-Å.** Biogeokemiska kartan 5–7, I–K och 8–10, E–G. Tungmetaller i bäckvattenväxter. 1991.
69. **Selinus, O.** (ed.). 2nd International Symposium on Environmental Chemistry. (Abstracts). 1991.
70. **Andersson, M.** Från Falkenberg till Blomstermåla; nuläge och framtida effekter av syrabelastning. 1992.
71. **Hopsu, V.** Norbergs gruvor på 1960-, 70- och 80-talen. 1992.
72. **Gustafsson, O.** Radonhalten i grundvatten från granitområden i Malmöhus län. 1992.
73. **Andersson, M. och Nilsson, C.A.** Markgeokemiska kartan 3–7, F–H. 1992.
74. **Cato, I.** Sedimentundersökningar längs Bohuskusten 1990 – Göteborgs och Bohus läns kustvattenkontroll. 1992.
75. **Ekelund, L., Nilsson, C.-A. och Ressar, H.** Biogeokemiska kartan 8–10, G–J och 11–12, H–J. Tungmetaller i bäckvattenväxter. 1993.
76. **Stephens, M.B. och Wahlgren, C.-H.** (Conveners). Workshop. Ductile shear zone in the Swedish segment of the Baltic Shield. Abstracts and excursion guide. Uppsala 1993.
77. **Sander, A.** Värderingsmodell för naturresurser. Tillämpning på ballasttillgångar.
78. **Nilsson, C.-A. och Ressar, H.** Biogeokemiska kartan 11–12, E–H, 12–13, G–J. Tungmetaller i bäckvattenväxter. 1995.
79. **Wahlgren, C.-H. (red.).** Regional berggrundsgeologisk undersökning. Sammanfattning av pågående undersökningar 1994. 1995.
80. **Bruun, Å., Nilsson, C.-A., Sundberg, A., Wik, N.-G. och Wikström, A.** Malmer, industriella mineral och bergarter i Östergötlands län. 1995.
81. **Andersson, M. och Nilsson, C.-A**. Markgeokemiska kartan 7–9 D–E, 7–9 E–H. 1995.
82. **Kornfält, K.-A., Andersson, M., Daniel, E. och Persson, M.** Kadmium i marken i sydöstra Skåne. 1996.
83. **Robertsson, A.-M., Erlström, M., Damell, D., Qvarfort, U. och Fredriksson, D.** Bakgrundsdata för metaller – surhet och landskapsutveckling från sedimentundersökningar. Sammanställning av data från Örebro. 1996.
84. **Wahlgren, C.-H. (red.).** Regional berggrundsgeologisk undersökning. Sammanfattning av pågående undersökningar 1995. 1996.
85. **Andersson, M. och Lax, K.** Markgeokemiska kartan 20–22, I–L. 1996.
86. **Selinus, O. (red.)**. Miljögeologi. Kartor för samhällsplanerare och miljövårdare. Exempel från Mittnordenområdet. 1996.
87. 14th Salt Water Intrusion Meeting. SWIM 96. 1996.
88. **Larsson, J.-O.** Diamanter – en blivande bristvara?. 1997.
89. **Wahlgren, C.-H. (red.).** Regional berggrundsgeologisk undersökning. Sammanställning av pågående undersökningar 1996. 1997.
90. **Holmberg, J. och Ressar, H.** Biogeokemiska kartan. Tungmetaller i bäckvattenväxter. Norra Värmland och Sydvästra Dalarna. 1997.
91. **Andersson, U.B.** Petrogenesis of some Proterozoic granitoid suites and associated basic rocks in Sweden (geochemistry and isotope geology). 1997.
92. **Frietsch, R.** The Iron Ore Inventory Programme 1963–1972 in Norrbotten County. 1997.

* Utgången

Distribution

SGU
Box 670
751 28 UPPSALA
Tel 018-17 90 00
Fax 018-17 93 70

Tryck: Gotab, Stockholm 1997

ISSN 0349-2176
ISBN 91-7158-557-5