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THE IRON ORE RESOURCES  
OF NORTHERN SWEDEN

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Statsrådet.

The highest summit of Kiirunavaara Iron Ore Ridge.  
Lapland, Sweden.



# THE IRON ORE RESOURCES OF SWEDEN.

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## I.

### NORTHERN SWEDEN,

BY

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With six Maps (22—27) and four Plates.

### INTRODUCTION

By HJALMAR LUNDBOHM.

The iron ore-fields of Lappland are the largest in Sweden, and several of them may well be compared with the largest fields known in the world. They are all situated north of the polar circle, between 17 and 22 degrees east of Greenwich and between 67 and 68 degrees north, thus within a region which, in consequence of the severity of the climate, is not to any great extent suitable for cultivation. Part of the territory belongs to the region of pine forests, other parts are situated in the region of birch forests and others again consist of woodless mountains. The situation of the metalliferous territory is shown on Pl. 3.

The abundance of iron ore in the district has been known for centuries, and the more important ore-deposits have been examined and described already in older times. It was, however, not until about 25 years ago, that the question of utilizing them was seriously taken up and railways built. As soon as this was done, extensive searches were made to find more deposits.

The largest ore-fields, known already of old, are *Gellivare*, *Luossavaara* and *Kiiruna-vaara*, *Svappavaara* and *Ruotevare*.

During the years 1895—1898 private expeditions geologically explored those parts of the territory considered to be metalliferous, and a number of persons were engaged by them, systematically searching for ore with the miner's compass. The result of this work was, later on, at the expense of the State, controlled by a more scientific expedition and this has reported on its work.<sup>1</sup> These expeditions discovered no less than

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<sup>1</sup> Jukkasjärvi malmtrakt. Sveriges Geologiska Undersökning. Ser. C, N:o 183. Stockholm 1900.

32 different deposits. Three of these, viz. *Leveäniemi*, *Mertainen* and *Ekströmsberg*, are very considerable ore-fields, the others, however, as far as is hitherto known, are mostly of little and some of them of no value. In most cases the ore-deposits consist of rock containing magnetite with great attraction on the magnetic needle, and as the ground is generally covered with a thick layer of soil, no exact knowledge of the quality of the deposits could be obtained till after the soil had been removed and borings made. A couple of lean ore-deposits, discovered in this manner, viz. *Nakerivaara* and *Ylipääsnjarka*, are of great extent, but are nevertheless, as far as we know at present, much too poor for exploiting.

Besides the above named fields, the ore-deposits at *Tuolluvaara* were discovered in 1897, also with the help of the miner's compass.

All the above mentioned deposits, with the exception of *Ruotevare*, also described in other connection, are situated in the parishes of *Gellivare* and *Jukkasjärvi* in the province of *Norrbotten*. The accompanying Pl. 3, mentioning only names of the most important fields, gives an idea of their situation (cfr also Map 22).

Most of the ore-deposits show a certain conformity to each other with regard to the quality of the ore and their geological relations and can be said to form a group, fairly well separated from the iron ore-fields of southern Sweden. As a rule the ores are more or less intimately connected with unmistakably eruptive, but often much altered rocks, quartz-porphyrines, syenite-porphyrines and fine-grained syenites, in all probability belonging to a younger division of the Archaean.

Particularly characteristic for most of the ores is their unusually high percentage of iron, in general a high percentage of phosphorus and an insignificant percentage of silicates. In the most important of the ores — those in *Kiirunavaara*, *Luossavaara*, *Gellivare* and *Tuolluvaara* — the sum of iron oxides and apatite varies, as a rule, between 92 and 98 per cent; at *Kiirunavaara* it is usually between 95.2 and 98.5 per cent. It is evident that this circumstance increases the value of the ores, especially so long as they cannot be used to any larger extent, for making iron in the vicinity of the mines, but must principally be reduced at distant places.

The percentage of iron in the ores, that are now mined, is only seldom less than 60 per cent, and occasionally amounts to 68—69 per cent, or still more. The percentage of phosphorus is, as a rule, very high, varying between 0.6 and 3.5 per cent, or more; but ore is also produced with a guaranteed maximum percentage of phosphorus of 0.6 and 0.3 and also an ore suitable for acid bessemer with a max. percentage of 0.05 and small quantities of ore with less than 0.015. The percentage of sulphur in the Lapland ores rarely exceeds 0.05—0.08.

The most important iron ore-deposits are found in mountains, rising more or less above the surrounding ground, and sometimes the tops of the mountains are pure iron ore. Such is the case with *Luossavaara*, *Kiirunavaara* and *Svappavaara*.

It is not known when the Lapland iron ore-fields were first discovered.<sup>1</sup> They were probably very early known to the first inhabitants of the country, the Lapps, but these were then, as now, very little communicative in such cases, because each new discovery reduced their right to exclusively own the country.

<sup>1</sup> The following historical notes are partly taken from other publications and partly gathered by Mr. H. WENNERSTRÖM, Luleå.

The first iron-mine, mentioned in old documents, was Junosuando, situated on Torne river in the parish of Pajala, which was reported in 1643 and shortly afterwards gave rise to an iron-work at the place, and to another at Kengis, both, however, not successful.

The great ore-deposits at Gellivare, Kiirunavaara and Luossavaara are spoken of at the beginning of 1700, but had, in all probability, been discovered already during the preceding century. At Gellivare, ore was mined at least as early as 1736 when, for its utilization, iron-works were built at several places nearer the coast through the instrumentality of JONAS MELDERCREUTZ, who was a pioneer in this part of the country, and also founded a great number of settlements in a large district, that had been allotted to him by the Government. Later on, this work was continued with great energy by S. G. HERMELIN who, during the years 1797—1808, made a great effort to colonize Norrbotten and to produce there a powerful iron-industry. He built roads, founded many settlements, developed manufacturing industry and thus contributed immensely to raise the cultivation of the country. But he did all this with great economical sacrifices and failed in his attempt to create an iron-industry.

The Gellivare iron-mountain made itself, however, continually prominent and many attempts were made to start mining, but without success, which can easily be understood, considering that suitable means for transport were wanting. During 1833—1860, according to official reports, 26 000 tons of ore were mined, a large portion of which was taken to the iron-works along the coast. During 1820 a great many mining claims were assigned and searches made. The so-called Gellivare works, which had received special privileges and consisted of mines and blast-furnaces, iron-works, saw-mills and considerable forests, had passed into the possession of King Karl XIV Johan; in 1855 they were sold for 57 805 £ Sterling to a Norwegian association, in 1861 to a Swedish company and by that in 1864 to the English »The Gellivare Company Ltd» for £ 172 570, half of which sum was for the mines. This company was to build a railway from Gellivare to Storbacken and thence to make the Lule river navigable to the coast, for which purpose the company received a very considerable Government loan, but the enterprise proved a failure, and the Gellivare works passed in 1869 to a new English company and, after several transactions and lawsuits, to Gellivare Aktiebolag with principally English capital. In 1889 a lawsuit about the mines was commenced between this company and a Swedish claimant, who, in the lower court, was awarded the greater part of the mining field and by a special agreement acquired definite possession of it, after which it passed, in 1891, to Aktiebolaget Gellivare Malmfält, which thereafter was the owner of the field till its amalgamation with Luossavaara-Kiirunavaara Aktiebolag.

Kiirunavaara and Luossavaara are for the first time mentioned at the end of 1600 or the beginning of 1700; in 1741 the Lapp Amund Andersson Mangi received a reward for pointing out Kiirunavaara; in 1736 both mountains had been examined by a Government commission, which established the great extent and purity of the ore. After that the ore deposits are often spoken of and grants of mining claims made, without giving any result. At Luossavaara, however, ore was mined in 1804 for the Kengis works; in 1825 an application for permission to export ore from Kiirunavaara to Norway was rejected; in 1830 100 tons were transported from Luossavaara, and from 1842—1856 together 255 tons. In 1860 a small quantity was sent to the southern part of Sweden to be tested as bessemer ore. Nothing was done, however, until 1890 when all claims in both mountains were bought by the then newly formed Luossavaara-Kiirunavaara Aktiebolag.

The essential and direct obstacle to the exploitation of the Lappland ores was, of course, the difficulty to transport them to the coast, and it is of great interest to study the efforts made in the course of time to find out cheaper means of conveyance. In older times, about 1637, when the Nasafjäll silver-mines, situated a little more to the south, near the Norwegian frontier, were to be worked, Government encouraged the enterprise by privileging the founding of colonies along the roads, and 100 years later MELDERCREUTZ' colonisation district shows how, on a large scale, they aimed at procuring a resident population, that could facilitate the transport of the ore.

The transport with reindeer was probably the most used, but also horses, and trials were likewise made with oxen. In HERMELIN's time the ore was transported with horses to Lule river at Edefors, was then carried in boats and then carted to the blast-furnace at Selet,

together about 120 miles. In 1819 an official investigation was made respecting the possibility of rendering the water-course between Gellivare and Öfver-Kalix practicable for the purposes of traffic, which however proved impossible, and in 1835 the regulating of Råne river was proposed, but also without result; in 1826 it was proposed to procure a steam sledge; in 1850 a horse-railway was planned from Malmberget to the coast, and the costs of transport on the same were calculated at about 6 sh. 6 d. pr ton; in 1856 a railway from Gellivare to Strömsund iron works, 112 miles, was calculated at about £ 300 000. As stated before, a serious attempt was made about the middle of 1860, to bring about a combined railway and canal communication between Malmberget and the coast, and in 1869 a new project for building a railway was put forth without leading to any result.

It was probably mostly due to the efforts of Dr ALRIK LJUNGGREN, who owned the Luossavaara and Kiirunavaara ore-field together with major ROBERT SCHOUGH, that in the years 1882 and 1883 concessions were obtained for a railway between Luleå at the gulf of Bothnia and the Ofotenfjord in Norway, and that English enterprise was interested in this project. The English holders of the concessions for this railway, which was to pass both Gellivare and Kiirunavaara, had taken the lease of the mines for a long time. The building of the railway was commenced both in Norway and Sweden, and already in 1887 the first train with ore ran from Gellivare to Luleå. There was, however, not sufficient capital, and in 1889 the work was stopped before the railway was completed. The railway was later on taken over by the Swedish and Norwegian States, and the former completed the line between Gellivare and Luleå. In 1896 the Luossavaara-Kiirunavaara Aktiebolag sought concession for a railway between Gellivare and Narvik at Ofotenfjord which, however, was not granted; in 1898 the national assemblies in Sweden and Norway resolved that the States built the railway; in November 1902 it was ready for the transport of ore, and in January 1903 commenced the shipments from Narvik. The Aktiebolaget Gellivare Malmfält, which, from 1892, had exported ore from Luleå, had at the same time acquired the majority of shares in Luossavaara-Kiirunavaara Aktiebolag; in 1903, shortly after the Narvik export had commenced, both companies were purchased by Trafikaktiebolaget Grängesberg—Oxelösund, which company already possessed the mines at Grängesberg, in the mining district of central Sweden, and has ever since had the management of the ore-production in all the fields. Already in the beginning of 1890 the persons controlling the interests of the then amalgamated Lappland ore-fields, invited the Swedish State to purchase the fields at a very low price, but the offer was not accepted, in 1902 a complete scheme was drawn up for the same purpose, but again without any result; in 1906 the negotiations were taken up, but in vain. In 1907, however, an agreement was made according to which Luossavaara-Kiirunavaara Aktiebolag took over the mines in the Gellivare iron-mountain and handed over half of its share capital to the Swedish State, which besides other engagements undertook to have 93 250 000 tons of ore transported from Kiirunavaara and Gellivare to the harbours at Narvik and Luleå at a certain fixed rate of freight. In connection herewith the Swedish State received the option to acquire by purchase, after 25 years and on certain fixed conditions, the other half of the shares in the ore-field company.

A certain smaller part of the Gellivare iron-mountain, called Koskulls-kulle, was bought in 1898 by Aktiebolaget Freja which belongs to the Witkowitz works in Moravia, and carries on ore-export over Luleå.

For the purpose of utilizing the ore-deposits at Tuolluvaara the Tuolluvaara Grufaktiebolag was, in 1900, founded by nine iron-works in central Sweden, which themselves consume all the ore containing little phosphorus and export the phosphoric ore.

All the Lappland ore-fields in which mining is carried on thus belong to the three companies Luossavaara-Kiirunavaara Aktiebolag, Aktiebolaget Freja and Tuolluvaara Grufaktiebolag. Luossavaara-Kiirunavaara Aktiebolag is controlled by Trafikaktiebolaget Grängesberg—Oxelösund, which owns half of the share capital, the other half belonging to the Swedish State. The ore-deposits at Svappavaara, Leveäniemi, Mertainen, Ekströmsberg and several other smaller ore-fields, all without any means of communication, belong to the Swedish State.

As mentioned before, the ore is exported from Gellivare and smaller quantities also from Kiruna and Tuolluvaara over Luleå, the port of which is usually open from the end of May to the middle of November, thus about 5½ months. During more than half of the year the ore is stored at Luleå.

From Kiirunavaara and Tuolluvaara it is chiefly exported over Narvik, the port of which is open all the year round.

A small part of the Lappland ore is consumed by the Swedish iron-works, but the principal part is exported to Germany, England, North America, Belgium and France. As is said before, the bulk of the ore is phosphoric and is used for basic bessemer and basic open hearth.

As now electricity has been introduced as a factor in the iron-industry, and there being very considerable water-power in the neighbourhood of the mines, it can scarcely be considered a very sanguine prediction that an iron-industry may rise in the very mining districts.

**Shipping from the iron ore-fields in Lappland.**  
(Metric tons.)

Year	Malmberget	Koskulls-kulle	Kiirunavaara	Tuolluvaara
1892.....	138 944.0			
1893.....	259 826.1			
1894.....	524 212.0			
1895.....	385 781.8			
1896.....	614 261.7			
1897.....	815.804.8			
1898.....	804 732.7			
1899.....	920 293.9	86 745.6	1 076.1	
1900.....	911 228.5	121 957.3	—	
1901.....	927 842.6	119 617.7	414.1	
1902.....	916 008.6	102.383.1	11 809.0	
1903.....	929 880.9	137 830.1	807 373.1	3 387.9
1904.....	932 403.5	148 021.7	1 188 520.2	11 013.3
1905.....	905 331.5	165 602.9	1 452 778.0	60 316.8
1906.....	1 015 158.6	199 308.0	1 602 252.1	70 298.5
1907.....	891 858.1	207 086.9	1 332 509.0	81 959.1
1908.....	838 893.3	199 576.8	1 610 956.7	75 459.6
1909 <sup>1</sup> .....	750 224.8	205 977.2	1 592 180.9	70 513.0

Of these quantities, total 25 149 612.1 tons, 15 460 271.1 tons have been shipped over Luleå and 9 689 341.0 tons over Narvik.

About 74 per cent of the whole quantity is exported to Germany, 17 per cent to England and 7 per cent to Belgium and France. To the United States of America and Canada have been exported only small quantities during the years 1903—1908. In 1909 were sent to the United States 127 496.2 tons and in 1910 the export to the States will be about 400 000 tons.

<sup>1</sup> The decrease in shipment during 1909 is due to the general strike, keeping the works idle about 10 weeks.

## KIIRUNAVAARA AND LUOSSAVAARA

By HJALMAR LUNDBOHRM.

The mountains Kiirunavaara and Luossavaara rise to a considerable height on either side of the flat valley, in which the railway between the ports of Luleå and Narvik has been built. The distance from Kiirunavaara to these ports is respectively 305 and 170 kilometres.

*Kiirunavaara*, situated south of the valley, is a ridge running north and south about 3.5 km and divided into a number of more or less isolated hills, of which the highest is about 748 m above the level of the sea and 248 m above the bottom of the valley. The whole ridge consists of an almost continuous body of iron ore, also extending northward in the boggy ground and in the neighbouring lake, so that the deposit, in its entirety, has a length of more than 5 kilometres. In the ridge itself the ore has either been altogether exposed or covered only by a comparatively thin layer of moraine.

*Luossavaara* is a 728 m high mountain north of the valley. The iron ore, commencing at the southern slope, and not connected with the Kiirunavaara ore, extends through the top of the mountain down the northern slope and has a length of about 1.2 km.

Besides these large deposits, which both have an eastern dip, there are in their hanging-walls several smaller deposits.

The geology of the mountains and the shape of the ore bodies is shown on the map and sections, Map 25.

The ore is surrounded by eruptive rocks of a somewhat different nature in the foot-wall and in the hanging-wall. The eastern slope of the mountain, thus the hanging-wall, consists of porphyries with an extremely fine-grained or felsitic, usually reddish-brown ground-mass with numerous, spread grains of microcline. In this porphyry there are often fragments of porphyry with another structure, and of an iron ore of the same kind as in the chief deposits.

The foot-walls consist of grey or brownish-grey syenite porphyries of very varying appearance. In Kiirunavaara, at a distance of about 400–500 metres from the ore, it changes to a distinctly grained syenite. Dikes of quartz-porphyry and syenite-porphyry are found in the foot-walls, and some of them pierce the ore.

The metalliferous porphyry-syenite area has a length of about 12 to 15 kilometres and a width of up to 3 or 4 km. It is surrounded on both sides by sedimentary rocks, in the east much metamorphosed layers of coarse conglomerates, called Kurravaara-complex, resting on greenstone and on tuffs, in the west by a series of conglomerates and shists with layers of syenite-porphyries and amygdaloids, which have been grouped together under the name of Hauki-complex. The uppermost part of this is a comparatively thick formation of quartzite sandstone. In the Hauki-complex there are at different levels small layers of lean hematite and a layer of conglomerate with numerous pebbles of hematite.

Kiirunavaara and Luossavaara hold a probably unique position among all the iron ore resources hitherto known, not only because of the unusually large quantities of ore they contain, but also, and especially, because of its chemical composition. The ore, consisting almost exclusively of magnetite, is remarkably free from non metallic constituents, except apatite, the percentage of silicates generally being very small, often not more than 1 to 3, sulphur about 0.05 and often less, titaniferous minerals seldom more than 0.5 per cent. At greater depths and within certain parts of the field calcspar is found in cracks.

A constituent which is always present is phosphorus and it occurs in the most varying proportions. In some parts of the ore body there are only some hundredths of a per cent, in others it may rise to 4 or 5 per cent or more, but in any case the ore is so uniform that with the knowledge of the percentage of phosphorus, one can, with considerable certainty, calculate the percentage of iron and vice versa. In the most northern and the most southern part of Kiirunavaara there is ore with such a low percentage of phosphorus, that it can be used for the acid bessemer and open hearth processes; in the other parts of this mountain the amount of phosphorus is very high; the Luossavaara ore contains, as a rule, comparatively little of this constituent. Sometimes the phosphoric mineral, apatite, is so finely disseminated in the magnetite, that it cannot be discovered without the microscope, though the ore contains up to 5 per cent phosphorus, sometimes it is found as smaller grains, as fine veins or fillings of cracks, or as irregularly formed drums and, in certain cases, as bed-like masses up to 0.3 metres in width and 10 or 15 metres in length. Broadly speaking, there is a certain regularity in the occurrence of apatite, but in each separate part of the field the changes are so considerable and rapid, that the ore cannot be sorted in the same manner as at other mines. In order to produce commercial qualities with a sufficiently uniform composition, it has thus been found necessary to use mixing instead of sorting, and such a system has been carried out very successfully. The mining, hitherto exclusively made in open quarries, is for this purpose always preceded by a minute examination of the face of the ore, in such a way that samples are taken from adjacent points, often with a distance of only 5 metres; each sample is analyzed and the amount of phosphorus marked on its right place on a map in large scale, contour-lines for similar contents of phosphorus are drawn, and the mining and mixing of the ore is regulated with the help of these maps. For such purpose some 25 000 to 30 000 analyses of general samples have been made, besides all the shipping assays.

Both Kiirunavaara and Luossavaara show, besides the above named, another peculiarity which distinguishes them from most of other deposits. In both mountains the ore-body itself is almost entirely devoid of deads, a circumstance which, of course, very favourably influences the mining. The only occurrences of rocks in the ore to speak of is a dike of porphyry about 15 metres broad, which is crossing the whole ore-body in the hill Geologen in the northern part of Kiirunavaara, a very small dike somewhat more south and some small masses of porphyry in the foot-wall in the same hill and in the hill Professorn. In general there is pure and rich ore close to the hanging-rock, and such is often the case also at the foot-wall. At some places, for instance in the hill Landshöfdingen, there has, however, been found some lean ore, a few metres thick, nearest the foot-walls.

From a commercial point of view and with principal regard to the percentage of phosphorus, the ore is at present classified as follows:

A-ore.....	maximum 0.05	per cent P;	about 69—70	per cent Fe.
C <sup>I</sup> -ore .....	» 0.3	» » »	» 67—68	» » »
C <sup>II</sup> -ore.....	» 0.8	» » »	» 66	» » »
D-ore .....	between 0.8 and 2.5	» » »	average about 62	» » »
G-ore .....	» 2.0 » 4.5	» » »	» 58	» » »

The following table gives the average contents of iron and phosphorus in the ore, calculated from all the shipping samples during the last years.

Tab. I.

Quality	Years	Number of cargoes	Tons	Average	
				per cent Fe	per cent P
A .....	1903—1909	378	1 141 302.16	69.63	0.024
B* .....	1905—1909	22	67 387.46	69.26	0.67
C .....	1904—1909	132	371 854.53	68.60	0.162
D .....	1903—1909	1 388	7 003 158.53	62.48	1.88
F* .....	1901—1905	87	278 966.93	59.34	2.78
G .....	1903—1909	186	708 636.73	57.77	3.09

\* Not produced any longer.

A few complete analyses (Tab. II, p. 561 [11]) will give an idea of the chemical composition of the ore.

#### QUANTITIES OF ORE.

The first more comprehensive examination of the ore-supplies was made in 1875 at the expense of the State and these were then calculated by O. GUMÆLIUS<sup>1</sup> at Kiirunavaara above the water level of the lake Luossajärvi at 265 110 000 tons; the area of the horizontal section of the ore-body at this level was estimated at 310 934 m<sup>2</sup>, and it was assumed that each sinking of one metre would give 1 481 920 tons of ore and that the ore-body extends to a considerable depth. The ore supply of Luossavaara above the level of the Luossajärvi was, at the same time, estimated at 27 700 000 tons.

In 1897 the writer made an examination of the ore-fields<sup>2</sup> for the State and estimated the quantity of ore above the level of the lake at 215 million tons in Kiirunavaara and at 18 million tons in Luossavaara. These estimations were only intended to ascertain whether the ore supply was sufficient to justify the building of a railway between Gellivare and Narvik and, in order to obtain a minimum quantity, it was assumed that the ore-body narrowed off, rather rapidly, in the depth, which, at later examinations, proved not to be the case.

Professor M. L. DE LAUNAY, who has written a detailed treatise on certain iron ore-deposits<sup>3</sup> in Scandinavia, expresses the supposition, that the quantity of the ore down

<sup>1</sup> Malmfyndigheter inom Gellivare och Jukkasjärvi socknar i Norrbottens län. Sveriges Geologiska Undersökning. Ser. C, N:o 24. Stockholm 1877. With a french summary.

<sup>2</sup> Kiirunavaara och Luossavaara järnmalmfält. S. G. U. Ser. C, N:o 175. Stockholm 1898. Translated to English.

<sup>3</sup> L'origine et les caractères des gisements de fer Scandinaves. Annales des Mines, 1903.

Tab. II.

Location of pit	Ferric oxide	Magnetic oxide of iron	Manganese protoxide	Magnesia	Lime	Alumina	Titanic acid	Silica	Phosphoric acid	Sulphur	Copper	Total	Iron	Phosphorus
<b>KIIRUNAVAARA.</b>														
Hill Direktören.....	4.58	76.01	0.93	0.75	8.92	0.79	0.13	1.80	6.713	0.050	—	100.673	58.25	2.931
» Grufingeniören.....	9.53	86.53	0.19	0.77	0.67	1.07	0.45	0.91	0.22	0.026	—	100.366	69.34	0.098
» » .....	0.94	91.50	0.20	1.45	2.22	0.81	0.21	1.74	1.28	0.018	—	100.368	66.92	0.561
» » .....	2.31	89.13	0.29	0.77	3.12	0.18	0.35	1.34	2.18	0.022	—	99.692	66.16	0.953
» Geologen .....	5.83	65.31	0.15	1.15	14.04	1.26	0.05	1.04	10.97	0.036	—	99.836	51.37	4.789
» Geologen and Grufingeniören .....	3.50	84.10	0.31	0.76	5.50	0.06	0.25	1.10	4.14	0.019	0.002	99.741	63.35	1.80
» Vaktmästaren .....	0.71	79.85	0.13	0.77	9.63	0.52	0.12	1.41	6.99	0.038	—	100.168	58.29	3.053
» » .....	0.76	96.10	0.13	0.62	0.60	0.20	0.50	1.02	0.016	0.026	—	99.972	70.12	0.007
<b>LUOSSAVAARA.</b>														
Hill Ragnar .....	4.91	90.19	0.21	0.72	0.60	1.39	0.26	1.88	0.046	0.016	0.005	100.227	68.75	0.020
» Ivar.....	7.56	88.16	0.19	0.54	0.50	1.37	0.32	1.34	0.046	0.025	0.006	100.157	69.20	0.020
» Heimdal .....	18.83	74.53	0.20	0.83	0.90	1.32	0.32	2.58	0.41	0.014	0.004	99.938	67.15	0.18
» Balder .....	26.33	68.73	0.22	0.54	0.60	1.38	0.30	1.94	0.122	0.014	0.003	100.179	68.20	0.053
» Gylfe .....	2.33	86.13	0.23	0.47	3.80	1.50	1.36	4.84	0.007	0.005	tr.	100.672	64.00	0.003
» » .....	24.79	71.05	0.17	0.25	1.74	1.09	0.28	1.50	0.099	0.011	tr.	100.98	68.80	0.043
» Gabriella .....	1.64	85.55	0.22	0.45	3.00	1.90	0.32	5.74	1.73	0.024	0.005	100.579	63.10	0.75

to a depth of 300 metres may amount to 600 to 800 million tons. He makes an attempt to reconstruct the whole deposit, before a part of it had become eroded and makes a guess at 1 500 to 2 000 million tons, and he considers that the deposit in any case is undoubtedly the greatest known mass of oxidized iron on the earth.

Professor W. PETERSSON, who 1907, by order of the Swedish Government, examined all the existing material, that could throw light upon the question of ore supplies, calculated the quantity within most of the Company's mining claims in Kiirunavaara at about 480 000 000 tons, of which about 200 million tons above the water level of the Luossajärvi.

All the older calculations of the quantity of iron ore are based only on surface examinations and some few deep-borings, but since the real mining was started, a large number of diamond drill holes have been sunk, and the knowledge gathered by these, by stripping, tunnels and drifts, executed for mining purpose as well as by extensive magnetic surveying has made it possible to calculate the mass of iron ore more accurately. With regard to the depth of the ore-body there is however still much uncertainty.

The map and sections (Map 25) illustrate to a certain extent what we know about the ore-body.

The part of it occurring below the lake is known only by magnetic survey and some drill holes.

Between the south shore of the lake and the railway at the northern end of the mountain, the horizontal width of the ore-body varies between 20 and 100 metres and averages 50 metres. The thickness of the ore, right angle to foot-wall and hanging-wall, is estimated to 41 metres as an average.

In the about 3 000 metres long mountain ridge, between the railway, above mentioned, and the southern end of the hill Professorn, the boundaries of the ore-body are very well known; its horizontal width is in average 96 metres and the thickness, right angle to hanging- and foot-wall, 78 metres, according to measurements made on 56 section-lines taken 50 metres apart. There is no exception from the rule that the ore-body is heavier in and around the highest tops and narrower in the lower parts of the ridge. The maximum thickness has been found in a cross section through the hill Geologen, where the horizontal width is 196 metres and the thickness about 164 metres. In the highest peak, Statsrådet, in a tunnel right across the ore-body, 138 metres above the level of the lake, the horizontal width is 188 metres. In the lowest parts of the ridge the width of the ore varies between 40 and 56 metres.

The horizontal area of the ore-body has been calculated by adding areas of horizontal sections, each of a length of 50 metres, taken at the outcropping of the hanging wall, and the following figures were obtained:

Bared or otherwise well known ore between the railway at the northern end of the mountain and the southern end of the hill Jägmästaren and the isolated deposits at the SE end of Kiirunavaara, known by magnetic survey and diamond drillings, about .....	329 000 m <sup>2</sup>
The deposits between the railway at the northern end of the mountain and the northern end of the ore-deposits below the lake, known chiefly by magnetic survey and diamond drillings, about .....	107 000 »
	<hr/>
Total about	436 000 m <sup>2</sup>

In order to obtain information as to the quantity and quality of the ore and also to secure the right to claims 37 diamond drill holes have been sunk to a total depth of 5 997 metres, and several of these drill holes have given very valuable information with respect to the dip and depth of the ore body. This has enabled a number of cross sections of the mountain to be made, of which 6 of the most characteristic are shown on Map 25.

The following table (p. 564 [14]) gives the more important data from the majority of the drill holes.<sup>1</sup>

According to these figures the dip of the hanging-wall is known at 21 different points, and it varies between  $38^{\circ}$  and  $83^{\circ}$ . The foot-wall has been reached at 13 points, its angle of dip varying between  $45^{\circ}$  and  $67^{\circ}$ .

The average of the observations indicates, that the dip of the hanging-wall and the foot-wall, as far as hitherto ascertained, is practically the same.

The figures of the table show certainly, that the thickness of the ore-body in several places is rather less deeper down than in the surface ground, but the opposite occurs just as often, which confirms the supposition first come to, that such variations in the thickness, as occur in the surface, also occur in the direction of the dip.

The drillings supply important information as to the depth to which the ore-body reaches. Under the surface of the lake Luossajärvi the boundary between the hanging-wall and the ore is struck at 8 different points of which 3 lay resp. 146.7, 205 and 236.7 metres under the surface of the water. The boundary between the ore and the foot-wall has been struck at 6 points of which two lay at a depth of 106.8 and 114.3 metres. The greatest known depth of the ore-body is in the claim Zenobia, where the drill hole finished in ore 300.6 metres under the Lake and thus 548 metres under the mountains' highest top. Here the ore must have a considerably greater breadth deep down than in surface.

The results of the drillings warrant the conclusion that the ore continues to a very great depth and this assumption has been very strongly confirmed by magnetic surveys made by Dr. V. CARHEIM-GYLLENSKÖLD which are described p. 565—567 [15—17]. It seems therefore to be a very reasonable assumption that below the lake Luossajärvi can be estimated to be at least as much the cubic mass obtained by multiplying the area at the surface of the lake by 300 metres. It is certainly possible that the area at the surface of the lake has not precisely the same size as at a depth of 300 metres below it, but on the other hand it is proved that the ore in some places extends even still deeper.

The estimation of the quantity is further based upon the assumption that its specific gravity averages 4.5, a number arrived at by weighing 59 larger pieces of ore with variable percentages of phosphorus. A check upon these figures was obtained by comparing the estimated quantity of ore within a certain part of the mountain with that quantity which later was mined and taken out from there.<sup>2</sup>

<sup>1</sup> When making out the sections, it has been assumed that no great distortion of the drill holes has occurred. In one hole — Statsrådet No II — the writer has found by special investigation that there is no deviation in the vertical plane of the hole to a depth of 100 metres below the surface.

<sup>2</sup> To arrange the working a diagram was drawn 1902, which showed the estimated quantities within certain small sections of the mountains. Up to the first of October 1908 so many of these sections had been removed as represented an ore quantity of about 7 318 625 tons. From the commencement of the working until the above mentioned date, the mining journals showed that 7 378 625 tons had really been taken out or a difference of only about 60 000 tons.

Drill hole Table.

Table III.

Drill hole		Contact between hanging-wall and ore-body		Contact between foot-wall and ore-body		Dip of	
Name	Dip	Below the highest peak of the ore-mountain metres	Above + below — the surface of lake Luossajärvi metres	Below the highest peak of the ore-mountain metres	Above + below — the surface of the lake Luossajärvi metres	hanging-wall	foot-wall
Zenobia .....	vertical	485.2	— 236.7	—	—	49°35'	—
Kiirunavaara .....	»	453.5	— 205.0	—	—	55°20'	—
Max .....	»	395.2	— 146.7	—	—	49°18'	—
Vaktmästaren 220 .....	»	240.1	+ 8.3	325.6	— 77.1	52°14'	54°25'
» III .....	58°	229.6	+ 18.8	272.1	— 23.7	64°0'	54°48'
» 190 .....	45°	210.6	+ 37.8	262.6	— 14.2	54°15'	55°16'
» V .....	55°	197.5	+ 51.3	254.6	— 6.2	58°1'	51°0'
» 180 .....	vertical	215.9	+ 32.6	355.3	+ 106.8	49°30'	51°0'
Brynnolf .....	»	245.9	+ 2.6	362.8	— 114.3	52°22'	53°15'
Stoll 160 I .....	45°	—	—	214.6	+ 33.8	—	65°45'
Bismarck .....	vertical	317.7	— 69.2	—	—	57°54'	—
Stoll 160 II .....	45°	—	—	215.6	+ 32.8	—	50°40'
» III .....	45°	—	—	207.6	+ 40.8	—	59°9'
Statsrådet I .....	45°	29.9	+ 218.5	115.4	+ 133.1	83°9'	53°50'
» II .....	67°	115.0	+ 133.5	198.4	+ 50.1	61°30'	67°30'
Hjalmar .....	vertical	220.1	+ 28.4	—	—	55°5'	—
Volter .....	»	230.5	+ 18.0	—	—	51°3'	—
John .....	»	261.4	— 12.9	—	—	63°33'	—
Kunigunda .....	»	319.7	— 71.2	—	—	53°20'	—
Professorn III .....	70°	—	—	144.1	+ 104.3	—	46°30'
» IV .....	70°	174.6	+ 73.8	241.6	+ 6.8	51°30'	45°0'
Ernst .....	vertical	333.6	— 85.1	—	—	58°16'	—
Nordenström .....	»	157.5	+ 91.0	—	—	37°54'	—
Napoleon .....	»	239.4	+ 9.1	—	—	55°33'	—
Elisabet .....	»	249.3	— 0.9	—	—	45°33'	—

Under the previously mentioned assumption, it has been estimated that Kiirunavaara contains the following ore-quantities:

Above the surface of lake Luossajärvi about ..... 240 000 000 tons

Below the surface of Luossajärvi according to the whole ore-area, except

the isolated deposits SE of the mountain, 559 000 000 tons say about 500 000 000 »

altogether about 740 000 000 tons

<sup>1</sup> Assuming a regular decrease of the ore-area from the upper part of the mountain down to a depth of 300 metres below the surface of the lake in the proportion of 0.11 per cent, a figure deducted from what we know by diamond drillings in a certain part of the mountain, the total quantity of ore to the said depth has been calculated to 672 000 000 tons.

The iron ore in Luossavaara during 1908 underwent a very close examination by Mining Engineer C. I. ASPLUND, who presented an official but unpublished report on it. From this it is gathered, that the deposits for the greater part consist of an ore low in phosphorus and with a percentage of iron somewhat higher than Kiirunavaara ore. ASPLUND has stated, that the deposits contain

down to about 100 metres depth 5 000 000 tons of ore with less than 0.075 per cent P

1 800 000	»	with .....	0.075—1.0	»	»	»
800 000	»	»	more than	1.0	»	»

There are qualities with very low percentage of phosphorus; these cannot, however, be specially mined but must be separated by a rather difficult and uncertain hand-picking.

ASPLUND gives five complete analyses showing:

Fe %	64.90	68.10	56.10	64.20	67.20
P %	0.007	0.066	3.01	0.0085	0.024

All these samples contain vanadic acid varying between trace and 0.16 %.

Some complete analyses are given in Tab. II (p. 561 [11]).

Respecting the ore-quantities it is not possible to give any other figures than those of 1898 — more recent examinations not having been made — viz. 18 million tons.

The small deposits of hematite, which occur in the eastern slope of Luossavaara and in Haukivaara, are not worth noticing, as the ore is of such a varying character and so poor in iron as to be of no value under present conditions.

#### MAGNETIC SURVEY.

In the year 1900 a very extensive magnetic survey of the iron ore-fields and their environs was commenced, and this was done for several very important reasons. The one was to find out and register with great scientific care the distribution of the earth's magnetic force in and around these gigantic deposits of strongly magnetic iron ore before any disturbance had taken place as a result of mining and export of the ore. The information gathered by such a work would become not only of great scientific interest but also of practical value; if renewed in the future when a large part of the ore has been carried away, it will afford an excellent possibility of testing our present theories for determination of the extension in depth of magnetic ore-bodies by magnetic measurements. And in fact it would also give some results immediately on account of the exceptionally regular shape of these ore-deposits, whose upper parts could be examined by means of diamond drilling. Thus it would be possible to get some information at once, regarding the depth of the ore-body.

The work has been carried out under the guidance of Dr. V. CARLHEIM-GYLLENSKÖLD, who will publish a special monography on the results. He has however kindly prepared the following notes, illustrated by the maps and sections on Map 26, from which very useful conclusions can be drawn regarding the quantity of ore.

»It should be carefully kept in mind that magnetic measurements alone are insufficient for determining the position of magnetic masses. It is well known to every physicist that a known distribution of forces in the space surrounding a closed surface is consistent with an infinite number of different distributions of magnetic matter inside the

main surface. Consequently, magnetic measurements are not sufficient for determining the dimensions and position of the attracting masses, unless we beforehand know something of their general form and position. Therefore, we must look for other evidence, geological or topographical, of the general position of the magnet. Together with such evidence, geological or other, the results of the magnetic measurements give us a valuable means of determining the approximate depth of the iron ore magnet.

Now we know from the boundaries of the ore at many places and from the dip of the layer at the surface, and from the results obtained from some very deep drill holes, that the ore forms a large, comparatively thin layer with an average thickness of about 80 metres, and a dip of about  $54^\circ$  to the east of the vertical. The hanging-wall and the foot-wall have the same dip, within the probable errors of the measurements, viz.  $54^\circ 19'$  and  $54^\circ 54'$ . The thickness of the deposit does not vary in a systematical manner with the depth, the deepest drill hole at the claim »Zenobia» situated close to the lake Luossajärvi proves that, in a level about 300 meters below the surface of the lake, the thickness of the ore is greater than it is at the surface. Accordingly, the ore deposit is supposed to form a very great elliptical cylinder, the dip and the thickness of which is known from geology.

If we then know the forces resulting from the attraction of the iron ore alone, the action of the earth's magnetism being subtracted from the directly measured forces, the problem of finding the depth of the centre of the magnet can be solved by strictly mathematical reasoning. The problem can also be solved graphically, in an approximate manner, by a single glance at the diagram representing the magnetic forces of the iron ore-deposit in a plane perpendicular to the axis of the elliptical cylinder.

In accordance with the principles here set forth, an area of some 4 kilometres and a half in length, and of the same breadth, was examined in detail. The base-line traversing this area coincided with the longer axis of the ore. The area was divided transversally by a number of lines passing normally to the longest axis of the supposed magnet. On every transverse line a great number of measurements were taken with a magnetometer, and the results were all reduced to absolute units of the C. G. S. system.

A matter of greatest importance is the exact knowledge of the earth's magnetic action as a whole, which ought to be subtracted from the observed forces in order to get the local forces attributable to the action of the iron ore alone. Much trouble arose from the small amounts of magnetite existing in almost every rock of this country. Special care was taken to get the true value of the earth's magnetic force by making a great number of measurements in the surrounding country, near the railway between Kiirunavaara and the bridge crossing the river Kalix älf to a distance of about 13 km and following this river up to Paittasjärvi, about 40 km from Kiirunavaara.

The magnetic force attributable to the iron ore alone was then worked out, and its rectangular components were calculated: 1<sup>st</sup> horizontally and parallel to the largest axis of the layer; 2<sup>ndly</sup> horizontally and transversally to the main axis; and 3<sup>dly</sup> vertically downwards. The first component proved very small and irregular and may be left out of consideration; the other components, transversally and vertically, may be composed to a resultant force, acting in the plane perpendicularly to the axis of the elliptical cylinder.

The results are shown in the accompanying diagrams (Map 26, B, C, D). The local forces proved extremely regular; between two transversal lines, at 800 and 3 200 metres to the

south of the zero point in the base-line, they may be said to be almost constant in strength, thus proving that the ore, to an extent of about 2 400 metres, forms an uninterrupted, continuous layer. The mean of the forces observed on the different transversal lines was then taken, and the result is graphically shown in the diagram D (Map 26).

This diagram shows at a glance that the upper pole of the magnet is situated at about 100 metres from the outcrop of the layer; according to our experience from other iron ores in Sweden, the whole transversal length of the ore should, therefore, be some 1 200 or 2 000 metres. Further, if we draw a line perpendicularly to the transverse axis of the cylinder from the point where the attraction is parallel with the main axis, this perpendicular will cut the axis at a point coinciding with the centre of the cylinder. Thus we find that the distance of the centre from the top of the cylinder is about 1 100 metres, or the transverse diameter some 2 200 metres.

Summing up the results, we find respecting the axes of the iron ore, which are supposed to have the form of a very flat ellipsoid: 1<sup>st</sup> that the longest axis, according to the chart, extends some 3 600 metres (from 200 to 3 800 to the south of the zero point in the base-line); 2<sup>ndly</sup> that the shortest axis (2 *c*) measures 102 metres (this figure has been calculated from the mean thickness, 80 metres, using the formula for the area of the ellipse of the section:  $\pi \times 500 \times c = 90$ ); 3<sup>dly</sup> that the intermediate axis measures *at least* 1 000 metres. — The volume will then be  $\frac{4}{3} \pi \times 1 800 \times 500 \times 51 = 192 300 000$  cubic metres, and the weight, supposing the specific gravity to be 4.5, some 865 million metric tons.»

## TUOLLUVAARA IRON ORE-FIELD.

By HJALMAR LUNDBOHRM.

Tuolluvaara is a comparatively small mountain, rising about 50 to 70 metres above the surrounding marsh land and about 505 metres above the sea level. It is situated 5 kilometres E from Kiirunavaara and the mines are connected with the railway Luleå-Narvik by an aerial tramway of 3.65 km length. All the ore-deposits at Tuolluvaara, except one claim, are owned by Tuolluvaara Grufaktiebolag and the share-holders in this company are eight Swedish iron works.

The mountain consists of a red porphyry of the same character as that in Kiirunavaara, and in the northern part of the hill, in the mining claims Emil, Ararat, Siam and Choulalongkorn this rock includes several ore-deposits with a total length of at least 500 metres (see Pl. 4). A number of smaller ore-bodies, known chiefly by magnetic survey, are scattered in the other parts of the hill. The big deposit has an horizontal width of up to 30 metres, the general dip is about 60° SE, but in the claim Siam the ore is folded in a rather interesting way and one part of it is dipping steeply to the East.

The ore is a fine-grained magnetite, sometimes containing small grains or larger pieces of hematite. Like all other iron ores in this region, it contains more or less

apatite, but the mineral is distributed in such a way that an ore with phosphorus below the acid bessemer limit can be mined separately from another, suitable for openhearth or basic bessemer. In the mining claims Siam and Choulalongkorn the ore low in phosphorus is regularly deposited in the lower part of the ore-body and ore high in phosphorus in the upper part nearer the hanging-wall. The latter contains thin layers of apatite, and the percentage of phosphorus rises sometimes to 1 per cent and exceptionally to 2 or 3 per cent.

For commercial purpose the ore is classified in:

A-ore with maximum 0.015 per cent P  
 C » » » 0.6 » » »

Table I gives the average contents of iron and phosphorus in these classes during 1905—1909.

Table I.

A - o r e :				C - o r e :			
Year	Tons	Average		Year	Tons	Average	
		per cent Fe	per cent P			per cent Fe	per cent P
1905.....	36 829.5	67.72	0.007	1905 .....	9 518.54	66.17	0.056
1906.....	31 217.6	68.18	0.010	1906 .....	37 145.27	67.38	0.064
1907.....	31 043.2	68.39	0.008	1907 .....	55 536.66	67.57	0.161
1908.....	24 946.4	67.94	0.009	1908 .....	46 576.54	67.33	0.349
1909.....	25 414.7	67.91	0.007	1909 .....	54 184.41	67.65	0.294
1905—1909.....	149 451.4	68.02	0.008	1905—1909 .....	202 961.42	67.44	0.217

Table II gives the chemical composition of some typical samples of the ore.

Table II.

	Magnetic oxide of iron	Ferric oxide	Manganese protoxide	Magnesia	Lime	Alumina	Silica	Titanic acid	Phosphoric acid	Sulphur	Total	Iron	Phosphorus
C-ore from a cargo weighing 2 794 tons; sample weight 14 tons.....	87.11	3.84	0.17	2.34	0.76	0.92	4.18	0.21	0.14	0.046	99.716	65.77	0.059
C-ore from stockpile; sample weight 200 kg.....	89.39	2.85	0.12	1.94	0.81	0.48	3.66	0.17	0.19	0.045	99.655	66.72	0.085
A-ore-sample from the mine	90.05	4.60	0.12	1.83	0.42	0.34	2.14	0.11	0.016	0.059	99.685	68.43	0.007

From the commencement of the work until the end of 1909 has been mined 165 900 tons A-ore and 213 922 tons C-ore.

The A-ore is exclusively used in Swedish iron works. The C-ore is exported to England, Germany, and America.

The horizontal areas of the outcrop of the ore-bodies have been estimated as follows.

Stripped, well known ore .....	11 630 m <sup>2</sup>
By magnetic survey known ore .....	3 170 »
	<hr/>
	total 14 800 m <sup>2</sup>

In order to ascertain the quantity of ore 13 drill holes, with a total depth of 1 091 metres, have been sunk and a few of the results are shown on the Pl. 4. According to the section through the drill hole No 7, the largest ore-body, that of Siam, decreases in such a way that it ceases at a depth of 230 metres below the surface. There are however strong geological reasons to believe, that this ore-body as well as some other has a pitch to SW and probably will continue to a much greater depth than the above mentioned. But as long as the extension of the ore is not at all known, it is not possible to make any certain estimation of the whole quantity. If the ore does not continue in the direction of the pitch, but is wedging out at a depth of 230 metres below the datum of the mountain, the ore quantities left in the beginning of 1910 have been estimated to be:

In the claims Siam, Choulalongkorn, Emil, and	
Ararat .....	5 480 000 tons,
in other claims, known by magnetic survey, about	<hr/> 1 370 000 »
	Total 6 850 000 tons

## GELLIVARE IRON-MOUNTAIN.<sup>1</sup>

*Gellivare-Malmberg* or the *Gellivare Iron-Mountain* is situated 100 km S of Kiruna, 210,6 km N of Luleå and 7 km NE of Gellivare station on the railway Luleå—Narvik. The mountain rises about 250 m above the surrounding district, differing little topographically from the adjacent tree covered mountains, which as a rule rise to a greater height, the summits being, like that of Malmberget, above the tree limit. Malmberget lies almost due east and west, the western and highest part Vålkomman being 617 m, and the eastern and south eastern parts, Kungsryggen and Kaptenshöjden, 580 m above sea level. The northern side of the mountain slopes abruptly to the valley of the Lina river, whilst the southern side slopes down gradually, broken by longer or shorter terraces.

<sup>1</sup> The calculation of the quantities of iron ore as well as the principal part of the description of the ore-deposits is delivered by AXEL DELLWIK, chief engineer at Gellivare Malmberg.

The railway is built from Malmberget station, 419 m above sea level, to the lowest of these terraces, and from it branch out sidings to different parts of the mountain, below the principal mines. In the east a railway has been built from the Gellivare station to the mines at Koskulls-kulle, 333 m above sea level.

Gellivare Malmberg (se Map 23) consists principally of a red, gneissic, fine-grained rock, intersected by large and small dikes of granite, sometimes so numerous as to minimize the older rocks. The ore-deposits occur as several complexes of lenses, crossed by numerous granite dikes.

The most important of these ore-complexes is the s. c. »Stora malmen» (the big ore) which, with a length of about 4 500 metres, extends from Tingvall hill to Välkomman hill, and in the continuation of these big deposits there are both on the eastern and the western slopes of the mountain larger and smaller collections of ore-lenses within districts, each of which has a length of about 1 500 metres.

South of the »Big ore» the miner's compass indicates that there exists ore within extensive areas, but on examination only insignificant deposits were found at the surface, such as within the claims Erik, Nils, Hedvig, and others. Here are, however, great masses of gangue rocks rich in magnetite. In the eastern part of the field are found important, although not particularly large ore-deposits within the claims Alliansen, Dennewitz and Hvitåfors. These are possibly geologically connected with the comparatively large ore-deposits, found in Koskulls-kulle, described elsewhere.

In the southernmost part of the mountain, there are also detached ore-complexes. The ore consists of several lenses, of which the largest is in the claim Selet, where a fairly large mine has been worked from the commencement of the mining.

The southernmost ore-complex is the s. c. »Kaptenslagret», with a length of over 1 000 metres. Here an ore is found which contains comparatively little phosphorus.

The greatest ore-bodies have a thickness of 40 to 70 metres and exceptionally as much as 100 metres. They usually have a lenticular shape and dip from 80 degrees down to 30 degrees mostly towards S or SSE. Moreover, the ore-bodies are always pitching to S or SSW.

All the ore-bodies have been exposed to hard pressure, and the large ore-complexes as well as the different lenses are, therefore, often very strongly folded and contorted.

As the thickness and length of the different bodies or lenses varies very much, their ore-area changes also very considerably, or from 20—25 000 m<sup>2</sup> to some hundred m<sup>2</sup>, or still less.

In certain cases, and mostly in the hanging-wall, the ore-bodies are sharply limited towards the rock, in other cases they are surrounded by gangue rock (»skarn»), consisting of hornblende, magnetite, apatite and sometimes also of feldspar, quartz and other minerals; not seldom the ore passes gradually into such a rock. The ore consists partly of magnetite and partly of hematite, the former in predominant quantities. The magnetite is usually coarse-grained, the hematite has a finer texture, but both are generally soft. Characteristic for both is the often very high, but always very varying percentage of phosphorus, depending on the occurrence of apatite.

Most of the ore-deposits are more or less mixed with rocks, consisting sometimes of granite, other times of gangue rock (»skarn»), and the percentage of ore, within the deposit

itself, averages about 70 per cent. In connection with the mining it is, however, necessary to remove considerable quantities of deads from the hanging-walls and the foot-walls.

During the years 1894—1908 have been mined 12 453 329 tons of ore and 9 672 384 tons of rock, comprising both »skarn» rich in magnetite and rock from the hanging-wall and foot-wall without any considerable percentage of ore. Since 1904 the metalliferous rock has been separately stored, and during the years 1904—1908 have been mined 4 586 844 tons of iron ore and 1 085 711 of ferriferous rock, averaging 45 per cent iron, and also 2 519 694 tons of waste rock.

At the mining the ore is picked by hand and classified as to its percentage of phosphorus in the following way:

A	Ore containing max.	.....	0.025	per cent P
C <sup>I</sup>	»	.....	0.35	» » »
C <sup>II</sup>	»	.....	0.80	» » »
D	» min.	.....	0.80	» » »

Table I gives the average percentage of iron and phosphorus in all the shipping samples, taken during the years 1904—1909.

Table II, p. 573 [23], contains complete analyses of some of the most important ores.

Table I.

Quality	Number of cargoes	Tons	Average	
			per cent Fe	per cent P
A ore .....	85	184 843	69.04	0.022
B »* .....	5	4 988	68.34	0.052
C <sup>I</sup> » .....	240	668 776	66.75	0.285
C <sup>II</sup> » .....	602	1 718 845	65.33	0.590
D » .....	658	2 687 358	63.41	0.979
F »* .....	2	497	60.44	1.160

\* not produced any longer.

The mining in Gellivare Iron-Mountain has hitherto reached only a comparatively inconsiderable depth, at the most 120 metres below the surface, but by a large number of diamond drill holes, some of which have been sunk to about 250 metres below the surface, it has become evident that the ore extends very much deeper. There is however at present no possibility of determining the real depth, and therefore we have no objective basis for calculation of the whole quantity of ore. Thus we must be content with an approximate estimation of the quantity, which with certainty can be assumed to exist above a certain level.

At the investigations made as yet, no decrease of the horizontal sections of the ore-bodies, or in other words of the ore-area, could be proved at the depths reached by

mining or diamond drilling. Certainly we can but exceptionally compare the horizontal sections in the surface with the sections, arrived at greater depths by means of drillings, because the folding and the pitch in most cases have produced a dislocation of the ore-bodies, which cannot always be followed in detail; but in a great many cases the mining has, nevertheless, given evident proofs that the thickness of the ore at the greatest known depths is generally equally large and not seldom larger than at the surface. Thus for instance, the Linné-ore, Map 24, at the 80 metres level<sup>1</sup> has a thickness of about 33 metres, and at the 160 m level, thus 80 metres deeper, the thickness is the same. The Tingvallskulle-ore whose average width is about 70 metres has, according to the section through the drill holes, Map 24, a width at the 80 m level of about 40 metres. At about 156 m level, thus 76 m deeper, the ore-body is by rock, wedging in from the west, divided into several ores of together about 38 m in width. By a vertical drill hole the ore is known between the 219 and the 310 m level and at about 260 m, thus 180 metres below the surface, the width of the ore can be estimated to about 50 metres. These circumstances are still further illustrated by horizontal projections, Map 24, selected from the mine-maps in order to elucidate the variations in thickness and dip of the ore.

The small ore deposits within the field give good information respecting the relation between the extent in the horizontal plane and in depth of the ore-bodies. Thus, for instance, the ore in the Fredrika mine, the most easterly in the Kaptén deposit, shows a somewhat larger area at a depth of 120 metres (the 237 metres level) than at higher levels and a smaller deposit near to it, »the western Kaptén», which has a pitch of about 45 degrees, has about the same area, viz. 500 m<sup>2</sup>, at the levels 170 m and 237 m.

Many other circumstances indicate with great certainty that the ore-deposits reach a considerable depth. Thus a detailed examination of the small lenses of different rocks, iron ore and »skarn» proves that these have been much stretched, and that the lengthening in the direction parallel to the pitch of the ore often is very considerable. It has been observed as much as 3 to 5 times larger measures in the direction of the pitch than in the horizontal direction. As before shown the great ore-complexes have a very large horizontal extent, and the different lenses often have a length of 400 to 600 metres; the largest — the »King Oscar-Sofia» deposit — is not less than 1 000 metres long.

By putting together all these circumstances and what is known of the extent of the deposits at the greatest depths under the surface as yet reached, we can with great certainty assume the continuation with a nearly unchanged thickness to the 500 m level. This level is, on an average, 382 metres below the average level of the bottoms of the mines in the beginning of 1909 and the surface of the deposits as yet not mined.

Although it must be taken for granted that considerable quantities of ore also exist below the 500 m level the calculations in the table below (Tab. III, p. 574 [24]) only give the quantities of ore to that level. The calculations are based on the surveyed or, in certain cases, assumed ore area for each special deposit, further on the percentage of ore won by

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<sup>1</sup> All levellings in the mining field are based on a common datum or zero, situated on the highest point of the mountain, 616.4 metres above sea level, and the figures given to mark different levels within the field indicate, therefore, the levels in metres below the said datum.

Table II.

Analyses of general samples of iron ores mined 1908.

Mine	Quality	Ferrous oxide (in insoluble matter)	Magnetic oxide of iron	Ferric oxide	Manganese protoxide	Lime	Magnesia	Alumina	Silica	Titanic acid	Phosphoric acid	Sulphur	Total	Iron	Phosphorus
Fredrika	A	0.18	94.24	0.54	0.15	0.60	0.73	1.05	1.90	0.82	0.04	0.03	100.28	68.76	0.018
Kungsgrufvan	A	0.24	94.96	0.30	0.09	0.63	0.93	0.81	1.55	0.73	0.04	0.06	100.34	69.16	0.017
Fredrika	C1	0.40	91.71	0.17	0.18	2.09	1.21	0.83	1.89	0.31	0.68	0.05	99.22	66.84	0.207
Kungsgrufvan	C1	0.18	91.79	0.65	0.19	1.60	1.12	0.86	2.61	0.42	0.74	0.06	100.22	67.06	0.325
Kapten	C1	0.44	91.16	0.00	0.13	1.67	1.14	0.95	3.72	0.18	0.51	0.04	99.94	66.35	0.224
Selet	C1	0.71	90.73	1.17	0.12	1.18	0.90	1.32	2.70	0.48	0.58	0.06	99.95	67.07	0.253
Dennewitz	C2	0.44	91.85	1.66	0.14	0.67	1.25	1.18	2.18	0.32	0.33	0.08	100.10	68.01	0.146
Tingvallskulle	C2	0.24	90.94	1.08	0.13	2.17	0.83	0.59	2.50	0.07	1.34	0.06	99.95	66.80	0.586
Kung Oscar	C2	0.24	81.64	10.72	0.14	1.45	0.64	0.87	3.18	0.08	0.95	0.04	99.95	66.81	0.414
Vulkan	C2	0.46	85.02	5.26	0.09	1.87	0.92	0.85	4.13	0.09	1.33	0.09	100.11	65.61	0.581
Sofia	C2	0.49	91.11	0.23	0.08	2.19	1.05	0.44	2.63	0.10	1.18	0.18	99.68	66.52	0.514
Upland	C2	0.13	81.43	10.90	0.16	1.65	0.59	0.80	3.05	0.07	1.12	0.04	99.94	66.70	0.532
Josefina	C2	0.15	59.43	32.86	0.07	1.88	0.42	0.69	3.04	0.06	1.30	0.01	99.94	66.16	0.569
Skåne	C2	0.19	67.04	22.73	0.11	2.15	0.62	1.08	4.45	0.09	1.40	0.04	99.90	64.61	0.610
Hermelin	C2	0.22	90.31	2.03	0.14	1.97	0.95	0.44	2.52	0.28	1.22	0.04	100.12	66.99	0.534
Baron	C2	0.37	89.25	1.83	0.10	1.75	1.50	0.74	3.40	0.27	0.83	0.04	100.08	66.20	0.361
Välkomman	C2	0.24	72.02	20.67	0.10	1.46	0.81	0.82	2.54	0.26	1.16	0.03	100.11	66.81	0.505
Tingvallskulle	D	0.35	82.48	1.80	0.11	5.16	1.45	0.82	4.20	0.18	3.33	0.05	99.94	61.26	1.454
Kung Oscar	D	0.37	80.79	3.92	0.11	4.68	1.36	0.93	4.28	0.31	3.18	0.04	99.97	61.54	1.388
Vulkan	D	0.44	81.21	3.04	0.13	4.49	1.20	1.26	5.00	0.43	2.83	0.06	100.09	61.28	1.234
Sofia	D	0.51	83.22	1.58	0.08	4.23	1.42	1.03	4.49	0.39	2.76	0.12	99.83	61.78	1.206
Upland	D	0.06	76.56	12.37	0.15	3.45	0.62	0.80	3.40	0.18	2.39	0.05	100.03	64.15	1.044
Josefina	D	0.15	34.16	50.93	0.15	4.23	0.52	1.71	4.80	0.29	3.90	0.03	99.99	60.51	1.312
Skåne	D	0.22	67.47	20.80	0.15	3.88	0.93	0.75	2.56	0.17	2.96	0.04	99.93	63.59	1.292
Hermelin	D	0.19	87.98	2.43	0.12	2.97	0.66	0.44	2.82	0.09	2.22	0.04	99.96	65.56	0.970
Baron	D	0.24	84.60	1.91	0.09	4.26	1.41	1.03	3.27	0.17	2.85	0.04	99.87	62.79	1.244
Välkomman	D	0.19	74.02	13.78	0.12	3.93	0.96	0.74	3.00	0.21	3.00	0.04	99.99	63.40	1.312

mining from each special deposit and on the specific gravity obtained for the different qualities of ore by direct weighing.

In the table the ore-bodies have been grouped as follows:

Group A consists of ore-deposits known by actual mining and also such as have been examined by stripping, by drillings and by magnetic survey and have been proved to be of economic value under the present circumstances; it also comprises some small deposits with an area of together 10 000 m<sup>2</sup>, which, in consequence of their insignificant size and their situation, cannot be mined at present.

Group B consists of lean ores which can only be utilized in connection with magnetic concentration.

For the calculation of the quantities of ore the field has been divided in 4 different parts:

»The Eastern field» (Östra fältet) situated on the eastern slope of the mountain, comprising the deposits Hvitåfors, Alliansen, Dennewitz, and others;

The eastern part of the »Big ore» (Stora malmen), comprising the deposits Norrbotten, Tingvallskulle, Sofia, and others;

Tab. III.

Quantities of iron ore in the deposits in Gellivare malmberg, belonging to Luossavaara—Kiirunavaara Aktiebolag.

Name of Deposit	Ore-area m <sup>2</sup>	Per cent of iron ore in the deposit	Average specific gravity	Iron ore per 1 metre depth	Estimated quantities of iron ore				Total
					from surface and from working levels in mines			from the 200,253 and 357 metres level resp. to the 500 m level	
					to Hermelin adit, 200metres level	to Ting- vallskulle and Hvitå- fors adits, 253metres level	to the 357metres level		
Hvitåfors—Dennewitz—Alliansen and some other deposits.....	23 800	70	4.8	79 968	—	4 381 400	—	19 752 100	24 133 500
Norrbotten—Tingvallskulle—Sofia and some other deposits .....	55 300	70	4.8	185 808	—	34 499 400	—	45 894 600	80 394 000
Upland—Hermelin—Välkomman and the small deposits in the western field .....	85 200	65	4.8	265 824	23 111 400	—	—	79 747 200	102 858 600
Kaptenslagret—Selet and some other deposits .....	17 120	75	5.0	64 200	—	—	9 774 800	9 180 600	18 955 400
Group A .....	181 420	—	—	595 800	23 111 400	38 880 800	9 774 800	154 574 500	226 341 500
» B .....	25 000	70	4.5	78 750	6 300 000	—	—	—	6 300 000
Total									232 641 500

All the western part of the »Big ore» from Upland to Välkomman and Johan, and the smaller deposits in the westernmost part of the field;

»The Southern field» (Södra fältet) comprising Kaptenslagret, Selet, and other deposits.

For the »Eastern field» and the eastern part of the »Big ore» the quantity of ore has been calculated separately from the surface and from the bottoms of the mines in the beginning of 1909 to the adits in Tingvallskulle and Hvitåfors, situated at the 253 metres level and from this level to the 500 metres level.

The quantity of ore in the western part of the »Big ore» has been calculated from the bottoms of the mines in the beginning of 1909 to the Hermelin adit, situated at the 200 metres level, and from this level to the 500 metres level.

In the »Southern field» the quantity has been calculated from the surface and the level of the present bottoms of the mines of the 357 metres level and between this and the 500 metres level.

### KOSKULLS-KULLE.<sup>1</sup>

The Mining Company Bergverks-aktiebolaget Freja, formed in the year 1898, owns 8 claims (»utmål») on the east side of the mountain »Gellivare-Malmberg». The claims are called: Koskulls-kulle, Försöket, NW-Bolagsgrufvan, SW-Bolagsgrufvan, SE-Bolagsgrufvan, Bolagsgrufvan No. 5, Elise, and Gotfried. At Koskulls-kulle there are two bodies of magnetic iron ore; the western one has a surface of 2 000 m<sup>2</sup> and dips SSW; the eastern and principal one is 250 metres long and 100—125 metres wide and has an area of 25 000 m<sup>2</sup> and a dip of 55° S.

Through the hanging-wall and the ore-body diamond drill holes with a total length of 1 383 metres have been sunk (Fig., p. 576 [26]). The hole *a* is drilled only in ore, and is 93 metres in depth; the hole *b* is drilled through the hanging wall and found the ore-body at 241,8 metres; the hole *c* found the ore-body at 135,84 metres. Thus the ore-body dips with the same width to this depth at least.

The mining work was begun in the year 1898 and the output has been:

in the year 1898.....	11 904 tons
» » » 1899.....	114 984 »
» » » 1900.....	127 360 »
» » » 1901.....	103 854 »
» » » 1902.....	111 274 »
» » » 1903.....	138 852 »
» » » 1904.....	142 989 »
» » » 1905.....	164 876 »
» » » 1906.....	210 053 »
» » » 1907.....	211 883 »
» » » 1908.....	195 885 »
» » » 1909.....	198 441 »

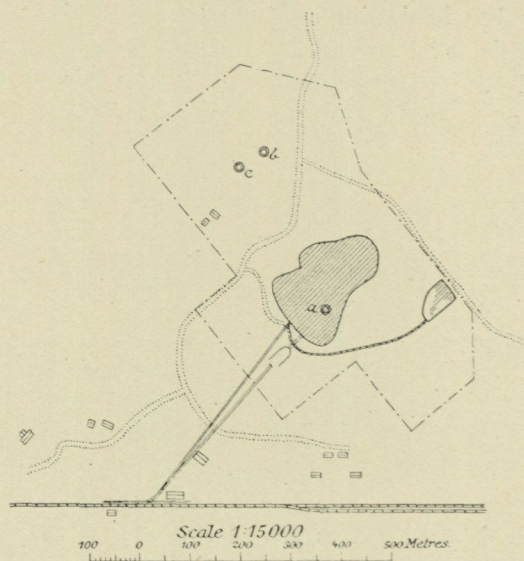
<sup>1</sup> Communicated by F. WANJURA, Mining Engineer, Koskulls-kulle.

Each metre in depth of the total area of the ore-body equals in round numbers 100 000 tons of ore, thus to a depth of 140.80 metres (bore hole *b*) we have 14 000 000 tons.

By experience from other Swedish districts it may be assumed, that the ore continues to a depth of at least 400 metres; thus this deposit contains at least

40 000 000 tons ore.

According to an analysis of 1898 a sample of the purest ore from the surface contained:



- Boundary of claims
- ▭ Mine
- Railway
- Incline
- Diamond drill hole
- ▨ Magnetite

SiO <sub>2</sub> .....	2.29 per cent	
FeO .....	31.18 » »	} 69.37 per cent Fe
Fe <sub>2</sub> O <sub>3</sub> .....	64.45 » »	
Al <sub>2</sub> O <sub>3</sub> .....	1.08 » »	
MnO .....	0.24 » »	0.18 per cent Mn
CaO .....	0.61 » »	
P .....	0.10—0.4 per cent.	

As at other Lappland-mines the ore is sorted by hand-picking at the mines into several grades. The purer is called »A-ore»; the ore with more than 0.035 % P or S is called Cp- or Cs-ore.

## OTHER DEPOSITS IN THE PARISH OF JUKKASJÄRVI

By WALFR. PETERSSON.

## SVAPPAVAARA.

The Svappavaara ore-mountain is situated at  $67^{\circ} 38\frac{1}{2}'$  north and  $21^{\circ}$  east of Greenwich, at a height of about 350 m above the level of the sea, 40 km ESE of Kiirunavaara, and 65 km NNE of Gellivare ore-mountain. Its top is about 100 m above the surrounding plain; towards the north the ore-mountain dips rather abruptly, and towards the south it gradually changes into a broad ridge called Danelivaara. In the 17<sup>th</sup> and 18<sup>th</sup> centuries there was from time to time a lively mining industry in copper ore carried on at this place. The copper ore-deposits are situated on both sides of the iron ore-deposits, near the top of the ore-mountain.

The iron ore-deposits extend from Danelivaara in a northern direction over the ore-mountain, the highest top of which, as well as the northern steep declivities, consist of ore at the surface, and continues towards the north below the bog area at that place. The deposit, which strikes in the direction N—S and dips  $70-75^{\circ}$  E, has a length of about 1.3 km and an average width of about 40 m. As shown on the geological map (Map 27) it is divided in several lenses of varying extent, the northernmost and largest of which has a length of 770 m and a width of 25—60 m. In the northern part of the deposit the ore consists of magnetite and in the southern part of hematite. These two kinds of ore pass into one another in the strike direction, immediately south of the top of the ore-mountain. The Svappavaara ore is fine-grained, sometimes almost compact, and consists of an intimate mixture of almost exclusively magnetite, resp. specular hematite, apatite and calcspar in greatly varying proportions. Amphibole in the magnetite, and garnet in the hematite occur very rarely.

The chemical composition of the ore varies somewhat in different parts of the field in regard to the percentages of iron, lime and phosphorus. In a great many general samples of magnetite ore from different parts of the field the percentage

of iron has varied between .....	43.2	and	65.8
» phosphorus                   » .....	0.608	»	3.188
» sulphur                       » .....	0.027	»	0.081
» lime                           » .....	1.1	»	11.6 % and
» titanitic acid               » .....	0.15	»	0.40.

The analyses of the hematite ore have given the following percentages:

iron .....	48.12 — 64.26
phosphorus .....	0.357 — 3.088
sulphur .....	0.05 — 0.06
lime .....	0.63 — 6.59
titanic acid .....	0.09 — 0.45

Within a limited area, in a small depression below some large, a couple of centuries old burrows at the old copper mines, situated close by the iron ore-deposits at Svappavaara, the hematite is particularly rich in iron (67.1—68.3 per cent) and low in phosphorus (0.033—0.074 per cent). Evidently the apatite and calcspar have here been dissolved and carried away from the originally compact ore by acid water from the old pyritous burrows. The highly phosphorous and the less phosphorous kinds of ore occur mixed over the whole ore-field. The hematite contains, however, on the whole, less phosphorus than the magnetite.

In case of mining on a large scale in the Svappavaara ore-field it has been calculated that the composition of the ore would average 61—62 per cent of iron, 0.6—0.7 per cent of phosphorus and about 3 per cent of lime, and the ore is, therefore, suitable for the basic processes.

The ore-area at Svappavaara is about 50 000 m<sup>2</sup>. Detailed investigations have shown that the specific gravity of Svappavaara ore is, on an average, 4.55, from which it has been calculated that 1 m<sup>3</sup> of the ore-deposit at this place represents 3.8 tons of picked ore.

Only few investigations have been made regarding the extent of the ore-deposit in depth. By means of diamond drilling it has been ascertained, that ore exists at the depths of 62.6, 150.7 and 168.24 m, respectively, below the top of the ore-mountain, but sufficient information for determining the extent of the ore at greater depths has not been obtained thereby.

At the calculations, made hitherto, of the ore-supply at Svappavaara, only the quantity existing above the level of the plain, surrounding the ore-mountain, has therefore been taken into consideration. This quantity has been estimated to about 15 000 000 tons. Both the geological appearance and the result of the magnetic measurements seem, however, to indicate, that the ore extends to a great depth, and one ought consequently to be entitled to add to the afore said quantity very considerable ore-supplies as in all probability existing. As, however, the investigations of the ore-deposit at greater depths have not been carried out to any greater extent, the ore-supply has not been estimated to more than about 30 000 000 tons representing a depth below the top of the ore-mountain of about 200 m. In all probability, however, the ore-supplies of this field will be found to be considerably underrated.

The Swedish state is the owner of this ore-deposit since 1908.

#### LEVEÄNIEMI.

This ore-field, discovered with the miner's compass in 1897, is situated about 2 km SSE of Svappavaara. The rock within the ore-field is entirely covered by soil, 3—15 m deep; a great part of the field is boggy. For this reason, and the cover of soil consisting to a large extent of clay, sand-drift and peat, the determination of the size and quality of the ore-deposit has met with great difficulties. Thus the rock could only be bared at a few places by removing the soil, and examined by means of blasting, and the investigation of the field had principally to be made by means of diamond drilling and by examining the cores. The determination of the supplies of ore has also been rendered very difficult by the fact, that, besides the rich ore to a large extent within the field, also some kinds of rocks are found, which partly contain plenty of

magnetite, either in fine particles in the rock, or as smaller lumps, spread in the rock. These rocks are, as a rule, not so rich in iron that they can be utilized as ore, but have a strong influence on the magnetic instruments and consequently render it exceedingly difficult to read the magnetic maps which have been made of the field.

It was, therefore, not possible before 1907 to estimate the quality and extent of the ore-supplies, and then only after particularly detailed magnetic measurements and diamond drilling in 73 holes of 2—166 m in depth, and with a total length of drill-holes of more than 1 700 m.

Fig. I—III (Map 27) show the maps based upon these magnetic surveys.

Fig. IV (Map 27) shows the geological map of the ore-field, made on the basis of these examinations.

The ore containing area at Leveäniemi has an extent of about 1 200 m in length, from north to south, and a width of 700—300 m.

Rich ore is found in the southern part of the field in the form of a number of larger and smaller longish lenses, somewhat displaced in relation to each other and so disposed, that they form an ore-deposit which, towards the south, extends in a curve of about 1 000 m in length. The different ore-lenses have a length, varying between some tens and 300 m, and a width from a few metres up to 40—50 m. In the northern part of the field there are several smaller, scattered ore-lenses, and in its western part there is a long ore-body, striking N—S of about 300 m in length and about 20 m in width. In the western part of the field, the different ore-bodies dip about 60—70° E, in the southernmost part they are more flat, dipping 30—40° nearest the surface, but at deeper levels 55—60°. In the eastern part of the field the dip is 60—75° W. These ore-bodies contain sometimes smaller intercalations of syenite-leptite, now with, now without interstratified magnetite in considerable quantities and, sometimes, a stratum of rich ore, 0.1 m to a couple of metres thick. This leptite containing magnetite is plentiful in certain parts of the field and contains, at many places, so much magnetite that, under certain circumstances, it ought to be possible to use it advantageously in connection with magnetic concentration.

The ore in the Leveäniemi ore-field is exclusively magnetite which, at some places of the northern part of the field, is somewhat mixed with hematite. The ore is fine-grained and compact, sometimes rather loose and often a little pipy. The ore contains, besides magnetite resp. specular hematite, also amphibole in varying quantities, in certain parts of the field calcspar, and at a few places apatite in considerable quantities.

The percentage of iron is generally high, usually more than 60 per cent and sometimes as much as 69 per cent. The percentage of phosphorus is within the largest part of the field very low, 0.005—0.05, in other parts, however, it is higher, 0.05—0.79, and reaches occasionally 1.0 per cent and more. The varieties of ore, containing little phosphorus and those containing more phosphorus are, in general, well separated from each other. Thus the ore low in phosphorus is found in the western and the southernmost parts of the field, where the ore contains, on an average, about 63.4 per cent iron and 0.014 per cent phosphorus, whereas the ore higher in phosphorus appears in the easternmore part of the field and contains, on an average, about 63 per cent iron and 0.35 phosphorus. The percentage of sulphur is very low (0—0.030); the percentage of titanitic acid varies between 0.05 and 1.35; and the percentage of vanadic acid between 0.17 and 0.20.

Complete analyses of general samples of cores from diamond drilling in different parts of the field have given the following result.

	Drill hole			
	o 0—16.4 m	I 0—28 m	Z 35—72 m	d 12.3—38.9 m deep
Fe <sub>2</sub> O <sub>3</sub> .....	0.80	—	1.76	4.14
Fe <sub>3</sub> O <sub>4</sub> .....	92.80	94.55	92.44	89.90
FeO.....	—	0.87	—	—
MnO.....	0.23	0.10	0.10	0.18
CaO.....	0.80	0.44	1.64	2.12
MgO.....	0.83	0.78	1.34	0.97
Al <sub>2</sub> O <sub>3</sub> .....	0.72	1.20	0.34	0.35
TiO <sub>2</sub> .....	1.34	0.41	0.10	0.05
SiO <sub>2</sub> .....	1.92	1.35	1.75	1.38
P <sub>2</sub> O <sub>5</sub> .....	0.010	0.032	0.69	1.00
V <sub>2</sub> O <sub>5</sub> .....	0.20	0.17	not determ.	not determ.
S.....	0.030	0.013	0.011	0.017
Loss of moisture.....	0.10	—	—	—
	99.780	99.915	100.171	100.107
Fe.....	67.76	69.15	68.06	68.00
P.....	0.005	0.014	0.30	0.49
S.....	0.030	0.013	0.011	0.017

The above mentioned bodies of rich ore cover a total area of about 32 000 m<sup>2</sup>. Regarding the extent of the ore-deposit in the depth, the said borings have shown, that the different ore-bodies vary with regard to thickness etc., but, taking everything into consideration, the ore-deposit is, on the whole, uniform as regards dimensions and composition down to the depth to which the investigations have hitherto been made, or about 100 m. On account of the high percentage of iron in the ore it has been calculated that 1 m<sup>3</sup> of the ore-deposit represents 4 tons of pure ore. To this level the ore-supply is therefore about 15 000 000 tons; as, however, the prospecting works, hitherto carried out, have proved ore at still deeper levels, and as the geological relations indicate a considerably greater depth of the ore-body, the said sum may be increased to about 30 000 000 tons. It is highly probable, however, that the total ore-resources are still larger.

The Swedish state is the owner of this ore-deposit since 1908.

#### EKSTRÖMSBERG.

This ore-field (Map 27) is situated on the northwestern declivity of the mountain Pidjastjåkko at 67° 48' N and 19° 40' E of Greenwich.

The ore-deposit consists of several longish, connected ore-bodies, separated by 3—12 m thick layers of slaty quartz-porphry, striking in NW—SE and dipping vertically. The surrounding rock is quartz-porphry. The largest of these ore-bodies,

"the Great magnetite ore" has a length of 1.2 km and a width, varying between 22 and 52 m. All the ore-bodies together have an area of about 50 000 m<sup>2</sup>.

The ore consists partly of magnetite and partly of hematite, either in separate bodies, or mixed. Besides magnetite, resp. specular hematite, the ore contains apatite and amphibole in smaller quantities.

As to the chemical composition, the ore contains, on an average, a rather high percentage of iron and a percentage of phosphorus which varies between a couple of tenths and 2 to 3; the percentage of sulphur is very low, as also the percentage of titanitic acid. Analyses of about hundred general samples of unsorted ore from different parts of the field have given the following result:

	The Great magnetite ore per cent	The Great hematite ore per cent	Other ores per cent
Iron.....	58.43—68.68	54.60—65.94	56.71—67.85
» on an average.....	64.10	61.07	63.15
Phosphorus .....	0.280—2.42	0.792—2.336	0.238—1.842
» on an average	1.27	1.46	1.094

Sulphur varies between 0.03 and 0.069 per cent.

Titanic acid varies between 0.17 and 0.56 per cent.

The chemical composition will be seen from the following complete analyses of magnetite from this deposit.

	I per cent	II per cent
Fe <sub>2</sub> O <sub>3</sub> .....	4.83	4.09
Fe <sub>3</sub> O <sub>4</sub> .....	82.28	80.12
MnO.....	0.18	0.35
CaO .....	3.84	4.68
MgO.....	0.50	0.73
Al <sub>2</sub> O <sub>3</sub> .....	0.61	0.88
SiO <sub>2</sub> .....	5.33	4.21
P <sub>2</sub> O <sub>5</sub> .....	2.52	3.46
TiO <sub>2</sub> .....	not determ.	0.17
S.....	0.06	0.03
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	100.15	98.72
Fe .....	62.96	60.86
P .....	1.10	1.57

In consideration of the high percentage of iron in the ore of Ekströmsberg and of the quality of the ore-bodies it has been calculated, that 1 m<sup>3</sup> of worked rock represents 4 tons of pure ore. As the ore-bodies at the surface have considerable dimensions and the ore-field shows certain geological analogies with the Kiirunavaara ore-field, in which the extent of the ore to a great depth has been established, one ought to be

entitled to assume a great depth for the ore-deposit at Ekströmsberg, and this so much the more, as the magnetic measurements, made at the field, indicate that such is the case. As, however, no more careful prospecting works have been made hitherto respecting the depth of the ore-deposit, one ought, at present, not figure on more than 50 000 000 tons of ore. In all probability, however, the ore supply, at this place, is considerably larger than stated above.

The ore-field at Ekströmsberg has hitherto not been worked. The Swedish state is the owner of it since 1907.

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There are several smaller iron ore-deposits in the neighbourhood of Ekströmsberg, as Njakak, Pajttasluspavaara, Laukkujärvi, Skuokimjokk, Tjoårika and others. Of these, however, only Laukkujärvi, situated 5 km north of Ekströmsberg ore-field, is of any considerable importance. The ore at that place consists of hematite, mixed with magnetite and calcspar. This hematite contains 57—60 per cent of iron and 0.013—0.016 per cent of phosphorus. The ore-area amounts to about 2 500 m<sup>2</sup>; prospecting works regarding its extent in the depth have not been made.

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#### MERTAINEN.

This ore-deposit is situated about 14 km NW of Svappavaara and 29 km SE of Kiirunavaara on the south-eastern slope of the mountain Mertainen.

The ore-deposit was discovered by means of the miner's compass, and the preliminary magnetic survey seemed to indicate rich supplies of ore, covered by layers of soil which are accumulated on the said slope. The extensive examinations by means of removing the soil, blasting and diamond drilling that have been carried out here have, however, proved that the strong influence on the magnetic instruments is principally to be attributed to a highly magnetic breccia, consisting of lumps of syenite porphyry, bound together by magnetite. This breccia contains sometimes lumps of magnetite which, however, very seldom have such a large extent that they can be considered workable. There are, however, also some larger bodies of rich iron ore, especially in the exposed part of the field where two ore-bodies have a length of 375 and 200 m and a width of 28—9 and of about 18 m, respectively. The total area of rich ore in the field amounts to about 10 000 m<sup>2</sup>. The magnetic breccia, which partly could be used in connection with magnetic concentration, has an area of about 75 000 m<sup>2</sup>. The surrounding rock is syenite-porphry. The ore in Mertainen consists exclusively of magnetite, and is remarkable for its unusually high percentage of iron and its generally very low percentage of phosphorus.

The iron ore has, in a great many general samples of unsorted ore, proved to vary between 56.7 and 68.81 per cent, or, on an average, 64.1 per cent, and the percentage of phosphorus between 0.003 and 0.322 or, on an average, 0.065.

The ore is, therefore, for the most part suitable for the acid metallurgical processes.

Regarding the ore-supply no reliable estimation can be made on account of the peculiar geological relations of the ore-deposit. If thus the ore-supply, suitable for the acid processes, is here stated to amount to about 5 000 000 tons, this calculation does not pretend to be more than approximate.

#### PAINIROVA.

Of the same nature as the ore-deposit at Mertainen is that at *Painirova* situated 8 km S of Mertainen. This deposit consists of brecciformous veins and nodules of magnetite in a syenite-porphry; there are also smaller bodies of rich iron ore, but of very inconsiderable dimensions. The ore being magnetite is rich in iron and contains a varying percentage of phosphorus. In the north-western part the ore contains 60.69—69.3 per cent of iron and 0.014—0.061 per cent of phosphorus, and in its south-western and eastern parts 50.92—66.72 per cent of iron and 1.380—0.244 per cent of phosphorus. An estimation of the ore-supplies, which in any case are relatively inconsiderable, could not here be made.

The Swedish state is the owner of *Painirova* since 1907.

Besides the above mentioned ore-deposits there are, within the district in question, a great number of ore-deposits, discovered by means of the miner's compass and consisting of rocks rich in magnetite in which, as far as has been ascertained hitherto, some rich iron ore is found in rather inconsiderable quantities, and which, therefore, under the present circumstances, cannot be considered workable.

Among them may be mentioned those which are situated along the railway line:

*Nakerivaara*, at the southern shore of Torne träsk, close to Torneträsk railway station.

*Tjabrak*, also at the southern shore of Torne träsk, 6 km east of Nakerivaara.

*Toppi*, 2 km west of the railway line, between the railway stations Rautas and Rensjön.

*Käyrävaara*, 5 km north of Krokvik's railway station.

*Rakkurijoki*, 1 km west of the railway line, between Kalixfors and Kiruna stations.

*Lopasjärvi*, close to the railway line, 2.5 km south of the railway station Fjällåsen, between Gellivare and Kiruna.

Here should also be mentioned:

*Tuollujärvi*, E of Tuolluvaara.

*Altavaara*, 3 km south of the village Jukkasjärvi.

*Kuosanen*, 9 km directly south of this village.

*Ylipääsnjarka*, 20 km south-west of Svappavaara.

*Salmivaara*, 3 km west of the village Neitisuando, about 30 km NNE of Gellivare iron-mountain.

*Tansari*, 3 km WNW of Svappavaara at the small river Tansarijoki.

RUOUTEVARE AND VALLATJ.<sup>1</sup>

Considerable deposits of titaniferous iron ore occur in the Ruoutevare and Vallatj mountains, situated on the eastern side of the Scandinavian mountain ridge, 450–600 metres above the sea level, at 67° 2' N lat. and 17° 35.5' E long. from Greenwich, in the parish of Kvikkjokk. The nearest inhabited place is the Kvikkjokk church-village at a distance of 15 kilometres SSE from the ore-mountains. From these to the Swedish Luleå-Ofoten railway it is not less than about 200 kilometres, some part of this distance, however, consists of a water-way, which could be canalized; to the nearest harbour on the Norwegian coast it is 110 kilometres straight across the mountain ridge.

The ore-deposits, which are the products of magmatic segregation in a highly metamorphosed anorthosite rock, occupying an area of about 71 km<sup>2</sup> and penetrating the probably cambro-silurian schists of the Scandinavian mountain ridge, occur as highly irregular masses elongated in the direction of the folding axis, dipping at an angle of 15–20° towards NW.

On the Ruoutevare mountain the ore-bearing district has a length of about 1 600 metres and an average width of about 200 metres; it occupies consequently an area of 300 000 m<sup>2</sup>, but of this the pure ore occupies only 135 000 m<sup>2</sup>, the rest are low grade products of the magmatic differentiation and also anorthosite. With regard to the results obtained by diamond drilling and to the geological relations the average vertical depth of the ore-body cannot be estimated to be greater than some tens of metres below the surface ground. The ore-supply is calculated at about 19 000 000 tons.

The ore, which consists of a mixture of principally titaniferous magnetite, ilmenite and spinel, contains on an average 45–50 per cent of iron and 10–12 per cent of titanic acid. Experiments carried out in the last years have proved that by means of magnetic concentration can be obtained a concentrate running about 60–65 per cent iron and about 5 per cent titanic acid; the output of concentrate amounts to 40–50 per cent of the treated crude ore. As concentrate expressed, the ore-supply in Ruoutevare should therefore be 7–8 000 000 tons.

In comparison with this deposit, the occurrence on Vallatj is of subordinate importance; the ore-area here can be estimated at only 4 000–5 000 m<sup>2</sup>. The ore is of about the same quality as in Ruoutevare.

Neither of these deposits has hitherto been worked.

<sup>1</sup> Communicated by F. R. TEGENGREN of the Geological Survey, Stockholm.

**SUMMARY**

of estimated quantities of iron ore in the deposits of Lappland, described in previous pages:

Kiirunavaara and Luossavaara .....	758 000 000 tons,	
Tuolluvaara.....	7 000 000 »	
Gellivare Malmberg .....	230 000 000 »	
Koskulls-kulle (Gellivare Malmberg) ...	40 000 000 »	1 035 000 000 tons,
Svappavaara .....	30 000 000 »	
Leveäniemi .....	30 000 000 »	
Ekströmsberg .....	50 000 000 »	
Mertainen .....	5 000 000 »	115 000 000 »
Ruotevare (concentrate) .....		8 000 000 »
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		Total 1 158 000 000 tons.

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CENTRALTRYCKERIET, STOCKHOLM 1918.

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