SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. Avhandlingar och uppsatser. N:o 514.

ÅRSBOK 43 (1949) N:o 12.

THE REKTOR ORE BODY AT KIRUNA

BY

PER GEIJER

With one Plate

Pris 1 krona

STOCKHOLM 1950
KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER
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Contents.

Introduction.

The Rektor iron ore body, on the eastern slope of the mountain Luossavaara at Kiruna, was discovered in 1887 by K. A. Fredholm, rektor (head) of the high school in Luleå, and received its name from this fact. Being entirely drift-covered, it was located magnetically. For about 30 years, no exploratory work was done beyond the first test pitting which was only sufficient for securing mining rights and showed the presence of a magnetite ore high in phosphorus. During geological work in the Kiruna region, carried out in 1905—1909 for the Luossavaara-Kiirunavaara mining co. by the present writer, the very limited exposures in the Rektor ore zone were duly investigated and described (1)[1]. As a result of this study, the Rektor ore was made the object of more extensive trenching and sampling when, in 1918, the writer, now working for the Geological Survey of Sweden, was sent to investigate the possibilities of a production of apatite for fertilizers out of the high-phosphorus iron ore deposits of northernmost Sweden. Exploration work in 1918, although on a very limited scale, revealed the presence of a considerable ore body (previously known only more sketchily) with a remarkably high percentage of apatite. However, the technique of concentration was, at that time, unable to produce out of such fine-grained raw material an apatite concentrate suitable for the making of superphosphate, and in consequence no mining followed. Later, however, work was started on the Rektor ore for the purpose of using such ore to regulate the phosphorus percentage in ore shipments from Kiruna. Thus, during the years 1925—1930 and 1936—1939, a total amount of 431 601 metr. tons was produced. The phosphorus percentage started at 7 (as P), but when larger quantities were mined it dropped towards 5, while iron generally lay about 36 per cent.

[1] See list of references at end of report.

In 1942, mining was revived, now for the purpose of obtaining raw material for the superphosphate industry during the total cut-off of all foreign supplies of such nature which was characteristic of Sweden's position during World War II. The technical situation was different from that of 1918: an efficient flotation method had now been worked out. Therefore, in 1942—1946, a quantity of 1 334 589 tons of ore was produced from the Rektor ore body. The phosphorus percentage averaged somewhat above 4. This means that the ore body in question supplied somewhat more than half the phosphorus that was used as superphosphate in Sweden during the war years.

Mining was done in a series of open cuts in the mountain slope, and to some extent underground by shrinkage stoping from an adit started at the foot of the slope. The open cuts naturally give very good exposures of the ore zone. As previous data (1, 2) on this zone were collected from a small number of test pits and a few trenches, it seemed of interest to use the opportunity presented by these recent developments to undertake a more thorough study of the Rektor ore and its geological setting than had previously been possible. Interest attaches to this ore body not only because of the important part it has played in Swedish agriculture during years of trade isolation, and its possible future use for similar purpose, but also from its character as an important and illustrative link in the remarkable assemblage of ore deposits and associated rocks at Kiruna.

Therefore a study of the open cuts and other exposures has been undertaken. The writer has been assisted by Mr. Pontus Ljunggren who mapped the actual ore zone; this map has served the writer as a base for further work.

The writer is very much indebted to the Luossavaara-Kiirunavaara mining co. for valuable aid in several ways.

Since the various open cut benches, with their greatly different levels, could not with profit be combined into one map, the writer has chosen to express the result in the form of a reconstruction of the original surface before mining started (Pl. 1). For this map picture there have been utilized also sheets of the official mine map. These alone were not satisfactory, because mapping had had to be done successively during stripping and mining, and limited time further hampered the work of the surveyors. However, by using these maps in combination with those resulting from the examination of the open cut workings, a map has been obtained that, even if possibly inaccurate in some contour details, yet gives a clear and essentially correct picture of the relations between ore and rocks.

General geological position of ore body (fig. 1).

While the main ore bodies of Kiirunavaara and Luossavaara occur on the contact between syenite-porphyry below (W.) and quartz-bearing porphyry above (E.), and the zone that parallels the northernmost part of the Kiirunavaara ore, below the waters of Lake Luossajärvi, is essentially a zone of ore dikes and veins within the latter porphyry, the Rektor ore body is situated on the next higher contact of importance, that is, it has for its foot-wall the quartz-bearing porphyry. This rock, from its position in relation to the main ores of the district, is often spoken of as the hanging-wall porphyry. In this report, it will be referred to as the quartz-bearing porphyry, although there may be some primary quartz also in other porphyries that will be described here. The term "hanging-wall porphyry" would obviously be misleading if used for this rock in a description of the Rektor ore body, as the relative position is just the reverse, since the dip throughout the series is (steeply) east. Everywhere the foot-wall contact of the Rektor ore thus rests upon this porphyry. Above the ore body, on the other hand, follow the volcanics of the "Lower Hauki" group, a series of flows, agglomerates, and tuffs, all generally in a rather advanced stage of hydrothermal alteration. The bottom unit of this sequence is the Rektor porphyry which forms the hanging-wall of the Rektor ore body in its main part, where mining has been going on, and extends for nearly one kilometer further N.N.E., while in the other direction its length is about half that amount. The ore body, on the other hand, continues along the contact much further south. Thus in a street (Lärargatan) in the town of Kiruna, there is exposed a band of apatite rock about one meter in width which corresponds to the Rektor ore both in its geological position (at the upper contact of the quartz-bearing porphyry) and its mineral composition and texture (1, p. 166). Already when originally discovered about 40 years ago, this occurrence was, naturally, supposed to be in close genetical relation to the Rektor ore. However, lack of exposures along the contact for a distance of about 1300 meters, between the southernmost exposure of the Rektor ore (Hilarius claim) and the street section just mentioned, still left it an open question whether a direct continuation existed, or not. Somewhat unexpected information on the subject was obtained when the writer in 1947, in the course of a brief visit, noted and studied some digging that was being done in order to lay out an athletic field in the bed of the drained tarn Matojärvi (1, map). As interpolated on the map (1), the contact in question should run along the eastern side of the lake basin. The section exposed (temporarily) in 1947 showed this construction to have been practically right.[1] W. of the exposed quartz-bearing porphyry there follows in the south a steeply dipping zone of apatite rock, closely similar to that of the Lärargatan outcrop mentioned above, and to the Rektor ore. Under the microscope, it shows a mass of prismatic apatite crystals and scattered tabular crystals of hematite, with — in patches — a matrix of quartz or of carbonate enclosing these earlier components; some plates of a brownish green mica are also noted. At the northern end of the lake basin, a weathered and crumbling similar apatite rock is exposed to a width

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[1] At the southern end, the contact had been placed a few meters to far to the east.

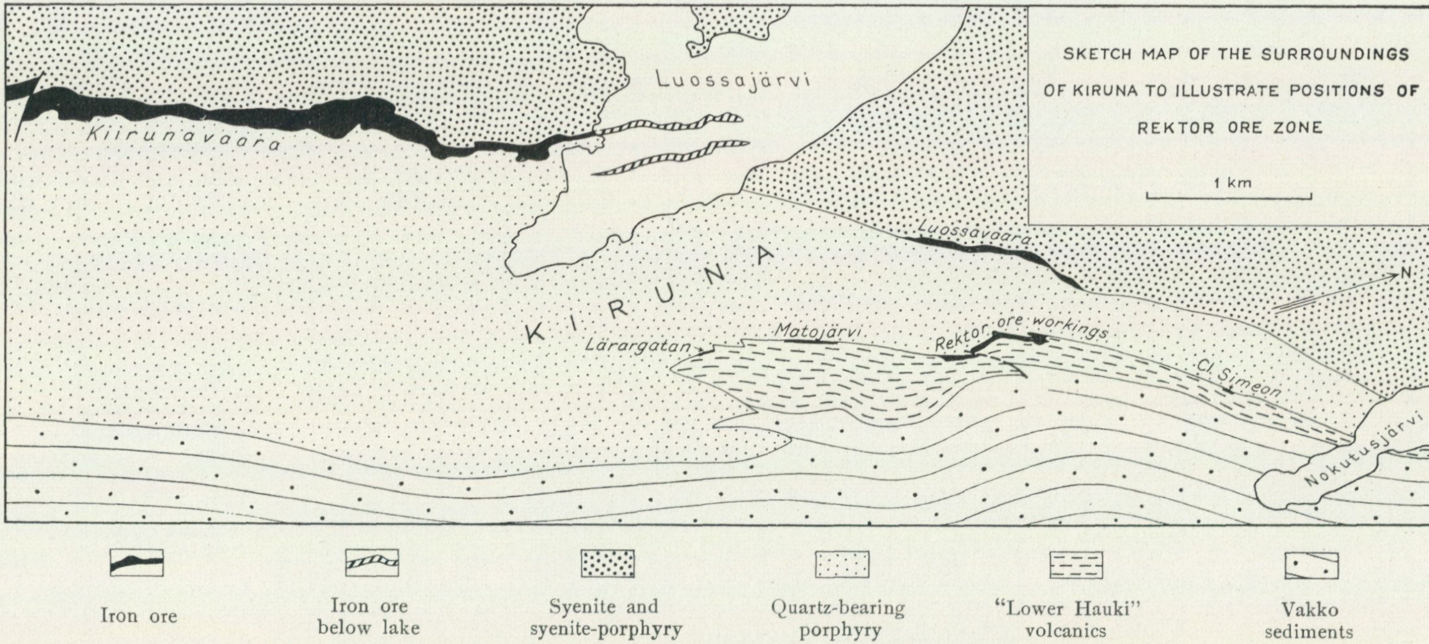


Fig. 1. Geological setting of Rektor ore zone. Ore at Lärargatan and Matojärvi greatly exaggerated.

of about 2 meters — a figure that probably holds also for the less satisfactory southern exposure —, adjacent is kaolinized quartz-bearing porphyry.

From what has been described it appears highly probable that one continuous body of apatite ore extends along the whole of the contact, at least from the Lärargatan exposure in the south to the northern end of the Rektor ore workings, a stretch of more than 2100 meters. This figure makes the Rektor unit a good deal longer than the main Luossavaara ore body, as far as known.

In the other direction — N.N.E. — from the Rektor ore workings, and at a distance of 2.5 kilometers from them, there occurs, just beyond Lake Nokutusjärvi, the Nokutusvaara ore deposit, of essentially the same character and with the same position in the volcanic rock series. In the intervening stretch, the contact in question (the upper surface of the quartz-bearing porphyry) is generally covered. It is clear, however, that no ore body of workable width occurs there. On the other hand there has been noted, in a partly collapsed prospecting trench in the Simeon claim, almost exactly half-way between the Rektor and Nokutusvaara deposits, a band of hematite ore very rich in apatite and texturally similar to the Lärargatan and Matojärvi exposures, and to the Rektor ore proper.[1] Its position is just on the contact in question, and it is accompanied by apatite veinlets in the underlying porphyry. It is, therefore, not excluded that the occurrence of apatitic ore, although with very narrow width, stretches along the contact for the whole distance. If so, the continuous deposit would have a length of about 4.8 kilometers, not much below the figure for the very much thicker and more iron-rich Kiirunavara ore body.

In the following, description will be restricted to the part that has been worked (Rektor workings), and to three geological units: the quartz-bearing porphyry immediately below the Rektor ore body, the Rektor porphyry above it, and the ore body itself and its contact phenomena. The hematite ore developed within the Rektor porphyry will also be treated. On the other hand, no new data have been obtained concerning those other rocks of the "Lower Hauki" complex that immediately overlie the apatitic ore south of Luossavaara (where the Rektor porphyry is lacking), therefore these parts are not further discussed and the reader is referred to the earlier description (1).

The quartz-bearing porphyry.

In its unaltered state, this is essentially an alkali feldspar-quartz rock, with almost isometric, somewhat rounded compound phenocrysts of feldspar in a very fine-grained groundmass, often poikilitic, sometimes spherulitic, but mostly with a texture that may be called microgranitic but is normally a product of devitrification. Generally, the feldspar phenocrysts

[1] The author's field notes have been in a decisive way supplemented by the study of samples taken here by Mr. N. Zenzén, and by him put at the author's disposal.

have a deep red colour, while the groundmass varies from red to bluish. The chemical character may be sufficiently illustrated by the norms calculated from two analyses on samples from Luossavaara (1):

	I	II
Q	23.38	14.68
Or	12.86	16.21
Ab	52.68	54.25
An	4.26	4.46
Al_2O_3(C)	0.20	—
P	1.70	3.56
M	3.18	4.99

Approaching the Rektor ore, the porphyry is found to be strongly altered, in a manner that decidedly suggests hydrothermal action. In the southern part of the mine, the width of this altered zone appears to be about 4—5 meters at the most; in the northernmost part, the alteration reaches 10 meters or more from the ore contact into the foot wall. The new-formed minerals are chiefly sericite and a slightly ferriferous dolomite (ankerite), sometimes also a biotite that is greenish brown in thin sections. Magnetite and some apatite frequently occur under conditions indicating their origin through the alteration. Locally, tourmaline occurs as a result of the same process. The quartz shows a peculiar development. While hardly increased in quantity — exact measurements are not possible — it shows a change in grain size, being present largely as grains up to about 0,2 mm in diameter, equidimensional but irregular in details. The altered porphyry has lost all the red colour of the fresh rock (in which the feldspar phenocrysts, at least, are always red) and has become dully gray, sometimes with a decided schistosity and a distinct sheen due to the parallel arrangement of the mica scales. A common surface feature is the appearance of small rusty spots due to the weathering of ferruginous carbonate. A peculiar feature, regularly observed at the microscopical study of the altered porphyry, is the tendency of quartz and certain other minerals to form sharply defined aggregates, rounded or angular in shape and reaching a size of 0,1 to 1,0 mm. With the quartz there may occur magnetite, apatite, carbonate, rutile, and tourmaline. Both magnetite and tourmaline show a kind of intergrowth with the quartz aggregate. Although these nodules, when rounded in shape, are similar to vesicle fillings, and again, when angular may suggest pseudomorphs after feldspar phenocrysts, only so much can be said with certainty about them that their mineral constituents belong to the products of alteration.

The Rektor porphyry.

The rock that forms the hanging wall of the northern part of the Rektor ore body and extends further northeastwards, is an extremely peculiar one, greatly varying in character but always without any distinct boundaries between differently developed phases. The term "porphyry" really is a misnomer, as a large portion of the rock body is not porphyritic at all and the rest not in a typical way, but it seems the only label that can be used without introducing either an entirely new term, or one containing an uncertain genetic interpretation. The unusual features call for a rather detailed description of this rock.

Briefly speaking, two main types can be discerned, which may be called the "homogeneous" and the "porphyritic" type. The homogeneous type forms the wall rock on most of the open cut stretch, within the whole width of the Rektor porphyry body, but there are also, both in the uppermost benches (now largely collapsed through stoping from below) and at the mountain foot (mainly Agabus and Malakias claims, compare Pl. 1) phases of the porphyritic type. This latter type is almost the only one represented within that part of the Rektor porphyry body that extends northeastwards from the end of the workable ore in the Julia claim.

The homogeneous type is a light brick-red rock, generally massive. Closer inspection mostly reveals small white patches of quartz, and occasionally coarse-grained aggregates of a carbonate, in the red feldspar mass which in itself displays no distinct granularity. Sometimes a banding is seen, the quartz forming white bands, about 1 mm in thickness, alternating with the red feldspar rock.

Under the petrographic microscope the main component is found to be a potash feldspar, very strongly coloured by red pigment. It is developed in isometric grains about 0.2—0.3 mm in size, sometimes distinctly rounded but close together, or with more complicated boundaries. A little albite is sometimes noted, mostly as forming peripheral portions of the grains. A determination of the alkalis in a specimen of this rock type, carried out in the laboratory of the Geological Survey, gave

Na_2O	3.45 per cent
K_2O	7.83 » »

This very decided preponderance of potash is unique among rocks of the Kiruna district. Grains of quartz, similar in shape and size to those of the feldspar, occur sparingly, totaling something like 5 per cent of the rock. The white quartz patches or thin bands, again, are formed of a fine-grained aggregate with a typical "pavement" texture. A carbonate containing some iron — as seen from its weathering — is sometimes present in crystalline aggregates, and sericite in the usual scaly development.

The porphyritic type develops from the preceding one in the way that the fine-grained quartz aggregates increase, with a corresponding reduction in the amount of feldspar. At the same time a marked change takes place in the textural appearance of the feldspar. The rounded grains tend to separate and lie isolated in the quartz matrix; at the same time they increase in size and sometimes, even megascopically, exhibit a distinctly spherulitic grouping.

The typical end product of this variation series is a rock made up of a flinty quartz mass, white, or sometimes gray to almost black from finely dispersed iron ore minerals, in which are scattered rounded feldspars, one or a couple of millimeters or even above one centimeter in size, and sometimes also larger, tabular feldspar phenocrysts with spherulitic fringes. This rock type has been described (1, p. 172—174) from the Ansgarius claim, just N.E. of "Julia" (map, Pl. 1), which was the best exposure before mining started on the Rektor ore. It occurs also in several parts of the mine area. The microscopical examination shows that the composition of the feldspar is the same as in the homogeneous type, and that primary quartz grains occur in the same frequency and the same size as in the latter. The spherulitic growth of the feldspar is one of the characteristic features of the porphyritic type. It shows in the "wandering" extinction of the rounded feldspar grains, or of the fringes on the tabular crystals.

The darkening of the quartz matrix is caused by an abundant development of finely distributed hematite. A little sericite is sometimes noted, and locally apatite.

As to the relations between the different types, an observation from the open cut within the Agabus claim (Pl. 1) may be cited. There, porphyry of the homogeneous type — to a large extent hydrothermally altered — is followed upwards by a zone forming the top of the porphyry bed and consisting of a flinty, white to almost black quartzitic rock with rounded red feldspar grains arranged in a kind of stratification. The zone of this character seems to have a width of a couple of meters, the matrix is darker in the upper part.

Also apart from the probability that at least the porphyritic type, as thus far described, has suffered intense hydrothermal alteration, there are abundant but more or less locally restricted signs of such action. Thus carbonated areas, or such with abundant sericite, are common. Particularly conspicuous is the development of compact bodies of grayish green sericite rock, generally sharply outlined against the surrounding rock and often of a lenticular shape. They vary in size, from a few centimeters up to several meters. Almost regularly they also contain radiating bunches of black tourmaline stalks.

To the results of hydrothermal action are also, in the writer's opinion, to be referred the siliceous, mainly hematitic ore beds that occur within the Rektor porphyry area and form the lowest element, stratigraphically speaking, among the ores of the "Lower Hauki" group.

While the general discussion of these hydrothermal phenomena may be left to a further section of this report, some remarks concerning the original character of the Rektor porphyry may properly find a place here. It has already been remarked that the petrographic characters are abnormal. Just to point out a few features: the comparatively coarse, even grain size, in a rock that both from its geological relations and other textural traits cannot be interpreted an as intrusive; the peculiar spherulitic developments of the feldspars; the combination of such feldspar with a groundmass that cannot be a product of magmatic solidification but has all the appearance of one of secondary (hydrothermal) silicification. Conclusions intended to explain such enigmatic features can only be tentative. The following interpretation is suggested by the writer.

The Rektor porphyry is a lava flow, originally in composition corresponding in a general way to the quartz-bearing porphyry that occurs between the main Luossavaara ore body and the Rektor ore body. As originally solidified, it contained, at least in some portions, phenocrysts of feldspar, and rare ones of quartz, while the bulk was made up of spherulites and a glassy basis. The glass was later replaced, hydrothermally, by secondary silica, and the spherulites may have undergone some structural changes. It is possible that also the remarkable predominance of potash is due to hydrothermal alterations, as has been proved to be the case with potash-rich lavas in other regions, e. g. in the Yellowstone areas of hydrothermal activity. The local sericitization and carbonatization may represent a later phase of the same process.

There would be little meaning in discussing the validity of this interpretation, as it can never claim to be more than a reasonable guess. Only two points deserve further comment. The flinty quartz mass, sometimes with much iron ore, that forms the matrix, is of the same character as that found generally in the "Lower Hauki" rocks, and its origin through hydrothermal replacement seems well established. Whether, in the Rektor porphyry, the substance it replaces was a volcanic glass, is more uncertain but seems likely. The stratified aspect often encountered, with the spherulitic feldspars rather regularly aligned, was early noted by the writer, who also described a case resembling cross-bedding. It was concluded, mainly from this evidence, that the Rektor porphyry was "at least to the greater part, a tuff, but part of it may perhaps be a lava rock" (1, p. 191). This conclusion now appears less well-founded, particularly as spherulites are known to develop in a volcanic glass also along several systems of shearing planes at once.

The ore.

The ordinary development of the Rektor ore body is a mixed magnetite-hematite ore of a distinctly blue colour, with a high content of apatite. Generally, the ore as such appears dense to the unaided eye, without any visible granularity. The apatite occurs both in mixture, more or less homogeneous, with the iron minerals, and in various forms of segregations. Thus one encounters considerable volumes of ore where a great amount of apatite is almost uniformly mixed with the iron minerals, and, on the other hand, large segregations of pure apatite. The latter do not appear to be surrounded by ore lower in apatite than usual, as has been noted frequently in the Kiirunavaara ore body (3,1). The segregations may be quite irregular in shape, and without any well-defined boundaries, or distinct veins that form a system brecciating the ore proper; again, the pure apatite may form bed-like bodies, conforming more or less regularly to the strike and dip of the ore body as such and often exhibiting a well-developed interior banding through the distribution of ore grains. Between these various developments there exist all kinds of transitional forms. One feature that is only rarely encountered but most striking is the presence of folds in the banded varieties. Unfortunately, the writer has never noted this phenomenon *in situ* and thus has not been able to ascertain whether the position of the folding axes conforms to the general structure of the ore body (compare the following). However, it seems highly improbable that it belongs to the ordinary folding. The conditions under which deformation has taken place in this district will hardly have permitted such movements without their also leaving traces in the texture of the apatite mass. An origin through fluidal movements is thus suggested. Features like those shown in fig. 2 also point the same way.

As to the relations between ore minerals and apatite, the Rektor ore thus has many features in common with the main Kiirunavaara—Luossavaara ore bodies (1), even if there are also some differences. In both cases there exist definite proofs that the pure apatite bodies form the latest element in the inhomogeneous mixture of ore minerals and apatite that constitutes the ore body. An interesting detail, in banded ore, is illustrated by fig. 2. It shows how the pure apatite rock obliquely cuts an enclosed slab of banded ore. It may be noted that similar features are known both from Tuolluvaara and from Grängesberg.[1]

The microscopical investigation of the ore further shows some carbonate of the type already described as occurring in the altered porphyry, also quartz, and occasionally sericite or albite. The albite, in the writer's original description regarded as a characteristic constituent, has now been found to be quite local in distribution and may perhaps be derived from the wall rock. Sericite sometimes occurs in some quantity, replacing apatite, but generally is quite unimportant. Quartz is a more regular constituent of the ore, and reaches some quantitative importance, particularly in the apatite-rich exposures at Matojärvi and Lärargatan.

The magnetite is developed in grains of an octahedral habit, single or in groups, with the size of the individual grains varying from about 0.02—0.05 mm in fine-grained phases to about 0.10 mm or more in the coarser varieties. The hematite is in part developed as tabular crystals and in part as grains enveloping such of magnetite. The former may reach about 0.2—0.6 mm in size. From the textural relations there seems little doubt that part of the hematite has formed through replacement of magnetite. However, the texture is not the one characteristic of martitization in the ordinary sense, and it appears probable that this oxidation of the magnetite has occurred in connection with the appearance of independent grains of primary hematite.

The apatite is always in prismatic grains, mostly with a length about 5 times the cross-section, sometimes considerably more, occasionally less. Gene-

[1] Specimens in the collections of the department of mineralogy and geology, Royal Inst. of Technology, Stockholm.

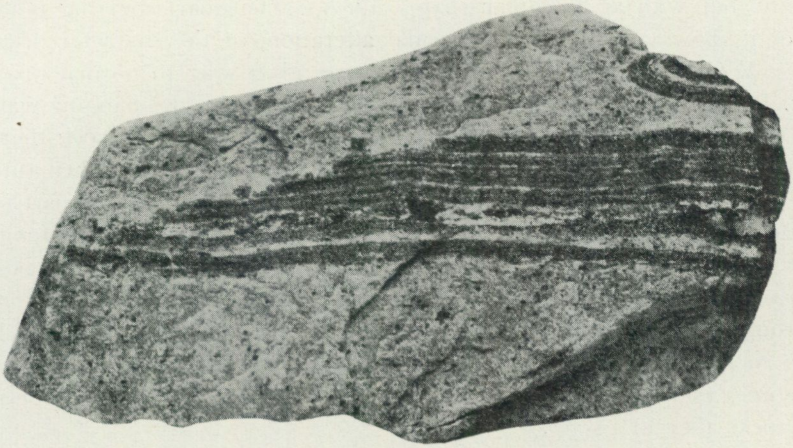


Fig. 2. Specimen of Rektor ore, nat. size. Shows banded ore cut by pure apatite mass. Carl Larsson foto.

rally, the length is about 0.1 mm. The quartz is always developed as interstitial fields, irregular in outline, up to about 1 mm in diameter, and crystallographically uniform or composed of several separate grains. Prismatic grains of apatite, often markedly smaller than those of the surrounding mass, are generally enclosed in these quartz spots. With the quartz, a little carbonate is sometimes associated.

A frequent feature in the microtextural properties of the apatite-rich ore is the conspicuous sub-parallel or trachytoidal arrangement of the apatite prisms.

Structure.

The only certain signs of plastic deformation within the deposit or its environs — if, as indicated above, the folds in the banded are to interpreted as primary features — are a locally apparent and weakly developed linear structure in the wall rocks, and a joint system perpendicular to this direction. The structure pitches approximately S. S. W. with 65°, or locally only 45°. An exposure of Hauki volcanics, about 1 200 meters S. of the Rektor workings, shows a well-developed linear structure pitching 65° S. S. W. Since a pitch in the same direction is more or less distinctly indicated also by the shape of the wall rock inclusions in the Rektor ore, it seems to express a general orientation pervading the whole mass.[1]

Details of ore body, and contact relations.

The northern end of the ore body, in the Julia claim, is not exposed, mining having ceased when the ore narrowed down too much. Southwards it widens

[1] It is probable that the same orientation occurs in the neighbouring main ore body of Luossavaara, but it is quite an open question what the relations are in the Kiirunavaara ore body.

quickly, but with an irregular shape (Pl. 1). The quartz-bearing porphyry W. of it shows a strong hydrothermal alteration, of the character described above. Westward this altered porphyry soon gives way to normal unaltered rock. Rektor porphyry of the even-grained type forms the hanging-wall and also the large inclusions in the ore body. In the hanging-wall rock there are patches of sericite with tourmaline. A wide band of siliceous hematite ore (Pl. 1) will be described in a later section. Characteristic of this part of the ore zone, and those nearest to the south, is also the occurrence of mineral veins, composed of quartz, carbonates such as calcite, ankerite and possibly siderite, specular hematite, red feldspar, and orthite. The amount of orthite, in groups of slenderly prismatic, unaltered crystals, is rather striking. These veins mostly have a steep dip and cross the general strike direction, but sometimes there is also seen a flat-lying system. The veins cut ore body and wall rocks alike.

Except in the northern end, where there is some low-phosphorus ore close to the hanging wall,[1] the ore body within the Julia and Rektorn claims (Pl. 1) is particularly rich in apatite, with band-like segregations near the hanging-wall that surpass one meter in width. Between the bulk of the ore body, and the northward-pointing tongue that branches off from its foot-wall in the Rektor claim (Pl. 1), the quartz-bearing porphyry is strongly altered and extensively brecciated by irregular veinlets of apatite. Bigger apatite veins accompany the foot-wall contact further north, while the foot-wall rock of the ore tongue just mentioned sends out ore veins of considerable width into the wall rock. In contrast to these foot-wall phenomena, the hanging-wall is conspicuously simple and clean-cut, with a straight contact between apatite-banded ore and even-grained Rektor porphyry, without any visible intrusions or any special, localized alteration.

The next section, mainly within the Bengt claim, has chiefly been studied in the lower portions of the open cut and two levels with their floors at 180 and 188 meters. There is thus a considerable vertical distance between these portions and the original surface of the ore, which has been reconstructed in Pl. 1, and the reconstruction cannot claim any accuracy except in those parts where the original rock surface has still been preserved and accessible. The foot-wall shows the same general features as further north: the adjacent porphyry is generally altered in the same way, and there is no great intermingling of ore and rock at the contact. Highly remarkable is the broad point of ore that protrudes into the foot-wall about 40 meters from the northern boundary of this claim (Bengt), opposite points 9—10 on the base line (Pl. 1). Little of this part has been accessible for study. It is apparently rich in apatite, except the westernmost tip which is very low in phosphorus, it has an almost vertical orientation and appears to enclose some slabs of highly altered porphyry (in inaccessible positions). Along the southern boundary

[1] In a drill hole, this ore quality has been proved to have a greater width in depth, occupying most of the width of the ore body below the end part of the mine opening in the Julia claim. This fact may in part be due to the pitch of the deposit.

of the ore point, the porphyry is altered in the ordinary way, but in the northern wall it is fresh-looking, with a normal deep red colour (Pl. 1). About 25 meters further south, some short ore veins again indicate a tendency of the ore to branch out into the foot-wall.

The rather abrupt turn of the contact at the northern side of the ore point, and the unaltered state of the porphyry along this part, both suggest faulting. Mr. Ljunggren from his field studies considered the northern contact to be determined by a fault. However, the writer's later examination did not reveal anything that could be interpreted as a fault plane, and the ore is "frozen to" the porphyry.

The hanging-wall contact in the Bengt claim is quite different from its development further north. There is a wide transition zone, consisting of apatite-rich ore with rock inclusions, generally elongated in the general direction of the ore body, and reaching a size up to one meter or more. The rock forming these inclusions belongs to the Rektor porphyry, and is obviously altered to a considerable degree. It is not clear from the accessible parts of the contact whether the zone with inclusions is continuous or not; on Pl. 1 it has been indicated only where known.

To the south, this section is bounded by the fault that cuts obliquely across the ore body in a general N.E.—S.W. direction. The course of this fault had been inferred by Dr. Zenzén from the rock distribution and topography N.E. of the point where it cuts the ore (2). On Pl. 1 it has been plotted according to Mr. Ljunggren's mapping.

Comparatively little has been satisfactorily exposed south of this fault, but some features of interest have been noted. The quartz-bearing porphyry of the foot-wall is unaltered, with some veins of apatite. The ore, mostly high in apatite, surrounds a big inclusion of this porphyry,[1] altered in the usual way, as described above. It contains a considerable amount of apatite in the form of streaks and interwoven veinlets, similar in their textural development to the apatite segregations in the ore body. According to the samples that have been examined microscopically, there is almost no "impregnation" of apatite in the rock, practically all the apatite belonging to the irregular vein pattern.

The hanging-wall contact of the ore body is developed, for a long stretch at least, with a zone several meters in width which carries abundant inclusions of more or less altered rock varieties. In some parts, in fact, it would be more appropriate to speak of a fragmental rock impregnated with iron minerals, than of iron ore with rock inclusions. When ore minerals are present in a small quantity only, they are mainly represented by scaly hematite. The rock inclusions, mostly rounded in shape but often elongated in the general strike direction, may reach up to a couple of meters in length, but often are only one cm or less. Already with the unaided eye, two rock types can be discerned. One in the Rektor porphyry, often partly silicified.

[1] The northern end of this inclusion, not now visible, has been plotted on Pl. 1 from the official mine map.

Under the microscope, the ore surrounding the fragments is found to be rich in quartz, and to contain a little sericite and feldspar, occasionally carbonate and barite, but almost no apatite. In part, the ore substance is very finely dispersed in the fine-grained quartz mass. The conspicuous silicified fragments are quartz aggregates free from ore minerals, but otherwise similar to the surrounding mass. The other rock type, again, is a grayish brown one, similar to the syenite-porphyry flows of the "Lower Hauki" group that overlies the ore zone. It is made up of lath-shaped alkali feldspars (coarsely lamellar perthite) some tenths of one mm in length.

These facts point to the obvious conclusion that the contact zone is made up of a fragmental tuff, with fragments of Rektor porphyry and of syenite-porphyry mixed, and that this tuff was incompletely replaced by quartz, magnetite, hematite, and small amounts of other minerals (carbonate, barite, apatite). Ore rich in apatite, representing the normal development of the Rektor ore, has been noted in one thin section as a narrow veinlet, with the appearance of a distinct intrusion.

It is of interest to note that we here find Rektor porphyry and syenite-porphyry intermingled as fragments, since above this zone follows the Rektor porphyry bed, and next, above the strongly silicified top of this bed (and here separated from it by a slip plane), the syenite-porphyry, in this case very much sericitized.

Siliceous hematite ore in the Rektor porphyry.

Along the worked length of the Rektor ore body and probably continuous, there occurs in the overlying Rektor porphyry a belt of siliceous iron ore, rich in enclosed fragments of silicified rock. Its position is seen from Pl. 1. Since parts of the hanging-wall in the open cuts have been inaccessible during the writer's examination, and there are some uncertain points in the official mine map, it cannot be stated with certainty whether there really is such a single and continuous zone as indicated on Pl. 1. One exposure of a similar occurrence at a higher stratigraphic level is also shown.

In geological position and general character, this ore body belongs to the "Hauki hematite ores" which form such a common and characteristic feature of the hydrothermally altered volcanic pile (the "Lower Hauki" group) above the Rektor ore horizon.The best opportunities for study have been in the northernmost exposure, where the ore band also appears to attain its greatest width (about 8 meters, the hanging-wall contact not exposed). It is a mixed hematite-magnetite ore with much quartz, rather evenly distributed in the ore and alone forming the enclosed fragments. The conclusion earlier reached, that the Hauki hematite ores are due to a replacement by quartz and hematite (with some magnetite) is here obviously applicable. There is a little apatite in the ore, and frequently copper stains.

In the continuation northeastwards of the Rektor porphyry, for a distance of about 900 meters from the end of the map, Pl. 1, there are a number of occurrences of similar hematite ore, at various levels within the Rektor porphyry bed. The writer's original map picture of these relations (1) indicated tongues of silicified rocks, with hematite in places, extending into the Rektor porphyry from a thoroughly silicified bed above. However, some later trenching has shown this complicated picture to be wrong. The various occurrences of ore within these parts of the Rektor porphyry bed are simply streaks where the porphyry, otherwise only in part silicified, has been more or less completely replaced by quartz, hematite, etc.

Theoretical conclusions.

The new data on the geological relations of the Rektor ore body that have resulted from the present investigation are in all essentials in accord with the genetical interpretation that was presented in 1910 by the writer, on the base of much scantier observations (1). At the same time, however, they give a much more complete picture. The chief point of theoretical interest is the character of the Rektor ore body as something combining features of the main ore bodies of Kiirunavaara-Luossavaara, of magmatic origin, and of the widely different type of mineralisation represented by the siliceous Hauki hematite ores, obviously products of hydrothermal replacements in shallow or moderate depths.

The contact relations of the Rektor ore mostly indicate that it has occupied its space through a process of intrusion, or in any case one of displacement. Only locally, at the hanging-wall contact, there has been replacement, and this process has characteristically resulted in another ore type: low in phosphorus, and siliceous. Whether one will concur with the writer in classifying the Rektor ore as a magmatic product will largely depend upon where, in temperature range and physical conditions generally, one wishes to limit the magmatic field. The facts are these: the geological picture of an intrusion, the textural features such as the frequent trachytoidal arrangement of the apatite prisms. With our present restricted knowledge of the magmatic processes, particularly in their lower temperature ranges, there seems no alternative to the term magmatic.

Again, the mineralogical composition of the ore shows both important similarities with that of the main Kiirunavaara-Luossavaara ores, and striking differences. Magnetite and apatite are characteristic in both cases, but the Rektor ore also contains great amounts of hematite. The accessories show still more conspicuous differences: diopside and an actinolitic hornblende locally in Kiirunavaara, quartz and carbonates regularly in the Rektor ore. The associated wall-rock alteration shows corresponding differences: on Kiirunavaara, the wall-rock is often replaced by hornblende, while at the Rektor ore one encounters sericitization, silicification, and carbonatization — on the whole, a much more ordinary set of hydrothermal changes, and one suggestive of a lower temperature range. This leads to the hypothesis that the Rektor ore originated from a magmatic solution in very much the same way as did the main Kiirunavaara-Luossavaara ore bodies, but with a lower temperature presumably due to a higher content of volatiles. The difference is the one that the terms pneumotectic and orthotectic are intended to express. No entirely new data in support of this hypothesis have come to light through the present investigation, but what has come out has certainly pointed to the same conclusion.

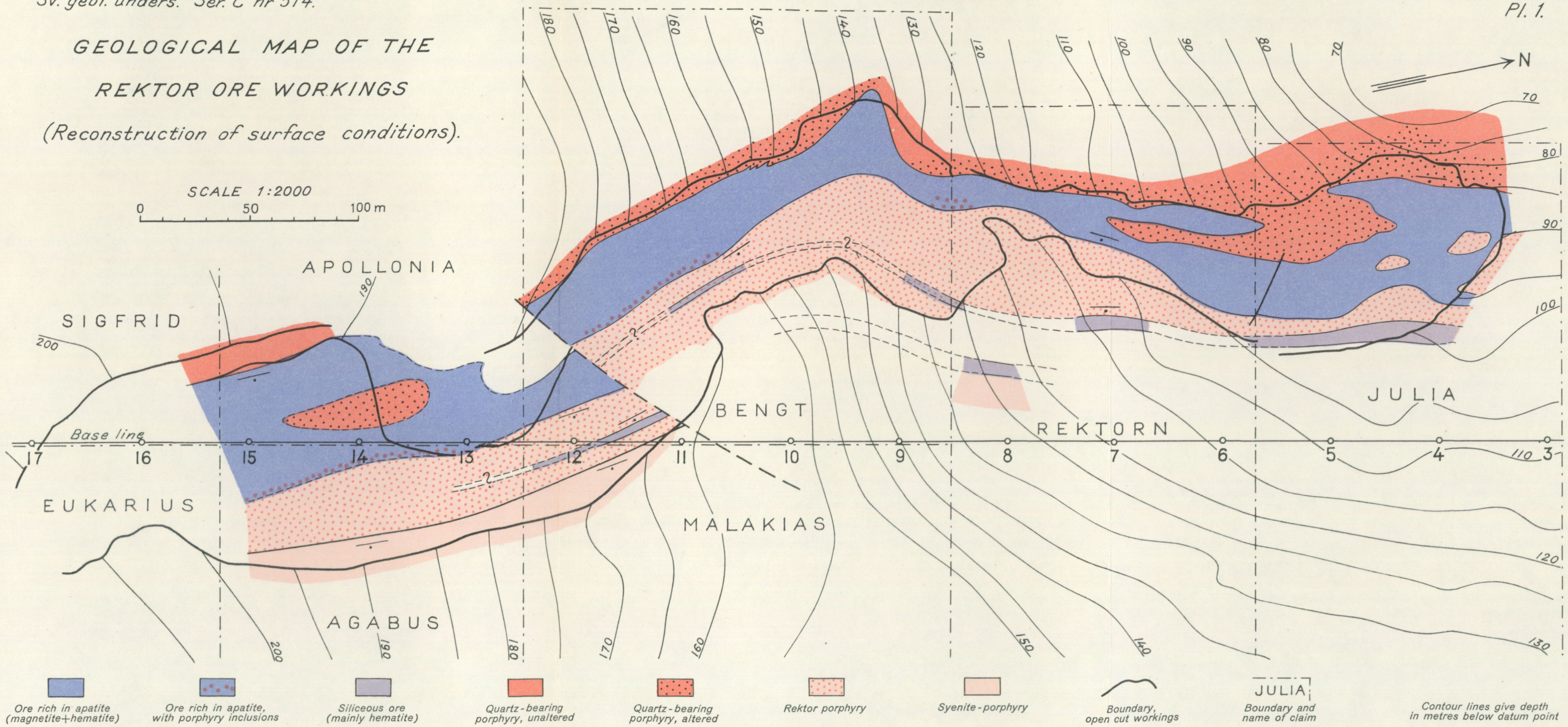
An interesting question concerns the time sequence of intrusion and alteration. Like the skarn-forming alteration that is so characteristic of the wall-rock in the Gällivare ore field, and is met with also at Kiirunavaara, the alteration around the Rektor ore body appears to emanate from the ore body itself, or, more correctly expressed, from the space occupied by it. Yet it is little probable that the wide-spread and intense hydrothermal alteration of the whole "Lower Hauki" rock complex can be derived from this local and limited source. Any distinction between general and local alteration does not seem possible. It may also be pointed out that the occurrence of apatite veinlets — however few and small — in the siliceous replacement ore with enclosed rock remnants, described on p. 16, seems to indicate that the metasomatic alteration was at least far advanced before the *mise-en-place* of the apatitic ore. This would also explain why this ore itself has almost entirely escaped such alteration. If so, however, the sequence of differentiation (broadly speaking) supposed by the present writer (1) to be represented by 1) the intrusive main ore bodies of Kiirunavaara-Luossavaara (magmatic, orthotectic), 2) the intrusive Rektor ore body (magmatic, pneumotectic), and 3) the metasomatic Hauki hematite ores (hydrothermal), would not be also a sequence in time.

References cited.

1. Geijer, Per: Igneous rocks and iron ores of Kiirunavaara, Luossavaara and Tuolluvaara (Scient. and pract. researches in Lapland arr. by Luossavaara-Kiirunavaara A. B.). Stockholm 1910.
2. Geijer, Per: Sveriges fosfattillgångar. Sveriges geol. undersökn. ser. C. n:o 294, 1919.
3. Stutzer, O.: Geologie und Genesis der lappländischen Eisenerzlagerstätten. Neues Jahrb. f. Mineralogie, etc., B. Bd XXIV, 1907, p. 135.

GEOLOGICAL MAP OF THE REKTOR ORE WORKINGS

(Reconstruction of surface conditions).



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