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DETERMINATIONS OF THE MAGNETIC SUSCEPTIBILITY OF ORES AND ROCKS FROM SWEDISH IRON ORE DEPOSITS

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Contents.

Introduction.

Rocks generally consist of several various minerals with different magnetic properties. Most rock-minerals are paramagnetic or diamagnetic. Of the common minerals only magnetite, pyrrhotite and hematite are ferromagnetic, while *e. g.* ilmenite, limonite, skarn minerals such as anthophyllite, actinolite, garnet and other iron minerals must be considered paramagnetic. Not very seldom also pyrrhotite can be included among them and hematite is only ferromagnetic in its α-form (maghemite) while its β-form is paramagnetic.

The ferromagnetic minerals, and in particular magnetite, occur as accessory minerals in almost every rock belonging to the Swedish iron-ore fields. And further, as magnetite has the largest susceptibility of all natural minerals, it is quite evident that this mineral must have a dominant influence on the magnetic properties of the rocks. A short review of the information hitherto obtained regarding the magnetic properties of magnetite may therefore be of interest.

According to the classical investigations of P. Weiss (16—18) crystals of magnetite and pyrrhotite are magnetically anisotropic and show remarkable differences in susceptibility in different directions. On test samples identical values are, however, usually obtainable in all directions, probably due to the completely arbitrary orientation of the ferromagnetic minerals as regards their crystal axes (pseudoisotropy).

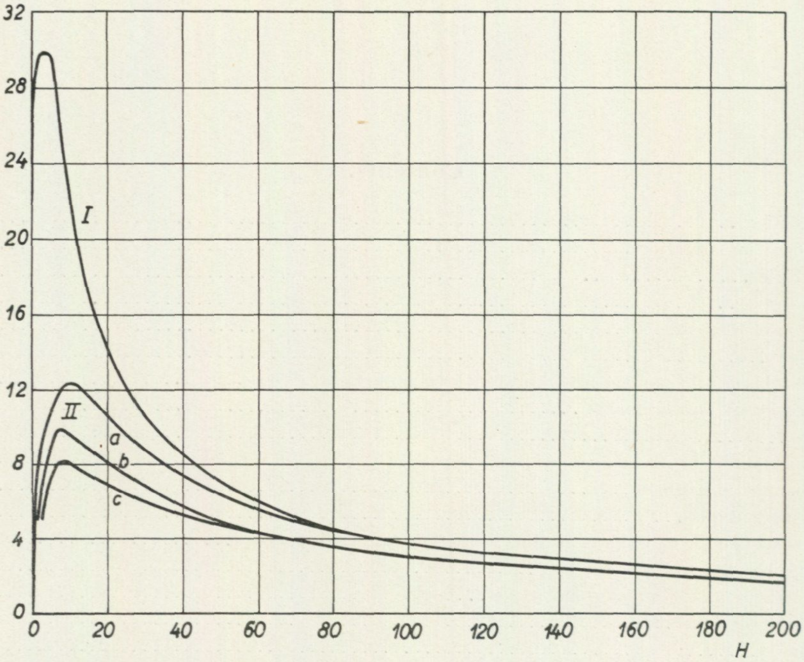

Fig. 1. The variation of the susceptibility ($\varkappa$) with the strength of the magnetic field (H) for:
I. Crystal of magnetite from Traversella,
II. » » » » Tyrol; a, b. and c indicate different directions of magnetization.
H expressed in Oersted.

The susceptibility of magnetite varies in a high degree in different deposits, and within the deposits themselves, and it also varies in a remarkable way according to the field strength applied. On crystals from Traversella and Tyrol (Fig. 1) P. Weiss has measured a maximum susceptibility of 29.5 and 12 respectively. However, magnetite ores, also when they are compact, as a rule show much lower values. Fig. 2 is a diagram showing a magnetite sample from Koskullskulle (9), where the maximum value of the susceptibility reaches the un-

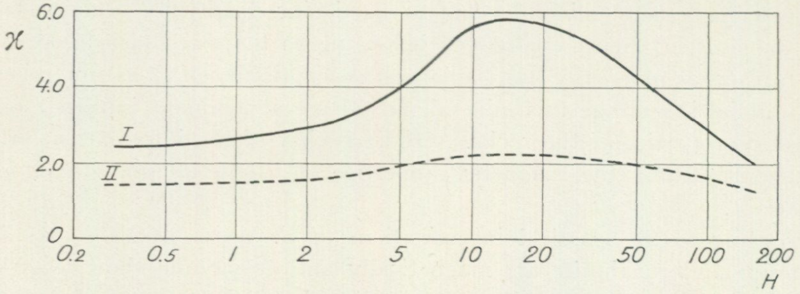

Fig. 2. The variation of the susceptibility ($\varkappa$) with the strength of the magnetizing field (H) for a sample of compact magnetite from Koskullskulle (Sweden):
I. According to Puzicha (see 9),
II. » » recalculation (see p. 23).
H set off in logarithmic scale and expressed in Oersted.

usually high value of 5.75 at a field strength of about 15 Oersted, and fig. 3 shows a corresponding diagram of a magnetite from Altenau (11) with a maximum susceptibility of 1.3 at 140 Oersted.

On comparing the diagrams in figs. 1—3 it appears that the maxima of the curves are displaced towards lower field strengths, when the maximum susceptibility increases. This rule seems to be quite generally valid. The character of the course of the hysteris-curves for magnetites from different localities seems to show a close relation between the manner in which the susceptibility varies with the field strength and the magnitude of remanence and coercitive power.

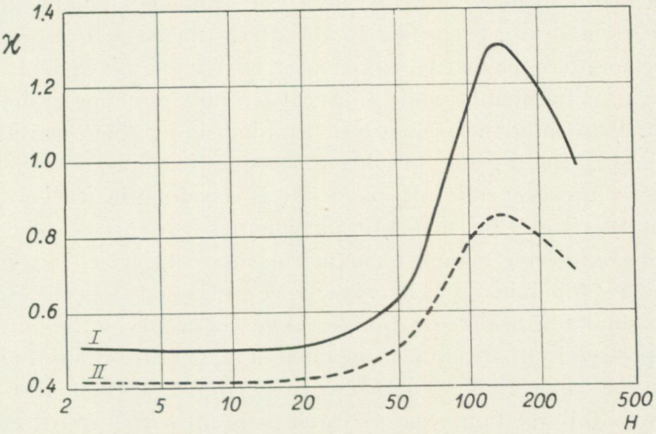

Fig. 3. The variation of the susceptibility (κ) with the strength of the field (*H*) for a sample of magnetite ore from Altenau (Germany).

I. According to Rettig (see 11)
II. » » recalculation (see p. 23)
H set off in logarithmic scale and expressed in Oersted.

According to Puzicha (9, 10) and Rettig (11) a fairly marked difference appears between those magnetic deposits which may be classified as magmatic differentiates and those which may be classified as exhalative-sedimentary or formed by contact metamorphosis.[1] The former (Group 1) are thus characterized

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[1] The investigations carried out by the authors quoted comprise only determinations on magnetites from Swedish and German iron ores. The former are represented by Koskullskulle, Striberg, Hoforsfield, Bastkärnsfield and Dannemora, the latter by Spitzenberg, Altenau, Holzberger, and Hüttenrode. Of the Swedish iron ores included only Koskullskulle may be considered formed through magnetic differentiation, while the others must be considered more or less to belong to the second group mentioned by the authors quoted (2). Puzicha and Rettig, however, classify all the Swedish ores mentioned, except Dannemora, as magmatic differentiation ores. Dannemora is stated to be a contact-pneumatolytic formation but in magnetic properties it very closely resembles the other Swedish ores and is therefore included in the same group. Thus, the results of Puzicha and Rettig mentioned in the following must first of all be regarded as examples of the variations in the magnetic properties of magnetites from different iron-ore fields, no simple relation being claimed to exist between the mode of formation of the ores and their magnetic characteristics.

The authors also mention that the Swedish ores investigated without exception contain larger or smaller amounts of titanium, while the German ores are quite free of titanium. The microscopic observations on which these statements are founded are, however, as regards the samples from Bastkärnfield, Hofors, Striberg and Dannemora (Rettig) of such a kind that it cannot be considered proved that those contain more titanium than the German iron ores.

by high values of suceptibility with a maximum at low field strengths (below 50 Oersted) while the latter (Group 2) have a lower susceptibility but the maximum at a higher field strength (140—250 Oersted) than the former. With reference to the hysteris-curves the ratio between intensity for remanent magnetism and saturated magnetism is considerably lower for Group 1 than for Group 2. In the same manner the values of the coercitive power are low (5—30 Oe) for the former group and high (50—100 Oe) for the latter.

These differences are, according to the above mentioned authors, probably due to the fact that magnetite of Group 1 is coarse-grained and contains titanium in various amounts while those of Group 2 are fine-grained and free of titanium. Especially the presence of titanium is by them considered to increase the susceptibility, but they leave the question open whether the effect of titanium on the properties of magnetite is due to substitution of titanium in the crystal lattice of the magnetite or whether it occurs in some other way.

When not considering compact magnetite but rocks which are more or less impregnated by this mineral it may easily be presumed that the susceptibility of the rocks should be in that relation to the susceptibility of the pure magnetite which is expressed by the volume proportion of magnetite. It has, however, been shown that the susceptibility of the rocks is considerably smaller than what corresponds to this relation. The investigations hitherto carried out (3, 4, 7, 9, 12) comprise only determinations on samples with small amounts of magnetite (a couple of volume % and less), so a general knowledge is lacking regarding the relation between the amount of magnetite and the susceptibility of ores and rocks.

The researches on the magnetic properties of rocks and ores from Swedish iron ore deposits, the results of which are published here, have been carried out under the auspices of the Research Board of Jernkontoret. The author wishes to express his sincere appreciation of the valuable aid thus given him, and of the permission to publish the results. The object has been in the first place to obtain data of importance for the interpretation of magnetic maps of ore deposits. For this purpose it is sufficient to determine the susceptibility of the rocks and ores with regard to a magnetizing field of the same strength as the earth's magnetic field and their remanent magnetism when *in situ.*

If applicable values on the remanent magnetism are to be obtained, the samples used in the determinations must be collected and kept in such manner that their remanent magnetism does not change. The material presented here contains measurements solely on diamond drill cores. During the drilling these cores have of course been subject to mechanical damage and heating caused thereby as well as to magnetic disturbances from the drillpipe, which may have changed the original remanent magnetism quite considerably. In spite of the fact that the measurements have been performed on the cores in such manner that it was possible, in additon to the susceptibility, also to calculate the remanent magnetic intensity, it has not been considered suitable on this occasion to publish the results of this quantity obtained, the question of the publication being postponed until more complete investigations have rendered more reliable criteria for the judgement of these values available.

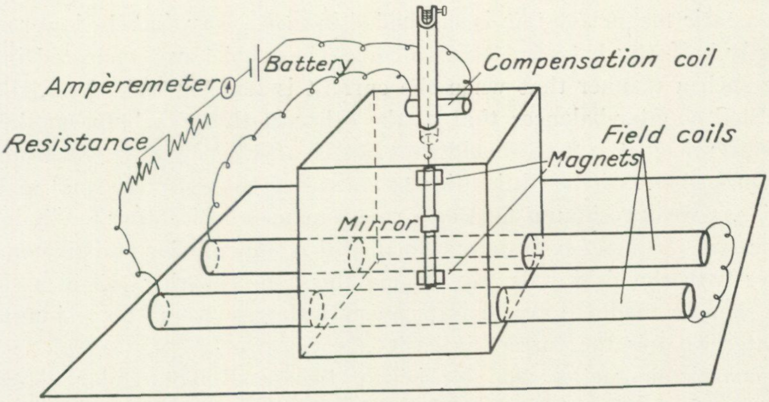

Fig. 4. Schematic picture of the apparatus used in the determinations of the susceptibility.

The investigations now published comprise determinations of the susceptibility on 525 drill cores from 27 different Swedish mines and mining fields. Special attention has been devoted to questions concerning the dependence of the susceptibility on the amount of magnetite, which is so important to rock magnetism, and to the varying susceptibility of different magnetites. On a small number of selected cores more comprehensive measurements have been carried out in order to determine the demagnetization factor of cylindrical samples. In this connection a contribution is furnished to the above mentioned problem of the remanent magnetism of diamond drill cores.

Method of investigation.

Principle.

A magnetometric method elaborated by the French scientist E. Thellier has been used in the determinations and the apparatus was in principle built according to a description made by Madame O. Thellier (15).

Generally these determinations are so performed that the core sample is inserted in a solenoid where it is magnetized in its longitudinal direction by a homogeneous field. The magnetic field from the core acts on a magnet outside the solenoid and causes the magnet to rotate. By comparing the magnitude of this deviation with the one caused by a current-carrying evaluation coil in the form of a solenoid, when this occupies the place of the core, the susceptibility of the core can be calculated.

Apparatus.

Fig. 4 is a schematic picture of the apparatus. This consists of two equal, parallel lying solenoids (field coils), a suspended astatic magnet system, a magnet case on the top of which the torsion pipe is fastened, and further (not shown in the fig.) a direction magnet for the regulation of the scale values, an evaluation coil, and a reading device consisting of an eye-piece and a scale.

The astatic magnet system is suspended in such a way that the lower magnet is exactly half-way between the two coils. These coils are connected in series and in such a manner that when the current is sent through them, the field of one coil counter-balances that of the other in the area between the coils. The astatic magnet system should thus not be affected by any field from these coils. On account of the difficulties to construct two exactly equal and ideal solenoids, a weak residuum field as a rule remains and in order to eliminate its influence on the magnet system a small coil (compensation-coil) is connected in series with the field coils. By placing this compensating coil in a suitable way it can be made to compensate every influence from the residuum field no matter what is the current intensity.

The astatic magnet system consists of two small rectangular magnets of equal size which are attached to the ends of a brass bar, their corresponding poles being in opposite directions. On the middle of the bar is a mirror. In order to make possible a slight adjustment of the astatic magnet system the upper magnet has a somewhat larger moment than the lower one and revolves round a horisontal axis through the middle of the magnet and perpendicular to its longitudinal direction.

The direction magnet is attached to a vertical bar on the top of the magnet case above the magnet system and is adjusted parallel to the longitudinal direction of the field coils. By changing the height of the direction magnet, the sensitivity of the apparatus can be changed.

As source of current a storage battery or ordinary dry batteries were used and in the circuit were inserted an ampèremeter, two adjustable resistances, which allowed of the necessary adjustemnt of the current, and a reversing switch in order to be able to reverse the current through the coils.

The evaluation coil consists of a solenoid coiled on a tube.

A suitable damping of the magnet-system is effected by a small damper immersed in thin oil. This damper is attached to the lower end of the magnet bar with a short torsion fibre.

Two aggregates have been built with the following dimensions:

Field coils:	First aggregate	Second aggregate
length	402 mm	500 mm
exterior diameter of coils	30	41.1
distance between center lines of the coils	68.8	85.7
wire winding (enamelled copper wire)	1 layer 0.30	3 layers 0.21
number of turns per cm length	30	125
Astatic magnet system:		
length of magnets	12.2	11.5
width » »	7.7	7.5
thickness of magnets	2.3	2.2
distance between magnets	74.5	74.0
Evaluation coil:		
length of winding	150	200
diameter of winding (counted from center to center)	22.12	22.19
winding	1 layer 0.30	1 layer 0.21
number of turns pr cm winding	30	41.5

The first aggregate was built with somewhat less accuracy than the second as regards the windings of the coils. When inserting the cores in the fieldcoil in the first aggregate they were gripped in a brass tube, sawn up longitudinally, which fitted into the field coil. It proved, however, that by this arrangement the orientation of the core in relation to the longitudinal axis of the field coil was not fixed quite so closely as was required in order to fully profit of the accuracy of the apparatus. In the second apparatus the core was fastened in a brass tube (core tube) between two telescoping rings of fiber material carefully fitted in the tube and with conical borings into which the ends of the core were pressed. The core tube fitted the tube of the field coil very closely.

The measurements.

For the astatisation of the magnet system a Helmholtz coil with a diameter of 50 cm was used which was placed above the apparatus with its axis horisontally and perpendicular to the magnets of the system and so that the magnets were midway between the circular windings of the Helmholtz coil and symmetrical in relation to its center. By passing a current through the Helmholtz coil, the two magnets were affected by identically the same field from this coil and the system caused a deflexion as long as the astatisation was not perfect. The adjustment of the system was accomplished by turning the upper magnet.

Before the measurements were started an observation was always made in order to ascertain that the small compensation coil was so adjusted that no deflexion could be noticed on the scale when a maximal current passed through the field coils. The direction magnet was further so adjusted that the astatic system of magnets in zero position (core coil empty) was parallel to the longitudinal axes of the field coils.

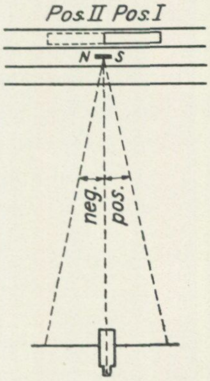

Fig. 5. Section through the longitudinal axes of the field coils, showing the position of the core sample when measured.

In the measurements the drill cores were always placed in one and the same field coil, in the following called the core coil, and there they were given certain definite positions, denoted position I and position II. These appear in Fig. 5, which shows a section through the centerlines of the field coils. When moving the cores from position I to position II and *vice versa* they were displaced in the core coil without the cores rotating round their longitudinal axes.

The measurements were accomplished according to the plan below where (i) indicates the strength of the current through the field coils and (s) the scale-readings. The scale used was graduated in mm and the numbering increased from one end to the other.

Positions of the core	Strength of current through the field coils	Readings
Zero-position	—	s_0
position I	i_1	s_1
» II	i_2	s_2
» II	i_3	s_3
» I	i_4	s_4
zero-position	—	s_0

The deflexions from the zero position were chosen so as to be about 100 mm where this was possible and so that s_1 and s_3 were on one side of the zero position and s_2 and s_4 on the opposite side.

With the exception of the iron-ore cores and some others with large amounts of magnetite the current strength could be kept constant during the entire measurement of a core, i_1 and i_2 being directed one way and i_3 and i_4 the opposite way.

On a fairly great number of cores measurements were accomplished according to a more comprehensive plan according to which every core was turned around its longitudinal axis. If we place the turning of the core in an initial position at 0°, readings were made in position I with the current i_1, in position II with the current i_2, etc., for turnings of the core 0°, 90°, 180° and 270°. The core was then reversed, so that its ends changed places, and an analogous series of observations was made. In the following these two observation series are denoted measurements with direct and reversed core respectively.

To determine the constant of the apparatus with the evaluation coil, the latter was inserted in the core coil so that its winding acquired a position corresponding to position I of the cores. A current (i_e) was then passed through the evaluation coil and the reading s_1 was made, whereupon the same current was reversed ($-i_e$) and the reading s_2 was noted.

Theory.

The field of the core coil, which may be considered entirely homogeneous along the length of the core, magnetizes the latter in the longitudinal direction. If the core consists of magnetically homogeneous material of small magnetizability, it will be homogeneously magnetized, whereby its two terminal faces, and only these, obtain a coating of free magnetism of the same quantity but of opposite character. If, on the other hand, the susceptibility of the core material is high, the magnetizing of the core will not be homogeneous and the consequence of this will be that the free magnetism spreads also to the cylindrical faces of the core. The investigations now made, show, however, that for the present purpose it is possible to calculate with a homogeneous magnetizing, even in the case of such high values of susceptibility on the part of the core material as those met with in magnetite ores.

Besides by the field of the core coil the core sample is also magnetized by the earth magnetic field and the field from the astatic magnet system and the direction magnet. The test sample itself may also have a remanent magnetization. This combined magnetizing in the longitudinal direction will thus give rise to a coating (q) of free magnetism on the terminal faces, which may be written:

$$q = q_i + q_j + q_m + q_r, \quad \ldots \ldots \ldots \ldots \quad (1)$$

if here, as well as in the following, the quantities belonging to the above-mentioned magnetizations in the order stated are denoted by the indices i, j, m, and r.

The following symbols are introduced:

The core sample:
S = terminal face
d = diameter
I = magnetization intensity
$\varkappa'$ = apparent susceptibility
l = length
N = demagnetization factor
$\varkappa$ = susceptibility

The core coil:
n = number of turns/cm
H = field caused by (i)
i = current strength
X = another field in the longitudinal direction

Astatic magnet system:
M = magnetic moment of each magnet
$2a$ = distance between the poles of the magnets
h = distance between upper and lower magnets.
b = distance from central axis of core coil to the lower magnet.

A = distance between scale and mirror (about 1 m).
Oe = Oersted.

The field of the core coil

$$H = 0.4\,\pi\, n\, i \text{ Oe}, \quad \ldots \ldots \ldots \ldots \quad (2)$$

if the strength of the current is expressed in ampères.

The magnetization intensity (I_i) which this field causes in the core sample brings about a field in the sample directed against H of the magnitude NI_i, for which reason

$$q_i = SI_i = S(H - NI_i)\,\varkappa = SH\varkappa'. \quad \ldots \ldots \quad (3)$$

From equation (3) is obtained the relation of the combination between $\varkappa$ and $\varkappa'$:

$$\varkappa = \frac{\varkappa'}{1 - N\varkappa'}. \quad \ldots \ldots \ldots \ldots \quad (4)$$

As expressions analogous to equation (3) are valid for q_j and q_m, the relation in equation (1) can be written in the following way:

$$q = S(\varkappa' H + \varkappa' X_j + \varkappa' X_m + I_r) = 0.4\,\pi\, nS\,(\varkappa' i + \mu), \quad \ldots \quad (5)$$

where

$$\mu = \frac{\varkappa'(X_j + X_m) + I_r}{0.4\,\pi\, n}. \quad \ldots \ldots \ldots \quad (6)$$

If the core sample is in position I (Fig. 5) and if the terminal face in front of the astatic magnet system has a coating q and the second a coating —q, the magnet system turns at an angle α_1 from the zero position. For the torsional moment that the core sample exerts on the system, the following expression can be derived:

$$M\left(\frac{qbc}{k}\cos\alpha_1 - qlc\,\frac{k-1}{k}\sin\alpha_1\right), \quad \dots\dots\dots\dots \quad (7)$$

where

$$c = \frac{1}{(a^2+b^2)^{3/2}} - \frac{1}{(a^2+b^2+h^2)^{3/2}} \quad \dots\dots\dots\dots \quad (8)$$

and

$$\frac{1}{k} = 1 - \frac{1}{2c}\left[\frac{1}{\{(l-a)^2+b^2\}^{3/2}} + \frac{1}{\{(l+a)^2+b^2\}^{3/2}} - \right.$$

$$\left. - \frac{1}{\{(l-a)^2+b^2+h^2\}^{3/2}} - \frac{1}{\{(l+a)^2+b^2+h^2\}^{3/2}}\right]. \quad \dots \quad (9)$$

The torsional moment that the core exerts on the magnetic system is counter-balanced by the torsional moment caused by the direction magnet and the torsion (τ) in the suspension fibre. If the difference between the field of the direction magnet at the sites of the upper and lower magnet is denoted F_x, this latter can be written

$$MF_x \sin\alpha_1 + \tau\alpha_1 \backsim M\sin\alpha_1\left(F_x + \frac{\tau}{M}\right) = MF\sin\alpha_1. \quad \dots\dots \quad (10)$$

For position I the expressions (7) and (10) give after some transforming

$$q\left(1 - \frac{l(k-1)}{b}\,\mathrm{tg}\,\alpha_1\right) = k\frac{F}{bc}\,\mathrm{tg}\,\alpha_1. \quad \dots\dots\dots\dots \quad (11)$$

If the core is reversed to position II and the angle of deflection is α_2, the result is that

$$-q\left(1 + \frac{l(k-1)}{b}\,\mathrm{tg}\,\alpha_2\right) = k\frac{F}{bc}\,\mathrm{tg}\,\alpha_2. \quad \dots\dots\dots\dots \quad (12)$$

In equations (11) and (12), if the angles of deflection (α_1, α_2) are counted with the symbols according to fig. 5, q obviously must be positive or negative resp. according as the core in position I causes a positive or negative deflection. According to equation (5) this means that the current through the core coil must be counted as positive, when it has such a direction that, when a paramagnetic sample is in position I, it causes a positive deflection, and as negative in the opposite case.

$\frac{F}{bc}$ can be considered a constant of the apparatus. It is, however, more practical for the calculation instead to introduce

$$\varepsilon = \frac{F}{0.4\,\pi\, n\, bc\, 2\, A\, S_0} \quad \dots\dots\dots\dots\dots \quad (13)$$

and as reduction factor for a chosen average value S_0 of the terminal faces of the testing cylinders

$$k_{\Phi} = \frac{S_0}{S}. \quad \ldots\ldots\ldots\ldots\ldots \quad (14)$$

If a $\varkappa$-determination is carried out according to the plan on page 10, we obtain two equations of the type (11) for the observations with the indices 1 and 4 and two equations of the type (12) for the observations with the indices 2 and 3. If in those equations the expression (5) for q is used, the symbols (13—14) are introduced and we put

$$p = \frac{l\,(k - 1)}{b} \text{ (equ. 15) and } \operatorname{tg} \alpha_1 = \frac{s_1 - s_0}{2\,A},\ \operatorname{tg} \alpha_2 = \frac{s_2 - s_0}{2\,A}$$

and so on, we can write the four equations:

$$\left.\begin{array}{rl} 1) & (\varkappa' i_1 + \mu)\,(1 - p \operatorname{tg} \alpha_1) = k k_{\Phi}\, \varepsilon\, (s_1 - s_0), \\ 2) & -(\varkappa' i_2 + \mu)\,(1 + p \operatorname{tg} \alpha_2) = k k_{\Phi}\, \varepsilon\, (s_2 - s_0), \\ 3) & -(\varkappa' i_3 + \mu)\,(1 + p \operatorname{tg} \alpha_3) = k k_{\Phi}\, \varepsilon\, (s_3 - s_0), \\ 4) & (\varkappa' i_4 + \mu)\,(1 - p \operatorname{tg} \alpha_4) = k k_{\Phi}\, \varepsilon\, (s_4 - s_0). \end{array}\right\} \ldots\ldots \quad (16)$$

From equations 1) and 4) a pair of values $\varkappa'$, μ is obtained, marked index I, since it corresponds to the measurements in position I; from equations 2) and 3) another pair of values $\varkappa'$, μ is obtained, marked index II as belonging to position II.

If the factor $\dfrac{1}{(1 - p \operatorname{tg} \alpha_1)\,(1 - p \operatorname{tg} \alpha_4)}$[1] for $\varkappa'_{\mathrm{I}}$ and μ_{I} and the factor $\dfrac{1}{(1 + p \operatorname{tg} \alpha_2)\,(1 + p \operatorname{tg} \alpha_3)}$[1] for $\varkappa'_{\mathrm{II}}$ and μ_{II} are omitted, we obtain:

$$\left.\begin{array}{ll} \varkappa'_{\mathrm{I}} & = k k_{\Phi}\, \varepsilon\, \dfrac{s_1 - s_4}{i_1 - i_4}, \\ \mu_{\mathrm{I}} & = k k_{\Phi}\, \varepsilon \left[\dfrac{i_1\,(s_4 - s_0) - i_4\,(s_1 - s_0)}{i_1 - i_4} - \dfrac{p\,(s_1 - s_0)\,(s_4 - s_0)}{2\,A}\right], \\ \varkappa'_{\mathrm{II}} & = k k_{\Phi}\, \varepsilon\, \dfrac{s_3 - s_2}{i_2 - i_3}, \\ \mu_{\mathrm{II}} & = k k_{\Phi}\, \varepsilon \left[\dfrac{i_2\,(s_3 - s_0) + i_3\,(s_2 - s_0)}{i_2 - i_3} - \dfrac{p\,(s_2 - s_0)\,(s_3 - s_0)}{2\,A}\right]. \end{array}\right\} \ldots\ldots \quad (17)$$

As definitive values of $\varkappa'$ and μ we get

$$\varkappa' = \tfrac{1}{2}\,(\varkappa'_{\mathrm{I}} + \varkappa'_{\mathrm{II}}), \qquad \mu = \tfrac{1}{2}\,(\mu_{\mathrm{I}} + \mu_{\mathrm{II}}); \quad \ldots\ldots \quad (18)$$

whereupon according to equations (4, 6) we obtain:

$$\varkappa = \frac{\varkappa'}{1 - N\varkappa'} \text{ and } I_r = 0.4\,\pi\, n\, \mu - \varkappa'\,(X_j + X_m). \quad \ldots\ldots \quad (19)$$

---

[1] These factors generally deviate less than 0.002 from 1.

For the calculation of I_r it is thus necessary also to know $(X_j + X_m)$. These fields are constant when the aggregate is arranged in a certain manner, for which reason they only need be determined once by a measurement of some kind. This is possible *e. g.* by measuring with the core "direct" as well as "reversed". If the μ-values in such cases are marked μ' and μ'' resp., it is obvious that

$$I_r = 0.4\,\pi\,n\,\mu' - \varkappa'\,(X_j + X_m),$$
$$-I_r = 0.4\,\pi\,n\,\mu'' - \varkappa'\,(X_j + X_m)$$

and thus

$$\left.\begin{aligned} I_r &= 0.2\,\pi\,n\,(\mu' - \mu''), \\ X_j + X_m &= \frac{0.2\,\pi\,n\,(\mu' + \mu'')}{\varkappa'}\,. \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (20)$$

Determination of instrumental constant and reduction factors.

When a current is passed through the evaluation coil, the magnetic field formed around the coil is identically the same as if the terminal faces of the coil were coated with free magnetism of the same quantity but of opposite kinds. If symbols with index e but otherwise analogous with the earlier notations are used, the magnetism quantity in this case becomes

$$q_e = 0.1\,n_e\,i_e\,S_e$$

and if evaluation measurements are made as outlined on page 10, two equations analogous with equation (11) will obviously be obtained. If these are subtracted, it appears after some transforming that

$$\frac{F}{bc} = \frac{1}{k_e} \times \frac{0.1\,n_e\,i_e\,S_e}{\operatorname{tg}\alpha_1 - \operatorname{tg}\alpha_2}\left[2 - \frac{l_e\,(k_e - 1)}{b}\,(\operatorname{tg}\alpha_1 + \operatorname{tg}\alpha_2)\right].$$

For the instruments that have been used $\operatorname{tg}\alpha_1 \backsim -\operatorname{tg}\alpha_2$ and $\frac{l_e\,(k_e - 1)}{b}$ are of the magnitude 0.02, on account of which the last term inside the brackets can be neglected. As $\operatorname{tg}\alpha_1 = \frac{s_1 - s_0}{2\,A}$ and $\operatorname{tg}\alpha_2 = \frac{s_2 - s_0}{2\,A}$ we obtain

$$\varepsilon = \frac{F}{0.4\,\pi\,n\,bc\,2\,A\,S_0} = \frac{n_e\,S_e}{2\,\pi\,n\,k_e\,S_0} \times \frac{i_e}{s_1 - s_2} \quad \ldots\ldots \quad (21)$$

The diameters of the cores are as a rule very constant for each separate sample along its entire length, but show variations for different testing cores from 21 to 22.8 mm. For S_0 the area of a circle with a diameter of 22 mm has therefore been chosen. Thus

$$k_\Phi = \frac{S_0}{S} = \left(\frac{22}{d}\right)^2, \quad \ldots\ldots\ldots\ldots \quad (22)$$

where d is expressed in mm.

The value of k for different lengths of the drill core can be calculated with the help of formula (9), but it can also be determined experimentally by measurements with the evaluation coil in the following manner.

The evaluation coil is first inserted in position I. It is then pulled out one cm at a time, and measurements are made for each position analogous to those made in the determination of ε. It is suitable to increase the current through the evaluation coil, the more this is pulled out of the core coil, as the magnitude of the deflexion otherwise decreases and lessens the accuracy of the measurements. The differences in the readings $s_1 - s_2$ for the different positions are recalculated to equal strength of current and are denoted n_0, n_1, n_2, etc., where the index indicates the displacement of the coil in cm from position I.

If the length of the evaluation coil is L cm and if we assume it to be substituted by a coil of infinite length, the values corresponding to n_0 and n_1 would obviously be

$$\left.\begin{aligned} \bar{n}_0 &= n_0 + n_L + n_{2L} + n_{3L} + \ldots\ldots \\ \bar{n}_l &= n_l + n_{l+L} + n_{l+2L} + \ldots\ldots \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (23)$$

For a core l cm long, k, which is a factor reducing the scale deflexion of a short core into the scale deflexion of a core of infinite length, can be written

$$k_1 = \frac{\bar{n}_0}{\bar{n}_0 - \bar{n}_l}, \quad \ldots\ldots\ldots\ldots\ldots \quad (24)$$

as $\bar{n}_0 - \bar{n}_l$ is the scale deflexion corresponding to an evaluation coil l cm long in position I.

The measurements did not need to be extended more than to the determination of n_{25}, as the following n-values were of negligible magnitude.

The table below shows the k-values for the second aggregate calculated according to (9) and values for that aggregate determined experimentally and according to equation (23, 24). The tabulated p-values are calculated from the latter.

Table I.

length of core cm	k calcul.	k experim.	$p = \frac{l(k-1)}{b}$	length of core cm	k calcul.	k experim.	$p = \frac{l(k-1)}{b}$
0	∞	∞		7	1.113	1.113	0.184
1	12.811	11.92	2.540	8	1 073	1.077	0.143
2	3.768	3.59	1.205	9		1.054	0.113
3	2.114	2.04	0.726	10	1.033	1.038	0.088
4	1.553	1.522	0.486	12		1.022	0.061
5	1.306	1.286	0 333	15	1.007	1.011	0 038
6	1.181	1.175	0.244	20	1.002	1.004	0.019

Accuracy of measurements.

Primarily it should be stated that the measurements with the first aggregate were less accurate than with the second, as the positions of the drill cores in the magnetization coil were not fixed in a fully satisfactory way in relation to the central axis of the coil. A number of cores have been measured with both aggregates and deviations in the $\varkappa'$-values have then been recorded, in single cases amounting to as much as 5 %.

In order to illustrate the reproducibility of measurements carried out with the second aggregate a series of measurements of a drill core sample Luossavaara Reg. Nr. 10 is listed in Table II, which is included in the investigation of the demagnetization factor (see Table III).

Table II.

Luossavaara Reg. Nr. 10; Length 70 mm.

rotation around longitudinal axis	$\varkappa'$ core direct	$\varkappa'$ core reversed
0°	0.4626	0.4696
90°	0.4648	0.4535
180°	0.4653	0.4607
270°	0.4633	0.4689
Mean =	0.4640 ± 0.0011	0.4632 ± 0.0061

Mean = 0.4636 ± 0.0004

The great difference in the average error for the series with direct and reversed core will be due to the fact that the core sample was not so well centered when the »reversed core» was inserted. For all the core samples included in Table III the measurements have been carried out according to the same complete plan as is shown in the table above. In many cases a similar marked difference between the average errors is apparent. The relative accuracy of a single determination of $\varkappa'$ (without rotation around the longitudinal axis of the core) will be about ± 1 %, assuming that the magnetite in the core sample is evenly distributed.

The absolute errors that affect the measurements are first of all dependent on the accuracy with which the instrumental constant ε is determined. The foremost cause of error lies in the measurement of the electric data of the evaluation coil, while the reproducibility of the evaluation measurements themselves lies within $^1/_2$ %. In order to obtain an idea of the absolute exactness with wich ε was determined, two evaluation coils have been used in the second apparatus, one of them with a diameter of about 22 mm and the other with a diam. of about 34 mm. The ε-values measured with these coils are lying within 1 % of each other.

Results.

Determination of the demagnetization factor.

The size of the demagnetization factor depends on the shape of the body. Strictly speaking N is constant at every point inside the body only when it is limited by a face of the second degree. In determinations of the susceptibility, however, one always calculates with a constant value of N for the entire

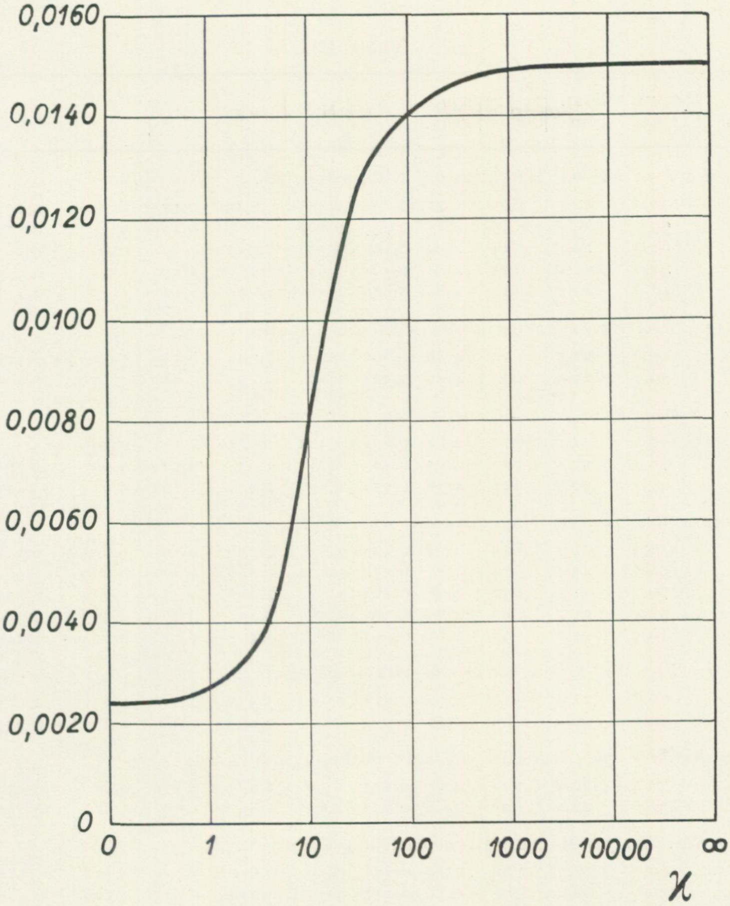

Fig. 6. The variation of the demagnetization factor (N) with the susceptibility (ϰ) for a cylinder with the axial ratio p = 50; according to J. Würschmidt (19).

body and the demagnetization factor is then conveniently defined as that value of N which gives the true value of the susceptibility. Consequently N is also to some extent dependent on the method used in the susceptibility measurements.

In the ϰ-determinations hitherto carried out on cylindrical ore samples (see *e. g.* 9—11, 13), values of N have either been used which are applicable to an ellipsoid with the same axial ratio as the cylinder or the N-values have been graphically determined with the aid of the values, determined by R. Mann (5) for cylindrical bars of iron. The investigations carried out by Mann comprise cylinders with a relation (p) between length and diameter from 5 to 300 and the N-values show only small divergencies from those which are valid for ellipsoids with corresponding axial ratios. J. Würschmidt has shown, however, that the demagnitization factor for cylinder-shaped samples is de-

Table III.

sections	length mm	diam. mm	p	spec. grav.	$\varkappa'$	N_e	$\varkappa_e$	N_c	$\varkappa_c$	I'_r	I
Grängesberg Reg. Nr. 6. Hematite ore with magnetite.											
f—s	130.0	22.0	5.91	4.87	0.785	0.555	1.39	0.173	0.909	0.235	0.272
f—o ...	99.0	22 0	4.50	4.85	0.757	0.808	1.95	0 299	0.979	0.177	0.229
f—l	69.0	22.0	3.14	4.84	0.590	1.30	2.53	0.594	0.909	0.207	0.319
a—e....	49.0	22 0	2.23	4.91	0.522	1.94	∞	1.103	1.23	0.349	0.823
h—l	48.5	22.0	2.21	4.86	0.487	1.96	10.7	1.123	1.07	0.118	0.260
Grängesberg Reg. Nr 8. Magnetite ore with some apatite skarn.											
	69.0	21.0	3.29	4.89	0.692	1.22	4.44	0.545	1.11	0.428	0.687
	50.0	21.0	2.38	4.96	0.544	1.80	26.2	0.980	1.17	0.322	0.690
Herräng, Viking Reg. Nr 1. Magnetite ore with some diopside											
	148	22.0	6.73	4.64	0.638	0.461	0.904	0.137	0.699		
	70.5	22.0	3.21	4.62	0.483	1.26	1.23	0.570	0.667	0.078	0.108
	47.5	22.0	2.16	4.66	0.371	2.00	1.44	1.16	0.654	0.442	0.778
Luossavaara Reg. Nr. 10. Magnetite ore with apatite.											
a—m ...	130.5	21.1	6.19	4.74	0.550	0.520	0.770	0.162	0.604	0 534	0.586
a—j	100.0	21.1	4.74	4.77	0.531	0.754	0.886	0.268	0.619	0.505	0.589
a—g....	70.0	21.1	3.32	4.78	0.464	1.21	1.06	0.534	0.616	0.420	0.558
n—v ...	56.5	21.1	2.68	4.65	0.386	1.56	0.97	0.794	0.557	0.350	0.505
a—d ...	49.5	21.1	2.35	4 81	0.393	1.83	1.40	1.01	0.652	0.345	0.572
Malmberget Reg. Nr. 8. Magnetite ore with some apatite.											
	69.5	22.0	3.16	5 16	0.678	1.29	5.41	0.586	1.13	0.065	0.107
	49.5	22.0	2 25	5.13	0.535	1.92	∞	1.08	1.27	−0.033	−0.079
Persberg Reg. Nr. 38. Magnetite ore with anthophyllite skarn.											
	70.5	22.0	3.21	4.35	0.475	1.26	1.18	0.570	0.650	0.320	0.410
	50.0	22.0	2.27	4.38	0.397	1.89	1.59	1.06	0.688	0.237	0.439
Persberg Reg. Nr. 50. Magnetite ore with diopside skarn.											
f—v....	160.5	22.0	7 30	4.32	0.496	0.409	0.622	0.119	0.528	0.108	0.115
f—r....	130.0	22.0	5.91	4.32	0.477	0.555	0.649	0.173	0.520	0.129	0.141
f—o....	99.5	22.0	4.52	4 32	0.425	0.801	0.644	0.229	0.487	0.154	0.176
f—l	70.0	22.0	3.18	4.35	0.399	1.27	0.809	0.575	0.527	0.158	0.208
J—j....	49.0	22.0	2.23	4.41	0.366	1.94	1.26	1.10	0.614	0.060	0.101
a—e....	48.5	22.0	2.21	4.37	0.364	1 96	1.27	1.12	0.615	0 099	0.167
Persberg Reg. Nr. 51. Magnetite ore with diopside skarn.											
f—z....	161.0	21.9	7.35	4.66	0.761	0.405	1.10	0.117	0.835	0.234	0.257
j—z....	130.0	21.9	5.94	4.66	0.744	0.551	1.26	0.175	0.856	0.209	0 240
m—z ...	100.0	21.9	4.57	4.70	0.697	0.792	1.56	0.293	0.875	0.193	0.242
m—t ...	70.0	21.9	3.20	4.70	0.576	1.27	2.15	0.575	0.864	0.159	0.238
o—t....	50,0	21.9	2.28	4.69	0.457	1.89	3.35	1.06	0.883	0.105	0.203
a—e....	48.0	21.9	2.19	4.43	0.366	1.97	1.31	1.14	0.627	0.144	0.246

pendent upon the magnitude of the susceptibility and that it decreases with the latter. Fig. 6 shows a diagram illustrating how N varies with $\varkappa$ for a cylinder with the axial ratio $p = 50$, this according to the theoretical calculations of Würschmidt. For $\varkappa = \infty$ N in the diagram assumes the value 0.0150, while for an ellipsoid with the same p-value N is 0.0158. When $\varkappa$ approaches zero, N approaches the value valid for a homogeneous magnetization of the cylinder.

Würschmidt has only theoretically treated the magnetization conditions of a cylinder with a high p-value, and no experimental determinations seem to have been made to determine the N-values for cylinder-shaped bodies with susceptibility values of such magnitude as have to be counted with in the case of magnetic ores.

In order to obtain reliable values of the demagnetization factor careful measurements have therefore been made on a number of selected ore cores, each of which has been sawn off successively in ever diminishing lengths. The results of these measurements are found in Tab. III. The lengths, diameters, p-values, spec. gravities, and $\varkappa'$-values of the drill cores are here adopted as primary values. For some of the experimental series the places occupied by the test samples in the original core are indicated by letter designations in the column »Sections». If $\varkappa$ is calculated from $\varkappa'$ with the aid of the values for N valid for an ellipsoid, viz.

$$N_e = \frac{4\pi}{p^2 - 1}\left[\frac{p}{2\sqrt{p^2 - 1}} \ln \frac{p + \sqrt{p^2 - 1}}{p - \sqrt{p^2 - 1}} - 1\right],$$

those values of $\varkappa$ are obtained which are found under $\varkappa_e$ in the table. As will be seen, $\varkappa_e$ increases very rapidly with decreasing length of the cylinder samples and becomes infinitely large for some of the shortest samples. It is thus obvious that the values of the demagnetization factor must be definitely lower than what is indicated by the formula for N_e.

The lowest value that the demagnetization factor possibly can assume corresponds to a homogeneous magnetization of the cylinder. If in this case that value of N is chosen which is valid for the centre of the cylinder,

$$N_c = 4\pi\left[1 - \frac{p}{\sqrt{1 + p^2}}\right]. \quad \ldots\ldots\ldots\ldots \quad (25)$$

The susceptibility values corresponding to N_c are found under $\varkappa_c$ and display a fairly satisfactory agreement within the various experimental series. In order to illustrate to what extent the $\varkappa_c$-differences in these may be explained by different magnetite contents in the sawn-off test samples, the $\varkappa_c$-values have been plotted in a diagram (fig. 7) with the spec. gravity as abscissa. This last-mentioned magnitude can be regarded as a measure of the amount of magnetite in the test samples, as the minerals that occur together with the magnetite in the cores have a spec. gravity about two units below that of magnetite. In the case of Grängesberg Reg. Nr. 6, however, where the hybrid material mainly consists of hematite whose spec. gravity is about the same as that of magnetite, this is not valid. It appears from Fig. 7 that the $\varkappa_c$-values of Grängesberg Reg. Nr. 8, Luossavaara Reg. Nr. 10 and Persberg Reg. Nr. 38, 50, 51 show a distinct tendency to decrease with declining spec. gravities, and the differences between the $\varkappa_c$-values in these experimental series that are not caused by differences in the magnetite contents of the test samples seem to

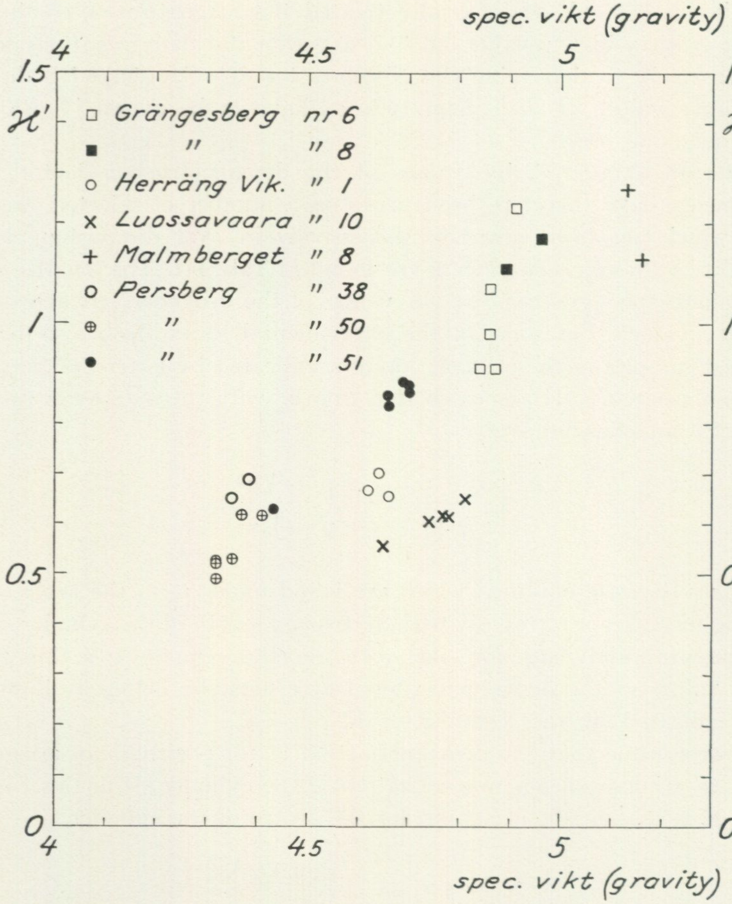

Fig. 7. Diagram showing the relation between the spec. gravity values and the $\varkappa_c$-values of the core samples listed in Table III (not $\varkappa'$ as erronously stated in the diagram).

be very small. Malmberget Reg. Nr. 8 shows a fairly marked discrepancy, the test sample with the higher spec. gravity showing a much lower $\varkappa_c$-value than that with the lower spec. gravity. It should be observed, however, that the core with the larger p-value also has the larger $\varkappa'$-value, but, on the other hand, the lower $\varkappa_c$-value. As this relationship cannot be explained by the difference in magnetite content but is further accentuated by it, the values of the demagnetization factor which bring the $\varkappa_c$-values in agreement with each other, must thus decrease still more slowly with declining p-values than in the case of the homogeneously magnetized cylinder. Seeing that from a theoretical point of view this is exceedingly improbable, the difference in the $\varkappa_c$-values for Malmberget 8 must probably be attributed to differences in the susceptibility of the magnetite in the two test samples.

As the susceptibility values calculated with the aid of N_c show such a good

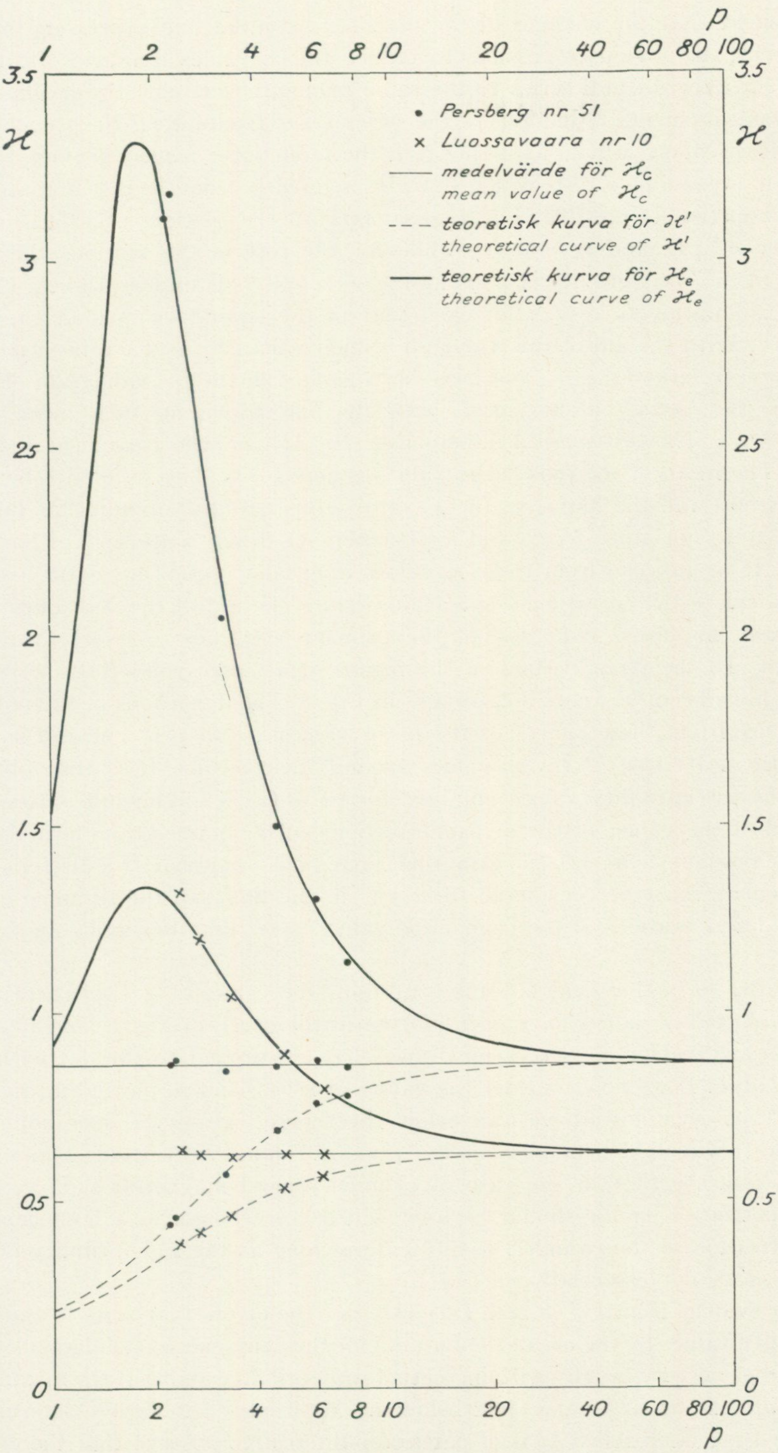

Fig. 8. The variation of $\varkappa'$, $\varkappa_c$ and $\varkappa_e$ with varying p-values. Signs · and × indicate measuring results, the curves theoretical calculations.

agreement that the changes in the magnetite content find expression in these values, it is obviously possible to reduce the $\varkappa_c$-values obtained within the different experimental series to the same magnetite content. Fig. 8 illustrates the result of such a reduction for the series Luossavaara Reg. Nr. 10 och Persberg Reg. Nr. 51, which, as is shown in the table, have a spec. gravity for sections n—v and a—e resp. which deviates so greatly from the rest that an accurate reduction is possible. For Luossavaara 10 the section n—v has a spec. gravity of 4.65 and $\varkappa_c = 0.557$ while for the rest of the sections the mean value of the spec. gravity is 4.775 and $\varkappa_c = 0.623$. This implies a linear change of $\varkappa_c$ amounting to 0.0053 for each unit in the second decimal of the spec. gravity. With the aid of this value all section values for $\varkappa_c$ have been reduced to the spec. gravity 4.775 and have been plotted in the p—$\varkappa$-diagram (Fig. 8) where they very closely agree with the line drawn for their mean value $\varkappa_c = 0.623$. The test series Persberg Reg. Nr. 51 has been treated in a similar way. The mean of the reduced $\varkappa_c$-values is here 0.863. The difference between the highest and the lowest of the $\varkappa_c$-values thus reduced amounts for Luossavaara 10 to not quite 3.5 % and for Persberg 51 to not quite 4 % of the total value. If we proceed from these $\varkappa_c$-values reduced to equal magnetite content and calculate the corresponding $\varkappa'$-values (with the aid of the N_c-values), this obviously implies a reduction of the primary $\varkappa'$-values to equal magnetite content. To the straight lines of the means of $\varkappa_c$ correspond those $\varkappa'$-curves which have been drawn as dotted lines in Fig. 8. The deviations of the reduced $\varkappa'$-values from these curves of the mean values are in per cent still smaller than the scattering of the $\varkappa_c$-values around their means. It is thus obvious that the susceptibility values obtained for these two experimental series with the aid of the values of the demagnetization factor obtained from formula (25) can be brought to a very good mutual agreement, and that the discrepancies that remain must be considered to lie within the limits of the summed errors of the determinations of the primary $\varkappa'$-values, spec. gravities and core dimensions.

In order to further elucidate the conditions the values of $\varkappa_e$ that correspond to the plotted $\varkappa'$-values have been plotted in the diagram Fig. 8, and in addition the curves for $\varkappa_e$ have been drawn that correspond to the dotted mean curves of $\varkappa'$. If we now consider the values of $\varkappa'$, $\varkappa_c$, and $\varkappa_e$ plotted in the diagram, their grouping above and below the theoretical curves does not show any indication of dependence on the p-value. The investigations made thus clearly indicate that in the case of cylinder-shaped magnetite samples that demagnetization factor should be used which corresponds to a homogeneous magnetization of the cylinder, in any case as long as the susceptibility of the sample does not essentially exceed 1.

It is evident from Fig. 8 and Tab. III that the errors that arise in the susceptibility values by the use of the formula for the demagnetization factor of the ellipsoid grow very rapidly with increasing susceptibility and that the maximum errors appear at a p-value just below 2. With regard to earlier determinations of the susceptibility it is of particular interest to observe that the errors also in the case of relatively high p-values may reach fairly considerable amounts. In the case of Luossavaara 10 and Persberg 50 with $p = 10$ and $p = 20$ *i. e.* core lengths of about 22 and 44 cm resp., with the core diameter here used, susceptibility values would be obtained that are 19.9 % and 13.6 % too high for the former and 6.3 % and 4.5 % too high for the latter. It is thus obvious that earlier published susceptibility values, which were performed on cylinder-shaped magnetite samples, must largely be recalculated. If an examination is made of *e. g.* those determinations on which the H-$\varkappa$-diagram in Fig. 2 (p. 4) is based, $p = 8$ according to the information published (10), which according to the formula for N furnished by Puzicha gives the value 0.327, while according to formula (25) the value 0.097 is obtained. This last-mentioned N-value corresponds to the dotted curve in Fig. 2. According to this the susceptibility values are considerably lower and their variations with the field strength essentially smaller than what is indicated by the continuous curve. While according to the latter $\varkappa = 2.50$ when H is the strength of the earth field and the maximum value at 15 Oe is $\varkappa = 5.75$, the corresponding values for the dotted curve are 1.52 and 2.30 resp.[1]. For the magnetite sample from Altenau (Fig. 3) $p = 5.30$ and the difference between the value used by Rettig and the correct N-value is about 0.41. The recalculated curve (dotted) here gives a $\varkappa$-value of 0.42 at 5 Oe and 0.85 for the maximum value at 140 Oe, corresponding to 0.50 and 1.30 resp. according to the original curve.

It should be emphasized that the derivation of the formula for N is founded on the assumption that the cylinder consists of homogeneously magnetized material. In the case of ore samples this is not the rule as the magnetite occurs here mixed with what in comparison may be called practically nonmagnetic minerals. In this case it is therefore a *sine qua non* that the magnetite broadly speaking shall be evenly distributed throughout the entire volume of the cylinder if the above expression is to be valid. Furthermore demagnetization conditions appear in the test body, which are not dependent on its external form. These conditions, however, are treated further on in another connection.

Remanent magnetism.

In order to ascertain whether the remanent magnetism that a drill core possesses to some extent may be regarded as corresponding to the remanent magnetism that an ore contains *in situ*, also the remanent magnetization intensity (I'_r) of the cores, listed in Table III, was determined.

It is obvious that also the remanent magnetization intensity gives rise to a

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[1] The investigation here published does not include any determinations on samples from Koskullskulle, but instead measurements on a number of core samples of various lengths from the adjacent and geologically similar Malmberget field. These show for fields of the strength of the earth field a mean of 1.57 as the susceptibility of pure magnetite (Table VI, page 61). This is in good agreement with the recalcuted $\varkappa$-value of 1.52 for the sample from Koskullskulle, which consisted of compact magnetite.

demagnetization field in the core of the magnitude NI'_r. As N increases when the length of the core decreases, I'_r becomes less the shorter the sawn-off pieces of the core. In order to obtain comparable values it is therefore convenient to reduce all I'_r-values to the values (I_r) that would be valid if the cores were of infinite lentgh, viz. the demagnetization factor $N = 0$.

The demagnetization field gives rise to a magnetization intensity NI'_r, which acts against I_r, and thus the relation below prevails

$$I'_r = I_r - \varkappa N I'_r$$

or

$$I_r = I'_r (1 + \varkappa N) = I'_r \frac{\varkappa}{\varkappa'} \dots\dots\dots\dots\dots \quad (26)$$

The table discloses that an unexpectedly good agreement exists between the I_r-values of the different sections in the series for Grängesberg 8, Luossavaara 10, Persberg 38, and Persberg 51. Obviously the sawing of the drill-cores, which was effected with an ordinary stone saw with a steel disk and steel claws for holding the cores, did not cause any changes in the remanent magnetization of these cores. Persberg 38 shows a somewhat more irregular I_r-series than those above mentioned, and Grängesberg Nr. 6 shows a value for sections a—e, which deviates quite considerably from the rest of the series. The drill-cores from Herräng and Malmberget, finally, seem to have a very varying remanent magnetization. The few determinations of the I_r-values that have been presented here of course do not constitute a sufficient basis to judge with certainty whether the cores drilled with a diamond drill machine in the ordinary way mainly retain the remanent magnetism that is possessed in the ores, or if that magnetism changes during the drilling. The uniform remanent magnetism along the entire length of the cores, which has been observed in several of the drill cores, makes it appear fairly probable, however, that at least for certain ores the ordinary drill cores can be used for an investigation of the remanent magnetism of the ores. In any case the results here presented seem to justify a closer investigation of these circumstances.

The Main Table.

All the susceptibility determinations are listed in Table IV. The various mining fields are listed in alphabetical order. The cores have been given a current number as well as a registration number. The latter is the number on the labels of the core samples.

The geological description of the drill-cores from the Lapland ore fields has been made by P. Geijer, Director-in-Chief of the Swedish Geological Survey, and of the others by Professor N. H. Magnusson of the Technical Highschool in Stockholm.

The specific gravity is given for almost all the drill cores. This has been determined in the usual way by weighing the cores in air and in water, and the error in the determinations will not exceed two units in the second decimal.

The volume fraction (v) of magnetite has been calculated for all those cores where this has been possible with fairly good accuracy. In doing so the following formula has been used

$$v = \frac{S - S_1}{S_2 - S_1}, \quad \ldots\ldots\ldots\ldots\ldots \quad (27)$$

where

S = spec. gravity of the core

S_1 = spec. gravity of that part of the core which is not composed of magnetite

S_2 = spec. gravity of pure magnetite.

The spec. gravity of pure magnetite has been appointed to 5.17. For the remaining minerals the following values have been used:

Galena	7.50	Augite	3.4	Dolomite	2.9
Pyrite	5.10	Epidote	3.4	Muscovite	2.8
Chalcopyrite	4.2	Diopside	3.3	Talc	2.75
Spessartite	4.2	Apatite	3.2	Calcite	2.7
Sphalerite	4.05	Hornblende	3.1	Chlorite	2.7
Knebelite	4.0	Antophyllite	3.05	Plagioclase	2.7
Andradite	3.7	Tremolite	3.0	Quartz	2.65
Hedenbergite	3.6	Grunerite	3.0	Microcline	2.6
Grossularite	3.5	Actinolite	3.0	Orthoclase	2.6
Dannemorite	3.45	Biotite	3.0		

Where two or more minerals with different spec. gravities occur together with magnetite, the proportions between these minerals have been estimated and the value of S_1 accordingly calculated. In the Table the volume percent magnetite is recorded.

Under the heading H in the Table is the field strength, used in the $\varkappa'$-determination, expressed in Oe.

The demagnetization factor (N) is only quoted in the cases where it was used for the calculation of $\varkappa$.

For the cores where the volume percent of magnetite is tabulated calculated values of the susceptibility of the pure magnetite is stated under the heading K and under the heading »Class» there is a number and in certain cases also a letter, which denotes the kind of distribution of the magnetite in the cores. These matters are, however, treated further on.

For references to geological descriptions, compare p. 79.

Table

No	Rocks	Reg. Nr.
	Basttjärn, Ljusnarsberg parish.	
1	Ore with knebelite, dannemorite, biotite, chlorite, calcite	13
2	Ore with knebelite, dannemorite, calcite, biotite, chlorite, garnet	15
3	Ore with knebelite	16
4	Lean ore with knebelite, dannemorite, calcite	14
5	Ore with knebelite skarn	17
6	Lean ore with much garnet, hornblende, biotite, chlorite, knebelite, and calcite	12
7	» » » »	11
8	Skarn of knebelite and dannemorite, with an inconsiderable amount of finely distributed magnetite	9
9	» » » «	10
10	Garnet-rich skarn with hornblende, chlorite, knebelite, dannemorite. Garnet more than 50 per cent. Very little magnetite	5
11	Garnet-rich skarn: garnet, pyroxene, some hornblende and calcite	6
12	Leptite, rich in skarn minerals: garnet, pyroxene, hornblende, calcite	8
13	Gray leptite with a low content of skarn minerals, mainly spots of garnet	7
14	Gray leptite almost free from skarn minerals	4
15	» » » » » » »	3
16	Limestone	1
17	»	2
	Bispberg (Gräsgruvan), Säter parish.	
1	Magnetite ore, rich	1
	Dalkarlsberg, Viker parish.	
1	Magnetite ore with tremolite, actinolite, biotite and chlorite	1
2	» » » » » » » »	2
3	Magnetite ore with some hematite	3
4	» » » » »	4
5	» » » » »	5
6	Hematite ore, coarse-grained, with magnetite	8
7	Leptite, on transition to mica schist, and with chlorite streaks	6
8	» » » » » » » » » »	7
9	» » » » » » » » » »	11
10	» » » » » » » » » »	12
	Finnmossen, Nordmark parish.	
1	Magnetite ore with very subordinated skarn	11
2	Magnetite ore with subordinated skarn	12
3	Magnetite ore, lean	10
4	» » »	9
5	»Green skarn» with irregular streaks of magnetite	8
6	Skarn, almost free from magnetite	3
7	Skarn without visible magnetite	4
8	Amphibolite with a rather high percentage of magnetite	6
9	» » » » » » » »	5
10	» » » » » » » »	7
11	Leptite with biotite spots	1
12	» » » »	2

IV.

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
1 —	4.16	49.5	0.2	469 000	0.407	579 000	2.55	1
1 —	4.30	44.6	1.1	270 000	0.463	309 000	1.09	2
1 —	4.41	37.7	1.4	232 000	0.569	267 000	1.28	3
1 —	3.84	28.9	0.2	202 000	0.450	222 000	1.93	4
1 —	4.46	39.3	0.4	170 000	0.392	183 000	0.647	5
1 —	3.76	22.5	0.4	159 000	0.278	166 000	2.29	6
1 —	3.82	19.2	0.4	129 000	0.396	136 000	2.47	7
1 —	4.19	15.2	0.2	9 060	0.343	9 090	—	8
1 —	4.18	15.4	0.2	9 000	0.725	9 050	—	9
—	3.63	—	4.7	280	—	280	—	10
—	3.54	—	4.7	149	—	149	—	11
—	2.89	—	4.7	83	—	83	—	12
—	2.83	—	4.7	13	—	13	—	13
—	2.64	—	4.8	16	—	16	—	14
—	2.67	—	4.8	10	—	10	—	15
—	2.73	—	4.8	6	—	6	—	16
—	2.74	—	4.8	6	—	6	—	17
1	4.94	90.9	0.7	546 000	0.358	680 000	0.787	1
1	4.68	77.4	0.2	735 000	0.166	839 000	1.34	1
1	4.32	61.2	0.5	524 000	0.213	591 000	1.41	2
—	4.45	—	0.5	394 000	0.286	444 000	—	3
—	4.35	—	0.8	61 200	0.723	64 200	—	4
—	3.71	—	2.5	48 000	0.866	50 100	—	5
—	4.72	—	0.8	314 000	0.353	354 000	—	6
—	2.77	—	8.3	1 740	—	1 740	—	7
—	2.76	—	8.3	17	—	17	—	8
—	2.72	—	8.3	5	—	5	—	9
—	2.73	—	8.3	5	—	5	—	10
1	4.58	68.4	0.9	561 000	0.481	769 000	1.57	1
1	4.45	61.5	0.2	427 000	0.564	563 000	1.31	2
1	3.66	30.4	0.2	200 000	0.473	220 000	1.59	3
1	3.70	27.2	5.1	176 000	0.675	200 000	1.83	4
—	3.30	—	5.1	47 000	0.319	47 800	—	5
—	3.03	—	9.8	74	—	74	—	6
—	3.15	—	9.8	63	—	63	—	7
—	3.16	—	0.3	15 100	0.244	15 200	—	8
—	3.16	—	0.9	9 000	0.469	9 030	—	9
—	3.27	—	7.2	4 170	—	4 170	—	10
—	2.65	—	9.8	8	—	8	—	11
—	2.66	—	9.8	6	—	6	—	12

No	Rocks	Reg. Nr.
	Fredmundberg, Ludvika parish.	
1	Magnetite ore with some skarn (actinolite)	3
2	» » » » » »	1
3	Magnetite ore with skarn (actinolite)	2
	Grängesberg, Grangärde parish.	
1	Magnetite ore with some apatite	7
2	» » » » »	8A
3	» » » » »	8B
4	» » » » »	9
5	Hematite ore with magnetite	6D
6	» » » »	6E
7	» » » »	6
8	» » » »	6B
9	» » » »	6A
10	» » » »	6C
11	Hematite ore with apatite, especially at one end of core	5
12	» » » » » » » » » »	5A
13	Amphibolite	3
14	»	3B
15	»	3A
16	Amphibolite, schistose	4
17	Diabase	2
18	Pegmatite (within ore body)	1
19	»	1A
20	»	1B
21	»	1C
	Herräng (Hägnaden), Häverö parish.	
1	Rich magnetite ore with skarn (mainly diopside)	1
2	» » » » » » »	2
3	Magnetite ore with skarn (mainly diopside)	3
4	» » » » » »	4
5	»Green skarn» with some magnetite	5
6	» » with epidote and a small amount of magnetite	6
7	Garnet skarn, more light-coloured than next specimen, very low content of diopside but with small magnetite grains in a tolerably even distribution	8
8	Garnet skarn without magnetite; garnet entirely predominating	7
9	Limestone with scattered grains of magnetite	9
10	Limestone with some skarn, mainly diopside	10
11	Amphibolite (»greenstone» dyke)	16
12	» » »	15
13	Greenstone (amphibolite), porphyritic, streaky	18
14	Porphyry (dyke)	17
15	Leptite, influenced by red granite and with some skarn, particularly at one end of core, and with some magnetite	20
16	Leptite, metasomatically altered (newformed mica)	21
17	Leptite, influenced by granite and at one end of core (nearly half) changed to schistose biotite rock	22
18	Leptite, largely altered to mica schist	23

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
I	4.94	89.4	0.2	736 000	0.250	902 000	1.09	1
I	4.90	87.6	0.4	660 000	0.376	878 000	1.10	2
I —	4.76	81.1	0.6	615 000	0.215	709 000	0.990	3
I	5.01	92.1	0.3	756 000	0.435	1 127 000	1.31	1
I	4.89	86.1	0.5	692 000	0.545	1 110 000	1.49	2
I	4.96	89.6	0.7	544 000	0.980	1 170 000	1.45	3
I	5.06	94.6	0.6	720 000	0.390	1 000 000	1.10	4
I	4.91	—	0.6	521 900	1.103	1 230 000	—	5
I	4.86	—	0.7	486 700	1.123	1 073 000	—	6
I	4.82	—	0.4	921 000	0.071	987 000	—	7
I	4.86	—	0.4	757 000	0.299	979 000	—	8
I	4.87	—	0.4	785 000	0.173	909 000	—	9
I	4.84	—	0.5	590 000	0.593	909 000	—	10
—	4.88	—	3.4	141 000	0.333	148 000	—	11
—	4.67	—	3.4	89 800	0.479	93 800	—	12
—	—	—	7.5	1 770	—	1 770	—	13
—	2.91	—	4.7	1 520	—	1 520	—	14
—	2.90	—	4.7	1 180	—	1 180	—	15
—	3.03	—	11.2	201	—	201	—	16
—	2.97	—	1.5	6 290	0.086	6 290	—	17
—	—	—	11.2	8	—	8	—	18
—	2.61	—	10.0	7	—	7	—	19
—	2.62	—	10.0	4	—	4	—	20
—	2.62	—	10.0	4	—	4	—	21
I	4.85	82.9	0.3	645 000	0.410	875 000	1.22	1
I	4.80	80.2	1.5	485 000	0.817	803 000	1.18	2
I —	4.10	44.3	0.7	506 000	0.283	591 000	4.62	3
I —	4.09	42.2	1.1	470 000	0.282	542 000	4.63	4
o	3.55	13.4	3.4	37 400	0.140	37 600	0.423	5
—	3.37	—	1.8	7 160	0.244	7 160	—	6
—	3.69	—	1.6	5 390	0.241	5 390	—	7
—	3.57	—	10.0	112	—	112	—	8
—	2.96	—	2.9	8 210	0.172	8 210	—	9
—	2.88	—	10.0	6	—	6	—	10
—	2.97	—	9.9	61	—	61	—	11
—	2.98	—	9.8	56	—	56	—	12
—	2.96	—	9.9	53	—	53	—	13
—	2.69	—	9.9	27	—	27	—	14
—	2.63	—	9.8	526	—	526	—	15
—	2.63	—	9.9	43	—	43	—	16
—	2.70	—	9.8	36	—	36	—	17
—	2.70	—	9.8	23	—	23	—	18

No	Rocks	Reg. Nr.
19	Leptite mixed with some granitic material	19
20	Aplitic granite, fine-grained, red	13
21	Granite with much leptite material	12
22	Aplitic granite, fine-grained, with subordinated patches of pyroxene and mica	14
23	Granite, with leptite material	11
	Herräng (Viking), Häverö parish.	
1	Rich magnetite ore with some diopside skarn	1
2	» » » » » » »	1 A
3	» » » » » » »	1 B
4	Rich magnetite ore with sphalerite and galena	4
5	Rich magnetite ore with sphalerite, galena and skarn	5
6	Rich magnetite ore with pyrite and sphalerite	3
7	Rich magnetite ore with diopside, pyrite and sphalerite	2
8	Granite with remnants of magnetite ore	12
9	» » » » » » diopside and hornblende	11
10	Granite	9
11	»	8
12	Skarn of epidote, garnet, diopside, and hornblende, with some calcite. Magnetite content low	6
13	Skarn, coarse-grained pyroxene with hornblende. Very little magnetite	7
14	Skarn of epidote, hornblende, and quartz	10
15	Amphibolite (greenstone dyke)	15
16	» » »	16
17	Leptite, gray to light pink	13
18	Leptite, gray, evengrained	14
	Hilläng, Ludvika parish.	
1	Magnetite ore, with knebelite	7
2	Lean ore: patches of magnetite and knebelite in limestone	5
3	» » » » » » » » »	6
4	Knebelite skarn with finely distributed magnetite and with subordinated amounts of galena, sphalerite, and calcite	4
5	Knebelite skarn with some garnet and dannemorite	3
6	Limestone with skarn	1
7	Leptite	2
	Idkerberget, St. Tuna parish.	
1	Rich ore with subordinated amounts of apatite and skarn	32
2	Magnetite ore with some skarn	1
3	Magnetite ore with apatite and skarn	49
4	» » » » » »	27
5	» » » » » »	40
6	» » » » » »	50
7	» » » » » »	28
8	» » » » » »	36
9	Magnetite ore with streaks of apatite and actinolite	22
10	Magnetite ore with streaks of apatite and some skarn	51
11	Magnetite ore with skarn	6
12	Magnetite ore with much skarn	4

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	2.64	—	9.9	20	—	20	—	19
—	2.62	—	9.9	967	—	967	—	20
—	2.72	—	9.9	430	—	430	—	21
—	2.67	—	9.9	235	—	235	—	22
—	2.67	—	9.9	156	—	156	—	23
1	4.64	71.6	1.4	638 000	0.137	699 000	1.25	1
1	4.62	70.6	0.5	483 000	0.570	667 000	1.22	2
1	4.66	72.7	0.8	371 000	1.164	654 000	1.12	3
1 —	4.80	68.5	0.4	628 000	0.155	695 000	1.37	4
1	4.77	59.0	1.2	506 000	0.329	607 000	1.61	5
1	4.66	52.3	1.3	495 000	0.145	533 000	1.81	6
1 —	4.37	45.6	1.6	325 000	0.336	365 000	1.36	7
2a	3.73	42.8	0.6	277 000	0.258	298 000	1.13	8
—	3.51	—	1.6	163 000	0.465	177 000	—	9
—	2.72	—	3.1	1 940	0.120	1 940	—	10
—	2.72	—	3.0	1 560	0.183	1 560	—	11
—	3.35	—	3.0	957	—	957	—	12
—	3.36	—	9.9	260	—	260	—	13
—	3.27	—	9.9	246	—	246	—	14
—	2.95	—	9.9	67	—	67	—	15
—	3.07	—	9.9	54	—	54	—	16
—	2.67	—	9.9	30	—	30	—	17
—	2.68	—	9.8	17	—	17	—	18
1 —	4.34	39.4	1.9	176 000	0.039	177 000	0.615	1
1 —	3.64	29.5	1.5	139 000	0.084	141 000	0.755	2
1 —	3.60	27.6	1.9	107 000	0.609	115 000	0.627	3
—	4.08	—	1.9	20 600	0.068	20 600	—	4
—	3.62	—	4.7	397	—	397	—	5
—	2.84	—	4.8	39	—	39	—	6
—	2.61	—	4.8	9	—	9	—	7
1	4.73	77.7	1.1	548 000	0.349	678 000	1.03	1
1 —	4.69	79.7	1.2	355 000	0.900	522 000	0.730	2
1 —	4.60	71.1	1.2	334 000	1.066	518 000	0.875	3
1	4.30	55.8	1.1	418 000	0.392	500 000	1.38	4
1	4.49	65.5	1.1	404 000	0.452	495 000	0.962	5
1 —	4.36	58.9	1.5	352 000	0.680	463 000	1.09	6
1	4.37	59.4	1.2	352 000	0.590	444 000	1.01	7
1 —	4.28	54.8	1.9	327 000	0.534	396 000	1.03	8
1	4.22	53.0	1.0	354 000	0.255	389 000	1.06	9
2a	4.24	53.3	2.2	271 000	0.572	321 000	0.807	10
1	4.00	40.6	1.8	211 000	1.38	298 000	1.28	11
1	3.97	39.7	1.5	248 000	0.328	270 000	1.14	12

No	Rocks	Reg. Nr.
13	Magnetite ore, skarn-rich	46
14	Magnetite ore with streaks of apatite and skarn	30
15	Magnetite ore, with predominating skarn	25
16	Contact between diabase and magnetite ore, rich in skarn	35
17	Lean ore with predominating skarn	20
18	» » » » »	9
19	Gneiss, impregnated with magnetite	24
20	Gneiss, grayish red, with some magnetite	31
21	Gneiss, red, with skarn minerals and some magnetite	47
22	Gneiss, grayish red, with some magnetite	41
23	Pegmatite, with some skarn and magnetite	10
24	Pegmatite, with some magnetite	26
25	Pegmatite, with skarn and some magnetite at one end of core	8
26	Pegmatite with skarn and some magnetite	5
27	Pegmatite with a low amount of magnetite	39
28	Pegmatite with some skarn and magnetite	7
29	Pegmatite with some magnetite	23
30	Pegmatite with a low amount of magnetite	29
31	Pegmatite with a few grains of magnetite	2
32	Pegmatite	12
33	Pegmatite with a low amount of magnetite	33
34	Pegmatite	15
35	»	17
36	Amphibolite	42
37	»	44
38	Amphibolite, with narrow veins of epidote	43
39	Diabase	21
40	»	38
41	Skarn with quartz and subordinated magnetite	3
42	Skarn	18
43	Leptite; no magnetite visible	19
44	Leptite with veins of pegmatite	45
45	Gray leptite, and pegmatite	48
46	Leptite, light gray, no magnetite visible	16
	Intrånget, Garpenberg parish.	
1	Magnetite ore with some skarn (amphibole)	5
2	Magnetite ore with some skarn	2
3	» » » » »	3
4	» » » » »	1
5	Magnetite ore with skarn	6
6	Magnetite ore with some skarn	4
7	Magnetite ore with skarn	9
8	Magnetite ore with some skarn	7
9	Magnetite ore with skarn	10
10	» » » »	8A
11	» » » »	8B
12	» » » »	11
	Kiirunavaara, Jukkasjärvi parish.	
1	Magnetite ore, rich	42
2	» » »	47

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
2a	4.16	50.0	1.5	242 000	0.435	270 000	0.718	13
2a	4.16	48.7	1.5	214 000	0.682	250 000	0.678	14
1 —	3.85	33.0	2.3	167 000	0.899	197 000	1.03	15
—	4.03	—	1.9	162 000	1.055	196 000	—	16
1	3.60	25.9	2.1	155 000	0.624	172 000	1.51	17
1 —	3.49	19.6	2.4	135 000	0.528	145 000	2.79	18
0	2.94	11.5	0.4	28 800	1.11	29 700	0.385	19
—	2.87	8.7	1.0	11 700	0.688	11 800	—	20
—	2.90	—	2.5	9 820	—	9 820	—	21
—	2.74	—	3.2	4 160	—	4 160	—	22
—	2.77	—	1.1	10 200	0.740	10 300	—	23
—	2.70	—	1.5	6 610	—	6 610	—	24
—	2.75	—	2.6	5 120	0.473	5 120	—	25
—	2.64	—	9.8	1 410	—	1 410	—	26
—	2.62	—	10.0	1 180	—	1 180	—	27
—	2.62	—	9.8	1 000	—	1 000	—	28
—	2.65	—	9.8	766	—	766	—	29
—	2.66	—	9.8	706	—	706	—	30
—	2.63	—	9.8	450	—	450	—	31
—	2.64	—	9.9	269	—	269	—	32
—	2.64	—	9.8	195	—	195	—	33
—	2.62	—	9.9	6	—	6	—	34
—	2.63	—	9.9	4	—	4	—	35
—	2.99	—	1.9	6 780	—	6 780	—	36
—	2.94	—	9.8	1 100	—	1 100	—	37
—	3.02	—	9.9	51	—	51	—	38
—	2.77	—	3.7	3 810	—	3 810	—	39
—	2.71	—	9.8	196	—	196	—	40
—	2.79	—	9.8	1 070	—	1 070	—	41
—	2.81	—	9.8	52	—	52	—	42
—	2.69	—	9.8	697	—	697	—	43
—	2.73	—	9.8	178	—	178	—	44
—	2.65	—	9.8	94	—	94	—	45
—	2.76	—	9.9	22	—	22	—	46
1	4.75	80.2	0.7	518 000	0.782	870 000	1.30	1
1	4.76	81.1	1.9	772 000	0.139	855 000	1.24	2
1	4.52	67.0	0.3	775 000	0.083	828 000	1.85	3
1	4.55	69.3	1.1	697 000	0.148	778 000	1.56	4
1	4.35	63.6	0.7	482 000	0.750	755 000	1.86	5
1	4.71	77.8	0.5	588 000	0.360	746 000	1.15	6
1	4.56	71.2	0.8	485 000	0.640	703 000	1.28	7
1	4.55	67.7	0.5	608 000	0.125	658 000	1.31	8
1	4.48	63.1	0.8	455 000	0.615	633 000	1.45	9
2a	4.45	66.8	2.0	340 000	0.855	478 000	0.890	10
2a	4.26	58.1	1.0	452 000	0.088	472 000	1.15	11
2a	4.38	60.9	0.9	318 000	0.408	366 000	0.752	12
1	4.92	87.3	0.7	486 000	0.289	565 000	0.690	1
1	4.87	84.8	0.7	475 000	0.266	544 000	0.692	2

No	Rocks	Reg. Nr.
3	Magnetite ore, with apatite in uneven, streaky distribution	43
4	Magnetite ore, with high, unevenly distributed content of apatite	39
5	Magnetite ore, rich, finely distributed apatite at one end of core, some open rusty fissures	44
6	Magnetite ore with uneven content of apatite in streaky distribution, possibly also actinolite	46
7	Magnetite ore with irregularly distributed spots of actinolite (and apatite?)	38
8	Magnetite ore with fairly high percentage of apatite unevenly distributed	37A
9	Magnetite ore with fairly high percentage of apatite unevenly distributed	37 B
10	Magnetite ore with even, probably low percentage of apatite	45
11	Magnetite ore with evenly distributed apatite	48
12	Magnetite ore with unevenly distributed apatite	41
13	Magnetite ore rich in columnar (uralitized?) diopside and some spots of apatite	40
14	Foot-wall porphyry, impregnated with amphibole and chlorite	18
15	Foot-wall porphyry, streaky with actinolite and magnetite	16
16	Foot-wall porphyry	1B
17	» » »	1A
18	Hanging-wall porphyry, fresh	34B
19	Hanging-wall porphyry, with sparsely scattered small spots of magnetite	5
20	Hanging-wall porphyry	25
21	Hanging-wall porphyry, fresh	34A
22	Hanging-wall porphyry, with sparsely scattered small spots of magnetite	6
23	Hanging-wall porphyry	2A
24	» » »	8
25	Hanging-wall porphyry, impregnated with secondary actinolite and some magnetite	22
26	Hanging-wall porphyry	2B
27	» » »	26
28	» » »	7
29	» » »	17
30	Hanging-wall porphyry, with some several mm thick veins of magnetite and actinolite	31B
31	Hanging-wall porphyry	12
32	Hanging-wall porphyry, groundmass altered	3A
33	» » », with new-formed magnetite, and some magnetite in the groundmass	31A
34	Hanging-wall porphyry	10
35	Hanging-wall porphyry with green, chloritized groundmass, feldspar phenocrysts chalky	35B
36	Porphyry with secondary actinolite	3B
37	Hanging-wall porphyry, strongly altered, with chloritized groundmass and chalky feldspar phenocrysts	35A
38	Hanging-wall porphyry	4A
39	» » »	19
40	» » »	28
41	» » »	30B

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
1	4.45	63.5	1.2	409 000	0.560	531 000	1.12	3
2b	4.63	72.6	5.5	505 000	0.080	526 000	0.86	4
1	4.67	74.6	1.0	398 000	0.330	458 000	0.700	5
1	4.36	59.9	1.5	438 000	0.096	458 000	1.04	6
1	4.45	66.0	8.5	383 000	0.278	428 000	0.791	7
2b	4.29	55.3	6.1	375 000	0.114	392 000	0.983	8
2c	4.02	41.6	7.0	248 000	0.609	292 000	1.17	9
1	4.80	81.2	1.1	318 000	0.240	344 000	0.450	10
1	4.57	69.5	2.2	238 000	0.920	305 000	0.492	11
1	4.19	50.3	3.0	243 000	0.565	282 000	0.751	12
1	3.95	35.4	2.3	145 000	0.336	153 000	0.607	13
—	2.60	—	0.4	16 600	0.388	16 700	—	14
—	2.81	—	0.9	11 000	—	11 000	—	15
—	2.79	—	6.2	1 950	—	1 950	—	16
—	2.71	—	6.2	1 790	—	1 790	—	17
—	2.65	—	1.1	8 930	0.184	8 930	—	18
—	2.64	—	1.7	8 710	—	8 710	—	19
—	2.65	—	1.6	8 510	—	8 510	—	20
—	2.66	—	1.4	8 450	0.082	8 450	—	21
—	2.64	—	1.9	7 790	—	7 790	—	22
—	2.65	—	2.1	6 840	—	6 840	—	23
—	2.64	—	1.7	6 830	—	6 830	—	24
—	2.52	—	1.8	6 090	0.167	6 090	—	25
—	2.61	—	2.5	5 080	—	5 080	—	26
—	2.68	—	2.8	4 820	—	4 820	—	27
—	2.64	—	3.8	3 620	—	3 620	—	28
—	2.73	—	4.4	2 840	—	2 840	—	29
—	2.78	—	3.9	2 720	—	2 720	—	30
—	2.64	—	5.1	2 640	—	2 640	—	33
—	2.73	—	6.0	1 740	—	1 740	—	32
—	2.72	—	8.6	1 530	—	1 530	—	33
—	2.71	—	7.3	1 500	—	1 500	—	34
—	2.68	—	9.9	1 110	—	1 110	—	35
—	2.75	—	8.8	929	—	929	—	36
—	2.66	—	9.9	911	—	911	—	37
—	2.64	—	9.9	785	—	785	—	38
—	2.71	—	9.9	704	—	704	—	39
—	2.57	—	10.0	527	—	527	—	40
—	2.61	—	9.9	493	—	493	—	41

No	Rocks	Reg. Nr.
42	Hanging-wall porphyry, with secondary actinolite	11
43	Hanging-wall porphyry	36 B
44	Hanging-wall porphyry, groundmass chloritized and with actinolite, chalky feldspar phenocrysts	36A
45	Hanging-wall porphyry, with impregnation of actinolite and some epidote	20
46	Hanging-wall porphyry, fresh	24
47	Hanging-wall porphyry	4B
48	» » »	30A
49	Hanging-wall porphyry with some new-formed actinolite or chlorite	32B
50	Hanging-wall porphyry, actinolite veins in groundmass	29B
51	Hanging-wall porphyry with new-formed actinolite	29A
52	Hanging-wall porphyry	15
53	Hanging-wall porphyry, with some secondary actinolite	21
54	Hanging-wall porphyry, somewhat altered	32A
55	Hanging-wall porphyry, with some coarse actinolite in groundmass	33B
56	Hanging-wall porphyry, with subordinated coarse, new-formed actinolite	33A
57	Hanging-wall porphyry, with actinolite	13
58	Hanging-wall or dyke porphyry with secondary actinolite	9
59	Hanging-wall porphyry	23
60	Hanging-wall porphyry, with some actinolite	27
61	Hanging-wall porphyry	14
	Luossavaara, Jukkasjärvi parish.	
1	Magnetite ore with a fairly even percentage of apatite	5
2	Magnetite ore with small apatite veins, unevenly distributed	7
3	Magnetite ore with apatite	10
4	» » » »	10A
5	» » » »	10B
6	» » » »	10C
7	» » » »	10D
8	Magnetite ore with rather evenly distributed magnetite	8
9	Magnetite ore with a few rusty vugs	9
10	Magnetite ore, dull, impure	6
11	Hanging-wall porphyry	1
12	» » »	2
13	» » »	3
14	Porphyry, somewhat altered	4
	Långban, Färnebo parish.	
1	Rich hematite ore with vein of magnetite in longitudinal direction of core	2
2	Hematite ore with quartz and very subordinated magnetite	4
3	Rich hematite ore with low, hardly discernible content of magnetite	1
4	Hematite ore with quartz and some skarn (yellow garnet)	3
5	Braunite-hausmannite ore in dolomite and with some skarn (schefferite)	7
6	» » » » » » » » » »	8
7	Hausmannite ore in dolomite	6
8	» » » »	5
	Malmberget, Gällivare parish.	
1	Magnetite ore, rich, with some apatite	20
2	» » » » » »	8

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	2.76	—	9.9	432	—	432	—	42
—	2.66	—	9.8	363	—	363	—	43
—	2.69	—	9.8	319	—	319	—	44
—	2.72	—	9.9	267	—	267	—	45
—	2.64	—	9.9	245	—	245	—	46
—	2.64	—	9.9	238	—	238	—	47
—	2.61	—	10.0	212	—	212	—	48
—	2.70	—	9.9	212	—	212	—	49
—	2.71	—	10.0	136	—	136	—	50
—	2.74	—	10.0	113	—	113	—	51
—	2.67	—	9.9	108	—	108	—	52
—	2.56	—	9.9	79	—	79	—	53
—	2.72	—	10.0	75	—	75	—	54
—	2.72	—	9.9	58	—	58	—	55
—	2.70	—	9.9	53	—	53	—	56
—	2.72	—	9.9	41	—	41	—	57
—	2.77	—	10.0	40	—	40	—	58
—	2.67	—	9.9	39	—	39	—	59
—	2.60	—	10.0	28	—	28	—	60
—	2.63	—	9.9	18	—	18	—	61
I	4.79	80.7	0.70	780 000	0.131	869 000	1.28	1
I	4.82	82.2	1.3	717 000	0.129	790 000	1.10	2
I	4.74	78.2	0.6	550 000	0.162	604 000	0.887	3
I	4.77	79.7	0.6	531 000	0.268	619 000	0.883	4
I	4.78	80.2	0.8	464 000	0.534	616 000	0.869	5
I	4.65	73.6	1.0	386 000	0.794	557 000	0.897	6
I	4.81	81.7	1.1	393 000	1.008	652 000	0.897	7
I	4.65	73.6	1.1	575 000	0.080	603 000	0.990	8
I	4.86	84.2	1.2	300 000	0.233	322 000	0.400	9
—	3.76	—	2.2	195 000	0.296	207 000	—	10
—	2.78	—	0.9	10 830	0.089	10 840	—	11
—	2.66	—	2.8	3 740	0.078	3 740	—	12
—	2.64	—	10.0	979	—	979	—	13
—	2.70	—	10.0	163	—	163	—	14
—	5.12	—	0.9	91 600	0.299	94 200	—	1
—	4.63	—	10.0	718	—	718	—	2
—	5.22	—	10.0	528	—	528	—	3
—	3.63	—	10.0	245	—	245	—	4
—	3.84	—	9.9	244	—	244	—	5
—	3.75	—	9.9	226	—	226	—	6
—	3.74	—	9.9	133	—	133	—	7
—	3.75	—	10.0	131	—	131	—	8
I	4.96	89.3	0.6	789 000	0.508	1 320 000	1.67	1
I	—	—	0.3	1 200 000	0.072	1 310 000	—	2

No	Rocks	Reg. Nr.
3	Magnetite ore, rich, with som apatite	8A
4	» » » » » »	8B
5	» » » » a little apatite	3A
6	» » » » » » »	3B
7	Magnetite ore, rich	7
8	Magnetite ore, with apatite and actinolite	21
9	Magnetite ore	4A
10	» »	4B
11	Hematite ore	29
12	» »	28
13	» »	27
14	» »	25
15	Hematite ore with impregnation remnants of leptite with scattered actinolite	26
16	Leptite, very strongly impregnated with hornblende (actinolitic)	9
17	» » » » » » »	10
18	Reddish leptite with an even impregnation of hornblende and magnetite	2
19	Biotite + actinolite + apatite + magnetite, with remnants of leptite	15
20	Reddish gray leptite with sparse impregnation of magnetite	22
21	Reddish leptite, unevenly impregnated with actinolite and magnetite	19
22	Reddish gray leptite with impregnation veinlets of magnetite and actinolite	16
23	Light gray biotite leptite, partly impregnated with magnetite	23
24	Light red leptite with splashes of green skarn (diopside and actinolite), a little magnetite and pyrite	1A
25	» » » »	1B
26	Leptite, gray, rich in biotite	5A
27	Gray syenite-leptite, rich in biotite	5B
28	» » » » » »	17
29	» » » » » »	24
30	Leptite with a little scattered pyrite	13
31	Gray syenite-leptite, rich in biotite. Pegmatitic granite with a few large grains of magnetite	11
32	Leptite, light red, with some impregnation veinlets of green skarn	14
33	White aplite granite with a few grains of magnetite	6
34	Granite	12
35	White aplite granite with a few grains of magnetite	18
	Nordmark, Nordmark parish.	
1	Rich magnetite ore with diopside	17
2	» » » » »	18
3	Lean magnetite ore with »sköl» skarn	16
4	» » » » » »	15
5	Skarn with streaks of magnetite	14
6	Skarn with irregular streaks of magnetite	13
7	Skarn	12
8	Skarn (pyroxene)	11
9	Amphibolite (greenstone dyke)	10
10	» » »	9
11	Dolomite, somewhat spotted with skarn (serpentine)	4
12	Dolomite with very little skarn	3

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
1	5.16	99.5	0.5	678 000	0.586	1 130 000	1.13	3
1	5.13	98.0	0.7	535 000	1.081	1 270 000	1.32	4
1	5.00	91.4	0.3	671 000	0.697	1 260 000	1.51	5
1	4.88	85.3	0.3	640 000	0.752	1 230 000	1.72	6
1	5.09	96.8	0.2	1 000 000	0.195	1 240 000	1.32	7
1	4.82	83.1	0.3	616 000	0.723	1 110 000	1.61	8
1	4.72	77.1	0.3	800 000	0.174	929 000	1.53	9
1	4.57	69.8	0.9	421 300	1.046	753 200	1.46	10
—	5.10	—	11.2	1 960	—	1 960	—	11
—	5.11	—	11.2	852	—	852	—	12
—	4.76	—	9.9	262	—	262	—	13
—	4.45	—	11.2	219	—	219	—	14
—	4.38	—	9.9	153	—	153	—	15
1	3.77	40.9	0.3	356 000	0.117	372 000	1.93	16
1	3.73	39.2	0.6	323 000	0.295	357 000	2.03	17
2a	3.39	24.9	0.7	104 000	0.020	104 000	0.652	18
2a	3.38	17.5	0.4	76 400	0.085	77 000	0.824	19
2a	3.11	16.6	0.9	71 200	0.103	71 800	0.82	20
0	3.00	11.4	0.2	34 700	0.133	34 900	0.501	21
0	2.95	10.8	0.2	32 600	0.065	32 700	0.500	22
0	2.90	6.2	0.2	30 800	0.077	30 900	2.25	23
—	2.97	—	0.8	27 300	0.110	27 400	—	24
—	2.91	—	1.0	16 600	—	16 600	—	25
—	2.85	—	0.7	24 000	—	24 000	—	26
—	2.84	—	0.5	19 500	—	19 500	—	27
—	2.84	—	0.5	14 600	—	14 600	—	28
0	2.88	4.2	0.5	11 700	0.508	11 800	0.544	29
—	2.65	—	1.9	7 060	—	7 060	—	30
—	2.64	—	2.7	4 150	—	4 150	—	31
—	2.63	—	2.7	1 510	—	1 510	—	32
—	2.63	—	9.8	97	—	97	—	33
—	2.61	—	9.8	276	—	276	—	34
—	2.61	—	9.9	61	—	61	—	35
1	4.68	73.8	0.7	575 000	0.655	922 000	1.68	1
1	4.73	76.5	0.5	647 000	0.430	895 000	1.49	2
1	3.63	29.0	0.4	216 000	0.666	252 000	2.69	3
1	3.50	23.0	0.8	176 000	0.400	189 000	3.23	4
1	3.62	23.3	1.5	137 000	0.416	145 000	1.42	5
1	3.62	21.3	0.8	110 000	0.325	114 000	1.09	6
—	3.19	—	5.4	1 890	—	1 890	—	7
—	3.23	—	9.7	94	—	94	—	8
—	3.04	—	9.7	215	—	215	—	9
—	3.05	—	9.7	115	—	115	—	10
—	2.84	—	9.7	157	—	157	—	11
—	2.86	—	9.8	81	—	81	—	12

No	Rocks	Reg. Nr.
13	Limestone, very pure	1
14	Limestone, pure	2
15	Leptite, gray, with spots of mica	7
16	» » » » » »	8
17	Granite, reddish gray, fine-grained	6
18	» » » » »	5
	Norrbergsfältet, Norberg parish.	
1	Quartz-banded magnetite ore	1
2	Quartz-banded hematite ore with fairly high content of magnetite	7
3	» » » » » » » »	6
4	Quartz-banded hematite ore with magnetite	4
5	Quartz-banded hematite ore with a low content of magnetite	5
6	Quartz-banded hematite ore	2
7	Quartz-banded hematite ore with a low content of magnetite	3
	Persberg, Färnebo parish.	
1	Magnetite ore with diopside skarn	44
2	» » » » »	51
3	» » » » »	51A
4	» » » » »	51B
5	» » » » »	51C
6	» » » » »	51D
7	» » » » »	51E
8	» » » » »	45
9	» » » » »	46
10	» » » » »	41
11	» » » » »	40
12	» » » » »	50
13	» » » » »	50A
14	» » » » »	50B
15	» » » » »	50C
16	» » » » »	50D
17	» » » » »	50E
18	» » » » »	47
19	» » » » »	49
20	» » » » »	48
21	Lean magnetite ore with diopside skarn	33
22	Lean magnetite ore with streaks of limestone and diopside	32
23	Lean magnetite ore with diopside skarn	35
24	» » » » » »	34
25	Magnetite ore with anthophyllite skarn	38
26	» » » » »	38A
27	» » » » »	38B
28	» » » » »	39
29	Magnetite ore with anthophyllite skarn and talk	43
30	Magnetite ore with anthophyllite skarn	42
31	Lean magnetite ore with anthophyllite skarn and talc	36
32	» » » » » » » »	37
33	Anthophyllite and talc skarn, with some magnetite	22
34	» » » » » » »	21

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	2.73	—	9.8	1	—	1	—	13
—	2.72	—	9.8	1	—	1	—	14
—	2.70	—	9.7	6	—	6	—	15
—	2.71	—	9.7	6	—	6	—	16
—	2.66	—	9.7	5	—	5	—	17
—	2.66	—	9.7	4	—	4	—	18
2a	4.03	54.8	0.7	291 000	0.418	331 000	0.796	1
—	4.03	—	0.6	184 000	0.277	193 000	—	2
—	—	—	0.5	129 000	0.047	129 000	—	3
—	4.08	—	0.7	106 000	0.410	111 000	—	4
—	4.37	—	3.0	20 600	0.486	20 800	—	5
—	4.34	—	7.5	6 030	0.525	6 050	—	6
—	4.12	—	7.5	560	—	560	—	7
1	4.80	80.7	0.6	743 000	0.330	984 000	1.48	1
1	4.66	72.9	0.4	761 000	0.117	835 000	1.52	2
1	4.66	72.9	0.4	744 000	0.175	856 000	1.57	3
1	4.70	74.9	0.4	697 000	0.293	875 000	1.52	4
1	4.70	74.9	0.5	576 000	0.575	864 000	1.49	5
1	4.69	74.3	0.8	457 000	1.057	883 000	1.56	6
1	4.43	60.4	1.0	366 000	1.135	627 000	1.60	7
1	4.58	69.3	0.5	580 000	0.405	759 000	1.50	8
1	4.35	56.1	0.7	487 000	0.258	557 000	1.61	9
1	4.40	59.9	0.6	493 000	0.188	545 000	1.32	10
1	4.32	56.9	1.2	499 000	0.120	531 000	1.44	11
1	4.32	54.5	0.5	496 000	0.119	528 000	1.59	12
1	4.32	54.5	0.6	477 000	0.173	520 000	1.55	13
1	4.32	54.5	0.6	425 000	0.299	487 000	1.40	14
1	4.35	56.1	0.7	399 000	0.575	527 000	1.47	15
1	4.41	59.4	0.7	366 000	1.104	614 000	1.62	16
1	4.37	57.2	1.1	364 000	1.121	615 000	1.79	17
1	4.22	49.2	0.9	417 000	0.406	502 000	1.95	18
1	4.26	51.3	0.5	438 000	0.178	475 000	1.57	19
1	4.00	37.4	0.5	336 000	0.111	349 000	2.28	20
1 —	3.83	32.0	1.6	274 000	0.174	287 000	2.56	21
2a	3.81	42.6	0.8	262 000	0.073	267 000	0.961	22
1	3.94	34.2	0.6	206 000	0.209	215 000	1.11	23
1	3.66	19.8	0.8	119 000	0.081	120 000	1.50	24
1	—	—	1.0	702 000	0.083	745 000	—	25
1	4.35	63.0	0.7	475 000	0.570	650 000	1.52	26
1	4.38	64.5	0.8	397 000	1.062	687 000	1.55	27
1	4.31	60.4	0.7	538 000	0.176	595 000	1.48	28
1 —	4.07	51.5	0.3	437 000	0.101	457 000	1.45	29
1 —	3.98	47.6	0.3	334 000	0.229	362 000	1.21	30
1 —	3.44	23.8	0.6	149 000	0.256	155 000	1.55	31
1 —	3.40	23.7	0.9	134 000	0.217	138 000	1.21	32
1	3.14	10.6	1.5	57 500	0.261	58 400	1.97	33
—	2.95	2.2	0.8	6 750	0.199	6 760	0.780	34

No	Rocks	Reg. Nr.
35	Anthophyllite and talc skarn	25
36	Anthophyllite and talc skarn; no magnetite visible	24
37	» » » » » » »	23
38	Diopside skarn with rather much magnetite	31
39	» » » » » »	30
40	Diopside skarn with insignificant amount of magnetite	13
41	Diopside skarn with some magnetite	14
42	Diopside skarn with very subordinated magnetite, finely distributed	11
43	Diopside skarn with some hornblende; very little magnetite	26
44	» » » » » » »	27
45	Diopside skarn almost free from magnetite	12
46	Skarn, mainly epidote, some garnet and magnetite, and remnants of leptite. Streak of magnetite ore at one end of core	20
47	Garnet skarn with some diopside and calcite; no magnetite visible	15
48	Garnet skarn with some epidote and diopside; no magnetite visible	17
49	Garnet skarn with some diopside; no magnetite visible	16
50	Garnet-pyroxene skarn; no magnetite visible	18
51	Leptite (reddish) with skarn (garnet, epidote, diopside) and some magnetite	19
52	Gray leptite with subordinated cordierite and gedrite	10
53	Light gray leptite, cordierite- and gedrite-bearing	5
54	Gray leptite, with very little skarn	9
55	» » » » » »	8
56	Light gray leptite with insignificant amounts of cordierite and gedrite	6
57	Leptite, very little skarn-bearing (mainly epidote)	7
58	Amphibolite	29
59	»	28
60	Dolomite, pure	4
61	» »	3
62	» »	2
63	Limestone, white, slightly skarn-spotted	1
	Pershyttan, Nora parish.	
1	Magnetite ore with evenly distributed quartz	22
2	» » » » » »	21
3	Magnetite ore with broken quartz bands	20
4	» » » » » »	19
5	» » » » » »	18
6	Hematite ore with broken quartz bands. Magnetite content difficult to estimate	15
7	Hematite ore with much pegmatite material. Magnetite content cannot be stated (certainly higher than in no 11)	11
8	Hematite ore very rich in pegmatite	13
9	Hematite ore with broken quartz bands	14
10	Hematite ore very rich in pegmatite. Magnetite content low, but cannot be stated with any certainty	12
11	Hematite ore mixed with pegmatite. Magnetite content impossible to state	10
12	Compact hematite ore with no or very low content of magnetite	16
13	» » » » » » » » » » »	17
14	Leptite, impregnated with pegmatite and with very subordinated hematite	8

DETERMINATIONS OF THE SUSCEPTIBILITY OF ORES AND ROCKS.

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	2.96	—	4.7	213	—	213	—	35
—	2.97	—	4.8	117	—	117	—	36
—	2.91	—	4.8	102	—	102	—	37
0	3.71	21.9	2.3	101 000	0.163	102 000	0.827	38
0	3.62	17.1	1.5	77 800	0.296	79 500	0.928	39
—	3.33	—	0.4	8 200	—	8 200	—	40
—	3.20	—	0.4	7 050	—	7 050	—	41
—	3.36	—	0.9	1 660	—	1 660	—	42
—	3.28	—	1.9	1 620	—	1 620	—	43
—	3.21	—	1.9	1 560	—	1 560	—	44
—	3.37	—	4.8	146	—	146	—	45
—	3.08	—	4.8	22 500	0.279	22 600	—	46
—	3.65	—	4.8	683	—	683	—	47
—	3.67	—	4.8	533	—	533	—	48
—	3.75	—	4.8	332	—	332	—	49
—	3.61	—	4.8	177	—	177	—	50
—	2.96	—	1.9	3 680	—	3 680	—	51
—	2.71	—	4.8	25	—	25	—	52
—	2.78	—	4.8	22	—	22	—	53
—	2.74	—	4.8	15	—	15	—	54
—	2.74	—	4.8	14	—	14	—	55
—	2.70	—	4.8	14	—	14	—	56
—	2.70	—	4.8	7	—	7	—	57
—	3.02	—	4.8	97	—	97	—	58
—	3.01	—	4.8	96	—	96	—	59
—	2.87	—	4.8	31	—	31	—	60
—	2.87	—	4.8	26	—	26	—	61
—	2.72	—	4.8	1	—	1	—	62
—	2.82	—	4.8	0	—	0	—	63
1 —	4.14	59.1	0.4	398 000	0.308	454 000	1.05	1
1 —	4.07	57.1	0.8	420 000	0.165	450 000	1.12	2
2a	3.80	44.5	0.4	210 000	1.43	300 000	1.05	3
2a	3.72	41.3	0.5	182 000	1.305	239 000	0.867	4
2a	3.79	44.1	1.3	190 000	0.444	207 000	0.627	5
—	3.86	—	1.4	67 500	0.360	69 200	—	6
—	3.62	—	0.9	51 800	0.580	53 500	—	7
—	3.70	—	1.9	34 200	2.41	37 400	—	8
—	3.81	—	1.9	20 300	0.318	20 500	—	9
—	3.47	—	4.7	11 400	0.770	11 500	—	10
—	3.57	—	4.7	7 180	0.500	7 200	—	11
—	4.57	—	4.7	6 510	0.153	6 520	—	12
—	4.45	—	4.7	1 100	0.383	1 100	—	13
—	2.75	—	4.7	810	—	810	—	14

No	Rocks	Reg. Nr.
15	Leptite, gray, rich in mica (incl. muscovite), somewhat impregnated with hematite	6
16	Leptite with much pegmatite, magnetite very subordinated	9
17	Leptite, gray, rich in mica (incl. muscovite), somewhat impregnated with hematite	7
18	Leptite, gray, rather rich in mica	4
19	» » » » » »	5
20	Pegmatite	1
21	»	3
22	»	2
	Sirsjöberg, Hällefors parish.	
1	Rich magnetite ore with diopside, actinolite and calcite	15
2	Rich magnetite ore with some calcite, diopside and actinolite	16
3	Magnetite ore with diopside	11
4	Rich magnetite ore with diopside, actinolite and calcite	14
5	Magnetite ore with diopside or actinolite, garnet and calcite. Skarn patches and rich magnetite concentrations alternate	12
6	Magnetite ore with diopside and calcite	13
7	Diopside skarn with actinolite. Within a few mm from one end of core fairly high content of magnetite	6
8	Skarn-banded limestone with chlorite and actinolite. A few grains of magnetite are visible	17
9	Skarn-banded limestone with chlorite and actinolite. No magnetite visible	18
10	Green skarn (diopside with subordinated actinolite). No magnetite visible	5
11	Garnet-rich green skarn (diopside and actinolite). No magnetite visible	3
12	Garnet-rich green skarn (diopside and actinolite), some calcite. No magnetite visible	4
13	Limestone	22
14	»	21
15	Hälleflinta (keratophyre dyke)	8
16	» » »	7
17	Hälleflinta, red, streaky with skarn (chlorite, actinolite)	1
18	Hälleflinta, red, with patches of skarn (chlorite, actinolite)	2
19	Greenstone, earlier type (dyke)	19
20	» » » »	20
21	Greenstone, later type (dyke)	10
22	» » » »	9
	Striberg, Nora parish.	
1	Magnetite ore with some skarn	7
2	Hematite ore, with garnet, and with longitudinal quartz-bands	5
3	» » » » » » » » »	4
4	» » » » » » » » »	6
5	Hematite ore, very low in magnetite, with spots and streaks of quartz	3
6	Hematite ore, very low in magnetite, with irregular quartz bands	1
7	» » » » » » » » » »	2
	Stripa, Guldsmedshyttan parish.	
1	Quartz-banded magnetite ore with remnants of hematite	5
2	Hematite ore with magnetite octahedra, quartz and skarn, irregular mixture	8

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	2.87	—	4.7	550	—	550	—	15
—	2.76	—	4.7	172	—	172	—	16
—	2.82	—	4.7	117	—	117	—	17
—	2.71	—	4.7	57	—	57	—	18
—	2.73	—	4.7	46	—	46	—	19
—	2.57	—	6.6	1	—	1	—	20
—	2.58	—	6.6	1	—	1	—	21
—	2.58	—	6.6	2	—	2	—	22
1	4.75	81.9	0.5	728 000	0.400	1 030 000	1.52	1
1	4.69	78.9	0.6	716 000	0.371	976 000	1.55	2
1	3.94	37.6	0.3	332 000	0.348	376 000	2.73	3
1 —	3.99	43.0	0.8	219 000	0.268	233 000	0.772	4
0	3.84	32.5	0.3	193 000	0.258	202 000	1.12	5
0	3.73	33.6	0.6	124 000	0.360	130 000	0.530	6
—	3.31	—	4.8	20 200	0.297	20 300	—	7
—	2.82	—	4.8	11 800	0.320	11 900	—	8
—	2.77	—	4.8	5 340	0.238	5 350	—	9
—	3.40	—	4.8	3 830	—	3 830	—	10
—	3.53	—	4.8	192	—	192	—	11
—	3.54	—	4.8	158	—	158	—	12
—	2.76	—	1.5	1 960	0.400	1 960	—	13
—	2.73	—	3.8	448	—	448	—	14
—	2.66	—	1.9	1 200	—	1 200	—	15
—	2.66	—	4.8	572	—	572	—	16
—	2.65	—	4.8	150	—	150	—	17
—	2.64	—	4.8	42	—	42	—	18
—	3.02	—	4.8	63	—	63	—	19
—	2.96	—	4.8	62	—	62	—	20
—	2.88	—	4.8	50	—	50	—	21
—	2.82	—	4.8	48	—	48	—	22
1	4.97	91.2	1.5	552 000	0.387	702 000	0.810	1
—	4.13	—	8.3	2 460	—	2 460	—	2
—	4.43	—	6.6	1 900	—	1 900	—	3
—	4.20	—	8.3	2 430	—	2 430	—	4
—	4.64	—	8.3	785	—	785	—	5
—	4.76	—	8.3	560	—	560	—	6
—	4.72	—	8.3	337	—	337	—	7
—	4.41	—	0.7	226 000	0.119	232 000	—	1
—	4.53	—	0.3	202 000	0.218	211 000	—	2

No	Rocks	Reg. Nr.
3	Quartz-banded hematite ore, with magnetite octahedra and skarn....	1
4	Hematite ore with irregular quartz bands and magnetite and fairly rich in pyrite	6
5	Quartz-banded and skarn-striped hematite ore with magnetite	3
6	Quartz-banded hematite ore	7
7	Quartz-banded hematite ore with skarn	4
8	Quartz-banded and skarn-striped hematite ore	2
	Ställberg, Ljusnarsberg parish.	
1	Magnetite ore with knebelite and carbonate	19
2	Magnetite ore with knebelite and some carbonate	21
3	» » » » » » »	22
4	» » » » » » »	20
5	Lean magnetite ore with carbonate and knebelite	17
6	Magnetite ore with knebelite and some carbonate. One third of core is impure limestone, with diopside and magnetite	18
7	Lean magnetite ore with knebelite skarn and carbonate	16
8	Brecciated pyroxene skarn with some magnetite	11
9	Breccia with fragments of limestone, calcite and skarn in biotite-chlorite matrix	10
10	Boundary skarn (»Ruk») with calcite, pyroxene, hornblende, garnet, biotite-chlorite	13
11	Boundary skarn (»Ruk»)	4
12	» » »	7
13	Boundary skarn (»Ruk») with garnet, pyroxene, dannemorite, and calcite	8
14	Boundary skarn (»Ruk»)	5
15	» » »	9
16	Boundary skarn (»Ruk») with garnet, diopside, dannemorite, and calcite	6
17	Boundary skarn (»Ruk») with garnet, diopside, hornblende, knebelite, biotite-chlorite, and calcite	12
18	Limestone with skarn, mainly diopside, some garnet	15
19	Limestone with skarn, mainly diopside	14
20	Limestone	1
21	Leptite, gray, finely micaceous	3
22	Leptite with mica spots	2
	Ställberg, Haggruvan, Ljusnarsberg parish.	
1	Magnetite ore with knebelite and calcite	26
2	Magnetite ore with calcite. Pure limestone at one end of core	25
3	Magnetite ore with calcite and subordinated knebelite. Pure limestone at one end of core	24
4	Magnetite ore with knebelite..	27
5	» » » »	28
6	Boundary skarn (»Ruk»)..	5
7	» » »	6
8	» » »	7
9	» » »	9
10	Boundary skarn with garnet, hornblende, biotite-chlorite, dannemorite and calcite	13

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	4.42	—	0.9	32 400	0.148	32 600	—	3
—	4.49	—	5.0	21 000	—	21 000	—	4
—	4.12	—	16.6	2 000	—	2 000	—	5
—	4.37	—	7.5	1 700	—	1 700	—	6
—	4.17	—	8.3	326	—	326	—	7
—	4.21	—	9.1	148	—	148	—	8
1	4.41	63.3	0.8	334 000	0.960	490 000	1.02	1
1	4.43	60.4	0.3	360 000	0.415	423 000	0.918	2
1 —	4.42	59.9	1.3	296 000	0.915	406 000	0.885	3
1 —	4.30	53.5	1.0	307 000	0.373	347 000	0.888	4
1 —	3.62	33.2	1.5	209 000	0.274	222 000	1.26	5
0	3.84	—	2.1	190 000	0.093	193 000	—	6
0	3.86	36.7	1.9	93 200	0.177	94 700	0.310	7
—	3.07	—	3.5	6 350	0.725	6 380	—	8
—	2.87	—	9.9	298	—	298	—	9
—	3.04	—	9.8	422	—	422	—	10
—	3.74	—	9.8	214	—	214	—	11
—	3.74	—	9.8	195	—	195	—	12
—	3.61	—	9.8	193	—	193	—	13
—	3.72	—	9.8	191	—	191	—	14
—	3.78	—	9.8	187	—	187	—	15
—	3.36	—	9.8	133	—	133	—	16
—	3.26	—	9.8	83	—	83	—	17
—	2.96	—	9.8	40	—	40	—	18
—	2.92	—	9.8	32	—	32	—	19
—	2.74	—	9.9	11	—	11	—	20
—	2.69	—	9.8	23	—	23	—	21
—	2.62	—	9.9	5	—	5	—	22
1	4.37	52.0	1.1	381 000	0.890	578 000	2.14	1
1 —	4.15	58.7	2.7	321 000	0.520	400 000	0.899	2
1 —	4.07	49.3	2.6	363 000	0.114	379 000	1.20	3
1	4.36	36.2	1.2	306 000	0.394	349 000	2.60	4
1	4.26	31.1	2.1	208 000	0.683	243 000	1.86	5
—	3.43	—	5.4	2 400	—	2 410	—	6
—	3.41	—	9.9	380	—	380	—	7
—	3.38	—	9.9	254	—	254	—	8
—	3.46	—	9.9	210	—	210	—	9
—	3.48	—	9.8	214	—	214	—	10

No	Rocks	Reg. Nr.
11	Boundary section, with magnetite ore and limestone with dannemorite at one end of core, limestone at the other, and garnet-biotite-chlorite skarn in the middle	12
12	Skarn (knebelite and dannemorite)	10
13	» » » »	11
14	Banded skarn: knebelite band, limestone band, garnet-biotite-chlorite band, limestone band (banding perpendicular to core)	17
15	Skarn with knebelite, garnet, and calcite	14
16	Leptite, gray, dense	4
17	Leptite	15
18	Leptite, gray, dense	3
19	Limestone with small grains of diopside	16
20	Limestone, slightly skarn-bearing	1
21	» » » »	2
	Taberg, Nordmark parish.	
1	Magnetite ore with diopside and tremolite	14
2	Magnetite ore, lean, with diopside skarn	18
3	» » » » » »	17
4	Magnetite ore, with tremolite and diopside	13
5	Magnetite ore, with tremolite	11
6	Magnetite ore, with tremolite and diopside. One end of core free from magnetite	12
7	Tremolite-actinolite skarn with magnetite impregnation, partly as spots	16
8	Diopside skarn with garnet at one end of core. Some magnetite	7
9	Diopside skarn with rather much magnetite	8
10	Diopside skarn with magnetite impregnation	15
11	Garnet skarn with diopside and calcite and some magnetite	9
12	» » » » » » » » »	10
13	Amphibolite	5
14	»	6
15	Limestone	1
16	»	2
17	Leptite, gray with mica spots	3
18	» » » » »	4
	Tuolluvaara, Jukkasjärvi parish.	
1	Magnetite ore, rich, with a little actinolite in aggregates	4
2	Magnetite ore, rich, with insignificant white veins (asbestos?)	3
3	Magnetite ore with a fairly even percentage of apatite	2A
4	Magnetite ore with an even percentage of apatite	2B
5	Ore breccia: fragments of porphyry in hornblende-bearing magnetite ore	1A
6	Porphyry with hornblende spots and vein streaks of magnetite	1B
	Ösjöberg, Hjulsjö parish.	
1	Magnetite ore with tremolite skarn	23
2	» » » » »	18
3	» » » » »	21
4	» » » » »	22
5	» » » » »	16
6	» » » » »	17

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
—	3.00	—	9.8	284	—	284	—	11
—	3.43	—	10.0	275	—	275	—	12
—	3.42	—	9.9	268	—	268	—	13
—	3.19	—	9.8	138	—	138	—	14
—	3.23	—	9.8	116	—	116	—	15
—	2.68	—	9.9	30	—	30	—	16
—	2.72	—	9.8	28	—	28	—	17
—	2.69	—	9.8	20	—	20	—	18
—	2.78	—	9.8	22	—	22	—	19
—	2.77	—	—	10	—	10	—	20
—	2.73	—	9.8	7	—	7	—	21
1 —	4.00	44.8	1.0	247 000	0.775	306 000	1.07	1
1	3.95	34.8	1.0	247 000	0.363	270 000	1.64	2
1 —	3.92	33.2	7.0	236 000	0.408	261 000	1.76	3
0	3.61	26.4	0.4	104 000	0.728	112 000	0.656	4
1	3.28	12.9	0.5	80 100	0.585	84 200	3.18	5
0	3.29	10.9	0.9	77 100	0.388	79 500	13.2	6
1 —	3.48	22.1	0.4	64 400	0.321	65 800	0.411	7
—	3.64	—	0.6	43 000	0.613	44 200	—	8
—	3.59	—	0.2	27 600	0.323	27 900	—	9
—	3.33	—	0.2	16 200	0.329	16 300	—	10
—	3.42	—	0.5	12 000	0.688	12 100	—	11
—	3.51	—	0.6	6 690	0.715	6 720	—	12
—	3.09	—	9.7	209	—	209	—	13
—	3.10	—	9.7	79	—	79	—	14
—	2.74	—	9.8	66	—	66	—	15
—	2.74	—	9.8	44	—	44	—	16
—	2.65	—	9.8	5	—	5	—	17
—	2.63	—	9.8	4	—	4	—	18
1	5.01	92.6	0.1	490 000	0.695	743 000	0.840	1
1	5.01	92.6	0.3	550 000	0.087	578 000	0.645	2
1 —	4.36	58.9	1.0	229 000	0.189	239 000	0.473	3
1 —	4.30	55.8	1.0	171 000	0.066	173 000	0.353	4
—	3.86	—	2.5	123 000	0 144	125 000	—	5
—	3.02	—	3.5	9 270	0.130	9 280	—	6
1	4.34	61.8	2.3	525 000	0.160	573 000	1.32	1
1	4.30	60.8	0.5	450 000	0.300	520 000	1.20	2
1	4.18	54.4	2.1	362 000	0.710	488 000	1.41	3
1	4.18	54.4	2.3	330 000	0.645	419 000	1.12	4
1 —	4.18	54.4	1.2	344 000	0.244	376 000	0.959	5
1	4.14	53.6	0.6	340 000	0.248	371 000	0.971	6

No	Rocks	Reg. Nr.
7	Magnetite ore with tremolite skarn	20
8	» » » » »	19
9	Lean magnetite ore with tremolite	15
10	Garnet-spotted greenstone, with the garnet partly altered to epidote. Insignificant amount of magnetite, difficult to state but higher than in next number	11
11	Greenstone like preceding number	12
12	Schistose skarn with streaks of magnetite	14
13	Green skarn with veins of epidote and calcite. No magnetite visible	10
14	Earlier greenstone (hornblende and plagioclase) with some magnetite at one end of core along a fissure forming the boundary of the greenstone dyke	9
15	Earlier greenstone, altered to skarn, with increase of hornblende. Possibly some magnetite introduced	13
16	Earlier greenstone (hornblende and plagioclase)	7
17	» » » » »	8
18	Later greenstone (hornblende, plagioclase, some magnetite)	6
19	» » » » » »	5
20	Dolomite, somewhat impure	1
21	Limestone, magnesia-bearing	2
22	Leptite, gray	3
23	Leptite, red	4

The dependence of the susceptibility on the magnetite content.

It was earlier quite generally known and this investigation also proves that it is first of all the magnetite content of the rocks that determines the magnitude of their susceptibility. It must therefore be considered as an object of first order to elucidate the dependence of the susceptibility on the magnetite content.

It seems obvious that the magnitude of the susceptibility of a core containing magnetite must first of all be determined by the susceptibility of the pure magnetite, the volume fraction of magnetite, and the distribution of the magnetite. In order to investigate these conditions the susceptibility values of all those cores for which the volume percentage of magnetite is listed in the main table, have been plotted in a diagram (Fig. 9) where the volume percentage is set off as abscissa and the susceptibility as ordinate, both quantities in linear scale. It appears from the diagram that

1) the susceptibility values show a very considerable scattering even for the same volume percentage of magnetite,

2) the susceptibility does not decrease linearly with the magnetite content but considerably faster,

3) the large scattering of the susceptibility values which is apparent also in the case of the very rich iron ores must necessarily indicate that the $\varkappa$-values of pure magnetite vary in a very high degree,

Class	Spec. grav.	Vol.-% Fe_3O_4	H in Oe	$\varkappa' \times 10^6$	N	$\varkappa \times 10^6$	K	No
I	4.14	52.5	0.3	307 000	0.553	370 000	1.01	7
I	4.11	51.2	0.4	296 000	0.253	320 000	0.863	8
I —	3.69	31.8	0.3	171 000	0.820	199 000	1.15	9
—	3.38	—	4.8	724	—	724	—	10
—	3.39	—	4.8	97	—	97	—	11
—	3.00	—	4.8	110	—	110	—	12
—	3.20	—	4.8	80	—	80	—	13
—	3.02	—	4.8	438	—	438	—	14
—	2.85	—	4.8	323	—	323	—	15
—	3.07	—	4.8	101	—	101	—	16
—	3.05	—	4.8	90	—	90	—	17
—	3.06	—	4.8	279	—	279	—	18
—	3.04	—	4.8	242	—	242	—	19
—	2.88	—	4.8	39	—	39	—	20
—	2.72	—	4.8	9	—	9	—	21
—	2.65	—	4.8	2	—	2	—	22
—	2.63	—	4.8	1	—	1	—	23

4) those points in the diagram which refer to cores from certain ore fields, are in a number of cases grouped in a quite regular way and at least a great many of the points display a regular decrease with the magnetite content. This applies especially to Persberg.

The circumstance that the susceptibility does not decrease linearly to the volume fraction of magnetite may theoretically be explained in the following way.

A drill core containing evenly distributed magnetite grains of a volume fraction v is assumed to be magnetized in its longitudinal direction by an external field H, whereby the single magnetite grains obtain a magnetization intensity I. The average magnetization intensity of the core then obviously becomes vI and the average inner field (H′) of the core becomes

$$H' = H - vN_cI, \quad \ldots\ldots\ldots\ldots \quad (28)$$

where N_c = the demagnetization factor of the cylinder. If the susceptibility of the core is $\varkappa$, the relation is

$$\varkappa H' = vI. \quad \ldots\ldots\ldots\ldots \quad (29)$$

The individual magnetite grain may be considered to be enclosed in a mass with the magnetization intensity vI. The coating of free magnetism on the walls in the hollow space of the mass which is occupied by the magnetite grain produces a field in the hollow space, which has the same direction as

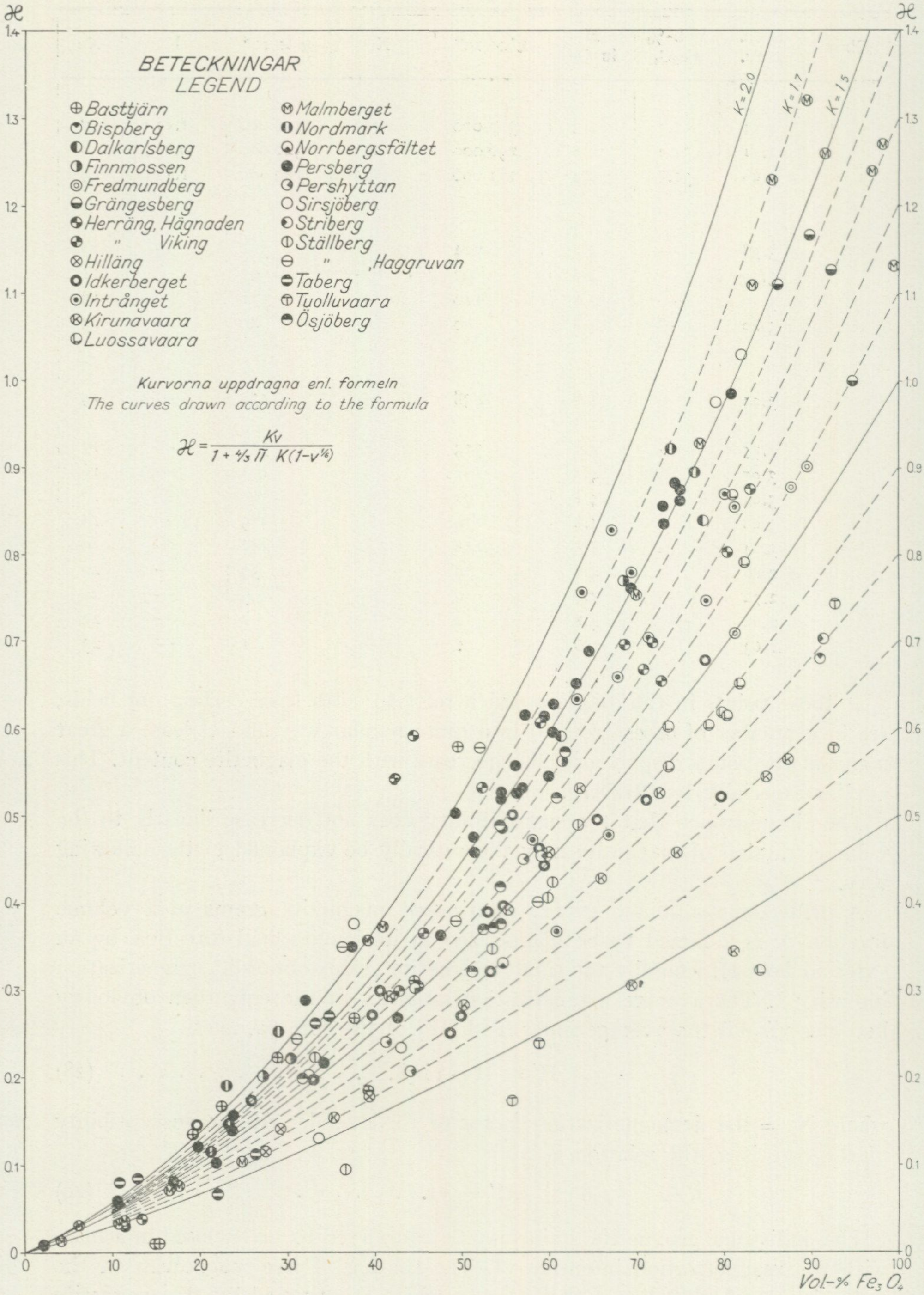

Fig. 9. The variation of the susceptibility ($\varkappa$) with the volume-% magnetite contained in the core samples.

H' and is of the magnitude $N_k vI$, where N_k is the demagnetization factor, valid for a body of the shape of the hollow space, *i. e.* the same demagnetization factor as for the magnetite grain. The external field that acts on the magnetite grain may thus be written

$$H' + vN_k I,$$

and the field prevailing inside the magnetite grain obviously becomes

$$H' + vN_k I - N_k I.$$

If the susceptibility of the pure magnetite is denoted K, the relation will be

$$I = K(H' + vN_k I - N_k I). \quad \dots\dots\dots \quad (30)$$

If this is written

$$KH' = I\left[1 + KN_k(1 - v)\right] \quad \dots\dots\dots\dots \quad (31)$$

it is immediately apparent that this together with equation (29) for $\varkappa$ gives the formula

$$\varkappa = \frac{Kv}{1 + KN_k(1 - v)}. \quad \dots\dots\dots\dots\dots \quad (32)$$

This formula has been advanced by Puzicha (9) and has proved to render quite a satisfactory explanation of the susceptibility values obtained in determinations on synthetic samples of grains of magnetite intermixed in nonmagnetic material up to a couple of volume percent. If the grains have a spherical form, N_k will have the value $^4/_3\,\pi$. With this value of N_k Puzicha obtained somewhat too low values for $\varkappa$, and for his test series he found that values varying between 3.2 and 3.9 should be used, if agreement should be attained between calculated and determined $\varkappa$-values.

If we now investigate how formula (32) agrees with the results illustrated in the diagram in Fig. 9, we find that no acceptable agreement is obtained, even if K and N_k are varied in different ways. The cause of this circumstance will be that at least some of the assumptions from which the formula was decuded imply a too far-reaching simplification of the conditions prevailing in the core samples, at least if the formula is to be used for the whole interval between $v = 0$ and $v = 1$.

From a magnetic point of view it is convenient to distinguish two fundamental types of magnetite occurrences in a test sample: when the magnetite occurs as disseminated grains in a nonmagnetic material and when the nonmagnetic material occurs as grains in a compact mass of magnetite.

The former type underlies the formula deduced above and we shall first investigate how different grain conditions influence its validity. It can then primarily be established that it is of no importance whether the grains are mutually of the same or different magnitude, this, however, under the assumption that all the grains are small in relation to the dimensions of the test sample.

Regarding the demagnetization factor it is true that this is dependent on the shape of the grain as well as on the magnetization direction, when the grains are not spherical. If a body is magnetized in a certain direction, quite different N-values are thus valid for different grains and the value N_k which is to be used in the formula, must attain a sort of average value of all N-values. But as these values change with the magnetization direction, also this N_k-value may be assumed to vary with the direction, and thus also the susceptibility. If this is to be identical for all magnetization directions, some kind of pseudo-isotropy must necessarily prevail in the orientation of the grains, as was earlier proved to be so essential for the magnetite crystals themselves on account of their magnetically ellipsoidic character. If these conditions are satisfied it will thus signify that N_k in the formula will be fairly little dependent on the shape of the grains included in the test sample, as *e. g.* longitudinal grains certainly have smaller N-values in relation to spherical ones, when they are magnetized in their longitudinal direction, but larger values when magnetized perpendicular to that direction. For a suitable chosen N_k-value, which may be expected to be about the same as that valid for a sphere though probably somewhat lower, the validity of the formula (32) ought therefore to remain, but for the limitation that, strictly speaking, it only expresses the average conditions in rocks.

It may be imagined that magnetite grains with different susceptibility occur in a core sample. It can then be shown that formula (32) is still strictly valid if the different kinds of magnetite grains are fairly evenly distributed within the core sample, and if K is understood to denote the susceptibility of a compact magnetite mass, where the different kinds of magnetite are included in magnitudes corresponding to their occurrence in the core sample. This implies, too, that it is not of any importance with reference to the validity of the formula if the grains consist of single magnetite crystals (pseudoisotropically distributed), in spite of their having a magnetically ellipsoidal character.

If, finally, an irregular distribution of the magnetite grains occurs on a small scale this does not either seem to have any influence on the validity of our formula. If we consider *e. g.* the case that grains are accumulated into groups in certain evenly distributed volumes within the body, these being small in relation to its dimensions, each such volume, where we denote the volume fraction of magnetite v_1, has a susceptibility

$$\varkappa_1 = \frac{Kv_1}{1 + KN_k\,(1 - v_1)}.$$

These magnetite-bearing volumes may thus be considered as grains with the susceptibility $\varkappa_1$. If also for these volumes the demagnetization factor is of the magnitude N_k, and if their volume fraction in the body is denoted v_2, the susceptibility of the body ($\varkappa$) will, as its volume fraction of magnetite is $v = v_1 v_2$, be

$$\varkappa = \frac{\varkappa_1 v_2}{1 + \varkappa_1 N_k (1 - v_2)} = \frac{Kv}{1 + KN_k\,(1 - v)},$$

which is in accordance with formula (32).

What has been shown above thus seems to prove the general validity of the formula if the grains are assumed to be fairly evenly distributed and the susceptibility independent of the magnetization direction. This latter condition is confirmed by the experience so far gained in this respect concerning magnetite ores. Regarding the former condition it should be pointed out that even earlier (p. 23) it has been necessary, with regard to the demagnetization factor, to assume a fairly even distribution of magnetite within the tests sample.

As to the second principal type of magnetite distribution, the relation between the susceptibility of a body and its volume fraction of magnetite will be different from (32). If the same assumptions are made here regarding the grains of the non-magnetic material as were earlier made for the magnetite grains, it seems possible also here to calculate with a general formula. For the same v-values this will, however, give higher susceptibility values than the former.

The reason why there is no linear relation between the susceptibility of a body and its volume fraction of magnetite is that besides the demagnetization which is dependent on the shape of the body and is eliminated by using the demagnetization factor, there also exists a demagnetization which is dependent on the manner of the distribution of the magnetite within the body. This effect on the susceptibility value is expressed in formula (32) by the factor

$$\frac{1}{1 + KN_k(1 - v)}.$$

Given a certain arbitrary v-value, the corresponding factor for the second principal case will obviously be larger than that for the first type and ought to have a value equal to the above quoted expression for a certain higher v-value v′. The same thing ought to be true if both types of distribution are represented in the test body. As obviously for the limit value $v = 1$ also $v' = 1$ and for the limit value $v = 0$ also v′ ought to be 0, seeing that magnetite in very small percentages must be considered to exist only in the shape of grains, and as further v′ ought to decrease continually with v, we put $v' = v^{1/n}$. Here n may be considered a function of v, but n must be $\geqslant 1$ as $v' \geqslant v$ and both < 1 except in the above-mentioned limit value. If now for N_k the value $^4/_3\,\pi$, valid for the sphere, is inserted, the following formula is obtained

$$\varkappa = \frac{Kv}{1 + {}^4/_3\,\pi K(1 - v^{1/n})}. \quad \ldots\ldots\ldots\ldots \quad (33)$$

The remaining task is then to try to find such an expression for n that a satisfactory agreement is obtained between the formula above and the results of the measurements illustrated in Fig. 9.

In order to test if this is possible in a simple case when n is an ordinary number, the v—$\varkappa$-curves were calculated for different values of n and K. Each group of curves that corresponded to a number of K-values for a certain fixed n-value was laid over the diagram in Pl. I and the course of the curves was compared with the distribution of the points in the diagram. In this way groups of curves for n = 1, n = 2, etc., were compared with the point diagram. It was then disclosed that the best agreement was obtained for n = 6. In Fig. 9 the curves for n = 6 and K = 0.5, 1, 1.5, and 2 are drawn with solid lines, and for K = 0.6, 0.7, 0.8, 0.9, 1.1, 1.2, 1.3, 1.4, and 1.7 with dotted lines. The diagram shows that if the whole distribution of the points is considered, it is scarcely possible to contemplate reaching an agreement between this and a formula better than that obtained whith formula (33). Viewing the distribution of the points from different mining fields, it is striking how good is the agreement between the great number of points for Persberg and the curve for K = 1.5. Another circumstance supporting the truth of the formula

$$\varkappa = \frac{Kv}{1 + {}^{4}/_{3}\,\pi\,K\,(1 - v^{1/6})} \quad \ldots\ldots\ldots\ldots \quad (34)$$

is apparent from Fig. 10. This is a K—v-diagram for the points in Fig. 9 (some points with extremely high K-values are omitted), where K has been calculated with the aid of equ. 38, (p. 58). The average value of K for all points within consecutive intervals of 10 volume percent are represented by coarsely dotted lines and drawn across the width of the corresponding volume intervals. The solid line across the entire breadth of the diagram at K = 1,21 indicates the average value of the interval values. The fact that according to the diagram there seems to exist no univocal tendency in the variation of the interval values for K with the volume fraction of magnetite must be considered to confirm the validity of formula (34).

It must be vigorously pointed out that the expression (34) for $\varkappa$ that has been obtained can only be considered to have statistical validity, as for the same arbitrary volume percentage of magnetite its distribution in one body may be more closely related to one of the two types of distribution treated above than is the case in another body.

It is convenient to introduce the designation

$$C = N_k \frac{1 - v^{1/n}}{v} \quad \ldots\ldots\ldots\ldots\ldots \quad (35)$$

and to write equation (33) in the form

$$\varkappa = \frac{Kv}{1 + CKv}. \quad \ldots\ldots\ldots\ldots\ldots \quad (36)$$

Between that susceptibility (Kv) which would be valid if the susceptibility of a body was proportional to the volume fraction of magnetite and the one ($\varkappa$) which really occurs, the relation is similar to that between $\varkappa$ and the apparent susceptibility ($\varkappa'$) (see p. 11 equ. (4)). C may thus be considered a demagnetization factor comparable with N. For the purpose of distinction the term *internal demagnetization factor* is introduced for C.

In the natural ore deposits a frequently prevailing condition is that also when the magnetite content is on the whole evenly distributed within an ore-body,

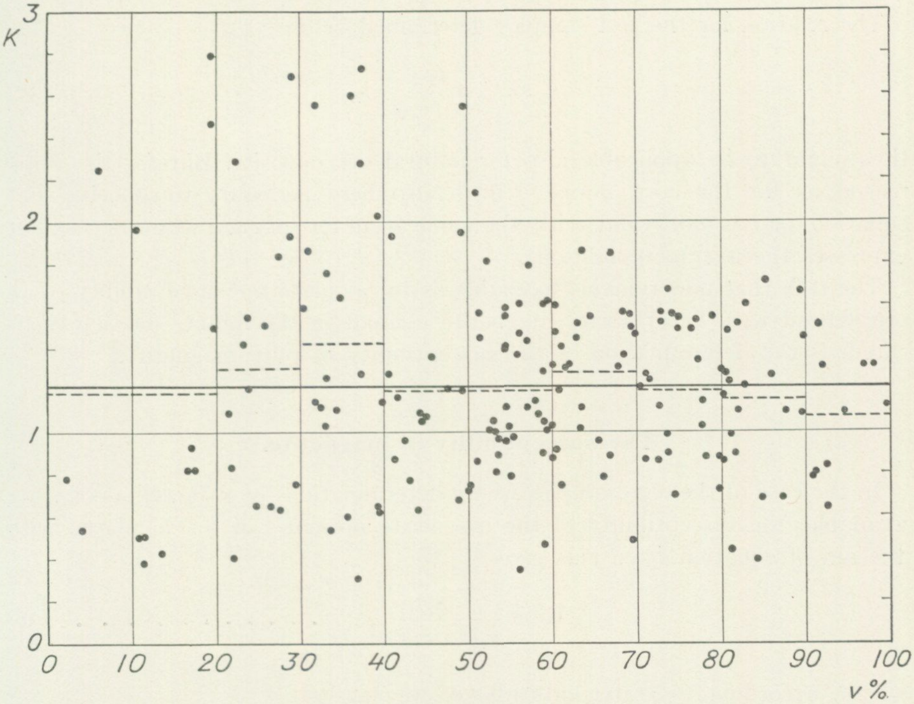

Fig. 10. The diagram shows the values of the susceptibility (K) of the magnetite and volume-% magnetite in them, calculated for the different core samples.

- - - - - - indicates the mean of K for different v-intervals

——— » » » » » » all K-values plotted in the diagram.

the magnetite is far more closely assembled within certain smaller parties of the body than within others. The extent of these volumes can be much larger than the test samples used in the susceptibility determinations, but for the ore-body as a whole formula (36) is nevertheless valid as this only assumes that the dimensions of the volumes are small in relation to that of the ore-body. A representative collection of core samples from such a deposit must necessarily display greatly varying magnetite contents. But as the average value of the volume fraction of magnetite of the test samples is thus equal to the value valid for the ore-body as a whole, the corresponding relation is not true of the susceptibility, as $\varkappa$ does not alter linearly with v. The correct method of proceeding in this case would therefore, mathematically, be to determine K and the relation for C and then, using the value for the volume fraction of magnetite of the ore-body, to calculate its susceptibility whith the aid of formula (36). The question is then if the relation obtained for C by measurements on the test samples is identical with that valid for the ore-body as a whole. This seems probable but it must be pointed out that this, strictly speaking, is a necessary condition if in a case similar to that mentioned above, it is to be possible to determine the susceptibility of an ore-body by measurements on test samples.

The relation for the test samples determined before

$$C = {}^4/_3\,\pi\,\frac{1 - v^{1/6}}{v}, \quad \ldots\ldots\ldots\ldots \quad (37)$$

thus ought to be applicable also for natural ore deposits. But for the same reason as for the core samples, it is also here necessary to conceive that equation (37) is not valid with the same accuracy for each separate case but expresses the average conditions.

The task that now remains to enable us to calculate the susceptibility of an ore deposit with an arbitrary magnetite content in the mining fields investigated, is the determination of the susceptibility of pure magnetite.

The susceptibility of magnetite.

In the case of the core samples where determinations of $\varkappa$ as well as of v are available, the susceptibility of the magnetite present can be calculated with the aid of equation (36). This gives

$$K = \frac{\varkappa}{v\,(1 - \varkappa C)}, \quad \ldots\ldots\ldots\ldots \quad (38)$$

where, according to statements above, we can put

$$C = {}^4/_3\,\pi\,\frac{1 - v^{1/6}}{v}. \quad \ldots\ldots\ldots\ldots \quad (37)$$

The K-values in the main table are calculated according to these formulas.

In order to get a more reliable basis for the judgement of the results obtained it is convenient first to discuss the errors that influence these K-values.

Primarily it should be pointed out that the demand for a broadly speaking even distribution of the magnetite, which proved to be necessary to assume earlier on, is not fullfilled by all the core samples. In order to make it possible for the reader to judge how different core samples behave in this respect, a column (Class) has been included in the main table with classification designations, 1 being used for a magnetite distribution which has been judged quite satisfactory, 1— for more doubtful cases, and 0 for extreme irregularity. Finally banded cores and cores with strongly marked "Schlieren" have been denoted 2a, 2b and 2c, the banding and the "Schlieren" in these respective cases being about at right angles to, forming an angle of 45° to or being parallel to the longitudinal axes of the cores. The samples marked 0 should of course be omitted in the following discussion of the results, and the banded cores as well as the cores with "Schlieren" should, if they be included, be judged on their respective merits.

But even if only those cores are chosen which have broadly speaking an even distribution of magnetite, the earlier theoretical discussion has already

Table V.

The relative error $/\frac{\Delta K}{K}/ = A + B$ expressed in per cent

v	A			B		
	K = 1	K = 1.5	K = 2	K = 1	K = 1.5	K = 2
1	3.0	3.0	3.0	5.9	8.9	11.9
0.8	3.5	3.7	3.9	8.0	12.0	16.0
0.6	4.0	4.5	5.1	11.6	17.4	23.2
0.4	4.8	5.7	6.6	19.1	28.7	38.3
0.2	6.0	7.4	8.8	44.3	66.5	88.7

shown that the relation (37) for C cannot be expected to be strictly valid for each single sample, only having statistical validity. How great errors this circumstance may cause in the K-values cannot be judged with the aid of the material here accessible, so we must be content to establish that in certain exceptional cases they can probably be quite considerable.

The uncertainty in the K-values caused by the errors in the $\varkappa$- and v-determinations can, however, be more safely gauged. It is possible to assume that the relative exactness with which $\varkappa$ is determined is independent of the magnitude of the $\varkappa$-value and put $/\frac{\Delta\varkappa}{\varkappa}/ = 0.03$. The following expression is obtained for Δv from formula (27):

$$\Delta v = \frac{\Delta S - \Delta S_1 (1 - v) - v \Delta S_2}{S_2 - S_1} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (39)$$

Here the maximum errors can be estimated as follows: $/\Delta S/ = 0.02$, $/\Delta S_1/ = 0.05 - 0.1$, $/\Delta S_2/$[1] $= 0.05 - 0.1$ and $S_2 - S_1 \backsim 2$. The maximum error for v is thus $/\Delta v/ = 0.035$ and 0.06 resp., according as the lower or higher values are chosen for ΔS_1 and ΔS_2. If now for K in the usual way an expression is chosen of the relative error $\left(\frac{\Delta K}{K}\right)$ from the equations (37, 38), and the part (A) caused by the error in $\varkappa$, and the part (B) dependent upon Δv are separated, we thus obtain for different v-values and for $/\Delta v/ = 0.035$ the values mentioned in Table V for cases when the correct K-values are 1, 1.5, and 2. A and B are expressed in per cent and the sum is obviously equal to the maximum value for $\left(\frac{\Delta K}{K}\right)$. The table values show that A as well as B increases with increasing K- and decreasing v-values, but B in a considerably higher degree than A. For small magnetite contents the K-values determined thus become very uncertain due to the errors in the v-determinations. It should be observed that the miscalculation formula is only exactly valid when

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[1] In the literature the spec. gravity is stated to range from 4.95 to 5.20.

the relative errors of $\varkappa$ and v are small. In reality the errors become larger or smaller than those stated in Table V according as Δv is negative or positive. This is shown in Fig. 11, where the curves drawn show how the calculated K-values vary according to the v-values, when these values have an error of $\Delta v = -0.035$ and $\Delta v = 0.035$ resp. and the real susceptibility of the magnetite is 1. Probably the errors of the separate K-determinations are generally smaller than those corresponding to $\Delta v = \pm 0.035$, but they must nevertheless especially for small v-values, be considered very substantial.

In order to get a general view of the results of the K-determinations from the different mines a compilation has been made in Table VI. To make the whole more surveyable the K-values within the different mines have been grouped in a natural way according to the accumulation of the values, and only the corresponding mean values for K and the number of determinations (n) have been quoted. The group values of the different mines have in turn been compiled according to magnitude in different columns. In the two columns at the extreme right of the table the mean values and average errors have been quoted for all K-values referring to cores with 10—100 and 30—100 volume % magnetite. The group values containing K-values for cores between 10—30 vol.-% are underlined (one — for every such K-value). Only the cores marked with 1 and 1— have been included and, furthermore, all those with less than 10 volume % magnetite or with K-values exceeding 3 have been omitted. These latter occur only at low v-values, so, with reference to what appeared from the discussion of the errors, this must be considered appropriate.

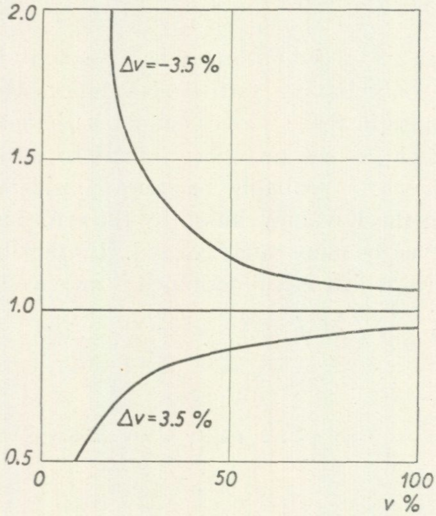

Fig. 11.

If the scattering of the K-values within the individual mines is considered, this is found to be considerable according to Table VI, in any case when a fairly large number of determinations are available. For several mines it is

Table VI.

Mining fields	K-groups																								Mean of K for cores with			
	1	n	2	n	3	n	4	n	5	n	6	n	7	n	8	n	9	n	10	n	11	n	12	n	10—100 vol. % Fe_3O_4	n	30—100 vol. % Fe_3O_4	n
Quartzeous iron ores.																												
Pershyttan							1.08	2																	1.08 ± 0.04	2	1.08 ± 0.04	2
Striberg					0.81	1																			0.81	1	0.81	1
Bispberg					0.79	1																			0.79	1	0.79	1
																											Mean = 0.89 ± 0.12	3
Skarn-bearing and calcareous iron ores.																												
Sirsjöberg					0.77	1					1.53	2											2.73	1	1.64 ± 0.55	4	1.64 ± 0.55	4
Nordmark							1.09	1			1.46	2	1.68	1									2.69	1	1.67 ± 0.41	5	1.58 ± 0.10	2
Persberg							1.11	3	1.25	3	1.53	22			1.90	3			2.28	1	2.56	1			1.58 ± 0.17	31	1.58 ± 0.17	27
Taberg	0.41	1					1.07	1					1.70	2											1.22 ± 0.48	4	1.49 ± 0.28	3
Finnmossen									1.31	1	1.58	2			1.83	1									1.58 ± 0.14	4	1.49 ± 0.12	3
Intrånget									1.26	5	1.50	2			1.85	2									1.44 ± 0.21	9	1.44 ± 0.21	9
Herräng (Viking)							1.12	1	1.30	4	1.61	1			1.81	1									1.39 ± 0.18	7	1.39 ± 0.18	7
Dalkarlsberg									1.37	2															1.37 ± 0.04	2	1.37 ± 0.04	2
Herräng, (Hägnaden)									1.20	2															1.20 ± 0.02	2	1.20 ± 0.02	2
Ösjöberg					0.95	4	1.16	3	1.36	2															1.11 ± 0.15	9	1.11 ± 0.15	9
																											Mean = 1.43 ± 0.13	10
Manganiferous iron ores.																												
Ställberg, Haggruvan					0.90	1			1.20	1					1.86	1	2.14	1			2.60	1			1.74 ± 0.55	5	1.74 ± 0.55	5
Basttjärn			0.65	1			1.09	1	1.28	1					1.93	1			2.29	1	2.51	2			1.75 ± 0.63	7	1.39 ± 0.58	4
Ställberg					0.93	4			1.26	1															0.99 ± 0.12	5	0.99 ± 0.12	5
Hilläng			0.67	3																					0.67 ± 0.05	3	0.67 ± 0.05	3
																											Mean = 1.20 ± 0.37	4
Apatitic iron ores.																												
Malmberget							1.13	1	1.32	2	1.50	3	1.67	3	1.98	2									1.57 ± 0.21	11	1.57 ± 0.21	11
Grängesberg							1.10	1	1.31	1	1.47	2													1.34 ± 0.13	4	1.34 ± 0.13	4
Fredmundberget							1.06	3																	1.06 ± 0.05	3	1.06 ± 0.05	3
Idkerberget					0.80	2	1.04	8	1.33	2	1.51	1											2.79	1	1.21 ± 0.30	14	1.05 ± 0.12	12
Luossavaara	0.40	1			0.89	5	1.05	2	1.28	1															0.91 ± 0.14	9	0.91 ± 0.14	9
Kiirunavaara	0.47	2	0.71	6			1.08	2																	0.73 ± 0.15	10	0.73 ± 0.15	10
Tuollavaara	0.41	2	0.65	1	0.84	1																			0.56 ± 0.17	4	0.56 ± 0.17	4
																									Mean =		1.03 ± 0.26	7
																									For all mining fields: Mean =		1.21 ± 0.29	24
																									For all cores: Mean =		1.27 ± 0.29	142

possible upon a closer examination of the measuring results to state with certainty that this scattering cannot be wholly explained by the earlier discussed errors in the K-determinations, but may to a not inconsiderable part be due to the fact that the susceptibility of the magnetite varies within these deposits. Especially for those mines, which mainly are represented by cores with low magnetite contents, it is, however, not possible to decide whether or not the magnetite of these ores has a broadly speaking constant susceptibility value. If we consider the sparse K-values for cores between 10—30 volume %, their scattering in relation to the means of K is much greater than that of the remaining values, which also was to be expected. It is thus convenient in the following mainly to consider the mean values of K and then only those referring to cores with 30—100 volume % magnetite.

In order if possible to obtain what from a practical as well as a geological point of view may be considered a convenient relation between the magnitude of the susceptibility of the magnetite and the character of the ores, these latter have in accordance with Table VI been divided into quartzeous iron-ores, skarn-bearing and calcareous iron-ores, manganiferous iron-ores and apatitic iron-ores. The mutual order between the mines within these groups has only been made on the basis of the magnitude of the mean values of K obtained.

Unfortunately the quartzeous iron-ores are only represented by three mines and a total of four K-determinations. To these may be added sample No. 1 from the Norrberg field, which has the designation 2a and K = 0.80. On account of the influence of the banding this value may be expected to be somewhat too low, but it further supports the fact that the magnetites of the quartzeous iron-ores have a susceptibility value in the vicinity of the mean value 0.89, quoted in the table.

Skarn-bearing and calcareous iron-ores are represented by 10 mines. With the exception of Ösjöberg and the mine Hägnaden in the Herräng field the K-values will be seen to be higher than the mean value 1.21 for all mining fields. For Hägnaden, however, there are only two determinations so it will be most correct to pool them with the measurements from the Viking mine. For these together we obtain K = 1.35. It further seems from the distribution of the values for Sirsjöberg as if the value of this mine is somewhat too high. If we calculate in this manner, excepting Ösjöberg, the results show a remarkably small variation from 1.35 to about 1.60 for the susceptibility of the magnetite, with a mean value of 1.49. Regarding Ösjöberg, there is nothing about the measurements that can prompt us to disregard the results obtained. This mine must therefore at least for the present remain as an exception from the rule that magnetites of skarn-bearing and calcareous iron-ores have high susceptibility values with an approximate mean value of 1.50.

The manganiferous iron-ores show a very irregular tendency. The observation series for Basttjärn and Ställberg Haggruvan display, in addition, a tremendous scattering of the K-values. This latter condition may, to a great extent at least, possibly be explained by the fact that the v-determinations are generally very uncertain for ores containing knebelite, partly on account of the high spec. gravity of knebelite (4.5) and partly because it is very difficult to decide to what extent other skarn minerals are present. The only possible conclusion regarding the magnetites of the manganiferous iron ores prompted by these investigations is therefore that they probably have a greatly varying susceptibility.

As a rule the apatitic iron-ores are rich in magnetite and this holds true also for the samples included here, for which reason the determinations must be considered to contain comparatively small errors. It is therefore possible with certainty to state that considerable variations in the susceptibility of the magnetite thus exist within several of the investigated ore deposits and especially then in the Lapland ore fields. According to Table IV the cores of Malmberget containing more than 85 vol.-% magnetite display K-values from 1.13—1.72. The errors in these determinations, however, can hardly be larger than about 10 %, so it must be considered that the variations of the susceptibility of the magnetite occur from at least 1.25—1.55. For *e. g.* Kirunavaara[1] and Luossavaara[1] it is possible from the measurements available to estimate that the susceptibility of the magnetite varies at least between the limits 0.5—0.9, and 0.45—1.1 resp. The investigated ore deposits show greatly varying K-means; from Malmberget, which in agreement with the skarn ores has a value of 1.57, to Tuollavaara, which shows the lowest value (0.56) for all the mines included in the investigation. If only the apatitic ores of Bergslagen are considered, the variations are much smaller, the highest mean being 1.34 for Grängesberg and the lowest 1.05 for Idkerberg and 1.06 for Fredmundberg. With the large variations for the mines of Norrbotten in mind, it will be appropriate, however, to await further studies of the apatitic ores of Bergslagen before any general judgement is pronounced regarding the susceptibility of the magnetites of these ores.

The susceptibility of ores and rocks.

As has earlier been shown (pp. 56, 58) it is possible with the aid of the relation

$$\varkappa = \frac{\mathrm{Kv}}{1 + \mathrm{CKv}}, \quad \ldots\ldots\ldots\ldots \quad (36)$$

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[1] The measurements of susceptibility on drillcores from Kirunavaara—Luossavaara published by V. Carlheim-Gyllensköld (1) show variations of the individual $\varkappa$-values from 0.25—1.82. These $\varkappa$-determinations, however, were carried out at a field strength of 71 Oe, the magnetite content of the core-samples are not mentioned. Further it may be suspected that especially the highest $\varkappa$-values are much too high as the values of the demagnetization factor used may be too large (see p. 22).

For 6 and 5 drill-samples from two drillholes in the ores 'Professorn' and 'Statsrådet' resp. at Kirunavaara Carlheim-Gyllensköld obtained the means 0.96 and 0.63 resp. for $\varkappa$. 9 determinations from two drillholes in Luossavaara gave a $\varkappa$-mean of 0.74. If the magnetite content is estimated at 85 vol.-% in all these three cases, the above mentioned $\varkappa$-values according to equations (37,38) give for the susceptibility of the magnetite the values 1.29, 0.81 and 0.96. For the ores 'Statsrådet' (0.81) and Luossavaara (0.96) these values are in fairly good agreement with the means of K in Table VI (0.73 and 0.91 resp.), though the two first mentioned K-values refer to a field strength much higher than that referred to by the two last mentioned K-values. Therefore the high K-value (1.29) for the ore 'Professorn' makes it probable, that the susceptibility of the magnetite also at the earth field strength in some parts of Kirunavaara considerably surpasses 1.

Table VII.

v	C	κ for								
		K = 0.1	K = 0.5	K = 0.8	K = 1	K = 1.2	K = 1.5	K = 2	K = 5	K = ∞
1	0 *0*	0.1	0.5	0.8	1 *1*	1.2	1.5 *1.5*	2	5	∞ *∞*
0.98	0.0144	0.0979	0.487	0.775	0.966	1.16	1.44	1.91	4.58	69.5
0.95	0.0375	0.0947	0.467	0.740	0.917	1.09	1.35	1.78	4.03	26.6
0.9	0.0810 *0.0817*	0.0894	0.435	0.681	0.839 *0.839*	0.994	1.22 *1.22*	1.57	3.30	12.7 *12.2*
0.8	0.191 *0.201*	0.0788	0.372	0.570	0.694 *0.689*	0.812	0.976 *0.966*	1.23	2.27	5.23 *4.98*
0.7	0.345 *0.364*	0.0684	0.312	0.469	0.564 *0.558*	0.652	0.771 *0.760*	0.944	1.58	2.90 *2.75*
0.6	0.570 *0.615*	0.0580	0.256	0.377	0.447 *0.438*	0.511	0.595 *0.580*	0.712	1.11	1.75 *1.63*
0.5	0.914 *1.005*	0.0478	0.204	0.293	0.343 *0.333*	0.388	0.445 *0.428*	0.523	0.761	1.09 *0.995*
0.4	1.48 *1.68*	0.0378	0.154	0.217	0.251 *0.240*	0.280	0.318 *0.299*	0.366	0.504	0.675 *0.597*
0.3	2.54 *2.95*	0.0279	0.109	0.149	0.170 *0.159*	0.188	0.210 *0.193*	0.238	0.312	0.394 *0.339*
0.2	4.93 *5.90*	0.0182	0.0670	0.0895	0.101 *0.0917*	0.110	0.121 *0.108*	0.135	0.169	0.201 *0.170*
0.1	13.3 *16.6*	0.00882	0.0300	0.0387	0.0428 *0.0376*	0.0461	0.0500 *0.0430*	0.0545	0.0651	0.0750 *0.0603*
0.05	32.9 *41.9*	0.0429	0.0137	0.0173	0.0189 *0.0162*	0.0202	0.0216 *0.0181*	0.0233	0.0271	0.0304 *0.0239*
0.01	224 *289*	0.00082	0.00236	0.00286	0.00308 *0.00257*	0.00325	0.00344 *0.00281*	0.00364	0.00409	0.00445 *0.00346*
0	∞ *∞*	0	0	0	0 *0*	0	0 *0*	0	0	0 *0*

$$\text{where } C = \frac{4}{3}\pi\frac{1 - v^{1/6}}{v} \quad \ldots\ldots\ldots \quad (37)$$

to calculate the susceptibility of an ore or a rock of arbitrary magnetite content (v) if the susceptibility (K) of the magnetite contained in it is known, and other minerals present are considered to be nonmagnetic. How the course of the κ-values appears when v varies, is illustrated by the curves in the diagram fig. 9. The K-values to which these curves refer are indicated at the upper ends of the curves. In order to further illustrate the significance of the formulas above, Table VII shows for a series of v-values partly the corresponding C-values, partly the κ-values (numbers in ordinary print) valid for a number of selected K-values.

If primarily the ratio is considered between the κ-value according to formulas (36, 37) and the susceptibility value that would be valid if the internal demagnetization did not exist, *i. e.* if $C = 0$, and $\varkappa = Kv$, it can obviously be written

$$\frac{1}{1 + CKv} = \frac{1}{1 + \frac{4}{3}\pi K (1 - v^{1/6})}.$$

This quotient thus decreases continually with decreasing v-values and approaches the limit value and minimum value $\frac{1}{1+\frac{4}{3}\pi K}$ when the magnetite content approaches zero. For a K-value of 0.01 this minimum value will be 0.96 while the corresponding values of $K = 0.1$ and $K = 1$ is 0.71 and 0.19 resp. If, however, the above-mentioned relation is calculated for *e. g.* $v = 0.05$ and $v = 0.01$ (see Table VII) we obtain for $K = 0.1$ the values 0.96 and 0.82 resp., and for $K = 1$ the values 0.69 and 0.33 resp. It is thus obvious that if the magnetically predominant substance in a body has a susceptibility (K) which does not exceeds 0.01, it is possible to quite disregard the influence of the internal demagnetization and put the susceptibility of the body $\varkappa = Kv$. When the K-value of the magnetically predominant substance is of the magnitude 0.1, the internal demagnetization still plays a certain rôle, especially at low contents of magnetic matter, but it is not of actual importance for the magnitude of the $\varkappa$-values at higher contents until the K-values approach the magnitude valid for the magnetites of the iron ores.

If the $\varkappa$-values in Table VII are studied for v-values just below 1, it is found that the $\varkappa$-values for higher K-values decrease considerably faster with decreasing v-values, if also calculated in per cent, than in the case of lower K-values. At $v = 0.98$ the $\varkappa$-value for $K = 0.5$ has thus decreased to 97.4 % of the K-value, while the corresponding percentages for $K = 1$, 1.5, 2, and 5 are 96.6, 96.0, 95.5, and 91.6 resp. For $K = \infty$ the $\varkappa$-value has dropped to 69.5. For the same series of K-values we get 93.4, 91.7, 90.0, 89.0 and 80.6 for $v = 0.95$. Here the $\varkappa$-value for an infinite large K-value has dropped to 26.6, *e. g.* it is not quite 40 % of that which is valid for $v = 0.98$. It thus appears that the internal demagnetization at such high K-values as those which occur in iron and steel, already at a very insignificant dilution of the magnetic substance (*e. g.* at a certain porosity) can be expected to cause a very considerable drop in the $\varkappa$-value. For the iron ores, on the other hand, where the susceptibility of the magnetite is mostly within the interval 0.5—2, the drop in the $\varkappa$-values with the volume fraction of magnetite at v-values just below 1 is not particularly accentuated.

It is of special interest to study how the susceptibility values behave at low magnetite contents. As the susceptibility values that correspond to a higher K-value decrease proportionally faster with decreasing v-values than those which correspond to a lower K-value, the ratio between the $\varkappa$-values valid for different K-values will be displaced more and more towards 1 (yet without reaching this value), the lower the v-values are. If the $\varkappa$-values stated in Table VII for $v = 0.01$ are regarded, it is found *e. g.* that the $\varkappa$-value has changed from 0.00236 to 0.00364 when K increases from 0.5 to 2. In this case a fourfold increase in the K-value thus corresponds only to an approx. 1.5 fold increase in the $\varkappa$-value. It will be seen that the conditions at higher K-values are still more accentuated in this respect. The $\varkappa$-value is thus only increased by about 20 % when the K-value grows from 2 to ∞. It is therefore possible to state that when the volume per cent of magnetite is but a couple of per cent or less the susceptibility of the rocks is comparatively little dependent upon the changes in the susceptibility of the magnetite.

Since the partly empirically obtained formulas (36, 37) are almost exclusively founded on measurements on samples with more than 10 volume % of magnetite (see fig. 9), it is of particular importance to compare how the conditions outlined above regarding the susceptibility at very low magnetite contents agree with the results that have been published earlier (see p. 3). Primarily it can be established that the results of the different scientists differ quite essentially from each other, and this is probably partly due to the uncertainty in the determinations of the magnetite content in the samples used. Slichter (12) and Puzicha (9), who mainly made determinations on fine-grained samples (fine-grained magnetite had been intermixed with non-magnetic material), obtained susceptibility values which for $v = 0.01$ give $\varkappa = 2\,700 \times 10^{-6}$ and $2\,400$—$3\,000 \times 10^{-6}$ resp. Grenet (3), who measured a large number of samples of the principal igneous rock types, determined the magnetite content in them by microscopically measuring the relation between the area of the dark minerals and the total area in thin sections of the samples, and he then assumed that all dark minerals were magnetite. For 86 of Grenet's determinations, which mutually display a large scattering, the mean value is $\varkappa = 1\,560 \times 10^{-6}$ at 1 volume % magnetite (8). For corresponding magnitudes Katô (4) and Nagata (7) found in their determinations on lavas from Japanese volcanoes, mean values amounting to $1\,150 \times 10^{-6}$ and $1\,160 \times 10^{-6}$ resp., but also in these cases the individual values have a considerable scattering. The two Japanese scientists based their magnetite determinations on chemical analysis of samples, the probable magnetite content being calculated with the aid of normative minerals. Finally it may be mentioned that Slichter carried out susceptibility determinations on two samples of gabbro, and Puzicha did the same on a granite sample from Schierke in the Harz, for which the magnetite content was determined by pulverization and separating. The data for these determinations as well as the $\varkappa$-values for $K = 1.5$ calculated according to (36, 37) are as follows:

Slichter,	sample	1	$v = 0.0015$	measured $\varkappa = 430 \times 10^{-6}$	calc. $\varkappa = 437 \times 10^{-6}$
»	»	2	0.0024	680×10^{-6}	726×10^{-6}
Puzicha	»	1	0.0042	$1\,330 \times 10^{-6}$	$1\,322 \times 10^{-6}$

From what is stated above it thus appears that except for the three last-mentioned samples, where the agreement with the formulas (36, 37) is good, the other $\varkappa$-determinations mentioned show lower values throughout than those that should be valid according to Table VII. If the methods for the determination of the magnetite contents of the samples are examined critically it would seem to be quite probable that the direct separating caused too low a v-value. It would further seem to be obvious that Grenet obtained too high values of the magnetite content, as no doubt the dark minerals in his samples did not all consist of magnetite. According to L. L. Nettleton and T. A. Elkins (8) a similar relation is probably true of the magnetite determinations of the two Japanese. The $\varkappa$-values for one vol.-% magnetite that have been quoted above as valid for the investigation materials of Grenet, Katô, and Nagata must thus be considered too low. For the fine-grained samples the v-values, on the contrary, must be considered very reliable, but there may possibly exist some uncertainty whether from magnetic point of view the shape of the magnetite grains and the way in which these are distributed in the test samples correspond to the average mode of occurrence of the magnetite in natural rock samples. From what has been said above it seems probable, however, that at least for a K-value as high as 1.5 a susceptibility of about $2\,700 \times 10^{-6}$ at 1 volume % magnetite must be reckoned. The corresponding $\varkappa$-value according to Table VII is $3\,440 \times 10^{-6}$.

It is thus necessary to modify formulas (36, 37) and then primarily the expression for C, so that these may be used also for very small magnetite contents. If the more general expression is considered (see p. 56)

$$C = \frac{4}{3}\pi \frac{(1 - v^{1/n})}{v},$$

this gives for *e. g.* n = 4 a C-value, which for K = 1,5 and v = 0,01 makes $\varkappa = 2\,860 \times 10^{-6}$. It is thus possible to state that it is necessary to express 1/n as a function of v, when this function must be so constituted that 1/n becomes equal or in any case almost equal to 1/6 for v-values from 1 down to 0.3—0.2 and that 1/n then rapidly approaches a value somewhat larger than 1/4 when v drops to 0,01. These conditions are satisfied quite well if we put

$$\frac{1}{n} = \frac{1}{6} + \frac{1}{6}(1 - v^{1/6}) = \frac{2 - v^{1/6}}{6}$$

and thus

$$C = \frac{4}{3}\pi \frac{1 - v^{\frac{2 - v^{1/6}}{6}}}{v} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (40)$$

If we consider *e. g.* the $\varkappa$-values that are found in Table VII under K = 1 and K = 1.5, the quotient $\left(\frac{\varkappa}{\varkappa}\right)$ between the values (printed in italics), which have been calculated with the aid of C according to formula (40), and those calculated with the aid of (37), will for different v-values be the following

	K = 1	K = 1.5
v = 1	$\frac{\varkappa}{\varkappa} = 1$	$\frac{\varkappa}{\varkappa} = 1$
0.9	1.00	1.00
0.8	0.99	0.99
0.5	0.98	0.96
v = 0.3	$\frac{\varkappa}{\varkappa} = 0.94$	$\frac{\varkappa}{\varkappa} = 0.92$
0.1	0.88	0.86
0.01	0.84	0.82

In view of the uncertainty in the determinations of the magnetite content attaching to the experimental values now published (see p. 59), especially with regard to drill-cores with small magnetite contents ($v \leq 0.3$), it may thus be stated that formula (36) for an internal demagnetization factor in accordance with expression (40) in a satisfactory way expresses the results of the investigation material now presented as well as of the investigations by other scientists quoted above for magnetite contents of the magnitude 1 volume %. It is also probable that according as new and more accurate measurements are carried out in order to study the relation between the susceptibility and the magnetite content of iron ores, these results will be displayed in a satisfactory way with the aid of an internal demagnetization factor with the general form

$$C = N \frac{1 - v^{a+bv^c}}{v},$$

where N, a, b, and c are constants whose numerical values are determined by the results of the measurements.

In figs. 12 and 13 are found diagrams showing the measuring results of all the core samples included in the main table. In the first-mentioned diagram the specific gravity has been plotted in linear scale along the abscissa and the susceptibility in logarithmic scale along the ordinate; in the last-mentioned diagram the susceptibility values are marked with crossbars on lines (one for each ore deposit) logarithmically divided. Regarding the notations, those of the magnetite ores have only been used for the samples in which hematite is entirely absent or only occurs in minute quantities, while all other iron ore samples have been given a hematite sign, also in the cases where the amount of magnetite essentially exceeds that of hematite. In the diagram in Fig. 12 the same notations have been used for limestone and dolomite samples as for acid rocks. In the diagram in Fig. 13 the notations for an unbroken sequence of the same rock have been limited to the highest and lowest $\varkappa$-value in the sequence.

The specific gravity of the barren rock material in the samples from quartzeous iron-ores on the one hand and apatitic ores, skarn- and calcareous iron ores as well as the manganiferous iron-ores on the other is on an average about 2.5 and 2 units resp. lower than that of magnetite. This thus signifies that the volume % magnetite of the samples which in the diagram in Fig. 12 are noted as magnetite ores, is indicated in a linear scale along the abscissa (see formula 27), when $v = 0$ for the specific gravity 2.67 and 3.17 for the first and second of the above-mentioned ore groups, and $v = 1$ at the specific gravity 5.17 of magnetite for both. As regards especially the samples of skarn and calcareous iron ores and the manganiferous iron ores there are frequently considerable deviations from the value 3.17 of the specific gravity (S_1) in that part of the core which does not consist of magnetite. For the fairly numerous samples of skarn iron-ores with actinolite and tremolite the value of S_1 (see p. 25) is about 3.0, and in those cases where talc, and above all limestone, is the dominant rock material in the core samples, S_1 can be another few tenths lower.

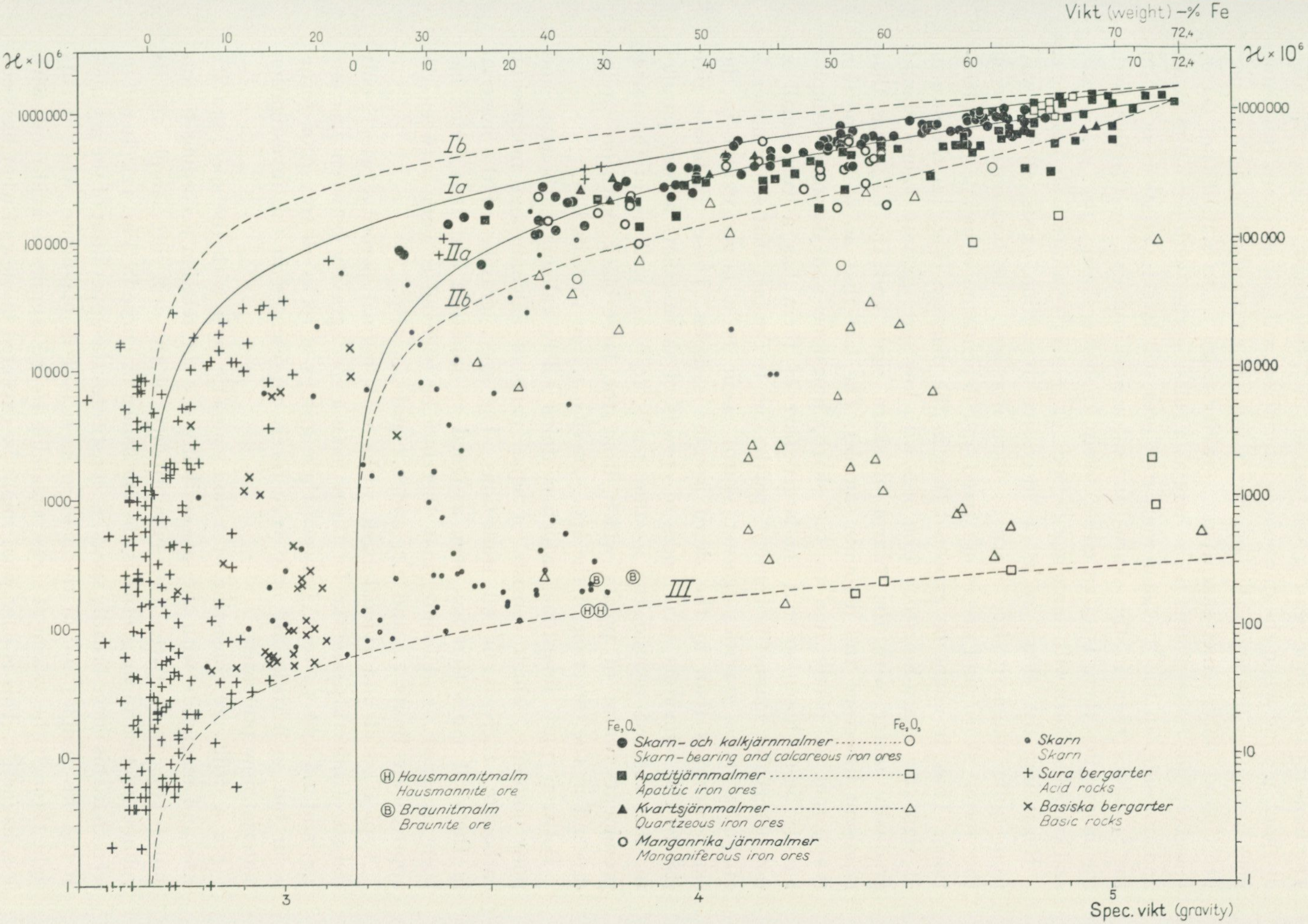

Fig. 12. The diagram includes all core samples of the main table. The spec. gravity is set off in linear scale, $\varkappa$ in logarithmic. The two scales, which indicate the weight % Fe, refer to core samples which besides magnetite contain rock material of the spec. gravity 2.67 an 3.17 respectively.

The numerous diopside-bearing samples, on the other hand, have an S_1-value of about 3.3 and when the diopside is intermixed with garnet skarn this value may be another few tenths higher. Skarn iron-ore cores, which besides magnetite contain only garnet skarn (spec. gravity from 3.5 to 4.2), do not occur, however, but these skarns occur here as a rule together with actinolite skarn and diopside. In the manganiferous iron ores still larger variations occur in the S_1-values than in the skarn- and calcareous iron-ores, for together with the magnetite there is often either solely knebelite skarn (spec. gr. = 4.0) and knebelite skarn with dannemorite (spec. gr. = 3.45) or almost only limestone.

Regarding the skarn rocks a successive transition exists all the way from quite magnetite-free skarn to skarn iron-ores. The boundary between the terms skarn and ore is not fixed and depends on economic considerations. Thus it might be expected that in the diagram (Fig. 12) the swarm of signs for skarn-limestone iron ores with low spec. gravity values should gradually merge with the swarm of skarn signs and the (+)-signs that represent limestone and dolomite samples. The fact that no such condition is apparent is partly due to the skarn, limestone and dolomite samples having been chosen so that the larger part of them has a very small or not observable magnetite content, partly due to the fact that skarn minerals of higher spec. gravities (garnet skarn) occur to a larger extent in the skarn samples than in the skarn iron-ore samples. These conditions give rise to the numerous occurrences of crowds of skarn points almost parallel to the abscissa around the $\varkappa$-value 100×10^{-6} as well as of the fairly prominent swarm of points which from the large black skarn ore circles descend in the direction of the spec. gravity 3.3 on the abscissa.

Between pure limestone, which contains solely calcium carbonate, and pure dolomite, which consists of equal parts of calcium and magnesium carbonate, there occur all transitions. The spec. gravity of the material in the drill cores that has been assigned as limestone and that which has been assigned as dolomite, may therefore be believed to vary between the approximate limits 2.7 and 2.8, and 2.8 and 2.9 resp.

Typical acid and typical basic rocks with normal porosity, which only consist of minerals essential for them, have a spec. gravity between 2.55 and 2.7, and 2.8 and 3.1 resp. Between these groups of rocks all transition forms occur but such rocks are only very rarely represented in the investigation material now presented.

For a drill core consisting of a non-magnetic rock with the spec. gravity 2.67 and magnetite with the susceptibility 1.5 the relation according to formulas (36, 37) between the susceptibility of the drill core sample and its volume fraction of magnetite is the one shown by curve Ia (Fig. 12). It will be seen that this curve broadly speaking constitutes the upper limit of the $\varkappa$-values of the ore samples and of the acid rocks richest in magnetite, while it cuts right through the swarm of signs pertaining to the samples of acid rocks with less magnetite. This is only what might be expected in view of what has been stated above regarding the spec. gravities of the materials contained in the samples and the K-values of the magnetite at different iron-ore deposits already obtained (see Table VI). If the susceptibility of an ore or rock had been directly proportional to the volume part of the magnetite contained in it ($\varkappa = Kv$), the dotted curve Ib instead of the curve Ia would have been the upper limit of the point distribution in the diagram. The fact that curves Ia and Ib coincide in the diagram on the steep part towards the abscissa from the $\varkappa$-value 1000×10^{-6} does not imply that Ia and Ib here have identically the same $\varkappa$-values for the same values of the spec. gravity but only that the curves approach each other so closely that they could not be separated in the drawing. In reality the $\varkappa$-values (see Table VII) corresponding to curve Ib for very low magnetite contents, are several times larger than those valid according to curve Ia for the same spec. gravity values.

For $K = 1.2$ and a non-magnetic mixed material with a spec. gravity of 3.17 the formula used for curve Ia gives curve IIa. As the mean value of K for all the values listed in Table VII (p. 64) that refer to apatitic iron-ores, skarn and calcareous iron-ores, and manganiferous iron-ores lies only a trifle above 1.2, it is thus to be expected that curve IIa will cut approx. straight through the magnetite signs of these ores in the diagram. It will be seen that this is actually the case except for the magnetite signs for the lowest spec. gravity values. This latter condition is, however, due to the fact that the boundary between the terms skarn ore and skarn is determined by the magnetite content or from a magnetic point of view by the $\varkappa$-value. The skarn ore notations for magnetite ores should thus, when they are uniformly used, end against a line parallel to the abscissa. This is almost the case in the diagram, where the boundary between the signs for skarn ore and skarn runs approximately at $\varkappa = 0.1$ (*i. e.* for about 20 weight % Fe). Due to these circumstances there is in the diagram an apparent lack of agreement between the course of curve IIa and the distribution of the magnetite signs for lower spec. gravities[1]. Curve IIb has been calculated according to the formula given by Puzicha (32 p. 53) for the same values of K and S_1 as those on which IIa is based. It is seen that curve IIb runs far below the notations for the majority of the magnetite ores and deviates quite considerably from the course of curve IIa. It thus appears as plainly as could be desired that Puzicha's formula can only be considered to represent the magnetization conditions at very low magnetite contents.

In summing up it can be said that the comparisons made above between the courses of curves Ia and IIa and the distribution of the points affords a further proof that the relation between the susceptibility of an ore or a rock and its magnetite content within the intervals $v = 1$ to about $v = 0.2$, with the accuracy which the present measuring results allow of, is shown by formulas (36, 37). On account of the scattering of the spec. gravity values of the rocks that is caused by other circumstances than the occurrence of magnetite, a com-

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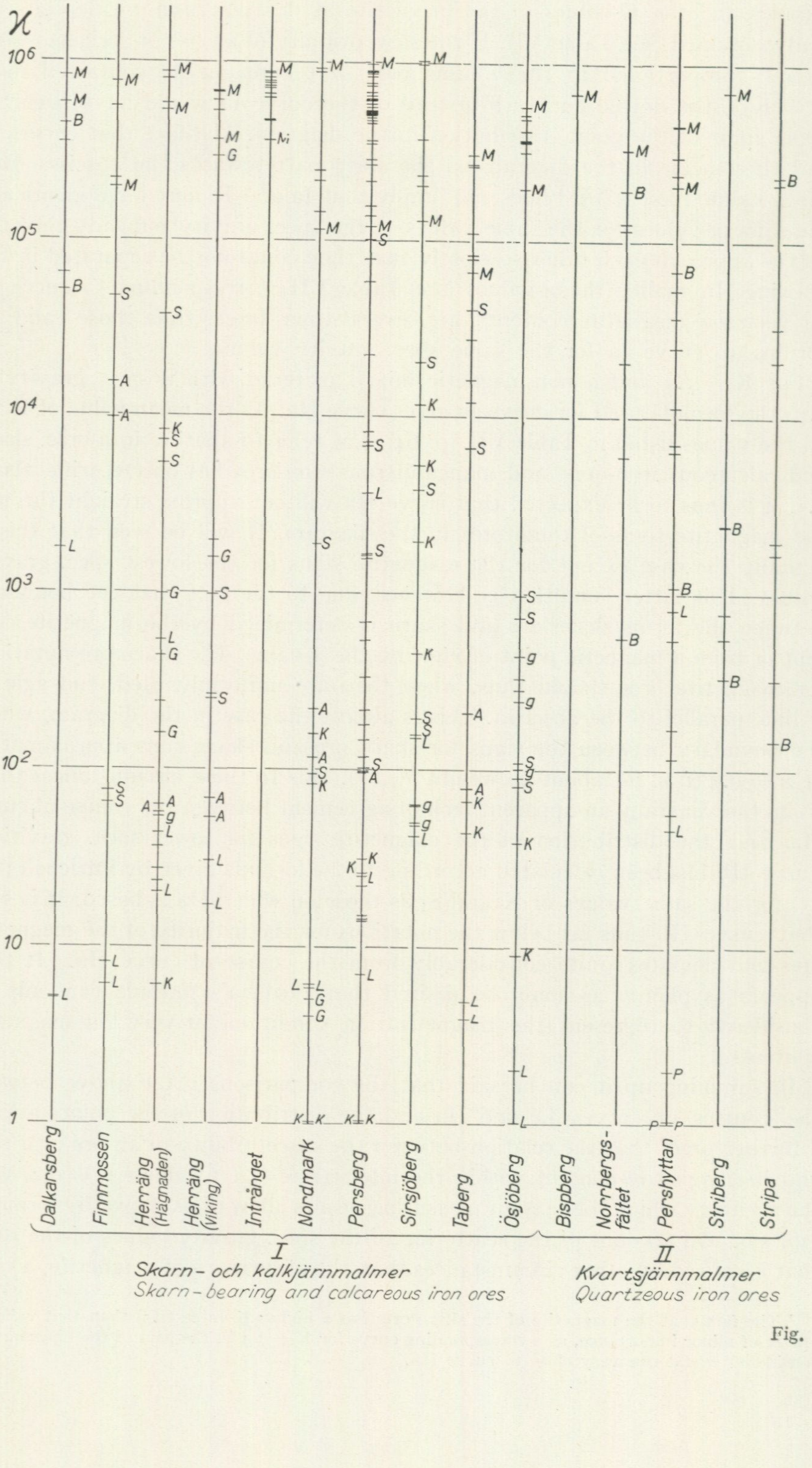
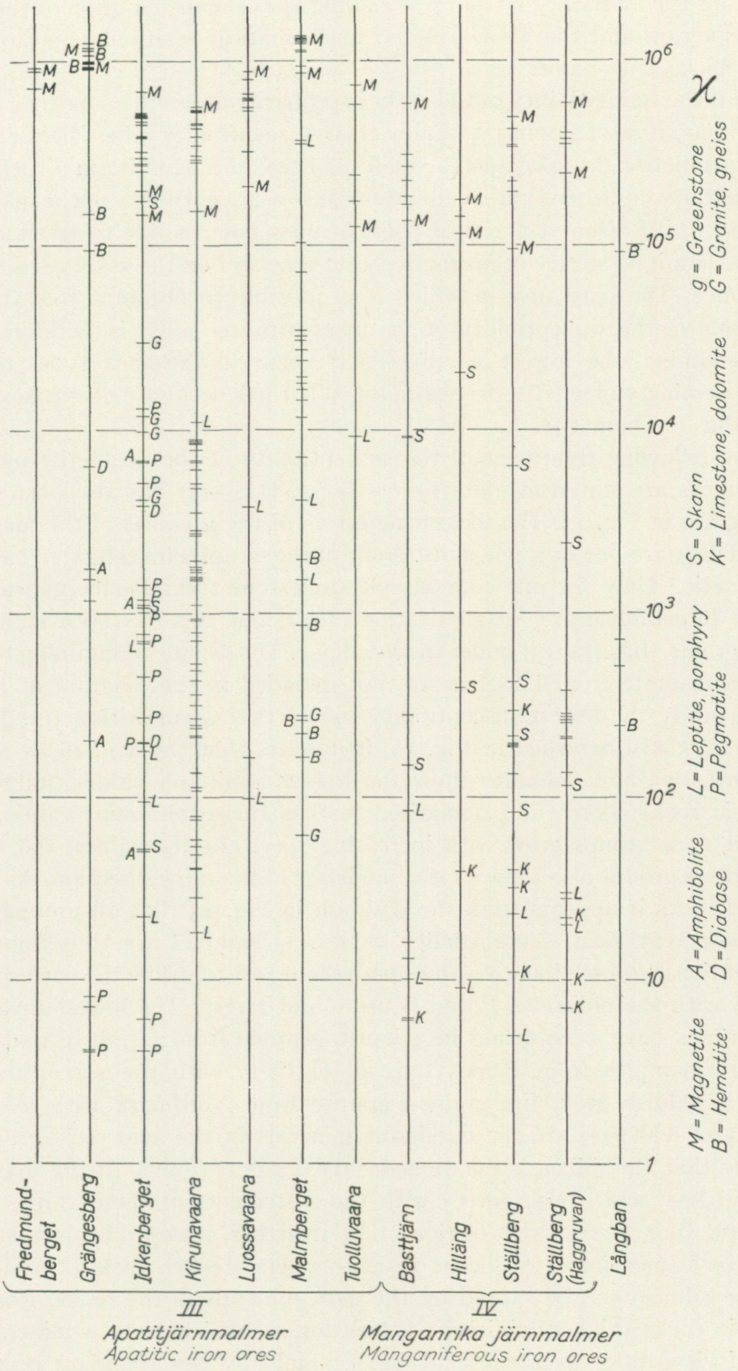
[1] The fact that the magnetite of the skarn ores has a higher K-value (1.5) than that valid for IIa is of minor importance, as a corresponding curve for $K = 1.5$ in the part of the diagram now considered would run very close to curve IIa.



$\varkappa$
10^6
10^5
10^4
10^3
10^2
10
1
Dalkarsberg
Finnmossen
Herräng (Hägnaden)
Herräng (Viking)
Intrånget
Nordmark
Persberg
Sirsjöberg
Taberg
Ösjöberg
Bispberg
Norrbergs-fältet
Pershyttan
Striberg
Stripa
M
B
S
A
K
L
G
g
Ni
P
I
Skarn- och kalkjärnmalmer
Skarn-bearing and calcareous iron ores
II
Kvartsjärnmalmer
Quartzeous iron ores

Fig.


Fredmund-berget
Grängesberg
Idkerberget
Kirunavaara
Luossavaara
Malmberget
Tuolluvaara
Basttjärn
Hilläng
Ställberg
Ställberg (Haggruvan)
Långban
III
Apatitjärnmalmer
Apatitic iron ores
IV
Manganrika järnmalmer
Manganiferous iron ores
1
10
10^2
10^3
10^4
10^5
10^6
$\varkappa$
M = Magnetite
B = Hematite
A = Amphibolite
D = Diabase
L = Leptite, porphyry
P = Pegmatite
S = Skarn
K = Limestone, dolomite
g = Greenstone
G = Granite, gneiss
M
B
A
D
L
P
S
K
G

parison for the interval v = 0 to v = 0.2 between the distribution of the points in the diagram and the above quoted mathematical relations is so uncertain that it lacks true value.

Even if the susceptibility of the rocks is primarily determined by their magnetite content, it is of interest to know their susceptibility when they are quite free of magnetite. As even such a small quantity of magnetite in a rock as one thousandths volume part can be found to cause a susceptibility of the magnitude 250×10^{-6}, it is from a practical point of view not possible to select samples, that are definitely so free of magnetite, that its effect on the $\varkappa$-values is without importance. The only way in which it is possible to obtain a tolerably true conception of the susceptibility of the magnetite-free rocks is therefore to critically examine the lowest $\varkappa$-values that occur in different types of rocks among seemingly magnetite-free samples. What has been said above is of course also valid for hematite.

In the following treatment of the susceptibility of the magnetite-free rocks the $\varkappa$-values are stated in units 10^{-6} C G S. This unit has also been used in the diagram in Fig. 13. The measuring errors of the $\varkappa$-values of the magnitude 10^2 and less are one or a few units. None of the samples investigated have been diamagnetic.[1] Only for one core sample (limestone from Persberg) was it impossible to establish any magnetization effect, but this has been included in the diagrams (figs. 12, 13) under the $\varkappa$-value 1. The samples containing braunite and hausmannite from Långban are not included in the diagram in Fig. 13.

If we study the lowest susceptibility values that occur within the different rock groups distinguished in Fig. 12, it appears that the acid rocks together with limestone and dolomite show the lowest minimum values, followed by the basic rocks, skarn and hematite. Just as these minimum values of the different rock groups grow with increasing spec. gravity values, the samples within these groups also show a clear tendency in the same direction. As regards the acid rocks it appears from the diagram in Fig. 13 that all groups of this kind show very small susceptibility values. 13 samples are thus found with the notation L, which have $\varkappa$-values between 0 and 10, while the corresponding number with the notations P and G are 9 and 2 resp. The lowest $\varkappa$-values in these groups have been found in a leptite sample from Ösjöberg and in two pegmatite samples from Pershyttan, all of them with the susceptibility 1, and in a reddish grey, fine-grained granite from Nordmark with $\varkappa = 4$. As quartz and feldspars are the dominant minerals in the acid rocks, it is thus probable that the minerals mentioned have a susceptibility of the magnitude 1 or still less, which also agrees with the statements of these values in the literature. It is further also obvious that if higher susceptibility values than those above mentioned do occur in acid magnetite-free rocks, this increase in the $\varkappa$-values must be caused by the dark minerals in the rocks. Regarding the basic rocks (higher minimum values for $\varkappa$), which from a mineralogical point of view differ from the acid rocks mainly by the abundant occurrence of dark minerals at the expense of the quartz content, the dark minerals must

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[1] In the literature it is stated that *e. g.* quartz and calcite are diamagnetic.

in like manner be decisive for the magnitude of the susceptibility. A quantitative expression for the influence of these minerals on the susceptibility of the rocks can, as will be shown in the following, be obtained by comparisons with the magnetization effect of other paramagnetic rocks.

In a hematite ore, which besides hematite (β-form) only contains, in relation to this, non-magnetic rock material, the susceptibility should be directly proportional to the volume fraction of hematite. According to my determinations on synthetically produced hematite[1] in pulverized form, the volume susceptibility ($\varkappa$) of compact hematite is 300, this assuming that the spec. gravity of this is 5.20. Assuming that this susceptibility value is valid also for the natural hematite deposits and if an expression is used for the volume fraction of hematite corresponding to formula (27, p. 25), the following expression is obtained for a magnetite-free hematite ore, where the non-magnetic material has the spec. gravity 2.67 (corresponding to the conditions in the quartzeous iron ores):

$$\varkappa = \frac{S - 2.67}{5.20 - 2.67} \times 300 \backsim 120\ (S - 2.67) \quad (\text{unit } 10^{-6}\ \text{C G S}), \qquad (41),$$

where S indicates the spec. gravity of the ore sample. The dotted curve (III) in the diagram (Fig. 12) is calculated according to this formula. It will be seen that most of the signs for hematite ores are far above this curve, but this is only to be expected, partly because the hematite notations have also been used for many samples mainly consisting of magnetite ore (see p. 68), partly because the Swedish hematite ores generally contain larger or smaller quantities of magnetite. Two samples, one a hematite ore from Malmberget with impregnation remnants of leptite and scattered actinolite, the other a quartz-banded and skarn-striped hematite core from Stripa, fall below curve III in the diagram. It does not appear, however, as if the occurrence of skarn, even if this is supposed to be quite non-magnetic, is sufficient to explain this circumstance.

It is particularly remarkable that according to the distribution of the points in the diagram (Fig. 12) also the minimum limit for the susceptibility of the skarns as well as the basic rocks seems to coincide with curve III. Just what is the position of the acid rocks in this respect does not appear quite clearly in the diagram, as limestone and dolomite are marked with the same signs as the rocks first mentioned. A closer examination discloses, however, that all (+)-signs below curve III refer to limestone samples, except two, which refer to a metamorphosed leptite from Dalkarlsberg and a leptite with some garnet skarn from Basttjärn (spec. gravity 2.73 and 2.83 resp.; $\varkappa = 5$ and 13 resp.). In these two cases $\varkappa$-values are obtained according to the formula (41), which are 2 and 6 units higher than the measured values. Further it deserves to be mentioned that the two hausmannite samples from Långban

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[1] The hematite grains were produced by B. Mason and kindly lent to me in connection with his investigations of the system $FeO - Fe_2O_3 - MnO - Mn_2O_3$ (6).

have susceptibility values, which lie on curve III, while the values of the braunite samples lie about 100 units above this.

If formula (41) has full validity for samples from different rock groups, it is obviously aslo valid for samples where rocks from different rock groups are intermixed. Thus it ought to be possible to use this formula for *e. g.* a limestone containing skarn, if the spec. gravity 2.67 is exchanged for the spec. gravity of the limestone.

If formula (41) is strictly valid for all the paramagnetic rocks treated above, this would mean that it also possesses validity for each separate mineral they contain. This does not seem to be probable in view of the complicated conditions that prevail in the paramagnetism of other compounds (see *e. g.* 14). Formula (41) should therefore only be attributed a limited signification, but in any case it seems to give a good conception of the lowest susceptibility values that appear in hematite ores (possibly also in the hasumannite and braunite ores), the skarns and the basic and acid rocks at the Swedish iron-ore fields.

The results that have appeared in the foregoing regarding the susceptibility of ores and rocks within the Swedish iron-ore fields may be summed up in the following way:

For magnetite ores

$$\varkappa = \frac{\mathrm{Kv}}{1 + \mathrm{C\,Kv}} \quad \ldots\ldots\ldots\ldots \quad (36)$$

For hematite ores (possibly also hausmannite and braunite ores), skarn, basic and acid rocks, limestone and dolomite

$$\varkappa = \frac{\mathrm{Kv}}{1 + \mathrm{C\,Kv}} + 120 \times 10^{-6}\,(\mathrm{S} - \mathrm{S_1}). \quad \ldots\ldots \quad (42)$$

K indicates the susceptibility and v the volume fraction of the magnetite, that is present in the ores and the rocks, and C may be considered an internal demagnetization factor. For this the following expression can be used in the case of magnetite ores:

$$\mathrm{C} = \frac{4}{3}\pi\,\frac{1 - \mathrm{v}^{1/6}}{\mathrm{v}}, \quad \ldots\ldots\ldots\ldots \quad (37)$$

but, at least for lower magnetite contents than those occurring in them, this ought to be replaced by the formula

$$\mathrm{C} = \frac{4}{3}\pi\,\frac{1 - \mathrm{v}^{\frac{2 - \mathrm{v}^{1/6}}{6}}}{\mathrm{v}}. \quad \ldots\ldots\ldots \quad (40)$$

S indicates the spec. gravity of that part of a rock, which does not consist of magnetite, $\mathrm{S_1}$ the spec. gravity of that part, which consists of quartz, feldspar, limestone and dolomite.

In the groups skarn-bearing and calcareous iron-ores and quartzeous iron-ores the susceptibility of the magnetite shows relatively small variations with a mean value for K of 1.5 for the first-mentioned and 0.9 for the last-mentioned group. In the apatitic iron-ores and the manganiferous iron-ores on the other hand, the variations in the K-values are very considerable (0.56 to 1.57 and 0.67 to 1.74 resp.), so the means for K (1.03 and 1.20 resp.) obtained for these two iron-ore groups as a rule far from represent the individual ore deposits. The susceptibility of a skarn-bearing and calcareous iron-ore or a quartzeous iron-ore may thus broadly speaking be considered known if only the magnetite content is known. For an apatitic iron-ore or a manganiferous iron-ore the susceptibility of the magnetite contained must as a rule be determined to allow of a reliable estimation.

The influence that the paramagnetic constituents of a rock have on its susceptibility is only visible when the magnetite content in the rock does not exceed one or a few volume %, so the second term in formula (42) may otherwise be disregarded. The lower the magnetite content of a rock the more independent is its susceptibility of the variations in the K-values of the magnetite.

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Mr P. V. Villner Min. E. has in his capacity of research engineer at the Technical Department of the Swedish Ironmasters' Ass. carried out a large part of the measurements and has done these with great care and accuracy. The English translation of this paper has been done by Dr E. Ygberg. For this and other help in connection with the printing I wish to express my sincere thanks. Finally I want to express my thanks to all those at the mines who have placed drill core material at my disposal.

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