NORGES GEOLOGISKE UNDERSØKELSE NR. 168b

# FLÅT NICKEL MINE

BY

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11 FIGURES AND 2 MAPS

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# Contents.

## Preface.

The author has worked as consulting geologist for Raffineringsverket A/S at the Flåt mine and other nickel ore deposits in the neighbourhood together with Dr. C. W. Carstens from 1939.

I wish to express my gratitude to Dr. Carstens and the mining company which have kindly placed at my disposal all results from the production work of the mine and from our investigations.

I especially want to thank the director S. Giertsen and the mining engineers B. Thorkildsen, S. Smith Meyer, and Gjøsteen for their interest and help.

The laboratory investigations have been carried out by the author by means of grants given by Norges Tekniske Høgskoles Fond.

Most of the photographs have been carried out by preparator Anker Iversen, and the drawings by Mrs. Singsås, Trondheim.

# Introduction.

The Flåt nickel mine is situated in the parish of Evje on the northern slope of the hill Mykleåsen, 65 km north of Kristiansand in southern Norway and about 400 m above the sea level. The distance from the melting plant near Evje railway station is about 6 km.

In the Iveland-Evje amphibolite area which has been geological and petrographical described by Tom Barth in the first part of this paper [1] there also occur many small deposits of nickel ore near the Flåt mine at Lomtjern, Byttingsmyr, Vikstøl, Gullregn, and Bjorvatn. Farther south, in Iveland, small deposits are known at Orreknappen and Bekken near Birkeland, at Mølland and Skripeland.

All of these deposits have recently been carefully investigated, some of them by means of electrical survey and diamond drilling, with negative results, all of them being to small and poor for economical mining. In some of these deposits small amounts of ore has been mined in previous periods and the ore transported to the smelting plant at Evje.

The ore deposit at Flåt was found in 1870 and the mine has been worked continuously since 1872—1945 with exception of the periods 1894—99 and 1920—27. The mine is now exhausted and the production was laid down the 1st January 1946 while no more ore was available in the mine and the extensive investigations carried out by the mine company in the last 15 years both in the mine and in the surrounding areas have not succeeded in finding any new ore.

Before 1917 the mine produced a smelting ore with 1¼ % —1½ % Ni and 1 % Cu. 1.8 t raw ore gave 1 t smelting ore.

[1] N. G. U. 168 a.

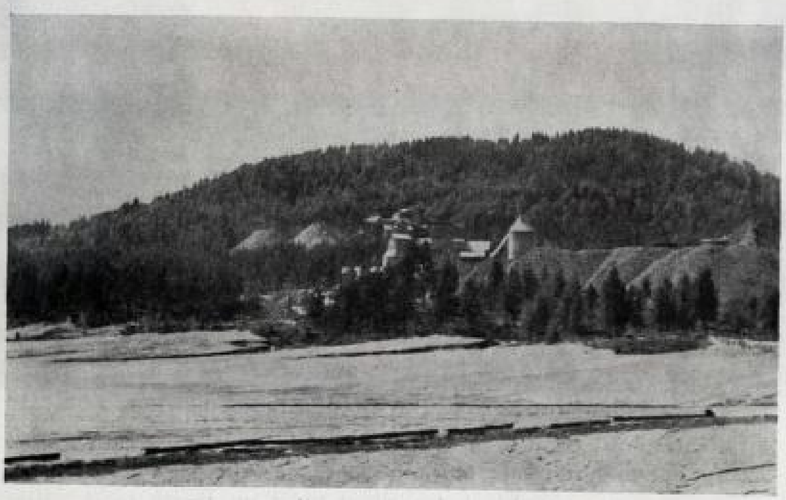

Fig. 1. Flåt nickel mine. From north.

In 1917 a flotation plant with a capacity of 1500 t a month was builded. In 1927 the plant was rebuilded for a capacity of 4500 t a month and in 1929 for 15 000 t a month.

Table 1.

*Production statistic of the Flåt mine in the periode 1927—44.*

| Year | Length of diamond drilling in m. | Raw ore t | Ni % | Cu % | Cu/Ni |
|---|---|---|---|---|---|
| 1927 .................. | | 17 360 | 0.892 | 0.582 | 0.65 |
| 1928 .................. | | 68 164 | 0.974 | 0.591 | 0.61 |
| 1929 .................. | | 70 771 | 0.954 | 0.636 | 0.61 |
| 1930 .................. | | 106 402 | 0.884 | 0.577 | 0.65 |
| 1931 .................. | | 77 342 | 0.898 | 0.584 | 0.65 |
| 1932 .................. | | 148 240 | 0.875 | 0.582 | 0.65 |
| 1933 .................. | 441.08 | 146 051 | 0.812 | 0.513 | 0.63 |
| 1934 .................. | 824.17 | 147 292 | 0.750 | 0.524 | 0.70 |
| 1935 .................. | 1 606.23 | 156 336 | 0.634 | 0.475 | 0.75 |
| 1936 .................. | 1 835.18 | 166 809 | 0.610 | 0.448 | 0.73 |
| 1937 .................. | 1 234.38 | 100 346 | 0.631 | 0.471 | 0.74 |
| 1938 .................. | 2 153 83 | 189 506 | 0.588 | 0.409 | 0.69 |
| 1939 .................. | 1 551.37 | 153 450 | 0.577 | 0.403 | 0.70 |
| 1940 .................. | 764.96 | 163 799 | 0.538 | 0.404 | 0.75 |
| 1941 .................. | 700.95 | 118 200 | 0.581 | 0.419 | 0.74 |
| 1942 .................. | 527.28 | 112 107 | 0.614 | 0.428 | 0.70 |
| 1943 .................. | 669.60 | 100 193 | 0.606 | 0.412 | 0.68 |
| 1944 .................. | 576.86 | 94 953 | 0.553 | 0.372 | 0.67 |
| Sum 1927—44...... | 12 885.89 | 2 137 343 | 0.690 | 0.475 | 0.688 |

In the periode 1932—1940 the flotation plant produced about 30 000 t concentrate a year, with 3—4 % Ni and near 3 % Cu. The concentration was about 5.7 and the effiency of the flotation was about 82 % for Ni and 90 % for Cu.

# I. The Ore Minerals.

The only primary sulphidic minerals in the nickel ores of Iveland-Evje are according to their sequence of crystallisation:

Pyrite ($FeS_2$).

Pyrrhotite ($Fe_n$ $S_{n+}$)

Pentlandite (Fe, Ni S).

Chalcopyrite (Cu Fe $S_2$).

No primary minerals which indicate a low temperature formation of the deposits have been observed.

Arsenic-bearing minerals have never been encountered. As secondary minerals millerite (Ni S) and violarite occur in some parts of the deposit a Flåt.

The oxydic ore minerals are magnetite ($Fe_3O_4$) and ilmenite ($FeTiO_3$) with lamellae of hematite ($Fe_2O_3$). Magnetite seems to belong to the silicate phase and has not been observed imbedded in sulphidic ore minerals. Ilmenite on the oher hand has in some samples been found imbedded in pyrrhothite. Both magnetite and hematite also occur as secondary minerals together with millerite near the ore contact against granite pegmatites.

## The Pyrite.

The pyrite of the nickel ore deposits in Iveland-Evje differs from the pyrite of the Norwegian pyrite ores by its crystal habit. The pyrite of the nickel ores is the first crystallized sulphidic mineral and generally developed in well defined crystals which always show the faces of the octahedron (111), the corners of which some times are cut off by the faces of the cube (100), while the crystals of the Norwegian pyrite deposits are developed as cubes or pyritohedron. (Figs. 2, 3.) The pyrite of the granite pegmatites of the district however has a similar crystal form as in the nickel ore deposits. If the temperature

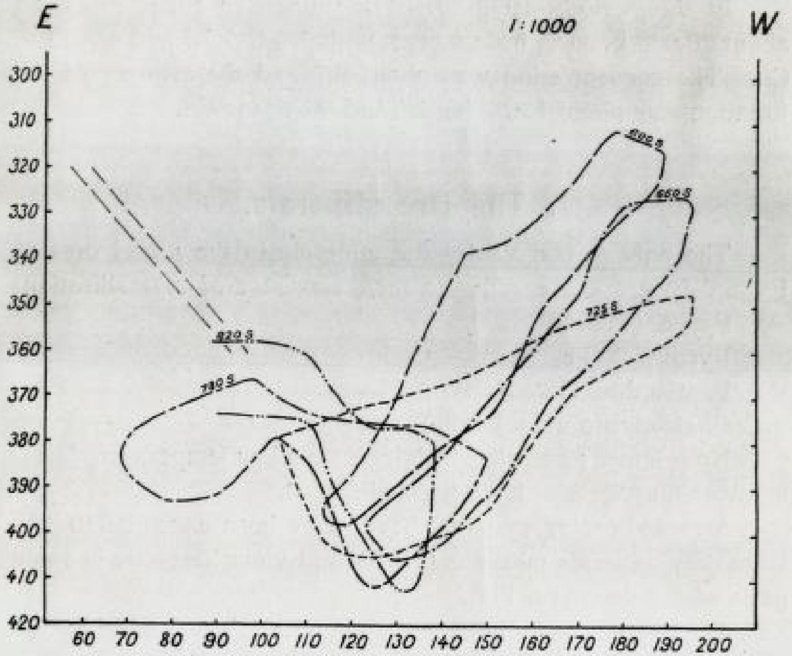


Fig. 2. Vertical sections of the ore in direction E—W in the southern part of the Flåt mine.

should be the chief factor for the development of the crystal form, this should be in good accordance with the temperature of 600° which has been mentioned by W. H. Collins as the probable temperature of the solidification of the nickel ores at Sudbury (7, p. 35).

As previously published by Bjørlykke (3) X ray spectrogramms of the pyrite from Norwegian nickel ores show considerable contents of Cobalt. In Table 2 are given the X ray spectral analyses of pyrites from the nickel ore deposits in the Iveland-Evje area.

Analyses of 7 different samples of pyrite from the Flåt mine show that the content of cobalt differs from 0.60—1,00 % with an average of 0.77 %. Analyses of samples from the outer and inner part of one crystal from this deposit gave the same value for the content of Co and thus shows that a homogenous compo-


Fig. 3. Ore, Flåt mine. Crystall of pyrite (Py) imbedded in pyrrhotite (Ph) and violarite (V), Q quartz. Pol. sec. ord. light 90 ×.

Table 2.

*X ray analyses of pyrite of the nickel ore deposits in the area Iveland-Evje.*

| | | Co % | Intensities of Ni $k\alpha_1$ | Cu $k\alpha_1$ |
|---|---|---|---|---|
| | Flåt mine: | | | |
| 1. | Octaedral crystals of pyrite | 0.62 | 0 | 0 |
| 2. | Pyrite in fine-grained rich ore | 0.60 | 0 | 0 |
| 3. | — without crystall outlines | 0.92 | weak | weak |
| 4. | — in fine-grained ore | 1.00 | 0 | 0 |
| 5. | — in poor impregnation | 0.88 | strong | 0 |
| 6. | — ore, level 402 | 0.60 | 0 | 0 |
| 7. | — without crystall outlines | 0.80 | 0 | 0 |
| | Ore deposits in Iveland: | | | |
| 8. | Pyrite (111) (100), Lomtjern | 0.55 | 0 | 0 |
| 9. | — with inclusions of chalcopyrite Lomtjern | 0.47 | 0 | strong |
| 10. | — Large crystall, Paascheskjerpet | 0.87 | 0 | 0 |
| 11. | — octaedral chystalls imbedded in pyrrhotite, Mølland | 0.87 | weak | 0 |
| 12. | — large crystall, Orreknappen | 0.98 | 0 | strong |
| 13. | — — — | 1.00 | 0 | 0 |

sition of the crystal. Of the analyses of pyrites from other deposits in the area, the pyrite from the Lomtjern deposit shows the lowest content with 0.47 % Co.

The pyrites from the nickel ores in this way differs from those from the Norwegian pyrite deposits which according to analyses given by C. W. Carstens (6) only contain 0.01—0.1 % Co. Analyses of pyrites from Norwegian magmatic granite pegmatites however show contents of Co around 0.3 %. Besides the similarity in the development of the crystals, the relative high content of Co in both types of deposits may indicate a similar temperature of solidification.

Some of the samples of pyrite showed lines of Ni and Cu which seemed to belong to inclusions of other minerals. In most of the samples however, no lines of Ni K$\alpha$, were visible indicating a content of Ni less than 0.01 %. Nickelliferous pyrites as described from South African nickel ore deposits by P. A. Wagner (19) and others have not been encountered in the nickel ore deposits of this area.

## The Pyrrhotite and Pentlandite.

The pyrrhotite is the most abundant sulphidic mineral in the nickel ores.

Usually the pyrrhotite occurs in finegrained masses, in some parts of the ores however it is rather coarse and with a somewhat darker brown colour. The pyrrhotite always occur together with pentlandite.

Most of the pentlandite builds small granular stringers around pyrrhotite grain boundaries and along fissures in this mineral. These often seem to replace the pyrrhotite and are distinctly younger than this mineral. (Figs. 4 and 5.) Small amounts of pentlandite also occur as oriented blades, lenses and flakes whithin the pyrrhotite crystals and seems to be formed by unmixing of a solid solution. (Fig. 6.)

Many attemps have been made to extract the fine pulverized pyrrhotite from the pentlandite by means of a magnet, but X ray spectrograms of the two fractions have always shown that it is impossible to get a real separation of the two minerals in this way.

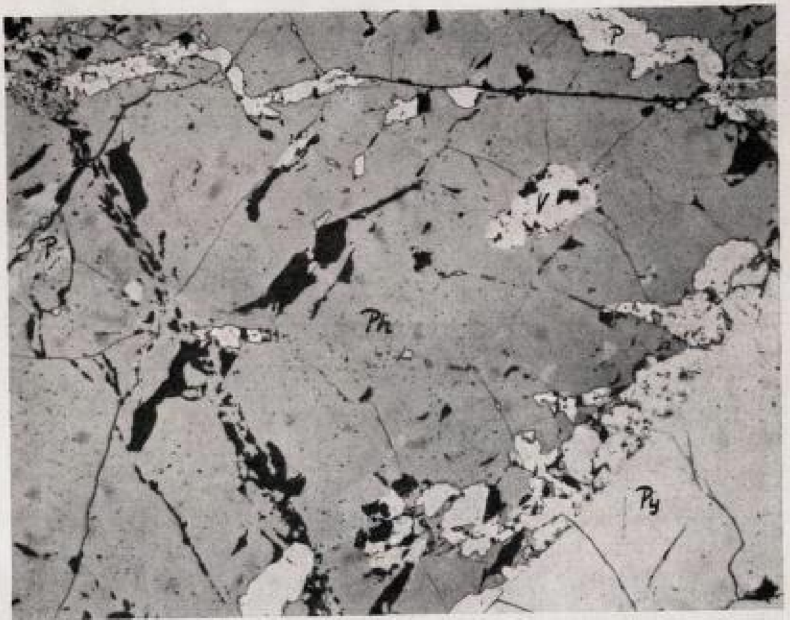


Fig. 4. Ore, Flåt mine. With pyrite (Py), pyrrhotite (Ph), pentlandite (P), and violarite (V). Pol. sec. ord. light 90 ×.



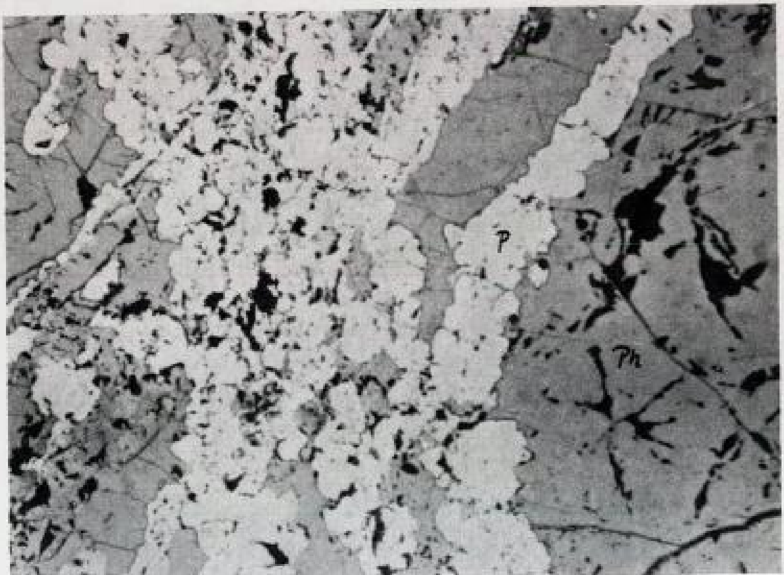


Fig. 5. Ore, Flåt mine. Fissure fillings of pentlandite (P) in pyrrhotite (Ph). Pol. sec. ord. light 90 ×.

The relation Ni : Co in pentlandite-bearing pyrrhotite, determined by means of the relative intensities between the Ni k$\beta$, and Co k$\alpha$, lines in the X ray spektrograms was found to be about 80 : 1. The quotient Ni : Co is thus higher than in the Sudbury ore where the same relation has been determined by C. W. Dickson (8) to be 41 : 1.

No distinct difference was found in the ratio between the unmagnetic fraction which consisted chiefly of pentlandite and the magnetic fraction with small content of pentlandite.

## Violarite.

In the ore samples from Mølland, nearly all of the pentlandite is converted into a rose coloured mineral which seems to be identical with a mineral described as violarite $(NiFe)_3S_4$) by M. N. Short and Earl V. Shannon (19). In many of the violarite grains small remeniscenses of pentlandite are visible (Figs. 9 and 10). Violarite has also been observed in some ore samples from the Flåt mine, especially near the contact against younger granite pegmatite veins. (Figs. 7 and 8.)

## Millerite.

(NiS) also occurs as a secondary mineral in some parts of the Flåt ore and previously been described by the author (2). It has not been observed in ore samples from the other nickel ore deposits of the area.

The millerite occurs in a special ore type which consists chiefly of hematite and magnetite with millerite and small amounts of pyrite, chalcopyrite and violarite. This ore type has been formed by hydrothermal metamorphism of the usual ore at the contact against younger granite pegmatites.

The millerite in the Flåt ore exhibits an unusual crystal form as short-prismatic crystals. It was identified as millerite by means of Debye-Sheerer diagrams. In polished sections the mineral is easely identified under the microscope by being distinctly anisotropic. Millerite of supergen origin has not been found in this area.


Fig. 6. Ore, Flåt mine. Pyrite and blades of pentlandite (P) in pyrrhotite (Ph). Pol. sec. ord. light 500 ×.

### Chalcopyrite.

The chalcopyrite is the latest sulphidic mineral in the nickel ores of the area. In polished sections under the microscope it is often seen to replace other sulphidic minerals, especially the pyrrhotite. It is also often observed filling fissures in the surrounding silicate minerals. X ray spectrograms of the chalcopyrites do not show any characteristic minor constituents.

### Ilmenite and Hematite.

In some types of pyrrhotiterich ore from Flåt mine ilmenite occur as well defined crystals imbedded in pyrrhotite. Polished sections under the microscope exhibit small lenses of hematite

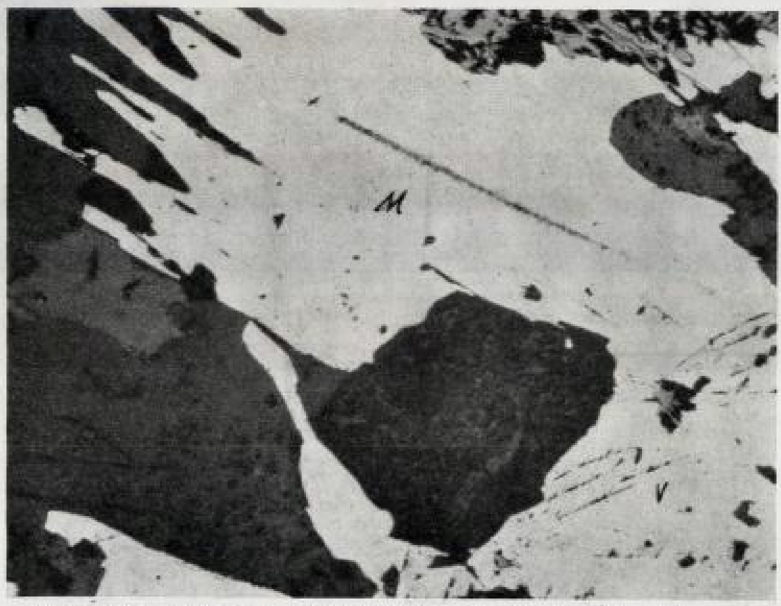


Fig. 7. Ore, Flåt mine. Millerite (M) and violarite (V). Pol. sec. ord. light 90 ×.

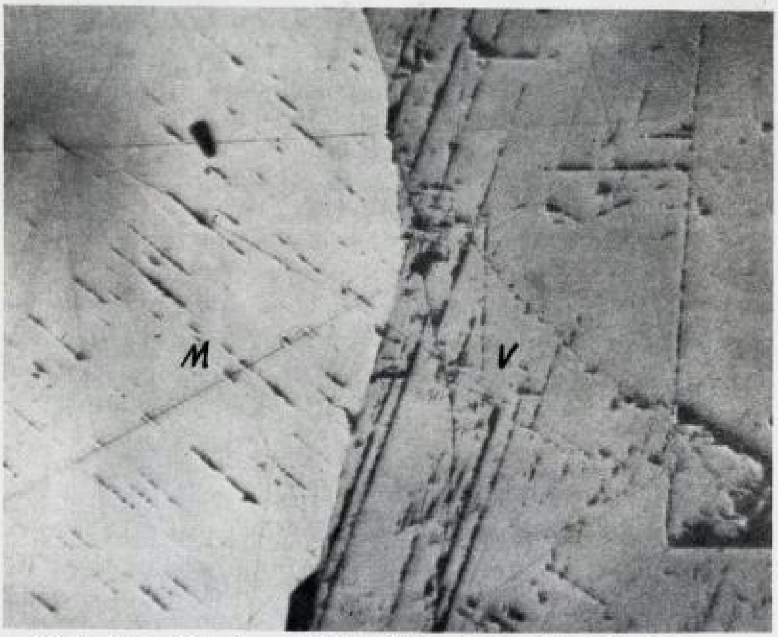


Fig. 8. Ore, Flåt mine. Millerite (M) and violarite (V). Pol. sec. ord. light 500 ×.

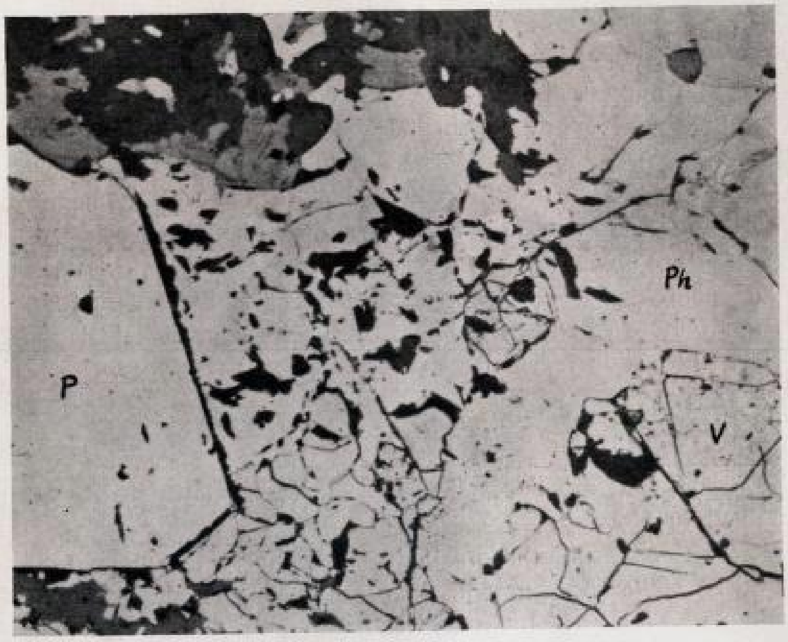


Fig. 9. Ore, Mølland. Pyrite and pyrrhotite with violarite (V) containing rests of pentlandite (white spots). Pol. sec. ord. light 90 ×.

within the ilmenite crystals. An X ray spectrogram showed no characteristic minor constituents.

Secondary formed hematite occurs together with millerite near the ore contact against granite pegmatites.

## Magnetite.

Magnetite with microscopical lenses of ilmenite occurs aboundantly in the gabbro rock and among the silicate minerals in the ore but has never been observed imbedded in sulphidic minerals. Magnetic extractions of the waste from the sulphidic flotation show that the raw ore from the Flåt mine contains an average about 8 % magnetite. X ray spectral analyses of nearly pure magnetite from this fraction showed a content of about 1 % Ni. The nickel in the waste from the sulphide flotation is therefore mostly present as a substitute for iron in the magnetite. The X ray spectrograms of the magnetite concentrate also show small amounts of Cr.

### Apatite.

The average content of phosporic acid in the raw ore of the Flåt mine is about 1.7 % $P_2O_5$ corresponding to about 4 % apatite. As Norway during the last war was without any supports of phosphoric acid for agricultural use, attempts were made to make use of this apatite content of the ore. By means of flotation of the waste from the sulphidic flotation it was possible to produce a concentrate with 28—30 % $P_2O_5$. This concentrate also contained 1—1.1 % S and 6—7 % Fe and was used for the manufacture of superphosphate by the Lysaker chemical plant. The production reached the last years 3000 t. a year.

## II. The Ores.

The Flåt nickel ore deposit is the largest which has been mined in Norway.

The shape of the ore body is shown by the maps (Pl. 1 and 2). The upper part of the ore has a very regular flattened elongated form which strikes NE, dipping 45° to SE. The length of the ore body in the direction of the strike is 100 to 150 m and the horizontal thickness varies from 15—30 m. The axis of the ore dips 45° to the south. From the 282 m level and downwards, however, the ore body gradually flattens out and the vertical thickness increases to a maximum of nearly 100 m. As indicated in the vertical profils 780 S and 820 S (Fig. 2) the ore in the southern part of the mine seems to split into two bodies. The western of these is situated about 20 m lower than the eastern. The total length of the ore along the ore axis is about 900 m.

The ore body chiefly consists of impregnated silicate rocks which have been petrographically described by Tom Barth in the first part of this paper.[1]

As an average the mined ore consists of about 75 % silicate minerals 12—13 % sulphides, about 8 % magnetite and 4 % apatite. In all the Flåt mine has produced about 2.7 mill. t. raw ore with an average content of about 0.72 % Ni and 0.48 % Cu. During the last periode of production fra 1927—44 the Flåt

[1] N. G. U. 168 a.

Fig. 10. Ore, Mølland. Pyrrhotite with violarite and rests of pentlandite (P). Pol. sec. ord. light 500 ×.

mine has produced about 2 mill. t. raw ore with an average content of 0.69 % Ni and 0.475 % Cu. In the same periode 12 885.89 m of diamond drill holes have been carried out in the mine and its near environments. The production and content of Ni and Cu together with the lenght of the drill holes for each year is given in Table 1.

The Table demonstrates that the average composition of the ore does not differ very much from year to year. The content of Ni in the raw ore decreases very slowly from values up to 0.95 % Ni in the first year to 0.55 % Ni in the last year 1944. At the same time the content of Cu in relation to the Ni is a little higher in the last years of the period. A study of the ore in the mine shows however that the ore is very different in the different parts of the ore body. The lumps of ore mined differ in composition from nearly 100 % sulphides to dioritic rocks only

Table 3.

*Analyses of diamond drill cords.*

| | Content of Ni | Number of analyses | Ni | Cu | Average content of: S | Cu/Ni | $S\text{-}S_{Ch}/Ni$ |
|---|---|---|---|---|---|---|---|
| Flåt: | | | % | % | % | | |
| Rich ore ...... | 1—2 % | 26 | 1.23 | 0.67 | 11.55 | 0.55 | 8.9 |
| Usual ore ... | 0.5—1 » | 44 | 0.68 | 0.48 | 5.32 | 0.71 | 7.1 |
| Poor ore ... | <0.5 » | 46 | 0.28 | 0.22 | 5.57 | 0.79 | 19.1 |
| Mølland: | | | | | | | |
| Rich ore ...... | 1—2 » | 7 | 1.03 | 0.13 | 6.10 | 0.13 | 5.8 |
| Usual ore ... | 0.5—1 » | 4 | 0.78 | 0.24 | 4.86 | 0.31 | 5.9 |
| Poor ore ... | <0.5 » | 35 | 0.30 | 0.07 | 1.92 | 0.23 | 6.2 |
| Hydrothermalmetamorphosed milleritebearing ore Flåt: | | | | | | | |
| Rich ore ...... | 1—2 % | 12 | 1.27 | 0.68 | 1.68 | 0.54 | 0.78 |
| Poor ore ... | <1 » | 10 | 0.60 | 0.30 | 0.68 | 0.50 | 0.93 |

slightly impregnated with sulphides. The relation between pyrrhotite and chalcopyrite also varies widely in different parts of the ore while the relation pyrrhotite to pentlandite seems to be rather constant in different ore types in the same ore body. The great variation in the composition of the ore makes it impossible to pick out a sample representing the average ore composition. The only way to find out the average composition is studying the values in the mined ore during a certain period of production.

The distribution of the different ore types in the ore body seems to be quite unregular. The diamond drill records given in the last part of this paper of the holes 303, 314, 323, 324, 336, 371, 374, 382 and 384 give a picture of the irregular variation of the ore within the ore body.

To get a picture of the composition of the different ore types the analyses of the drill cores may be divided in groups according to their content of Ni. The average composition of these groups will in this way give the average of different ore types. Table 3 gives the results of the calculation of three groups of ore from the Flåt and the Mølland mines. The average composition of these groups shows that the quotient between the content of Cu and Ni increases with decreasing amounts of Ni, and at the same time the quotient of the amount of total sulphur minus the sulphur present in chalcopyrite ($S-S_{Ch}$) and the amount of Ni, also will increase. In other words *the poor nickel ores have a relative larger content of chalcopyrite than the rich ores.*

The usual ore analyses carried out by the chemical laboratory of the Flåt mine do not include the determination of iron. It is therefore impossible to calculate the relative amounts of the sulphidic minerals of the ore by means of these analyses. But at the smelting plant at Evje complete analyses have been carried out of the nickel ore concentrate from the flotation of the Flåt ore.

In a previous paper the author (3) have carried out such a mineral calculation and I found the following composition of sulphidic minerals in this concentrate:

| | |
|---|---|
| Chalcopyrite ........................... | 11.48 % |
| Pentlandite [1] ........................... | 14.44 » |
| Pyrrhotite ............................... | 70.77 » |
| Pyrite .................................. | 3.31 » |

This gives a ratio of 4.9 : 1 between pyrrhotite and pentlandite. However, the composition of the concentrate does not correspond exactly to that of the raw ore, for the concentrate is enriched in pentlandite. The ratio between pyrrhotite and pentlandite calculated from the analysis of a rich ore without pyrite from the Flåt mine was found to be 5.4 : 1.

The average content of Ni in the sulphides is about 4.5 %. X ray spectrograms of samples of the ground raw ore and the flotation concentrate from the Flåt mine showed that the quotient Ni/Co was 8 : 1 for the raw ore and 12 : 1 for the concentrate. The waste from the flotation must therefore be relatively enriched in Co.

From an analyzed sample of rich ore without pyrite from Mølland with 3.78 % Ni and 0.98 % Cu, the following composition of sulphidic minerals was calculated:

[1] The pentlandite is calculated with 34 % Ni according to analyses by J. H. L. Vogt (18).

| | |
|---|---|
| Chalcopyrite | 5.88 % |
| Pentlandite | 22.97 » |
| Pyrrhotite | 71.15 » |

According to this the ratio between pyrrhotite and pentlandite is 3.1 : 1 for the Mølland ore.

As previously published by the author (3) the amounts of pyrite and chalcopyrite are variable factors in the composition of the ore samples. The relation between the amount of pyrrhotite and pentlandite however seems to be constant in all types of ore in the same deposit. This relation may also be expressed as the quotient of the total sulphur minus the sulphur present in chalcopyrite and pyrite on one hand, and the amount of Ni on the other which can be expressed in the formula: $(S-(S_{Ch}+S_{P})):Ni$.

By means of this factor it is possible to calculate the amount of pyrite in an analyzed ore sample.

Analyses on Au, Pt, and Pd of the Flåt ore carried out in 1918 show according to S. Foslie and M. Johnson Høst (8) that ore with 1.00 % Ni and 0.65 % Cu contained 0.023 g Pt, 0.047 g Pd, and 0.111 g Au pr. t. According to this the Flåt nickel ore is relatively poor in platin metals.

## The Ore Deposit at Mølland.

The nickel ore deposit at Mølland in Iveland consists of many small ore bodies seggregated in a rock of noritic composition near the border against a gneiss flake. The deposit has been investigated by some small openings on the surface and a shaft 19.5 m deep with a crosscut of 50 m lenght. 16 diamond drill holes to a total lenght of 690 m have been drilled after indications found by electrical surway which was carried out in 1937. However, the investigations gave as result that no ore body of any economic importance was found. 4 analyses of pieces of rich ore gave following results:

| | | | |
|---|---|---|---|
| 1. | 1.50 % Ni | 0.40 % Cu | 11.31 % S |
| 2. | 1.71 — | 0.35 — | 10.72 — |
| 3. | 1.79 — | 0.30 — | 10.31 — |
| 4. | 1.14 — | 0.10 — | 7.97 — |

Average analyses of drill cords divided in groups according to their content of Ni are given in Table 3.

The analyses give an average of 5.5 % Ni in the sulphides. The ore at Mølland differs from the Flåt ore as previously mentioned by having a lower ratio between pyrrhotite and pentlandite. In polished sections under the microscope the Mølland ore is characterized by most of the pentlandite beeing converted into violarite. Only small amounts of pentlandite are seen as small white spots in the violet coloured violarite.

In the district south and east of the Flåt mine many small nickel ore deposits are known. In some of them small amounts of nickel ore have formerly been produced and transported to the smelting plant at Evje. In all these deposits the nickel ore has seggregated against flakes of gneiss.

Electrical survey and diamond drillings have given as result that none of them contain ore of any economic importance. The Lomtjern deposit is situated about 2.8 km E of the Flåt mine about 500 m above the sea level. Diamond drillings carried out according to indications found by electrical survey did not locate any ore but only gabbro with poor sulphidic impregnation carrying up to 0.18 % Ni.

Similar disseminations of sulphides are found in the neighbourhood at Øygardsvatn, Vikstøl, Byttingmyr, and Gullregn. At Orreknatten in Iveland a little nickel ore has previously been mined on some small dykes of coarsegrained pyrrhotite with large crystals of pyrite.

## The Hydrothermal Metamorphism of the Ore at the Contact Granite Pegmatites.

The nickel ore in the Flåt mine is frequently intersected by granite aplites and granite pegmatites which are younger than the ore. The granite aplites usually form regular dikes with sharp borders against the surrounding rock, while the pegmatites, as usual in this district, often form large irregular bodies. One of the pegmatites which occur in the midst of the ore body seems to have the shape of a large horseshoe with a thickness of up to 10 m. The record of the diamond drill hole nr. 336 (page 36) shows that this hole has been stopped after being drilled more than 4 m in granite and the hole 323 has been drilled 18.81 m in pegmatite from 24.03—42.84 m. The study of the ore boundaries against the pegmatites shows that the hydrothermal influence has changed the primary sulphidic minerals into a mixture of magnetite, hematite, chalcopyrite, millerite, violarite, and pyrite. This mineral paragenesis has previously been described by the author (2).

Ore of this type is astonishingly rich in Ni in relation to the amount of sulphidic minerals visible and it was generally called "iron ore" by the mine workers.

In this ore all of the nickel is present as millerite and often a little violarite. The transition of the ordinary ore into "iron ore" consists chiefly in a decomposition of the pyrrhotite forming magnetite and hematite while the sulphur of the pyrrhotite must have been carried away. In the same way the pentlandite has been converted into millerite and a little violarite. The chalcopyrite and the pyrite of the ore do not seem to have been disturbed by these processes. As will be seen from the drill report, especially of the hole 323, it is characteristic that near a granite pegmatite the ratio between S and Ni is lower than usual, indicating a decomposition of the pyrrhotite and a transition of pentlandite into millerite.

The zone of metamorphism may vary with the thickness of the pegmatite from some dm to 4—5 m.

The calcuated quotients Cu/Ni and $S—S_{Ch}/Ni$, given in Table 3 based on analyses of drill cords show that this metamorphozed ore has about the usual quotient Cu/Ni while the content of S in relation to the amount of Ni is about one tenth of that of the primary ore.

## Faults.

On the level 84 in the Flåt mine a fault striking N—S with a dip 70° W is visible at the eastern side of the ore bdoy. The striae on the fault plan dip 18° S.

The position of granite aplite dikes near the fault seems to indicate a relative sinking of the eastern side.

A fault which probably correspond with this occur in the lower part of the mine on the level 402. To ascertain wether some part of the ore has been displaced by movement along this fault, an exact study of the fault, and diamond drill holes has been carried out. This investigation led to the conclusion that the movement along the fault must have been negligible and that no ore of any importance has been displaced by this movement.

## III. Origin of the Ore.

Geological investigations carried out by C. W. Carstens and the author during the years 1937—45 have led to the conclusion that the occurrence of the nickel ore in the flåt mine is restricted to a special dioritic rock which we have called the "ore diorite". This rock differs but slightly in chemical and mineral composition from the other surrounding amphibolite rock which we have called the "Mykleås type". By appearance however it is possible to distinguish the two types be means of the somewhat ophitic and massive texture of the ore diorite, while the Mykleås type always is more or less foliated.

The ore diorite often exhibits a finegrained or porphyritic texture along the borders against the surrounding Mykleås type and in this way seems to have been intruded into and cooled against this rock.

According to the opinion of C. W. Carstens and the author the nickel ore deposit in the Flåt mine has been formed by a magma especially enriched in sulphides, which has intruded the older gabbro of the Mykleås type and during the cooling the sulphidic ore has seggregated along gneiss flakes included in the ore gabbro.

This opinion is based on the following facts:

1. The ore exhibit a very distinct sequence of crystallization.

2. The absence of low-temperature minerals in the ore.

3. The high content of Co varying from 0.5—1 % in the pyrite indicate a high temperature of formation of this mineral.

4. The distribution of the Ni and Cu content in the different types of the ore seems to indicate a magmatic differentiation.

Table 4.

*The relation between the average content of $SiO_2$ and Fe from analyses of drill cores in the Flåt mine.*

| % $SiO_2$ | Number of analyses | Average content of: $SiO_2$ | Fe |
|---|---|---|---|
| | | % | % |
| >58 | 9 | 61.6 | 6.30 |
| 58—54 | 11 | 55.6 | 8.25 |
| 54—50 | 9 | 52.2 | 9.86 |
| 50—46 | 8 | 48.2 | 10.34 |
| <46 | 8 | 43.18 | 12.80 |

5. The hydrothermal metamorphism of the ore at the border against the granite pegmatites shows that the mineral paragenesis of the ore has been unstable against the influence of gases and solutions from the pegmatite magma.

This hydrothermal metamorphism of the ore against the pegmatites also after the opinion of the author indicate a magmatic origin of the irregular ,rare mineral-bearing pegmatites of the area. The absence of feeding channels for these pegmatites may be due to that the granite pegmatite magma has been intruded into rocks with a temperature above the temperature of crystallization of the pegmatite. In this way the pegmatite magma may have been present in the rocks in a liquid or partly liquid state for a long time and has through orogenic movements been kneaded into the surrounding rock. This opinion has also been maintained by me in a previous paper (1).

Flakes of gneiss have been observed in diamond drill holes under the ore at many places in the mine, and are also observed on the surface near the ore outcrop.

Many drill holes have been drilled to locate underlying flakes of gneiss and the cores have been analyzed for $SiO_2$ and Fe to study the variation in the composition of the rock. To illustrate this variation I have picked out records of some of these drill holes nr. 302, 309, 319, 326, 374, 387, 388 and 391. The situation of these holes is given on the map of the ore body.

The mining of the ore body of the Flåt mine has in all directions reached the limits for economical mining. Diamond drill holes in all directions from the ore body against the surrounding rock show that the ore grades into the dioritic rock and no new ore has been found in the surroundings of the mined ore.

During this diamond drill survey a tunnelshaped pipe of ore about 40 m long was found by diamond drilling carried out from the stope on 360 m level against the hanging wall. Further survey showed that this pipe ore was but ca. 5 m in diameter and was a protuberance of the main ore body.

Also in the southern part of the mine the ore body grades into the silicate rock and diamond drill holes carried out to investigate the wall rock in south direction showed that this contained an average of 0.28 % Ni and therefore was far below the limit of economical mining.

The diamond drill holes in the ore show that the Flåt ore is not a homogeneous ore body but ore and silicate rock change within short distances. The ore body may in this way be described as built up by "Schlieren" of sulphides in a dioritic rock.

Sulphide masses with sharp borders against the silicate rock are never encountered in the ore body, and no offset dikes have been observed. Ore breccias with fragments of silicate rocks imbedded in sulphides occur frequently and show that the silicates have solidified before the sulphidic minerals. The silicate rock fragments in these breccias never exhibit sharp borders against the surrounding sulphides.

The relation between the sulphides and the silicates in the Flåt ore seems to indicate a close connection between the two phases during the cooling. This close connection between the sulphides and the silicates may be caused by the fact that the original solution has been poor in water which is indicated by the absence of hydroxyl-bearing and low-temperature minerals in the rocks. Consequently the sulphides must have seggregated at an early stage in the solidification of the magma.

According to the opinion of Carstens and the author the Flåt ore must have been formed by seggregation in a diorite magma (magma of the "ore gabbro") which was especially

Fig. 11. Polished sections of a drill core showing the border between ore and silicate rock in the hanging wall of the ore body. Flåt mine. 2 ×.

enriched in sulphides and has been intruded into an older amphibolite rock of nearly the same composition, which, however, was poor in sulphides (the Mykleås type).

In this way the Flåt ore may be classified as a marginal deposit against gneiss flakes within the ore gabbro.

A characteristic feature of the diorite rocks in the Flåt area is that it shows very little differentiation. This has been discussed by Tom Barth in the first part of this paper. The diamond drill hole 326 shows that the ore gabbro continues 116 m in this hole, but no ore was found at the contact against the underlying gneiss.

To get a picture of the seggregation of the sulphides it is important to study the border between the sulphides and the silicates.

The Fig. 11 shows a photo of a polished section of a drill core at the border between the silicate rock and the sulphidic ore in the hanging wall of the ore body. It is seen how the fine dessiminated sulphides gradually seem to gather into larger sulphidic grains in the ore body.

Small fissure fillings of chalcopyrite are often seen penetrating from the sulphides into the surrounding rocks. This phenomena has also been observed by S. Gavelin (10) and O. H. Ödman (20) in the Boliden ore and has been explained by them as differentiation from the sulphidic ore body. The previously mentioned analyses given in Table 3 show that the dessiminated sulphides are richer in pyrite and chalcopyrite than the rich ores. This suggests that relatively much pyrite was left in the silicate rocks during seggregation, caused by the higher melting point of this mineral, while the enrichment of chalcopyrite was due to a secondary differentiation of the sulphides.



## Records of Diamond Drill Holes from the Flåt Mine.

*Diamond drill hole No. 326. 402 level Coord. 245 S, 90 W, Az. 3°, Dip 45°.*

| Length in m From | To | | Fe % | $SiO_2$ % |
|---|---|---|---|---|
| 0.00 | 21.58 | Diorite with bands of quarts and aplite Sample at 9.80 m ........................................ | | 45.4 |
| 21.58 | 21.78 | Diorite with red feldspar. | | |
| 21.78 | 46.51 | Diorite partly with red feldspar, some small veins of granite, gradually richer in biotite. Sample at 34.40 .................................... | | 46.1 |
| | | — 41.70 .................................... | | 47.3 |
| 46.51 | 46.94 | Granite pegmatite. | | |
| 46.94 | 47.95 | Schistose Gabbro, rich in biotite. Sample at 47.70 .................................... | | 51.6 |
| 47.95 | 48.35 | Granite pegmatite. | | |
| 48.35 | 53.10 | Diorite. Sample at 51.40 m .................................... | | 49.2 |

| Length in m From | To | | Fe % | $SiO_2$ % |
|---|---|---|---|---|
| 53.10 | 68.30 | Diorite rich in biotite, intersected by many granite pegmatite veins. | | |
| | | Sample at 57.75 m | | 53.6 |
| | | — 65.00 - | | 52.9 |
| | | — 67.70 - | | 51.5 |
| | | — 69.70 - | | 69.8 |
| 68.30 | 71.50 | Granite, red coloured. | | |
| 71.50 | 81.80 | Diorite, rich in biotite with some veins of aplite. Gradually porphyric texture, at last fine grained rich in biotite. | | |
| | | Sample at 72.30 m | | 46.7 |
| | | — 76.60 - | | 47.2 |
| | | — 80.00 - | | 55.0 |
| | | — 80.70 - | | 54.4 |
| | | — 81.50 - | | 50.4 |
| 81.80 | 82.30 | Gneiss. Sample at 82.20 m | | 56.9 |
| 82.30 | 86.60 | Gneiss, fine grained, rich in biotite | | 72.8 |
| 86.60 | 87.90 | Granite aplite. | | |
| 87.90 | 88.40 | Gneiss. Sample at 87.90 | | 60.2 |
| 88.40 | 90.23 | Crushed core. | | |
| 90.23 | 91.50 | Granite pegmatite. | | |
| 91.50 | 94.80 | Diorite, rich in biotite with veins of granite aplite. Sample at 93.80 | | 43.1 |
| 94.80 | 95.40 | Granite aplite. | | |
| 95.40 | 107.00 | Diorite, rich in biotite. | | |
| | | Sample at 96.50 m | | 49.4 |
| | | — 100.00 - | | 53.7 |
| | | — 104.00 - | | 51.9 |
| 107.00 | 116.18 | Diorite, rich in biotite. The core lost from 108.66—112.56 m. | | |
| | | Sample at 107.35 m | 8.70 | 54.4 |
| | | — 112.08 - | 8.35 | 53.9 |
| | | — 113.77 - | 8.35 | 50.2 |
| | | — 114.30 - | 2.15 | 54.3 |
| 116.18 | 117.25 | Light-coloured granitic rock with orthoklas, quartz, a little plagioclase and some biotite. Sample at 116.44 m | 2.15 | 72.0 |
| 117.25 | 119.08 | Banded and foliated rock with more mica than feldspar. Sample at 117.60 | 5.95 | 57.3 |
| 119.08 | 121.60 | Light-coloured granite. | | |
| | | Sample at 118.60 m | 5.25 | 59.6 |
| | | — 119.00 - | 2.55 | 70.1 |
| | | — 119.30 - | 3.20 | 67.6 |
| 121.60 | 124.75 | Dark coloured, foliated rock, rich in mica. Sample at 122.40 m | 8.60 | 49.7 |
| 124.75 | 127.60 | Gneiss. At 126.20 a granitic vein 10 cm with some sulphides. | | |
| | | Sample at 124.00 m | 9.50 | 54.5 |
| | | — 125.30 - | 6.95 | 62.1 |
| 127.60 | 128.10 | Fine-grained rock. Sample 127.80 | | 50.1 |
| 128.10 | 135.25 | Gneiss. Sample at 128.70 m | | 72.7 |
| 135.25 | 135.60 | Granite. | | |

| Length in m From | To | | Fe % | $SiO_2$ % |
|---|---|---|---|---|
| 135.60 | 136.35 | Gneiss. | | |
| 136.35 | 136.90 | Granite pegmatite. | | |
| 136.90 | 139.60 | Dark coloured, fine grained rock, foliated, rich in mica. Gradually decreasing foliation. | | |
| | | Sample at 137.80 m | | 61.6 |
| | | — 138.50 - | | 54.9 |
| 139.60 | 142.03 | Crushed core. | | |
| 142.03 | 145.60 | Very like the rock from 136.90—139.60. Sample at 143.45 m | 4.70 | 67.9 |
| 145.60 | 146.00 | Acid rock, rich in plagioclase. | | |
| 146.00 | 151.70 | Light-coloured, fine grained rock. Sample at 148.00 | 2.75 | 75.1 |
| 151.70 | 160.35 | Gneiss. Sample at 152.10 | 7.05 | 58.2 |

*Diamond drill hole No. 388. Level 365,5 m, Coord. 844 S, 89 W, Az. 190°. Dipping 3 : 4.*

| Length in m From | To | | Fe % | $SiO_2$ % |
|---|---|---|---|---|
| 0.00 | 5.08 | Fine-grained, green-coloured diorite | | |
| 9.88 | 18.18 | Fine-grained, green-coloured rock partly porphyric. | | |
| | | At 11.35 Diorite-porpfyrite | 7.2 | 60.4 |
| | | - 14.25 Diorite-aplite | 7.3 | 54.4 |
| 18.18 | 19.68 | Green-coloured diorite. Sample at 18.45 | 10.4 | 41.2 |
| 19.68 | 20.04 | Diorite, porphyric, saussuritized. Sample at 19.80 m | 14.4 | 51.8 |
| 20.04 | 25.00 | Diorite porphyric, dark-coloured | 10.0 | 53.2 |
| 25.00 | 26.85 | Dioritic aplite. Sample at 22.50 m | 5.3 | 65.2 |
| 26.85 | 27.40 | Diorite, normal. | | |
| 27.40 | 27.96 | Diorite, porphyric. Sample at 27.50 m | 13.5 | 44.4 |
| 27.96 | 30.09 | Diorite, porphyric. Sample at 29.60 m | 11.4 | 53.8 |
| 30.09 | 30.60 | Diorite, dark-coloured, fine-grained. | | |
| 30.60 | 30.98 | Light-coloured, acid rock. | | |
| | | Sample at 30.70 m | 6.2 | 61.0 |
| 30.98 | 31.50 | Diorite, dark-coloured, fine-grained. | | |
| 31.50 | 31.90 | Light-coloured rock. | | |
| 31.90 | 49.00 | Diorite. | | |
| | | Sample at 33.80 m | 11.5 | 48.0 |
| | | — 35.00 - | 11.8 | 49.0 |
| | | — 40.25 - | 10.9 | 52.2 |
| | | — 44.20 - | 11.7 | 48.4 |
| 49.00 | 57.30 | Diorite with a little sulphidic minerals. | | |
| | | Sample at 51.25 m | 7.5 | 59.8 |
| | | — 54.50 - | 8.0 | 58.6 |
| 57.30 | 60.64 | Diorite, foliated. | | |
| | | Sample at 57.50 m | 8.0 | 53.6 |
| | | — 59.00 - | 6.1 | 63.2 |

*Diamond drill hole No 387. Level 402. Coord. 792 S, 168,6 W. Az. 215° Dip. 1 : 1.*

| Length in m From | To | | $SiO_2$ % |
|---|---|---|---|
| 0.00 | 16.43 | Diorite, normal with some veins of pegmatite. | |
| 16.43 | 17.06 | Diorite, porphyric with large white feldspar crystals. | |
| 17.06 | 17.66 | Diorite with red feldspar. | |
| 17.66 | 18.62 | Granite pegmatite with pink and white feldspar. | |
| 18.62 | 19.16 | Diorite with red-coloured feldspar. | |
| 19.16 | 19.50 | Granite pegmatite. | |
| 19.50 | 20.26 | Diorite, very fine-grained. | |
| 20.26 | 21.26 | Diorite with red-coloured feldspar. | |
| 21.26 | 23.50 | First 26 cm pegmatite, than diorite and at last 25 cm pegmatite. 90 cm core lost. | |
| 23.50 | 34.14 | Diorite rich in epidote. From 31.50—32.07 distinctly foliated. | |
| 34.14 | 36.30 | Dark-coloured acid rock .................................... | 66.2 |
| 36.30 | 39.60 | Granite, gradually foliated. | |
| 39.60 | 41.62 | Gneiss ............................................................ | 72.0 |

*Diamond drill hole No 391. Level 410. Coord. 683,6 S, 150,5 W. Az. 399, Dip. 1 : 1.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 3.20 | Diorite, impregnated .................. | 0.30 | 0.10 | 70.3 | 3.00 |
| 3.20 | 6.32 | Diorite $SiO_2$ = 54.6 % $P_2O_5$ = 4.21 %. | | | | |
| 6.32 | 6.61 | Diorite, impregnated ................. | 0.25 | 0.19 | 75.5 | 2.92 |
| 6.61 | 10.00 | Diorite. | | | | |
| 10.00 | 15.11 | Diorite, foliated and rich in mica. | $SiO_2$ | | $P_2O_5$ | |
| | | Sample at 10.50 m .................. | 50.0 % | | 3.00 % | |
| 15.11 | 20.00 | Diorite-with abundant veins of pegmatite and aplite. | | | | |
| | | Sample at 19.30 m ...................... | 43.2 - | | 3.42 - | |

*Diamond drill hole No. 309. Level 410 m. Coord. 707 S, 127,5 W. Vertical.*

| Depth in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 0.81 | Impregnated diorite .................. | 0.55 | 1.05 | 54.7 | 9.85 |
| 0.81 | 0.90 | Diorite with some sulphides. | | | | |
| 0.90 | 1.77 | Granite aplite. | | | | |
| 1.77 | 2.22 | Diorite, distinctly foliated. | | | | |
| 2.22 | 2.70 | Granite aplite. | | | | |
| 2.70 | 11.13 | Light-coloured gneiss | | $SiO_2$ | | |
| | | Sample at 2.75 m ..................... | | 65.1 % | | |
| | | — 4.57 - ..................... | | 61.6 - | | |
| | | — 7.75 - ..................... | | 63.2 - | | |
| | | — 10.13 - ..................... | | 65.2 - | | |
| 11.13 | 11.63 | Granite aplite. | | | | |
| 11.63 | 13.38 | Dark-coloured gabbro, rich in biotite with veins of aplite and pegmatite. | | | | |
| 13.38 | 20.03 | Dark-coloured diorite rich in biotite. | | | | |
| | | Sample at 13.60 m ..................... | | 44.1 - | | |
| | | — 14.90 - ..................... | | 46.7 - | | |
| | | — 17.05 - ..................... | | 46.9 - | | |
| | | — 20.03 - ..................... | | 48.2 - | | |

*Diamond drill hole No. 319. Level 402 Coord. 629,5 S, 127 W. Vertical.*

| Depth in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 1.21 | Poor impregnation in diorite ...... | 0.30 | 0.26 | 71.8 | 3.84 |
| 1.21 | 1.92 | Granite aplite. | | | | |
| 1.92 | 2.80 | Poor impregnation in diorite ...... | 0.30 | 0.26 | 71.8 | 3.84 |
| 2.80 | 2.91 | Granite aplite. | | | | |
| 2.91 | 5.82 | Poor impregnation in diorite ...... | 0.20 | 0.13 | 73.9 | 3.16 |
| 5.82 | 8.83 | Poor impregnation in diorite ...... | 0.35 | 0.27 | 71.9 | 3.69 |
| 8.83 | 9.68 | Diorite. | | | | |
| 9.68 | 10.07 | Granite aplite. | | $SiO_2$ | | |
| 10.07 | 13.96 | Diorite. Sample at 13.37 m ......... | | 43.5 % | | |
| 13.96 | 16.74 | Light-coloured gneiss. | | | | |
| | | Sample at 14.00 m ..................... | | 55.6 - | | |
| | | — 16.70 - ..................... | | 55.8 - | | |

*Diamond drill hole No. 302. Level 410. Coord 697 S, 128 W. Vertical.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 0.68 | Diorite and aplite. | | | | |
| 0.68 | 3.67 | Diorite, impregnated ................ | 0.45 | 0.18 | 71.4 | 3.86 |
| 3.67 | 6.33 | Diorite with a little impregnation. | | | | |
| 6.33 | 6.67 | Granite aplite. | | | | |
| 6.67 | 9.39 | Light-coloured rock with small veins of aplite. | | | | |
| 9.39 | 10.82 | Granite aplite. | | | | |
| 10.82 | 21.06 | Dark-coloured gabbro rich in biotite. | | | | |
| 21.06 | 27.25 | Orthoclase rock, rich in biotite some quartz and hornblende. | Fe % | | $SiO_2$ % | |
| | | Sample at 21.30 m .................... | 9.60 | | 47.3 | |
| | | — 23.30 - .................... | 11.45 | | 43.4 | |
| | | — 25.55 - .................... | 9.20 | | 51.0 | |
| 27.25 | 28.03 | Granite pegmatite. | | | | |
| 28.03 | 31.26 | Diorite. Sample at 28.50 ........... | 1.25 | | 42.4 | |
| 31.26 | 41.17 | Diorite with two granite pegmatite veins 12 cm and 20 cm. | | | | |
| | | Sample at 32.90 m .................... | 10.70 | | 52.7 | |
| | | — 36.95 - .................... | 11.05 | | 48.9 | |
| | | — 38.90 - .................... | 11.20 | | 45.0 | |
| | | — 41.00 - .................... | 10.15 | | 45.2 | |
| 41.17 | 51.10 | Diorite. Aplite from 49.22—49.38 m. | | | | |
| | | Sample at 43.56 m .................... | 10.85 | | 44.0 | |
| | | — 46.54 - .................... | 10.45 | | 43.6 | |
| | | — 50.95 - .................... | 10.45 | | 43.6 | |
| 51.10 | 55.27 | Diorite. Sample at 51.30 m ......... | 10.25 | | 45.5 | |
| 55.27 | 58.17 | Granite pegmatite. | | | | |
| 58.17 | — | Diorite. | | | | |
| | | Sample at 60.00 m .................... | 11.15 | | 48.0 | |
| | | — 65.60 - .................... | 10.10 | | 48.7 | |

*Diamond drill hole No. 303. Level 363.35. Coord. 821.2 S, 11.4 W, Az. 266°. Horizontal.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 2.56 | Poor impregnation in diorite ...... | 0.40 | 0.23 | 64.2 | 3.54 |
| 2.56 | 4.97 | — — — ...... | 0.30 | 0.06 | 76.5 | 2.77 |
| 4.97 | 9.05 | — — — ...... | 0.65 | 0.24 | 69.2 | 4.90 |
| 9.05 | 11.43 | — — — ...... | 0.15 | 0.18 | 74.4 | 1.66 |
| 11.43 | 11.98 | Diorite. | | | | |
| 11.98 | 14.75 | Poor impregnation in gabbro ...... | 0.25 | 0.33 | 69.6 | 3.04 |
| 14.75 | 16.30 | — — — ...... | 0.15 | 0.16 | 74.2 | 1.95 |
| 16.30 | 17.80 | — — — ...... | 0.35 | 0.18 | 68.2 | 3.14 |
| 17.80 | 18.61 | Granite aplite. | | | | |
| 18.61 | 19.68 | Poor impregnation in gabbro ...... | 0.15 | 0.20 | 72.0 | 1.58 |
| 19.68 | 20.83 | Diorite rich in mica. | | | | |
| 20.83 | 21.16 | Granite aplite. | | | | |
| 21.16 | 22.23 | Diorite. | | | | |
| 22.23 | 22.28 | Granite aplite. | | | | |

*Diamond drll hole No. 371. Level 339.0. Coord. 784.2 S, 78.5 W, Az. 281°. Horizontal.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 1.30 | Diorite, poor impregnated ......... | 0.50 | 0.79 | 55.5 | 1.3 |
| 1.30 | 2.45 | Diorite with red-coloured feldspar. | | | | |
| 2.45 | 3.40 | Diorite with red-coloured feldspar impr. ...................................... | 0.50 | 0.79 | 55.5 | 1.3 |
| 3.40 | 4.65 | Diorite. | | | | |
| 4.65 | 5.15 | Diorite, impregnated ................. | 0.93 | 1.76 | 38.5 | 2.3 |
| 5.15 | 5.95 | Diorite. | | | | |
| 5.95 | 6.10 | Granite aplite. | | | | |
| 6.10 | 11.84 | Diorie. | | | | |
| 11.84 | 12.56 | Diorite with grains of sulphides ... | 0.08 | 0.12 | 57.9 | 1.0 |
| 12.56 | 15.40 | Diorite. | | | | |
| 15.40 | 15.77 | Impregnated diorite chloritic ...... | 0.98 | 0.33 | 44.3 | 1.2 |
| 15.77 | 16.00 | Diorite. | | | | |
| 16.00 | 17.90 | Impregnated diorite, chloritic ...... | 0.45 | 0.38 | 54.4 | 0.9 |
| 17.90 | 21.17 | Diorite. | | | | |
| 21.17 | 27.50 | Diorite, very fine-grained. | | | | |

*Diamond drill hole No. 382. Level 402. Coord. 860 S, 132 W, Az. 300°. Horizontal.*

| Depth in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 12.84 | Diorite. | | | | |
| 12.84 | 15.25 | Granite pegmatite. | | | | |
| 15.25 | 15.91 | Dark-coloured, fine-grained rock with magnetite and millerite ...... | 0.30 | 0.22 | 48.1 | 1.60 |
| 15.91 | 17.20 | Dark-coloured, finegrained rock ... | 0.28 | 0.42 | 56.2 | 1.70 |
| 17.20 | 17.95 | — — — ...... | 0.23 | 0.22 | 72.6 | 1.10 |
| 17.95 | 20.24 | Diorite. | | | | |
| 20.24 | 20.95 | Poor impregnation in diorite ...... | 0.25 | 0.21 | 69.5 | 1.60 |
| 20.95 | 21.75 | — — — ...... | 0.40 | 0.50 | 59.3 | 4.80 |
| 21.75 | 22.00 | — — — ...... | 0.05 | 0.24 | 75.4 | 0.60 |
| 22.00 | 22.81 | — — — ...... | 0.25 | 0.35 | 65.7 | 2.50 |
| 22.81 | 24.25 | Diorite. | | | | |
| 24.25 | 25.65 | Poor impregnation in diorite ...... | 0.13 | 0.20 | 73.7 | 0.70 |
| 25.65 | 26.48 | — — — ...... | 0.10 | 0.15 | 74.0 | 0.80 |
| 26.48 | 28.52 | Diorite. | | | | |
| 28.52 | 28.72 | Poor impregnation in diorite ...... | 0.48 | 0.65 | 60.3 | 6.20 |
| 28.72 | 39.28 | Diorite. | | | | |

*Diamond drill hole No. 384. Level 402. Coord. 861 S, 132 W, Az. 250°. Horizontal.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 10.42 | Diorite. | | | | |
| 10.42 | 10.71 | Granite pegmatite. | | | | |
| 10.71 | 13.14 | Diorite with veins of pegmatite. | | | | |
| 13.14 | 13.80 | Granite pegmatite. | | | | |
| 13.80 | 15.76 | Chloritic Rock. | | | | |
| 15.76 | 16.20 | Poor impregnation in diorite ...... | 0.20 | 0.10 | 63.4 | 2.20 |
| 16.20 | 17.32 | — — — ...... | 0.65 | 0.35 | 61.6 | 3.30 |
| 17.32 | 18.77 | — — — ...... | 0.23 | 0.15 | 73.6 | 1.80 |
| 18.77 | 20.90 | — — — ...... | 0.25 | 0.15 | 73.7 | 1.80 |
| 20.90 | 22.97 | — — — ...... | 0.15 | 0.25 | 77.3 | 1.50 |
| 22.97 | 44.30 | Diorite. | | | | |

*Diamond drill hole No. 336. Level 357.9. Coord 782.6 S, 98.3 W, Az. 397.5°. Elevation 13 : 5.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 2.00 | Impregnation in diorite ............ | 1.25 | 0.75 | 48.2 | 8.33 |
| 2.00 | 4.18 | Diorite. | | | | |
| 4.18 | 4.38 | Poor impregnation in diorite ...... | 0.20 | 0.15 | 71.5 | 0.71 |
| 4.38 | 4.57 | Diorite. | | | | |
| 4.57 | 6.86 | Diorite impregnated ................. | 0.58 | 0.25 | 62.6 | 3.89 |
| 6.86 | 7.89 | Diorite. | | | | |
| 7.89 | 8.12 | Impregnation with magnetite and millerite ................................. | 0.98 | 0.50 | 52.8 | 1.57 |
| 8.12 | 8.54 | Diorite. | | | | |
| 8.54 | 9.13 | Poor impregnation in gabbro ...... | 0.30 | 0.20 | 64.4 | 3.23 |
| 9.13 | 9.36 | Diorite. | | | | |
| 9.36 | 10.16 | Poor impregnation in diorite ...... | 0.30 | 0.20 | 64.4 | 3.23 |
| 10.16 | 11.32 | Ore ....................................... | 1.50 | 0.65 | 51.6 | 8.10 |
| 11.32 | 11.60 | Diabas. | | | | |
| 11.60 | 11.84 | Impregnated diorite .................. | 0.70 | 1.72 | 60.3 | 6.22 |
| 11.84 | 22.65 | Diorite with 17 cm granite pegmatite dyke at 16 m. | | | | |
| 22.65 | 26.80 | Pegmatite. | | | | |

*Diamond drill hole No. 314. Level 322. Coord. 556.5 S, 151.2 W, Az. 200°. Dip 1 : 1.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 1.70 | Ore ....................................... | 1.28 | 0.72 | 47.5 | 12.80 |
| 1.70 | 6.40 | Poor impregnation in diorite ...... | 0.30 | 0.28 | 70.5 | 2.64 |
| 6.40 | 9.50 | — — — ...... | 0.45 | 0.28 | 62.5 | 3.25 |
| 9.50 | 13.20 | Varying impregnation .............. | 0.95 | 0.43 | 57.5 | 8.70 |
| 13.20 | 16.25 | — — .............. | 0.65 | 0.42 | 61.8 | 5.45 |

*Diamond drill hole No. 323. Level 363.5. Coord. 772.7 S, 101.5 W, Az. 1.25°. Horizontal.*

| Length in m From | To | | Fe % | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|---|
| 0.00 | 1.18 | Diorite. | | | | | |
| 1.18 | 2.83 | Poor impregnation .......... | | 0.15 | 0.06 | 69.7 | 1.65 |
| 2.83 | 3.17 | Diorite. | | | | | |
| 3.17 | 4.03 | Diorite impregnated ......... | | 0.75 | 0.06 | 51.3 | 5.39 |
| 4.03 | 4.98 | Ore ............................ | | 1.03 | 0.05 | 48.4 | 12.20 |
| 4.98 | 5.81 | Diorite with some sulphide grains. | | | | | |
| 5.81 | 6.68 | Diorite, impregnated ......... | | 0.53 | 1.18 | 55.9 | 6.02 |
| 6.68 | 6.83 | Diorite. | | | | | |
| 6.83 | 8.43 | Diorite, impregnated ......... | | 0.53 | 0.63 | 66.4 | 4.69 |
| 8.43 | 8.85 | Granite aplite. | | | | | |
| 8.85 | 9.87 | Ore rich in copper ......... | | 1.10 | 4.06 | 40.6 | 10.63 |
| 9.87 | 11.56 | Diorite impregnated ....... | 18.80 | 0.38 | 0.90 | 63.8 | 4.33 |
| 11.56 | 12.92 | — — ....... | 22.10 | 0.53 | 0.24 | 52.0 | 12.26 |
| 12.92 | 13.24 | Diorite. | | | | | |
| 13.24 | 13.74 | Diorite, impregnated ....... | 20.50 | 0.80 | 0.90 | 50.4 | 8.06 |
| 13.74 | 14.22 | Diorite. | | | | | |
| 14.22 | 14.59 | Impregnated diorite ........ | 22.40 | 0.68 | 0.82 | 52.7 | 6.28 |
| 14.59 | 15.18 | Ore rich in copper ......... | 30.00 | 0.68 | 7.18 | 34.7 | 16.70 |
| 15.18 | 16.16 | Diorite impregnated ......... | 23.00 | 0.78 | 1.36 | 50.1 | 4.70 |
| 16.16 | 17.09 | Poor impregnation ........... | 19.65 | 0.35 | 0.16 | 55.3 | 0.84 |
| 17.09 | 19.21 | Diorite, impregnated ........ | 20.80 | 0.73 | 0.28 | 49.4 | 0.81 |
| 19.21 | 19.33 | Poor impregnation, with magnetite and millerite ... | 36.35 | 1.40 | 0.62 | 36.0 | 1.82 |
| 19.33 | 21.22 | — — ... | 26.70 | 1.38 | 0.73 | 44.6 | 2.16 |
| 21.22 | 21.82 | — — ... | 16.70 | 0.30 | 0.02 | 56.5 | 0.78 |
| 21.82 | 23.05 | — — ... | 23.30 | 1.25 | 0.06 | 43.7 | 1.24 |
| 23.05 | 24.03 | — — ... | 24.95 | 1.50 | 0.34 | 41.3 | 1.82 |
| 24.03 | 42.84 | Granite Pegmatite. | | | | | |
| 42.84 | 43.46 | Diorite. | | | | | |
| 43.46 | 43.78 | Granite pegmatite. | | | | | |
| 43.78 | 44.58 | Diorite. | | | | | |
| 44.58 | 45.22 | Granite pegmatite. | | | | | |
| 45.22 | 45.94 | Diorite with chlorite and magnetite. | | | | | |
| 45.94 | 46.14 | Impregnated chloritebearing with magnetite and millerite | 29.95 | 1.20 | 2.12 | 40.2 | 3.56 |
| 46.14 | 47.42 | — — — | 21.05 | 0.85 | 0.40 | 53.4 | 1.47 |
| 47.42 | 48.10 | Poor impr. in normal diorite | 14.25 | 0.25 | 0.16 | 62.6 | 0.68 |
| 48.10 | 48.62 | Impregnated diorite ......... | | 0.60 | 1.87 | 50.0 | 7.77 |
| 48.62 | 48.74 | Poor impregnation ......... | | 0.15 | 0.20 | 70.3 | 1.84 |
| 48.74 | 53.59 | Diorites with small dykes of diabas. | | | | | |
| 53.59 | 53.98 | Impregnated diorite ......... | | 0.53 | 0.37 | 71.9 | 3.91 |
| 53.98 | 59.22 | Diorite, the last 35 cm with very poor impregnation. | | | | | |

*Diamond drill hole No. 374. Level 158.5. Coord. 181 S, 3.5 E, Az. 9°. Horizontal.*

| Lenght in m From | To | | S % | Fe % | $SiO_2$ % |
|---|---|---|---|---|---|
| 0.00 | 12.30 | Diorite. Sample at 5.50 m ........... | | 8.45 | 56.8 |
| 12.30 | 14.00 | Diorite with some sulphide grains. Sample at 13.20 m ........................ | | 8.00 | 56.4 |
| 14.00 | 15.58 | Diorite. | | | |
| 15.58 | 21.50 | With some sulphide grains. Sample at 17.70 m ........................ | | 8.05 | 54.8 |
| 21.50 | 23.31 | Granite aplite. | | | |
| 23.31 | 44.45 | Diorite with some sulphide grains. | | | |
| | | Sample at 27.8 m .......................... | | 7.80 | 57.6 |
| | | — 32.85 - .......................... | | 8.45 | 54.0 |
| | | — 36.70 - .......................... | 0.58 | 8.90 | 56.0 |
| | | — 42.50 - .......................... | 0.55 | 7.90 | 55.0 |
| 44.45 | 44.80 | Granite aplite. | | | |
| 44.80 | 48.92 | Diorite with two dykes of aplite 32 cm and 61 cm. | | | |
| 48.92 | 50.84 | Diorite with some sulphide grains...... | 1.13 | 12.00 | 41.4 |
| 50.84 | 51.21 | Granite aplite. | | | |
| 51.21 | 59.60 | Diorite with some sulphide grains. | | | |
| | | Sample at 54.50 m ........................ | 1.02 | 13.10 | 43.2 |
| | | — 59.20 - ........................ | 0.88 | 13.25 | 45.22 |

*Diamond drill hole No. 324. Level 363. Coord 772.7 S, 100.5 W, Az. 50°. Horizontal.*

| Length in m From | To | | Ni % | Cu % | Insol. % | S % |
|---|---|---|---|---|---|---|
| 0.00 | 0.30 | Poor impregnation ................. | 0.33 | 0.15 | 68.1 | 3.71 |
| 0.30 | 0.47 | Diabas. | | | | |
| 0.47 | 0.90 | Poor impregnation ................. | 0.25 | 0.24 | 66.3 | 3.11 |
| 0.90 | 2.55 | Diorite. | | | | |
| 2.55 | 2.72 | Diorite impregnated ................. | 0.65 | 0.24 | 55.8 | 4.93 |
| 2.72 | 3.52 | Ore .................................... | 1.95 | 1.93 | 55.8 | 23.80 |
| 3.52 | 4.12 | Diorite impregnated ................. | 0.70 | 0.76 | 58.8 | 7.26 |
| 4.12 | 4.34 | Poor impregnation ................. | 0.28 | 0.40 | 66.8 | 2.75 |
| 4.34 | 4.97 | Diorite. | | | | |
| 4.97 | 5.36 | Coarse-grained impregnation ...... | 1.45 | 1.04 | 25.8 | 19.66 |
| 5.36 | 5.88 | Fine-grained impregnation ......... | 0.55 | 0.46 | 55.1 | 4.13 |
| 5.88 | 6.09 | Diorite | | | | |
| 6.09 | 6.56 | Poor impregnation ................. | 0.25 | 0.14 | 69.8 | 2.48 |
| 6.56 | 6.78 | Impregnation ........................ | 0.78 | 0.31 | 52.2 | 4.59 |
| 6.78 | 7.79 | Poor impregnation ................. | 0.20 | 0.05 | 73.2 | 1.46 |
| 7.79 | 12.54 | Diorite with some sulphide grains. | | | | |
| 12.54 | 13.56 | Chloritic rock. | | | | |
| 13.56 | 40.67 | Granite pegmatite. | | | | |
| 40.67 | 51.32 | Chloritic rock, rick in magnetite. | | | | |
| | | Sample at 48.15 Fe = 16.30 % ... | 0.00 | 0.04 | 63.0 | 0.41 |
| | | — 49.55 Fe = 10.85 - ... | 0.00 | 0.02 | 80.5 | 0.63 |
| 51.32 | 52.32 | Poor impregnation. ................. | 0.15 | 0.11 | 70.2 | 1.67 |
| 52.32 | 58.72 | Diorite with some sulphide grains. | | | | |
| | | Sample at 53.85 Fe = 13.55 % ... | 0.00 | 0.03 | 65.6 | 0.44 |
| | | — 54.04 Fe = 15.05 - ... | 0.00 | 0.03 | 74.9 | 0.44 |

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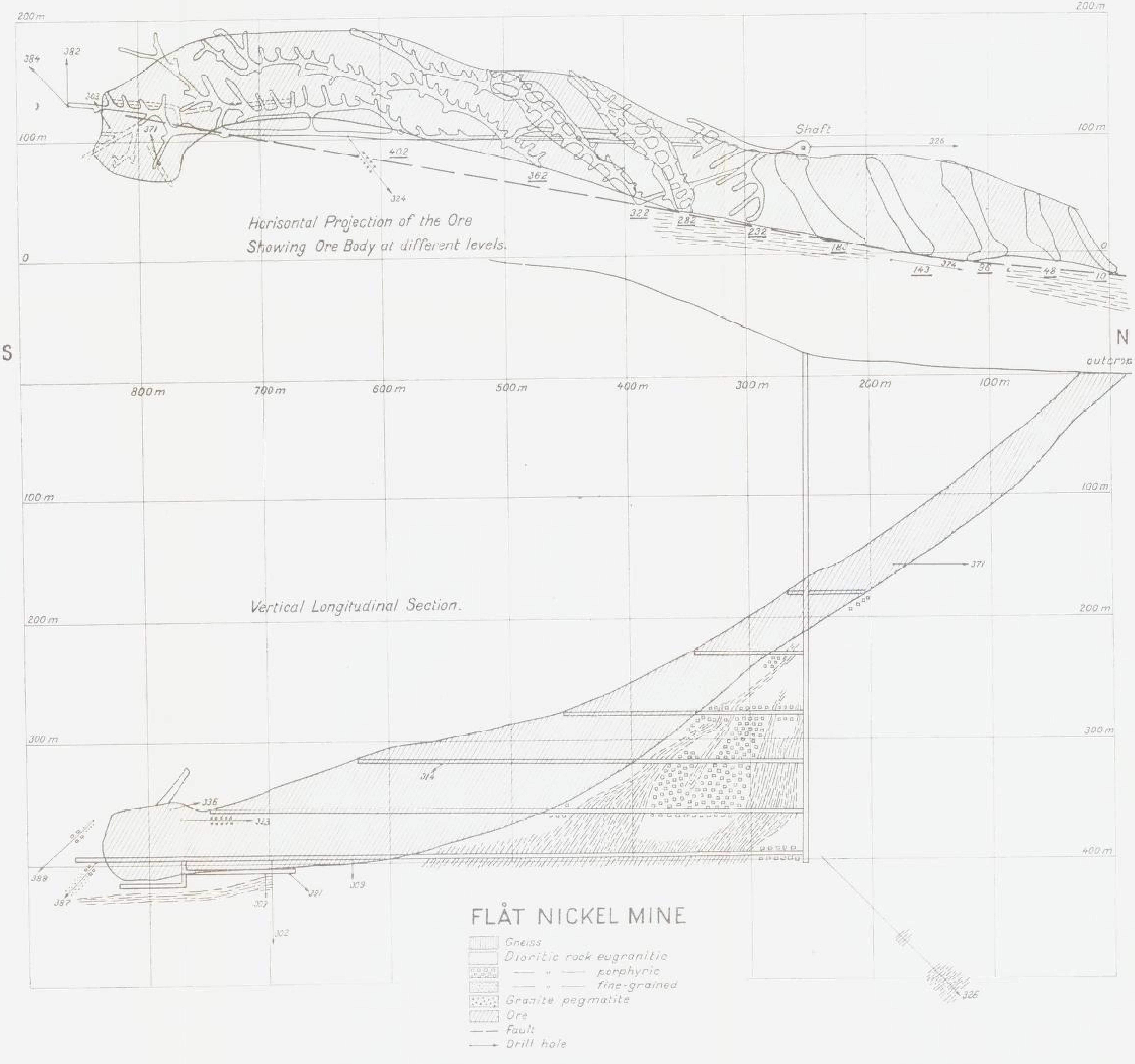
Horisontal Projection of the Ore
Showing Ore Body at different levels.
Shaft
S
N
outcrop
800 m
700 m
600 m
500 m
400 m
300 m
200 m
100 m
Vertical Longitudinal Section.
FLÅT NICKEL MINE
Gneiss
Dioritic rock eugranitic
— " — porphyric
— " — fine-grained
Granite pegmatite
Ore
Fault
Drill hole


FLÅT NICKEL MINE
0
50 m
100 m
150 m
200 m
Amphibolite "Mykleåstype" and covered area
Ore Diorite eugranitic
— " — fine-grained
— " — porphyritic
Granite pegmatite
Gneiss
Ore
Ore outcropping
Drill hole
S
N
Shaft
+200
0
÷200
÷600
÷400
÷200
0
+200
+400