GEOLOGIAN TUTKIMUSKESKUS

GEOLOGISKA FORSKNINGSCENTRALEN
GEOLOGICAL SURVEY OF FINLAND

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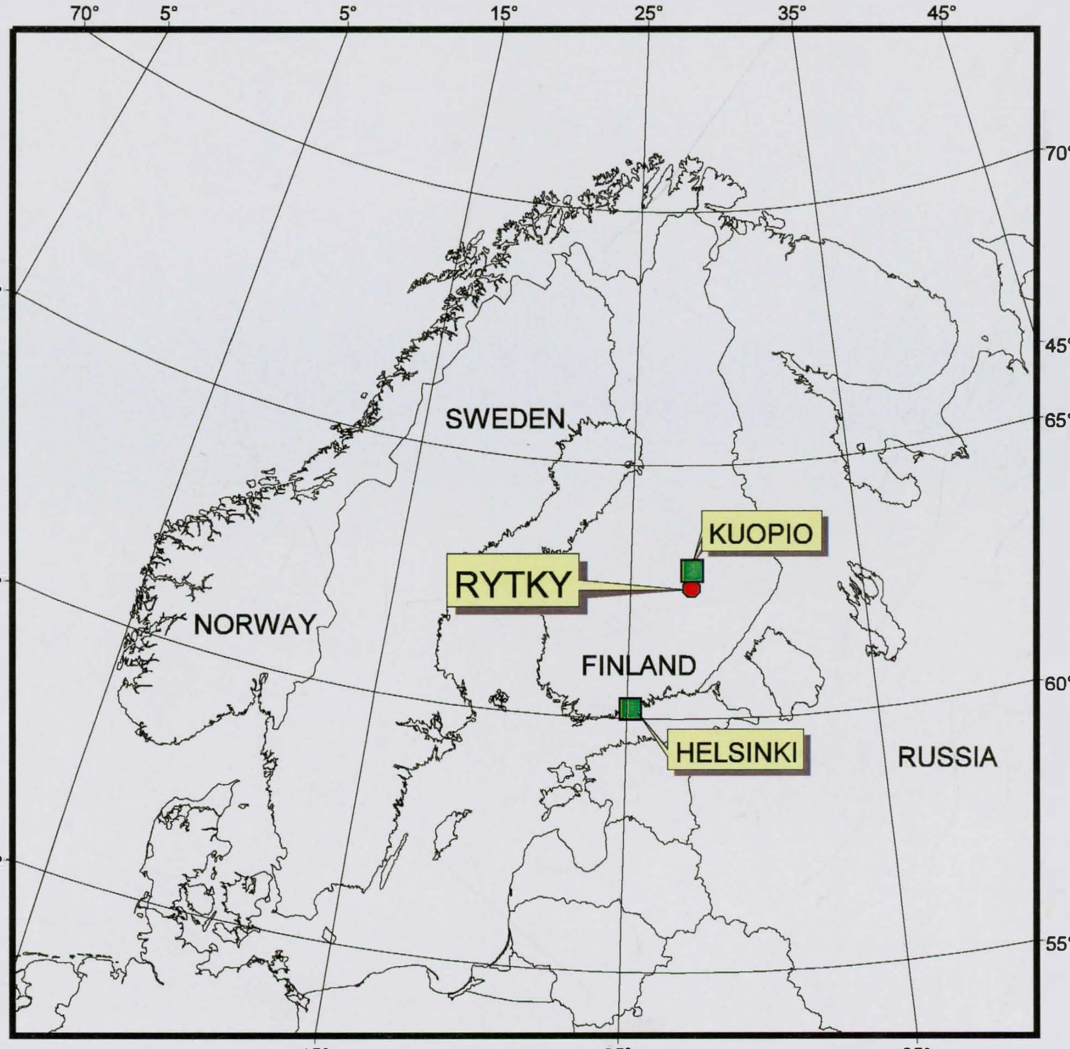
REPORT OF INVESTIGATIONS OF THE RYTKY NICKEL OCCURRENCE IN LEPPÄVIRTA, CLAIM AREAS RYTKY 2-5 (5629/2, 7081/1, 7227/1, 7318/1), IN 1994-2001



GTK

ABSTRACT

The Rytky nickel occurrence is located in the municipality of Leppävirta in Eastern Finland, 40 km south of the city of Kuopio. The mafic-ultramafic Rytky intrusion (c. 1.9 Ga) lies within the Palaeoproterozoic Savo schists between the Archaean gneisses and the Central Finland Granitoid Complex (c. 1.88 Ga), only about one kilometre SE of the Kotalahti nickel deposit.

GTK started exploration at Rytky in 1994 as a part of an extensive research and exploration project concerned with the Svecofennian (1.9 Ga) Kotalahti Nickel Belt initiated in 1992, and the Rytky occurrence was found in 2000. Exploration included geological mapping, petrological and lithogeochemical studies, geophysical surveys and diamond drilling. GTK completed only a preliminary drilling programme in 1995 – 2001, totalling 10 332 m.

The Rytky intrusion is composed of two blocks, together about 0.5 x 1 km in surface section. The W block is mainly composed of gabbros and has no ore potential, while the southeastern block is mainly composed of peridotites and pyroxenites and hosts the nickel occurrence. This is a subvertical ore body in the contact zone between the intrusion and the Archaean gneisses, extending from a depth of around 100 m to at least 300 m.

The mineral resource assessment gives the following results:

MEASURED					
CUTOFF	TON	Ni %	Cu %	Co %	S %
0.35 % Ni	1 265 700	0.56	0.19	0.022	3.28
0.50 % Ni	904 787	0.75	0.26	0.029	4.42
MEASURED + INDICATED					
0.35 % Ni	1 632 548	0.58	0.19	0.023	3.45

The main carrier of Ni is pentlandite, which occurs as subhedral to euhedral grains several hundreds of microns, even millimetres in diameter, as pentlandite bands between pyrrhotite grains of size 75-200 microns, and as flame-formed inclusions in pyrrhotite, usually 10-30 microns long and 5-10 microns wide. The average chemical composition of all the pentlandite analyses (N=754) is: Fe 32.75 wt %, Ni 32.45 wt %, Co 1.15 wt % and S 42.80 wt %. The main copper carrier is chalcopyrite.

Preliminary concentration tests with one ore type showed that the best results were achieved using flotation as the concentrating method and reducing the ore to the required fineness (about 80-85% below 90 μm) before flotation. The recovery rate was 57-65% with a concentrate having a nickel content of 12-14%, 60-70% with a nickel content of 10-12% and 75-90%with a nickel content of 5-8% .

In view of the quantity of magma represented by the intrusion, Rytky has a potential for yielding several million tons of ore with a grade of 1% nickel. The main potential for an increase in resources lies in the stratigraphic footwall of the intrusion, below and to the SE of the present intrusion body. The area between Rytky and the Kotalahti deposit also has an ore potentiality.

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INTRODUCTION

The Geological Survey of Finland (GTK) is a government organization operating under the Ministry of Trade and Industry. Its statutory duties include mapping of the Earth's surface using geological, geophysical and geochemical methods. GTK provides basic geological information on the sustainable use of natural resources, especially for exploration purposes and for the mining industry, construction, land use planning, nature conservation and environmental studies. Its main office is located in Espoo, near Helsinki, and it also has regional offices in Kuopio and Rovaniemi. It has a permanent staff of 700, including about 300 geologists, geochemists and geophysicists.

Historically, GTK has been closely involved in exploration for minerals in Finland, with projects ranging from regional to prospect scale that have led to the discovery of a number of significant deposits. Today its role is to acquire data on new areas and prospects in order to encourage further evaluation in the private sector. All discoveries and prospects which are considered to host a significant mineralization are offered for global private sector tender through the Ministry of Trade and Industry at the earliest possible stage in exploration, as GTK has no direct role in the mining industry. Finland can be considered an attractive exploration target in several respects. Geoscientific data coverage is excellent, but large areas can be considered under-explored. It is a modern, western country with a highly educated population, the infrastructure is highly developed, with good port facilities, an extensive high-voltage power grid and a comprehensive road and airport network, and the taxation laws are favourable and the mining law strong. In addition, the country is close to major markets.

GTK also provides confidential, customized expert services for exploration and mining companies operating in the Fennoscandian Shield and worldwide. These include all aspects and scales of mineral exploration and prospect evaluation, from the planning and implementing of regional exploration programmes to detailed mineralogical studies and deposit modelling.

GTK started exploration at Rytky in 1994 as a part of an extensive research and exploration project initiated in 1992 on the Svecofennian (1.9 Ga) Kotalahti Nickel Belt. The Rytky nickel occurrence was found in 2000. It is located only about one kilometre from the Kotalahti nickel deposit, which was mined in 1957 – 1987 (12 Mt, 0.66% Ni, 0.26% Cu, Puustinen et al. 1995). The host rocks and ore composition are similar in the two deposits. The Rytky occurrence and its surroundings are considered to have the potential for a significant nickel deposit and are being offered for purchase through an international tendering process.

GENERAL DESCRIPTION

Location, access and infrastructure

The Rytky nickel occurrence is located in the municipality of Leppävirta in Eastern Finland, 40 km south of the city of Kuopio, at Lat. 62.563808, Long. 27.642629 (decimal degrees), Finnish KKJ Zone 3 coordinates 6940100N, 3533050E (Fig. 1). The claims of GTK are located on the national 1:20 000 scale map sheets 3241 11 and 3241 12 (Fig. 3). The municipality of Leppävirta has a total population of about 11 000, of whom about 5000 live in the main centre, also known as Leppävirta.

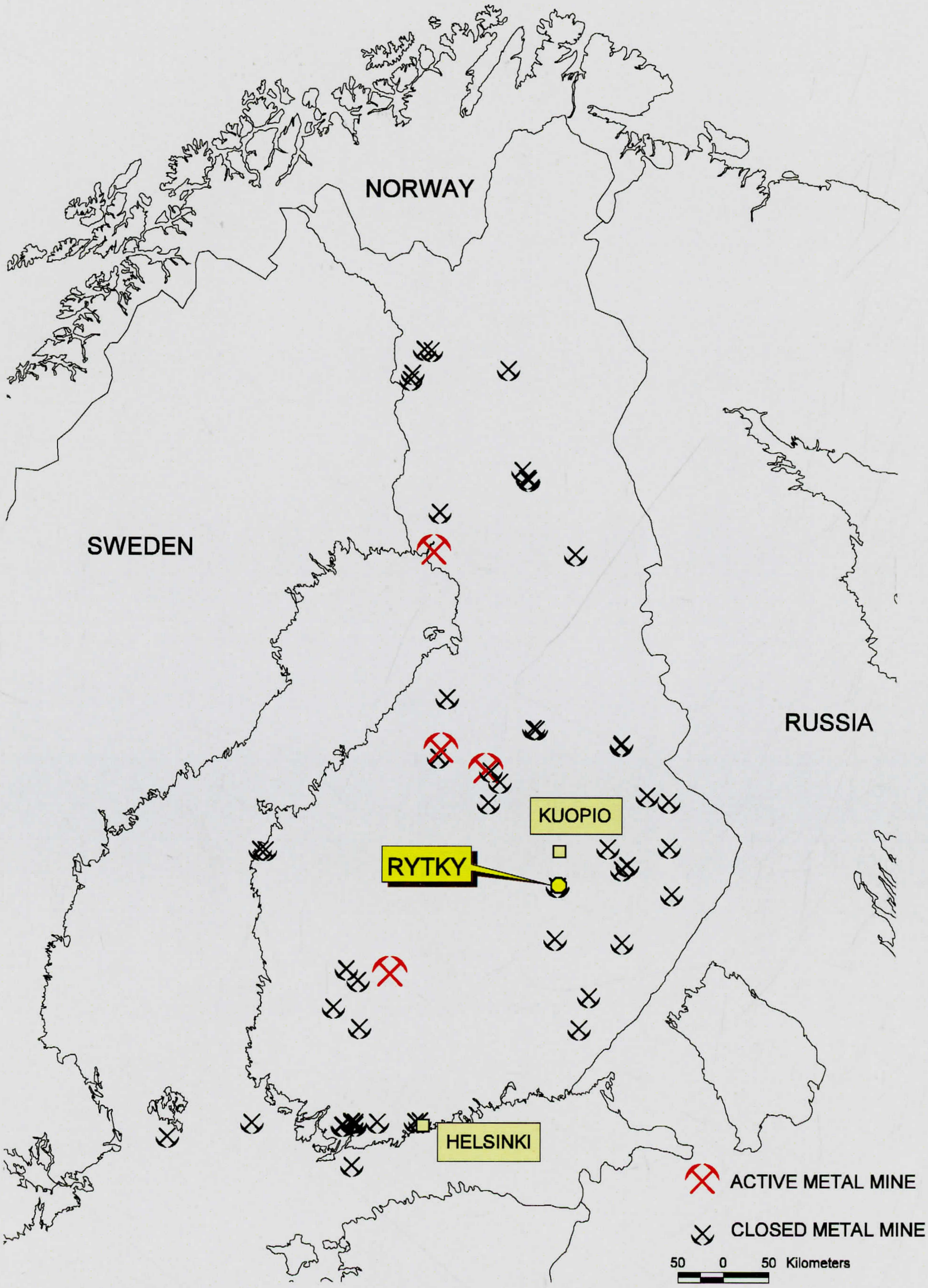

Figure 1. Location of the Rytky Ni occurrence and metallic ore mines in Finland.

Access to the Rytky occurrence is 2 – 3 km from the main highway 5 by a village road and/or a timber haulage road, which are passable for heavy vehicles all the year round. The nearest railway stations are at Suonenjoki (35 km) and Kuopio (40 km). The Saimaa deep shipping channel, which connects the lakes of central Finland to the Baltic Sea, runs within 5 km of the occurrence. The distance to Kuopio airport is 60 km and that to Varkaus airport 55 km. The area is served by a high voltage power line (20 kV).

Titles

GTK currently possesses four claims for exploration in the Rytky area, covering 175.7 hectares (Table 1 and Fig. 3). Outokumpu Mining has a claim on the Särkiniemi nickel occurrence (0.3 mill.ton, 0.9% Ni, 0.5% Cu) about 2 km NE of the Rytky occurrence (Figs. 2 and 3). The land within the claim areas is privately owned, with the exception of 11.6 hectares of the claim Rytky 3 and 51 hectares of Rytky 4, which are owned by Hackman Oy.

Figure 2. Location of the Rytky and other Ni occurrences near Kotalahti.

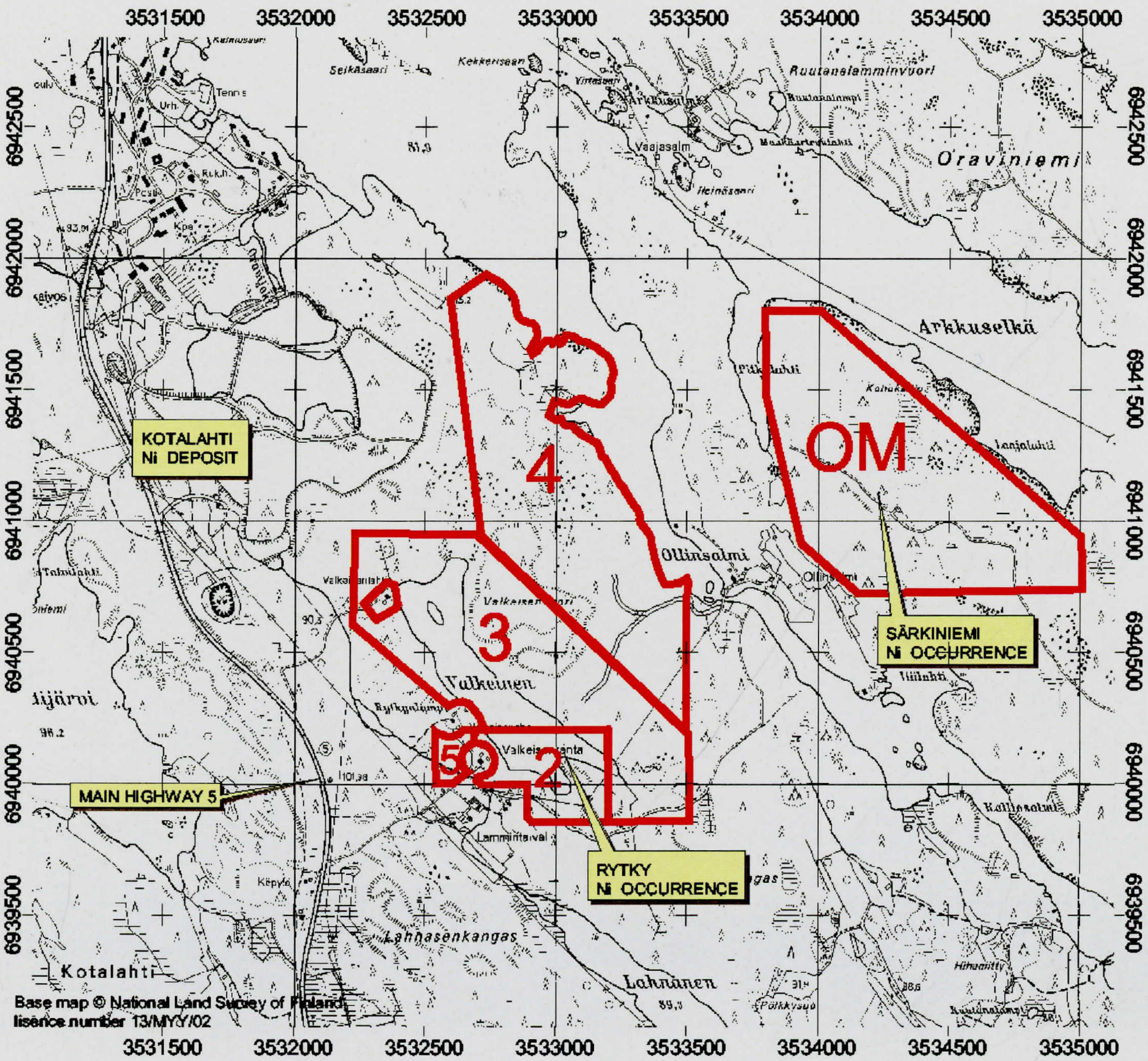

Figure 3. Location of the exploration claims on the topographic map. Numbers 2 – 5: GTK claims, OM: Outokumpu Mining.

A claim entitles the holder (individual or company) to carry out exploration activities in the claim area with or without the consent of the landowner. The claimant must nevertheless compensate the landowner in full for any permanent or temporary damage or inconvenience caused by the exploration activities inside or outside the claim area. The claimant shall also act in compliance with environmental legislation and other laws and regulations.

Table 1. Claims at Rytky.

Name of the claim	Register number	Map sheet 1:20 000	Area (hectares)	Registration date	Expiry date
Rytky 2	5629/2	3241 11	13.8	09.06.1995	31.12.2002
Rytky 3	7081/1	3241 11,12	64.0	15.02.2001	15.02.2006
Rytky 4	7227/1	3241 12	79.5	10.05.2001	10.05.2006
Rytky 5	7318/1	3241 12	2.2	29.12.2002	31.12.2006

Physiography, climate and vegetation

The Rytky occurrence is located in an area with many lakes and bedrock hills. The large lakes have their surface level at 82 m asl and smaller ones at up to 125 m asl. The highest hills reach 210 m asl. Outcrops are quite abundant and the bedrock is usually covered by less than 5 m of glacial deposits (mainly till).

Weather conditions follow the typical northern Fennoscandian climate, with a temperate summer and cold winter. The temperature is mostly between 10°C and 25°C during the summer months (June-August) and between 0°C and -30°C during the winter months (December-March). The terrain is covered by snow for 5 to 6 months in the year, during which time the bogs, lakes and small rivers are frozen. The maximum snow depth, which is reached in March, averages 60 cm.

Most of the land areas are forested with mainly spruce and pine.

History

Nickel exploration in the Kotalahti area started in 1954, when nickel-bearing samples were sent to Outokumpu Oy. Soon after this the Kotalahti nickel ore was discovered, and it was then mined from 1957 to1987 by Outokumpu Oy (Papunen and Koskinen 1985). The company also carried out geological mapping, geophysical surveys and a great deal of explorative drilling in the surroundings of the deposit, and most of the drill cores are nowadays stored by GTK at its depot in Loppi.

GTK started explorations at Rytky in 1994 as part of an extensive research and exploration project concerned with the Svecofennian (1.9 Ga) Kotalahti Nickel Belt initiated in 1992. Detailed mapping showed that the stratigraphic footwall of the intrusion is subvertical at the eastern contact of the body, and exploration was focused there. In 1995 - 1996 disseminated sulphides were found in pyroxenite-peridotite, but the nickel grade was low. The lithogeochemical characteristics nevertheless pointed to a good nickel potential in this intrusion (Forss et al. 1999), and magnetic measurements, both ground surveys and borehole measurements, suggested high susceptibility material at a greater depth. After detailed structural mapping, drilling was directed at the most promising part, and the first borehole intersected nickel ore in peridotite at a depth of 140-200 m in August 2000.

REGIONAL GEOLOGY

Geological setting

The Archaean basement in the central part of the Fennoscandian Shield extends from Russia into central Finland, while to the west the bedrock is composed of Svecofennian rocks, which cover the central and southern parts of Finland and the main part of Sweden. The largest Svecofennian plutonic complex in Finland is the Central Finland Granitoid Complex, which is separated from the Archaean basement in the NW by the Palaeoproterozoic Savo schists. Structurally, this latter belongs to the Raahe-Ladoga Zone, which hosts most of the Finnish volcanogenic massive sulphide deposits (e.g. Pyhäsalmi, Vihanti) and nickel deposits (e.g. Kotalahti, Hitura). A narrow part of the belt has been named the Kotalahti Nickel Belt by Gaál (1972). In this report however, the name Kotalahti Nickel Belt applies to a larger area within the Raahe-Ladoga Zone (Fig. 4).

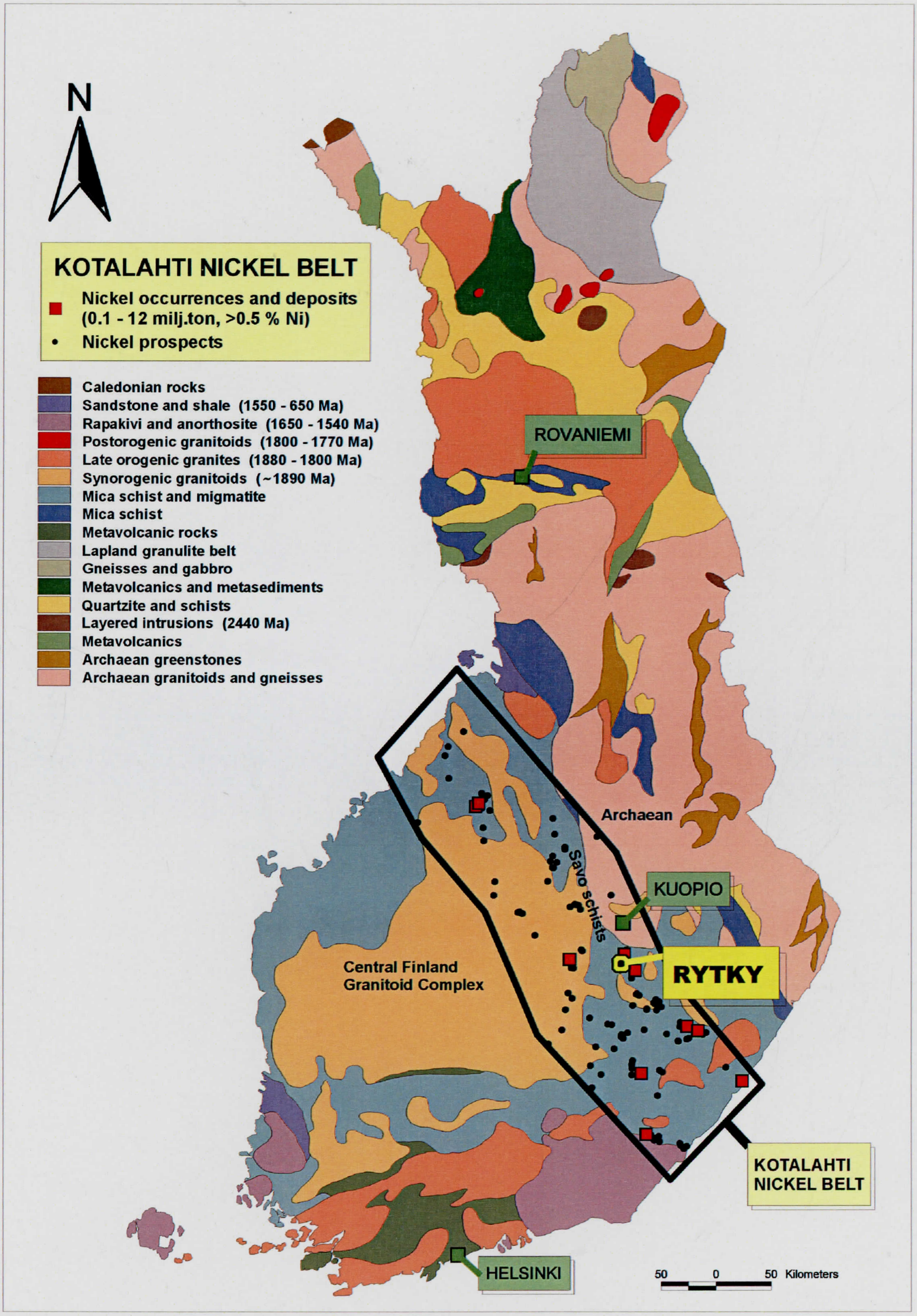

Figure 4. Bedrock map of Finland with the Kotalahti Ni Belt. Simplified after Korsman et al. (1997).

The predominating supracrustal rocks of the Svecofennian Domain are turbidites, which are migmatised in many places. Detrital zircon in these shows a bimodal age distribution, the majority being Palaeoproterozoic, between 2.1 and 1.9 Ga in age, but a significant contribution of Archaean zircons has also been recorded. Svecofennian volcanic rocks form major belts, but also occur in narrow discontinuous belts or limited occurrences within both metasedimentary and intrusive complexes. The volcanics occurring in Finland represent two age groups, c. 1.92 and 1.88 Ga, with the VMS-hosting volcanics belonging to the older group. The age of the Central Finland Granitoid Complex is c. 1.88 Ga (Kousa and Lundquist 2000 and references therein).

Typical structural features of the Raahe-Ladoga Zone include faults and shears running in NW and NS directions, caused by later deformation phases (D_{3-4}). The earlier structures (D_{1-2}) were the results of recumbent folding when the Svecofennian crust collided with the Archaean one and was partly overthrusted onto it. As a result of the multiphase folding, interference structures such as antiforms and synforms, separated into individual blocks by late faults in places, are now present in schist belts. The metamorphic conditions reached a peak around 1.88 Ga with medium amphibolite to granulite facies conditions.

The Rytky nickel occurrence is located in the border zone between the Archaean rocks in the east and the Savo schists in the west. This border zone features the Archaean Kotalahti tonalite gneiss dome, surrounded by Palaeoproterozoic supracrustals, and Rytky is located near the centre of the dome (Fig. 5).

Economic geology

The Kotalahti area has been under exploration since the discovery of the Kotalahti nickel deposit in 1954. Up to the 1990's this work was done exclusively by Outokumpu Oy, and GTK started exploration in the area in 1992 (Forss et al. 1999).

Besides Kotalahti, three small nickel occurrences have been found in the area: Sarkalahti, Hanhisalo and Särkiniemi (Fig. 2). *Sarkalahti,* located about 10 km SE of the Rytky occurrence, was found in 1971 by Outokumpu Oy and has 0.17 Mt of resources of grade 0.94% Ni and 0.30% Cu. The host rock is metapyroxenite. *Hanhisalo* is located about 10 km NNE of Rytky and is a gabbro-hosted occurrence with 0.14 Mt at 0.61% Ni and 0.20% Cu (Kontoniemi & Forss 1998) found by GTK in 1993. *Särkiniemi* lies in the Kotalahti area, only about 2 km NE of Rytky. Found by GTK in 1994, its host rocks include peridotite and gabbro and its total resources are 0.29 Mt, of grade 0.91% Ni and 0.53% Cu (Kontoniemi & Forss 1997). Outokumpu Oy holds the claim to Särkiniemi at present. In addition to these occurrences, many nickel prospects occur in the area, some of them still having a significant nickel potential (see Forss et al. 1999).

EXPLORATION

Current exploration programme

The exploration work at Rytky was carried out by J. Mäkinen (mapping, drilling, geochemistry), H. Makkonen (drilling, geochemistry), H. Forss (geophysics), O. Kontoniemi (drilling) and R. Lempiäinen (assistance). The research was led by H. Makkonen.

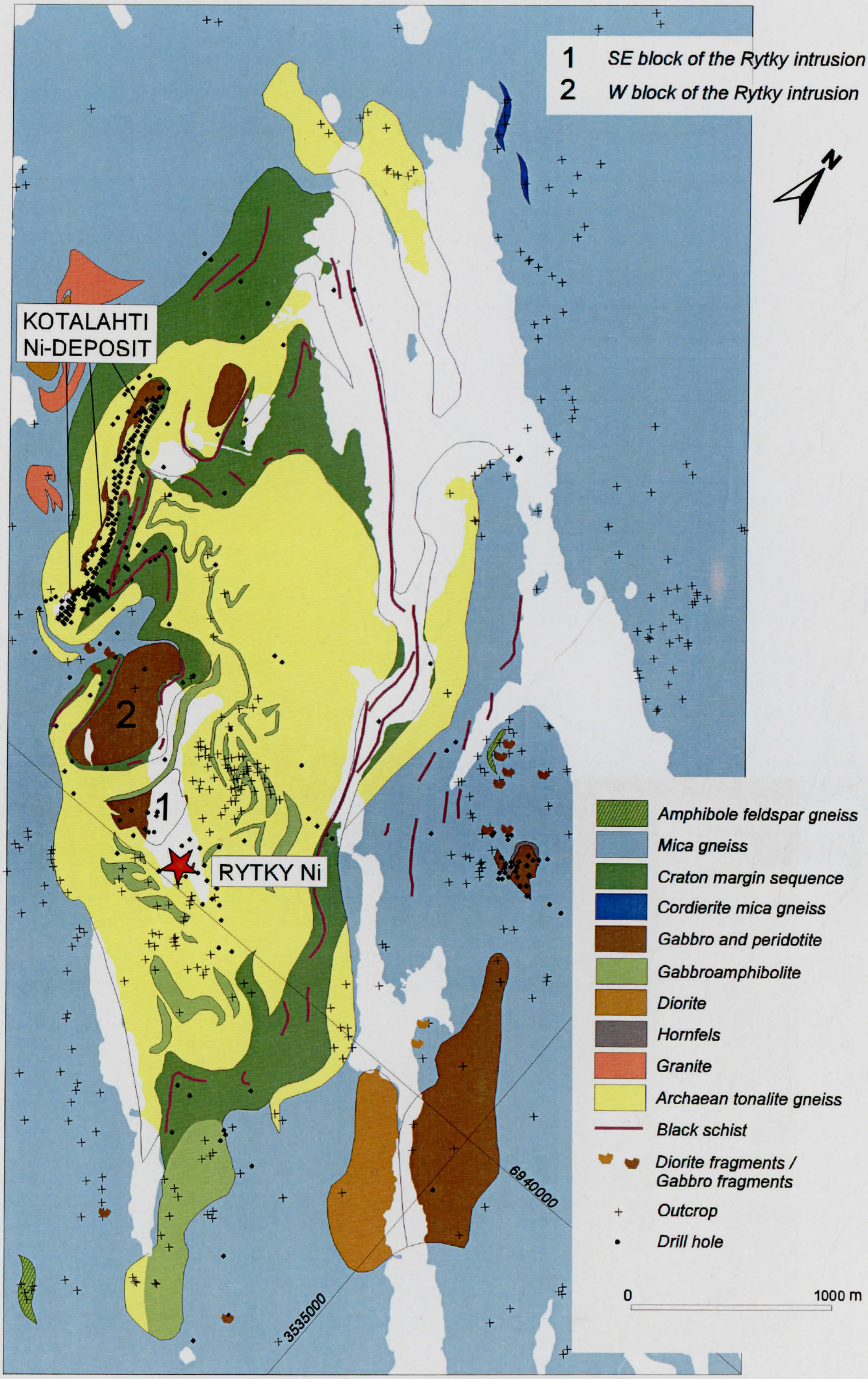

Figure 5. Location of the Rytky Ni occurrence in the Kotalahti Dome. Lake areas are shown by white colour. Geology modified after Gaál (1980), Kontoniemi & Forss (1997) and Parkkinen (1972) by J.Mäkinen and O.Äikäs.

Exploration started in 1994 with detailed geological mapping of the W block by J. Mäkinen (Fig. 5). This revealed tectonically turned vertical layering with a stratigraphic footwall towards the east. In 1993 -1994 mapping and structural investigations were carried out by J. Jokela over a larger area including that of Kotalahti (Jokela 1994), and later, in 1996 – 2001, lithological and structural investigations were performed by J. Mäkinen.

Outokumpu Oy had done some exploration in Rytky earlier, and some of the boreholes made by Outokumpu were studied at the beginning. A geological map of the Kotalahti area by Gaál (1980) was also available.

One important set of material on the Rytky area consisted of ground geophysical measurements purchased from Outokumpu Oy. These clearly showed a magnetic and gravimetric anomaly at the stratigraphic footwall of the intrusion (SE block, fig. 5). This was drilled by GTK using a light diamond drilling machine in 1995. The work was supervised by O.Kontoniemi. Later, in 1996, drilling was continued under the supervision of J.Mäkinen. Only a low-grade nickel sulphide dissemination was encountered.

It was decided on the basis of the geochemical data from the drillings in 1995-1996 to continue investigations in 2000, with the intention of intersecting the stratigraphic footwall of the intrusion on its SE margin. Borehole R460 did indeed intersect the ore in August 2000, and drillings were then continued until September 2001. Altogether 45 boreholes (10 332.15 m) were drilled in the area (Apps. 1 and 2).

Exploration techniques and results

Sampling, drilling, sample preparation and assays

Holes R473 and R479 down to 156 m and 216 m, respectively, were produced with a T56 diamond drill of core size 42 mm and the lower parts with a T46 of core size 32 mm. Each core was halved with a diamond saw, and divided into samples usually of length one metre (maximum 1.2 m) for assay purposes. Massive ores were analysed separately. Automatic sample treatment at the Kuopio laboratory of GTK involved crushing the half core in a Mn steel jaw crusher and pulverisation in a ring mill with a Mn steel bowl.

The following elements were analysed by GTK method 511P, which is based on the ICP-AES technique with aqua regia digestion: Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, La, Li, Mg, Mn, Mo, Na, Ni, P, S, Sb, Sc, Si, Sr, Th, Ti, V, Y, Zn and Zr. In addition, Au, Pd and Pt were analysed by GTK method 521U (GFAAS; aqua regia digestion, Hg-coprecipitation) . Altogether 972 samples were analysed.

For the whole rock analyses, 142 samples, mainly sulphide-poor ones, were taken from the outcrops and drill cores. Polished thin sections were made from the drill core samples. Each sample was crushed in a Mn steel jaw crusher and pulverised in a carbon steel bowl before analysis by GTK method 175X (pressed powder pellets). The following elements and compounds were determined: Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, CaO, TiO_2, MnO, Fe_2O_3, As, Ba, Bi, Ce, Cl, Cr, Cu, Ga, La, Mo, Nb, Ni, Pb, Rb, S, Sb, Sc, Sn, Sr, Th, U, V, Y, Zn and Zr. Some samples were also analysed for REE and Tl by GTK method 308M (HF-$HClO_4$ digestion, lithium metaborate – sodium perborate fusion; ICP-MS determination).

192 polished thin sections and 69 polished sections were made at GTK's Kuopio and Espoo laboratories. Analyses of olivine, and in some cases pyroxenes and amphibole, were performed on 69 polished thin sections at the Espoo laboratory using a Cameca SX50 microprobe with an acceleration potential of 25 kV and a current strength of 45nA. The main sulphide minerals in polished sections were analysed systematically and accessory sulphides were also identified (acceleration potential 20 kV and current strength 20 nA).

Digital photos were taken of the drill cores representing the intrusion rocks and the nearest contact rocks.

Geophysical surveys

The use of geophysical methods during the exploration will be explained in this chapter. A detailed description of the geophysical studies, interpretations and ore potential analysis will be presented in a special report in Finnish (Forss 2002).

Regional geophysical surveys

GTK carried out regional *low altitude airborne measurements* in this area in the 1990's, employing magnetic, electromagnetic and radiometric methods. The prospect area and its surroundings are thus well covered, and low altitude surveys now extend to almost the whole of Finland. GTK has also performed *regional gravity surveys* covering the whole of map sheet 3241 (scale 1:100 000) with a density of about 6 stations/ km^2.

Locations, staked lines

Line staking was carried out in four stages corresponding to the phases of the geophysical survey.The first stage took place 1995, when two small, separate staked grids were set up to locate the first-stage drilling targets. The second phase was associated to an increment in the survey area, while the third and fourth stages were for focusing purposes. Descriptions of the staked lines are given in Table 2 below.

Table 2. Line staking.

Co-ordinate system	Staked area	Method/device used	Accuracy	Time
Finnish KKJ	0.18 km^2	Total station	< 0.5 m	February 1995
Special LK [1)]	1.6 km^2	Line staking / aiming	< 2 m	March 2000
Finnish KKJ	0.35 km^2	Line staking/DGPS [2)]	< 2 m	January 2001
Finnish KKJ	0.53 km^2	CPD-RTK-GPS [3)]	< 0.1 m	May 2001

1) LK is rotated 45 degrees counter-clockwise from KKJ.
2) Differential corrected GPS, Fokus service 2 m Precision
3) Carrier Phase Differential-Real Time Kinematic-GPS

Ground geophysics

A summary of ground geophysical measurements is given in Table 3. Basic *magnetic, electromagnetic and gravity* data were obtained from Outokumpu Company (OKU) through a data exchange in 1994. Two small, detailed, dense grid magnetic measurements were performed in 1995 to locate the anomalies found in the OKU data, and the survey area was expanded with magnetic, electromagnetic and gravity measurements in 2000. In 2001 we focused on the vicinity of the ore body and made detailed, dense grid fill-in magnetic and gravity measurements. A combined magnetic total field and gravity Bouguer anomaly map is presented in Figure 6.

Mise a la masse measurements were performed both in the drill holes and on the ground. The ground measurements were intended to locate the topmost part of the ore body and establish its horizontal dimensions.

Sampo-EM broadband soundings were employed in an attempt to find deep-lying conductors and thus follow the ore extensions and find other possible separate conductors. The transmitter loop was a circle of 20 m diameter, and several coil separations were used.

Table 3. Ground geophysics

Method/Device	Survey area	Station spacing	Line spacing	Method parameters	Measured by	Survey time
Magnetic/	1.5 km^2	20 m	50 m	Z-comp	Outokumpu Oy	1994
Scintrex EnviMag	0.18 km^2	10 m	10 m	Total comp	GTK, VSA [1]	February 1995
Scintrex EnviMag	1.6 km^2	10 m	50 m	Total comp	GTK, VSA [1]	March-May 2000
Scintrex EnviMag	0.35 km^2	10 m	10 m	Total comp	GTK, VSA [1]	January 2001
Electromagnetic (Slingram)/	1.5 km^2	20 m	50 m	F=1775 Hz Coil sep 60m	Outokumpu Oy	1994
GTK-NP	1.6 km^2	20 m	50 m	F=3600 Hz Coil sep 60m	GTK, VSA [1]	March-May 2000
Gravity/ Worden	1.5 km^2	20 m	100 m		Outokumpu Oy	1994
Scintrex CG3	1.6 km^2	20 m	100 m		GTK, VSA [1]	March-May 2000
Scintrex CG3	0.4 km^2	10 m	50 m		GTK, VSA [1]	May 2001
Mise –a la masse/						
Gefinex 100	0.4 km^2	10 m	40 m	4 different	GTK, VSA [1]	Jan – Feb 2000
Gefinex 100	0.4 km^2	10 m	40 m	groundings	GTK, VSA [1]	April 2001
EM broadband Sampo / Gefinex 400 S	49stations (4 lines)	50 – 100 m	50- 100 m	Coil sep 100-300 m f=2–2000 hz	GTK, VSA [1]	February 2001

[1] Geological Survey of Finland (GTK), Regional Office for Central Finland, Technical Group

Drill hole geophysics

A summary of drill hole geophysical measurements is given in Table 4, and detailed information on each drill hole is presented in Appendix 3.

3-component magnetic measurements formed one of the main methods for finding a magnetic source (sulphide ore or ultramafic part of the intrusion) in the case of drill holes that do not intersect such a source.

The most commonly used drill hole geophysical method was *mise a la masse measurement*, which provides a tool for defining connections between ore intersections in the same drill hole or in different drill holes. It can also be used to estimate the continuity and dimensions of an ore body. Four ore groundings were used.

SlimBoris and Protem EM measurements were used to locate conductors which do not intersect the measured drill hole. SlimBoris was used as a slingram-type device, with the transmitter and receiver probes both in the same drill hole. The Protem EM transmitter was a loop on the surface, while the receiver probe was in the drill hole. Only one transmitter loop was used.

Drill hole loggings were performed in several stages in the course of the drilling. Susceptibility and apparent resistivity were usually measured, and also density in many of the drill holes, see Appendix 3.

Table 4. Drill hole geophysics.

Method	Number of holes	Station spacing	Device	Measured by	Survey time
Mise-a-la-masse	9	2.5 – 5 m	Gefinex 100	GTK, VSA [1]	January 2001
	6	5 m	Gefinex 100	GTK, VSA [1]	March-April 2001
	1	2.5 -5 m	Gefinex 100	GTK, VSA [1]	June 2001
	7	5 m	Gefinex 100	GTK, VSA [1]	Sept- Oct 2001
Magnetic 3D	2	2 m	Magprobe 3D	Suomen Malmi Oy	March 1996
	3	5 m	Magprobe 3D	Suomen Malmi Oy	June 1998
	4	5 m	Magprobe 3D	Suomen Malmi Oy	April 2001
SlimBoris	3	10-20 m	SlimBoris	GTK, T&K [2]	Sep-Oct 2000
	3	10-20 m	SlimBoris	GTK, T&K [2]	June 20001
Protem	6	5 - 10 m	Protem, EM37	Suomen Malmi Oy	October 2001
Loggings	3	5 cm	{app. resist RROM-2,	Suomen Malmi Oy	March 1996
	3	5 cm	susc. RRK-10,	Suomen Malmi Oy	June 1998
	1	5 cm	dens. Gamma-Gamma}	GTK, VSA [1]	October 2000
	1	5 cm		GTK, VSA [1]	January 2001
	5	5 cm		Suomen Malmi Oy	Marc-April 2001
	4	5 cm		GTK, VSA [1]	April 2001

[1] Geological Survey of Finland (GTK), Regional Office for Central Finland, Technical Group
[2] Geological Survey of Finland, Research and Development

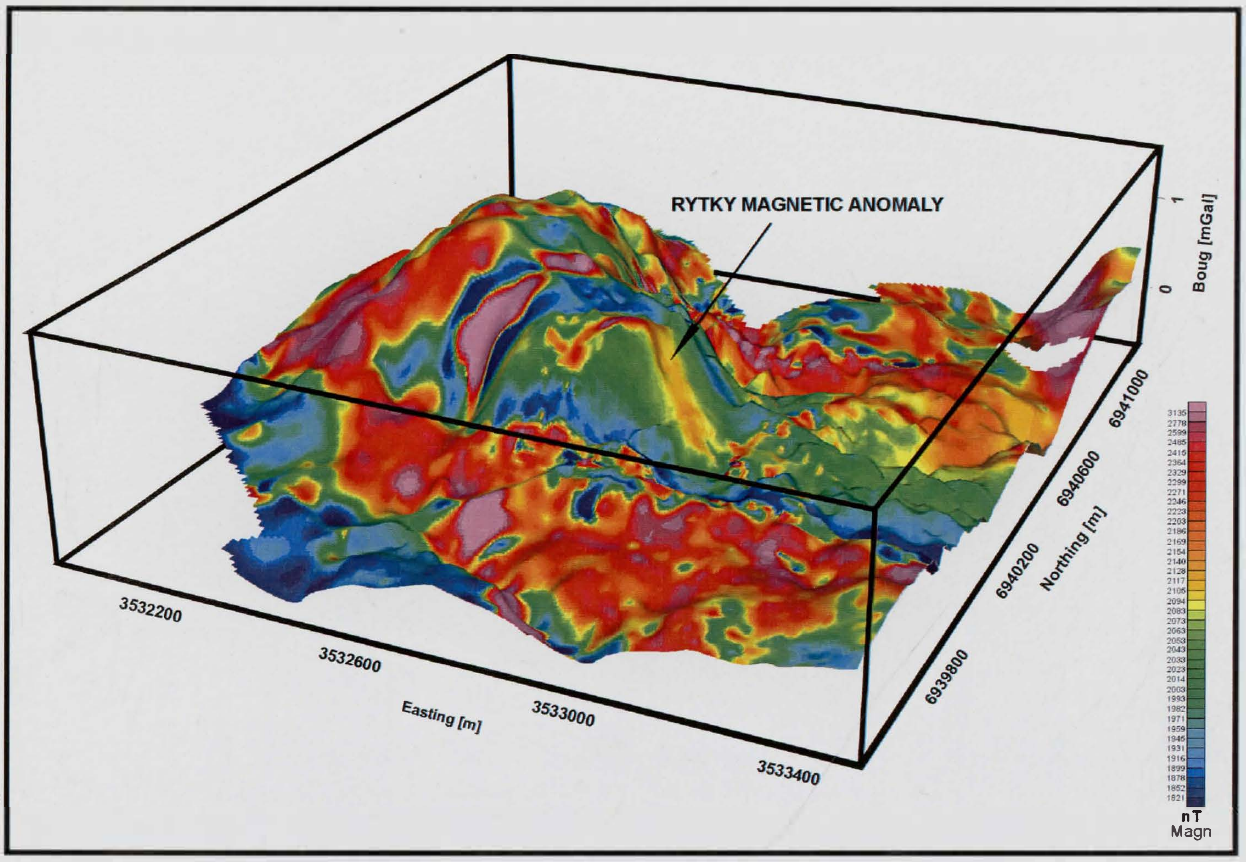

Figure 6. A magnetic total field (coloured) on a gravity Bouguer anomaly (relief). The Rytky magnetic anomaly is caused by ore-bearing and barren peridotites.

Drill core petrophysics

A total of 222 drill core samples were measured in GTKs Petrophysics Laboratory in Kuopio, including 114 from drill hole R460, 70 from R461, 6 from R462, 20 from R464 and 12 from R465. Susceptibility, remanent magnetization and density were measured in all of these. Apparent resistivity was analysed in 159 samples (74 from R460, 70 from R461, 3 from R462 and 12 from R464), and inductive conductivity in 88 (71 from R460, 17 from R461).

Geological mapping

Outcrop conditions in the area are good, but the intrusion itself is exposed only with respect to its western block (Fig. 5). The geology of the Kotalahti mine area and its surroundings is well-known because of the large amount of drilling and detailed geological mapping that has been carried out there.

The Rytky intrusion is located in the SW part of the Kotalahti Dome, which is formed of Archaean tonalite-quartzdiorite gneisses cut by gabbroamphibolitic dykes. The Archaean rocks are overlain by Palaeoproterozoic quartzites, limestones, calc silicate rocks, black schists, and banded diopside amphibolites (craton margin sequence in Fig. 5). Above these in the stratigraphy are amphibole feldspar gneisses, cordierite mica gneisses and mica gneisses.

The contacts between the Archaean gneisses and the Rytky intrusion are tectonic in places, so that it is not clear whether the magma intruded directly into Archaean gneisses or whether there were also Proterozoic rocks in the contact zone. At least stratigraphically, there are Proterozoic supracrustals to be found above the intrusion and in its western part. Black schist inclusions are also encountered in the western and northern parts of the intrusion.

Metamorphism took place in amphibolite facies, causing the supracrustals to gain gneissous and migmatitic textures. Metamorphism is seen in the intrusion in the form of the amphibolization and biotitization of pyroxenes, for instance.

Four deformation phases, D_1 – D_4, were determined in the area. D_1 is seen as flame-like and isoclinal folds in mica gneisses, while D_2, the most intensive deformation phase, is seen as a penetrative schistosity and isoclinal folding in the area, the measured schistosities in the mapping area being attributable to the S_2 phase. At the peak of the deformation, mica gneisses formed varying amounts of schollen-schlieren migmatites with supacrustic or intrusive mafic-ultramafic fragments locally. The Archaean rocks were also oriented in this phase, although some of the structures in them were formed in Archaean times. During the D_2 deformation, fragments of the Rytky intrusion were detached and entered the Archaean gneisses, the largest ones being the coarse-grained peridotite and pyroxenite-containing fragments to be found east and southeast of the intrusion.

The SW-NE-oriented D_3 compression folded the S_2 schistosity and created open to tight F_3 folds together with the SE-oriented lineation parallel to the fold axis. The Archaean-Proterozoic Kotalahti antiform is also attributable to this D_3 compression.

The F_3 fold axes of the antiform edges plunge in opposite directions, which is attributed to the NW-SE-oriented D_4 compression. This D_3-D_4 interference structure is the present Kotalahti Dome. Deformation was already brittle in the late D_4 stage, and D_4 compression was directed to some extent at the right handed NW-SE faults and shear zones. One pronounced shear zone occurs in the NE part of the intrusion, in the direction of Lake Valkeinen (App. 4).

GEOLOGY

Deposit description

Quaternary geology

The average soil thickness in the area is 2-3 m, and the soil is composed of a sandy basal till with large numbers of boulders. Till occurs as an ablation moraine in places.

General geology

The Rytky intrusion consists of two blocks separated by supracrustals and tonalite gneiss. The intrusion dimensions in the surface section are about 0.5 x 1 km. The W block is mainly composed of gabbroic rocks, and no important nickel concentration has been found there, whereas the SE block, which hosts the nickel occurrence, has a surface section only about 0.3 km in diameter, but widening downwards (Figs. 5 and 7, App. 4).

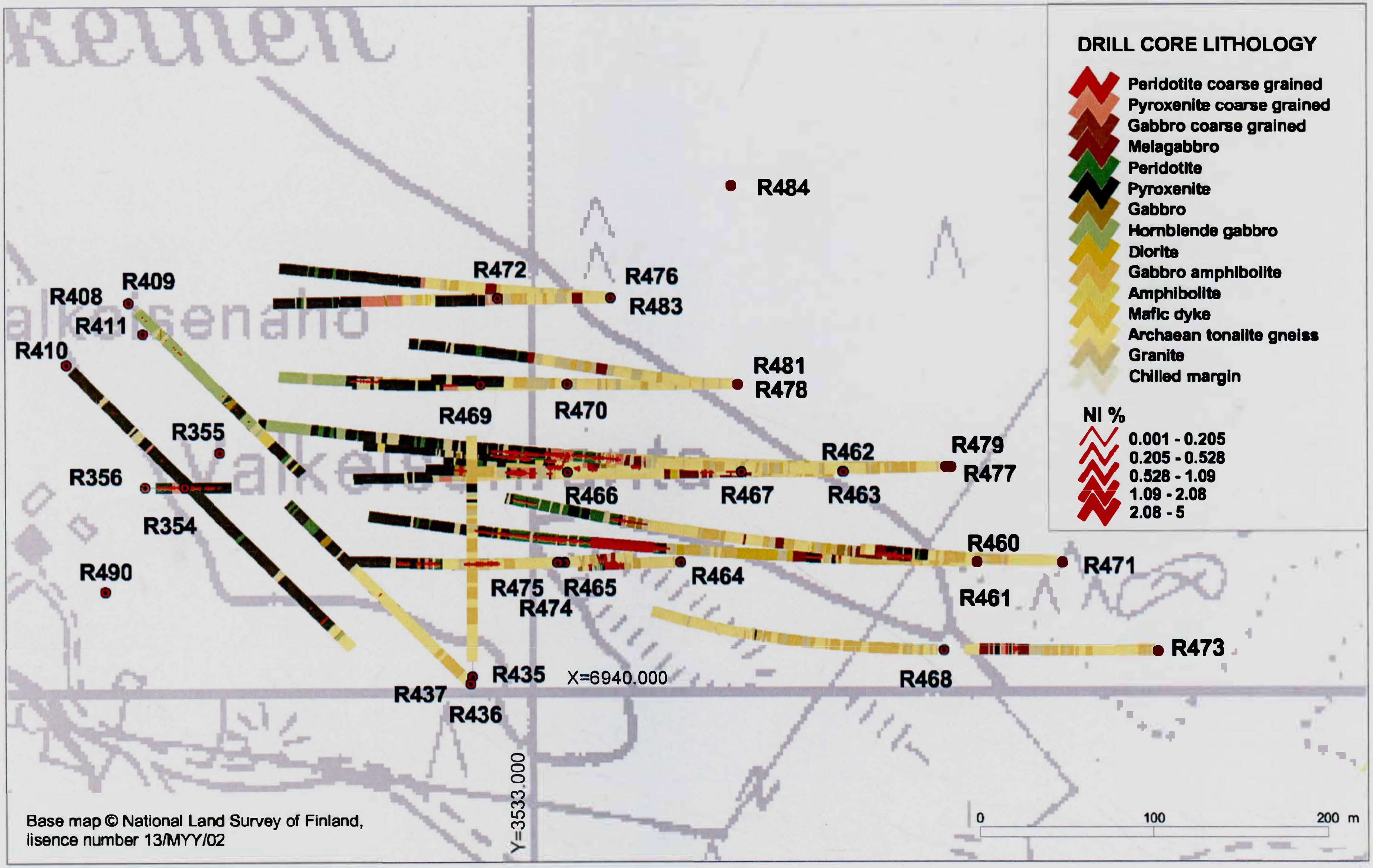

Figure 7. Drill core lithology and nickel content projected to the surface section.

Rytky is a layered intrusion primarily having a funnel-shaped basal contact, with the sulphide concentration located in the deepest part of the funnel. Because of tectonic movements, the layering is now vertical and the stratigraphic footwall of the intrusion towards east. This is the reason why the sulphide concentration is now found at the eastern contact.

Three main rock series of differing age can be distinguished in the intrusion: 1) the oldest, a coarse-grained peridotite and coarse-grained pyroxenite-melagabbro, 2) peridotite and pyroxenite, and 3) the youngest, a hornblende gabbro. The first two have ore potential, the peridotite-pyroxenite series is the more voluminous.

Lithology

Coarse-grained peridotite. The most typical feature for this rock type is the occurrence of euhedral to subhedral elongated grains or medium to coarse-grained grain aggregates (< 10 mm) of serpentinised olivine, which represent an adcumulus structure. Magnetite pigment is often found in the olivine. The other main minerals in the rock are orthopyroxene and to a lesser extent clinopyroxene.

Peridotite. The mineral composition is the same as in the coarse-grained peridotite, but the grain size of the serpentinised olivine is 1-2 mm. Olivine occurs as euhedral or rounded grains. Adcumulus structures and magnetite pigment are not so common as in the coarse-grained type. Peridotite gradually changes through olivine pyroxenite to pyroxenite. With the increasing amount of plagioclase, the rock changes to plagioclase peridotite and olivine gabbro, although these occur only in small amounts in the intrusion.

Pyroxenites. Orthopyroxene predominates over clinopyroxene in the coarse-grained pyroxenite, while orthopyroxene grains often occur in laminated layers in the pyroxenite and clinopyroxene is present in places in the form of large poikiloblasts (< 1 cm). Primary brown clinoamphibole occurs in large anhedral grains (< 1 cm).

The *melagabbro* is mainly composed of plagioclase and metamorphic greenish clinoamphibole, cummingtonite and biotite. Relicts of primary orthopyroxene are encountered in places.

Gabbros form a heterogeneous group of small volume. The main minerals are plagioclase, clinopyroxene, orthopyroxene and sometimes olivine. Gabbros often intersect with pyroxenites, but pyroxene gabbros and olivine gabbros also occur, gradually differentiating from the pyroxenites and peridotites.

Hornblende gabbros cut across the other intrusion rock types, forming veins in places. The main minerals include dark hornblende and plagioclase. The grain size is medium to coarse.

Other rock types. Pieces of *chilled margin* (< 2 m), probably originating from the intrusion roof, are met with in outcrops near the western margin of the intrusion. The youngest rock types include fine-grained *mafic dykes* and *pegmatitic granites.* The pegmatites have caused metasomatic alteration in the surrounding pyroxenites, which is reflected in biotitization.

Structure of the intrusion

The lowest and oldest rock types in the stratigraphy are the coarse-grained peridotite and coarse-grained pyroxenite together with melagabbro, all of which belong to the same differentiation series. These rocks are cut by the peridotite-pyroxenite-gabbro series. The age difference and contact relations between the two peridotites are clear but those between the pyroxenites are unclear.

Layering and lamination are clearest in the peridotites and pyroxenites, with peridotitic and olivine pyroxenitic layers of thickness 0.2 – 1.0 m occurring in the pyroxenites. Outcrop evidence suggests that the layering is linear in the W block of the intrusion, while that in the basal part (SE block) conforms more closely to the bottom outlines of the intrusion.

Geochemistry of the intrusion

The Al_2O_3/CaO ratio of > 1 in the intrusion rocks (Fig. 8) is reflected in the orthopyroxene and plagioclase-rich rock types. The Kotalahti intrusion has a similar Al_2O_3/CaO ratio, which is thought to indicate crustal contamination and ore potentiality (Makkonen 1996).

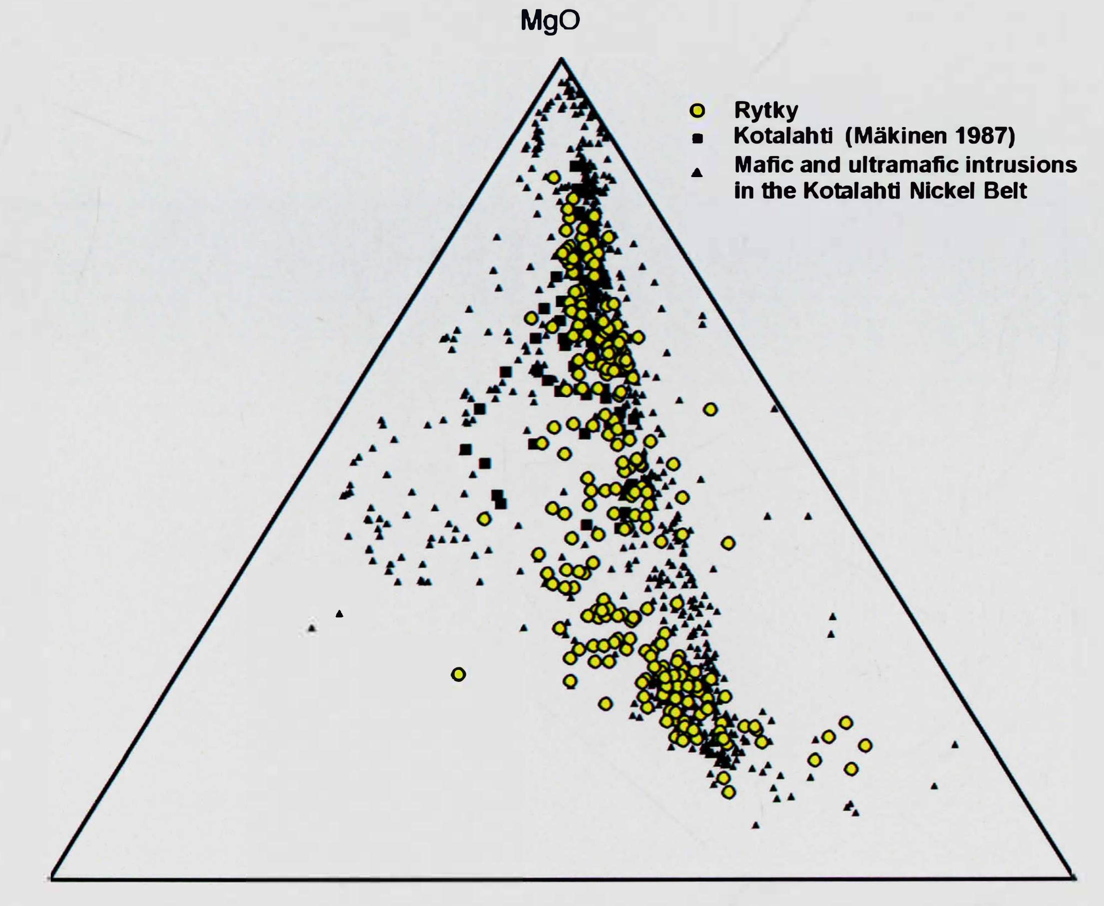

Figure 8. Rytky has a distinct orthopyroxene-dominated fractionating trend, reflecting crustal contamination – and hence ore potentiality.

Lithological studies suggest that the coarse-grained peridotite is the older rock type and the peridotite that intersects it the younger. As there are no differences in the TiO_2/Zr ratio (Fig. 9), they probably both originate from the same magma, although the slightly higher TiO_2 and Zr contents indicate that the coarse-grained peridotite may be more contaminated.

The main difference between the pyroxenites and metapyroxenites lies in the higher K_2O content of the latter (Fig. 10). This K_2O originates from the pegmatitic granites, as seen in the biotitization of pyroxene in the contact zone between the pegmatites and pyroxenites

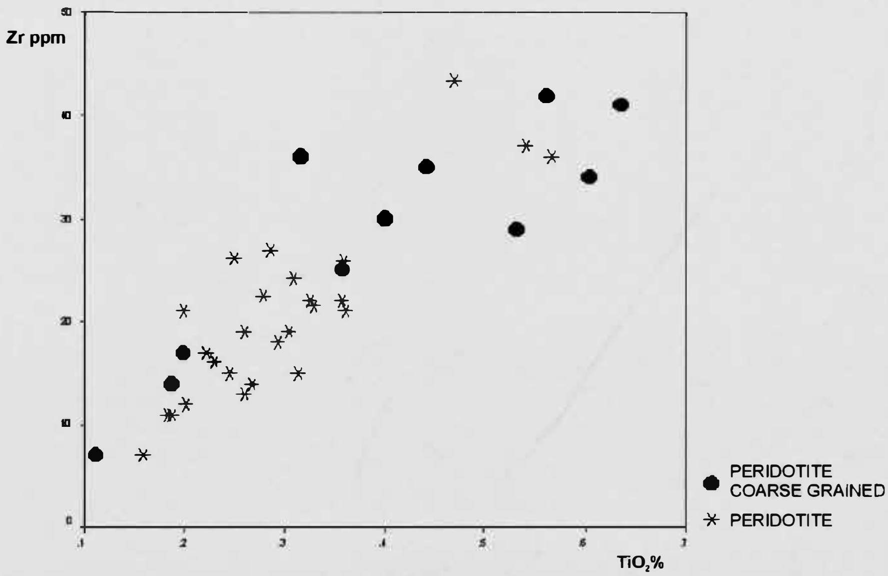

Figure 9. The peridotites differ in TiO_2 and Zr content.

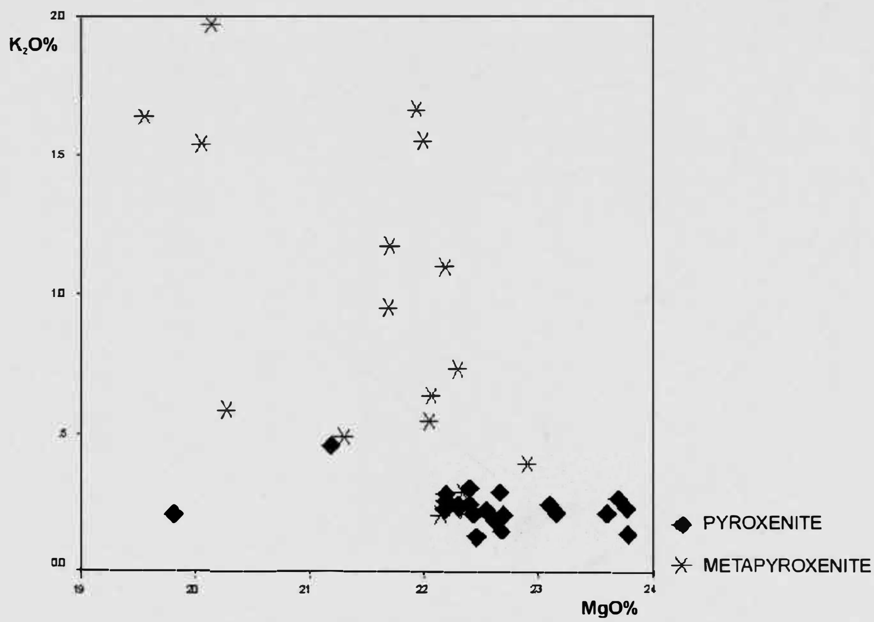

Figure 10. The metapyroxenites have higher K_2O content than the pyroxenites.

The olivine forsterite and nickel contents are high relative to other intrusions in the Kotalahti belt (cf. Forss et al. 1999), which indicates ore potentiality, and the substantial variation in the nickel content of the olivine within a narrow forsterite range means that *in situ* sulphide segregation took place in the intrusion (Fig. 11).

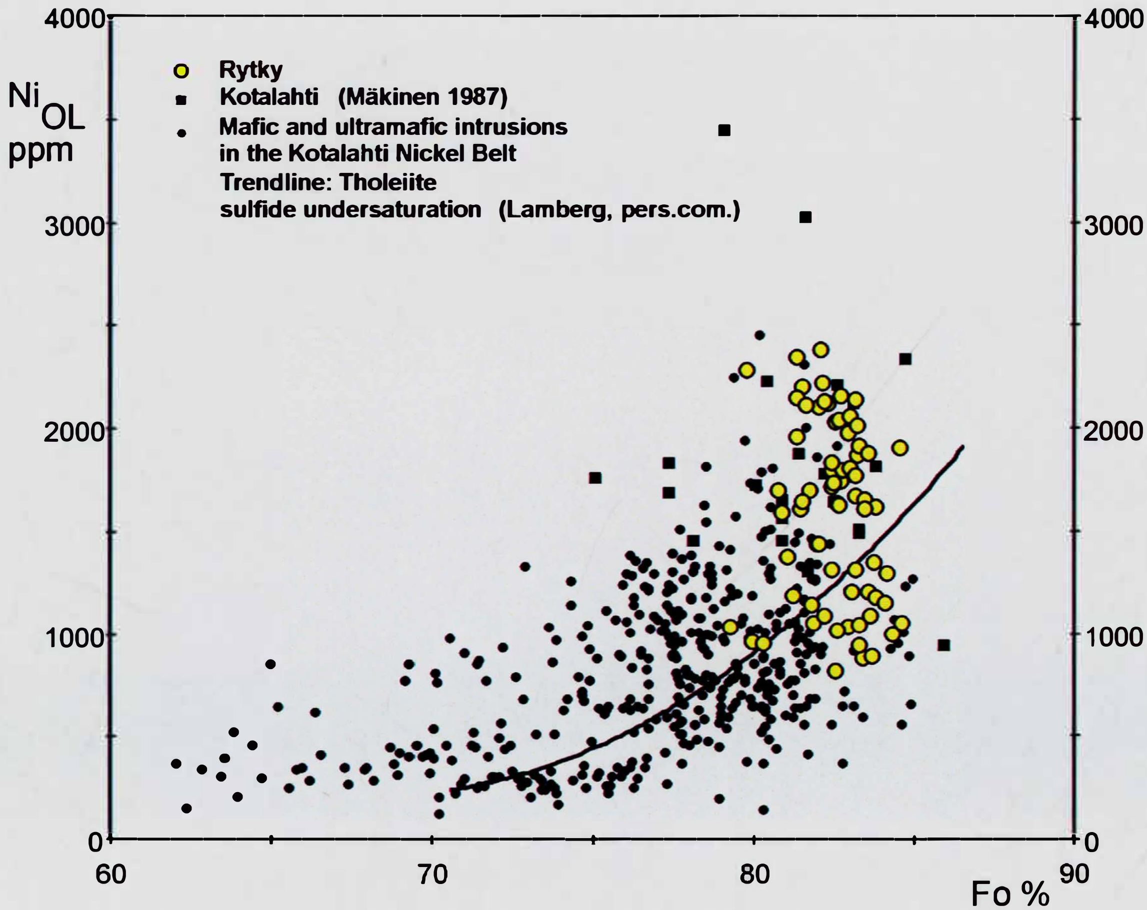

Figure 11. The steeply descending trend from high olivine nickel and forsterite indicates an ore-forming process at Rytky.

Ore mineralogy

The ore types in the Rytky occurrence are weak, fine-grained disseminations, coarse disseminations, matrix (net-textured) ore and massive ore (Fig. 12). The following is the abstract of a report by Kojonen et al. (2002) on the ore mineralogy.

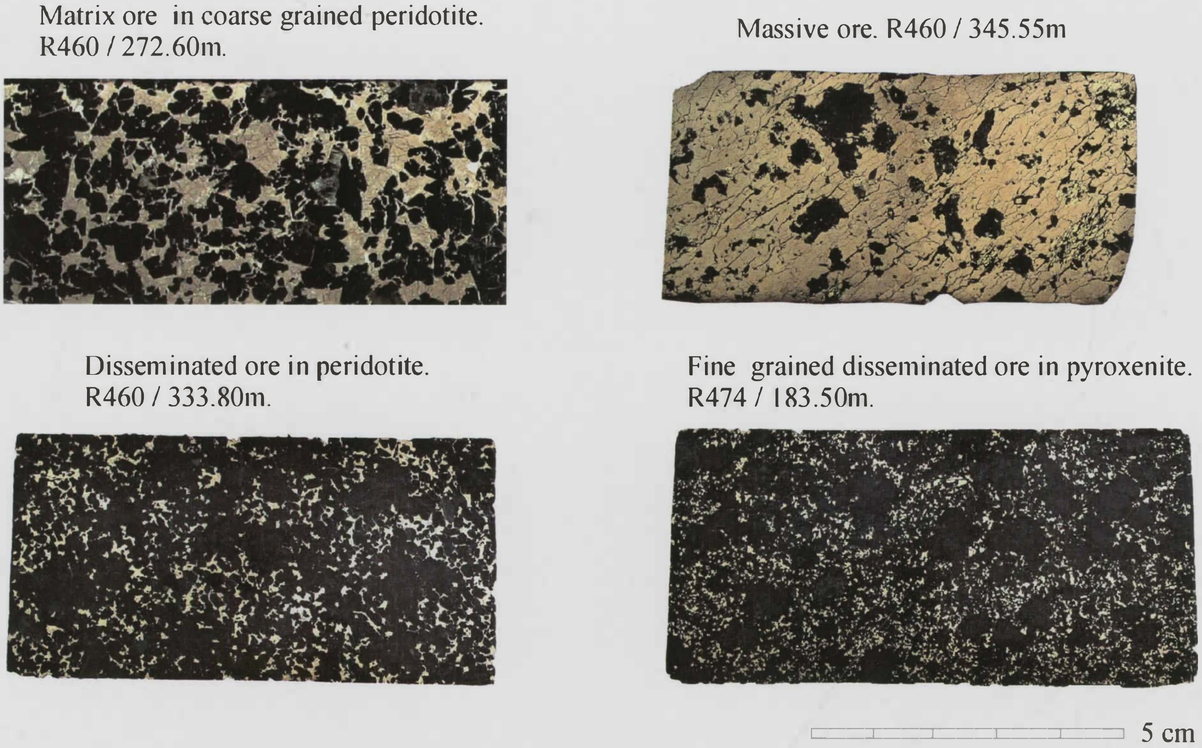

Figure 12. Ore types in the Rytky occurrence.

The major sulphide ore minerals are pyrrhotite, pentlandite and chalcopyrite. Cubanite is occasionally observed as inclusion laths in chalcopyrite, a few euhedral cobaltite grains are found in the sulphides, and mackinawite inclusions occur in the chalcopyrite and pentlandite.

Samples taken from near the surface contained secondary pyrite and violarite as alteration products while primary pyrite was found in the deeper parts intergrown graphically with chalcopyrite and pentlandite and in corroded euhedral grains. Minor sphalerite occurrences were found with the chalcopyrite, and occasional inclusions of lead, silver and bismuth tellurides in the sulphides.

The oxide ore minerals consist of magnetite, ilmenite, chromite and spinel. The magnetite occurs as a secondary alteration product in the fractures of the altered olivine and as fracture fill material in the sulphides. Primary magnetite is also found in some samples containing lamellae of ilmenite and inclusions of spinel. Ilmenite occurs mostly as primary inclusions in pyroxene or amphibole. Euhedral zoned chromite and spinel grains are observed in some samples.

Electron microprobe analyses of pyrrhotite (N=572) show mainly a hexagonal NC (57.5%), NC + 4C (21%) or troilite composition (8.7%). Only a minor proportion of the analyses (4.7%) have a monoclinic 4C composition. The average chemical composition of all the pyrrhotite samples has Fe 47.75 wt %, corresponding to the hexagonal NC type.

The main carrier of Ni is pentlandite, which occurs in subhedral to euhedral grains several hundreds of microns, or even millimetres, in diameter, in bands between pyrrhotite grains having a grain size of 75-200 microns and in flame-formed inclusions in pyrrhotite, usually 10-30 microns long and 5-10 microns wide. The average chemical composition of all the pentlandite analyses (N=754) was: Fe 32.75 wt %, Ni 32.45 wt %, Co 1.15 wt % and S 42.80 wt %. The large pentlandite grains contain more Co than the flame-formed inclusions. The mackinawite inclusions also have fairly high Ni, with an average composition(N=54) of Fe 57.40 wt %, Ni 6.34 wt %, Co 0.10 wt %, Cu 0.50 wt % and S 35.79 wt %.

The main copper carrier is chalcopyrite, with cubanite doing so to a lesser extent. The average composition of the chalcopyrite (N=326) is: Cu 34.21 wt %, Fe 40.37 wt % and S 34.47 wt %. It usually has a smoothly curved, anhedral grain form with occasional twinning and a rather large grain size, but fine-grained inclusions and intergrowths with silicates were also found.

Sulphide fraction chemistry

The economically important metals in the Rytky occurrence are nickel, copper and cobalt. Ni concentrations of up to 4.82%, Cu 2.08% and Co 0.172% have been recorded, but the PGE values are usually low (highest analysed Pt = 374 ppb, Pd = 162 ppb, Au = 679 ppb). The highest Au concentrations occur in the marginal series rocks in the eastern part of the intrusion (melagabbro, metapyroxenite), while Pt is mainly concentrated in the lowermost parts of the intrusion and ore body (hosted by the coarse-grained peridotite). Pd does not show any clear spatial control.

The sulphide fraction (SF) nickel concentrations vary with grade, and also within the occurrence. The average Ni_{SF} decreases with increasing grade at first, until about 0.5% Ni (Table 5, Fig. 13), partly because of the silicate nickel leached together with the sulphides in aqua regia digestion, but it starts to increase with increasing nickel content (> 0.5%), possibly a reflection of the primitive nature of the more massive ore types, which represent the first sulphide segregations and have accumulated at the bottom of the intrusion.

The Ni/Co ratio, and also Ni_{SF}, is higher in the marginal parts of the intrusion, as can be clearly seen in Fig. 14. There are different possible explanations for this fact, including 1) that the most primitive sulphides formed early within the marginal series, with a high nickel tenor, and 2) later pulses of new, fresh magma have increased the sulphide fraction nickel content in the marginal zones of the chamber (see Li & Naldrett 1999).

Table 5. Sulphide fraction Ni at different average Ni values. S content is assumed in calculation to be 37.5%.

Average Ni (%)	Calculated Ni_{SF} (%)
> 0.1	7.64
> 0.2	6.99
> 0.3	6.65
> 0.4	6.48
> 0.5	6.42

The internal stratigraphy of the intrusion is also reflected in the Ni/Co ratio of the sulphide fraction, which is highest in the basal part of the ore body (Fig. 15). This indicates fractional segregation of sulphides, those with the highest Ni/Co ratio having been formed first and settled at the bottom of the intrusion.

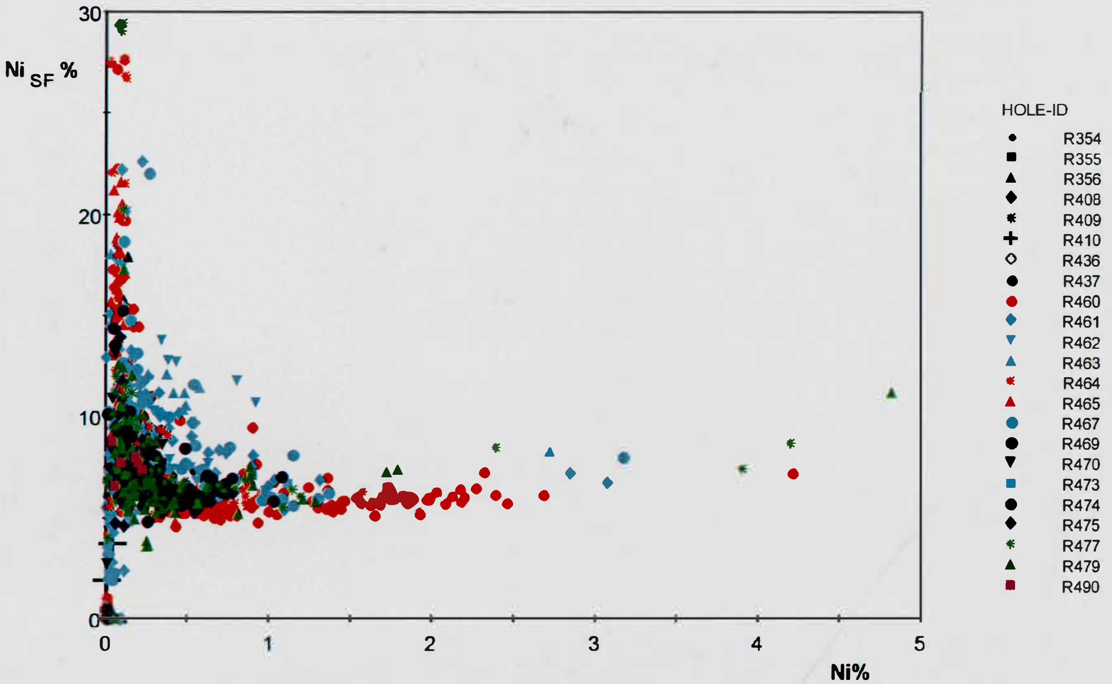

Figure 13. Nickel in the sulphide fraction (Ni_{SF}) increases with increasing nickel content. The marginal zones of the Rytky occurrence have the highest Ni_{SF} (colours: red = olivine cumulates, green = olivine pyroxenites and peridotites, dark blue = pyroxenites, blue = pyroxenites and melagabbro in the marginal zone).

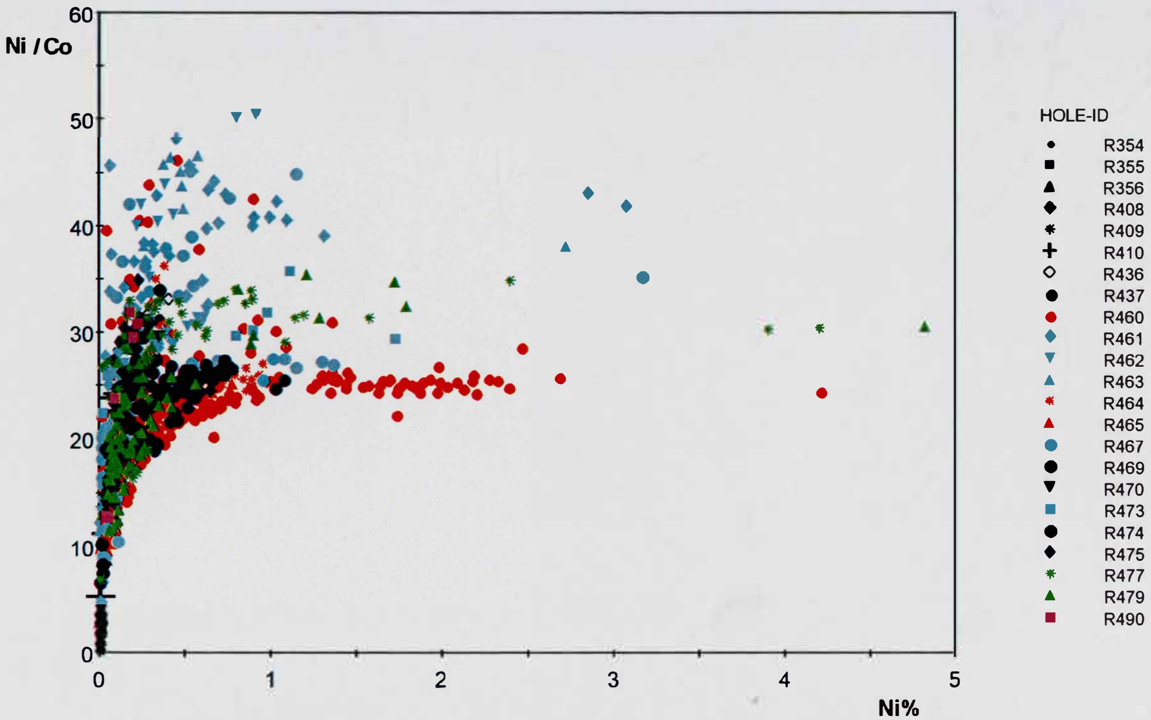

Figure 14. Ni/Co is higher towards the marginal zone in the Rytky occurrence. Colours as in Fig. 13.

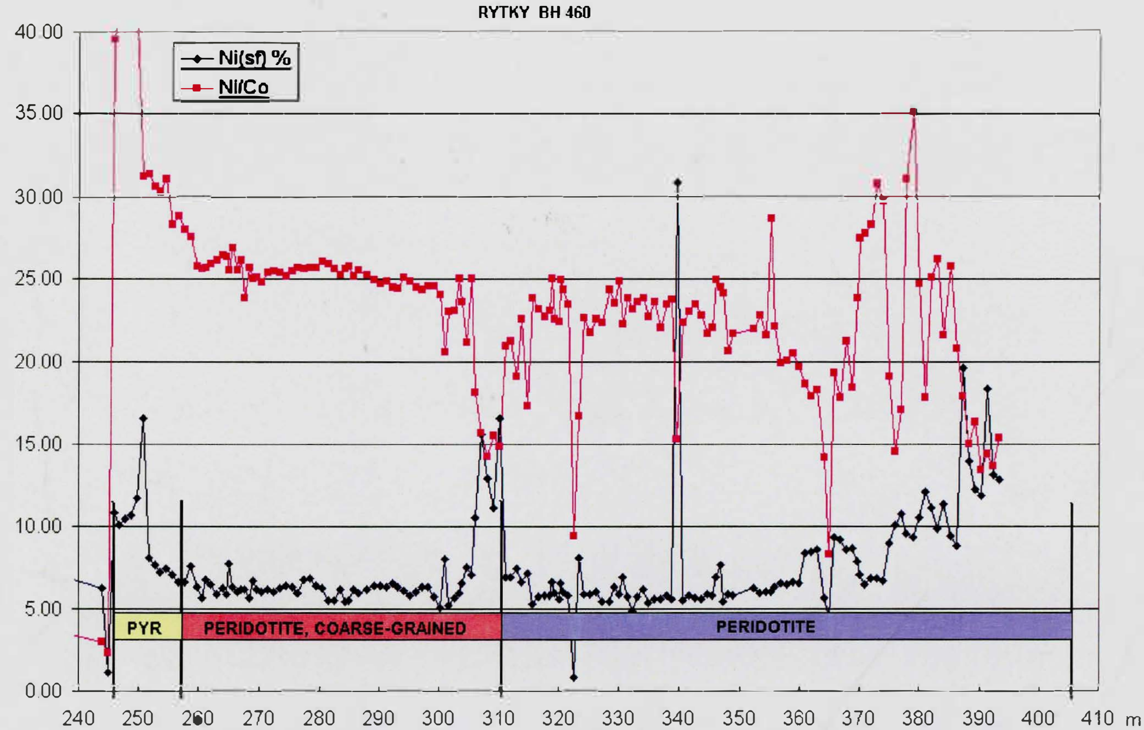

Figure 15. Ni/Co and Ni_{SF} in drillhole R460. Pyr = pyroxenite.

Geological interpretation

Intrusion near the contact of Archaean basement with the overlying supracrustal rocks took place in three stages. There were sulphide-bearing rocks in the vicinity of the intrusion itself, and probably also at the footwall contact. The magma that intruded at the first stage crystallized as coarse-grained peridotite, pyroxenite and melagabbro. The large euhedral olivine grains with adcumulus growth indicate dynamic crystallization conditions, possibly in a flow conduit, and these features also indicate a large magma volume, although the coarse-grained peridotite is now in the minority in the SE part of the intrusion. The magma was already saturated with sulphides at an early stage in the intrusion process, and sulphide segregation took place continuously during magma crystallization.

The second stage involved the intrusion of a magma which crystallized as peridotite, pyroxenite and olivine gabbro. This was also saturated with sulphides at an early stage, and marked variation in the nickel content of the olivine indicates sulphide segregation during crystallization. Rock types representing this differentiation series form the majority in the SE block of the intrusion, where the layering conforms to the footwall contact and probably the sulphide concentrations were also controlled by the footwall topography. Stratiform sulphides also occur, however, because there is a continuous sulphide layer in the southern part of the intrusion that extends from the main ore body, at a depth of 200 m, up to the surface (ore bodies A and D in Fig. 16).

The hornblende gabbro that intruded during the third stage, intersects with the older rock types and does not have any ore potentiality.

The Rytky intrusion is pre-syn-D_2 kinematic, because after intrusion and crystallization the D_2 deformation detached fragments into the Archaean gneisses. The Kotalahti antiform was formed in D_3, and and the Rytky intrusion turned into a vertical position with its stratigraphic footwall towards the east. The structures near the intrusion that had been directed by F_3 were reoriented in D_4, and they now plunge SE.

RESOURCE ESTIMATION

Deposit modelling

Peridotites and the related sulphide concentration (the main ore body) occur subvertically as a platy projection at the SE contact of the intrusion (orebody A in Fig. 16). This extends from the 100 m level to at least 300 m. The borders of the ore body are conformable with the intrusion contacts, which makes the ore body slightly funnel-shaped. The thickest part of the ore body lies between 200 and 250 m. Massive sulphides occur at the contact between the coarse-grained and medium-grained peridotites and in the northern side of orebody A, at the 200 – 300 m level.

Sulphide-rich pyroxenites occur to the west of the main ore body A (in R474), and this dissemination continues along the intrusion contact for a distance of 300 m as a low grade ore up to the bedrock surface below Lake Valkeinen (D in Fig. 16). The dip of this layer is 45° to the SE.

Two tectonically separated ore bodies, B and C, occur east of the intrusion (Fig. 16). These are oriented according to the F_3 fold axis (c. 120°/35°), which is dominant in the area. Thus these ore bodies differ in orientation from those at the contact of the intrusion. In ore body C, which extends from the surface to a depth of at least 200 m, the ore occurs near the surface at the eastern contact of the intrusion rocks and basement gneiss but at deeper levels in the coarse-grained peridotite in the middle of the intrusion rocks.

Resources explored to date

Resource assessments

The mineral reserves were estimated by Heino (2002) using the Windows Gemcom software for the calculations and employing solid modelling with conventional sectional outlining of the mineralised bodies with two cut-off grades for nickel (0.35% and 0.50%). The maximum length of an accepted sample below the cut-off was 5 metres, and the measured average density for the samples (3.15 g/cm^3) was used in the calculations. The deep continuation of ore body C (intersecting borehole R473 at 6.10 m, with 0.99% Ni) is not included in the assessment. The assessment is summarised in Table 6 and the measured+indicated resources indicated in the table are shown in Fig. 16.

Table 6. Assessment of mineral resources in the Rytky nickel occurrence.

MEASURED					
CUTOFF	**TON**	**Ni %**	**Cu %**	**Co %**	**S %**
0.35 % Ni	**1 265 700**	**0.56**	**0.19**	**0.022**	**3.28**
0.50 % Ni	**904 787**	**0.75**	**0.25**	**0.029**	**4.42**
MEASURED + INDICATED					
0.35 % Ni	**1 632 548**	**0.58**	**0.19**	**0.023**	**3.45**

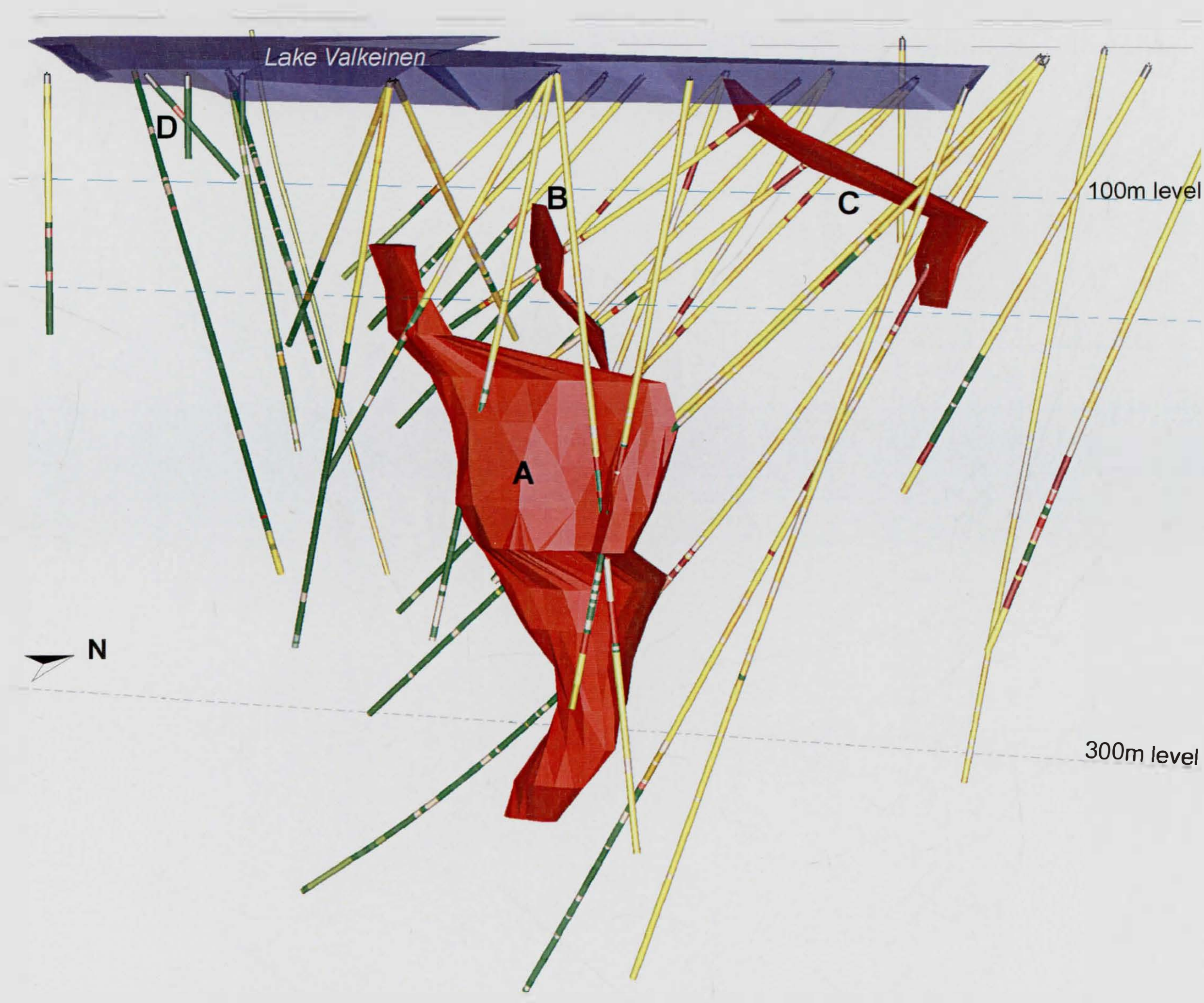

Figure 16. 3D model of the Rytky nickel occurrence. Red solid line = Ni > 0.35% (measured + indicated resources in Table 6).

Exploitation

Concentration tests

Preliminary concentration tests were performed by the VTT/Chemical Technology/Mineral Processing Laboratory in Outokumpu (Hintikka & Laukkanen 2002) on a sample (c. 15 kg) from drill core R460 in the interval 273.00-292.60 m, where the host rock is coarse-grained peridotite. The following is a short summary of the report.

XRF analysis showed the sample to contain 1.68% Ni, 0.37% Cu, 0.071% Co and 11.2% S. The PGE values were low: 0.003 ppm Pt, 0.028 ppm Pd and 0.043 ppm Au (FA method). The minerals present were pyrrhotite (25%), pentlandite (5%) and chalcopyrite (1%) as the main sulphides, amphiboles (23%), serpentine (12%), pyroxenes (7%), olivine (5%), clay (3%), chlorite (1%), plagioclase (1%) and phlogopite (1%) as the main silicates and magnetite (2%) as an alteration product.

The best results were achieved using flotation as the concentrating method and treating the ore to obtain the desired fineness (about 80-85% below 90 µm) before flotation. The recovery rate was 57-65% with a concentrate having a nickel content of 12-14%, 60-70% with a nickel content of 10-12% and 75-90 % with a nickel content of 5-8%.

The nickel recovery level and/or the grade of the concentrates produced can be raised by using alkaline conditions in the rougher flotation and in the cleaning steps (pyrrhotite rejection).

It should be noted that the coarse-grained peridotite is only one of the four main ore types present in the Rytky occurrence, and that the manner of concentration may be different in the pyroxenite and melagabbro-hosted types .

Exploration potential

Potential for resource increase

A rough estimate of the amount of ore in an intrusion can usually be made on the basis of the mass of the intrusion. There are many assumptions and uncertainties involved in such an approach, of course, but it does give an idea of the size class of the ore body we are dealing with.

If the Rytky intrusion is assumed to continue down to 400 metres, its mass will be c. 400 Mt, with a density of 3 kg/dm^3. Taking into account 1) the absence of intermediate-felsic differentiates in the intrusion and 2) the eroded part of the intrusion, this should be regarded as a *minimum* estimate for the mass of the original intrusion. One positive fact is that the *ore* has not been eroded, because it lies below the present bedrock surface.

Assuming that the whole 400 Mt of silicate magma was equilibrated with the sulphide liquid, and taking an R-value (mass ratio between silicate magma and sulphide magma) of 750 (from Fig. 17), we can calculate that there must have been c. 0.53 Mt of sulphide liquid. As the Ni_{SF} in the Rytky occurrence is c. 6.5%, we have c. 34 670 tonnes of Ni in the sulphide liquid. If ¾ of this lies above the cut-off, it can be assumed that 26 000 tonnes of Ni is left in the ore, which means 2.6 Mt of ore with a grade of 1% Ni.

The main potential for increasing the resources lies in the stratigraphic footwall of the intrusion. None of the drill holes intersects the part with the greatest potential, at the bottom contact, although R460 goes very near to it. Another place with a potential for resource increase is the continuation of the separate eastern ore body plunging SE (ore body C in Fig. 16).

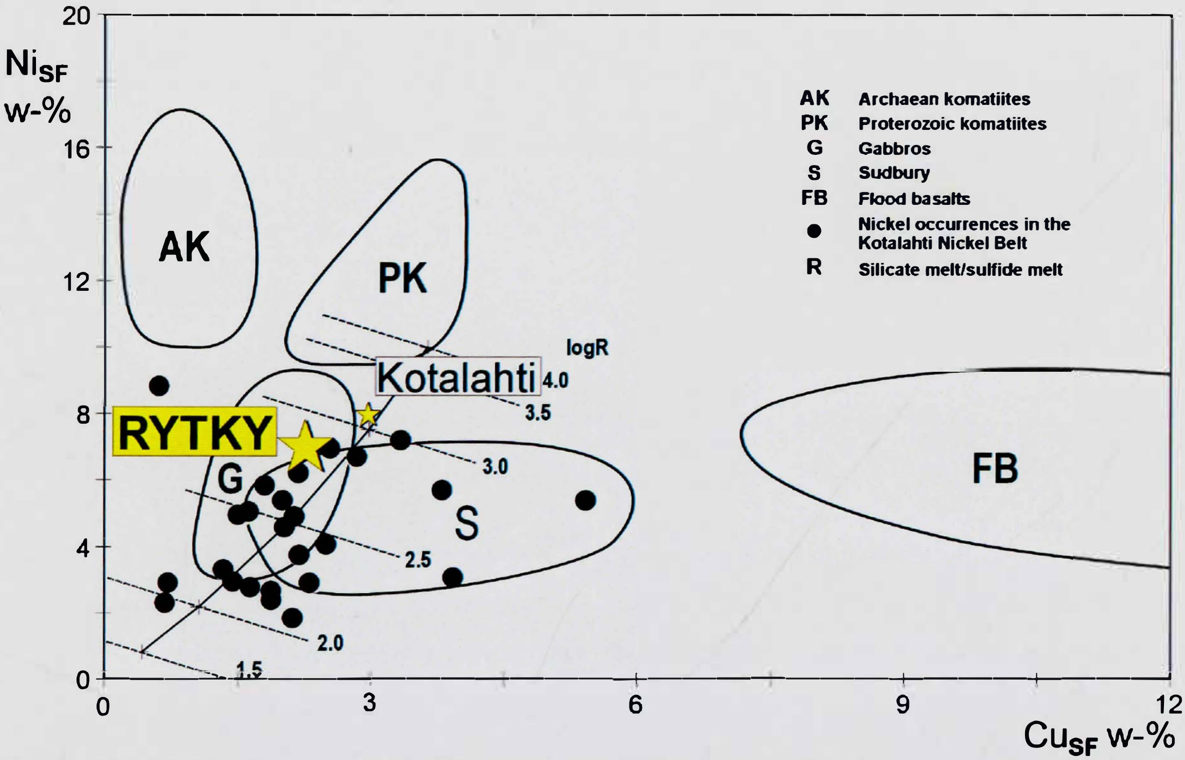

Figure 17. Sulphide fraction nickel (Ni_{SF}) and copper (Cu_{SF}), reflecting the composition of the parent magma, and the R value (mass ratio between the silicate melt and sulphide melt). Rock type fields after Naldrett (1989) and R values after Makkonen (1996).

ENVIRONMENTAL STATEMENT

Protected areas

There are two areas to the east of Lake Valkeinen that are protected under the forest legislation: no. 561) a *wet area* and no. 562) a *precipice*.

DISCUSSION AND CONCLUSIONS

Rytky is one of the Svecofennian (c. 1.9 Ga) mafic-ultramafic intrusions in Finland, which host a number of Ni deposits, mainly within the Kotalahti and Vammala Ni Belts. It is clear that Rytky is one of the most primitive Ni occurrences and deposits in the Kotalahti Ni Belt, as reflected by the relatively high nickel and forsterite contents of the olivine and the high nickel content of the sulphide fraction. The sulphide fractions in Svecofennian nickel occurrences differ in composition from those in komatiites, for example, because of differences in the parental magma. The gabbroic composition of the Svecofennian magma is reflected in a lower Ni/Cu ratio and lower Ni content of the sulphide fraction than would be found in a more Mg-rich magma (Fig. 17).

Rytky and Kotalahti are similar in their host rock and ore composition, and also in their internal stratigraphy: medium-grained peridotite overlain by coarse-grained one (in Kotalahti e.g. drillhole KL-468). The layering in both intrusions is now vertical, with the stratigraphic footwall in the east. In Kotalahti a high-grade massive offset ore (the Jussi orebody) is hosted by mafic and ultramafic rocks, but also to a great extent by calc-silicate rock and silicic intrusion wall rocks (Papunen and Koskinen 1985), and offset ores of this kind are also common in other Finnish Svecofennian Ni deposits, but no offset ore body has yet been found at Rytky.

Rytky and Kotalahti were intruded at the same time, in a D_2 shear zone represented by the schlieren migmatites lying west of the intrusions. Tectonic thrusting was from south to north. The Rytky intrusion was formed in a depression above the Archaean rocks.

The first magma to be intruded at Rytky crystallized as coarse-grained peridotite and the later one as peridotite, but the interval between the magma pulses was short. Massive sulphide concentrations have been encountered only in peridotites. Since on the basis of their olivine texture the coarse-grained peridotites must represent a large magma volume, and since it is probable that they also host a massive ore, there is still a good ore potentiality left. The most probable direction for the continuation of the main ore body is downwards, along the intrusion contact.

As the thrust was from south to north, the upper formations were pushed further north relative to the lower (Archaean) ones. If there were any offset ore bodies below the intrusion, for instance, they would now be found below it and/or east and southeast of it, as the structures were turned into a vertical position in D_3. It is also necessary to take into account the reorientation of the fragments along the F_3 fold axis.

RECOMMENDATIONS FOR FURTHER WORK

The main potential for resource increase lies in the stratigraphic footwall of the intrusion. None of the drill holes intersects the part with the highest potential, at the bottom contact, although R460 goes very near to it. The most probable direction for the continuation of the main ore body is downwards, along the intrusion contact. Another place having potential for resource increase is the continuation of the separate eastern ore body that plunges SE (ore body C in Fig. 16). The possibility of other intrusion fragments east and southeast of the intrusion should also be checked.

The fact that peridotites occur between Rytky and Kotalahti, together with the structural interpretation, makes the area between these two intrusions promising for further exploration.

Kuopio 28.02.2002

Jari Mäkinen Hannu Makkonen Heikki Forss

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APPENDICES

1. Drill hole details.
2. Drill hole map (includes also the holes drilled by Outokumpu Oy).
3. Detailed drill hole geophysics.
4. Location of the Rytky Ni occurrence in the Rytky intrusion

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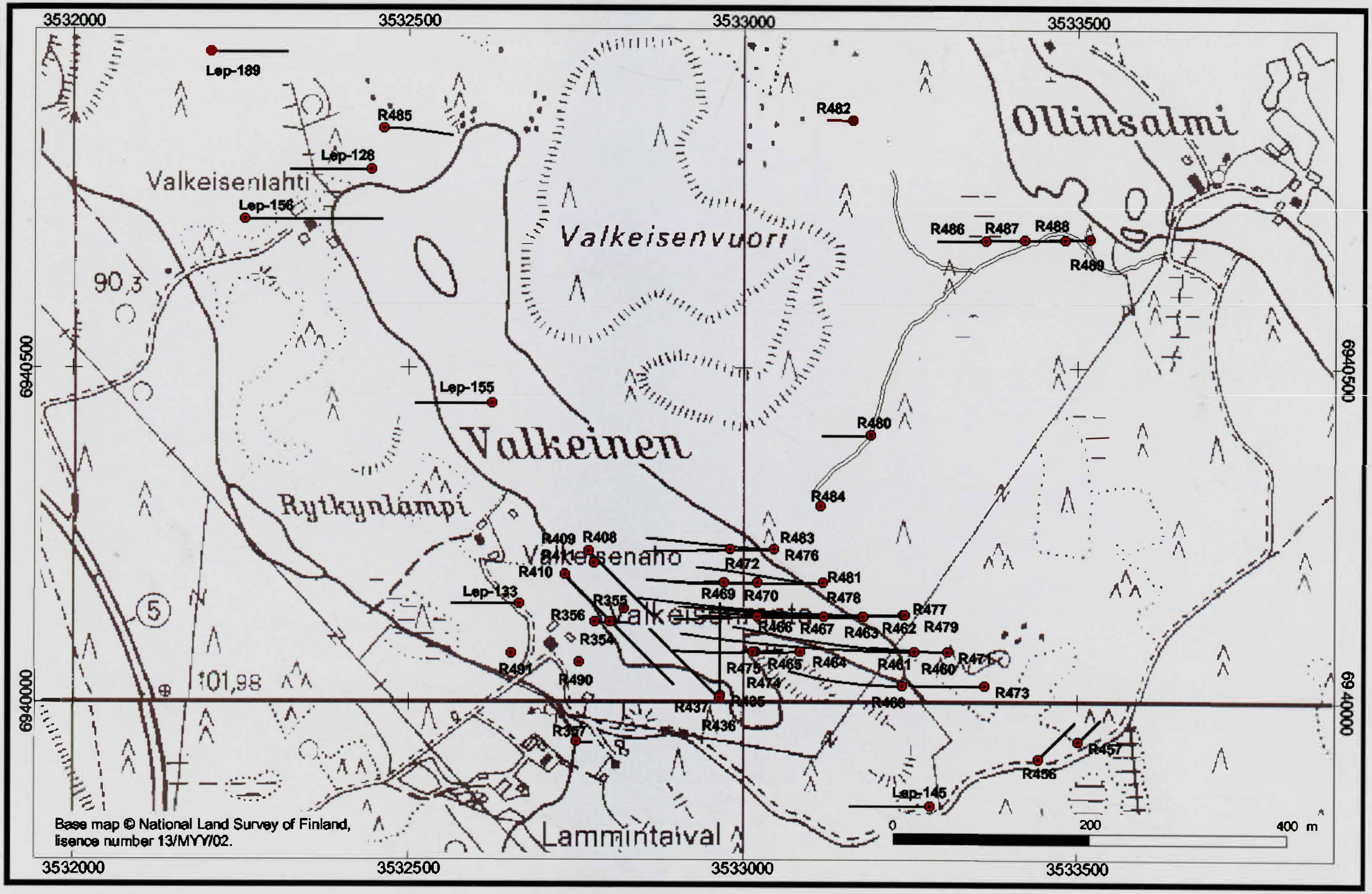
Useful Internet links:
http://www.gsf.fi/explor/

APPENDIX 1 (1)

HOLE	EASTING	NORTHING	ELEVATION	LENGHT m	AZIMUTH	DIP	DEVIATION MEASUREMENT METHOD	PHOTOS	DRILLCORE DIAMETER mm	YEAR	CONTRACTOR
R354	3532800	6940120	91	41,2	0	90			32	1995	GTK
R355	3532820	6940140	91	25,1	0	90			32	1995	GTK
R356	3532777	6940120	91	70,8	90	45			32	1995	GTK
R357	3532750	6939940	91	34,45	90	45			32	1995	GTK
R408	3532768	6940227	91	199,1	135	45	INCLINOMETER		32	1996	Suomen malmi Oy
R409	3532768	6940227	91	216,7	135	45	INCLINOMETER		32	1996	Suomen malmi Oy
R410	3532732	6940191	91	328,5	135	45	INCLINOMETER		32	1996	Suomen malmi Oy
R411	3532776	6940209	91	15,7	90	45	INCLINOMETER		32	1996	Suomen malmi Oy
R435	3532965	6940010	92	189,85	0	45	INCLINOMETER		32	1996	Suomen malmi Oy
R436	3532964	6940006	92	315,2	315	65	INCLINOMETER		32	1996	Suomen malmi Oy
R437	3532964	6940006	92	198,15	315	42	INCLINOMETER		32	1996	Suomen malmi Oy
R456	3533440	6939914	101	113	45	45			32	2000	GTK
R457	3533500	6939940	101	69,7	45	45			32	2000	GTK
R460	3533256	6940076	100	475,2	270,6	45	MAXIBOR	230-475.20	42	2000	Kalajoen timanttikairaus Oy
R461	3533256	6940076	100	529,5	273,6	60	MAXIBOR	72.00-147.60, 370-529.50	42	2000	Kalajoen timanttikairaus Oy
R462	3533178	6940128	92	283,2	270	37	MAXIBOR	69.00-100.00, 174.00-283.20	42	2000	Kalajoen timanttikairaus Oy
R463	3533179	6940128	92	384,4	271,14	47	MAXIBOR	72.00-99.90, 163.00-384.40	42	2000	Kalajoen timanttikairaus Oy
R464	3533085	6940076	92	302,8	268,3	80	BOREMAC	167.00-302.80	42	2000	Geotek Oy
R465	3533018	6940076	95	370	85,4	83	BOREMAC	165.00-273.60	42	2001	Geotek Oy
R466	3533020	6940128	91	173,8	268,3	45	INCLINOMETER	79.00-173.80	42	2001	Suomen malmi Oy
R467	3533120	6940128	91	218,4	269,5	38	MAXIBOR	18.00-59.00, 127.00-218.40	42	2001	Suomen malmi Oy
R468	3533237	6940025	91	450,45	271,6	68	MAXIBOR		42	2001	Geotek Oy
R469	3532970	6940179	91	154,7	270,9	45	MAXIBOR	40.00-154.70	42	2001	Suomen malmi Oy
R470	3533020	6940179	91	179,8	268,8	45	MAXIBOR	78.00-179.80	42	2001	Suomen malmi Oy
R471	3533305	6940076	100	228,15	271,26	60	MAXIBOR	149.00-228.15	42	2001	Geotek Oy
R472	3532980	6940229	91	182,2	268,9	45		66.60-182.20	42	2001	Suomen malmi Oy
R473	3533360	6940025	100	281,5	269,2	66	MAXIBOR	172.30-281.50	42, 32	2001	Geotek Oy, Suomen malmi Oy
R474	3533015	6940076	94	277,95	268,7	78	MAXIBOR	144.00-279.95	42	2001	Geotek Oy
R475	3533014	6940076	94	230,05	268,7	60	MAXIBOR	121.65-230.05	42	2001	Geotek Oy

HOLE	EASTING	NORTHING	ELEVATION	LENGHT m	AZIMUTH	DIP	DEVIATION MEASUREMENT METHOD	PHOTOS	DRILLCORE DIAMETER mm	YEAR	CONTRACTOR
R476	3533045	6940229	92	266	274,17	45	MAXIBOR	137.90-266.00	42	2001	Geotek Oy
R477	3533238	6940131	103	383,1	269,4	45	MAXIBOR	288.45-383.10	42	2001	Suomen malmi Oy
R478	3533118	6940179	95	246,1	269,6	45	MAXIBOR	177.30-246.10	42	2001	Geotek Oy
R479	3533241	6940131	103	589,15	268,1	55	MAXIBOR	287.50-599.15	42, 32	2001	Suomen malmi Oy
R480	3533190	6940400	102	396	268,9	80	INCLINOMETER		42	2001	Geotek Oy
R481	3533118	6940179	95	322	271,5	60	MAXIBOR	199.50-322.00	42	2001	Suomen malmi Oy
R482	3533163	6940871	99	202,9	271,37	79	INCLINOMETER		42	2001	Geotek Oy
R483	3533045	6940229	92	274,1	269,8	70	MAXIBOR	155.40-274.10	42	2001	Suomen malmi Oy
R484	3533115	6940294	108	102,2	0	90			32	2001	GTK
R485	3532462	6940860	103	376,3	84,2	80	MAXIBOR	151.50-343.10	42	2001	Suomen malmi Oy
R486	3533361	6940692	86	101,3	270	45			32	2001	GTK
R487	3533419	6940693	86	95,1	270	45			32	2001	GTK
R488	3533480	6940693	84	91,6	270	45			32	2001	GTK
R489	3533517	6940695	81	85,3	270	45			32	2001	GTK
R490	3532754	6940060	92	126,75	0	90		66.50-126.50	32	2001	GTK
R491	3532652	6940073	91	134,7	0	90		51.40-134.70	32	2001	GTK

APPENDIX 2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R485
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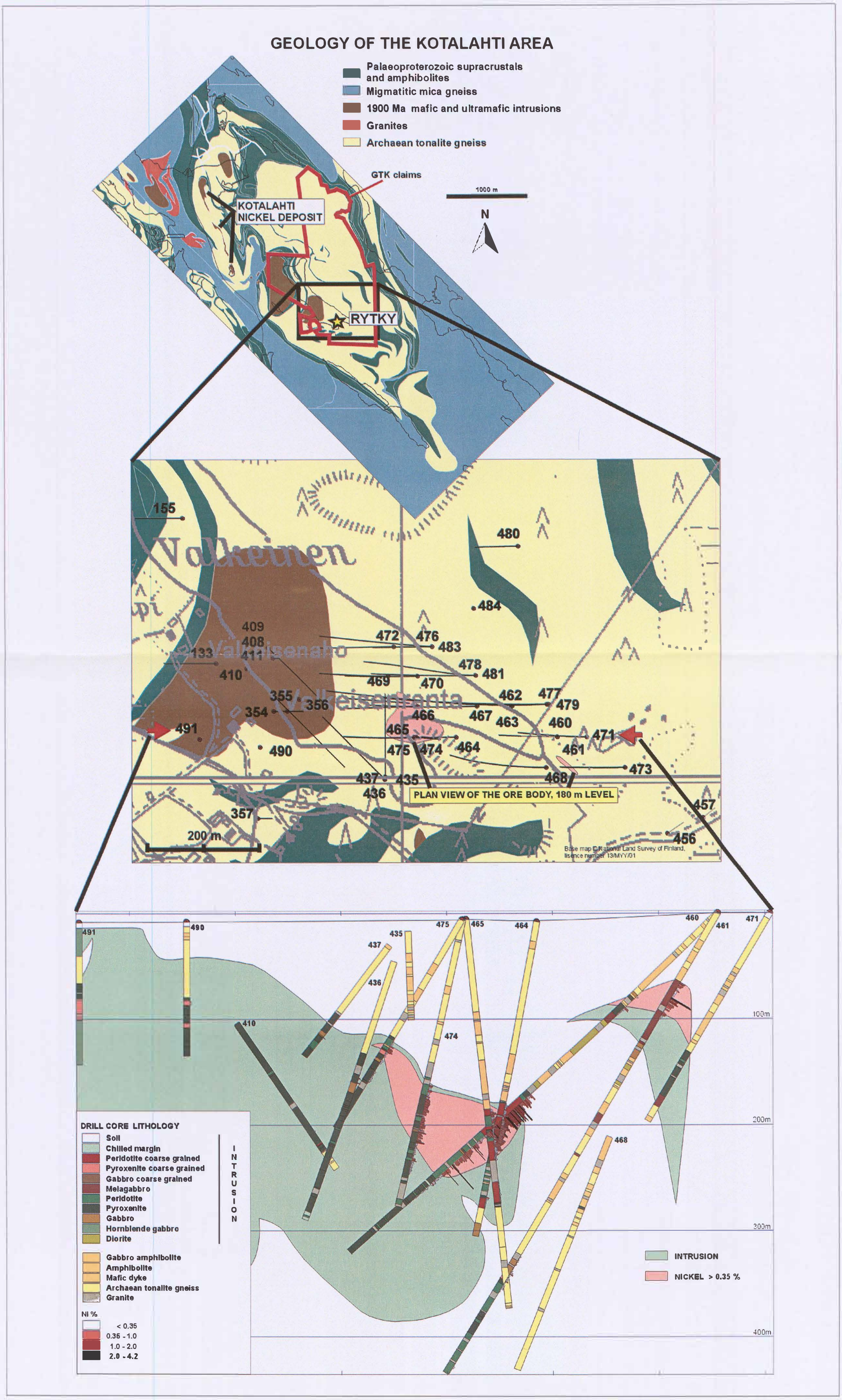
90,3
Valkeisenvuori
R482
Ollinsalmi
R486
R487
R488
R489
Lep-155
Valkeinen
R480
R484
Rytkynlampi
R409
R408
R411
R410
Valkeisenaho
R483
R476
R472
R481
R469
R470
R478
Lep-133
R355
R356
R354
R477
R466
R467
R463
R462
R479
R491
R490
R475
R465
R464
R461
R460
R471
R474
R473
R468
R437
R435
R436
101,98
R357
R457
R456
Lep-145
Lammintaival
0
200
400 m
Base map © National Land Survey of Finland, lisence number 13/MYY/02.

Detailed drill hole geophysics

Drill hole	Mise-a-la-masse	3D magnetic	SlimBoris	Protem	Drill hole loggings		
					Susceptibility	App. Resistivity	Density
408							X
409		X			X	X	X
410		X			X	X	X
435	X	X			X	X	X
436	X	X			X	X	X
437	X	X			X	X	X
460	X, partly						
461	X	X	X	X	X	X	
462	X		X	X	X	X	
463	X	X	X	X	X	X	
464	X				X	X	
465	X		X	X	X	X	
466	X	X			X	X	X
467	X				X	X	X
468	X	X	X	X	X	X	X
469	X				X	X	X
470	X				X	X	X
471	X						
472					X		
473	X						
477	X						
478	X						
479	X			X			
480	X						
481	X						
483	X						
485	X						


GEOLOGY OF THE KOTALAHTI AREA
Palaeoproterozoic supracrustals and amphibolites
Migmatitic mica gneiss
1900 Ma mafic and ultramafic intrusions
Granites
Archaean tonalite gneiss
GTK claims
1000 m
N
KOTALAHTI NICKEL DEPOSIT
RYTKY
PLAN VIEW OF THE ORE BODY, 180 m LEVEL
200 m
DRILL CORE LITHOLOGY
Soil
Chilled margin
Peridotite coarse grained
Pyroxenite coarse grained
Gabbro coarse grained
Melagabbro
Peridotite
Pyroxenite
Gabbro
Hornblende gabbro
Diorite
INTRUSION
Gabbro amphibolite
Amphibolite
Mafic dyke
Archaean tonalite gneiss
Granite
Ni %
< 0.35
0.35 - 1.0
1.0 - 2.0
2.0 - 4.2
INTRUSION
NICKEL > 0.35 %
100m
200m
300m
400m