NIINIMÄKI NICKEL DEPOSIT

Exploration history

Niinimäki nickel deposit is located in Juva community, SE Finland, about 25 km southwards from the Juva community center. Geological Survey of Finland (GTK) discovered the first ore body at Niinimäki, the *surface ore body*, in 1993, after finding the intrusion with a nickel-rich outcrop in 1990. GTK studied the ore body by geophysics and core drilling (27/3235.10m) and made a resource estimate. The mining rights of the surface ore body were transferred to Outokumpu Finnmines Oy in May 1994 and the company studied the ore body by 6 drill holes (308.80m) and flotation test in 1995. GTK continued exploration in other parts of the intrusion and discovered the *disseminated orebodies A and B* and the *plate ore body* during 1994-1995. In 1997 Outokumpu Mining Oy studied the eastern block of the intrusion by bedrock mapping, geophysics, surficial geochemistry and core drilling (6/888.40 m). These studies did not bring out any additional mineralization. GTK studied still in 1998 the disseminated mineralization in the western part of the intrusion by geophysics and core drilling (4/966.60m). No additional resources were discovered.

Outokumpu Mining Oy sold the mining rights of the Niinimäki surface ore body in 2004 to Suomen Nikkeli Oy (later named Finn Nickel Oy). The company performed a resource estimate and a preliminary open pit plan for the surface ore. The deposit was sold to Vulcan Resources from the Finn Nickel Bankruptcy in 2009. Vulcan Resources (later Altona Mining/Vulcan Kotalahti Oy) did not make any field work or other notable studies and the claim expired in 2012.

Total core drilling in the Niinimäki target is now 86 holes and 13148.95 meters:

Organization	Year	Drill holes	meters
GTK	1991	4	678.20
GTK	1992	5	515.80
GTK	1993-1995	61	9791.15
Outokumpu Finnmines Oy	1995	6	308.80
Outokumpu Mining Oy	1997	6	888.40
GTK	1998	4	966.60
Total		**86**	**13148.95**

More detailed data on the exploration work can be found in http://tupa.gtk.fi/karttasovellus/mdae/raportti/46_Niinimäki.pdf and references therein.

Resource estimates

GTK made in situ geological mineral resource estimates for the different ore bodies during 1994 and 1995:

Ore body	ton	Cut off (Ni-eq. %)	Ni %	Cu %	Co %	S %
Surface ore	99 600	0.4	1.09	0.36	0.040	8.37
Plate ore	122 800	0.4	0.69	0.19	0.045	8.16
Disseminated ore A	2 400 000	0.3	0.36	0.13	0.015	1.55
Disseminated ore B	76 500	0.3	0.32	0.12	0.019	2.19

Part of the nickel in olivine (and pyroxene) is included in the nickel assay results in peridotites. Based on the amount of olivine and its nickel content it can be estimated that the sulphidic nickel content in the Disseminated ore A is around 0.31 %.

Based on additional drillings in 1998 the most uniform part of the *disseminated ore A* was estimated by GTK to:

Ore body	ton	Cut off (Ni %)	Ni %	Cu %	Co %	S %
Disseminated ore A	1 599 318	0.2	0.24	0.07	0.012	0.84

Finn Nickel Oy calculated the following JORC code resource estimation for the *surface ore body:*

Ore body	ton	Classification	Ni %	Cu %	Co %
Surface ore	60 000	Indicated	1.13	0.33	0.040
Surface ore	20 000	Inferred	0.89	0.30	0.030
Total surface ore	80 000	Indicated+inferred	1.07	0.32	0.040

Geology of the Niinimäki intrusion

The horizontal section of the Niinimäki intrusion at the 100 m level is 1 x 2 km and the total thickness according to gravimetric interpretation and some bore holes is around 300 m. At the surface, the intrusion occupies only an area of 1 km^2 being widely overlaid by the surrounding garnet-cordierite gneiss. The intrusion body is divided into two main blocks by young faults. The NW block is composed of gabbro and peridotite while the SE block is composed mainly of gabbro (Figs. 1 and 2).

The layering and schistosity in the surrounding gneisses conform to the intrusion contacts. Because of the granulite-facies metamorphic grade there are no primary magmatic minerals left in the gabbro, the main mineral phases being metamorphic orthopyroxene and plagioclase, or in places hornblende and biotite. In mineralized zones near peridotite, gabbro is altered, and the main minerals are plagioclase, chlorite+serpentine and biotite. Peridotite occurs as 50-150 m thick layers having sharp contacts within the gabbro near the stratigraphic footwall of the intrusion. In contrast to the gabbro, in peridotite olivine and orthopyroxene occur as the predominant primary magmatic minerals. The rock can thus be classified as a harzburgite. Olivine is always partly serpentinized and clinoamphibole occurs as an alteration product after orthopyroxene. Minor pyroxenite, composed of orthopyroxene and clinoamphibole, is associated with peridotite.

More data on the geology can be found in http://tupa.gtk.fi/karttasovellus/mdae/raportti/46_Niinimäki.pdf and references therein.

Ni-Cu-Co deposits and showings

Locations/surface projections of the ore bodies are marked in Fig. 1.

The *surface ore body* has been drilled in several sections, enough to enable modelling. It is relatively uniform, having a folded antiformal structure with the fold axis plunging probably towards NE. It extends down only to around 70 meter's level from the ground surface (Figs. 1 and 3).

The *plate ore body* is formed by a 1.5 – 5 m thick plate, which has a dip of around 40° towards NNW. Additional modelling is needed utilizing the existing bore hole EM and mise-à-la-masse results and other ground geophysics.

The *disseminated ore body A* is of low grade. It seems to conform the layering within the peridotite. Thickness of the dissemination in intercepts varies mostly within 4 – 7 m. Drilling is too sparse for detailed modelling.

The *disseminated ore body B* is of low grade and intersected only by a few drill holes.

Disseminated sulphides (pyrrhotite, pentlandite, chalcopyrite) occur in disseminated ore bodies A and B and almost throughout the peridotites. Disseminated, net-textured and massive sulphides (secondary pyrite, pyrrhotite, pentlandite, chalcopyrite, violarite) of the surface ore body and the plate ore body are hosted by the altered gabbro.

More data on the ore mineralogy can be found in:
http://tupa.gtk.fi/karttasovellus/mdae/raportti/46_Niinimäki.pdf and references therein.

The composition of the ore bodies differs from each other. Nickel in sulphide fraction, Ni(sf), is as highest in the disseminated ore A and lowest in the plate ore. Cobalt content is highest in the plate ore:

Ore body	Ni %	Cu %	Co %	S %	Ni(sf) %	Ni/Co	Ni/Cu
Surface ore	1.09	0.36	0.040	8.37	4.9	27.3	3.0
Plate ore	0.69	0.19	0.045	8.16	3.2	15.3	3.6
Disseminated ore A	0.36	0.13	0.015	1.55	8.7	24.0	2.8
Disseminated ore B	0.32	0.12	0.019	2.19	5.5	16.8	2.7

Ni(sf) is calculated using 37.5 % as the sulphur content of the sulphide fraction. If the estimated sulphidic nickel content, 0.31 %, is used for the Disseminated ore A the Ni(sf) % for it turns to 7.5 %.

Exploration potential

Based on the lithogeochemical studies so far, the Niinimäki intrusion fulfils critical factors to host nickel sulphide deposits: 1) There was enough magma for formation of several Mt of ore grade rock, 2) parental magma was high enough in nickel (MgO around 10 w-%) and 3) the whole rock and olivine data show distinct nickel depletion, from undepleted to strongly depleted.

Nickel (Co-Cu) grades are near economic level in the surface and plate ore. However, ore tonnage is still low, and further studies should focus to increase the tonnage. The depth continuations of these ore bodies should be studied and their possible mutual connections (e.g. by the bore hole EM and mise-à-la-masse results). Also, the north and north-eastern intrusion contacts are potential for new discoveries. The gravity data suggests the intrusion dipping towards NE.

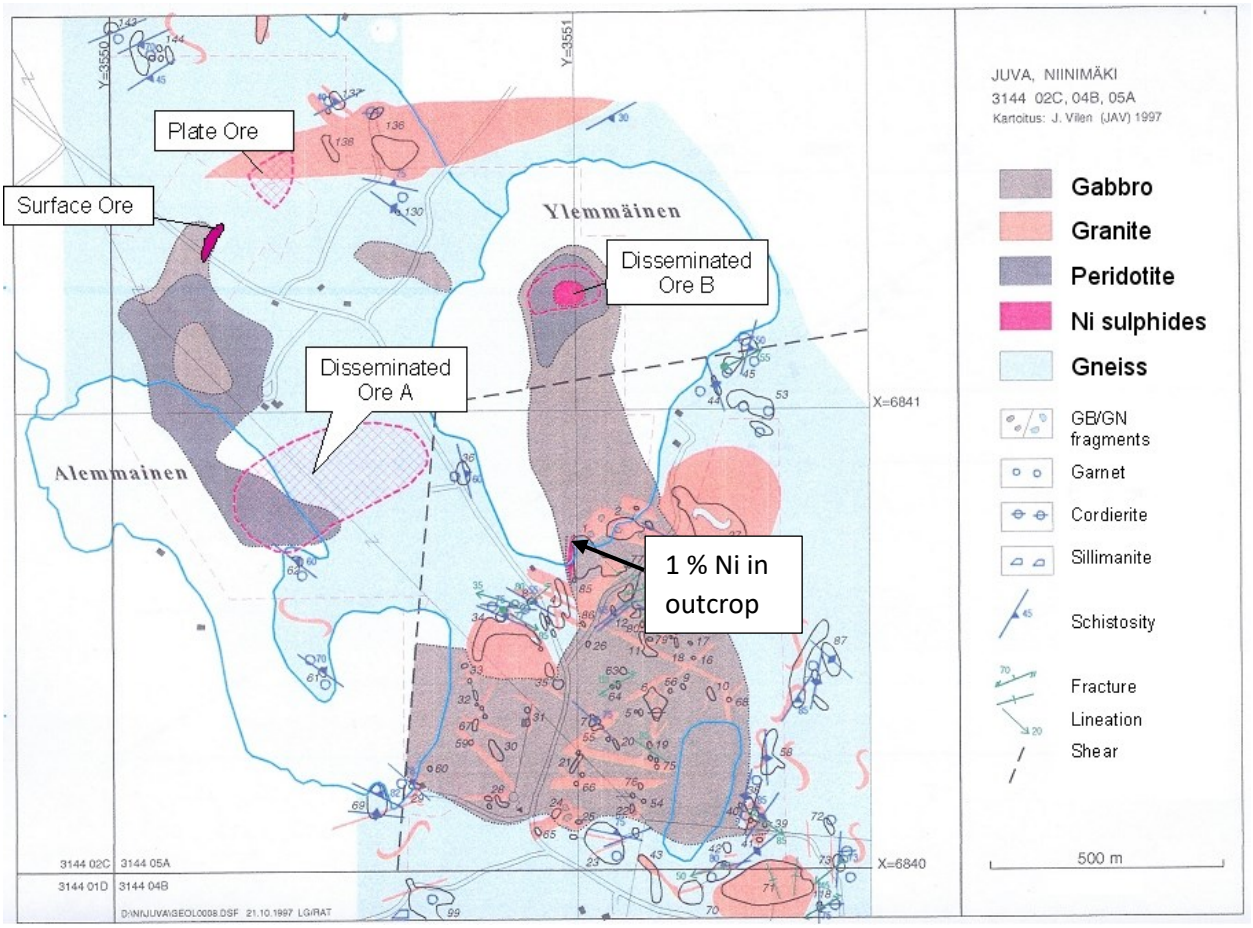
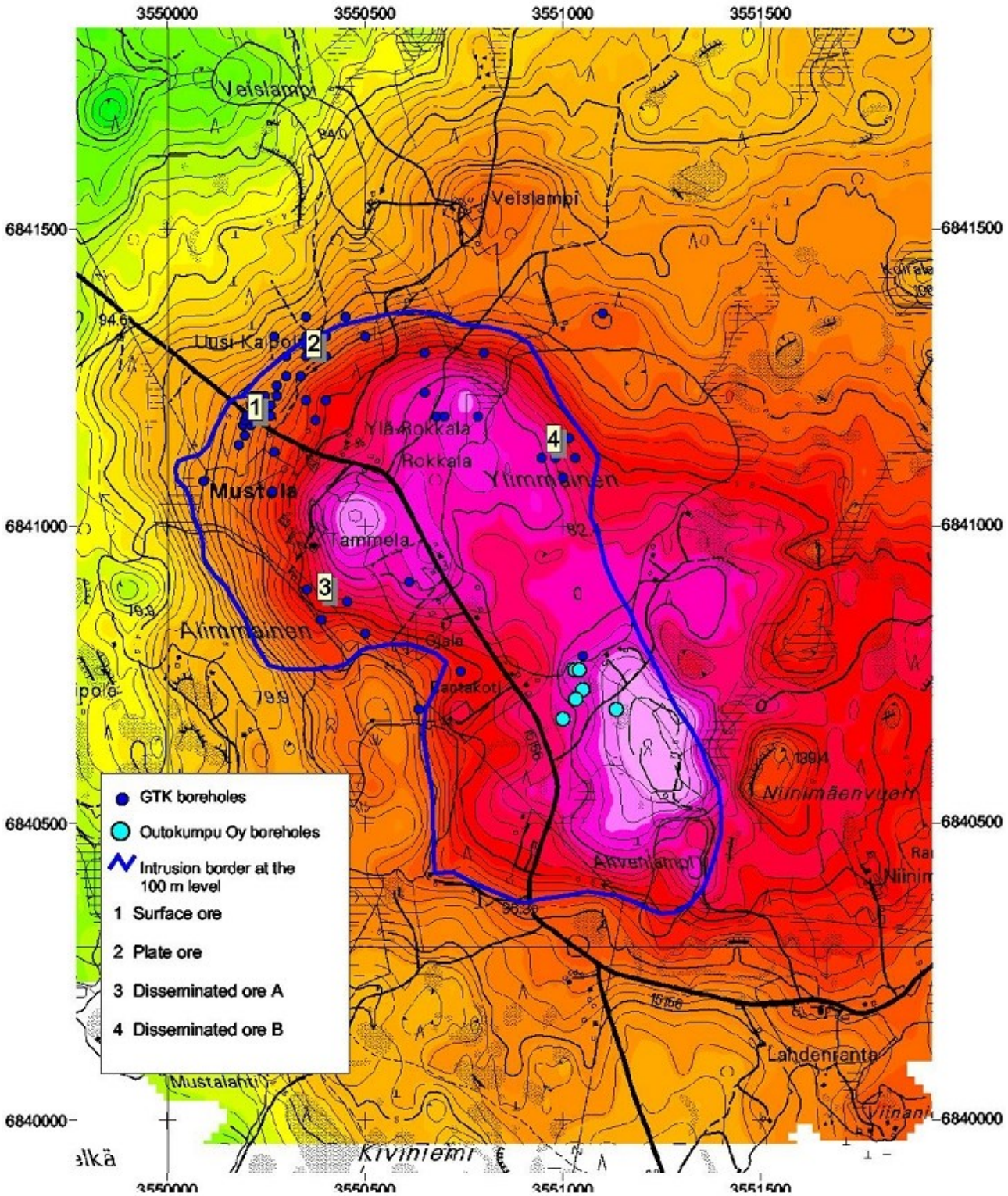
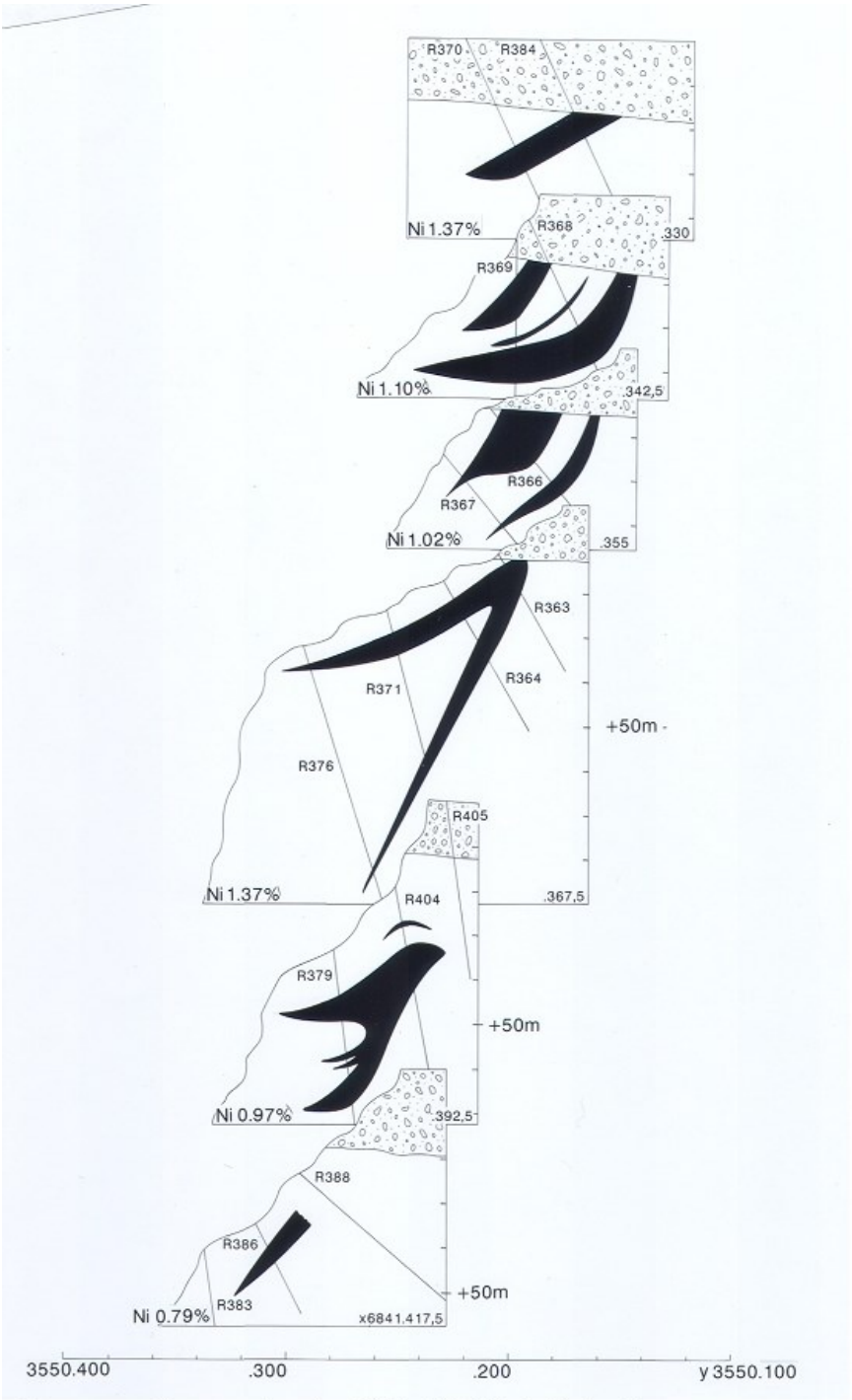


Figure 1. Surface bedrock map of the Niinimäki intrusion and related Ni-Cu-Co deposits and showings, figure modified from GTK website: http://tupa.gtk.fi/karttasovellus/mdae/raportti/46_Niinimäki.pdf



Gravimetric map on the Niinimäki intrusion (green = minimum, violet = maximum). Modified after Makkonen and Forss (1995) by H.Makkonen.

Figure 2. From GTK website: http://tupa.gtk.fi/karttasovellus/mdae/raportti/46_Niinimäki.pdf



Ore sections (cut off 0.40 % Ni) in the Niinimäki surface ore. View from north to south. Average Ni content marked on each section. From Makkonen & Forss (1994).

Figure 3. Niinimäki surface ore, figure from GTK website: http://tupa.gtk.fi/karttasovellus/mdae/raportti/46_Niinimäki.pdf