Enonkoski

Alternative Names: Laukunkangas
Occurence type: deposit

Commodity	Rank	Total measure	Total production	Total resource	Importance
nickel	1	55316,69 t	50486,89 t	4829,8 t	Medium sized deposit
cobalt	2	82,46 t	0 t	82,46 t	Occurrence
copper	2	15574,31 t	14396,31 t	1178 t	Small deposit

Easting EUREF: 592551,884
Northing EUREF: 6880476,392

Easting YKJ: 3592760
Northing YKJ: 6883361

Discovery year: 1980
Discovered by: Outokumpu Oy
Province: Kotalahti (Ni, Co)
District: Laukunkangas (Ni, Co)
References: 1, 2, 4, 7, 10, 11, 12, 13, 14, 17, 20

Mineral deposit type

Group: Metallogenic deposit
Main type: Metamorphic hydrothermal
Comments: Possible concentration of sulphides during deformation/metamorphism.
References: 8

Group: Metallogenic deposit
Main type: Ultramafic-mafic (magmatic)
Sub type 1: Orogenic intrusion Ni-Cu
References: 8

Dimension

Expression: exposed
Form: discordant
Shape: irregular
Length (m): 250
Width (m): 150
Thickness (m): NA
Depth (m): 350

Area (ha): NA
Dip azim: 315
Dip: NA
Plunge azim: NA
Plunge dip: NA
Orientation method: NA

Holder history

Current holder: Outokumpu Mining Oy
Years: 1983
Holding type: Mining concession (old law)

Previous holders:

Company	Years	Holding type	Comments
Outokumpu Oy	1969-1983	Claim (old law)	End year uncertain.

EXPLORATION ACTIVITY

Outokumpu Oy

Years	Activity type	Geologist	Exploration result	Ref
1980-1980	subsurface exploration	Leo Grundström, Tapio Karppanen, Risto Juhava, Jorma Eeronheimo	NA	
	The main ore body was found in 1980 as a result of the second drilling campaign directed by lithogeochemical studies (Outokumpu Oy, nickel program) and ground geophysical surveys.			

1969-1980	detailed geophysics	Leo Grundström, Tapio Karppanen, Risto Juhava, Jorma Eeronheimo	NA	
	Ground geophysical surveys.			

1969-1980	regional geochemistry	Leo Grundström, Tapio Karppanen, Risto Juhava, Jorma Eeronheimo	NA	
	Lithogeochemical studies (Outokumpu Oy, nickel program).			

RESOURCES AND RESERVES

Most recent

Type:	Company:	Year:	Date:	Calc Method:	Reference:
Resource	Outokumpu Oy	1996	NA	Non-compliant resource estimate	6, 8, 11
	Category:	**Measured, indicated and inferred mineral resource**			
	Tonnage:	**1,178 Mt**			
	copper	0,1 %			
	cobalt	0,007 %			
	nickel	0,41 %			
	Cutoff:	**NA**			

Previous calculations

Type:	Company:	Year:	Date:	Calc Method:	Reference:
Resource	Outokumpu Oy	1996	NA	NA	2, 6
	Comments: Four orebodies: 1) The main orebody hosted by peridotite and norite, 2) The slope orebody hosted mainly by norite, 3) The deep orebody, 4) The offset-orebody in the mica gneiss.				
	Category:	**NA**			
	Tonnage:	**7,9 Mt**			
	nickel	0,72 %			
	copper	0,2 %			
	Cutoff:	**copper 0,3 %**			
	Comments: Original, pre-mining size (mined ore included)				

MINING

Enonkoski

Easting EUREF: 592551,884
Northing EUREF: 6880476,392
Status: Closed
Operating years: 1984-1994
Years in production: 11
Total ore mined: 6707515 t
References: 16, 21, 22

Total production:

Product	Product measure
copper	14396,31 t
nickel	50486,89 t

Other materials:

Material type	Material measure
Waste rock	1684050 t

Mining activity:

Year	Ore mined	Ore processed	Activity type	Production	Other material
1994	978877 t	978877 t	NA		
				nickel 3523,95 t copper 1370,42 t	Waste rock 18690 t
1993	1065717 t	1065717 t	NA		
				nickel 4689,15 t copper 1492 t	Waste rock 129179 t
1992	838134 t	838134 t	NA		
				nickel 4358,29 t copper 1341,01 t	Waste rock 51079 t
1991	668350 t	668350 t	NA		
				nickel 3341,75 t copper 1069,36 t	Waste rock 207577 t
1990	651355 t	651355 t	NA		
				nickel 4429,21 t copper 1237,57 t	Waste rock 98974 t
1989	736276 t	736276 t	NA		
				nickel 5374,81 t copper 1472,55 t	Waste rock 336107 t
1988	684938 t	684938 t	NA		
				nickel 7739,79 t copper 2054,81 t	Waste rock 204823 t
1987	591264 t	541264 t	NA		
				nickel 8064,83 t copper 2110,92 t	Waste rock 48770 t
1986	424970 t	453250 t	NA		
				nickel 8249,15 t copper 2084,95 t	Waste rock 94332 t
1985	62769 t	40680 t	NA		
				nickel 715,96 t copper 162,72 t	Waste rock 316384 t
1984	4865 t	0 t	NA		

	Waste rock 178135 t

GEOLOGY

Host rock: Harzburgite, Mica gneiss, Olivine gabbronorite, Norite

Harzburgite (Host rock)

Rock type: Host rock
Proportion: present
Grain size: NA
Color: NA
References: 2, 3, 8, 9, 18
Comments: Olivine-orthopyroxene cumulate. The peridotite zone consists of olivine, olivine-plagioclase and olivine-orthopyroxene cumulates. Olivine in peridotite is largely serpentinised and orthopyroxene altered into cummingtonite. The main minerals include also phlogopite, chlorite, hornblende and sulphides. In metaperidotite the main minerals are hornblende, phlogopite ans serpentine.

Ore minerals:

Mineral	Proportion	Mineral texture
Anatase	minor	
Chalcopyrite	major	Intercumulus, Dissemination, Stringer
Gersdorffite	minor	
	In veins in the contact zone and in the peridotite hosted ore.	
Graphite	minor	
Ilmenite	minor	
Magnetite	minor	
	Secondary	
Pentlandite	major	Intercumulus, Dissemination, Stringer
	Ni content in pentlandite is 33.22 - 38.54 w-% and Co content 0.02 - 3.17 w-%. Alteration to violarite is more common in peridotite than in norite. Alteration took place during serpentinisation.	
Pyrrhotite	major	Intercumulus, Dissemination, Stringer
	Ni in pyrrhotite is 0.29 - 0.50 w-% and Co 0.01 - 0.06 w-%. Euhedral or subhedral inclusions and exsolution "flames" of pentlandite.	
Rutile	minor	
Violarite	minor	
	After pentlandite	

Other minerals:

Mineral	Proportion	Mineral texture
Biotite	present	Alteration product
Chlorite	present	Alteration product
Cummingtonite	present	Alteration product
Garnet	present	Alteration product
Olivine	present	
	Fo 74.9-81.6 mole%, Ni 778-1519 ppm	
Orthopyroxene	present	
	Ni 134-296 ppm	
Serpentine	present	Alteration product

Structures
Folded

Textures
Cumulate

Alteration:	Distribution:	Degree:	Relation to mineralization:
uralitisation	NA	NA	NA
Comments: Olivine in peridotite is largely serpentinised and orthopyroxene altered into cummingtonite.			
serpentinisation	NA	Strong	NA
Comments: Olivine in peridotite is largely serpentinised and orthopyroxene altered into cummingtonite.			

Metamorphic description:

Type:	Facies:	Degree:	Relation to mineralization:	Min P- Max P (kbar)	MIn T- Max T (°C)
Regional	amphibolite metamorphic facies	high metamorphic grade	NA		
Comments: Peaked at upper amphibolite facies during D2.					

Geological age:

Geological era:	Max age - Minage (Ma):	Inferred age (Ma):	Age of mineralization:		
Paleoproterozoic (2500-1600 Ma)	1880-1880	1880	N		
Radiometric age:	**Method:**	**Age:**	**Error (Ma):**	**Mineral:**	**Reference:**
	NA	1880	3		5

Mica gneiss (Host rock)

Rock type: Host rock
Proportion: present
Grain size: NA
Color: NA
References: 2, 9
Comments: Hosts together with the tronjhemite and black schist the offset-ore.

Structures
Folded
Breccia

Textures
Massive
Disseminated

Metamorphic description:

Type:	Facies:	Degree:	Relation to mineralization:	Min P- Max P (kbar)	MIn T- Max T (°C)
Regional	amphibolite metamorphic facies	high metamorphic grade	NA		
Comments: Peaked at upper amphibolite facies during D2.					

Geological age:

Geological era:	Max age - Minage (Ma):	Inferred age (Ma):	Age of mineralization:
Paleoproterozoic (2500-1600 Ma)	1600-2500	1900	N

Olivine gabbronorite (Host rock)

Rock type: Host rock
Proportion: present
Grain size: Coarse grained 5 - 50 mm
Color: NA
References: 2, 9
Comments: Plagioclase-olivine- orthopyroxene cumulate. Coarse-grained, fairly equigranular rocks. The main minerals are olivine, orthopyroxene, hornblende, plagioclase and sulphides. In metanorite olivine has completely altered into serpentine and the rock often contains coarse phlogopite.

Structures
Folded

Textures
Cumulate
Equigranular
Disseminated

Alteration:	Distribution:	Degree:	Relation to mineralization:
serpentinisation	NA	Total	NA
Comments: In metanorite olivine has completely altered into serpentine and the rock often contains coarse phlogopite.			

Metamorphic description:

Type:	Facies:	Degree:	Relation to mineralization:	Min P- Max P (kbar)	MIn T- Max T (°C)
Regional	amphibolite metamorphic facies	high metamorphic grade	NA		
Comments: Peaked at upper amphibolite facies during D2.					

Geological age:

Geological era:	Max age - Minage (Ma):	Inferred age (Ma):	Age of mineralization:
Paleoproterozoic (2500-1600 Ma)	1600-2500	1900	N

Norite (Host rock)

Rock type: Host rock
Proportion: present
Grain size: Fine grained 0.2 - 1 mm
Color: NA
References: 2, 3, 9

Comments: Orthopyroxene-plagioclase cumulate. The most common rock type in the intrusion. Grain size varies from coarse to fine. The main minerals are orthopyroxene, hornblende, plagioclase, biotite and sulphides.

Structures
Folded

Textures
Cumulate
Disseminated

Metamorphic description:

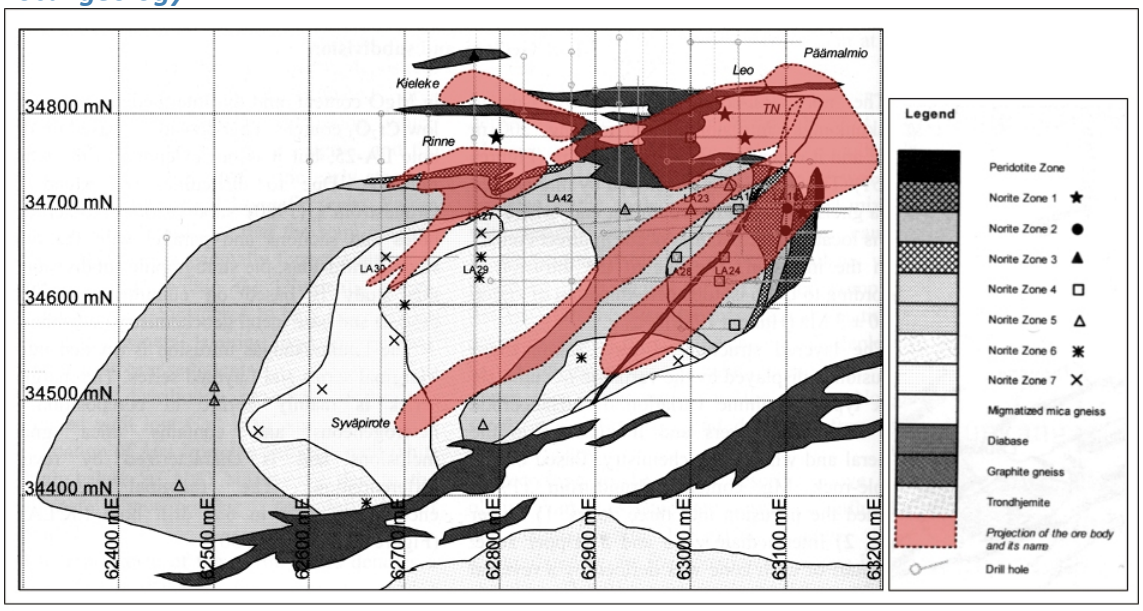
Type:	Facies:	Degree:	Relation to mineralization:	Min P- Max P (kbar)	MIn T- Max T (°C)
Regional	amphibolite metamorphic facies	high metamorphic grade	NA		
Comments: Peaked at upper amphibolite facies during D2.					

Geological age:

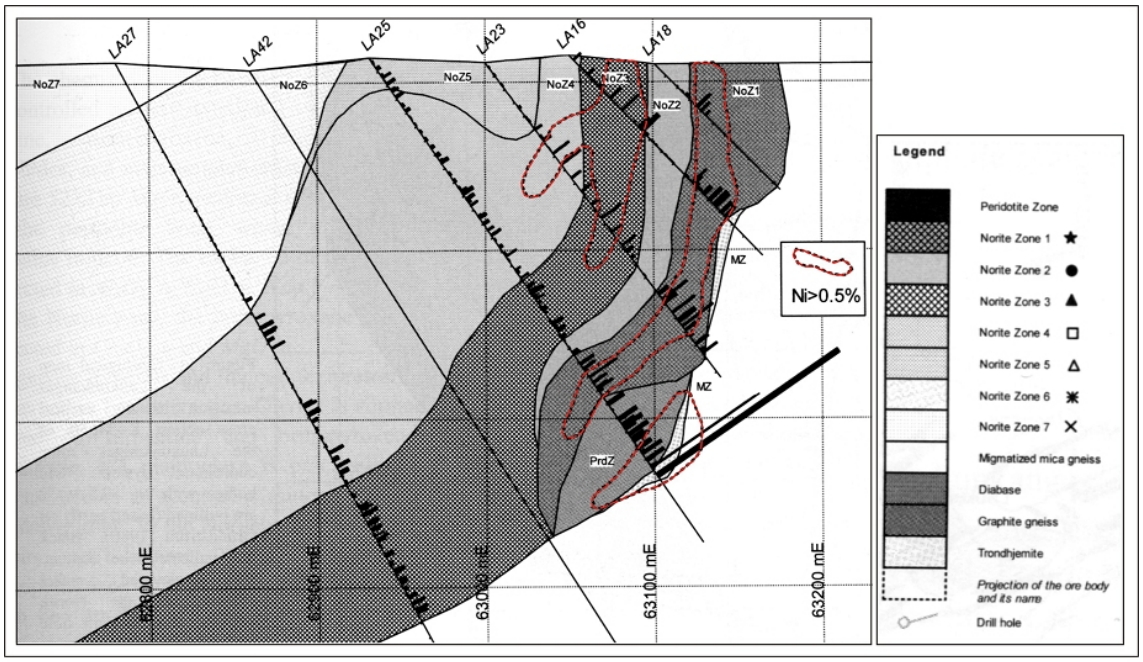
Geological era:	Max age - Minage (Ma):	Inferred age (Ma):	Age of mineralization:
Paleoproterozoic (2500-1600 Ma)	1600-2500	1900	N

Figures

Local geology:

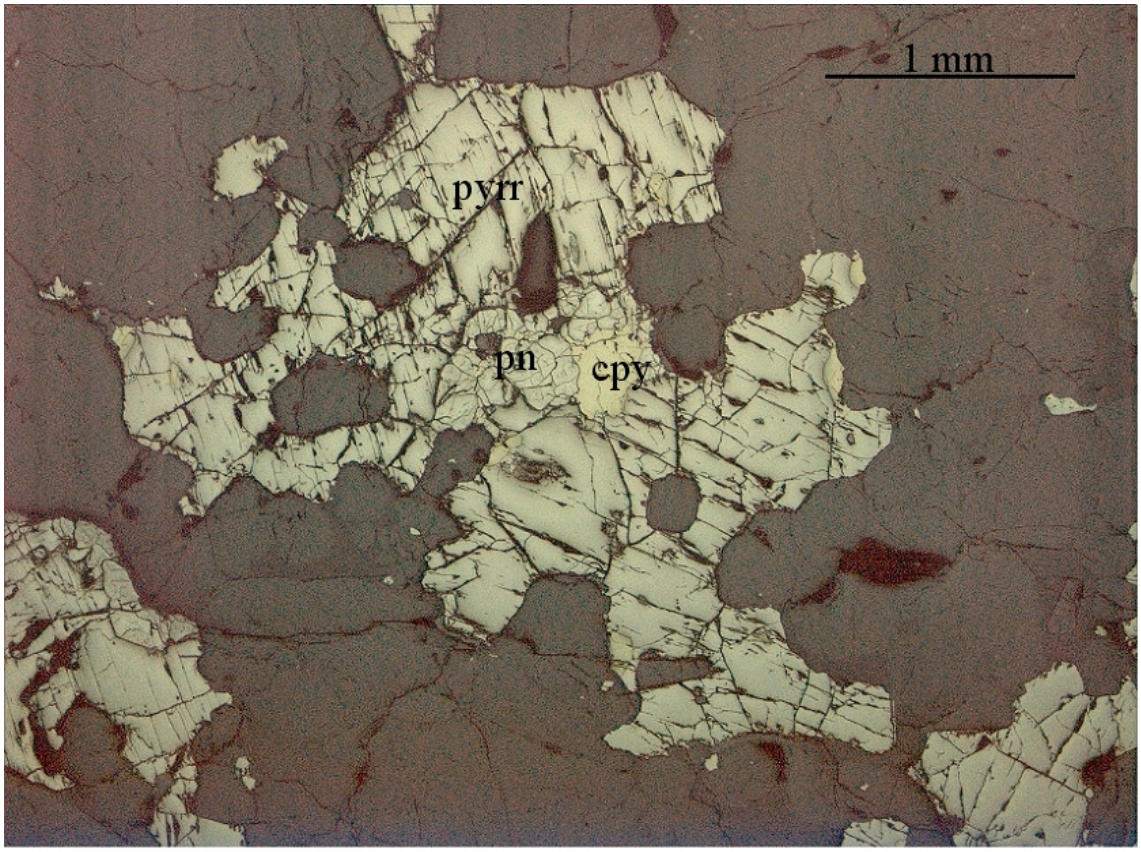


Lithology of the Laukunkangas intrusion with the projections of the ore bodies. Modified after Lamberg (2005).



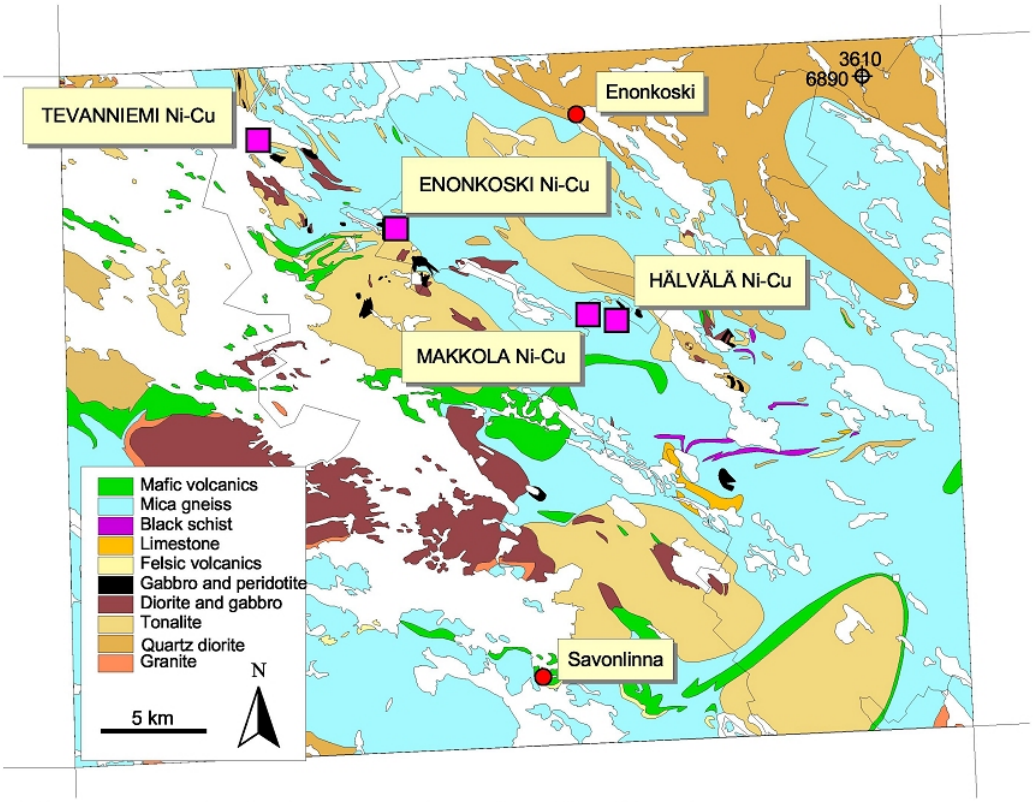
Cross section K = 34700 of the Laukunkangas intrusion. Modified after Lamberg (2005).

Polished section:



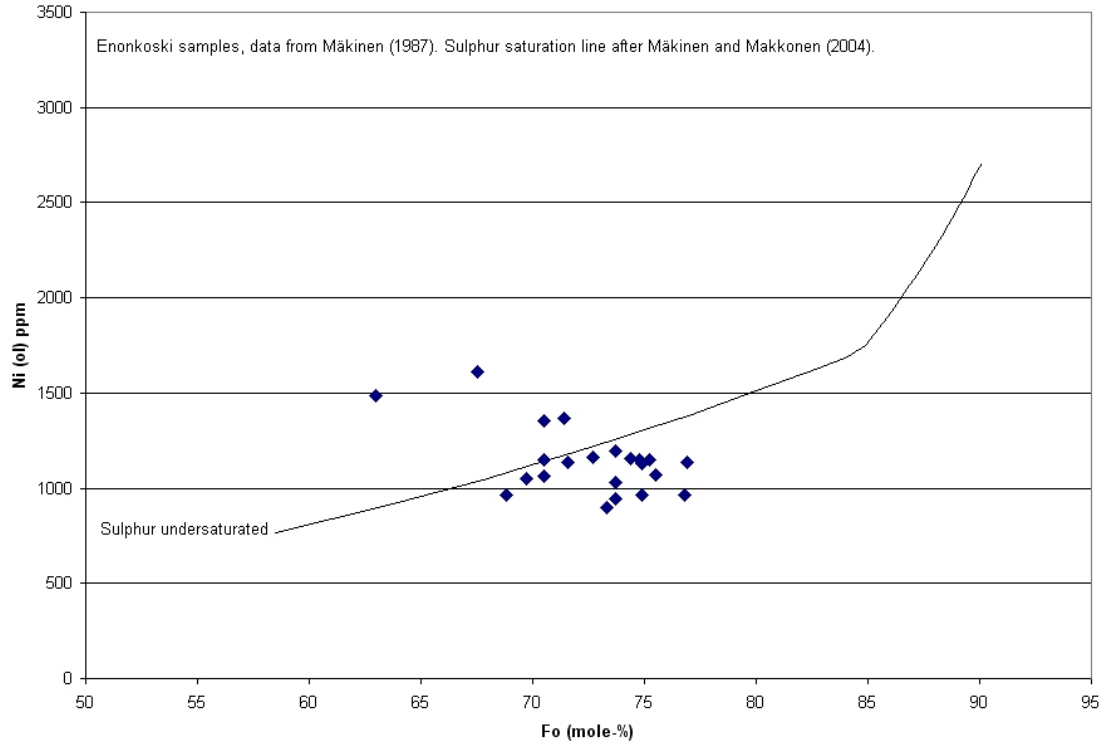
Pyrrhotite-pentlandite-chalcopyrite in gabbronorite at Enonkoski. Photo H.Makkonen.

Lithological map:

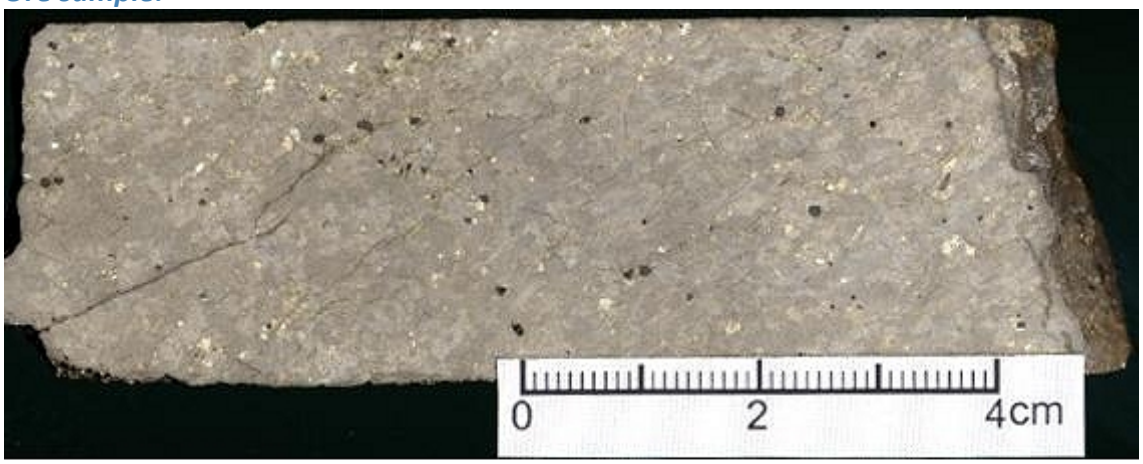


Lithology and nickel-copper deposits of the Enonkoski area.
Lithology compiled by H.Luodes.

Olivine nickel vs. olivine forsterite plot:

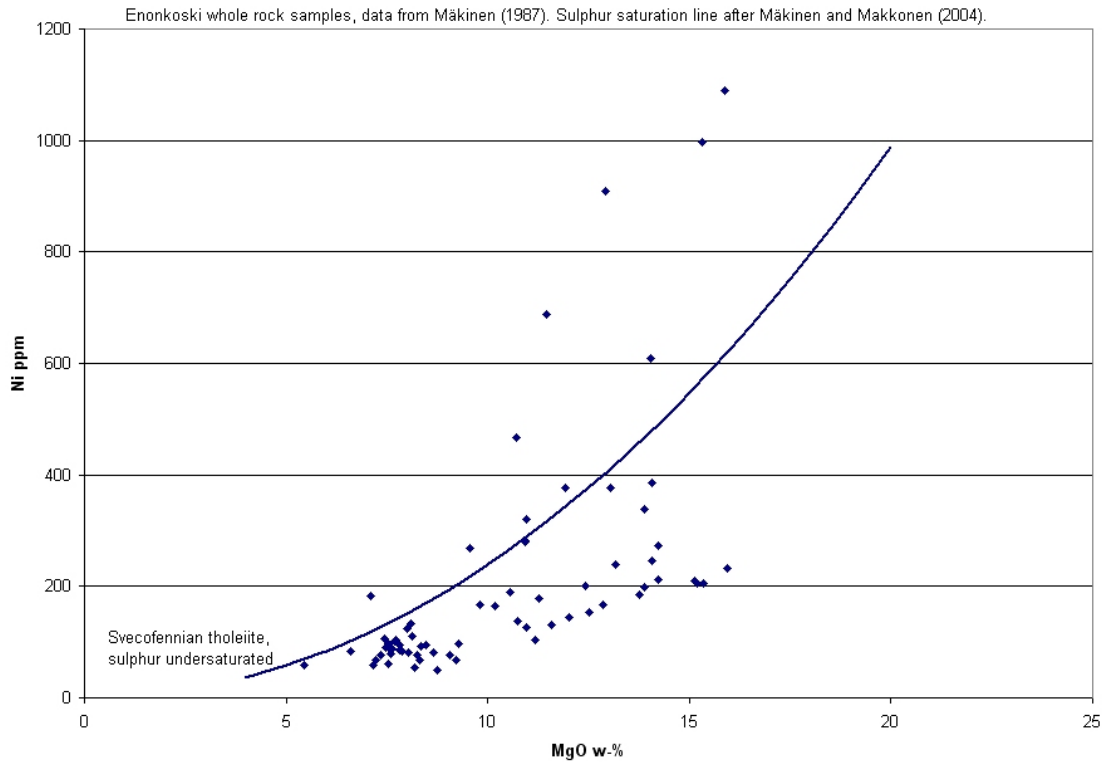


Ore sample:

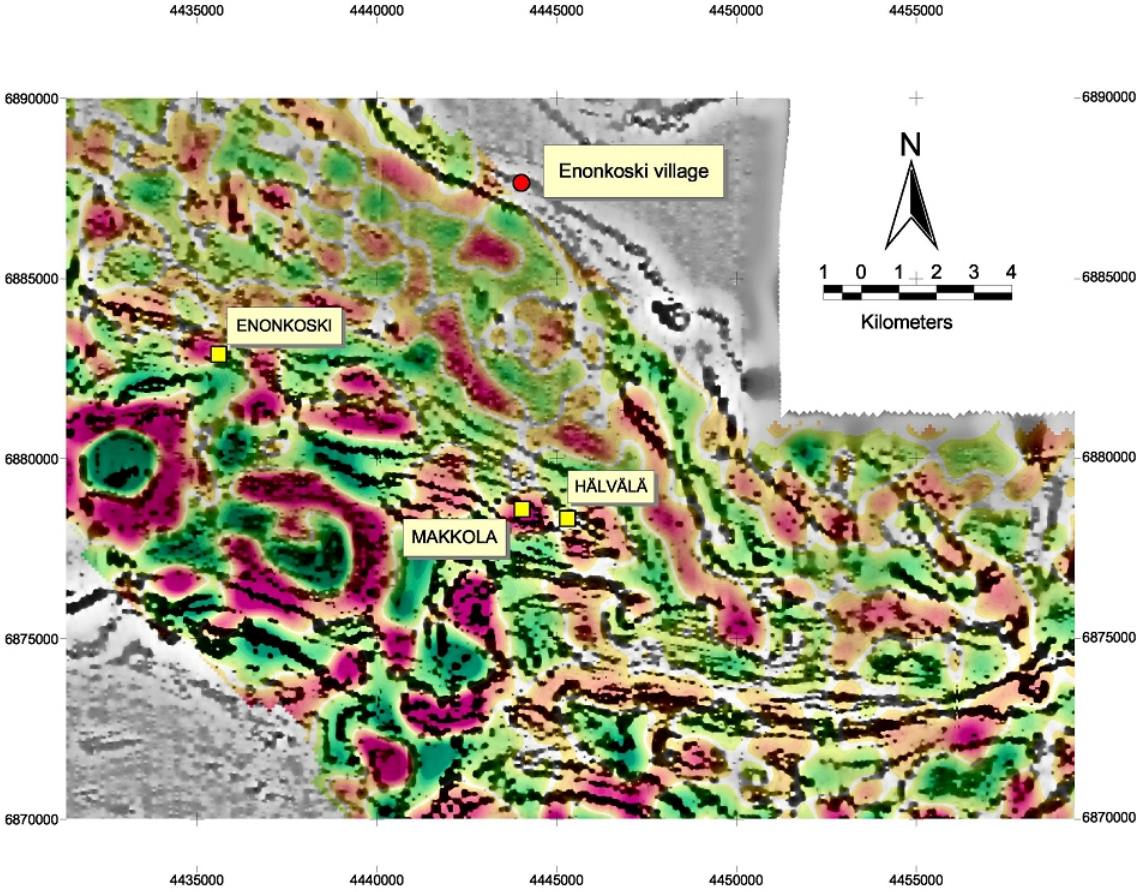


Massive pyrrhotite-pentlandite ore at Enonkoski.
BH EK/LA-67/259.95 m.

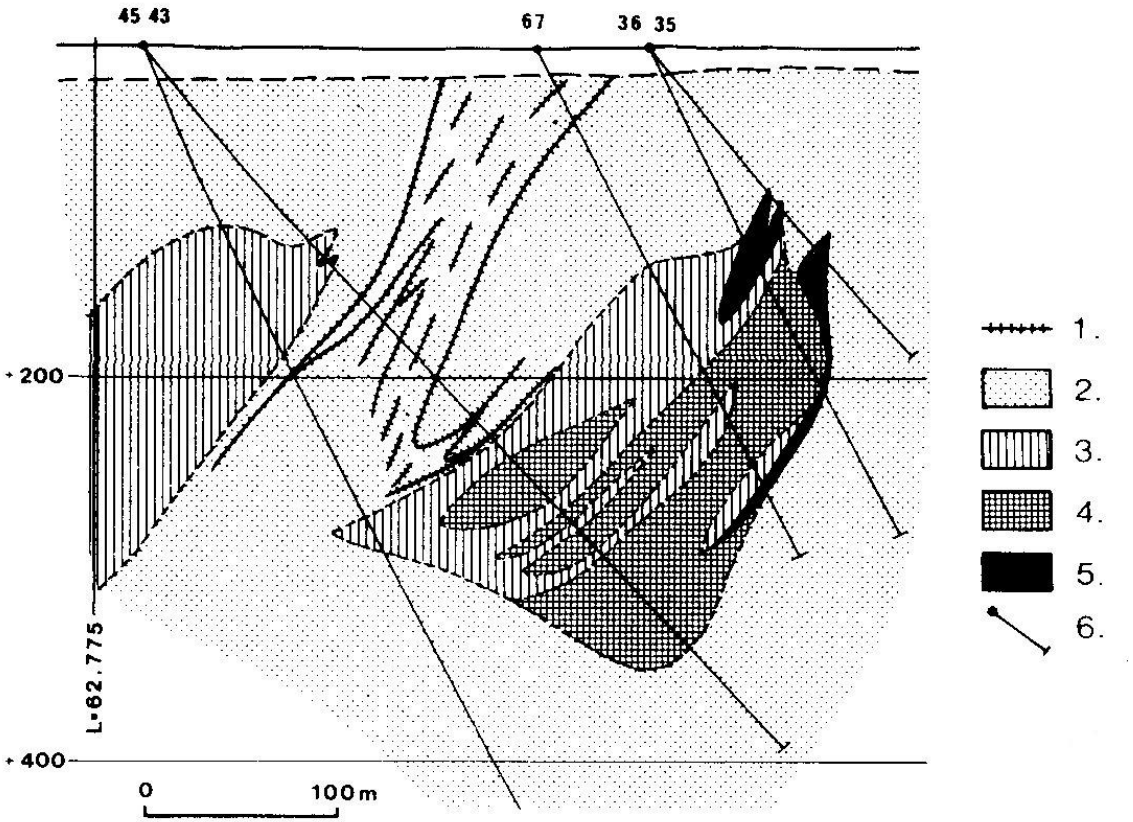
Whole rock Ni vs MgO:



grav+magn map of the Enonkoski area:



Ni deposits of the Enonkoski area on the combined map of areal gravimetrics (red = maximum, green = minimum) and low altitude airborne magnetics (black = maximum). Geophysical map from Makkonen and Forss (2004).



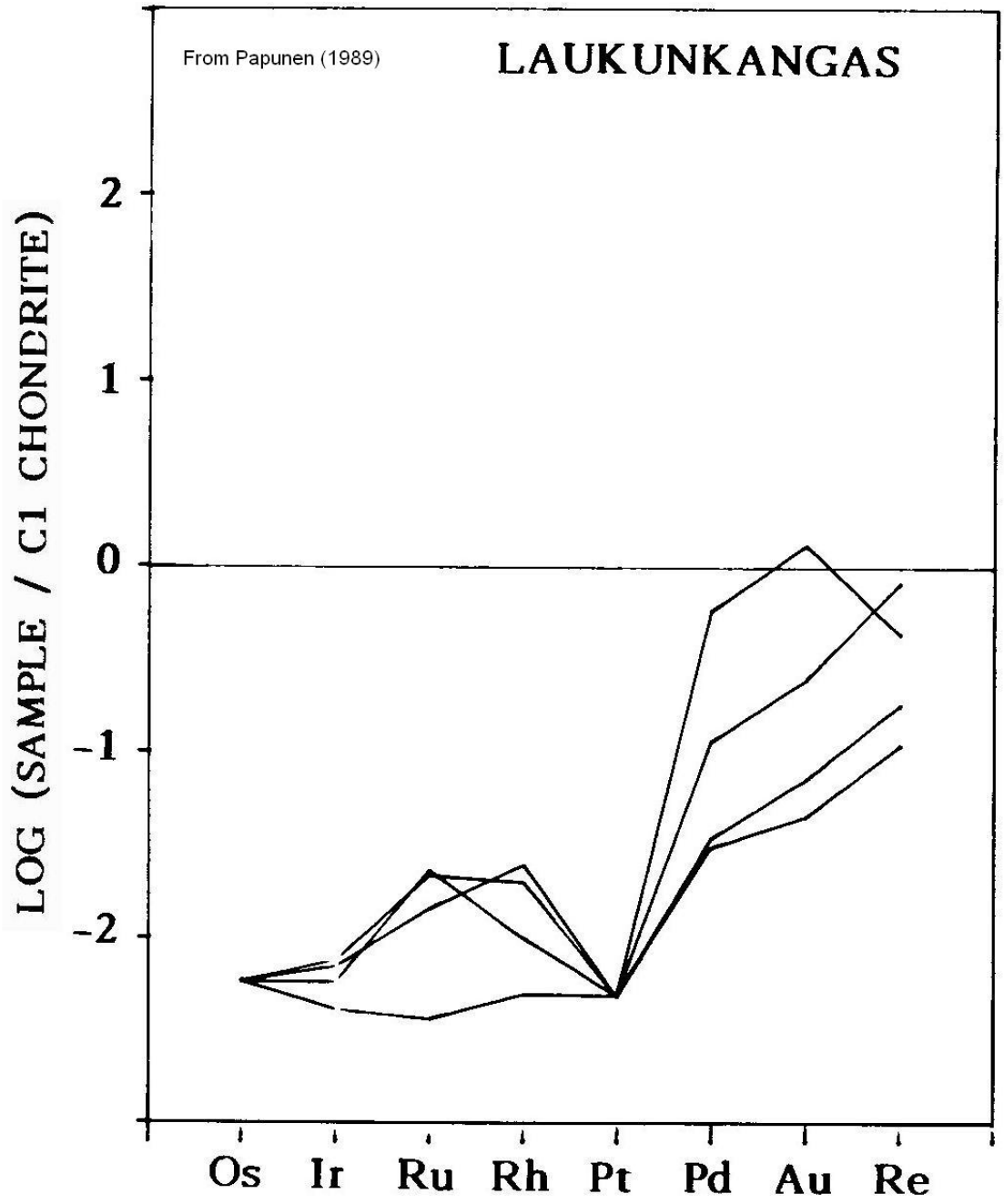
Enonkoski cross section. 1 = Black schist and graphite gneis. 2 = Mica gneiss. 3 = Norite, gabbro, diorite. 4 = Peridotite, olivine gabbros. 5 = Massive ore. 6 = Diamond drill hole. From Grundström (1985).

Whole rock composition:

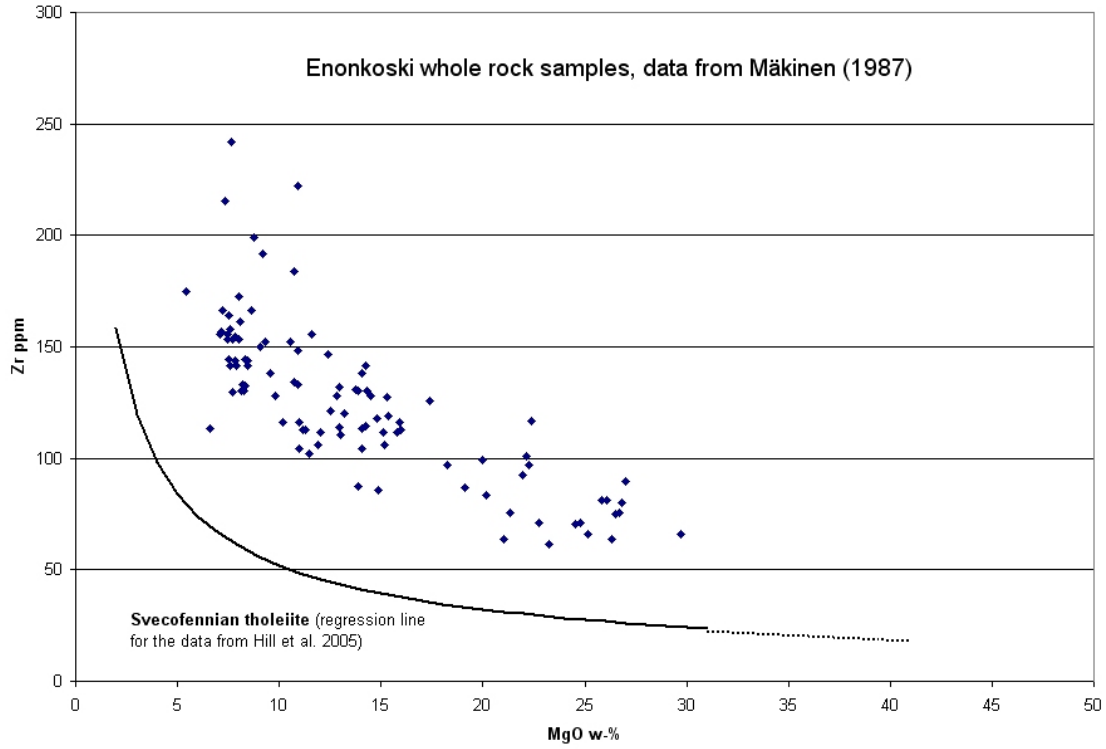
Rock Type	Lherzolite	Olivine norite	Norite	Gabbronorite	Amphibole gabbro
n	20	15	22	29	18
SiO2	45.76	48.54	51.44	52.71	53.50
TiO2	0.80	0.72	1.26	0.81	1.01
Al2O3	9.18	10.21	12.21	15.99	16.88
Cr2O3	0.23	0.25	0.23	0.12	0.06
FeO	12.28	12.37	11.70	8.34	8.18
MnO	0.20	0.19	0.19	0.16	0.15
MgO	22.68	19.34	13.09	10.43	8.15
CaO	5.65	5.89	6.49	8.27	8.31
SrO	0.03	0.03	0.04	0.07	0.07
BaO	0.06	0.06	0.08	0.06	0.08
Na2O	1.33	1.39	1.72	2.09	2.29
K2O	0.43	0.44	0.94	0.69	0.96
P2O5	0.2674	0.2531	0.5832	0.3062	0.4365
ZrO2	0.0126	0.0124	0.0175	0.0184	0.0214
Cu	0.1117	0.0261	0.0042	0.0056	0.0076
Ni	0.3768	0.0896	0.0083	0.0162	0.0166
Zn	0.0078	0.0056	0.0059	0.0052	0.0079
S	2.49	0.61	2.07	0.30	0.40

Average whole rock compositions of Enonkoski (w-%, XRF, vol. free).
Data from Mäkinen (1987).

PGE pattern:


From Papunen (1989)
LAUKUNKANGAS
LOG (SAMPLE / C1 CHONDRITE)
2
1
0
-1
-2
Os
Ir
Ru
Rh
Pt
Pd
Au
Re

Zr vs MgO plot:



ore sample:

Massive pyrrhotite-pentlandite ore at Enonkoski.

ore sample:

Disseminated ore in gabbronorite at Enonkoski.

ore composition table:

	Ni/Co	Ni/Cu	Cu/Co	Ni content in 100 % sulphides
1. Main orebody	15.0—23.0 av. 21.1	3.4—3.8 av. 3.5	4.4—6.2 av. 6.1	5.0—3.7 av. 4.5
2. Slope orebody	15.0—17.4 » 17.4	1.8—3.8 » 2.8	4.3—9.3 » 6.1	2.9—3.3 » 3.0
3. Deep orebody	17.1—18.8 » 18.2	3.1—3.7 » 3.4	5.0—6.0 » 5.3	3.4—4.0 » 3.5
4. Off-set orebody	25.5—37.8 » 34.2	1.0—2.3 » 1.8	14.3—24.7 » 19.2	1.6—6.4 » 1.9

Characteristic parameters of the orebodies at Enonkoski. From Grundström (1985).

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