A summary report on the Ni-Cu-PGE
occurrences and their host rocks in the
Precambrian of Finnmark, Northern Norway.

NGU Report 2005.085

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

Geological Survey of Norway
NO-7441 Trondheim, Norway
Tel.: 47 73 90 40 00
Telefax 47 73 92 16 20

REPORT

Report no. 2005.085	ISSN 0800-3416	Grading: Confidential until 25.01.2009

Title:
A summary report on the Ni-Cu-PGE occurrences and their host rocks in the Precambrian of Finnmark, Northern Norway.

Authors: Lars Petter Nilsson & Morten Often		Client: Anglo American plc	
County: Finnmark		Commune: several	
Map-sheet name (M=1:250.000) several maps		Map-sheet no. and -name (M=1:50.000) several maps	
Deposit name and grid-reference: several deposits		Number of pages: 79 Map enclosures:	Price (NOK): 135,-
Fieldwork carried out:	Date of report: 25.01.2006	Project no.: 2631.00	Person responsible: [signature]

Summary:

The report gives a summary of registered and unregistered magmatic Ni-Cu-PGE occurrences in Finnmark County, northern Norway. In addition possible target areas for such deposits are briefly treated. Finally an annotated bibliography is included.

Keywords: Ore	Nickel	Copper
PGE	summary report	

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1. INTRODUCTION

1.1 The scope and contents of the present report

The following short and preliminary draft report gives a summary of information on the Ni-Cu-PGE occurrences in Finnmark County. Since the known occurrences count so few in number we have here briefly treated also potential target host lithologies for Ni-Cu-PGE mineralisation. In addition reported and published results from the prospecting companies' activities on nickel in Finnmark during more than four decades are also briefly summarised. The geological map of Finnmark 1:500 000 is enclosed. Described localities in Western Finnmark are shown in Fig. 1.

Since the required work is of such limited duration we have not systematically gone into detail, but instead emphasised compiling a rather extensive bibliography. This bibliography is partly accompanied by already existing digital summaries provided by the NGU Library and partly with our own short annotations. The bibliography also includes a selection of compulsory reports from the prospecting companies to the Directorate of Mining (Bergvesenet). This relates to reports up to 1998, whereas reports delivered to the Directorate younger than 7 years are kept confidential. In the present case we have only consulted reports from the Directorate related to the Gallujavri occurrence, Karasjok.

In NGU's ore database there are currently only four occurrences registered as "Ni Cu" occurrences, whereas, for comparison, there are more than one hundred occurrences registered as "kis Cu", i.e. chalcopyrite associated with Ni free pyrrhotite and/or pyrite in Finnmark. In addition some are registered just as "Cu" or as "kis Cu Fe". The "kis Cu" occurrences are mainly occurring as vein deposit in mafic volcanics, volcaniclastics, psammitic metasediments or carbonates. (e.g. Raipas, Borras (with Co), Porsa, Kåfjord, etc.).

The four registered Ni Cu occurrences, i.e. occurrences of ultramafic-mafic magmatic Ni-Cu-PGE sulphide mineralisation, are all situated within the Karasjok Greenstone Belt (KGB). The larger one, the **Gallujavri** occurrence is situated 20 km to the north of Karasjok, whereas the other three, **Raddjevarri**, **Abmutjavrit** and **Anarjåkka (Njullas),** are all lying in the southern part of the large Anarjohka National Park in the very south of the Norwegian part of the greenstone belt.

Though mafic-ultramafic intrusive and extrusive rocks are abundant in several of the other greenstone belts, particularly in the Repparfjord tectonic window (Raipas Supergroup of Pharaoh et al. (1983), in the Paleoproterozoic Pasvik belt and in the Archean of South Pasvik, there are no Ni-Cu-PGE occurrences in these greenstone belts, as recorded in the official NGU ore database.

The following well defined greenstone belts and other terranes hosting greenstone belt associations occur in Finnmark:

1. The Karasjok Greenstone Belt, Paleoproterozoic
2. The Pasvik-Polmak belt (Paleoproterozoic, the western extension of the Pechenga belt)
3. The South Pasvik terrane (late Archean, western extension of the Tersk–Allarechka greenstone belt)
4. The Sør-Varanger terrane (late Archean, hosts large BIF deposits, but greenstones make up only a minor constituent)
5. The Kautokeino belt, Paleoproterozoic

In the tectonic windows to the northwest:

6. The Paleoproterozoic Raipas Supergroup in the Repparfjord window.
7. The Paleoproterozoic Raipas Supergroup in the Alteneset window.
8. The Paleoproterozoic Raipas Supergroup in the Alta-Kvænangen window.

In the following chapters the treatment of the different greenstone belts will be in this order.

A search in older review–reports and papers (Poulsen 1941, 1945, 1961, 1964, Bugge1978, Bjørlykke et al. 1984, Boyd & Nixon 1985, Czamanske et al. 1986) confirms the picture of a true scarcity of known mafic-ultramafic magmatic Ni Cu mineralisation/occurrences in the Finnmark Precambrian. In the large Caledonian Seiland Magmatic Province (Roberts 1974) on the Finnmark cost there are, however, indications of a possible Ni-Cu-PGE potential several places, e.g. in the Lille Kufjord layered intrusion at Seiland (Gading 1987, Oosterom 1956).

In the 1990's NGU (Dalsegg & Often 1991, Ludvigsen 1993, Davidsen 1994) recognised and documented anomalously high PGE contents associated with some of the hornblendite hosted Cu occurrences in the Lakselvdalen area in the northernmost part of the KGB. The **Karenhaugen**) deposit has been known for a long time as a Cu occurrence (registered as "kis Cu" or just "Cu") (see summary in Bugge 1978, p. 209-210), but its high PGE content was not discovered until the late 1980's. The Karenhaugen twin, the Porsvann Cu-Pd-Pt deposit was discovered during successive fieldwork in search of Karenhaugen type mineralisation.

1.2 A few background words about Finnmark and the recent status of geologic map compilations

Finnmark is the northernmost and largest county in Norway. The area is some 48 000 km^2 which is more than the whole of Denmark. The geology of Finnmark, unlike the rest of Norway, has extensive areas of Paleoproterozoic and Archaean gneiss-greenstone belt terranes (Siedlecka & Roberts 1996). The various terranes occupy the peneplaned and strongly overburdened low mountain plateau to the south of the Caledonides and in addition a few tectonic windows within the Caledonides.

Until today prospecting has been at a very low level in the inner parts of Finnmark (Finnmarksvidda) due to the fundamental and extensive conflicts with regard to the ownership and use of the land. The map basis, however, is very much better today than only one to two decades ago. It is now possible to make a much better target selection by comparing and contrasting the various map compilations from the Norwegian as well as the bordering Finnish and Russian sides.

In addition to the 1:500 000 map of Finnmark county (Roberts & Siedlecka 1996), NGU has recently issued several 1:250 000 scale and a large number of 1:50 000 scale maps based mainly on the Finnmark project (1982-1992). On the Finnish side there is a new (1998?) 1:1 mill. map of the country plus many maps at various scales from greenstone belts in Finnish Lapland. Deposit information from Finland will serve to indicate where in the greenstone belt stratigraphy and in what kind of lithologies the best target areas for Ni-Cu-PGE deposits are to be found. The Kola Peninsula is also covered by a fairly recently updated 1:500 000 scale geological map (Mitrofanov 1996) (the most recent edition we have, but later editions may well exist?). A geological map compilation of the whole Fennoscandian Shield is also recently accomplished (Koistinen et al. 2001) as well as a compilation of the whole of Northern Europe (Sigmond 2002). All these geological map compilations as well as related geophysical and geochemical maps will facilitate the exiting task of comparing and contrasting the geological conditions and the ore potential across the national boundaries.

2. THE KARASJOK GREENSTONE BELT

2.1 Introduction

The Paleoproterozoic (2.3 – 2.0 Ga. Marker and Melezhik, pers. com.) Karasjok Greenstone belt (KGB) is together with the Kautokeino Greenstone Belt the two major greenstone belts in Finnmark (Siedlecka & Roberts 1996). Unlike its western neighbour the KGB seems to have evolved from an early rift phase and gone through a complete Wilson orogenic cycle (Often 1985, Krill 1985).

The KGB is unique among the Norwegian greenstone belts in having both abundant ultramafic intrusions as well as komatiites. There are also abundant gabbroic intrusions within the KGB, intrusions that also have their extrusive counterparts in the widespread greenstones, amphibolites and even migmatites.

2.2 The Karasjok komatiites

The komatiites in the Paleoproterozoic Karasjok Greenstone Belt are clearly the most important ones in Norway by volume, covering some 80 km^2 (Barnes & Often 1990). They have invariably a metamorphic mineral assemblage of Mg-chlorite + tremolite ± antigorite ± carbonate ± olivine (Henriksen 1983, p.25), though more rarely serpentinised or talcified komatiites occur. There is an extensive literature on the Karasjok komatiites, especially stemming from the NGU Finnmark programme (1982-1992). The whole greenstone belt was then mapped at 1:50 000 scale, and the most important references which might be useful in a future evaluation of the metallic ore potential are listed:

- Geological publications dealing with Karasjok komatiites: Wennervirta 1968, Henriksen 1983, Often 1985, Krill 1985, Barnes & Often 1990, Davidsen 1994, Braathen & Davidsen 2000.
- Combined geophysical-geological reports and publications: Midtun 1986, 1987, 1988, Nilsson 1988.
- Maps covering areas with Karasjok komatiites:
  1:50 000 scale maps:
  Often & Krill 1986, Krill & Often 1986, Nilsen 1986a,b, Henriksen 1984, Nilsson 1987, Siedlecka 1987, Roberts & Davidsen 1992, Roberts & Rice 1990

  1:250 000 scale maps:
  Roberts 1998 (northernmost part)
  Skålvoll 1972 (central part, now very much outdated)
  Olsen & Siedlecka 1996 (southern part),

  1:500 000 scale map of Finnmark:
  Siedlecka & Roberts 1996 (summarises all the recent work up to printing)

Barnes & Often (1990) give detailed descriptions of the typical Karasjok komatiites. Here we will give only two short examples on Mg-rich varieties of komatiites in the KGB as illustrations:

Rievdnjesvadda:
This is an occurrence of a partly talcified, serpentinitic Mg-rich komatiite that is situated close to the main road E-6 between Lakselv and Karasjok at the highest point of the road. The location is registered as an ancient soapstone occurrence. The komatiite here makes up a small flow near the western margin of the KGB (Henriksen 1984, Nilsson 1987, Midtun 1987).
The Rievdnjesvadda komatiite is essentially a serpentinised rock with some chlorite and hence, an anomalously Mg rich flow for the Karasjok belt where most of the komatiites are chlorite-amphibole rocks as mentioned above.

The Rievdnjesvadda komatiite belongs to the stratigraphically lowermost in the belt and is possibly on average more Mg rich than the komatiites (chlorite-amphibole-(carbonate) rocks) in the Bakkilvarre Formation (Henriksen 1983, Often 1985, Barnes & Often 1990). The Rievdnjesvadda talc/soapstone occurrence is located close to the margin of the ultramafic body.

The Bakkilvarre komatiite
The Bakkilvarri komatiite was first mapped by Wennervirta (1969), and in greater detail by Nilsen (1986a). In addition, the combined geophysical-geological reports and publication give valuable information on the distribution of the highly magnetic komatiite contrasting neighbouring low magnetic amphibolite (metabasalt) and metasediments in this heavily overburdened terrain (Midtun 1986, p.22, etc., Midtun 1988, Nilsson 1988). Wennervirta (1969, p.152-153) reports metamorphic olivine in the rock, locally so abundantly that it represents the main mineral in the komatiite. According to Wennervirta olivine (i.e. metamorphic olivine) is otherwise only locally present in the Karasjok komatiites. The reported variations in MgO contents in the Karasjok komatiites are in general large: 21-35wt-% (Henriksen 1983, p.28-29), 18-37wt-% (Often 1985, p.81).

2.3 The Gallujavri ultramafic intrusion and Ni-Cu-PGE prospect

Location:
The Gallujavri Ni-Cu-PGE sulphide bearing ultramafic intrusion is located on the north, east and south side of the 0.7 x 1.6 km lake Gallujavri. The intrusion is situated c. 20 km to the north of Karasjok and 3 km east of the main road E-6 at Nattvatn (Iddjajavri). See fig. 1, 2 and 3.

UTM-coordinates:
Centre coordinates (full coordinates) (at the southern shore of lake Gallujavri):
^{4}37 000 / ^{77}25 000 (ED 50), zone 35 W.

Topography:
The lowest point in the terrain is lake Guorbmetluobbal at 274 masl., whereas lake Gallujavri is at 317 masl. The highest point within the intrusion is in the NE corner that reaches about 370 masl.

Size, form and dimensions:
The ultramafic intrusion measures some 0.5 x 4.5 km according to the 1:50 000 scale map of Henriksen (1984). Geophysical maps, however, indicate that the highly magnetic ultramafic intrusion bends orthogonally to the east about a km north of the lake Guorbmetluobbal (373217) (Midtun 1987, map 1, 3 and 6, etc.), and further indicate that the southern end of Henriksen's Gallujavri intrusion may be a separate minor intrusion.

Outcrops:
Outcrops are marked, roughly, on Henriksen's map, but several additional ones occur, especially in the northern part of the intrusion, north of lake Gallujavri. The rather rough terrain with small local hills indicates that the till cover cannot be very thick on the north and east sides of the lake. Outcrop degree is not good (less than 5 % as judged by Tertiary Minerals), but not as bad as the average within this part of the KGB, or the KGB as a whole.

Accessibility:
Easiest access is from the main road at the Stadduluokta bay at the southern shore of lake Iddjajavri (350230). It is, however, here necessary with a small boat to cross the 200 m wide southern branch of Iddjajavri. It is also possible to reach the intrusion on a footpath or four-wheel motorcycle track from the southern side of lake Sieidejavri (360200). This path crosses the small local rivers at the easiest places were wading is not necessary.

Intrusive episodes and petrographic composition of the intrusion:
The Gallujavri intrusion may be interpreted as a single, slightly in-situ differentiated primary peridotitic to olivine pyroxenitic or pyroxenitic intrusion, now on average strongly altered.

The intrusion is hosted by 45 to 70º eastward dipping metapsammites (Henriksen 1984) and lies concordant or semi-concordant to these, at least in the north. It is a question if the intrusion is overturned or is facing right way up to the east. This is because both olivine-rich cumulates and significant sulphide mineralisations are located to the eastern, upper part of the body (cf. Fig. 3). On the other hand, there are significant Turam anomalies in the central and western part of the body, partly under lake Gallujavri. According to Tertiary Minerals (web release) they have observed in the north that olivine contents are highest towards the western margin of the body, while feldspar increases to the eastern contact with the gabbro, suggesting some settling of olivine in the magma. The base of the intrusion is therefore interpreted to be the western margin of the intrusive they further conclude.

If the bottom portion follows the western margin of the body, which originally was the richest in olivine, this olivine is now seen as serpentine + magnetite pseudomorphs set in a matrix of amphibole (mostly tremolite) after pyroxene(s). Higher up sequence in the intrusion a massive, dark green to nearly black, medium grained metapyroxenite is the major rock. Higher up also plagioclase enters the mineral assemblage. There are, however, also olivine-rich cumulates in the upper part of the intrusion. Specimens sampled to the south of lake Gallujavri in addition show phlogopite as a minor constituent.

Along the northern part of the eastern margin the ultramafite borders a normal gabbro for 500 m, but there are no outcrops observed in the transition zone between the two. According to Henriksen's map the gabbro is of equal size to the ultramafite. In the far south of the intrusion, near the lake Guorbmetluobbal, we recognised a relatively coarse-grained normal gabbro with leucocratic parts in contact with the eastern side of the ultramafite during a revisit to the Gallujavri intrusion in 2003 (Henriksen's map shows only a large outcrop of metapsammite here). In this southern part we further recognized that the rock locally contains 2-4 mm large black crystals of augite relics(?) or amphibole(?) set in a green, fine grained tremolite-(chlorite) groundmass with c. 50/50 distribution of crystals and groundmass. At other places we observed only a green, monomineralic amphibole (tremolite) rock.

Internal phenomena (layering, etc.).
We did not recognise any signs of rhythmic modal layering or any other visible "meso-scale" physical phenomena within the intrusion, but large local variations in mineralogical and chemical composition may indicate that a modal layering is present.

Mineral chemistry:
Not yet conducted.

Whole rock geochemistry:
Bulk analyses of hand size specimens show that the intrusion generally has evolved from a MgO rich composition in the lower and central parts to a MgO poor composition in the upper parts. Complementary, the contents of CaO, Na_2O and K_2O have increased as MgO has decreased.

There are however distinct exceptions to this general trend. Samples 8 and 10 are e.g. both taken from the upper part of the intrusion some 100 m from the hanging wall contact (see the map in Fig. 3). They show remarkably different composition as shown below:

	Content in wt-%			
Sample No.	MgO	CaO	Na_2O	K_2O
8	29.19	5.20	0.28	0.08
10	12.21	10.53	1.42	0.69

This large compositional difference can be explained by modal layering in this part of the body, though this is not pronounced or even visible. The build up of the intrusion may therefore in detail be rather complicated.

Metamorphism and hydrothermal alteration:
The primary olivine and pyroxene rich assemblage is thoroughly strongly hydrothermally altered to secondary minerals as tremolite, serpentine, magnetite and eventually also chlorite.

Exploration work carried out:
Both regional geochemical sampling (soil sampling and other media), regional bedrock mapping in 1:50 000 scale (Henriksen 1984) as well as regional helicopter geophysics (magnetic, EM, radiometric and VLF measurements) (Håbrekke 1979) are conducted. Follow up work included ground geophysics and drilling.

Drilling:
The company A/S Sydvaranger, later ASPRO, drilled 10 holes in the intrusion during the period 1978-82. Holes no. 1ø, 1v, 2, 2b and 2c are short packsack holes, whereas holes no. 3 to 7 are normal diameter long holes. In spring 2003 UK based Tertiary Minerals drilled additional 3 holes in the same part of the intrusion on a combined IP and magnetic anomaly associated with Ni-Cu-(PGE) sulphide mineralisation hosted in a meta-olivine cumulate (see Fig. 3).

Table 1: Compilation of drill hole data, Gallujavri.

Drill hole no.	Dip	Azimuth	Length
03GD001, Tertiary Minerals	45	270	125
03GD002, Tertiary Minerals	45	270	125
03GD003, Tertiary Minerals	45	270	127
Sydvaranger bh 6	45	200	161
Sydvaranger bh 3	45	279	89
Sydvaranger bh 4	45	112	107
Sydvaranger bh 7	45	30	160
Sydvaranger bh 5	45	279	180
Sydvaranger bh 2	45	270	10
Sydvaranger bh 1 east	45	90	20
Sydvaranger bh 1 west	45	270	12

At NGU's drill core store at Løkken only 2 core boxes (with 10 m core each) are preserved. They contain remaining split cores from about 60 to 80(?) m depth in hole no. 5. The three holes drilled by Tertiary Minerals (Tertiary Gold Ltd) are stored at Løkken in full length (we have however not seen these cores yet).

Sulphide mineralisation:
Ni-Cu-PGE-Au mineralisation occurs as an uneven dissemination here and there throughout the intrusion, not only in the bottom portion of this. In addition a Ni and Cu free pyrite mineralisation ("false ore") is occurring. The ground geophysics, geochemistry and the drilling conducted before 2000 have picked up some weakly mineralised zones, including the pyrite mineralisation, whereas other mineralised spots/local areas/zones (?) have been lost. This applies, e.g. to mineralised spots localised by NGU in 1987-88 in the northern part of the intrusion. According to information released on the web by Tertiary Minerals (Financial Express, 31.10.2001) the company has located a 2.5 km long Ni-Cu sulphide zone with Pt+Pd+Au grades up to 2.45 ppm.

Metal grades:
Analyses of samples collected by NGU (Finnmark Programme) in 1987-88 showed anomalously high noble-metal grades in chip samples and in sulphide concentrates extracted from a large bulk sample taken. Metal grades are compiled in Table 2 below.
The noble metal analyses (PGE+Au) were analysed by Sheen Analytical Services, Perth, Western Australia (now Analabs), whereas the remaining analyses were conducted at the NGU Lab. Chip samples were analysed by XRF + bromine soluble Ni ($Ni_{sulph.}$), whereas the concentrates were assayed followed by an AA or IC finish.

Microscopy and microprobe analyses of the sulphides:
Sulphide minerals present
Microscopy and microprobe analyses of the sulphide concentrates tabulated below showed pure concentrates with varying proportions of pentlandite (ptl), pyrrhotite (po) and chalcopyrite (cp) and very much composite sulphide grains (polyphase grains). Only the least magnetic concentrate (No. 5 in Table 2) is free of pyrrhotite, but in return it hosts as much as c. 5 – 10 % arsenopyrite (apy).

Noble metal minerals
No platinum-group minerals (PGM) were observed with reflected light microscope or with the microprobe. Tiny discrete grains of hessite (Ag_2Te) and electrum (Ag>Au) were the only noble metal phases encountered on the microprobe. This was however not in the concentrates, but in ordinary polished sections of the sulphide mineralised rock.

Occurrence of gold

Microprobe analyses of arsenopyrite in concentrate No. 5 showed that this contains significant amounts of gold (cf. Table 2). The Au content was semi-quantitatively measured to 0.33 % ± x in the apy. The Pt content was measured to 0.28 % ± x. Both analyses were significant. For gold we have that peak X-ray intensity > 3√ background X-ray intensity, that is 593>138, i.e. significant with a wide margin.

<u>Occurrence of PGE/PGM</u>
Referring to Table 2 we have a small or no enrichment factor for **Pt** in concentrates 1 and 2 in relation to the raw material. We see however a strong enrichment factor for **Pt** in conc. 3 (6x enrichment), conc. 4 (4x) and conc. 5 (23x). Due to the very limited amount of material available this must be regarded only as a qualitative estimate for the latter three concentrates.

For **Pd** we have a 10 – 20 x enrichment factor in conc. 1 and 2 compared to the raw material. In concentrates 3, 4 and 5 we see a gradually stronger enrichment, conc. 3 (60x), conc. 4 (130x) and conc. 5 (230x). Also here the laboratory faced problems related to limited sample amounts, and the numbers are therefore only indicative.
However:
The high PGE grades in the concentrates and the fact that no PGM were located using the microprobe may indicate that Pt and Pd as well as the other PGEs are accommodated in ptl, po and cp in solid solution. The analyses show e.g. a positive correlation between PGE and Cu. A similar behaviour of the PGE is known both from experimental studies (Mackovicky et al. 1988) and from research with the proton microprobe on sulphides from the Stillwater Complex, Montana (Cabri et al. 1984).

Table 2: Gallujavri Ni-Cu-PGE prospect. Compilation of PGE + Au + BMS analyses

Specimens analysed for Os, Ir, Ru, Rh, Pt, Pd and Au (in ppb) and Ni_{total}, $Ni_{sulph.}$, Co, Cu and S (in wt-%)

Sample No.	Os	Ir	Ru	Rh	Pt	Pd	Au	$Ni_{tot.}$	$Ni_{sulph.}$	Co	Cu	S
6								0.11		0.01	0.01	<0.10
7	18	21	21	12	260	250	52	0.22	0.16	0.01	0.18	0.68
7 (dup)	*68*	*24*	*17*	*12*	*190*	*180*	*58*					
8								0.13		0.01	0.01	
9								0.12		0.01	0.02	<0.10
10	2	<0.5	<0.5	0.5	72	18	26	0.07	(0.29)	<0.01	0.11	0.44
11								0.10		0.01	0.04	
12								0.09		0.01	0.02	
168/1	8	16	15	12	120	120	24	0.22	0.13	0.016	0.20	0.27
168/2	10	16	15	11	130	110	34	0.22	0.13	0.015	0.16	0.24
168/3	6	12	8	6	60	63	20	0.17	0.09	0.013	0.14	0.16
168/4	<2	7.5	6	4.5	42	45	28	0.15	0.10	0.010	0.22	0.20
168/c. 1	420	96	560	400	140	2000	40	10.3		0.58	1.60	34
168/c. 2	300	94	310	220	100	1100	64	6.8		0.33	1.45	34
168/c. 3*	2200	300	2100	1400	650	6200	280	8.5		1.12	3.75	38
168/c. 4*	3800	660	4100	2800	420	13 000	2800					
168/c. 5*	13 000	5100	9300	6400	2300	23 000	9900					
168/c. 6	34	8.5	40	30	99	320	36	0.99		0.05	0.54	3.1

* Comments from analyst: SHEEN Analytical Services Ltd, Perth, Western Australia who analysed the samples in 1989: "Due to extremely low sample weights results of concentrates 3, 4 and 5 should be regarded as qualitative".

Specimen nos. 6 to 12 are normal hand size surface specimens taken with hammer.

Specimen No. 168 was originally a 30 – 40 kg sulphide mineralised surface sample taken with hammer or sledge. At first 4 hand size specimens were knocked off and analysed as nos. 168/1 to 168/4. The rest was crushed, sieved and the fraction 105 – 246 µm (microns) was table washed. The table concentrate was then treated by weak field magnetic separation (removal of magnetite, ferrichromite, etc.) and the nonmagnetic fraction further treated with heavy liquids in three steps (sp. gravity 2.96, 3.3 and 4.0 g/cm^3 respectively) followed by high magnetic Frantz separation.

No. 168/concentrate 1: Specific gravity > 4.0 g/cm^3 (heavy liquid) and magnetic at 0.07 Ampere (Frantz separ.).

No. 168/concentrate 2: Specific gravity > 4.0 g/cm^3 and magnetic at 0.3 Ampere.

No. 168/concentrate 3: Specific gravity > 4.0 g/cm^3 and magnetic at 0.5 Ampere.

No. 168/concentrate 4: Specific gravity > 4.0 g/cm^3 and magnetic at 1.0 Ampere

No. 168/concentrate 5: Specific gravity > 4.0 g/cm^3 and nonmagnetic at 1.0 Ampere

No. 168/concentrate 6: Reject (i.e. magnetic fraction) from weak field magnetic separation.

Comparison with other massifs:
We were both visiting the Keivitsa Complex during the IGCP 336 excursion in 1996 (Mutanen 1996). When looking at the Keivitsa drill cores it at once struck us that these very much resembled the Gallujavri cores in many ways (lithologies, colours and darkness, grain size, or just "general habit"). Also fresh hand size specimens, both mineralised and unmineralised, look very similar when compared. Both the 2057 Ma Keivitsa Complex and the Gallujavri intrusion contain low grade Ni-Cu sulphide mineralisation with a relatively high PGE+Au tenor. And both have a Ni- and Cu-free pyrite mineralisation, the so-called "false ore" in Keivitsa (Mutanen 1996, 1997).
During the Keivitsa excursion in 1996 we were told that neither geophysics, nor geochemistry or quaternary geology were particularly helpful tools during the prospecting work. We were told e.g. that the ore body did not give any geophysical signature. The quaternary geology was difficult to interpret. Due to pre-glacial weathering there were no till anomalies. Just at the boundary of the ore the till starts to reflect that the ore is there we were told. The extensive trenching was perhaps the most helpful mean to locate the ore. The huge amount of experience won from the exploration work on the Keivitsa-Satovaara complex (e.g. Mutanen 1996, 1997) should in any case be drawn upon when evaluating the ore potential of the Gallujavri intrusion.

Positive elements in an evaluation of the ore potential of the Gallujavri intrusion and other similar intrusions within the Karasjok greenstone belt:

- The accumulated prospecting experience from Keivitsa-Satovaare is unparalleled for this type of ore deposits, a type that may occur also on the Norwegian side of the frontier.
- Both Gallujavri and Keivitsa belong to the same greenstone belt and may have the same age, similar rock compositions and hosting a similar type of ore mineralisation.
- The geophysics used has not identified / picked up all the present mineralisations in the Gallujavri intrusion, i.e. it should be possibilities for additional sulphide mineralisations.
- Other, both neighbouring and more remote intrusions of the same type as Gallujavri, are more poorly investigated than Gallujavri. Some of them (most of them are probably outlined on the 1:50 000 scale maps) are perhaps not investigated all. Some of them may have an ore potential that exceed that of Gallujavri.

Negative elements and conditions not yet clarified:

- The size of the Gallujavri intrusion may be too small for the possibility of hosting an ore deposit of the size needed for such a low-grade deposit to be mined economically both presently and in the foreseeable future. At the Keivitsa deposit some 260 mill. tons of ore down to 300 m depth are drilled, thereof 30 mill. tons with a high cut off grade. Mining of such a deposit would be comparable to mining e.g. the Aitik deposit in Sweden.

- Even if the noble metals seem to be strongly enriched in the sulphide and sulpharsenide phases, neither the Ni-Cu-Co grades, nor the PGE+Au grades, are particularly high within the Gallujavri intrusion, -on the contrary we would rather say: Analyses performed for ASPRO around 1980, for NGU in 1987-88 and recently for Tertiary Minerals (cf. web information) mostly show sub-ppm grades for total PGEs+Au as well as fairly low grades for both Ni, Cu and Co. Despite of the prospecting efforts made so far on the Gallujavri intrusion, an eventual economic ore deposit still seems far ahead with regard to both size and grades. The PGE+Au cut off grade for such a Ni and Cu poor occurrence should probably be at least in the order 1-2 ppm assuming that the size was large enough (cf. e.g. recently released information on the Marathon PGM-Cu project on the Port Coldwell Complex in Ontario, Canada as a comparable project) (www.marathonpgm.com/projects.html).

2.4 The Ni occurrences in the southernmost part of the Karasjok Greenstone Belt

There are three registered Ni occurrences in the southernmost part of the KGB, the Raddjevarri, Abmutjavri and Anarjokka (Njullas) occurrences. According to database information there are no NGU-reports or NGU-Bergarkiv reports (i.e. the older NGU reports) dealing with them. The occurrences are relatively closely spaced with some 12 km between the southern and the northern one. We consider this spatial information to be sketchy. Better data can be obtained from filed reports with the Commissioner of Mines.

The Anarjohka area was investigated primarily by Sulfidmalm/Falconbridge, without very significant positive results prior to the establishment of the Øvre Anarjohka National Park in the mid seventies, when they were not allowed to continue. 9 drill holes (before 1973, totalling about 1000m. 5 of these holes are stored at the NGU Løkken core store, totalling 584m, marked «Njullas») were made on geophysical and partly combined geophysical/geochemical anomalies in a N-S oriented zone with abundant boulders and outcrops of ultramafic rocks. Many of these rocks were later recognised as komatiites.

The best drill core intersections reported, from drill hole DDH 2/72, show 0,37% Ni and 0,30% Cu (6,5m of talc rich UM), with no reference to method of analysis, so sulphide Ni is difficult to estimate (Gammon 1972, Band 1972a,b). In our view it is questionable whether this should be regarded as an occurrence to be registered in our mineral resource database. See Fig. 4.

The map sheet Inari, M 1:250 000, was compiled during NGU's Finnmark Programme based on existing data with some additional, regional field mapping, and covers the southern part of the KGB. The existing data is presently being compiled into 3 1:50 000 scale maps (2032 I, 2032 III, 2032 IV). The extensive overburden, lack of good quality airborne geophysics and only regional scale geological mapping hamper correlations with units on the Finnish side, and also make correlations with the established tectonostratigraphy further north uncertain. The descriptions of the komatiitic rocks in this area are commonly referring to talc. Whether this is a real observation and a distinction from the normal, rarely talc bearing metakomatiites further north or if it is merely an unprecise term applying to the soft, chlorite bearing, typical metakomatiites, is hard to say. The southeasternmost area is characterised as albite gneiss (albitite) by Sulfidmalm. Both phenomena, if they are real, may be suggesting regional scale alteration.

3. THE PASVIK-POLMAK GREENSTONE BELT

Paleoproterozoic, the western extension of the Pechenga belt.

Key references:

The most important works in recognizing, mapping and describing the Pechenga stratigraphy on the Norwegian side are the works of Victor Melezhik, NGU and co-workers.

Practical results from the last prospecting campaign (Sulfidmalm/Falconbridge) in Pasvik are summarized in the works of Falconbridge geologists Karen Hudson (Edwards), Daryl Hodges and co-workers.

4. THE SOUTH PASVIK GREENSTONE BELT TERRANE

4.1 Regional setting

The South Pasvik area, the Norwegian area to the south of the Paleoproterozoic Pechenga – Pasvik greenstone belt, makes up but a tiny (400 km^2) part of adjoining, foreign territory, late Archean typical granitogneiss (TTG gneiss) - greenstone belt terrane, the Inari Terrane of Berthelsen & Marker (1986a,b), Marker (1990, 1985). In Russian map compilations South Pasvik makes up the western extension of the late Archean Tersk–Allarechka greenstone belt, characterized as "the largest late Archean structure" on the Kola Peninsula (Vrevsky p. 25, 43, 48-51 in Rundqvist & Mitrofanov 1993). This terrane is probably in many respects analogous to classical granite-greenstone belt terranes in Canada, Australia, southern Africa, Finland with Russian Karelia, etc.

In the early 1990's, after glasnost, it has been focused on the E-W axis Allarechka-Runnijoki-Rømlingsås (Norway)-Kessijarvi (Finland) in Ni-Cu prospecting connection. An important outcome of this was the airborne geophysics covering large parts of Russian territory plus the whole of the Pasvik valley (the adjoining Finnish territory was unfortunately not covered during these measurements) (maps published by NGU in 1997, see below).

4.2 The Allarechka deposit

Prospecting in South Pasvik started just a few years after the Allarechka deposit was discovered in 1957. Presumably, however, the prospectors in South Pasvik (A/S Sydvaranger and Sulfidmalm) hardly knew at that time that the Allarechka deposits existed, definitely not how outstanding this deposit, located only 45 km to the east of their own ground was, even in a world context. It was probably not until 1985 that the western mining community in general got a glimpse of this deposit. The data then released was a result of the long lasting collaborative Soviet-Finnish efforts that was crowned with the large monography of Papunen & Gorbunov (1985). For comparison: Allarechka is not even mentioned with a single word in the important review of Haapala (1969). Already in 1968, however, a large monography on the Pechenga deposits, including some 35 pages on the Allarechka deposit with its surroundings was compiled by Gorbunov (1968). Also Smirnov (editor) (1977, p. 20-25) in the three volumes monography on the Soviet ore deposits briefly treats the Allarechka deposit, and for the first time the dimensions of the ore body are made known for western geologists, but the grades were of course kept secret (the length of the ore body is 1060 m, the thickness vary from 3 up to 15 – 20 m and the maximum depth is 80 m).

The Allarechka deposit was exceptionally rich, with grades far exceeding those of the Pechenga deposits.

Data from Gorbunov et al. (1985), p. 80:

Ore type	Ni-content % (max.)	Cu-content % (max.)	Co-content %
massive ore:	28	12	0,1 - 0,7
rich impregnation ore:	10	from 0,2	0,01
poor impregnation ore:	2		0,001

When it comes to size not much have been published, not even after glasnost. In this whole region no other deposits than the Allarechka deposit and its satellite Vostok have come into production although several ore occurrences have been located and exploration, including deep drilling, has been very extensive in the whole area up to the Norwegian border.

The Allarechka mine came into production shortly after its discovery in 1957 and was regarded as exhausted in the paper by Gorbunov and co-workers from 1985. The Vostok deposit came into production later than Allarechka and was in operation until the spring 1992.

According to Vrevsky (1993) there is no general consensus about the age of the Allarechka deposit. It is considered to be from early Archean to early Proterozoic. It has for a long time been known that the ultramafic "bodies" at Allarechka occur as "interleaved sheets (flows?) of ultrabasic rocks with amphibolite, amphibole and biotite schists (Zak 1980) suggesting that Ni-Cu deposits of the region are associated with a volcano-plutonic complex" (Vrevsky 1993, p. 50-51). Though the Russians had been suspicious about the origin of the deposit for many years, based e.g. on the komatiite like chemistry and the "interleaved sheet" morphology of the ultramafic rocks, they did not have any final evidence.

During an excursion to Allarechka in 1992 Victor A. Melezhik, NGU picked up, by incidence he claims, a sample at the huge dump at the mine site, a sample that LPN later that same autumn identified as a *random olivine spinifex texture*. Melezhik really located the "needle in the haystack", but fully unaware that it was the needle. This because the spinifex texture did not reveal at all before the sample was cut into two and where the elongated olivine needles were visible on the plane cut surface. Later efforts the next summer by Melezhik to locate more of the spinifex bearing material failed, of course, though bringing the original sample back to the deposit as a reference. The whole story must be regarded as a once in a lifetime happening for both of us.

4.3 The Runnijoki Ni camp close to the Norwegian border

The discovery of the Allarechka deposit naturally prompted an enormous prospecting activity for similar deposits in this region of the Kola Peninsula all the way up to the Norwegian frontier where we find the Runnijoki Ni camp situated close to the border. According to Gorbunov et al. (1985, p. 78) the Severnaya orebody (located near the Allarechka deposit) and the Runnijoki are the most interesting of all the well-known oreshowings in the Allarechka area (defined as the area greater around the Allarechka deposit delimited to the west by the Norwegian frontier). Further, according to Gorbunov et al., there is an economic nickel-copper mineralisation in association with intrusive ultramafics in the Runnijoki area. For that particular reason it is understandable that the prospecting efforts have been tremendous in this area.

Up to our visit at the site in 1992 this target area was penetrated, or perforated, with as much as 181 drill holes, some of them up to several hundred meters deep. Due to the thick and continuous quaternary cover many holes were just geological holes. Exploration was conducted in many ways. One of the methods was winter blasting of large trenches to get large and stable outcrops. In this way they prevented downfall of thick water-saturated boggy material from the margins into the fresh trench. We visited one such trench where the moraine cover was 6 – 8 m thick and with a small exposure of peridotite at the bottom. Otherwise peridotites were not exposed in natural outcrops in the Runnijoki area, but we visited a few rather large outcrops of pyroxenite.

A branch of greenstone belt runs perpendicularly into Norway from the Runnijoki area. The ultramafic bodies in the area are partly situated within this branch and partly in the tonalitic gneisses to the south of this belt. The gneisses make up a dome structure that corresponds to the Vaggatem Gneiss on the Norwegian side (Siedlecka & Nordgulen 1996). The ultramafic intrusions that consist of variably altered harzburgites, wehrlites and pyroxenites are up to 1.5 km long, but not more than 100 – 150 m wide. The best result when it comes to sulphide mineralisation was a 0.7 m section with 9 % Ni and 5 % Cu at the base of one of the ultramafic bodies, partly as off-shot ore in the pink footwall orthogneiss (cf. Gorbunov et al. 1985, p. 78).

Geochemical prospecting conducted showed Ni-Cu-Co anomalies in till. Anomalies were defined as >6 x background values (possibly >6 x std-deviation??). The anomalies were always situated on the northern side of the ultramafic bodies and not quite near the bodies. Also boulder tracing has been used in the prospecting.

4.4 Prospecting on the Norwegian side

On the Norwegian side of the national border the ground has been extensively investigated by A/S Sulfidmalm (Falconbridge) in the periods c. 1975-82 and 1992-93?. Later Outokumpu has also worked in the area. In addition several small groups have been active in South Pasvik. Among them we find Erkki Kreivi (Ivalo, Finland) with one or several local Norwegian companions who have been among the most active, especially in the Rømlingsås area. Kreivi has conducted ground geophysics and drilling, very much of it by himself, quite alone we think.

So far, according to newspaper release in 1997, Kreivi and his group have located massive Ni-Cu-PGE-Au ore in the Rømlingsås area, and still today they hold one claim that shows the location of their find. This is within an area of several small ultramafic (metaharzburgite) intrusions that show excellent magnetic signatures in a nonmagnetic environment. In this area there are also abundant Ni-Cu mineralised boulders, mostly metaharzburgite, and several of these are given type names (e.g. "Bjørntjern type boulder") according to their petrographic characteristics and their most abundant location or place of first find.

The prospecting has focused much on these boulders since outcrops are very scarce in the whole of South Pasvik. Actually there is only *one single outcrop of ultramafic rock in the whole of South Pasvik* according to D. Hodges, Falconbridge who made an excursion with LPN to this area 22.07.92. The actual outcrop is in the Tommabekken-Blankvatn area (UTM 585619/7669145, ED 50), and it is excavated with a 5 m long trench. We brought a large-scale Sulfidmalm outcrop map made by B. Lieungh (formerly Sulfidmalm) that was very good. The later compilation for the 1:50 000 scale geological map Krokfjellet (Lieungh 1986 is unfortunately incorrect both for this and several other areas in South Pasvik. The currently most correct and updated map of South Pasvik is therefore the 1:250 000 compilation of Siedlecka & Nordgulen (1996). That map shows the greenstone-belt slivers (mica schists with some amphibolites) in South Pasvik set in tonalitic to granitic gneiss and with the small ultramafic intrusions located both within and outside of these micaschist and amphibolite slivers.

The greenstone belt amphibolites do host komatiite. This was recognised by Melezhik and LPN during relogging of altogether 41 of the old Sulfidmalm drillholes at NGU Løkken in 1992 (cores drilled up to 1982 were then made available to us). A typical pale green metakomatiite was located in Dh 20 at 56.5-57.0 m at lake Keilolammet (a small tarn only) (UTM 582880/7670910, ED 50). The komatiite has a nice transitional border towards the host amphibolite and doesn't represent any crosscutting dyke. Core samples of this komatiite did not show anomalous magnetic numbers by petrophysical measurements later conducted at NGU. Eventual other komatiites in South Pasvik is therefore probably hiding among the amphibolites without magnetic signatures. For comparison: the Allarechka deposit did not show up well by geophysics.

4.5 Existing material from the prospecting campaigns

Available key material in the interpretation of the area:

- Helicopter geophysics 80 km^2 area covered between Rømlingsås and the Russian border (data released Nov. 1999) (Walker & Olesen 1992).
- Fixed-wing aero-geophysics conducted in 1993 by the Russians in a joint Norwegian-Russian cooperation. This covers Russian and Norwegian areas (South Pechenga – Pasvik Area, magnetic anomaly map and electromagnetic anomaly map (3 frequencies), scales 1.200 000 and 1:100 000, data processed and maps produced by NGU in 1997. The Finns did not attend this collaborative project but they have themselves carried out geophysical measurements and made maps that include the bordering Kessijärvi area in Finland (the area between lake Inari and the Norwegian border).

Russian geological maps made available to us during the Kola project 1989-92 have often been characterized by showing very different interpretations of the bedrock in these strongly overburdened areas. The new airborne geophysics surely will meet these problems and represent a much better basis for future geological maps in the region.

Older, released material is available through NGU and the Directorate of mining (Bergvesenet):

- airborne geophysics (conducted by NGU in 1960)
- ground geophysics
- geochemical prospecting
- boulder tracing (both with and without dog)
- geological mapping and interpretation
- core logging with analyses and descriptions of thin sections, etc.

All the old Sulfidmalm drill cores are stored at NGU Løkken, and also the cores from the most recent drillings (Outokumpu) are stored there.

In later years there has been a considerable northwards extension of the *Øvre Pasvik nasjonalpark* against the Finnish border, and also the establishing of the *Fjørvatn naturreservat* (bird reserve) along the Pasvik River. The actual target area for Ni-Cu-PGE exploration on the Norwegian side of the border has therefore been considerably delimited in later years. The Fjørvatn nature reserve is e.g. preventing investigation of one of the larger greenstone belt branches just where it is crossing the border from Russia with the Runnijoki Ni-camp.

All together the major prospecting companies have been present in South Pasvik through nearly 40 years since the start at lakes Villreinvatn and Ellenvatn. Prospecting focus has nearly all this time been on the small metaharzburgitic intrusions due to the tracing of relatively Ni-Cu rich boulder of such rocks.

5. THE SØR-VARANGER TERRANE

The late Archean Sør-Varanger terrane is the terrane to the north of the Pasvik greenstone belt and to the east of the Polmak belt. It hosts large greenstone hosted BIF deposits, but greenstones generally make up only a minor constituent of this terrane.

Ultramafic intrusives, mostly metadunites, do occur in the supracrustal series (Bjørnevann Group and Garsjø Complex), but they are small and widespread (Nilsson & Iversen 1991, Iversen & Nilsson 1991, Iversen & Krill 1990). A large ultramafic amphibole and mica rich dyke is located within the Neiden Granite Complex (Wiik 1966, Iversen & Nilsson 1991).

Komatiites do also occur in this terrane, and contrary to the intrusive ultramafites the most prominent ones are located along a single major lineament (The Langfjord Fault or Langfjord Fracture Zone, see below).

The komatiites in Sør-Varanger are Mg-rich metakomatiites now found as serpentine or talc rich rocks. Some komatiites occur as lava-flows interbedded with amphibolitic volcanics, whereas others occur as dykes in the basement TTG suite orthogneisses (Føyn 1937/38, Iversen 1990, Iversen & Nilsson 1991, Iversen & Krill 1991, Dobrzhinetskaya et al. 1995, Siedlecka & Nordgulen 1996).

Where the komatiite is strongly talcified it has developed as soapstone, and at least three such deposits have been known and partly worked in the past. On one of the worked quarry faces at the *Straumdalen* occurrence (described below), located close to the Langfjord, e.g., the year "1862" is engraved. At this occurrence there are also pre-historical pottery found, according to Iversen (1990).

Straumdalen is one of three talc/soapstone occurrences situated on or very close to the large and pronounced morphological lineament, the Langfjord Fault or Langfjord Fracture Zone, which runs towards the south to SSE from the south side of the Varanger Fjord just southeast of Bugøynes. Here occurs the *Kjøøya* occurrence, on the small island with the same name, as the northernmost of the three. Towards the SSE, across the large island Skogerøya at the bottom of the small fjord Sør-Leirvåg, is the *Sør-Leirvåg* occurrence; farther towards the SSE, not far from the northern end of the Langfjord, is the Straumdalen occurrence. The location of these three talc/soapstone occurrences, in close association to the pronounced lineament, was noted already by Reusch (1892, p. 26, 49), but apparently neither emphasised nor mentioned, during the next hundred years.

The *Langfjord Fracture Zone* (LFZ) is particularly prominent on satellite images. On an image taken from the SPOT satellite the lineament can be followed 45 km from near Bugøynes in the north to Strand at the south end of Langfjordvatn in the south (Siedlecka & Nordgulen 1996, Karpuz et al. 1995, p.123), where it disappears under the bogs towards the south. Farther south it is not visible within the E-W running Pasvik-Pechenga Greenstone Belt, but seemingly reappears south of this belt on the Russian side in the Shuonn'yavr - Allarechka tract where it can be traced some 45 km towards the south all the way to the northern margin of the Lapland Granulite Belt ending orthogonally against this margin. The large komatiite flow-, or dike-(?), hosted Ni-Cu deposit (the Allarechka deposit) is virtually situated on the southern segment of this twofold lineament. A large portion of the Allarechka komatiite is made of olivine rich cumulates, though serpentinisation or talcification is not notably developed here. The Langfjord lineament may be interpreted as a large Late Archean (?) fracture zone, subsequently reactivated, probably more than once. The protoliths for the Kjøøya, Sør-Leirvåg and Straumdalen talc/soapstone occurrences are, at least partly, Mg rich komatiite flows (Straumdalen) or dikes (Sør-Leirvåg and Kjøøya). At Straumdalen the ultramafic extrusives occur conformably within a basaltic (amphibolitic) sequence belonging to the Late Archean Bjørnevatn Group (Iversen & Nilsson 1991, Iversen 1990, fig.9, etc.). The talcification here clearly increases over a 1 km distance from the east (mostly serpentinite) to the west where talc rich soapstone occurs in small quarries close to the fjord, i.e. close to the LFZ that follows the fjord (studied by LPN in 1994). Field relations of the two other occurrences are little known.

Also other ultramafic bodies of possible komatiitic origin in this part of eastern Finnmark and Kola Peninsula are clearly associated with faults. The large Rovno group of Ni-bearing ultramafics located to the south east of Pechenga is e.g. associated with major fault systems (Titovka fault). "The Ni-bearing intrusives of the Rovno type and the Allarechka ultrabasites are analogous in morphology, mode of occurrence, mineral composition and chemistry" according to Gorbunov et al. (1985, p. 108).

Kjøøya:
Wanvik briefly treats the talc/soapstone occurrences in a review report (Wanvik 1985, p. 23). He did not visit the 0.4 km^2 large island Kjøøya, but quotes personal information from S. Bakke (earlier at NGU) who visited the small island in 1982. There are two small occurrences of good quality, green and attractive soapstone. According to the map sheet Kirkenes (1:250 000) (Siedlecka & Nordgulen 1996) the talc/soapstone occurrence on Kjøøya is situated within tonalitic to granodioritic orthogneisses (TTG gneisses), far away from the nearest metasedimentary sequences. The soapstone occurrence therefore most probably represents a talcified komatiitic dyke.

Sør-Leirvåg:
The talc/soapstone locality is most probably situated within TTG orthogneisses (Siedlecka & Nordgulen 1996) and the protolith therefore probably is also a komatiittic dyke. The terrain is strongly overburdened in the actual area. S. Føyn (manuscript map) mapped a c. 3 km long ultramafic ("amphibolite or serpentinite") dike running parallel to the Langfjord lineament (defined by the small fjords Nord-Leirvåg and Sør-Leirvåg) and situated 2 km to the ENE of this (Føyn 1937/38).

Straumdalen (Vardhaugen):
This occurrence was visited in 1994, by LPN, and the following is mostly taken from the field diary: There appear to be several minor overburdened pits scattered in the terrain, though the main worked occurrence is in an isolated field of talcified komatiite situated on the steep slopes between the flat top of a 65m high knoll overlooking the sea and the shore (Iversen 1990, fig.9 and Iversen & Nilsson 1991). The field is c. 150 m (E-W) x 40 m (N-S). The soapstone, however, is located nearly 900 m farther east, on the main komatiite branch. The komatiite is highly magnetic with a 100-200x susceptibility contrast with the enclosing amphibolites. This is the case whether or not the komatiite is serpentinised or talcified. Generally there are fairly sharp borders between komatiite and amphibolite, though occasionally they are transitional. In such cases, there is a passage, over c. 2 - 4 m, from basic amphibolite through ultramafic amphibolite (hornblendite) to moderately altered pyroxenite into serpentinised or talcified komatiite. Along this zone there are parts with only partly talcified komatiite together with amphibolite and hornblendite. The soapstone, everywhere where quarried, is, however, a massive, homogeneous, light talc-rich potstone with some carbonate and apparently little or no chlorite.
The above study was mainly a comparison between the Straumdalen komatiite and the Allarechka komatiite on the Russian side.

Though the above Late Archean komatiite derived talc/soapstone occurrences are quite insignificant by volume, as are the komatiites themselves, covering only c. 1 km^2 or less in area (Iversen & Nilsson 1991, Iversen & Krill 1990), they represent a distinctive and hitherto non-investigated type among Norwegian talc/soapstone occurrences. The komatiites seem to be clearly different (e.g. in average richer in Mg) from the volumetrically more important Karasjok komatiites (Barnes & Often 1990, Siedlecka & Roberts 1996) that are basically chlorite–amphibole rocks.

6. THE KAUTOKEINO GREENSTONE BELT

Ultramafic intrusives and extrusives are not particularly abundant in the Kautokeino belt, but basaltic komatiites make up a significant unit in the stratigraphically lowermost part of the belt (the Sådnabei Formation) (Olsen & Nilsen 1985).

There are examples of very Mg-rich rocks (among them soapstones) within this belt too: There is for example an occurrence of soapstone in the northern part of the *Vir'dnegiellasat* area (UTM 116260) on map sheet *Suoluvuobmi* (Zwaan 1985). The occurrence is situated within a c. 250x700m large area of strongly sheared and talcified ultramafic rocks (Zwaan, pers. comm. 1999). Also 1 km to the SE of the occurrence, and 2.5 km to the SSE, respectively, there occur strongly altered ultramafic intrusives according to Zwaan. Further north, and close to the Alta river canyon (100345), there are talc-chlorite schists of probable komatiitic origin.

In the southwestern part of the Kautokeino belt there are also reports of talcified rocks. At the contact between a granitic rock and amphibolite, 4.5 km N of *Raisjavrre* a talc-serpentine rock has been found by Gjelsvik according to Holmsen et al. (1957, p. 76).

The key references for the strongly overburdened Kautokeino greenstone belt are the following:
Olesen & Solli (1985), give a combined geophysical and geological interpretation of the belt.
Olesen & Sandstad (1993), give an updated version with a combined geophysical and geological interpretation of the belt.

7. THE REPPARFJORD TECTONIC WINDOW

7.1 Introduction

The tectonic Repparfjord Window exhibits together with the Karasjok Greenstone Belt by far the largest and densest concentration of ultramafic to mafic intrusions within the Precambrian of Finnmark.

During the years 1972-1979 the company Folldal Verk A/S mined the Ulveryggen conglomerate hosted Cu deposit situated on the southern side of the Repparfjord (Stribrny 1980). Unfortunately for the company with its newly established mine the Cu price already in 1975 fell to a low level, but at the same time the Ni price rose markedly. The company naturally then started looking for possible Ni sulphide mineralisations within the window that could feed the new dressing plant that included flotation of the copper ore. In this connection the larger mafic-ultramafic and ultramafic bodies in the window were systematically and densely grid sampled and analysed for Ni, Cu, Co, etc. by the company in 1977. Simultaneously a detailed mapping with a petrographic characterisation of the bodies sampled was carried out (Skaldebø 1977). The result of this first Ni Cu sulphide prospecting campaign on the ultramafics was definitely negative with no Ni Cu sulphide enrichments detected (the analysed material is now stored together with other Folldal Verk material at NGU Løkken, observed by LPN 22.9.2005). In spite of the negative results the company nevertheless wanted a closer inspection of the ultramafics and their eventual sulphide ore potential. It was therefore set up for a joint Folldal Verk/NGU project in 1978, and LPN was then engaged to make a closer look at the ultramafics of the window. Field efforts were concentrated on the Raudfjell, Raudfjell syd, Breidryggen and Småhaugane intrusions that were studied in some detail, specimens sampled and analysed. Additional specimens from the remaining major intrusions were made available by Skaldebø and others. The conclusion with respect to sulphide mineralisation was quite negative also here (Nilsson & Juve 1979).

On later occasions during the 1980's and 90's LPN made new trips to the window completing mapping and petrographic characterisation of several of the major ultramafic bodies, in the first instance for compilation of the 1:50 000 scale geologic map sheet Vargsund (Nilsen & Nilsson 1996). The following section summarises some of LPN's findings in the Repparfjord window as a whole.

7.2 Distribution of mafic-ultramafic intrusions throughout the window (stratigraphic location)

The majority of the mafic and ultramafic bodies are located in the Holmvatn Group, the lowermost stratigraphic unit in the window (Pharaoh et al. 1983). Higher up in the sequence intrusions are much more scarce and at the coast in the NW there are only a few scattered small gabbroic bodies known.

7.3 The mafic-ultramafic intrusions: petrographic composition and mode of emplacement

Both purely ultramafic, differentiated ultramafic-mafic and purely mafic intrusions together constitute the Raudfjell mafic-ultramafic intrusive Suite (Pharaoh 1980). This suite exhibits a continuous mineralogical and chemical spectre of rock compositions from ultramafic to gabbroic. Bodies of quite different composition (i.e. harzburgite and gabbro) are often conspicuously clustered throughout the window, and closer investigations of such clusters in several areas (Stjernevann, Mikalvatnan, Småhaugane, Raudfjell and other places) have revealed that the older intrusions that invariably are the gabbroic ones are crosscut by successively more Mg-rich bodies.

It is considerable field evidence for a mafic-ultramafic Raudfjell Suite showing multiple intrusions with several generations of crosscutting relationships. We therefore postulate that successively more Mg-enriched bodies intrude the preceding ones by ascending through the same or very closely spaced magma conduits.

Looking at the Repparfjord window as a whole we have the following sequence of events in the Raudfjell Suite:

1. The oldest episode is intrusion of homogeneous normal gabbros. These intrude both metasediments (conglomerates, psammites, pelites and calcareous rocks) and metavolcanics (mafic, intermediate and felsic lavas and tuffs).

2. Homogeneous pyroxenitic or differentiated pyroxenitic to gabbroic intrusions crosscut the early gabbros. The former intrusions typically show a pyroxenitic to olivine-pyroxenitic lower part and a melagabbroic to monomineralic hornblenditic upper part.

3. Non-differentiated or moderately differentiated lherzolites and harzburgites are observed crosscutting pyroxenites or gabbros. Further there are examples where differentiated intrusions with a pyroxenitic lower part and an olivine rich peridotitic upper part have intruded early gabbros.

4. Dunites or olivine rich harzburgites represent the latest intrusion phase, and there are examples of such bodies intruding gabbros and/or pyroxenites.

Conclusion and working hypothesis:
The mafic to ultramafic bodies that constitute the Raudfjell Suite of the Repparfjord Window represent multiple intrusions with successively more Mg-rich magma batches ascending in the same or nearly the same conduits as the preceding intrusion.

The continuous compositional change from gabbro (and gabbronorite and possible norite) via melagabbro, hornblendite, pyroxenites, lherzolites to olivine rich harzburgites and possible dunites as the most Mg-rich end member favours a comagmatic/cogenetic origin.

The formation of the Raudfjell Suite through multiple intrusive episodes as outlined above stands in contrast to the conclusions and hypotheses of Pharaoh who covered the entire window during the field work for his Ph.D. thesis. Pharaoh (1980, p.183, fig. 5.13, p. 216) and Pharaoh et al. (1983) mostly on a theoretical basis, consider the various mafic and ultramafic wall and pipe-shaped intrusive bodies in the window just as horizontal cross sections through various levels of numerous intrusive complexes, all with a gabbroic upper part and a progressively more Mg-rich ultramafic cumulate lower part. All these bodies formed in a uniform way from closed-system fractionation in-situ of a parent tholeiitic basaltic liquid derived by partial melting of the upper mantle. The parental liquid upon emplacement had a similar chemistry in each intrusive body in the Repparfjord Window according to Pharaoh. The very different composition of the bodies observed in the field is simply explained by the present level of erosion of the individual bodies Pharaoh further argues.

The field relations observed by LPN throughout the window clearly testify to such a uniform in-situ differentiation process of originally similar melt batches leading to a common internal build up of all the intrusions through a similar differentiation process.

In the following key information from a few selected intrusions is given (see Fig 5 for overview). This also serves to give characteristics for the Raudfjell mafic-ultramafic Suite as a whole.

1) Mikalvatnan (Korsfjord) complex *(Fig. 6)*

Location and topography:
The complex is located on the northern side of the inner part of Korsfjord at the coast east of Vargsund. The complex reaches from the fjord up to c. 400 masl.

Shape and size/dimensions:
Approximately 1.5 x 3.5 km. A small tongue of remnant Caledonian rocks from the north separates the complex into two parts. Irregular form

Accessibility and outcropping:
Generally good outcropping, but with some local scree and/or glacial boulder fields. A several km long E-W trending steep cliff towards the fjord in the south with a large scree accumulated at the foot of the cliff. The easiest access is from the road in the west.

Intrusive episodes (petrographic composition):

A differentiated gabbroic-melagabbroic-pyroxenitic intrusion is crosscut by an olivine-rich peridotite where the latter is occurring in one large and one small body. In the differentiated body an up to 40 m wide transition zone separates typical melagabbro from a two-pyroxene pyroxenite (websterite) west of the tarn Mikkelfjellvatnet. Also southwest of nearby Mikkelvatnet there are transitional rocks between melagabbro and feldspar-free pyroxenite. The gabbro-pyroxenite body shows gabbroic chill margin against conglomerate and felsic tuff in the west.

Internal phenomena (modal layering, etc.):
Not observed

Metamorphism and hydrothermal alteration:
The gabbro-pyroxenite intrusion is generally fresh looking and often two pyroxenes are distinguishable on weathered outcrop. The peridotite, however, is thoroughly serpentinised.

Interpretation:
The Mikalvatnan complex is clearly consisting of two separate intrusive episodes.
The first episode is a melt batch that crystallised *in situ* under closed system conditions. A lower two-pyroxene websteritic cumulate part with an overlying equally large melagabbroic-gabbroic part, were produced by fractionated crystallisation. The two main parts of this intrusion are separated by a narrow transition zone. The gabbroic part shows chilled margin against the enclosing host rocks.
The second episode is constituted by a crosscutting, fairly homogeneous, primary olivine-rich peridotite. It is possible to argue that a bordering pyroxenite on the NE side of the main body may represent an upper differentiate belonging to this intrusive episode, but the overall field evidence with the strong crosscutting relationships (e.g. between peridotite and melagabbro) between the two intrusive episodes strongly indicates that all the pyroxenitic rocks belong to the first intrusive episode.

2) ***Goaŋkečåkka complex*** *(Fig. 7)*

Location and topography:
The complex is located on the southern side of store Lerresfjordbotn on the coast. It crops out in partly steep terrain that gives a good 3D picture of the complex. The complex reaches from the fjord up to 500 masl.

Shape and dimensions:
The complex measures some 0.5 x 2.5 km or 0.5 x 4.5 km if following the outcropping sheet. It consists of several elongated bodies, sheet formed in the west.

Accessibility and outcropping:

There is access on footpath from store Lerresfjord along the river Elvebuktelva on the south side of the mountain Goaŋkečåkka. Alternative but longer route from bottom of the fjord to Stjernevatn (Nastejavri), 327 masl., then towards the SW to the complex.
There are good outcrops, but considerable areas covered with coarse ultramafic boulders in scree (the term "ur" is used in Norwegian on the topographic maps).

Intrusive episodes (petrographic composition):
Two parallel mafic sills run SSW-NNE along the crest of the Goaŋkečåkka -Gargovarri ridge. To the south of these a differentiated pyroxenitic-gabbroic intrusion lies inverted with the pyroxenitic bottom part facing up northwards. This body is later truncated by a sheet of lherzolite.

Internal phenomena (modal layering, etc.).
The subdivision in an upper (inverted) pyroxenitic and a lower gabbroic part is clearly observable in the field within the differentiated intrusion. Nothing but a nearly black homogeneous serpentinite is however observable within the latest Mg-rich intrusion.

Metamorphism and hydrothermal alteration:
The serpentinisation is very strong in this western part of the window.

Interpretation:
Multiple intrusions: first generation is non-differentiated gabbroic sills hosted in a conglomerate. These were followed by a differentiated pyroxenitic-gabbroic intrusion that in its turn was intruded by a homogeneous lherzolite.

*3) **Stjernevatn (Nastejavri) complex** (Fig. 7)*

Location and topography:
Situated around lake Stjernevatn (Nastejavri) 2-3 km due east of Lerresfjordbotten at the coast. Small hills around the 327 masl. lake Stjernevatn (Nastejavri). Several inaccessible cliffs facing NW.

Shape and dimensions:
There are several small gabbroic bodies and two larger ultramafic ones. The largest measures c. 1 x 2.5 km.

Accessibility and outcropping:
A good foot path from Lerresfjordbotn. Outcrops are very good.

Intrusive episodes (petrographic composition):
There are two distinct intrusive episodes. The first consists of a series of minor gabbroic bodies. The second consists of two large ultramafic bodies of lherzolite to olivine websterite

composition where the latter two bodies clearly are the later ones. The largest ultramafic body has an apophysis within one of the gabbroic bodies, and there are several small xenoliths of gabbro within this. There is also a small gabbro xenolith in the eastern part of the ultramafite. In the ultramafic body east of lake Stjernevatn there is a large inclusion of felsic tuff, gabbro and pyroxenite where the pyroxenite may represent a differentiate within a gabbroic body now appearing in a "window" within the ultramafic body.

Internal phenomena (layering, etc.).
Not observed, but due to the strong serpentinisation an eventual modal layering could have been obliterated.

Metamorphism and hydrothermal alteration:
There is a very strong serpentinisation of the ultramafic bodies in these western areas of the window, but still the relict magmatic textures are usually very well preserved. These indicate the primary magmatic distribution of olivine, opx and cpx aided by tiny scattered relics of these minerals.

Interpretation:
Two distinct magmatic episodes, one gabbroic and one ultramafic, occur. One of the gabbros exposed shows a pyroxenitic rim, interpreted as a differentiated part of the gabbro, on one side.

*3) **Fjellvatn intrusion** (Fig. 8)*

Location and topography:
Remote location in the interior of the window half way between the coast and the main road E-6 passing the Sennalandet plateau.

Shape and dimensions:
0.7 x 7 km long ultramafic two fold intrusion (a small corridor separates the intrusion into two)

Accessibility and outcropping:
Remote location, but easy walking terrane. Good outcrops.

Intrusive episodes and petrographic composition:
One major ultramafic intrusive episode, but relics of gabbro along the ultramafic body are indicating a preceding gabbroic body at the same position. Microscopy of three sample profiles across the intrusion shows internal variations in ol, opx and cpx proportions, but not in a way that indicates replenishment of new magma. The central portion along the axis of the intrusion contains up to c. 70 % olivine (ol) and equal amounts of opx and cpx, whereas the border areas on each side contain some 40 % ol. There are also inner areas close to the axis

that contain as little as 30 % ol with equal amounts of opx and cpx. The forsterite content (i.e. the Mg number or just Mg #) in the olivine as well as the enstatite component in the opx correspond closely to the modal content of olivine in the investigated samples, see below.

Internal phenomena (layering, etc.).
None observed. On the surface the intrusion gives the impression of a homogeneous body without any sign of rhythmic modal layering, etc.

Mineral chemistry:
Detailed microprobe analyses of sampled profiles show a positive correlation between the content of olivine in the samples and the forsterite content of the olivine as well as the enstatite content in opx. The values shown below are the extremes. Remaining microprobe analyses fall between these both the content of modal olivine as well as for olivine and orthopyroxene compositions.

Example:

Sample No.	Modal olivine content (in thin section)	Fo in olivine	En in orthopyroxene
96	c. 30	0.80	0.81
92	c. 70	0.87	0.87

Analyses of clinopyroxenes also follow a similar trend. This indicates an in situ differentiation of the ultramafic body.

Metamorphism and hydrothermal alteration:
The Fjellvatn intrusion is significantly less hydrothermally altered (serpentinised) than the Stjernevatn intrusion, se section on metamorphism below.

Interpretation:
Petrographic examination of samples in three profiles crossing the intrusion shows an ultramafic body that may be interpreted as an in situ differentiated intrusion of lherzolite to olivine websterite composition without indicative signs of replenishment of new magma during the differentiation.

7.4 Sulphide mineral assemblage in the Raudfjell Suite

In all the investigated material (Nilsson & Juve 1979) sulphides are very rare. Thin sections of samples contain from a few scattered grains up to a weak dissemination of sulphides. No sulphide enrichments were detected, neither primary magmatic, nor in association with later processes affecting the rocks. Grain size is in the range < 10 µm to 100 µm, occasionally up to 1 mm in late crushing zones. Sulphides are however more abundant in altered rocks than in fresh ones. Even in one and the same polished thin section it is possible to study how very fine sulphide "dust clouds" exclusively accompany the serpentinised part of the section, but is fully absent in the magmatic mineral assemblage.

The following sulphides were observed in thin sections of the larger ultramafic bodies (Nilsson & Juve 1979): pentlandite (most abundant sulphide), pentlandite/bravoite intergrowths, pyrrhotite/pentlandite intergrowths, pyrrhotite/cubanite intergrowths, chalcopyrite and heazlewoodite. In addition there are a few uncertain ones: awaruite, godlevskite and marcasite. The heazlewoodite (Ni_3S_2) is only positively determined in a 1 mm large grain in a late crushing zone, but may of course be abundant in the secondary sulphide dust clouds together with awaruite (± $Ni_{2.5}Fe$) in the form of <5 – 20 µm grains.

7.5 Metamorphism

Metamorphism increases from low greenschist facies in the NNW (qtz-ab-msc-chl) to upper greenschist or epidote-amphibolite facies in the SSE (qtz-ab-ep-bt and locally qtz-staurolite). This has also affected the ultramafics giving strongly serpentinised bodies in the N and NNW and less secondary altered bodies in the SSE where the density of bodies is at its highest. The Fjellvatn intrusion for example which is situated some 7 km due east of the Stjernevatn intrusion is considerably less serpentinised than the latter body. A large number of thin sections from the Stjernevatn body show from 0 to 50 % magmatic minerals (ol, opx and cpx) with an average about 10 %, whereas the Fjellvatn intrusion, which in this connection is not very far away situated, comes up with between 20 and 80 % primary minerals, averaging c. 60%. That is a very notable change in metamorphic alteration over few kilometres, and indicates possible locally steeper metamorphic gradients than previously claimed by Reitan (1963), Pharaoh (1980).

The highest metamorphic grade occurs in the Mikkeldalselv area. The metamorphic grade here coincides with the area that shows the highest density of ultramafics within the window (Reitan 1963, p. 38-39). Here the ultramafics and their host supracrustals reach the same metamorphic facies (qtz-ab-ep-bt), locally (qtz-staurolite) according to Reitan.

7.6 Ultramafic extrusive rocks:

Within the Repparfjord window there are also extrusive ultramafics occurring in the volcanite dominated Nussir Group, a unit which occupies a significant portion of the window (Siedlecka & Roberts 1996). Pharaoh has studied the Nussir Group in very detail (Pharaoh 1985), and he reports laterally persistent ultramafic tuffs altered to serpentine schists or serpentinous tuffs (max 17 wt-% MgO) within the type area of the Nussir Group in the eastern part of the window (see also Roberts 1998 for location). The ultramafic tuff horizons can be followed some 15 km further to the southwest into the Porsa area as serpentine schists (Nilsen

& Nilsson 1996). There are no komatiitic lavas so far discovered within the Repparfjord window, but there are all gradations from basalts via andesites to rhyolites.

8. ALTENESET TECTONIC WINDOW

There are several large differentiated mafic sills or slightly discordant dykes in the metasupracrustal series. There are also some minor serpentinite dykes. The supracrustal series is a direct southern continuation of the lower stratigraphical units of the Repparfjord window.

Key references:
Pratt & Nilssen (1989) (dealing specifically with the differentiated mafic intrusions),
Pratt & Nilsen (1985) (dealing with the host supracrustals and correlations with the neighbouring windows),
Pratt & Nilsen (1984) (dealing with Cu, Fe and Ti mineralisations),
Jensen (1996) (a series of unpublished manuscripts together making up a doctoral thesis, Univ. of Tromsø; available through the NGU Library. Basically dealing with interpretation of the plate tectonic setting based on whole rock geochemistry),
Fareth (1979) (first geological treatment that includes a detailed map of the whole window).

9. ALTA-KVÆNANGEN TECTONIC WINDOW

There are both komatiites and ultramafic intrusions in the Alta-Kvænangen Tectonic Window, but to the authors' knowledge there are no known associated Ni mineralisations. The komatiites in the western (Kvænangen) part of the window (situated in neighbouring Troms County) are lava flow komatiites (Haug 1990). They are probably very little investigated in terms of ore mineralisation

10. MAIN POINTS SUMMARY

Karasjok greenstone belt (KGB)

- Occurrence of large volumes of both extrusive and intrusive ultramafic rocks in a large greenstone belt extensively covered by thick glacial overburden. There is possibly a larger potential for undiscovered Ni-Cu-PGE mineralisation in this belt than in any of the other greenstone belts in Finnmark, even, perhaps (?), the South Pasvik area.

- By far the most important geologic unit in Norway when it comes to komatiites. Some 80 km^2 komatiites are mapped or inferred. The komatiites mostly occur as pyroclastics, and in this respect they are rare, in a world context. They have large, associated Fe-Mn deposits (BIF) and S mineralisation (py/po), both interpreted as exhalites, but no known Ni-Cu mineralisations.

- A peculiar and unusually Pd rich and Ni-poor Cu-Pd-Pt type sulphide mineralisation occurs in the minor Karenhaugen and Porsvann meta-pyroxenite bodies in the northernmost part of the belt (See Fig. 9). The PGEs are occurring in the form of a large number of platinum-group mineral phases as discrete or composite grains that are hosted both in copper sulphides and silicates.

- Known significant Ni-Cu-PGE-Au sulphide mineralisation in the Gallujavri intrusion resembling that of the Keivitsa-Satovaara Complex in Finland. A 2.5 km long Ni-Cu mineralised zone showing assays up to 2.45 ppm Pt+Pd+Au is located, but still, the Gallujavri prospect is far from an economic ore deposit both with regard to proven tonnages and average grades.

- In the Gallujavri sulphide mineralisation the PGEs seem to occur principally in solid solution in the sulphide phases, preferentially, perhaps, in the chalcopyrite. PGMs have so far not been encountered. Gold has a clear preference for arsenopyrite where it probably mostly occurs as "invisible gold".

- Extensive knowledge to draw upon from neighbouring Kittilä belt and other adjoining belts in Finnish Lapland.

- Basic geologic map coverage, mainly in 1:50 000 scale, is fairly recently accomplished by NGU and hitherto not much utilized in prospecting.

- Earlier prospecting activities in the Anarjohka area in the very south of the KGB during the early 1970's has yielded very little of encouraging results (best assay: 0,37 % Ni and 0.30 % Cu) in spite of heavy efforts including both extensive geochemistry, ground geophysics, geological mapping and drilling (9 holes).

- As a whole this greenstone belt is under-prospected.

Pasvik-Polmak greenstone belt

- Very well prospected belt, also in recent years (1990's). The actual target area is not large. The Ni-ore bearing ultramafic intrusions and ferropicritic extrusives are confined to the "Productive Formation" on the Russian side, and this stratigraphic marker formation can also be followed all the way across the Norwegian part of the belt in Pasvik, further through Finland and up to Polmak.

- Extensive knowledge to draw upon from neighbouring Pechenga belt with its many nickel deposits in operation since 1935.

South Pasvik greenstone belt terrane

- Very well prospected area, also in recent years (1990's). The actual target area is small (c. 400 km^2).

- Extensive knowledge to draw upon from the Russian Allarechka deposit in operation since 1957 and the extensive prospecting in the neighbouring area around this deposit all the way up to the Norwegian frontier due to the exceptionally high grades of Ni, Cu and Co in the Allarechka deposit.

- Sulphide mineralised presumed local boulders with grades up to 3.5 % Ni and 0.5 % Cu as well as a drill hole cutting 2 m(?) massive Ni-Cu-PGE-Au sulphide mineralisation in situ are positive indicators of economic ore.

- There has been an expansion of the existing national park as well as establishing of a new nature reserve in the area in recent years. The nature reserve is cutting the greenstone belt corridor to the Runnijoki Ni camp on the neighbouring Russian side.

Sør-Varanger terrane

- The komatiites present are very limited in outcrop, c. 1 km^2, but they are of a Mg-rich type occurring both as lavas and dykes. They have earlier been exploited as soapstone deposits.

- A comparison is made with the Allarechka deposit in Russia when it comes to similarities in setting with the Norwegian komatiite locations.

- The known ultramafic intrusives are rare and represent small olivine rich bodies barren in sulphides.

Kautokeino greenstone belt

- Ultramafics, both intrusives and extrusives are scarce in this belt, but komatiitic basalts are widespread in the lowermost tectono-stratigraphic unit above the gneissic basement (the Sådnabei Fm).

- The belt is known for hosting the Bidjovagge copper-gold deposit that has been in production during two periods. Prospecting has therefore been much focused on this type of copper-gold mineralisation in large parts of the belt (especially in the strike direction of the Bidjovagge deposit), whereas Ni prospecting has been accordingly less emphasized in this belt, probably mostly due to lack of good targets.

Repparfjord tectonic window

- A mafic-ultramafic suite (the Raudfjell Suite) is composed of multiple intrusions, the gabbroic ones first, then the gabbroic-pyroxenitic ones and at last the most Mg-rich ones, the lherzolites and harzburgites.

- The mafic-ultramafic intrusions are abundant in the stratigraphically lowermost parts of the window. Higher up in the sequence they become successively more rare.

- The ultramafics and mafics are barren with respect to known magmatic Ni-Cu-PGE sulphide enrichments, at least as far as all prospecting attempts to date has shown.

Alteneset tectonic window

- Represents similar units as in the lower units in the Repparfjord window, but ultramafic intrusions are occurring more scarcely than in the Repparfjord window.

Alta-Kvænangen tectonic window

- Represents a higher stratigraphical level than Repparfjord and Alteneset. Represents the northern extension of the Kautokeino belt.

- Komatiitic flows are occurring in the western part of the window.

Caledonian Seiland Province

- A series of petrologically very well investigated layered mafic-ultramafic intrusions due to the works of Prof. Brian Robins and co-workers at the University of Bergen. The Lille Kufjord intrusion on the island of Seiland and the Reinfjord complex on the Øksfjord peninsula are examples.

- Several of these intrusions are not much investigated with respect to their contents of PGE and gold.

11. REFERENCES

11.1 Total reference list with summaries and annotations

The references are to a large extent taken (cut & paste) from The NGU Library references database. In many cases summaries are here provided by the NGU Library (some are in Norwegian). Short annotations are in most cases our own.

Band, R.B. 1972a: Till geochemistry investigations in the Njullas area, Finnmark, Norway, 1971-72. A/S Sulfidmalm (Sul 198-72-1), report to Bergvesenet, BV 1220.

Band, R.B. 1972b: Preliminary report on 1972 Diamond drilling, Njullas area, Finnmark, Norway. A/S Sulfidmalm (Sul 197-72-1), report to Bergvesenet, BV 1221.

Barnes, S.-J. & Often, M. 1990: Ti-rich komatiites from northern Norway. Contrib Mineral Petrol 105, 42-54.

Barnes, S.-J., Boyd, R., Korneliussen, A., Nilsson, L.P., Often, M, Pedersen, R.-B. & Robins, B. 1987: Geochemistry of platinum metals in rocks and ores in Norway: Pilot project. Draft report. NGU-Rapport 87.021, 52 pages + map enclosure.
Gives results from the first "modern" PGE analyses of Karasjok komatiites.

Barnes, S.-J., Boyd, R., Korneliussen, A., Nilsson, L.P., Often, M, Pedersen, R.-B. & Robins, B. 1988: The use of mantle normalization and metal ratios in discriminating between the effects of partial melting, crystal fractionation and sulphide segregation on platinum-group elements, gold, nickel and copper: examples from Norway. *In:* Prichard, H.M. et al. (eds.), GEO-PLATINUM 87, Elsevier, 113-143.
Includes data on Karasjok komatiites.

Berthelsen, A. & Marker, M. 1986a: Tectonics of the Kola collision suture and adjacent Archean and Early Proterozoic terrains in the northeastern region of the Baltic Shield. In: D.A. Galson & St. Mueller (eds.), The European Geotraverse, Part 1, Tectonophysics 126, 31-55.

Berthelsen, A. & Marker, M. 1986b: 1.9-1.8 Ga old strike-slip megashears in the Baltic Shield, and their plate tectonic implications. In: D.A. Galson & St. Mueller (eds.), The European Geotraverse, Part 2, Tectonophysics 128, 163-181.

Bjørlykke, A., Olerud, S. & Sandstad, J.S. 1985: Metallogeny of Finnmark, North Norway. NGU Bull. 403, 183-196.
Metalliferous ore deposits and mineralisations in the county of Finnmark occurring rocks ascribed to three specific periods of geological time: 1) Archean 2) Early Proterozoic 3) Caledonian. The only Archaean ore

deposits is located at the largest iron mine in Norway, Sydvaranger; this was deposited in a shelf environment. The Early Proterozoic volcano-sedimentary belts can be divided into three major metallogenetic provinces. In the easternmost Pasvik area no significant deposits are known and only a few minor nickel mineralisations are present. The rocks of the Karasjok Greenstone Belt are thought to have accumulated during a complete "Wilson orogenic cycle" and contain both stratiform and stratabound copper deposits, banded iron formations and nickel mineralisations. A continental rifting model is more likely for the rocks of the Kautokeino Greenstone Belt and for correlative units in the tectonic windows to the northeast. Stratabound copper deposits are dominant, occurring in both metavolcanites and metasediments, but gold, uranium and REE mineralisations are also found. This province includes the second operating ore mine in Finnmark at present, the Bidjovagge copper-gold mine. The Caledonian province contains lead deposits in both amphibolite-facies and very low grade metasandstones and Fe-Ti occurrences in mafic and ultramafic intrusive bodies in the Seiland magmatic province.

Boyd, R. & Nixon, F. 1985: Norwegian nickel deposits – a review. *In:* Papunen, H. & Gorbunov, G.I. (Eds.) Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geol. Surv. Finland Bulletin 333, 363-394.

Bugge, J.A.W. 1978: Norway. *In:* Mineral deposits of Europe, vol. 1, Northwest Europe. Bowie, S.H.U., Kvalheim, A., Haslam, H.W., Notholt, A.J.G. & Jones, M.J. (eds.), 199-249.

Braathen, A. 1991: Stratigrafi og strukturgeologi sentralt i Karasjok grønnsteinsbelte, Finnmark. Cand. Scient. Thesis, University of Tromsø. (thesis available at the University of Tromsø, Institute for Biology and Geology).

Braathen, A. & Davidsen, B. 2000: Braathen, A & Davidsen, B. 2000: Structure and stratigraphy of the Paleoproterozoic Karasjok Greenstone Belt, North Norway – regional implications. *Norsk Geologisk Tidsskrift*, Vol. 80, pp 35-50.

Cabri, L.J., *et al.* 1984: Quantitative trace-element analyses of sulfides from Sudbury and Stillwater by proton microprobe. The Canadian Mineralogist 22, Pt. 4, 521-542.

Carstens, C.W. 1931: Die Kiesvorkommen im Porsangergebiet (Preliminäre Mitteilung). Norsk Geologisk Tidsskrift 12, 171-177.

Chepik, A.F. 1994: Report on the results of ground geophysical surveys for verifying airborne local magnetic anomalies in Norway (South Pasvik Area) NGU-rapport 95.035, 41 pp.
Ground geophysics covering 4 selected anomalies from the fixed-wing geophysics conducted by the Russians in 1993 (covers extensive areas of Russian ground plus South Pasvik on the Norwegian side). Emphasise was on diatremes for the selection of ground follow up work. Four of the airborne anomalies were followed up on the ground. At least one has a circular (tube like?) shape.

Czamanske, G., Papunen, H., Boyd, R. & Nilsson, G. 1986: Comprehensive bibliography on mineralised and unmineralised mafic-ultramafic intrusions in Scandinavia. USGS Open-File Report 86-442-A + B, 34 p. + diskette. IGCP Project 161. Diskette of this report is available as Open-file report 86-442-B.

Dalsegg, E. & Often, M. 1991: Geologiske- og geofysiske undersøkelser av Porsvann PGE/Cu-forekomst, Porsanger, Finnmark. NGU Report 91.052, 13 pp + 7 map enclosures.

Rapporten omfatter geologiske- og geofysiske undersøkelser i et område ved Porsvann PGE/Cu-forekomst. Den geofysiske undersøkelsen bestod i kombinerte elektriske målinger (indusert polarisasjon, ledningsevne og SP). Den geofysiske undersøkelsen har vist at det innenfor interessante meta-pyroksenittområdet nord for vannet er tre mineralliseringer av betydning. Strøkutstrekningen er ca. 75 m for de to sterkeste sonene og ca. 200 m for den svakeste sonen. Ingen av sonene går ut i vannet. Dyptgående for den ene eller begge av de to sterkeste sonene er trolig minst 100 m. Utenfor dette området er det i tillegg påvist mineraliseringer både i gabbroen i vest og i amfibolitten i øst. Disse synes å være uten interesse da det ikke er påvist palladium i mineraliseringene i disse bergartene.

Davidsen, B. 1994*: Stratigrafi, petrologi og geokjemi med vekt på komatiittiske bergarter innen den nordligste del av Karasjok grønnsteinsbelte, Brennelv, Finnmark*. Unpublished cand. scient. thesis. University of Tromsø, 380p + 6 app. + 1 map enclosure.

Davidsen, B. 1989: Feltrapport fra Lakselvområdet, Finnmark, sommeren 1988. NGU-rapport 89.016, 35pp.
Børre Davidsen, hovedfagstudent ved UiTromsø, har arbeidet 4 uker i Lakselv- området. Rapporten beskriver 4 utførte deloppgaver hvorav del 4 er den viktigste. 1. Detaljkartlegging av nederste del av Lakselv-områdets stratigrafi, fra området nord for Karinhaugen. 2. Kartlegging i målestokk 1:25 000 i området Lakselv-Porsangmoen. 3. Feltstøtte for Rejean Girard ved hans beskrivelse av mineraliseringer. 4. Detaljbeskrivelse av mineraliseringer i Porsanger-feltet.

Dobrzhinetskaya, L.F., Nordgulen, Ø., Vetrin, V.R., Cobbing, J. & Sturt, B.A. 1995: Correlation of the Archean rocks between the Sørvaranger area, Norway, and the Kola Peninsula, Russia (Baltic Shield). Norges geologiske undersøkelse, Special Publication Series 7, 7-27.
The Archaean rocks of the Kola Peninsula and adjacent areas in Norway and Finland occur as NW-SE-trending blocks of medium to high-grade gneisses separated by shear zones and medium- to low-grade greenstone-belt successions of Early Proterozoic age. A detailed study of some of the gneisses in the border zone between Russia and Norway has enabled the correlation of a number of units across the border zone. The Archaean crustal rocks were formed, and went through polyphase, tectonomagmatic events during the period 2.9-2.5 Ga. Crustal blocks with contrasts in age, rock types and types of igneous activity and metamorphic development indicate that the Archaean rocks were assembled from different tectonic terranes. The terrane boundaries are probably located along major shear zones and greenstone belts. The Late Archaean rocks formed the basement on which the Early Proterozoic Polmak-Pasvik-Pechenga Greenstone Belt developed.

Fareth, E. 1979: Geology of the Altenes area, Alta-Kvænangen window, North Norway. Alteneset NGU Bulletin. NGU Bulletin 351, 13-29 + pl.
Precambrian supracrustal and intrusive rocks of the Raipas Group of supposed Karelian age are unconformably overlain by Vendian to ?Lower Cambrian sedimentary rocks, which have in turn been overridden by allochthonous rocks of the Kalak Nappe Complex. The Raipas rocks are divided into 3 formations; the lithologies of these units and of the autochthonous cover sequence are described. The structural history of the area includes a Precambrian, post-Karelian to pre-Vendian deformation episodes as well as Caledonian events. It is shown that in the north-western part of the window, the Raipas "basement" together with its autochthonous cover has been affected by high-angle, SE-directed thrusting and imbrication during the Caledonian orogeny.

Føyn, S. 1937/38: Kartblad Æ 5 NEIDEN, 1:100 000. Geologisk manuskriptkart. NGU Kartarkivet nr. 7/1937 – 3/1938.

Føyn, S., Chapman, T.J. & Roberts, D. 1983: ADAMSFJORD, 2135-1 – berggrunnsgeologisk kart – M 1:50 000. Norges geologiske undersøkelse.

Gading, M. 1987: Sulfidmineralisering innen Lille Kufjord intrusjonen - geologiske, mineralogiske og petrogenetiske betraktninger. Cand. Real. Thesis, Geologisk inst. Avd. A, Univ. of Bergen.

Gammon, J.B. 1972: Undersøkelser i Anarjokka området. Indre Finnmarksvidda. A/S Sulfidmalm (Sul 206-72-1), report to Bergvesenet, BV 872. 21p + figs.

Gorbunov, G.I., Yakovlev, Yu.N., Goncharov, Yu.V., Gorelov, V.A. & Tel'nov, V.A. 1985: The nickel areas of the Kola Peninsula, Geol. Surv. Finland Bull. 333, p. 41-109.

Gorbunov, G.I. 1968: Geology and origin of the Copper-nickel sulphide ore deposits of Pechenga (Petsamo), Nedra, 352 pp. (in Russian).

Grenne, T., Ihlen, P. & Vokes, F.M. 1999: Scandinavian Caledonide metallogeny in a plate tectonic perspective. Mineralium Deposita 34, 422-471.
Notes on occurrences of Fe-Ti and Ni-Cu-PGE from the Seiland Igneous Province on p. 432

Haapala, P.S. 1969: Fennoscandian Nickel Deposits. *In:* Wilson, H.D.B. (ed.) Magmatic Ore deposits, - a symposium. Economic Geology Monograph 4, Econ Geol Publ Co, p.262-275.

Haug, T. 1990: Vulkanologisk-geokjemisk og stratigrafisk undersøkelse av den proterozoiske lagrekken fra Dorras i Kvænangen, Nord-Troms. Cand. Scient Thesis, University of Tromsø.

Henriksen, H. 1983: Komatiitic chlorite-amphibole rocks and mafic metavolcanics from the Karasjok Greenstone Belt, Finnmark, Northern Norway: a preliminary report. NGU Bull.382, 17-43.
A general account is presented of the field relationships, geochemistry and petrology of mafic and ultramafic metavolcanics within the Precambrian Karasjok greenstone belt. These metavolcanic rocks make up the major part of this greenstone belt, and variably deformed and metamorphosed in middle greenschist to lower amphibolite facies. Based on their unusual chemistry (21-39% MgO volatile-free) and extrusive textures, the ultramafic chlorite-amphibole rocks are considered to belong to the komatiite association. The mafic metavolcanics (amphibolites) form a tholeiitic series (5-8% MgO volatile-free), and are chemically similar to intermediate and iron-rich tholeiites of Archaean age. The mutual occurrence of these komatiitic and tholeiitic series as well as the presence of exhalative-sedimentary Fe-Mn formations in association with the komatiites, would suggest that the Karasjok greenstone belt forms an extension of the 2.6-2.75 Ga Archaean greenstone belts of eastern and northern Finland.

Henriksen, H. 1984: IDDJAJAV'RI, foreløpig berggrunnskart 2034-2, 1:50 000. Norges geologiske undersøkelse.

Hodges, D.J. 1995: Nickel-copper exploration along the extension of the Pechenga Zone in Pasvik, Norway. NGU Special Publication Series 7, 373-374.

Hodges, D.J. & Green, A.H. 1993: Nickel - copper exploration along the extension of the Pechenga zone in Pasvik, Norway. (Abstract), First Barents Symposium. Kirkenes, October 1993.

Holmsen, P., Padget, P. & Pehkonen, E. 1957: The Precambrian geology of Vest-Finnmark, Northern Norway. NGU 201, 107p.

Hudson, K.A., Melezhik, V.A. & Green, A.H. 1992: Potential for Pechenga-type Ni-Cu deposits in Pasvik, northern Norway. *In:* Foster, R.P. (ed.) Mineral deposit modelling in relation to crustal reservoirs of the ore-forming elements. Abstract volume. Inst. Mining and Metall. London, April 22-23, 1992, 3 pp.

Hysingjord, J. 1971: Tungmineralundersøkelser i Finnmark. NGU-rapport 968 D, 28 pp.
Heavy mineral panning on 1:250 000 sheets HONNINGSVÅG, KARASJOK, INARI, ENONTEKIØ and NORDREISA.
Rapporten omhandler en kjemisk/mineralogisk undersøkelse av moreneprøver fra Finnmark. Undersøkelsen er både en metodeundersøkelse og et malmletings- prosjekt. Av resultatene nevnes: Kismineralene i finfraksjon i morener er vitret bort, men tungelementene er i stor utstrekning absorbert i lettløselig form på andre mineraler. Det ble funnet anomaliområder på kobber, nikkel og tinn. Videre er det funnet høye enkeltstående gehalter på arsen, wolfram og sølv. Niobmineralet pyroklor er funnet i vaskeprøver fra Storfossen, Karasjokka. I Beivasgiedde området hvor en har et tett prøvenett, opptrer høye nikkelgehalter på linjer som ligger i isbevegelsesretningen. Transportlengder på 0 - 5 km for hovedmengden av bunnmorenen er sannsynlig i dette området. Indisiene for at en geokjemisk undersøkelse av bunnmorenen er anvendelig som malmletingsmetode i Finnmark er gode.

Håbrekke, H. 1979: Magnetiske, elektromagnetiske, radiometriske og VLF-målinger fra helikopter over et område nord for Karasjok. NGU rapport 1728, 13 pp + map enclosures.
Covering parts of the following 1:50 000 scale map sheets: 2034 2 Iddjajav'ri 2034 3 Stiipanav'zi and 2134 3 Valljåkka
Rapporten inneholder resultater fra geofysiske målinger fra helikopter over 440 km2 stort område nord for Karasjok i Finnmark. Antall profilkilometer fløyet er 2 200. Flyhøyde og profilavstand var henholdsvis 200 fot og 200 m. Som navigasjonsgrunnlag ble vanlige topografiske kart i 1:50 000 serien benyttet etter oppfotografering til målestokk 1:20 000. 45 av de 71 profilene som ble fløyet har både digitale og analoge registrerte data, mens de resterende bare har analoge orginalopptak. Dette skyldes en feil som oppstod på det digitale utstyret under oppdraget. Magnetiske data fra profiler med bare analoge opptak er digitalisert og presentert på samme måte som de øvrige digitale data.

Håbrekke, H. 1981a: Magnetiske-, elektromagnetiske-, VLF-og radiometriske målinger fra helikopter over Karasjok Nord, Karasjok og Porsanger, Finnmark. NGU rapport 1784, 12 pp + map enclosures.
Covering parts of the following 1:50 000 scale map sheets: 2034 1 Hal'kavarri, 2034 2 Iddjajav'ri and 2034 4 Skoganvarre.

Håbrekke, H. 1981b: Magnetiske-, elektromagnetiske-, VLF- og radiometriske målinger fra helikopter over Karasjok Syd. NGU rapport 1800/38C, 12 pp + map enclosures.
Covering parts of 1:50 000 scale map sheets 2033 3 Bæivasgiedde and 2033 4 Iesjåkka
Rapporten inneholder resultater fra geofysiske målinger fra helikopter over et område syd for Karasjok tettsted i Karasjok kommune, Finnmark fylke. Det ble utført både magnetiske-, elektromagnetiske-, VLF- og radiometriske mål- inger over et ca. 470 km2 stort område, i rapporten kalt Karasjok Syd. Flyhøyde og profilavstand var henholdsvis 700 fot og 250 meter, og tilsammen ble det fløyet 1 900 profilkilometer. Resultatene fra målingene er behandlet ved hjelp av forskjellige program i NGU's HP 3000 datamaskin og er deretter tegnet ut på Calcompplotter som profilkurvekart og kotekart i målestokk 1:50 000. Som navigasjonsgrunnlag er benyttet vanlige topografiske kart i 1:50 000-serien etter oppfotografering til 1:20 000 målestokk.

Iversen, E. 1990: Kartblad 2434 3 HØYBUKTMOEN - kartbladbeskrivelse. Internal report PROSPEKTERING A/S no. 2170, 85p. (released 1995).

Iversen, E. & Krill, A. 1990: KIRKENES berggrunnskart 2434 2, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Iversen, E. & Krill, A. 1991: BØKFJORDEN berggrunnskart 2434 1, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Iversen, E. & Nilsson, L.P. 1991: HØYBUKTMOEN berggrunnskart 2434 3, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Jensen, P.A. 1996: The Altenes and Repparfjord tectonic windows, Finnmark, northern Norway. Remnants of a Palaeoproterozoic Andean-type plate margin at the rim of the Baltic Shield. Dr. Scient. thesis, Univ. of Tromsø.

Juve, G. 1968: Porsanger kobber- og kisforekomster, Finnmark, Norge (Abstract). Geol. För. Stockholm Förh. 90, 461-462.
Translated title: Copper and iron sulphide deposits of Porsanger, County of Finnmark, Norway.

Juve, G., Størseth, L.R., Vetrin, V.R. & Nilsson, L.P. 1995: Mineral deposits of the international 1:250 000 map-sheet Kirkenes. (Extended abstract). Norges geologiske undersøkelse Special Publication 7, 375-378.

Karlsen, T. A. og Nilsson, L. P. 1999: Talc deposits in Norway. NGU rapp. 99.135, 146 p.
Includes a chapter on talc and soapstone deposits in Finnmark written by LPN.

Karpuz, R., Roberts, D., Moralev, V.M. & Terekhov, E. 1995: Regional lineaments of eastern Finnmark, Norway, and the western Kola peninsula, Russia. NGU Special Publication 7, 121-135.
Regionally penetrative lineaments in eastern Finnmark and western Kola Peninsula trend NW-SE, NNW-SSE to NNE-SSW and NE-SW. Synergistic analysis of multiple data-sets with selective field investigation and microtectonic studies have shown that the principal lineament zones have had protracted, polyphase deformational histories ranging from ductile to brittle regimes. Fault rocks exposed along the lineaments vary from breccias to ultramylonites, and phyllonites are also encountered locally.
(this is only parts of the original summary)

Koistinen, T., Stephens, M.B., Bogatchev, V., Nordgulen, Ø., Wennersrøm, M. and Korhonen, J. 2001: Geological map of the Fennoscandian Shield, scale 1:2 000 000. Geological Surveys of Finland, Norway and Sweden and the North-West Department of Natural resources of Russia.

Krill, A.G. 1985: Svecokarelian thrusting with thermal inversion in the Karasjok-Levajok area of the northern Baltic Shield. Norges geologiske undersøkelse Bulletin 403, 89-101.
Recent mapping, isotopic dating, and metamorphic and structural observations from the Karasjok-Levajok are, lead to a tectonic interpretation that is similar in many ways to Phanerozoic plate tectonic models. Three major belts of Early Proterozoic rocks lie between two Archean gneiss complexes: the Jer'gul Gneiss Complex on the west and the Baisvarri Gneiss Complex on the east. The E-dipping Early Proterozoic belts are, from west to east: the Karasjok Greenstone Belt, the Tanaelv Migmatite Belt, and the Levajok Granulite Belt. Earlier

geochemical studies suggested that the Tanaelv Migmatite Belt consists mainly of tholeiitic metavolcanites of an outer volcanic are, and that the Levajok Granulite Belt represents geosynclinal metasediments intruded by calc-alkaline rocks of an inner magmatic arc. It is suggested here that basaltic rocks related to the Karasjok Greenstone Belt were subducted eastward, generating the arc magmatism, and contributing heat and CO2 to produce the granulite-facies metamorphism. During later stages of the Svecokarelian event, thrusts developed parallel to the subduction zone. The granulites were thrust westward over the migmaties, which were in turn thrust also developed within and beneath the Karasjok Greenstone Belt. Thrusting of the granulite belt occurred at granulite-facies conditions and the heat from these rocks contributed to an inverted regional metamorphic gradient within the underlying Tanaelv Migmatite Belt and Karasjok Greenstone Belt. The metamorphic grade within the Karasjok Greenstone Belt increases from low grade in the western, deepest parts, to medium grade and migmatitic high grade upward, near the overlying Tanaelv Migmatites. Kyanite-bearing rocks in the deeper parts of the Karasjok Greenstone Belt contrast with sillimanite-bearing rocks in the shallower parts, and demonstrate that the metamorphism was in-situ, and not the result of thrusting of previously cooled high-grade rocks.

Krill, A.G. & Often, M. 1986: GALMATSKAI'DI berggrunnskart 2033-2, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Levchenkov, O.A., Levsky, L.K, Nordgulen, Ø., Dobrzhinetskaya, L.F., Vetrin, V.R., Cobbing, J., Nilsson, L.P. & Sturt, B.A. 1995: U-Pb Zircon ages from Sørvaranger, Norway, and the western part of the Kola Peninsula, Russia. NGU Special Publication Series 7, 29-47.
New U-Pb age determinations on zircon and titanite are reported from Archaean rocks in the Sørvaranger area, Norway, and the adjoining parts of western Kola Peninsula of Russia. The oldest date (2903+-9Ma) was obtained from granuiite facies rocks of the Hompen Gneiss. Several tonalitic gneisses (the Varanger and Svanvik Complexes and the Kirkenes Gneiss) Yield ages of c.2.8 Ga. A similar date is suggested for tonalitic bands of the Garsjø Complex. Plutons of hypersthene-bearing granodiorite were included into high-grade metasupracrustal rocks of the Kola/Jarfjord Gneiss at c. 2.76 Ga, whereas hornblende-biotite- quartz monzonites intruded the Kola/Jarfjord Gneiss and the Varanger Complex at c. 2.73 Ga. A strongly deformed pegmatite dyke in the Garsjø Complex yielded a date of c. 2.65 Ga. A number of the Late Archaean gneiss complexes were cut by the Neiden and Geahcoaivi Plutons which have been dated of c. 2.5 Ga.

(Not complete summary)

Lauritsen, T. & Gellein, J. 1996: Oppfølgende bakkegeofysikk for verifisering av to lokale flymagnetiske anomalier ved Myrbekk-koia i Pasvik, Sør-Varanger kommune, Finnmark, 1995. NGU-rapport 96.092, 13 pp.
I samarbeid mellom NGU, Pechenganikel og Petersburg Geophysical Survey (PGE) ble det i august 1994 utført oppfølgende bakkegeofysikk over 4 utvalgte flymagnetiske anomalier (anomaliene 1,2,3 og 4) i de sørlige deler av Pasvik (NGU Rapport 95.035). Det ble antatt at disse anomaliene hadde en rør-liknende årsak, og de ble valgt med bakgrunn i PGEs erfaring i leting etter diamantførende diatremer. Arbeidet i 1994 omfattet detalj-undersøkelser av anomali 1 med magnetometri, susceptibilitet, gravimeter og elektriske målinger. De øvrige anomalier (2,3 og 4) ble gjenstand for bare rekognoserende studier med magnetometri og susceptibilitet. Ved anomali 3 ble det i tillegg utført rekognoserende undersøkelser med elektriske målinger. Med bakgrunn i resultatene fra 1994, og etter anbefaling fra PGE, valgte NGU å videreføre undersøkelsen av anomaliene 2 og 3 (ved Myrbekk-koia) i 1995. Denne rapporten presenterer resultater fra arbeidet i 1995. Målemetodene som ble benyttet var magnetometri, gravimetri og IP/RP. Både modelleringer og observasjoner av blotninger indikerer at anomaliene som kom fram, kan tilskrives ultramafiske bergarter.

Lieungh, B. 1985: Archean and Early Proterozoic rocks of the southern Pasvik and western Polmak parts of the Sørvaranger District. P. 27-35. *In:* Siedlecka, A., Krill, A., Often, M., Sandstad, J.S., Solli, A., Iversen, E & Lieungh, B. Lithostratigraphy and correlation of the Archean and Early Proterozoic rocks of Finnmarksvidda and Sørvaranger district. Norges geologiske undersøkelse Bulletin 403, 7-36.

Lieungh, B. 1986: Geologisk kartblad Krokfjellet, 1:50 000. Norges geologiske undersøkelse.

Makovicky, E., Makovicky. M. & Rose Hansen, J. 1988: Experimental evidence on the formation and mineralogy of platinum and palladium ore deposits. *In:* Boissonnas, J. & Omenetto, P. (eds.), Mineral deposits within the European Community. Special Publication of the Society for Geology Applied to Mineral Deposits, Vol. 6, Springer Verlag, p. 303-317.

Marker, M. 1990: Tectonic interpretation and new crustal modelling along the POLAR Profile, northern Baltic Shield. Proceedings of the Sixth Workshop on the European Geotraverse (EGT) Project: data compilations and synoptic interpretation, Einsiedeln, 29 November - 5 December, 1989. European Science Foundation, 9-22.

Marker, M. 1985: Early Proterozoic (c. 2000-1900 Ma) crustal structure of the northeastern Baltic Shield: tectonic division and tectogenesis. Nor. geol. unders. Bulletin 403, 55-74.
Recent structural investigations in the Precambrian of northern Finnish Lapland and Norwegian Sørvaranger and their extrapolation into the neighbouring Kola Peninsula have stablished that the northeastern part of the Baltic Shield can be divided into several tectonic units consisting of Archaean to Early Proterozoic crust. The tectonic units are separated by Early Proterozoic, Svecokarelian linear thrust zones with clear evidence of deep-seated, high ductile strain deformation. From norteast to southwest, the units are: the Murmansk unit, the Sørvaranger unit, the Kola suture belt, the Inari unit, the Granulite belt, and the Tanaelv belt. The structural work combined with recently published petrological and geochronological results provides new evidence for the interpretation of the Secokarelian crustal structures in the northeastern part of the Baltic shield in terms of a plate tectonic model. The Kola suture belt is considered to mark the site of a continent-continent collision suture, which was formed by the closure of a former Kola ocean. The metaflysch sequence of the Granulite belt is interpreted as having been deposited in a back-arc basin to the southwest of the Kola ocean. This basin was floored by attenuated, partly oceanized continental crust (now the Tanaelv belt). As a result of the collision between the Sørvaranger and Inari units and the closure of the Kola ocean, the Granulite and Tanaelv belts were thrusted upon the southern foreland.

Melezhik, V. & Often, M. 1996: The geology and ore deposits of the Pechenga Greenstone Belt. (Field trip guidebook) NGU-rapport 96.123, pp. 91.
This field excursion guide, 'The geology and ore deposits of the Pechenga Greenstone Belt', prepared for the International Field Conference and Symposium 'Layered Mafic Complexes and Related ore Deposits of Northern Fennoscandia, Finland, Norway, Russia' in relation with the International Geological Correlation Program (IGCP) Project 336. A part from the excursion itinerary the guidebook contains description on: (1) 'General geology and evolutionary history of the Early Proterozoic Pechenga Greenstone Belt'; (2) Differentiated gabbro-wehrlite intrusions, 'ferropicritic' lava flows and associated sulphide Ni-Cu ores';(3) 'Early Proterozoic layered mafic-ultramafic massif of Mt. General'skaya'. The geological map of the Pasvik-Pechenga Greenstone Belt 1:200.000 is provided.

Melezhik, V.A., Sturt, B.A., Mokrousov, V.A., Ramsay, D.M., Nilsson, L.P., Balashov, Y.A. 1995: The Early Proterozoic Pasvik-Pechenga Greenstone Belt: 1:200 000 geological map, stratigraphic correlation and revision of stratigraphic nomenclature. NGU Special Publication Series 7, 81-91.
As a result of Norwegian-Russian co-operation, the first 1:200 000 geological map that covers the border areas of both countries is presented. A new lithostratigraphic subdivision of the Pasvik Greenstone Belt and lithostratigraphic correlation between the Pechenga and Pasvik Belts is proposed. Common Pechenga-Pasvik stratigraphic and intrusive subdivisions and stratigraphic nomenclature are introduced as the basis for the legend of the forthcoming 1:250 000 international map-sheet Kirkenes.

Melezhik, V.A., Hudson-Edwards, K.A., Skufin, P.K. & Nilsson, L.P. 1994: Pechenga area, Russia – Part 1: geological setting and comparison with Pasvik, Norway. Transactions Institute Mining and Metallurgy, (Sect. B: Appl. Earth Sci.), 103, B129-B145.

The Pechenga Rift Zone is located in the northwestern part of the Kola Peninsula in Russia near the norwegian border, where it forms part of the 1000 km long early Proterozoic Polmak-Opukasjärvi-Pasvik-Pechenga-Imandra/Varzuga-Ust'Poney Greenstone Belt. The rift zone is divided into three major transverse blocks, the Western, Central and Eastern Rift Grabens, which are bounded by long-lived syndepositional faults. It is filled by the 16 000-18 000 m thick Petsamo Supergroup, which is divided into the North Pechenga and south Pechenga Groups. The North Pechenga Group (NPG) comprises four cycles of predominantly mafic volcanism, separated by tuffogenic sedimentary rock, that are between 2453 and 1970 m.y. on Achaean basement. The thickest accumulation of each NPG sedimentary and volcanic formation is found in the Western Rift Graben. The South Pechenga Group (SPG), which was deposited between 1970 and 1800 m.y., is composed of synorogenic andesitic-picritic bimodal volcanic rocks interbedded with volcaniclastic sediments and is probably tectonically imbricated. Equivalents of the North Pechenga and South Pechenga Groups (the Pasvik and Langvannet Groups) occur in Pasvik, Norway. The North and South Pechenga Groups and the lithologies, sedimentary facies and whole-rock and rare-earth element geochemistry of their Norwegian correlatives support a three-stage rift model for the Petsamo Supergroup: first, an intracontinental rift stage (2450-2100 m.y.), comparable to the present-day Afar Triangle and East African rifts; next, a transitional rift stage (2100-1970 m.y.) with both intra- and intercontinental tectonic settings and possible short-term, aborted spreading at about 1990-1970 m.y.; and, finally, a possible collision-related intercontinental rift stage (1970-1800 m.y.).

Melezhik, V.A., Hudson-Edwards, K.A., Green, A.H. & Grinenko, L.N. 1994: Pechenga area, Russia – Part 2: nickel-copper deposits and related rocks. Transactions Institute Mining and Metallurgy, (Sect. B: Appl. Earth Sci.), 103, B146-B161.

Melezhik, V.A. & Sturt, B.A. 1994: General geology and evolutionary history of the early Proterozoic Polmak-Pasvik-Pechenga-Imandra/Varzuga-Ust'Ponoy Greenstone Belt in the northeastern Baltic Shield. Earth-Science Reviews 36, 205-241.

Melezhik, V., Nilsson, L.P. & Sturt, B:A. 1992: Geological correlation of the Pechenga and Pasvik zones. Norges geologiske undersøkelse Report 92.236, 82 pp. + map enclosure in scale 1:100 000.
As the result of an agreement between NGU and A/S Sulfidmalm, NGU has carried out geological investigations of the Pechenga and Petsamo Group rocks. The main purpose of these investigations was to provide a stratigraphic/tectonic correlation between the Pechenga Group rocks of the Nickel - Zapolyarny region and the equivalent Petsamo Group of the Pasvik Valley. The result of NGUs field investigations demonstrate that a detailed correlation of all significant horizons across the border-zone between Russia and Norway can be made. The result of this work also show the need for a number of significant revi- sions of the detailed stratigraphy of the Petsamo Group in both the Pasvik and Polmak areas. The results of NGUs rock geochemical studies are presented in the report. A/S Sulfidmalm has previously received the analytical data for 220 samples. Recommendations are given concerning the potentially best Ni-Cu prospective areas.

Midtun, R.D. 1986: Geofysisk og geologisk tolkning av regionale strukturer innenfor kartbladene Karasjok, Galmatskai'di, Bæivasgieddi og Iesjåkka, Karasjok kommune, Finnmark. NGU rapport 86.209, 63p + 1 map enclosure.

Midtun, R.D. 1987: Geofysisk og geologisk tolkning av regionale strukturer innen Karasjok Grønnsteinsbelte i et område nord for Karasjok, Finnmark. NGU rapport 87.063, 61p + 1 map enclosure.
Covers 1:50 000 map sheets 2034 2 Iddjajav'ri and 2034 1 Hal'kavarri
Datagrunnlaget for tolkningen har vært: 1) Geologiske blotningskart samt en tektonostratigrafisk tolkning av disse 2) Petrofysikk: 2600 in situ susceptibilitetsmålinger, 370 bergartsprøver målt på susceptibilitet, tetthet og remanens. 3) Magnetiske og elektromagnetiske helikoptermålinger. 4) Gravimetriske bakkemålinger. Den aeromagnetiske tolkning har resultert i et magnetisk strukturkart inneholdende informasjon om magnetiseringsmønster/nivå, kontakter, bånd, ganger og fallangivelser basert på modellberegninger. En tolkning av magnetiske dislokasjoner viser tre hovedretninger: 1) 50-60 g, 2) 310-320g samt flere skyvesoner.

Detaljert gravimetrisk tolkning er gjort langs et vest-øst gående profil. En 3-dimensjonal strukturanalyse basert på magnetisk tolkning og gravimetriske data har klarlagt flere regionale strukturer, blant annet en oppdoming av basement i de sentrale deler. Tolkningsmetoden beskrevet i rapporten ansees som et godt redskap for å klarlegge regionale geologiske strukturer.

Midtun, R.D. 1988: Karasjokgrønnsteinsbeltet Regional geofysisk og geologisk tolkning. NGU Skrifter 88, 19 p. + 6 enclosed plates.
A geophysical interpretation of geological structures within 5 map-sheets in 1:50, 000 scale (AMS M711) has been done. Petrophysical properties of 1350 rock samples and about 11000 in situ susceptibility measurements have been analysed. The interpretation is based on all available information including geological and petrophysical data, low altitude magnetic and electromagnetic measurements and gravimetric data. The aeromagnetic interpretation includes a magnetic structure map showing patterns, contacts, magnetization levels and dip estimations. From this map the outcropping of the tectonostratigraphic units and the internal layering can be seen. An interpretation of magnetic dislocations together with a topografic lineament study has been made, revealing 3 directions of dislocation maxima, NE, E and NV. The NE-direction is thought to be the youngest. Thrusts are also detected from the magnetic data. Detailed gravimetric interpretations have been made along 5 profiles. These model calculation show alternating culmination and depressions with a maximum depth to basement being 4 km. By combining the magnetic and gravimetric interpretation . The map shows two foldsystems, NNE and ESE. The oldest NNE-system is thought to be connected with suturing in this area. These two interfering fold systems are producing 4-5 km deep synclinorias separated by shallow basement-ridges within the Karasjok Greenstone Belt. A regional gravimetric model calculation crossing the Precambrian terrain of the Northern Fennoscandia has been made. This interpretation supports the theory of a suture between the Karasjok Greenstone Belt and Levajok Granulite Belt.

Mitrofanov, F.P. (editor in chief) 1996: Geological map of the Kola Region, 1:50 000. Russian Academy of Sciences, Apatity, Russia.
Intas-Program, Project 93-0754 "Tectonic evolution, deep structure and metallogeny of the Kola peninsula, Arctic Russia. Map editors: F.P. Mitrofanov (editor in chief, Russia), A.T. Radchenko (editor, Russia) and C. Gillen (editor), Great Britain.

Mutanen, T. 1997: Geology and ore petrology of the Akanvaara and Koitelainen mafic intrusions and the Keivitsa-Satovaara layered complex, northern Finland. Geological Survey Finland Bulletin 395, 233 pp. + map enclosures.

Mutanen, 1996: The Akanvaara and Koitelainen intrusions and the Keivitsa – Satovaara Complex. Guide to the pre-symposium field trip in Finland, August 20-21, 1996. Geol Surv Finland IGCP Project 336 Field Conference on layered mafic Complexes and related Ore deposits of northern Fennoscandia. 113 pp. + 4 map enclosures.

Nilsen, K.S. 1986a: KARASJOK berggrunnskart 2033-1, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Nilsen, K.S. 1986b: HAL'KAVARRI berggrunnskart 2034-1, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Nilsen, K.S. 1988: Beskrivelse til det berggrunnsgeologiske kartblad Karasjok 2033-1, M 1:50 000. NGU rapport 88.208, 64 s. pluss appendiks.

Nilsen, K.S & Nilsson, L.P. 1996: VARGSUND berggrunnskart 1935-4, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Nilsson, L.P. 1987: STIIPANAV'ZI, berggrunnskart 2034-3, M 1.50 000, foreløpig utgave, Norges geologiske undersøkelse.

Nilsson, L.P. 1988: Geofysisk og geologisk tolkning av regionale og lokale strukturer innenfor kbl. 2033-4 Iesjåkka, Karasjok kommune, Finnmark. NGU rapport 88.170.

Nilsson, L.P. & Iversen, E. 1991: Berggrunnskart Neiden, M 1:50 000, foreløpig utgave, NGU.

Nilsson, L.P. & Juve, G. 1979: En kjemisk-mineralogisk undersøkelse av ultramafiske bergarter I Komagfjordvinduet med henblikk på å bestemme eventuelle økonomiske konsentrasjoner av malmmineraler. NGU rapport 1682/1, 58 pp. + 9 sketch maps

Often, M. 1985: The Early Proterozoic Karasjok Greenstone Belt, Norway; a preliminary description of lithology, stratigraphy and mineralization. Norges geologiske undersøkelse Bulletin 403, 75-88.
The Karasjok Greenstone Belt of Finnmark, Norway, is a sequence of medium-grade metamorphic supracrustal rocks in the northernmost part of the Baltic Shield. Regional mapping has revealed a tectonostratigraphy with the greenstone belt resting on Archean sialic basement, dipping away under the Tanaelv Migmatic Complex with the Levajok Granulite Complex on top. Major thrust zones separate the lowermost part of the greenstone belt, the clastic Skuvvanvarri Formation, from the mixed volcanic-sedimentary Iddjajav'ri Group. High grade thrust zones also separate the migmatite and granulite complexes from the greenstone belt. Pyroclastic komatiites constitute an important part of the Iddjajav'ri Group, suggesting volcanism in a shallow-water environment. A plate-tectonic concept is applied to describe the evolution of the greenstone belt which is probably of Earth to Middle Proterozoic age. Mineralizations within the Karasjok Greenstone Belt are classified and briefly described. The two most important types are manganiferous banded iron-formations of Algoma type and large low-grade disseminated copper-gold mineralizations of uncertain origin.

Often, M. & Krill, A.G. 1986: BÆIVASGIED'DI berggrunnskart 2033-3, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Often, M. & Nilsson, L.P. 1990: Ny type palladium og platina-mineralisering i Karasjok grønnsteinsbelte, Finnmark. 19. Nordiske Geologiske Vintermøte, Stavanger. Abstract Geolognytt, 85-86.

Olesen, O. & Sandstad, J.S. 1993: Interpretation of the Proterozoic Kautokeino Greenstone Belt, Finnmark, Norway from combined geophysical and geological data. Norges geologiske undersøkelse Bulletin 425, 42-62.
Processed images of aeromagnetic, gravimetric and topographical data and geological maps combined with EM helicopter measurements, petrophysical data and digitised geological field observations have been used in a geological interpretation and structural analysis of the Kautokeino Green- stone Belt, KGB. The data were analysed with an image-processing system (geophysical data) and a geographic information system (geological data and interpretations). The bulk of the mafic volcanic rocks in the Kautokeino Greenstone Belt is situated within a NNW-SSE-trending, 35 km wide and up to 5-6 km deep trough which is thought to represent and Early Proterozoic rift deformed by strike-slip faulting along the Bothnian-Kvænangen Fault Complex,BKFC. The margins of the Alta-Kautokeino Rift, AKR, can be outlined from the geophysical data. The Ciegnaljåkka-

Boaganjavri Lineament and the Soadnjujavri-Bejasjavri Fault are the main bordering fault zones and arc continuous along the entire greenstone belt. The supracrustals between these two zones are continuous to great depth (5-6 km) and the contracts along these bordering zones are steeply dipping. Gravity interpretations show that the outer amphibolite-facies rocks are just as deep as the central greenschist-facies unit. Results of the present study suggest that the amphibolite-facies volcano-sedimentary rocks situated along the flanks of the KGB should also be included in the rift.

Olesen, O. & Solli, A. 1985: Geophysical and geological interpretation of regional structures within the Precambrian Kautokeino Greenstone Belt, Finnmark, North Norway. Norges geologiske undersøkelse Bulletin 403, 119-129.
The Kautokeino Greenstone Belt comprises a synclinorium of volcano-sedimentary rocks. This sequence of Early Proterozoic age is situated between two culminations of gneisses. Large areas of the belt have been mapped in detail (1:50.000) and petrophysical properties of about 1150 rock samples have been measured. Geophysical interpretation based on aeromagnetic and gravimetric maps have been made. The aeromagnetic interpretation includes a magnetic dislocation map showing three directions of dislocation maxima (NNW, N, NE). From an inter- pretation of magnetic structures showing patterns, contacts and magnetization levels, the basement and intrusions can be separated from the supracrustals, primary layering in supracrustals can be seen, and the boundaries between rock units can be located. The gravity interpretation includes model calculations along four profiles. The profiles show alternating culminations and depressions within the greenstone belt with maximum depth up to 6 km. By combining a magnetic interpretation map and a gravity anomaly map a threedimensional analysis can be made. Anticlines and synclines in the greenstone belt emerge clearly on this map. It is concluded that most of the deformation is caused by gravitational tectonics.

Olsen, K.I. & Siedlecka 1996: Geologisk kart over Norge, berggrunnskart INARI 1:250 000. Norges geologiske undersøkelse.

Olsen, K.I. & Nilsen, K.S. 1985: Geology of the southern part of the Kautokeino Greenstone Belt: Rb-Sr geochronology and geochemistry of associated gneisses and late intrusions. NGU Bulletin 403, 131-160.
The southern part of the Kautokeino Greenstone Belt is divided into four volcanic formations separated by sedimentary units. The formation represent a development from Archaean komatiitic sequences to Middle Proterozoic possible rift-forming environments. The earliest volcanism is represented by basaltic komatiitic enclaves within the eastern gneiss complex, and may be equivalent to parts of the lowermost formation within the greenstone belt. The latter consists of up to 50% basaltic to peridotitic komatiites (12-30% MgO) and was probably deposited after the formation of the gneiss complex. The tonalitic-trondhjemitic gneisses arc dated to 3.0+-0.2 b.y. and represent primary magmas resulting from the crust-forming events at that time. They are similar in age and composition to gneisses in East and North Finland. The late plutonic complexes are ca. 1700 m.y. old and may be the Middle Proterozoic counterparts to the Archaean gneisses. Regional metamorphism within the belt reached middle to high amphibolite facies and occurred ca. 1950 m.y. ago on the basis of Rb-Sr radiometric dating on metasediments and amphibolites. Granitic gneisses southwest of the main greenstone belt are very uniform geochemically and represent products of differentiation. Widespread and intensive brecciation, shearing and carbonatization are later than the main deformation and metamorphism, and may be associated with faulting and block movements in connection with possible rift tectonics.

Oosterom, M.G. 1956: Some notes on the Lille Kufjord layered gabbro, Seiland, Finnmark, Northern Norway. NGU 195, 73-88
The first recognition that this layered intrusion (layered gabbro with abundant ultramafic layers in the lower part) is sulphide bearing. Sulphide enriched layers contain up to 5% pyrrhotite, pentlandite, chalcopyrite and sphalerite. The metal contents in sulphide concentrates is 4-6% Cu, 3-4% Ni and 0,2-0,4% Co. Pt was not detected in the concentrates.

Papunen, H. & Gorbunov, G.I. 1985: Nickel-copper deposits of the Baltic Shield and Scandinavian Caledonides. Geol. Surv. Finland Bull. 333, 394 pp.

Pharaoh, T. 1985: Volcanic and geochemical stratigraphy of the Nussir Group of Arctic Norway-an early Proterozoic greenstone suite. Journal of the Geological Society 142, 259-278.

Pharaoh, T.C., Ramsay, D.M. & Jansen, Ø. 1983: Stratigraphy and structure of the northern part of the Repparfjord - Komagfjord window, Finnmark, Northern Norway. Norges geologiske undersøkelse 377, 1-45.
In the northern district of the Repparfjord-Komagfjord Window, supracrustal and intrusive rocks of Early Proterozoic age are unconformably overlain by a thin sequence of Vendian sediments. Both of these units are overthrust by allochthonous rocks of the lavas, tuffs and sediments of the Raipas Supergroup and intrusions of the Raudfjell Suite, regionally metamorphosed at greenschist facies during the polyphase Svecokarelian Orogeny, c. 1840 Ma. The c. 8 km thick supracrustal sequence is divided into four groups and eleven formations on a lithostratigraphic basis. The lithological characteristics of these units are described and compared with rocks of similar age elsewhere in N. Norway. The stratigraphy and sedimentology of the thin (<200 m thick), autochthonous, ?Vendian cover sequence is also described. The caledonian Orogeny resulted in complex deformation of the autochthonous cover as well as considerable reactivation of the underlying basement.

Poulsen, A.O. 1945: Forekomster av talk og kleberstein. NGU Bergarkivet nr. 5877, 3p.
This is a simple but useful list of Norwegian talc/soapstone occurrences with information about name of occurrence and municipality in which it is located, and sorted according to county.

Poulsen, A.O. 1941: Nikkelmalm i Norge. NGU Bergarkivet rapport 297, 15 pp. + 1 map enclosure.
Early report on nickel ore in Norway with map enclosure in c. 1:500 000. No occurrences north of Senja are mentioned in the text or marked on the map.

Poulsen, A.O. 1945: Magnetkis i Norge. NGU Bergarkivet rapport 661, 10 pp. + 1 map enclosure.
Early report on pyrrhotite in Norway with map enclosure in 1:1 mill. The Cu-occurrences in the Lakselvdalen area in Porsanger are marked, but non of Ni-bearing pyrrhotite occurrences treated in the report are in Finnmark.

Poulsen, A.O. 1961: Nickel Ore Deposits in Norway. NGU Bergarkivet rapport 3152, 19 pp.
No occurrence north of Senja mentioned.

Pratt, A. O. 1989: Petrology of differentiated gabbro sheets in the Altenes tectonic window, North Norway. Norges geologiske undersøkelse Bulletin 414, 21-35.
The petrography of two differentiated gabbro sheets in the low-grade metamorphic Karelian supracrustal sequence of the Altenes Tectonic Window is described. The intrusion has generally undergone extensive deuteric alter- ation. Detailed petrographic studies established the primary parageneses and variation in the gabbro sheets and formed the basis for an interpretation of the geochemical profiles. Both intrusions have a distinct mineralogical and chemical variation suggesting that gabbro sheets in the window probably comprise both sills and slightly inclined intrusions. Magmatic rocks in the Altenes Window describe a definite tholeiitic trend. Zr-FeO/MgO and Zr-Y plots of the two studied intrusions suggest the existence of two magmatic suites. The Trollvatn sill is interpreted as syngenetic with the mafic extrusive rocks while the Sagelv intrusion probably intruded at a low angle in an early stage of the Svecokarelian orogeny.

Pratt, A. & Nielsen, L. M. 1985: The geology of the Altenes Window and its correlation to the Alta-Kvænangen and Komagfjord-Repparfjord windows, Finnmark, Norway. NGU report 85.186, 57-60.

Pratt, A. & Nielsen, L. M. 1984: Geologisk kortlægning på Alteneset, og beskrivelse af de Cu, Fe og Ti-mineraliseringer og de intrusive bjergarter. NGU-rapport 84.072, 31 pp.
Formålet med undersøkelsen var å oppklare genesen av de forskjellige typer mineraliseringer på Alteneset. Innenfor Altenesområdet er mineraliseringer og gabbro intrusiver, der danner sidebjergart til et flertal af mineraliseringerne, blevet undersøgt. Mineraliseringerne forekommer overvejende i mindre centimeter- til meterstore calcit og/eller kvartsudfyldte sprækker, som er mineraliseret med Cu/Fe-sulfider og Fe-oxider. Den største mineraliserede sprække har et udgående på 40 X 20 meter. Udover sprække-minerlaiseringer er der en massiv Fe-Ti-mineralisering i en mindre gabbro-intrusiv og desuden Cu-mineraliseret breccizoner og jaspisgange i en dolomitzone. Gabbro intruderer ofte konkordant med sidestenen. Tre af dem er undersøgt nærmere og beskrevet i denne rapport. Det konkluderes at, i alle tilfælde en af dem er oprindeligt intruderet som en sill.

Reitan, P.H. 1963: The geology of the Komagfjord tectonic window of the Raipas suite Finnmark, Norway. NGU 221, 71 p + 2 map enclosures.
The report is based on four summers (1956-59) of field work in an area of approximately 860 km2. The area is located in western Finnmark, northern Norway, between 70 degrees 10' and 70 degrees 31' N latitude and 12 degrees 40' and 13 degrees 50' E Oslo longitude. The purpose of the investigation was to study the rocks within a hitherto mainly unexamined area of Precambrian rocks surrounded by Caledonian rocks. Portions of the area near the sea had been visited by a few geologists prior to the initiation of this investigation. It was therefore quite certain that the rocks were Precambrian in age and constituted a window in the Caledonides, but the size of the window was unknown nor had most of the window been studied geologically. This report establishes the Precambrian age of the rocks and delineates the boundaries of the window. The Precambrian rocks along the western coast of Finnmark were previously called the Raipas formation and known to outcrop in (at least) two windows. As this report differentiates seven formations which constitute two groups within the Komagfjord (the northernmost) tectonic window, it is purposed that the Precambrian rocks of the two windows be known as the Raipas suite.

Reusch, H. 1892: Iagttagelser fra en reise i Finnmarken 1890. In: Det nordlige Norges geologi (ed. Reusch, H.). NGU 4, 23-111.

Roberts, D. 1973: Geologisk kart over Norge, berggrunnskart HAMMERFEST 1:250 000. Norges geologiske undersøkelse.

Roberts, D. 1981: Geologisk kart over Norge, berggrunnskart NORDKAPP 1:250 000. Norges geologiske undersøkelse.

Roberts, D. 1990: SKARSVÅG, berggrunnsgeologisk kart 2137-3 – 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Roberts, D. 1998: Geologisk kart over Norge, berggrunnskart HONNINGSVÅG 1:250 000. Norges geologiske undersøkelse.

Roberts, D. & Davidsen, B. 1992: LAKSELV, berggrunnsgeologisk kart 2035-3, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Roberts, D. & Rice, A.H.N. 1990: MUN'KAVARRI, berggrunnsgeologisk kart 2035-2, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse

Robins, B. 1996: The Seiland Igneous Province, North Norway. Field trip guidebook,

Part II. IGCP project 336 Field Conference and symposium "Layered Mafic Complexes and Related Ore Deposits of Northern Fennoscandia: Finland, Norway, Russia, NGU report 96.127, 30 pp.
Field trip guidebook for the International Geological Correlation Program (IGCP) Project 336: Field conference and symposium on Layered Mafic Complexes and related ore deposits of Northern Fennoscandia: Finland, Norway and Russia August 18-31, 1996. Contains a comprehensive description of the general geology and magmatic evolution of the Seiland Igneous province in addition to a guide to 10 localities in the Hakkstabben area of Seiland.

Robins, B., Gading, M., Yrdakul, M. & Aitcheson, S.J. 1991: The origin of macrorhytmic units in the Lower Zone of the Lille Kufjord Intrusion, northern Norway. NGU Bulletin 420, 13-50.
The Lille Kufjord intrusion is one of the youngest mafic plutons in the Seiland Magmatic Province which forms part of the Middle Allochthon of the North Norwegian Caledonides. It was emplaced at a mid-crustal level into Proterozoic, sillimanite-grade paragneisses during the Middle Cambrian, probably in an extensional tectonic regime. Caledonian deformation is locally penetrative in the envelope but the intrusion is little affected and retains its original form, orientation and synformal internal structure.
(Only the first part of the abstract in the NGU Bulletin is here provided by the library).

Rundqvist, D.V. & Mitrofanov, F.P. (eds.) 1993: Precambrian geology of the USSR, developments in Precambrian Geology 9, Elsevier, 527 pp.

Siedlecka, A. & Roberts, D. 1996: Finnmark Fylke. Berggrunnsgeologi M 1:500 000. Norges geologiske undersøkelse.

Siedlecka, A. & Nordgulen, Ø. 1996: Geologisk kart over Norge, berggrunnskart KIRKENES, M 1:250 000. Norges geologiske undersøkelse.

Siedlecka, A. 1987: SKOGANVARRE, berggrunnsgeologisk kart 2034-4, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse

Siedlecka, A., Iversen, E. & Krill, A. 1985: Lithostratigraphy and correlation of the Archean and Early Proterozoic rocks of Finnmarksvidda and Sørvaranger district. Norges geologiske undersøkelse Bulletin 403, 7-36.
Archean and Early Proterozoic rocks of Finnmarksvidda and the Sørvaranger District are grouped into lithostratigraphic and lithodemic units are systematically described. Some correlations are proposed and the foundations for these correlations are discussed. The lithostratigraphic successions of the Kautokeino and Karasjok greenstone belts are correlated with each other and with the older Precambrian rocks exposed in the tectonic windows. From this emerges an outline of geological events which occurred in the Early Precambrian in these terranes. Contacts between the Archean rock units of the Sørvaranger District are often faulted and therefore stratigraphic relationships between the various gneiss complexes and groups are uncertain. There are, however, indications that the Bjørnevann Group and part of the Jarfjord Gneiss are correlative, the same is true for parts of the Varanger and Kirkenes Gneiss Complexes. There seem to be two, stratigraphically unrelated banded-iron formations, both formerly assigned to the Bjørnevann formation and now described separately as the Bjørnevann and Garsjø Groups. The Early Proterozoic Petsamo Group is subdivided into four formations and stratigraphic relations within the group are discussed. The complex Archean stratigraphy of the Sørvaranger district does not have equivalents on Finn- marksvidda. The volcano-sedimentary sequences of the Kautokeino and Karasjok greenstone belts may at the present stage of work only roughly be compared with the Petsamo Group.

Sigmond, E.M.O. 2002: Geologisk kart over land- og havområder i Nord-Europa, målestokk 1:4 millioner. Norges geologiske undersøkelse.

Skaldebø, O.A. 1977: geologisk beskrivelse av 4 områder med ultrabasiske intrusivbergarter i Komagfjord tektoniske vindu i Vest-Finnmark. Intern rapport til Folldal Verk A/S.

Skålvoll, H. 1972: Geologisk kart over Norge, berggrunnskart KARASJOK, M 1:250 000. Norges geologiske undersøkelse.

Smirnov, V.I. (ed.) 1977: Ore deposits of the USSR, Volume II. Pitman Publishing, London, 424 pp.
Pages 20-25 deal with the Allarechka ore field and ore deposit. The chapter on nickel deposits is written by Glazkovsky, Gorbunov and Sysoev. Allarechka is here named Allarechen.

Stribrny, B. 1980: The Conglomerate-hosted Repparfjord Copper Ore Deposit, Finnmark, Norway. Monograph Series on Mineral deposits, No. 24, Gebrüder Borntraeger, Berlin, 71 pp.

Sørdal, T. 1983: Geokjemisk bekkesedimentundersøkelse Iesjav'ri og Anarjåkka- området, Finnmark 1982. NGU-rapport 1886/1, 8 p.
Stream sediment survey. Covering map sheets 1:50000 1934 2 Iesjavri 2032 4 Noarvas 2033 2 Galmatskai'di 2033 3 Bæivasgiedde.
Det er utført geokjemisk bekkesedimentprøvetaking på kartbladene 19342, 20332 og 3 samt 20324, i tidsrommet 29.6 -10.8.82. Analyser fra undersøkelsen viser ingen anomali-områder på kartblad 19342 Iesjav'ri. I det sørlige området, Anarjåkkaområdet, (2033 -3 og 2032-2) framkommer tre områder hvor Ag- verdiene skiller seg vesentlig ut over bakgrunnsnivå. Disse områder har også en forhøyet konsentrasjon av Fe og Mn (også Zn og tildels Ni har forhøyet konsentrasjon i forhold til bakgrunnsnivå). Innholdet av Pb er lavt, med en viss forhøyelse i den nordlige del av det prøvetatte området. Cu-verdiene er overraskende lave når en ser på geologien, med bl.a. grønnsteinen og amfibolitter som vanligvis gir relativt høye Cu-verdier.

Walker, P. & Olesen, O. 1992: Helicopter Survey of South Pasvik, Finnmark, Norway. NGU-report 92.306, 51 pp.
A helicopter borne geophysical survey was completed in the South Pasvik area near the border with Russia. The primary target formation was the Gjøkvatn Formation which extends into Norway from Russia, and which is known to host nickel mineralization on the Russian side. The survey was commissioned by A/S Sulfidmalm, with liason and supervision carried out by Falconbridge Nickel Mines. The total area surveyed covered approximately 80 square kilometers at a line spacing of 100 meters, for a total of approximately 800 line kilometres. The instrument package included a four frequency helicopter electromagnetic system, magnetometer, VLF, and spectrometer. Results are presented as a series of colour geophysical maps, with a report on the radio-metric results planned to follow. A preliminary geologic interpretation has been made based on the geophysical data as well as petrophysical measurement. The geophysical data indicates that the Blankvatn gneiss constitutes a dome structure with the Gjøkvatn Formation stratigraphically above and folded to the north of it. Several sets of faults are evident on both the magnetic and resistivity maps, and small high intensity magnetic anomalies in the Gjøkvatn Formation are interpreted to be due to serpentinites. They seem to be located near the contact of the two units.

Wanvik, J.E. 1985: Forekomster / registreringer av industrimineraler og bygningsstein i Finnmark. Status våren 1985. NGU rapport nr. 85.046, 28 p + 2 map enclosures.

Wennervirta, H. 1969: Karasjokområdets geologi. NGU 258, 131-184.

Wiik, V.H. 1966: Petrological studies of the Neiden granite complex. NGU 237, 99 pp.

Zwaan, B. 1985: SUOLUVUOBMI, berggrunnsgeologisk kart 1934-3, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

11.2 Karasjok references (key references for the whole greenstone belt. Cf. separate lists for the Porsanger area and the Gallujavri intrusion)

Braathen, A. 1991: Stratigrafi og strukturgeologi sentralt i Karasjok grønnsteinsbelte, Finnmark. Cand. Scient. Thesis, University of Tromsø. (thesis available at University of Tromsø, Institute for Biology and geology).

Henriksen, H. 1983: Komatiitic chlorite-amphibole rocks and mafic metavolcanics from the Karasjok Greenstone Belt, Finnmark, Northern Norway: a preliminary report. NGU Bull.382, 17-43.

Hysingjord, J. 1971: Tungmineralundersøkelser i Finnmark. NGU-rapport 968 D, 28 pp.

Håbrekke, H. 1979: Magnetiske, elektromagnetiske, radiometriske og VLF-målinger fra helikopter over et område nord for Karasjok. NGU rapport 1728, 13 pp + map enclosures.

Håbrekke, H. 1981a: Magnetiske-, elektromagnetiske-, VLF-og radiometriske målinger fra helikopter over Karasjok Nord, Karasjok og Porsanger, Finnmark. NGU rapport 1784, 12 pp + map enclosures.
Covering parts of the following 1:50 000 scale map sheets: 2034 1 Hal'kavarri, 2034 2 Iddjajav'ri and 2034 4 Skoganvarre.

Håbrekke, H. 1981b: Magnetiske-, elektromagnetiske-, VLF- og radiometriske målinger fra helikopter over Karasjok Syd. NGU rapport 1800/38C, 12 pp + map enclosures.
Covering parts of 1:50 000 scale map sheets 2033 3 Bæivasgiedde and 2033 4 Iesjåkka.

Krill, A.G. 1985: Svecokarelian thrusting with thermal inversion in the Karasjok-Levajok area of the northern Baltic Shield. Norges geologiske undersøkelse Bulletin 403, 89-101.

Often, M. 1985: The Early Proterozoic Karasjok Greenstone Belt, Norway; a preliminary description of lithology, stratigraphy and mineralization. Norges geologiske undersøkelse Bulletin 403, 75-88.

Siedlecka, A., Iversen, E. & Krill, A. 1985: Lithostratigraphy and correlation of the Archean and Early Proterozoic rocks of Finnmarksvidda and Sørvaranger district. Norges geologiske undersøkelse Bulletin 403, 7-36.

Sørdal, T. 1983: Geokjemisk bekkesedimentundersøkelse Iesjav'ri og Anarjåkka- området, Finnmark 1982. NGU-rapport 1886/1, 8 p.
Stream sediment survey. Covering map sheets 1:50000 1934 2 Iesjavri 2032 4 Noarvas 2033 2 Galmatskai'di 2033 3 Bæivasgiedde.

11.2.1 Porsanger references (Karenhaugen and Porsvann literature)

This list includes literature on the geological setting of the deposits.

Braathen, A. & Davidsen, B. 2000: Structure and stratigraphy of the Palaeoproterozoic Karasjok Greenstone Belt, North Norway – regional implications. Norsk geologisk tidsskrift 80, 33-50.

Crowder, D. 1959: The Precambrian schists and gneisses of the Lakselv valley, Northern Norway. Norges geologiske undersøkelse 205, 17-40.

Dalsegg, E. & Often, M. 1991: Geologiske og geofysiske undersøkelser av Porsvann PGE/Cu-forekomst, Porsanger, Finnmark. NGU Rapport 91.052. 13 p. + enclosures.

Davidsen, B. 1994: *Stratigrafi, petrologi og geokjemi med vekt på komatiittiske bergarter innen den nordligste del av Karasjok grønnsteinsbelte, Brennelv, Finnmark.* Unpublished Cand. Scient. Thesis. University of Tromsø.
Comprehensive treatment of the area, emphasizing the komatiites. Thesis available through the NGU Library.

Davidsen, B., 1990: Feltrapport fra den nordlige del av Karasjok grønnsteinsbelte, 1990. NGU rapp. & dagbokarkiv No 070/90.031D, 28 p + enclosures.

Davidsen, B. 1989a: Feltrapport fra Lakselvområdet, Finnmark sommeren 1988. NGU-Rapport 89.016. 35 pp.
Describes the mineralised areas.

Davidsen, B. 1989b: Stratigrafi og strukturgeologi i deler av Karasjok grønnsteinsbelte nord for Porsangmoen, Finnmark. NGU upublisert feltrapport, 33 p.

Juve, G. 1968: Corgusområdet, Lakselvdalen, Porsanger kommune, Finnmark. Rapport om kobberforekomstenes type og utbredelse.
Internal report A/S Sydvaranger report, 40 pp.

Ljøkjell, P. 1991: Oppredning av malm fra Karenhaugen. SINTEF rapport No STF36 F91052.
SINTEF Bergteknikk. 11 p + 15 enclosures.
Confidential report required by NGU.

Ludvigsen, Erik 1993: Karenhaugenforekomsten. Det økonomiske potensialet.
SINTEF rapport No STF36 F93077. SINTEF Bergteknikk. 3 p + 2 enclosures.
Confidential report required by NGU.

Ludvigsen, E., Nielsen, K. & Sandvik, K.L. 1990: Karenhaugforekomsten. Det økonomiske potensialet. SINTEF rapport No STF36 F90045: SINTEF Bergteknikk. 9 p + 3 enclosures.
Confidential report required by NGU.

Nilsson, L.P. & Larsen, R. B. 1998: Edle mineraler i mafiske og ultramafiske bergarter – en oppsummering av platina-gruppe mineraler (PGM) funnet i Norge i de senere år. Kongsberg Mineralsymposium 1998. Bergverksmuseet Skrift nr. 14, 40-49.
Gives a summary of the PGM recorded at the Karenhaugen deposit.

Often, M. & Nilsson, L. P. 1990: Ny type palladium og platina-mineralisering i Karasjok grønnsteinsbelte, Finnmark. 19. Nordiske Geologiske Vintermøte, 8.-12. januar 1990, Stavanger. Abstract Geonytt 1/1990, 85-86.
First report on the PGE-enrichments and the PGM at the Karenhaugen, Porsvann and Gallujavri deposits.

Roberts, D. & Davidsen, B. 1992: Lakselv, berggrunnsgeologisk kart 2035-3, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.
Includes the Porsvann deposit and the western part of the Karenhaugen deposit.

Roberts, D. & Rice, A.H.N. 1990: Mun'kavarri, berggrunnsgeologisk kart 2035-2, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.
Includes the eastern part of the Karenhaugen deposit.

Røsholt, B. 1969: Rapport over prøvetaking av kobbermineraliseringer i Lakselvdalen 1968.
Internal report, A/S Sydvaranger.

Siedlecka, A. & Roberts, D. 1996: Finnmark Fylke. Berggrunnsgeologi M 1:500 000. Norges geologiske undersøkelse.

Tertiary Minerals PLC 2001:
Cf. the company's web site for detailed information).

11.2.2 Gallujavri references (Company reports, NGU reports and maps dealing with the Gallujavri Ni-Cu-PGE prospect and surrounding areas)

Introductory work:

1) Helicopter geophysics (960 km^2 covered in 1979 and 1980):

Håbrekke, H. 1979: Magnetiske, elektromagnetiske, radiometriske og VLF-målinger fra helikopter over et område nord for Karasjok. NGU rapport 1728, 13 pp. + map enclosures.
This report covers a 440 km^2 area that includes the Gallujavri intrusion).

Håbrekke, H. 1981a: Magnetiske-, elektromagnetiske-, VLF- og radiometriske målinger fra helikopter over Karasjok Nord, Karasjok og Porsanger, Finnmark. NGU rapport 1784, 12 pp. + map enclosures.
Covering parts of the following 1:50 000 scale map sheets: 2034 1 Hal'kavarri, 2034 2 Iddjajav'ri and 2034 4 Skoganvarre. The measured area borders the area measured in 1979 to the north.

Midtun, R.D. 1987: Geofysisk og geologisk tolkning av regionale strukturer innen Karasjok Grønnsteinsbelte i et område nord for Karasjok, Finnmark. NGU rapport 87.063, 61p + 1 map enclosure.
Geophysical and geological interpretation of the helicopter-borne survey by Håbrekke 1981a listed above.

2) Regional soil sampling

3) Geological mapping (1:50 000, sheet Iddjajav'ri)

Henriksen, H. 1984: IDDJAJAV'RI, foreløpig berggrunnskart 2034-2, 1:50 000. Norges geologiske undersøkelse.

Reports:

4) A/S Sydvaranger report 1245: **Summary of prospecting activity in Karasjok 1981 with results and plans for the 1982 season** by geologist Bernt Røsholt. 35 p + 3 map enclosures.

5) A/S Sydvaranger **Årsrapport 1981** (annual report) (in Norwegian).

6) A/S Sydvaranger report S 20: **Statusrapport fra 1982-feltsesongen** (in Norw.)
NGU carried out ground geophysics for ASPRO that year.

7) A/S Sydvaranger report 1232: **Geological mapping in the Karasjok area, 1981** by geologist Helge Henriksen

Basis for the preliminary map sheet Iddja'javrri 1:50 000), 40 p + map enclosures.

8) A/S Sydvaranger report 1161: **Summary of prospecting activity in Karasjok 1980 and plan for the 1981 season** by B. Røsholt, 4p.

9) A/S Sydvaranger report 1147: **Diamond drilling program on target area no. 11 and sample drilling in Karasjok area**. by B. Røsholt (8 p.) and **Target area 11 – Finnmark, Sept. 1980. Magnetics and self potential** by Steve Medd (4 p.).

10) A/S Sydvaranger report 1122**: Geologisk kartlegging i området Karasjok – Skoganvarre** (in Norw. with English summary) by H. Henriksen, 15 p. + 2 enclosures.

11) A/S Sydvaranger 1071: **A/S Sydvarangers prospekteringsarbeider i Karasjok 1979,** by B. Røsholt (6 p + 7 enclosures).
Includes results of diamond drilling on the Gallujavri intrusion)

12) A/S Sydvaranger report 1090: **Geological description of the area N of Karasjok,** by Gudmund Grammeltvedt and **Note on ore microscopical investigations of the Gallujavrri-mineralization** by Ragnar Hagen (10 p + 1 enclosure)

13) A/S Sydvaranger report 455: **Rapport over A/S Sydvarangers arbeider i Karasjok 1978** by …? (9 p).

14) A/S Sydvaranger report 453: **….. 413.3 Karasjok** by B. Røsholt (4 p).
Possibly an extract from a larger report?)

15) A/S Sydvaranger report 1057: **Gallojavrre Cu – Ni – mineralisering, Karasjok. VLF - , Motstands- og Fase-målinger**, by geophysicist Ørnulf Logn (10 p + 9 enclosures).
Results of VLF, resistance and phase measurements)

16) NGU rapport 1840 *(report date: January 1982)*: **Geofysiske bakkemålinger i Karasjok**, **Finnmark,** by Einar Dalsegg. (7 p. + 25 p enclosures)
Reports ground geophysics conducted on 63 objects N of Karasjok. A follow up of the helicopter geophysics mentioned above.

17) NGU rapport 1892 (*report date: May 1983*): **Geofysiske bakkemålinger Gal'lujav're, Karasjok, Finnmark** by E. Dalsegg (11 p + 3 map enclosures)
Reports TURAM measurements covering a 3 km^2 large area at Gal'lujav're, i. e. the Gallujavri intrusion.

18) Henriksen, H. 1984: Iddjajav'ri, foreløpig berggrunnskart 2034-2, M 1:50 000, Norges geologiske undersøkelse.

19) Midtun, R.D. 1988: Karasjok grønnsteinsbeltet. Regional geofysisk og geologisk tolkning. Norges geologiske undersøkelse Skrifter 88, 1-19.

20) Midtun, R.D. 1987: Geofysisk og geologisk tolkning av regionale strukturer innen Karasjok Grønnsteinsbelte I et område nord for Karasjok, Finnmark. 61 p (including enclosures).

Comments:

The NGU reports (Nos. 16 and 17 on the list) are normally released after 7 years if the work is fully paid by a client as in this case. Otherwise reports are normally released after a shorter period, often only 1 or 2 years.

When it comes to company material later than 1982 I do not know what exists from ASPRO and other companies, because I was denied access to these (even the titles) at the time I was working on the Gallujavri intrusion (1987-88).

My own work is limited to sampling for XRF majors + minors on a suite of rocks collected in 1987 and –88. Furthermore I've done reconnaissance petrography on the collected material as well as worked on the setting of the PGEs and gold in rocks and sulphide concentrates.

In 2001 the UK based company Tertiary Minerals PLC started prospecting activity on the Gallujavri intrusion and have staked preclaims. See Tertiary's web site for more information. Their activities are also shortly reported in the SEG Newsletters No. 48 and 50.

11.3 Pasvik and South Pasvik reference list

Hodges, D.J. 1995: Nickel-copper exploration along the extension of the Pechenga Zone in Pasvik, Norway. NGU Special Publication Series 7, 373-374.

Hodges, D.J. & Green, A.H. 1993: Nickel - copper exploration along the extension of the Pechenga zone in Pasvik, Norway. (Abstract), First Barents Symposium. Kirkenes, October 1993.

Hudson, K.A., Melezhik, V.A. & Green, A.H. 1992: Potential for Pechenga-type Ni-Cu deposits in Pasvik, northern Norway. *In:* Foster, R.P. (ed.) Mineral deposit modelling in relation to crustal reservoirs of the ore-forming elements. Abstract volume. Inst. Mining and Metall. London, April 22-23, 1992, 3 pp.

Lieungh, B. 1985: Archean and Early Proterozoic rocks of the southern Pasvik and western Polmak parts of the Sørvaranger District. P. 27-35. *In:* Siedlecka, A., Krill, A., Often, M., Sandstad, J.S., Solli, A., Iversen, E & Lieungh, B. Lithostratigraphy and correlation of the Archean and Early Proterozoic rocks of Finnmarksvidda and Sørvaranger district. Norges geologiske undersøkelse Bulletin 403, 7-36.

Lieungh, B. 198…: Geologisk kartblad Krokfjellet, 1:50 000. Norges geologiske undersøkelse.

Marker, M. 1990: Tectonic interpretation and new crustal modelling along the POLAR Profile, northern Baltic Shield. Proceedings of the Sixth Workshop on the European Geotraverse (EGT) Project: data compilations and synoptic interpretation, Einsiedeln, 29 November - 5 December, 1989. European Science Foundation, 9-22.

Marker, M. 1985: Early Proterozoic (c. 2000-1900 Ma) crustal structure of the northeastern Baltic Shield: tectonic division and tectogenesis. Nor. geol. unders. Bulletin 403, 55-74.

Melezhik, V. & Often, M. 1996: The geology and ore deposits of the Pechenga Greenstone Belt. (Field trip guidebook) NGU-rapport 96.123, pp. 91.

Melezhik, V.A., Sturt, B.A., Mokrousov, V.A., Ramsay, D.M., Nilsson, L.P., Balashov, Y.A. 1995: The Early Proterozoic Pasvik-Pechenga Greenstone Belt: 1:200 000 geological map, stratigraphic correlation and revision of stratigraphic nomenclature. NGU Special Publication Series 7, 81-91.

Melezhik, V.A., Hudson-Edwards, K.A., Skufin, P.K. & Nilsson, L.P. 1994: Pechenga area, Russia – Part 1: geological setting and comparison with Pasvik, Norway. Transactions Institute Mining and Metallurgy, (Sect. B: Appl. Earth Sci.), 103, B129-B145.

Melezhik, V.A., Hudson-Edwards, K.A., Green, A.H. & Grinenko, L.N. 1994: Pechenga area, Russia – Part 2: nickel-copper deposits and related rocks. Transactions Institute Mining and Metallurgy, (Sect. B: Appl. Earth Sci.), 103, B146-B161.

Melezhik, V.A. & Sturt, B.A. 1994: General geology and evolutionary history of the early Proterozoic Polmak-Pasvik-Pechenga-Imandra/Varzuga-Ust'Ponoy Greenstone Belt in the northeastern Baltic Shield. Earth-Science Reviews 36, 205-241.

Melezhik, V., Nilsson, L.P. & Sturt, B:A. 1992: Geological correlation of the Pechenga and Pasvik zones. Norges geologiske undersøkelse Report 92.236, 82 pp. + map enclosure in scale 1:100 000.

11.4 Repparfjord references

Jensen, P.A. 1996: The Altenes and Repparfjord tectonic windows, Finnmark, northern Norway. Remnants of a Palaeoproterozoic Andean-type plate margin at the rim of the Baltic Shield. Dr. Scient. thesis, Univ. of Tromsø.

Nilsson, L.P. & Juve, G. 1979: En kjemisk-mineralogisk undersøkelse av ultramafiske bergarter I Komagfjordvinduet med henblikk på å bestemme eventuelle økonomiske konsentrasjoner av malmmineraler. NGU rapport 1682/1, 58 pp. + 9 sketch maps

Pharaoh, T. 1985: Volcanic and geochemical stratigraphy of the Nussir Group of Arctic Norway-an early Proterozoic greenstone suite. Journal of the Geological Society 142, 259-278.

Pharaoh, T.C., Ramsay, D.M. & Jansen, Ø. 1983: Stratigraphy and structure of the northern part of the Repparfjord - Komagfjord window, Finnmark, Northern Norway. Norges geologiske undersøkelse 377, 1-45.

Reitan, P.H. 1963: The geology of the Komagfjord tectonic window of the Raipas suite Finnmark, Norway. NGU 221, 71 p + 2 map enclosures.

Skaldebø, O.A. 1977: geologisk beskrivelse av 4 områder med ultrabasiske intrusivbergarter i Komagfjord tektoniske vindu i Vest-Finnmark. Intern rapport til Folldal Verk A/S.

11.5 Alteneset references

Fareth, E. 1979: Geology of the Altenes area, Alta-Kvænangen window, North Norway. Alteneset NGU Bulletin. NGU Bulletin 351, 13-29 + pl.

Jensen, P.A. 1996: The Altenes and Repparfjord tectonic windows, Finnmark, northern Norway. Remnants of a Palaeoproterozoic Andean-type plate margin at the rim of the Baltic Shield. Dr. Scient. thesis, Univ. of Tromsø.

Pratt, A. O. 1989: Petrology of differentiated gabbro sheets in the Altenes tectonic window, North Norway. Norges geologiske undersøkelse Bulletin 414, 21-35.

Pratt, A. & Nielsen, L. M. 1985: The geology of the Altenes Window and its correlation to the Alta-Kvænangen and Komagfjord-Repparfjord windows, Finnmark, Norway. NGU report 85.186, 57-60.

Pratt, A. & Nielsen, L. M. 1984: Geologisk kortlægning på Alteneset, og beskrivelse af de Cu, Fe og Ti-mineraliseringer og de intrusive bjergarter. NGU-rapport 84.072, 31 pp.

11.6 Alta-Kvænangen references

Bøe, P. & Gautier, A. M. 1978: Precambrian primary volcanic structures in the Alta-Kvænangen tectonic window, northern Norway. Norsk Geol. Tidsskr. 58, s 113-119.

Gautier, A. M., Bakke, I., Vik, E. og Zwaan, K. B. 1986: Berggrunnskart Flintfjellet 1834.4 M 1:50 000. Prelim. utgave, NGU.

Haug, T. 1990: Vulkanologisk-geokjemisk og stratigrafisk undersøkelse av den proterozoiske lagrekken fra Dorras i Kvænangen, Nord-Troms. Cand. Scient Thesis, University of Tromsø,

Zwaan, K. B. 1973: Berggrunnskart Nabar 1834.3, M 1:50 000. Prelim. utgave, NGU.

Zwaan, K. B. 1988: Geologisk kart over Norge, berggrunnskart Nordreisa, M 1:250 000. NGU.

11.7 Kautokeino references

Holmsen, P., Padget, P. & Pehkonen, E. 1957: The Precambrian geology of Vest-Finnmark, Northern Norway. NGU 201, 107p.

Olesen, O. & Sandstad, J.S. 1993: Interpretation of the Proterozoic Kautokeino Greenstone Belt, Finnmark, Norway from combined geophysical and geological data. Norges geologiske undersøkelse Bulletin 425, 42-62.

Olesen, O. & Solli, A. 1985: Geophysical and geological interpretation of regional structures within the Precambrian Kautokeino Greenstone Belt, Finnmark, North Norway. Norges geologiske undersøkelse Bulletin 403, 119-129.

Olsen, K.I. & Nilsen, K.S. 1985: Geology of the southern part of the Kautokeino Greenstone Belt: Rb-Sr geochronology and geochemistry of associated gneisses and late intrusions. NGU Bulletin 403, 131-160.

Siedlecka, A. 1987: Berggrunnskart 1934-2 Iesjavri M 1:50 000. NGU.

Zwaan, B. 1985: SUOLUVUOBMI, berggrunnsgeologisk kart 1934-3, 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

11.8 Caledonide references

Bennet, M.C. 1974: The emplacement of a high temperature peridotite in the Seiland province of the Scandinavian Caledonides. Journal of the Geological Society, 130, 205-228.

Føyn, S., Chapman, T.J. & Roberts, D. 1983: ADAMSFJORD, 2135-1 – berggrunnsgeologisk kart – M 1:50 000. Norges geologiske undersøkelse.

Gading, M. 1987: Sulfidmineralisering innen Lille Kufjord intrusjonen - geologiske, mineralogiske og petrogenetiske betraktninger. Cand. Real. Thesis, Geologisk inst. Avd. A, Univ. of Bergen.

Grenne, T., Ihlen, P. & Vokes, F.M. 1999: Scandinavian Caledonide metallogeny in a plate tectonic perspective. Mineralium Deposita 34, 422-471.
Notes on occurrences of Fe-Ti and Ni-Cu-PGE from the Seiland Igneous Province on p. 432

Oosterom, M.C. 1963: The ultramafites and layered gabbro sequences in the granulite facies rocks on Stjernøy, Finnmark, Norway. Leidse Geol. Medd. 28, 177-296.

Oosterom, M.G. 1956: Some notes on the Lille Kufjord layered gabbro, Seiland, Finnmark, Northern Norway. NGU 195, 73-88

Pedersen, R.-B., Dunning, G.R. and Robins, B. 1989: U-Pb ages of nepheline syenite pegmatites from the Seiland Magmatic Province, N. Norway. In: Gayer, R.A. (ed.): The Caledonide Geology of Scandinavia. Graham and Trotman, London. 3-8.

Roberts, D. 1973: Geologisk kart over Norge, berggrunnskart HAMMERFEST 1:250 000. Norges geologiske undersøkelse.

Roberts, D. 1981: Geologisk kart over Norge, berggrunnskart NORDKAPP 1:250 000. Norges geologiske undersøkelse.

Roberts, D. 1990: SKARSVÅG, berggrunnsgeologisk kart 2137-3 – 1:50 000, foreløpig utgave. Norges geologiske undersøkelse.

Roberts, D. 1998: Geologisk kart over Norge, berggrunnskart HONNINGSVÅG 1:250 000. Norges geologiske undersøkelse.

Robins, B. and Gardner, P.M. 1975: The magmatic evolution of the Seiland province, and Caledonian plate boundaries in northern Norway. Earth and Planetary Science Letters, 26, 167-178.

Robins, B. and Tysseland, M. 1979: Fenitization of some mafic igneous rocks in the Seiland province, northern Norway. Norsk Geologiske Tidsskrift, 59, 1-24.

Robins, B., Gading, M., Yrdakul, M. & Aitcheson, S.J. 1991: The origin of macrorhytmic units in the Lower Zone of the Lille Kufjord Intrusion, northern Norway. NGU Bulletin 420, 13-50.

Robins, Brian & Often, M. 1996: The Seiland Igneous Province, North Norway. Field Trip Guidebook, IGCP project 336. NGU Report 96.127.

Sturt, B.A. & Ramsay D. 1965: The alkaline complex of the Breivikbotn area, Sørøy, N. Norway. Norges geologiske undersøkelse Bulletin, 231, 1-142.

Sturt, B. A., Speedyman, D. & Griffin, W.L. 1980: The nodre Bumandsfjord Ultramafic Pluton, Seiland, North Norway. Part I. Field relations. Norges geologiske undersøkelse Bulletin, 358, 1-30.

Svensen, S. Å. 1990: Kvalfjordkomplekset, Stjernøy. Thesis, Univ. of Bergen.

Wanvik, J.E. 1991: Undersøkelse av Vadasbak'ti serpentin/brucitt – forekomst i Lebesby kommune, Finnmark. Norges geologiske undersøkelse, Rapport 89.108, 1-20.

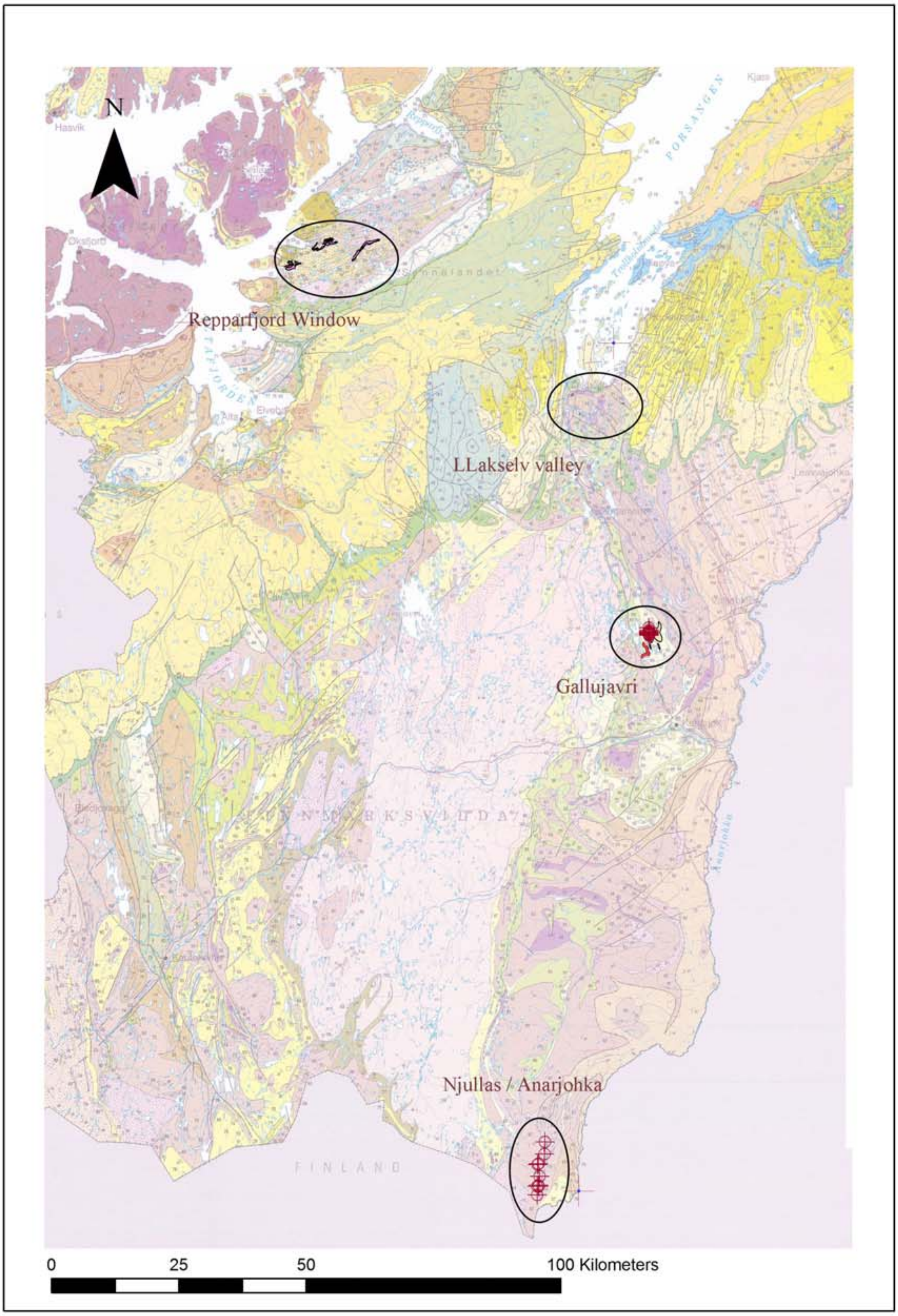

Figure 1: Localities in Western Finnmark

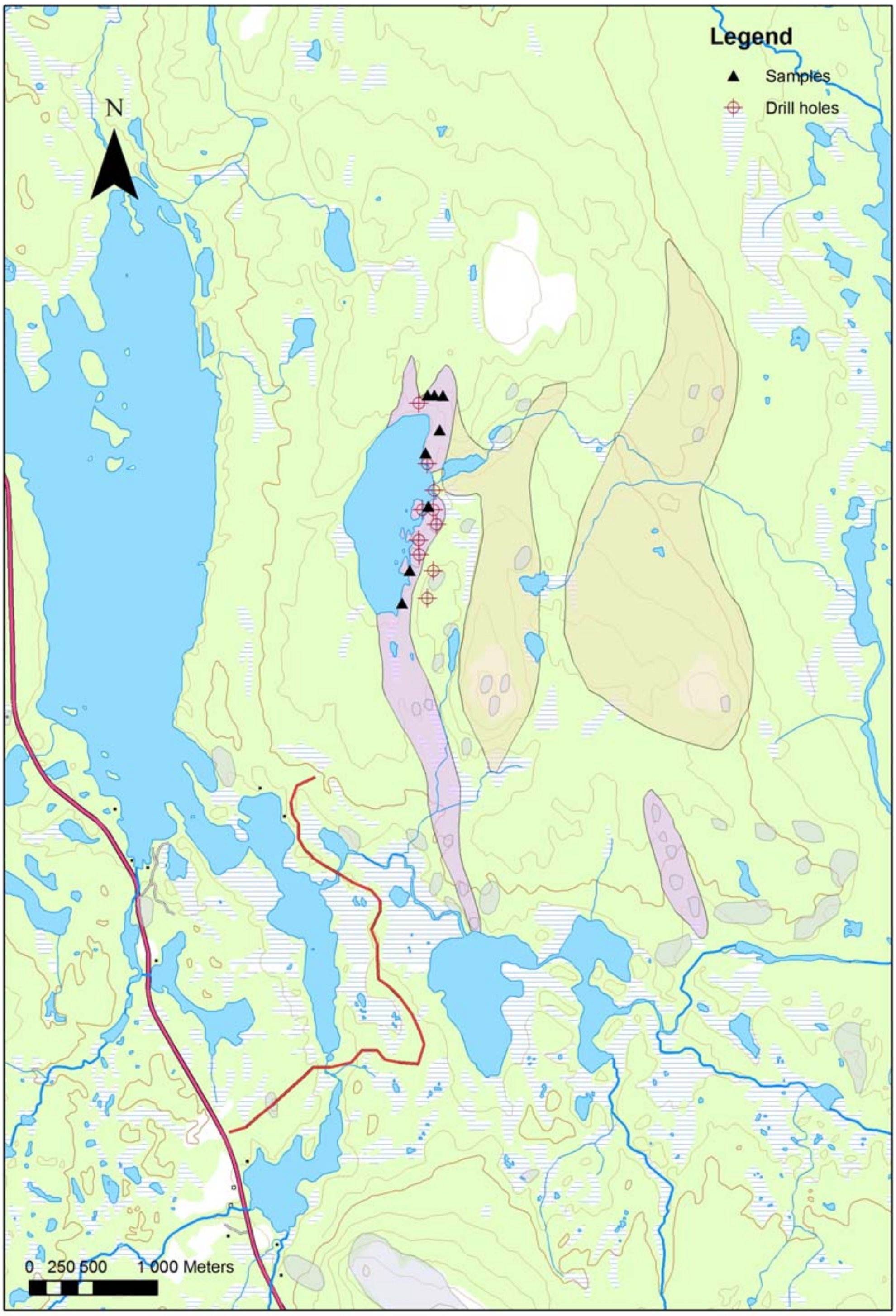

Figure 2: Gallujavri overview

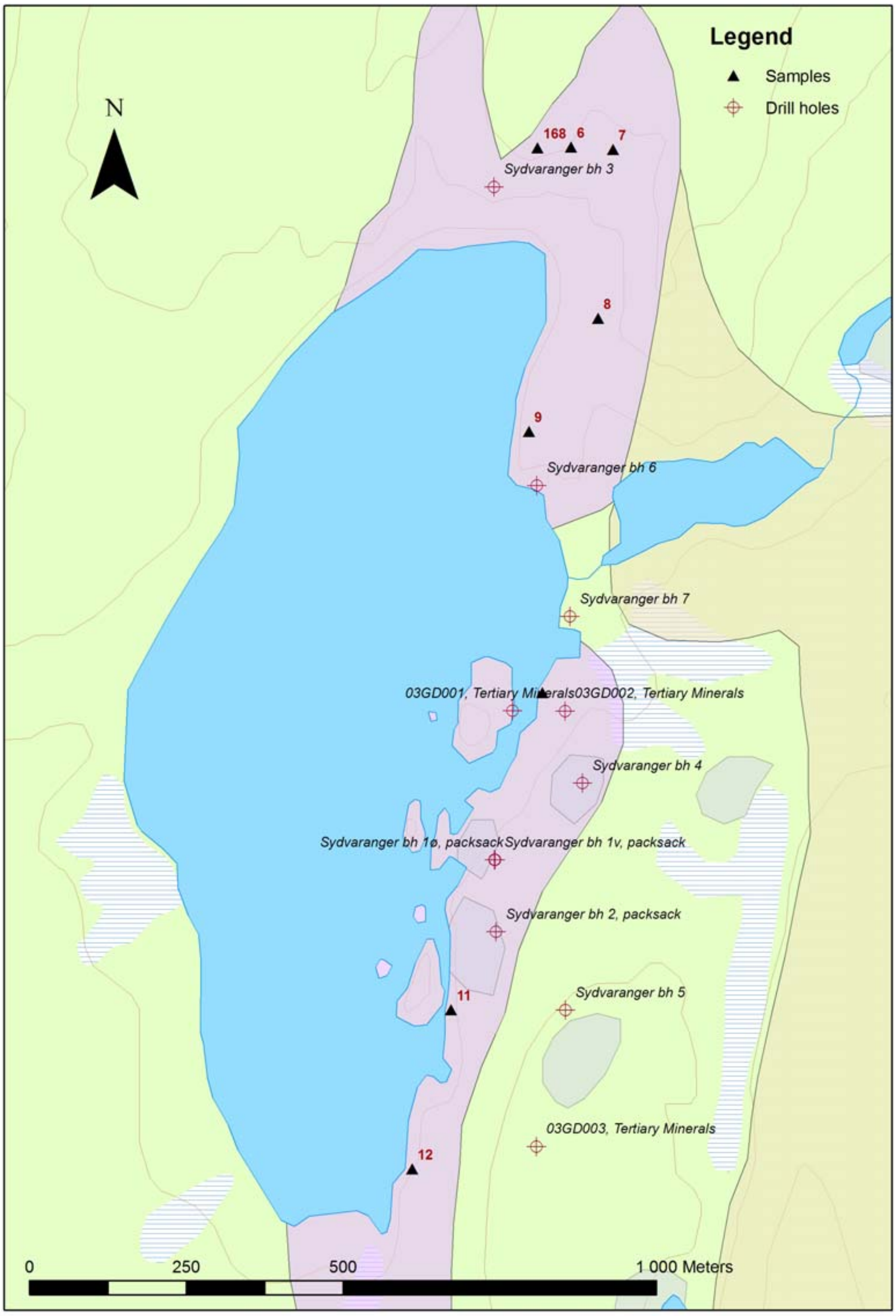

Figure 3: Gallujavri detail, with drill holes and samples as referred in the text.

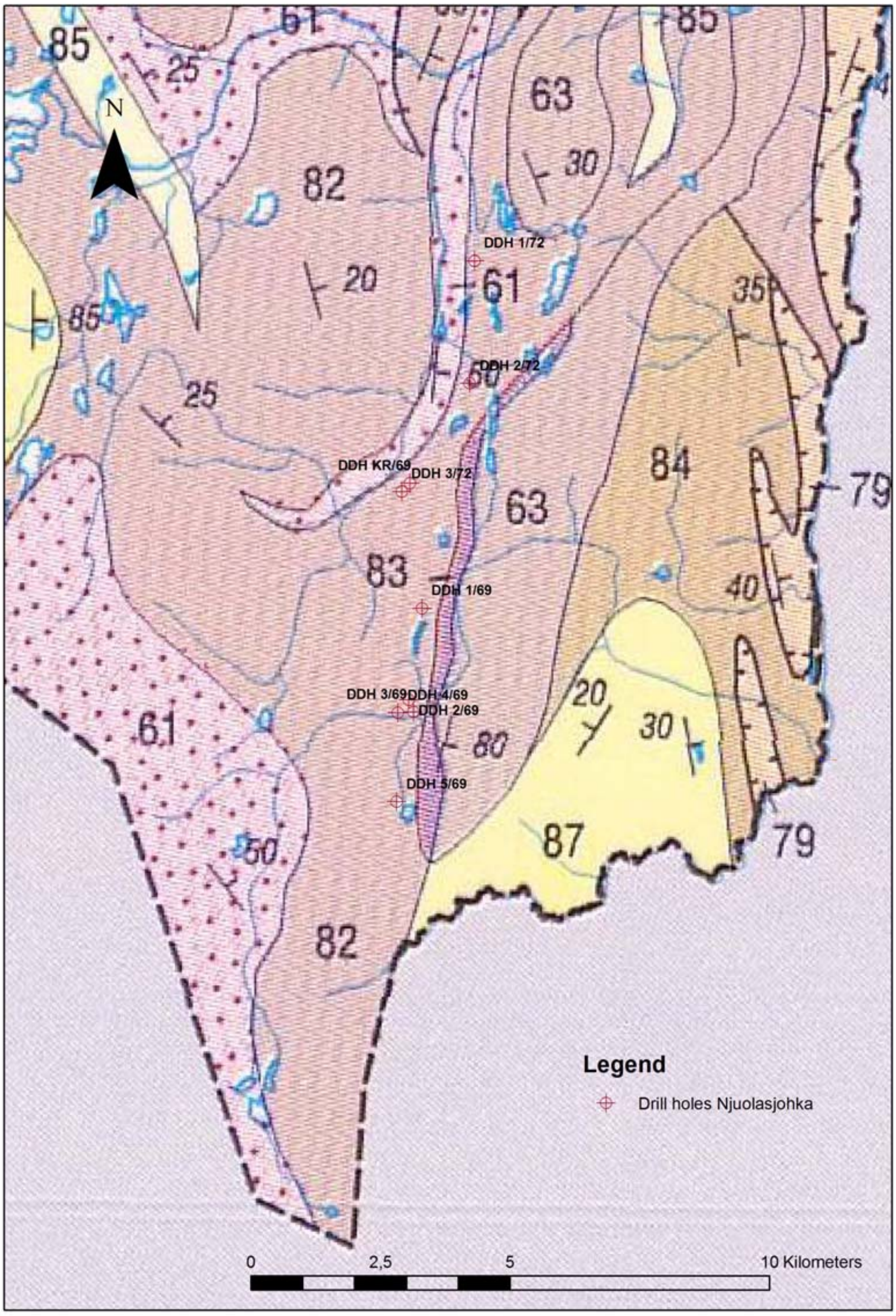

Figure 4: Anarjohka area, showing drill hole locations.

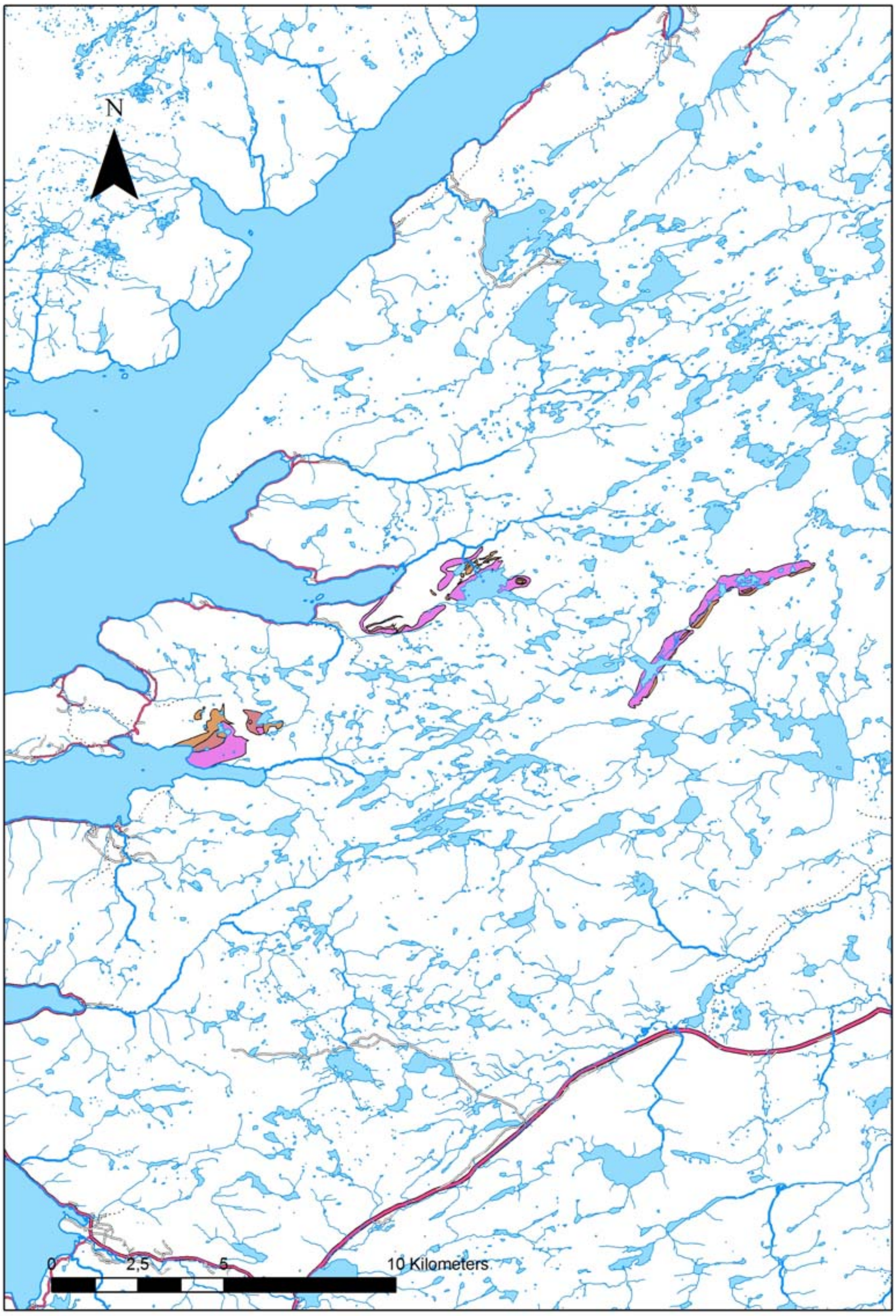

Figure 5: Described localities in Repparfjord tectonic window.

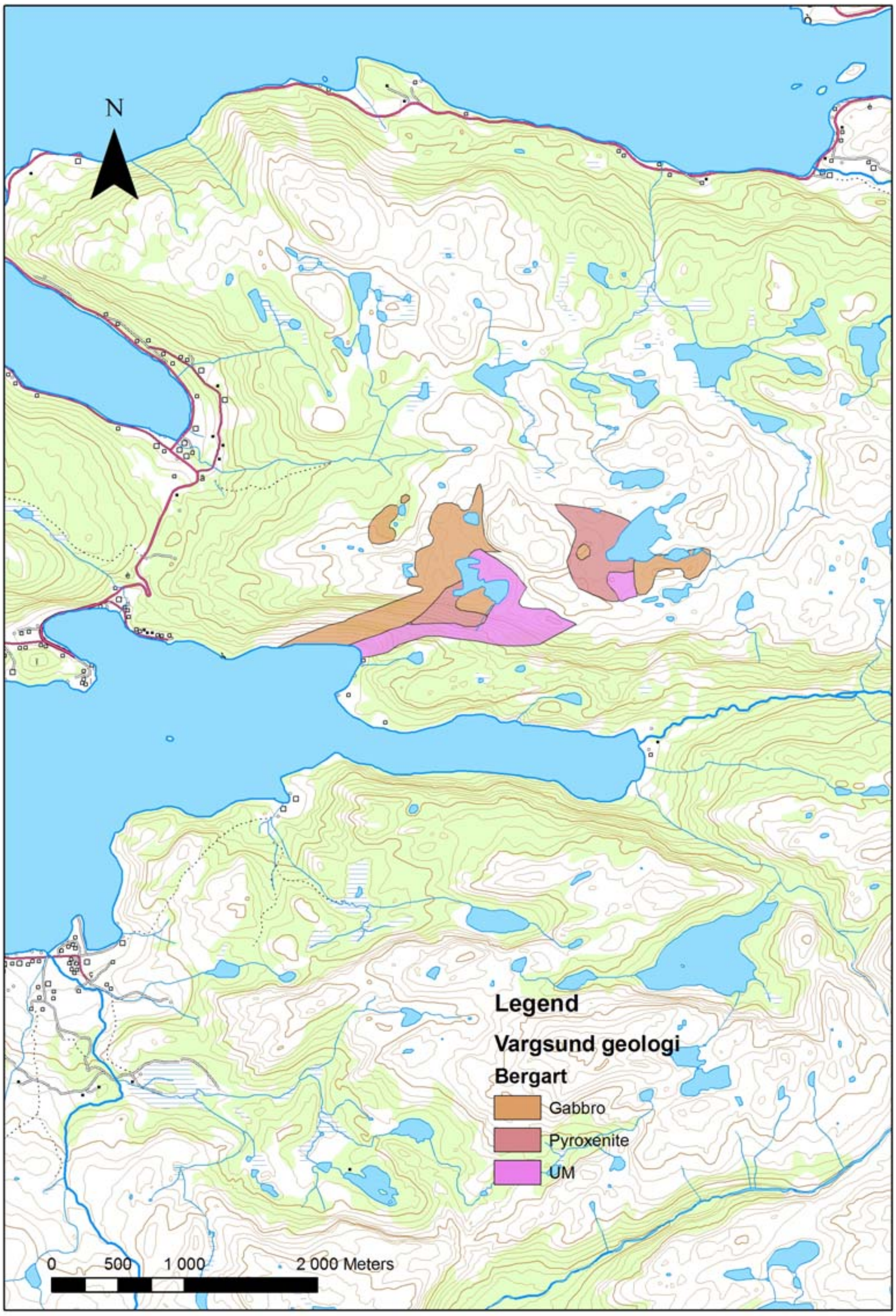

Figure 6: Mikalvatnan (Korsfjord) Complex

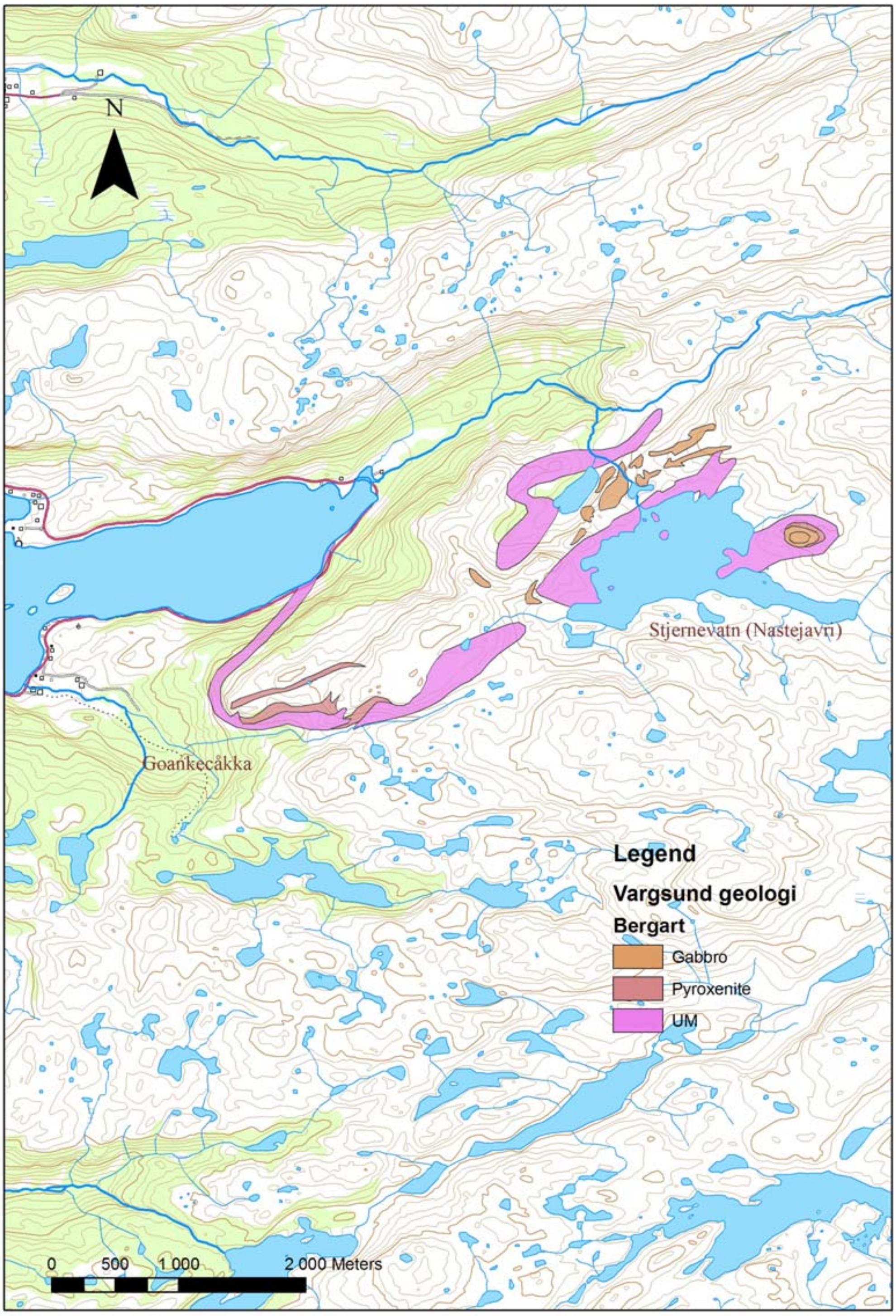

Figure 7: Goaŋkečåkka and Stjernevatn Complexes.

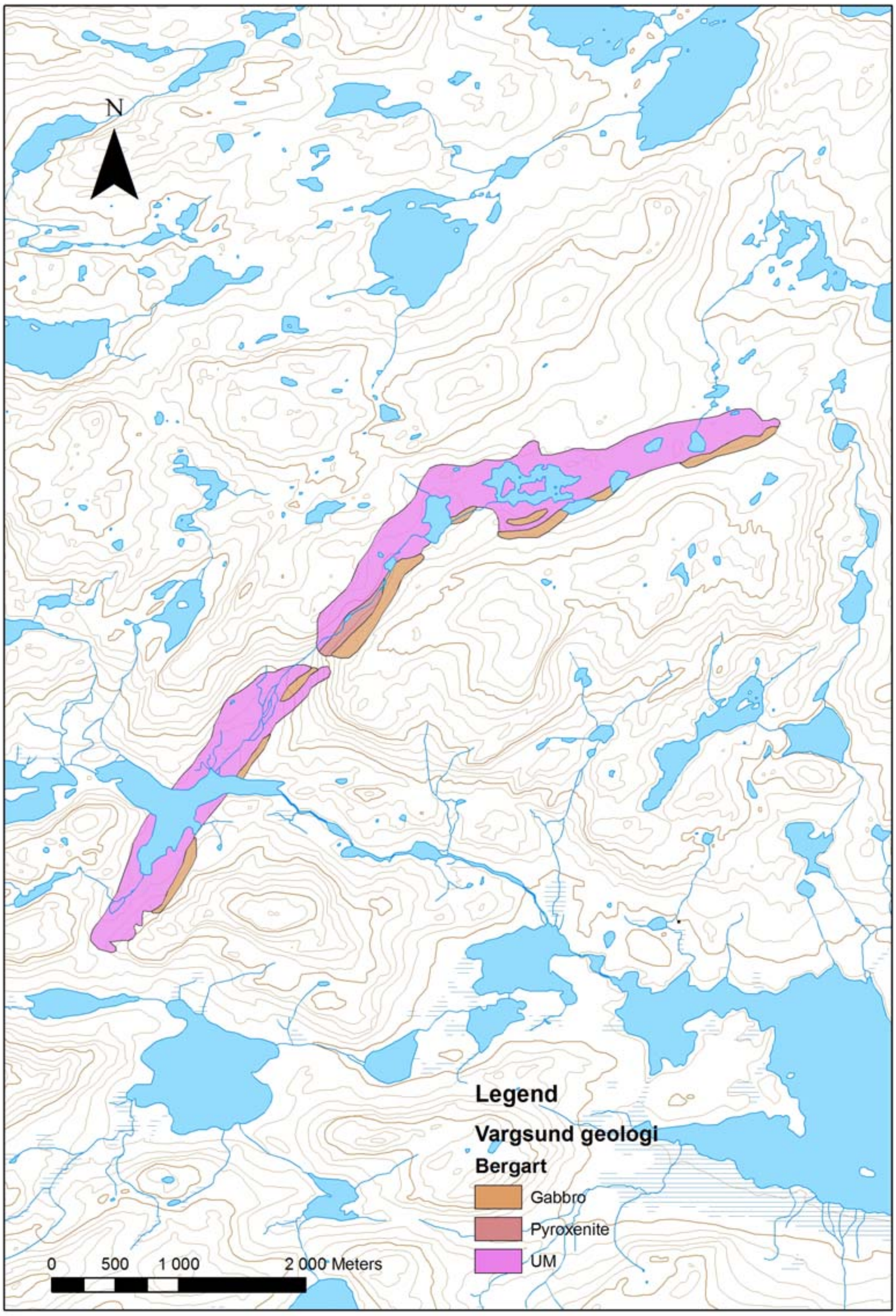

Figure 8: Fjellvatn Intrusion.

Figure 9: Location of Karenhaugen and Porsvann Cu-Pd-Pt deposits near Lakselv.