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Tittel

A Proposal for the Nikkel og Olivin Exploration Program, Phase 2 in 1998

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Bedrift (Oppdragsgiver og/eller oppdragstaker)

Outokumpu Mining for Ni & Ol

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Ballangen	Nordland		13311	Narvik

Fagområde

Geologi
Geofysikk
Geokjemi
Boring

Dokument type

Forekomster (forekomst, gruvefelt, undersøkelsesfelt)

Bruvannsfeltet
Råna
Arnes
Arneshesten
Rånabogen
Råntindvann

Råstoffgruppe

Malm/metall

Råstofftype

Ni, Cu

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Rapporten presenterer resultatene fra prospektering i 1996-97 når det gjelder litogeokjemi, imag. prosess og tolkning av geofysiske bakke/luftmålinger.
Det utrykkes usikkerhet om det fortsatt skal letes etter tilleggsmalm for gruven. Kommentar på at Nordlandsbanken har bakket ut og at NHD ikke støtter med midler.
Det blir benyttet litogeokjemiske kriterier til å vurdere bergartspakken. 8 objekter er prioritert i fase 2.

Vedlagt geologisk kart over måleområdene i Rånabogen og borområder fra gruva.

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A PROPOSAL FOR THE NIKKEL OG OLIVIN AS EXPLORATION PROGRAM, PHASE 2 IN 1998

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Outokumpu 16.1.1998

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BASE METALS
BUSINESS AREA

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TABLE OF CONTENTS

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BASE METALS
BUSINESS AREA

1. SUMMARY

The results from the Nikkel og Olivin AS Exploration project phase 1 of years 1996-97 are presented. The latest results are from the fields of lithogeochemistry and image processing and interpretation of ground and aerogeophysical data.

For continuation of the project in phase 2 eight targets have been proposed: SW Bruvann, Rikmalmen, Arnes, Arneshesten, Råna, Rånbogen, Brudalen and Råntindvann. The exploration program, budget and schedule is presented.

2. GENERAL

The area to be investigated is delimited to comprise the north-western segment of the Råna intrusion, which covers the highest concentration of ultramafic rocks, from Bruvann in the west to Rånbogen in the east. The grounds are quite natural: the existing dressing plant and other infrastructure, accessibility, current geological intrusion model and known occurrencies of sulfides all favor the delimitation. In retrospect, even this area was large with respect to the duration and budget of phase 1 of the Project.

The background of the Project, the Project team, previous work in the area, bibliography and the exploration methods used have been dealt with in detail in ***The Nikkel og Olivin AS - Exploration Project; Interim Report on Exploration during 1996-1997,*** released in May 1997 by the team, and won't be repeated here.

In summer 1997 the digital helicopter survey data was image processed to produce various multicomponent derivative maps in order to enhance the geology (Jussi Aarnisalo).

In the previous studies the exploration methods have been limited to the use of geological mapping, ground geophysics and drilling. No model for the genesis of the Ni-Cu ore has been presented.

The Project (phase 1) was finished in October 1997, clearly unaccomplished regarding the size of the area and number of targets potential for nickel that should be studied. Drilling concentrated on the immediate vicinity of the mine, and the long drillholes required consumed the budget rapidly.

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BASE METALS
BUSINESS AREA

There is uncertainty about whether to continue with exploration to find additional ore reserves for the exhausting mine. The withdrawal of Nordlandsbanken from financing, and the decision by the Norwegian Ministry of Trade and Commerce not to support the activity have cast shadows over the expectations to continue the unfinished work.

3. TARGET SELECTION AND PRIORITIZATION

Within the selected area eight of the most attractive targets have been named. These have been given priorities according to their rated likelihood of becoming mineable orebodies. High priority is not only a function of expected grade and quantity, but is also affected by verified occurrence of sulfides in favorable host rocks, as well as by location in relation to the existing infrastructure.

Priority 1 is given to the two targets close to the mine, SW Bruvann and Rikmalmen. The proximity can be utilized in both diamond drilling and potential mining. Both targets are believed to be genetically related to the Bruvann deposit.

Arnes and Arneshesten are rated as **priority 2a** targets. The Arneshesten target is seen to be a repetition of the Bruvann ultramafics to the east by faulting. Arnes represents the most primitive ultramafic magma encountered in the Råna intrusion. The more elevated parts can easily be connected to the dressing plant with a 3 km long access road.

Priority 2b targets Råna and Rånbogen do not seem to differ much from Arnes, hence 2b. They are not as well studied and are located further away from the plant.

The final two classified targets, Brudalen and Råntindvann, are rated as **priority 3.** They are hard to access, mainly geophysically attractive targets with no sample database.

4. EXPLORATION PHASE 1 WORK AND RESULTS

4.1. SW Bruvann

Seven of the nine holes drilled in 1996 met ultramafics (App.1.). The two which didn't (P-1, 207 m and P-2, 189 m) would probably have done so if they had been made deeper, but they were stopped after they passed the target anomaly. The main ultramafic pile was encountered about 200 m (or appr. at Z=-200) below surface under a gneiss blanket. All holes were finished above the sea level Z=0).

It is obvious, that at Bruvann the either originally or through early nappe movements rather flat-lying ultramafics have been broken up by later subvertical faults or shear

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BASE METALS
BUSINESS AREA

zones into blocks, where the primitive magmatic fractionates with associated orebodies are relocated at different levels in relation to each other. This situation proven between the Øst- and Vestmalmen orebodies is anticipated to stand between the Vestmalmen and the assumed SW Bruvann orebody as well, inferred from:

- the E-W fault/syncline zone along the N shore of Lake Bruvann proven roughly by earlier drilling, mapping and geophysics
- the geochemical similarity (unprimitivity) of the intersected ultramafics at SW Bruvann with those lying above the Vestmalmen orebody.

When comparing the thickness of ultramafics above the ore horizon in Vestmalmen with that in SW Bruvann it seems that the ore-bearing horizon lies beneath the reach of the holes drilled so far, at an estimated 50 m below sea level.

4.2. Rikmalmen

This is interpreted by down hole Protem survey in holes P-11 and P-13 to be a small massive orebody situated close to the Elefantmalmen orebody just above level -200. The narrow massive intersections in holes P-17 and PG-1 support the interpretation.

4.3. Arnes

Arnes is a large zoned ultramafic block in the NW corner of the intrusion (App.2.). Geological mapping and the relogging of the old NGU drillhole BH-345-400 which cuts across the ultramafic pile have clarified its structure and provided an extensive geochemical database. The independently made aeromag profile interpretation is reasonably supported by the drillhole geology.

The Arnes block is considered to have potential by virtue of

- its volume of ultramafics
- the anomalous contents of Ni, MgO, MnO, V_2O_5, graphite and trace elements
- geophysical analogy with the Bruvann block
- its location at or near the intrusion channel according to regional gravimetry

4.4. Arneshesten

Arneshesten is a small peridotite body on the NE extension of the Østmalmen orebody at an elevation of ca. 650 m (App. 1.). Sulfides were recorded in mapping by NGU, and there is a ground magnetic anomaly equal to Bruvann on the target. The body was mapped in detail and sampled in summer 1997. One aim of the mapping, to find more evidence of faulting, didn't bring anything new to the NGU work. On their map the more or less N-S trending faults and thrusts are located

between the Østmalmen and the Arneshesten target, as well as between that and the more intense anomaly to the east.

4.5. Råna

The target was mapped and sampled in summer 1997 (App.2.). The vertical NGU drillhole on the N side of the regionally strong (bullseye) aeromag anomaly was relogged and sampled. Ultramafics are scarce on the surface, but are expected to abound at shallow depth.

The regional gravimetric anomaly high indicates the intrusion channel being in the area and plunging towards NW beneath the Ofoten fjord.

4.6. Rånbogen

The target (App. 3.) was elevated in ranking recently, when it turned out to be geophysically analogous with the Bruvann, Arnes and Råna blocks in the image processed derivative aeromagnetic maps. The nearest parts of the target are a few hundred meters away from the E6 highway.

Two holes (645-413 B/456.1 m and 645-413C/207.4 m) were drilled by NGU at the same spot and azimuth (215 deg) but with differing inclinations (45 and 60 deg) in a sulfidic zone. The holes have never been logged, but were found incomplete at NGU/Løkken. NGU has also made three test pits in the same zone. Reportedly the sulfide Ni content is low.

The occurrence of several ultramafic lenses with disseminated primary and semimassive epigenetic sulfides mapped by NGU was confirmed in detailed mapping and sampling in autumn 1997. A couple of samples rich in sulfide returned assays with over 1% Ni. Most of the area was mapped before heavy snowfall set in.

4.7. Brudalen

The target is mainly represented in ground geophysics. There is a subtle chain of magnetic and EM anomalies appr. 500m in length starting from the SE corner of Lake Bruvann and fanning out to the east. The zone also comes out in the gravimetric survey of 1997. The roughly E-W oriented anomalies seem to originate from below a blanket of gneisses having schistosities dissimilar to the strike of the zone.

4.8. Råntindvann

The target is the easternmost Bruvann-analogy on the image processed derivative map of the airborne geophysical survey. The anomaly originates from an oval 450 by 160 m peridotite body mapped by NGU. There is no record of sulfides in their report.

The altitude is about 500 m asl. The distance from the nearest road - highway E6 - is over 3 km as the crow flies.

5. UTILIZATION OF GEOCHEMICAL AND MINERALOGICAL DATA

The extensive data collected during the project mainly for the GeoNickel WP 1 -project is available in graphic form in "Figures to summarize the lithogeochemical and mineralogical features of Ni exploration targets in the Råna intrusion: Arnes, Arneshesten,Bruvann, Bruvann SW, Råna and Rånbogen."

5.1. BRUVANN

The features associated with Ni ores at Bruvann are according to the GeoNickel results as follows:

- The ores are located stratigraphically some 100-300 meters above the basal contact
- The ore is located in a ca. 500 m thick cumulate sequence, which comprises cyclic units of the following cumulates: olivine cumulate, olivine-orthopyroxene cumulate, orthopyroxene cumulate, orthopyroxene plagioclase cumulate, and plagioclase orthopyroxene cumulate
- Two ore types exist: 1) Disseminated ore and 2) (semi)massive ore

- The **disseminated ore** is hosted by olivine cumulate, which is

* relatively thick
* the most primitive one with a forsterite content of ca. 82%

- **The (semi)massive ore**

* is hosted by orthopyroxene cumulate (pyroxenite), orthopyroxene-plagioclase cumulate (norite) or hybridic rock containing crustal fragments
* shows clearly contamination features by country rocks

Both ore types show clear contamination features, and the evidence comes from the following observations:

- presence of gneiss and black schist inclusions and xenoliths in or close to the ore
- graphite in massive ore
- anomalous high lithophile element contents adjacent to the ore

The high V content and presence of graphite refers to black schist contamination. A preliminary conclusion is that the black schist contamination has increased especially SiO2 and S contents of the magma, which have caused

1) the crystallization series to drift to olivine-orthopyroxene-plagioclase route instead of olivine-clinopyroxene-orthopyroxene series, and

2) sulfide oversaturation and segregation.

5.2 COMPARISON OF EXPLORATION TARGETS WITH BRUVANN

Next the exploration targets are compared by the following petrological key features determined on the basis of lithogeochemical and mineralogical data:

- primitivity of the magma,
- crystallization series,
- contamination features,
- sulfide segregation features,
- openness of the magmatic system.

The number of samples studied per target is

TARGET	*n*		
Bruvann	226		
Bruvann SW	179		
Arnes	125		
Arneshesten	29		
Råna	15	TOTAL	574

Primitivity of the magma

According to magma primitivity the targets can be put in the following favourableness order:

Target	*Max MgO_n%*	*Max Fo% of ol, interpreted (calculated)*	*Ni of olivine max Fo (calculated)*
Arnes	**43.9**	**89 (85.0)**	**250**

N-8540 Ballangen, Norway

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BASE METALS
BUSINESS AREA

Bruvann	**41.5**	**87 (83.0)**	**900**
Rånbogen	**40.2**	**87 (83.0)**	**400**
Bruvann SW	**37.2**	**85 (81.0)**	**900**
Råna	**37.0**	**85 (81.0)**	**800**
Arneshesten	**38.6**	**83 (79.5)**	**400**

Crystallization series

The favorable crystallization series is according to Bruvann ol-opx-pl.

Target	*Favorable series*	*max ol in oC*	*max opx in bC*	*Thickness of thickest bC*
Arnes	**Yes**	**oAC (93%)**	**bMC (88%)**	**Thick**
Bruvann	**Yes**	**oAC (93%)**	**bMC (76%)**	**Thick**
Rånbogen	**Yes**	**oMC (81%)**	**bMC (62%)**	**??**
Arneshesten	**Yes**	**oMC (78%)**	**bMC (77%)**	**??**
Bruvann SW	**Yes**	**oOC (70%)**	**bOC (70%)**	**Lacking?**
Råna	**Yes**	**oOC (72%)**	**obC (40%)**	**Lacking?**

Bruvann is the only target where the MCUII with crystallization series ol-cpx-opx-pl was detected. At Arnes a specific baC cumulate has been encountered.

Contamination features

Crustal contamination is the most important process leading to the ore formation. At Bruvann the favorable contaminant has been sulfur bearing graphite schist. The black schist is relatively rich in V, and therefore the contamination will increase the V content of the magma, and the cumulates thereafter will be richer in vanadium. A normal gneiss or calc-silicate rock is rich in lithophile elements. Especially increased zirconium and yttrium contents will be reflected also in the cumulates thereafter.

Arnes is as a whole anomalously rich in vanadium, which may indicate a high amount of contaminated black schist. Bruvann SW is anomalously rich in zirconium, yttrium, titanium and also potassium. This indicates, that the magma has assimilated crustal material, but no black schist.

The following table summarizes the contamination features of each target.

Target	*Black schist contamination*	*Evidences*	*Other crustal contamination*	*Evidences*
Arnes	**Yes**	**Graphite, high V (n=42)**	**Weak**	**high Y in some samples**
Bruvann	**Yes**	**Graphite, high V (n=12)**	**?**	
Rånbogen	**Probably**	**high V (n=3)**	**?**	
Arneshesten	**Probably**	**high V (n=6)**	**?**	
Bruvann	**Possibly**	**high V (n=1)**	**Clear, strong?**	**high Zr, Ti, Y,**

SW			
Råna	No?	-	?

Olivine cumulates adjacent to Ni ores are anomalously rich in manganese at Bruvann. Rånbogen is in general rich in manganese, but the most primitive olivine cumulate is not anomalously rich in Mn. Especially manganese rich olivine cumulates are also encountered at Arnes and Arneshesten.

Sulfide segregation features

Segregation of sulfides will deplete magma in chalcophile elements. In the Råna intrusion this is not very clearly visible, because of replenishment of the system by a new pulse of magma (which normalizes the composition of magma with respect to chalcophile elements).

Ni depletion is visible in most of the studied Bruvann drillholes, but usually it extends stratigraphically only a few tens of meters above the ore.

Target	*Olivine Fo-Ni figure*	*Conclusion*
Arnes	**Scattered**	**Highly prospective**
Bruvann	**Scattered**	**Ore features**
Rånbogen	**Uniformly**	**Depleted**
Arneshesten	**Scattered**	
Bruvann SW	**Coherent**	**Slightly depleted**
Råna	**Coherent**	

Openness of the system

The presence of one-mineral adcumulates is evidence of a flowing system, where the intercumulus liquid has constantly been removed by flowing magma.

Target	*max ol in oC*	*Thickness of thickest oAC or oMC*	*max opx in bC*	*Thickness of thickest bMC*
Arnes	**oAC (93%)**	**??**	**bMC (88%)**	**Thick**
Bruvann	**oAC (93%)**	**Thick**	**bMC (76%)**	**Thick**
Rånbogen	**oMC (81%)**	**??**	**bMC (62%)**	**??**
Arneshesten	**oMC (78%)**	**Thin**	**bMC (77%)**	**??**
Bruvann SW	**oOC (70%)**	**Thin**	**bOC (70%)**	**??**
Råna	**oOC (72%)**	**Thin**	**obC (40%)**	**??**

6. PLAN FOR EXPLORATION PHASE 2

For the time being, drilling contractors have only been contacted with inquiries about their capability of doing the underground job in the SW Bruvann target. In other cases the inquiries will be included in the invitation of bids, after the program in phase 2 has been approved by the management.

6.1. SW Bruvann

The area below the sea level is best investigated by drilling from a drift in Vestmalmen, currently the one to the Dinosaur orebody at Z=-80. Two holes, each 400 m long, are considered sufficient for testing the area (App. 4.-6.).

The alternative, drilling from the surface would call for holes some 550 to 600 m long. These would cut through at least 350 m of gneisses on top of the ultramafics.

6.2. Rikmalmen

Two drillholes from the new access drift at Z=-220 to Elefantmalmen, both about 100 m in length, are needed to check this target.

6.3. Arnes

The irregularity of the surface geology is to be expected also down-dip, despite the overall seemingly uniform layering in the aeromag profile interpretation. The NGU hole cuts the lower ultramafics at a depth of some 400 m below the surface, or ca. 500 m along dip. Therefore, a couple of shorter holes should be drilled closer to the south contact where the geochemical anomalies indicate ore potential. Two 250 m holes are needed to start with.

The drillsite elevation is 300-350 m, and helicopter transportation is necessary due to steep terrain. The drilling would be best performed in summertime.

6.4. Arneshesten

The target could be drilled either from the existing road on the mountainside or from a location higher up. In the former case a bulldozer is needed to clear the road and prepare the drillsite. In the latter case helicopter transportation is needed. In both alternatives summer would suit best for the work.

Drilling from the road requires two 250 m holes with slightly upward inclination. An underground rig with an aggregate could do the job.

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BUSINESS AREA

N-8540 Ballangen, Norway

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In the mountainside alternative finding a level site for the rig is problematic. On the other hand some saving would be achieved in drill meters.

6.5. Råna

One 400 m hole is proposed to be drilled from the same spot as the old BH-475-447. A reservation is made for another hole (helicopter?) pending results from the first.

6.6. Rånbogen

The NGU drillholes were drilled away from the "Bruvann-type" anomaly in order to test a zone of epigenetic sulfides.

Without knowing the terrain in detail a 400 m hole is proposed to be drilled from point Y=6650E/X=4500N at an altitude of 75 m asl with a southerly azimuth and 50 degree's inclination. It is possible that helicopter transportation is required, in which case the point of time should be scheduled to match with other similar targets.

6.7. Brudalen

One drillhole is needed to test the westernmost part of the target: Y=2700, X= 700, northerly azimuth, inclination 50 deg. Further program depends on the results.

6.8. Råntindvann

The potential of the ultramafic body should first be evaluated by light methods, detailed mapping, ground geophysics etc.

6.9. Others

There is a pronounced well-defined N-S-trending aeromag anomaly some 200 meters east of the Arneshesten target, on top of the Arneshesten fjeld. This is part of the east side of the over three km long rectangular N-S -trending aeromag anomaly ranging from Arnes in the north to the east side of Lake Bruvann. Only a small peridotite/pyroxenite body has been recorded in previous mapping.

The old NGU holes in the area were directed past the anomaly. Because it now on the basis of aeromagnetics seems that the entire huge rectangle originates from ultramafics covered more or less by norites, this part which is nearest the mine deserves attention. It is proposed that this target is kept in reserve while waiting for drilling results from Arneshesten.

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7. BUDGET

The following is a budget proposal for exploration phase 2. The duration is slated til the end of September 1998. Operating and administrative costs are included.

SW Bruvann: Two 400 m holes, NOK 500/m. Down hole geophysics. Assays.
Rikmalmen: Two 100 m holes, NOK 350/m. Assays.
Arnes: Two 250 m holes, down hole geophysics. Helicopter. Assays.
Arneshesten: Two 250 m holes, downhole geophysics. Assays.
Råna: One 400 m hole, downhole geophysics. Assays.
Rånbogen: One 400 m hole, downhole geoph. Helicopter(?). Assays.
Brudalen: One 400 m hole, downhole geoph. Helicopter. Assays.
Råntindvann: Mapping. Ground geophysics(?). Assays.
Others: Ground geophysics, profile interpretations. Mapping. Assays.

TARGET	DRILLING	GEOPHYSICS	ANALYSES	MAPPING	HELICOPTER	TOTAL
SW Bruvann	400 000	20 000	25 000	0	0	445 000
Rikmalmen	70 000	5 000	5 000	0	0	80 000
Arnes	250 000	15 000	20 000	0	30 000	315 000
Arneshesten	250 000	15 000	15 000	0	0	280 000
Råna	200 000	10 000	15 000	0	0	225 000
Rånbogen	200 000	15 000	15 000	10 000	30 000	270 000
Brudalen	200 000	15 000	10 000	0	30 000	255 000
Råntindvann	0	15 000	15 000	15 000	0	45 000
Others	0	15 000	5 000	10 000	0	30 000
Contingencies	150 000	20 000	30 000	0	20 000	220 000
TOTAL	1 720 000	145 000	155 000	35 000	110 000	2 165 000
Geology and administration						750 000
GRAND TOTAL						2 915 000

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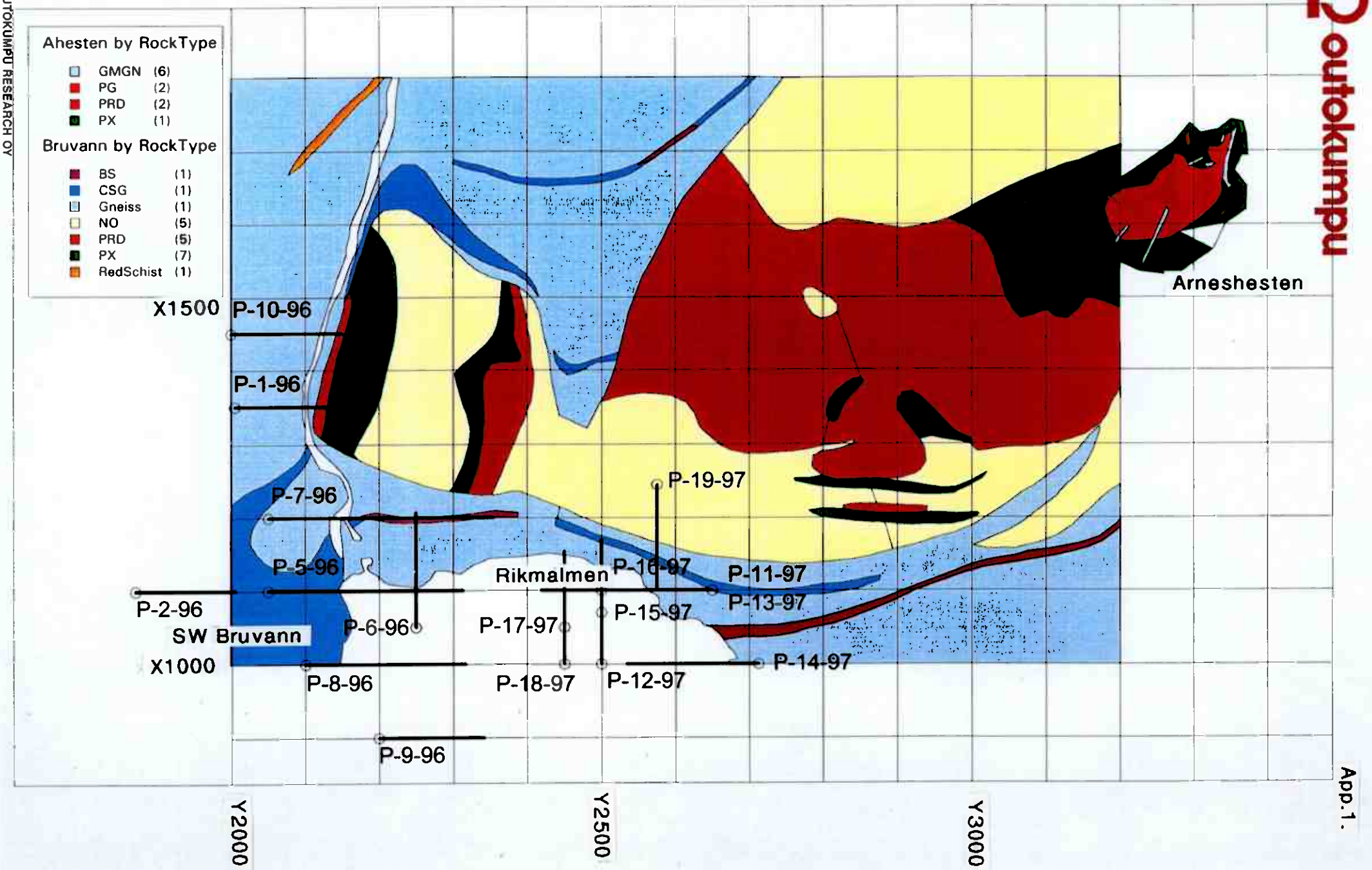

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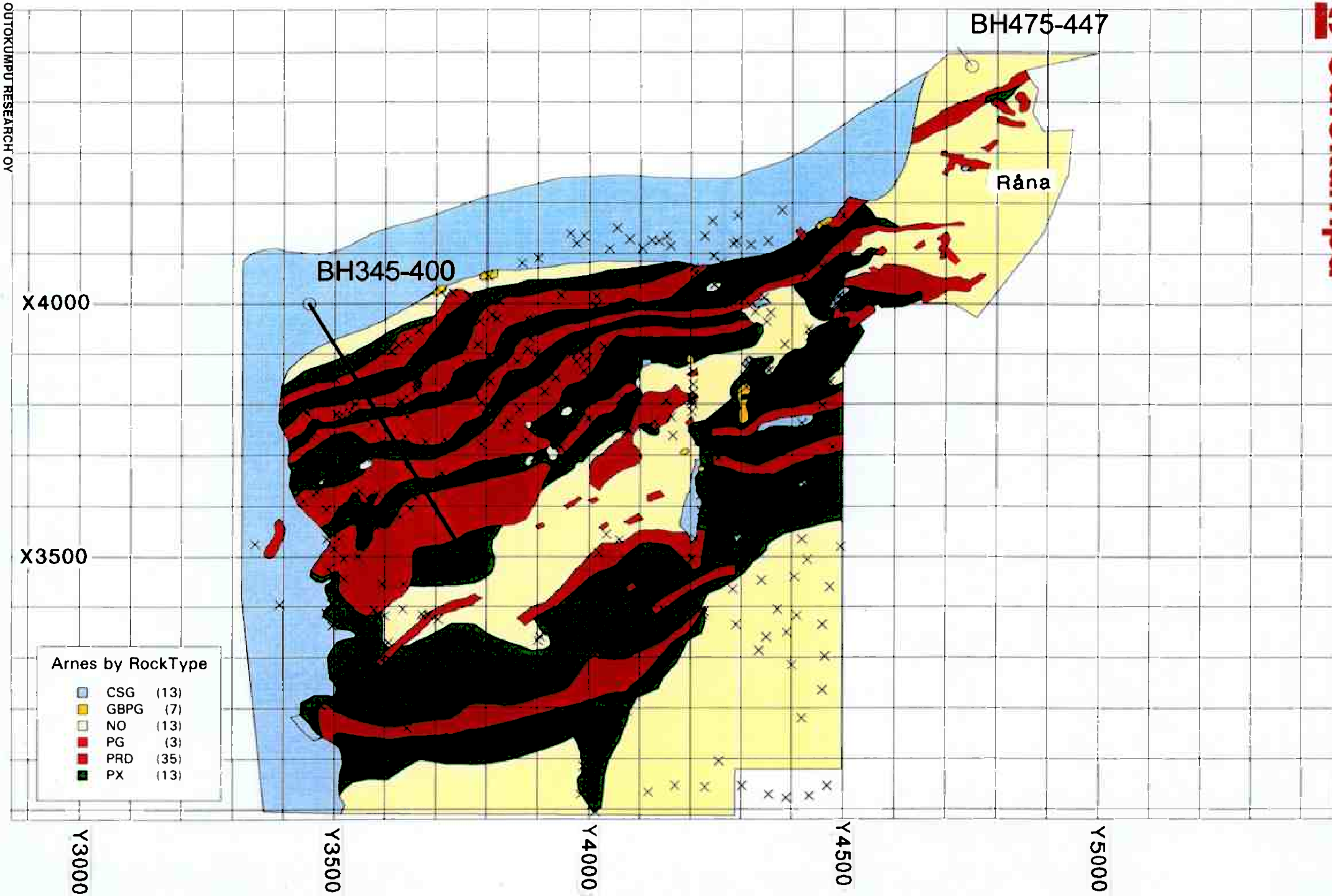
App.1.



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App. 2.

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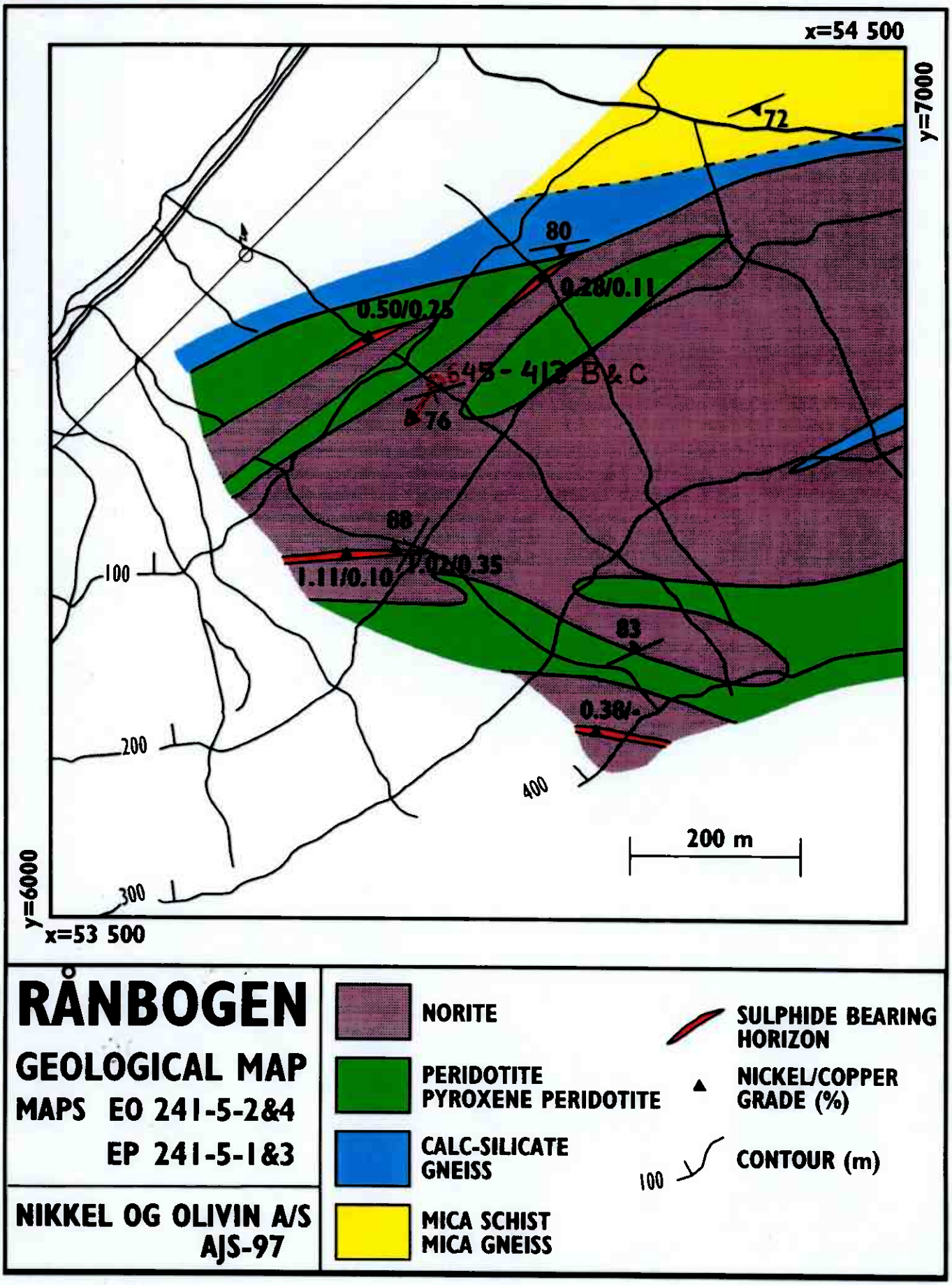

RÅNBOGEN

GEOLOGICAL MAP

MAPS EO 241-5-2&4

EP 241-5-1&3

NIKKEL OG OLIVIN A/S

AJS-97

NORITE

PERIDOTITE
PYROXENE PERIDOTITE

CALC-SILICATE GNEISS

MICA SCHIST
MICA GNEISS

SULPHIDE BEARING HORIZON

NICKEL/COPPER GRADE (%)

100 CONTOUR (m)

11.12.97
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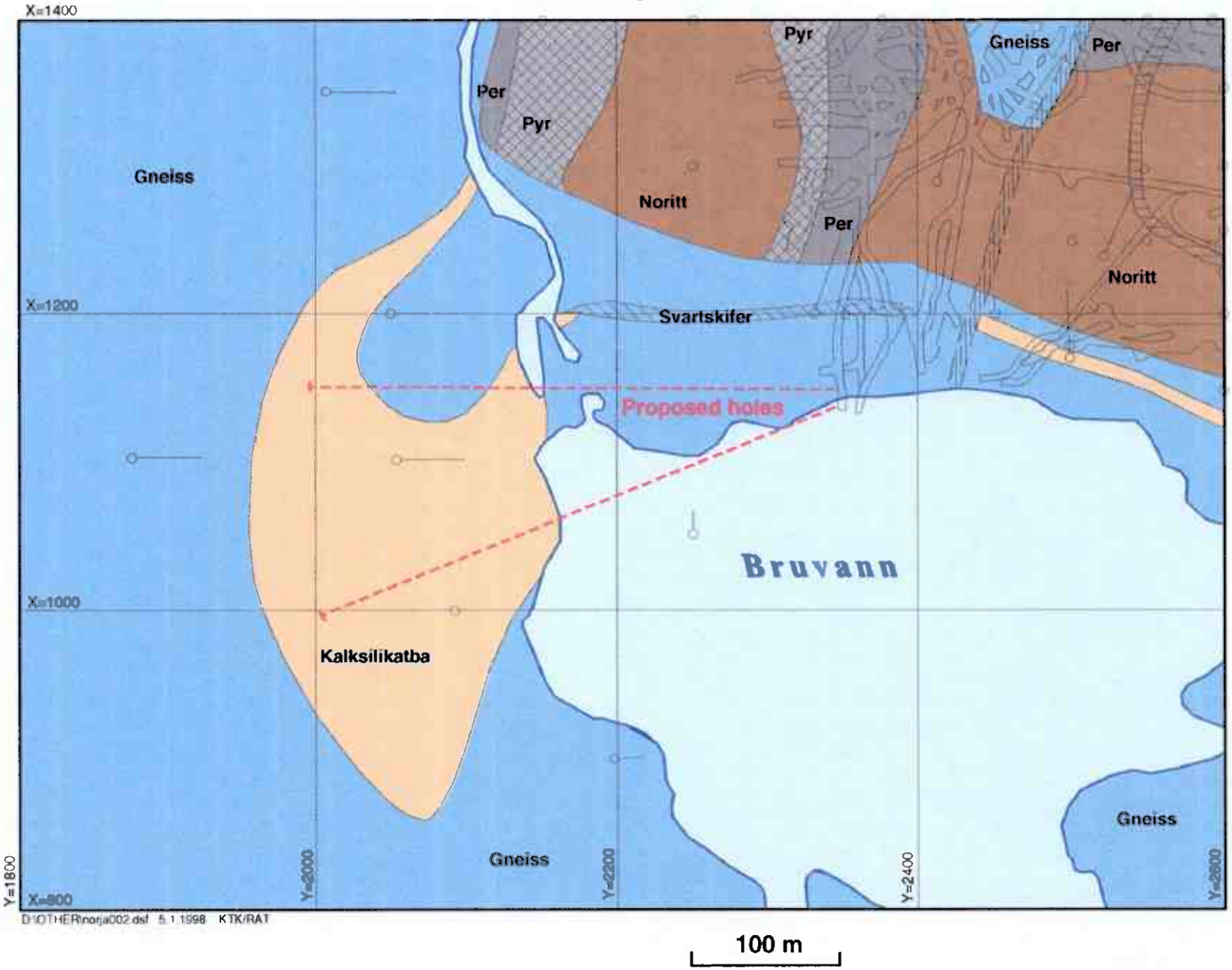

App. 4.

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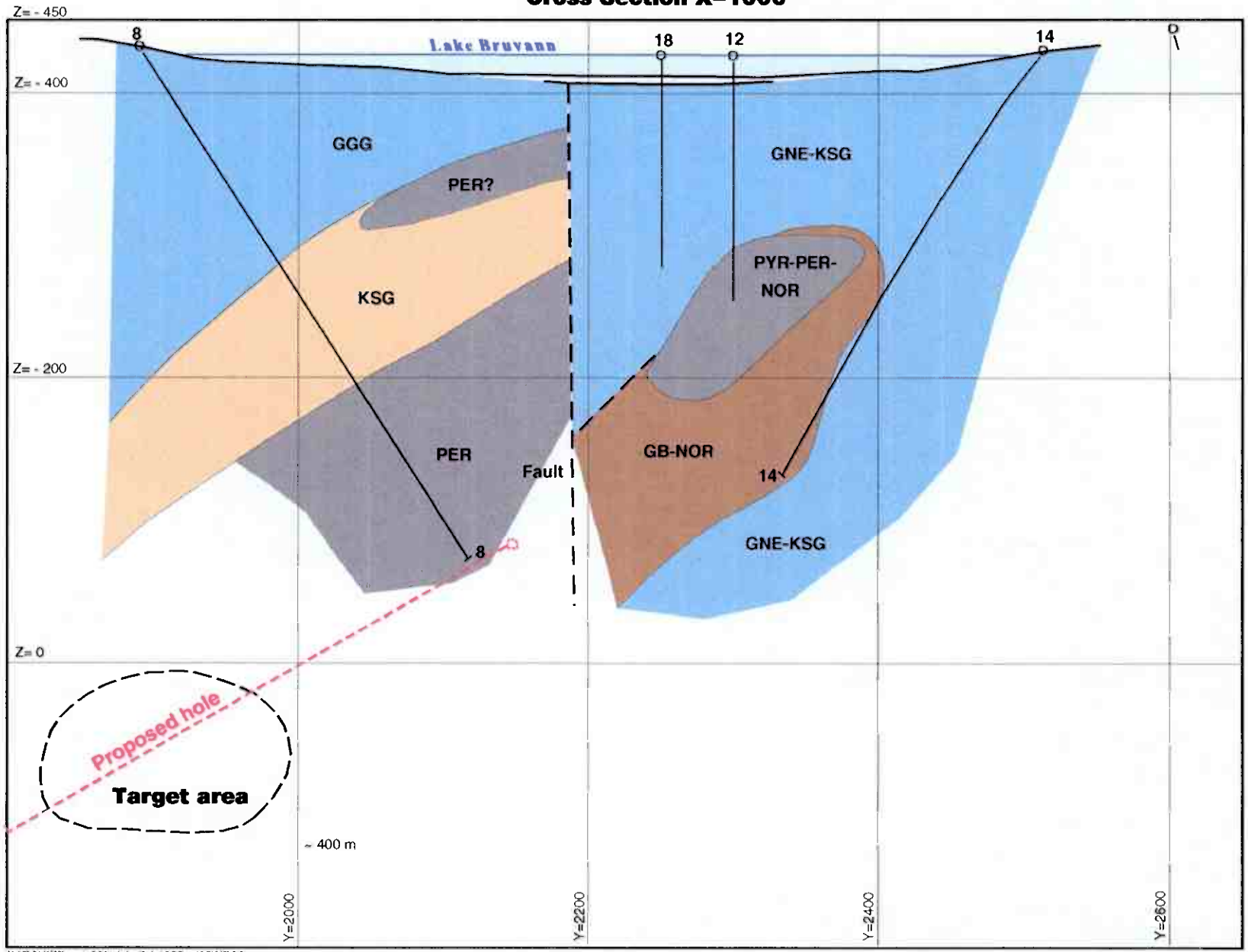
Cross Section X=1000

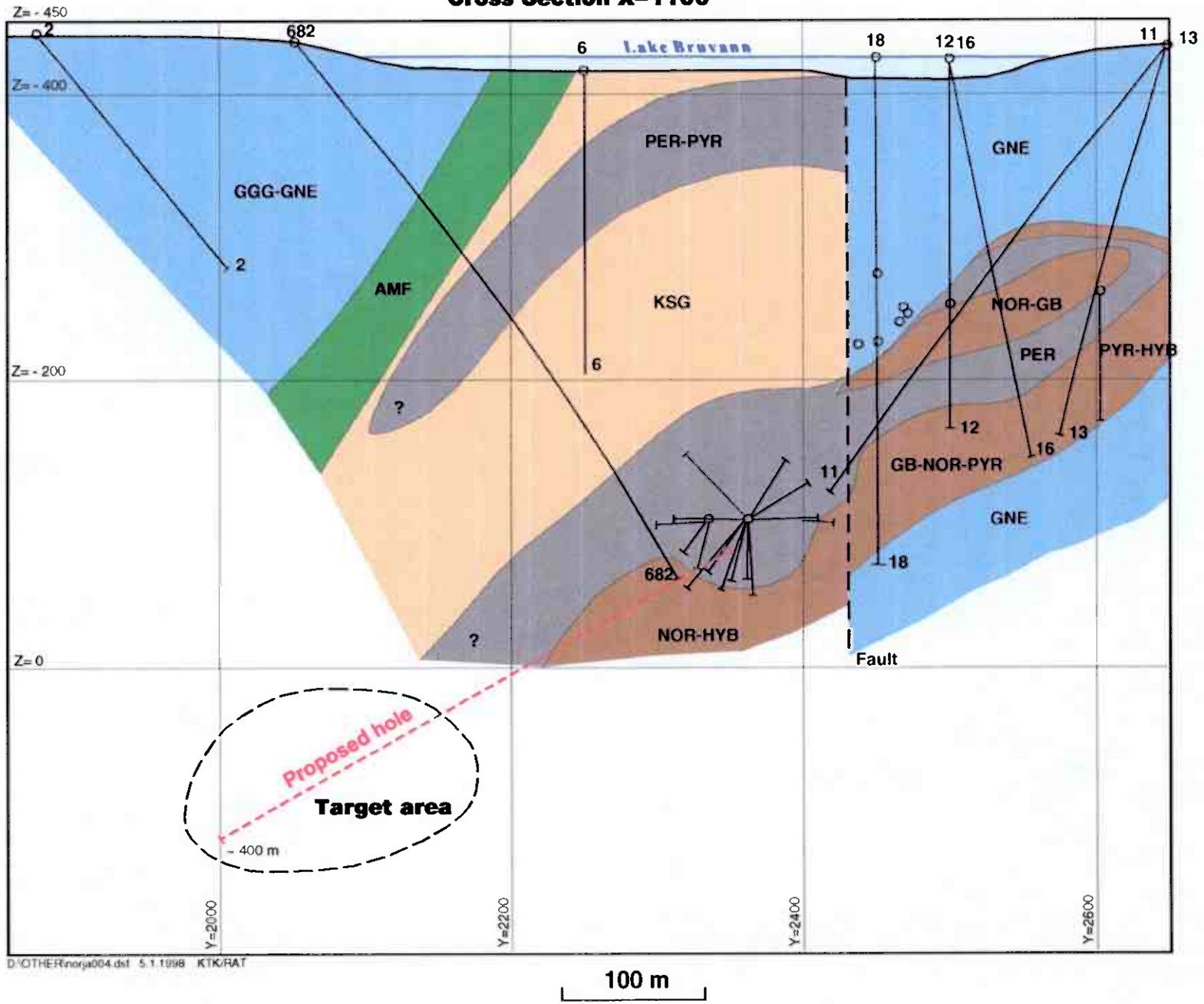


App. 5.

outokumpu

Nikkel og Olivin

Cross Section X=1100



App. 6.