Bergvesenet

Postboks 3021, N-7441 Trondheim

Rapportarkivet

Bergvesenet rapport nr	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering
4696	2130/99			**Åpen**
Kommer fra ..arkiv	**Ekstern rapport nr**	**Oversendt fra**	**Fortrolig pga**	**Fortrolig fra dato:**
		Ecuanor AS		

Tittel

Report on Core Drilling at Prins Fredrik Mine, Øvre Årdal, West Norway

Forfatter	Dato År	Bedrift (Oppdragsgiver og/eller oppdragstaker)
Røsholt, Bernt Westhead, Keith	aug. 1999	Ecuanor AS

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Årdal	Sogn og Fjordane		15174	Årdal

Fagområde	Dokument type	Forekomster (forekomst, gruvefelt, undersøkelsesfelt)
Geologi Geofysikk Geokjemi Boring		Prins Fredriks gruve

Råstoffgruppe	Råstofftype
Malm/metall	Au Cu

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Five drillholes with a total of 255,5 coremeter intersected a 800m target zone. The drilling campaign has confirmed that the copper mineralization in the very old Prince Fredric Mine is discontious. No further drilling are recomended.

ECUANOR ASA

Vedlagt følger ett eksemplar av rapporten fra undersøkelsene i Årdal i Sogn sommeren 1999.

Dessverre ble resultatet fra undersøkelsen ikke slik som en hadde håpet, men det det for oss et klart svar.

Rapporten er for internt bruk og ikke tenkt brukt av mottaker i markedsføring.
Laboratorierapport legges ikke ved.

Kristiansand, 2.11.99

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REPORT
on
Core Drilling
at
PRINCE FREDRIK MINE
Øvre Årdal, West Norway

August 1999

Bernt Røsholt
Consultant

Contents

Enclosures: 1 Lithological report by Keith Westhead.
2 Core log.
3 Bibliography.

Summary and conclusions.

The first copper mineralization at Årdal, Western Norway was registered as early as 1702. In total eight mines were in operation on a high grade ore type with the ore minerals chalcocite, bornite and native copper. The different mines were located over large areas mostly in rough elevated terrain with one mine located as high as more than 1500 metres above sea level. Due to the difficult access and location, the mines were never reported to give any profit in spite of the high content of copper.

In recent years several mining companies as well as The Norwegian Geological Survey (NGU), University of Oslo and the local "Office of employment ideas" have been involved in the follow up of the Årdal Copper Mines.

Ecuanor's interest in the Prince Fredrik Mine property came up through the drilling proposals made by NGU after their IP-measurements 1976. The IP- measurements revealed a distinct anomaly in the continuation of the Prince Fredrik Mine in the NE direction which was believed to be a geophysical response to the mineralization. Total length of the anomaly zone including the length of the mineralised zone amounts to more than 800 metres. The width of the copper mineralization in Prince Fredrik's Mine was reported to be up to two metres. Due to collapsing of the mine openings, no person has been able in this century to enter the old mine except for the writer with Mr. Hans Kr. Hauge who was able to enter the upper adit (24m) of the mine.

The objectives of the drilling was:

1. To have a response to the geophysical anomalies which clearly indicated a continuity of the rich ore type from Prince Fredrik's Mine.
2. To have a response of the continuity of the ore zone.

The proposed drilling program at Prince Fredrik Mine in Øvre Årdal with three to five holes are now completed with three holes totalling 255,5 metres of core. All three drill holes intersected the 800 metres target zone. No core losses have occurred in the drilling campaign.

Copper minerals are visually only confirmed in hole no 2 in negligible amounts. No copper minerals could be confirmed visually in holes no 1 and no3.

In total 12 rock samples and one soil sample are shipped for chemical analysis.

The drilling campaign has confirmed that the copper mineralization in the Prince Fredrik's Mine is discontinuous. Since the potential ore zone is discontinuous, the total copper potential is most likely considerably reduced, and no further drilling is recommended. The pending results from the core samples shipped for analysis should be awaited and assessed before a final conclusion is made.

Mine History.

The first findings of copper ore in Årdalen dates back to year 1680 when copper ore was found at "Grubefjell"about 1500 metres above sea level ("Mining Mountain") by two farmers from Årdal. In 1702 the deposit was first claimed, and in 1705 gold was found together with the copper ore. At that time it was not allowed to continue the mining operation privately since all precious metals belonged to the King. King Fredrik the IV bought the mine 1708 and it was operated until 1743 when the operation ceased. Prince Fredrik's Mine was found 1723. In 1755 the mines were reopened and operated until 1767 when the operation finally ceased. Little or no activity in the mines took place in the 18th century. Early in the 19th century several visits to the mines took place, but no mines were put back into operation. Some limited activity must, however, have taken place since old hand-drilled holes may be observed at mine openings of Prince Fredrik's Mine.

Regarding gold in the Årdal type of ore, recent analysis of the ore indicates that little or no gold occurs together with the Årdal type of ore. In the rock collection at the Technical University of Trondheim (NTNU) very nice samples with visible gold from Gruvefjellet may be seen.

Exploration Work.

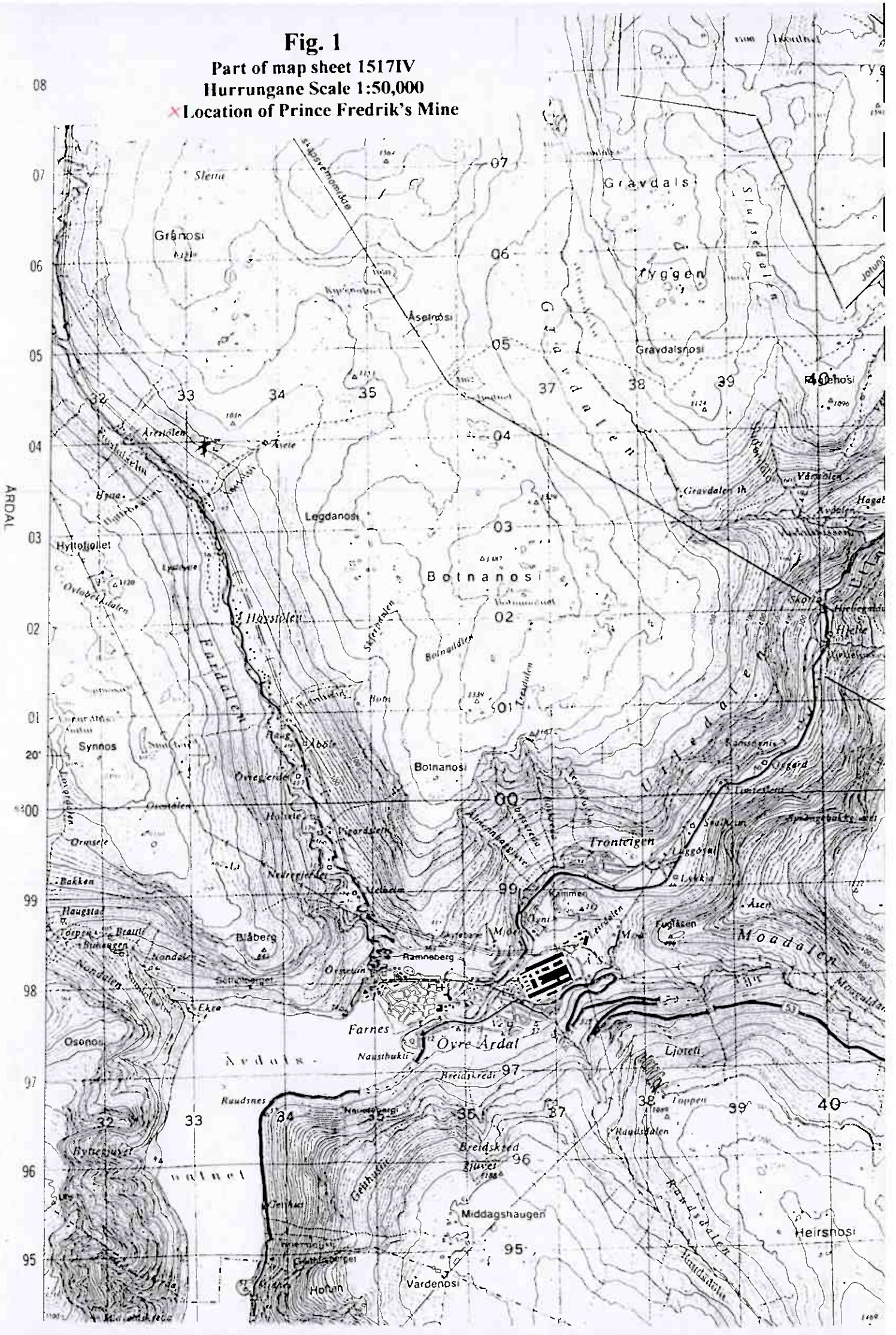
Much attention was paid to the old Årdal copper mines from the seventies and onwards. The mining companies A/S Sydvaranger and Orkla Grubeaktiebolag made some visits to the area. A local prospector claimed some of the mines and the County geologist together with the local "Office of employment ideas" showed strong interest in promoting the area for investors.

The Norwegian Geological Survey (NGU) made a considerable effort in the period 1976 to 1977 to gain a better knowledge of the area. Regional geological mapping, description of the individual deposits, regional stream sediment sampling, local soil sampling and ground geophysical measurements with IP and Mag was carried out. It was in this campaign the IP anomaly in the extension of the Prince Fredrik mine was revealed. NGU made also in 1980 additional measurements and a reinterpretation of the IP-measurements from 1978. The conclusion of the study recommended a recognition follow of the anomalies with a few shallow drill holes.

The University of Oslo has also made some studies of Prince Fredrik's Mine.

Fig. 1

Part of map sheet 1517IV
Hurrungane Scale 1:50,000
× Location of Prince Fredrik's Mine



Motivation for exploring the mineral potential at The Prince Fredrik mine.
There were several strong reasons for following up the possible ore potential at Prince Fredrik's Mine. Fig no 1 shows a section of the topographic map in scale 1:50 000 over the area. A red cross at 33,2E/03,9N marks the position of the Prince Fredrik's Mine located about 850m a.s.l. The access is fairly good apart from the last 250 steep metres above the Fardalen valley. Below, the different reasons for following up the mineral potential at The Prince Fredrik's Mine are listed.

IP – Anomalies: Fig no 2A from NGU – IP measurements 1978 with the upper adit opening marked with the its strike direction. It can clearly be seen that the strike of the adit and the strike of the anomalies are parallel and coinciding since both are dipping to the SE and the adit is located about 170m below the surface of the IP- measurements.
Fig no 2B is a topographic map in scale 1:5000 showing the location of the drill holes and trace of IP anomalies.

Initial Work: The writer was in 1998 able to get into the upper adit of Prince Fredrik's Mine. See fig no 3 which is a section through The Prince Fredrik's mine. The sketch is from a local history book. There is no connection between the upper adit and the rest of the mine.
No copper mineralization could be seen in the adit which was driven along a fault zone.

The fault zone runs partly along a lithological contact between a gabbroic rock towards the NW and a amphibolitic gneiss towards the SE. Copper ore is described to occur along the fracture zone, but in the upper adit no mineralization was observed. Since no stoping has taken place in the upper adit, it is not likely that the old miners did find any economic mineralizations here. Rock chip sampling across the fault zone with five samples confirmed that no copper was present.

However, about one and five metres below the upper adit, in the gabbro, where good exposures could be seen, patches op to 0,5x0,2m of disseminated chalcocite, azurite and malachite in amphibole lenses were found. It seemed that the occurring of the copper minerals in Prince Fredrik's Mine is patchy and similar to the other Årdal deposits.

Further detailed work along the gauge where the mine is located was very difficult due to talus, falling rocks and risky conditions. Some rich samples were, however, found in the talus and near the entrance of the presumed lowest adit. One sample returned a copper content at 21%.

The total length of the mine in the gauge between the presumed lowest adit and the upper adit was measured to 103 metres.

Detailed geological mapping: During the drilling campaign, a detailed geological survey was carried our by Mr. Keith Westhead, geologist of British Geological Survey. Mr. Westhead covered an area of about one sq. kilometre around Prince Fredrik's Mine. Below are the conclusions of the work, confirming that the mineralization occurs in association with a SE-dipping deformed and sheared zone. Mr. Westhead also concludes that the mapped continuation of the rocks enclosing the mineralised zone corresponds closely to the geophysical IP anomaly.
The geological report is enclosed as enclosure no 1.

Fig. 2A

Part of NGU IP anomaly map 1977-78 with

- **Entrance of upper adit and**
- **Trace of upper adit**
- **Drill hole**

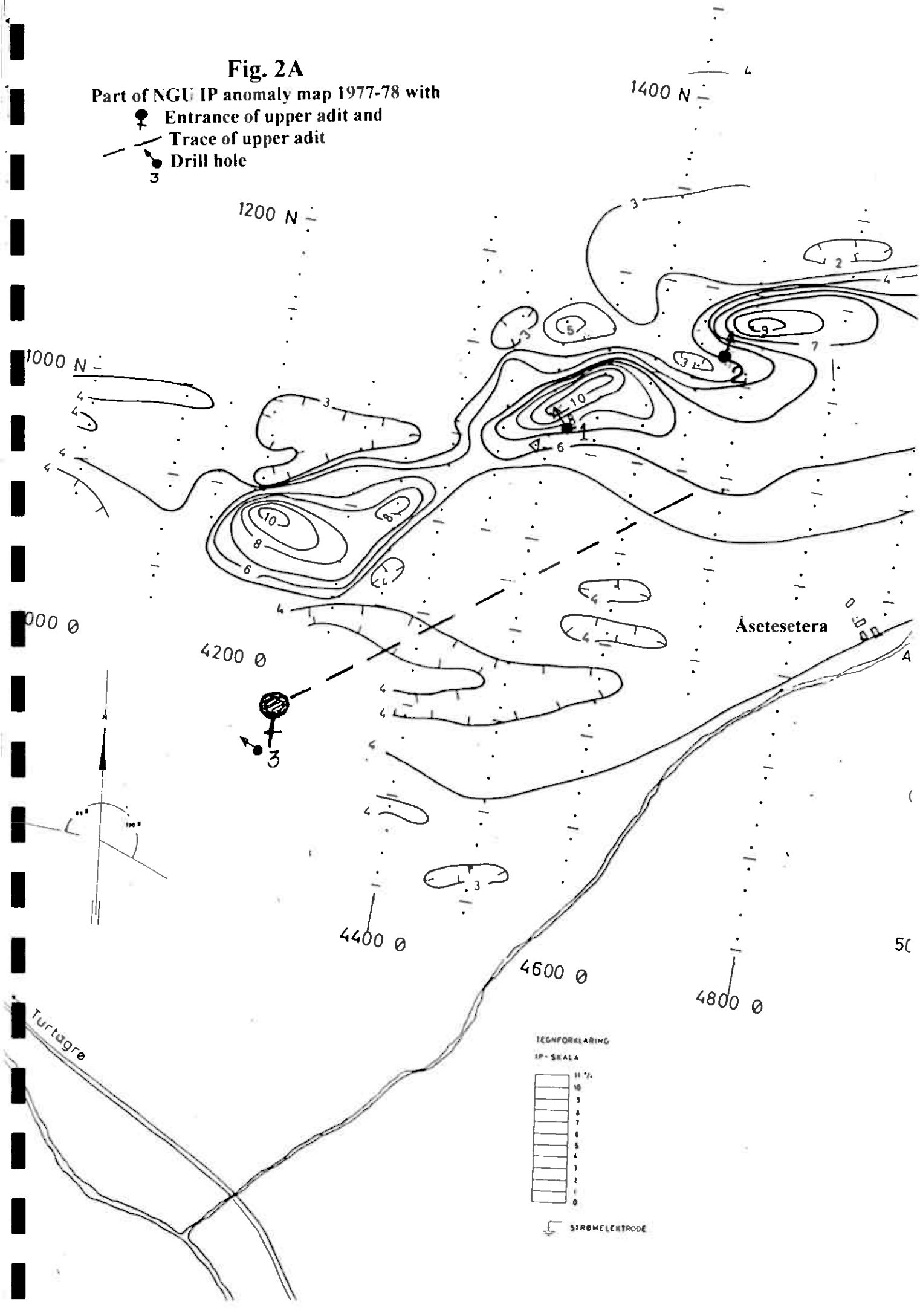


Fig. 2B

Topographic map scale 1:5,000

Trace of IP-anomaly

Drill hole with direction

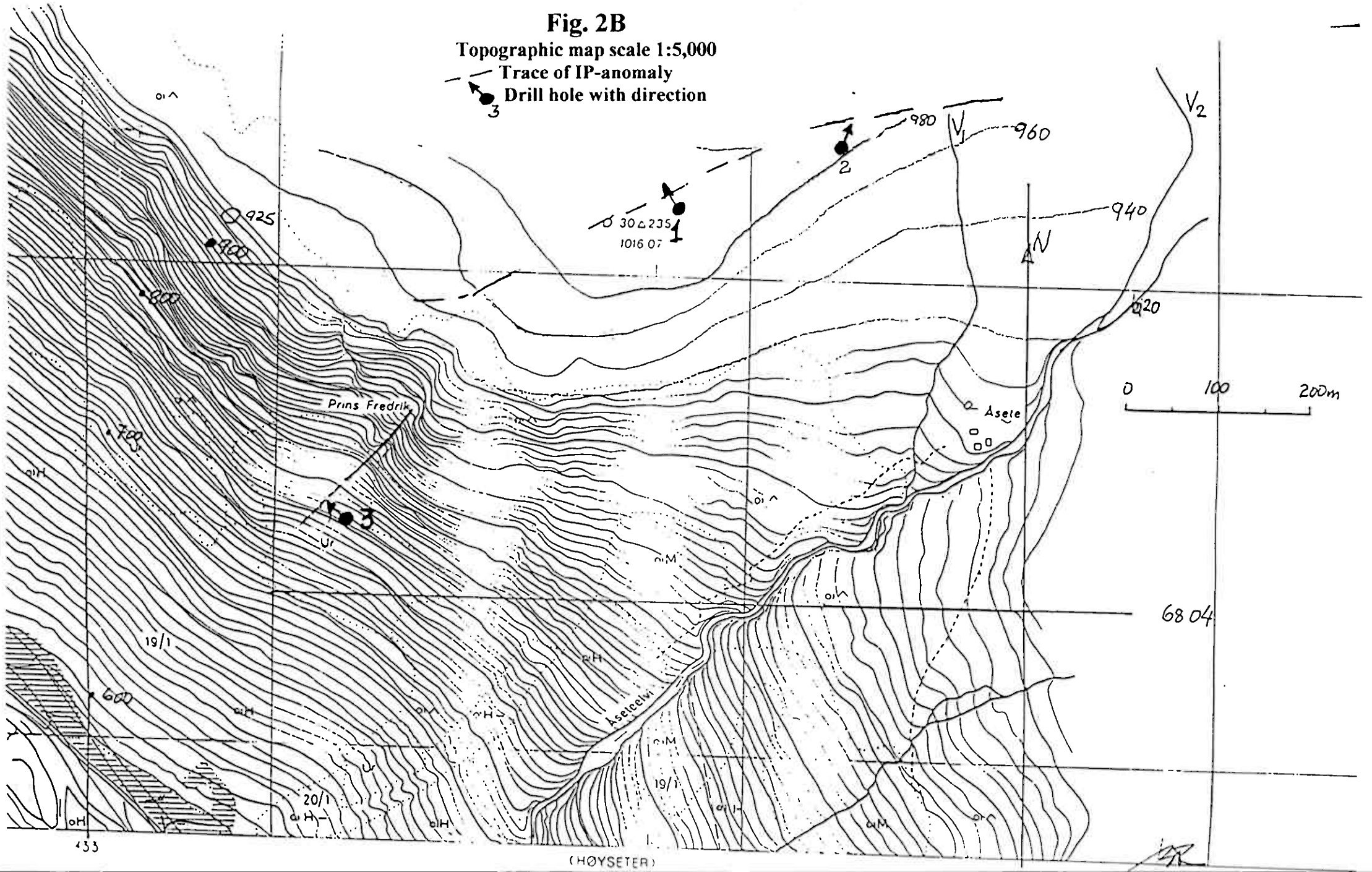
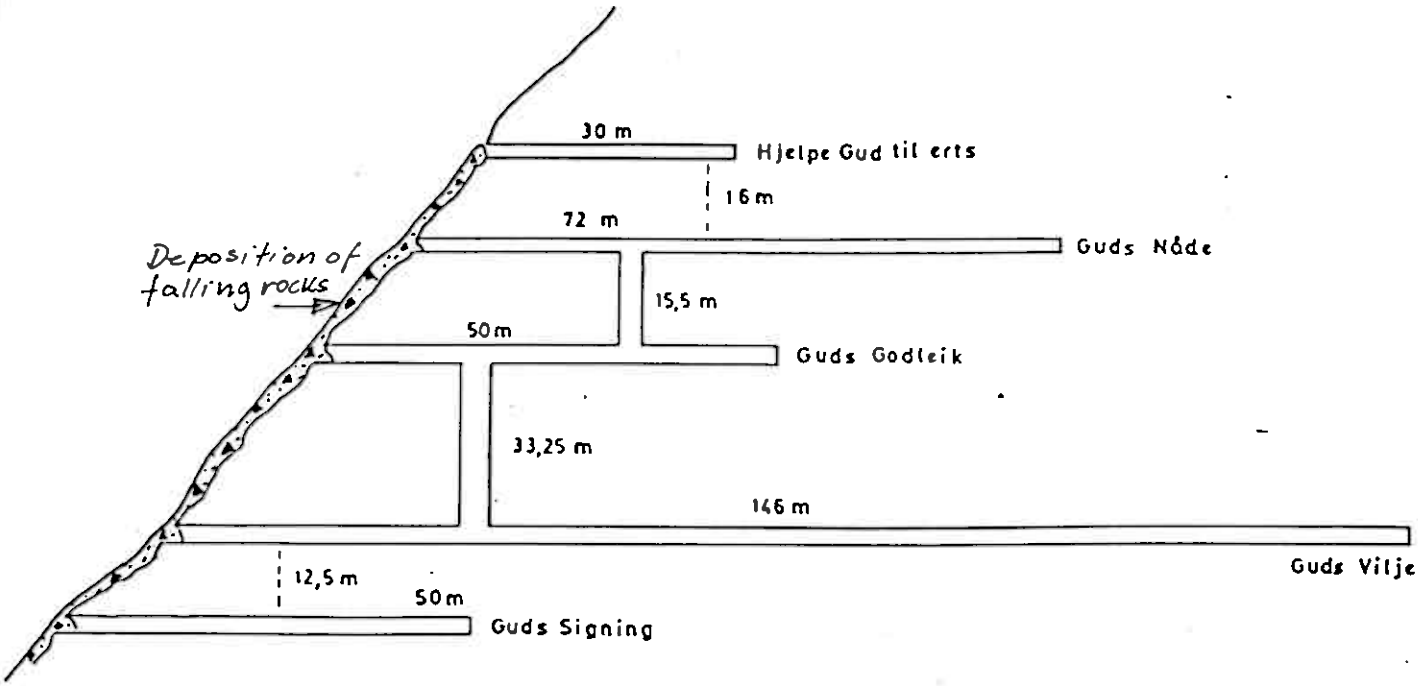


Fig. 3

Section of Prince Fredrik's Mine
"Bygdebok of Årdal" pp425

PRINS FREDRIKS GRUVE
Etter Bygdebok for Årdal (side 425)



Skisse av de 5 ortene

VESTLANDSPROGRAMMET 1977 MALMUNDERSØKELSER KARTSKISSE AV PRINS FREDRIKS GRUVE ÅRDAL, SOGN OG FJORDANE	MÅLESTOKK ca 1 : 940	OBS.	
		TEGN.	
		TRAC. J.S.	MARS -78
		KFR.	
NORGES GEOLOGISKE UNDERSØKELSE TRONDHEIM	TEGNING NR. 1560/9D-11	KARTBLAD NR. 1517 IV	

Fig. 4
Photo of Viscaria Alpina
Near drill hole no 1.

Conclusions

a. A combination of structural and lithological mapping suggests strongly that the rocks containing the mineralised zone at Prins Fredriks mine continue in a NE direction for at least 1km.
b. The mapped continuation of the rocks enclosing the mineralised zone corresponds closely to the geophysical IP anomaly.
c. The mineralised zone occurs in association with a SE dipping deformed and sheared zone between gabbroic and mafic gneisses to the NW and feldpathic gneisses to the SE.
d. Observations in a stream section 2km to the NE of the mine indicate that the same rocks may continue well beyond the mapped area.
e. Comparison of the stream section observations with those in the mapped area at Asete suggests that the mineralised zone may occur in association with a late clay-rich fault zone. The orientation of the fault zone is controlled to a certain extent by the earlier gneissic fabric, although the dip may be steeper.

Geochemistry: NGU did also a detailed geochemical survey at Åsete area (Prince Fredrik) in 1977 to confirm the IP anomalies from the area. No copper soil anomalies showed up near the IP-anomalies, but a line of high copper values parallel to the IP-anomalies occurs about 400m to the East. The soil samples were collected from 0,1 to 0,2m depth. It should be noted that most of the area is covered by a thick layer of glacial till and it is most likely that it will effectively seal most metallic ions from the bedrock surface.

Some places, however, the so called "Copper Flower" (Alpina Viscaria) may be located in patches covering up to 5 sq metres. The "Copper Flower" may be a good guide to ore in Scandinavian mountains. It often grows on locations where other plants will suffer and perish due to high copper (and lead) contents in the soil. The Swedish mine "Viscaria" – a major massive sulphide deposit located near Kiruna was found because of the abundance of the plant Alpina Viscaria.

Photo, fig 4, showing the Alpina Viscaria plant 10 metres north of drill hole no 1. Sample no 399563 is a soil sample from this location.

Potential of drill target: The strike length of the drill target including the outcropping of the mineralization with the adits in the gauge and the IP anomalies is measured to 800 metres. At the NE side of the IP anomaly there is no continuity of the IP. Along strike, however, about 400 metres to the NE, outcrops of the techtonic zone may be found in a small waterfall (Re. Keith Westhead report, encl. No 1). This registration supports the IP anomalies to be related to copper mineralization rather than the clay zones occurring in the techtonic zones. Towards the SW, no IP- measurements are made due to the rough terrain with steep cliffs and talus. The target zone is therefore open towards the SW and makes the total length of the potential drill target up to about 1200 metres ending in the Fardalen valley.

The ore thickness described from Prince Fredrik's Mine is up to and some times more than two metres. From Blåberget Mine with the same type of mineralization, ore stopes up to 5 metres are reported. Blåberget mine is also related to a techtonic zone.

Finally, when the high grade ore type from the area is added to the potential of the strike and thickness of the possible ore horizon, an economic body could be envisaged. It would also have a favourable access position for extraction from the bottom of Fardalen.

Drilling program and performance:
Field observations and discussions with NGU- geophysicist Jan S. Rønning who made the last IP survey, were made prior to the working out of the drilling proposal.
The ore minerals occurring at Prince Fredrik are all solid and should cause no core loss, and the techtonic zone with some narrow zones of clay could cause some partial core losses. It was, however, for this reason decided not to operate with "triple core barrel" which would minimise any core loss on the behalf of drilling costs and time of operation.

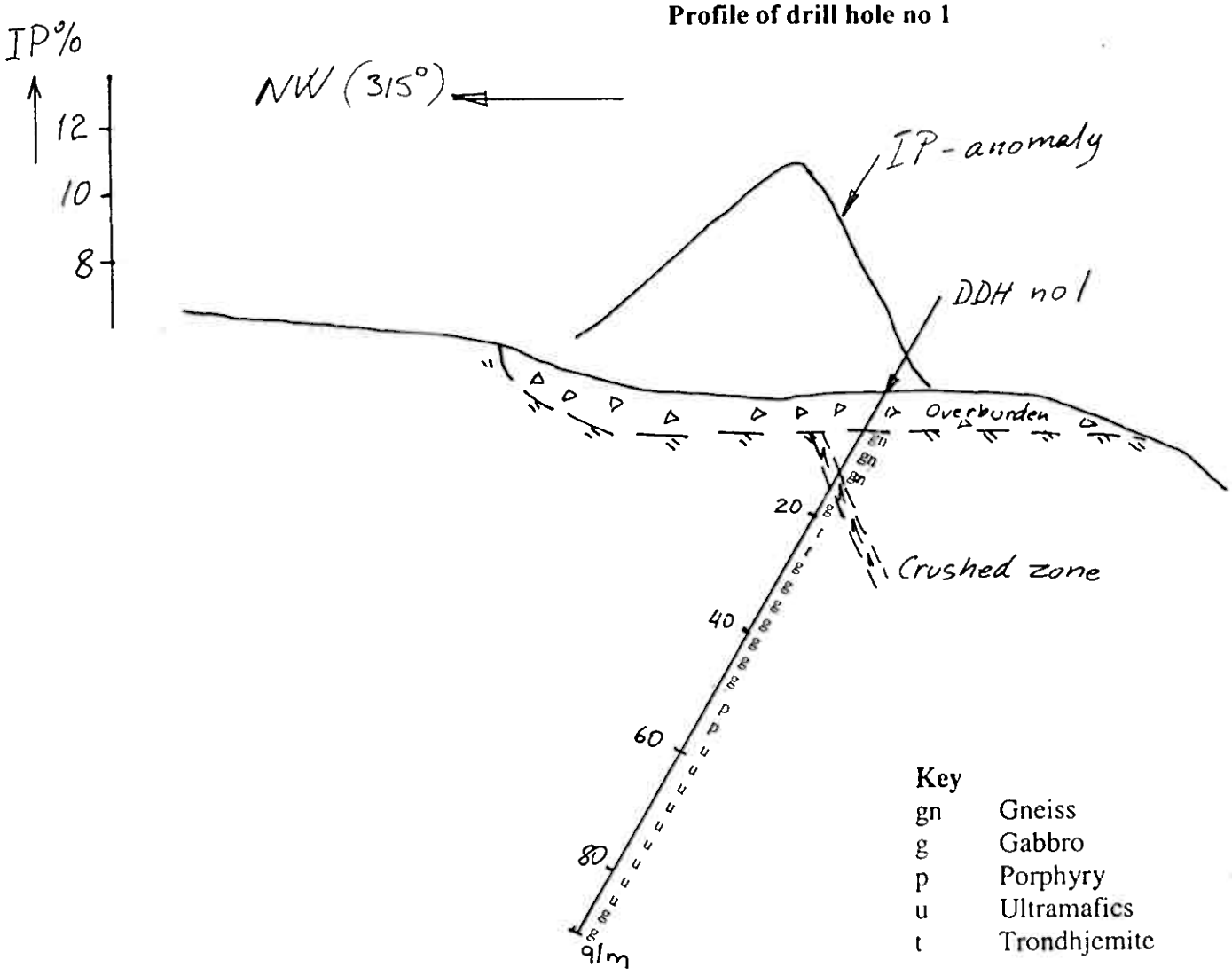
A drilling program at around 400m on four to five holes was decided. The drilling program was aiming at a response to the IP-anomalies occurring NE of the Prince Fredrik's mine. Further, it was also proposed one hole – if technically possible – from a small plateau on top of the talus, just below the lowest adit of Prince Fredrik's Mine. With a positive attitude from the drilling and helicopter team this hole was also drilled.
It was also decided with the Ecuanor leadership that all three drill locations could be drilled with a second hole in the same profile as the first with a steeper inclination under the condition that the first had given a positive section of copper minerals. The three drill locations are marked on fig no 2.

Drill Hole 1A:
The hole is located from summit point 1016m a.s.l. direction 74^g (=67^0) distance 47m. It should be drilled with a 60^0 inclination towards NW (=350^g =315^0). Length of hole about 100m. The proposed length of the hole is much longer than necessary to intersect the IP anomaly. However, in order to ensure that possible copper mineral dissemination's below the IP anomaly was not lost it was decided to drill it to about 100m.
Prior to the logging results on Drill Hole 1A, a preliminary program for the remaining drill holes were set up as follows:
Drill Hole 1B;
Same location as 1A. The hole should be drilled vertically. Depth about 100m.
Drill Hole 2A:
The hole is located in distance 228m from summit point 1016m a.s.l. and direction 75^g (=68^0). The hole should be drilled vertically.
Drill Hole 2B:
Same location as 2A. The hole should be drilled with a 60^0 inclination towards SE (=150^g =135^0).
Drill Holes 3A, 3B:
Drilling of hole no 3A is proposed under the condition that the four first holes could be interpreted as positive and that it was technically possible to establish a drilling pad at the proposed site. The proposed location is located 63m SSW of the lower portion of the expected mineralised zone (lowest adit). The hole should be drilled to a depth of about 60m with an inclination of 60^0 in direction 344^g (=310^0).
If also this hole turned out positive, one more hole (3B) should be drilled from the same position and same direction with an inclination of 80^0. This hole should be sunk to 100m.

The performing of the drilling went well with the operator Tekobor AS. No core loss was reported, and the campaign lasted from August 3rd until August 27th. A delay for one week was caused by the helicopter company Airlift that was grounded due to lack of spare parts. Three holes were completed totalling a core length of 255,5 metres.

Fig. 5

Profile of drill hole no 1



Results of drilling:
The drilling campaign was continuously supervised in co-operation with the leadership of Ecuanor. After the completion of drill hole no 1, Ecuanor geologist Warren Timoty Pratt visited the site. At the same time the "Mining Inspection Office" was represented in the field with Mr. Bjarne Lieungh, (Overingeniør.)
Each drill hole is described separately. A drill log is attached as enclosure no 2.

Drill Hole 1:
Drill hole no 1 was drilled from location 47m from summit point 1016m a.s.l. direction 74^g (=67^0) and inclination 60^0 towards NW (=350^g =315^0) as planned.
The overburden drilling was 5 metres, and the hole was sunk to 91,00m.
The techtonic zone was intersected as expected between 8,1 and 11,9m. It showed a similar appearance as seen under ground in the upper adit with hydrothermal quartz, calcite, a bright red mineral (most likely oxidised pyrite), chlorite and epidote. No ore minerals could be seen.
Fig no 5 shows a profile of drill hole no 1 with IP anomaly and intersected rocks.
The following samples were collected for analysis:

399559	8,1-9,0m	Techtonic zone.
399560	9,0-10,0m	Techtonic zone.
399561	10,0-11,0m	Techtonic zone.
399562	11,0-11,9m	Techtonic zone.

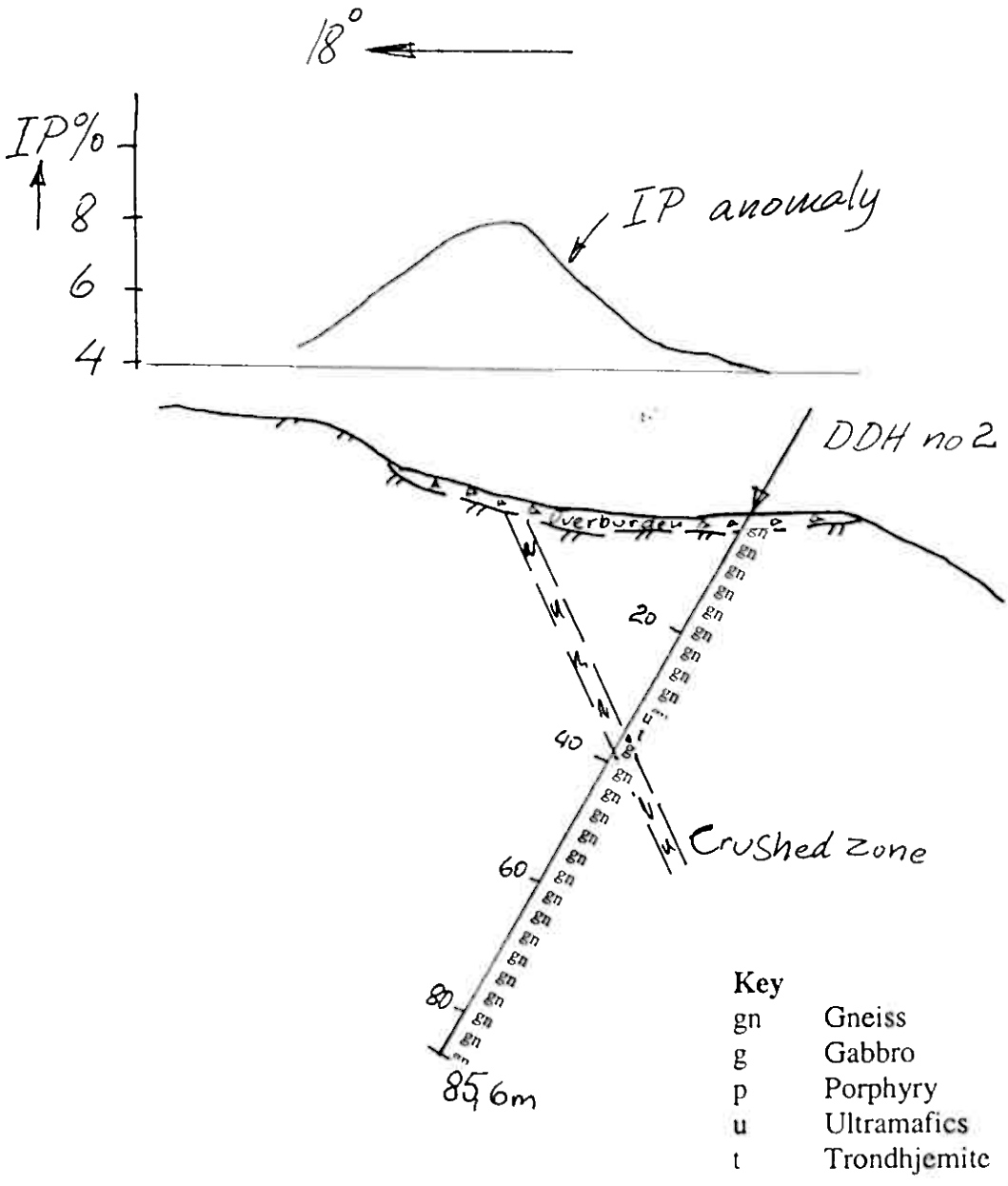
Drill Hole 2:
Drill hole no 2 was drilled from the location as planned in distance 228m from summit point 1016m a.s.l. and direction 75^g (=68^0). It was, however, drilled in direction 20^g (=18^0) to intersect the peak area of the Eastern IP anomaly. It was drilled with an inclination of 60^0.
The overburden was 3,0m, and the hole was sunk to 86,5 metres.
A techtonic zone was intersected between 35,0 and 38,4m. Most of the techtonic zone comprised of a coarse crystalline gabbro which was located from 32,5 to 38,1m. Some very weak mineralizations of chalcopyrite and chalcocite was observed in the gabbroic rock.
Fig no 6 shows a profile of drill hole no 2 with IP anomaly and intersected rocks.
The following samples were collected for analysis:

399551	33,0-34,0	Coarse grained amphibolite with traces of Cpy.
399552	34,0-35,0	Coarse grained gabbro (Hornblendite)
399553	35,0-36,0	Coarse grained gabbro. 35,6-36,0 a techtonised light coloured gneiss.
399554	36,0-37,0	Coarse grained gabbro with epidote and serpentine.
399555	37,0-38,0	Coarse grained gabbro. 37,5-37,8 a light coloured techtonised zone.
399556	38,0-38,4	Light coloured techtonised pegmatitic gneiss.

Drill Hole 3:
This hole is located 52m SW of the lowest adit at Prince Fredrik and 23m in distance towards the SE from the projected line of the mineralised zone. The direction of the drill hole is 356^g (=320^0) and inclination 75^0.
The overburden was 6,0m, and the hole was sunk to 78m.
The performance of drill hole no 3 was of great importance since this position was the only and closest possible to obtain a section of the ore bearing zone at Prince Fredrik's Mine.

Fig. 6

Profile of drill hole no 2



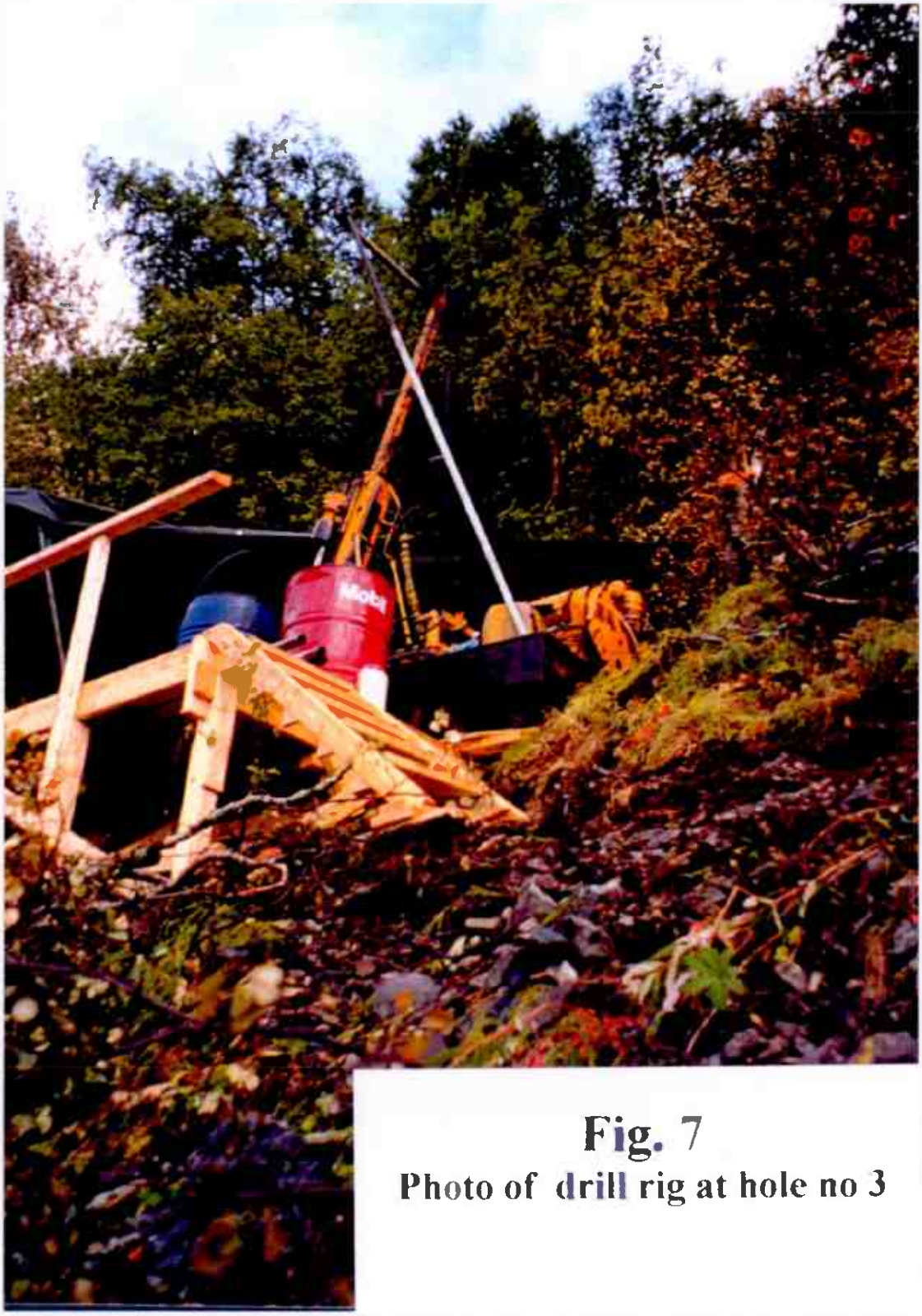


Fig. 7

Photo of drill rig at hole no 3

Both the drilling and helicopter crew carried out high skills in their performance of this task. It was also limited water available for the drilling at this location. Photo fig 7 shows the drill rig on site.
Fig no. 8 shows a profile of drill hole no3 and the trace of the presumed continuation of the mineralised zone of Prince Fredrik's Mine.
A techtonic zone was intersected from 40,3 to 41,9 with epidote and calcite veins. At the hanging wall from 32,5 to 40,3 a coarse grained amphibolite gneiss occurred. No copper mineralization could be seen in the zone nor in the rest of the cores from drill hole no 3.
The following samples were collected for analysis:

399557	40,3-41,0	Techtonised micagneiss with epidote and calcite veins.
399558	41,0-41,9	---------- " ----------

Conclusions:
The proposed drilling program at Prince Fredrik's Mine has been completed with three holes totalling 255,5 metres of core. All three drill holes intersected the 800 metres target zone. No core losses have occurred in the drilling campaign.

The objectives of the drilling was:

1. To have a response to the geophysical anomalies which clearly indicated a continuity of the rich ore type from Prince Fredrik's Mine.
2. To have a response of the continuity of the ore zone.

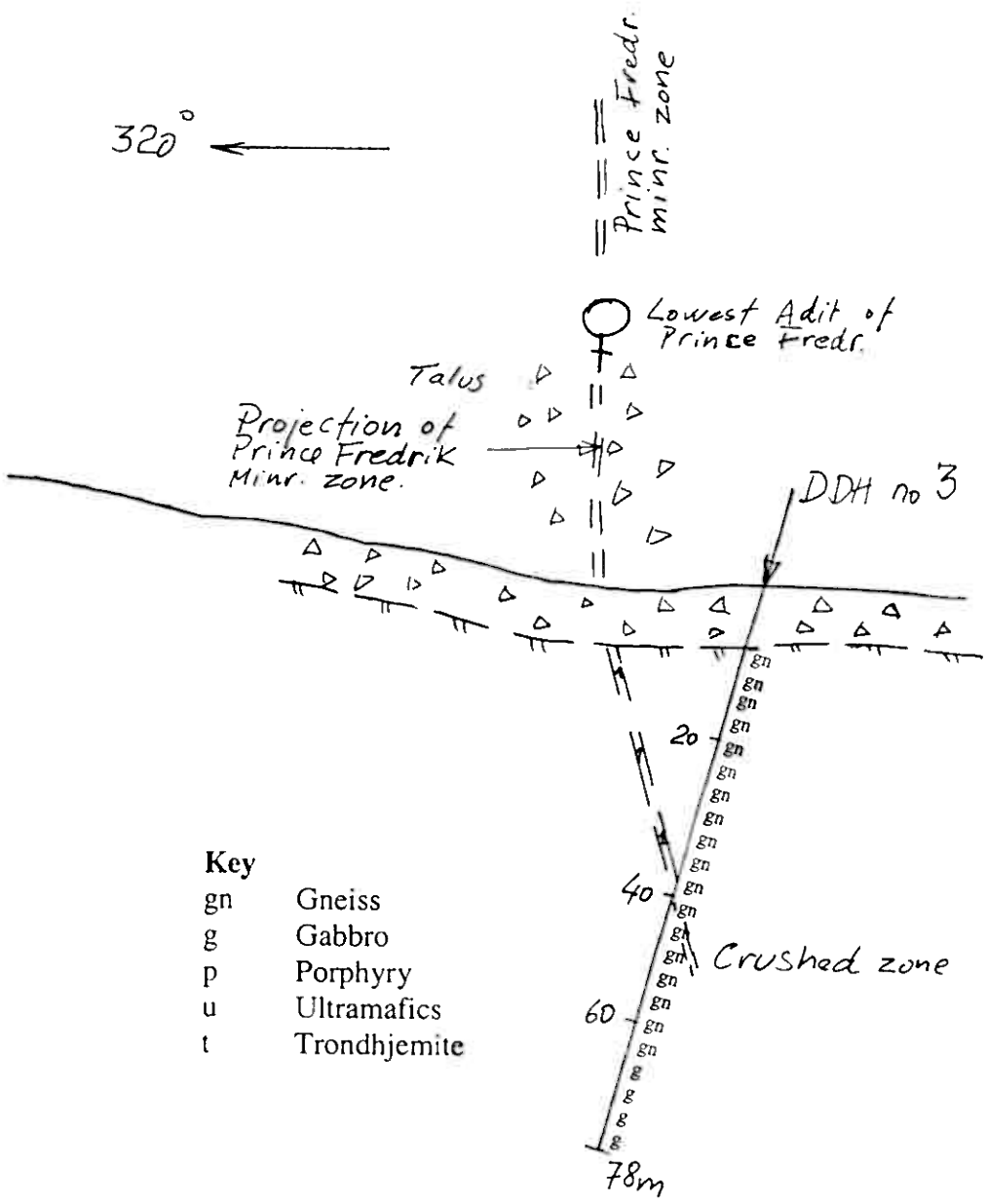
Copper minerals are visually only confirmed in hole no 2 in negligible amounts. No copper minerals could be confirmed visually in holes no 1 and no3.

In total 12 rock samples and one soil sample are shipped for chemical analysis.

The drilling campaign has confirmed that the copper mineralization in the Prince Fredrik's Mine is discontinuous. Since the potential ore zone is discontinuous, the total copper potential is most likely considerably reduced, and no further drilling is recommended. The pending results from the core samples sent for analysis should be awaited and assessed before a final conclusion is made.

Fig. 8

Profile of drill hole no 3



Enclosure no 1

Summary report on structural mapping, Prins Fredrik Mine, Åsete

Keith Westhead, 19/8/99

1. Summary

A 1km^2 area has been mapped between Åsete and Prins Fredrik mine in support of the drilling program. Both lithological and structural mapping has been undertaken. The results are summarised in a series of diagrams (Figures 1 to 7).

2. Lithologies

Although exposure is limited (Figure 1), a conjectural geological map has been made (Figure 2). This demonstrates that the area comprises a series of crystalline gneisses, dipping in layers towards the SE. These gneisses form part of the Caledonian Jotun Nappe Complex, representing a displaced slice of Precambrian Baltic basement.

In the present area, the lowest mapped unit comprises mixed gabbroic and mafic-rich amphibolite gneisses. These are generally massive to fairly highly deformed. The rocks form a resistant ridge running SW-NE across the NW side of the mapping area, and form a 10m high cliff feature running N-S down the main valley side in the SW of the area. This cliff feature can be observed from the main valley bottom near the ski-hut.

The highest mapped unit consists of pale-coloured, more feldspathic amphibolite gneisses, containing up to 70% feldspar. These form the hillside in the SE of the mapping area. The lower part of these felsdpathic gneisses is very highly deformed in a broad shear zone that can be mapped SW-NE across the area (Figure 2). The shear zone rocks consist of augen gneiss (<1cm feldspar augen) with a very strong linear fabric (defined by aligned amphibole) and planar fabric (defined by aligned and segregated mineral growth). The shear zone rocks appear to be relatively strong in relation to the less deformed surrounding gneisses, and form a ridge feature trending SW-NE across the mapping area, and 5 m high cliff feature running N-S down the main valley side. This cliff feature can also be observed from the ski hut, lying in the hillside above the cliff feature formed by the lower mafic gneisses.

The shear zone rocks can be mapped to the top of the old mine workings, which suggests their may be a relationship between the mineralised zone and the shearing (see Section 4).

3. Structure

The structure of the gneisses is dominated by a penetrative planar fabric (dipping on average at 40° to the SE) and an associated penetrative lineation (plunging SE). There is some evidence of an earlier, steep, weaker gneissic fabric trending NW-SE, although this is only preserved in the more massive gabbroic rocks in the NW of the area.

The penetrative lineation is defined by aligned amphibole crystals and 'stretched' feldspar and other minerals. The planar fabric is defined by gneissic compositional banding and aligned mineral growth.

Both the linear and planar fabrics are related to the same deformation episode, and show consistent trends across the area (Figures, 3, 4, 5, 6), with only minor fluctuations apparently due to lithology contrasts around more resistant rocks units. The trend of lithological units (Figure 2) follows the planar fabric, indicating that the broad geological trends are controlled by the deformation.

The intensity of the fabrics varies between geological layers, and becomes particularly intense a c.10 m thick 'shear zone' as mapped in Figure 2 and described in Section 2. This zone has been mapped from the NE end of the mine workings, and could indicate an association between the shearing and mineralisation. Within the shear zone, feldspathic acidic veining is common, appearing late in relation to the shearing but deformed within the zone. In places, the geometry of the veining suggests that late movement on the shear zone was top-to-SE i.e. down-plunge parallel to the lineation.

4. Trend of the mineralised zone

Mapping has demonstrated that the structural and lithological strike of the rocks is consistent across the area from SW-NE. This can be seen in the topographical featuring of the ground, in particular to the SE of the Åsete river where ridges defined by more resistant rocks trends SW-NE (Figure 7).

Rocks can be traced from the area of the old mine workings at least 1km to the NE across the mapping area. This suggests that the rocks containing the mineralised zone also continue across the area in this direction. At the mine itself, earlier information demonstrates that the orientation of the mineralised zone appears to be sub-parallel to the gneiss banding, supporting this hypothesis. From the mapping, it is suggested that the mineralised zone trends parallel to the NW 'edge' of the shear zone, approximating to it base, and lies in the unexposed ground in the centre of the area.

The trend of the geophysical anomaly collected earlier closely follows the base of the mapped shear zone, even following the swing to a more E-W orientation in the SW of the area, again supporting a link between the shear zone and mineralised zone.

Reconnaissance observations were also made in the ground to the NE of the main mapping area to test the hypothesis that the rocks mapped may continue along strike in this direction. Exposure on the hillsides is very poor. However, there is well-exposed river section running from grid reference 3427 0453 to 3430 0470 on the northern branch of the river upstream from Åsete. Preliminary observations are recorded at Locality 23 (grid reference 3428 0461; see appendix and Figure 7). A very similar geological framework to that mapped at Åsete can be observed in the stream section. Resistant gabbroic gneisses form a waterfall and appear to be overlain or intersected by an extensive fault zone to the SE, in turn overlain by SE-dipping paler feldspathic gneisses. The fault zone itself comprises several metres of feldspathic and altered rocks with well-defined clay rich shear zones, and it is suggested that this could represent a continuation of the 'mineralised' zone at Prins Fredriks mine. No

mineralisation was observed in the field by the present author, but this would need to be tested with further investigation.

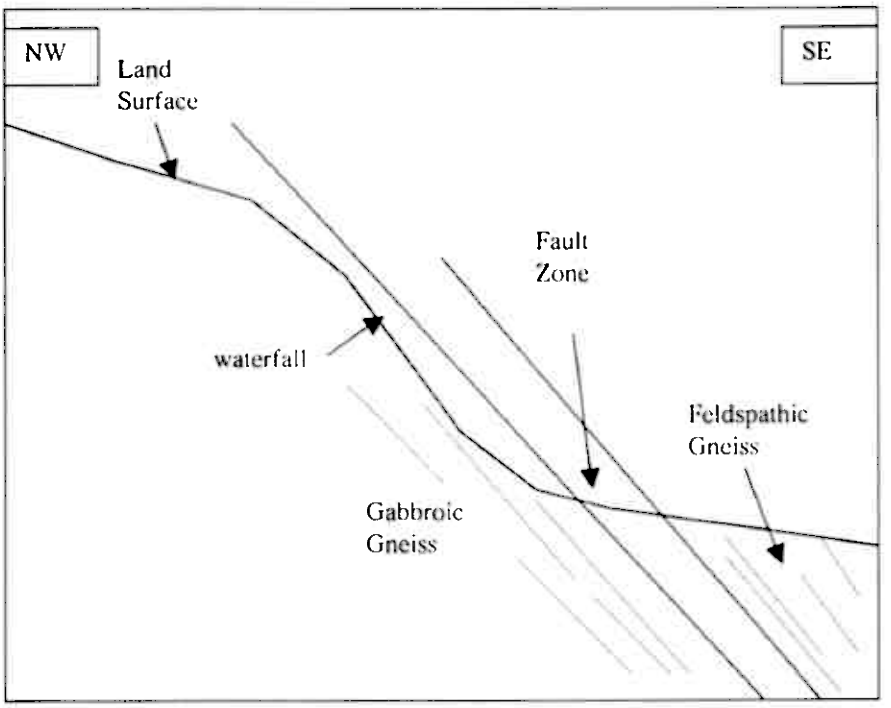
The nature of the faulting in the stream section at Locality 23 suggests very late movement in relation to the deformation that formed the planar and linear fabrics within the gneisses. Firstly, the clay-rich nature of the fault zone, and the associated veining and alteration suggest much lower grade metamorphism than the amphibole grade of the gneisses. Secondly, in places, the faulting apparently deforms the gneiss fabric itself, forming a shear augen in one exposure (see notes on locality 23). Thirdly, within the fault zone, slickensides were observed on some surfaces, suggesting sub-horizontal NE or SW directed strike slip motion.

The orientation of the principal fault plane was recorded as 060/64SE, close to the orientation of the shear fabric within the surrounding gneisses. The strike appears to be parallel to that of the planar fabric in the gneisses, but the dip may be slightly steeper. The dip of the gneiss fabric is closer to 40 or 50° away from the fault zone, but may steepen and swing into the fault zone (this observation is tentative and requires further field investigation).

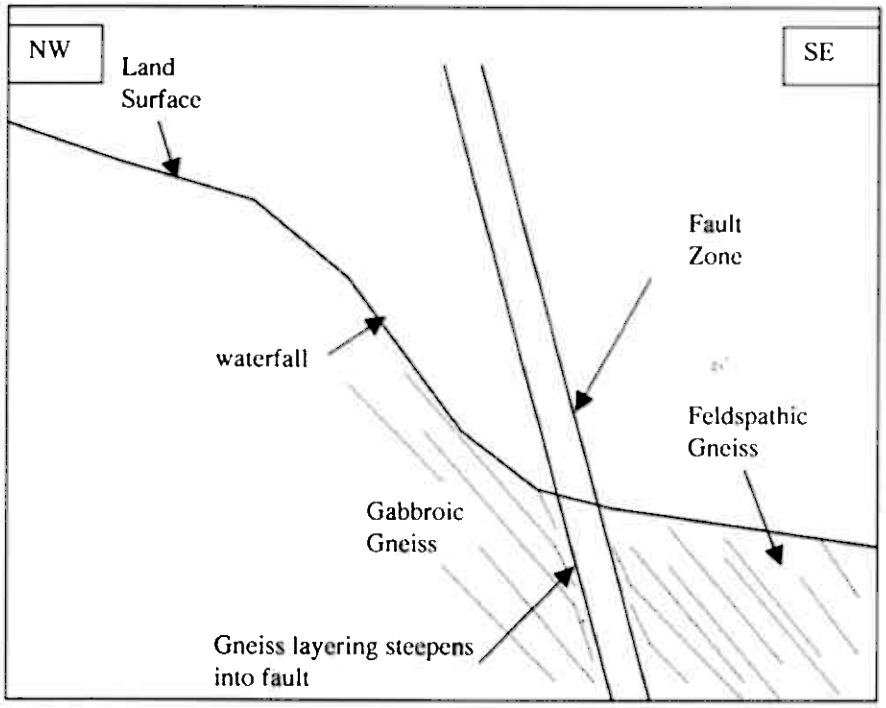
There are two possible models for the formation of the fault zone at locality 23:

a) The faulting occurred late in relation to the deformation in the gneisses, but was controlled closely by the pre-existing shear fabric, i.e., the fault plane is parallel to the gneiss shear fabric (see Sketch A below)
b) The faulting occurred late in relation to the deformation in the gneisses, the strike orientation controlled by the pre-existing fabric, but the dip steeper, i.e., the fault plane cross-cuts gneiss layering in dip section (see Sketch B below). In this scenario, the gneiss layering may be expected to swing into the fault zone

Sketch A: Fault Zone parallel to gneiss layering



Sketch B: Fault Zone steeper than gneiss layering

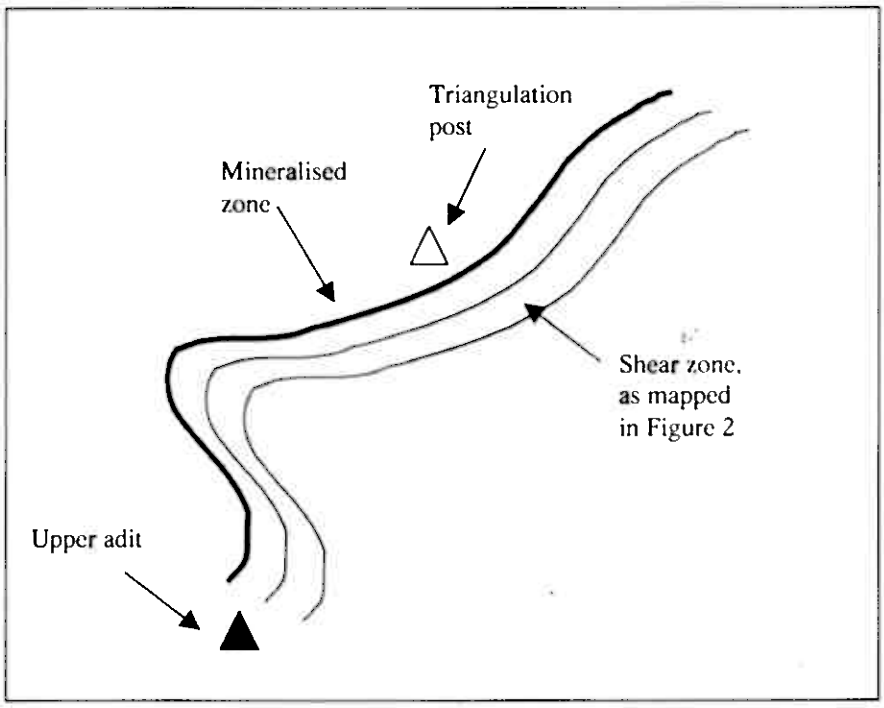


In either case, it can be further suggested that the formation of the fault itself may have resulted from competency contrast between the more resistant gabbroic gneisses and the less resistant feldspathic gneisses.

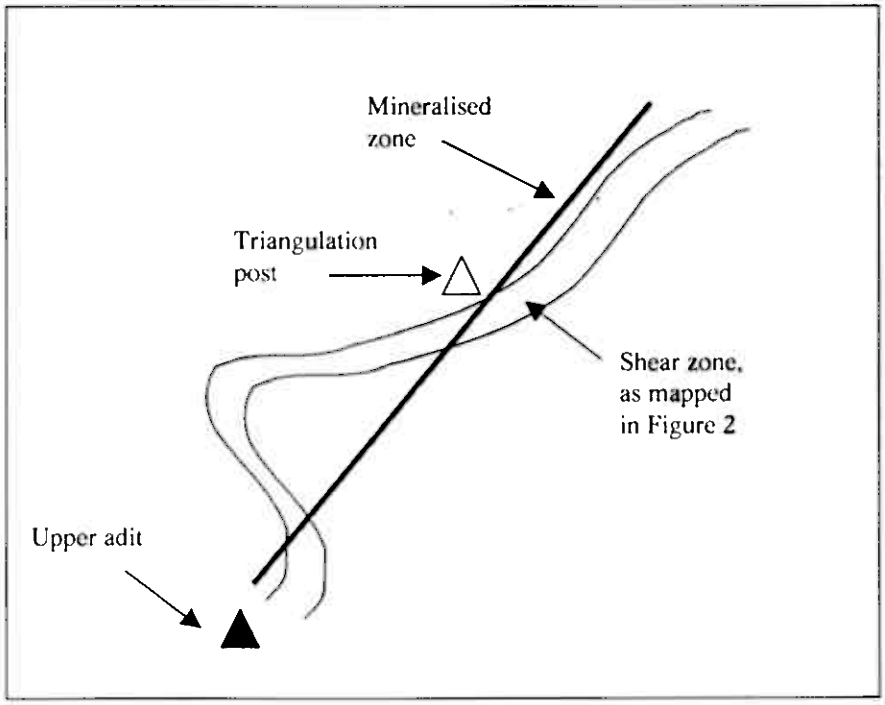
As suggested above, it is possible that the fault zone at locality 23 represents a continuation of the rocks containing the mineralisation from Prins Fredriks mine. If this is the case, the two interpretations in the sketches above may apply to the area of the mine itself.

If the interpretation in Sketch A applies to the mine area, then the mineralised zone would be expected to closely follow the mapped base of the shear zone as shown in Figure 2 (see sketched interpretation A below). If the interpretation in Sketch B applies, then the mineralised zone would be expected to cross-cut the shear zone in the hillside above the mine, and return to parallelism with the base of the shear zone in the vicinity of the 1016 triangulation post (see sketched interpretation B below). Above the top adit of the mine, a negative topographical feature is seen trending SW-NE up the hillside; it is possible that this could be a continuation of a fault zone upwards from the mine.

Interpretation A, mineralised zone parallel to gneiss layering



Interpretation B, mineralised zone steeper than gneiss layering



5. Conclusions

a. A combination of structural and lithological mapping suggests strongly that the rocks containing the mineralised zone at Prins Fredriks mine continue in a NE direction for at least 1km.

b. The mapped continuation of the rocks enclosing the mineralised zone corresponds closely to the geophysical IP anomaly.

c. The mineralised zone occurs in association with a SE dipping deformed and sheared zone between gabbroic and mafic gneisses to the NW and feldpathic gneisses to the SE.

d. Observations in a stream section 2km to the NE of the mine indicate that the same rocks may continue well beyond the mapped area.

e. Comparison of the stream section observations with those in the mapped area at Asete suggests that the mineralised zone may occur in association with a late clay-rich fault zone. The orientation of the fault zone is controlled to a certain extent by the earlier gneissic fabric, although the dip may be steeper.

Appendix: Locality information

Locality numbers are those in Figure 1:

1. Dark mafic-rich metabasite (amphibolite). Gneissic banding defined by cm-thick feldspathic layers = 319/61NE. Amphibole lineation trends 140.
2. Metagabbro, with garnet, feldspar and amphibole. Coarse-grained. Weak gneissic banding 323/27E. Lineation trends 185, defined by aligned amphiboles.
3. Pale feldspathic gneiss with elongate amphibole pods. Vague lineation trends 146.
4. Strong amphibole lineation in gabbroic gneiss trends 165, lying on 040/14SE fabric surfaces.
5. Coarse-grained metagabbro with amphibole, feldspar and garnet. Lineation trends 12/135.
6. Sheared gabbroic gneiss with acidic veining, Strong amphibole lineation 46/145 and planar fabric 062/52S.
7. Large exposure of heavily sheared gneiss with pegmatite acidic veining. Sheared acidic veins suggest top-to-SE (down-dip) shear parallel to 37/147 lineation. Strong planar fabric measured at 065/35SE, 070/40SE, 049/25SE. Acidic veins are late in relation to shearing as they cross-cut shear fabric. Large pegmatite vein near base of exposure contains mica pods.
8. Coarse metagabbro gneiss with strong amphibole lineation trending 150.
9. Strong shear fabric 080/46S and amphibole lineation 33/147.
10. Hillside above top of old mine workings (above upper adit). Strong shear fabric 063/40SE. Maps as a continuation of the shear zone in Locality 7. Pink feldspar pegmatites are common.
11. Weak gneissic banding 240/15NW (opposite direction to general dip). No lineation.
12. Dark amphibolite with vague lithological banding 155/76NE. Variable amphibole lineation trends 155. Rock unit is massive and stands up as a positive feature.
13. Feldspathic gneiss (60% feldspar). Strong amphibole lineation 15/139, steeper in places, association with 085/20S planar fabric. Lineation is stronger than planar fabric.
14. Same rock as at 13. Late epidotic shears 053/37NE sub-parallel to shear fabric in gneiss, 063/47SE.
15. Strong planar fabric in augen gneiss 085/35S.
16. Strong amphibole lineation 33/143, 21/130 on surfaces 095/41S, 112/51S, defining a sub-mylonitic shear fabric. Feldspathic pegmatite veining up to 1m wide.
17. Intense shear fabric 068/41SE with very strong amphibole lineation 36/130.
18. Feldspathic gneiss with pegmatite veining. Planar fabric 053/56SE containing amphibole lineation 54/147.
19. Augen gneiss (cm augen), 50% feldspar. Amphibole lineation 40/147.
20. Very strongly sheared gneiss developing micro-augen texture with sheared and folded feldspathic pegmatite veins. Very intense amphibole lineation 33/158.
21. Intense linear fabric 35/126, 41/139 defined by aligned amphibole. Intense planar fabric 039/40SE, 048/40SE. Feldspathic gneiss with pegmatite veining.
22. Coarse-grained metagabbro with amphibole lineation 40/142, 40/159. Highly variable and diffuse lithological gneiss banding. Sheared in some layers parallel to 128/26W, 075/17SE. Varies from gabbroic to amphibolitic with up to 70% mafic minerals. Shearing increases upwards and to NE (towards mapped shear zone).

23. River section at lower waterfall (grid reference 3428 0461) 1km NE of Borehole 2 site. Waterfall is formed by gabbroic gneiss, with overlying feldspathic gneisses forming lower ground to south. Two exposures:
    a. Exposure in SE riverbank at base of waterfall shows a fault zone several metres wide trending 060/64SE. The centre of the zone contains a 10 to 20cm wide clayey fault plane comprising green and pink coloured highly sheared clays. Footwall formed by creamy feldspathic rock, heavily sheared with amphibolite pods. Hangingwall comprises micro-augen gneiss with shear fabric sub-parallel to fault. Fault plane splits to west to enclose a shear augen (0.5 m wide) of feldspathic gneiss. Slickensides on clay surfaces trend 110-290, subhorizontally. Geometry suggests strike slip motion parallel to lineation.
    b. SE river bak 70m downstream from lower waterfall exposes another shear zone within feldspathic gneiss. Gneiss layering trends 044/32SE and is deformed by a sub-parallel shear zone.

Enclosure no 2.

Årdal drill core log 1999.

Drill hole no 1. The hole is located from summit point 1016m a.s.l. direction 74^g ($=67^0$) distance 47m. It is drilled with a 60^0 inclination towards NW ($=350^g$ $=315^0$). Length of hole is 91m.

Depth (m).	**Description.**	
0-5	Covered by glacial till.	
5-8,1	Light grey medium grained gneissic rock with pink coloured feldspar porphyroblasts up to 5 mm in size. Disseminated rusty spots most likely from oxidised pyrite up to 0,5mm in size. Foliation angle 60-80°.	
8,1-11,9	Same type of rock as above, but strongly techtonized. The techtonized zone is very much like the tectonic zone that may be seen under ground in the upper adit with hydrothermal quartz, calcite, rust (oxidised py), chlorite, some clay and epidote. The whole zone is mostly recemented.	
8,1-9,0	Split sample assayed for Au + 32 elements. Sample no	399559
9,0-10,0	----------"----------	399560
10,0-11,0	----------"----------	399561
11,0-11,9	----------"----------	399562
11,9-21,9	Foliated coarse grained gabbro with gneiss xenolites. Magnetic susceptibility up to15000κ.	
21,9-25,6	Intrusive sill of trondhjemite. (Diorite). Magnetic susceptibility up to only 5κ.	
25,6-53,3	Mainly a foliated gabbro with amphibole altered to chlorite and epidote. Magnetic susceptibility from 4000 up to15000κ. A felsic sill from 32,2-32,9.	
53,3-58,0	Porphyritic felsic sill. Magnetic susceptibility up to only 60κ.	
58,0-88,2	Dark ultramafic coarse grained rock with serpentine. Some magnetite may be seen in the serpentinised contacts. Magnetic susceptibility from 2000 up to7000κ.	
88,2-91,0	Mafic gneiss with small garnets. Magnetic susceptibility up to only 40κ.	

Drill hole no 2. The hole was drilled from a location 228m from summit point 1016m a.s.l. and direction 75^{g} (=68^{0}). It was drilled in direction 20^{g} (=18^{0}) to intersect the peak area of the Eastern IP anomaly. It was drilled with an inclination of 60^{0}. The hole was sunk to 86,5 metres.

Depth (m)	**Description.**		
0-3,0	Overburden with glacial till.		
3,0-7,9	A medium grained light coloured gneiss with biotite and chlorite in alternation with several trondhjemitic intrusions 3-50cm.		
7,9-15,5	Medium grained augengneiss with rounded feldspar eyes less than one cm in size. Some sections are rich in amphibole and micas. As in drill hole no 1 some small rusty spots most likely caused by oxidised pyrite may be found. Som silification and epodotization may be seen.		
15,5-27,9	A transitional zone over to a more amphibolitic type of a medium to coarse grained gneiss. From 21,4-21,7 a fine grained type. Veins of carbonate and epidote.		
27,9-31,6	Ultramafic intrusion zone with serpentine and talc minerals. A few mm thick and up to 4-5mm long py-po stringers.		
31,6-32,5	Trondhjemite intrusion.		
32,5-38,1	Coarse grained amphibole-gabbro. Strongly techtonized from 35,6 to 38,4. A very weak mineralization of chalcocite and chalcopyrite may be seen.		
33,0-34,0	Coarse grained Amph. With trace Cpy, Split smpl. Au + 32 elem.	Sample no	399551
34,0-35,0	Coarse grained gabbro (Hornblendite) --"-----		399552
35,0-36,0	Coarse grained gabbro (Hornblendite) 35,6-36,0 a techtonic zone with a light coloured gneiss --"-----		399553
36,0-37,0	Coarse grained gabbro (Hornblendite) Techtonized with epidote and serpentine --"-----		399554
37,0-38,0	Coarse grained gabbro (Hornblendite) Techtonized A light coloured techtonized rock 37,5-37,8 --"-----		399555
38,0-38,4	Light coloured gneiss, techtonized. -----"------		399556
38,1-40,0	Light grey coarse grained pegmatitic gneiss.		
40,0-46,0	Light grey coarse grained foliated gneiss with weakly developed feldspar porphyroblasts.		
46,0-51,6	Pink coloured coarse grained foliated gneiss.		
51,6-56,0	A light grey foliated coarse grained gneiss with biotite, muscovite and a little amphibole.		
56,0-72,0	As above with more amphibole and some pink (feldspar) sections.		
72,0-85,6	Light grey gneiss with epidote fracture fillings.		

Drill hole no 3. The hole is located 52m SW of the lowest adit at Prince Fredrik and 23m in distance towards the SE from the projected line of the mineralised zone. The direction of the drill hole is 356^g (=320^0) and inclination 75^0. The hole was sunk to 78m.

Depth (m)	Description	
0-6,0	Overburden, mostly talus. Casing drilled to 10,5m due to falling rocks in the hole.	
6,0-14,0	Coarse grained light grey foliated gneiss with micas and amphibole.	
14,0-22,0	As above, but a few feldspar porphyroblasts. A little epidote.	
22,0-30,6	As above.	
30,6-32,5	Pink coarse grained gneiss with amphibole and chlorite.	
32,5-40,3	Coarse grained amphibole gneiss with chlorite.	
40,3-46,0	Mica gneiss with a techtonic zone 40,3-41,9 with epidote and carbonate veins.	
40,3-41,0	Split sample assayed for Au + 32 elements. Sample no	399557
41,0-41,9	----------"----------	399558
46,0-50,7	Micas – amphibole gneiss.	
50,7-54,0	Light grey to pink coarse grained gneiss.	
54,0-63,4	As above, but a dark amphibole-chlorite type from 57,7-58,0 and 59,1-59,5.	
63,4-65,0	Amphibolitic foliated gneiss.	
65,0-78,0	Coarse grained gabbro with a little magnetite. Susceptibility 600 to 1000κ.	

Encl. 3

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