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Tittel

Joint Venture Folldal Verk A/S - Norske Fina A/S.
Knaben area. Exploration 1983

Forfatter	Dato	Bedrift
Olav Limyr	17/2 1983	Folldal Verk A/S Norske Fina A/S

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
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Fagområde	Dokument type	Forekomster
		Knaben1 Knaben2 Kvina Ørnehommen Reinshommen, Gursli Mysseskjerpene

Råstofftype	Emneord
Malm/metall	Mo Cu Ag Au

Sammendrag

Norske Fina a/s
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FINA

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Ørsdalen, Exploration Works 1982.

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Med hilsen
for NORSKE FINA A/S

Olav Limyr

Vedlegg

6.6

JOINT VENTURE

FOLLDAL VERK A/S - NORSKE FINA A/S

KNABEN GRUVOR

EKSPLORATION WORKS 1982

17.02.1983
Olav Linnyr

KNABEN

Previous work

The Knaben area is the oldest and largest molybdenum mining district in Norway (Map 1). From 1885 to 1972 the district produced 18.8oo tons of MoS_2 from 8,8 mill tons of ore.

A detailed account on the geology and mineralization in the Knaben district is presented in Bugge (1963). The mine-geologist from 197o to 1973 summarized the prospection and explotation work undertaken in the district prior to the closure of the mine (Gustavsen, 1973). He also prepared a detailed geological/ mineralization map in scale 1:5ooo of the Knaben area. From 1979 to 1981 Sydvaranger A/S did extensive exploration in the area (Gvein & Rui, 198o and Gvein, 1981).

Activities

During 1982 the joint venture Norske Fina A/S - Folldal Verk A/S rented the claims in the area from the government. The tailing from the Knaben II mine was sampled, and at the same time the old mines and major showings in the area were visited. The above mentioned investigations and descriptions of the area were studied and compared with own fieldobservations.

Geological setting

In the Knaben district it is possible to discriminate between various rocktypes.

The most frequent rocktype is from old time called red granite. Actually it is an orthogneiss. It is a massive, pink, coarse-grained rock with a vague foliation and granitic composition. The foliation is due to elongated kalifeldspar grains, platy quartz and a minor content of biotite.

The other important rocktype is the grey gneisses. They are found as concordant layers and lenses in the red granite. Three varities of the grey gneisses can be discriminated. A light grey, finegrained, well foliated or banded biotite-hornblende gneiss often with a minor content of iron-sulphides. Along strike the biotite-hornblende gneiss is transitional into augengneiss, which is a grey, coarsegrained, vaguely foliated gneiss with characteristic large blastoporphyres of kalifeldspar. The augengneiss also contains a minor amount of biotite and iron-sulphides. Associated with the leucocratic gneisses it is frequent to find concordant lenses or bands of amphibolite.

A rare rocktype is discordant amphibolites which are migmatized and contain folded quartz-feldspar mobilizations. Such an amphibolite can be followed from just north of the open pit at Knaben II and towards SE (Map 2). A hornblende foliation in the amphibolite is oriented lo-2o^{o} SSE.

In connection with the mineralizing episode the above mentioned rocktypes were altered and quartz veins were formed. These newformed rocks shall be described below.

Various post-tectonic rocks also occur in the area. Their age-relation to the mineralizing episode is not well understood. They comprise coarsegrained, discordant, subvertical pegmatites and finegrained, discordant aplites.

The youngest geological episode is the intrusion of E-W striking subvertical dolerites up to lo m thick and several km long.

The red granite predominates in the Knaben area. The grey gneisses are mainly found within a loo to 3oo m thick horizon which also contains many thin layers and lenses of red granite (Map 2 and Map 3). A distinct marker layer has not been mapped out and therefore the detailed structure of the gneiss horizon is not well known.It was mentioned above that the augengneiss is transitional into biotite-hornblende gneiss. It is characteristic that the augengneiss predominates in the area from Knaben II to Kvina, as the biotite-hornblende gneiss mainly is found in the area south of Knaben II. The grey gneisses are also found as scattered layers and lenses enclosed in the red granite, and especially in the area below the main gneiss horizon.

The general strike of the gneiss is N-S with deviations of up to 3o degree. The dip is 2o-5o^{o} E. Isoclinal folding and minor dragfolding have been observed a few places. The small variation in strike/dip of the gneiss is due to open folding. The orientation of the gneiss foliation are plotted in Fig. 1 to Fig. 4. It is possible to recognize two foldaxes. One dipping 25^{o} to 3o^{o} SE and one dipping c. 1o^{o} S. Individual open folding structures have been measured at Ørnehommen and Knaben I and on the structural map of Knaben II (Map 3). The measurements (Fig 5) define all the approximate same foldaxis, which dips c. 35^{o} SE. The 1o^{o} S dipping axis has not been identified in individual foldstructures, but it is identical with the plunge of the orebodies at Knaben II and Kvina (see below).

Mineralization, types

The most frequent oreminerals in the Knaben area are molybdenite, chalcopyrite, pyrrhotite and pyrite. Several types of mineralization can be recognized.

Disseminated MoS_2 in various altered rocktypes is the most important type. The most frequent type is the socalled gangfjell. It is a bleached red granite enriched in quartz. The bleaching is caused by the break-down of the feldspar with seritization in the core of the grains and albite formation at the rim. The enlarged quartz content is mainly found in diffuse quartz veinlets. Molybdenite is found disseminated in the gangfjell often associated with the quartz. In addition to MoS_2 the gangfjell also contains 2oo to 4oo ppm Cu in the form of chalcopyrite. The upper part of the Knaben II orebody was gangfjell, and o,5 to

1,o mill tons contained o,3 to o.5 % MoS_2. It must be noted that large volumes of gangfjell contains no molybdenite. Where amphibolite has underwent alteration there is formed a massive glimmerite. At Knaben I glimmerite is formed at the bottom of a folded amphibolite, and it is impregnated with MoS_2 (Table 1).

Mineralized quartz veins represent an other important type of mineralization. Two variations can be discriminated. The first is thin (less than o,5 m thick), concordant quartz veins which occur enclosed in gangfjell, glimmerite, red granite and in the grey gneisses. Molybdenite and traces of chalcopyrite is concentrated at the contact of the veins. Swarms of quartz veins in gangfjell make up the low grade mineralization in the lower part of the Knaben II orebody. The other type of quartz vein comprises the metre-thick veins at Kvina, upper Reinshommen and possible also Knaben I. In addition to quartz the veins also contain feldspar, hornblende and biotite. Molybdenite and chalcopyrite are found disseminated in the veins. The Mo/Cu ratio is 2 to 3 times less than in the gangfjell, but still above 1.

A third type of mineralization,comprising semi-massive sulphides is found above the Knaben II orebody within the gneiss horizon, and above the Kvina orebody also within the gneiss horizon. Semimassive sulphide accumulations are found in concordant and discordant veins of brecciated hostrock. Individual veins are up to o,5 m thick. Pyrrhotite predominates with minor amounts of chalcopyrite, pyrite and molybdenite. The Mo/Cu ratio is less than 1, and characteristic this type also contains minor amounts of silver (Table 1).

The grey gneisses with a low content of iron-sulphides and occasionally also traces of molybdenite and chalcopyrite represent a fourth type of mineralization.

Locality	Rock description	Mo (ppm)	Cu (ppm)	Ag (ppm)	Au (ppm)
Knaben II	Gangfjell with MoS_2-bearing quartz vein	1.2 %	260	< 2	< 0.1
300 m E of Knaben II	Semi-massive sulphides in biotite-rich rock	380	1.7 %	14	< 0.1
Reinshommen	Quartz vein with disseminated chalcopyrite and molybdenite	1200	5300	8	< 0.1
Knaben I	Glimmerite with c. 10 % disseminated molybdenite	13.7 %	320	< 2	< 0.1
Kvina	Glimmerite and quartz vein rich in molybdenite	19.6 %	360	< 2	< 0.1
Kvina	Quartz-hornblende vein with disseminated MoS_2 and $CuFeS_2$	1000	1700	< 2	< 0.1
Cu-skjerp east of Šmalvatn	Semi-massive sulphides in quartz-feldspar rock	380	3.0 %	65	< 0.1
Gursli	Anorthosite with disseminated molybdenite	1.7 %	280	< 2	< 0.1
Gursli, Mysse-skjerpene	Semi-massive sulphides in feldspar rock	5500	2200	< 2	< 0.1

Table 1 Analyses of rocksamples from the Knaben and Gursli areas.

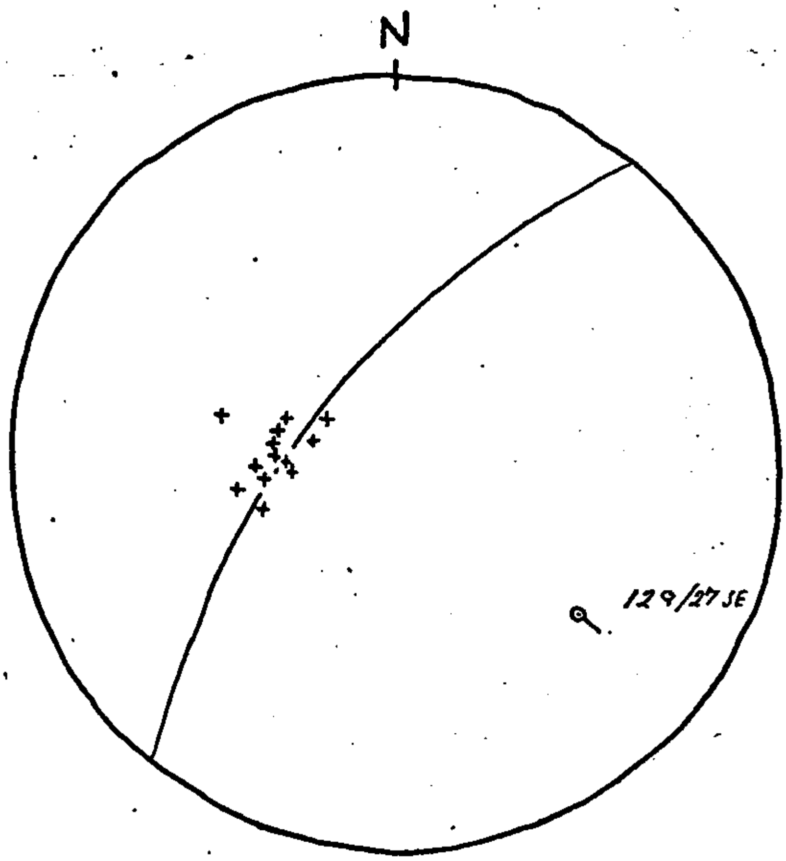


Fig. 1 Foliation measurements and constructed foldaxis from the area south of Knaben II to Reinshommen.

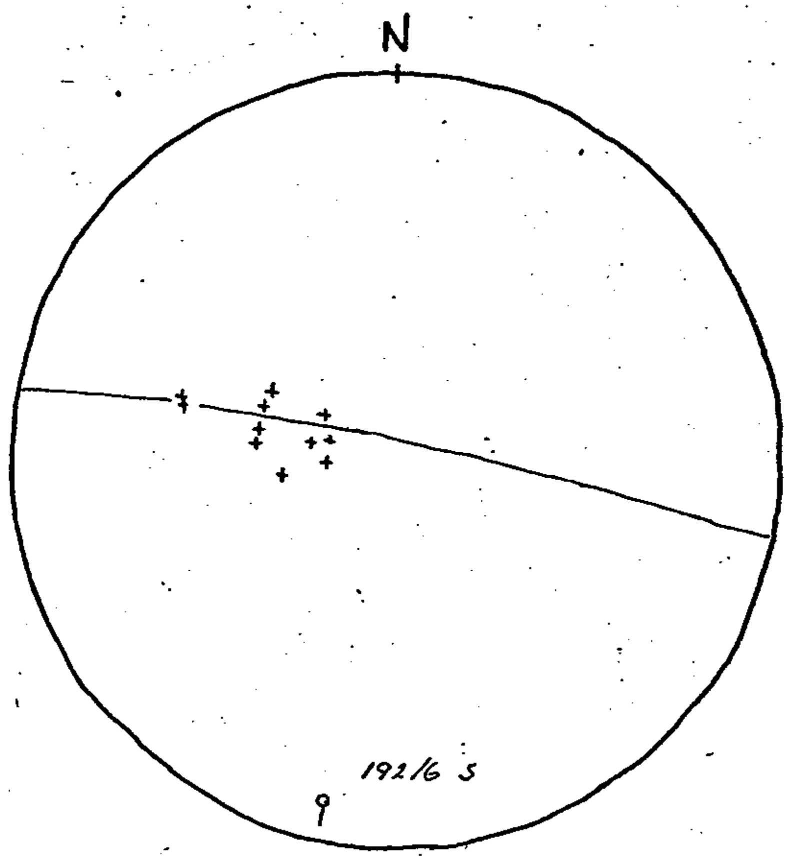


Fig. 2 Foliation measurements and constructed foldaxis from the area between Reinshommen and Knaben I.

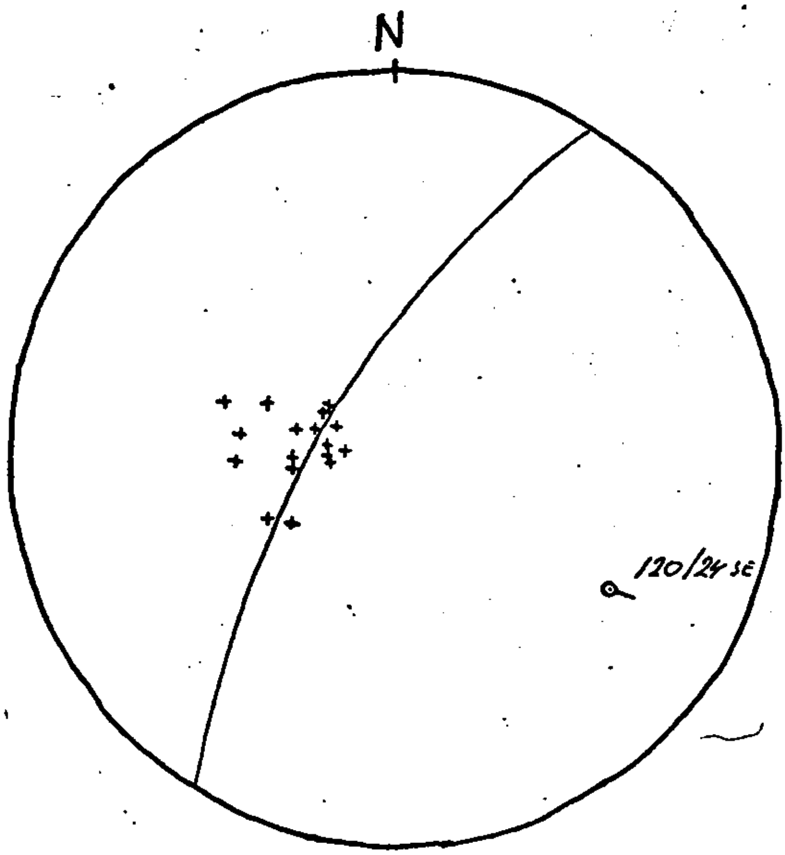


Fig. 3 Foliation measurements and constructed foldaxis from the area between Knaben I and Smalvatn.

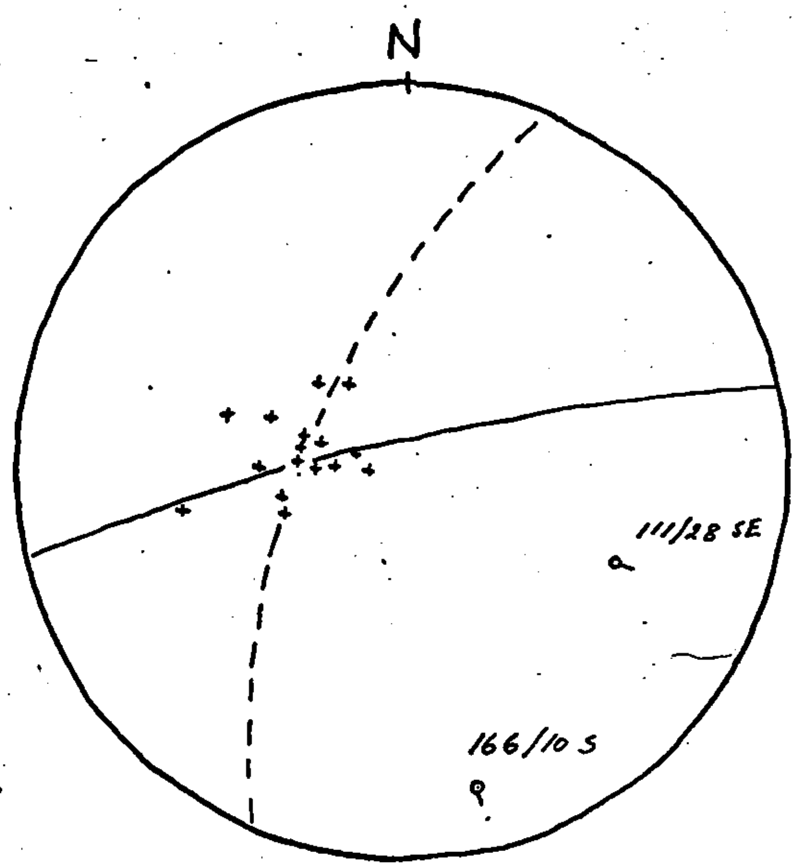


Fig. 4 Foliation measurements and constructed foldaxes from the area around Kvina.

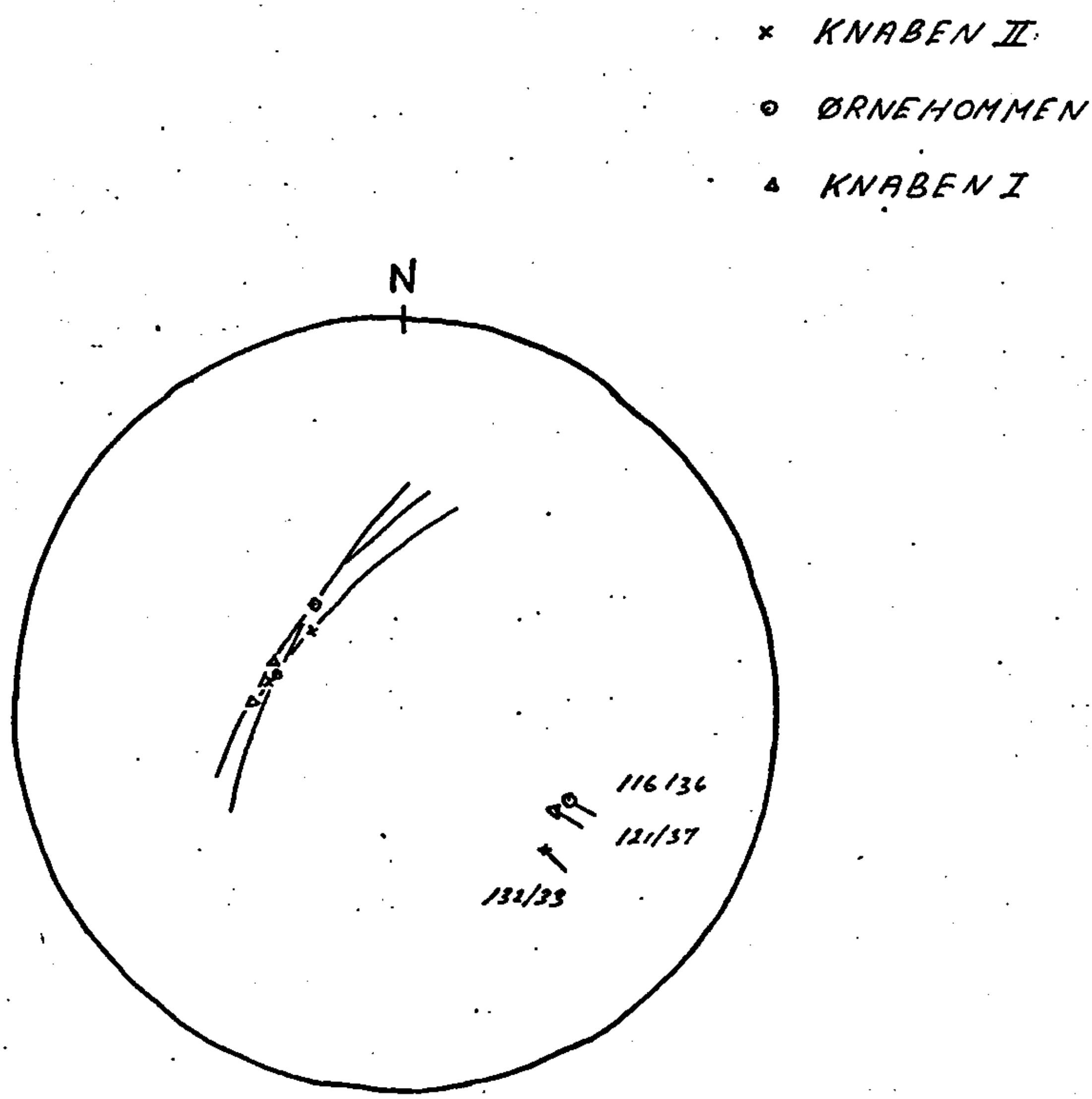


Fig. 5 Orientation of the flanks of the ore controlling fold structures at Knaben I and II and Ørnehommen. The foldaxes are constructed.

Mineralization, description of localities

Mining has taken place from a few large mines and many small mines and showings. The most important ones are described below.

Knaben II is the largest mine (Map 2). From 1918 to 1972 it has produced 18.000 tons of MoS_2 from 8,6 mill tons of ore. The orebody is rulerformed with a length of more than 1300 m, a width of up to 400 m and a thickness of up to 40 m. The orebody is situated within the red granite below the gneiss horizon. The oreplane is concordant with the structure of the gneisses and forms an open anticlinal structure (Map 4). The long axis is dipping 10-15° S. There is a pronounced zonation within the orebody with molybdenite-bearing quartz veins in gangfjell in the lower part and disseminated molybdenite in gangfjell in the upper part. The later with higher grades than the first.The Knaben II orebody is well-investigated with diamond drilling, and it is estimated that there remains 5 mill tons of ore with 0,15 % MoS_2 in the lower part of the orebody.

The Kvina orebody was mined from 1908 to 1955. The production totalled 230 tons of MoS_2 from 100.000 tons of ore. As with Knaben II the Kvina orebody is rulerformed. The maximum dimensions are 240 m x 80 m x 16 m. The orebody occurs enclosed in red granite below the main gneiss horizon. The oreplane (22°/30°E) is concordant with the structure of the red granite, and the long axis is dipping c. 10°S. Molybdenite and chalcopyrite are found at the contact of and disseminated in metre-thick quartz veins and pegmatites. The continuation at south has never been diamond drilled. There is drilled one hole 150 m east of the Kvina orebody, and it does not show any mineralization.

Knaben I is the oldest mine in the area. From 1885 to 1939 it produced 570 tons of MoS_2 from 80.000 tons of ore. Knaben I is situated in the lower part of the gneiss horizon (Map 2). The orebody is found below a syncline in amphibolite. The flanks are oriented 18°/37° E and 18o°/41° E. The foldaxis of the structure is dipping 37°SE. The orebody is only loo m long and has been followed 25 m below the surface, which corresponds to a down-dip length of 45 m. Molybdenite is found disseminated in glimmerite and associated with quartz veins. The extend of underground exploration is not known. Relevant diamond drilling from the surface comprises one hole (4.1). There is not reported any mineralization in this hole, and it may be placed to far to the south to catch up a possible continuation of the ore in the direction of the foldaxis.

Ørnehommen mine produced 4,2 tons MoS_2 from 2ooo tons of ore. The deposit is situated below a syncline in biotite-gneiss enclosed in red granite and well below the main gneiss horizon. The flanks are oriented 14°/36° E and 5o°/38° SE. The mineralization type is quartz veins in gangfjell.

For description of the many smaller mines and showings, see Bugge (1963).

Discussion/conclusion

The formation of altered rocks, the formation of quartz veins and sulphide accumulations and the occurrence of a zonarity pattern with the variation in the Mo/Cu ratio and the distribution of silver values point to the existence of migrating hydrothermal solutions in the area during the mineralizing episode.

The structure of the gneiss controlled the distribution of the hydrothermal solutions. Anticlines and synclines formed during open folding have acted as sites for alteration and precipitation of quartz and the oreminerals.

Knaben II is formed within an anticlinal structure (Map 4), and this obvious facilitated the formation of a very elongated and large orebody. The only other orebody with an elongated geometry is the Kvina deposit. It is proposed that the zonarity seen in Knaben II is the result of cooling of Mo-bearing hydrothermal solutions migrating upwards along the axis of orebody. It is further proposed, that the oretype at Kvina represents formation at an even lower temperature. This opens the possibility, that an orebody of a Knaben II model may be found south of Kvina Map 2 It is interesting to see, that the only drillhole in the area (D 1) has lo to 15 m with traces of molybdenite at the expected depth,

Knaben I and Ørnehommen are found below synclinal structures. They seem not to have the same elongated geometry, but characteristically these deposits seem to have a higher grade than the type in anticlinal structures.

It shall bee noted that the total amount of molybdenite per metre in the Kvina/Knaben I area equals the amount in the Knaben II area, namely 5o-loo tons MoS_2/metre. Therefore, in the Kvina/ Knaben I area it is only a question of finding a structure which was able to concentrate the molybdenite. Such a structure could very well exist at depth in the continuation of the Kvina orebody.

THE TAILING AT KNABEN II

Introduction

During the mining period at Knaben II (1918 - 1972) a total of 8,6 mill tons of ore with o,21 % MoS_2 (o,13 % Mo) was mined and milled. The tailing was in the entire period discharged at the east end of Lille Knabetjern. First Lille Knabetjern was filled and later also most of Store Knabetjern (Map 5). The tailing contains minor amounts of Mo and Cu in the form of molybdenite and chalcopyrite.The Mo-content depends on the mill-head grade and the recovery. The recovery has increased from perhaps 7o-8o % during the first years of operation with high grade ore (o,3 % MoS_2) and up to 9o % at the time when the mine was closed. The expected content would then vary from 8oo to 15o ppm MoS_2. The Cu-content corresponds to the original content of Cu in the ore, and it is 2oo to 4oo ppm.

The background idea for sampling the tailing was twofold:

- To identify tailing deposited during the first years of operation with the expected high Mo-content.
- To identify areas with heavy mineral enrichment where molybdenite and chalcopyrite would be concentrated.

Activities

The sampling program was limited to the Lille Knabetjern bassin. Two profiles approximate 2oo m apart and both parallel with the assumed flow direction was sampled. On each profile, holes - 5o m apart - were sampled for each metre (Map 5 and Map 6). The sampling was done with a 1 m iron-tube , which mounted with rods was hammered down in the sand 1 m at a time. A total of 252 samples were collected from 21 holes Table 2. In most holes it was possible to reach the bottom of the tailing pond. Each sampled weighed c. 1 kg. It was blended and c. 2oo g was sent for Mo-analysis (Table 3). One heavy-mineral sample

Drillhole	Length	Sample numbers	Terminated in:	Remarks
PROFILE 1	Totally 117 samples			
o	4.4 m	1 - 5	Peat	
25	1o.6	1 - 11	Peat	Started 1.5 m below surface of tailing
75	17.7	1 - 18	Peat/stone	
125	16.o	1 - 16	Stone	
175	16.o	1 - 16	Soil	
225	18.o	1 - 18	Sand	Not drilled through ?
275	15.9	1 - 16	Soil	
325	1o.5	1 - 11	?	
375	5.9	1 - 6	Peat	
PROFILE 2	Totally 131 samples			
o	4.5	1 - 5	Peat	
5o	13.o	1 - 13	Soil	
1oo	2o.2	1 - 2o	Sand	
15o	15.3	1 - 16	Peat/sand	
2oo	16.6	1 - 17	Soil	
25o	11.8	1 - 12	Stone	
3oo	6.8	1 - 7	Peat	
35o	8.3	1 - 9	Peat	
4oo	11.7	1 - 12	Peat/sand	
45o	1o.5	1 - 11	Peat	
5oo	8.9	1 - 9	Peat	
Hole A, at the NW-corner of the football field. Totally 4 samples				
-	3.9	1 - 4	Peat	

Table 2 Sample list from the sampling of the tailing

PROFILE 1

Sample No.		Mo ppm
1-0	1	140
	2	170
	3	90
	4	180
	5	200
1-25	1	95
	2	100
	3	210
	4	480
	5	460
	6	420
	7	1100
	8	520
	9	480
	10	330
	11	480
1-75	1	45
	2	50
	3	140
	4	250
	5	370
	6	280
	7	400
	8	310
	9	290
	10	250
	11	120
	12	70
	13	240
	14	310
	15	110
	16	80
	17	80
	18	110
1-125	1	230
	2	150
	3	70
	4	130
	5	170
	6	230
	7	150
	8	130
	9	140
	10	190
	11	130
	12	120
	13	80
	14	100
	15	80
	16	100

Sample No.		Mo ppm
1-175	1	80
	2	50
	3	80
	4	130
	5	140
	6	260
	7	170
	8	130
	9	230
	10	160
	11	180
	12	160
	13	100
	14	230
	15	320
	16	360
1-225	1	80
	2	50
	3	60
	4	90
	5	160
	6	160
	7	120
	8	120
	9	130
	10	160
	11	180
	12	160
	13	170
	14	130
	15	130
	16	90
	17	130
	18	160
1-275	1	80
	2	40
	3	90
	4	70
	5	120
	6	100
	7	140
	8	100
	9	160
	10	280
	11	230
	12	160
	13	150
	14	130
	15	190
	16	140

Sample No.		Mo ppm
1-325	1	50
	2	80
	3	60
	4	80
	5	60
	6	60
	7	80
	8	150
	9	90
	10	70
	11	80
1-375	1	40
	2	70
	3	90
	4	60
	5	50
	6	110
Hole A	1	45
	2	40
	3	18
	4	160

Table 3 Analyses of the Mo-content in sand samples from the tailing at the Knaben II mine.

PROFILE 2

Sample no		Mo (ppm)
2-0	1	160
	2	80
	3	170
	4	190
	5	150
2-50	1	100
	2	350
	3	380
	4	240
	5	480
	6	560
	7	760
	8	390
	9	450
	10	470
	11	400
	12	710
	13	400
2-100	1	210
	2	480
	3	430
	4	180
	5	430
	6	290
	7	160
	8	150
	9	220
	10	290
	11	170
	12	140
	13	130
	14	90
	15	110
	16	140
	17	160
	18	180
	19	170
	20	160

Sample No.		Mo ppm
2-150	1	130
	2	300
	3	250
	4	140
	5	380
	6	200
	7	250
	8	270
	9	220
	10	240
	11	220
	12	160
	13	170
	14	100
	15	130
	16	80
2-200	1	130
	2	200
	3	130
	4	100
	5	420
	6	250
	7	170
	8	240
	9	190
	10	240
	11	130
	12	140
	13	150
	14	150
	15	120
	16	140
	17	210
2-250	1	180
	2	140
	3	80
	4	140
	5	300
	6	140
	7	220
	8	170
	9	180
	10	240
	11	170
	12	160

Sample No		Mo ppm
2-300	1	80
	2	130
	3	90
	4	90
	5	130
	6	130
	7	140
2-350	1	130
	2	60
	3	70
	4	80
	5	130
	6	130
	7	130
	8	160
	9	230
2-400	1	150
	2	60
	3	70
	4	100
	5	90
	6	130
	7	100
	8	160
	9	240
	10	270
	11	290
	12	190
2-450	1	190
	2	40
	3	80
	4	90
	5	90
	6	90
	7	90
	8	400
	9	270
	10	300
	11	220
2-500	1	50
	2	90
	3	160
	4	130
	5	110
	6	220
	7	300
	8	280
	9	120

Table 4 Continued

has been panned from the tailing and analysed for various elements (Table 5).

Results

The Lille Knabetjern bassin contains c. 3,o mill tons of sand. The distribution of Molybdenum is shown in Map 6 and Fig 6 The aritmetric average MoS_2 content is o,o3o % MoS_2. A higher grade lens with o,o62 % MoS_2 occurs from 25 m to 125/225 m from the discharge point. The size of the lens is estimated to be o,5 mill tons. The Cu-content is one half of the Mo-content (Table 5). This is in accordance with the expected content. Even in concentrates with c. 1 % Cu no Ag and Au are detected.

Conclusion/recommendation

It has been demonstrated that a lens with heavy mineral enrichment exists within the tailing. The grade and tonnage of this lens is to low to be of any economic potential. No further work is recommended.

Spectrographic analysis:

Fe, Si, Al and Ti	are in the range	o,5 %	to	5 %
Mn, Ca and Na	are in the range	o,o5 %	to	o,5 %
Cr, Pb, V abd Ni	are in the range	5o ppm	to	5oo ppm
Co	is in the range	5 ppm	to	5o ppm
Mo	is approximately	2 %		
Cu	is approximately	1 %		

Analysis by atomic absorbtion:

Se	2o	ppm
Te	< 1	ppm
Au	< o,1	ppm
Ag	< 1	ppm

Table 5 Analysis of heavy-mineral concentrate panned from the tailing. The factor of enrichment is approximately 25o times.

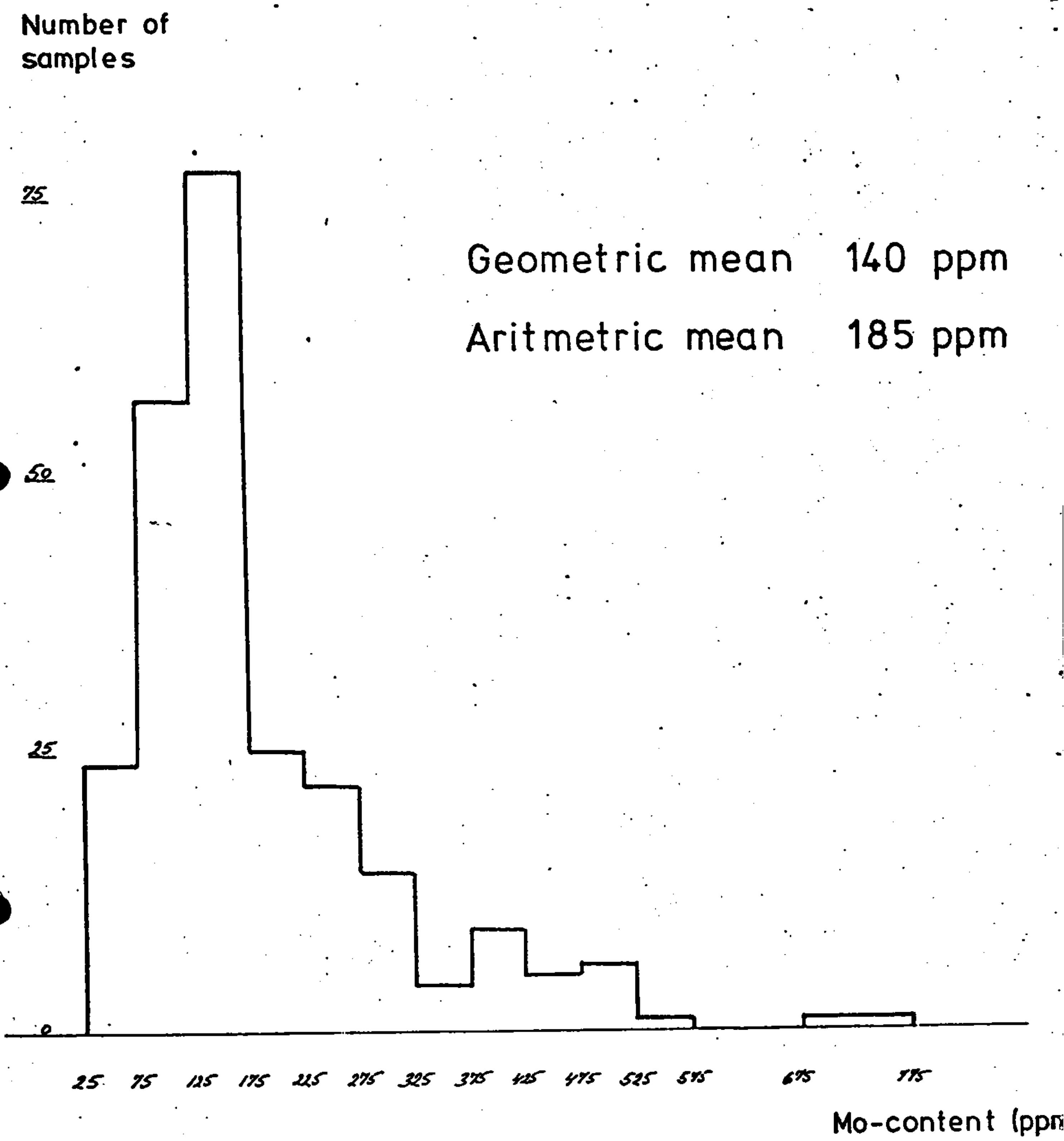
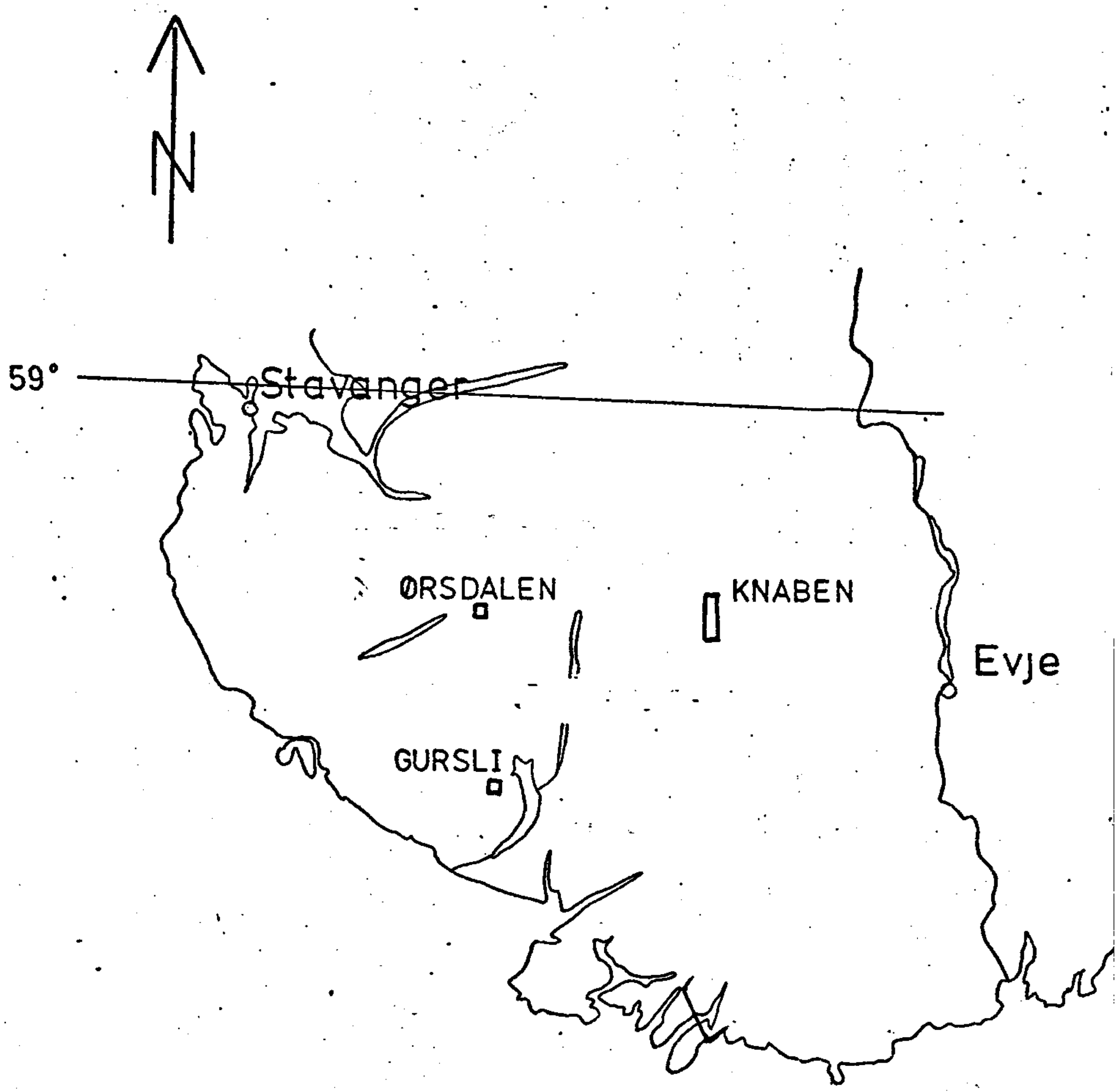
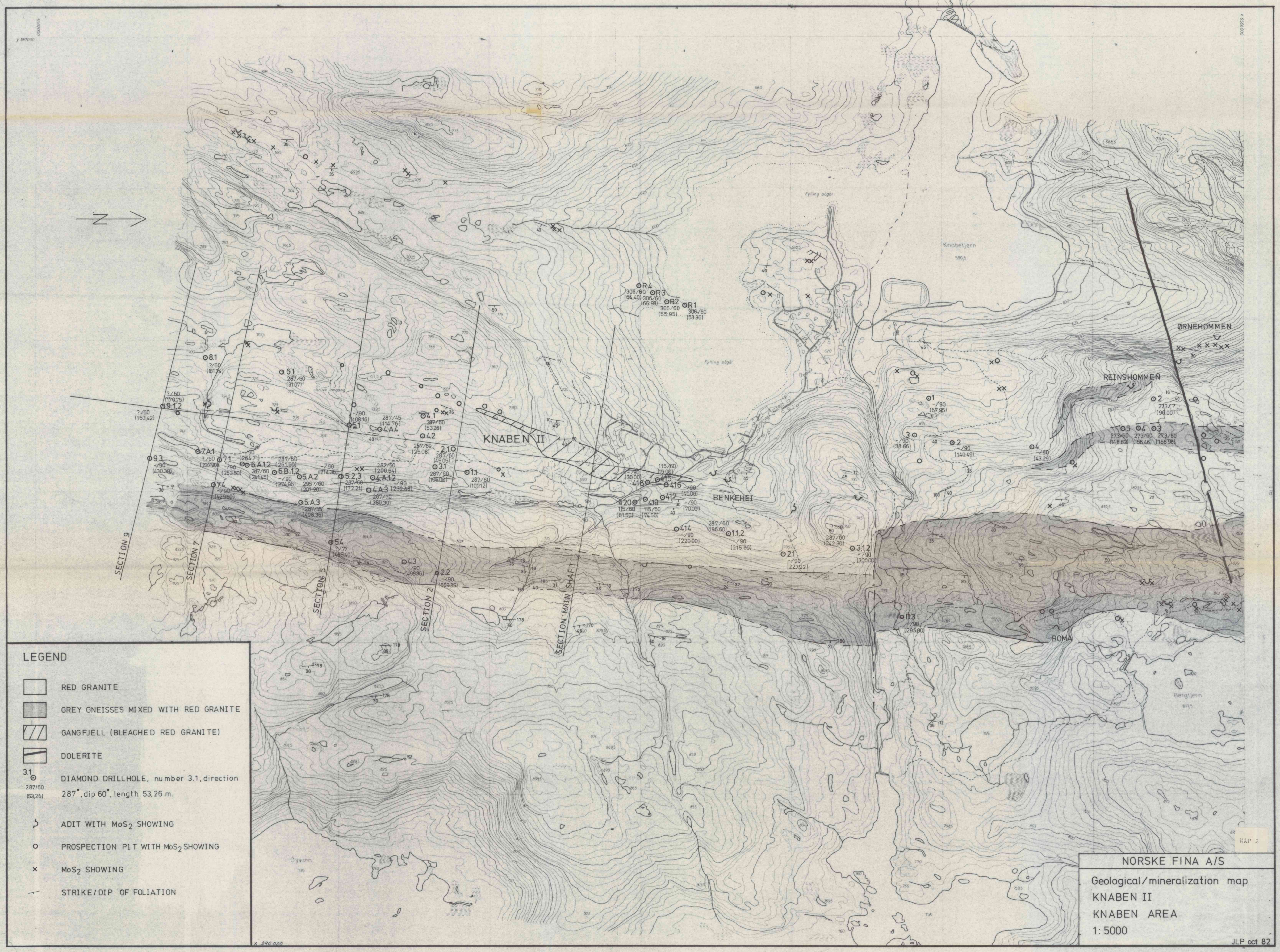


Fig. 6 Distribution of Mo-values in the Lille Knabetjern tailing pond. Total number of samples is 248.



MAP 1

NORSKE FINA A/S
Locality map SW - NORWAY 1:1000000 JLP oct 82



KNABEN GRUBER

2 00.151

1

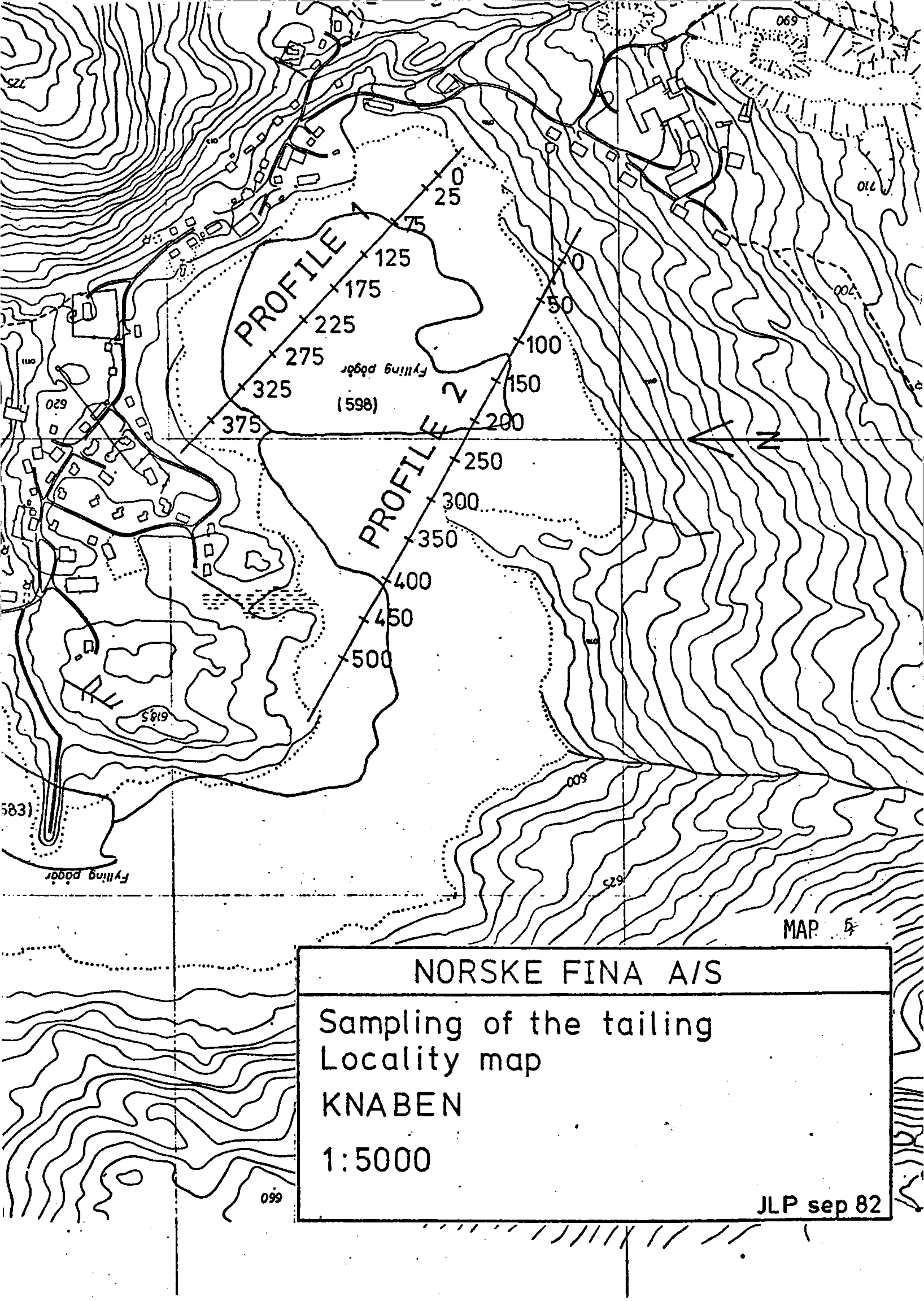
Konstruert av Widerøe's Flyveselskap etter fotogrammer opptatt aug. 1961

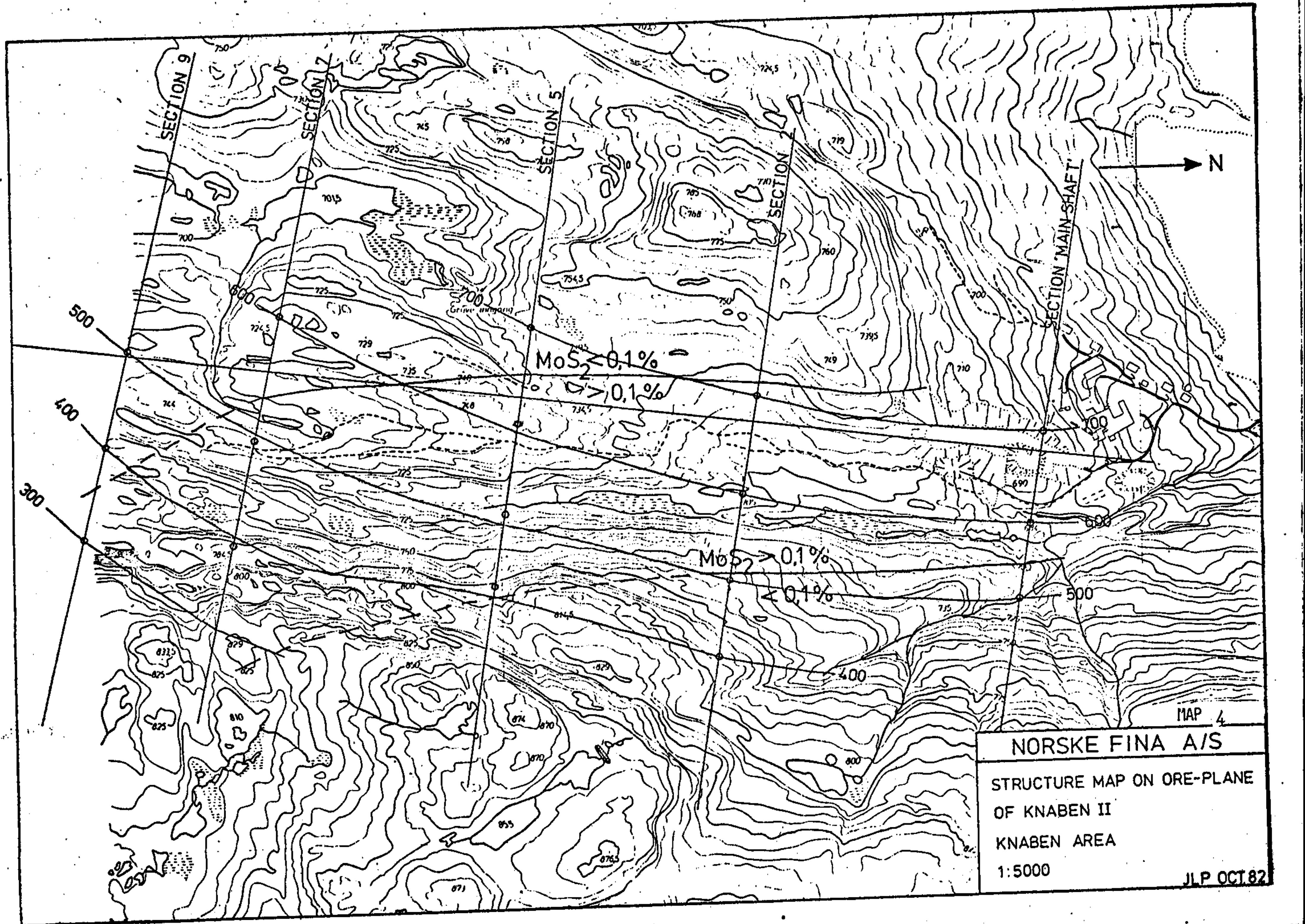
1:5000

Ekv.5m

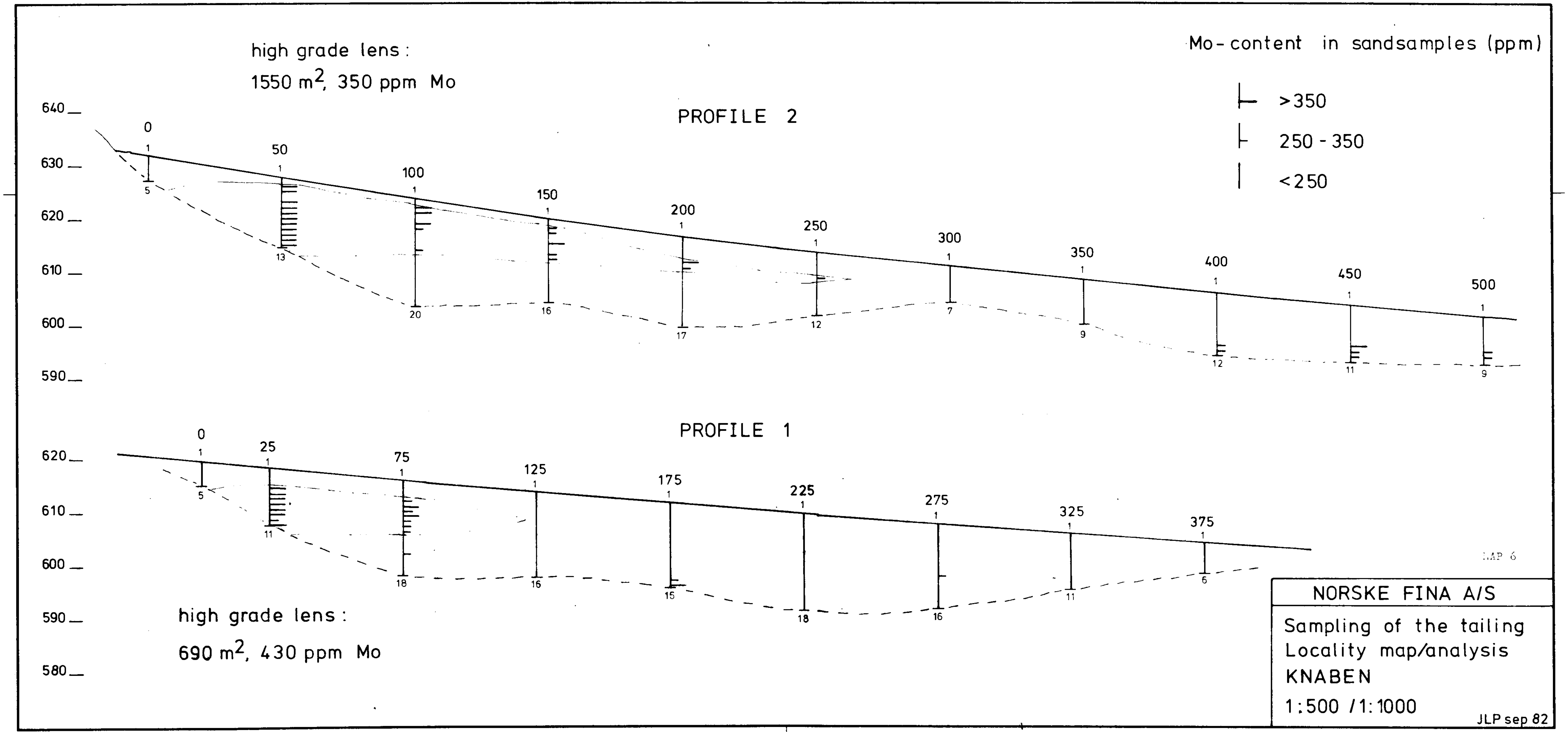
KNABEN GRUBER

Bl. 1 / K.M.00,150


PROFILE 1
0
25
75
125
175
225
275
325
375
PROFILE 2
0
50
100
150
200
250
300
350
400
450
500
Fylling pågår
(598)
620
618.5
(583)
Fylling pågår
600
625
660
690
710
700
725
N
MAP 5
NORSKE FINA A/S
Sampling of the tailing
Locality map
KNABEN
1:5000
JLP sep 82



SECTION 9
SECTION 7
SECTION 5
SECTION 2
SECTION 'MAIN SHAFT'
N
500
400
300
600
700
MoS_2 < 0,1 %
> 0,1 %
MoS_2 > 0,1 %
< 0,1 %
600
500
400
Gruve inngang
MAP 4
NORSKE FINA A/S
STRUCTURE MAP ON ORE-PLANE
OF KNABEN II
KNABEN AREA
1:5000
JLP OCT.82



high grade lens :
1550 m2, 350 ppm Mo
Mo-content in sandsamples (ppm)
>350
250 - 350
<250
PROFILE 2
640
630
620
610
600
590
0
50
100
150
200
250
300
350
400
450
500
PROFILE 1
620
610
600
590
580
0
25
75
125
175
225
275
325
375
high grade lens :
690 m2, 430 ppm Mo
NORSKE FINA A/S
Sampling of the tailing
Locality map/analysis
KNABEN
1:500 /1:1000
JLP sep 82