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Tittel
Down-Hole VLF Vakkerlien. Vakkerlien Ni, Cu deposit Kvikne

Forfatter	Dato	Bedrift
Ø Logn	1978	Sulfidmalm A/S

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Tynset	Hedmark	Østlandske	16202	Røros

Fagområde	Dokument type	Forekomster
Geofysikk Boring	Rapport	Vakkerlien
Råstofftype	**Emneord**	
Malm/metall	Ni Cu	

Sammendrag

FAGRAPPORT
TECHNICAL REPORT

A/S SULFIDMALM

Dato/Date	Rapport Nr./Report No	Kartblad/Mapsheet
6.2.79	493.78.20	1620 III

Forfatter
Author Ø. Logn. F. Hansen. R. Sivertsen. F. Nixon.

Tittel/Title

DOWN-HOLE V.L.F. MEASUREMENTS. VAKKERLIEN Ni/Cu DEPOSIT. KVIKNE.

Resyme/Summary

1. Clear down-hole VLF anomalies are observed in drill holes at a distance of up to 50m. from the ore.
2. Weak anomalies can be seen in holes up to 80m. from the ore, but these anomalies are unclear.
3. The form of the curves indicate which side of the ore body the holes have been drilled.
4. The anomalies are explained by the assumption that the ore body acts as an antenna which receives VLF signals from the transmitter station.
5. Evidence for a southerly continuation of the ore body is presented.

Andre relevante rapp.
Other relevant reps.

399.74.20
351.74.20
360.75.20
373.75.20
379.75.20
403.76.20
422.76.20
424.76.20
433.76.20
466.77.20

Kommentarer/Comments

Fordeling
Distribution

- [x] Canada
- [x] Nikkelverket
- [x] Kristiansand
- [x] Oslo
- [x] R. Sivertsen
- [x] D. Watkins
- [ ]
- [ ]

INTRODUCTION

The Vakkerlien deposit is a nickel-copper ore discovered and investigated by Sulfidmalm in the period 1975 - 1978. The ore is associated with a gabbro lens which lies in Caledonian (cambro-silurian schists). The deposit has a very special form forming a ca. 1.3 km long rular or cigar shaped body with a weak plunge to the south. At its northern extremity the ore subout crops. The ore cross-section is small: width 25 - 40 m and thickness up to 7 m.

The deposit has been subjected to a number of electrical surveys all of which indicate that the ore is a good electrical conductor. V.L.F. surveys give good indications.

The deposit has also been investigated by an extensive drilling program and the ore cross-section is relatively well known along the entire body.

The continuation of the deposit towards the south is at the moment uncertain. Increasing thicknesses of conductive overburden, increase in depth to top of ore and tectonic disturbances have made investigations difficult.

It was realized that the body was well-suited to testing by down-hole V.L.F. techniques. This geophysical method is at the moment being investigated by BVLI (Mining Industry Research Division) of which Sulfidmalm is a member. Sulfidmalm offered BVLI the opportunity to test the deposit and at the same time we hoped to obtain some positive information concerning the southerly continuation of the deposit.

THE SURVEY

The survey was carried out in two periods, 21.-22. June and a period in September. F. Hansen, Sulfidmalm, and Ø. Logn and S. Paulsen BVLI carried out the work.

The deposit has mainly been drilled off with vertical drillholes in profiles at right angles to the ore axis. The distance between profiles is usually 100 m. (See pl. 1), and distance between holes in the profiles is usually 10 m. (See pl. 2-14). The drillholes are not measured for deviation.

A number of holes were chosen for surveying - holes on either side of the body were preferred. In addition some holes that intersected the ore were also measured.

The sender stations used were NAA (17.8 kHz) and FUO (15.1 kHz). A total of 33 holes were measured using the American station (NAA) and 6 holes using the French station (FUO).
Readings were taken for every 2.5 m. In certain holes it was experimented with both 5 and 10 m intervals results, however, indicate that readings over 2.5 m are necessary.

The V.L.F. probe measures the field component along the drillhole (VD) relative to the maximum horizontal field component (Ho) on the surface at the hole collar. As all the holes, apart from one (DDH 6, pl. 3), are vertical, we are in reality measuring the relation between the vertical field at depth D and the horizontal field Ho on the surface. The real and imaginary parts of this complex relationship (in %) are determined at each measuring point (pl. 2-14 where curves are shown for both real and imag. components).
The survey was carried out without any major problems.

RESULTS

Measurements taken in the same hole with signals from both NAA and FUO show that NAA gives the best results. This is in accordance with the station directions (pl. 1), where we see that NAA wavelength has a much more optimal direction than FUO. All conclusions are therefore based on the NAA results.

The results are presented in plates 2 - 14. The real component is drawn with a continous line between points, the imaginary components value is given by a cross and drawn by a discontinuous line.

It can be seen from all the sections that the ore gives anomalies (which reflect as curve max. or min.) in drillholes which:

1) Intersect the ore flanks (east or west side).

2) Pass just outside the ore both on the east and west sides.

3) Pass up to a distance of 50 m from the ore. (Profil 650 S pl. 6). In the same profile at a distance of 80 m from the ore a very weak curve maximum is developed at the "right" depth but this cannot be said to be indicative. It does seem, however, that for an ore type such as Vakkerlien a possible "identification distance" of 50 m is possible at the present time.

The real and imaginary curves show some interesting features.

1) Maximum and/or minimum values correspond to a central line through the deposit.

2) Maximum (+ve) for the real comp. is found on the western side of the ore whereas the minimum (-ve) is found on the eastern side.

3) The opposite to 2) is the case for the imag. comp.

4) In the vicinity of the centre of the ore the curves change character and a "S" shape (pl. 3 and 5) is developed instead of the usual "U" shape developed on the flanks.

5) The measurements taken in the central parts of the body don't show a marked low field within the ore which one would expect when this is a good electrical conductor. However, in these holes both the real and imag. component show a change in sign (+ve, -ve), when the hole passes the ore boundaries (hanging and foot walls).

6) This change in sign is not observed in holes that intersect the flanks of the ore

On the whole the real and imaginary anomalies are of the same order of magnitude and show clear maximums and minimums on the ore bodies' eastern and western flanks. There are, however, exceptions, as the following table shows:

- 3 -

PROFILE	REAL ANOMALY WESTERN FLANK	REAL ANOMALY EASTERN FLANK	IMAGINARY ANOMALY WESTERN FLANK	IMAGINARY ANOMALY EASTERN FLANK
250 S	-	max = + 75%	-	min = - 66%
350 S	-	max = +112%	-	max/min = 0%
450 S	-	max = +122%	-	min = -110%
550 S	-	max = +100%	-	max/min = 0%
650 S	min = -110%	max = +160%	max = +122%	min = -122%
750 S	min = - 82%	-	max = + 84%	-
850 S	-	max = +123%	-	min = -125%
950 S	min = - 85%	max = +136%	max = + 15%	min = -152%
1050 S	min = -135%	max = +125%	max = + 55%	min = - 50%
1150 S	min = -140%	max = +150%	max = + 10%	min = -120%
-	-	-	-	-
1250 S	min = -132%	-	min = - 13%	-
1300 S	min = - 80%	?	min = - 55%	?
1400 S	min = - 43%	-	min = - 15%	-

\- no measurements

? uncertain where hole has intersected ore body

A very characteristic feature is apparent from the table:

A) On the western flank of the ore body the real component shows a negative minimum, where the value is dependent on the distance between the ore and the drillhole. The average minimum for 8 holes is - 101%.

B) The real component shows a corresponding positive maximum on the eastern flank. The average max for 9 holes is + 122%.

The real component in the drill-holes lying on the flanks of the ore body seem to indicate a "one way" current concentration which flows near to the central portions of the ore cross-section, as indicated by pl. 15 where one has displayed a circular field from a straight current concentration. As mentioned previously, in the vertical drill-holes we are measuring the vertical component of the field strength and it should be noted that above and below the central parts of the ore there are no vertical components (see pl. 15)

The secondary electromagnetic field around the ore body is therefore not a result of induction by the primary E.M. field in the ore. Induction in the ore body would have resulted in opposite directed current-concentrations over the east and western ore margins, however, in the ca. 50 m wide ore body the two opposite current concentrations lie quite close to each other and the corresponding circular E.M. fields from the currents will to a certain extent cancel each other out, especially near the surface, where the depth to ore is generally the same as the ore width.

It seems most probable that it is the V.L.F. waves' electrical field that indirectly causes the strong secondary fields around the ore body. If we assume that:

A) The VLF wave to a certain extent is horizontally polarised when it penetrates the ground (i.e. the electric field has an horizontal component), and that

B) the ore-body acts as a receiver antenna for the polarized wave,

then alternating current (voltage) will be developed in the antenna i.e. the ore-body. As the antenna has good electrical connection with earth at the sub-outcrop of the ore-body, it is possible that the ore-body can behave as a quarter wave-length antenna and that alternating current will arise in the ore-body which in turn causes a circular secondary E.M. field around the ore.

There are two factors that are important for the amplitude of the currents in the "ore antenna".

A) The length of the ore-body. The known length of the ore-body is ca. 1/10 of the wave length of NAA which is ca. 17 km.

B) Good electrical connection to "earth". Swampy conditions at the ore sub-outcrop should give good contact.

It is probable that secondary V.L.F. fields around electrical conductors are caused by a combination of a voltage generated by

a) the electrical field and

b) the magnetic field which effect is the more dominant will depend on the physical conditions (ore plate, ore dip, strike, wave direction etc.).

The imaginary component (see table) shows mainly a similar picture as the real component (between 650 S and 1150 S) however, with opposite sign i.e. positive maximum on the western flank and negative minimum on the eastern flank. To the north and south of this "central ore portion" there is a deviation from the normal picture.

A) Between 250 S and 650 S there are two holes on the eastern flank (in profile 305 S and 550 S) which don't show a clear maximum/minimum in the imaginary component when passing the ore.

B) South of 1150 S the imaginary components maximum on the western flank is replaced by a weaker minimum.

In case A) increases in ore thicknesses have been registered in the mentioned profiles and in case B) the southern area, various irregularities in the ore distribution have been noted. Whether these irregularities can cause the noted variation in the imaginary component is not clear, but it is regarded as an important observation.

CONCLUSIONS

A) GENERAL

The down-hole V.L.F. measurements in vertical holes at Vakkerlien have shown good results. The equipment works well and is relatively easy to operate. Clear anomalies are recorded on the flanks of the ore body and the results indicate to which side of the hole the ore body lies. Results from profile 650 S seems to indicate that the ore can be indicated with relative certainty at a distance of 50 m. Results can also indicate if holes are drilled deep enough.

B) P.E.M. ANOMALY

Results of a pulse E.M. survey carried out in 1977 indicated a possible parallel conductor to the east of the Vakkerlien body. This "anomaly" was tested by three drill holes which proved negative. These holes on 650 S have been surveyed with down-hole V.L.F. and the results concur with the drilling and indicate no new lateral orebody.

C) CONTINUATION OF THE OREBODY TO THE SOUTH

During the 1975 drilling of the Vakkerlien deposit the ore body was "lost" in the south mainly due to lack of surface geophysical response. C.P. measurements indicated an electrical break in this region, and drill logs indicated the presence of a late acid intrusive invading the gabbro from the west. These facts coupled with a believe that the ore might be offsett led to sporadic and widely spaced drilling in the south to try and pick up the extention of the gabbro. No new mineralization was discovered.

A reappraisal of the original data and the results of some subsequent work have thrown new light on the problem and the most relevant question in the continued exploration of the Vakkerlien ore body is whether the ore body

A) Thins and wedges out around profile 1400 S or

B) The ore body is cut and/or faulted in the area 1300 S- 1400 S, but continues south beyond this break.

The down-hole V.L.F. survey does not give a clear answer to this question. However, a number of factors would seem to suggest that the ore body does continue.

1) In the region 1150 - 1200 S the ore body is at its greatest width (indeed down hole V.L.F. in DDH 48 may suggest that the ore extends even further east than was previously known). If we regard Vakkerlien as the boudinaged body that it seems to be, then statistically one would expect a considerable southerly extention before thinning out takes place.

2) Surface geophysics (V.L.F. and TURAM) although heavily masked by increasing thicknesses of conductive overburden and increasing depth to the ore body, do give anomalous results. Detailed V.L.F. measurements carried out in 1978 give similar anomalies on profiles 1300 S - 1350 S and 1400 S. Turam measurements indicate a continous but weak anomaly to 1700 S - picking up again on 1850 S and continuing off grid at 2400 S.

3) Gabbro with weak mineralization is in fact intersected on profile 1400 S in holes 42 and 41.

4) In DDH 94 on 1850 S a one meter intersection (106 - 107 m) of marginal gabbro with schist inclusions has been identified. Very minor sulphides are present.

5) Drill hole logging and surface geology in the critical area indicate that a later acid intusive strikes in from the west and cuts the gabbro (DDH 92 is drilled entirely in this rock type).

Looking only at the down-hole V.L.F. results the following comments can be made:

A) DDH 92 (profile 1350 S) gives a clear indication of a western flank anomaly.

B) DDH 42 gives a western flank indication.

C) DDH 44 gives a very weak and dubious imag. comp. anomaly? at ca. 120 m. If this anomaly is a reality then the responsible conductor is at a good distance from DDH 44, probably in the 100 m range.

In pl. 14 the ore cross-sections in profiles 1150 S, 1250 S and 1300 S have been projected on to 1400 S. It can be seen that DDH 41 and 42 have been drilled a relatively short distance under the ore level in profile 1300 S and that the intersections obtained in holes 41 and 42 maybe "inclusions of gabbro" in acid intrusive and do not represent the main body.

There are no clear indications in DDH 41 but this might only mean that the fields above a possible ore position as indicated in pl. 14 are horizontal in this hole. (compare pl. 15).

The highly uncertain indication in DDH 44 fits in well with the postulated ore position.

As mentioned previously these results give no clear indications of whether the ore thins out or is cut off and continues.Both explanations are geophysically acceptable.

The indications in holes 42 and 48 may indicate that the body has been moved eastwards and the geophycisist has postulated a simple lateral faulting as shown in pl. 16.

However based on a combination of all the available data as presented above, it seems more probable that the model presented in pl. 17 is the more plausible - the ore being cut by a later acid intusive and continuing south beyond the break. This picture also satisfies the down hole V.L.F. data.

RECOMMENDATIONS

It would seem that there is a reasonable chance that the Vakkerlien ore-body continues south of line 1300 S. To test this it is recommended that holes 48, 42 and 41 be deepened and surveyed with down-hole V.L.F. If ore is intersected a desicion can then be taken on the form of a further drilling plan. Hole 94 should also be opened and surveyed with down-hole V.L.F. Results of this survey will indicate if drilling is necessary. Once ore has been intersected C.P. will become a usefull tool.

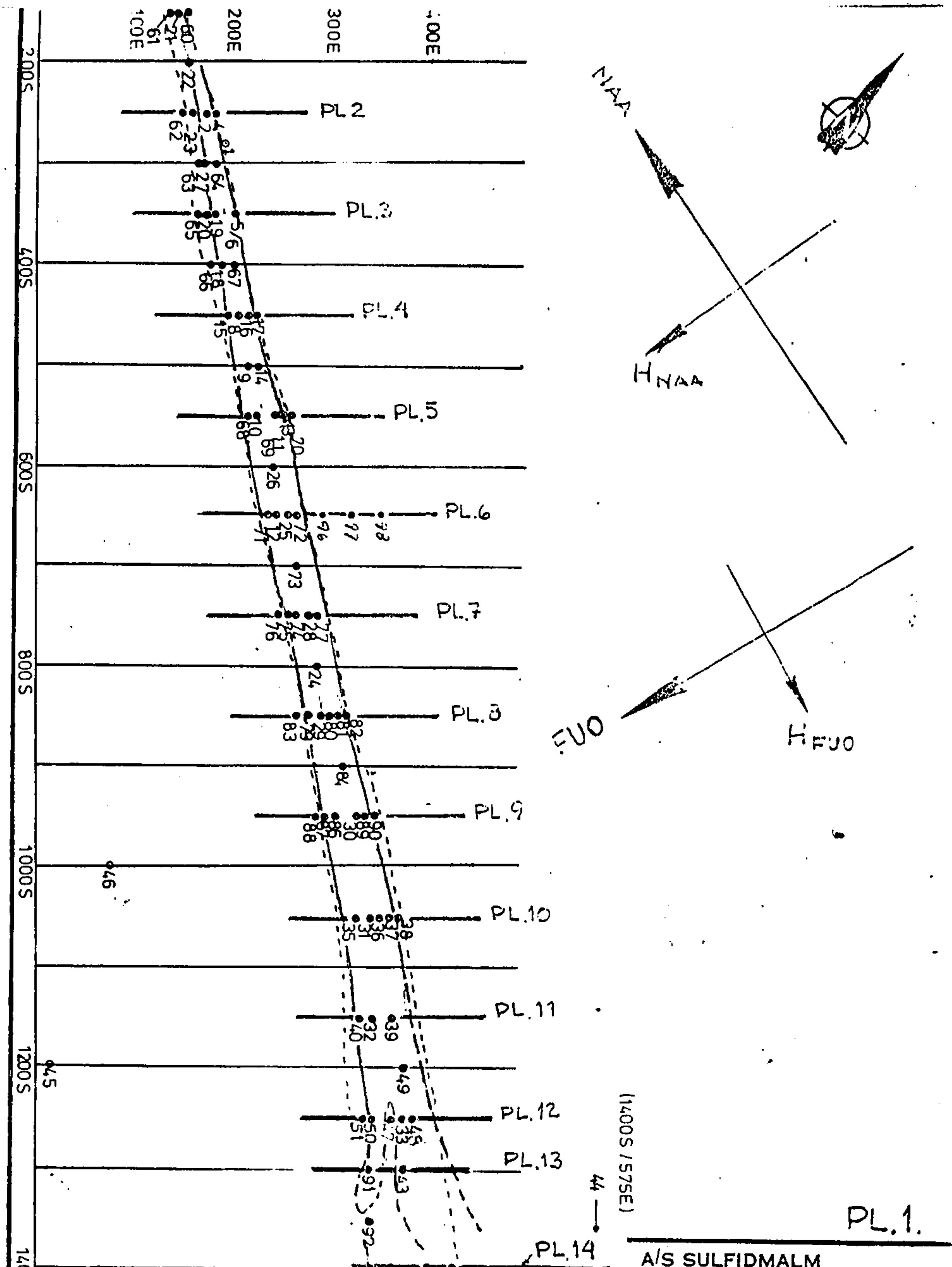
A future application that may be possible if we regard the orebody as an "antenna" is that by measuring the voltage distribution within this "antenna-like orebody" we may be able to predict roughly the length of the orebody relative to the transmitters wavelength. (i.e. if the Vakkerlien body has one or two times the known length or whether the known length constitutes most of the ore body). This intriging idea is being looked into at the moment.

PREPARING PROBE FOR DOWN HOLE VLF SURVEY
VLF RECEIVER ON STATIVE.

TAKING A MEASUREMENT IN DRILL-HOLE.

DETAIL OF RECEIVER.
(CABLE SPOOL IN BACKGROUND)

DETAIL OF PROBE AND CABLE SPOOL.

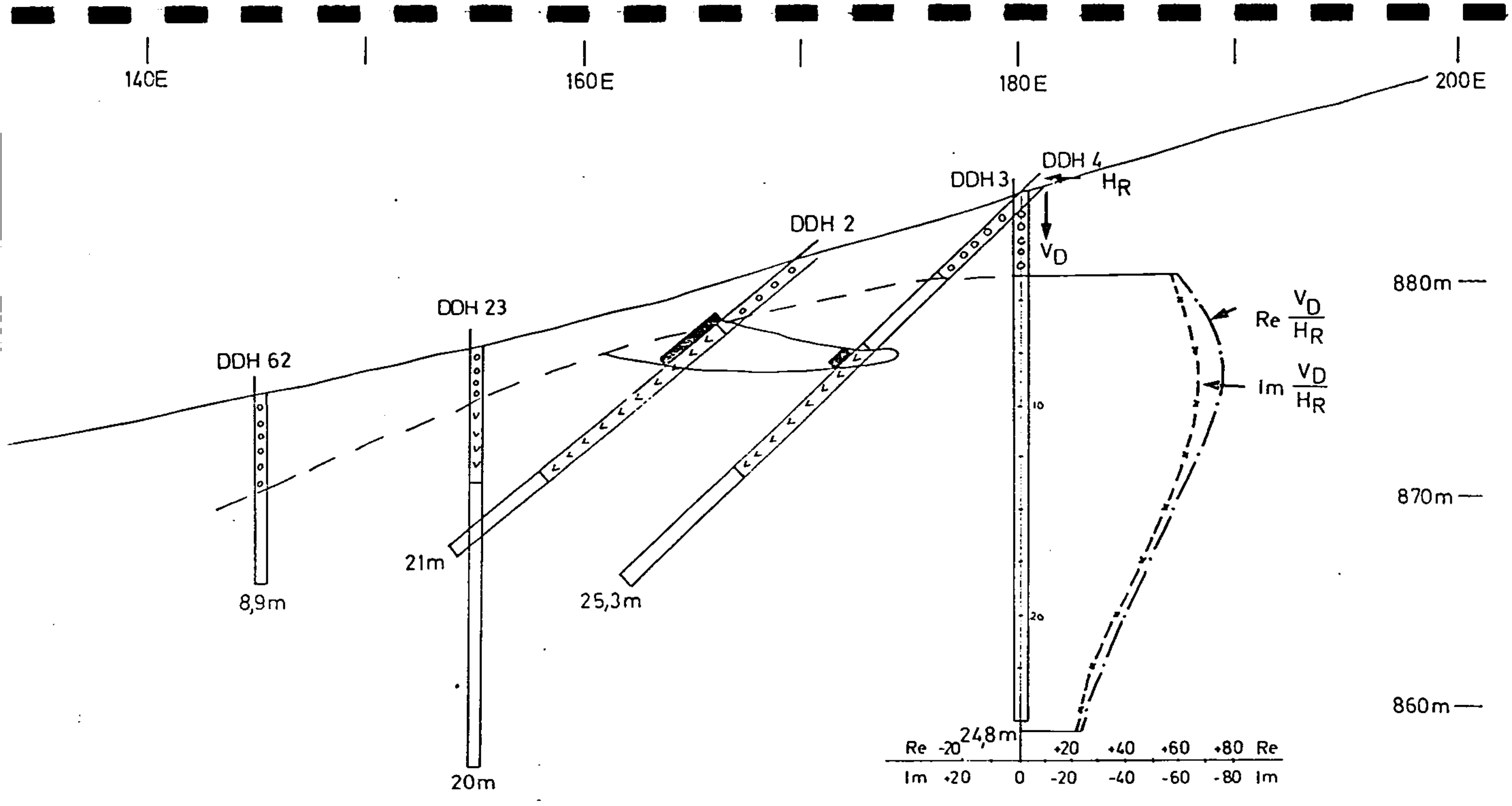


PL.1.

A/S SULFIDMALM

Vakkerlien, KVIKNE
loc. of drillholes

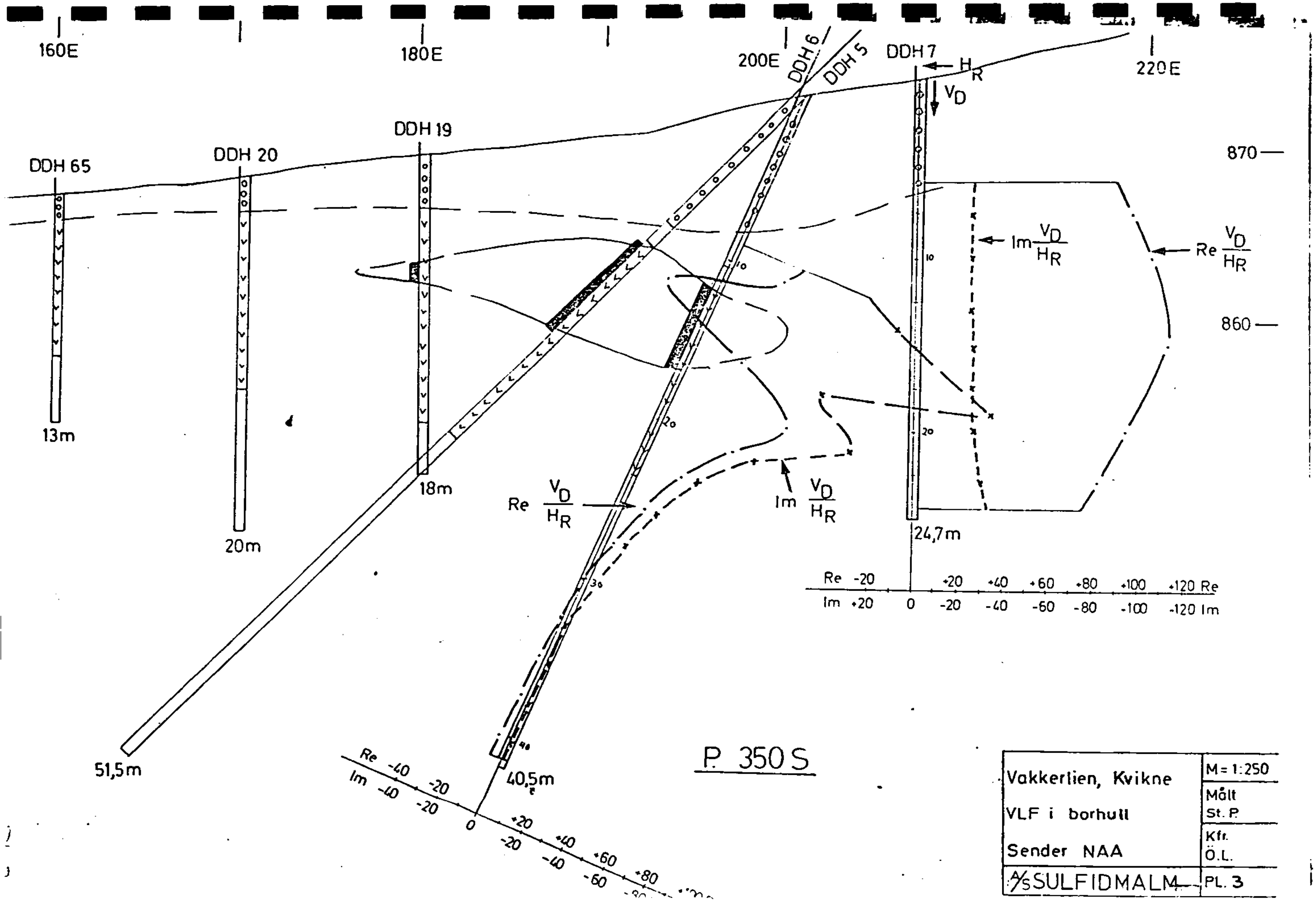
SCALE	1:5000	DRAWN	
DATE		TRACED	



P. 250 S

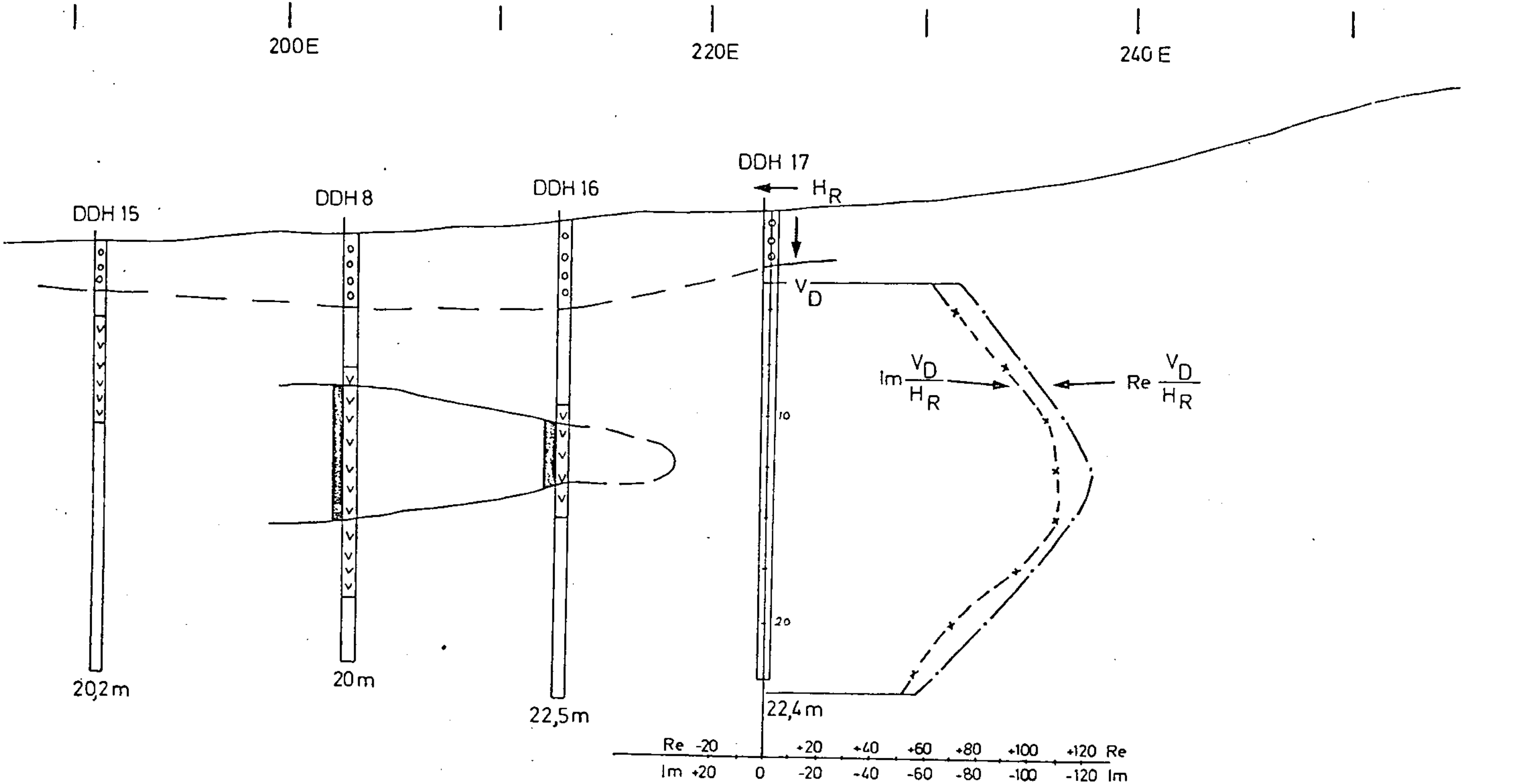
Vakkerlien, Kvikne	M= 1:250
VLF i borhull	Målt St. P.
Sender NAA	Kfr. Ö.L.
A/S SULFIDMALM	PL. 2

PL. 2



P 350 S

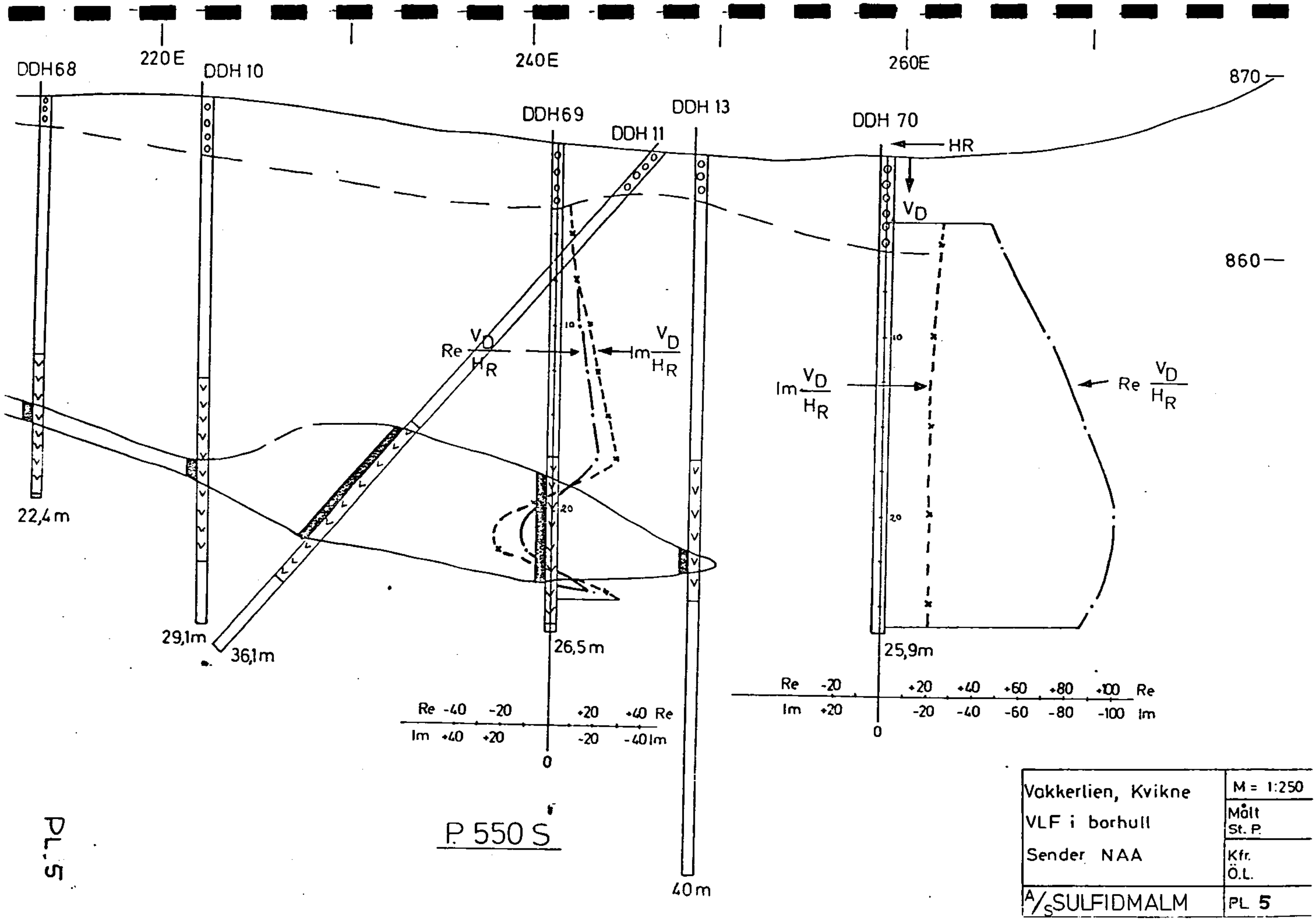
Vakkerlien, Kvikne	M = 1:250
VLF i borhull	Målt St. P.
Sender NAA	Kfr. Ö.L.
A/S SULFIDMALM	PL. 3



P 450 S

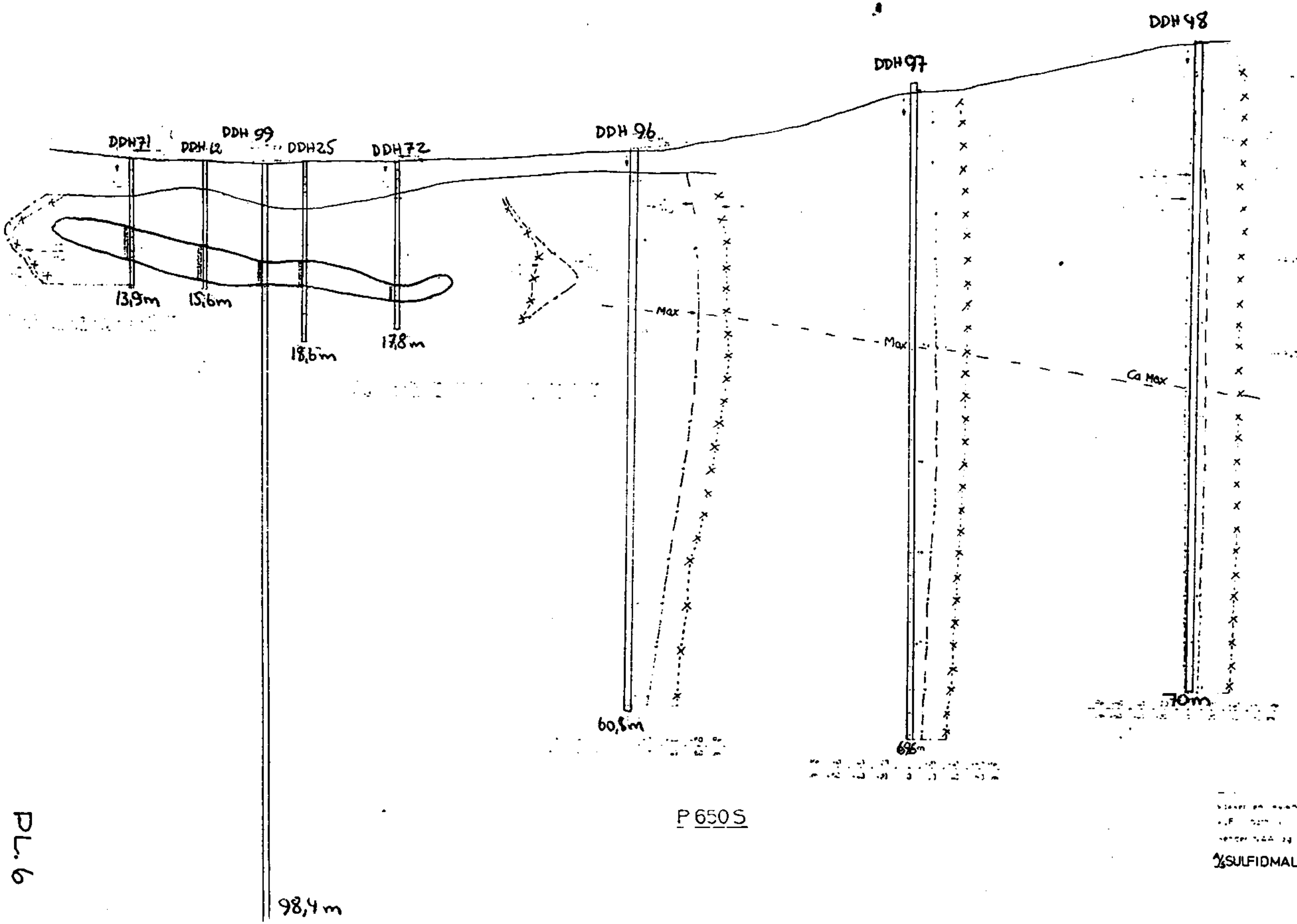
Vakkerlien, Kvikne	M = 1:250
VLF i borhull	Målt St. P.
Sender NAA	Kfr. Ö.L.
A/S SULFIDMALM	PL. 4

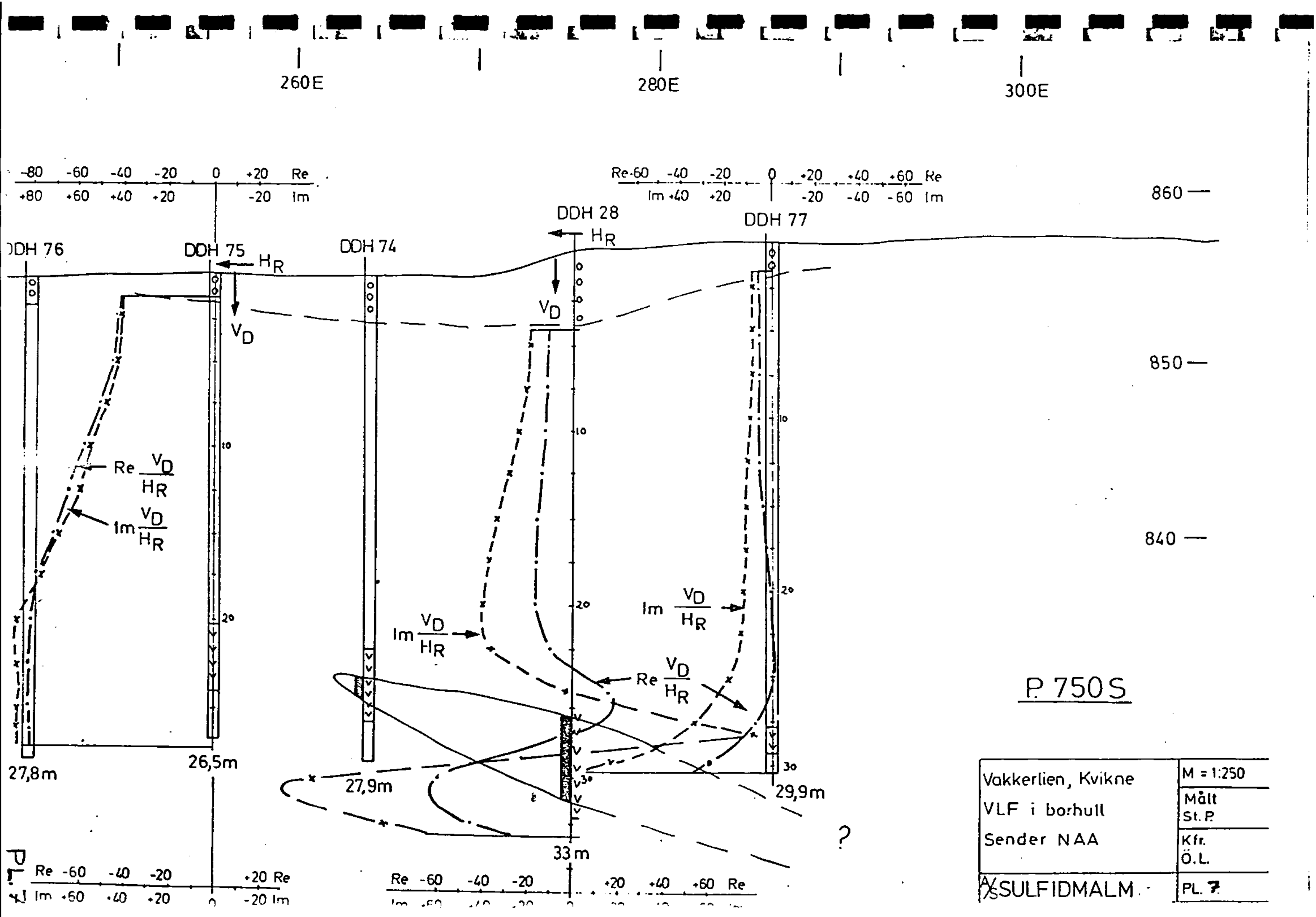
PL. 4

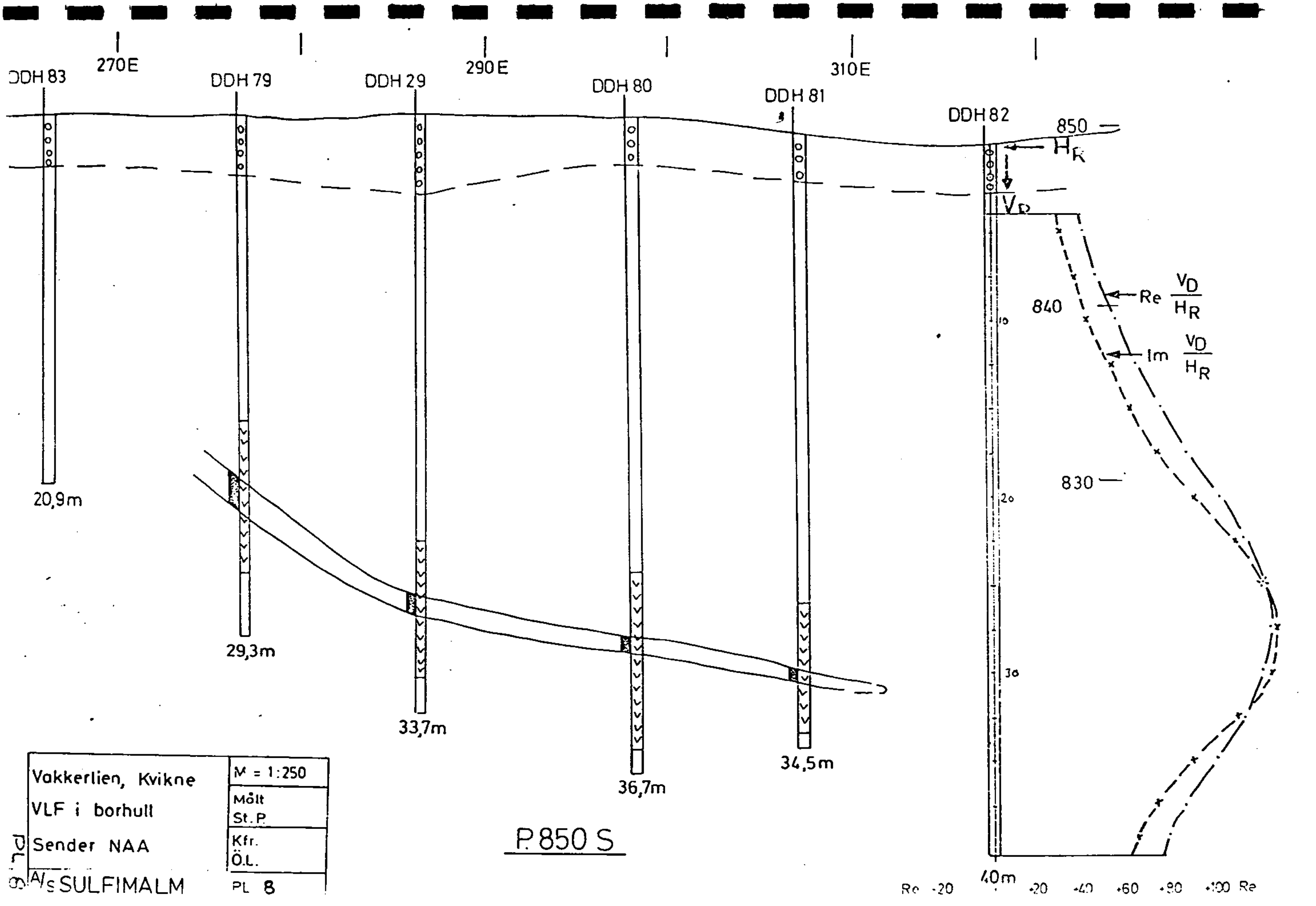


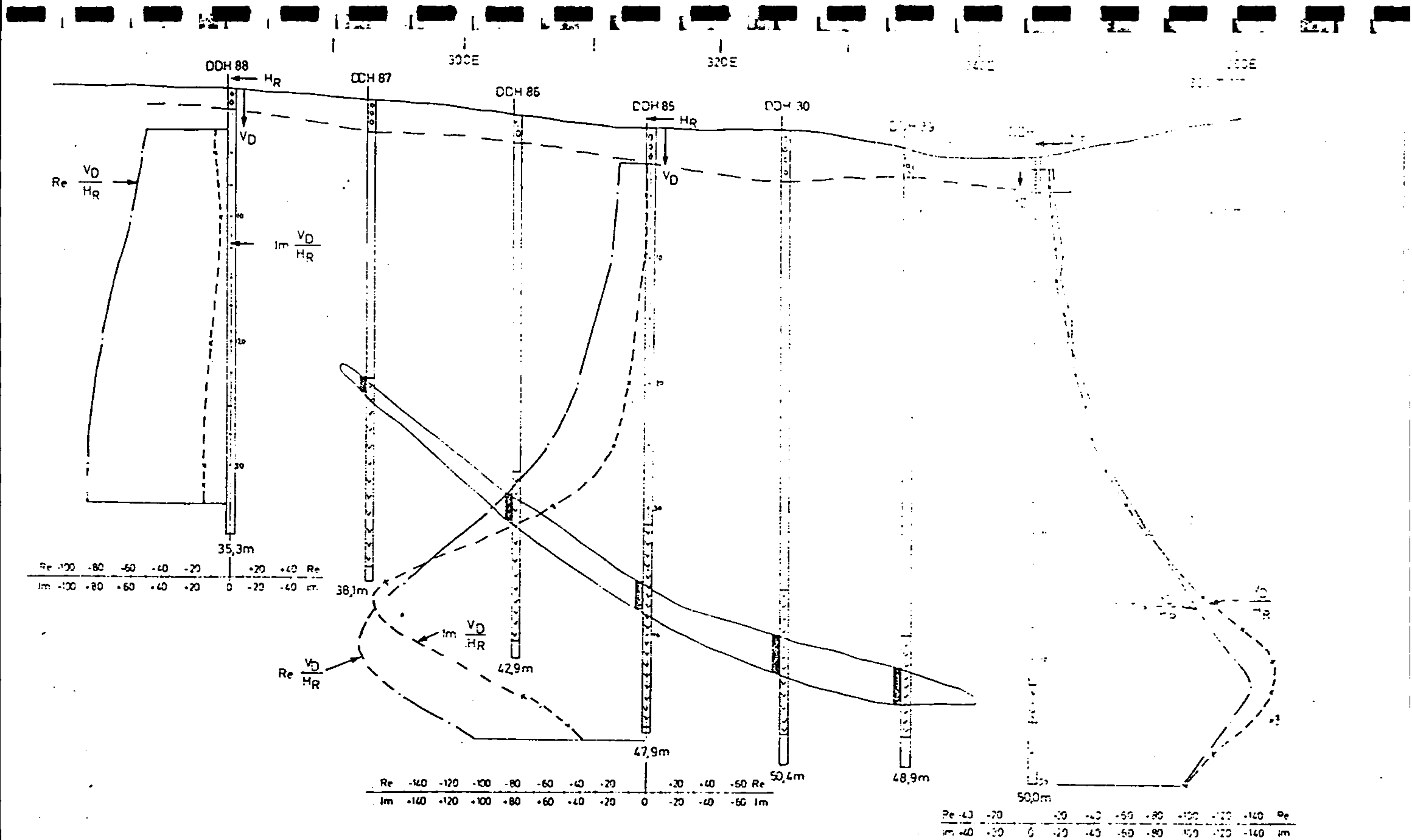
220 E
240E
260E
DDH68
DDH 10
DDH69
DDH 11
DDH 13
DDH 70
HR
V_D
870
860
$Re \frac{V_D}{H_R}$
$Im \frac{V_D}{H_R}$
$Im \frac{V_D}{H_R}$
$Re \frac{V_D}{H_R}$
10
20
22,4 m
29,1 m
36,1 m
26,5 m
25,9 m
40 m
Re -40 -20 +20 +40 Re
Im +40 +20 -20 -40 Im
0
Re -20 +20 +40 +60 +80 +100 Re
Im +20 -20 -40 -60 -80 -100 Im
0
P 550 S
PL. 5
Vakkerlien, Kvikne
VLF i borhull
Sender NAA
M = 1:250
Målt St. P.
Kfr. Ö.L.
A/S SULFIDMALM
PL 5

PL. 6


DDH 71
DDH 12
DDH 99
DDH 25
DDH 72
DDH 96
DDH 97
DDH 48
13,9 m
15,6 m
18,6 m
17,8 m
98,4 m
60,8 m
69,6 m
70 m
Max
Max
Ca Max
P 650 S
⅓ SULFIDMALM 6


260E
280E
300E
860
850
840
DDH 76
DDH 75
DDH 74
DDH 28
DDH 77
H_R
V_D
Re $\frac{V_D}{H_R}$
Im $\frac{V_D}{H_R}$
27,8m
26,5m
27,9m
33 m
29,9m
?
P 750 S
Vakkerlien, Kvikne
VLF i borhull
Sender NAA
M = 1:250
Målt St.P.
Kfr. Ö.L.
A/S SULFIDMALM
PL. 7

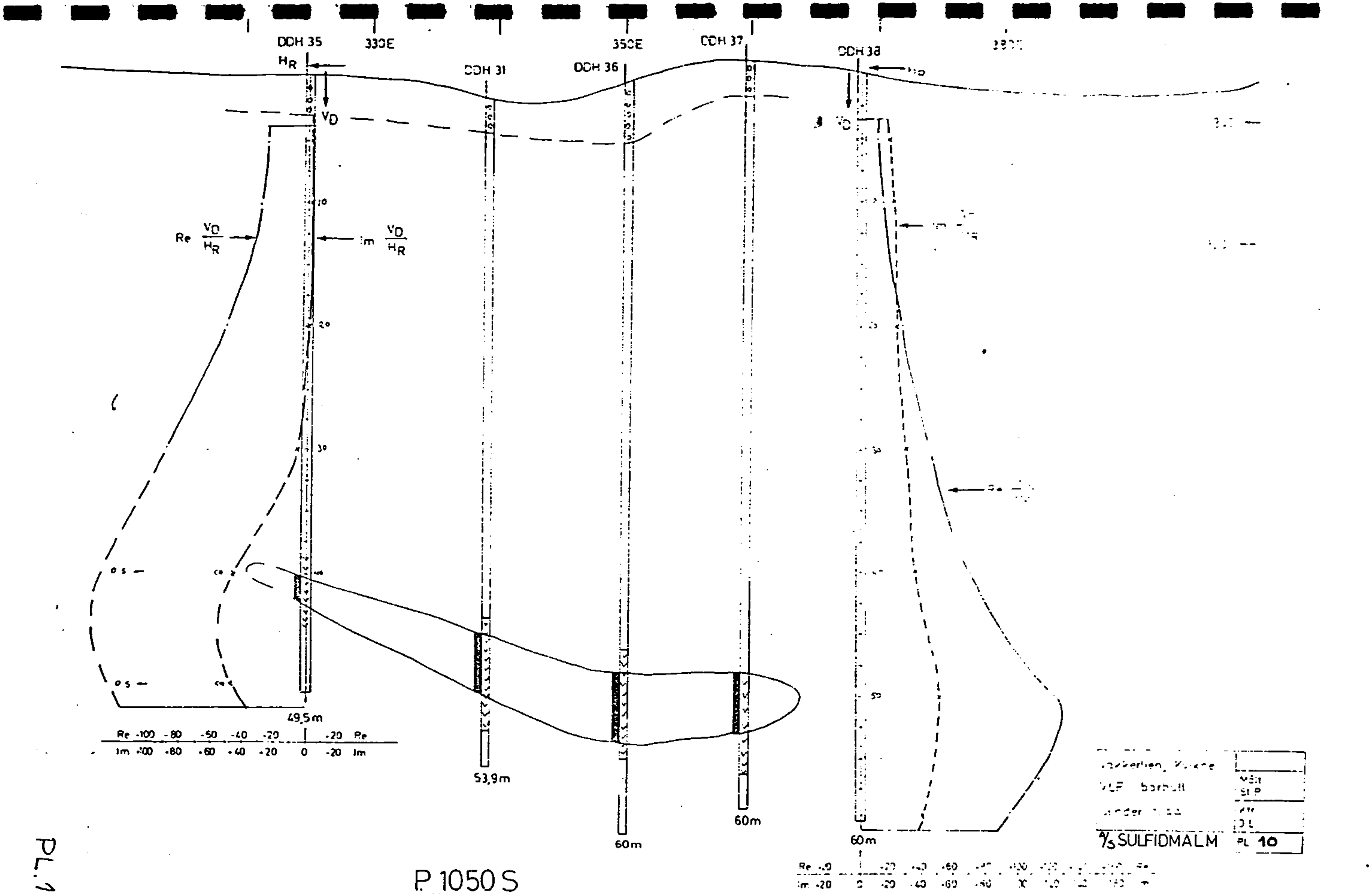

270E
290E
310E
DDH 83
DDH 79
DDH 29
DDH 80
DDH 81
DDH 82
850
840
830
H_R
V_D
Re $\frac{V_D}{H_R}$
Im $\frac{V_D}{H_R}$
20,9m
29,3m
33,7m
36,7m
34,5m
40m
10
20
30
Re -20
+20
+40
+60
+80
+100 Re
P 850 S
Vakkerlien, Kvikne
VLF i borhull
Sender NAA
A/s SULFIMALM
M = 1:250
Målt St.P.
Kfr. Ö.L.
PL 8



P 950 S

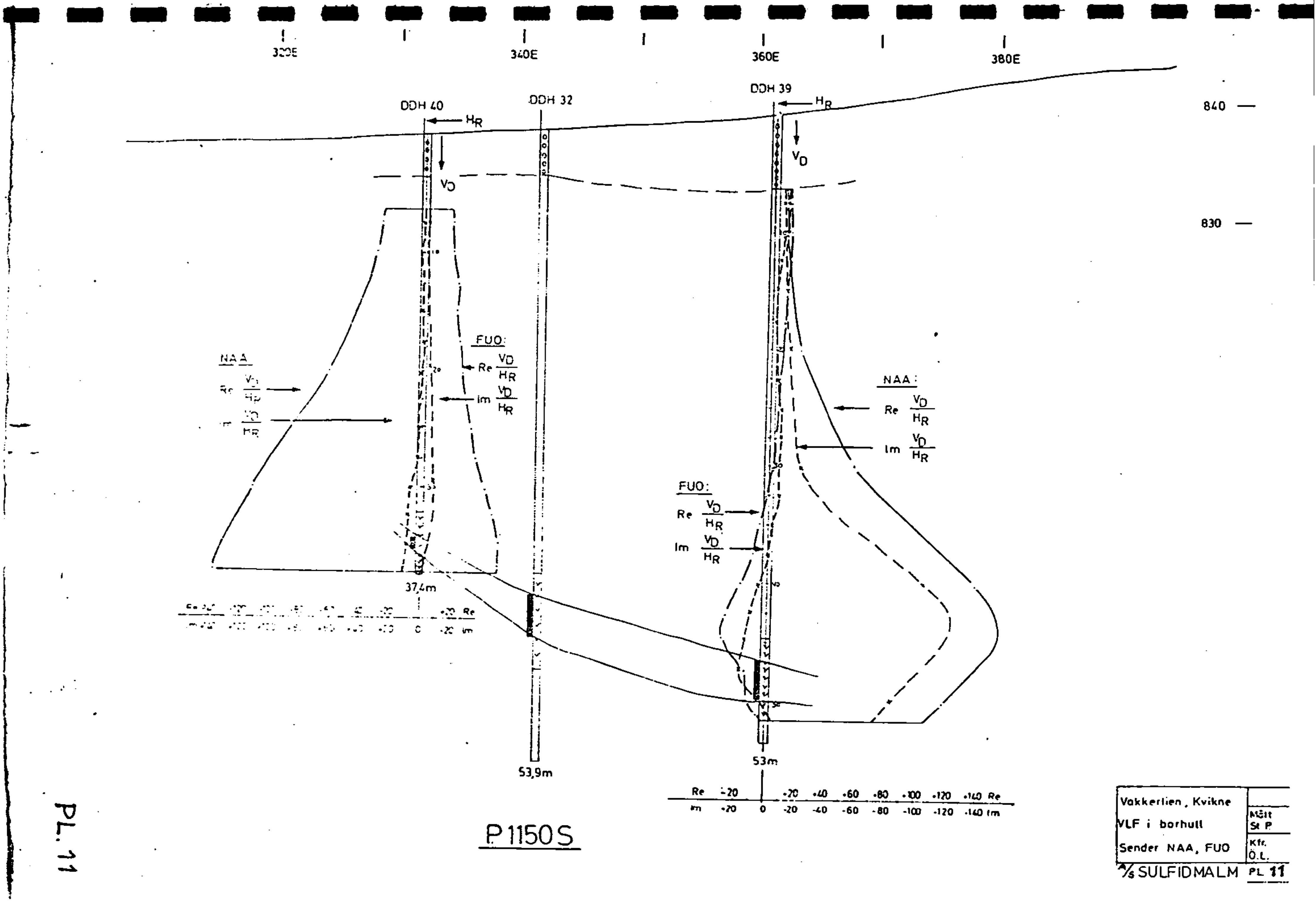
Lokkerlien, Kvikne
VLF i borhull
Sender NAA
1/5 SULFIDMALM 9

PL. 9

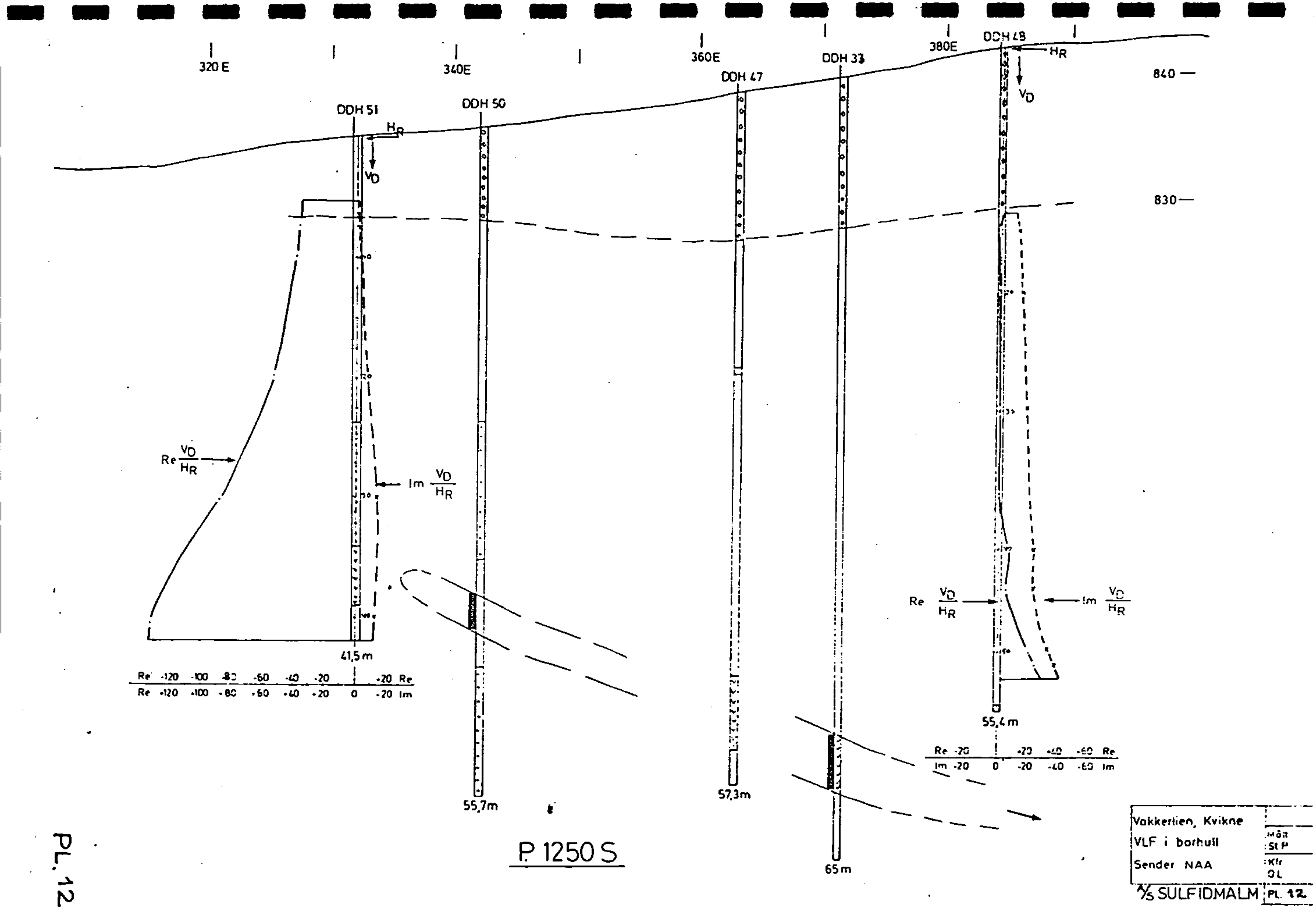

DDH 35
330E
350E
DDH 37
DDH 38
DDH 31
DDH 36
H_R
V_D
Re $\frac{V_D}{H_R}$
Im $\frac{V_D}{H_R}$
49,5m
53,9m
60m
60m
60m
A/S SULFIDMALM
PL 10

P 1050 S

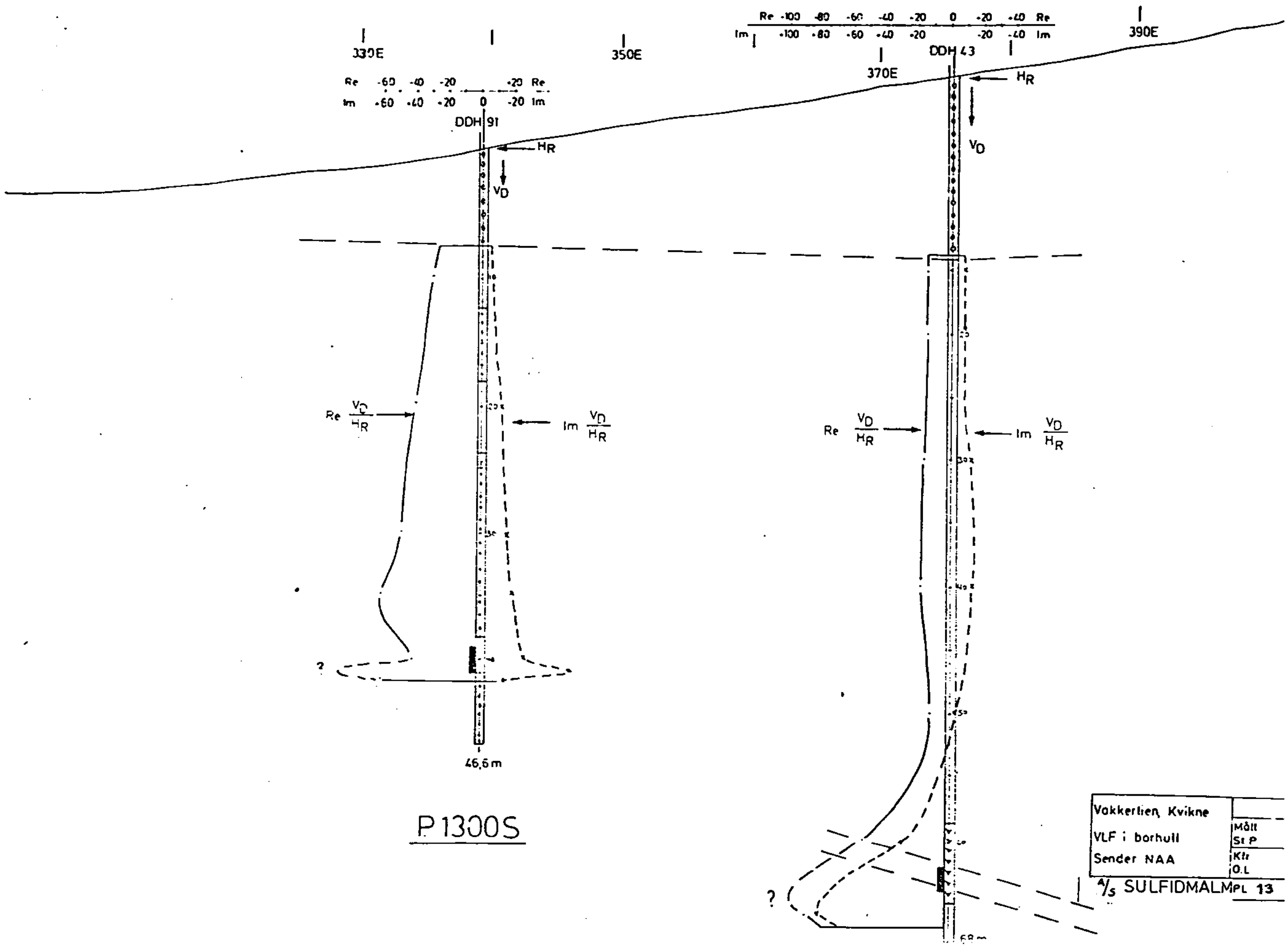
PL.10



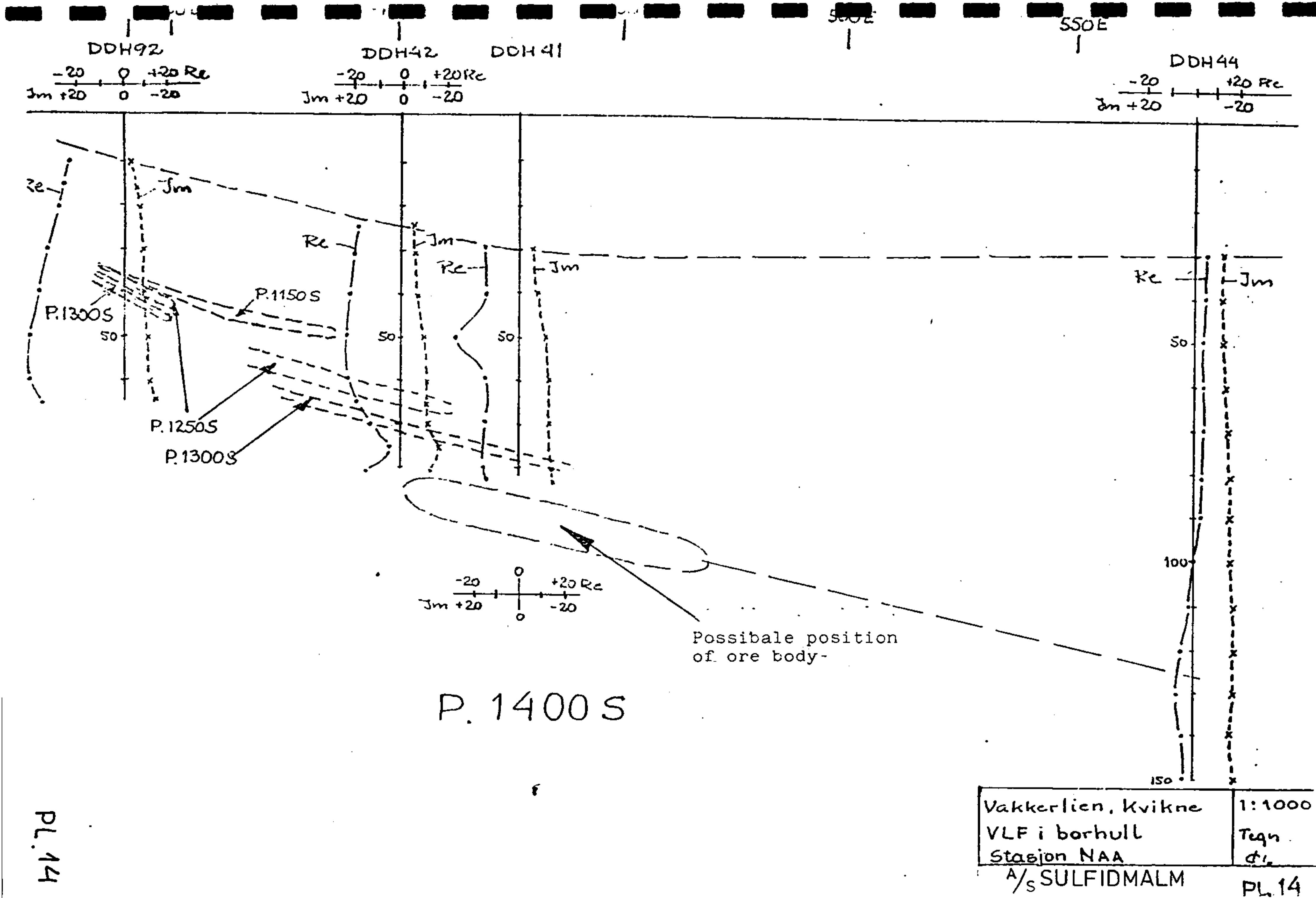
320E
340E
360E
380E
DDH 40
DDH 32
DDH 39
H_R
V_D
840
830
FUO:
Re $\frac{V_D}{H_R}$
Im $\frac{V_D}{H_R}$
NAA:
37,4m
53,9m
53m
Re -20 0 +20 +40 +60 +80 +100 +120 +140 Re
Im +20 0 -20 -40 -60 -80 -100 -120 -140 Im
P 1150 S
PL. 11
Vakkerlien, Kvikne
VLF i borhull
Sender NAA, FUO
Målt St P.
Ktr. Ö.L.
A/S SULFIDMALM
PL 11


320 E
340E
360E
380E
DDH 51
DDH 50
DDH 47
DDH 33
DDH 48
H R
V D
840 —
830 —
Re V D / H R
Im V D / H R
41,5 m
55,7m
57,3m
65m
55,4 m
Re -120 -100 -80 -60 -40 -20 +20 Re
Re +120 +100 +80 +60 +40 +20 0 -20 Im
Re -20 +20 +40 +60 Re
Im -20 0 -20 -40 -60 Im
P 1250 S
Vokkerlien, Kvikne
VLF i borhull
Sender NAA
Målt St P
Kfr OL
A/S SULFIDMALM
PL. 12

PL. 12


330E
350E
370E
390E
DDH 91
DDH 43
Re -60 -40 -20 -20 Re
Im -60 -40 -20 0 -20 Im
Re -100 -80 -60 -40 -20 0 -20 -40 Re
Im -100 -80 -60 -40 -20 -20 -40 Im
H_R
V_D
Re $\frac{V_D}{H_R}$
Im $\frac{V_D}{H_R}$
46,6 m
68 m
?
P 1300S
Vakkerlien, Kvikne
VLF i borhull
Sender NAA
Målt St.P
Ktr O.L
A/S SULFIDMALM PL 13

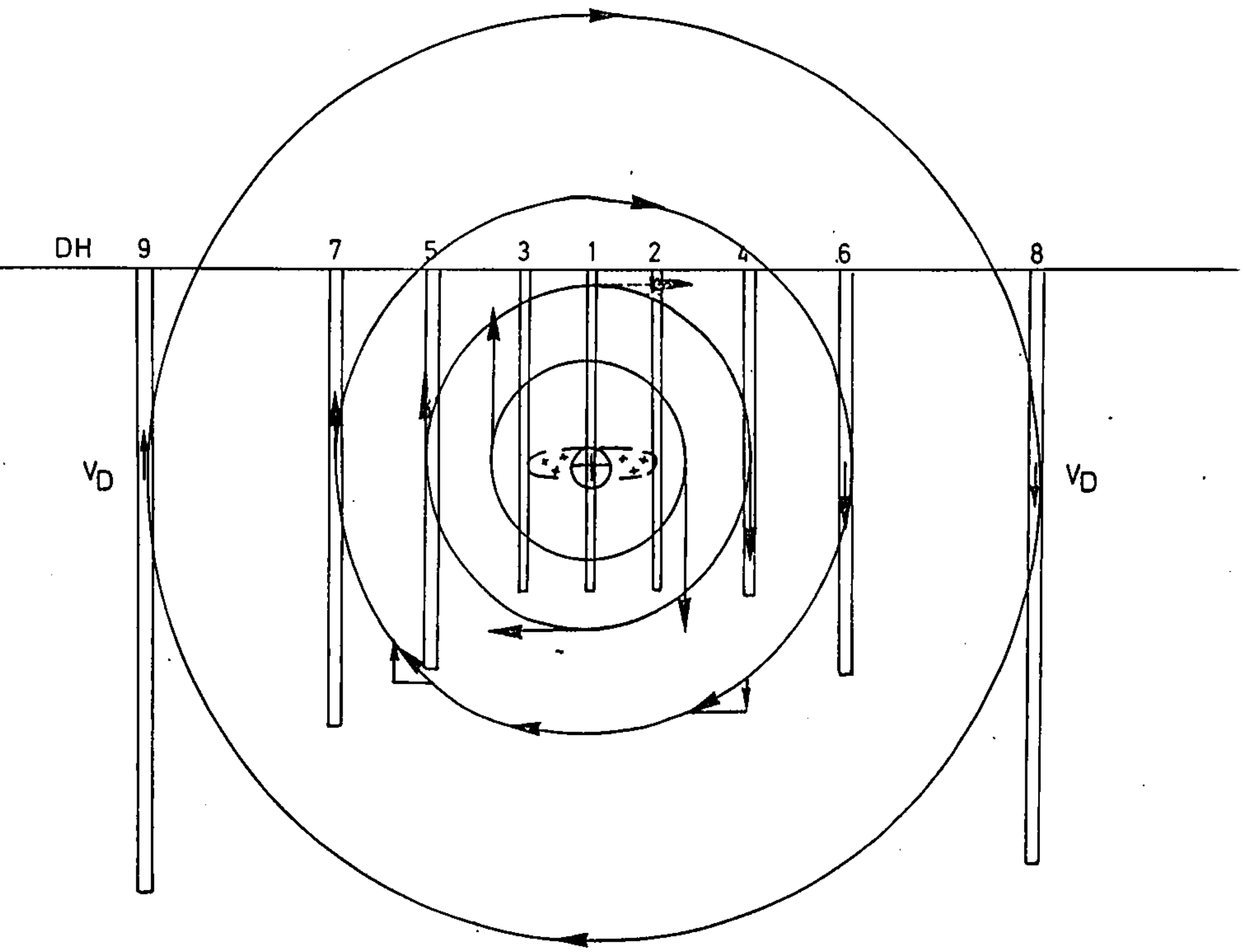
PL. 13

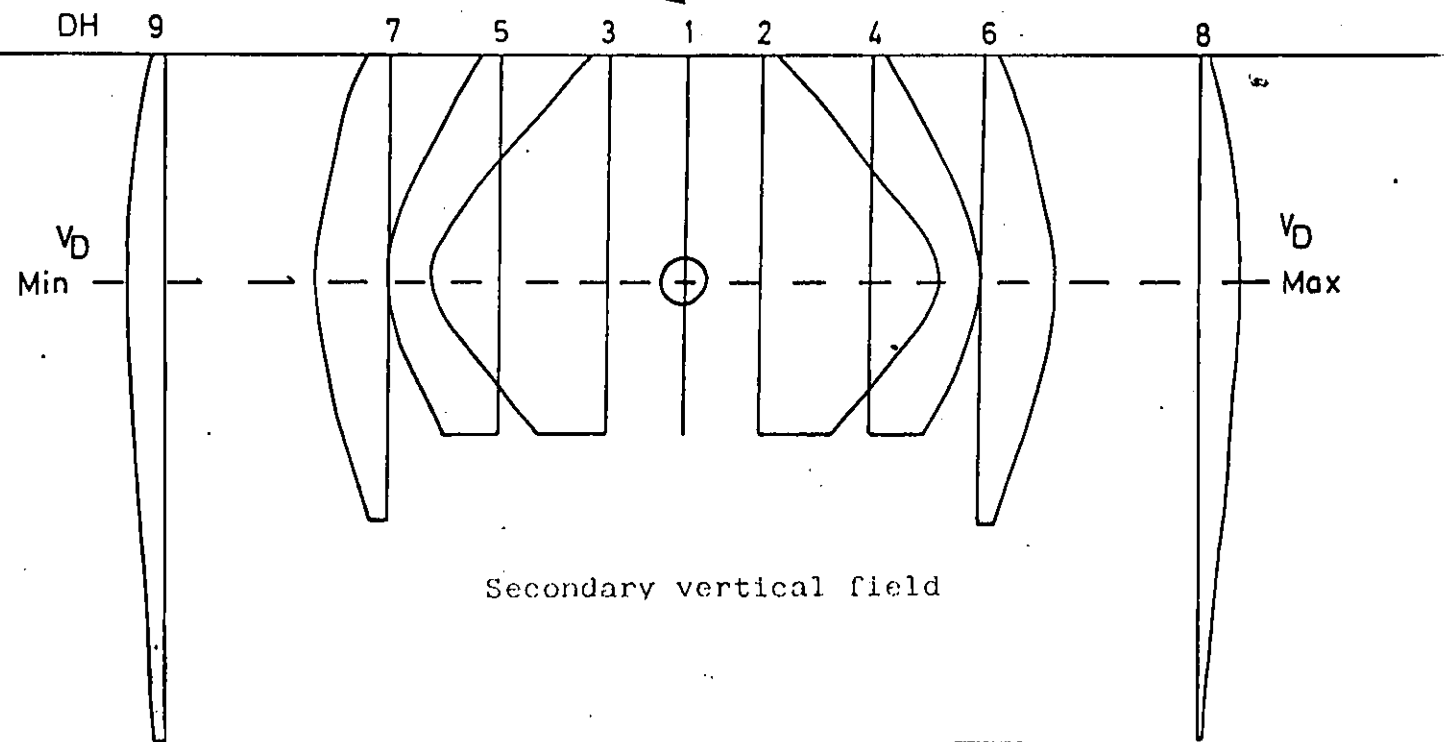


550E
DDH92
DDH42
DDH41
DDH44
-20 0 +20 Re
Jm +20 0 -20
Re
Jm
P.1150 S
P.1300 S
P.1250 S
P.1300 S
50
100
150
Possibale position
of ore body-
P. 1400 S
Vakkerlien, Kvikne
VLF i borhull
Stasjon NAA
1:1000
Tegn
A/S SULFIDMALM
PL. 14

PL. 14

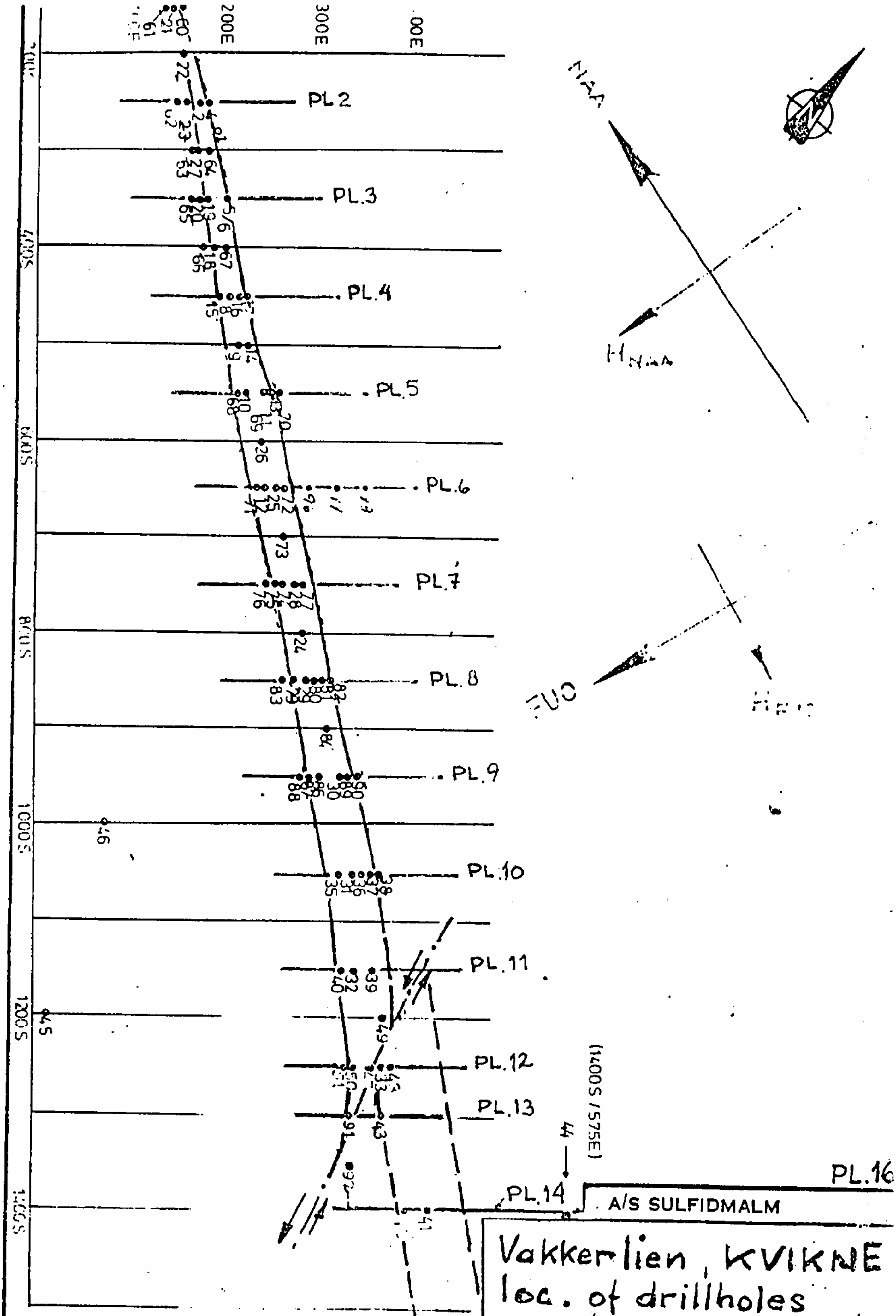
Secondary totalfield





Secondary vertical field

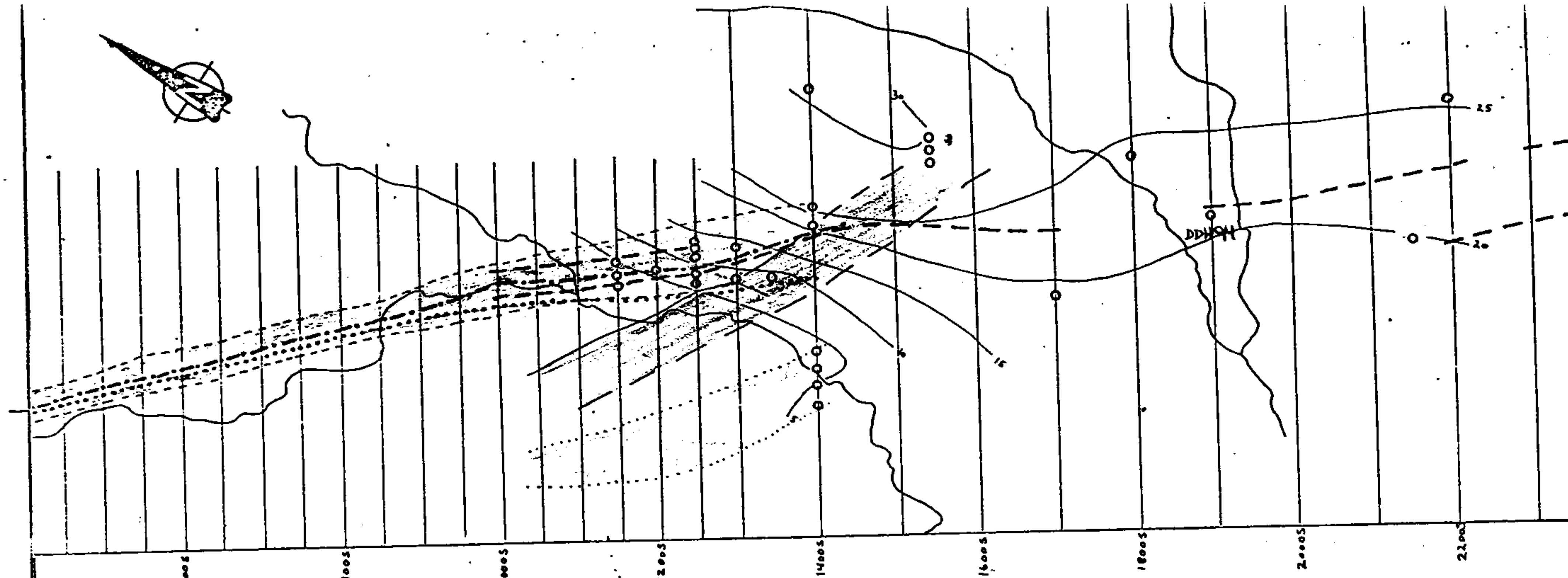
Prinsippskisse	
VLF-EM	Tegn. Ö.L.
Vakkerlien, Kvikne	
A/S SULFIDMALM	Pl. 15



A/S SULFIDMALM

Vakkerlien, KVIKNE
loc. of drillholes

SCALE	1:5000	DRAWN	
DATE		TRACED	Ø. Logn



METAGABBRO

ACID INTRUSIVE

OVERBURDEN THICKNESS CONTOUR

DIAMOND DRILL HOLE

VLF ANOMALY TRACE

TURAM " "

CHARGE POTENTIAL " "

ANOMALY SITUATION MAP VAKKERLIEN SOUTH KVIKNE	SCALE 1:7500	OBS.	
		DRAW. FN/RS	10. 7?
		TRAC. FN/RS	10. 7?
		CHK.	
A/S SULFIDMALM	MAP NO.		
	MAP SHEET		