Bergvesenet

Postboks 3021, N-7441 Trondheim

Rapportarkivet

Bergvesenet rapport nr	Intern Journal nr	Gammelt internt rapp. nr.	Rapport lokalisering	Gradering
5172				

Kommer fra ..arkiv	Ekstern rapport nr	Oversendt fra	Fortrolig pga	Fortrolig fra dato:
Elkem AS Hovedbibl		Elkem AS		

Tittel

The Fen Project: A geophysical survey of the Tufte area

Forfatter	Dato	År	Bedrift
Carstens, C.W	okt	1982	Elkem AS, eng. div.

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Nome	Telemark		17134	Skien

Fagområde	Dokument type	Forekomster
Geofysikk		Tuftestollen Hydrogangen Fenfeltet

Råstoffgruppe	Råstofftype
Malm/metall	Nb, RE

Sammendrag / innholdsfortegnelse

Gjennomføring av magnetiske, gamma stråling, VLF og suseptibilitetsmålinger, samt studier av petrofysiske parametre.
En finner interessante lavverdier på magnetometer gammamåling. Det finnes et elektrisk ledende melloborområdet i Tuftehavna og veien til Skien. I Melteig er et nytt Søvitt-område påvist ved sjekk av magnetiske anomalier.
Det anbefales gravimetriske målinger, radonundersøkelser, ledningsevnemålinger og seismiske undersøkelser for best mulig å velge ut de mest lovende anomalier for boring.

Se også BV 419 og BV 420

Elkem a/s
Engineering Division

THE FEN PROJECT

A GEOPHYSICAL SURVEY OF THE TUFTE AREA

BY

C.W.CARSTENS, ELKEM A/S
Engineering Division

Oslo, October 1982

Elkem a/s
Engineering Division

ABSTRACT

What is done:

1) Magnetic surveys on surface
2) Gamma ray " " "
3) VLF-Resistivity " "
4) Gamma ray investigations on cores
5) Susceptibility " " "
6) Study of petrophysical parameters on cores
7) Susceptibility investigations in the field

What have we learnt from the investigations:

1. Most findings of Nb_2O_5 and P_2O_5 can be correlated from borehole to borehole using Magnetic susceptibility and gamma ray dataes

2. 50% of the drilled mineralizations of Nb_2O_5 can be traced up to surface, revealing magnetic low or high and gamma ray anomalies.

3. By VLF the resistivity technique rødberg can be differed from søvite and Raudhaugitt. Fault zones and hematite dikes within rødberg are also detectable.

4. The density contrast between søvite and lamprophyr is 0,3 g/cm^3. (That contrast indicates possibilities to indicate lamprophyr by gravity techniques).

5. The magnetic content of søvite is generally higher than surrounding rock types. (søvite borders can be infered from magnetic investigations).

Obtained results:

1. Interesting magnetic low and gamma ray anomalies within the Tufte/Holla area.

2. An electrical conductive area in between the Tuftehavna drilling area and the main road to Skien/Ulefoss (may represent rødberg or thick scale overburden).

3. At Melteig a new søvite area has been discovered by checking magnetic anomalies.

Recommendation to follow up Exploration techniques.

In addition to already used techniques the following should be tried:

1) Gravity investigations
2) Radon investigations
3) Direct current investigations
4) Seismic investigations

The objective by trying other techniques is to increase the probability to drill the most correct and most promising anomalies.

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CONTENT

1. INTRODUCTION

Most of the investigations have been carried out within an area of 230.000 m^2 (see fig. 15). The categories of work are as follows:

1. Total magnetic field investigations.

2. Gamma ray investigations on the surface.

3. VLF resistivity investigations.

4. Susceptibility and gamma ray investigations on all drillcores from Tuftehavna.

5. Susceptibility investigations in the field.

6. Petrophysical studies on core materials from Tuftehavna.

C.W.Carstens, Elkem a/s, J.E.Wanvik, Elkem a/s, G.Kompen, A/S Sydvaranger and different field assistents have been involved.

The investigations have been carried out step by step to see whether such mineralizations as obtained by drillhole 1 could be followed by magnetic and gamma ray investigations. Most of the drilling in Tuftehavna were done to check the step by step anomalies, and better results than expected were obtained.

The magnetic and gamma ray investigations were first carried out using a rather detail grid of 12,5m x 5m. The profile space were later increased to 25m. Susceptibility and gamma ray readings on the drillcores were generally taken 4 times per meter.

Step by step investigations are rather time consuming. We did also have some navigation problems and problems with the magnetometer, and we felt "helpless" when a farmer plowed down our gridsystem before it had been used.

2. RESULTS

2.1. Presentation of the results.

The results from the magnetic and gamma ray investigations are presented as isomaps see fig. 1,2,12 and 13. The apparent resistivity from the VLF resistivity survey is also presented as an isomap, see fig. 3. Fig. 11 represents a semi crossprofile between Tuftehavna and Grubeåsen on which significent resistivity contrast between søvite and rødberg is indicated.

To make the susceptibility dates from the drillcore investigations most applicable for geological purposes, the dataes have been transformed into volumpercent magnetite (mt.). Average values of percent mt. and the intensity of gamma radiation from the cores are presented as curves in the drilling profiles, see fig. 4-9.

It was essential to learn about the correspondence between geophysics and anomale grades of niobium and apatite. For that purpose the anomale grades of Nb_2O_5 and P_2O_5 was figured out and plotted into the drilling profiles.

A fig. 10 is constructed to indicate true thickness, possible extensions and values of some of the drilled mineralizations.

Finally a map within Tufte have been made in which the søvite border has been infered. Geophysical structures which should be followed up are also indicated. See fig.15.

2.2. Structural results.

Both the isomagnetic and the isogamma maps are revealing structures striking in the S.SE. direction, see fig. 1, 2, 12 and 13.

The isomagnetic map from the investigations in 1981 reveal a rather uniform magnetic high within the Tuftehavna drilling area. The present isomap based on much more detailed measurements is showing much more local variability. It is reasonable to expect that the present map is reflecting much variability of the geological structures.

With reference to the drilling profiles (fig. 4-9), the so called structure lines (dip lines) are lines making connections between zones of equal mt. content. The lines are generally diping rather steeply torwards west. It is assumed that the lines are giving a good information about the dip of the geological formations.

Two possible faultzones have been indicated by the VLF investigations (see fig. 3). From a geophysical point of view the thin conductors are not too cleare and it may be possible to separate one faultine into more faults. The mineralized lamprophyre within the drilling area is of intrusive character and therefore may be associated with later faultzones.

2.3. About the correspondence between geophysics and the drilled mineralizations.

Zone A. The most interesting grades of Nb_2O_5 and P_2O_5 are bound to the lamprophyre in drillhole 1 and 2 (see fig. 6) 9 meters of drillhole 3 are showing a grade of 2,7% Nb_2O_5 and 12% P_2O_5. It is worth noticing that all of that zone is very low in mt. and the gamma radiation shows a high.

Further on the mineralized zone are clearly indicated on surface by both magnetic and gamma ray investigations.
The thinner zones in drill hole 7, 8 and 12 (see fig.7 and 8),are also low in mt. and shows a higher gamma radiation than the environments, but the zone cannot be traced up to the surface.

All the mineralizations are associated with lamprophyre and they have geophysical similarities. On that bases it is reasonable to make a connection of the zones (see fig. 10).

The mode of occurence of the zone based on drilling results is a wedging out just south of drillholes 1 and 3, but the surface gamma anomaly may indicate a further extension towards south. Concerning a continuity of the zone towards north the drillholes 9 and 10 abandoned as a duster. However, one of the radioactive zones in the drillholes may show a correspondence to zone A (see fig.10).

<u>Zone B.</u> Drillhole 11 reveals rather interesting mineralization within a mixture of hollaite and søvite. 10 m of that hole which is all that has been analyzed is showing 0,4% Nb_2O_5 and 7% P_2O_5. From a geophysical point of view that zone is showing similarities to zone A (see fig.4 and 10), and the low mt. content is revealed by the magnetic isomap (see fig.2). The isolines itselves indicate a rather limited extension of that zone. Studying the magnetic results in more detail, there is a weak indication that the zone may extend more than indicated by the isolines itself.

<u>Zone C.</u> Geologically the mineralized zone in drillholes 5 and 6 are bond to søvite. The mt. content of that zone is high (see fig.5 and 10). Strange enough, the drilled mineralization is not indicated by the surface magnetic measurements. However, the magnetic isomap (see fig.2) does indicate mt. rich zone just south of it. That zone is running about 100 m towards south and it is worth noticing that it is partly corresponding to a radioactive zone. There is a possibility that the mineralized zone to some degree may correspond to that magnetic and radioactive zone.

<u>Zone D.</u> Similar to drillholes 5 and 6 the upper mineralization in drillholes 3 and 4 are bond to søvite. Within a thickness of 3 m the value of the mineralization value is equal to that of drillhole 11 (see fig. 6 and 10). The mineralizations are rich in mt. which also is revealed by the magnetic isomap (see fig.2). With basis on the magnetic results and the susceptibility investigations of

drillhole 12, the zone may be traced up to that drillhole.

Zone E. The first 2 m of drillhole 9 turned out to contain interesting grades og apatite a zone which shows a low mt.content and high gamma activity (see fig.9 and 10). Through rather detailed magnetic investigations on the surface in the drill hole direction, we can indicate a possible thickness of the zone to be in the order of 3,5m. The magnetic isomap is showing that a structure low in mt. may continue towards W.N.W. to a considerable distance (see fig.2). We cannot look away from the possibility that the mineralizes zone may have a correspondence to that structure.

The geophysical study of the mineralizations can be summarized up as follows: About 50% of the drilled mineralizations can be correlated to the surface magnetic measurements to some degree. Within the drill holes 35% of the drilled mineralized zones correlate good with low mt. content and high gamma activity. About 40% correlates with high mt.content and medium to high gamma activity.

2.4. Economic considerations of the drilled mineralizations.

It is beyond the scope of the geophycists work to start economic evaluations. That is not done either, but it is always a support for the geophysicists to have a feeling of the economical potentials of the area he is working within.

The mineralizations on fig.10 are referring to a true thicknes on the basis of drilled thickness and the geophysical dip structures. For underground mining purposes an estimate of some of the mineralization values have been indicated within a thickness of 3m. Ore grade of the mineralizations is limited to zone A (see fig.10) but unfortunately the mass is rather limited. The mass of proved and possible mineralizations is in the order of 15000 t and 35000 t respectively.

The grades of the other mineralizations are considered to be of sub marginal to marginal character. The upper part of drillhole 10 may represent one of the most interesting apatite mineralizations. As previously mentioned that zone may have a consiberable extension.

The mineralized zones within Tuftehavna drilling area may represent valuable additional tonnage at ore if high grade deposits of great tonnage are found not too far away. Further drilling to explore the findings should not be given special high priority.

2.5. Anomalies in Tufte.

In the following descussion of magnetic and radioactive structures on which further investigations should be done, it is recommended for the reader to look at fig.12 using fig.13 and 14 as overlays.

In order to throw light on interesting geophysical structures a preliminary drilling proposal has been indicated (see fig.14). Looking back at the isomagnetic structures within the Tuftehavna drilling area (see fig.12), we can see a variable magnetic low structure running through the magnetic high. The most interesting drilling results have been obtained within that variable magnetic low structure. That magnetic low structure is continuing towards N.N.W. out of the drilling area. The structure gets more open, but it should be followed up.

Toward west there is another magnetic low structure running through the investigated area. That low structure corresponds to some degree with gamma ray anomalies.
In the following more focus will be given to that structure:

East of the Old Holla church ruins (N.W.part of the maps) there are zones of rather diffuse magnetic highs and lows. (The most geologically significant anomalies on a given map may be the subtle anomalies). It is worth noticing that the anomalies correspond with the highest gamma activity which so far have been registrated in the Tufte area. Tere are a lot of outcrops in the area. The procedure to follow up exploration must in that way depend on results from detail geological mapping and sampling. A drillhole numer 1 is, however, indicated (fig.14) to focus on the structures.

Drillhole number 2 (fig.14) is throwing light upon a dominant magnetic low structure. It is so low that one could suspect the anomaly to reveal basic silicate rocks. However, we have registrated a søvite outcrop in the middle of the magnetic low. According to susceptibility investigations on that outcrop the mt. content is almost zero.

Drillholes 3 and 4 are plotted to draw attention to a magnetic low structure which corresponds with a magnetic high. N.W. of the structures there is a magnetig high, which also should be focused on. During the field survey we registrated one søvite outcrop and one hollatic outcrop in the area where we measured the highest radioactivity. However, the outcrop was not radioactive at all, so that the reason for the gamma ray anomaly should be found within a circle with a diameter of approximately 20 m.

Finally drillholes 5 and 6 are put on the map to focus on a magnetic low corresponding to a gamma ray anomaly. The structures are situated in between 2 small magnetic highs.

2.6. Rødberg anomaly.

According to the VLF-resistivity isomap (fig.3) there is an electrical low resistivity area in between the drilling area and the main road to Skien/Ulefoss.

The semi cross profile fig.11 shows clearly that the low resistivity values can be compared to values obtained in the rødberg in Gruveåsen.

The low resistivity area may represent rødberg or rather thick shale overburden. In 1952 - 1953 geophysicist Ø.Logn, A/S Sydvaranger carried out electrical soundings to investigate the thickness of the overburden within the southern part of Tufte. One of his profiles coincide with one VLF station indicating an overburden thickness of 11 m with resistivity 90 ohm m. To find out whether the low resistivity area represents rødberg or shale overburden some direct current resistivity investigations should be done.

2.7. Results from Susceptibility field investigations.

By checking a magnetic anomaly at Melteig area (an anomaly which in accordance to Sæthers geological map should reveal damtjernite) a new søvite area was found. On the basis of previous magnetic investigations a potential søvite area of 190.000 m^2 is indicated (see fig.15 area 5). Nowadays having a situation where landowners use all legal means to prevent Fenco from exploring their land, it should be of importance to find new areas of søvite.

3. EVALUATIONS OF SOME GEOPHYSICAL TECHNIQUES

3.1. General considerations.

It does not exist any geophysical method which directly respond to ores of niobium and apatite.

So far we have learnt that magnetic and gamma ray investigations are useful tools in delineating structures that may be favourable for the occurence of ore. Based on such investigation techniques the number of structures that should be investigated will be very large. In order to minimize the numbers of structures and to increase the probability to find the most promising ones, we must be willing to experiment with other geophysical tools. In this context it must of course be underlined that the usefulness of geophysics will always depend on frequent feedback from the geologists.

Similar to the Fen area the carbonite complex at Sokli (in eastern Finish Lappland) is covered by much overburden. The thickness of the glacial materials of Sokli varies between 0,5m to 60 m.

That carbonite was discovered by airborne geophysical surveys. It is known that all the carbonite massive have been studied systematically by ground geophysics including magnetic, radiometric, gravimetric electromagnetic, electric and reflection seismic methods. Since the area is studied systematically it is reasonable to expect that reasonable good results are obtained.

3.2. Radon investigations.

Unlike conventional gamma ray scintillometry, it offers the opportunety to see in the third dimmension due to the mobility of radon gass. The Norwegian Geological survey (NGU) has good experiences after having used the method for some years. We have learnt that the gamma ray method often misses radioactive zones below overburden. Such zones are of considerable importance for exploration purposes,and we should try the radon method to increase the probability in detecting them.

3.3. Resistivity investigation techniques.

We have learnt that the VLF resistivity method respond to the resistivity contrast between rødberg and søvite. The method can also delineate fault zones and hematite dikes. Due to the high frequency the depth of penetration is limited. Thick shale overburden will probably screen.

The most sensitive method to map resistivity contrast is the direct current resistivity methods. The objective by trying the method in Fen is as follows:

1) Try to differ rocks as søvite raudhaugite, hollaite, fenite and lamprophyre. We cannot expect fantastic results, but the method should be tried.

2) Delineate the resistivity and thickness of the overburden at some representative places. Having more of such data we will know more about the possibilities to indicate faults and rødberg using the cheeper VLF resistivity method.

3.4. Gravity investigations.

According to density investigations by N.G.U.and H.Qvale, the density contrast between søvite and lamprophyre is about 0,3 g/cm^3. Some tentative model experiments have been carried out to learn what the size of a lamprophyre body must be to make the gravity method applicable. Assuming a lamprophyre sheet being 100 m long which is cropping out below an overburden thickness of 2 m, then the thickness must be in the order of 30-40 m to get significant gravity anomalies.

The conclusion must be that the gravity method represents an attractive method for localizing rather big(mineralized)lamprophyres.

3.5. Seismic investigations.

At the carbonatite complex at Sokli in eastern Finish Lappland good results are obtained by reflection seismic techniques. Due to different acoustic properties of the rocks they have managed to deliniate the structures of the carbonatite plug down to about 5 km. Unfortunately, little is published about the investigations.

Due to different density contrasts between gneis, søvite and lamprophyr, it is reasonable that the accoustic rock properties are different in Fen too. If the reflection coefficients are large enough to delineate søvite and potential lamprophyre boundaries will have to be investigated.

Such investigations can be done within one week, and the price will be about 150 000 N.kr. The Norwegian Company Geoteam has good references from seismic soundings in crystaline rocks at Løkken Verk A/S and A/S Sulitjelma Gruber.

Further studies of the seismic results at Sokli is recommended before trying the method at Ulefoss. However, the seismic method must be condisered as a method which can open interesting perspectives.

4. SUMMARY - FOLLOW UP INVESTIGATIONS

4.1. A proposal to guide to further exploration:

1) Magnetic and gamma ray investigations should be carried out systematically. A proposal to grid system is 25 m x 5 m, which must depend on feed back from geologists.

   Also VLF resistivity investigations should continue.Susceptibility and gamma ray investigations on drill core have turned out to be valuable and such investigations should also continue.

   Within søvite areas focus should be made on magnetic low structures. Such structures are of special interest when they correspond with gamma ray anomalies. VLF resistivity anomalies may reveal zones of rødberg, shale overburden or faults.

2) By magnetic and gamma ray investigations we will obviously get a lot of anomalies on which a further selection should be done.

   To save drilling costs one should increase the probability of finding the most promising anomalies. That may probably be done by trying other geophysical techniques.

a) radon investigations
b) gravity investigations
c) direct current resistivity investigations
d) seismic soundings.

At the Sokli carbonatite the techniques a,b,c,d are used systematically. By using the reflection seismic method the structure of the carbonatite has been indicated down to about 5 km. That method should open interesting perspectives in Feen too.

4.2. Exploration objects.

Within the limited area of Tufte, we have already obtained interesting findings and we have deliniated geophysical structures on which more focus should be made.

So far priority should be given to exploration within potensial søvite areas. Unfortunately, the interesting Vipeto area is not accessible. Therefore, we for the time being must concentrate exploration to land belonging to "Fenco sympatic" landowners.

On the basis of previous regional magnetic investigations such areas have been indicated (see fig.15). The size of such areas (area 3, 4 and 5) are about 900.000 m^2.

According to S.P.Olmore the areas 6 and 7 may represent potensials for nepheline and apatite. Especially within area 6 there are significant structures of magnetic highs, which are not explained by Mr. Olmore's detailed mapping due to lack of outcrops. Mr. Olmore has focused on the magnetic anomalies and indicated that they may represent a possible apatite resource. Another theoretical possibility is nepheline being associated with magnetite. The nepheline at Stjernøy is mixed up with 2% magnetite in average. The anomalies at Melteig seem to reveal about 1,7% magnetite. It is worth to pay attention to Mr. Olmore's proposal saying it may be worth to check the magnetic anomaly by drilling.

4.3. Field work - timescedule.

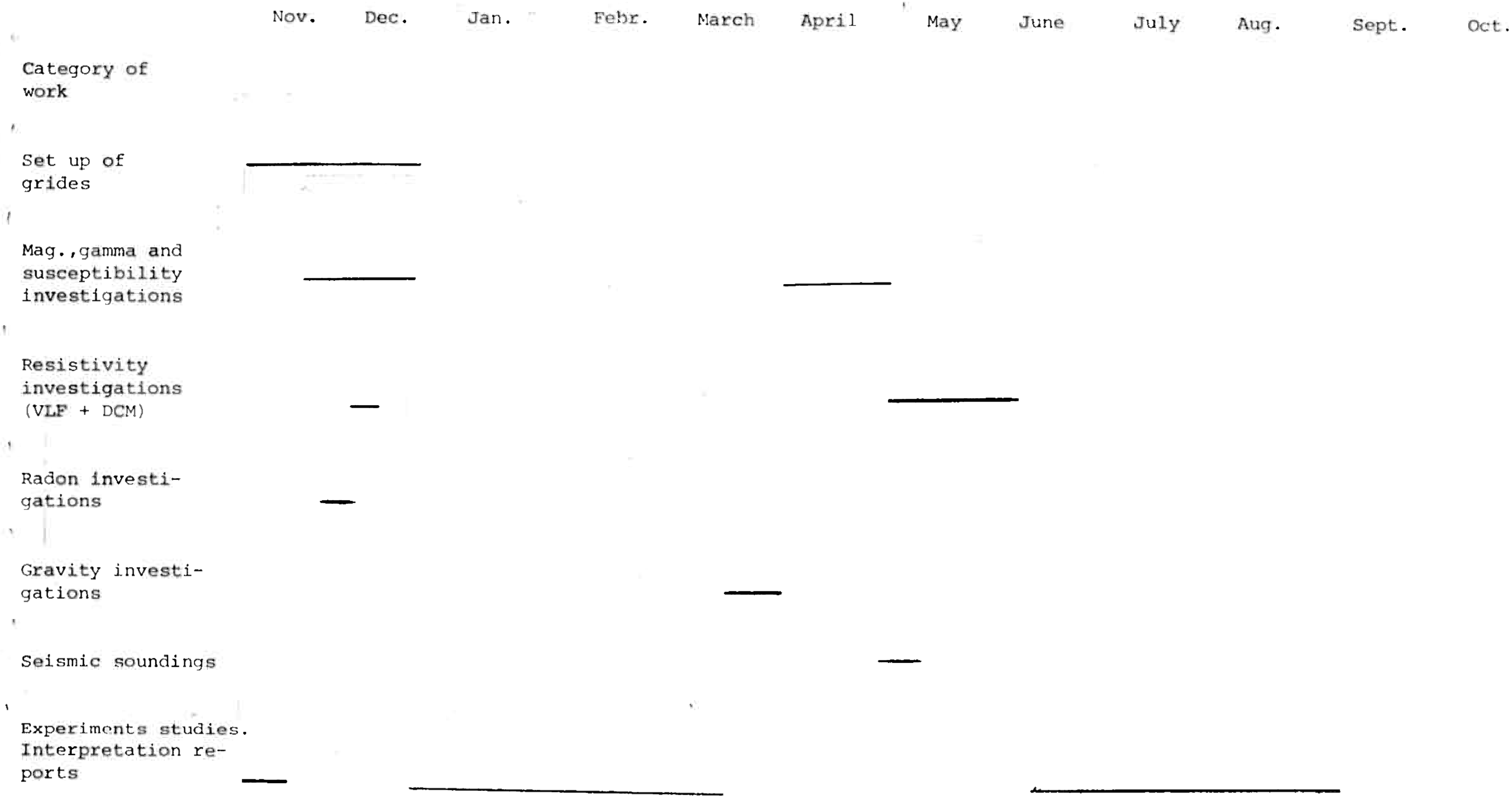
At the end of this chapter it follows a timescedule including different work categories.

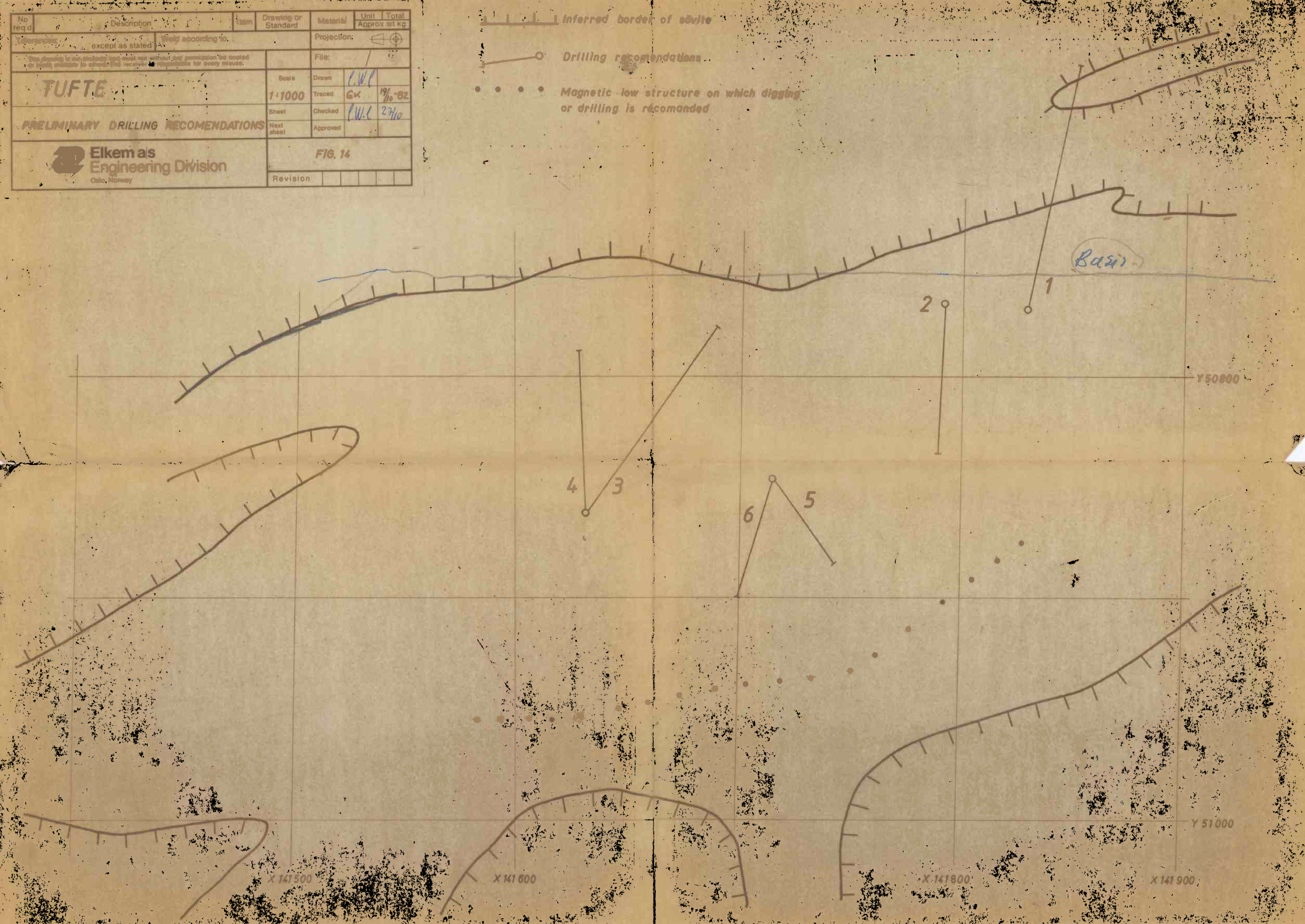
The geophysicist plan to take part in most of the field work within a periode of 4-5 months. Further on 4-5 months should be used to studies of different techniques and to make interpretations and reports.

Detail magnetic, gamma ray, VLF-R and susceptibility investigations we can do ourselves. Direct current resistivity investigations should be considered to be done by a contractor, because we do not have modern equipments. Gravity, radon and seismic investigations should be done by contractors.

From May until October we have indeed learnt that it is difficult to carry out geophysical fieldwork in the Fen area. The most suitable time is probably during late Fall until Christmas. For that reason field investigations have to start as soon as possible. In order to carry out an intensive field work campaign before Christmas there will be a need for 2-3 assistants.

A PROPOSAL TO TIMESCEDULE

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PRELIMINARY DRILLING RECOMENDATIONS
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FIG. 14
Revision
Inferred border of sövite
Drilling recomendations
Magnetic low structure on which digging or drilling is recomanded
Basis
1
2
3
4
5
6
Y 50800
Y 51000
X 141 500
X 141 600
X 141 800
X 141 900

LIST OF FIGURES

Fig.

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TUFTEHAVNA DRILLING AREA

GAMMARAY INVESTIGATIONS

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FIG. 1

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TUFTEHAVNA DRILLING AREA

MAGNETIC SURWEY (TOTAL FIELD)

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FIG. 2

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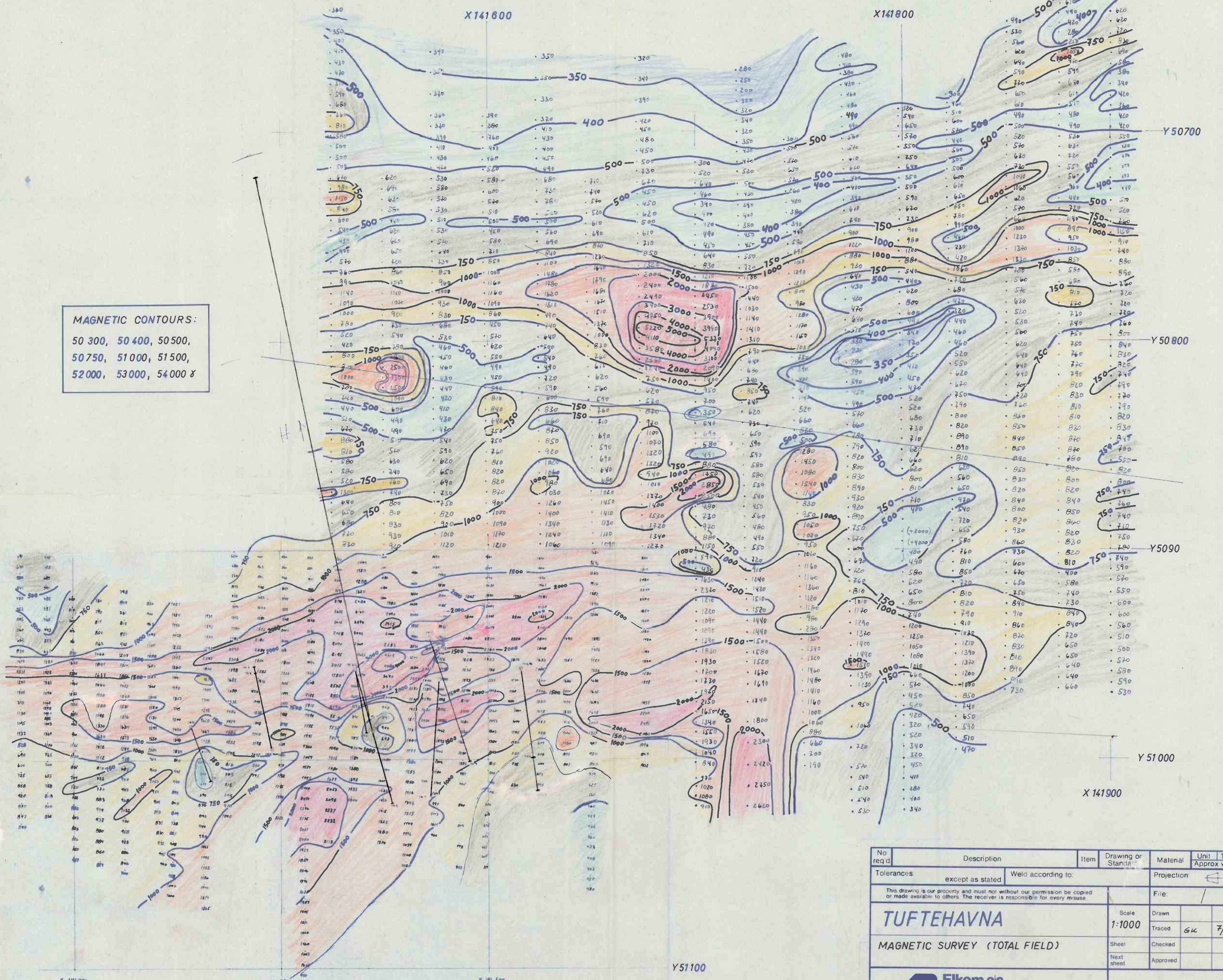

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MAGNETIC SURVEY (TOTAL FIELD)

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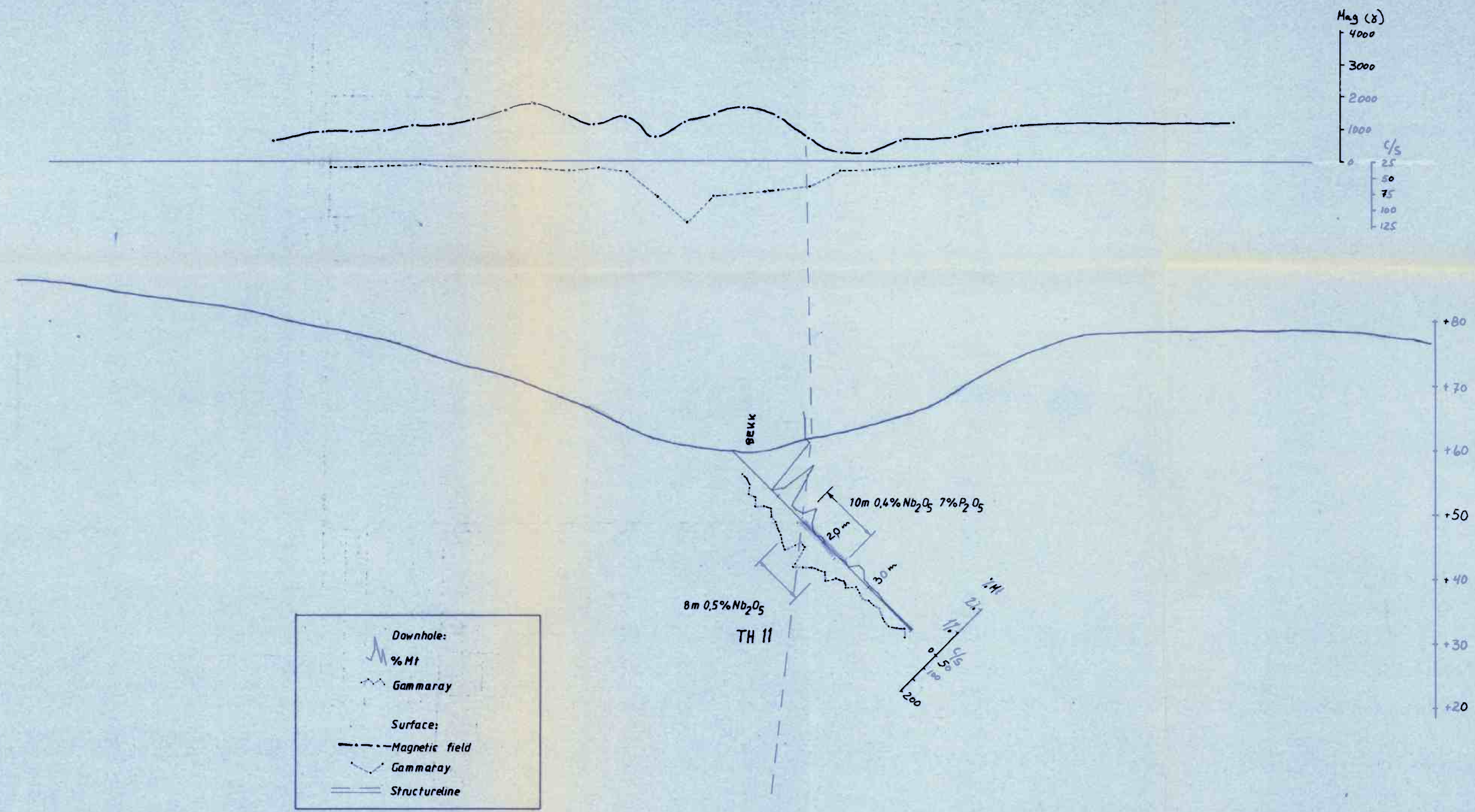

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PROFILE 1 **FIG. 4**

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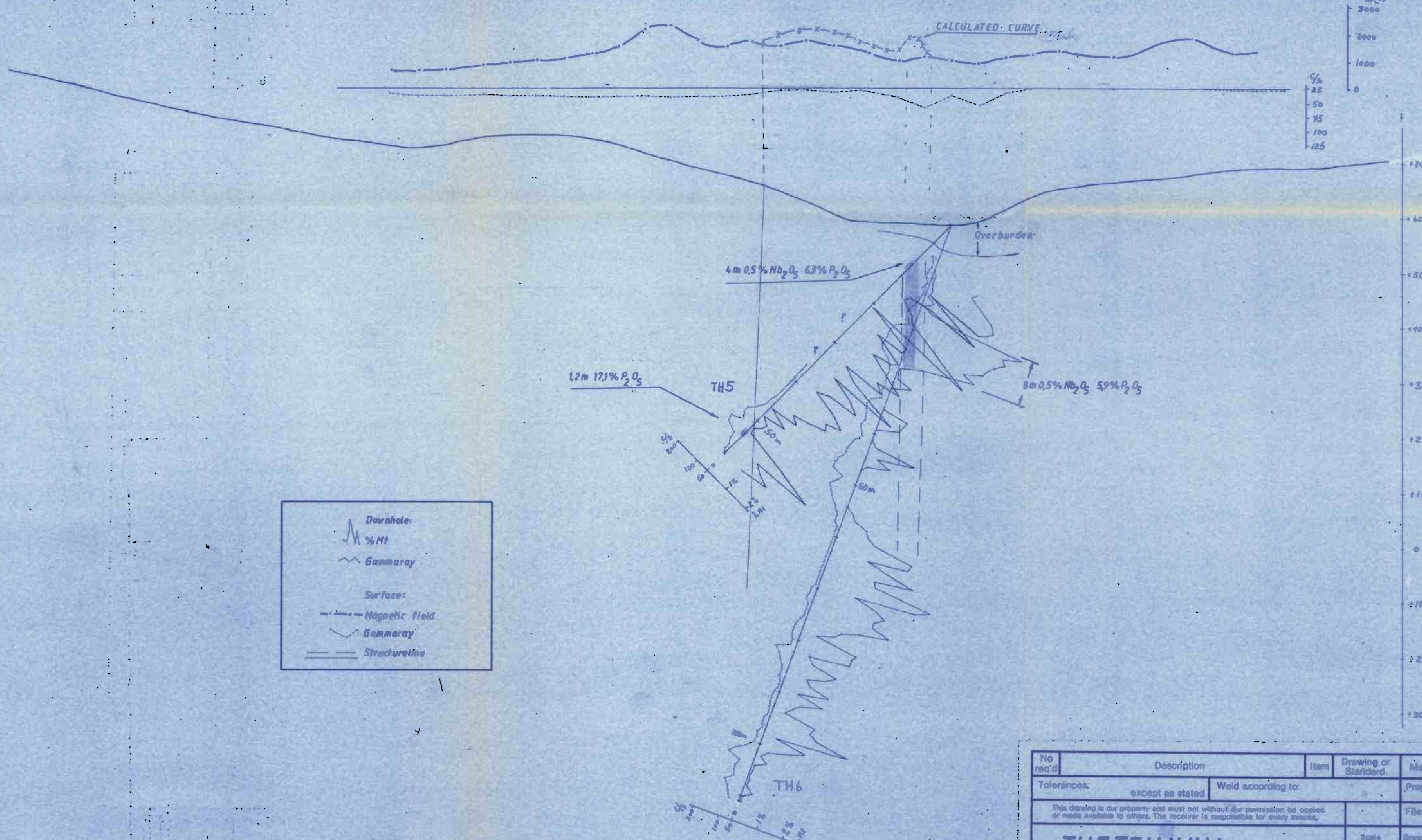

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PROFILE 2

FIG. 5

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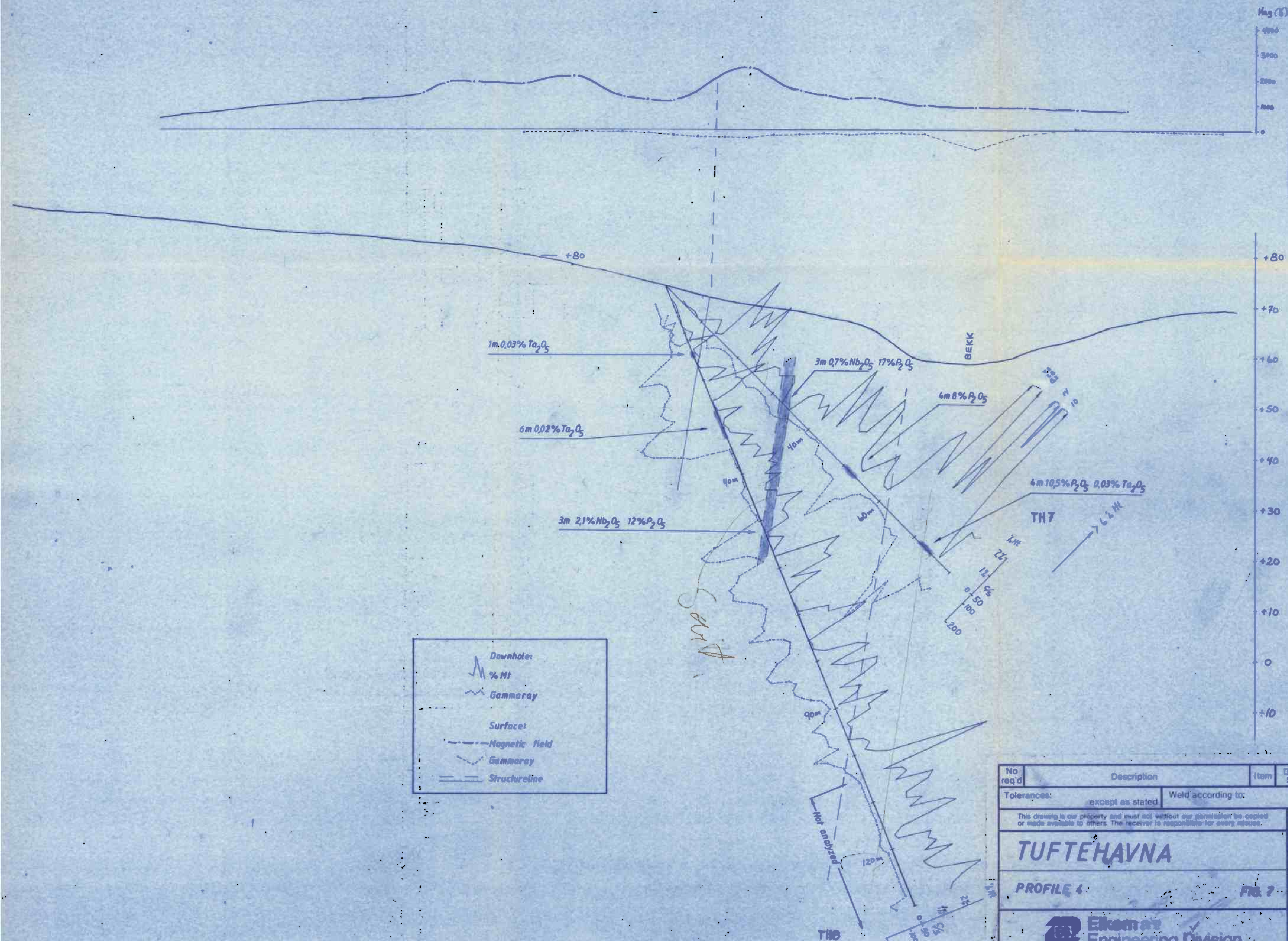

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PROFILE 4

FIG. 7

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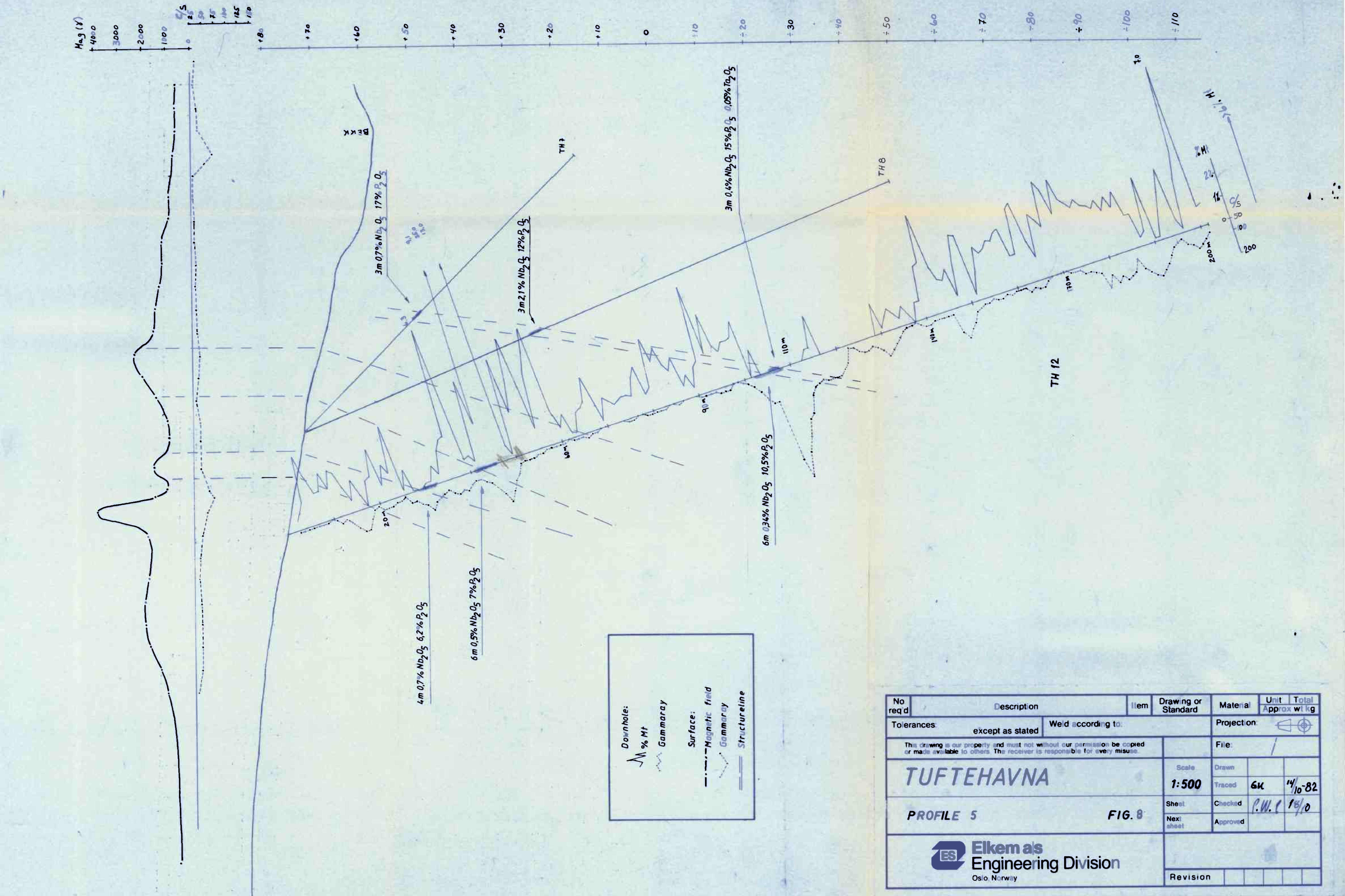

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PROFILE 5 — **FIG. 8**

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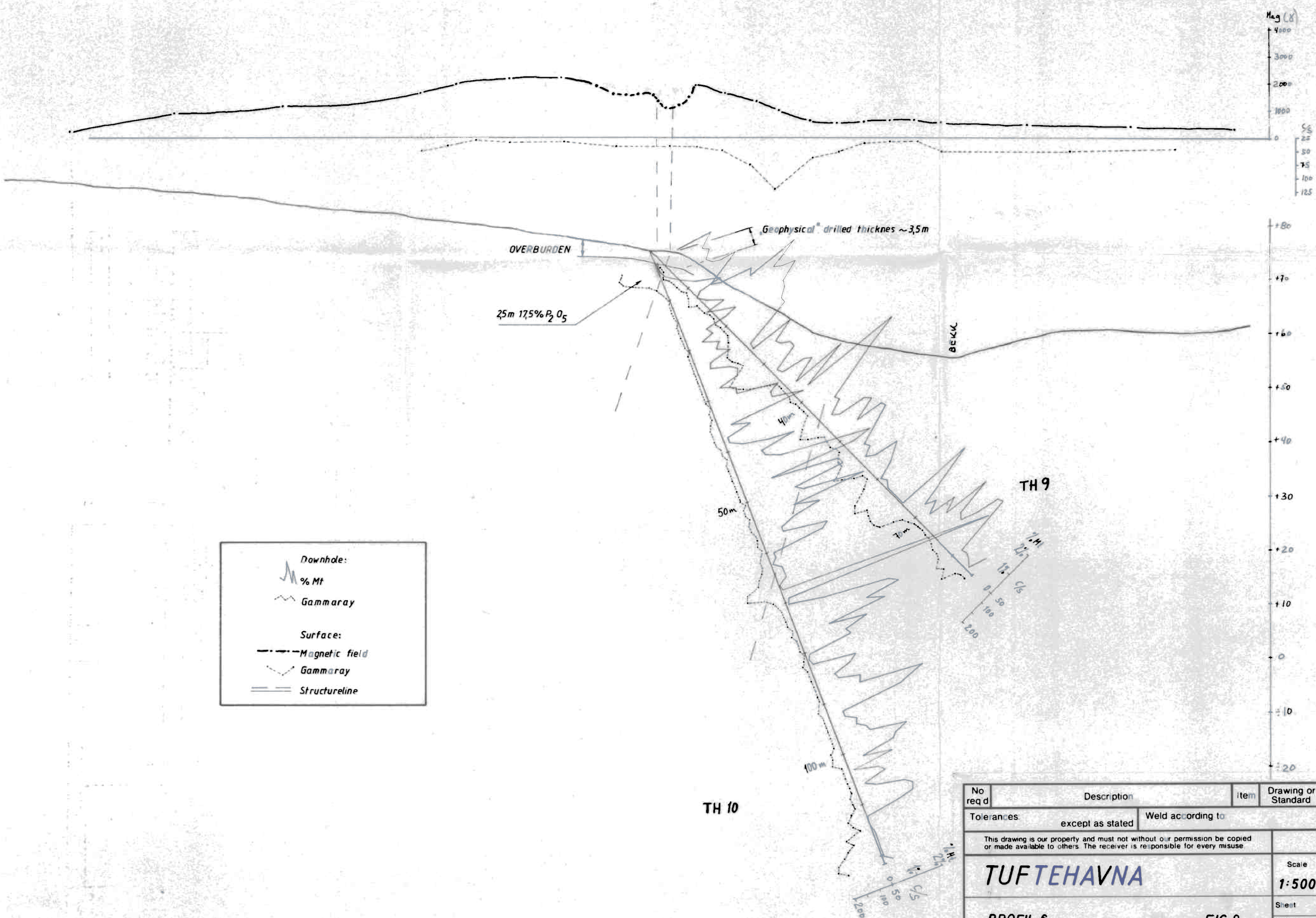

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Tolerances: except as stated — Weld according to: — Projection:

File: /

TUFTEHAVNA

Scale 1:500

Drawn:
Traced: GK. 14/10-82
Checked: E.W.C 19/10
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PROFIL 6 — FIG 9

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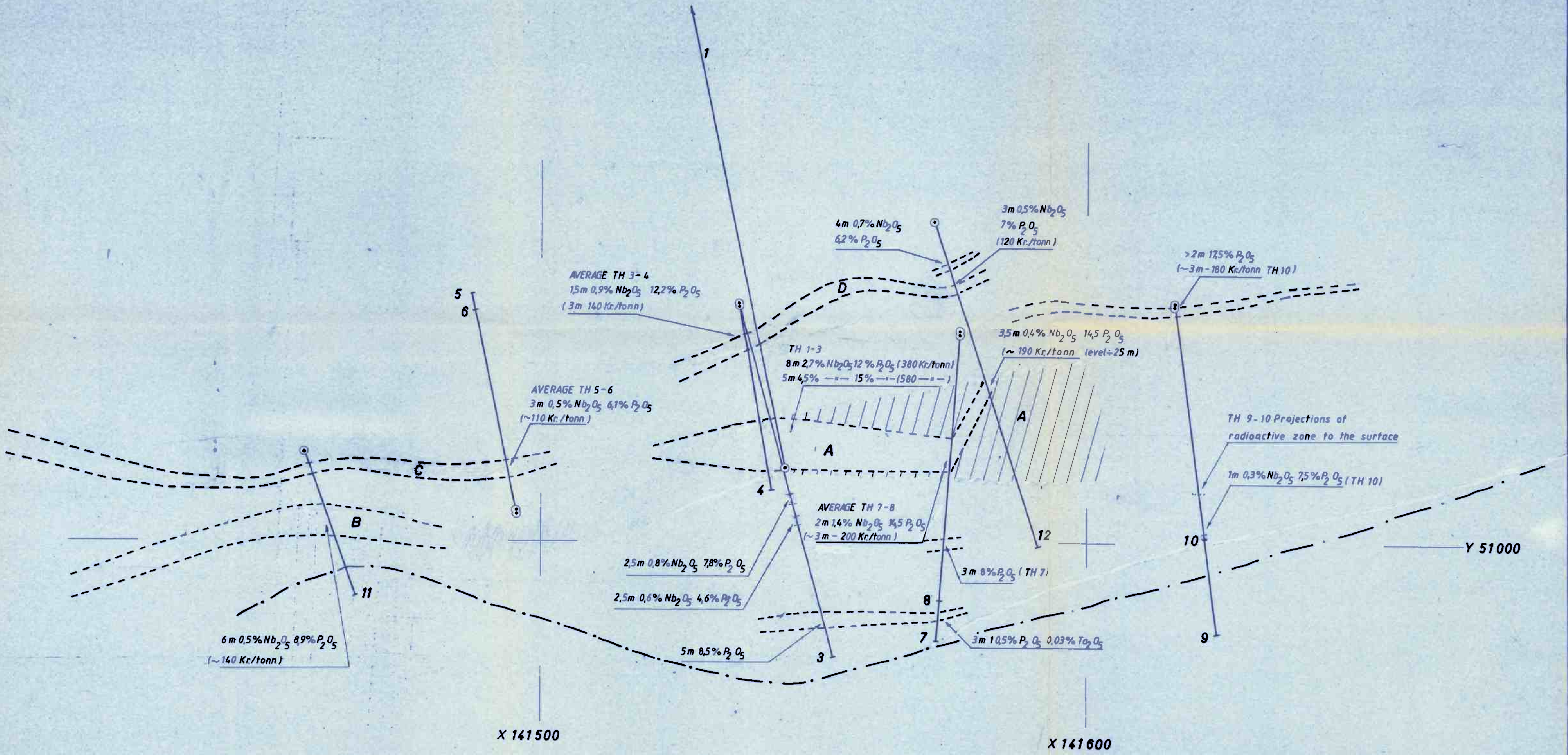

Drilled mineralized zones

Projections of mineralizations

The meters (m) are refering to approximate true thickness of the zones

Kr./tonn An estimate of mineralization value

Thin conductor ~ faultzone

No req'd	Description	Item	Drawing or Standard	Material	Unit / Total Approx wt kg
Tolerances: except as stated	Weld according to:			Projection:	

File: /

TUFTEHAVNA DRILLINGAREA

ZONES OF Nb_2O_5 AND P_2O_5

Scale 1:500

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FIG. 10

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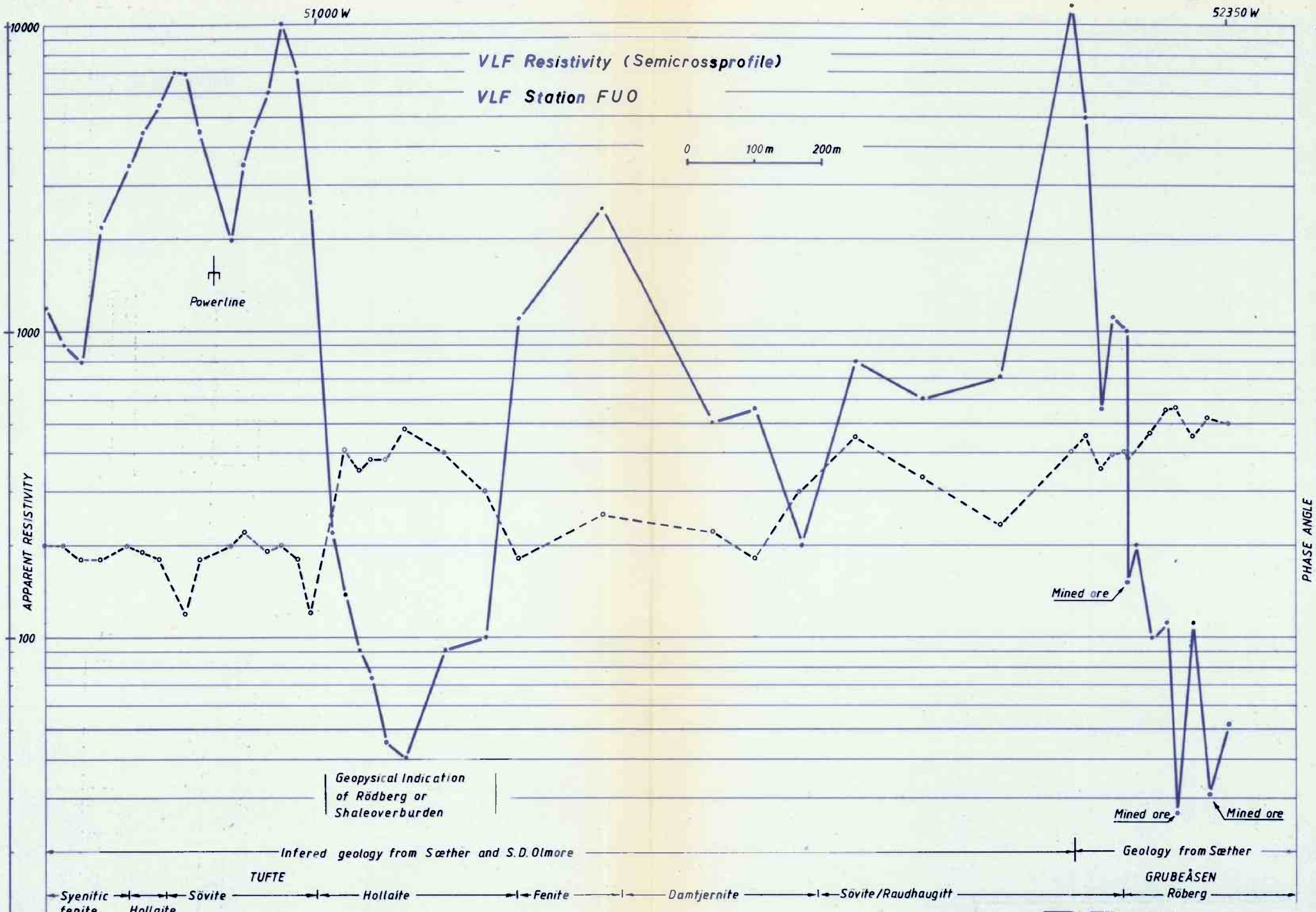

FIG. 11

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No req'd	Description	Item	Drawing or Standard	Material	Unit / Total Approx wt kg
Tolerances: except as stated	Weld according to:			Projection:	

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TUFTEHAVNA

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PROFILE 3 GEOPHYSICS FIG. 6

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