Bergvesenet

Postboks 3021, N-7441 Trondheim

Rapportarkivet

Bergvesenet rapport nr	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering
5700				

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

Tittel

Detail magnetic an gamma-ray investigations of the Fen complex.

Forfatter	Dato År	Bedrift (oppdragsgiver og/eller oppdragstaker)
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Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Nome	Telemark		17134	Skien

Fagområde	Dokument type	Forekomster (forekomst, gruvefelt, undersøkelsesfelt)
Geologi		Fensfeltet

Råstoffgruppe	Råstofftype
Malm/metall	RE

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Rapporten er detaljert magnetisk og gammaståle undersokelse i Westhagen og i Melteig området og en test-undersokelse i den nordlige del av Fenkomplekset.

Vedlegg mangler i rapporten.

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FEN PROJECT

Detail magnetic and gamma-ray investigations of the Fen complex

by

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Oslo, January 1984

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January 1984

ABSTRACT

Investigation results discussed in the report are:

1. Detail magnetic and gamma-ray investigation within the Westhagen and Melteig area.

2. Test investigation of the northern portion of the Fen complex.

Background

The Tuftehavna story points towards interesting occurence of niobium and phosphate within søvitic domains. Concerning known igneous phosphate deposits, the most prominent in commecial terms on a world basis is represented by ijolite-urtite rocks which are similar to the rocks occuring in the Melteig area. The lack of bedrock exposures places geological methods at a disadvantage, and therefore interactive use of geophysics was used to promote the understanding of the geology.

Objectives

1. The main objective in using geophysics has been to get information on the occurence and the extent of søvitic and urtite-ijolite structures below the overburden.

2. Give proposals for exploration drilling to follow-up known findings as well as to get geological information in virgin areas of the Fen complex.

Obtained Results

The area of the søvitic domain within Tuftehavna Westhagen area may be in the order of 250,000 m^2. That area is assumed to be open towards east into the land of the Vipeto-group which is not accessible for exploration.

The exploration drilling carried out during summer 1983 was based on geophysics. Very good results were obtained. The finding intersected by drillhole 13 is grading to 2% Nb_2O_5 and 15% P_2O_5. Drilled thickness was 4 m.

A potential søvitic area is also indicated within the Melteig area. The melteigite itself is assumed to be more extentive towards south-east compared to the geological results of S.D. Olmore. A variable radioactive anomaly is delineated in the Tveithåven area which makes a peripheral part of the Fen complex.

The test investigations in the northern portion of the Fen complex show that detail geophysics promote a better correlation between the variability of geology. The narrow hydro-søvite dike as well as the intrusion edge of carbonatites are indicated by geophysics.

Further Investigations

The results of this report alone do not open the prospects of finding the big deposit. However, on the basis of the results we propose to follow-up known findings, as well as anomalies, to promote the understanding of the occurrence of mineralizations as well as to improve understanding of the geological model of the Fen complex.

Priority should be given to follow up the radioactive anomaly on which drillhole 13 was directed. If positive results are obtained, magnetic structures associated with the radioactive anomaly should be drilled. Further drilling should also be considered in the Old Holla Church area.

It was a magnetic anomaly in Tuftehavna that gave rise to the first drilling. Even if we so far have not detected any large mineralisations, drilling is recommended in the Melteig area to check magnetic anomalies both within the potential søvitic and melteigitic area. Finally, exploration drilling should be considered to check a radioactive anomaly in the Tveithåven area.

The aim of the further prospecting should be to define minimum 4-5 million tonnes of ore. The minimum ore grade should be in the order of 0.7% Nb_2O_5 and 7% P_2O_5.

Current beneficiation technology is such that igneous apatite ores of lower grade can be up-graded to yield marketable concentrates of high grade. On that basis the Tuftehavna søvite is a potential phosphate resource.

The gravimetric anomaly may be the key to finding a big deposit of both niobium and apatite. That anomaly can be explained by a mass having a density similar to that of the lamprophyre.

Total mining, ore dressing and refinery costs will be in the order of 150 NOK/tonne. The minimum ore value required to think of a production should be in the order of 240 NOK/tonne. A pay-back period of 10 years is included in that figure.

A consequence of the above factors should be to define minimum 4-5 million tonnes of ore in which the minimum grade should be in the order of 0.8% Nb_2O_5 and 7% P_2O_5.

The last finding intersected by drillhole 13 in Tuftehavna represents an insitu value in the order of 600 NOK per tonne crude ore, and in that figure 50% recovery of niobium has been included.

Current beneficiation technology is such that igneous phosphate ores of extremely low grade can be treated successfully, to yield marketable concentrates of high grade. In Siilinjärvi in Finland a deposit grading 4.1% P_2O_5 is presently being exploited. Mining costs are rather low due to open pit operations and high capacity. Ore reserves of this deposit are 400-500 million tonnes.

A potential roast-leaching process of rare earth elements in Grubeåsen improves the economic potential in the Fen complex.

Even if we so far have not detected any large mineralizations of niobium, the Fenco project is assumed to have a better economic potential than it has ever had.

To check these possibilities exploration drilling must be given a high priority.

A resumé and conclusion of the test investigations are as follows:

1. The narrow Hydro-Søvite dike as well as the intrusion edge of carbonatites are reflected by the detail geophysical investigations. Halo effects are also a diagnostic feature.

2. Radioactive properties from bedrock exposures are much influenced by "allochthonous" (marine shale) overburden.

3. Within an overburden terrain, it is worth paying attention to even very weak radioactive anomalies.

Due to the correlation between radioactivity and anomalous grades of niobium apatite and rare earth elements, it is recommended to study figures 9 and 10 further to define the radioactive sources within the Tuftestollen more precisely. Follow-up investigations should be considered to find the reasons for the radioactive peak anomalies within the Tuftestollen area.

6. SOME ECONOMIC CONSIDERATIONS

The Tuftehavna story points towards lamprophyre occuring within søvitic domains as being the most interesting exploration target. If we assume that a potential ore occurs as lamprophyre dikes, then the tonnage may be a critical factor due to great variability in geology. The minimum tonnage required to start a mining operation should be in the order of 4-5 million tonnes. It is assumed that it may be difficult to find that tonnage within one single dike. More probably a potential mining operation must be based on a certain number of dike-like deposits.

Continuing to assume that a potential ore body will have a certain relationship with lamprophyric rocks, then the gravimetric anomaly may be the key to further exploration. The gravimetric anomaly may be explained by a cylindrical or cone-shaped mass having a density similar to that of the lamprophyre.

To minimise the disturbances from a potential mine production is it assumed that underground mining will be most appropriate within the Fen area.

Referring to figure 8, the present detail magnetic iso-map reflects a structure direction which is in accordance with known geological structures. There are somewhat higher magnetic values than the background above and in the vicinity of the Hydro-Søvite dike. What is more evident on the map is a correlation between the Hydro-Søvite dike and radioactivity. The gamma-ray anomaly is somewhat broader than the dike itself revealing halo effects of radioactive minerals in the country rocks at each side of the dike. The overburden thickness above the Hydro dike is assumed to vary between 0.5-3 m.

Gamma-ray investigations within the Tuftestollen, and both magnetic and gamma-ray investigation on its surface, were carried out to check geophysical results against Olmore's detail geologic map of the adit.

Referring to figure 9, the Hydro-Søvite dike is exposed by gamma-ray investigations within the adit as well as on the surface. Not so clearly this is also indicated by the magnetic results. Also in this section we can study the halo effect of the søvite dike. Concentrations of radioactive minerals positioned up to 50 m outside the dike seem to have a certain relationship with the søvite dike. Towards south it seems to be a similar effect concerning the distribution of magnetite.

The intrusive søvite mass comes up 300 m from the opening of the adit. Radioactive anomalies within the søvitic mass are very diagnostic, but unfortunately that diagnosis cannot be made on the basis of the surface radioactivity due to screening effects from the overburden. The magnetic trend on the surface does, to some degree, reflect the cutting through of the søvite mass.

The southern section of the Tuftestollen, figure 10, shows to what degree the radioactivity is screened from the overburden. Parameters from the overburden nature and its thickness are available through Ø. Logn's geoelectrical investigations dating back to 1953. The overburden thickness varies between 2.5 m and 20 m. It is conductive, and this indicates that the overburden materials are mixed up with marine shales. The example shows that such overburden very much screens the radioactivity. However, it is worth noticing that the radioactive zones located at 700 m and 840 m are also reflected by the surface radioactivity, showing weak anomalies 10-30 c/s above normal background radiation.

The radioactive anomalies in the south western peripheral portions are rather weak. There is a lot of bedrock exposures in the area and in general the over-burden is thin. On the basis of radioactive investigations of bedrock exposures it is assumed that the radioactivity represents normal background radiation from gneis and fenite.

4.3 Proposal for further investigations

Previously we have said that further exploration of gamma-ray anomalies should be given priority. Even if those are situated in peripheral areas, one should pay attention to such anomalies. This means that we do not have good enough statistical data to suggest that mineralized lamprophyre has a typical occurrence in søvite. We therefore propose further examination of the radioactive anomaly in the south-western portion. Further gamma-ray investigations on blocks should be carried out. In addition some digging is recommended to localities in which the radiation is highest. Exploration drilling should be considered.

It must be in the interest of the Fen project to promote a better understanding of the geology in order to build up a geological model on which logical prospecting philosphy can be utilized. To do so, more drilling has to be done in areas where there is a lack of bedrock outcrops. Furthermore, to obtain valuable geological information drilling should, if possible, be carried out in localities in which there are some chances of finding economic minerals. In that way we will propose to direct two drillholes at magnetic anomalies within the melteigite and potential søvite area (see figure 5).

5. TEST INVESTIGATION OF THE NORTHERN PORTION OF THE FEN COMPLEX

On the basis of the previous magnetic investigations of regional character it was not possible to reconcile geophysical and geological observations in the northern portion of the Fen complex.

In 1983 a few days was spent carrying out more detail investigations in that area. Both magnetic and gamma-ray investigations were carried out. Through Olmore's geological mapping in that area, it was possible to make a good check of the geophysical results.

A søvite exposure at the coordinate 140600N 50900W was found by Carstens and Olmore in 1982 when carrying out susceptibility investigations in the area. The outcrop is situated in a creek in which the water content was minimal due to a dry summer time period. The bedrock exposure is located outside Olmore's map. Unfortunately the finding deviates from Sæther's geological map indicating that there is a melteigite outcrop in the same locality. Maybe Sæther did not locate the søvite because of too much water in the creek. Apart from this discrepancy, our søvitic area is outlined within a virginal area concerning bedrock exposures. The contours of the søvitic area are based on susceptibility investigations of the outcrop as well as statistical parameters concerning the magnetic level.

The size of the potential søvitic area is approximately 50,000 m^2. On the basis of the location, it should be possible to view it as a possible prosperity of the Tuftehavna søvite.

Another potential søvite dike structure has been indicated on the basis of a magnetic anomaly in the northern portion. See figure 5. According to Sæther's map and observations during the geophysical field investigation there are not any signs of bedrock exposures in the area. Basically there are alternative rock units that may explain the anomaly. In that district melteigite and søvite should be alternatives. Melteigite primarily does not occur as dikes. To throw light upon the possibility we have chosen to call it a potential søvitic structure.

4.2 Discussions of the radioactive anomalies

The radioactive anomalies are concentrated to the more peripheral parts of the area (see figures 3 and 5). On the basis of our field investigations we have the impression that the bedrock exposures are generally covered by thick overburden in the central part. We assume the overburden thickness to be 5-6 m at each side of the creek in which the søvite bedrock was found. It is assumed that signals from the radioactive bedrock sources to a large degree are screened by overburden material.

Referring to figures 3 and 5 there is a radioactive anomaly in the Tveihåven area situated in the north western portion. According to Sæther's geological map, that area is dominated by fenitic breccias. We have, however, investigated rock exposures and blocks without finding the radioactive source. The question of the radioactive source can therefore at present not be answered.

A rather narrow band of the Tuftehavna søvitic structure is assumed to be reflected by a magnetic high in the most north eastern portion of the map. That structure stops gradually towards the south. However, the structure may be open towards the east.

Moving further towards south (see figure 3), the magnetic structure changes from a low to a higher area. Using the 500 gamma-ray isoline as a borderline between high and low areas, the area can be divided into 3 magnetic high areas. The two most prominent magnetic high areas in the southern portion have semi-elliptical structure which is assumed to reflect the penetration of Fen rocks through precambrian structures.

Mr. Olmore had earlier focused on magnetic high areas as being potential exploration targets for an apatite Fe-Ti body of similar nature to that in Kodalen. In addition it may represent a potential for nefelin rocks. He has done detail geological mapping in the area. The bedrock outcrops are clearly defined and that makes a good basis for our intepretations.

It can be concluded that the melteigite is among the most magnetic rock units in that area. The magnetic properties are variable, but it is assumed that the melteigite reflect much of the magnetic anomalies.

Because of the possibilities that the melteigite may represent a potential host rock for apatite and nefelin, we have tried to outline a potential melteigite area. See figure 5.

Compared to Olmore's geological map which was much drawn on the basis of erosional features and soil characteristics, our melteigite area is more extentive towards north-west. There is a rather good correspondance towards east-south-east. In the southern portion there are some discrepancies between geological bedrock exposures and the mean statistical magnetic properties of the melteigite. The reason is the variability of the magnetic property, and in that portion we have drawn the borders on the basis of the mapped outcrops.

Referring to figure 5 we have taken the liberty of delineating a potential søvitic area. This has been done to throw light on this possibility, and the basis for doing so is discussed in the following.

Due to overburden we cannot so far comment much on the single and small anomaly at the western portion of the map at 1.799 N. It is found within a rather magnetic low area and is therefore assumed not to represent mineralizations within søvitic domains. However, we cannot exclude the possibility that it may represent mineralized lamprophyre or perhaps SrO mineralizations outside the søvite complex.

The weak anomaly close to the basis line at 2.100 N is located within a small creek in which there are hollaite bedrock exposures. The anomaly fades out at each side of the creek. That anomaly probably represents background radiation from hollaite.

The north western portion of the map also reveals weak radioactive anomalies. In that area there are bedrock exposures and the overburden thickness is generally small. The anomalies are assumed to reflect background radiation from fenite and gneis.

3.4 Proposal for further investigation

So far anomalous grades of niobium and apatite have been found within søvite dominated rocks. On that basis it is reasonable to focus on our potential søvite area within the Tuftehavna-Westhagen area, which is approximately 250,000 m^2. So far we have discovered interesting findings. There is hardly enough space to find a large mineralized zone, but reasonable chances may exist to detect a rich deposit of medium size.

We think priority should be given to follow up the niobium and apatite findings obtained by drillhole 13. These findings should have a relationship with the radioactive anomaly at the surface. If positive results are obtained by further drilling of the anomaly, we propose to check magnetic structures which are assumed to have a relationship with radioactive findings. Referring to figure 14, such zones are indicated by dotted lines.

4. RESULTS FROM THE MELTEIG AREA

4.1 Interpretations/discussions of magnetic results

Moving out of the Tuftehavna area into the Melteig area we get a change from magnetic high to magnetic low (see figures 2 and 3). On the basis of the magnetic properties of rock, the magnetic low areas are assumed to reflect fenite and hollaite. According to Sæther's geological map there are very few bedrock outcrops in that area.

The Tuftehavna story stated by drilling a magnetic anomaly, and the story points towards søvitic domains being disseminated by magnetite. For exploration purposes in more virgin areas we propose to focus on magnetic anomalies. Magnetic structures which seem to be related to already known findings may add useful information concerning the strike directions to which further drilling should be concentrated. Recommendations on follow-up exploration are discussed in chapter 3.4.

3.3 Interpretation and discussions of gamma-ray results

The gamma-ray technique has turned out to be applicable within the Tuftehavna area. Drillhole 13 was drilled to check a radioactive anomaly and the following results were obtained: 4 m 2% Nb_2O_5 and 14% P_2O_5. Referring to figure 6, the geophysical results show that there seems to be a relationship between the surface anomaly and the drilled mineralizations located 65 m below the surface. Referring to Carsten's geophysical report 1982, proposals had been given to drill that anomaly. Later Logn improved the arguments to drill the same anomaly.

A new radioactive anomaly has been discovered south of the Tuftehavna drilling area. The anomaly is situated in the Creek Valley (Bekkedal) at 1.350 N. The isolines have been connected to the radioactive anomaly within the Tuftehavn. It is worth noticing that this relationship may be wrong, because of higher background radiation from bedrock exposures within the Creek Valley. Alternatively the anomaly may have a relationship with the radioactive and anomalous niobium/apatite findings obtained by drillhole 13.

The drillhole 14 within the Old Holla Church area was also made to check a radioactive anomaly. Analyses of the drillcores have so far showed submarginal uranium mineralizations and interesting SrO-mineralizations. Referring to the drillhole section figure 7, the mineralizations have a relationship with weak downhole gamma-ray anomalies. From a geophysical point of view, it also seems possible that the zones may be associated with small maximum anomalies at the surface. The additional gamma-ray investigations this year show the radioactive anomaly at the Old Holla Church area to be more extensive towards west-north-west.

Even if the Tuftehavna story points towards the existence of anomalous grades of mineralization within søvitic domains, the possibility of the existence of lamprophyre dikes outside the søvitic domains should not be neglected.

An alternative interpretation is made on the basis of mean values of magnetic properties from the known søvitic area in the Tuftehavna. Referring to chapter 2 søvite should be more magnetic, but the variances of the measurements are, however, significant. By using these data combined with drilling results the potential søvitic area is reduced. The results are presented in figure 4.

Referring to H. Qvale's geological report dated 31.12.82, a geological map has been prepared by himself and S.D. Olmore within the Tuftehavna complex. The authors have closed the søvite structure towards east and south. On basis of the magnetic results we think there should be openings in the søvite structure in these directions. In the Tuftehavna area our interpretations correspond not too badly with Sæther's geological map. Sæther did take magnetic results into considerations when drawing his map and on the basis of the limited magnetic results to which he had access, we think he has done a good job.

Our interpretations in the Old Holla church area are based on geophysics and on geological results from drillhole 14. Unfortunately a compiled version of Qvale's and Olmore's geological mapping in that area was not available.

People who happen to study more than the summary of this report, may think that our indicated potential continuation of the Hydro søvite dike must be most optimistic. See figure 4. We have done this to throw light upon one possibility. Referring to the dominating fault in the north western portion of Sæther's geological map there should be a possibility that the offset søvite dike may occur where we have drawn it and where there is a magnetic high. According to Sæther's map, there are no outcrops in that area which can support, or discount, our interpretations.

Having outlined potential areas for søvitic domains we shall discuss magnetic diagnoses in more detail. The Tuftehavna story points towards søvitic rock being rich in magnetite as the host rock for lamprophyre. The most typical diagnostic feature of lamprophyre was a lack of magnetite. Less typical was some magnetite in the lamprophyre. Our investigation grid is basically too rough to get magnetic reflections of thin dikes of lamprophyre. Even if the grid had been reduced to half it would have been difficult.

An interesting fact is that there seems to be a relationship between radioactivity and the occurence of niobium, apatite and rare earths elements.

The applicability of gamma-ray investigations is very dependent on the overburden thickness and its nature. This will be discussed later on.

3. RESULTS FROM TUFTEHAVNA - WESTHAGEN AREA

3.1 Magnetic structure descriptions

The majority of the magnetic structures in the central part of the map are dominated by structures in which the magnetic isolines make a semieliptical geometry. We can classify them as being of the semi-two-dimensional type. Those structures make a contrast to the more one-dimensional line-structures which are more dominating towards the west at the border of the complex.

The semi-two-dimensional structures are generally magnetic highs, exposing a structure direction towards north-north-west.

A characteristic feature is that the magnetic high forms an east-west wall towards south where it is stopped by a magnetic low. Towards north-north-west the magnetic high is more irregular and it partly fingers out.

3.2 Interpretation and discussions of magnetic results

The semi-two-dimensional structures are assumed to reflect the cutting through of the Fen carbonatite complex, while the more one-dimensional structures reflect a transition zone and originally pre-cambrian structures.

The abrupt changes concerning the magnetic high structures toward south should reflect changes of the geology due to different magnetic properties of rocks.

On the basis of known søvite geology in Tuftehavna it is reasonable that the magnetic high should reflect bedrock exposures which are dominated by søvite. Based on the average magnetic properties of søvite from different localities in Fen, we can say that the area within the 500 gamma-ray isoline may represent a certain possibility for the occurence of søvitic rocks. Interpretations do not fit too well with vertical projections of drillhole geology up to the surface.

1) The magnetic properties of søvite/raudhaugite, melteigite and rødbergite are so similar that it is difficult to differentiate those rock units from each other on the basis of magnetic properties. However, the difference in geographic distributions of special rock units, makes it possible to foresee a certain relationship between magnetic anomalies and the rock units.

2) The above mentioned rock units can clearly be differentiated from hollaite, fenite and gneis in which there is a lack of magnetite.

2.2 Radioactive properties

In the Vipeto, Rullekolen and Grubeåsen area thorium seems to be the predominant source of radioactivity. (Wiik-report 1982, Hultin report 1982). Uranium seems to be the main source in Tufehavna (Qvale-report 1982).

The radioactive properties of some rock units have been studied on the basis of the following materials:

a) Gamma-ray investigations on drillcores in Tuftehavna (Carstens 1982).

b) Gamma-ray investigations in Tuftestollen (Carstens 1983).

c) Gamma-ray investigations in Grubeåsen (Hultin 1982).

d) Investigation of outcrops (Carstens 1982-83).

Referring to figures 9 and 10, studying the gamma-ray within the Tuftestollen, the following radioactive properties can be indicated: the søvite and raudhaugite have similar properties, and these rock units are about twice as radioactive as hollaite, fenite and gneis.

The radioactive properties are compiled in the following table:

Rock units	Radioactivity
Gneis, fenite hollaite, melteigite	1
Søvite, raudhaugite	2
Lamprophyre	4
Rødbergite	20

Concerning the whole Fen complex the tentative statistical results are as follows:

Rock unit	Number of readings	Mean value gamma	Standard deviation
Søvite	71	610	280
Raudhaugite	52	613	893
Rødbergite	45	550	482
Hollaite	22	280	90
Damtjernite	20	570	474
Melteigite	25	590	350
Fenite/gneis	30	290	150

The new results do not differ very much from the previous results. From the standard deviation figures, we can see that the magnetic values generally vary very much within the same rock unit. Especially raudhaugite and søvite showed a considerable variance which must be related to lumps of magnetite.

Concerning the søvite and raudhaugite there are also geographical differences of the magnetic properties.

Referring to the Tuftestollen profiles figures 9 and 10, the magnetic properties of søvite and raudhaugite in the northern portion of the Fen complex are as follows:

	Mean value	Standard deviation
Raudhaugite	260 Gamma	120
Søvite	160 "	125

The reason for having much lower magnetic properties in this portion may be due to fenitization.

In contrast the magnetic values in the Tuftehavna area are higher, and the variability is more prominent.

	Mean value	Standard deviation
Søvitic rocks	890 Gamma	430

On basis of the susceptibility examination of drillcores in that area, the average magnetic content of søvitic rocks is 1.1% magnetite, and that figure corresponds well with the obtained magnetic readings.

The consequences of the magnetic properties are as follows:

Figures 4 and 5 present the results from our qualitative interpretation.

The interpretation maps show the interpreted extention of rock units which are assumed to be most favourable for the occurrence of niobium, apatite and perhaps nefelin-rocks. Proposals for further examinations are also given in the maps.

Figures 6 and 7 present sections of drillholes 13 and 14. Results from geophysical investigations on drillcores, as well as on the surface, are plotted into the sections.

The results from the test investigations in the northern portion of the Fen complex are presented in figures 8, 9 and 10.

Figure 8 presents a magnetic and gamma-ray isomap while figures 9 and 10 present geological/geophysical sections of the northern and southern part of Tuftestollen.

2. GEOPHYSICAL PARAMETERS OF SOME ROCK UNITS

2.1 Magnetic properties of rocks

In connection with the regional magnetic investigations which were carried out in 1980, a rough qualitative evaluation of magnetic properties of rocks was done. Sæther's geological map was compared to the magnetic map.

Referring to the geophysical report 1980 by C.W. Carstens, the results were:

Raughaugite	:	500-700 Gamma
Rødberg	:	600-700 "
Søvite	:	300-500 "
Damtjernite	:	400-500 "
Basic Silicate rocks	:	100-300 "

These results have been further checked. In addition to Sæther's geological map, S.D. Olmore's geological map of the Melteig area and Tuftestollen, have been compared to obtained magnetic results. To eliminate errors from geological interpretations, we have evaluated known bedrock exposures against magnetic results.

The objective of using geophysics is set up as follows:

1) The main objective of the geophysical investigations has been to indicate what rock units and structures are exposed below the overburden. Special attention has been paid to søvite, raudhaugite and melteigite - rock units which are assumed to be favourable for the occurrence of economic mineralizations.

2) Give inputs where to drill to obtain geological information and information of potential economic mineralizations.

3) Give inputs how to follow-up exploration on already known findings.

4) Further tests of the applicability of geophysics.

1.3 Presentation of the results

Figure 1 shows the area in which the investigations were concentrated.

Originally magnetic and gamma-ray results were drawn in the scale 1:1000. However, that scale has been changed to 1:2500 for presentation in this report. By that reduction the resolution has been somewhat reduced, but the original maps are available on special request. Magnetic and radioactive results are presented on the same map sheets.

The follow-up magnetic and gamma-ray investigations results in Tuftehavna and Westhagen area have been compiled with results from previous investigations. Figures 1 and 2 present those results, while figure 3 presents the results from the Melteig area.

On the basis of petrophysical examinations of some rock units we suggest (as a first rule of thumb) that magnetic structures higher than 500 gamma represent a certain potential for søvite, raudhaugite and melteigite. In order to focus on such structures we have drawn the 500 gamma isocontour line thicker than the others.

The magnetic isocontour lines are assumed to reflect variances in geologic structures. Magnetic structures higher than 750 gamma have been symbolised by H-H. Structures between 500 and 750 gamma-ray are symbolized by h-h. Structures below 300 gamma are in the same way symbolized by L-L.

1. INTRODUCTION

1.1 What has been done

The author has spent about 8.5 weeks in the field, of which 5 weeks were used for magnetic and gamma-ray investigations comprising:

a) Follow-up investigation within Tuftehavna area.

b) Detail investigations between Tuftehavna and Westhagen.

c) Detail investigations between Tuftehavna and Melteig area.

d) Test investigation of the northern position of the Fen complex.

e) Investigations of susceptibility and gammaradiation on drillcores.

A grid of 50x10 m has been utilized. The author carried out the field measurements.

G. Kompen Aspro A/S was responsible for the navigations. In difficult terrain a third person assisted in sticking of the lines.

A 3.5 weeks period was spent on VLF-resistivity, spontaneous potential investigations and on supervision of gravimetric investigations. Results from those investigations will be reported by geophysicist Ø. Logn, Aspro A/S.

1.2 Objective

It is assumed that some work remains to be done before the the Fen complex geology is understood well enough to build up a geological model as a good basis for practical exploration work. The reason is lack of information within areas which are not accessible. Further there is a lack of bedrock exposures due to widespread occurrence of overburden.

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Abstract

The results of the research work concerning a roast-leaching process to extract rare earths elements (REE) from rødbergite is opening interesting perspectives.

Even if we so far have not detected any big deposit of niobium the Feco project is more interesting than it has ever been. To explore the possibilities of the Fen complex major parts of the future exploration budgets should be spent on exploration drilling.

Future demand for niobium is expected to be rather good. Phosphate deposits of igneous origin also represent a significant and growing source of supply.