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Mineral Potential of the Fen Alkali complex
Ulefoss, Norway

Forfatter	Dato År	Bedrift (oppdragsgiver og/eller oppdragstaker)
Landreth	Februar 1979	Forskningsgruppen for sjeldne jordartselementer

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ammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Rapporten er meget fyldig sammenfatning av geologiske undersøkelser som er utført i Fensfeltet. Rapporten inneholder geologisk beskrivelse, geofysiske undersøkelser som grvimetrisk undersøkelse, magnetsk og radiometriske undersøkelser, økonomisk geologi med analyseresultater både fra prøver i området og fra diamantboringer.

Minerals Exploration Company

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Braaten

UNION
MINERALS

H. Eakland, Jr.

February 23, 1979 received March 5, 79
03

Mr. Orvar Braaten
General Manager
Metal Extractor Group of Norway
P. O. Box 5430
Oslo 3, Norway

Dear Orvar:

Enclosed is John Landreth's summary report on the Fen District and his recommendations for the work to be done during the coming field season. I have not yet had time to read in detail but John gave a verbal presentation of the report yesterday. I think he has done a thorough job of evaluating the present state of knowledge on the Fen area. I hope you and your staff will have a chance to review it before the meetings in Oslo.

I am still planning to arrive in Oslo on March 4 and to meet with you March 8 and 9 to discuss the operating agreement. I will be accompanied by Mr. Robert Humphrey of Union Oil Company's Los Angeles Legal staff, and Malcolm Groom, whom you met on our previous visit.

With best regards,

Ed Eakland

EHE:mn
Enclosure

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MINERAL POTENTIAL
OF THE
FEN ALKALINE COMPLEX
ULEFOSS, NORWAY

BY J.O. LANDRETH

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February, 1979

MINERALS EXPLORATION COMPANY

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SUMMARY AND CONCLUSIONS

A mineral evaluation was made of the Fen alkaline complex, near Ulefoss, Norway, by John O. Landreth. A joint venture exploration program between Union Minerals and a consortium of Norwegian companies is being considered for a complete mineral evaluation of the complex. A trip was made to Norway in late 1978 to review and collect data from all available sources, including published and unpublished company information about the many varied resources within the Fen complex. Several personal interviews were held with people having first-hand knowledge of the mining and/or geology of the area. This evaluation is based solely on data collected and presented to the writer as no field investigation was made. The Fen complex was visited for part of one day but the area was covered by snow.

The Fen alkaline complex consists of an oval-shaped structure, 2.3 km by 3.0km, where alkaline rocks and solutions have been intruded forming fenite, basic silicate rocks, and carbonatites. The complex is enriched in several elements and minerals of economic interest, including: columbium, iron, nepheline, phosphate, rare earths, scandium, thorium, vanadium, and yttrium. Of these, rare earths, columbium, and apatite have potential for economic concentrations while vanadium and yttrium may be byproducts of columbium and rare earth production, respectively. Little is known about the distribution of nepheline in the complex but it may be an economic resource. Thorium is considered a resource of the future.

The complex has a history of mining for columbium, apatite, magnetite, and calcite, and research investigations for rare earths, yttrium and thorium. This data will need to be reviewed and compiled. All of the potentially interesting elements and minerals are restricted to geologic units and it is imperative that these units be geologically mapped in detail. This is hampered by the fact that over 60% of the complex is covered by glacial overburden. Therefore, a detailed interpretation of existing magnetic and gravity data is required. + laumalite? cfr. p.11→13

Existing core should be relogged paying particular attention to the petrology, mineral assemblage, and structures in areas of mineral enrichment. Assay data from all samples should be evaluated and check assaying should be considered for data confidence. There is virtually no information about the complex below 150m. Drilling will be required after existing data is fully evaluated.

INTRODUCTION

During the period November 27 through December 14, 1978, Geyza I. Lorinczi and John O. Landreth visited Norway to examine data on certain Norwegian mineral occurrences submitted to Union Minerals by A/S MEGON and Aktieselskabet Sydvaranger as possible joint venture properties.

Lorinczi is reporting separately on his area of investigation in a report entitled "Review of the exploration program conducted by A/S Sydvaranger in the Karasjok area of Finnmark, Norway".

The evaluation by Landreth is concerned with the mineral potential of the Fen alkaline complex at Ulefoss, Norway. The Fen complex has a rather interesting mining history which includes nearly 300 years of iron mining, a short period (1952-1965) when niobium, apatite, calcite and magnetite was mined and potential for further mining of these ores as well as for nepheline, rare earth minerals and thorium. All of these occurrences lie within an oval-shaped structure about 2.3km by 3.0km.

The initial contact about the Fen complex was made with MEGON (Metal Extractor Group), a consortium of companies producing high-grade yttrium oxide from xenotime concentrates purchased from Malaysia. MEGON had been formed from various companies participating in a rare earth research group, Forskningsgruppe for Sjeldne Jordarter (FSJ). The FSJ, during its investigations of rare earth properties in Norway had obtained premining concessions on part of the Fen complex, and carried out a moderate investigation of the rare earths by drilling and with mineralogic studies.

As premining concessions in the area are controlled by the FSJ (<u>not</u> MEGON) and S. D. Cappelen, a meeting was held in December 1978 consisting of the FSJ membership to decide what companies would participate in a possible joint venture with Union Minerals. A tenative agreement was reached whereby the following four companies would participate in the joint venture:

A/S Sydvaranger
Elkem - Spigerverket
A/S Årdal og Sunndal Verk
S. D. Cappelen

Personnel from three companies MEGON, Sydvaranger, and Elkem-Spigerverket provided assistance in data collection for the evaluation. In addition conferences were held with personnel in the mining commissioner's office (Østlandske-Bergmester-Embede) and the Norwegian Geological Survey, Norges Geologiske Undersøkelse (NGU). About two hours was spent at the Fen complex to see the "lay of the land" but no geological work was done as the area was snow covered.

LOCATION AND ACCESS

The Fen alkaline complex lies about 110km southwest of Oslo at the town of Ulefoss, in Telemark County, Norway (Figure 1). The complex is bordered on the north by lake Norsjø that provides a connection with the sea by a river system of locks which can take ships up to 200 - 300 tons. The distance by water to the port of Skien is about 24 km.

MINERAL OWNERSHIP AND CONCESSIONS

All mineral rights to the land in the Ulefoss area are vested with the Norwegian government. The Fen alkaline complex is roughly 40 per cent covered by premining mineral concessions (Figure 2). The two claim holders are: S. D. Cappelen - 5 concessions (1,265,000m^2) and Forskningsgruppe for Sjeldne Jordarter (FSJ) - 4 concessions (1,075,000m^2). The 1974 mining law allows a Norwegian citizen or company to hold premining mineral concessions for a period of seven years with a possible extension of three years before mining production plans are submitted to the government. The above concessions were obtained in 1974 and are due to expire in 1981.

In discussions with the MEGON group, it was pointed out that Union Mineral's possible future interest would be to evaluate the entire Fen alkaline complex, not just a part of it. They agreed that additional concessions could easily be obtained and should be immediately obtained by someone in the newly formed rare earth group, probably in the name of S. D. Cappelen. It would be necessary to obtain approximately 12 additional 300,000m^2 concessions to cover the remainder of the complex. Apparently there is no annual work commitment for the premining concessions, only a nominal tax.

While at the Bergmester's office in Oslo, the official mineral records were checked and no adverse claimants were found in the area. However, until 1974 a different mining law was in effect. That law required a point of discovery, either above ground or underground. Apparently extralateral rights did apply on those claims. Although claimants were required to obtain the new mineral concessions in 1974, no one was quite sure what grandfather rights might apply. Therefore, the old mining records were also checked. About 60 old claims were found in the Fen alkaline complex, ranging in time from 1902-1969. These claims are completely covered by the 1974 concessions. Happily the old claims were in the names of S. D. Cappelen (about 20) and Norske Bergverk (about 40). Norsk Bergverk, a government company, is said to have turned back its claims following the closure of the niobium mines.

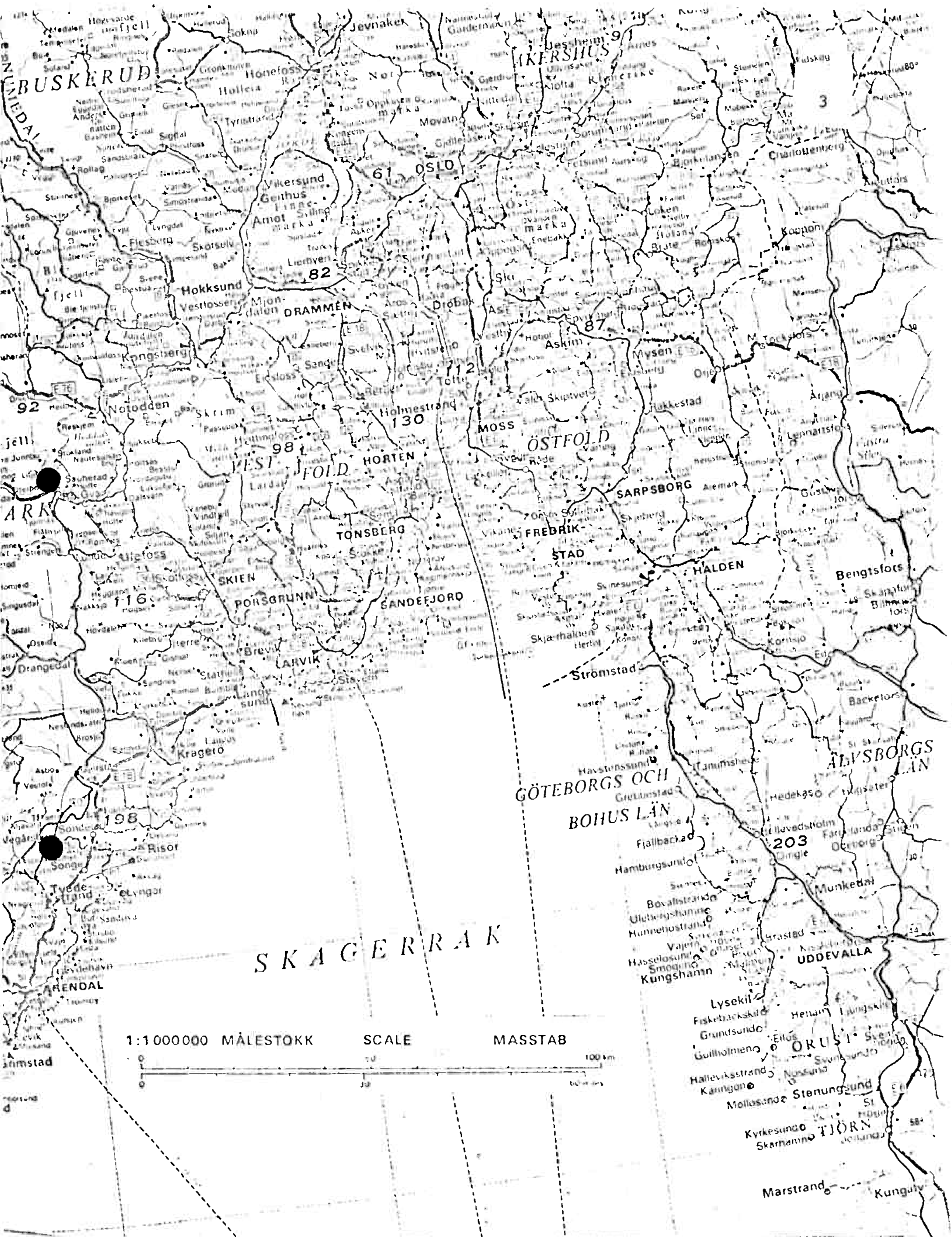

Figure 1. Location map of Fen Alkaline Complex, Ulefoss, Norway.

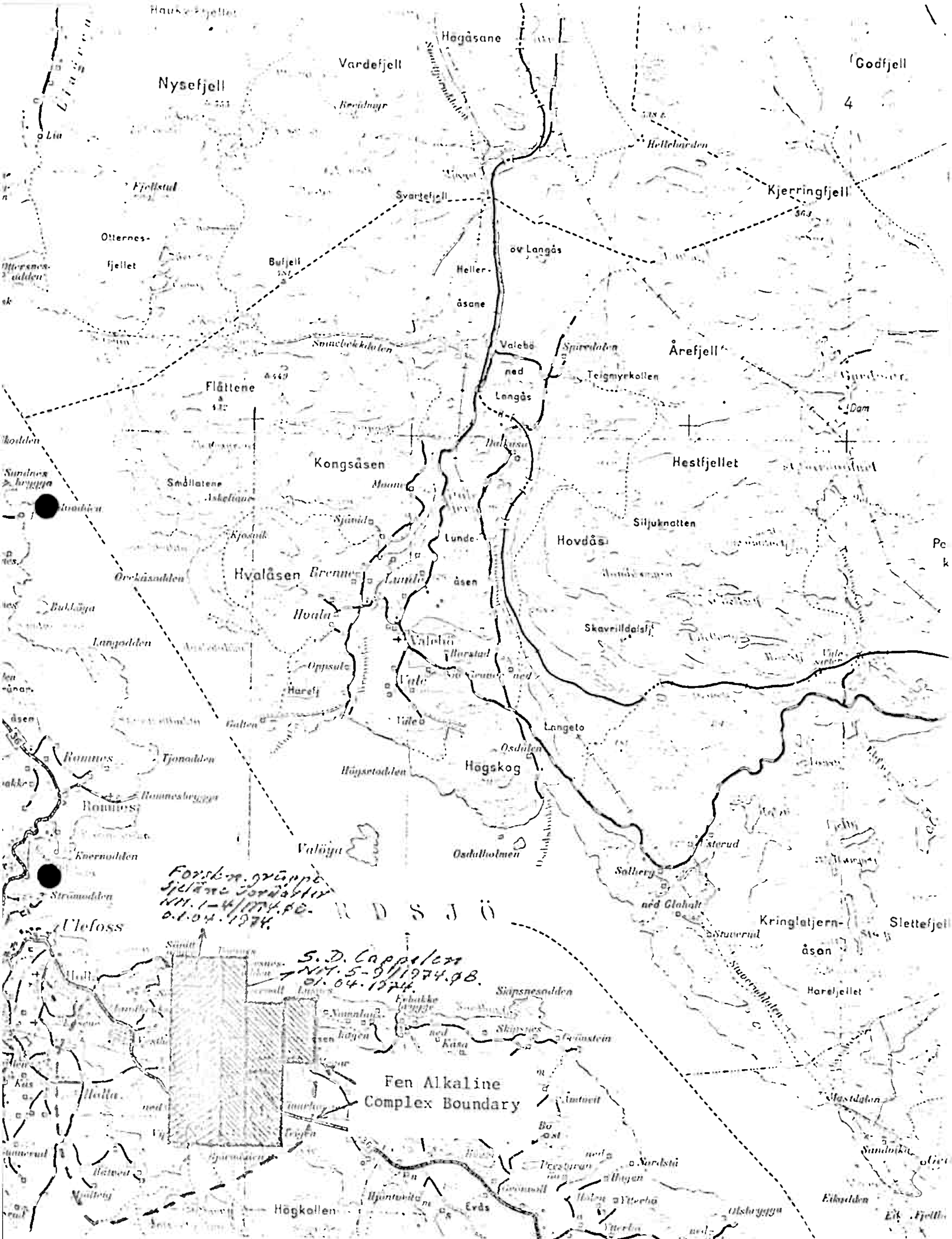

Figure 2. Property map of Fen Alkaline Complex, Ulefoss, Norway.

GEOGRAPHY

The topography of the Fen area consists of rolling hills of moderate relief (±160m). Most of the area is covered by glacial clay and gravels which have been cultivated and used for farming purposes. The town of Ulefoss is expanding and subdivisions are being developed within the complex. The infra-red photo (Figure 3) displays the cultural development of the Fen complex. Areas where the land is intensily utilized will be difficult for certain types of exploration and mining activity. Agricultural land is at a premium in Norway and could present additional problems.

PREVIOUS INVESTIGATIONS

The general geology and petrography of the Fen alkaline complex has been well documented by the classic works of Brøgger (1921) who promoted the idea of carbonatites being derived from a magmatic origin and by Saether (1957). Other works on the general geology of the Fen include Bergstøl and Svinndal (1960), Barth and Ramberg (1966) and Heinrich (1966). The petrography of the columbium occurrences was studied and discussed by Aubert (1947), Adamson (1950) and Bjorlykke (1952, 1952a, 1953). Griffin and Taylor (1975) studied the petrology of the damtjernite and Jennings and Mitchell (1969) investigated the temperature of intrusion at Fen. Mineralogical studies were conducted on the rare earth bearing rocks by Hazen Research, Inc. (1971) and by Semb (1972). Geophysical investigations include a magnetic survey conducted by Geofysisk Malmleting in 1948-1949 (Plate 2) and a gravity survey by Ramberg (1973). Geochemical studies include investigations on scandium by Mitchell and Brunfelt (1974), Åmli (1977) and on rare earth, cobalt, and iron by Mitchell and Brunfelt (1974, 1975). In addition, the Germans did considerable research work on the columbium occurrences in the complex during World War II. A/S Norsk Bergverk, prior to and during mining of the columbium ore was responsible for the significant development and exploration work in the Fen complex. During the late 1960's and early 1970's the FSJ initiated the exploration and mineralogical studies in the rare earths area. These works are largely documented in Svinndal's (1967, 1968, 1970) reports. In 1973 Svinndal documented work done on thorium in the area.

It should be noted that all of the references in this report are in the possession of the writer with the exception of Brøgger's (1921) report. These will be made available upon request.

AVAILABILITY OF SAMPLES AND DATA

While in Norway, the writer attempted to inventory the existance and availability of samples and information from the Fen complex. All reports, correspondance, and maps dealing with the mining of columbium by Norsk Bergverk are stored in the Østlandske Bergmester-Embede Office

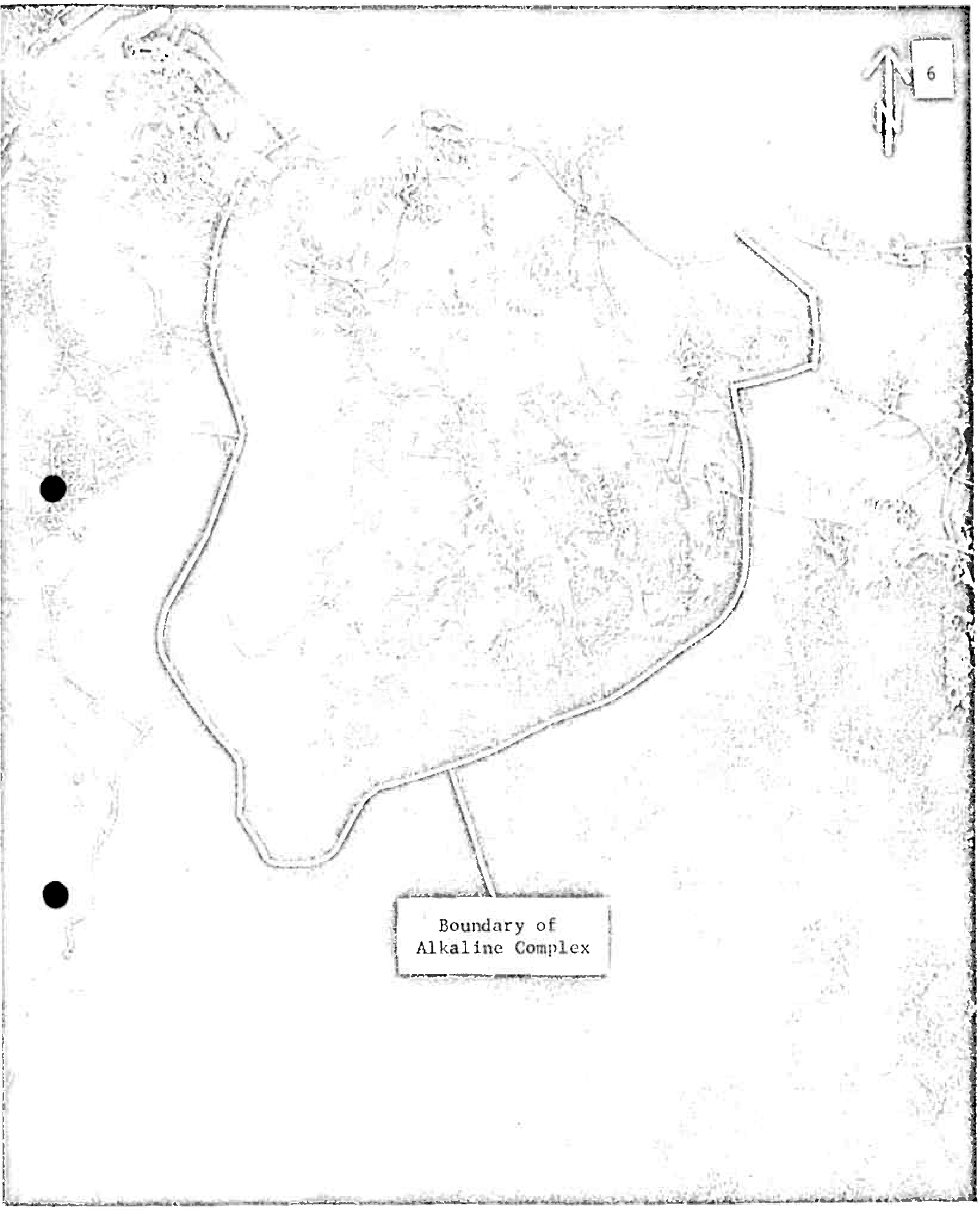

Figure 3. Cultural map of Fen Alkaline Complex, Ulefoss, Norway.

in Oslo and are available for inspection. This includes assays, drill logs, mine plans and sections. All reports dealing with rare earth research in the Fen complex are available for inspection at the MEGON office in Oslo. This data includes assay data, mineralogical studies, and work on beneficiation. Reports by the NGU on rare earths and thorium are available at A/S Sydvaranger's Lysaker office in Oslo, as well as data on columbium from the Fen complex.

All of the available cores and other samples are stored at the NGU in Trondheim. Apparently there was originally about 35,000 meters of drill core associated with A/S Norsk Bergverk's mining of columbium, however, much of it was discarded after the closing of the mine. Svinndal was able to retrive some of it though and about 4-5000m of that core is randomly stored in a warehouse at the NGU. It was established that most of the cores from the rare earth area, the Tufte area and the Capplen deposit are intact. Representative samples from splits of the cores and surface rock samples are stored at the NGU chemical laboratory. All of these samples are available for further testing.

ACKNOWLEDGEMENTS

Several people were very helpful in making data available for inspection and arranging conferences with persons knowledgeable about the geology and mining in the Fen complex. Of particular note were Messers Orvar Braaten, Roar Jensen, and Thor Sverdrup of the companies MEGON, Elkem-Spigerverket, and Sydvaranger respectively. Particular acknowledgement is made to S. Bergstøl, Prof. J.A.W. Bugge, T. Johnsen, and S. Svinndal for sharing their first-hand knowledge of the Fen geology and mining with the writer. Grateful acknowledgement is made to I. Ålstad for making the Geofysisk Malmleting magnetic map available. Special acknowledgement is made to K. Mørk and J. Wanvik who spent many hours assisting the writer with translations, interpretation of geological data and acquiring reports, maps and photos of the Fen area.

GEOLOGY

The following geological description of the Fen alkaline complex relies heavily on Saether's (1957) report. Plate I shows the geology on a base map prepared by Svinndal (1968) which has been modified to include more geologic detail as described by Saether (1957). It is fortunate that Saether so thoroughly documented Brøgger's (1921) work as the later was written in Norwegian.

The Fen alkaline complex is considered as the "type locality" of carbonatites as it was here that Brøgger first recognized that carbonatites could be of magnetic origin. Brøgger throughly described the associated alkaline rocks naming them after small farms and other localities either within or near the Fen alkaline complex. ? magmatic?

PRECAMBRIAN COUNTRY ROCKS

The country rock in the Fen area is predominently composed of medium-grained gneissic granite with interbedded units of mica schist, amphibolite and mica-rich gneiss. The rock has a strong foliation marked by a parallel orientation of biotite which uniformly strikes NE - NNE and dips 70-90°SE.

Near the boundaries of the alkaline complex the gneisses have been strongly brecciated. In this "thermal shock zone", the breccia has been locally fenitized.

FENITE AND FENITIZATION

The Fen area is the type locality for fenite and fenitization. It was first recognized by Brøgger (1921) as an alkali metasomatism of the country rocks. During this process Na_2O, K_2O, Al_2O_3, CaO, CO_2, and small quantities of BaO, P_2O_5 and other minor constituents were added to the country rocks while SiO_2 was being removed. The process is called fenitization and when it is complete the resulting rock is called a fenite.

At Fen, fenitization is found peripheral to the complex in the granite gneiss and the "shock zone" gneissic breccia. The effects of fenitization extend up to a few hundreds of meters out into the country rock. As one moves from the unaltered country rock into the alkaline complex, aegirine and sodic amphibole formed at the expense of biotite and amphibole, potash feldspars were changed to microperthite, oligoclase became albite and calcite, and quartz and plagioclase formed alkali feldspars with excess SiO_2 being totally removed. The complete fenitization process resulted in an alkali syenite consisting of microperthite and aegirine with minor amounts (usually $<1\%$) of soda amphibole, apatite, titanite, zircon, pyrite and magnetite. Calcite can occur in amounts up to several percent. The resulting rock is massive and has removed all evidence of foliation.

A thin band (100-400m) of fenite rock is found surrounding the complex (see Plate 1) except on the east, where faulting has placed carbonatized basic alkaline rocks against the gneissic granite rocks.

IJOLITE-MELTEIGITE-URTITE-VIPETOITE AND OTHER BASIC SILICATE ROCKS

Along the border zones between fenite and the carbonate rocks are a series of basic silicate rocks. In the southern and southwestern part of the complex, the rocks belong to the ijolite-melteigite-urtite series. These rocks have the same mineral composition, mainly aegirine-augite and nepheline in varying amounts with small quantities of apatite, calcite, titanite, melanite, koppite and columbite. The content of nepheline determines the rock name in this series: urtite - 70-90% nepheline, ijolite - about 50% nepheline, and melteigite - up to 30% nepheline. Ijolite and melteigite are the dominant alkaline rocks which are cut by small pegmatitic urtite dikes in an area southwest of Melteig.

Vipetoite is exposed in the south-central part of the complex. The coarse-grained rock consists of pyroxene, amphibole, biotite and minor amounts of calcite, apatite, magnetite and pyrite. The vipetoite is strongly carbonatized and appears to be a roof pendant in søvite and rauhaugite type I rocks.

Other basic silicate rocks are found along the western and northern borders of the complex but are strongly carbonatized transitional rocks largely transformed into biotite-calcite and feldspar-biotite-calcite rocks.

SØVITE

Closely associated with the foidal rocks are the søvitic melteigite and pyroxine søvite. These rocks are not only spacially associated with the basic silicate rocks but carry a similar mineral assemblage - only the content of calcite has varied.

The main søvite body lies in the west-central part of the complex near the Tufte farm. The body is made up of a number of arcuate dike-like bodies (cone sheets) that are intimately mixed with alkaline rocks on the west and dolomitic and ankeritic rocks near the center of the complex. The søvites dip steeply toward the center of the complex and are primarily calcite with 5-10% apatite, small amounts of magnetite, biotite, pyrite, pyroxene and other dark minerals including the columbium minerals koppite and columbite. Although the average content of mined søvite in the Tufte area was 0.25% Cb_2O_5, values over 1.0% Cb_2O_5 have been reported.

Other søvites, which the writer believes may be transgressive dikes similar to those found at Palabora in South Africa, are found near the northern and southern borders of the complex. These dikes have a different mineralogical distribution but some are enriched in columbium minerals, viz. Cappelen dike and Hydro dike. These dikes are not arcuate but cut the fenite in E-W and NE-SW directions respectively. Little is known about the søvites south of the complex border near Damtjern.

RAUHAUGITE TYPE I

Intimately associated with the søvite in the center of the complex is an ankeritic rock (beforesite) called rauhaugite type I by Saether (1957). This rock also has formed cone sheets alternating with the søvite in the Tufte area. The rock consists mainly of ankerite and varying amounts of calcite, 0-25%; apatite, 2-10% and accessory microcline, albite, quartz, barite, magnetite, pyrite, biotite, chlorite, hematite, fluorite and columbite. In the Tufte area the rauhaugite was the main columbium ore rock. It generally contained 0.3-0.5% Cb_2O_5 and about 3-5% P_2O_5.

DAMTJERNITE

According to Saether (1957), the intrusion of damtjernitic rocks began the second cycle of alkaline intrusions. These rocks are found only in the eastern half of the complex. In the central part of the complex only altered xenoliths and roof pendants seem to remain whereas dikes and pipe-like bodies are found near the complex borders and outside of the complex as far away as 50km.

The damtjernite rocks consist of biotite, amphibolite, pyroxene, and olivine in a matrix of the same minerals with additional nepheline, microcline, albite, and calcite. Some diatremes and breccias are filled with damtjernitic material and by xenoliths of gneiss, fenite, rocks of the ijolite-melteigite series, søvite and rauhaugite type I. Søvite fragments were never found in damjternite breccias outside of the complex (Bergstøl, personal communication).

Saether (1957) referred to the rocks as kimberlites as did many other writers, however, Griffin and Taylor (1975) say that the damtjernite rocks bear no chemical similarity to kimberlites but are similar in chemical composition to alnöites.

Saether (1957) and later Ramberg (1973) feel that much of the damtjernite has been affected sufficiently with widespread carbonatization that locally it has been converted to carbonatite - both rauhaugite type II and rødberg.

RAUHAUGITE TYPE II

Saether's rauhaugite type II forms a large irregular mass of ankeritic carbonatite in the eastern half of the Fen complex. The rock is similar to rauhaugite type I but type II contains about twice as much Mn and Fe, and there is no visible flow structure. It is within this unit that rare earth values are found to be anomalously high but the columbium content is much lower than in rauhaugite type I. As roof pendants of damtjernite are found to have gradational contacts with the rauhaugite type II rocks, Saether (1957) believes the carbonatite has been formed by metasomatism of the damtjernite.

RØDBERG

This carbonatite rock unit is located on the eastern margin of the complex. It is mostly calcitic in composition and receives it's name "red rock" from finely dispersed hematite as poikilitic inclusions in the carbonate crystals, as well as between grains. Locally the hematite is concentrated along NW-SE striking fissures sufficiently to have been exploited as iron ore. In addition to calcite and hematite, the rock contains minor ankerite, chlorite, barite, quartz, albite, brucite, pyrite, biotite, and magnetite. Bodies of damtjernite are also found within rødberg and are carbonatized grading into the hematitic carbonatite.

This unit is anomalously high in rare earths and thorium, largely due to the monazite content of the rock.

EVENTS YOUNGER THAN THE RØDBERG

Small veins of chlorite-rich material cut the rødberg and hematite orebodies in the eastern part of the complex. They have been called "latten dikes" by the miners of the area but they do not appear to have any relationship to the alkaline rocks.

Several diabase dikes are found throughout the complex. These rocks cut through all of the complex rocks but according to Brøgger (1921) and Saether (1957), they are associated with the igneous rocks of the Oslo region and have no association with the alkaline rocks of the complex.

Faulting has been treated by Saether (1957) but except locally, little is known about the extent of adjustment, that normally occurs in alkaline complexes, because of the amount of glacial cover. Perhaps a detailed evaluation of the magnetics will shed some light on the structure of the area.

GEOPHYSICS

At least four types of geophysics have been utilized in the Fen area. These include regional and detailed gravity measurements, airborne and ground magnetics, a resistivity survey, and ground and bore hole radiometrics.

GRAVITY SURVEYS

Ramberg (1973) made a rather complete regional gravity survey of the Fen region and a more detailed study of the complex itself. The regional study showed a sharp and almost circular gravity high above the Fen complex. After removing the regional field a residual anomaly map of the Fen area was constructed (Figure 4). Note the nearly circular gravity high that is coincidental with the Fen complex; also that the complex appears to be bordered on the northeast by lake Norsjø. As some of the søvite dikes cutting the fenite in that area extend under the lake, it was of concern that more of the complex might occur under the lake. This would appear to be minimal. Ramberg's detailed work was directed at modeling the complex at depth and provides thought provoking theories of petrogenesis.

MAGNETIC SURVEYS

The NGU has compiled aeromagnetic data for most of the country. Figure 5 shows the aeromagnetics of the Fen region. Only three flight lines crossed the complex but the magnetic anomaly (high) is quite pronounced.

In 1948-1949, Geofysisk Malmleting conducted a ground magnetic survey over the Fen alkaline complex and the surrounding region to extend geologic mapping into areas covered by overburden. Saether (1957) utilized this data and shows a generalized magnetic map in his report. A copy of the original magnetic map was obtained from the NGU (see Plate 2). This writer has colored selected intervals to enhance various levels of magnetism. The original survey was conducted on a 25m X 100m grid over most of the complex measuring the vertical magnetic intensity. Saether (1957) briefly treats the relationship between the geology and magnetism. The Eocambrian gneisses and the fenite are magnetically low compared to the other alkaline rocks of the complex. The low on the northern border of the complex, along lake Norsjø indicates a closure of the complex supporting the gravity data. The data was reviewed by and discussed with R. Ellis (MINEX), and although a part of the map was not contoured, the information and contrast seem to be adequate. It appears that little would be gained from another magnetic survey and would be difficult because of the works of man in the area (Figure 3). However, Ellis expressed a desire to obtain the raw data for review. Magnetic susceptibility measurements should be made in the field at Fen and on the drill core for a better interpretation of the geology and for modeling purposes.

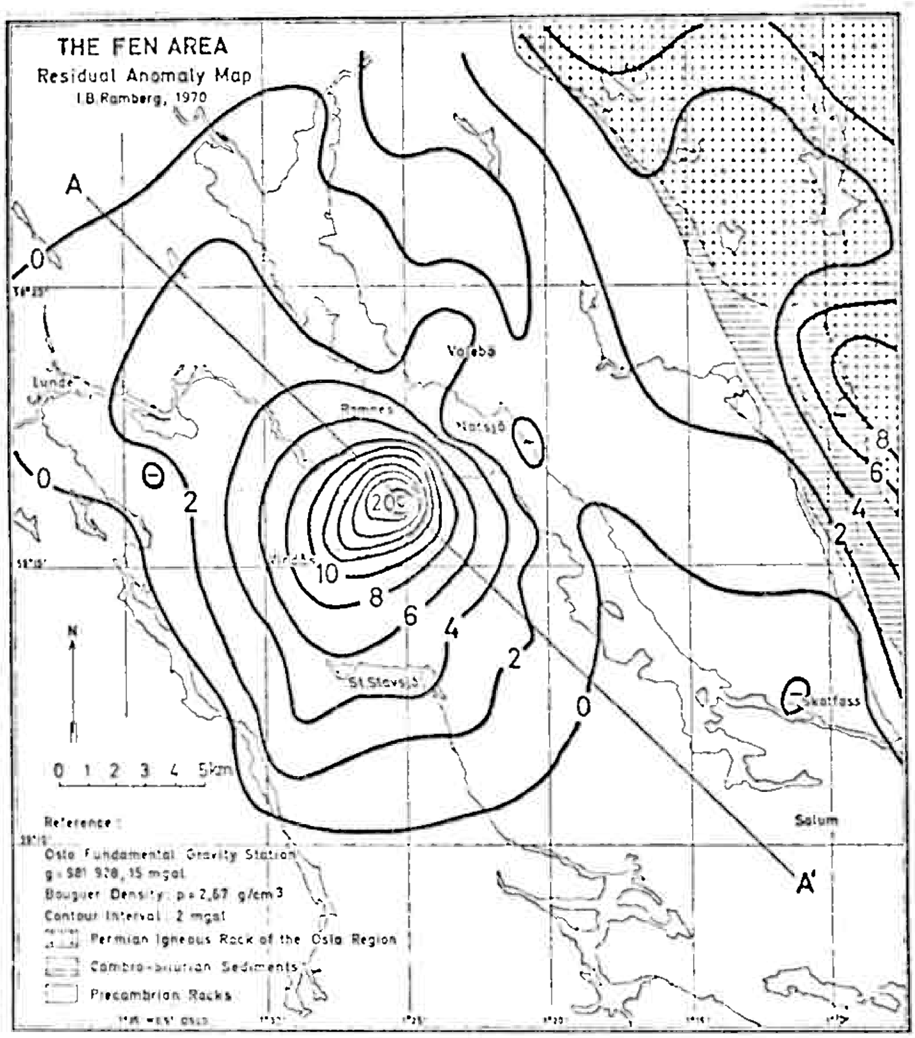

Figure 4. Residual Anomaly Map of the Fen Area and Surroundings (Ramberg, 1973)

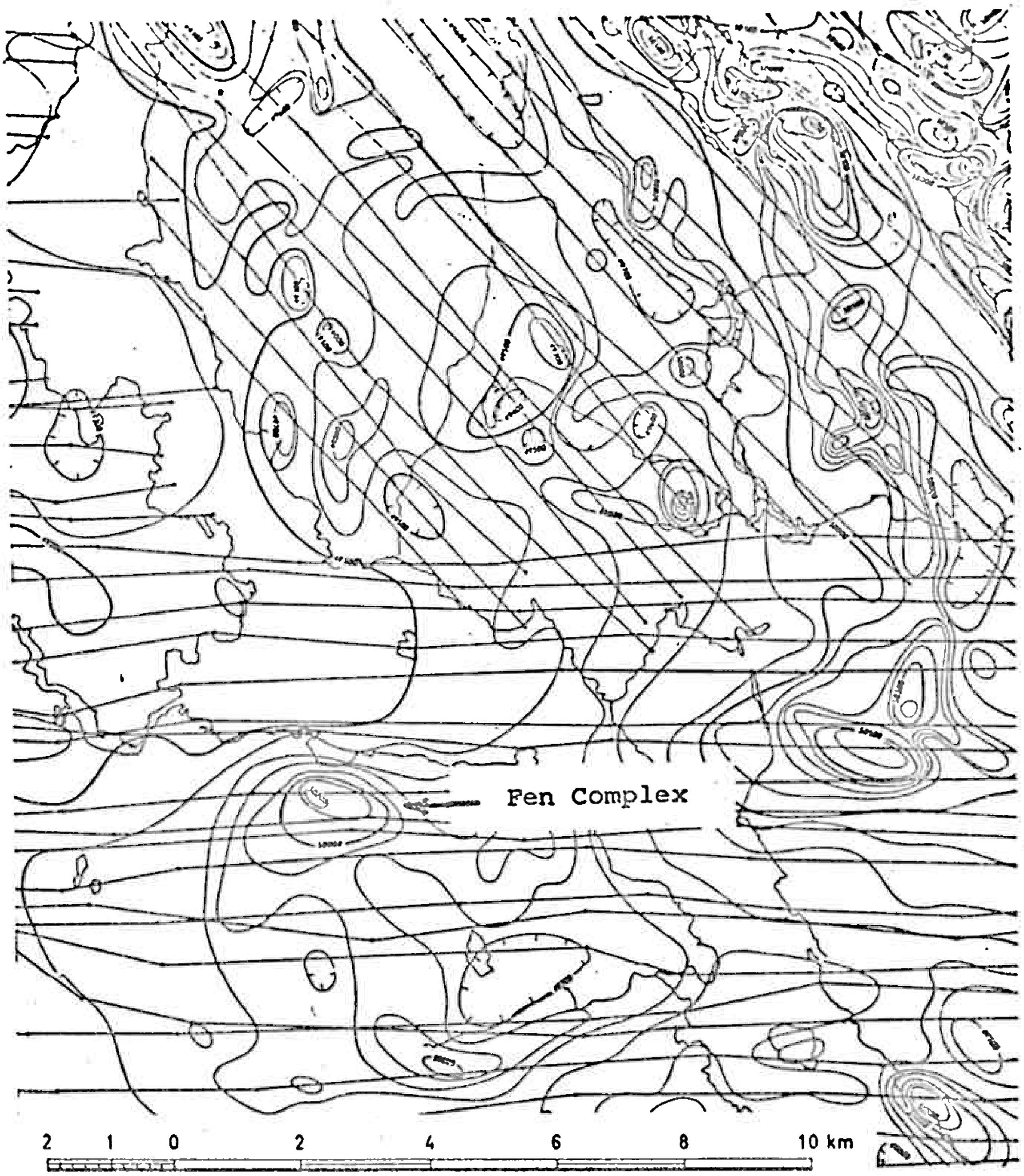

Figure 5. Aeromagnetic Map of the Fen Area, Norway. (NGU April 1968)

RESISTIVITY SURVEY

A resistivity survey was conducted for A/S Norsk Bergverk to determine the depth of overburden in the Tufte area. The clay and gravel cover were usually 2-10m deep but in the NW part of the Tufte area the overburden reached depths of 20-30m.

RADIOMETRIC SURVEYS

Svinndal (1970) shows that both bore holes B-1 and B-2 were logged radiometrically. The holes were drilled in rødberg and rauhaugite type II in the Bolladal/en area. The radiometric data was very erratic but showed values two to three times background. That report also showed autoradiographs (gamma-ray scans) of rødberg core indicating that the radioactive mineral monazite was not disseminated in the rock but found concentrated in fractures and blebs.

In 1968 a small radiometric survey was conducted in the Rauhaug area. Svinndal's 1973 report shows an area about 100m in diameter, about where the word Rauhaug appears on the geologic map (Plate 1), containing greater than 1000ppm Th. The anomalous area is in rauhaugite type II rock adjacent to the rødberg and is probably due to the presence of monazite.

The writer would not recommend any further ground radiometric surveys in the complex as more than 60% of the area is covered with transported overburden material.

ECONOMIC GEOLOGY

The following elements and minerals have been produced from the Fen complex or have been considered to be in sufficient quantities to be considered a future resource.

COLUMBIUM

The rocks of the Fen complex are geochemically enriched in columbium in amounts ranging from 0.05-0.3% Cb_2O_5. Columbium minerals were first recognized in 1918 near the shore of lake Norsjø and considerable mineralogical work has been carried out on the columbium minerals of the area. The main occurrences of columbium are in the northern part of the complex near lake Norsjø where NE-SW and E-W søvite bodies, enriched in columbium, cut through fenite rock. The two main occurrences in this area are the Hydro and Cappelen deposits. Numerous smaller dikes of a similar nature are also found in the area. The other main occurrence is near the Tufte farm near the center of the complex.

The northern dike-like bodies are very similar in nature. They contain the minerals koppite and columbite in nearly equal amounts. These columbium bearing søvite dikes contain the highest grade ore near their margins and when the dikes widen more than 30m, the cores of the søvite dikes are nearly barren.

In the Tufte area the mineralogy is different and nearly all of the columbium is contained in columbite. The ore rocks in this area are alternating bands of søvite and dolomitic rauhaugite type I.

Norsk Bergverk began mining columbium in the Fen complex in 1952 producing 130,000t of ore per year - 100,000t from the Cappelen and 30,000t from the Tufte deposits. The columbium concentrates were sold to the American government, byproduct phosphate from apatite was sold to Norsk Hydro for fertilizer, byproduct magnetite was sold to Poland, and residual calcite was sold for agricultural purposes. Mining was terminated in 1965 when the American government contract expired. The operation was unable to compete with the rich columbium ores from Araxá, Brazil.

The three main columbium deposits of Fen are treated individually below:

Cappelen Deposit. The Cappelen occurrence is an irregular søvite dike that trends E-W and dips about 60°S. The dike, located on the lakeshore in the northern part of the complex, was faulted down on the east. The faulted extension was picked up again underground and was called the "New Cappelen Dike". The body was mined for a short distance under lake Norsjø but was terminated due to a weakening of grade as the dike widened.

The Cappelen søvite consists of about 80% coarse-grained (2-4mm) anhedral calcite, 3-7% medium-grained (1-2mm) euhedral but corroded prisms of apatite, 3% magnetite, 1% pyrite, 0.7% koppite and columbite, and small amounts of amphibole, mica, barite, topaz, corundum, zircon, and rutile. The magnetite and koppite occur as crystals up to 5mm across. There is no megascopic flow texture.

During the period 1952-1965 approximately 1,000,000t of ore was mined from the Cappelen deposit at an average grade of 0.34% Cb_2O_5. The columbium minerals are koppite and columbite, in about equal amounts, and like the Hydro deposit when the søvite dike widens more than 30m the central part of the dike becomes nearly barren.

According to the former Norsk Bergverk mine manager at Fen, T. Johnsen, (personal communication) about 1 million tons of 0.3 - 0.4% Cb_2O_5 ore remains.

The Cappelen deposit is structurally complex and a detailed review of the mine records and detailed study of the core is necessary to further evaluate this area.

Hydro Deposit. This occurrence consists of a tabular igneous intrusion of søvite cutting through fenite rock. The body is located on the north edge of the Fen complex where it strikes about N55°E and dips from 50-75° to the southeast. This dike-like body is exposed on the surface from lake Norsjø in a southwesterly direction for about 550 meters where it peters out. The dike also undoubtedly extends under the lake. It has been explored by 15 surface trenches and more than 25 diamond drill holes. The width of the søvite dike averages 25.5m at the surface but widens with depth so that at 50m below the surface the dike has widened about 35%. This marked increase of ore width, with depth, forms a basis for assuming that the orebody should continue to a considerable depth. Two vertical drill holes did penetrate the søvite at depths of 235m and 280m below the surface. In addition the core samples are generally a little richer than surface samples.

The søvite dike is fairly homogeneous and consists of about 90% medium-grained (0.5-1.0mm) anhedral calcite, 5% euhedral apatite, and minor amounts of euhedral magnetite, biotite, pyrite, pyroxene, and other dark minerals including koppite and columbite. The koppite and columbite appear to be in equal amounts with crystal sizes up to 5mm. Streaks of non-carbonate minerals impart a weak flow texture to the rock.

In the Hydro deposit, columbium minerals are enriched in the outer portion of the body. When the dike is more than 30m wide the core is nearly pure carbonate.

In 1952 Bjorlykke reported measured reserves of about 1,000,000t at 0.177% Cb_2O_5. However, indicated reserves to about 100m below the surface were given at nearly 2 million tons and inferred reserves at 5 million tons.

Only a minor amount of rock was mined from the Hydro quarry and from the Tufte adit (Tuftestollen) when it passed through this søvite dike. The body was too low-grade to be mined economically at the time.

Tufte Deposit. The Tufte occurrence lies near the center of the complex. The deposit consists of interlayered bands of søvite and rauhaugite type I rocks. These bands lie in a north-south direction, dip steeply to the east, and are bordered by rocks of a similar composition except with less columbium. The Tufte deposit is exposed by 6 trenches and many surface and subsurface drill holes. Two veins (bands) were mined in the area - Tufte I vein and Tufte II vein. The Tufte I vein strikes about N15°W, dips nearly vertical and is about 15m wide. A second parallel vein, Tufte II vein, lying east of the Tufte I is 10m wide. Both veins are petrographically the same and have the same columbium content. East-west drilling show continuous alternating bands of søvite and dolomite in a ratio of about 1 to 3.

The rock types at the Tufte deposit are søvite, a biotite-calcite rock or chlorite-calcite rock called "greenstone", and rauhaugite type I. These rocks form an intimate intermixture forming a "schlieren". In some places large, fairly homogeneous masses of søvite have formed, in other places similar masses of rauhaugite type I have formed. The rauhaugite type I contains the highest columbium content in the area, ranging from 0.3 - 1.0% Cb_2O_5. The søvite and "greenstone" generally have a content less than 0.1% Cb_2O_5, except for the large homogeneous mass of søvite in the Tufte quarry that contains up to 1.0% Cb_2O_5. Although zones 10-30m wide have formed in the rauhaugite type I containing up to 1.1% Cb_2O_5, it is difficult to mine them without considerable contamination from surrounding rocks of lower grade. The higher grades seem to be in N-S brecciated zones.

During Norsk Bergverk's 1952-1965 columbium mining, about 300,000t of ore was mined from the Tufte area by room and pillar methods. The ore was hauled about 900m along a horizontal adit (Tuftestollen) north to a road along lake Norsjø near the Cappelen deposit where it was processed. While driving this adit, a 1-2m radioactive zone was encountered, in the area of Ts-7, containing the mineral ellsworthite. This is the only area reported to contain uranium in the complex. Bjorlykke (1952) reported that scheelite had been detected in some of the ore samples from the Tufte deposit.

From data reported by Bjorlykke (1953) the probable reserves of this area would be in excess of 4,000,000t at a grade of about 0.25% Cb_2O_5.

Considerable data is available about this deposit and it deserves a detailed study as well as relogging selected drill core before any additional drilling would be recommended in this area.

Columbium Economic Comparison. As a comparison with other columbium producers, the following data is given:

Property	Location	Grade-% Cb_2O_5	Type Mine	Ore Mineral
Araxá	Brazil	3.00	Open Pit	Pyrochlore
Catalão	Brazil	2.00	Open Pit	Pyrochlore
Niobec	Canada	0.72	Underground	Pyrochlore
Oka	Canada	0.45	Underground	Pyrochlore
Fen	Norway	0.30	Underground	Columbite/Koppite

As an estimate of the economic grade required for production, the St. Lawrence Columbium mine at Oka, Quebec, Canada was closed by economic conditions while it was producing ore at a grade of 0.45% Cb_2O_5. On the other hand a relatively new mine (Niobec) at Chicoutimi, Quebec, Canada is profitably producing columbium ores at a grade of 0.72% Cb_2O_5. It appears that one must look for a grade of at least 0.6% Cb_2O_5.

IRON

According to Saether (1957) about one million tons of hematite ore was mined from the northeastern part of the Fen complex during the period 1652-1927. This ore was mainly exploited as raw material for the Ulefoss ironworks. However, the company stopped producing iron from the ore and now imports pig iron to produce castings, largely for coal and wood stoves.

The main underground workings are located near the shore of lake Norsjø at Fensgruvene. The workings followed north-south striking veins and lenses that filled fissures in the rødberg. The hematite zones are from 3-8m wide, discontinuous (rarely over 100m in length), and were mined to a depth of 200m below the surface. Minor quantities of hematite ore were also obtained from pits in the southeastern part of the complex in the Vipeto and Rauhaug areas.

The ores contain about 70% fine-grained hematite, 1-2% MnO and minor amounts of magnetite, pyrite, calcite, chlorite, quartz, apatite, brucite, and thorium and rare earth minerals. It has been reported that the ores contain up to 1.0% REO's and 0.2% thorium. Although its estimated that at least another 1,000,000 tons of hematite ore remains, its doubtful that this material will be mined unless for its rare earth and/or thorium content.

Relative to other carbonatites, the Fen complex rocks are low in magnetite. However, some small magnetite bodies were exploited in the Rauhaug area. The workings are inaccessible but as the ground magnetics show only small anomalies, it appears the deposits have been worked out.

A rather large magnetic anomally (about 0.25km dia.) is found immediately south of Skippervoll. Following the magnetic survey, the area was found to contain lumps and veins (up to a few cm.) of magnetite in rauhaugite. There is a paucity of outcrops in the area but the magnetite is fine-grained and nearly without impurities. Little more is known about the area but the magnetite reserve has been estimated at some hundred thousand tons.

During 1952-65, A/S Norsk Bergverk concentrated magnetite from the columbium ores of the Cappelen and Tufte deposits. As the content of the ores was only 3% magnetite, only about 3000 - 4000 tons was developed annually. This magnetite was shipped to Poland.

NEPHELINE

Little is known about the nepheline potential in the Fen area. However three rock types have been reported by Saether (1957) to have significant quantities of the mineral: urtite, 70-90%; ijolite, 50% and melteigite, 30% nepheline. These rocks form a series intimately related to each other and are mainly located in the Håtvet - Melteig area. Unfortunately, in most of these rocks, the nepheline has been altered to aggregates of albite, muscovite and chlorite. Unaltered melteigite and ijolite, cut with small pegmatite dikes of urtite, are found in the tongue-shaped body lying southwest of Melteig. This area presently offers the only potential for nepheline (see Plate 3).

Even though the area of nepheline bearing rocks is quite limited, further petrographic work should be done in the Melteig area to determine the actual nepheline potential in these rocks. Elkem Spigerverket, which currently mines 30% nepheline-bearing alkaline rock at Stjernøy, has shown an interest in the nepheline potential of the Fen complex.

PHOSPHATE

Production of phosphate rock from the Fen area was begun in 1943. About 2000t of søvite was mined from the Tufte quarry, ground to rock flour, and sold as a fertilizer (Adamson, 1950).

When A/S Norske Bergverk began mining niobium from the complex in 1952, apatite was concentrated as a byproduct, acid treated and sold as phosphate fertilizer. Up to the time the mine closed in 1965, approximately 100,000t of apatite was produced from the niobium ore that averaged 7% apatite.

The following analytical data shows the distribution of apatite in the Fen complex rocks (Saether, 1957):

Rock Type	% Apatite	Rock Type	% Apatite
Fenite	1- 2	Søvite (Hydro deposit)	7
Melteigite	1- 3	Søvite (Cappelen deposit)	7
Ijolite	1- 2	Søvite (Tufte deposit)	10
Vipetoite	7-12	Søvite (general)	1- 7
Damtjernite	2	Pyroxene Søvite	1- 3
Rauhaugite Type I	2-10	Søvitic Melteigite	2
Rauhaugite Type II	2	Gneiss	1
Rødberg	1- 3		

As can readily be seen, within the complex, only the søvites, rauhaugite type I, and vipetoite have sufficient quantities of apatite to have a potential phosphate deposit. The søvites and rauhaugite type I contain apatite prisms ranging from 0.1 - 1.0mm long. At the Tufte deposit the søvite may contain up to 20% apatite and even 60% apatite in certain "schlieren". Although sampling in the vipetoite is limited, some analyses show up to 20% apatite. Another favorable characteristic of vipetoite is that it is a course-grained rock, having prisms of apatite 5-20mm in length.

There is considerable assay data available from the underground workings at the Hydro, Cappelen and Tufte deposits that should be compiled and correlated with a detailed study of drill core.

As a comparison to a known operating phosphate mine, unweathered carbonatite containing an average of only 5% P_2O_5 (12% apatite) is currently being mined from the Jacupiranga mine near Saõ Paulo, Brazil. The apatite is concentrated by flotation to yield 36% P_2O_5.

It is anticipated that world-wide consumption of phosphate will increase 3½ times by the year 2000, and coupled with advanced beneficiation, lower grades of phosphate rock will be mined.

RARE EARTHS

A considerable amount of work was done by the Forskningsgruppe for Sjeldne Jordarter (FSJ) during the period 1967-1970. They cored 510m of rock in the Bolladallen and Vegskjaering areas with bore holes F-1, F-2, and F-3 but most of their investigation was directed at processing and mineralogical studies. In addition, samples from bore holes B-1, B-2, Ts-7, T-9, T-11, T-13, T-14, T-16, T-18, T-21, and T-23 were also made available to them. These drill hole analyses and analyses from surface samples are given in the Appendix and have generally delimited the area of REE potential shown in Plate 3.

Rare earth enrichment is confined to two rock types - rødberg and rauhaugite type II. Bedrock is exposed in only about 20% of the area and one must rely heavily on the few outcrops and shallow drilling information. The known rare earth enrichment does appear to correspond to a large magnetic high (See Figure 2) about 1.5km by 1km.

Rare earth mineralogy varies within the REE potential area. According to Svinndal (1970) three types of rare earth ores exist:

1. Vegskjaering - 3½% RE minerals (parisite & synchisite)
2. Bolladalen - 3% RE minerals (parisite & synchisite)
3. Hematite - 5% RE minerals (monazite, parisite & synchisite)

The Vegskjaering type of ore occurs in the rauhaugite type II rock between Skippervoll and Bolladalen, and includes the area drilled by holes F-1 and F-2. Mineralogical and beneficiation studies were conducted on bore hole F-2 by Hazen Research, Inc. (1971) and by Semb (1971). Hazen reported bastnaesite, parisite, monazite and synchisite occurring in the bore hole. The rare earth minerals are very fine-grained and badly locked giving a poor recovery. Semb indicated the main rare earth elements were synchisite (probably a mixture of the bastnaesite group minerals bastnaesite, parisite and synchisite) with subordinate orthite, in a ratio of about 5 to 1. Svinndal (1970) noted that 50-70% of the bastnaesite minerals were greater than 43 microns in size.

The Bolladalen type of ore occurs in a mixture of rauhaugite type II and rødberg. It has been drilled by bore holes B-1, B-2 and F-3. According to Svinndal (1970), 70-90% of the bastnaesite minerals are greater than 43 microns in size.

The hematite type of ore occurs in the rødberg of the Gruveåsen area where hematite zones have formed along N-S striking fractures. Thorium and rare earths have been enriched in these zones due to the introduction of the rare earth mineral monazite. Some beneficiation was tried on this material but without success as the monazite is about 1 micron in size.

The average values for the three rare earth areas and calculated averages for drill holes in the area are as follows:

Sample	La%	Ce%	Pr%	Nd%	Sm%	Eu%	Gd%	Dy%	REO%
Vegskjaering	0.30	0.65	0.08	0.18	0.031	0.0071	0.007	0.007	1.48
Bolladallen	0.22	0.69	0.09	0.29	0.046	0.0086	0.006	0.011	1.59
Hematite	0.48	0.98	0.20	0.57	0.106	0.0130	0.006	0.027	2.78
B-1	0.22	0.66	N.A.*	N.A.	0.028	0.0052	0.033	N.A.	≈1.41
B-2	0.25	0.73	N.A.	N.A.	0.030	0.0069	0.040	N.A.	≈1.57
F-1	0.20	0.54	N.A.	N.A.	0.021	0.0046	0.028	N.A.	≈1.18
F-2	0.23	0.57	N.A.	N.A.	0.023	0.0054	0.031	N.A.	≈1.28
F-3	0.20	0.62	N.A.	N.A.	0.027	0.0053	0.011	N.A.	≈1.39

*N.A. - No Assay

Listed below is a comparison of rare earth elements from the three areas at Fen, calculated from assays (Svinndal, 1970), with the rare earth distribution at Mtn. Pass, CA:

	La%	Ce%	Pr%	Nd%	Sm%	Eu%	Gd%	Dy%	REE%
Vegskjaering	23.9	50.9	6.5	14.5	2.5	0.6	0.5	0.6	100
Bolladallen	15.9	51.0	6.7	21.3	3.3	0.6	0.4	0.8	100
Hematite	20.0	41.2	8.4	24.0	4.5	0.5	0.3	1.1	100
Mtn. Pass	34.0	50.0	4.0	11.0	0.5	0.1	0.2	--	99.8

Note that several of the element distributions are quite different between the Fen and Mtn. Pass rocks. If the reported values are correct, elements like Pr, Nd, Sm, Eu, and Gd become very interesting as they occur in amounts 2 to 9 times greater at Fen per % of total rare earth elements than at Mtn. Pass. Assays of Gd in drill holes B-1, B-2, F-1, F-2, and F-3 show values about five times greater than were shown by Svinndal of the three ore types above.

In addition to the above areas, bore holes T-16, T-21 and T-23 show high rare earth values in the upper 50 meters of the holes. (See Appendix - Tables XII, XIV, and XV).

Further work on mineralogical and elemental distribution is certainly justified in the large rare earth potential area at Fen. The delineated rare earth area encompasses drill hole and surface data having greater than 1% REO content. Detailed core logging and surface mapping will be required before a drilling program can be determined.

SCANDIUM

According to Mitchell and Brunfelt (1974) and Åmli (1977), the damtjernite, rauhaugite and rødberg rocks at Fen have been enriched in Scandium. The number of samples analyzed ( ) and their average scandium contents are: (4) 24ppm, (75) 52ppm and (53) 73ppm respectively. The scandium mineral, thortveitite, has been observed in both the rauhaugite and rødberg rocks as trace minerals. Scandium has also been noted in the columbite and niobian rutile minerals taken from these rocks.

Although certain rocks are considerably enriched in scandium in the Fen complex, the demand for scandium is so small (about 20kg.) that there is no exploration or mining specifically for scandium. Virtually all scandium is recovered from uranium and wolframite tailings, iron and tin blast furnace slag, and phosphate ores. Supply is far in excess of demand. Scandium is also substituted by other less costly metals, such as rare earths and yttrium, which have similar properties and applications. The occurrence of scandium in the Fen complex can only be considered as a resource of the future.

THORIUM

During the 1950's and 60's A/S Norsk Bergverk prospected the entire Fen complex and found high radioactivity associated with the rødberg. This radioactivity has been found to be associated with thorium in the mineral monazite and a minor amount in the rare earth mineral synchisite. The entire unit of rødberg would average about 0.10% ThO_2. In the hematite veins and lenses of the rødberg, radioactivity is very high and the thorium content will average about 0.23% ThO_2. Approximately 1,000,000 tons of this material still remains in the Fensgruvene area. The quantity of rødberg is in the hundreds of million tons range. This makes the Fen area one of the worlds largest resources of ThO_2 and certainly the largest in Norway. In addition to demand problems for thorium mentioned below, it will be difficult to separate the monazite as this mineral is about 1 micron in diameter throughout the complex.

During the mining of Niobium ores (1952-1965) the iron-rich pyrochlore mineral koppite was found to contain about 2% thorium. The concentration of the pyrochlore minerals increased the radioactivity sufficiently that workers in the concentrator were required to wear film badges.

The future of thorium is uncertain and to date the supply exceeds demand. The energy situation can have a direct influence on the future of thorium particularly if governments begin to produce electricity from thorium reactors.

A 1978 U.S. Geological Survey report on thorium gives resource data in the U.S. that can be compared with the Fen area thorium. The report states that about 80% of thorium resources are found in alkaline rocks. The data of the major thorium alkalines is as follows:

Location	% ThO_2	Total Reserves	Potential Resources
Hicks Dome, Illinois	0.1 - 0.2	22,000 tons	803,000 tons
Iron Hill, Colorado	0.0043	31,080 tons	114,900 tons
Bear Lodge, Wyoming	0.023 - 0.042	338,000 tons	1,280,000 tons
Mtn. Pass, California	0.026	9,750 tons	9,750 tons

The Elk Creek, Nebraska carbonatite contains large volumes of 0.03 - 0.04% thorium.

VANADIUM

Much of the magnetite in the alkaline rocks at Fen are enriched geochemically in vanadium. A listing of spectrographic analyses for vanadium in magnetite from the Fen rocks follows (Saether, 1957):

Rock Type	V%	Rock Type	V%
Gneiss	0.04	Søvite (Cappelen Quarry)	0.4
Fenite	0.04	Søvite (Tufte Quarry)	0.2
Melteigite	0.20	Biotite Søvite	0.15
Vipetoite	0.30	Rauhaugite (Magnetite Deposit)	0.02
Damtjernite	0.30	Rødberg (Magnetite Deposit)	<0.01

The highest values are found in magnetite from the Cappelen quarry. According to Bjorlykke (1952), chemical analyses of the magnetite from the columbium ores showed a vanadium content of 0.5%. As the magnetite content of Søvite mined for columbium is only about 3%, it would be very difficult to develope any tonnage. In areas of magnetite concentration, like the magnetite deposits shown above, the vanadium contents were only 0.02%V (rauhaugite) and <0.01%V (rødberg). In addition, (Saether, 1957) indicates a lack of vanadium in the concentration of magnetite south of Skippervoll.

It would appear that there are different generations of magnetite and the later generations of magnetite, which have formed magnetite deposits, are essentially devoid of vanadium. Vanadium is considerably enriched in magnetite in melteigite, vipetoite, damtjerite and søvite and further investigations should be made of these rocks for vanadium. Svinndal is trying to obtain a sample of magnetite concentrate from the Søve mine to send to us for analysis for vanadium.

As a comparison to a known deposit, Union Carbide's vanadium deposit near Hot Springs, Arkansas, mines about 1600 tons per day of material averaging 0.56% V. It is the only producer of vanadium in the U.S. that was mined exclusively for vanadium. All other vanadium in the U.S. is recovered as a coproduct or byproduct.

YTTRIUM

Anomalous quantities of yttrium are found within the area of rare earth potential (Plate 3). The yttrium content however does not correlate with the rare earth content, but appears to correlate with niobium. Hazen Research, Inc. (1971) and Semb (1971) have both done mineralogical work on rocks within the rare earth zone and in particular on samples from bore hole F-2.

Hazen indicated that the yttrium primarily occurs with niobium in the mineral kobeite, (Y, Fe, U) (Ti, Nb, Ta)$_2$ (O, OH)$_6$, and to a lesser amount in xenotime, Y PO_4.

Semb on the other hand reported that about 50% of yttrium may occur in association with niobium in distinct zones of altered pyrochlore crystals and about 30% of the total yttrium in synchisite and orthite. Both agree that very little yttrium occurs in apatite.

Large areas contain greater than 0.02 % Y as indicated by bore hole values for F-1, F-2, F-3, B-1, and B-2; and surface samples from the Gruveåsen and Søve Mine/Fen Mine areas (See Appendix and Plate III).

Considerable mineralogical work needs to be done in the rare earth area to determine what is the mineralogical distribution of yttrium. Values as low as 0.02 % Y become economically interesting as a by-product.

RECOMMENDED ADDITIONAL WORK

The data compiled for this report indicates that additional work on the Fen alkaline complex is justified. As was pointed out above, however, no sizeable areas of economically viable material has been blocked out. At best, known areas of potential could only be considered as byproduct material, and for the most part it's difficult to consider anything as a byproduct since seldom do any two economically interesting elements overlap (see Plate 3).

Of the several comodities dealt with above, the following offer economic possibilities at the present time: rare earths, columbium, and phosphate. There is some potential for nepheline in the complex and perhaps for yttrium as a byproduct of rare earths. Vanadium should be looked for in magnetite but it is doubtful enough tonnage could be generated to make it an economic venture. Thorium still has to be thought of as a resource of the future.

The complex is virtually untested 150m below the surface and of course more than 60% of the surface is covered by overburden. The greatest potential does lie at depth but before any drilling program is outlined, several projects in a first phase sould be carried out. These include but are not limited to the following:

1. Acquire premining concessions on all open land within the Fen alkaline complex.

2. Inventory and organize all Fen drill core stored in Trondheim in preparation for logging.

3. Review all A/S Norske Bergverk records stored at the Østlandske-Bergmester-Embede Office in Oslo. Once the review is made begin compiling geologic and assay data on sections and plan maps. This includes the deposits: Cappelen, Hydro and Tufte. Look for surface sampling data on west side of complex.

4. Determine if magnetic raw data is available from the NGU on Geofysisk Malmleting's 1948-49 survey for review. Collect magnetic susceptibility readings for alkaline rocks within complex for detailed evaluation of magnetic data.

5. Determine if gravity raw data is available from Ramberg on his detailed survey at the Fen and for the region.

6. Compile foliation data on alkaline rocks within the complex, especially from carbonatites. Data may be available at NGU from field maps by Brøgger, Saether, and Svinndal. If not, field measurement should be made.

7. See if other elements were analyzed for in surface samples collected for rare earth investigation - especially for P. Most of the samples from the complex should be analyzed for REO, Y, P, Th and Cb. Mass spectrographic analyses should be made on selected samples to avoid overlooking some important element.

8. Collect available data on vanadium in magnetite at Fen. (Search A/S Norsk Bergverk's records for magnetite shipments to Poland). Collect additional samples of magnetite from ijolite-melteigite rocks and søvite for V analysis.

9. Map and sample ijolite-melteigite-urtite rocks southwest of Melteig for petrographic study to determine distribution of nepheline in the area.

10. Log core - All core should be scanned with U/V lamp both filtered and unfiltered, and data recorded. Unfiltered light will luminesce green where lathanides are present. Magnetic susceptibility measurements should be made of the core. Petrology should be recorded. The use of cathodoluminescence would be helpful especially for differentiating between dolomite and calcite.

11. Consider re-opening adit to Tufte area (Tuftestollen) for mapping purposes, depending on how well the adit was geologically mapped and sampled.

12. Determine distribution of rare earth minerals in eastern half of complex and distribution of rare earth elements within those minerals - including Y.

13. Check elemental assays for rare earths by wet methods. Run correlation coefficiants on various elements.

14. Study petrography of explosion vents around the complex and analyze samples.

Additional drilling is not recommended until the data has been compiled and evaluated. Properly evaluating the general subsurface geology is imperative before drilling begins. It is apparent that in the western portion of the complex, angle drilling will be required as the geologic structures are steeply dipping. Less is known about the structures in the eastern half but chances are good that the area will require angle drilling as well.

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APPENDIX

I. ANALYTICAL RESULTS OF BORE HOLES *

*Note - All analytical data adapted from NGU Report Nos. 776 and 966

TABLE I

Analytical Results of Bore Hole B-1

Direction - West, Inclination - 0°, Length - 97.00m

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
0.00- 4.55	0.022	0.22	0.70	0.030	0.0053	0.035	0.110	0.049	0.23
4.55- 9.75	0.031	0.22	0.65	0.035	0.0061	0.041	0.130	0.090	0.44
9.75- 15.55	0.033	0.25	0.75	0.038	0.0051	0.046	0.150	0.110	0.36
15.55- 20.50	0.019	0.22	0.64	0.026	0.0056	0.033	0.110	0.058	0.11
20.50- 24.70	0.021	0.22	0.64	0.024	0.0049	0.031	0.110	0.078	0.17
24.70- 30.25	0.023	0.24	0.67	0.031	0.0062	0.037	0.150	0.058	0.35
30.25- 36.05	0.024	0.25	0.75	0.037	0.0058	0.044	0.150	0.059	0.37
37.45- 41.40	0.029	0.24	0.74	0.043	0.0067	0.043	0.120	0.078	0.22
41.40- 45.50	0.027	0.20	0.56	0.030	0.0047	0.025	0.120	0.082	0.22
45.50- 51.80	0.021	0.31	0.76	0.028	0.0040	0.035	0.110	0.100	0.10
51.80- 55.60	0.018	0.08	0.21	0.016	0.0055	0.011	0.063	0.110	0.23
55.60- 60.60	0.025	0.25	0.64	0.028	0.0053	0.029	0.120	0.093	0.14
60.60- 65.25	0.037	0.30	0.81	0.037	0.0063	0.046	0.110	0.120	0.87
65.25- 70.05	0.035	0.29	0.80	0.026	0.0052	0.038	0.100	0.110	0.17
70.05- 75.55	0.023	0.25	0.68	0.025	0.0051	0.029	0.083	0.086	0.15
75.55- 81.00	0.027	0.15	0.46	0.024	0.0043	0.022	0.110	0.091	0.44
82.00- 87.75	0.025	0.13	0.46	0.024	0.0047	0.022	0.100	0.059	0.36
87.75- 92.75	0.017	0.22	0.80	0.022	0.0041	0.034	0.079	0.032	0.08
92.75- 97.00	0.017	0.22	0.74	0.017	0.0036	0.031	0.066	0.014	0.14

TABLE II

Analytical Results of Bore Hole B-2

Direction - West, Inclination - -25^{o}, Length - 88.70m

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
0.00- 4.85	0.020	0.19	0.60	0.035	0.0060	0.031	0.088	0.038	0.27
4.85- 9.65	0.032	0.29	0.83	0.037	0.0090	0.047	0.130	0.090	0.40
9.65- 15.35	0.030	0.27	0.80	0.036	0.0074	0.047	0.140	0.078	0.31
15.35- 19.70	0.026	0.24	0.69	0.031	0.0064	0.039	0.140	0.088	0.27
19.70- 25.00	0.023	0.22	0.68	0.029	0.0062	0.038	0.110	0.056	0.32
25.00- 29.80	0.018	0.19	0.58	0.034	0.0036	0.034	0.100	0.059	0.30
29.80- 35.00	0.022	0.36	1.00	0.038	0.0100	0.048	0.130	0.078	0.43
35.00- 38.20	0.025	0.37	1.10	0.047	0.0038	0.058	0.120	0.073	---
40.00- 45.20	0.022	0.26	0.80	0.032	0.0059	0.047	0.100	0.068	0.23
45.20- 51.30	0.027	0.31	0.86	0.030	0.0054	0.047	0.092	0.085	0.11
51.30- 56.55	0.031	0.23	0.65	0.023	0.0054	0.035	0.110	0.100	0.25
56.55- 62.50	0.018	0.15	0.48	0.020	0.0045	0.029	0.086	0.043	0.08
62.50- 68.50	0.014	0.11	0.39	0.013	0.0031	0.021	0.050	0.040	1.00
68.50- 73.80	0.017	0.15	0.42	0.012	0.0032	0.023	0.068	0.071	0.13
73.80- 78.30	0.021	0.25	0.75	0.025	0.0043	0.041	0.089	0.052	0.52
78.30- 84.00	0.021	0.27	0.83	0.028	0.0051	0.044	0.089	0.028	0.38
84.00- 88.70	0.025	0.37	0.98	0.038	0.0063	0.056	0.120	0.054	0.49

TABLE III

Analytical Results of Bore Hole F-1

Direction - S28°W, Inclination - -11°, Length - 251.10m

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
1.25- 3.20	0.022	0.19	0.46	0.027	0.0051	0.024	0.094	0.120	0.09
3.20- 6.80	0.037	0.10	0.26	0.017	0.0034	0.020	0.078	0.084	0.18
6.80- 11.40	0.022	0.07	0.18	0.015	0.0019	0.011	0.046	0.055	1.01
11.40- 12.70	0.022	0.08	0.21	0.011	0.0029	0.014	0.058	0.061	0.95
16.00- 18.00	0.027	0.11	0.28	0.017	0.0051	0.017	0.100	0.092	0.11
18.00- 21.20	0.033	0.16	0.46	0.031	0.0070	0.036	0.100	0.086	0.19
21.20- 25.20	0.022	0.22	0.63	0.037	0.0063	0.034	0.130	0.081	0.19
25.20- 30.30	0.024	0.20	0.58	0.023	0.0057	0.034	0.084	0.076	0.18
30.30- 35.20	0.022	0.15	0.41	0.019	0.0040	0.020	0.077	0.110	0.46
35.20- 39.20	0.025	0.21	0.54	0.028	0.0055	0.029	0.098	0.100	0.25
39.20- 42.90	0.023	0.19	0.50	0.030	0.0054	0.027	0.086	0.150	0.07
42.90- 47.90	0.024	0.16	0.45	0.022	0.0048	0.025	0.074	0.100	0.19
47.90- 48.10	0.025	0.21	0.54	0.029	0.0051	0.032	0.110	0.130	0.08
54.80- 57.00	0.024	0.19	0.44	0.024	0.0064	0.026	0.087	0.140	0.07
57.00- 60.55	0.013	0.11	0.31	0.018	0.0035	0.016	0.072	0.130	0.04
60.55- 65.60	0.025	0.48	1.00	0.032	0.0061	0.044	0.160	0.052	0.16
65.60- 70.00	0.019	0.69	1.25	0.021	0.0037	0.050	0.110	0.023	0.08
70.00- 75.40	0.032	0.20	0.54	0.040	0.0066	0.035	0.110	0.140	0.18
75.40- 80.20	0.021	0.17	0.46	0.025	0.0051	0.024	0.085	0.093	0.12
80.20- 85.00	0.016	0.10	0.24	0.014	0.0026	0.014	0.059	0.100	0.21
85.00- 89.90	0.015	0.04	0.12	0.011	0.0021	0.007	0.042	0.053	1.12
89.90- 94.80	0.021	0.13	0.39	0.015	0.0036	0.020	0.076	0.055	0.27
94.80- 99.10	0.020	0.15	0.43	0.018	0.0037	0.023	0.060	0.070	0.24
99.10-103.20	0.024	0.17	0.52	0.021	0.0044	0.028	0.067	0.070	0.37
103.20-109.90	0.035	0.12	0.41	0.029	0.0074	0.028	0.130	0.110	0.50
109.90-114.00	0.023	0.15	0.50	0.025	0.0051	0.031	0.090	0.091	0.40
114.00-119.40	0.015	0.16	0.58	0.020	0.0044	0.033	0.080	0.060	0.29
119.40-125.00	0.013	0.26	0.89	0.027	0.0056	0.044	0.100	0.064	0.13
125.00-130.10	0.026	0.22	0.70	0.027	0.0060	0.037	0.082	0.074	0.40
130.10-135.50	0.026	0.26	0.72	0.022	0.0054	0.037	0.094	0.069	0.29
135.50-140.80	0.030	0.23	0.65	0.030	0.0080	0.040	0.066	0.140	0.16
140.80-145.80	0.030	0.23	0.64	0.032	0.0089	0.038	0.065	0.082	0.43
145.80-149.90	0.040	0.32	0.77	0.034	0.0046	0.036	0.091	0.170	0.30
149.90-154.30	0.025	0.26	0.72	0.025	0.0052	0.037	0.091	0.170	0.34
154.30-157.40	0.030	0.26	0.78	0.021	0.0049	0.039	0.070	0.210	0.32
157.40-162.70	0.027	0.32	0.78	0.021	0.0048	0.035	0.095	0.170	0.63
162.70-167.50	0.023	0.31	0.72	0.019	0.0043	0.034	0.069	0.120	0.49
167.50-170.60	0.024	0.24	0.52	0.013	0.0027	0.023	0.059	0.089	0.51
170.60-174.40	0.027	0.15	0.44	0.015	0.0041	0.020	0.043	0.060	1.47
174.40-177.60	0.015	0.25	0.70	0.022	0.0042	0.035	0.042	0.057	0.36

TABLE III (continued)

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
177.60-182.10	0.023	0.27	0.70	0.020	0.0045	0.036	0.060	0.067	0.74
182.10-187.80	0.022	0.29	0.72	0.018	0.0043	0.032	0.085	0.100	0.40
187.80-192.30	0.017	0.23	0.56	0.016	0.0032	0.027	0.077	0.078	0.39
192.30-196.50	0.034	0.20	0.52	0.018	0.0044	0.026	0.088	0.100	1.70
196.50-201.00	0.017	0.12	0.31	0.013	0.0029	0.014	0.036	0.054	0.22
201.00-206.65	0.030	0.11	0.30	0.014	0.0031	0.013	0.035	0.130	2.95
206.65-212.00	0.041	0.20	0.47	0.017	0.0039	0.022	0.060	0.078	3.16
212.00-216.60	0.021	0.15	0.46	0.021	0.0045	0.032	0.045	0.070	0.49
216.60-217.60	0.018	0.17	0.41	0.014	0.0032	0.023	0.053	0.160	0.43
217.60-219.20	0.014	0.26	0.72	0.020	0.0049	0.041	0.044	0.020	0.48
219.20-223.10	0.030	0.27	0.70	0.021	0.0062	0.039	0.092	0.052	0.47
223.10-228.70	0.023	0.20	0.52	0.016	0.0037	0.028	0.055	0.090	0.19
228.70-234.30	0.024	0.24	0.60	0.017	0.0044	0.030	0.061	0.090	0.16
234.30-239.00	0.026	0.19	0.49	0.022	0.0059	0.029	0.089	0.044	0.31
239.00-244.00	0.016	0.15	0.39	0.013	0.0027	0.023	0.064	0.083	0.12
244.00-251.10	0.015	0.17	0.44	0.013	0.0028	0.019	0.056	0.070	0.55

TABLE IV

Analytical Results of Bore Hole F-2

Direction - S20°W, Inclination - -10°, Length - 195.45m

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
0.00- 2.40	0.024	0.29	0.73	0.029	0.0070	0.041	0.130	0.071	0.27
2.40- 5.90	0.016	0.20	0.50	0.022	0.0054	0.024	0.092	0.064	0.20
5.90- 9.30	0.018	0.24	0.59	0.023	0.0051	0.033	0.090	0.080	0.20
9.30- 11.40	0.018	0.08	0.21	0.015	0.0029	0.015	0.051	0.080	0.24
11.40- 13.70	0.022	0.24	0.70	0.033	0.0073	0.045	0.110	0.053	0.15
13.70- 18.80	0.019	0.21	0.51	0.024	0.0052	0.028	0.095	0.060	0.18
18.80- 23.80	0.024	0.35	0.82	0.030	0.0070	0.042	0.095	0.073	0.23
23.80- 28.20	0.031	0.23	0.59	0.028	0.0060	0.034	0.130	0.080	0.29
28.20- 33.60	0.027	0.27	0.70	0.033	0.0077	0.040	0.140	0.062	0.28
33.60- 38.00	0.020	0.30	0.71	0.022	0.0060	0.033	0.100	0.038	0.20
38.00- 42.60	0.017	0.24	0.58	0.017	0.0043	0.028	0.093	0.083	0.20
42.60- 47.10	0.019	0.20	0.53	0.032	0.0070	0.032	0.120	0.056	0.12
47.10- 51.70	0.017	0.21	0.51	0.023	0.0050	0.029	0.100	0.058	0.12
51.70- 56.70	0.018	0.22	0.52	0.020	0.0055	0.027	0.082	0.057	0.12
56.70- 60.70	0.016	0.36	0.83	0.023	0.0066	0.037	0.092	0.044	0.12
60.70- 65.80	0.018	0.27	0.66	0.025	0.0054	0.035	0.083	0.070	0.09
65.80- 70.00	0.017	0.26	0.65	0.021	0.0052	0.032	0.089	0.082	0.12
70.00- 74.30	0.016	0.24	0.60	0.024	0.0054	0.029	0.088	0.064	0.10
74.30- 80.30	0.020	0.26	0.62	0.022	0.0046	0.029	0.092	0.089	0.18
80.30- 85.30	0.032	0.43	1.00	0.028	0.0077	0.050	0.120	0.061	0.33
85.30- 89.50	0.024	0.24	0.59	0.024	0.0066	0.031	0.110	0.090	0.25
89.50- 92.50	0.019	0.27	0.72	0.032	0.0062	0.041	0.079	0.066	0.10
92.50- 98.20	0.017	0.21	0.54	0.022	0.0045	0.028	0.085	0.078	0.34
98.20-100.00	0.009	0.16	0.45	0.028	0.0048	0.027	0.054	0.013	0.11
100.00-105.85	0.014	0.18	0.47	0.022	0.0054	0.025	0.092	0.056	0.21
105.85-110.25	0.017	0.21	0.52	0.024	0.0053	0.028	0.100	0.062	0.22
110.25-115.65	0.010	0.28	0.68	0.023	0.0057	0.031	0.089	0.060	0.09
115.65-120.65	0.013	0.28	0.68	0.027	0.0050	0.031	0.090	0.100	0.22
120.65-126.05	0.019	0.29	0.76	0.027	0.0073	0.037	0.110	0.044	0.29
126.05-131.15	0.019	0.42	1.00	0.029	0.0072	0.045	0.110	0.080	0.34
131.15-136.65	0.015	0.20	0.49	0.020	0.0050	0.024	0.087	0.059	0.31
136.65-140.05	0.025	0.20	0.50	0.022	0.0061	0.028	0.100	0.100	0.53
140.05-145.55	0.021	0.22	0.54	0.022	0.0062	0.029	0.130	0.082	0.37
145.55-148.20	0.017	0.08	0.22	0.012	0.0029	0.018	0.078	0.075	0.58
148.20-152.15	0.018	0.13	0.36	0.019	0.0044	0.023	0.090	0.060	0.36
152.15-157.25	0.015	0.18	0.45	0.017	0.0045	0.026	0.078	0.063	0.19
157.25-162.25	0.026	0.19	0.49	0.026	0.0061	0.030	0.093	0.071	0.61
162.25-167.95	0.018	0.18	0.46	0.024	0.0055	0.025	0.085	0.053	0.26
167.95-173.35	0.017	0.26	0.66	0.029	0.0065	0.034	0.094	0.057	0.27
173.35-178.75	0.020	0.21	0.56	0.021	0.0046	0.033	0.099	0.080	0.17

TABLE IV (continued)

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
178.75-183.25	0.024	0.26	0.66	0.027	0.0059	0.037	0.120	0.066	0.16
183.25-186.60	0.018	0.19	0.51	0.018	0.0041	0.029	0.100	0.081	0.08
186.60-188.15	0.011	0.08	0.20	0.007	0.0012	0.011	0.041	0.017	0.17
188.15-192.75	0.028	0.10	0.26	0.015	0.0040	0.018	0.065	0.076	1.61
192.75-195.45	0.023	0.13	0.37	0.018	0.0037	0.023	0.065	0.110	1.63

TABLE V

Analytical Results of Bore Hole F-3

Direction - East, Inclination - -15°, Length - 63.80m

Interval (m)	Y%	La%	Ce%	Sm%	Eu%	Gd%	Th%	Nb%	P%
0.00- 5.00	0.023	0.19	0.67	0.034	0.0068	0.010	0.170	0.120	0.15
5.00- 8.80	0.015	0.15	0.51	0.041	0.0056	0.007	0.110	0.080	0.19
8.80- 12.50	0.031	0.38	1.20	0.034	0.0079	0.014	0.150	0.090	0.25
12.50- 16.90	0.046	0.19	0.60	0.025	0.0058	0.015	0.110	0.130	0.11
16.90- 21.30	0.034	0.20	0.64	0.027	0.0065	0.017	0.100	0.120	0.17
21.30- 24.10	0.046	0.25	0.81	0.027	0.0073	0.017	0.130	0.140	0.37
24.10- 26.60	0.024	0.43	1.34	0.045	0.0071	0.009	0.120	0.130	0.48
26.60- 31.00	0.062	0.21	0.69	0.028	0.0080	0.025	0.190	0.130	0.89
31.00- 36.10	0.023	0.09	0.26	0.018	0.0035	0.006	0.083	0.081	0.63
36.10- 41.00	0.015	0.08	0.19	0.010	0.0027	0.008	0.063	0.100	0.23
41.00- 47.00	0.026	0.29	0.72	0.021	0.0025	0.005	0.110	0.090	0.25
47.00- 47.50	0.013	0.11	0.31	0.016	0.0026	0.006	0.055	0.083	0.17
53.70- 58.10	0.012	0.12	0.37	0.030	0.0043	0.006	0.130	0.050	0.24
58.10- 63.80	0.011	0.10	0.31	0.024	0.0033	0.006	0.070	0.057	0.23

TABLE VI

Analytical Results of Ts-7

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.003	0.01	0.017	0.0018	-0.0050
2	0.004	0.01	0.001	0.0023	-0.0050
3	0.005	0.01	0.002	0.0024	-0.0050
4	0.005	0.01	0.001	0.0016	-0.0050
5	0.005	0.01	0.002	0.0010	-0.0050
6	0.005	0.01	0.001	0.0010	-0.0050
7	0.004	0.02	0.002	0.0018	-0.0050
8	0.004	0.02	0.001	0.0015	-0.0050
9	0.004	0.02	0.002	0.0013	-0.0050
10	0.005	0.01	0.002	0.0010	-0.0050
11	0.004	0.01	0.001	0.0016	-0.0050
12	0.009	0.01	0.002	0.0014	-0.0050
13	0.005	0.01	0.001	0.0017	-0.0050
14	0.005	0.01	0.001	0.0010	-0.0050
15	0.005	0.01	0.001	0.0019	-0.0050
16	0.005	0.00	0.001	0.0010	-0.0050
17	0.004	0.01	0.002	0.0021	-0.0050
18	0.004	0.02	0.007	0.0025	-0.0050
19	0.006	0.02	0.002	0.0025	-0.0050
20	0.005	0.02	0.004	0.0010	-0.0050
21	0.005	0.02	0.002	0.0010	-0.0050
22	0.006	0.01	0.021	0.0016	-0.0050
23	0.005	0.14	0.003	0.0015	-0.0050
24	0.005	0.02	0.001	0.0013	-0.0050
25	0.008	0.02	0.002	0.0015	-0.0050

TABLE VII

Analytical Results of T-9

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.009	0.01	0.005	0.0021	-0.0050
5	0.009	0.05	0.004	0.0023	-0.0050
10	0.006	0.02	0.002	0.0020	-0.0050
13	0.002	0.02	0.001	0.0012	-0.0050
16	0.004	0.03	0.001	0.0016	-0.0050
19	0.004	0.03	0.001	0.0019	-0.0050
22	0.006	0.01	0.002	0.0010	-0.0050
25	0.005	0.02	0.001	0.0018	-0.0050
29	0.006	0.02	0.003	0.0014	0.0060
33	0.009	0.01	0.002	0.0010	-0.0050
36	0.005	0.03	0.003	0.0022	-0.0050
40	0.009	0.01	0.003	0.0010	-0.0050
44	0.006	0.02	0.002	0.0015	-0.0050
47	0.006	0.02	0.004	0.0021	-0.0050
50	0.006	0.03	0.001	0.0022	-0.0050
54	0.006	0.02	0.002	0.0019	-0.0050

TABLE VIII

Analytical Results of T-11

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.006	0.01	0.001	0.0022	0.0090
3	0.003	0.01	0.001	0.0010	0.0060
6	0.004	0.02	0.001	0.0019	0.0050
9	0.004	0.02	0.001	0.0017	-0.0050
12	0.004	0.01	0.001	0.0020	-0.0050
15	0.004	0.02	0.001	0.0020	0.0050
18	0.006	0.04	0.001	0.0025	-0.0050
21	0.003	0.01	0.001	0.0014	-0.0050
24	0.003	0.01	0.001	0.0015	-0.0050
27	0.006	0.01	0.001	0.0019	-0.0050
30	0.004	0.01	0.001	0.0018	-0.0050
33	0.007	0.03	0.004	0.0024	-0.0050
36	0.007	0.02	0.004	0.0019	-0.0050
39	0.006	0.02	0.002	0.0021	-0.0050
42	0.005	0.03	0.005	0.0027	-0.0050
45	0.006	0.01	0.004	0.0021	-0.0050
48	0.003	0.02	0.002	0.0021	-0.0050
51	0.007	0.04	0.007	0.0027	-0.0050
54	0.005	0.02	0.003	0.0018	-0.0050
57	0.003	0.02	0.002	0.0018	-0.0050
60	0.005	0.01	0.002	0.0021	-0.0050
63	0.002	0.01	0.003	0.0014	-0.0050
66	0.005	0.02	0.009	0.0042	-0.0050
69	0.002	0.01	0.003	0.0010	-0.0050
72	0.003	0.01	0.002	0.0010	-0.0050
75	0.005	0.04	0.006	0.0027	-0.0050
79	0.005	0.01	0.003	0.0022	-0.0050
82	0.002	0.01	0.002	0.0016	-0.0050
85	0.004	0.02	0.001	0.0019	-0.0050

TABLE IX

Analytical Results of T-12

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Nb_2O_5%
1	0.007	0.04	0.004	0.0020	-0.0050	
4	0.006	0.03	0.008	0.0020	-0.0050	
7	0.009	0.04	0.013	0.0040	-0.0075	
10	0.006	0.04	0.006	0.0020	-0.0050	
13	0.007	0.08	0.004	0.0020	-0.0050	
18	0.010	0.22	0.008	0.0025	-0.0050	0.07
20	0.012	0.05	0.009	0.0030	-0.0050	0.07
24	0.011	0.04	0.005	0.0015	-0.0050	0.02
27	0.011	0.07	0.006	0.0015	-0.0050	0.02
31	0.009	0.02	0.004	0.0015	-0.0050	0.20
32	0.008	0.04	0.007	0.0020	-0.0050	0.26
33	0.008	0.05	0.007	0.0020	-0.0050	0.26
34	0.008	0.03	0.004	0.0020	-0.0050	0.07
35	0.006	0.03	0.005	0.0015	-0.0050	0.24
36	0.015	0.04	0.007	0.0020	-0.0050	0.06
37	0.006	0.02	0.003	0.0015	-0.0050	0.21
38	0.008	0.02	0.004	0.0015	-0.0050	0.35
39	0.009	0.08	0.008	0.0025	-0.0050	0.40
40	0.009	0.05	0.007	0.0035	-0.0050	0.55
41	0.004	0.14	0.006	0.0015	-0.0050	0.17
42	0.004	0.04	0.009	0.0020	-0.0050	0.65
43	0.007	0.05	0.012	0.0035	-0.0050	0.31
44	0.008	0.06	0.009	0.0035	-0.0050	0.31
45	0.003	0.06	0.009	0.0025	-0.0050	0.14

TABLE X

Analytical Results of T-13

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Nb_2O_5%
2	0.009	0.07	0.012	0.0040	-0.0050	
5	0.005	0.02	0.003	0.0010	-0.0050	
8	0.004	0.02	0.003	0.0010	-0.0050	
10	0.006	0.03	0.007	0.0020	-0.0050	
14	0.008	0.06	0.007	0.0020	-0.0050	
17	0.004	0.05	0.004	0.0015	-0.0050	
21	0.008	0.04	0.006	0.0020	-0.0050	
23	0.008	0.05	0.005	0.0015	-0.0050	
26	0.008	0.05	0.008	0.0020	-0.0050	
30	0.009	0.04	0.007	0.0025	-0.0050	
31	0.005	0.04	0.005	0.0020	-0.0050	
32	0.004	0.03	0.006	0.0015	-0.0050	
33	0.006	0.03	0.008	0.0015	-0.0050	
34	0.007	0.03	0.005	0.0020	-0.0050	
35	0.008	0.02	0.005	0.0020	-0.0050	
36	0.009	0.04	0.005	0.0020	-0.0050	0.04
37	0.006	0.03	0.004	0.0015	-0.0050	
38	0.007	0.03	0.007	0.0020	-0.0050	0.55
39	0.006	0.03	0.008	0.0020	-0.0050	
40	0.005	0.14	0.009	0.0020	-0.0050	0.16
42	0.007	0.06	0.007	0.0020	-0.0050	
45	0.008	0.14	0.021	0.0040	-0.0050	
48	0.005	0.07	0.009	0.0015	-0.0050	

TABLE XI

Analytical Results of T-14

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Nb_2O_5 %
1	0.021	0.04	0.006	0.0025	-0.0050	
3	0.010	0.30	0.009	0.0050	-0.0050	
5	0.005	0.09	0.009	0.0050	-0.0050	
7	0.007	0.13	0.006	0.0035	-0.0050	
10	0.012	0.09	0.010	0.0045	-0.0050	
13	0.009	0.05	0.007	0.0030	-0.0050	
14	0.006	0.07	0.008	0.0030	-0.0050	0.20
15	0.007	0.07	0.009	0.0030	-0.0050	0.23
16	0.008	0.09	0.008	0.0035	-0.0050	0.23
17	0.006	0.05	0.006	0.0030	-0.0050	0.10
20	0.011	0.06	0.011	0.0035	-0.0050	
23	0.009	0.08	0.009	0.0040	-0.0050	
26	0.006	0.05	0.010	0.0035	-0.0050	0.11
29	0.008	0.06	0.012	0.0040	-0.0050	0.15
33	0.007	0.12	0.009	0.0040	-0.0050	
34	0.009	0.03	0.009	0.0040	-0.0050	
35	0.004	0.03	0.005	0.0025	-0.0050	
38	0.008	0.24	0.013	0.0040	-0.0050	
41	0.007	0.08	0.009	0.0030	-0.0050	
44	0.007	0.08	0.009	0.0030	-0.0050	
47	0.006	0.05	0.009	0.0030	-0.0050	
48	0.010	0.07	0.009	0.0030	-0.0050	
49	0.007	0.10	0.008	0.0030	-0.0050	
52	0.008	0.11	0.011	0.0035	-0.0050	
53	0.007	0.06	0.007	0.0030	-0.0050	
54	0.005	0.04	0.007	0.0020	-0.0050	
59	0.006	0.05	0.007	0.0050	-0.0050	
61	0.007	0.05	0.008	0.0020	-0.0050	

TABLE XII

Analytical Results of T-16

Sample No.	Y%	La%	Sm%	Eu%	Yb%
6	0.004	0.09	0.005	0.0024	-0.0050
10	0.002	0.77	0.015	0.0073	-0.0050
13	0.003	0.09	0.005	0.0029	-0.0050
16	0.004	0.05	0.001	0.0025	-0.0050
19	0.004	0.18	0.011	0.0052	-0.0050
22	0.001	0.17	0.010	0.0043	-0.0050
25	0.002	0.16	0.013	0.0052	-0.0050
28	0.002	0.22	0.005	0.0030	-0.0050
31	0.001	0.17	0.006	0.0028	-0.0050
34	0.001	0.12	0.001	0.0024	-0.0050
37	0.004	0.05	0.003	0.0030	-0.0050
40	0.005	0.10	0.003	0.0038	-0.0050
43	0.003	0.09	0.006	0.0019	-0.0050
46	0.004	0.03	0.001	0.0018	-0.0050
49	0.005	0.03	0.004	0.0031	-0.0050
52	0.004	0.03	0.005	0.0035	-0.0050
55	0.004	0.02	0.004	0.0034	-0.0050
58	0.003	0.17	0.016	0.0069	-0.0050
61	0.007	0.06	0.003	0.0033	-0.0050
64	0.007	0.07	0.001	0.0032	-0.0050
67	0.006	0.05	0.002	0.0030	-0.0050
70	0.018	0.04	0.004	0.0033	-0.0050

TABLE XIII

Analytical Results of T-18

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.004	0.02	0.001	0.0018	-0.0050
3	0.005	0.04	0.001	0.0023	-0.0050
6	0.004	0.03	0.001	0.0017	-0.0050
9	0.004	0.02	0.001	0.0024	-0.0050
12	0.005	0.02	0.001	0.0025	-0.0050
15	0.006	0.03	0.001	0.0020	-0.0050
18	0.006	0.03	0.001	0.0017	-0.0050
21	0.004	0.02	0.001	0.0018	-0.0050
24	0.002	0.01	0.001	0.0010	-0.0050
27	0.002	0.01	0.001	0.0015	-0.0050
30	0.004	0.03	0.001	0.0023	-0.0050
34	0.012	0.02	0.002	0.0035	-0.0050
36	0.006	0.02	0.004	0.0032	-0.0050
40	0.006	0.02	0.001	0.0020	-0.0050
45	0.004	0.03	0.001	0.0023	-0.0050
48	0.004	0.02	0.001	0.0018	0.0050
51	0.005	0.02	0.001	0.0018	-0.0050
54	0.004	0.02	0.001	0.0018	-0.0050
57	0.004	0.01	0.001	0.0018	-0.0050
60	0.006	0.02	0.001	0.0014	-0.0050
63	0.007	0.02	0.004	0.0022	-0.0050

TABLE XIV

Analytical Results of T-21

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.001	0.43	0.004	0.0037	-0.0050
3	0.002	0.74	0.010	0.0055	-0.0050
6	0.003	0.61	0.014	0.0057	-0.0050
9	0.001	0.74	0.008	0.0040	-0.0050
12	0.001	0.68	0.007	0.0036	-0.0050
15	0.001	0.49	0.009	0.0032	-0.0050
18	0.001	0.23	0.008	0.0023	-0.0050
21	0.001	0.24	0.013	0.0031	-0.0050
24	0.001	0.47	0.006	0.0040	-0.0050
27	0.001	0.31	0.005	0.0024	-0.0050
30	0.005	0.56	0.003	0.0042	-0.0050
33	0.002	0.16	0.003	0.0022	-0.0050
36	0.007	0.05	0.001	0.0027	-0.0050
39	0.003	0.11	0.003	0.0024	-0.0050
42	0.004	0.44	0.011	0.0062	-0.0050
45	0.001	0.18	0.009	0.0037	-0.0050
48	0.002	0.14	0.005	0.0033	-0.0050

TABLE XV

Analytical Results of T-23

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.007	0.04	0.006	0.0033	-0.0050
3	0.004	0.03	0.005	0.0026	-0.0050
6	0.004	0.02	0.002	0.0025	-0.0050
9	0.004	0.05	0.002	0.0035	-0.0050
12	0.006	0.35	0.003	0.0049	-0.0050
15	0.004	0.36	0.009	0.0038	-0.0050
18	0.006	0.09	0.011	0.0046	-0.0050
21	0.002	0.06	0.007	0.0040	-0.0050
26	0.002	0.07	0.016	0.0052	-0.0050
29	0.002	0.05	0.009	0.0043	-0.0050
32	0.002	0.05	0.015	0.0049	-0.0050
35	0.004	0.05	0.012	0.0041	-0.0050
39	0.002	0.08	0.010	0.0052	-0.0050
42	0.001	0.09	0.007	0.0038	-0.0050
45	0.003	0.09	0.006	0.0033	-0.0050
48	0.001	0.15	0.009	0.0040	-0.0050
51	0.002	0.19	0.007	0.0049	-0.0050

TABLE XVI

Analytical Results of C-43

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Nb_2O_5%
8	0.011	0.02	0.006	0.0020	-0.0050	0.15
15	0.008	0.02	0.005	0.0015	-0.0050	0.83
16	0.008	0.03	0.007	0.0015	-0.0050	0.76
17	0.008	0.03	0.007	0.0015	-0.0050	0.64
18	0.006	0.03	0.007	0.0015	-0.0050	1.14
19	0.006	0.02	0.004	0.0010	-0.0050	0.08
20	0.006	0.03	0.007	0.0015	-0.0050	0.26
21	0.009	0.04	0.007	0.0015	-0.0050	0.40
22	0.008	0.03	0.005	0.0015	-0.0050	0.48

APPENDIX

II. ANALYTICAL RESULTS OF ROCK SAMPLES*

*Note - All analytical data adapted from NGU Report Nos. 776 and 820

TABLE XVII

Analytical Results of Rock Samples - Rauhaug Area

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Gd%
1A	0.022	0.02	0.009	0.0050	-0.0050	0.0134
1B	0.018	0.04	0.007	0.0045	-0.0050	0.0069
2	0.021	0.06	0.007	0.0047	-0.0050	0.0048
3	0.017	0.06	0.008	0.0042	-0.0050	0.0030
4	0.012	0.02	0.004	0.0035	-0.0050	0.0022
5A	0.012	0.02	0.003	0.0037	-0.0050	0.0017
5B	0.015	0.05	0.008	0.0046	-0.0050	0.0061
6A	0.011	0.05	0.009	0.0025	-0.0050	0.0078
6B	0.018	0.04	0.009	0.0051	-0.0050	0.0061
8	0.005	0.13	0.025	0.0066	-0.0050	0.0043
9	0.010	0.09	0.012	0.0042	-0.0050	0.0048
10	0.004	0.42	0.044	0.0145	-0.0050	0.0087
10A	0.007	0.55	0.046	0.0152	-0.0050	
10B	0.006	0.57	0.043	0.0163	-0.0050	0.0065
11	0.012	0.04	0.010	0.0046	-0.0050	0.0035
12	0.008	0.09	0.009	0.0046	-0.0050	0.0052
12B	0.008	0.12	0.014	0.0045	-0.0050	0.0030
13	0.441	0.19	0.023	0.0103	-0.0050	0.0160
14	0.232	0.17	0.015	0.0050	-0.0050	0.0087
15	0.008	0.30	0.040	0.0078	0.0070	0.0043
16	0.012	0.07	0.009	0.0039	0.0070	0.0048
103	0.003	0.35	0.011	0.0020	-0.0050	
104	0.006	0.18	0.014	0.0035	-0.0050	
105	0.004	0.11	0.013	0.0030	-0.0050	
106	0.012	0.03	0.011	0.0035	-0.0050	
107	0.006	0.13	0.015	0.0030	-0.0050	
108	0.012	0.07	0.015	0.0030	-0.0050	
109	0.006	0.14	0.024	0.0050	-0.0050	
110	0.003	0.13	0.009	0.0030	-0.0050	
182	0.009	0.22	0.017	0.0040	-0.0050	
183	0.009	0.03	0.006	0.0020	-0.0050	
184	0.005	0.15	0.010	0.0015	-0.0050	
185	0.007	0.08	0.007	0.0015	-0.0050	
186	0.012	0.04	0.006	0.0030	-0.0050	

TABLE XVIII

Analytical Results of Rock Samples - Gruveåsen

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Gd%
1	0.004	0.04	0.015	0.0018	0.0100	-0.001
2	0.010	0.08	0.015	0.0068	0.0160	0.001
3	0.014	0.11	0.017	0.0065	-0.0050	0.010
4	0.026	0.06	0.016	0.0060	0.0160	0.009
5	0.012	0.03	0.005	0.0034	-0.0050	0.002
6	0.036	0.09	0.030	0.0098	0.0130	0.009
7	0.018	0.12	0.030	0.0081	-0.0050	0.011
8	0.011	0.07	0.016	0.0034	0.0120	0.001
9	0.022	0.07	0.055	0.0138	0.0140	0.010
10	0.010	0.07	0.027	0.0061	0.0180	-0.001
11	0.010	0.16	0.015	0.0054	-0.0050	0.003
12	0.003	0.15	0.026	0.0033	0.0510	-0.001
13	0.009	0.07	0.014	0.0026	0.0120	-0.001
14A	0.007	0.07	0.017	0.0054	0.0180	-0.001
14B	0.022	0.07	0.014	0.0039	0.0090	0.004
15	0.025	0.17	0.040	0.0133	0.0120	0.008
16	0.020	0.26	0.060	0.0168	0.0080	0.002
17	0.006	0.28	0.033	0.0088	0.0070	-0.001
18	0.014	0.07	0.006	0.0037	-0.0050	0.001
20	0.011	0.06	0.012	0.0038	0.0200	0.003
21	0.019	0.20	0.057	0.0156	0.0150	0.003
22	0.008	0.07	0.026	0.0045	0.0170	-0.001
23	0.004	0.03	0.010	0.0014	0.0100	-0.001
24	0.004	0.11	0.016	0.0020	0.0520	-0.001
25	0.025	0.18	0.041	0.0060	0.0170	-0.001
26	0.010	0.39	0.014	0.0057	0.0050	0.004
27	0.009	0.24	0.029	0.0063	0.0070	-0.001
28	0.012	0.18	0.024	0.0066	0.0100	-0.001
29	0.017	0.10	0.030	0.0065	0.0070	-0.001
30	0.010	0.28	0.058	0.0128	-0.0050	-0.001
31	0.039	0.05	0.029	0.0091	-0.0050	0.008
32	0.001	0.11	0.031	0.0044	0.0100	-0.001
34	0.005	0.24	0.021	0.0049	0.0300	-0.001
36	0.009	0.26	0.031	0.0076	0.0140	-0.001

TABLE XIX

Analytical Results of Rock Samples - Melteig Area

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1	0.012	0.01	0.002	0.0012	0.0070
2	0.007	0.02	0.002	0.0010	-0.0050
2B	0.008	0.03	0.001	0.0014	0.0060
3	0.019	0.02	0.005	0.0021	0.0150
4	0.006	0.02	0.002	0.0015	-0.0050
5	0.003	0.02	0.002	0.0010	0.0060
6	0.008	0.02	0.001	0.0010	0.0050
7	0.005	0.00	0.002	0.0010	0.0110
8	0.004	0.01	0.002	0.0010	-0.0050
9	0.006	0.01	0.001	0.0010	-0.0050

TABLE XX

Analytical Results of Rock Samples - Vipeto Area

Sample No.	Y%	La%	Sm%	Eu%	Yb%
1A	0.010	0.02	0.001	0.0013	-0.0050
1B	0.008	0.02	0.001	0.0024	-0.0050
2	0.008	0.02	0.001	0.0010	-0.0050
3	0.005	0.02	0.001	0.0024	-0.0050
3A	0.008	0.01	0.004	0.0018	-0.0050
3B	0.002	---	0.005	0.0015	-0.0050
4	0.008	0.03	0.004	0.0021	-0.0050
4A	0.003	0.01	0.002	0.0014	-0.0050
4B	0.008	0.03	0.005	0.0015	-0.0050
5	0.006	0.02	0.001	0.0017	-0.0050
6	0.006	0.02	0.002	0.0014	-0.0050
7	0.002	0.01	0.002	0.0010	-0.0050
9	0.004	0.01	0.005	0.0010	-0.0050
10A	0.004	0.01	0.002	0.0010	-0.0050
10B	0.006	0.02	0.004	0.0019	-0.0050
11	0.005	0.00	0.001	0.0014	-0.0050
12	0.006	0.01	0.004	0.0014	-0.0050
12A	0.004	0.01	0.005	0.0010	-0.0050
12B	0.008	0.02	0.006	0.0028	-0.0050
13A	0.005	0.01	0.002	0.0022	-0.0050
13B	0.001	0.01	0.001	0.0010	-0.0050
14	0.004	0.01	0.001	0.0014	-0.0050
15	0.009	0.03	0.001	0.0010	-0.0050
16	0.009	0.03	0.001	0.0024	-0.0050
17	0.008	0.07	0.005	0.0032	-0.0050
18	0.006	0.02	0.001	0.0014	-0.0050

TABLE XXI

Analytical Results of Rock Samples - Søve Mine/Fen Mine Area

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Gd%
100	0.012	0.13	0.032	0.0065	0.0130	
101	0.015	0.21	0.035	0.0050	-0.0050	
102	0.017	0.25	0.038	0.0100	-0.0050	
111	0.009	0.03	0.007	0.0010	-0.0050	
112	0.005	0.02	0.007	0.0010	-0.0050	
113	0.006	0.11	0.011	0.0025	-0.0050	
114	0.007	0.39	0.016	0.0035	-0.0050	
115	0.004	0.25	0.013	0.0025	-0.0050	
116	0.005	0.16	0.006	0.0020	-0.0050	
117	0.004	0.55	0.016	0.0030	-0.0050	
118	0.004	0.34	0.013	0.0030	-0.0050	
119	0.006	0.86	0.034	0.0110	-0.0050	
120	0.012	0.27	0.026	0.0050	-0.0050	
121	0.011	0.27	0.022	0.0060	-0.0050	
122	0.009	0.39	0.035	0.0075	-0.0050	
123	0.012	0.86	0.054	0.0160	-0.0050	
124	0.012	0.50	0.048	0.0110	-0.0050	
125	0.009	0.32	0.036	0.0075	-0.0050	
126	0.012	0.48	0.032	0.0090	-0.0050	
127	0.013	0.36	0.024	0.0060	-0.0050	
128	0.040	0.33	0.034	0.0080	-0.0050	
129	0.015	0.35	0.030	0.0070	-0.0050	
130	0.018	0.29	0.028	0.0060	-0.0050	
131	0.017	0.29	0.027	0.0055	-0.0050	
132	0.016	0.35	0.028	0.0060	-0.0050	
133	0.016	0.35	0.027	0.0075	-0.0050	
134	0.023	0.25	0.028	0.0070	-0.0050	
135	0.020	0.33	0.028	0.0065	-0.0050	
136	0.013	0.36	0.025	0.0065	-0.0050	
137	0.024	0.39	0.035	0.0080	-0.0050	
138	0.016	0.20	0.020	0.0055	-0.0050	0.004
139	0.013	0.17	0.018	0.0040	-0.0050	0.003
140	0.011	0.09	0.009	0.0010	-0.0050	0.003
141	0.011	0.16	0.015	0.0030	-0.0050	0.004
142	0.010	0.14	0.010	0.0030	-0.0050	0.003
143	0.014	0.29	0.020	0.0095	-0.0050	0.008
144	0.022	0.08	0.015	0.0045	-0.0050	0.006
145	0.014	0.36	0.029	0.0080	-0.0050	0.007
146	0.014	0.11	0.020	0.0060	-0.0050	0.004
147	0.026	0.13	0.020	0.0050	-0.0050	0.010
148	0.020	0.28	0.030	0.0065	-0.0050	0.011
149	0.018	0.22	0.024	0.0050	-0.0050	0.008
150	0.036	0.29	0.044	0.0110	-0.0050	0.012

TABLE XXI (continued)

Sample No.	Y%	La%	Sm%	Eu%	Yb%	Gd%
151	0.021	0.15	0.020	0.0050	-0.0050	0.004
152	0.014	0.10	0.012	0.0035	-0.0050	0.003
153	0.018	0.17	0.026	0.0045	-0.0050	0.003
154	0.018	0.12	0.019	0.0045	-0.0050	0.004
155	0.022	0.26	0.034	0.0075	-0.0050	0.005
156	0.030	0.21	0.031	0.0090	-0.0050	0.007
157	0.026	0.12	0.023	0.0065	-0.0050	0.007
158	0.028	0.29	0.036	0.0100	-0.0050	0.012
159	0.023	0.11	0.014	0.0060	-0.0050	0.005
160	0.014	0.04	0.007	0.0020	-0.0050	
161	0.012	0.05	0.014	0.0025	-0.0050	
162	0.010	0.05	0.005	0.0015	-0.0050	
163	0.005	0.12	0.014	0.0010	-0.0050	
164	0.008	0.08	0.006	0.0010	-0.0050	
165	0.010	0.03	0.005	0.0020	-0.0050	
166	0.018	0.06	0.010	0.0030	-0.0050	
167	0.022	0.14	0.028	0.0060	-0.0065	
168	0.025	0.07	0.014	0.0040	-0.0050	
169	0.024	0.19	0.033	0.0060	-0.0050	
170	0.013	0.08	0.007	0.0025	-0.0050	
171	0.015	0.05	0.012	0.0025	-0.0050	
172	0.011	0.03	0.004	0.0020	-0.0050	
173	0.014	0.02	0.003	0.0015	-0.0050	
174	0.012	0.01	0.003	0.0010	-0.0050	
175	0.014	0.03	0.009	0.0010	-0.0050	
176	0.008	0.03	0.006	0.0010	-0.0050	
177	0.012	0.03	0.005	0.0010	-0.0050	
178	0.011	0.02	0.005	0.0010	-0.0050	
179	0.011	0.02	0.004	0.0010	-0.0050	
180	0.012	0.03	0.003	0.0010	-0.0050	
181	0.012	0.02	0.003	0.0010	-0.0050	
187	0.008	0.04	0.006	0.0015	-0.0050	
188	0.003	0.48	0.009	0.0025	-0.0050	
189	0.003	0.23	0.012	0.0035	-0.0050	
190	0.004	0.16	0.013	0.0035	-0.0050	
191	0.005	0.12	0.007	0.0025	-0.0050	
192	0.008	0.07	0.008	0.0025	-0.0050	
193	0.007	0.15	0.010	0.0025	-0.0050	
194	0.022	0.14	0.020	0.0060	-0.0050	