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Tittel

The Fen Project - a progress report 1st oktober 1980

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Geologiske undersøkelser utført i Gruveåsen - Bolladalenområdet sydost for Ulefoss. Undersøkelene er gjort med henblikk på skjeldne jordartselementer.

R. Jensen.

THE FEN PROJECT

A Progress Report
1^{st} October 1980

Skien

17134

By K.Mørk
A/S Sydvaranger
Project leader

Co-authors: S.D.Olmore
Union Minerals Norge A/S

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Årdal & Sunndal Verk A/S

C.W.Carstens
Elkem

CONTENTS

INTRODUCTION

This report is a review of the work that has been done on the Fen Project over the last six months. As we are still in the field season and the mapping work is in progress, we find it somewhat premature to present elaborate theories concerning geologic models and genetic relationships at this stage. However, some ideas have developed and will be presented.

Also, results of analytical work and detailed petrographic examinations are lacking at this stage, but will be dealt with and reported after the field season.

WORK PROGRESS

General

Subsequent to the signing of the Joint Venture Agreement on February 14., a work program and budget for the remainder of 1980 was worked out and presented to the Parties. On the management committee meeting on May 5. the work program and budget were approved.

Meanwhile, preparations were made at Ulefoss (organization of field base etc.) so that we were ready to start field work as soon as the program was approved.

Union geologist, Mr.Stephen Olmore, arrived in Norway in late March, and was subsequently introduced to the project. Trips were made to NGU, Trondheim (to inspect drill cores and discuss the project with NGU geologists) and to the Fen area.

Practical work in the field commenced on May 7.

Sampling grid

As a basis for a geochemical sampling program and for geophysical measurements, a (50 x 50) m grid was layed out over the Gruveåsen - Bolladalen West area (see plate 1M). A 1,5 km long, EW-running base-line was measured in detail by a professional surveyor. Profiles were then run and marked at each 50 m to the north and south of this base-line, by Fenco personell.

This grid has proven to be of major importance for orientation purposes in this densely vegetated area.

Geochemical sampling

A program for systematic sampling of bedrock from the Gruveåsen - Bolladalen West area was approved by the management committee. The objectives of this program were:

1. As previous sampling and drilling were done in limited parts of the area, additional data were required for an "utmål" application. During discussions with Bergmesteren it was concluded that systematic surface sampling would be as adequate as diamond drilling for this purpose.

2. A geochemical dispersion pattern map was considered of value as a base for future search for various elements, e.g. REE.

3. Petrographic descriptions of rock samples would also provide a basis for subsequent geological mapping.

The sampling was carried out by four local students, using portable diamond drill samplers (J.K.Smith and Pack-Sack machines). (50 - 60) cm holes were drilled as close to the grid intersections as possible.

At each point two types of sample were collected:

1. Soil sample - if possible, one from the top and one from the bottom of the soil layer, otherwise one sample.
2. Bedrock sample. A total of 70 samples were collected (see plate 1M).

The soil samples will be sent to NGU. They are presently conducting a more general geochemical soil study in an area including the Fen, and are willing to carry out the chemical analyses at no cost to the Joint Venture, in return for the samples.

The rock samples were described petrographically, a 5 cm reference sample was kept and the rest sent off to the chemical laboratory at SI.

Tuftestollen

The adit was inspected by Arbeidstilsynet and Bergmesteren. We were enjoined to have an experienced miner to go over the adit and clean the roof and sides of loose rocks. This was subsequently done by a man from A/S Sydvaranger's Mofjellet Mine.

At the management committee meeting it was also decided that a radiometric survey of the adit should be done, as part of an environmental baseline study. "Statens Institutt for Strålehygiene" measured radon and thoron and their daughter products in the air at 7 localities. A report has been received, which concludes that there is no health hazard involved in working in the adit under the present conditions for limited periods.

The Tuftestollen is thereby ready for geological mapping and sampling.

Application for "utmål"

Mr. Svinndal will prepare the application for "utmål" concerning the norwegian Government's claims. He is presently compiling data from the Søve operations, and will base the application on the modelling and reserve calculations worked out by Norsk Bergverk A/S.

For the Gruveåsen - Bolladalen West area, i.e. on Cappelen's "mutinger", Fenco shall have to prepare the application. Excisting data from this area comprise:

1. Surface from the Veiskjæring (road cut) area (FSJ 1968).
2. Systematic surface samples from this year's sampling program.
3. Diamond drill holes (F1, F2, F3, B1 and B2).
4. Mine maps from the Fen iron mine, showing the extension of the hematite dykes.

This material has been presented to Bergmesteren, and in his opinion this is adequate for an "utmål" application. He accepts the view that the whole rock suite must be regarded as potential RE-ore (provided that analyses of this year's surface samples will not disprove the picture obtained from previous assay work that there is a general "anomalous" RE-content in the rocks from this area), and that we have sufficient evidence for the downward extension of the rocks to do some tonnage calculations.

Geologist J.E.Wanvik from Elkem is compiling these data on maps and profiles. Mr. Svinndal will assist us in writing the application.

Removal of drill cores

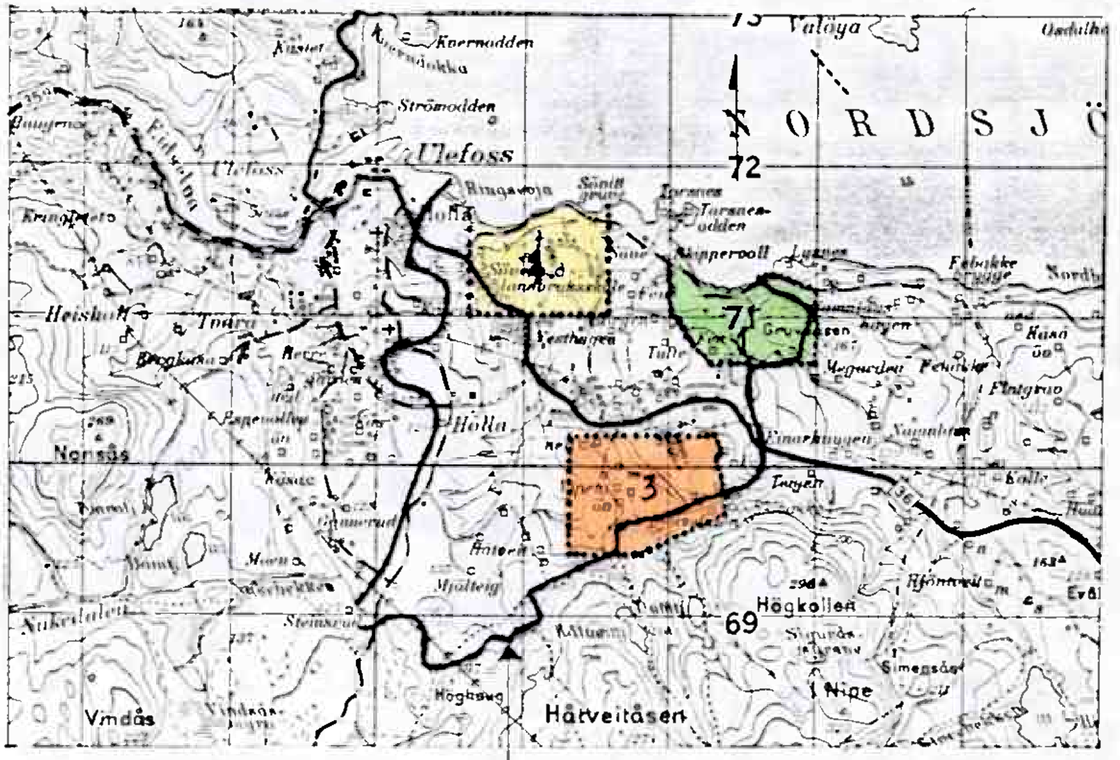
All drill cores from Fen, which were stored at NGU in Trondheim, have been moved to Ulefoss, where we are building proper core handling facilities on Cappelen's premises.

Geological mapping

Geological mapping is accomplished on scale 1 : 1000. Three areas were given priority in 1980: (fig. 1)

1. Gruveåsen - Bolladalen West (responsible: K.Mørk)
2. Hydro - Cappelen - Tufte (including Tuftestollen) (responsible: S.Olmore)
3. Rauhaug - Vipeto (responsible: V.Wiik)

Rock descriptions and classifications are largely based on mesoscopic examinations, but some microscopy has been carried out (see Olmore's report).



Scale = 1 : 50 000

Approx. boundary of Fen Complex

Fig. 1

Index to the 1980 mapping activities.

Area 1:	(green)	Gruveåsen - Bolladalen West	K.Mørk
" 2:	(yellow)	Hydro - Cappelen - Tufte	S.Olmore
" 3:	(orange)	Rauhaug - Vipeto	V.Wiik

A major problem has been the characterization and classification of rocks and rock varieties, and the three geologists have made a point of exchanging experiences and visiting each other's fields, in an attempt to set up uniform criterions for classification of rocks. This is not and easy task and it has resulted in (at times) vivaceous but inspiring discussions.

Olmore, Wiik and undersigned present separate reports from each sub-area. Since time is an important factor at this late stage of the field season, no attempt has been made to edit and compile the results from the three sub-areas into a comprehensive presentation. The three reports (as well as Mr. Carstens report on geophysics, see below) are therefore presented in an unabridged version.

Stabekk, September 29., 1980

Kristen Mørk

Kristen Mørk

og Tantal
UO indikerer U i pyroklore.
Har ikke analyser.

Nb-Th-V-R
ZFFE

NGU

GEOLOGICAL MAPPING OF THE GRUVEÅSEN - BOLLADALEN AREA

By K.Mørk

Introduction

This area has been considered as having the largest potential for RE mineralization. Existing geologic map is from Sæther (1957). This map is incorporated in Landreth's report (1979).

This year's mapping activities started along the road to Febakke (see plate 1M), where there is almost continous exposure from the gneis east of the Fen complex, through the red carbonatite (Rødberg) on Sæther's map (where the old iron mines are situated) and into the Rauhaugite rock in the central parts of the complex. The relationships between the various rock types can here be studied in detail and a sequence of events can be documented.

The boundary between the gneis and the complex rocks was then mapped from the road to the SE, towards the Gruveåsen. Here, outcropping is less good, but a picture of the border relations has emerged.

The drill cores from the geochemical sampling were described petrographically, and this serves as a preliminary guide to the geology of the as yet unmapped parts of the Gruveåsen (see plate 1M).

The main problem has been to establish criteria for rock classification, as it soon became evident that Sæther's map gives a simplified and generalized picture of the geological conditions.

Rock types

Archean gneis.

Well foliated gneis make up the precambrian rocks immidiately east of the Fen complex. The gneis here represent parts of a supracrustal series of rocks of the Telemark suite, and is different to the more granittic gneis west and south of the complex (S.Dahlgren, personal comm.).

Along the road cut the gneis sustain it's foliated texture quite close to the contact. Dykes and lenses of fine grained red, felspatic rocks are commonly encountered. Fenitization has probably taken place to some extent, but on a mesoscopic scale it is difficult to recognize the degree of fenitization.

NW-running fault zones (crushed rock, 10 - 20 cm) cutting the gneis are also commonly encountered, and in some of these, massive hematite is deposited.

Approaching the boundary from E towards W, crosscutting lenses and dykes of red carbonatite start to appear. A banding parallell to the contact is developed, and is interpreted as flow banding.

Within 2 - 3 m of the complex boundary, a porous, highly altered and appearently tectonized rock is developed, which is difficult to classify, but which is believed to be of gneissic origin.

Volcanic breccia.

The first rock to appear west of the gneis in the road profile, is a breccia, i.e. angular fragments in a fine-grained matrix. The actual boundary is sharp. A hematite vein is developed on the contact.

Fragments of red carbonatite dominates in the breccia close to the boundary, thus indicating that the breccia was emplaced after crystallization of the red carbonatite. Fragments of felspar-amphibole rocks are also common, i.e. of gneis derivation, but they look more fenitized than the gneis just east of the contact. Also, fragments of light colored carbonatite are seen.

It is difficult to give a general description of the breccia matrix, as it varies throughout the breccia body. In parts it is rich in carbonates, in other parts siliceous material dominates. It also vary in grain size.

Red carbonatite (Rødberg)

Just above (south of) the old Fen iron works there is a topographic depression, which is covered along the road. East of this "valley" the volcanic breccia dominate, on the western side we run into massive, red carbonatite. Fragmental structures are observed also in this rock, but is not so prevalent. The main adit to the Fen mines was worked on a hematite vein in the red carbonatite.

Further west along the road, the red carbonatite is tectonically bordering another volcanic breccia, which prevail up to Bolladalen. West of Bolladalen, red carbonatite again appear. Further west there is the Rauhaugite of Sæther, but the boundary and the light carbonatite have not yet been studied in detail.

The gneis - Fen complex boundary

As mentioned, this boundary is defined at the road cut as the contact between altered gneis and volcanic breccia, with indications of tectonization along the contact. Up along the slope towards SE the same picture prevails. Towards the crest of the hill the gneis change in character: the rock appear to be crushed, the foliation becomes diffuse or lacking, and the rock is more fenite-looking. The term f e n i t e b r e c c i a is used.

Inside the complex, the volcanic breccia rock disappears, and the fenite breccia is in contact with massive, red carbonatite. The contact between volcanic breccia and this red carbonatite has not been studied yet.

There is indication of tectonic movement along the complex boundary, or close to it, in this area, which complicates the picture. This is where mapping is going on at present.

Structural geology

As mentioned, several fault zones have been observed, cutting both the gneis and the "Fen rocks". They have a rather constant strike of 130 - 150^g, with vertical or nearly vertical dip. Some of them are characterized by a 10 - 20 cm zone of crushed rock, and in some hematite mineralization occur.

This direction coinside with a prominent topographic feature, of which Bolladalen is one example, but there are others parallell or nearly parallell to it across the Gruveåsen. As mentioned, some movement appear to have taken place along such a structure at the eastern margin of the complex.

Also, this direction coinside with the direction of most of the hematite ore bodies, as revealed on old maps. The highest RE-assays from previous work were encountered in samples of hematite ore, and therefore such structural features may be a controlling factor both for hematite- and possibly also for enriched RE-mineralization.

Stabekk, September 29., 1980

Kristen Mørk

Kristen Mørk

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Molycorp Report.

Sæther, E. 1957: The Alkaline Rock Province of the Fen Area in Southern Norway.
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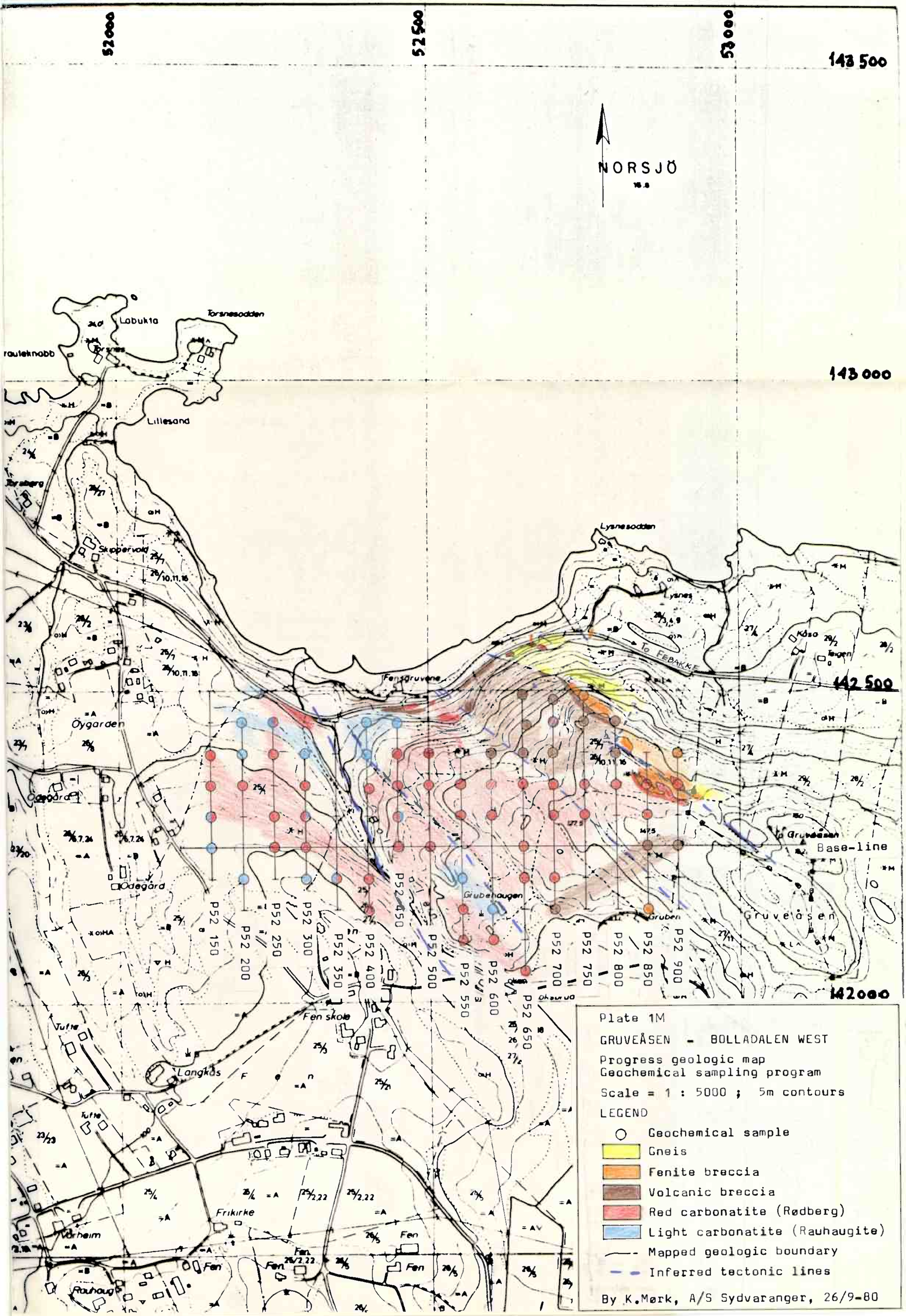

Plate 1M
GRUVEÅSEN - BOLLADALEN WEST
Progress geologic map
Geochemical sampling program
Scale = 1 : 5000 ; 5m contours
LEGEND
Geochemical sample
Gneis
Fenite breccia
Volcanic breccia
Red carbonatite (Rødberg)
Light carbonatite (Rauhaugite)
Mapped geologic boundary
Inferred tectonic lines
By K.Mørk, A/S Sydvaranger, 26/9-80
NORSJÖ
52000
52500
53000
143 500
143 000
142 500
142000
Base-line
P52 150
P52 200
P52 250
P52 300
P52 350
P52 400
P52 450
P52 500
P52 550
P52 600
P52 650
P52 700
P52 750
P52 800
P52 850
P52 900
Torsnesodden
Lobukta
Lillesand
Lysnesodden
Lysnes
To FEBAKKE
Fensgruvene
Gruvåsen
Gruveåsen
Grubehaugen
Gruben
Øygarden
Odegård
Ødegård
Skippervold
Fen skole
Langkås
Frikirke
Fen
Rauhaug
Køsa
Teigen

UNION MINERALS NORGE A/S
Post Box 377
4301 Sandnes - Norway

APPENDIX II

September 20, 1980

Mr. Thor L. Sverdrup
Exploration Manager
A/S Sydvaranger
Post Office Box 83

1321 STABEKK

Dear Mr. Sverdrup:

Attached herewith is a report summarizing my thoughts regarding the Fen Complex to date. This is intended principally for K. Mørk's use in compiling a more comprehensive picture of the deposit for the upcoming management committee meetings in October.

Sincerely,

S.D. Olmore
Manager of Exploration
Union Minerals Norge A/S

CC: J.W. Keim
G.H. Laughbaum, Jr.
W.R. Moran

PROGRESS REPORT

1980 FIELD SEASON

FEN PROJECT

by: S.D. Olmore
Manager of Exploration
Union Minerals Norge A/S

September 20, 1980

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FIGURES

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SUMMARY

The Hydro-Cappelen area of the Fen alkaline complex has been mapped in detail. Field relationships and megascopic geology indicate the presence of a diverse fenite mass peripheral to a multiple-phase carbonatite body (see Figure 1). The emplacement of carbonatite and fenitization are strongly influenced by structure.

Multiple stages of fenitization have been superposed on gneissic wall rocks in the Hydro-Cappelen area. As sovite is approached gneiss grades from a weakly altered rock containing agerine, riebekite and magnetite to an intensely-altered hybrid rock that has been flooded with carbonate. This carbonate-flooded rock may be referred to as metasomatic carbonatite.

Three phases of carbonatite are recognized, each exhibiting excellent intrusive relations with enclosing wall rocks. The earliest phase is sovite which has been injected along northeast striking fractures that dip towards the central portion of the complex. Sovite is cut by later dolomitic dikes. The latest carbonate phase is conspicuously iron-bearing and is intruded along northwest striking fractures.

Structures of the complex have two principal orientations - northeast (about N55°E) and northwest (about N30°W). The northeast-striking fractures developed prior to, or contemporaneous with, the development of the complex and controlled the emplacement of carbonate dikes and fenitization. There is an alignment of northeast-trending magnetic anomalies over the central portion of the Fen complex. This could reflect a large magnetite concentration at depth with a northeast trend.

Northwest structural trends are later than the northeast ones and appear to form substantial fault zones. Northwest-striking faults are interpreted as having offset the <u>source</u> of the northeast-striking anomaly.

The overall geometry of the complex is visualized as that of an ellipse with its major axis aligned in an approximate N55°E direction.

Figure 1. Two separate phases of carbonatite transecting fenitized granitic gneiss - a visual representation of a portion of the geologic sequence of events in the Fen area.

INTRODUCTION

The purpose of this report is to document field exploration activities and concepts developed while aiming toward a geologic understanding for commercial purposes of the Fen alkaline complex. This information shall then be presented during the FENCO-Union management committee meeting in October of 1980.

Largely what is presented here is the megascopic geology of a small, but important portion of the complex. A detailed geologic map of the Hydro-Cappelen portion of the complex is presented (Plate 1). Mapping activities (Figure 2) covered an area of approximately 3/4 km^2. Exposure is generally poor owing to thick soil cover, but there are a few exceptional areas; these have received the most attention: the Hydro open cut, Cappelen open cut, the Tufte adit and road cuts along Ulefossveien and the road to Febakke. A total of fifty-eight representative rock samples have been taken and thirty-eight of these have been cut for polished thin section and scanned under the microscope. The attempt here is to do enough petrography to help define and sort out the principal mappable rock units.

The present goal is to develop a rock classification and a systemmatic geology of the sequence of events in the deposit. These shall then serve as a frame of reference for detailed core logging and underground mapping in the Tufte adit. A first-hand understanding will also facilitate interpretation of previous geologic efforts on the deposit - for example Sæther (1957).

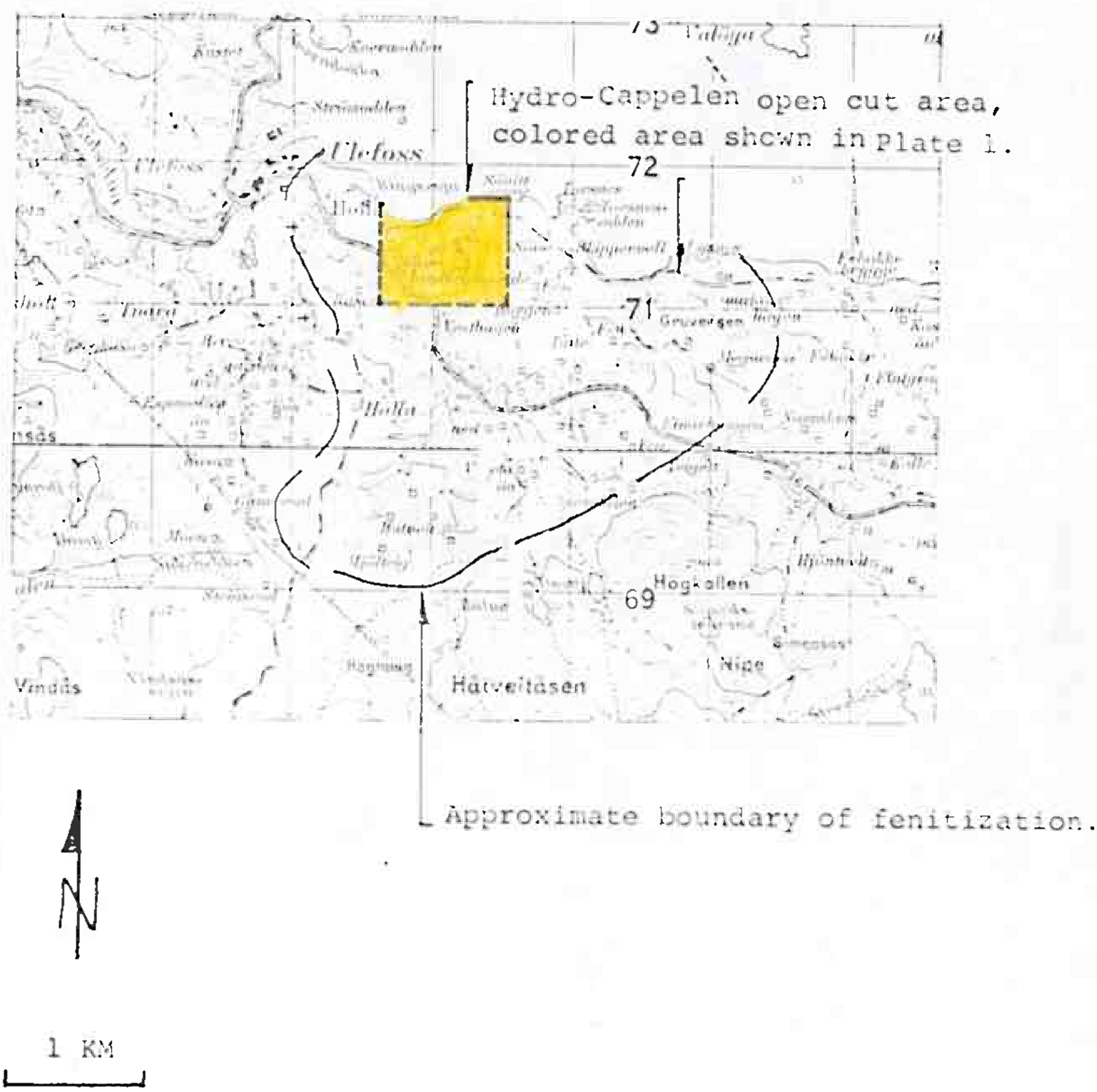

Figure 2. Index to 1980 activities in the Fen Project area.

ROCK UNITS

Granitic Gneiss

Granitic gneiss of Archean age comprises the country rock surrounding the Fen alkaline complex. Brief examination of unweathered gneiss along a road cut about 5 km northwest of the Fen area was made. Magascopically the rock is well foliated with numerous dikes and veins of apatite and pegmatite that cut across foliation. Also included in the gneiss are local patches of amphibolite. Locally the gneiss contains large 2 - 5 cm augen of K-feldspar.

Under the microscope the gneiss has an average grain size of about 1 mm and is seen to consist principally of strongly undulose quartz, microcline, perthitic K-feldspar, plagioclase, biotite (with alteration rims of chlorite), and accessory apatite and zircon.

Fenite

Fenite is perhaps the most varied rock type in the complex. Its characteristics are best observed in road cut at the intersection of Ulefossveien and Grandvoldveien (see geologic map) adjacent the Hydro steinbrudd in road cut, and underground in the first 50 meters of the portal of the Tuftestollen. Fenite is extremely varied in mineralogy and texture, and rock classed as fenite here will undoubtedly be separated into several sub-units as the work progresses. Fenite formed from the hydrothermal alteration of granitic gneiss adjacent carbonatite injections (Sæther, 1957).

A rapid scan of thin sections allows a few comments regarding fenite mineralogy. Primary or residual minerals relict from the granitic gneiss parent are quartz, K-feldspar, biotite and apatite. Secondary fenitization minerals result from hydrothermal introduction of new minerals and replacement of old minerals or introduction of new minerals in veins. Carbonate minerals occur as replacements of primary minerals as well as occur in veinlets. The following mineral occurences are common: riebekite in veinlets and open spaces, small .05 - .5 mm flakes of disseminated biotite, agerine augite in veinlets and veins (one of the earliest and most widespread of the fenite minerals). K-feldspar occurs in grains averaging 1 - 2 mm that have been flooded through fenite; it also occurs as veinlets and occasionally as large dikes in dark fenitized gneiss (Figure 3). Albite also is found as .1 mm grains flooding fenitized granitic gneiss. Magnetite occurs as hairline veinlets and also replaces biotite in weakly fenitized rock.

Fenitization appears to be the strongest adjacent to carbonatite dikes and is typified by introduced K-feldspar and albite along with agerine. The best example of this is in

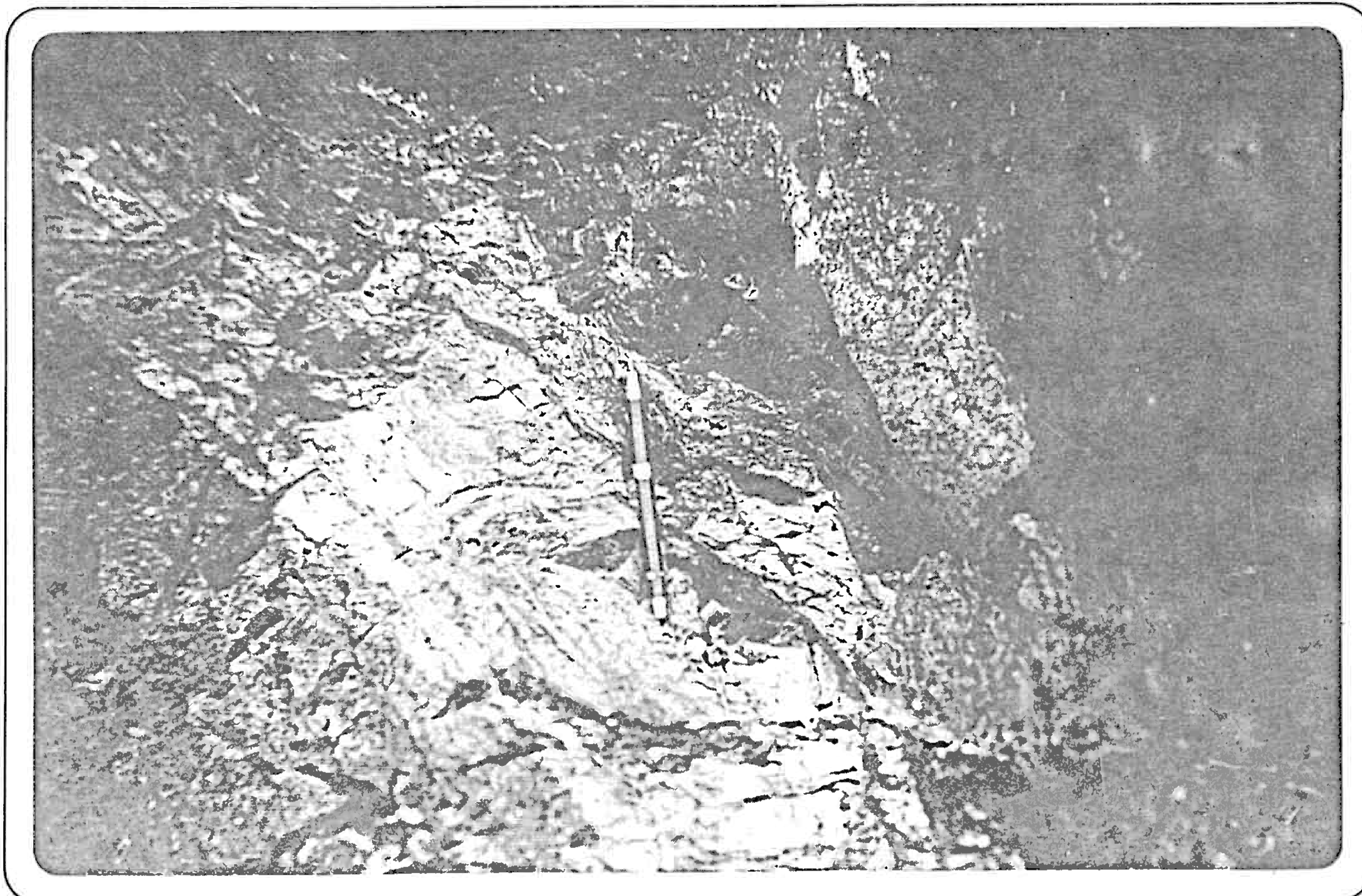

Figure 3. Dike of pink, fine-grained K-feldspar cutting through dark fenite with abundant agerine augite and riebekite veinlets.

sample F0037 from the Cappelen quarry. Where fenitization is less intense it is typified by reibikite and agerine forming veinlets, and magnetite replacing primary biotite.

As can be seen in Figure 1 there are at least two events of fenitization superposed on one another and the descriptions above include the minerals formed from perhaps several spatially overlapping events. For example, Figure 4 is an illustration of sovite dikes and veins with alteration haloes cutting previously fenitized gneiss.

Carbonate Flooded Fenite

Carbonate-flooded fenite, the equivalent of metasomatic carbonatite is observed at three localities. One is adjacent the Hydro dike on the east side, one is adjacent the foundation of the old niobium smelter and one is inside the Cappelen open cut. Carbonate-flooded fenite is observed to be a hybrid rock resulting from carbonate introduction into fenite in contact with sovite intrusions. This rock unit may correspond to the basic silicate rocks of Sæther (1957) and perhaps the Hollaite of Svindal (personal communication, 1980).

Evidence for the metasomatic origin of the rock is: the gradation from carbonate rock to fenite with the lack of well-defined contacts between the two, and the presence of mixed, hybrid textures with mixed mineralogy. Minerals present are albite, biotite, K-feldspar, pyrite and agerine immersed in a carbonate matrix. The rock clearly has a trashy texture with grains ranging from .2 mm to 2 mm in largest dimension. As the ratio of silicates to carbonate increases to about 10:1 the rock is best classified as a soda and potash metasomatized fenite. Carbonate-flooded fenite and potash metasomatized fenite are believed to occur as numerous inclusions in sovite and can easily be mistaken for primary, magmatic silicocarbonatite lenses.

Silicocarbonatite

Silicocarbonatite is a contemporaneous igneous phase of sovite. The best exposures of this unit are on the north side of the Cappelen open cut and along the Ulefossveien road cut. The best exposure along Ulefossveien is diagrammed in Figure 5. This unit has been separated from sovite where the percentage of silicates exceeds about 50 percent. In many localities sovite and silicocarbonatite are so intimately related and mixed it is impossible to separate them by mapping, so one must in these instances choose the dominant rock type and make the appropriate designation.

Principal mineral phases comprising silicocarbonatite are biotite, magnetite, pyrochlore and apatite.

Figure 4. Sovite dikes with biotite - agerine? alteration haloes cutting previously fenitized granitic gneiss.

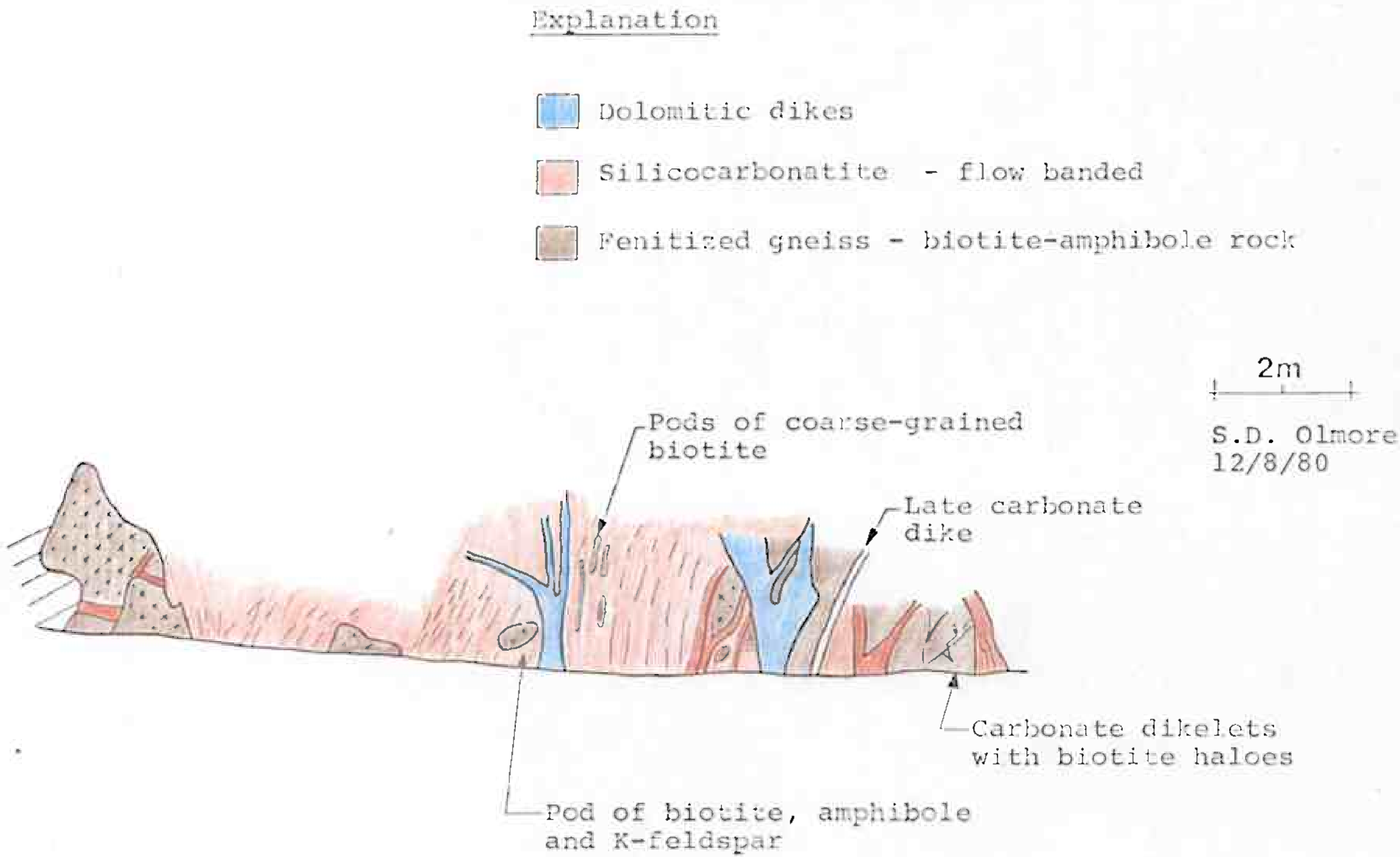

Figure 5. Cross sectional sketch of carbonatite relations in roadcut. Looking northeast. Shows inclusions of fenitized granitic gneiss in flow-banded silicocarbonatite. Later dolomitic dikes cut across foliation.

Sovite

The best exposures of sovite are in the Hydro and Cappèlen quarries and underground in the Tufte adit about 50 meters from its portal (see geologic map, Plate 1, and Figure 6).

Sovite on fresh surface is a white to yellowish gray, medium to fine-grained equigranular rock. On weathered surfaces the unit is gray and minerals more resistent to weathering than calcite such as pyrochlore and apatite stand out in relief.

Under the microscope the rock is seen to be comprised dominantly of anhedral calcite grains in an interlocking tightly-fit mosaic. The grain size is variable, for example at the Hydro open cut the grains average .2 - .4 mm in largest dimension and in the Cappelen open cut the sovite is typified by grains averaging 1 - 3 mm in largest dimension. Dolomite is also undoubtedly mixed in with the calcite but its abundance is yet to be established. Apatite grains are common and tend to occur in clusters of grains on the order of .1 - .5 mm in maximum dimension. Other accessory minerals are magnetite, pyrochlore, phlogopite, pyrite and sphene. Apatite columns are commonly arranged in radial patterns.

A quick scan in thin section indicates that the sovite is foliated, this is especially evident in specimens taken near the margins of the dike, where it comes in contact with fenitized wall rocks. The foliation is defined by sub-parallel alignment of apatite and phlogopite.

Electron microprobe analysis of the mica in the sovite (Table 1) shows that it is an "Mg-rich biotite (phlogopite) and that despite the high Mg content of the biotite, fluorine content is relatively low". (A.J. Gunow, personal communication, 1980).

Dolomitic Carbonatite

Dolomitic carbonatite is exposed in three small outcrops along Ulefossveien. It also may subcrop in the southeast portion of the Tuftestollen where it is termed Rauhaugite by Sæther. It is a medium grained white to light gray dense carbonate, lacking conspicuous silicates and containing trace amounts of sulfides, where the unit transects country rocks fenitic haloes are developed. Figure 5 shows dense white dolomitic carbonate dikes cutting well foliated silico-carbonatite in road cut along Ulefossveien.

Late Dolomitic Veins

Late dolomitic veins are apparently widespread in the Fen

ELEMENT	WT% OXIDE	WT%
Si	41.33	19.32
Al	11.15	5.90
Cl	0.01	0.01
F	1.97	1.97
Ti	0.27	0.20
Mn	0.52	0.40
Fe^{2+} Fe^{3+}	2.70	2.10
Mg	27.86	16.80
Cr	N.D.	N.D.
K	9.93	8.24
Ba	N.D.	N.D.
Ca	1.33	0.95
Na	N.D.	N.D.
H_2O^+ (calc)	3.72	N.D.
P	N.D.	N.D.
Sn	N.D.	N.D.
Cs	N.D.	N.D.
(F=O)	0.87	
TOTAL	99.92	

Table 1. Electron microprobe analysis of biotite in sovite from Hydro Steinbrudd. (see text for discussion)

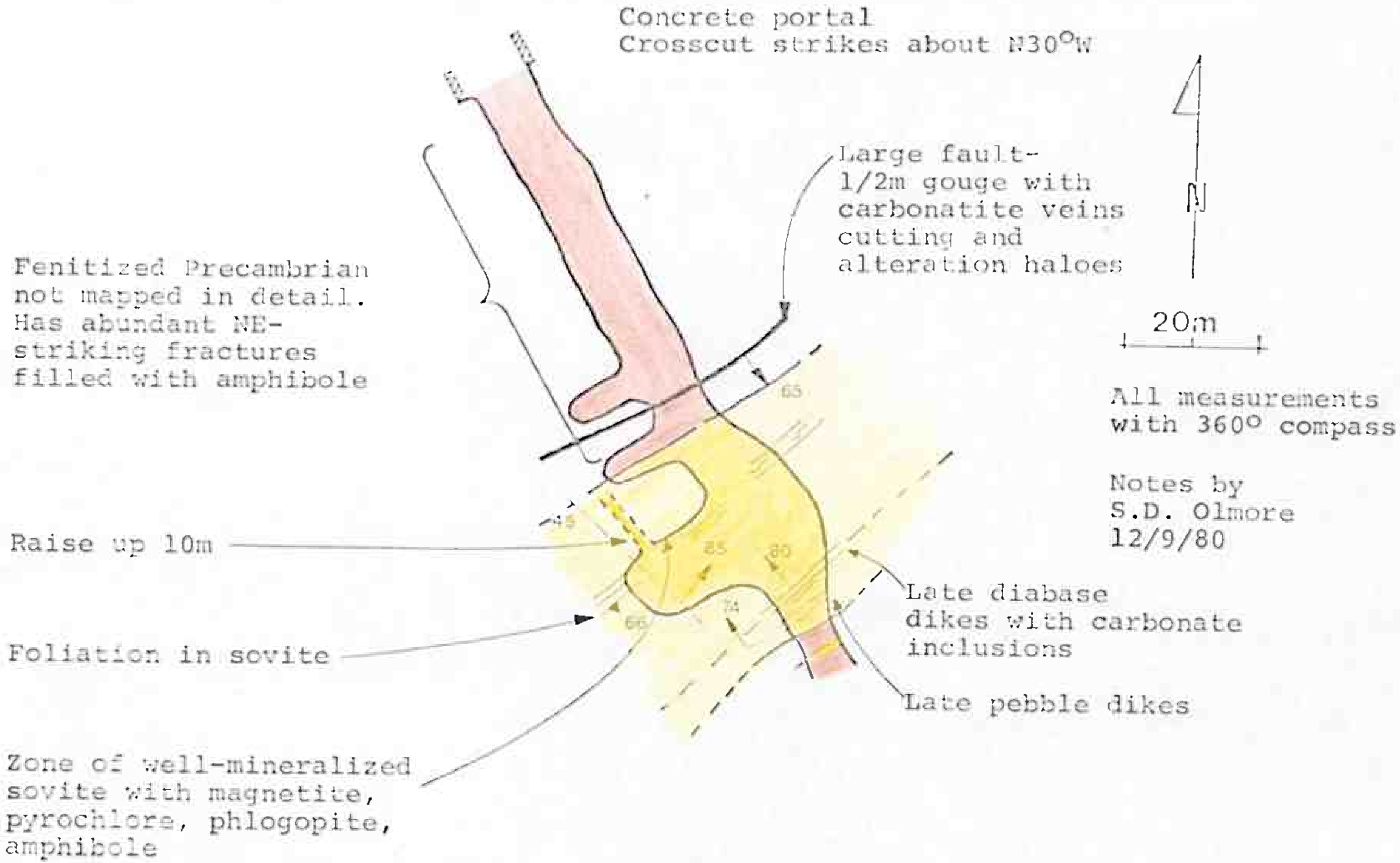

Figure 6. Sketch map of Tuftestollen workings near portal. shows partially mined 40m thick Hydro dike (sovite). The dike was probably injected along a pre-existing northeast-trending fault zone. The dike is inferred to dip southeast about 65°.

area. They are especially well exposed in the Hydro and Cappelen open cuts. They are conspicuous in outcrop because they are the latest crosscutting carbonate phase and because they usually weather brown. Locally the veins occur as swarms, and were evidently so numerous at the Cappelen workings that they presented a considerable ore control problem (Svindal, personal cummunication). Generally the veins have a northwest strike (see Plate 1).

Under the microscope the grain size of the veins is conspicuously finer than the sovite and ranges from .05 to .1 mm. Minerals present are dolomite, trace amounts of pyrite, magnetite and apatite. Perhaps some of the carbonate is ankeritic or sideritic, for there are numerous ferruginous haloes developed on margins of carbonate grains.

Damtjernite

Damtjernite is thought to be the youngest intrusive rock in the Fen complex that is related to the genesis of the complex, sensu stricto. A few patches of damtjernite and associated breccia crop out in the map area. Cross cutting relations at the Hydro steinbrudd indicate that this unit clearly cuts sovite and late dolomitic carbonatite veins, for here it contains inclusions of both.

The damtjernite consists of phlogopite and angular wall rock fragments of carbonatite ranging from about 1 cm to 15 or 20 cm in largest dimension immersed in a black matrix of pyroxene and amphibole. The angular fragments of carbonate give evidence for the high melting temperature of carbonate as well as the insolubility of carbonate in damtjernite magma.

It is suspected that the damtjernite was introduced along northwest -striking fractures, and thus may be a sample of the carbonate-phase-depleted parent magma of the complex.

Diabase

Diabase dikes are the youngest igneous phase in the complex area. These may be of Permian age and thus unrelated to the genesis of the alkaline complex, where the diabase contains abundant inclusions of carbonate from adjacent wall rocks it becomes an intrusion breccia. The diabase has been intruded in late fractures exposed in the Hydro open cut, the Cappelen open cut, underground in the Tuftestollen and in a cut near the Esso station along Ulefossveien.

STRUCTURE

Fractures

Fractures in the Hydro-Cappelen area exerted important controls on the introduction of carbonatite dikes and fenitizing solutions.

One well defined set of fractures strikes about N60°E plus or minus 10° and dips to the southeast about 55° plus or minus 20°. This set is exceptionally well exposed in the Tufte adit and along the Ulefossveien road cut. The set is particularly easy to map because it has been invaded by fenitizing solutions and carbonatite dikes and veins. The former presence of fenitizing solutions is made apparent by agerine and riebekite (see Plate 1). The Hydro dike has been injected along a fault zone striking approximately N55°E and dipping about 65° to the southeast (see Figure 6). That the fault zone preceded carbonatite injection is considered proven because an adjacent sub-parallel fault zone is cut by carbonate veins and the gouge adjacent the veins is fenitized. Carbonatite dikes filling fractures in the Cappelen open cut also have a northeast strike (see Plate 1).

The definition of northeast structural trends in the complex as a whole is aided by aerial photo studies and topographic analysis. In Plate 2 the linear features taken from photographic and topographic examination are plotted on a sketch copy of the 1949 magnetic map of the complex. It is interesting to note that the main northeast alignment of magnetic highs is subparallel to the faults which have guided carbonate emplacement and fenitization in the Hydro-Cappelen area.

A northwest-striking set of fractures is perhaps as well defined as the northeast set described above. The northwest set developed later than the northeast set and has been invaded by late dolomitic carbonatite veins (see Plate 1). There are also a few faults with a northwest strike. A large northwest-striking fault is inferred along the trace of Ulefossveien. Another northwest-striking fault is inferred between the Hydro and Cappelen open cuts; this fault may truncate the Hydro dike. Several large northwest faults crop out in the Cappelen open cut. One in particular extends from the Cappelen open cut southeast to the old smelter.

Topographic analysis of the Fen area using aerial photographs permits the inference of a number of northwest-striking faults on the magnetic-structural map (see Plate 2). A veritable swarm of northwest-striking faults is inferred in the Gruveåsen, the largest of which appears to extend along the Bolladal. This fault may be expressed by the abrupt truncation of the northeast-trending magnetic high. Another large northwest linear can be traced from Damtjern Lake to Vipeto Mellom and from here to Ullefossveien. This fault may be expressed on the magnetic map by the gap between the two segments of the northeast-trending magnetic high (see Plate 2).

Carbonatite Emplacement

The carbonatite masses are generally strongly foliated. Foliation is well defined in the silicocarbonatite and sovite units by the alignment of dark silicate minerals, magnetite and pyrochlore. Generally the foliation is sub-parallel to the trace of the geometry of the carbonate dike. This is well exhibited underground in the Tufte adit (see Figure 6).

The foliation, or flow structure, of the carbonate units is accentuated by the sub-parallel alignment and plastic stretching of fenite inclusions in the magma.

The foliated nature of the carbonatite mass, as well as the apparent insolubility of fenite in carbonate magma, leads to the hypothesis that it may have been emplaced as a mass of relatively dry viscous paste and may have been forced into every major crack and crevice in the overlying fenitized wall rocks. Thus, the emplacement of the carbonatite mass is hypothesized to be structurally controlled.

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APPENDIX - SAMPLE DESCRIPTIONS

See geologic map for sample location.

F0001		Gruveåsen, gneiss with vein of specular hematite and quartz.
F0002	(TS)	Granitic gneiss, medium grained, fenitized.
F0003	(TS)	K-feldspar dike, pink, near collar of Tuftestolien, typical of fenitized gneiss.
F0004	(TS)	Granitic gneiss, fenitized.
F0005	(TS)	Granitic gneiss, fenitized.
F0006	(TS)	Granitic gneiss, fenitized.
F0007	(TS)	Granitic gneiss, well foliated - from outside complex.
F0008	(TS)	Dike rock from outside complex.
F0009	(TS)	Hydro carbonatite (sovite), Hydro steinbrudd.
F0010	(TS)	Biotite - amphibole rock at contact with hydro carbonatite, also 1-3 percent pyrite, Hydro steinbrudd.
F0011	(TS)	Dolomite dike, late, with finely disseminated pyrite, Hydro steinbrudd.
F0012	(TS)	Carbonatite, sovite, typical, with disseminated sulfides and magnetite.
F0013	(TS)	Fenitized gneiss, Hydro steinbrudd.
F0014	(TS)	Carbonatite, sovite, 1mm flakes of green phlogopite, magnetite, Hydro steinbrudd.
F0015	(TS)	Carbonatite, sovite, with late dolomitic veing cutting.
F0016	(TS)	Carbonatite disseminated biotite, magnetite, sulfides, pyrochlore, east margin of Hydro steinbrudd. Radial aggregates of carbonate grains.
F0017	(TS)	Carbonate-flooded granitic gneiss?
F0018	(TS)	Carbonate-biotite rock with disseminated sulfides.
F0019	(TS)	Same as F0018.
F0020	(TS)	Slag from old smelter at Fen, biotite rich.

F0021	(TS's)	A,B,C,D,E. Fine carbonatite samples from underground at Tuftestollen locations are uncontrolled.
F0022	(2 TS's)	Foliated hydro carbonatite with inclusions, Hydro steinbrudd.
F0023	(TS)	Mafic inclusion in sovite, mostly chlorite.
F0024	(TS)	Sovite, Hydro steinbrudd.
F0025	(1)	Late dolomite vein on northwest trend - Hydro steinbrudd.
F0025	(2)	Late dolomite vein - same as above.
F0026		Silico carbonatite on margin of Hydro dike - Hydro steinbrudd.
F0027	(2 TS's)	Sovite with 20 to 30 percent magnetite from the back of the Cappelen steinbrudd - check magnetite for vanadium content.
F0028	(2 TS's)	Biotite-rich carbonatite from Cappelen steinbrudd.
F0029	(TS)	Intrusive breccia adjacent diabase dike in Cappelen steinbrudd, has a northeast strike.
F0030	(TS)	Biotite-rich fenite - compare with primary magmatic biotite.
F0031	(TS)	Fenitized granitic gneiss with exceptionally pink K-feldspar - abundant chlorite.
F0032	(2 TS's)	Silico-carbonatite.
F0033	(TS)	Granitic gneiss - fenitized, is it K-feldspathized at this locality?
F0034A	(TS)	Sovite, Cappelen steinbrudd.
F0034B	(TS)	Sovite, Cappelen steinbrudd.
F0035	(TS)	Sovite magnetite rich, Cappelen steinbrudd.
F0036	(TS)	Sovite, Cappelen steinbrudd.
F0037	(2 TS's)	Fenite, could be carbonate flooded zone.

Samples F0038 - F0058 have not been sent for thin section as of this writing.

29/9/80
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GEOLOGICAL MAPPING IN THE RULLEKOLL-VIPETO AREA

In accordance with the work schedule drawn up for the 1980 field season, ASV-geologist Wiik assumed responsibility for the detailed re-mapping of this south-eastern quadrangle of the Fen complex. The work started in May-June, but was severely hampered by the demand for simultaneous supervision of the Gruveåsen grid-sampling programme. No progress was made during July, when Wiik was away on ASV assignments and vacation.

Upong resumption of the field work in early August, top priority was given to the Vipeto area, where visiting Union and Fenco geologists had earlier discovered pyrochlore-rich carbonatite in fresh road cuts along the cart track to Håtveit-tjern. This søvite body was regarded as a possible drilling target for the 1981 operations, and project leader Mork joined Wiik in mapping and sampling the surface expressions of this so-called Vipeto søvite.

By mid-September most of the necessary field work had been completed, and a detailed documentation: "The Vipeto Søvite - A drilling Proposal" is now under preparation. No chemical data are as yet available to substantiate the claim that the Vipeto søvite must be explored by drilling as potential niobium ore. Mapping has, however, indicated that the isolated søvite occurences might well belong to one fairly large intrusive body of carbonatite extending from Rullekoll in the east to somewhere W of Håtveitbekken in the west. According to Ramberg's gravity modelling, such a body of søvite could extend to a depth of 1000 m in this area.

While the geologic setting of the area cannot be claimed to be resolved, certain important age relationships have been established. The main søvite intrusion appears to be younger than the vipetoite and other silico-carbonatite rocks occurring around the margins and occasionally as bodies thought to be roof pendants relative to the søvite. The Vipeto søvite has in turn been intruded by damtjernite and associated volcanic breccias of variable character and composition. Still later, damtjernite and associated breccia rocks have in part been transformed to the red carbonate - hematite rock called rødberg.

Young veins and minor intrusive bodies of dolomitic carbonatite seem somehow to be connected with the process of rødberg formation, whereas elsewhere damtjernite appears to grade via volcanic breccia into carbonatite breccia and massive dolomitic carbonatite.

This relatively orderly picture is to some extent complicated by faulting and brecciation caused by tectonic movement, and more ominously, by observations that do not fit the model, e.g. the appearance of rødberg fragments in an otherwise normal damtjernite.

An estimated 4 - 6 weeks of additional geological mapping will be required to complete the map in scale 1:1000 covering the Rullekoll-Vipeto quadrangle. Even if better here than in the areas further north and west, the rock exposure is relatively poor, and surface mapping should not be expected to yield full information about the distribution of the different rock types in the area. Geophysics and data from diamond drillholes are expected to provide valuable supplementary information.

As regards the economic potential of the quadrangle, RE-mineralization in connection with the rødberg (and rauhaugite?) the Rullekoll area stands alongside the pyrochlore-bearing Vipeto søvite as a prospect worthy of further investigation. Whereas the distribution of pyrochlore within the Vipeto sovite probably is a matter of primary dispersion within one or more homogeneous carbonatite intrusives and thus largely independent of later geologic events, the RE mineralization appears to be influenced by several factors such as presence of young dolomitic carbonatite, rødberg and tectonic shearing. For this reason geologic mapping should be completed before more direct RE exploration is undertaken.

If weather conditions permit, further mapping and sampling in the Rullekoll area will be carried out this year. When it comes to more direct exploration for REE, such a programme should be based on the experience gained from the investigations in Gruveåsen.

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GEOCHEMISTRY

Following negotiations with analytical laboratories in early 1980, an agreement was made with SI (Central Institute for Industrial Research, Oslo) concerning quick, routine analysis of large series of samples e.g. core samples from exploration drillholes. A similar agreement with IFE (Institute for Energy Technology, Kjeller) was designed to provide Fenco with more accurate information about REE contents of selected samples of particular interest.

As a start-up exercise, SI was given 20 drillcore samples from earlier exploration drilling carried out by FSJ in the NE part of the Fen complex. According to the agreement, SI should determine La, Ce, Nd, Y, Nb, Th, V and P by XRF on rock powder. It turned out, however, that the high content of Ba in the Fen carbonatites precludes the XRF determination of V. SI has therefore proposed an alternative scheme, where V has been excluded from the first-step routine XRF assay but will be determined along with several other elements in an optional second step that requires decomposition of the sample material in acid.

SI has proposed the following two-step scheme:

Step one: XRF on powder - determination of La, Ce, Nd, Y, Nb, Th and P with an accuracy of at least $\pm$ 30 relative %.
Price per sample: NOK 130,-

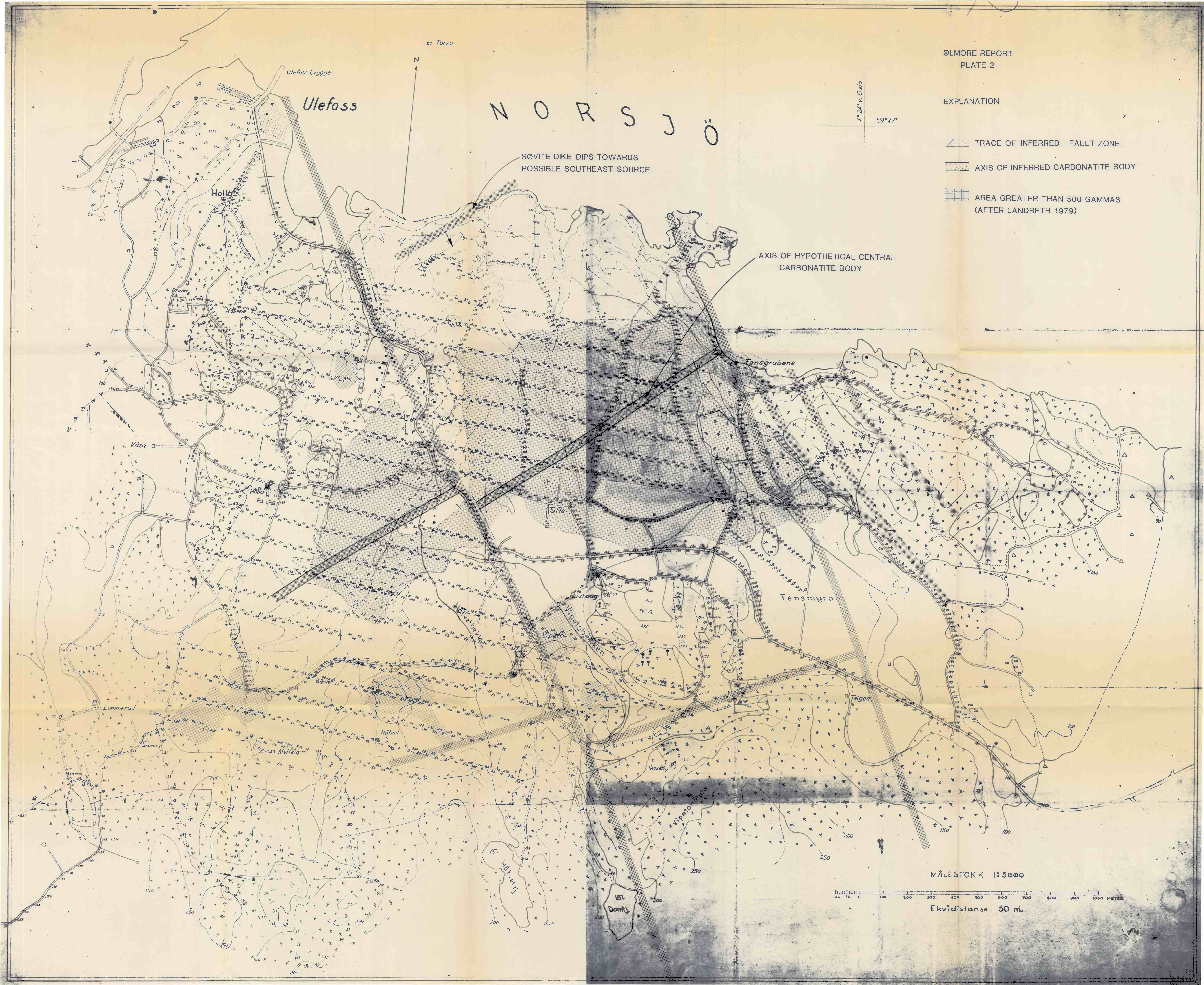
Step two: Complete decomposition of sample by treatment with HCl, HF, and H_3BO_3 - determination of Ca, Mg, Fe, P and V by ICP (plasma spectroscopy).
Price per sample: NOK 170,-

Note: A large number of additional elements may be determined during the ICP run for an additional charge of NOK 5,- to 10,- per element, the exact charge depending on the number of elements requested.

As an alternative second step, SI proposes HCl treatment of the sample followed by ICP analysis of the solute, no attention being paid to the insoluble residue which will consist mainly of silicate minerals. For this simplified procedure SI charges NOK 150,- per sample. It is felt that the price difference is too small to justify the loss of accuracy caused by ignoring an unknown and variable weight% of insoluble residue.

In the same way, IFE was asked to re-analyse 50 rock samples representing a wide range of Fen rocks. This laboratory will use a combination of XRF on fused sample material and neutronactivation to determine La, Ce, Nd, Y, Sm, Gd and Eu with high precision and accuracy. IFE expects of the order of 250 samples to be analysed by this procedure and will charge a price of NOK 375,- per sample.

Both IFE and SI have had certain difficulties in reconciling their new results with those initially reported for the same samples and have had to carry out much additional work in order to resolve this problem. Both laboratories will submit their reports early next month. SI will then proceed to analyse the drilled-out grid samples from Gruveåsen and handspecimen-samples from the Vibeto sovite, altogether around 100 samples.


OLMORE REPORT
PLATE 2
EXPLANATION
TRACE OF INFERRED FAULT ZONE
AXIS OF INFERRED CARBONATITE BODY
AREA GREATER THAN 500 GAMMAS
(AFTER LANDRETH 1979)
NORSJÖ
Ulefoss
Ulefoss brygge
Torva
N
1°24' v. Oslo
59°17'
SØVITE DIKE DIPS TOWARDS
POSSIBLE SOUTHEAST SOURCE
AXIS OF HYPOTHETICAL CENTRAL
CARBONATITE BODY
Holla
Fensgrubene
Fensmyra
Kåsa
Tufte
Vipetobekken
Lommerud
Teigen
Hætvet
Hætvettj
Damtj
MÅLESTOKK 1:5000
Ekvidistanse 50 m.