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Tittel

THE FEN PROJECT GEOLOGY OF THE NORTHEASTERN SECTOR OF THE FEN COMPLEX - THE GRUVEÅSEN - BOLLADALEN SUB AREA

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Rapporten er resultatav feltarbeider som er gjennomført i perioden mai - sept.1981.

Klassifisering og petrografisk beskrivelse av bergartstyper er basert på mikroskopering av innsamlede prøver.

Rapporten inneholder to mindre notater av Tom Andersen: Ree-Analytical techniques at the microprobe
: Surface geology of the central Grubeåsen area, Eastern Fen complex

T H E F E N P R O J E C T

GEOLOGY OF THE NORTHEASTERN SECTOR OF THE FEN COMPLEX - THE GRUVEÅSEN-BOLLADALEN SUB-AREA.

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C O N T E N T S

T H E F E N P R O J E C T

GEOLOGY OF THE NORTHWESTERN SECTOR OF THE FEN COMPLEX - THE GRUVEÅSEN-BOLLADALEN SUB-AREA.

1. INTRODUCTION.

The geological map accompanying this report (Plate I) is the result of field work carried out in this part of the Fen Complex during the period May - September, 1981.

Classification and petrographic descriptions of rock types are based on mesoscopic examination of samples, and the limited amount of microscopic studies presented later is based on samples collected during the reconnaissance stage of the project.

Under "ordinary" circumstances, a geological report would be more becoming when petrographic and geochemical data for the samples collected are produced, but since the three geologists who have been mapping the area - G. Foslie, T. Andersen (presents a separate report) and K. Mørk - are all leaving the project, we shall try to compile our present knowledge and ideas in writing for future reference for our successors.

The accompanying map (Plate I) is a compilation on scale 1:5000. Field mapping was done in scale 1:1000, and a compiled version of the field sheets (outcrop map) has been worked out and submitted to the new project leader.

The main objective of this seasons work has been to recognize and classify the main rock units in the field, rather than produce a 100 % "correct" geologic map. In areas with good exposure, for instance along the lake Norsjø, the Vegskjæring section and along the eastern side of Bolladalen, we have been able to work in reasonable detail and feel relatively confident about rock types, their relations and extensions. In the Gruveåsen itself, where outcrops are small and sparse, the map is less reliable, and more work is required.

Representative samples of most of the rock units have been collected (marked on the maps) and submitted for chemical analyses and preparation of polished thin sections. More samples are obviously required, but (in my opinion) a sampling procedure should preferably be designed by geologists who are doing the investigations of the samples.

Some ideas about the age relations between the rock units have developed, and the petrographic descriptions following are listed according to this supposed genetic sequence.

2. PETROGRAPHIC DESCRIPTIONS.

2.1 Precambrian rocks.

2.1.1 Foliated gneiss.

Generally, the rocks outside the Fen Complex are dominated by granittic gneisses (Sæther, 1957, Olmore, 1981). East of the Complex, such gneisses are more finegrained, with inlayers of micagneisses and amphibolites, this sequence probably belonging to a more heterogeneous supracrustal series than the more coarsergrained unit along the Western part of the Complex (S. Dahlgren, pers.com.).

In the field, a distinction was made between a distinctly foliated fsp. - qtz - biotite - chlorite -gneiss and an unfoliated fsp. - chlorite rock (fenite, see below), i.e. a distinction based dominantly on a structural criterion.

Mapping was extended outwards (from the Complex) into the foliated gneiss, and only reconnaissance mapping has been done in this unit 500-1000 m east of the contact, the gneiss appear to have biotite as the dominant mafic component, but within 100 m of the contact, chlorite predominates.

Two samples have been studied in the microscope, one taken along the Grønvoldveien (loc. 142588/52747, i.e. 150 m east of the contact), and one at Gruveåsen (Loc. 142328/52945). Only traces of biotite are retained, the dominant mafic mineral being chlorite associated with calcite. Quartz is present in both samples. Examination under the Cathodoluminoscope (CL) reveal that some of the pЄ K-fsp. (microcline) is retained, but is extensively replaced by a red luminescing (Fe^{+++}-activated) felspar, i.e. a fenitization process (acc. to A. Mariano, pers.com.), showing that fenitization of the precambrian has taken place along this eastern contact of the Fen Complex (contrary to previous descriptions).

Even in the samples of foliated gneiss, there is evidence of crushing of the rock, particularly of the felspar, with introduction of chlorite and calcite along the cracks.

2.1.2 Gneiss breccia.

This rock unit has been described by Sæther (1957). It is a breccia with fragments of foliated gneiss, which have rotated relative to each other and cemented by a finegrained granittic matrix. We have seen it, but haven't done much about it.

2.1.3 Fenite.

Approaching the Complex contact from the east, the gneiss graduall[y] loose it's foliated texture and become a more massive, but heterogranular felspar - chlorite - calcite -rock, i.e. quartz is no longer detectable in hand specimen. CL shows that the p€ felspar is totally repaced by a red luminescing variety. The rock is extensively crushed, the felspar is broken up and calcite and chlorite fill interstices and fractures. If the crushing is obvious in hand specimen, the term "fenite breccia" has been applied in the field, but since there are gradational differences, such varieties have been grouped together on the geological map to one unit - fenite.

2.2 Basic silicate rock - "syenite".

In the Western portion of the map, along the lake Norsjø (Loc. 142800/52050), a basic silicate unit has been separated out. It is a dark to dark green, finegrained rock with minor pink felspar. It occurs as inclusions in rauhaugite (see below). Further east along the shore, similar inclusions in rauhaugite are dominated by pink felspar associated with chlorite. These inclusions have been mapped as fenite i.e. altered precambrian.

Olmore (pers.com.) describes K-fsp.-flooding of basic silicate rocks at Torsnesodden and further westwards, and in his opinion, much of the fenite on the map (Plate I) can be K-fsp.-flooded basic silicate.

Hopefully, petrographic studies will clearify the origin of the basic silicate rock, but an extract of the discussions is here presented :

1. The basic silicate rock is a separate magmatic unit, which was later intruded by rauhaugite, causing K-fsp.-flooding (replacement) of the basic silicates (Olmore).
2. The basic silicate represents an immiscible equivalent of the rauhaugite carbonatite. The felspar is then either formed by late segregations of this intrusive event or by later intrusives - or the K-fsp. - chlorite rock is altered precambrian inclusions in rauhaugite, i.e. basic silicate and fenite have a separate origin.
3. The basic silicate represents altered, more basic layers (amphibolitic) of the precambrian sequence, i.e. no potassium metasomatism took place, only recrystallization of mafic minerals and K-fsp. from the original fsp.-containing precambrian.
4. There is also a possibility that an intrusive event resulted in magmatic segregation within a magma of more syenitic composition, i.e. segregation of a basic silicate and a syenite phase. The K-fsp. is then primary magmatic.

2.3 Rauhaugite.

Within the mapped area, this rock type belongs to the rauhaugite type II of Brøgger's classification, (1921), and described by him and Sæther (1957).

The road-cut along Grønvoldveien, west of Bolladalen, (Loc. 142650/51050 - 142550/51180) offers a well exposed section throug this rock unit. Also DDHs F1 and F2 are dominated by this rock type. These sections clearly demonstrate the variations and heterogenity of this unit, but it has certain characteristics which were described by Sæther (1957) and which we have also observed in the field.

2.3.1 Petrographic description.

It is generally a finegrained, but somewhat heterogranular, massive carbonate rock. It varies in colour from light grey to brownish grey, in some parts it is greenish grey.

It contains chlorite as the dominant mafic mineral, either finely dispersed - and hence the greenish varieties - or as more irregular patches or veinlets. Larger, more massive inclusions of chlorite-dominated basic silicate rock are also regularly seen.

Generally, dolomite is the dominant carbonate (little or no effervescence with HCl) but in some parts calcite may become a significant component (also evidenced by CL examination). Pyrite impregnation is characteristic. Impregnation of small hematite flakes are also observed in places, whereas magnetite seem to occur as secondary mineral along veins and fractures.

Possibly, the most characteristic feature is the brown surface weathering of this rock. It extends generally 1-2 cm from the surface as a brown, porous zone.

Generally, this rock unit is massive, with no significant or mappable structural features. However, a foliation, due to a fine banding of darker silicaterich material (especially evident on weathered surface) has been described in some localities (e.g. 142715/52130). This structure is interpreted as a flow banding (similar structures are found in the søvite carbonatite) - and thus indicate that the rauhaugite - or at least a rauhaugite phase - has an intrusive origin, i.e. is a carbonatite.

5 samples of rauhaugite has been studied in thin section. They have a generally finegrained, but heterogranular texture of irregular, sutured carbonate grains. 3 of the samples (DDH F1-22,4m, F1-210,5 and 10KM79) are dominantly calcitic, but with some dolomite (CL-examination), and 2 (DDH F1-66,4m and 11KM79) are virtually all dolomitic (no luminescence in CL, indicating a certain Fe-content, i.e. an ankeritic dolomite).

2.3.2 Special mineralogy.

Irregular grains of baryte, sometimes gathered in clusters, are observed in the microscope. Under CL it shows a pale bluish grey luminescence. It seems to be a characteristic mineral of rauhaugite. Euhedral grains of apatite are also seen.

Radial aggregates of RE-minerals (see chapter 3) are dispersed throughout the carbonate rock. Sample 10KM79 are enriched in RE-minerals, associated with baryte along veins (fig. 1).

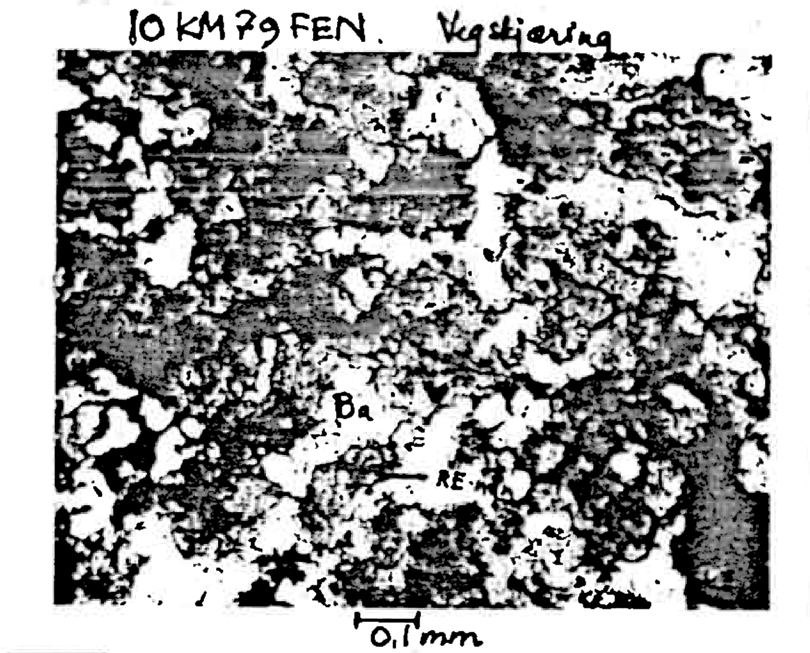

Fig. 1: RE-minerals and baryte in vein in rauhaugite. Sample 10KM79.

Brown: radial aggregates of RE-mineral
White: baryte
Dark : opaques

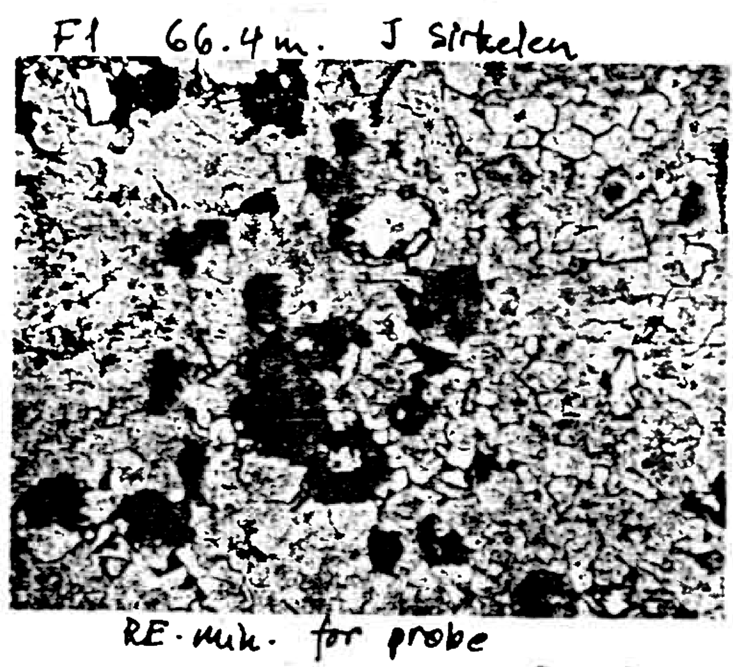

Fig. 2: RE-aggregates (brown) in dolomite.
Sample DDH F1 - 66,4 m

Sample 11KM79 contain a significant amount of euhedral crystals of rutile - or aggregates of crystals - evenly dispersed. It is a niobean variety, i.e. an ilmenorutile. This mineral was also reported by Åmli (1974) and has been found in many of the rauhaugite samples. The mineral chemistry of this phase and of the RE-minerals are discussed in chapter 3.

2.3.3 Conclusion.

The rock mapped as rauhaugite has various expressions in outcrop, but it is distinctly separable as a unit in the field. The brown weathering is characteristic, it is generally dolomitic and therefore gives little effervescence with HCl. Chlorite is the only mesoscopically detectable mafic mineral. The rock may contain patches or fragmental inclusions of mafic silicate rock, but lack the special (smaller scale) fragmental and orbicular texture that characterize the dolomite-rich damkjernite variety which is described in chapter 2.4.2.

According to the discussion on the genesis of the basic silicate (and fenite) in the preceeding chapter, the rauhaugite was emplaced either contemporaneous with, or later than the basic silicate unit.

The rauhaugite is a carrier of RE-minerals, baryte and ilmenorutile, and is therefore an important target for exploration.

2.4 Damkjernite.

The type locality for this rock is east of the lake Damtjern, south of Vipeto. It occurs here as a dike in precambrian gneiss. The rock is porphyritic, with phenocrysts of biotite, pyroxene and amphibole in a dark, basic silicate dominated matrix. Altered olivine (⟶ serpentine) is also reported. (Brøgger, 1921, Sæther, 1957).

From inside the Fen Complex, Sæther describes a number of plugs of damkjernite, which, in addition to the mentioned phenocrysts also contain xenoliths of rocks which occur adjacent to them.

According to Sæther's map, damkjernite plugs also crop out within the presently mapped sector of the complex. This has been confirmed, and a few "new" localities have been found, but the picture is more complex since there are at least two separate rock types within this unit.

2.4.1 Damkjernite with dark basic silicate matrix.

"Typical" damkjernite with biotite and amphibole phenocrysts occur as two bodies at the north end of Bolladalen, along the lake Norsjø. A ½ - 1m wide dike, cutting rauhaugite, has also been mapped further west (Loc. 142770/52095). Also up in the Gruveåsen it has been observed in a number of localities.

The outcrops in the creek bed at the northern part of Bolladalen show little xenolitic inclusions of surrounding rocks. Some small fragments of light-coloured carbonate material may be of rauhaugite composition, but they have not yet been properly identified.

By careful examination of hand specimen it is possible to detect some rounded or orbicular, dark coloured inclusions and also some small (less than 1 cm) angular dark fragments in the dark matrix. We are suspicious that at least some of them might be composed of serpentine.

The dark to dark green, finegrained, dense and massive damkjernite rock with characteristic "booklets" of biotite is relatively easy to recognize in the field.

2.4.2 Damkjernite with grey, dolomitic matrix.

Appearently associated with the damkjernite described above, but occuring in separate zones, is a porphyritic/breccia rock with biotite phenocrysts and rounded (orbicular) and fragmental inclusions (generally less than 1 cm across), set in a grey, finegrained, dense matrix of dolomitic composition. The overall texture is, in other words, similar to the damkjernite described above.

Presumably it is this rock type, which appears to form a contact zone between the typical damkjernite and rauhaugite, that led Sæther to believe that rauhaugite was formed by replacement of damkjernite.

The contact relations between the three rock types rauhaugite - damtjernite with dark matrix - damkjernite with grey matrix, can be seen in outcrop at Loc. 142525/52245. The pictures here demonstrates that intrusive relationships are more probable, and that the rock type in question is a separate igneous phase, distinct from both rauhaugite and "typical" damkjernite.

2.4.3 Genetic relationship between damkjernite types.

The similarity in texture and spatial association of the two damkjernite types, has led this author to the conclusion that they are genetically related, as part of damkjernite igneous event. They have segregated as a result either of magmatic immicibility or of crystal differentiation of silicates and dolomite (i.e. a temperature separation). What we now see, are "composite bodies" (analogous to composite dikes).

2.4.4 Relationship to other rocks.

Damkjernite dikes clearly cut rauhaugite and are therefore younger

Large fragments of damkjernite (1 m across, maybe larger) occur in the explotion breccia described in the next chapter, and it was therefore emplaced before this explosive event.

Both types of damkjernite are "rødbergized" in places, but as explained in chapter 2.6 and in T. Andersen's report, rødbergization is a process that overprints most of the rock types in this area.

2.5 Explosion breccia.

The geologic map (Plate I) shows that this rock unit forms a body along the eastern contact of the Fen Complex. It was recognized as a separate unit during last year mapping and Pack-Sack-sampling in the Gruveåsen area.

The rock is a cataclasite, with fragments of a variety of rock types and of very variable size. In fact, it is difficult to describe a genuine matrix in this breccia, as the groundmass between the larger visible fragments also consist of fragmented material down to a fine powder (almost mylonitic).

The rock is therefore distinguished from a damkjernite breccia (damkjernite with numerous xenoliths) and other breccia types by not having an igneous matrix.

Such a totally powdered rock can presumably only form by a violent explosive process, and the rock is therefore called an explosive breccia.

The larger fragments of the breccia are mainly of rødberg and/or fenite composition, but rauhaugite and damkjernite fragments have also been recognized, showing that the explosion was one of the later events to occur in this part of the Complex.

The eastern contact towards fenite (Loc. 142550/52610) has indication of tectonic activity, with intense crushing and deposition of hematite, i.e. a fault zone. In my opinion these features are results of the explotion, whereby the fenite was intensely shattered and crushed. Gases and/or fluids from this volcanic eruption caused alteration and recrystallization of the adjacent rocks.

The explosion breccia rock unit is recognized in the field by the variation in size and composition of the rock fragments. It is distinguished from damkjernite breccia by lacking the biotite phenocrysts, and not having the equigranular, finegrained, appearently igneous matrix.

2.6 Rødberg - rødbergization.

Variations within the rødberg is described by T. Andersen in an accompanying report. A few general comments shall be added :

Andersen describes a variety of textural and compositional relations within the rocks mapped as rødberg. The title of this chapter indicate that this author regards rødberg as being the result of a process, which has overprinted and altered other rock types, i.e. not an igneous unit, and the geological map therefore shows the areal extension of this process.

It was our intention to try to split up the rødberg unit and classify the varieties according to what they were before rødbergization. This turned out to be very difficult. Only in some outcrops we were able to see and recognize textural features which could indicate the original rock, but in most cases such "primary" features have been either obliterated, or the rock did not originally have any specific characteristics.

We see clear evidence of rødbergization of fenite (mainly as patches), rauhaugite (along certain zones, possibly structural) and the damkjernite varieties. The explosion breccia contains, as mentioned, fragments of massive rødberg, but rødbergization of the groundmass has also been observed. This indicate that the rødbergization process took place over a time span, probably related to various pulses of igneous activity.

Where we see clear texture features in the rødberg, the rock has been given a special symbol on the map.

It has been considered whether the rødbergization process merely involved recrystallization of preexisting rocks, with exsolution of hematite derived from Fe-rich (ankeritic) dolomite, i.e. without introduction of Fe and alteration of the overall chemistry. This is suggested and discussed by T. Andersen.

Assays data for F1, F2 and F3 drill cores does not totally support such a hypothesis. Average Fe-content of F1 (32 assay zones) is 8,6 % Fe, whereas rødberg in the same drillhole has an average of 14 % Fe (23 assay zones). Average for F2, which is virtually all rauhaugite (40 assay zones) is 10,4 % Fe. F3 consist dominantly of rødberg with an average of 17,7 % Fe. It therefore appears that the rødberg is higher in Fe than rauhaugite, indicating an introduction of Fe during the rødbergization process. The differences are, however, not so marked, and it is possible that rauhaugite might have originally been enriched in Fe in certain zones, which later have been preferably subjected to rødbergization.

Examination of massive rødberg (from the mine dump) under CL reveals that it is composed of both calcite and dolomite, in accordance with Andersen's observations. The dolomite generally show a red luminescence, indication a Fe-poor variety (luminization will be quenched with a Fe-content > 1 % in dolomite, A. Mariano, pers.com.). The rauhaugite dolomite, on the other hand, show no luminization generally, and therefore appear to be richer in Fe. This should support the idea of "isochemical" transformation of rauhaugite ⟶ rødberg (Andersen), but petrography done so far is far to scarce to be conclusive.

2.7 Magnetite-rich basic silicate rock.

This is generally a finegrained, dense, dark grey to greenish rock, characterized by high magnetic susceptibility (5-10 % mt). It has mainly been observed along mine walls and in mine dumps. It's relation to the rødberg and in particular to the massive hematite veins has not been studied in detail, but it appears to cut the rødberg and is itself transected by hematite veins.

In an area NW of the farm Gruben (Loc. 142200/52700 - 142300/52750) there appear to be a more extensive body of this rock (mainly revealed by magnetic susceptibility measurements in a sparsely outcropping area).

2.8 Late dolomite - carbonatite (breccia).

In the Fen Adit there occur a body of white-grey, massive dolomite-carbonatite with frequent inclusions of red patches of rødberg - partly hematite-rich. A fragmental (breccia) structure is marked in some parts, with angular fragments of a more grey, "impure" dolomite rock resembling "ordinary" rauhaugite. Similar features have also been noted in rauhaugite in the "vegskjæring" section, but here we have not seen rødberg inclusions, and they were therefore regarded as variations within the rauhaugite.

Because of the rødberg inclusions and rauhaugite fragments, this rock has been interpreted as a late dolomite intrusive body. Bearing in mind a model of enrichment of special (and valuable) elements in late stage magmatic segregations, this rock is of special interest, and it has been sampled in the Fen Adit by Olmore.

2.9 Pink felspar-rich rock.

Within the area comprised in this report, this rock has been observed in two outcrops (Loc. 142415/52675 and Loc. 142420/52630) i.e. some 50 m apart. It possibly forms a dike-like body, which, in case, appear to cut through damkjernite (see Plate I).

The rock is pink, massive, with variations in grain size. Pink fsp. is the dominant mineral, but some chlorite and possibly other mafics are observed as irregular patches. A similar rock has been mapped by Olmore further west (along the shore of lake Norsjø). We have considered the possibility of calling it a syenite, but hesitate to do so with the limited petrographic data we have.

2.10 Diabase.

Two dikes of finegrained, grey, massive rock are mapped as diabase, and believed to be related to the Oslo Graben igneous event. They occur in the road-cut approx. 75 m W of the Fen Adit portal.

The distinction between this rock and the magnetite-basic-silicate rock (if any !) should be established.

3. MINERALOGY.

In addition to the mineralogical studies carried out by T. Andersen (see accompanying report), this author has done some detailed studies of three mineral phases which were encountered during microscopic examination of rauhaugite samples.

3.1 RE-minerals.

In three thin sections (samples DDH F1 - 22,4m, F1 - 66,4m and 10KM79), a fibrous mineral was detected. It occurs as radial aggregates dispersed throughout the dolomite rock, and in sample 10KM79 it is enriched in veins associated with baryte. This sample was examined by microprobe, which gave the following composition :

Element	% element	% oxide	formula
Ca	3.336	4.668	1.040
Ce	31.348	36.717	2.796
La	20.769	24.357	1.868
F	5.635	8.007	3.706
Th	1.034	1.177	0.056
O	12.804	0.000	10.000
Total	74.925	74.925	

SEM examination showed that the fibres were composed of two phases (Fig. 3), and EDAX-spectra revealed that both phases were Ca-containing RE-fluorides, but with different Ca-content (Figs. 4 and 5). They are probably an intergrowth between parisite and synchisite.

3.2 Baryte.

This mineral occurs as aggregates of equant, low birefringent grains, evenly dispersed. As mentioned, it is enriched along veins in sample 10KM79.

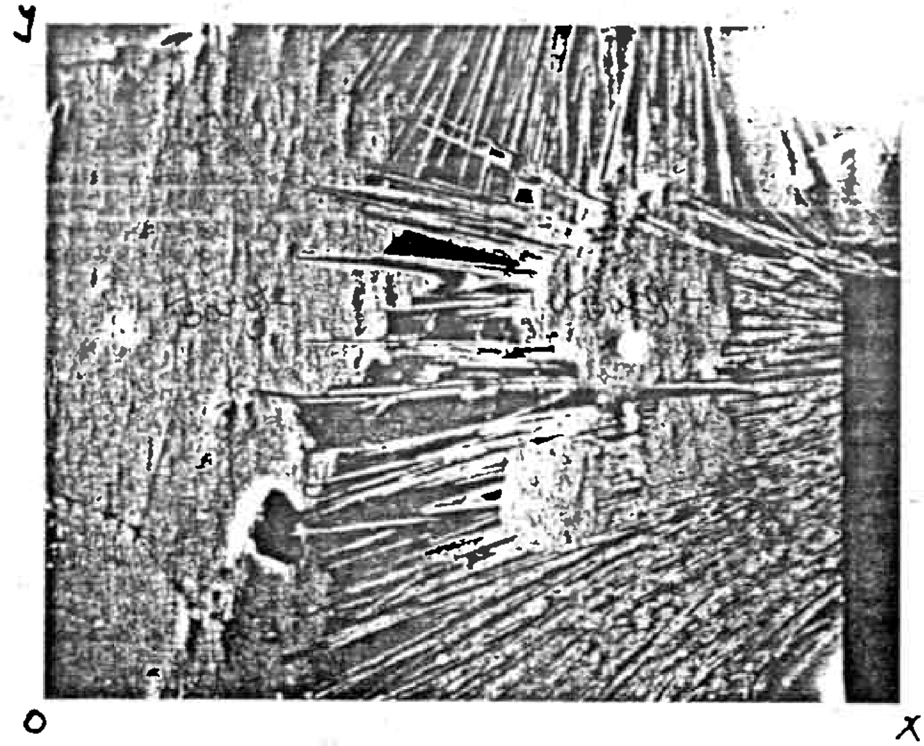

Fig. 3 SEM Secondary Electron Image of RE-minerals in sample 10KM79. Grey fibres and interstitial dark areas are RE-minerals. Grey masses = baryte.

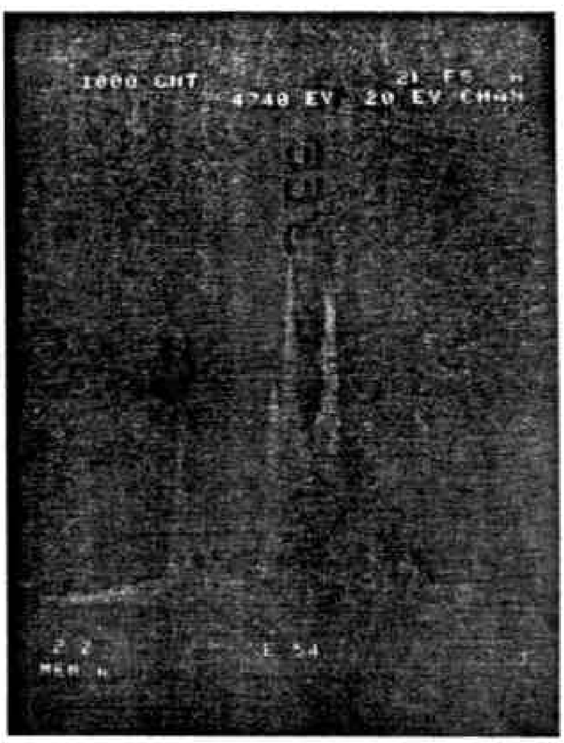

Fig. 4 EDAX spectrum of grey fibres in fig,3. Ca-"poor" variety.

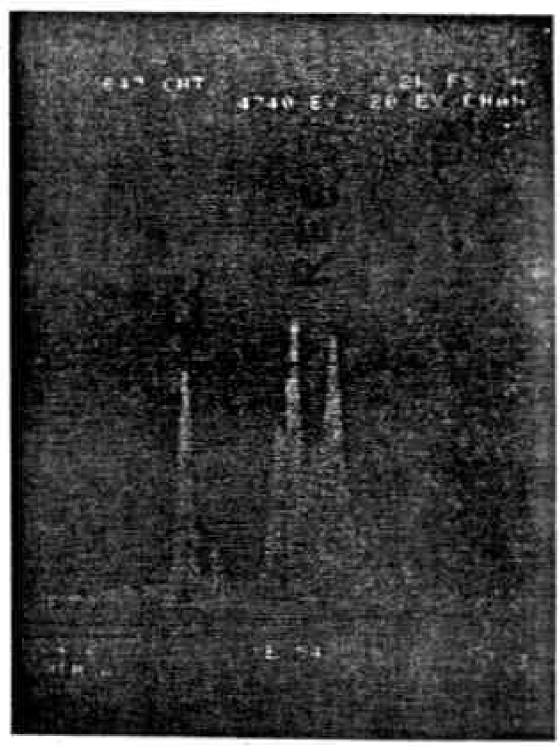

Fig. 5 EDAX spectrum of dark phase in fig. 3. Ca-"rich" variety.

Under CL it shows a pale bluish grey luminescence. Microprobe analyses confirmed the presence of Ba and S-lines on EDAX-spectra.

3.3 Ilmeno-rutile.

This mineral was first detected in sample 11KM79, where it makes out approximately 5-10 % of the TS (visual estimate), as euhedral crystals and crystal aggregates dispersed throughout the rock. It was identified under the microscope as rutile, but microprobe analyses revealed a rather complex composition :

Element	% element	% oxide	formula
Ti	43.562	72.664	8.217
Nb	7.354	10.519	0.715
Ta	6.936	8.469	0.346
Fe	3.648	4.693	0.590
Mn	0.060	0.077	0.010
Ca	0.356	0.498	0.080
Sn	1.139	1.446	0.087
V	0.216	0.318	0.038
O	35.414	-	20.000
Total	98.685	98.685	

According to this analyses the mineral contains a significant amount of Nb and Ta, and some Sn, in addition to Ti and Fe.

The Ta_L-line, which the analyses is based on, lies very close to a Si_L-line, and the computer was therefore also programmed to analyse for Si. This, of course, changed the value for Ta dramatically, as most of this peak was counted as Si :

Element	% element	% oxide	formula
Ti	44.287	73.873	7.874
Nb	7.188	10.282	0.659
Ta	0.052	0.063	0.002
Fe	3.737	4.307	0.570
Mn	0.061	0.079	0.010
Ca	0.355	0.497	0.075
W	0.0	0.0	0.0

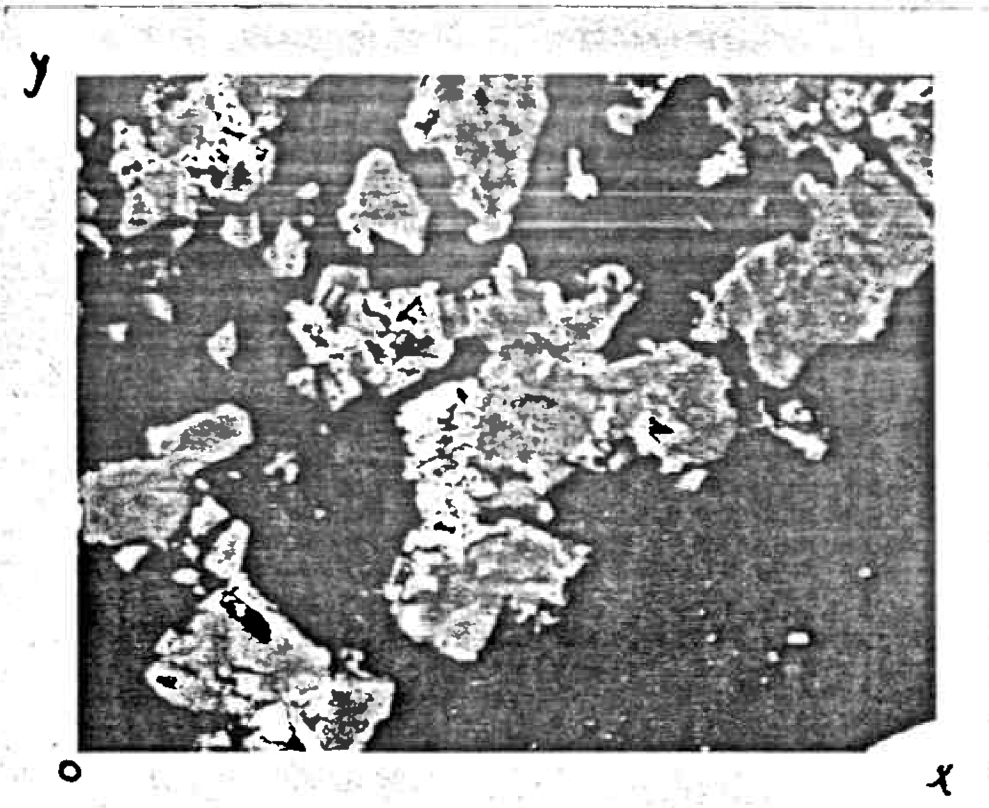

Fig. 6 SEM Back-Scattered Electron Image of ilmeno-rutile in sample 11KM79. White = Nb-poor; Grey = Nb-"rich"

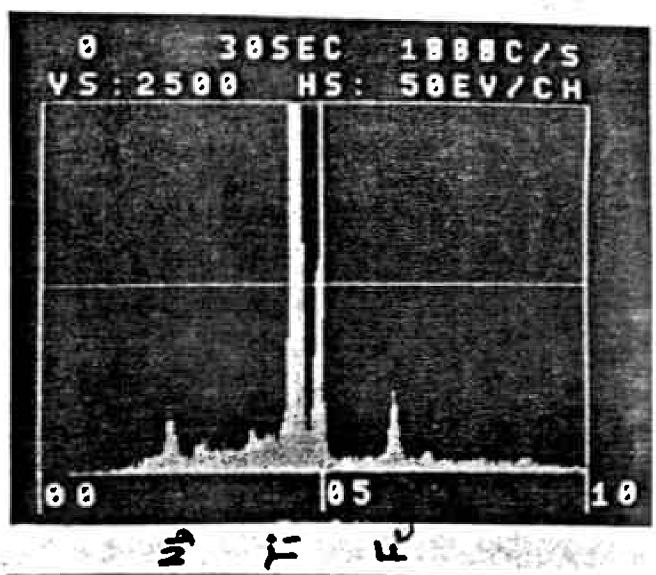

Fig. 7 EDAX spectrum of grey area in fig. 6 Note low Nb-peak

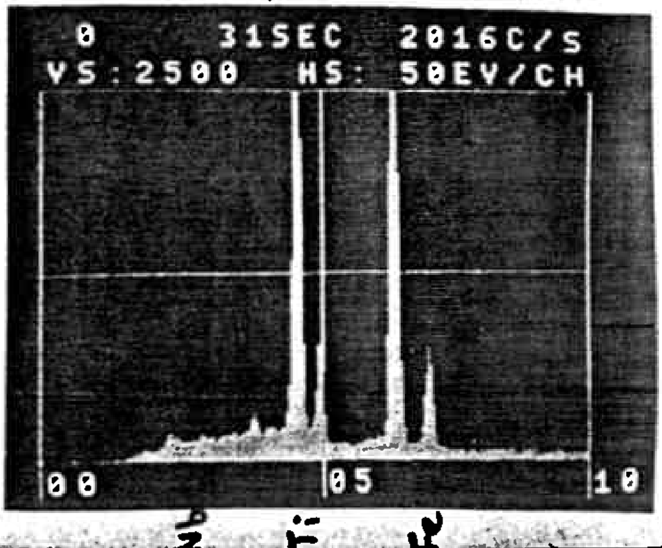

Fig. 8 EDAX spectrum of white area in fig. 6. Note abscence of Nb, but strong Fe-lines.

Element	% element	% oxide	formula
Sn	1.134	1.440	0.081
V	0.220	0.323	0.037
Cr	0.0	0.0	0.0
Si	2.845	6.087	0.863
O	37.573	-	20.000
Total	97.452	97.452	

I.e. negligible amount of Ta, but we also got a poorer "total"-figure.

The rutile mineral was subsequently examined by SEM, and fig. 6 is a back-scatter-electron image showing that the crystals consist of the two phases :

1. a grey phase, with Ti, Fe and some Nb as the major components (EDAX, Fig. 7),
2. a white phase, with Ti and more Fe, but with little Nb (EDAX, Fig. 8).

Ta did not show up on EDAX on any of these phases, but a Sn-peak was obtained in phase 2.

Based on the SEM BSI-picture, the two phases were again analysed by another microprobe (at SI), with a spectrometer attached to it, which enables a more specific analyses of the exact wavellengths for Ta and Si. Neither Ta nor Si showed up !

The rock sample 11KM79 was also assayed by XRF ($\pm$ 30 % relatively accuracy), but no Ta was detected.

The composition of the ilmeno-rutile is however not resolved. The two microprobes used, and the SEM unit give deviating results as far as Ta is concerned, and more work is required, preferably by someone who can offer better standards for the elements in question.

In Deer, Howie and Zussman (1966), ilmeno-rutile with 15 % Ta and 10 % Nb is described, and Sn is appearently "typical" in Ta-rich varieties.

Rutile grains were detected in a number of rauhaugite samples, and it is also present in the matrix of carbonate-rich (dolomitic) damkjernite and in rødberg. Åmli (1974) described ilmeno-rutile as a relatively common mineral in rauhaugite and rødberg samples from the "vegskjæring" area, but he did appearently not analyse for Ta.

4. MINERALIZATIONS.

4.1 Hematite mineralization.

Study of the extent and nature of hematite mineralization has not been a priority matter this season. Most of the mine pits are marked on the maps. The walls of these pits represent good outcrop,but they are very difficult to get to. So far only general mapping has been done on accessible sections.

Hematite deposition seem to be associated with fault zones, with a general NW direction (120^g). Crossing directions are also developed.

It is remarkable that massive magnetite-bearing basic silicate rock often seem to occur along the walls of the stopes. A possible genetic connection is therefore indicated, for instance that fault zones cutting the magnetite-bearing rocks formed channelways for oxidizing fluids with alteration of magnetite and Fe-silicates to hematite.

4.2 RE-mineralization.

As mentioned in a preceeding chapter (3.1), RE-minerals occur as dispersed aggregates in rauhaugite, and are enriched along veins together with baryte.

The average REE-content of rauhaugite and rødberg is too low to make ore grade (FSJ-investigations). A secondary vein type of mineralization may, however, result in a local enrichment in certain zones in the carbonate rocks. Such appearent secondary enrichment has been described from Tuftestollen (Olmore, 1981), where it is associated with magnetite and pyrite along an assumed fault zone.

4.3 Nb-mineralization.

Åmli (1974) identified both columbite and Nb-containing ilmenorutile in his samples of rauhaugite from the "Vegskjæring" area. He states that : "A general impression is that Nb-rutile occur in orders of magnitude more frequent than columbite" (page 41).

Chemical assays show an average Nb-content of all samples analyzed so far of only about 0,1 % Nb. A Nb : Ta ratio of about 10:1 will, however, greatly enhance the value of this mineral. This means approximately 1 % Ta in ilmeno-rutile, or 0,01 % Ta in an "average" rock sample. This is close to the detection limits for the analytical methods we have used, so the rutile remains an important piece in the puzzle.

4.4 Fluorite mineralization.

Rather massive fluorite mineralization has been observed in two localities :

1. Loc. 142800/52065.
2. Loc. 142900/51955.

Loc. 1 has been chip-sampled over a 2 x 2 m area. The sample contained 9,5 % F, equivalent to approx. 20 % CaF_2.
This locality is situated at the edge of a basic silicate rock, but the fluorite seem to sit in rauhaugite.

A careful search for more CaF_2 along the shore of lake Norsjø, towards Bolladalen, was carried out, as this zone may represent a continuation of a possible "Bolladalen fault zone". We did not find any CaF_2 along this section, nor any evidence of tectonization.

5. GENERAL COMMENTS.

It is, of course, premature to suggest a model for the evolution of the Fen Complex based on the work that has been done far, but this author should like to point out some striking features.

The Fen Alkaline Complex is assymetrical. The SW sector is dominated by basic silicate rocks - melteigites etc., at least partly relatively coarsegrained. Towards NE, søvitic carbonatites start to appear, as dikes and larger masses, probably associated with a mafic silicate phase. A central zone, extending from Tufte to Vipeto, is dominated by mixed carbonatites (calcite and dolomite). Further NE-wards, rauhaugite (type II of Brøgger) has the largest areal extent. In the NE sector of the complex, rødberg become more frequent. The rødbergization process has therefore been more extensive in these parts. An explosive event created the rock along the NE margin.

This picture may indicate an evolution, from more deepseated magmatic rock to the SW, possible higher level intrusives in the central parts and a sub-surface explosive phase in the NE corner, i.e. a younging and higher level volcanism from SW to NE.

The rødbergization process has accordingly been more pronounced in the higher levels of this sequence, and therefore an oxidation process in a near the surface environment might be a possibility, as opposed to a chemical one (stabilization of Fe^{3+} by introduction of alkaline solutions, A. Mariano, pers.com.).

Stabekk, 30-9-1981.

Kristen Mørk

Kristen Mørk

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R E P O R T I 1 9 8 1 :

REE-ANALYTICAL TECHNIQUES AT THE MICROPROBE

By: Tom Andersen

27-8-1981

TA/bs

REE-ANALYTICAL TECHNIQUES AT THE MICROPROBE.

REE-analysis do not ordinarily belong to the routine methods at an electron microprobe. Analytical difficulties are caused by the closeness of the X-ray emission lines in the spectra of the individual elements. The REEs show interference-, mass-absorbance- and fluorecence-effects stronger than any other group of elements in the periodic system. Nevertheless several labs have developed techniques to determine REEs in high consentrations in minerals.

Åmlie & Griffin (1975) developed a method for quantitative analysis of all the REEs with a wavelength-dispersive microprobe. This method is both time- and work consuming, and demands extensive computer treatment of the microprobe data. It is, however, possible to do this kind of work at the Museum.

The existing microprobe setup at the Museum (ARL-probe with LINK-system energy dispersive analyser, program ZAF-4/FLS), allows simultaneous quantitative determination of 14 elements, when the REEs are excluded. Because of the complexity of REE-spectra more computer capacity is demanded, which implies that fewer elements may be analysed at the same time.

The Fen-rocks and minerals are generally heavily enriched in the lighter REEs (La-Ce-Nd). Therefore it was decided to try standardizing these elements (and maybe Eu) at the microprobe. By excluding certain overlapping areas in the spectra, satisfying analytical results were obtained for La and Ce. So far standardization for Nd has not been possible, due to lack of a suitable standard. (A Nd-standard was ordered from IFE in early August, it has not yet been delivered).

The table below shows an analysis of a glassy mix of La and Ce oxides. (Elemental Ce/La = 4/1). The fit to the true composition must be considered acceptable. Note however that the large ZAF-correction factor for each of the REE-elements decreases the analytical precision.

The main advantage of this technique as compared to the wavelength-dispersive method, is its extreme rapidness. A partial analysis of a simple REE-mineral such as bastnäsite is completed in about 5 minutes On the other hand, its applicability to more complex REE-minerals (e.g. silicates) has so far not been tested.

An expanded version of the computer-program used (LINK's ZAF-4/FLS +), with a capacity of altogether 30 elements has lately been developed. The Museum is considering buying this system in the near future, at a cost of around 25 000 Nkr.

If this system is installed at the probe, it would be possible to expand the field of interest to all the REEs, and probably also to analyse REEs in more complex phases than is possible today.

Reference :

Åmlie, R. and Griffin, W.L. (1975) : Microprobe analysis of REE-minerals using empirical correction factors. Am. Mineralogist, 60, pp 599-606.

SPECTRUM : LA/CE STD N8 30-6-1981

LAST ELMT BY STOICHIDMETRY

FLMT	ZAF	% ELMT	% OXIDE	FORMULA
LA	1.004	17.105	20.060	373
CE	985	64.899	76.015	1.402
SI	986	1.348	2.883	145
AL	689	252	476	028
CA	1.317	078	110	005
O	399	15.862	000	3.000
TOTAL		99.544	99.544	

Electron microprobe analysis of a standard glass with elemental Ce/La ratio of 4/1 (obtained result 3.6).

R E P O R T II 1 9 8 1 :

SURFACE GEOLOGY OF THE CENTRAL GRUBEÅSEN AREA, EASTERN FEN-COMPLEX.

By: Tom Andersen

28-8-1981

TA/bs

SURFACE GEOLOGY OF THE CENTRAL GRUVEÅSEN AREA, EASTERN FEN-COMPLEX.

This part of the common report (written by Andersen) is concerned with the occurrence of "rødberg" (a carbonatite stained red by dispersed hematite) in the Gruveåsen-Bolladalen area in the eastern Fen-complex. It is based on fieldwork done by Andersen in May, July and parts of August 1981. Some laboratory results (microprobe data) obtained in the same period are also considered. The descriptive parts of the report are concluded by some speculative gnetic remarks. There must be viewed as ideas that could (or should) be tested by further field-, geochemical- and mineralogical work. The author leaves the Fenco-staff at the 1. september 1981, but he hopes to be able to continue work with these and other Fen-problems in his new position at the University. He also looks forward to cooperate closely with the Fenco-Union staff.

a) Rødberg, petrography and field occurrence.

In hand specimen the rødberg is characterized by a dark red to carmine colour on weathered surfaces, and by a grey to reddish grey colour on fresh fractures.

The mesoscopi structure of the rock varies widely. It has proved convenient to define the following four "field-types" of rødberg :

i) Homogenous rødberg - A finegrained, "structureless" rock, sometimes with minor medium grained veins or blebs of red calcite. Small scattered megachysts of greyish green chlorite (presumably altred biotite) occur in some areas. Hematite can be found as small, specular tablets dispersed in the rock. This subninit is dominating in the western part of Gruveåsen and in the southern Bolladalen.

ii) "Impure" or silicate bearing rødberg. - This is a rock dominated by carbonate, but it has abundant fine grained silicate (mainly chlorite), forming lenses and veins. These are not clearly visible on weathered surfaces. Magnetic susceptibility measurements indicate that this rock-type is locally rather rich in magnetite. The "impure" rødberg can be found locally in the western and central Gruveåsen associated with the former unit. Gradual transitions seem to separate these to varieties of rødberg.

iii) Rødberg with fragmentary structure. This unit is a silicate-bearing rødberg variety, recognized by a pronounced "breccia" structure easily visible on weathered surfaces.

Angular fragments of red carbonate, each between a few mm and more than a dm across are embedded in a grey to red silicate bearing matrix. This unit, which is in places difficult to distinguish from the eastern borderbreccia (described by Mørk in this report) occupies a considerable area in the east-central part of Gruveåsen.

iv) "Rødbergized" damtjernite or damtjernitic rauhaugite. This rock differs from the other units mainly in that a relict "primary" texture can be observed on a mesoscopic scale, and that it grades into an obvious parent rock in the field.

Randed chlorite or serpentine-rich fragments, a few mm in diameter and chlorite megachysts (bigger than those in the homogenous rødberg, upto 3 cm across) occur abundantly. The matrix is also more silicate rich than in the other varieties. The unit can be found in an area south and southwest of the entrance to the Fen-adit.

As long as no systematic thin section data exist the mesoscopic classification outlined above should be returned. According to the approved IUGS nomenclature of carbonatite-rocks (Streckeissen 1980) the different types of rødberg should be named hematite-calcite carbonatite or hematite-dolomite-calcite carbonatite, depending on their carbonate mineralogy. The silicous rødberg might be called hematite-chlorite-calcite carbonatite etc.

To clarify the mineralogical differences between rødberg and rauhaugite and the variations within the rødberg itself, a few microprobe analysis of carbonate-phases were performed. The results of these are shown in fig. 1. An iron-bearing dolomite or ankerite is the dominating phase of the rauhaugite, which accordingly should be classified as ankerite-ferrocarbonatite (Streckeissen 1980).

The two rødberg samples show some differences. The sample from F-3 drill-core is a pure hematite-calcite carbonatite with very minor relict ankerite. Sample 8 from the entrance of the Fen-adit is a hematite-dolomite-calcite carbonatite (according to the apparent abundanceratio of the phases). The texture is somewhat porphyritic. The bigger crystals show Fe-contents below the detection limit, but the calcite contain some manganese (max. 2,7 mt % MnO). The rather erratic Fe-rich calcite represent point-analysis in the very fine-grained groundness. It is more than probable that the iron-values are artifacts due to exitation of hematite inclusions and crystals along grain boundaries.

b) Contact- and age-relations of the Rødberg.

Where the contact between rødberg and raugaugite is exposed, the rødberg can be shown to cut through the older rock. This is observed both at the apparent contact of the main rødberg area (loc. 52400, 142400) and in a minor scale where rødberg is developed along fractures and crush-zones (e.g. at several places in the brecciated rauhaugite exposed in the roadcut west of the Fen-adit).

No definal contacts between the units i) to iv) are exposed in the central Gruveåsen. The petrographic variations observed indicate that gradual transitions exist between units i), ii) and iv). On the other hand, the fragmentary rødberg might have an unexposed, sharp contact towards the other units (the most promising area being the densly covered woodland west and southwest of loc. 52700, 142300).

In the breccia exposed in the roadcut east of the mine adit rødberg occurs among the inclusions, and must therefore at least in part be older than the formation of the breccia zone. The eastern border-zone of the rødberg-field has been studied in detail by Mørk and Foslie, and will therefore not be considered any further in this part of the report.

c) Veins and dikes.

Several veins and dikes are observed in Gruveåsen. Where the contact-relations are exposed, these are indicated on the map.

i) Hematite dikes. Hematite dikes occur all over the Gruveåsen-area, most of them have been partly removed by mining activities. The old mine-map therefore gives some structurally important information.

The main mineral in the dikes is always hematite (mostly as fine-grained masses, specular hematite has not been observed in dikes from the rødberg area). Magnetite and silicates occur in variable amounts. Some composite veins with alternating bands of hematite and coarse enhedral calcite parallell to the walls have been observed (e.g. at loc. 52475, 142345).

ii) Oxidized crush-zones. These are zones of veins a few dm to a couple of meters wide, consisting of a finegrained, bright and porous material. The veins are enriched in hematite relative to the surrounding rock, whether this is rødberg or rauhaugite. The contact to the wall-rock is a gradual transition over a few centimeters.

iv) Magnetite-rich silicate dikes. These dikes are finegrained and of a grey colour. They have been found at a number of localities all over Gruveåsen, and in most cases they seem to occur in connection to mine-systems, (the dikes themselves do not seem to have been mined) as at localities 52720, 142405 (sample F 00649) and 52605, 142400. The magnetite-rich dikes are cutting the rødberg, and show sharp contacts towards it. At loc. 52390, 14320 a magnetite-rich dike is cut by a (permian ?) diabase dyke.

Minor veins and blebs of light brownish-yellow, translucent ankerite occurs in the dyke at loc. 52495, 142364 (sample F 00646).

Both the mine-map and observations in the field indicate that hematite dikes follow a rather well defined structural pattern with a most abundant direction of N 120°Ø. This direction coincides with the most pronounced fracture orientation in the area (as interpreted from aerial photographs). Magnetite-silicate dikes and the few possible permian dikes observed (diabases) do not follow this pattern.

d) Altred gneiss.

Altred gneiss as described by Mørk from outside the complex is present as fragments in damtjernite intrusive breccia and as a bigger "raft" in the rødberg around loc. 52550, 142400. The contacts toward the surrounding rocks are not exposed.

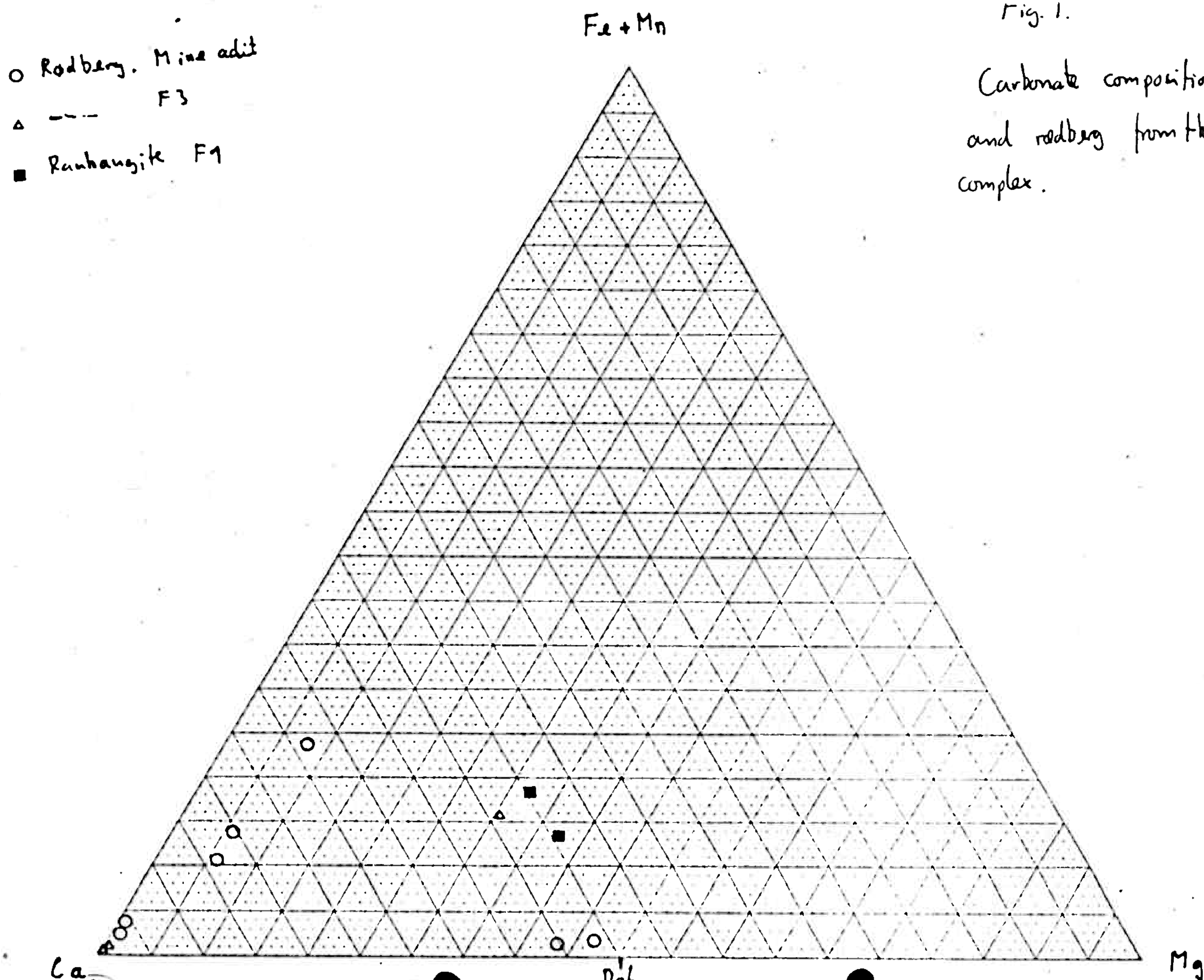
The gneiss is brecciated, with a large number of veins of fine-grained hematite-silicate material. These have little or no calcite and an overall hardness greater than the rødberg.

e) Damtjernite intrusive breccia.

(The photographic characteristics of damtjernite and its inclusions are described elsewhere by Mørk).

Fig. 1.

Carbonate composition of rauhaugite and rødberg from the eastern Fen complex.



Unaltred damtjernite and a damtjernite intrusive "megabreccia" occupies a rather well defined area southwest of the Fen-adit entrance (around 52600, 142400).

The inclusions in this damtjernite are mainly altred gneiss, ranging in size from centimetres to bigger than the individual outcrops. Westwards this unit grades (?) into the gneiss "raft" described above, to the east it is cut by the eastern breccia zone.

The groundmass is locally oxidized, and might in places be considered a true rødberg (loc. 52605, 142410).

f) Genesis of the rødberg.

The rødberg has since the work of Brøgger (1921) been thought to be of metasomatic origin. Fe^{3+}, REEs etc. should then have been introduced to the rock system by a fluid phase of unknown origin.

Another possible "rødbergization mechanism" is that the pure hematite-calcite (or hematite-dolomite-calcite) carbonatite was produced by otherwise isochemical oxidation of ferrocarbonatite of rauhaugite type. The data presented in fig. 1 above seem to support this possibility.

It is however beyond doubt that iron must have been mobilized during the formation of the Fe-ore dikes. An aqueous volatile phase in equilibrium with solid carbonate at low to moderate temperature is unable to carry ferric iron in solution in the necessary concentrations to produce a massive hematite deposit (compare Garrels & Christ (1965), fig. 7.11). On the other hand addition of a proper complexing agent to the system could increase the mobility of iron. Under reducing conditions Fe^{2+} concentrations in a fluid in equilibrium with sulfides are high enough to allow considerable mobility of iron (Helgeron 1969).

If the rødberg itself has been oxidized without mobility of iron, the hematite dikes <u>could</u> be produced by oxidation of previous ferrous dikes (e.g. magnetite-pyrite rocks of the type known from Tuftestollen, Olmore (1981)). This problem should be considered in the future work with the rødberg. The problem of metasomatism vs. "isochemical" oxidation is also of economic importance in this part of the Fen-complex. It would be of great value to find out whether the high concentrations of REEs locally in the rødberg area really are due to some kind of metasomatism, or simply inherited from the parent rock.

R E P O R T III 1 9 8 1 :

MINERALOGY :
IDENTIFICATIONS AND CHEMISTRY OF FEN MINERALS 1981, A PRELIMINARY REPORT.

By : Tom Andersen
31-8-1981

TA/bs

MINERALOGY :

IDENTIFICATIONS AND CHEMISTRY OF FEN MINERALS, 1981, I - A PRELIMINARY REPORT.

This preliminary report summarises work done in the period 15/3 - 1/9, 1981.

The mineralogical studies done on Fen-material so far are restricted to :

A) Identification of phases and intergrowths of phases from samples with suspected REE-mineralization by means of X-ray diffraction. (Debye-Scherrer camera). The X-ray runs and the film developing were made by cand.real. Borghild Nilsen at the Mineralogisk-Geologisk Museum, Oslo.

B) Analysis of known or suspected REE-minerals and other phases of possible economic interest by electron microprobe (at the Mineralogisk-Geologisk Museum, Oslo).

Laboratory facilities and technical assistance were available at the Museum due to an agreement with Fenco. In addition to the work reported here,the author has in cooperation with dr. phil E.-R. Neuman, been trying to develope analytical techniques for REE-minerals at the probe. The results of this work are reported separately.

Results :

i) High REE-sample from Tuftestollen, F 00113 (provided by S.D. Olmore).

The sample consists of medium- to coarse grained subhedral magnetite and pyrite, with minor gypsumand chlorite. Interstitial parisite (Museum film no. 25738) and bastnäsite replacing parisite (film no. 25734) were identified.

Table 1 gives partial composition of one point of each REE-phase. (Note that Nd is not determined). An analysis of magnetite from the same sample shows very pure Fe_3O_4 with Ti and V below detection limit.

ii) Mineral segregations from rødberg and magnetite-rich dikes, Gruveåsen.

Clusters of yellow to light brown grains occurring in minor blebs and veins in several samples from the dump of the Fen iron-mines were examined, also were some light segregations in a magnetite rich silicate dyke from central Gruveåsen (sample F 00646).

The X-ray films show intergrowths of different phases, the most common are : Ankerite, hematite, magnetite, goethite, quartz and monazite (the only REE-mineral found, occurring as intergrowths with ankerite and goethite in a sample from the mine dump).

No microprobe analysis has been performed on this material.

iii) Yellow, porous material from a dyke at the border of the Carbonatite, E. Gruveåsen (K. Mørk, sample 11, 1980).

The sample examined consists mainly of a soft, finegrained, yellow mass with minor opaques and quartz. In thin sections it has a pronounced pleochroism (yellow-brown). The mineral gaves no lines on an X-ray film, the chemical composition seems to show little variation (table 2). The analysis and the optical properties indicate a sheet silicate. Certain identification is not possible without X-ray data.

iv) Fibrous mineral from søvite, Håtveitbekken (K. Mørk, sample 14, 1980).

This mineral (suspected to be wollartonite) is proved by the probe analysis (table 3) to be an alkali-amphibole of the riebeckite-magnesioriebeckite compositional series (Lake 1978).

v) Sheet silicate from the entrance of Tuftestollen (S.D. Olmore, 1980 - sample).

A probe-analysis of the mineral (suspected vermiculite, Olmore, 1981) shows it to be a biotite.

vi) Nepheline from the Melteig area.

A sample of pegmatite nepheline from "Urthite-pegmatite" (Brøgger, 1921) south of Melteig farm was analysed with the microprobe. The nepheline shows no compositional variations within the single-crystal examined, (tab. 4 gives the composition of one point), but it is unfortunately rather high in iron. Along cracks the nepheline is altred to a white mica. This alteration product is present only in minor amounts in the section.

Even if the iron content of this sample is much too high for the nepheline to be of any economic interest, some more analytical work should be carried out to check whether this is representative for the entire "melteigite-complex". Unfortunately the existing thin sections (Hydro-samples) are all glass covered.

More analytical work is currently being done by the author in cooperation with S.D. Olmore and project leader Mørk. Hopefully we will be able to present more compositional data for REE- and Nb-Ta-minerals during the autumn. Further analyses of REE-phases should however be postphoned until it is possible to obtain satisfying results for Nd.

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Lenke, B.E. (1978) : Nomenclature of Amphiboles. Min. Mag. vol. 42 pp. 533-563.

Olmore, S.D. (1981) : Fenco-Union Minerals Joint Venture. Unpubl. report.

Table 1.

Partial composition of parisite and bastnæsite, sample F 113, Tuftestollen.

SPECTRUM: PARISITE TUFTESTOLLEN FEN

LAST ELMT BY STOICHIOMETRY

ELMT	ZAF	%ELMT	%OXIDE	FORMULA
LA	.921	21.168	24.825	.522
CE	.903	27.442	32.143	.670
SI	.978	.041	.087	.005
AL	.693	.060	.113	.008
FE	1.098	.000	.000	.000
CA	1.228	6.863	9.603	.586
F	1.185	6.716	9.543	1.210
O	.351	14.025	.000	3.000
TOTAL		76.314	76.314	

6/7-81 T.A. FENCO

SPECTRUM: BASTNAESITE, FEN

LAST ELMT BY STOICHIOMETRY

ELMT	ZAF	%ELMT	%OXIDE	FORMULA
LA	.917	10.406	12.204	.353
CE	.898	13.432	15.733	.452
SI	.976	.443	.949	.074
AL	.598	.435	.822	.076
FE	1.085	11.555	14.865	.976
CA	1.200	1.253	1.753	.147
F	1.273	3.264	4.638	.810
O	.411	10.176	.000	3.000
TOTAL		50.964	50.964	

Table 2.

Composition of yellow mineral, sample KM11, from the eastern border of the Fen carbonatite, E.Gruveåsen. The 'probe analysis also indicates some fluorine.

SPECTRUM: GULT MINR. FEN 11/K.M.

LAST ELMT BY STOICHIOMETRY

ELMT	ZAF	%ELMT	%OXIDE	FORMULA
SI	1.006	14.832	31.729	2.296
TI	.886	.012	.020	.001
AL	.835	9.779	18.478	1.576
FE	.949	23.184	29.825	1.805
MN	.839	.000	.000	.000
MG	.782	5.665	9.426	1.017
CA	1.011	.160	.224	.017
NA	.622	.298	.401	.056
K	1.039	3.160	3.807	.351
O	.490	36.801	.000	10.000
TOTAL		93.910	93.910	

NEXT=6

Table 3.

'Probe analysis of alkali amphibole from søvite, Håtveitbekken (an intermediate member of the riebeckite-magnesioriebeckite series) from sample KM 14 .

SPECTRUM: K.M. 14/FEN/UKJENT FIBRIG T.A./FENCO/31.7.81

LAST ELMT BY STOICHIOMETRY

ELMT	ZAF	%ELMT	%OXIDE	FORMULA
SI	1.069	26.440	56.551	8.056
TI	.829	.161	.268	.029
AL	.839	.000	.000	.000
FE	.910	3.099	3.987	.476
MN	.806	.000	.000	.000
MG	.876	12.994	21.547	4.581
CA	.972	4.057	5.676	.857
NA	.786	4.319	5.822	1.510
K	1.001	.748	.901	.164
V	.815	.000	.000	.000
O	.476	42.944	.000	23.000
TOTAL		94.763	94.763	

Table 4.

'Probe-analysis (scan over one single crystal) of nepheline from urthite pegmatite, S of Melteig farm. (Sampled by T. Andersen 1981)

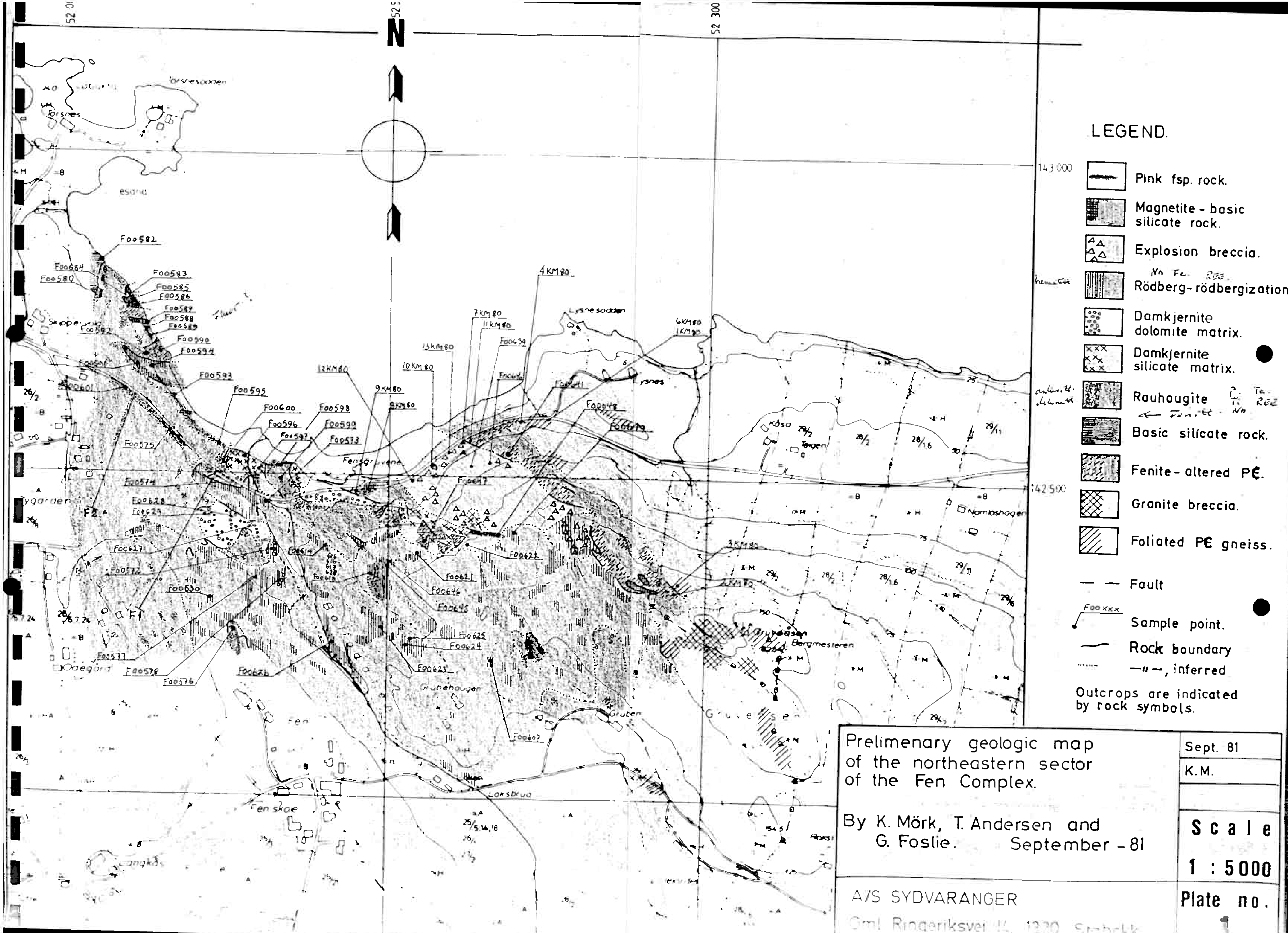
TA FENCO 29.06.81

SPECTRUM: FORTS. SCAN/NEF.

LAST ELMT BY STOICHIOMETRY

ELMT	ZAF	%ELMT	%OXIDE	FORMULA
SI	1.005	19.615	41.960	4.034
TI	.829	.041	.069	.005
AL	.922	18.288	34.555	3.915
FE	.914	.490	.630	.051
MN	.808	.000	.000	.000
MG	.850	.084	.139	.020
CA	.962	.347	.486	.050
NA	.834	11.759	15.851	2.955
K	1.000	6.117	7.369	.904
O	.483	44.318	.000	16.000
TOTAL		101.059	101.058	

NEXT=1



Prelimenary geologic map of the northeastern sector of the Fen Complex.

By K. Mörk, T. Andersen and G. Foslie. September - 81

Sept. 81	
K.M.	
Scale 1 : 5000	
Plate no.	1

A/S SYDVARANGER

Gml. Ringeriksvei 14, 1320 Stabekk