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The Fen project:
A geological survey of the Vippeto-Rullekoll subarea

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Vennlig hilsen
for A/S SYDVARANGER PROSPEKTERING

Thor L. Sverdrup
Prospekteringssjef

Ivar Hultin

1 eks. av rapporten sendt Industridepartementet v/Bergverkskontoret.

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

A GEOLOGICAL SURVEY

OF

THE VIPETO-RULLEKOLL SUB-AREA

Report on
field investigations carried out
in August-September 1980
and November 1981

by

ÅSV-geologist Viggo H. Wiik

Oslo, September 1982

OSLO - NORWAY

C O N T E N T S

SUMMARY AND CONCLUSION

The Vipeto-Rullekoll area offers good opportunities for studying age relationships between the various rock types of the Fen complex. Observations made in the course of this study indicate that the basic silicate rocks were the first rocks to form within the complex, either by crystallization from a basic silicate magma or through extreme fenitization of regional gneiss rocks.

Fenitization, the metasomatic transformation of wallrock, caused by an alkaline, mobile phase, preceeded the emplacement of søvite, which is the oldest of the Fen carbonatites. The søvite appears to have reached its present position as a slow-flowing crystal mush, unable to assimilate fragments of wallrock that became enclosed in it.

A period of cooling and solidification was followed by a second period of volcanic activity, characterized by extreme fracturing and disruption, probably caused by a high-energy gas phase released from a boiling carbonatite magma.

As in the first period of volcanic activity, an alkaline silicate magma was the first to intrude. These pipe-like intrusions of damtjernite were followed by intruding rauhaugite, a carbonatite composed of ankeritic dolomite. Rauhaugite and damtjernite are both seen to grade into volcanic breccia rocks in addition to their appearance as normal magmatic instrusions. The rauhaugite magma must have been chemically aggressive and capable of digesting fractured wallrock.

Rødbergization is the only visible result of a third period of carbonatite volcanism, this time in the form of alkaline fluids moving upwards along fractures and local passageways, transforming the adjacent wallrock into red carbonate rock. Deposition of massive hematite ore as vein-fillings took place towards the end of this final period of volcanic activity in the Fen complex.

While the Vipeto-Rullekoll area offers sufficient bedrock outcrops to allow contact relationships between rock types to be studied, the true spatial distribution of the various rocks cannot be mapped out with certainity. This lack of bedrock exposure also places conventional prospecting methods at a disfavour, and results can be expected only through the interactive use of geophysics, geology and diamond drilling.

From the information accumulated so far, the Vipeto-Rullekoll area offers interesting possibilities for finding niobium ore as well as rare earth elements. Most exiting is the possibility of locating high-grade pyrochlor/apatite-ore of the Tuftehavna lamprophyre type. The proposed investigation of the Vipeto søvite should explore this possibility and at the same time provide information on the low-grade, primary pyrochlor mineralization that ranges as a second-order target worthy of being explored.

The most interesting REE mineralization occurs on the western slope of Brillekåshaugen, within a wedge-shaped rauhaugite intrusion locally affected by rødbergization. Current data indicate that this could be a late fracture filling-type REE mineralization that might extend 500 m to 1 km towards the northwest. With this type of mineralization, viable ore deposits might well have been generated along the zone, and further exploration work would seem well justified.

Much work remains to be done before the geology of the Fen complex is fully understood. It is in the interest of the current Fen project to promote a better understanding of the geology, because such insight is indispensable also in practical exploration work.

INTRODUCTION

The current Fen project has exploration for exploitable ores and minerals as its primary objective. Even so, detailed geological mapping of the carbonatite complex was found to be an important and necessary first step when field work got under way in 1980. To each of the 3 field geologists then available to the project was allocated a particular sub-area, to be mapped in scale 1:1000 in the course of the 1980 and 1981 field seasons.

The Vipeto-Rullekoll area was allocated to the ÅSV-geologist, who started field work in May 1980. Unfortunately, much time in May and June of that year was taken up by an unforeseen demand for supervision of a grid-sampling programme to be carried out in Gruveåsen in support of an urgent application for "utmål" on that area.

By late September 1980 a total of 20 field days had been spent on detailed geologic work in the Vipeto-Rullekoll area. A decision was then made to suspend all further investigations on privatly owned land as a response to mounting concern among the local landowners about Fenco and its exploration activities and possible future mining enterprises.

No further work was done in the Vipeto-Rullekoll area until November 1981. It was then felt that the negative attitude of the landowners towards Fenco might be on the wane, and project geologists Olmore and Wiik revisited parts of the area in order to discuss the geological mapping done by Wiik in this area, before its incorporation in the overall geological map of the Fen complex.

Conversations with a number of landowners soon made it clear that Fenco was still unwelcome in the area, in fact the landowners as a group had agreed to use all legal means to prevent Fenco from exploring their land. Geologic activity on cultivated acreage was ruled out as against the law, while some reconnaissance work was carried out in the forested areas to the south. Wiik spent an additional 3 field-days on follow-up of a geochemical anomaly on the W-ern slope of Brillekåshaugen E of Rullekoll, as this forested area was believed to remain accessible in terms of the law.

Fenco, with responsibility for promoting the exploration rights in the Vipeto-Rullekoll area on behalf of the Government, can hardly allow the present situation to continue. Not only does the impasse hinder a possible discovery of orebodies within the forbidden areas, but the lack of geologic and geophysical information from these parts of the Fen complex hampers the general understanding of the detailed geology of the complex as a whole and thus affects the progress of the exploration work in general. The intention behind this report is to summarize the information available from the Vipeto-Rullekoll area so far, and to present recommendations for further investigations, with the hope that the necessary permissions will somehow be obtained.

The area

The 1 km portion of the Fen complex here referred to as the Vipeto-Rullekoll area, is delimited by the Ulefos-Skien main road to the north and the brook Håtveitbekken to the east, while the steep hill-slopes expressing the geologic boundary between the soft carbonatite rocks and the regional gneiss, mark the limitation of the area towards south and southeast.

Exposures of bedrock are in general small and scattered, the larger assemblages of outcrops being confined to topographic highs such as the Vipeto ridge between Håtveitbekken and the stream from Damtjern, the hillock of Rullekoll, and the southernmost part of the area, from Kåsahavna to the abandoned Juve farm.

At altitudes between 100 m and 150 m a.m.s.l. elevated portions of the Vipeto-Rullekoll area are mostly covered with a layer of glacial till of rather local origin, whereas the bedrock depressions have been filled with thick deposits of marine clay in turn dissected by a younger drainage system.

Some 12 farmsteads and a larger number of single-house residences are located within the area. A proposed housing scheme on Rullekoll has been barred by local authorities on the grounds that the area might have mineable resources, and that the higher-than-normal levels of thorium radiation might constitute a health hazard.

The geologic setting

A substantial amount of both scientific and technical geological work has been directed towards the Fen area already before the onset of the current Fen project. The geologic setting has thus been well established, thanks in particular to the contributions by Brøgger(1921) and Sæther(1957), but in recent years also through supplementary studies by specialized earth scientists of different categories.

The Fen carbonatite complex appears at surface as a roughly circular structure, about 2 km in diameter, cutting through the Precambrian gneiss terrain at Ulefoss, 12 km west of the Oslo area. While age-dated at 560 my and thus some three hundred million years older than the Permian Oslo intrusives, the Fen complex is now thought to be an early manifestation of the same rift system that later gave passage to the magmatic extrusions and intrusions constituting the major parts of the Oslo area.

Gravity studies reported by Ramberg(1973) indicate that the Fen complex extends vertically downwards as a narrow, pipe-like intrusion to a depth of at least 15 km. The rock distribution observed within the accessible parts of the Fen complex cannot explain the recorded gravity anomaly, and Ramberg postulates that the carbonatites and carbonate-silicate mixed rocks prevalent at surface probably do not extend more than one kilometer, and perhaps less than 0.5 km below the present erosional level. The rock type most likely to be encountered below the lighter carbonatite rocks, is damtjernite and/or possibly vipetoite. These two rock types are present in minor quantities also at the surface.

GEOLOGY

The main geologic features of the Fen carbonatite complex are shown in Fig. 1, a generalized geological map presented by Ramberg(1973), based on Sæther(1957). The Vipeto-Rullekoll area has been outlined, and it is seen that - with the possible exception of nepheline-bearing basic silicate rocks (Urtite, Melteigite, Ijolite) - all the main rock types of the Fen complex are represented within this particular sub-area of the complex.

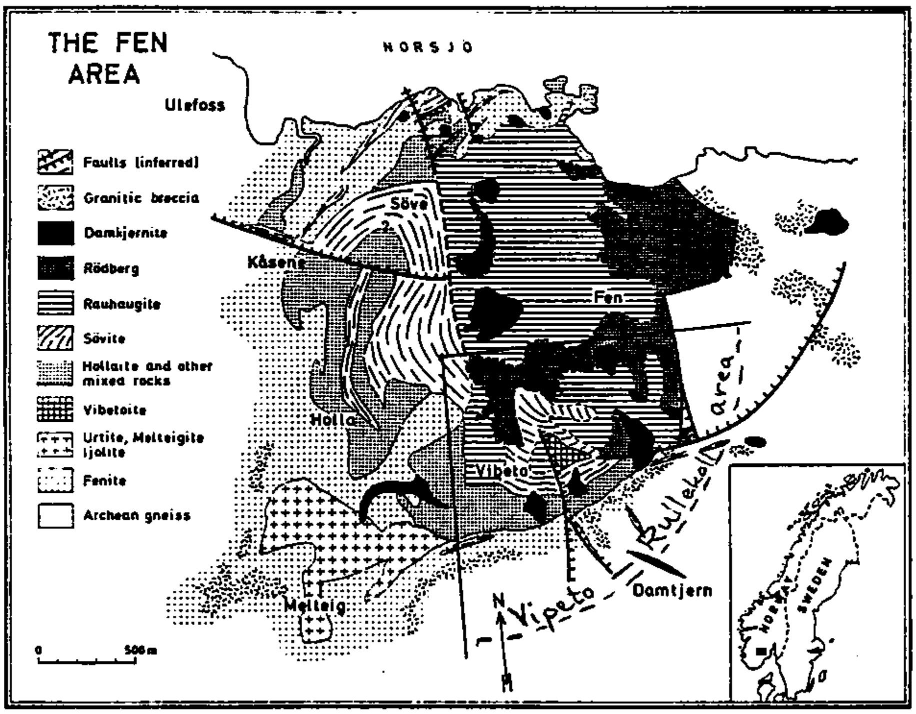


Fig. 1. Generalized geologic map of the Fen complex.

The fact that the Vipeto-Rullekoll area does comprise all the major rock types of the Fen complex makes the area well suited for studying the rock types and their interrelationships. With its considerable volumes of mineralized carbonatites, the area also holds promise as exploration territory.

In the following the individual rock types are described with an emphasis on observed field relationships and features considered to be of particular relevance to the current exploration project. A tentative geologic map has been constructed from the limited field data available and is presented as Fig. 2. This map incorporates much subjective guesswork and should be regarded as a preliminary model to be revised in the light of new information.

The actual field observations in support of Fig. 2 are shown as a fold-out map attached to this report. The legend of this map applies also to Fig. 2. Sampling locations and other localities described in the field notes are shown in Fig. 3, which has also been provided as a transparent overlay, Enclosure I, for use with the 1:5000 maps.

Rock types and their interrelationships

As one approaches the Fen complex from the south, the regional granitic gneiss is seen to be brecciated and/or transformed by fenitization in a border zone that may extend 100 to 200 m into the gneiss. Within this border zone, the explosive forces and the chemically reactive fluids accompanying the early carbonatite intrusions have brought about different degrees of transformation of the pre-existing rock. Nevertheless, both the granitic breccia and the homogeneous, re-crystallized fenite are clearly recognizable as "country rock" with respect to the carbonatite complex. The characteristic mineral assemblage of the fenite is alkali-feldspar and ægirine, but the rock composition is variable and may range from quartz-fenites to those carrying nepheline.

While transgression of niobium mineralization from the carbonatite into adjacent fenites has been reported from some African carbonatites, there is nothing to indicate that the border zone in this area does accomodate ore deposits of economic interest. The fenite has normally less than 1/2 % magnetite.

The next rock type encountered on passing from the south towards the centre of the complex is of more questionable origin. The rock is hybrid in nature, comprising a dark phase of mafic silicate minerals and a white-coloured phase with calcite as the major constituent.

Map scale 1:5000

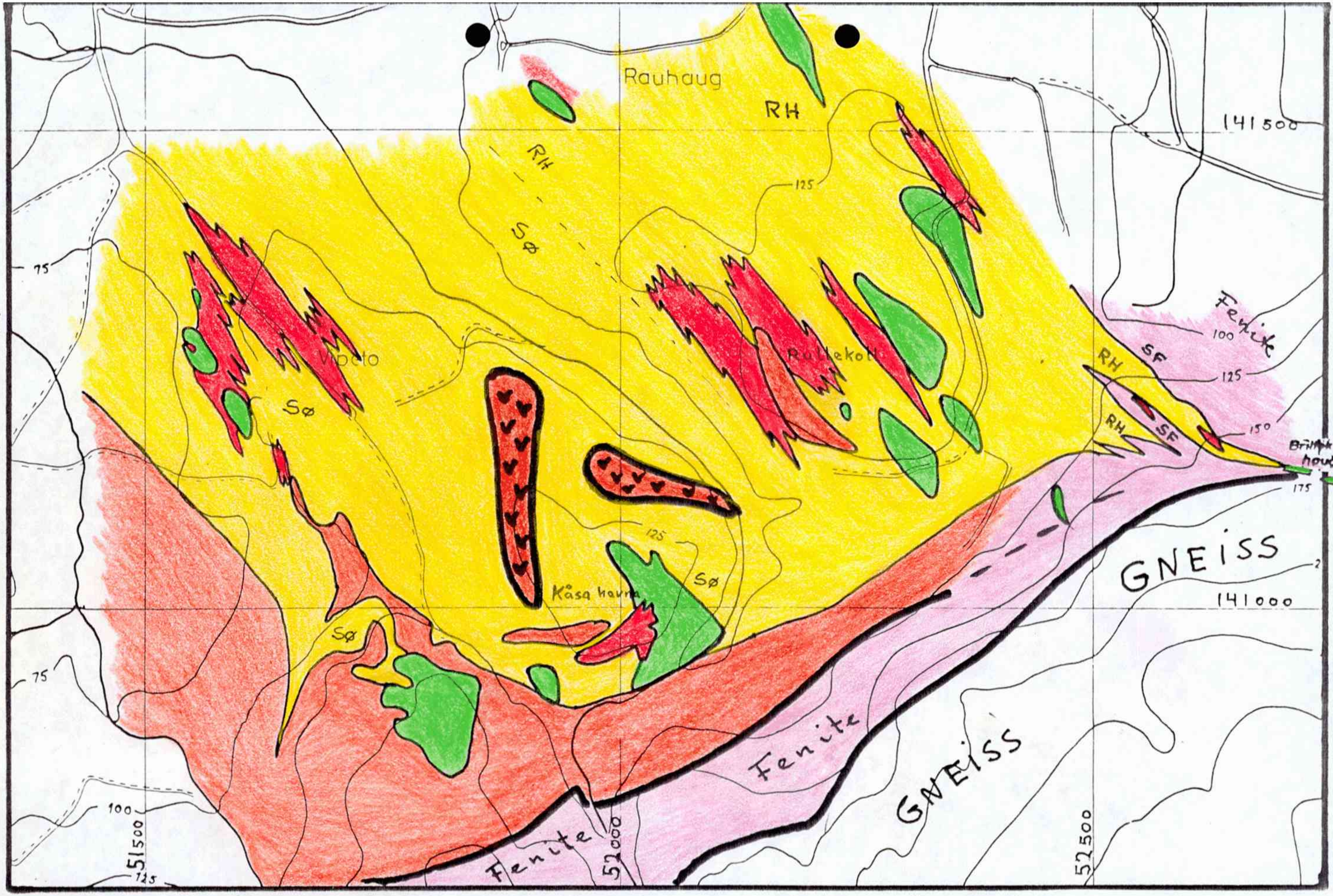


Fig. 2 Tentative geological map of the Vipeto - Rullekoll area

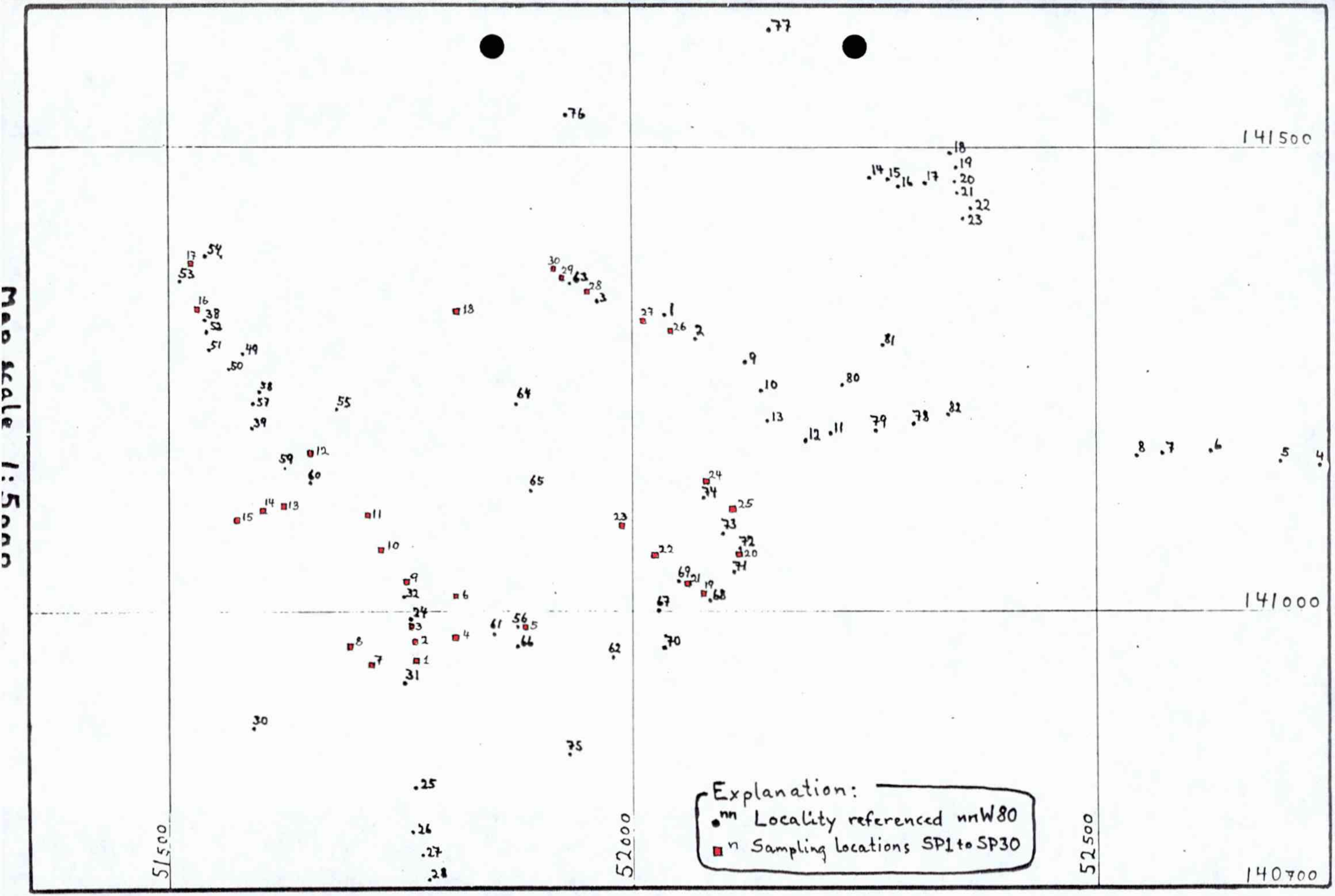


Fig. 3 Sample Locations and Localities referred to in field notes. VHW 1980/81.

During the 1980 field work this rock type was mapped as silico-carbonatite, with an index to indicate the percentage content of carbonate minerals, (e.g. SC_{15} signifying a dark, silicate-rich variety). Within the current Fen project, the old term "hollaite" is now being used as a general name for this hybrid silicate/carbonate rock.

In the Vipeto-Rullekoll area, hollaite occurs in a wide zone along the southeastern boundary of the carbonatite complex, giving way towards the north, to søvite and other genuine carbonatites. South of the Vipeto farms hollaite is observed to be intruded by massive, white søvite, whereas further to the south, along the road to Håtveittjern (loc. 28W80), the hollaite is observed to pass gradually into fenite.

In the eastern part of the area, towards Brillekåshaugen, a dark, heterogranular rock occupies the border area between gneiss and white carbonatite. This rock may resemble hollaite except for its sometime breccia-like structures and conspicuous content of red K-feldspar. Under the microscope, aggregates of fresh carbonate appear to replace the feldspar and other minerals, and it is not inconceivable that this border zone of dark syenitic fenite may represent an intermediate stage in the metasomatic transformation of gneiss to hollaite. This interpretation is corroborated by observations made by Olmore(1982) on drillcore from Tuftehavna.

Along the southwestern hillside of Rullekoll, there are several outcrops of massive, grayish rock, which on weathered surface appears to be intensely brecciated. In thin section this rock is seen to be dominated by a carbonate mineral of low HCl-reactivity, with minor amounts of chlorite forming at the expense of biotite and -notably- remnants of large feldspar crystals under attack by the carbonate described above. The observation is an indication that this rock, which is now essentially an ankeritic dolomite - type carbonatite, could be the remains of a raft of syenitic fenite, engulfed in, and transformed by, an intruding rauhaugite magma.

Hollaite clearly was among the early rocks to be formed within the Fen complex. In the Vipeto-Rullekoll area the hollaite is not known to carry significant amounts of ore minerals. It´s content of magnetite is so much lower than that of søvites and rauhaugites that the contrast was used by Carstens(1981) in the interpretation of the magnetometric data.

Vipetoite is a coarse-grained basic silicate rock resembling hollaite but for the lack of the white carbonatite schlieren. Bodies of vipetoite occur north and west of Kåsa-havna, where they appear to float as rafts embedded in søvite. In contrast to the aggressive rauhaugite magma mentioned above, the søvite magma receiving these huge fragments of older rock material must have been rather docile.

As a dark, coarse-grained, hornblende pyroxenite, the vipetoite hardly deserves particular attention in connection with the ongoing exploration campaign. However, the apatite content of vipetoite is in the range 7 to 12 percent, and if vipetoite should prove to be as abundant at the deeper levels of the Fen complex as suggested by the gravimetric model of Ramberg, its significance as a future source of phosphate might become a question for consideration.

Ramberg, in his papers on the Fen complex, makes the point that vipetoite is transitional into damtjernite (kimberlite). This cannot be reconciled with my observations which so far indicate that vipetoite and damtjernite are separated in time by the intrusion and solidification of the Vipeto søvite.

Søvite, a carbonatite with calcite as the main constituent, is the dominant rock type in the Vipeto area. A carbonatite of similar macroscopic appearence in Rullekoll has ankerite or ferrodolomite as the dominant carbonate mineral and is named rauhaugite. In the field, dilute HCl was used to distinguish the two rock types.

It soon turned out, however, that dikes and diffuse intrusions of rauhaugite appear within the western, søvite-dominated area, whereas reactive calcite also may be present in quantity in the rauhaugite in the eastern parts of the complex. For this reason, the initial mapping was performed using the same colour code for both kinds of white-coloured carbonatite, the letters SØ and RH being added when the diagnosis was clear.

The Vipeto søvite intrudes hollaite and is in turn fragmented and transsected by damtjernite. Dikes and veins of rauhaugite are also seen as intrusions cutting the søvite. Typical søvite is a white to brownish, equigranular rock of variable grain size. Biotite and apatite are common accessories, and sometimes these minerals are oriented and concentrated in parallel bands, giving the rock a faint foliation.

Under the microscope, large calcite crystals often show signs of mechanical strain, indicating that the søvite probably moved as a largely solidified crystal mush during its final stages of intrusion. Boulder-size and larger, angular fragments of fenite occur as inclusions in coarse-grained, igneous-looking søvite west and east of Kåsa-havna. This also indicates that the søvite magma must have been cool and non-aggressive when stoping into its present position. It has not been possible so far to make a meaningful interpretation of the sparse structural observations obtained within the søvite area.

Søvite is known as a carrier of niobium mineralization, and the Vipeto søvite does offer prospects of considerable interest which will be discussed later in this report.

After emplacement of the søvite, the next important event appears to be the intrusion of damtjernite. This dark, porphyritic rock is characterized by the occurrence of cm-size fenocrysts of biotite, set in a greyish, finegrained matrix of carbonates and mafic silicate minerals. The commonly euhedral biotite fenocrysts are sometimes seen to have got their edges rounded as if worn by mechanical abrasion in the ascending magma.

surface. Ferro-dolomite or ankerite is the main mineral component, and calcite, biotite/chlorite, and apatite are common minor constituents.

Within the Vipeto-Rullekoll area, however, the rauhaugite frequently assumes the character of a volcanic breccia carrying a multitude of small fragments of predominantly light-coloured, carbonate-rich rock material. Fragments of other, darker rock types are also seen, and sometimes pyrite and other base-metal sulphides occur as a dispersed, non-economic mineralization. The rauhaugite breccia is often seen to pass gradually into dark damtjernite breccia or possibly brecciated damtjernite (e.g. between loc.s 77W80 and 16W80). Gradual transition is also observed between rauhaugite breccia and rauhaugite which is massive, homogeneous, and seemingly magmatic of origin.

While the nature of the observed field relationships as yet remains obscure, the chemical data indicate that niobium as well as rare earth elements were introduced or concentrated as a result of rauhaugite magmatism. Further study of the petrology and mineralogy of the rauhaugite is therefore deemed necessary in the context of further exploration work.

Rødberg is the obvious local name for the third kind of carbonatite rock found at Fen. And in this case the local name stands unchallenged because the rock type is hardly known from other carbonatites. Rødberg is a typically red-coloured carbonate rock where minute flakes of hematite occur as a finely dispersed red dust clouding the grains of calcite or dolomite that constitute the major mineral phase.

Rødberg is found as irregular or poorly outlined patches or bodies in different parts of the Vipeto-Rullekoll area. It is interpreted as a product of some peculiar metasomatic process that has attacked rauhaugite as well as søvite, and evidence of rødberg having been formed also as a result of metasomatic transformation of damtjernite is seen in several places within the Vipeto-Rullekoll area. A certain spatial association between rødberg and damtjernite points towards a

At the time of intrusion of the damtjernite, the søvite must have been cold and capable of brittle fracturing. This is evidenced by chilled margins of the damtjernite intruding søvite at loc. 69W80, and by the occurrence of numerous sharply angular fragments of søvite embedded in the damtjernite near the contact.

A variable load of rock fragments comprising gneiss, fenite, søvite and other carbonate rocks is a normal feature of the damtjernite intrusions that occur within the borders of the actual Fen complex. Small dikes and pipe-like intrusions of damtjernite are also found in the outside gneiss areas, but here the contamination of the intrusive by wallrock debris is less conspicuous.

Some peculiar, egg-like nodules made up essentially of coarse-grained olivine are sometimes found in the damtjernite, e.g. in the low ridges of outcropping damtjernite and rauhaugite breccia that run SE-wards from loc. 77W80 north of Rullekoll. These inclusions are seen as evidence for a deep-seated origin of the damtjernite magma.

It is my general impression from the Vipeto-Rullekoll area that the damtjernite intrusions might be controlled by a system of deep, NW-SE trending fracture zones. Whether, in the context of the Fen complex as a whole, these fractures can be regarded as radials, has not been considered.

While kimberlites in Africa are known to carry diamonds, no minerals of particular value are known to be associated with the damtjernites at Fen. The importance of damtjernite in the geologic evolution of the Fen complex cannot be denied, but so far, the economic potential of these intrusive bodies is judged to be low.

Rauhaugite has been referred to on several occasions already. This important component in the geologic fabric of the Fen volcanic complex is not easily fitted into place in the sequence of events. The typical rauhaugite is a white medium to fine-grained, equigranular carbonatite of igneous appearence, best recognized by its dark brown weathering possible common structural control for the two rock types.

As described from Gruveåsen further to the north, schlieren and dike-like bodies of massive hematite ore are found in association with rødberg also at Rullekoll. In both areas, concentrations of rare earth elements seem to accompany the hematite ore along with associated thorium which, on account of its radioactivity may be used as a guide to the other, more valuable metals.

Faults and other late features were more or less ignored during the early stages of mapping, and few field observations are therefore available. The occurrence of a vertical diabase dike, 1 m wide, running N-S over the top part of Rullekoll, may be noted. This dike appears to transsect all other geologic features, and is thought to belong to the Permian of the Oslo area.

In concluding this section on rock types and their relationships, I must confess to having made certain field observations that are difficult to explain within the simple petrogenetic model suggested above. These observations range from søvite intruding rauhaugite and rødberg to fragments of rødberg and damtjernite embedded in rauhaugite and vice versa. The observations are, however, duly recorded in field notes and on the detailed, 1:1000 scale geological map sheets, filed with the Fen project management.

Studies on the collected sample material

In an effort to get as much information as possible out of the limited data and samples obtained before the Vipeto-Rullekoll area was closed to Fenco, a total of 51 geological rock samples were submitted to chemical analysis along with a set of 30 samples from the Vipeto area collected specifically for geochemical assessment of the søvite. The analytical results are tabulated in Appendix I and will be discussed under GEOCHEMISTRY.

As the political situation developed, the Vipeto-Rullekoll area was assigned a low priority which impeded the petrological studies that would normally accompany geological mapping and exploration. Eventually, a total of 36 polished thin sections were prepared, but so far these have been used mainly as a means of getting familiar with the rather exceptional petrology of the Fen rocks. No systematic and detailed description has as yet been worked out for the individual thin sections. Some of them could, however, be of value in a future, problem-oriented study of certain rock types, and a listing of the polished thin sections available from the Vipeto-Rullekoll area is presented as Appendix II to this report.

For a geologist unfamiliar with carbonatites, recognition of the different main-phase carbonate minerals is definitely a problem. In an attempt at clarification, 20 samples of crushed carbonatite material were examined by powder-microscopy and cathodoluminescence. The results of this pilot study are presented in Appendix III, where the most interesting outcome seems to be that the red-coloured dolomite in rødberg, full of tiny exsolution(?)-lamellae of hematite, has a lower refractive index ($n = 1.67$) and thus a lower content of iron in solid solution than has the white, ankeritic dolomite of normal rauhaugite ($n = 1.69$).

From the important locality 10 m south of loc. 24W80, where pyrochlore mineralization had been observed in a road-cut through Vipeto søvite, a 1 kg sample of mineralized søvite was collected for rather special treatment. After careful breaking up into coarse fragments, the sample was treated in hot, concentrated hydrochloric acid until all soluble carbonates had been destroyed. The retained unsoluble residue comprising phlogopite, apatite, magnetite, pyrochlor and remnants of a greyish carbonate is now available for mineralogical studies of various kinds on crystals having their original habitus preserved.

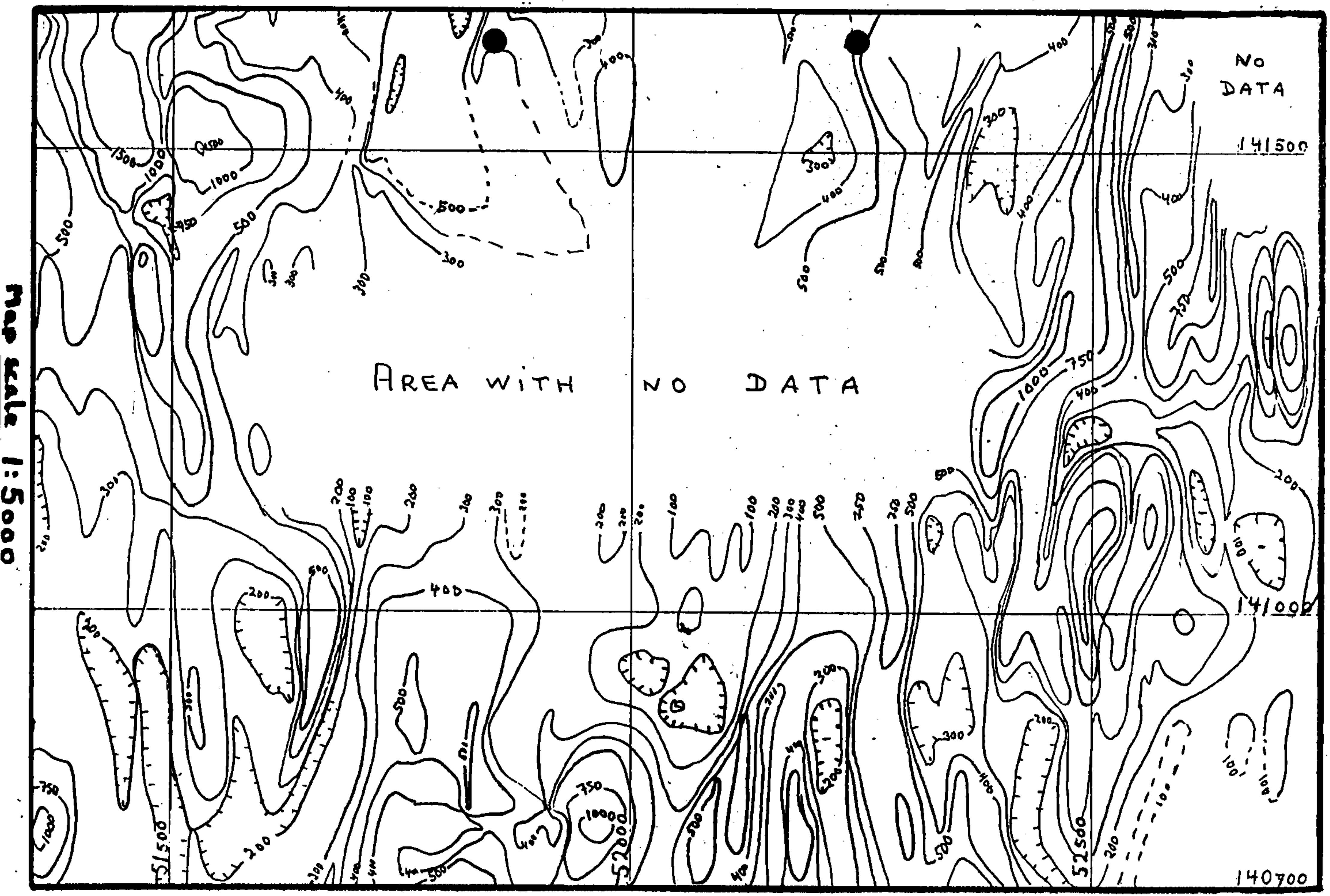


Fig. 4 Magnetic total field contour map redrawn from Carstens (1981).

GEOPHYSICS

With the limited access to bedrock exposures in the Fen area as a whole, geophysical measurements become an important secondary source of information already at the stage of geological mapping. None of the existing geophysical methods respond directly to ores of niobium or rare earth elements, and geophysics as an exploration tool must therefore be used with great care and subject to frequent feed-back from detailed geological investigations.

Magnetometry

A geomagnetic map of the Fen area was prepared by Geofysisk Malmleting already in 1949. The vertical component of the magnetic field was measured on sections 20 m apart along profile lines running E-W at intervals of 100 m. Sæther(1957) made extensive use of this geophysical information when compiling his geological map of the Fen complex.

Carstens (1980) reports on supplementary magnetometric measurements carried out during the summer of 1980 as part of the current Fen project. His work was concentrated on the Vipeto-Rullekoll area, because this area had been poorly covered by the earlier survey. As an experiment, conductivity measurements were carried out along with the mag-survey. The instruments used were a VLF receiver and a proton (total field) magnetometer.

For various reasons it proved difficult to reconcile the new with the old mag-data, and during November 1980 an effort was made to cover the whole Fen area with new measurements on a 20 m by 100 m grid. At that time, however, landowners' opposition to Fenco had begun to develop, and certain areas had to be excluded from the new survey for this reason. Fig. 4 is a magnetic total field contour map, redrawn from Carstens(1981). This figure is also presented as a transparent overlay marked Enclosure II.

The most conspicuous feature of the geomagnetic map Fig. 4 is a deplorable lack of data from the central part of the Vipeto-Rullekoll area. Nevertheless, several distinct, N-S trending structures emerge in the south and east. These structures are not readily apparent from the geological maps and, unless some correspondance can be shown to exist between these mag-anomalies and late features such as the diabase dike cutting N-S through Rullekoll, it seems at present not possible to reconcile geophysical and geological observations in this case.

The immediate action in such a case would be to prescribe additional magnetometry on a closer grid, in order to see if the present interpretation can be verified. From a geologic point of view, high local variability can be expected in the areas in question, and it is conceivable that non-representative data might have been given undue weight in the interpretation. Supplementary measurements along intermediate profile lines should clarify the situation.

On the other hand, there is the high-grade, Tuftehavna lamphrophyre now under study further to the northwest. This important mineralization seems to be associated somehow with distinct N-S trending geomagnetic structures. As pointed out by Carstens in his reports, there is in the Vipeto area an interesting spatial correlation between high niobium contents in the søvite and magnetic high´s that extend in a due south direction. This situation will be discussed in a later section on the Vipeto søvite.

Radiometry

Within the Fen complex, thorium appears to be the predominant source of radioactivity. Measurements of γ-radiation have been used both in the earlier investigation by FSJ (1967-1970) and in connection with the current project.

Application of radiometric methods on a regional scale is ruled out because of the widespred occurrence of quanternary deposits acting as an efficient shield that absorbs the radiation from unexposed bedrock before it reaches the surface. Applied to specific local problems, however, measurements by a scintillometer may provide important information to guide further exploration. This is indicated by the positive results arrived at in a preliminary radiometric survey carried out over the Brillekåshaugen prospect in November 1981.

Other methods

Gravity measurements as discussed by Ramberg (1973) clearly carry information of great importance for unraveling the broader geologic setting of the Fen complex. Within a local area such as Vipeto-Rullekoll, with its irregular surface topography, gravimetry does not appear to be directly applicable, neither in mapping out the individual geologic units nor as a direct guide to ore. This question might, however, warrant expert advice and/or limited field trials.

Castens (oral comm. 1982) points out that the VLF method appears to respond to the conductivity contrast between rødberg and surrounding rauhaugite. With the considerable depth range of the VLF method, the possibility of tracing zones of rødbergization below quarternary deposits and at depth opens interesting perspectives, and the necessary trials should be given high priority.

GEOCHEMISTRY

With the unexpected developments which led to restrictions on exploration activities in the Vipeto-Rullekoll area in late 1980, systematic sampling for a whole-rock geochemical survey was never carried to completion. Nevertheless, the geochemical data obtained from the area have served as a valuable supplement to the geological and geophysical information. It is essentially these data that form the basis for my recommendations for further work to be undertaken in order that a satisfactory assessment of the Vipeto-Rullekoll area can be made.

The sample material

From some ninety hand specimens collected as reference material during the geological mapping in 1980, fifty samples were selected for analysis. The rock types søvite, rauhaugite, rødberg and basic silicate rock were represented in the sample material with approximately 20% each, with the last 20% comprising damtjernite, fenite and various dark, unclassified silicate/carbonate rocks. The fifty samples are identified by their locality number in the _W80 series.

As a special project, thirty 1 kg samples of carbonatite material assumed to represent the Vipeto søvite were collected in September 1980 for the purpose of geochemical assaying. These samples are labeled SP01 to SP30.

In November 1981, seventeen samples of rauhaugite and syenitic fenite were collected from the prospect at Brillekåshaugen. These samples, (numbered 741 - 755 with the letter A, B or C to distingnish different rock types sampled at the same locality) were analysed in February 1982 along with one sample from a fluorite-rich volcanic breccia rock from Rullekoll (79W80).

The analytical procedures

Under an agreement with the Central Institute for Industrial Research (SI), the Fen samples were first submitted to a Stage I analytical procedure for determination of the eight elements Nb, Y, Th, P, S, La, Ce and Nd by X-ray fluorescence (XRF). This standardized, low-cost procedure used tablets pressed from rock material ground to minus 200 mesh. The results were presented with an accurracy of +- 30% relative, and detection limits 0.01% or better. The procedure was standardized on the assumption that the sample matrix would be essentially calcium carbonate, and that the content of TiO_2 would be approximately 0.1%. To cut costs in the routine analysis of drillhole samples determination of P, S, La and Nd was later excluded from the Stage I procedure.

The SI laboratory also provided a Stage II procedure where the elements Fe, Si, Mg, Al, P, Na, Ti, K, Ca, Mn, Ba, Sr and V were determined by the ICP (plasmaspectrometric) method after complete decomposition of the sample in hot acids. Only samples of particular importance would be selected for Stage II analysis. In connection with a special study, samples with a high Nb-content were selected for XRF determination of U and Ta.

The results

All analytical results are tabulated in Appendix I of this report. The chemical data with corresponding sample number and location coordinates were stored on a computer-accessible file as part of the larger data set, FENDATA.

Fig. 5A is a scaled-down map plot where all sample locations with a Nb content of 0.1% or more are marked with a star symbol. The size of the symbol varies in proportion to the niobium percentage. This figure is also provided as a transparent overlay in scale 1:5000, Enclosure III, and if this is superimposed on the geologic map, niobium is seen to be concentrated in rødberg and rauhaugite as well as in søvite, the occurences being spred out over the Vipeto-Rullekoll area.

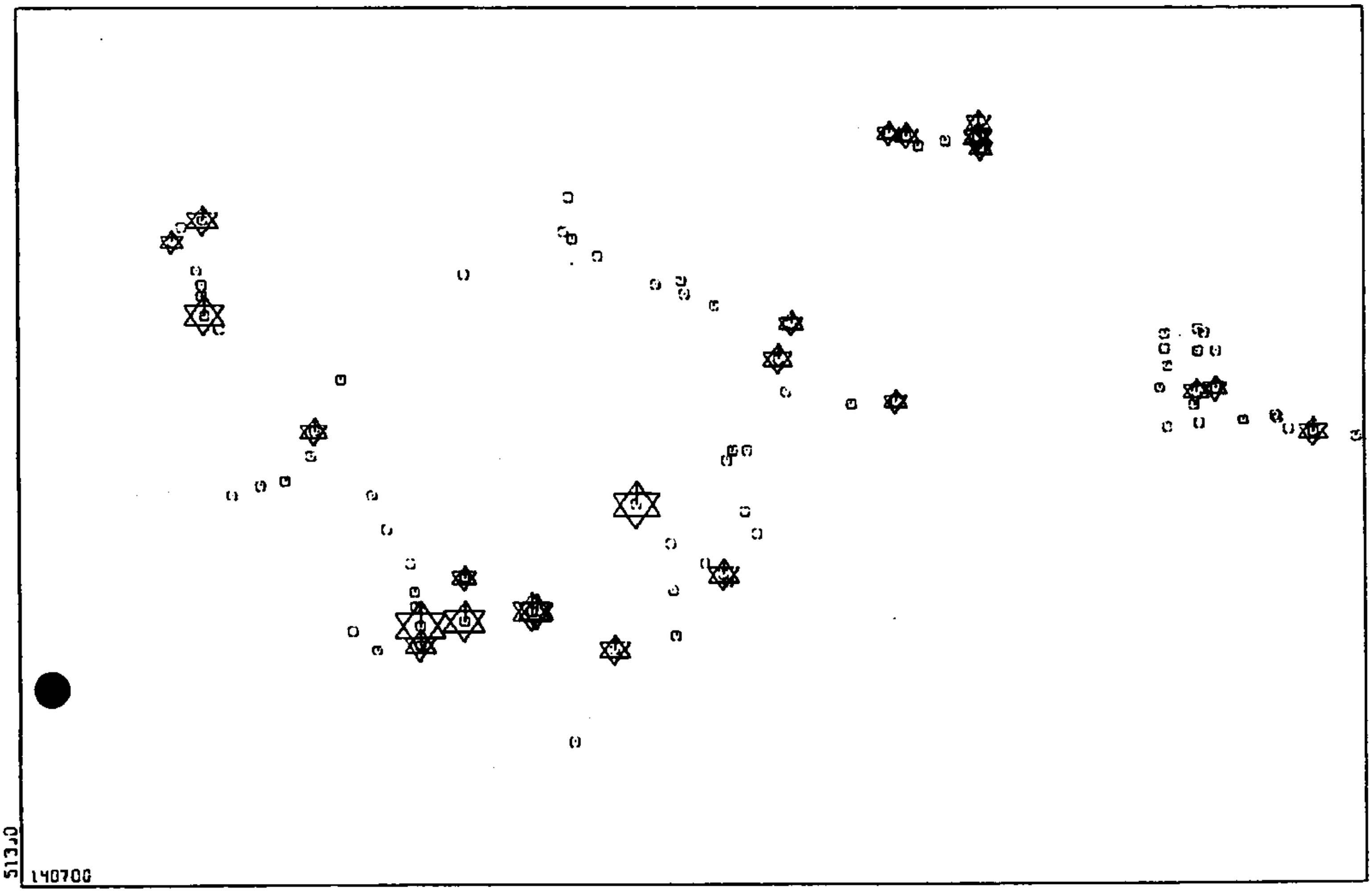


Fig. 5A VIPETO-RULLEKOLL AREA - NIOBIUM - STAR IF > 0.1 % MAP 1:~~5000~~

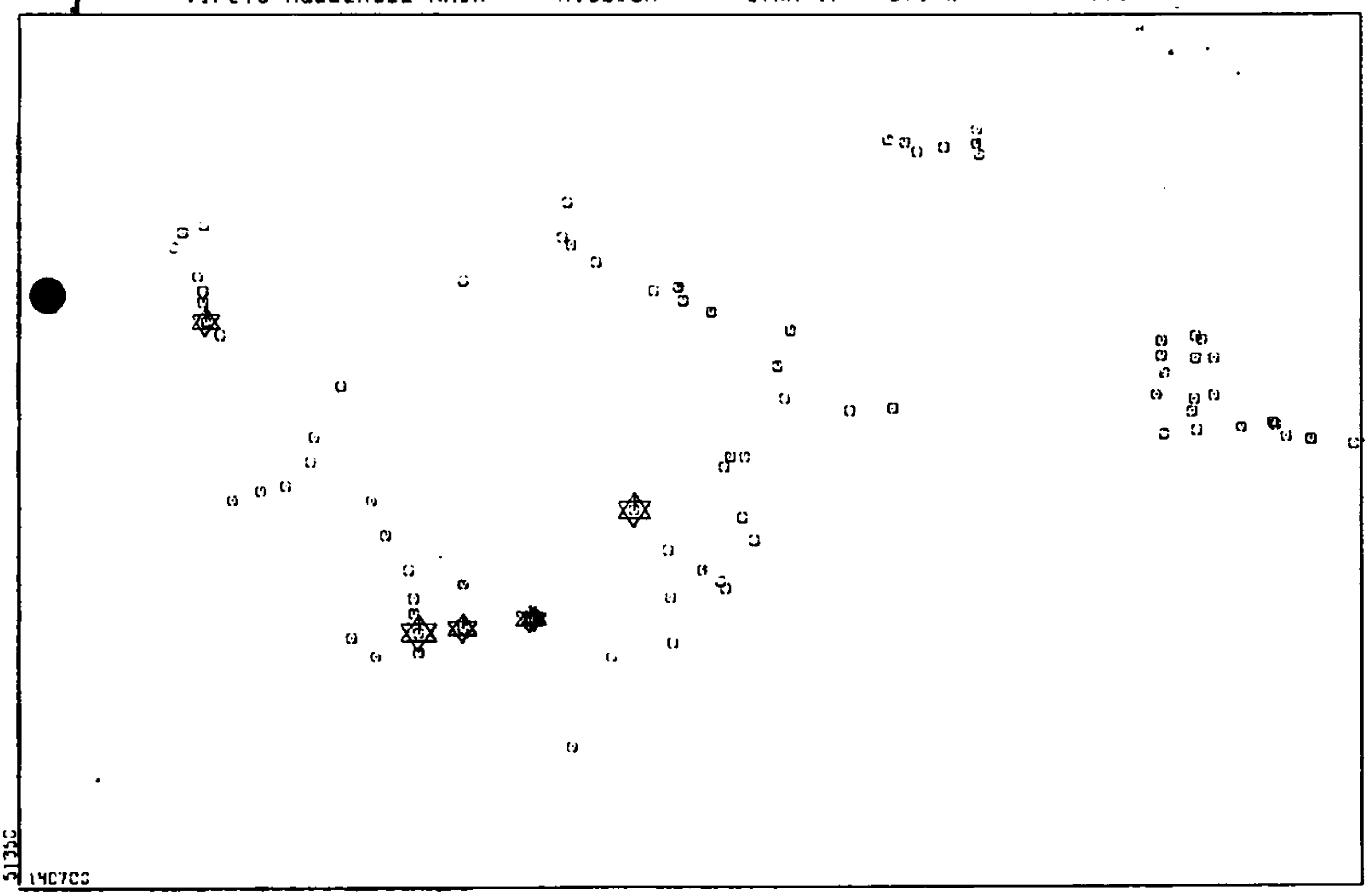


Fig. 5B VIPETO-RULLEKOLL AREA - NIOBIUM - STAR IF > 0.2 % MAP 1:~~5000~~

Fig. 5 NIOBIUM

If, however, the screen is set at 0.2% Nb as in Fig. 5B, the remaining anomalies are seen to be concentrated along the southern boundary of the Vipeto søvite. This fits the subjective impression gained through geological mapping, that the border zone between søvite and hollaite seems to have the highest concentrations of pyrochlor in the søvite.

Treating all the analysed rock specimens from the Vipeto-Rullekoll area as one statistical sample, the histogram for niobium percentages, Fig. 6, at first glance shows a positively skewed, almost lognormal, frequency distribution. Such a distribution would be expected if one single process were to be responsible for the dispersion of niobium throughout the area. This is difficult to accept from a geological point of view and, by closer scrutiny of the diagram, one might admit the possible presence of one or several minor populations of higher-grad values superimposed on the dominant lognormal (?) population. For further speculations along these lines, the reader should turn to the subsequent discussion on the prospectivity of the Vipeto søvite.

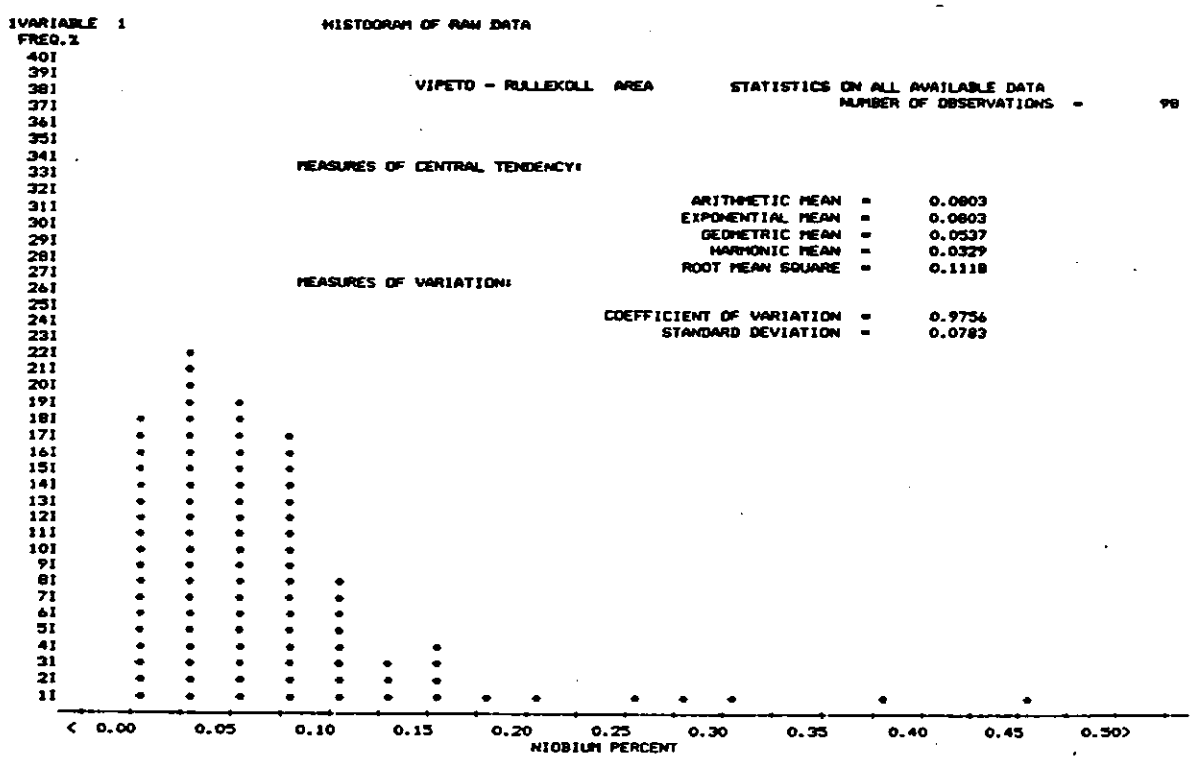
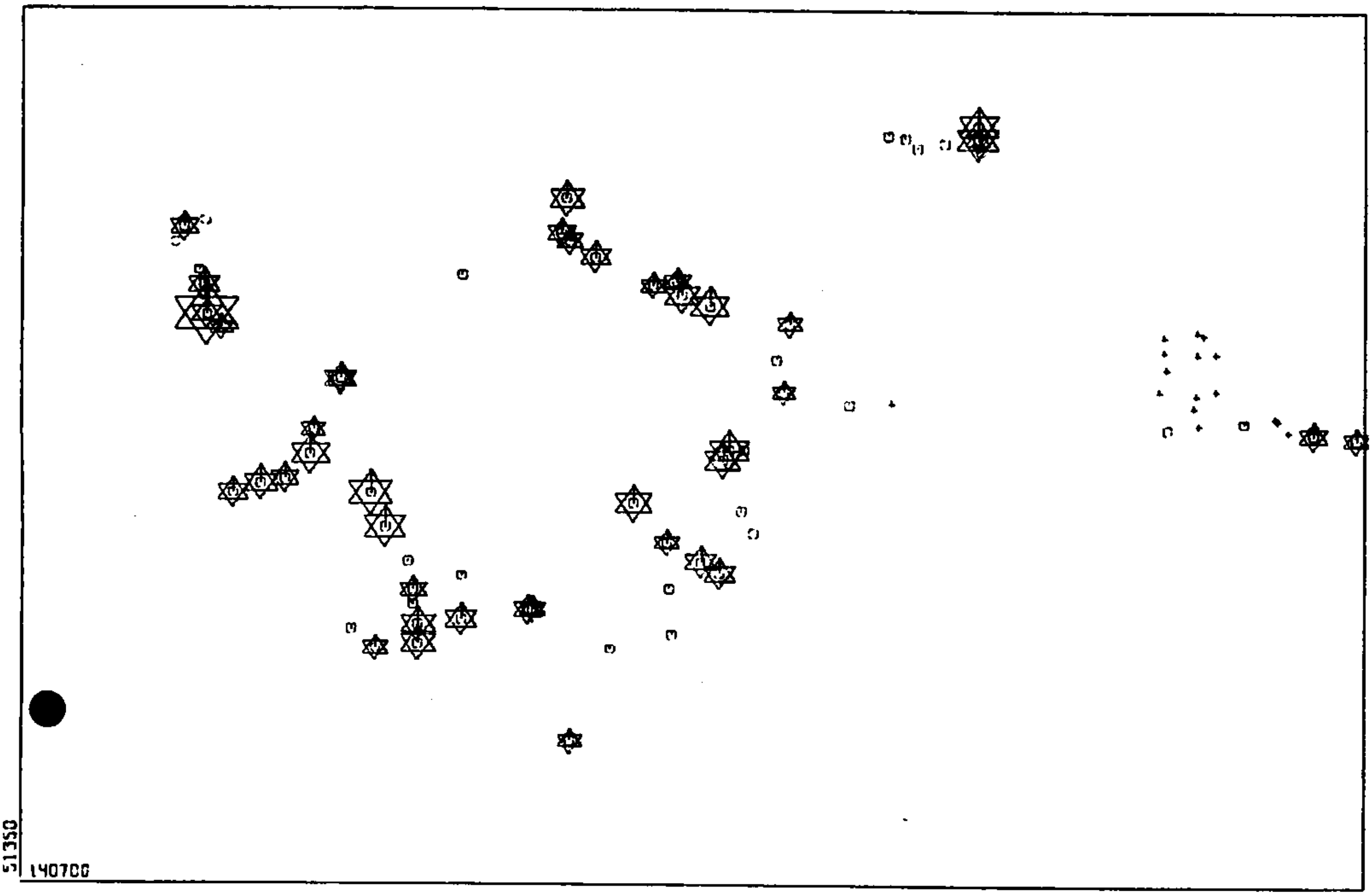
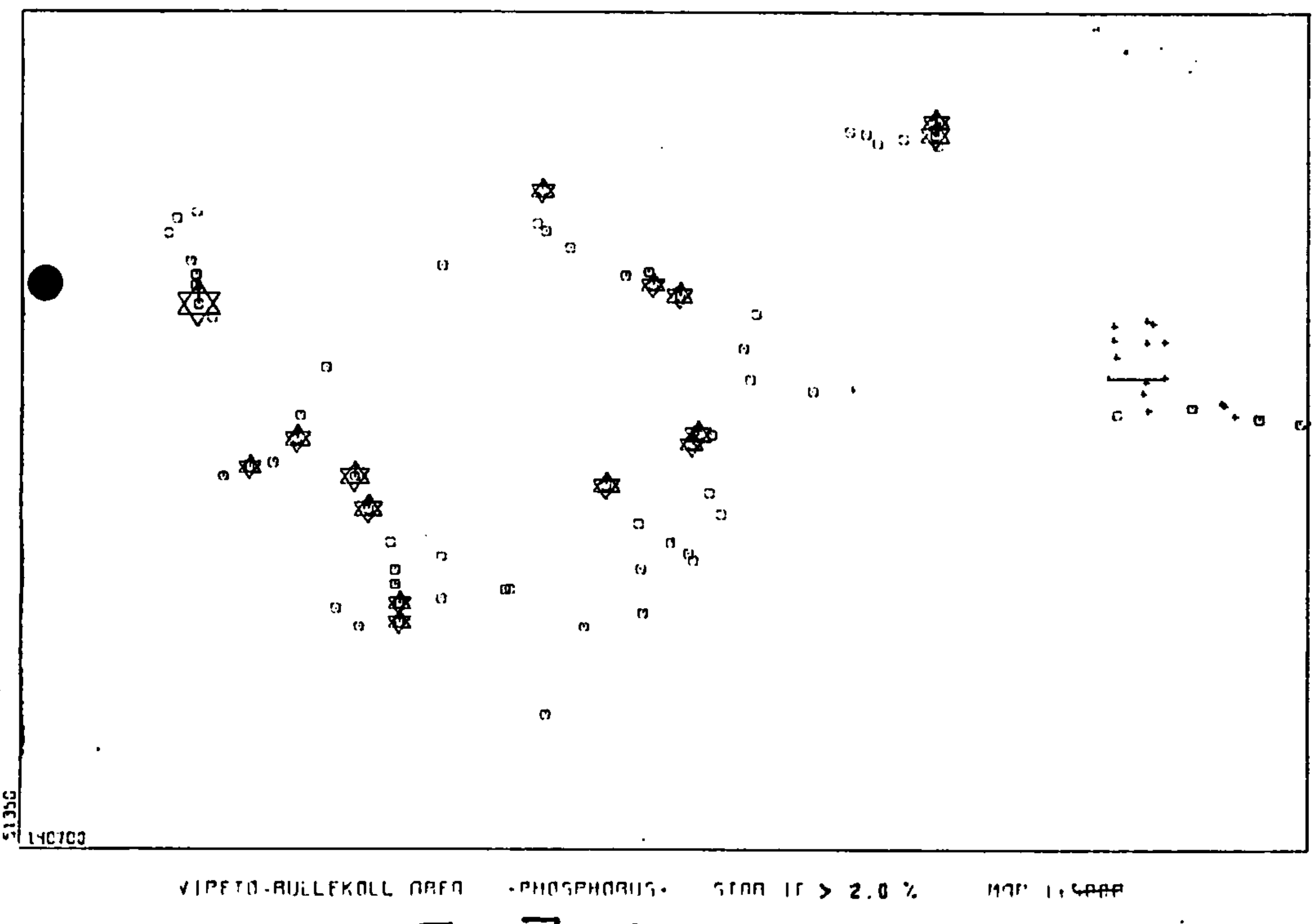


Fig. 6. Histogram of Nb percentages in all Vipeto-Rullekoll rocks



VIPETO-RULLEKOLL AREA -PHOSPHORUS- STAR IF > 1.0 % MAP 1:5000



VIPETO-RULLEKOLL AREA -PHOSPHORUS- STAR IF > 2.0 % MAP 1:5000

Fig. 7 PHOSPHORUS

Apatite concentrate is a commodity of considerable economic importance, and the combined extraction of pyrochlor and apatite from finely ground søvite, the remainder of which might be marketed as agricultural limestone, is an interesting concept in the context of the Fen project. The areal distribution of whole-rock phosphorus contents is shown in Fig. 7. Comparison with Fig. 5 shows no covariation of P and Nb, and this is confirmed by statistical analysis which yields a correlation coefficient $r = 0.04$.

The highest concentration of phosphorus (7.4% P) was found in sample 51W80X, a coarsegrained, white søvite which appears as a young, intrusive phase transsecting a damtjernite/rauhaugite breccia and patches of rødberg, all occuring locally within the older Vipeto søvite.

Notably, the Nb-high (0.29% Nb) shown by Fig. 5 for the same locality stems from sample 51W80B which represents the grey, volcanic breccia. This rules out the possibility that, in this case, the association Nb-high with high phosphorus might reflect a mineralization of the Tuftehavna lamprophyre-type.

Coming finally to the distribution of rare earth elements (REE), Fig. 8 and Enclosure IV show that this distribution is far from uniform. The star symbols in this case identify those localities where La, Ce and Nd contents in sum exceed 0.3%. The highest concentrations of REE are seen to occur in the wedge of rauhaugite extending towards Brillekåshaugen. Here, as in other parts of the Vipeto-Rullekoll area, an introduction of REE related to the process of rødbergization might be indicated, but is by no means demonstrated.

Figures 9 and 10 show how the anomalous values of respectively Ba and Th are distributed over the Vipeto-Rullekoll area. The + signs in Fig. 9 show samples not analysed for barium. Mørk(1981) observes that baryte seems to be a common mineral of rauhaugite, and he describes a sample from Gruveåsen where enrichment in REE-minerals is associated with baryte along veins.

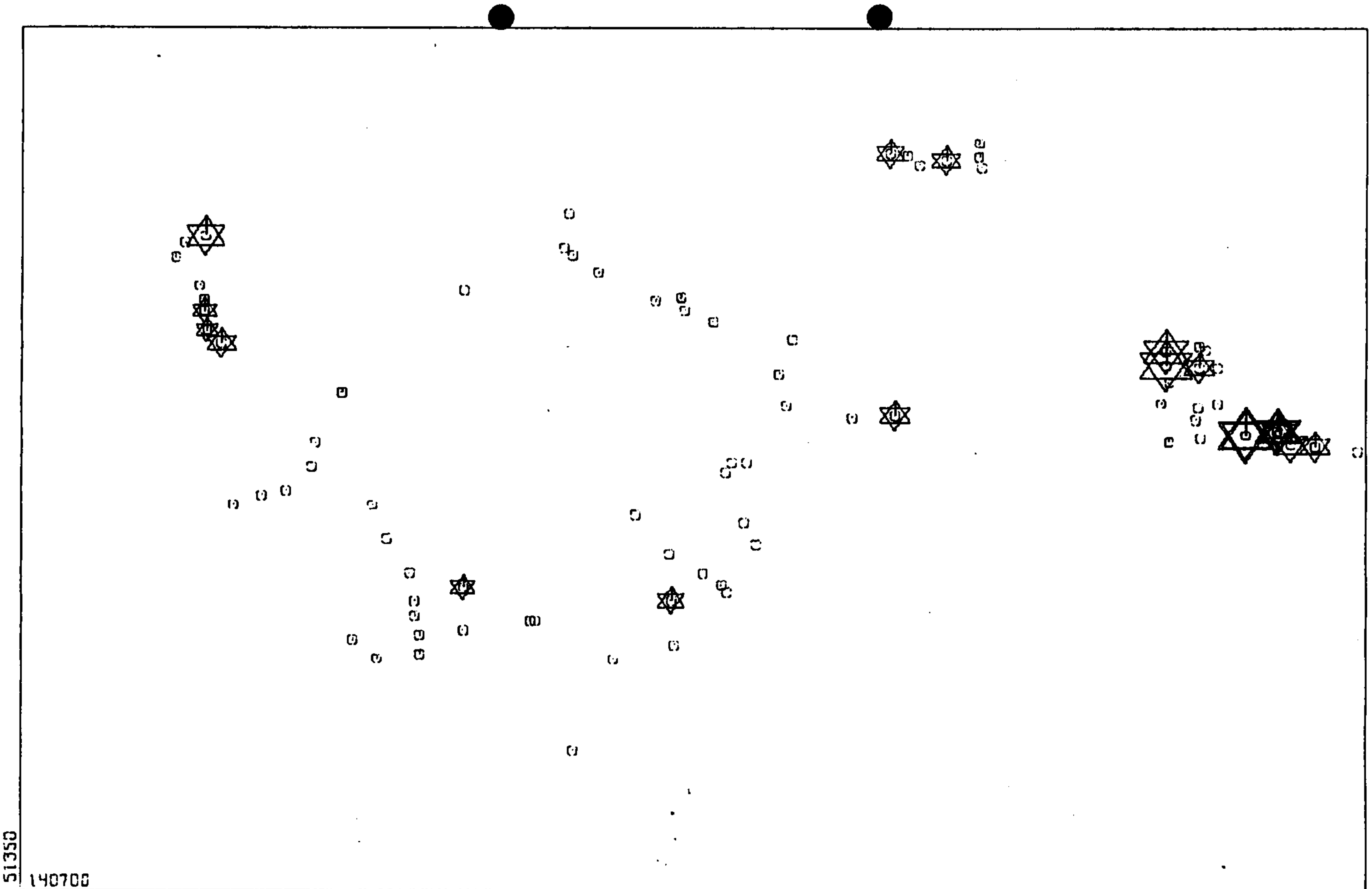


Fig. 8 VIPETO-RULLEKOLL AREA •LA+CE+NO• STAR IF > 0.3% MAP 1:5000

In this light Fig. 9 assumes importance in the sense that it lends support to the hypothesis that the REE mineralization at Brillekåshaugen is related to deep, NW-SE trending zones of tectonic movement, striking along the northeast side of Rullekoll and extending towards loc. 77W80 at the northern boundary of the Vipeto-Rullkoll area.

From a comparison of figures 9 and 10 it would appear that Th tends to follow Ba. If the assumed genetic relationship between the REE and Ba is correct, radiometry should be an appropriate prospecting tool in this case.

In my opinion, the whole corridor between loc. 5W80 at Brillekåshaugen and loc. 77W80 at the northern extremity of the Vipeto-Rullekoll area warrants detailed exploratory investigation as a zone with moderate to good potential for REE orebodies of economic importance.

Under the present circumstances, the Brillekåshaugen prospect presents itself as the best starting point for such an investigation.

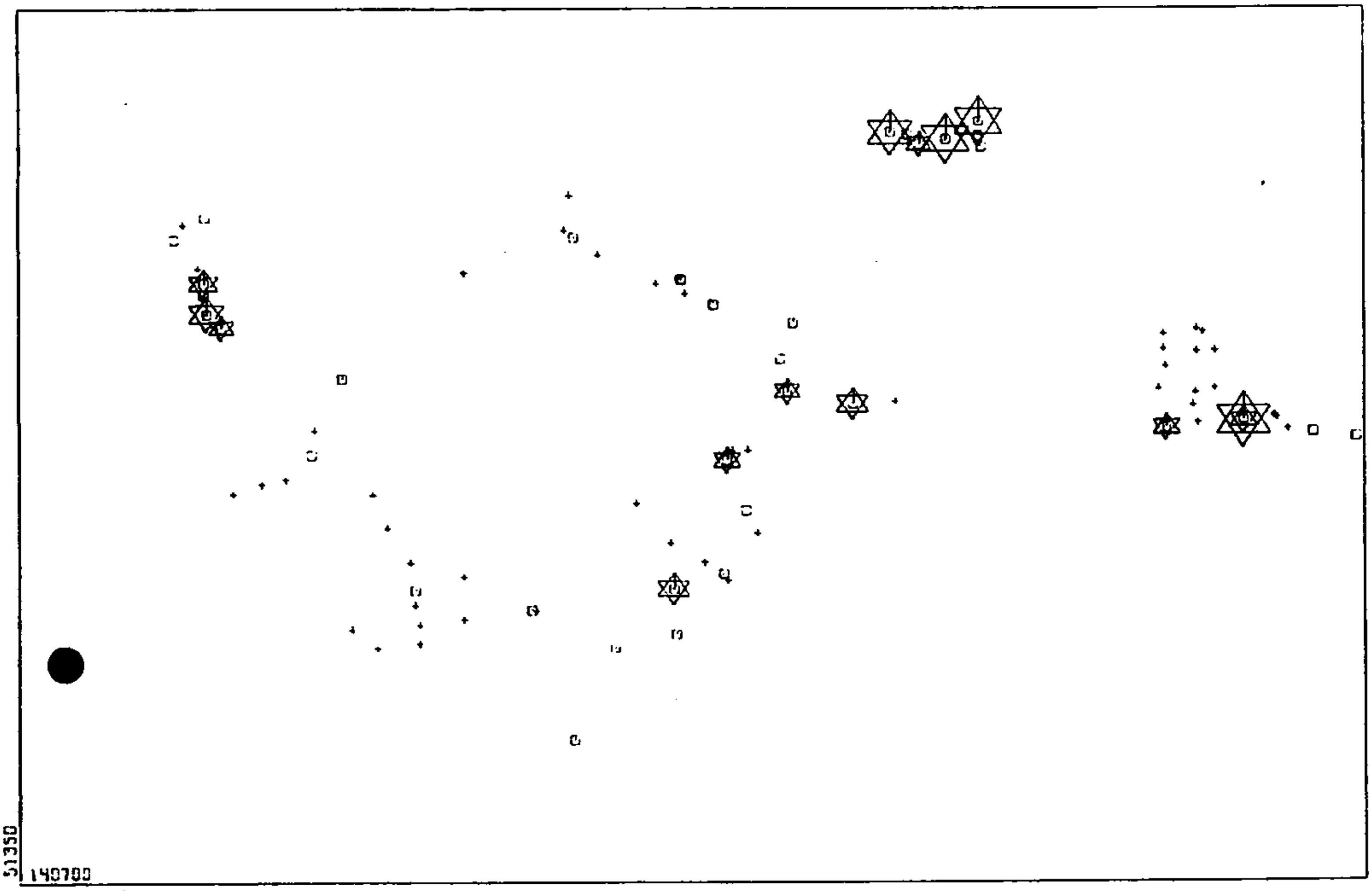


Fig. 9. VIPETO-RULLEKOLL AREA - BARIUM - STAR OF % > 0.5 MAP

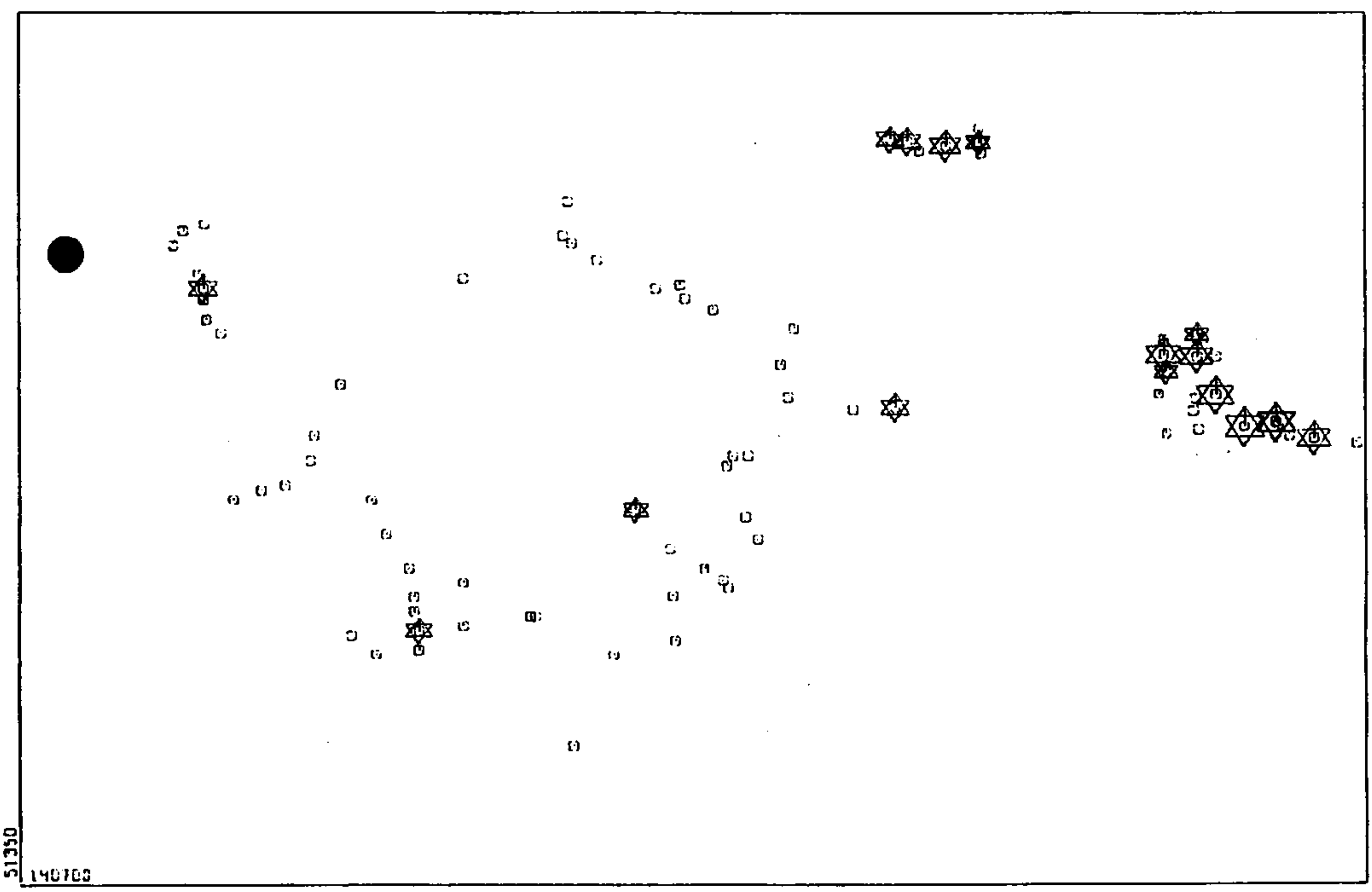


Fig. 10 VIPETO-RULLEKOLL AREA - THORIUM - STAR OF % > 0.05 MAP

PROPOSALS FOR FURTHER WORK

Even with the limited amount of work so far carried out in the Vipeto-Rullekoll area, it is quite clear that the area is important, both in the sense that it probably holds several keys to a fuller under= standing of the geologic evolution of the Fen complex, and as an exploration area of unquestionable potential.

Continued geological mapping would certainly be desirable, but in the given situation the best approach will probably be to organize further work in the area in the form of specific, target-oriented exploration projects with clearly defined objectives and firm budgets and time schedules. Three possible exploration targets are described and discussed below.

The Vipeto søvite

In a road-cut along the cart-track to Håtveittjern, loc. 24W80, geologists from Union and Fenco already in 1979 discovered a dispersed, primary mineralization of 1-5 mm large, euhedral crystals of pyrochlor along with similar-size magnetite and phlogopite in massive, brownish-white søvite which also carries streaks and irregular clusters of yellow-green apatite.

From the geochemical plots, this locality is seen to belong to a belt of Nb-high anomalies running east-west along the boundary between the Vipeto søvite and adjacent hollaite to the south.

Carstens (1980 and 1981) points to the significant spatial correlation between the Nb-enriched søvite (SP 02 assying 0.46% Nb and 2.1% P) and a positive magnetic anomaly passing in a N-S direction alongside the abovementioned locality. In his interpretation the N-S trending magnetic anomalies in this area represent dikes of magnetite-, and possibly pyrochlor-, bearing søvite that extend towards the south beneath a thin cover of basic silicate rocks.

The suite of carbonatite samples marked SP1 to SP30 were collected in September 1980 as representative of the Vipeto søvite. While a few of the samples could be hollaitic carbonate material or rauhaugite, mistaken for søvite, this possibility does not alter the fact that the distribution of niobium within the presumably massive søvite body is distinctly non-uniform. Fig. 11A indicates that the frequency distribution of the niobium concentrations in the 30 SP-samples might be polymodal: a lognormal distribution of low-grade, magmatic dispersion-type background values, upon which scattered high-grade values of no apparent regularity have been superimposed through the interference of some ore forming process as yet unknown.

The concept of a primary, low-grade dispersion of pyrochlor crystals throughout the Vipeto søvite and, superimposed, local high-grade mineralizations, has as yet not been substantiated by geologic observations from the Vipeto-Rullekoll area. However, the Tuftehavna lamprophyre appears to be just such a phenomenon, and the possibility that a similar process has been active in the Vipeto area, cannot be ignored.

The fabric of geophysical anomalies brought out by the recent magnetometric survey is difficult to reconcile with a model of the Vipeto søvite as a homogeneous intrusive body. It would, however, be conformable with other models e.g. of the Vipeto søvite as a system of N-S trending multiple dikes, each dike having a different magnetite/ pyrochlor content. Alternatively, the Vipeto søvite could be a massive body of intrusive carbonatite transsected by younger, lamprophyre type mineralization along N-S trending zones of fracture.

It is this possibility of finding high-grade, Tuftehavna type pyrochlore/apatite mineralization that provides the real incentive for continued exploration of the Vipeto søvite. With the knowledge that this kind of ore has in fact been deposited in a similar geological environment 1 km further to the northwest, it is difficult to see how the Vipeto søvite can now be left unexplored.

NUMBER OF OBSERVATIONS =

MEASURES OF CENTRAL TENDENCY:

ARITHMETIC MEAN	=	0.0896
EXPONENTIAL MEAN	=	0.0897
GEOMETRIC MEAN	=	0.0442
HARMONIC MEAN	=	0.0238
ROOT MEAN SQUARE	=	0.1451

MEASURES OF VARIATION:

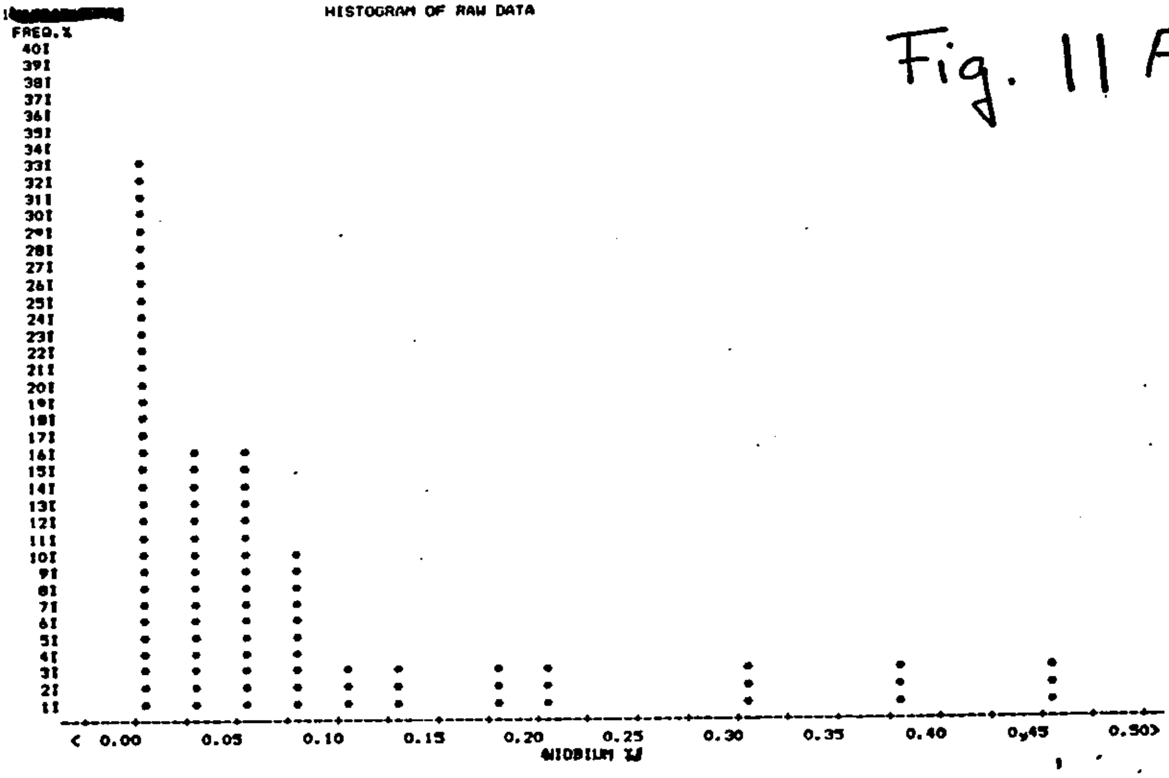
COEFFICIENT OF VARIATION	=	1.2963
STANDARD DEVIATION	=	0.1161

MOMENTS OF THE DISTRIBUTION:

1ST MOMENT	=	0.0896
2ND MOMENT	=	0.0130
3RD MOMENT	=	0.0030
4TH MOMENT	=	0.0010

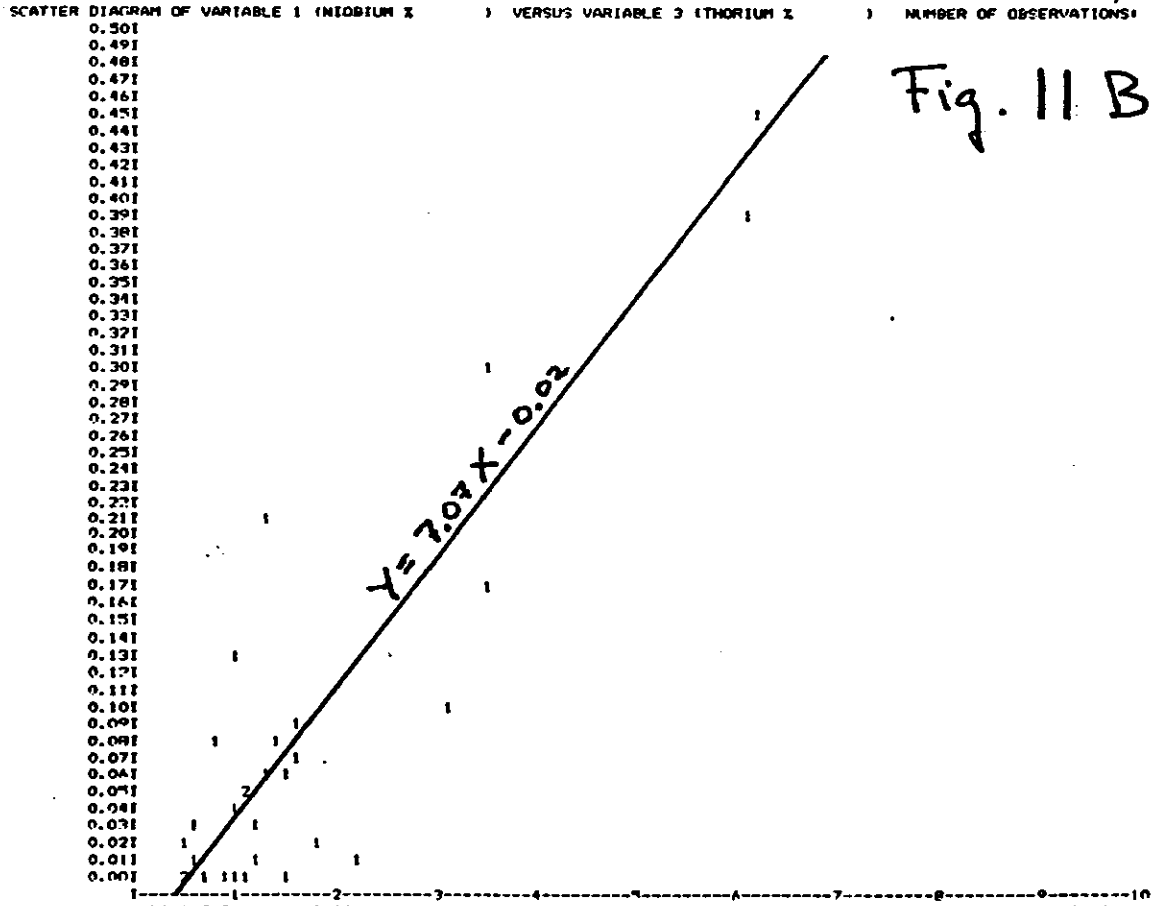
1[redacted] HISTOGRAM OF RAW DATA

Fig. 11 A



SCATTER DIAGRAM OF VARIABLE 1 (NIOBIUM %) VERSUS VARIABLE 3 (THORIUM %) NUMBER OF OBSERVATIONS:

Fig. 11 B



VARIABLE 3 ALONG HORIZONTAL AXIS PRINT-UNIT(-)= 0.001 UPPER LIMIT REPRESENTS THE VALUE 0.100
(FURTHER INFORMATION REGARDING THE RELATIONSHIP BETWEEN THE TWO VARIABLES UNDER INVESTIGATION:

CORRELATION COEFFICIENT = 0.8834 REGRESSION EQUATION Y = 7.06942 X + -0.0221

Fig. 11 Statistics from Vipeto søvite data on Nb and Th.

As the next step in exploring the Vipeto søvite, the recent magnetometric data should be supplemented with measurements along intermediate profile lines in the southern part of the area. Normal coverage will also be needed in those parts currently without data. A VLF survey should be carried out at the same time, as this might provide information of help both in tracing fault zones and for outlining areas of rødbergization.

The scatter diagram of Nb versus Th, Fig. 11B, shows for the Vipeto søvite data a strong correlation (r=0.88) to exists between niobium and thorium. This relationship is valid in particular for søvite with high Nb-values, which consequently also carries relatively much thorium. The implication is that the radioactivity from the thorium might perhaps serve as a guide to concentrations of Nb in the Vipeto søvite, and the use of a scintillometer should be considered.

It is difficult to see how a serious appraisal of the Vipeto søvite can be made without using diamond drilling in selected areas.

If the N-S trending geophysical anomalies are verified, the drilling should aim at intersecting vertical zones of mineralization having a N-S extension. An inclined hole, drilled at an angle of 50 degrees in direction due west, from a collar position near loc. SP 04 might be considered.

Should the magnetic data fail to give any clear indications, the drilling of several vertical holes, sited on the basis of surface geochemistry, might be the option to prefer.

In the latter case, however, the prospect would have to be down-graded with regard to the possibilities for finding high-grade ore.

The Brillekåshaugen prospect

Attention was turned to this rather remote part of the Fen complex as a result of the decision to assay the rock samples collected during the geological mapping in 1980. Samples collected at localities 5W80 and 6W80 in the western part of Brillekåshaugen showed highly anomalous concentrations of REE, and in November 1981 these findings were followed up by a scintillometer survey along with some geological mapping and collection of additional rock samples.

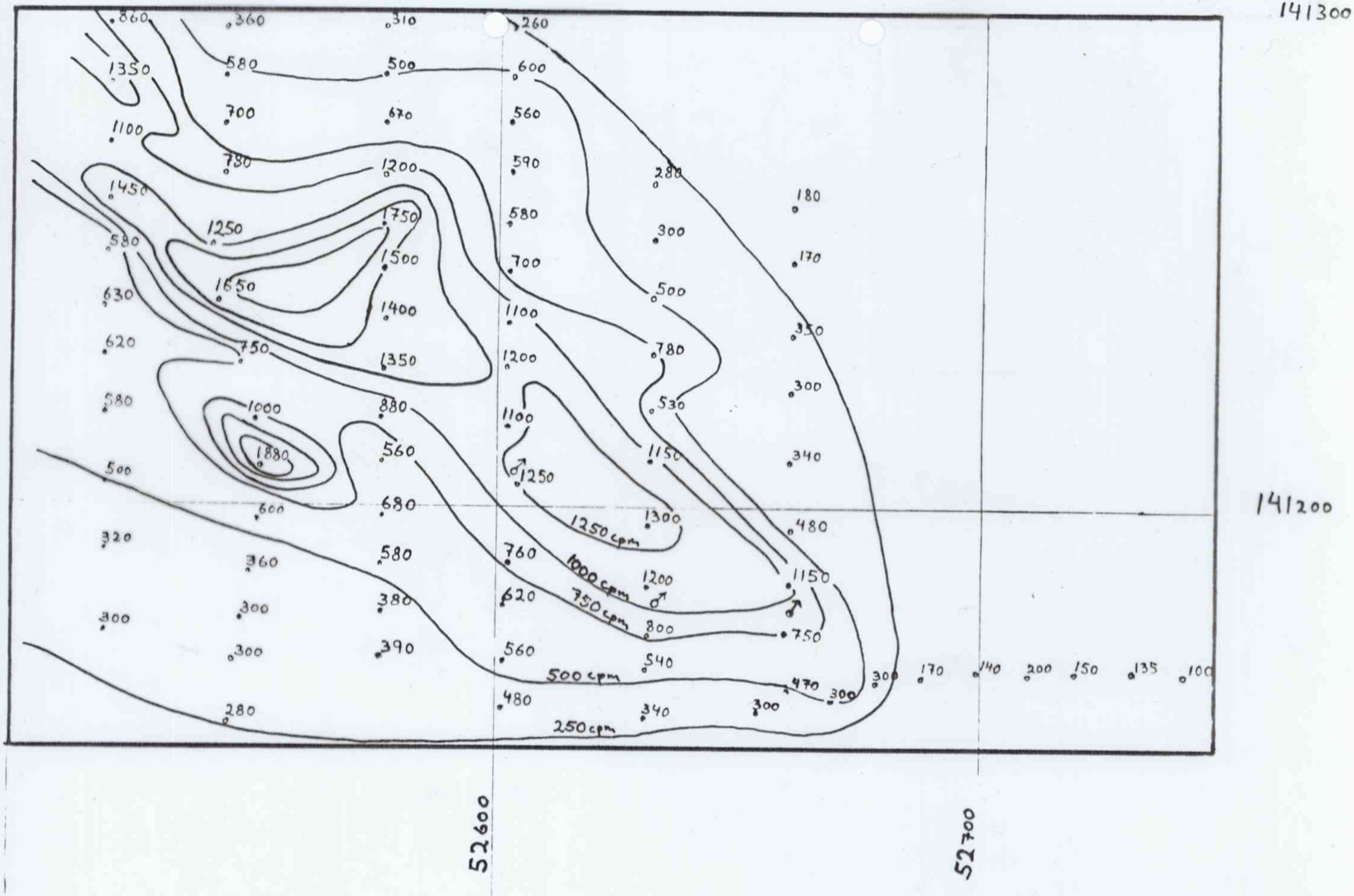
Fig. 12 shows the preliminary geological map of the prospect in scale 1 : 1000, with the radiometric counts-per-minute contour map attached as an overlay. The radiation measurements were taken at approximately 10 m intervals along profile lines running N-S with a spacing of about 25 m. The survey was carried out by one person using a compass for direction and pacing for the distances.

A total of 17 rock samples were taken from sample locations numbered 741 to 755, shown on Fig. 12. All samples were subsequently assayed with results as shown below:

TABLE I

ASSAY-DATA FROM THE BRILLEKÅSHAUGEN PROSPECT, FEN

SANO	NORTH	EAST	%NB	% Y	%TH	% P	% S	%LA	%CE	%ND
4W80X	141158	52741D	.018	.007	.005	1.30	0.17	.030	.055	.025
5W80B	141163	52697K	.140	.024	.100	1.40	0.10	.130	.290	.100
5W80C	141163	52697R	.035	.005	.005	0.40	0.11	.021	.036	.015
6W80A	141175	52625H	.038	.014	.140	0.40	3.40	.470	1.00	.300
6W80C	141175	52625J	.035	.005	.015	0.25	0.38	.380	.740	.160
8W80	141168	52545K	.049	.005	.005	0.40	0.14	.010	.012	.010
F00741	141172	52578F	.043	.021	.020			.040	.070	.030
F00742	141191	52572H	.062	.011	.015			.020	.025	.012
F00743	141204	52575R	.120	.018	.013			.025	.033	.016
F00744	141246	52576H	.079	.025	.094			.160	.270	.090
F00745	141268	52576F	.084	.039	.052			.023	.065	.030
F00746	141265	52583F	.069	.010	.045			.035	.050	.021
F00747	141246	52595F	.072	.011	.047			.065	.110	.053
F00748	141207	52595F	.110	.019	.125			.060	.130	.065
F00749	141208	52537H	.068	.013	.028			.030	.047	.025
F00750	141230	52545C	.054	.015	.054			.034	.070	.035
F00751	141248	52542H	.092	.023	.110			.320	.830	.350
F00752	141263	52542H	.035	.014	.042			.180	.650	.300
F00753A	141179	52658H	.082	.031	.120			.200	.650	.300
F00753B	141179	52658C	.086	.026	.130			.110	.260	.090
F00753C	141179	52658J	.072	.029	.135			.190	.520	.220
F00754	141177	52660H	.080	.025	.040			.120	.380	.200
F00755	141165	52671H	.077	.019	.035			.130	.380	.180



Radiometric map, Cpm-values

WW, Nov.-81

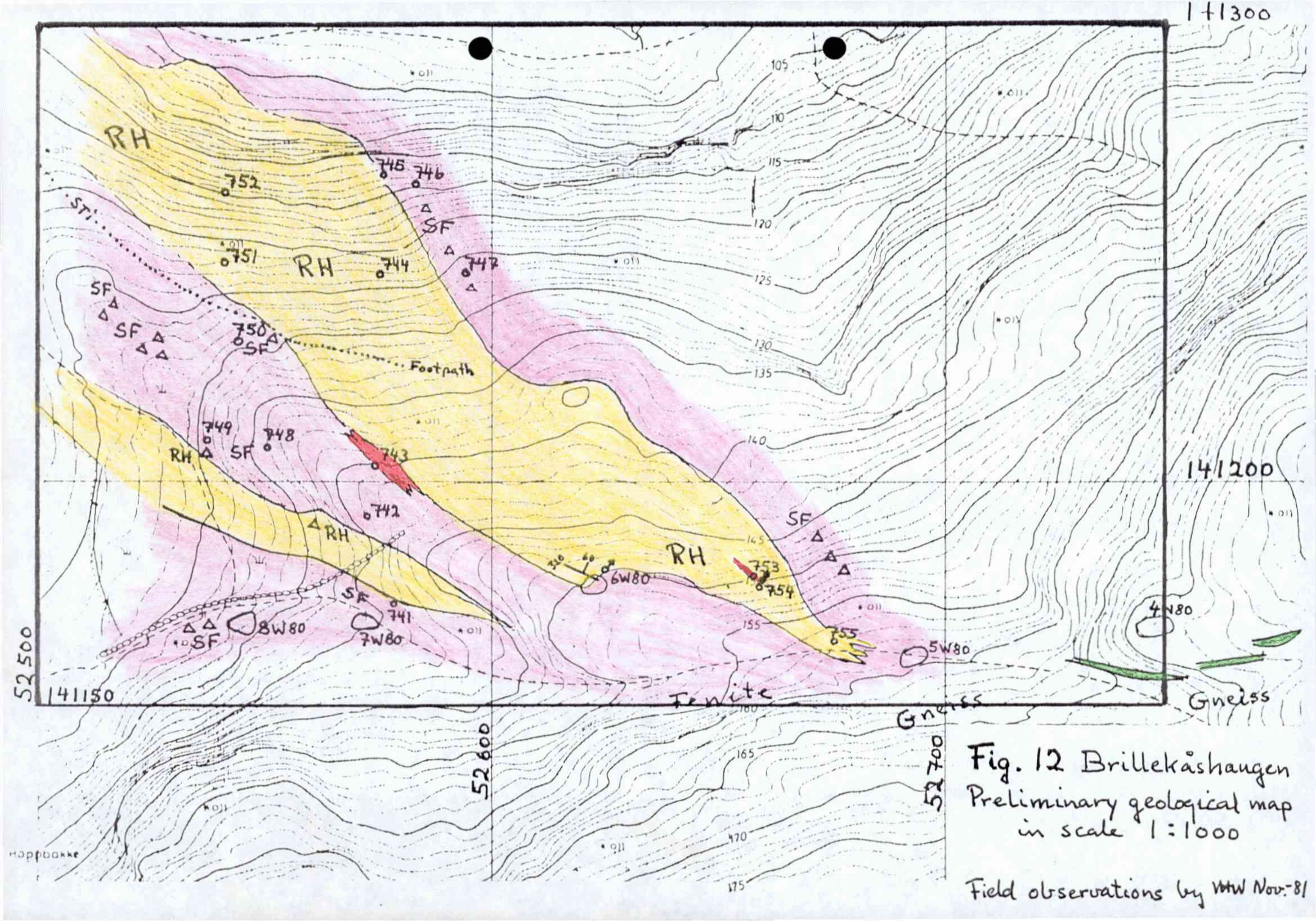


Fig. 12 Brillekåshaugen
Preliminary geological map
in scale 1:1000

Field observations by WW Nov.-81

The new assay data confirmed the earlier results and showed the REE to be enriched in certain parts of a 50 m wide, wedge-shaped body of rauhaugite surrounded by dark syenitic fenite. Similar, smaller wedges of rauhaugite occur nearby, all thinning out towards ESE. The occurrence of narrow damtjernite dikes in the eastward continuation of this trend, leads one to think in terms of deep, persistant fracture zones that probably served as passageway for the rauhaugite as well as for the damtjernite.

The rauhaugite in turn has been affected by local rødbergization and deposition of dm-size veins and schlieren of massive hematite ore. Not unlikely, these late, metasomatic effects were caused by mineralizing fluids migrating upwards in connection with still another reactivation of the fracture zones mentioned above. The REE mineralization appears to be somehow connected with hematite deposition and rødbergization, but the concentration of REE does not seem to be restricted to these geological environments in particular.

Under the microscope, rauhaugite can sometimes be seen in the process of digesting older silicate rock, whereas in other instances clear-cut intrusive relationships may be observed. As for the remnants of foreign rock material within the rauhaugite, there are cases where this might resemble damtjernite more than syenitic fenite. More microscopy remains to be done in order to clarify the mineralogy of the REE carriers and to fix the time of deposition of the ore minerals in relation to the broader sequence of events.

As reported under GEOCHEMISTRY, the Brillekåshaugen prospect has come up with the highest REE values yet encountered in the Vipeto-Rullekoll area. Furthermore, the radiometric data are indicative of a strong and persistent mineralization associated with the central wedge of rauhaugite, but of greater areal extention.

In my opinion, the documentation presented here should be sufficiently encouraging to justify further investigations of the Brillekåshaugen prospect and its presumed extension towards northwest. The following work program is suggested:

Lab work

1. Studies of thin sections and rock samples with emphasis on ore mineral paragenesis and the conditions that have governed the deposition of the ore minerals.
2. Nature of the relationship between REE and Th. Is radiometry a guide to ore?
3. Determination of petrophysical parameters such as magnetic susceptibility, electric conductivity and S.G. to find out if these geophysical methods will be of help in exploration.

Field work

1. Lay-out of baseline and an appropriate survey grid for reference during mapping and sampling as well as for geophysics. Baseline direction should be NW-SE to allow for extension towards loc. 77W80 if required.
2. Detailed geological mapping, supplemented by selected geophysical methods.

Next stage

Diamond drilling to provide continuous intersections of possible ore zones, provided that such targets are identified in the course of the preceding investigations.

Rullekoll - the problem area

Through studies conducted by "Forskningsgruppe for Sjeldne Jordarter" (FSJ) in the Fen complex between 1967 and 1970, the area from Rullekoll to Rauhaug was found to have local concentrations of REE as well as anomalous radioactivity due to enrichment in thorium. These phenomena were observed in rauhaugite as well as in zones of rødbergization and hematite deposition.

The FSJ reports emphasize the great similarities between the Rullekoll area and the Gruveåsen-Bolladalen area, and because of the much larger rock volumes involved in Gruveåsen-Bolladalen, FSJ with good logic decided to concentrate their exploration efforts in the latter area.

It is difficult to see that the current investigation has produced any results which should justify a change of priorities. With the exception of sample 79W80, which assayed 32.9% F, none of the geochemical results from Rullekoll are particularely outstanding. Furthermore, the geological observations indicate that the area has an extremely complex lithology, and that, accordingly, concentrations of ore minerals are likely to be irregular and of limited dimensions.

The very first action to be taken in the Rullekoll area is to complete the regional magnetometric survey. After that, VLF and radiometric measurements should be taken on a closer grid system, which should also be used as reference for detailed geologic observations and systematic sampling for geochemical and mineralogical studies.

My recommendation is that the low-cost geophysical work is carried out at Rullekoll as soon as practically feasible, but that all work demanding more resources is postponed until the ongoing assessment of the Gruveåsen-Bolladalen area has been brought to its conclusion.

EPILOGUE

Anyone who has taken the effort of reading this report must have had some good reason for doing so. Whether this reason was of a business nature: (where to look for the orebodies) or academical: (geologic evolution of the Fen complex), the reader by now shares with me the disappointment of not having found the final answers. Perhaps he/she also feels, like I do, that the net effect of this study has been to generate new questions in addition to those that were there before.

Most perplexing, perhaps, are the questions posed by the observed similarities and differences among the different carbonatites of the Fen comples.

The søvite intruded first, as a melt or mush of calcite crystals with apatite and pyrochlor widely dispersed as early formed phases. Probably, the søvite magma was immiscibly coexistant with the alkaline silicate magma that gave rise to the basic silicate rocks. Moving upwards ahead of the søvite intrusion, there must have been a reactive fluid phase capable of transforming adjacent country rock into fenite. The søvite itself seems to have had little potency for digesting or transforming foreign rock material.

The rauhaugite is chemically and mineralogically similar to the søvite, and further similarity is found when the close association between rauhaugite and the alkaline silicate rock damtjernite is compared to the field relationship observed between søvite and e.g. vipetoite. When considering intrusive behavior, however, it is the differences between søvite and rauhaugite that are remarkable.

While all evidence show the søvite intrusion to have dissipated its energy slowly and quietly, it appears as if the rauhaugite magma experienced a sudden pressure drop that triggered a release of internal gas, i.e. a state of boiling. A gigantic fluidized bed reactor can be envisaged running out of control and digesting all foreign rock material encountered as it cored its way upwards until finally solidifying in its present position.

Rødberg is the third and youngest carbonatite in the Fen complex. While its overall chemical composition is somewhere between the two, rødberg otherwise differs remarkably from both søvite and rauhaugite.

Firstly, there is no sign of an alkaline silicate magma being associated with rødberg at the present surface level of the Fen complex. Then, neither is there any sign of an intruding carbonatite magma that might qualify as rødberg. What is observed are the effects of a reactive fluid phase, capable of attacking older rocks, be it silicate or carbonate, and replacing them with a homogeneous, red-coloured mass of dolomite or calcite. The Vipeto-Rullekoll area offers many localities where this process of metasomatic transformation has been frozen in a transitional stage between e.g. damtjernite and rødberg, and a petrological study of these phenomena would be of great interest as a research project.

The most characteristic feature of the rødberg is, however, the predominance of iron in ferric, the most highly oxydized state. The red colour of rødberg is due to the iron oxide hematite. This is in striking contrast to the older carbonatite, rauhaugite, which not only has ferro-dolomite as its dominant mineral but also carries pyrite and other basemetal sulphides as common accessories.

The different states of oxydation thus stand as the most remarkable chemical difference between rauhaugite and rødberg, and if this difference can be explained, that might well provide insight also into how the REE were transported and precipitated during the late stages of development of the Fen complex.

Korshinskij(1965) explains how, both in magmas and hydrothermal solutions an increase in alkalinity may cause an increase also in the activity of oxygen. If this is applied to our carbonatite systems, the rauhaugite with its pyrite and ankerite reflects a low-alkalinity magma, being so, perhaps, because of its coexistence with the highly alkaline damtjernite magma. The rødbergizing fluids, on the other hand, having no silicate phase as its opposite, conceivably had to assume a more alkaline composition.

These wild speculations terminate the present report on the geology of the Vipeto-Rullekoll area. The writer, who now leaves the project and the fascinations of carbonatite geology, is thankful for having been given the opportunity to get a glimpse into this problem-area, and he takes this opportunity to wish the best of luck to those who now step in to bring the work to completion.

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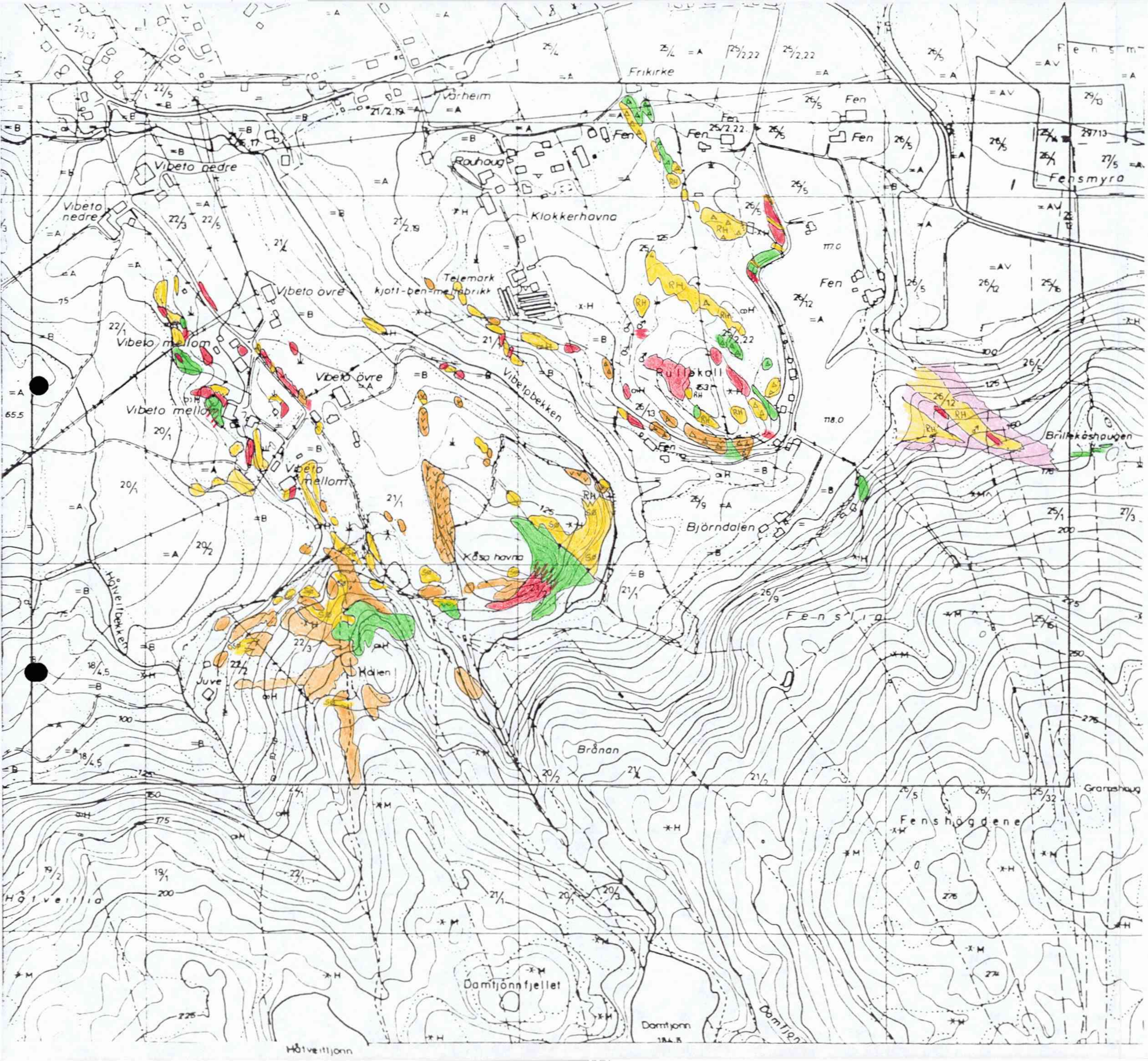


FEN PROJECT

Vipeto - Rullekoll sub-area

Field observations from detailed geological maps in scale 1:1000 shown compiled onto map 1:5000

LEGEND:

- Precambrian gneiss
- SF Fenite/Syenitic fenite
- Hollaite/Vipetoite
- Sø Søvite
- RH Rauhaugite
- Damtjernite
- Rødberg
- rødbergization
- explosion breccia
- hematite ore

For locality identification, use overlay marked Enclosure I.

VHW Sept.-8

Appendix I

Geochemical data for the Vipeto - Rullekoll sub-area

Fen project
Sept. 1982

FEN PROJECT
SURFACE ROCK SAMPLES FROM THE VIPETO-RULLEKOLL AREA
COLLECTED BY WIIK, AUG.-SEPT. 1980 ANALYSED SI 1981

SANO	COORDINATES		NB%	Y %	TH%	P %	S %	LA%	CE%	ND%	U %	TA%
1W80A	14131952035	S	.018	.012	.014	1.50	0.10	.028	.053	.027		
2W80A	14129452069	R	.029	.015	.025	2.80	0.10	.035	.072	.042		
4W80X	14115852741	D	.018	.007	.005	1.30	0.17	.030	.055	.025		
5W80B	14116352697	K	.140	.024	.100	1.40	0.10	.130	.290	.100	.002	.003
5W80C	14116352697	F	.035	.005	.005	0.40	0.11	.021	.036	.015		
6W80A	14117552625	H	.038	.014	.140	0.40	3.40	.470	1.00	.300		
6W80C	14117552625	J	.035	.005	.015	0.25	0.38	.380	.740	.160		
8W80	14116852545	K	.049	.005	.005	0.40	0.14	.010	.012	.010		
9W80	14127552153	B	.110	.022	.025	1.30	0.36	.045	.085	.039	.001	.004
10W80	14123852139	R	.160	.043	.045	0.50	0.12	.070	.170	.060	.003	.003
11W80	14119252215	B	.089	.014	.028	0.65	0.44	.023	.037	.021		
13W80	14120552147	R	.044	.029	.033	1.10	0.31	.065	.140	.058		
14W80	14147052255	H	.100	.018	.070	0.70	1.30	.140	.250	.085	.001	.004
15W80	14146852273	B	.110	.018	.075	0.40	0.27	.070	.140	.060	.004	.005
16W80	14145852285	D	.041	.005	.046	0.30	0.11	.017	.037	.029		
17W80	14146352313	B	.053	.016	.093	0.38	0.25	.120	.250	.100		
19W80	14148152348	R	.120	.023	.032	2.80	1.10	.060	.130	.060		
20W80A	14146752347	R	.150	.018	.052	1.20	0.06	.040	.075	.041	.001	.008
20W80B	14146752347	H	.120	.035	.053	3.20	0.09	.052	.110	.051	.002	.007
21W80	14145552350	R	.110	.011	.041	0.80	0.18	.075	.170	.052	.005	.007
32W80	14100051760	C	.006	.012	.008	1.30	0.06	.022	.043	.023	.001	.009
33W80	14092551185	F	.060	.010	.008	1.90	0.16	.040	.095	.042		
34W80A	14093051115	C	.038	.005	.005	0.83	0.05	.028	.045	.020		
34W80B	14093051115	S	.035	.005	.005	0.40	0.07	.010	.010	.010		
38W80	14131551540	R	.065	.018	.076	1.80	0.07	.040	.066	.040		
38W80X	14131551540	S	.060	.005	.007	0.44	0.35	.014	.023	.018		
41W80A	14140051260	C	.027	.005	.005	0.35	0.24	.010	.010	.010		
47W80	14093050460	K	.028	.008	.005	0.72	0.52	.018	.029	.017		
50W80	14127051558	D	.054	.005	.007	1.10	0.16	.150	.250	.067		
51W80A	14128451543	R	.086	.006	.009	0.95	0.19	.029	.064	.039		
51W80B	14128451543	B	.290	.010	.016	1.70	0.58	.047	.110	.065	.002	.002
51W80X	14128451543	S	.005	.023	.005	7.40	0.08	.065	.160	.080		
52W80	14130451540	H	.066	.009	.006	0.84	0.23	.110	.180	.052		
52W80X	14130451540	S	.065	.010	.017	1.00	1.11	.081	.140	.050		
53W80	14136051510	H	.100	.005	.011	0.60	0.39	.042	.084	.037	.001	.002
54W80	14138251541	H	.170	.005	.034	0.44	0.21	.250	.430	.120	.001	.004
55W80A	14121751683	S	.010	.007	.005	1.20	0.24	.023	.050	.021		
55W80B	14121751683	R	.015	.012	.012	1.90	0.21	.030	.070	.035		
56W80A	14098051880	S	.270	.008	.008	1.50	0.25	.030	.070	.035	.001	.002
56W80B	14098051880	C	.041	.009	.005	1.40	0.09	.016	.040	.025		
56W80C	14098051880	S	.013	.012	.005	1.50	0.06	.028	.065	.031		
60W80X	14111451652	H	.022	.017	.010	2.80	0.31	.037	.090	.044		
62W80	14094051967	R	.170	.005	.007	0.93	0.03	.010	.017	.014	.001	.005
63W80	14136251923	S	.093	.008	.024	1.40	0.10	.025	.055	.031		
67W80	14100252027	R	.065	.005	.011	0.75	0.40	.110	.250	.065		
68W80	14101852080	S	.170	.011	.037	1.80	0.06	.025	.060	.028	.005	.020
70W80	14095552030	R	.048	.013	.017	0.82	0.14	.085	.140	.063		
73W80	14108352103	H	.079	.017	.011	0.72	0.38	.018	.028	.26		
74W80	14113552083	C	.031	.026	.039	2.40	0.46	.030	.076	.043		
75W80	14084551925	C	.042	.008	.007	1.10	0.06	.017	.035	.024		
79W80	14119552260		.100	.030	.073			.095	.270	.130		

SAMPLES OF VIPETO-SØVITE COLLECTED BY MØRK AND WIIK, SEPT. 1980

SANO	COORDINATES		NB%	Y %	TH%	P %	S %	LA%	CE%	ND%	U %	TA%
SP01	140945 51765	S	.180	.013	.034	2.10	.150	.028	.061	.029	.002	.021
SP02	140965 51765	S	.460	.012	.061	2.10	.590	.020	.053	.027	.001	.016
SP03	140985 51760	S	.030	.009	.004	0.47	.110	.019	.048	.023		
SP04	140970 51810	S	.310	.010	.034	1.80	.230	.019	.050	.028	.001	.009
SP05	140980 51885	S	.220	.009	.012	1.20	.350	.022	.056	.028	.001	.007
SP06	141015 51810	S	.110	.010	.030	0.97	.160	.110	.180	.043	.001	.002
SP07	140940 51720	S	.009	.010	.004	1.20	.290	.021	.051	.024		
SP08	140960 51695	S	.009	.015	.008	1.00	.180	.020	.049	.027		
SP09	141030 51755	S	.014	.009	.011	0.64	.340	.025	.055	.023		
SP10	141065 51730	S	.009	.015	.014	3.10	.190	.030	.081	.046		
SP11	141100 51715	S	.009	.014	.010	3.50	.060	.028	.076	.040		
SP12	141165 51655	S	.140	.011	.009	1.20	.350	.020	.050	.024	.001	.003
SP13	141115 51625	S	.009	.013	.009	1.60	.190	.020	.047	.024		
SP14	141110 51600	S	.082	.015	.013	2.10	.140	.020	.050	.029		
SP15	141100 51570	S	.030	.020	.017	1.70	.180	.024	.054	.029		
SP16	141330 51535	S	.060	.004	.010	0.48	.180	.039	.072	.026		
SP17	141375 51520	S	.090	.005	.007	1.50	.260	.032	.072	.033		
SP18	141325 51810	S	.094	.004	.015	0.64	.170	.050	.089	.029		
SP19	141010 52085	S	.071	.010	.015	0.92	.050	.018	.042	.023		
SP20	141060 52115	S	.020	.007	.005	0.46	.140	.021	.047	.021		
SP21	141030 52060	S	.054	.008	.010	1.90	.270	.018	.045	.022		
SP22	141050 52025	S	.031	.009	.005	1.20	.140	.017	.041	.020		
SP23	141090 51990	S	.400	.016	.060	2.60	.260	.018	.051	.026	.001	.037
SP24	141145 52090	S	.009	.013	.006	2.90	.230	.019	.050	.025		
SP25	141145 52105	S	.009	.012	.004	0.93	.120	.020	.052	.027		
SP26	141305 52040	S	.016	.012	.021	2.30	.090	.022	.059	.031		
SP27	141315 52010	S	.037	.012	.011	1.30	.260	.017	.046	.024		
SP28	141345 51950	S	.065	.008	.014	1.80	.200	.016	.046	.027		
SP29	141370 51915	S	.042	.009	.009	1.50	.250	.018	.045	.021		
SP30	141405 51920	S	.068	.009	.012	2.20	.420	.035	.078	.034		

WHOLE-ROCK SURFACE SAMPLES FROM THE BRILLEKÅSHAUGEN PROSPECT COLLECTED NOVEMBER 1981 BY WIIK

SANO	COORDINATES		NB%	Y %	TH%	LA%	CE%	ND%
F00741	141172 52578	F	.043	.021	.020	.040	.070	.030
F00742	141191 52572	H	.062	.011	.015	.020	.025	.012
F00743	141204 52575	R	.120	.018	.013	.025	.033	.016
F00744	141246 52576	H	.079	.025	.094	.160	.270	.090
F00745	141268 52576	F	.084	.039	.052	.023	.065	.030
F00746	141265 52583	F	.069	.010	.045	.035	.050	.021
F00747	141246 52595	F	.072	.011	.047	.065	0110	.053
F00748	141207 52595	F	.110	.019	.125	.060	.130	.065
F00749	141208 52537	H	.068	.013	.028	.030	.047	.025
F00750	141230 52545	C	.054	.015	.054	.034	.070	.035
F00751	141248 52542	H	.092	.023	.110	.320	.830	.350
F00752	141263 52542	H	.035	.014	.042	.180	.650	.300
F00753A	141179 52658	H	.082	.031	.120	.200	.650	.300
F00753B	141179 52658	C	.086	.026	.130	.110	.260	.090
F00753C	141179 52658	J	.072	.029	.135	.190	.520	.220
F00754	141177 52660	H	.080	.025	.040	.120	.380	.200
F00755	141165 52671	H	.077	.019	.035	.130	.380	.180

FEN PROJECT
SURFACE ROCK SAMPLES FROM THE VIPETO-RULLEKOLL AREA
COLLECTED BY WIIK, AUG.-SEPT. 1980 ANALYSED BY SI 1981(STAGE II-ANALYSIS)

SANO	FE%	SI%	MG%	AL%	P %	NA%	TI%	K %	CA%	MN%	BA%	SR%	V %
1W80A	1.300	4.200	0.910	0.280	1.700	0.050	0.140	0.500	35.00	0.420	0.030	0.140	0.009
2W80A	4.100	0.800	3.200	0.390	3.000	0.050	0.170	0.500	24.00	0.590	0.140	0.140	0.008
4W80X	7.500	6.000	3.500	1.800	1.100	0.050	1.100	0.900	24.00	.0180	0.190	0.270	.0025
5W80B	6.400	8.000	4.000	1.000	1.700	0.040	0.071	0.500	21.00	0.81	0.053	0.180	0.004
5W80C	2.800	26.00	1.600	6.300	0.150	1.800	0.078	5.100	4.800	0.120	0.230	0.041	0.009
6W80A	8.100	1.800	6.200	0.075	0.180	0.030	0.039	0.500	16.00	1.200	2.600	0.210	0.004
6W80C	25.00	4.100	0.180	0.130	0.130	0.010	0.021	0.500	0.270	0.001	0.660	0.010	0.014
8W80	7.200	22.00	4.000	7.000	0.220	0.220	0.210	4.000	4.900	0.110	0.670	0.250	0.014
9W80	8.200	9.000	4.400	2.700	1.700	0.400	0.720	0.500	19.00	0.280	0.280	0.077	0.012
10W80	8.700	3.000	2.000	1.300	0.320	0.040	0.130	0.500	29.00	0.250	0.053	0.056	0.005
11W80	8.000	5.200	7.300	2.200	0.570	0.080	0.180	0.500	17.00	0.390	0.910	0.140	0.015
13W80	5.000	1.400	8.800	0.730	1.100	0.070	0.072	0.500	19.00	0.440	0.630	0.066	0.004
14W80	6.100	1.100	7.300	0.330	0.450	0.200	0.030	0.500	18.00	0.730	1.800	0.160	0.006
15W80	7.200	1.500	7.700	0.490	0.140	0.070	0.044	0.500	18.00	0.670	0.350	0.150	0.009
16W80	7.000	16.00	5.400	5.900	0.040	0.280	0.120	4.300	7.800	0.230	0.580	0.082	0.014
17W80	9.400	6.600	6.900	3.300	0.150	0.100	0.029	0.500	13.00	0.580	2.200	0.130	0.007
19W80	10.00	0.900	0.730	0.270	3.000	0.150	0.100	0.500	27.00	0.230	2.100	0.155	0.007
20W80A	6.400	15.00	0.700	0.320	1.200	0.030	0.098	0.500	20.00	0.250	0.054	0.068	0.008
20W80B	0.820	6.300	0.480	0.170	3.500	0.050	0.081	.500	30.00	0.220	0.074	0.100	0.002
21W80	24.00	3.600	1.100	0.930	0.620	0.030	0.200	0.500	16.00	0.150	0.170	0.054	0.017
32W80	4.500	4.800	3.000	2.200	1.700	0.030	0.140	0.500	25.00	0.190	0.096	0.059	0.009
33W80	12.00	17.00	3.200	8.000	2.800	0.070	0.550	4.400	5.300	0.074	0.200	0.095	0.019
34W80A	4.000	17.00	2.200	8.000	0.770	1.500	0.220	3.000	11.00	0.210	0.200	0.200	0.006
34W80B	7.500	22.00	2.400	9.300	0.240	0.600	0.260	6.300	3.500	0.100	0.460	0.037	0.010
38W80	4.700	1.400	7.400	0.740	2.600	0.040	0.021	0.500	24.00	0.880	0.150	0.078	0.002
38W80X	6.500	0.200	7.200	0.058	0.150	0.030	0.008	0.500	22.00	1.100	0.750	0.260	0.002
41W80A	4.600	24.00	1.900	8.800	0.140	0.330	0.083	8.300	3.200	0.074	0.490	0.560	0.003
47W80	7.200	19.00	2.000	7.000	0.530	5.800	1.600	1.800	8.400	0.220	0.034	0.110	0.023
50W80	7.800	7.200	5.400	2.300	1.200	0.050	0.510	0.500	20.00	0.490	0.570	0.410	0.012
51W80A	6.500	1.900	9.800	0.790	1.000	0.020	0.170	0.500	18.00	0.740	0.380	0.160	0.006
51W80B	6.600	1.900	6.900	0.650	1.900	0.030	0.150	0.500	19.00	0.790	1.100	0.390	0.005
51W80X	1.900	2.300	5.500	0.021	8.700	0.100	0.005	0.500	27.00	0.350	0.094	0.580	0.001
52W80	6.000	1.200	7.700	0.420	0.670	0.030	0.030	0.500	20.00	0.830	0.110	0.120	0.003
52W80X	6.700	0.800	7.900	0.190	0.890	0.020	0.023	0.500	22.00	0.700	0.097	0.140	0.004
53W80	5.400	0.600	8.500	0.038	0.330	0.030	0.009	0.500	20.00	0.870	0.490	0.210	0.002
54W80	6.800	0.700	8.600	0.072	0.220	0.030	0.014	0.500	19.00	1.200	0.420	0.290	0.003
55W80A	2.000	0.700	4.900	0.092	1.400	0.030	0.019	0.500	28.00	0.380	0.007	0.050	0.003
55W80B	2.800	0.600	9.100	0.093	2.500	0.040	0.054	0.500	22.00	0.380	0.005	0.077	0.005
56W80A	1.500	0.600	2.500	0.002	1.900	0.030	0.028	0.500	33.00	0.350	0.130	0.350	0.001
56W80B	7.500	9.700	3.700	3.100	2.100	0.020	0.370	0.500	19.00	0.190	0.022	0.150	0.009
56W80C	1.200	1.400	0.540	0.410	1.900	0.040	0.058	0.500	33.00	0.180	0.072	0.480	0.002
60W80X	3.000	1.200	5.200	0.310	3.400	0.050	0.052	0.500	26.00	0.320	0.005	0.120	0.005
62W80	2.000	1.000	10.00	0.220	0.910	0.020	0.039	0.500	20.00	0.400	0.007	0.330	0.002
63W80	3.100	1.000	1.400	0.043	2.000	0.040	0.056	0.500	32.00	0.220	0.067	0.380	0.012
67W80	6.100	4.800	8.500	1.700	0.620	0.030	0.430	0.500	16.00	0.390	0.930	0.094	0.006
68W80	0.650	0.700	1.000	0.077	2.600	0.050	0.013	0.500	35.00	0.180	0.060	0.240	0.001
70W80	7.600	3.100	5.600	1.100	0.600	0.020	0.200	0.500	22.00	0.290	0.055	0.074	0.011
73W80	8.100	3.800	6.300	1.400	0.610	0.030	0.670	0.500	19.00	0.280	0.150	0.110	0.018
74W80	6.600	2.900	6.600	1.400	2.700	0.050	0.390	0.500	18.00	0.360	0.630	0.150	0.008
75W80	4.100	16.00	1.500	0.700	1.100	0.010	0.220	0.500	18.00	0.150	0.014	0.010	0.003
7[illegible]W80													

ASV GRUPPEN

APPENDIX II

A listing of polished thin sections from the Vipeto-Rullekoll area.

Sample no.	Rock field name	Comments
8W80	Dark syenitic fenite	Invaded by carbonate
9W80	Dark silicocarbonatite	
11W80	Silicocarbonatite breccia	Invaded by rauhaugite
16W80	Silicocarbonatite ?	Gneiss remnant ?
18W80	Damtjernite Rødberg ?	Fsp./chl./calcite
32W80	Silicocarbonatite w/intr. carb.	Pyrochlor & apatite
50W80	Silicocarbonatite w/rauhaugite	N.B.: Ore minerals
56W80	Søvite or Rauhaugite	N.B.: 0.27% Nb
58W80	Carbonatite breccia	
63W80	Søvite	Much apatite/pyrochl?
64W80	Vipetoite in Søvite	
65W80	Hollaite	
66W80	Søvite	Abundant apatite
69W80A	Damtjernite/Søvite	Intrusive contact
69W80B	Damtjernite	
72W80	Fenite Søvite	
74W80	Silicocarbonatite breccia	
79W80	Volcanic breccia w/Fluorite	

Brillekåshaugen prospect

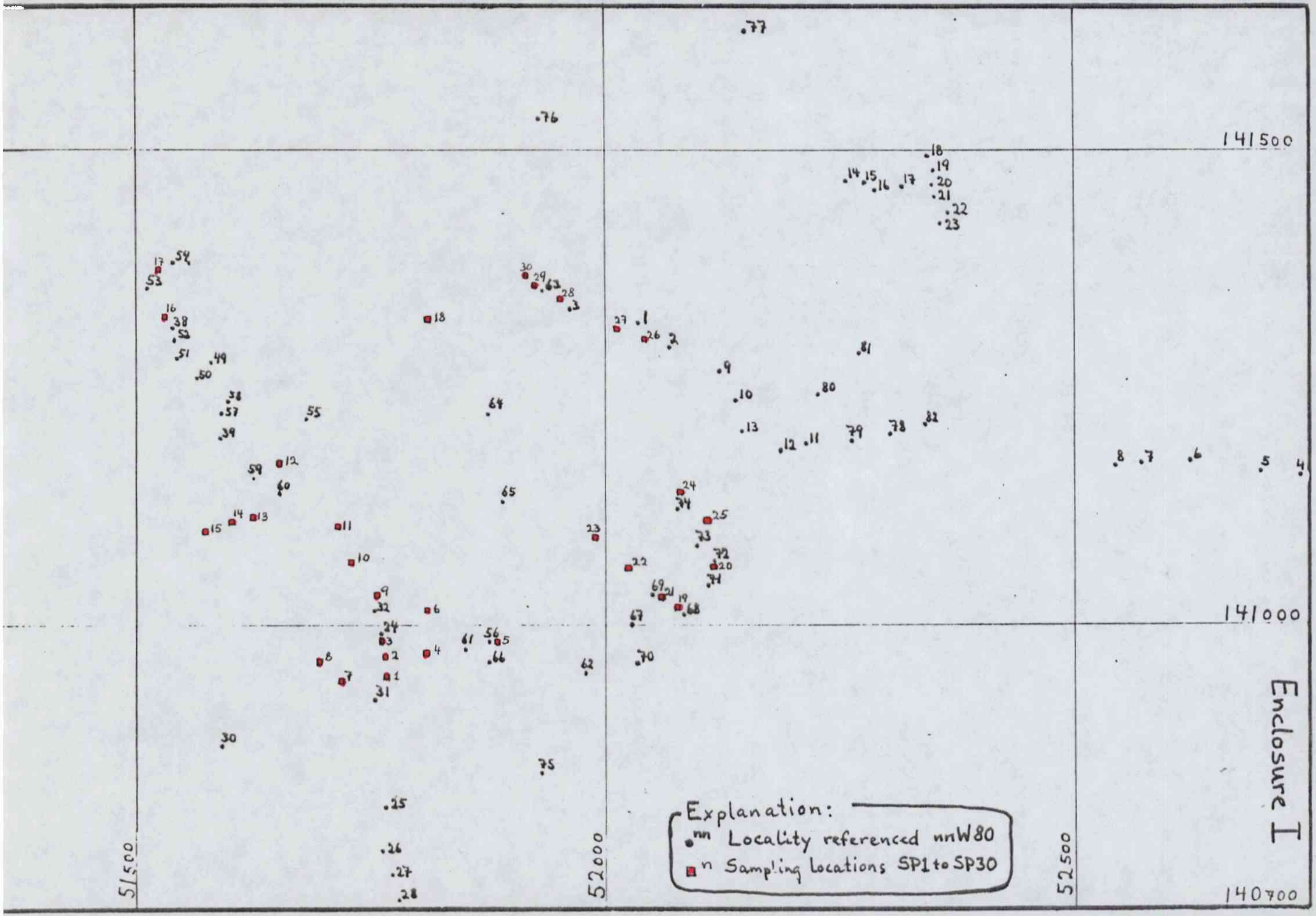
The samples numbered: 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753A, 753B, 753C, 754, and 755 are all available as polished thin sections.

ISV GRUPPEN

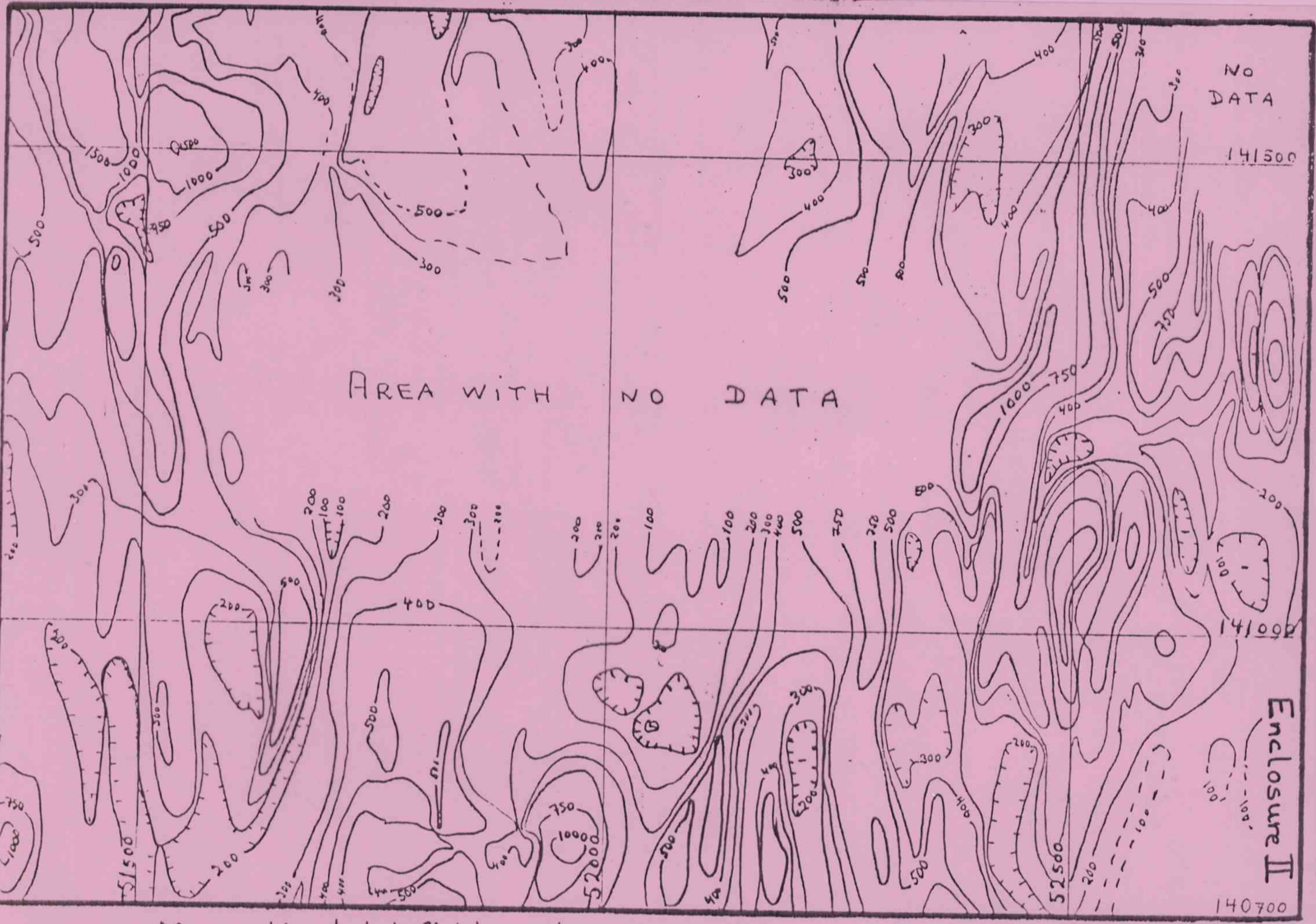
APPENDIX III

Identification of carbonates by powder microscopy.

Sample number	Rock type	Refr.Index (n) of carbonate min.	HCl reaction	Cathodo-luminescence	DIAGNOSIS
2W80	D-breccia	1.670	(+)	Strong red	Ca/Mg-dolomite
3W80	Søvite	1.67	(++)	Yellow brown	Calcite ?
6W80	Rauhaugite	1.700	(0)	Weak, brownish	Ank. dolomite
14W80	Rauhaugite	1.700	(0)	Nil	Ank. dolomite
20W80	RH Rødberg	1.67			Calcite?
38W80	Søvite?	1.700	(++)	Neutral	Ank.dol.+Cal.
40W80	Hollaite	<1.69	(++)	Yellow brown	Calcite + Fsp.
41W80A	Hollaite	1.66			Calcite/K-fsp.
42W80A	Hollaite/Søvite	<1.70	(+)	Darkbrown/Orange	Dolomite/Cal.
46W80B	Fenite	1.66	(++)		Calcite
51W80A	Rødberg ?	1.700		Brick red	Ank. dolomite
51W80B	RH breccia	>1.69	(+)	Dark	Ank. dolomite
51W80X	Søvite?	1.69	(+)		Dolomite
52W80	Rauhaugite	1.70	(+)	Dark brownish	Ank. dolomite
60W80	Søvite	1.66			Calcite + Fsp.
61W80	Søv. intrusion	1.66			Calcite
74W80	RH breccia	1.690	(0)	Dark brownish	Ank. dolomite
78W80	Rauhaugite	1.700	(0)	Dark brownish	Ank. dolomite
80W80	Hollaite/Damtj	1.69			Dolomite
81W80	Rødberg	1.67	(0)	Strong red	Ca/Mg dolomite

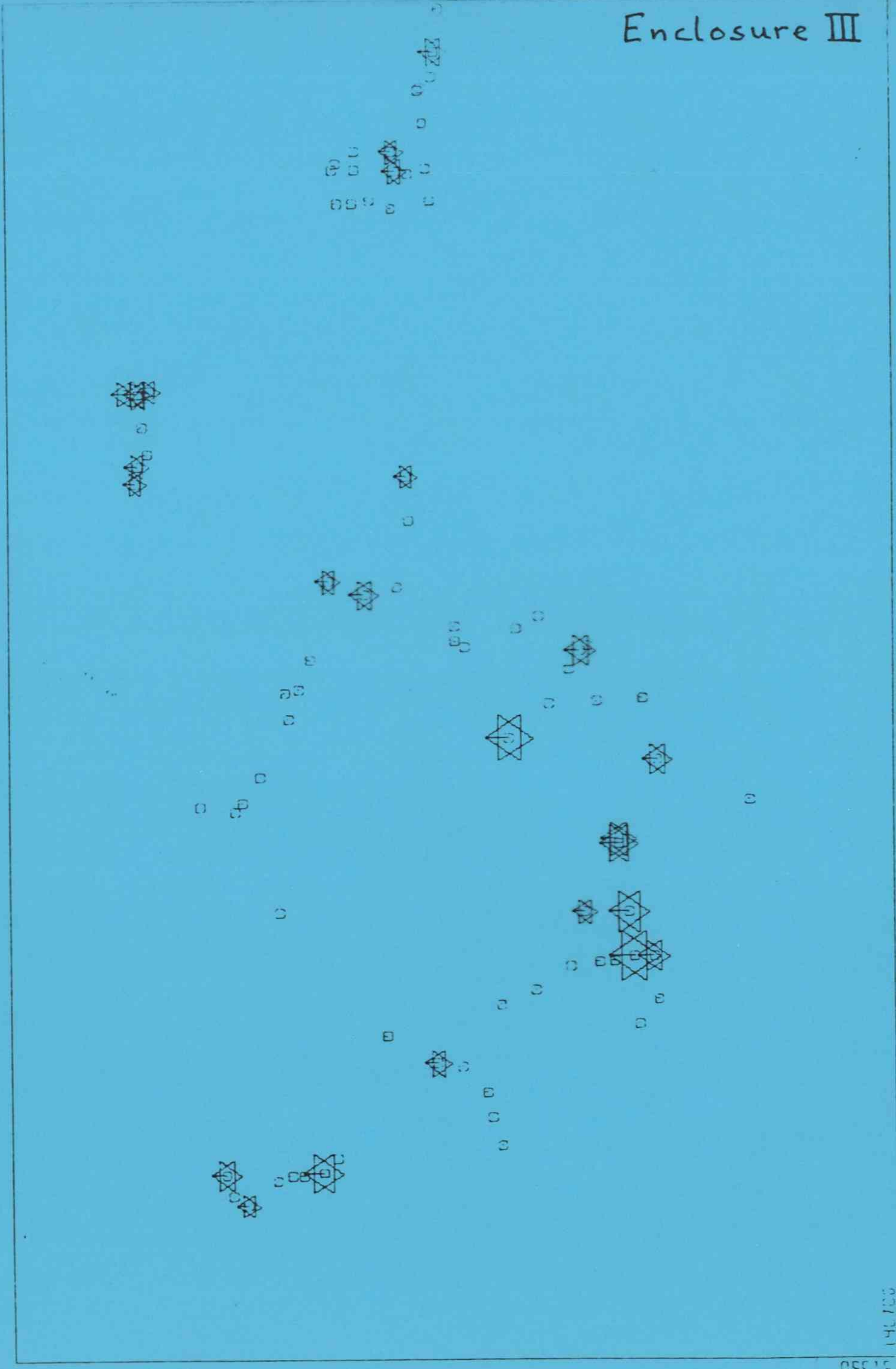


Sample Locations and Localities referred to in field notes. VHW 1980/81.



Magnetic total field contour map redrawn from Carstens (1981)

Enclosure III



KIPETO-BULLEKOLL AREA . NIOBIUM . STAR IF > 0.1 % MAP 1:5000

Enclosure IV