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Sammendrag

The Tuftehavna Nb-mineralizations occur within a wedgeshaped søvitic body, enclosed in fenitic rocks. Mineralized rocktypes are søvites, with columbite and pyrochlore; rauhaugites predominently with columbite, and lamprophyric rocks and related segregation with fersmite, columbite and pyrochlore.

Only in the latter group Nb2O5 exeeds 1 wt %. Apatite is abundant in most of the mineralized rocktypes, expect early rauhaugites.
The mineralized lamprophyric rocks are among the most radioactive (gamma-rays), show among the highest spesific garvities, and contain either no or very much magnetite.

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RESYMÉ:

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KOMMENTAR:

CONTENTS

1. INTRODUCTION

This report presents the results of the geological work carried out in the Tuftehavna area, central Fen Complex, in 1982 by the colaborators within the Union Minerals - Fenco joint venture, as a continuation of the work reported by S. Olmore resently (Olmore, 1982).

In 1982 the area along the stream in Tuftehavna has been mapped in scale 1:500 with reference to a surveyed grid system. The area is also covered by detailed surface magnetic susceptibility and γ-ray measurements as well as reconnaissance VLF-measurements described in detail in a separate report (Carstens, 1982).

A drilling program comprising 11 diamond drill holes of alltogether 1405,80 m has been completed in 1981 through 1982. Partial chemical analysis of selected core sections has been carried out at "Sentral institutt for industriell forskning" (SI) and "Institutt for energiteknikk" (IFE). A reconnaiscance survey of petrography and mineralogy of presumed economically important lithologies is fulfilled. This survey also include chemical analysis of minerals by means of electronmicroprobe atMineralogisk-geologisk museum.

Unfortunately a decision has recently been made to discontinue the writers work within the project, leaving behind numerous unanswered questions concerned with the geology, petrology and metallogeny of the area.

Oslo, 31. December 1982

Henning Qvale

Henning Qvale

2. GEOLOGY OF THE TUFTEHAVNA AREA

2a Regional geology

The Fen alkaline Complex is located on the southern shore of the lake Nordsjø. The geology of the complex is described in detail by Brøgger (1921) and Sæther (1957). Regional geological maps including the Fen Complex are recently compiled by Dahlgren (1978) and Dons & Jorde (1978).

The rocks of the Fen Complex are exposed over an area of appx. 8 km^2. They are enclosed in Precambrian gneisses which are often brecciated or metasomatically altered along the contacts, through fenitization to the south and west and cloritization to the east (Andersen, pers. comm.).

The major rock types of the complex may be divided in five groups: The basic rocks belonging to the ijolite-melteigite-urtitle series dominating the southwestern part of the complex (see key map, Plate 1; vipetoites in the same area; carbonatites (søvites, rauhaugites and rødberg) in the central and eastern part; Lamprophyric damtjernites occuring all over except in the southwestern part; and the country rock-derived fenites, biotite-calcite fels and other metasomatically altered rocks along the southern and western contact as well as internally in the central part of the complex. In addition a large number of hybrid and "intermediate" rock types are registred from all parts of the complex.

The area subject to the present study are located in the central part where, according to Sæther (1957), søvitic and rauhaugitic rocks are intermixed with and surrounded predominantly by biotite-calcite fels and other altered basic rocks.

2b Detailed surface geology, Tuftehavna

The restricted area along the stream in Tuftehavna has been carefully searched for exposures. The result is shown on Plate 1.

The four major groups of rocks occuring show a preferental distribution. To the east and west rock types derived from the enclosing gneisses dominate.

These are fenite, hollaite and, dominating, syenitic fenite and biotite calcite fels, rock types which will be described in Ch. 3. They are cut by dikes of rauhaugite I. To the south there is no exposures indicating what is the structural relation between the two fenite-derived domains. However, the present coworkers have adopted the interpretation of earlier workers (e.g. Sæther, 1957) suggesting a enclosure around a core of carbonatites.

The eastern part of the "core"is dominated by more or less massive rauhaugite (I) exposed in an up to 20 m wide zone between fenites and søvites. The latter, dominationg the central and western part of the "core", are in this general interpretation further subdivided in a zone of blue amphibole-bearing søvites, and the area where the blue amphibole are virtually lacking. This subdivision seems to support the interpretation of a structural closure to the south, as the blue amphibole-bearing søvites are rimming the søvite massiv, whenever the rim is exposed.

Within the blue amphibole-bearing søvite (and presumably also the rauhaugites to the east) lamprophyric rocks are exposed at one locality at bottom of the valley.

The structural pattern of the area is characterized by a general north to north-west-trending strike of planar structures (Foliation, schistosity and banding) with steep to vertical dips.

2c Geology, as observed in drillholes 1 and 3-12

The geological logs for drillhole 1 (TH-1) are already reported by Olmore (1982). The complete logs for drillholes 3 through 12 (TH-3 - TH-12) are enclosed in Appendix 1 and visualized in Plate 2. The geological data are transferred to their appropriate drilling profiles in Plates 3A - 3F. These are then simplified and interpreted in Plates 4A - 4F, respectively.

Examination of the different profiles, in the order from south to north in the area, reveal some valuable information:

Profile TH-11 (Plate 4A) TH-11 is dominated by søvitic rocks in the upper part, rauhaugite (I) in the middle, and metasomatically altered country rock, mainly syenitic fenite and biotite-calcite fels are in the lower part. These registrations correspond well to the observed and interpreted surface geology by implying more or less vertical contacts between the major rock types.

At TH-11, 20.10 m an apatite-rock strongly mineralized with subhedral columbite is observed to be intercalated with rauhaugitic (I) material . This apatite-rock should on textural and compositional reasons not be confused with the lamprophyric biotite-apatite rocks, as will be discussed in Chap. 3.

Profile TH-5/6 (Plate 4B) This profile exposes a sequence, from east to west, of syenitic fenite and biotite-calcite fels, rauhaugite (I), and søvites with clusters of biotite-calcite fels as well as numerous veinlets of late rauhaugite (II). The most easterly exposed søvites are blue amphibole bearing. Biotite-apatite-rocks are not exposed at surface, but intersected in TH-5 in alltogether 87 cm at 44 m (2 cm) and 53 m (85 cm). No transection is obsreved in TH-6.

In both holes the relative well defined contact between søvite-dominated and rauhaugite (I) -dominated volumes indicate a steep easterly dipping position for this major structural element.

Profile TH-1/3/4 (Plate 4c). In this profile the central and western limitation of the søvite-dominated volume into the surrounding biotite -calcite fels and fenitic rocks which are cut by frequent dikes of rauhaugite (I). TH- 3 and 4 are drilled exclusively within the søvitic domain, TH-4 with a large fraction of rauhaugite (1) and biotite-calcite fels near the lower termination of the hole.

Lamprophyric rocks appear in all three holes as well as being exposed at surface near the top of TH-1.

In TH-1 the intersections measure appx. 8 m between 2,35 (top) and 11,50 m. In TH-3 corresponding intersections are found between 32 and 42 m totally measuring 3,60 m including minute appearances at 23 and 49 m. In TH-4 the total registration of lamprophyric rocks amount to 59 cm with 19 cm at 12 m, 25 cm at 53 m and the rest shared between locations at 27 m and 54 m.

The profile indicate a semivertical or steeply westerly dipping relation between major registrations of lamprophyric rocks. However, the total thickness decreases drastically at depth, the correlation between the shallowest appearance of altered countryrocks in TH-1 and the probable position of the same at surface (according to interpretation on the geological map, Plate 1) confirm a steep easterly dipping contact between søvites and surrounding country rocks to the west.

Profile 7/8/12 (Plate 4D & 4E). Despite the fact that TH-12 is offset by an angle of 20^{g} relative to the other two, their structural relationship are well documented, and they are therefore treated together here.

There are no exposures of bedrock in the immediate vicinity of this profile. The three holes are all drilled eastwards within the cental søvitic massif, and probably into the rauhaugite (I)-dominated area indicated on the geological map (Plate 1). However, the predominance of rauhaugite (I) is here at best, in TH-7, weak, and in YH-8 and YH-12 not present, and the rauhaugite (I)-body is therefore terminated in this area.

Rauhaugite (II) dikes and veilets, as well as the correlated apatite-veins are common rock types in both TH-8 and TH-12. Lamprophyric dikes and dikelets are common in upper parts of TH-7 and 8 and middle depths of TH-12. TH-7 totally intersects 3,02 m of this rock type, TH-8 ca. 3,2 m and TH-12 ca. 4,85 m. The registrations in the three holes match well by suggesting a steep westerly dipping orientation of the major concentration of lamprophyric rocks.

The termination of TH-7 was determined by the appearance fo a major discontinuity: a strongly oxydized fracture zone with less than 10% core recovery over the central 5,5 m.

This transection is the only one cutting the inferred fault zone running along the Tuftehavna creek and restricts the possibilities for orientation of this major structural element as will also be discussed later.

Profile 9/10 (Plate 4F). This northernmost profile are exclusively displaying data from the central søvite-dominated volume, and therefore give no information about contact relation. The exposed søvites are predominantly blue amphibole-bearing. Minor fractures of the core section contain other rock types as rauhaugites (I and II), apatite veins and lamprophyre. The latter only occur in the lower half of TH-10, where it totally amounts to 0,42 m.

2d Synthesis and conclusions from drill log examination.

The general structure of the Tuftehavna area can be a wedge-like zoned søvitic body surrounded by rauhaugites in the east and subsequently fenitic and fenite-derived rock types on either sides. "Either sides" is used here refering to east and west, because the actual structural pattern to the south is not fully known.

At depth the western contacts between carbonatites and fenitic rocks dips eastwards, whereas the eastern contact are more or less vertical, i.e. the structure narrows at depth. The general orientation of the lamprophyric are on the other hand dipping steeply to the west, at low angle with the søvite contact.

The zoning mentioned above refers to the predominance of blue-amphibole-bearing søvites along the margins.

The suggested orientation of the Tuftehavna creek fault zone ar based on the fact that it is only transected in one drillhole: TH-7. The other holes drilled eastwards do not go deep/far enough to reach this possible planar structure. Thereby the orientation is restricted to just a very small angular deviation from the direction indicated on the geological map (Plate 1).

Some additional "interrock" relations seem to be generally valid and of possible importance for further exploration work.

1) There is no spatial relationship between lamprophyre and fenitic rocks or rock types derived from fenites. They are always well separated.

2) The appearance of rauhaugite (type I) is not a clue to the occurrence of lamprophyre. The former occur spread all over the investigated area as well as more massive in the (south-) eastern part, whereas lamprophyres are restricted to the søvitic domain.

3) Rauhaugite (I) occur together with all other major rock types but are especially enriched in or near to fenitic domains.

4) Lamprophyres occur together with different types of søvites, which are generally high in magnetite.

5) Rauhaugite (II) and apatite-veins are not easily separated macroscopically. They usually are of the same thickness (i.e. very thin in this area), have caused similar metasomatic alteration features in surrounding rocks, and they show comparable cross-cutting relations to other rock types indicating approximately the same relative age.

6) The occurrence of rauhaugite (II) is restricted to carbonatite domains. They do generally not appear within areas dominated by fenitic and rock types metasomatically derived form those.

3. PETROGRAPHY

This account on the petrography of the major rocktype in the Tuftehavna area are concentrated on the potensial ores, but will also give a general introduction to the nature of the other rock types.

3a Fenite, syenitic fenite and biotite-calcite fels.

This group of rocktypes has at least one feature in common: They do all of them appear to be devided from the surrounding gneisses through the action of metasomatic processes. They are cut by dykes and veins of later carbonatites and occur as xenoliths in the søvites (Fig. 1). The alteration of original host gneisses have led to formation of a large variety of rock types, of which those appearing in the heading of this chapter are the most characteristic. They often occur in a zoned pattern, in the same order as listed, in large or small scale (Fig. 1).

Fig. 1

3a1 Fenite. This rock type are characteristically composed of microperthitic alkalifeldspar and aegitine with soda amphibole, apatite, sphene, zirkon, pyrite, calcite and quartz as minor, highly variable constituents (Brøgger 1921, Sæther 1957, Olmore 1982). It is mainly recorded from lower sections of TH 1 (Olmore 1982) and is therefore possibly making up larger volumes along the western margin of the mapped area.

3a2 Syenitic fenite. This term was introduced by Vartiainen & Wolley (1976) for completely fenitized rocks. That is rocks which no more contain quartz any other relics of the phases present in the original granitic host rock, neither any of its structural or lectural characteristics. Olmore related the term to Sæthers (1957) "pulaskite syenite" but also pointed out the appearance of biotite and chlorite as the effects of retrogression becomes more distrinct.

The syenite fenites are most common along the western edge of the mapped area.

Further metasomatic alteration leads to the complete breakdown of the ferromagnesian phases of the fenite to biotite and chlorite as well as sericitization of the feldspar. The result is a felsic pink medium grained rock common along the eastern and western margin of the carbonatite massif, and making up the central part of larger bodies as well as definite xenoliths (e.g. Fig. 1).

3a3 Biotite-calcite fels. This is a mafic rock rimming the fenites at the contact with carbonatites. Widths are extremely variable, from a few millimetres to several meters. Its major constituents are biotite, calcite, chlorite often intergrown with sericite, magnetite, riebeckite and pyrite. Relict sericitized alkalifeldspar is common.

The term was introduced by Brøgger (1921) and also used by Sæther (1957) in slightly altered form ("biotite calcite rock"). Brøgger (1921) did also introduced the term "hollaite", which Sæther (1957) abolished, as the rock type concerned could simply be called "pyroxene-søvite". However, during the 50's the use of "hollaite" as a field term for all mafic rocks in the carbonatite domains led to confusion. This is also adopted by the coworkers within the present project (eg. Olmore 1982, p.2) as hollaite proper is virtually absent within the Tuftehavna area.

This rock type is generally mineralized with Nb-oxides, the nature of which is not studied in detail. The corresponding Nb_2O_5 -content is usually below 0.5 % wt. over narrow zones along the interface between adjacent søvite and biotite-calcite fels.

3b Søvite

3b1 Terminology Søvites, in several varieties, dominate the area of concern. Brøgger (1920) introduced this term to cover the nearly pure calcite-rocks. These are "calcite-carbonatites" according to Streckeissen (1979).

Brøgger (1920) applied separate names, like hollaite, kåsenite and ringite to calcite-rocks dominated by different non-carbonates. Sæther (1957) refined the term "søvite" by restricting it to calcite-rocks with non-carbonates $<$ 10 %, and used the appropriate pre-fixes for those rocks carrying between 10 and 50 % non-carbonates e.g. pyroxene-søvite. This latter principle of terminology will be applied here, whenever possible. However, these terms will nevertheless be compared with those of Brøgger, in an attempt to clear up the confusion introduced by unfortunate use of certain terms in recent year.

The following account will be subdivided on the basis of structural, textural and mineralogical characteristics of the different varieties of søvites in an attempt to disclose any systematic variations within the area. Tentatively 6 types of søvite are defined. The importance of this subdivision is left to future workers to decide upon.

3b2 Søvite I. This type is usually coarsegrained with a patchy appearance and purple to grey colour. Reference sample: TH 1: 21.70 m (Fig. 2).

Fig. 2

The major non-carbonate phases are biotite, magnetite, apatite, green amphibole and pyrite. All occur in highly variable amounts, and usually only 3 or 4 are present in an sample.Accessorial constituents are clinopyroxene, muscovite, chlorite and zirkon.

The rock type exhibit a heteroblastic texture coarse calcite, biotite and magnetite crystals and interstitial mediumgrained calcite, apatite and other phases present. Magnetite often show a skeletal habitus where large grains are cut into seperate elongated pieces in optical continuity with each other, and with mainly calcite and apatite in between. This is probably due to late magmatic resorption. Magnetite also occur as overgrowth on strongly elongated pyrite grains.

The coarse calcite grains are zoned with increasing dolomite contents along the rims (Cathodeluminiscence: core: orange, rim: more reddish.

Apatite occur as medium sized rounded sub. to anhedral grains, often strongly elongated, and zoned with respect to amount of microscopic inclusions These, which nature is not known, are clouding the cores of many grains, whereas virtually absent in the rims. The green amphiboles are secondary relative to the calcite: tiny single fibres or radial aggregates of such along restricted granulated zones, or more rarely spread in the massive parts of the rock.
No significant Nb-mineralizations are observed.

3b3 Søvite II. This type show a coarse-grained patchy texture and white to blue colour, the latter being due to the content of alkaliamphibole.
(Reference sample. Th 3, 84.80 m).

Major non-carbonate phases are blue amphibole, magnetite,biotite, apatite and pyrite. Among the accessorial minerals are small euhedral zirkon inclusions in calcite the most characteristic.

Calcite is the only primary carbonate present. The mineral occur together with apatite in a granular texture. A cathode luminiscence survey revealed a weak zoning pattern in the coarsest calcite grains: orange rims and slightly more reddish cores. The significance of this observation is not stated.

The blue amphibole, a riebickite acc. to Andersen (1981), occur cm-sized radial aggregates. The mineral seems colourless i thin section. The aggregates are often rimmed by granular medium grained apatite. This apatite-modification as well as the matrix type are zoned in the same way as in the Søvite I.

Magnetite occur as eu – to subhedral up to 1 cm large crystals which have exsolved Ti-ores. Dendritic and/or skeletal development of magnetite are also often observed.

This søvite type contribute significantly to the total phosfor content of the area, but is not of any importance as source of Nb.

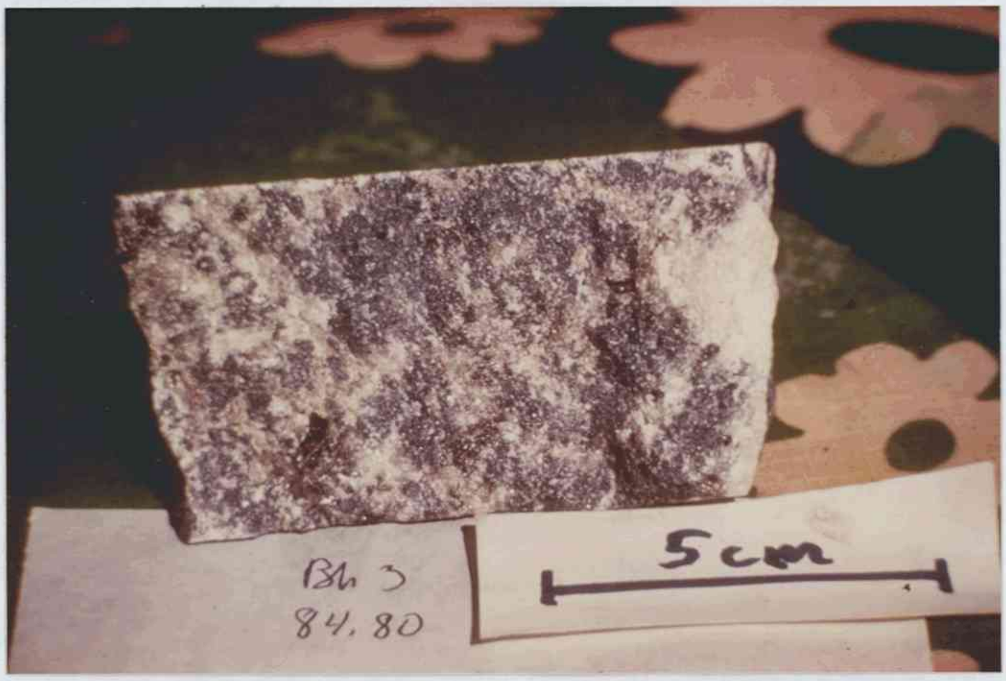

Fig. 3a

Fig. 3b

3b4 Søvite III. This type is mediumgrained with grey-green to light pink colour, and often inhomogeneous, patchy as the preceding type I and II. It is generally massive without distinct foliation developed. The major non-carbonate-phases are green amphibole, biotite, magnetite, apatite and pyrite, whereas zirkon and columbite occur in accesorial amounts. Reference sample is TH-3, 58.40 m (Fig. 4).

Fig. 4

This rocktype is dominated by calcite of highly variable grain size between 1 and 0.05 mm. The calcite is zoned, i.e. it is dolomitic along grain boundaries, which are usually uneven. The apatite grains are medium to fine grained, sub to euhedral and often consentrated in polyonal aggregates. The apatites are full of inclusions, equally distributes, allthough some grains enclose large (~ 0.1 mm) carbonate grains in the core. The nature of this carbonate is not known.

Pyrite occur as rounded, often strongly elongated medium sized grains. Occationally euhedral cubes are also observed. It is often surrounded by secondary magnetite. Magnetite do also occur as euhedral individual crystals, often enclosing ilmenite exsolution lamellaes. Either modification are extremely impure with large amount of calcite inclusions, or appear as skeletal remnants intimately intergrown with calcite.

The zirkons occur as minute grains interstitially between or included in calcite.

The columbite occur as eu - to anhedral homogeneous grains, < 2 mm, but are often rounded and full of intergrowths and inclusions of calcite. This Nb-mineralization is common and is estimated to be comparable to max. 0.5 wt % Nb_2O_5.

3b5 Søvite IV. This type is more finegrained, grey, often with a weakly developed layering due to concentration of mafic minerals. These are biotite, apatite, chlorite and pyrite and occessional amounts of quartz, magnetite, phyrochlore and columbite.

In addition to calcite, ankerite and dolomite are present in significant comments.

Reference sample: Bh 4: 64,50 m

Fig. 5

The rock exhibits a polygonal texture of mediumgrained calcite and fine grained apatite, the latter often concentrated in aggregation. The calcite is zoned in the way that it is rimmed by dolomite along grain boundaries and secondary biotite + chlorite -rimlets.

An early generation of mediumgrained sub- to euhedral green biotite is generally broken down to radial, very finegrained aggregates of brown biotite and chlorite along the rims. Thorough alteration has caused exsolution of quartz in the core of the biotite-grains. These altered biotites are subsequently surrounded by anhedral finegrained aggregates of dolomite and ankerite, and, as an outer rim of this coronalike structure (Fig 6), polygonal medium to fine grained strongly zoned apatite.

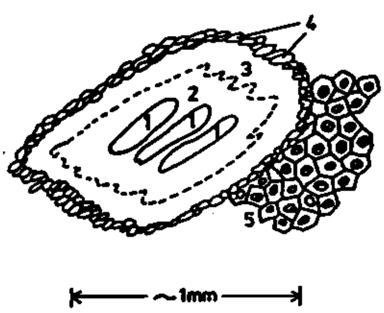

Fig. 6

The zoning shows as shadings in blue in cathode luminoscope and to some extent as a decrease in density of inclusions towards the rim.

Pyrite is the most abundant opaque, occuring predominantly as < 0.05 mm euhedral cubes. Minor amounts of euhedral magnetite is also observed.

Pyrochlore and columbite are intimately intergrown. They occur as euhedral, strongly zoned, 0.05-0.1 mm large crystals. The cores are dominated by pyrochlore, which are translucent with a deep red-brown colour.

Towards the rim the amount of opaque columbite increase gradually within the pyrochlore zones as "blebby" inclusions, as well as constituting separate zones with pyrochlore as the minor phase. This mineralization is a general feature, resulting in an estimated Nb_2O_5 -content of ca. 0.3 and less than 0.5 % wt. in the whole rock.

3b6 Søvite V. This type is characterized by a very peculiar orbicular texture, defined by incomplete, often multiple complex spheres of mica + a REE-mineral in weakly foliated søvitic material (Fig. 7). Most of the spheres are strongly elongated (e.g. 10 : 1 : ratio between longest or shortest axis), but some are obviously not. These latter are the most distinct suggesting a synmagmatic origin. The average diameter is around 0.5 cm. Reference sample is TH-12, 122,50 m (Fig. 7).

Calcite is completely dominating also this rock. Minor constituents are dolomite, REE-silicates, pyrite, pyrrhotite, a fibrous mica of unknown identity.

Fig. 7

The calcite is generally mediumgrained with uneven grainboundaries. It is crowded with included minerals as well as with two phases fluid inclusions (gas - liquid).

The graphite spheres are zoned (Fig. 8). The spheres themselves have unevenly distributed cores of a unidentified REE-mineral surrounded by a green fibrous mica. Both are in coexistance with pyrite and pyrrhotite.

On either sides of the spheres there is a zone of dolomite wich subsequently are in contact with calcite.

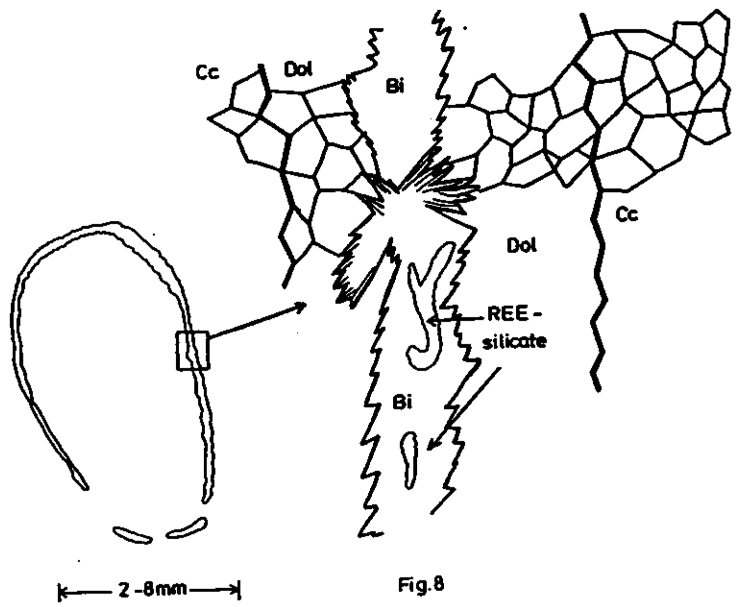

Fig. 8

Søvite VI. Søvite dikes. In a number of cores crosscutting relationship between different types of søvites can be observed. In these cases the later dike-like søvites are generally mediumgrained white to grey with low contents of mafic minerals. In the two reference samples chosen (TH-4, 28.45 m and TH-12, 104.20 m) blue-amphibole bearing søvite (Søvite II) and a layered lamprophyric biotite-apatite rock are cut this later generation (Fig. 9A and B, resp.)

Fig. 9a

Fig. 9b and 10a

Equigranular calcite make up more than 95 vol. % of these dikes. The rest is rounded, elongated crystals of apatite crowded with very finegrained unidentified included minerals, and occational larger subhedral biotite-crystals. The biotites are usually strongly oxidized and/ore chloritized. No Nb-mineralization are observed in these dikes.

3c Late segregations associated with søvites

A number of different rocktypes appear as segregations or dikelike bodies within søvites. They are usually coarse grained and predominently composed of two or more of the "phases" biotite, apatite, magnetite and Nb-oxides. Rarely, monomineralic varieties are developed. The two most significant types are discussed below.

3cl Biotite-apatite rock/lamprophyre. This rocktype occur as irregular segregations, lenses, veinlike bodies or dikes predominantly related to biotite bearing søvites. The thickness of single bodies varies from a few millimeters to more than 1 m. The small lenses and segregations are usually elongated parallell to foliation if present in the surrounding søvite. (Fig. 10a). Veins and dikes do, however, often cross-cut such features (Fig. 10b), suggesting that multiphase or continues subsolidus deformations has taken place, in accordances with the conclusions of Sæther (1957). The biotite-apatite rocks are on the other hand post-dated by intrusion of rauhaugite I (Fig. 10C), and all the present rocks have subsequently been subjected to local thorough deformation and gneissification (Fig. 10d).

The petrography of the biotite-apatite rocks has already been introduced by Olmore (1982), but it is intended here to go into some more detail.

The rocks may be massive, homogeneous without visible linear of planar structures, or expose well developed banding. This is defined either compositionally by the large modal variations (e.g. 4.8 - 66.3 vol % apatite (Olmore, 1982)) or variations in grain size. The interface between bands may be planar or irregular.

The grain size varies from the coarsest biotite up to 5 mm, to oxides less than 0.001 mm, thereby giving the rock a heterogeneous appearance both in macro and microscopic scale.

The major phases are biotite, apatite, fersmite, pyrochlore and columbite with minor, or accessorial amounts of carbonate and pyrite.

Fig. 10b

Fig. 10c

Fig. 10d

Biotite occur as single and to euhedral phenochrysts or aggregates 2-0.1 mm. The larger grains show undulating extinction and are strongly zoned. The general pattern is a (yellowish) green core, and towards rim the mineral is strongly pleocroitic dark bluegreen to light brown with dark brown zones. (Fig. 11A and Fig. 3A, Olmore 1982) This correspond to chemical variations: the core are enriched in F, Mg and Al and depleted in Si and Fe relative to the rim. The dark brown zones are charachteristically enriched in Fe and Ti, but depleted in F (Fig. 11b). For further chemical data, se next chapter.

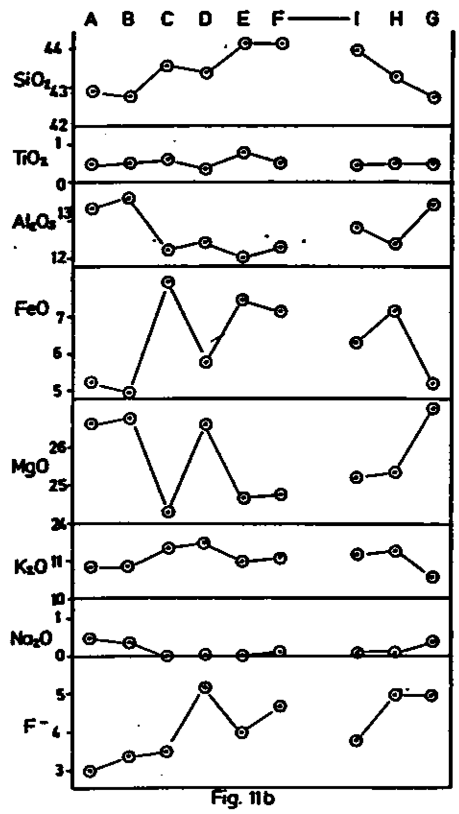

Fig. 11 a and b

x

Inclusions are common. These include sub- to euhedral very fine grained pyrochlore (and columbite (?)), and fersmite most abundant near rim, (Fig. 12), and occasionally a finegrained euhedral Ta-mineral not yet identified (Fig. 13), and rounded pyrite and apatite. The latter may in turn enclose pyrochlore and fersmite crystals. Characterstics are also radial aggregates of 0.0001-0.001 mm thick needles of fersmite (Fig. 14) with growth centres along rims and internal fractures.

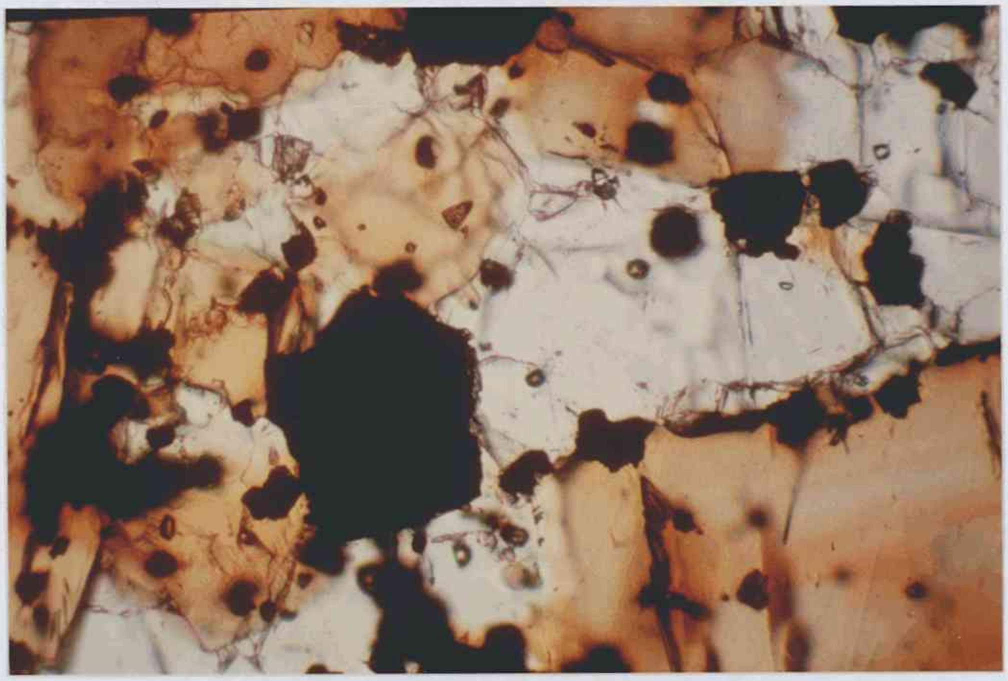

Fig. 12

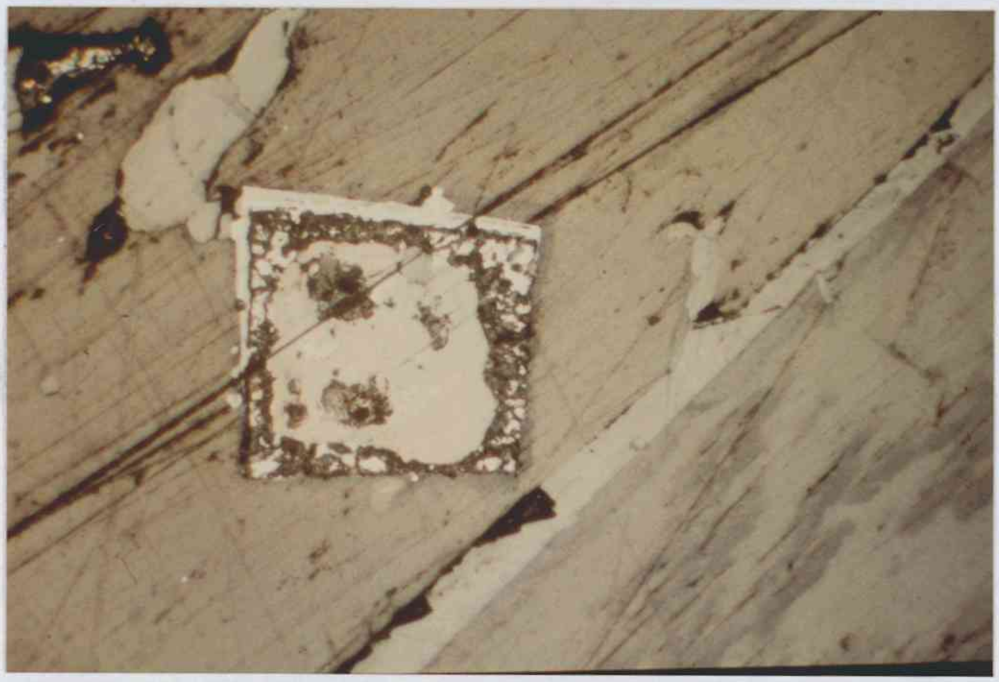

Fig. 13

Fig. 14a

Fig. 14b

Apatite occur in a granular texture interstitial relative to biotite, with an average grain-size around 0.1 mm. The mineral may include large amounts of Nb-oxides, both pyrochlore, columbite and fersmite.

Pyrochlore occur as euhedral, often perfect octahedral crystals, with size ranging from 0.001 to 0.05 mm (Fig. 15). The crystals are colourless to light brown, locally metamict, and exhibit extensive zoning, the nature of which is not yet identified for this rock type. As part of the zoning are also observed local accumulations of yet unidentified inclusions of size < 0.0001 mm. Preliminary data show that these are enriched in Ta relative to the host pyrochlore.

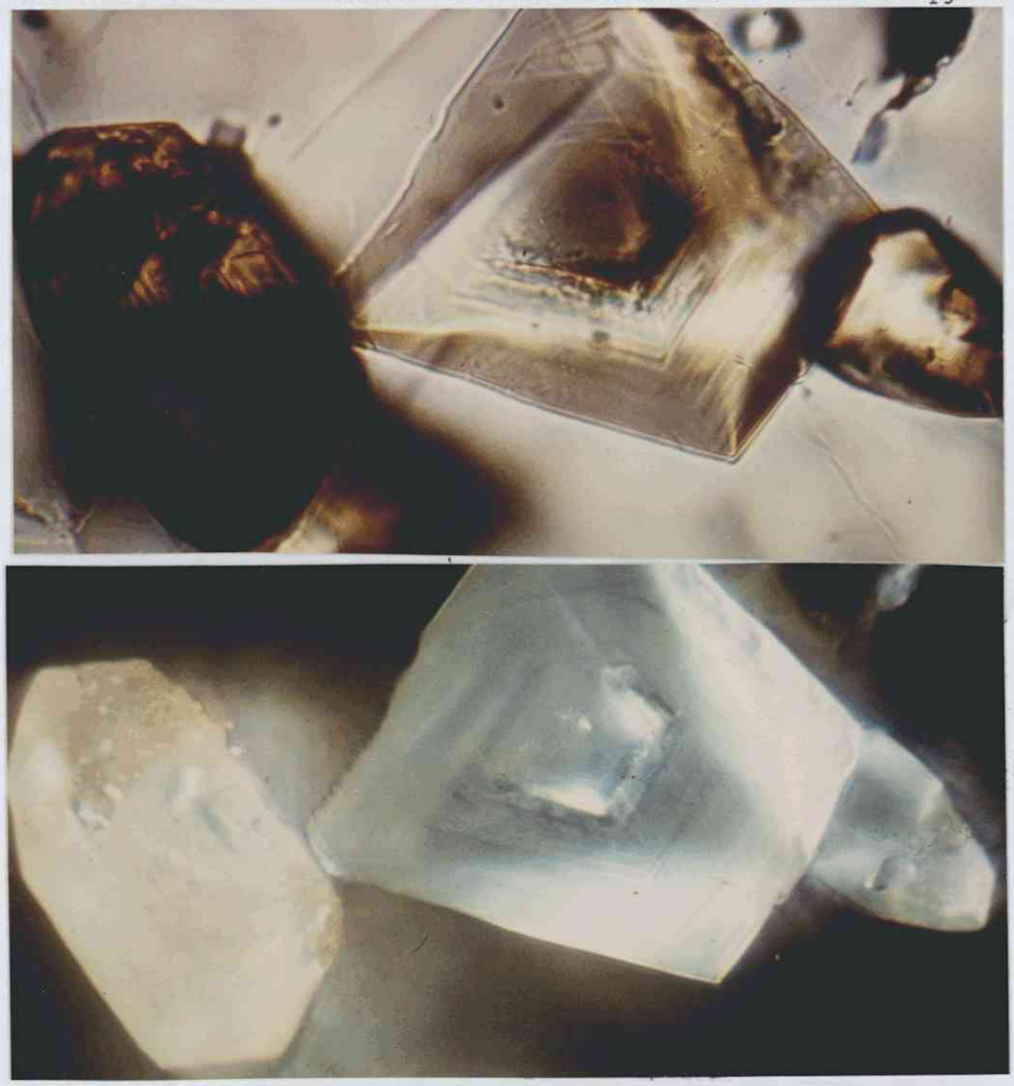

Fig. 15a and 15b

Columbite is the least abundant of the "common" Nb-oxides. Just scattered occurences are recorded indicating a general coexistance or emplacement relation between columbite and fersmite, as they occur in the same textural relation to other phases or with columbite as inclusions in fersmite.

Fersmite occur as sub- to euhedral crystals, desiminated or as inclusions in apatite or biotite (Fig. 12). Grain-size ranges from 0.01 to 0.1 mm. The crystal faces are rough and uneven, as are also the brown colour of the

Partly metamictized mineral (Fig. 16a). The crystals are extremely inhomogeneous. The fersmite matrix enclose at least two other oxide phases as well as apatite (Fig. 16b). One of the oxides are most probably columbite. Although the small grain size prevents a conclusive identification. Secondary carbonate appear througout the rocks as very finegrained veinlet fillings and along grain boundaries. These veinlets are up to 0.5 mm thick.

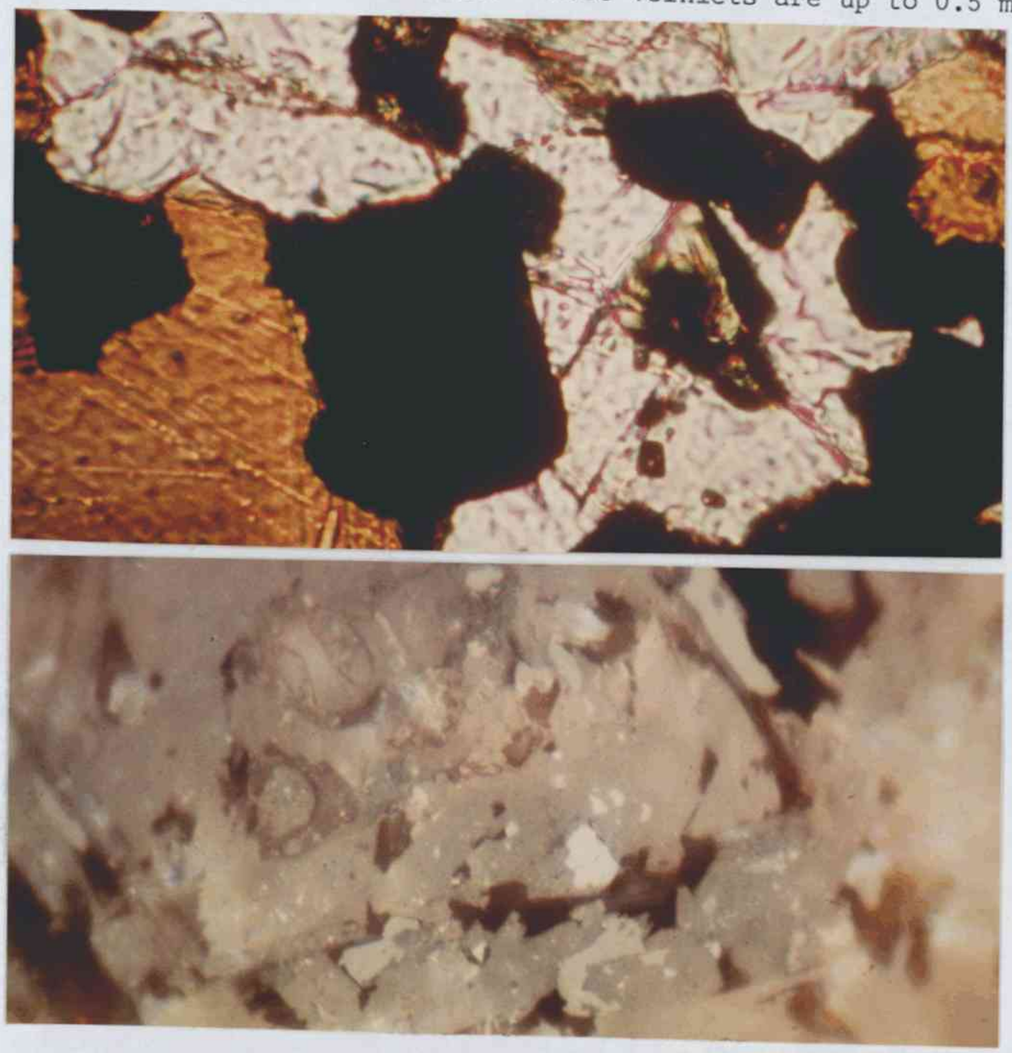

Fig. 16a and 16b

3c2 Magnetite- biotite- apatite rock. In this lamprophyric variety, magnetite is one of the dominant phases. The appearance is in most respects identical to the former biotite- apatite rock, massive and coarse grained. However, the mineralogy differs considerably. Major Nb-phase is columbite, and calcite is as well as a major "primary" phase. Pyrite and green amphibole occur as accessional amounts. Reference sample and sole registrated occurense is TH-4 around 16.70 m.

The biotite are originally zoned, but is often strongly oxidized and broken down to very finegrained clouded aggregates in which fibrous green amphibole is present as an important phase. The zoning pattern indicates that the crystals have grown in two steps: The core has a uniform very light green to brown colour and show just weak pleochroism. This core is overgrown concordantly by a fine laminated, strongly pleocroitic zone of brown to dark redbrown colour. The outer rim of the biotites show a zonation in lightbrown to redbrown colour discordant with the former, indicating a brake in the growth.

Magnetite occur as up to 5 mm euhedral very impure crystals. They are crowded with inclusions of non-opaque minerals, probably mainly apatite and biotite, which at least appear as the larger grains.

Columbite occur as rounded sub- to anhedral homogeneous crystals of size up to 5 mm. No indications of exsolution or zoning phenomena are observed. The columbite-content is estimated to ca. 5 vol % at this specific core section, thereby classifying this rock type as an important source of ore if present in larger volumes.

3c3 Magnetite- blue amphibole- apatite-rocks. This heterogeneous group of rocks are composed dominantly of the minerals giving name to the group, in highly variable fractions, with no or just minor amount of biotite and carbonates. The rocks occur as concentrations of one or more of the major phases in the parent søvite, mostly with gradual contacts. Dike-like or cross-cutting relations, like those exhibited by the biotite- apatite-rocks, has never been observed. These rocks are therefore regarded as integral parts of søvite bodies. Referanse sample in TH-3: 88.80 m (Fig. 17).

Fig. 17

From the cores, thicknesses between a few cm and 2-3 m are observed, most common are 10-30 cm. The grainsize is also highly variable from sample to sample and from one phase to another.

Magnetite occurs as sub- to euhedral single crystals up 1 cm, and as up to 5 cm large aggregates (Fig. 17), often with developed octahedral exsolution pattern.

Blue amphibole, a riebeckite (Andersen, 1981), occur as cm-sized semiradial fibrous aggregates. Individual fibres are usually around 0.25 mm long and less than 0.05 mm thick. The mineral is macroscopically bluish, but colourless in microscope.

Apatite are usually subhedral rounded granular with grainsize up to 1 mm. It is distinctly zoned: the central parts are crowded with inclusions, mostly carbonate (no opaques), whereas the rim are free from inclusions. Secondary minute grains and aggregates of calcite and unidentified mica are very common. Apatite are not found in contact with blue amphibole.

Green to brown zoned biotite occur as up to 0.5 mm anhedral grains next to magnetite crystals, and as very fine grained aggregates together with blue amphibole. Chlorite and anhedral magnetite, up to 0.1 mm are also recorded from this environment.

Calcite show a granular very fine to medium grained texture in equilibrium with as well as replacing apatite.

Pyrite occur as up to 0.1 mm and to subhedral grains dessiminated througout the amphibole-free parts of the rocks. A strongly anisotropic sulphide (?), not yet identified is recorded next to large magnetite crystals.

No distinct grains of Nb-oxides are observed.

Occasional euhedral grains of zirkon are recorded in apparent coexistence with magnetite, apatite, biotite and calcite.

3c4 Apatite-rock. In TH-11 at around 20 m depth is locally developet a "pure" apatite-rock strongly mineralized by columbite. It is developet within a sequence of intermixed rauhaugites and søvites, but the structural relation to these rocks are not clarified.

The rock is massive, fine to mediumgrained and has a grey to pink colour.

Fig. 18a

Fig. 18b

3d2 Rauhaugite (II). This late, multiple generation of the rocks are not studied in detail by the present author. Within the Tuftehavna area they are seen as numerous veinlets, of thicknesses usually less than a few millimeters, cutting the other carbonatite types. When cutting søvite rocks, a charachteristic grey metasomatic haloe is developed, probably due to dolomitization of the calcite.

This alteration feature is also observed around late apatite veinlets, which for convenience therefore are grouped together with the rauhaugite (II), although their relative age-relations are not known.

Sæther (1957) reports a general Nb_2O_5 - content of 0.2-0.5 % wt. in the rauhaugite (II), and low content of apatite. In practice, however, these contents are of no importance, as the total volumes of these rocks are negligible.

3e Summary on the Nb - and P-mineralizations.

As a summary of this petrographic account I will compare the occurring rock-types as potential sources for Nb-oxides and apatite.

The rich ores are represented by what is in this report denoted as "late segregations". Three of those (see Table 1) have both apatite and Nb-oxides as major constituents. The fourth, which are blue amphibole bearing, has no Nb-oxides. Magnetite is a major phase in this one as well as in one of the Nb-mineralized, but the latter is of subordinate importance when registred volumes in Tuftehavna is considered.

Of subeconomic importance are the Nb-mineralizations of different søvite types (III with columbite; IV with pyrochlore and columbite) which also contain substantial amounts of apatite; the rauhaugites, which are generally low in apatite; and apatite veinlets associated with the second generation of rauhaugites, and the biotite-calcite fels.

So far no Nb-mineralization are reported from rocks containing blue amphibole (søvite and segregations). The textures (fibrous radial aggregates) of these alkali-amphiboles exclude a pure magmatic origin of the mineral. Chemical considerations suggest that the necessary alkalies are supplied from (fenitized ?) gneisses, and therefore that these søvitic rocks are strongly contaminated.

Rocktype	Mineralizations		
	Nb-oxides	Apatite	Magnetite
Fenites			
Biotite-calcite fels	x		
Søvite I		x	x
" II		x	x
" III	x	x	x
" IV	x	x	
" V	-	-	-
" VI	-	-	-
Biotite-apatite rock (Segrega type I)	xx	xx	-
Magnetite-biotite-apatite rock (Type II)	xx	xx	xx
Magnetite-blue amphibole-apatite rock	-	xx	xx
Apatite-rock	xx	xx	-
Rauhaugite I	x	-	-
" II	x	-	-
Apatite veins	-	xx	-

Table 1. Major mineralizations and the relation to their host rocks.

- not enriched

x enriched

xx strongly enriched

4. MINERALOGY

This chapter will give an uneven presentation of the mineralogy of the major rock types. For obvious reasons the activities have been concentrated on those mineralgroups making the economic potential of the area, primarily the Nb-oxides and apatite. The other mineral groups will be discussed to the extent new data are available.

4a Mineral analysis.

An ARL- EMX- electronmicroprobe attached to a LINK quantitative energy-dispersive analyzer at Mineralogisk-geologisk Museum in Oslo.

Standard settings have been:

Acceleration voltage:	15 kV
Emission current:	100 mA
Beam current:	$1 \cdot 10^{-7}$ A

The analytical detection limits defined as 20 based on counting statistics, recalculated to wt %, are given below.
These values are approvimate, as they vary somewhat from phase to phase. This is mainly related to variations in background level due to fluctuation in amounts of interfering elements.

SiO_2	.26	Nb_2O_5	.31
TiO_2	.27	Ta_2O_5	.36
Al_2O_3	.19		
FeO	.30	Y_2O_3	.39
Mn	.30	Ce_2O_3	.61
MgO	.19	La_2O_3	.36
CaO	.17	UO_2	.42
Na_2O	.24	ThO_2	.69
K_2O	.13		
P_2O_5	.43		
SO_4^{--}	.15		
F^-	2.65		
Cl^-	.11		

In analytical tables positive detections corresponding to values between 1 σ and 2 σ are indicated as traces ("tr").

The energy-dispersive analyses of Ta do however introduce a separate problem because of the Ta-peaks complexity and overlap with other elements. This problem are not yet fully overcome, and have resulted in low reliability upon exactly stated high Ta-values, despite good reproducability.

To control the quality on the different elements a number of pre-analyzed standards, minerals and glasses, are analyzed as unknowns.

Data on three apatites, from Gloserheia, South Norway, Durango, Mexico and Huddersfield, Quebec are included in Table 2. A general reproducable agreement between the analyses and published values for CaO, Na_2O, P_2O_5 and Cl^-. A reasonable proportionality is shown by $SO_4{}^{2-}$ although the exact values are way off the "recommended". For the other elements the result is at best indicative at these low amounts around or below detection limit.

The specific problem exhibited by F^- caused by three factors

1) Low counting rates for this light element.
2) The element is easily vaporized from the surface as a result of overheating through electron bombardment. This effect has been minimised by defocusing the electron beam.
3) Overlap between the FK - line and the FeL - line making F^- analyses of Fe-bearing minerals even more dubious.

For the specific aim of detecting Mg^{+2}, F^- and Cl^- in the apatites more accurately, the elements were analysed on the manual spectrometers. ADP-crystal was used for the two former, and RbAP for the latter.

4b Oxides

4b1 Pyrochlore. This cubic mineral fulfil the requirement of the general formula. $X_2Z_2O_6$ (OH,F) where X where the X-position may be occupied by Na, Ca and V among others, and Z by Ta and Nb (Phillips and Griffen, 1981). It occurs in several mineralized rock, either intergrown with columbite or as separate crystals, the former in søvite, the latter in biotite-apatite rock. (lamprophyre).

The søvite-pyrochlore (Søvite IV) occurs as coarse grains (usually 0.05- 1 mm), intimately in cyclic concentric zoning pattern with columbite. The mineral has a dark brown colour in transmitted light, and a reflectivily higher than

Table - 2a Microprobe analysis of Std. 85, apatite from Gloserheia, South Norway.

Values in "( )" are below detection limits, set here to be 2σ.

1) O≡ (SO_4^{2-} + F^- + Cl^-)

2) Sum includes other R_2O_3 = 0,50%

O≡ is calculated by the present writer.

Analysis by Åmli (1973).

Table - 2b Microprobe analysis of Std. 112, apatite from Durargo, Mexico.

Values in "( )" are below detection limits, set here to be 2σ.

1) O≡ (SO_4^{2-} + F^- + Cl^-)

2) Sum includes R_2O_3 = 1,43, K_2O = 0,01

SrO = 0,07, As_2O_5 = 0,09

Calculated by the present writer:

- O≡

- FeO from Fe_2O_3

- SO_4^{2-} from SO_3

Analysis from Young et al (1969).

Table - 2c Microprobe analysis of Std. 148, apatite from Huddersfield, Quebec.

Values in "( )" are below detection limits, set here to be 2σ.

1) O≡ (SO_4^{2-} + F^- + Cl^-)

2) Sum includes CO_2 = 0,88 and H_2O^- = 0,29

Calculated by the present writer:

- O≡

- FeO from Fe_2O_3

Analysis from Trzcienski (1974).

Table - 2a

ANALYSIS

Anal. no.	Date	SiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	P_2O_5	Y_2O_3	Ce_2O_3	La_2O_3	SO_4^{2-}	F^-	Cl^-	$O=^{1)}$	SUM
1	14/7	,69	0	0	0	53,40	(0,14)	39,09	1,34	0	0	,45	2,80	,18	1,29	96,80
2	"	,68	0	0	0	54,99	(,20)	40,29	,98	(,50)	(,39)	,60	(1,83)	,20	,92	99,74
3	"	,48	0	0	(,16)	54,72	,28	40,94	(,79)	(,18)	(,24)	,51	(2,53)	,19	1,19	99,83
4	"	(,13)	na	na	0	54,55	(,13)	41,23	0	0	0	(,14)	(2,02)	,16	,91	97,45
5	"	,35	na	na	0	55,90	(,13)	41,52	(,42)	0	0	0	(,30)	,13	,16	98,59
Mean		,47	0	0	0	54,71	,18	41,61	,71	,14	,13	,34	1,90	,17	,89	99,47
St. dev		,24				,90	,07	,97	,52	,22	,18	,26	,97	,03	,44	
Recommended(2)		,49	na	na	na	54,47	na	40,67	,71	,10	na	na	2,92	na	1,23	98,13

Table - 2b

ANALYSIS

Anal. no.	Date	SiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	P_2O_5	Y_2O_3	Ce_2O_3	La_2O_3	SO_4^{2-}	F^-	Cl^-	$O=^{1)}$	SUM
1	14/7	,34	0	(,13)	(,11)	54,17	,46	40,53	0	(,69)	(,64)	,69	2,85	,39	1,40	99,60
2		,28	0	0	0	55,02	(,11)	41,27	(,24)	(,34)	(,16)	,87	(2,18)	,44	1,16	99,75
3	15/7	(,20)	0	(,18)	0	54,21	,32	40,66	0	(,33)	(,18)	,87	3,49	,36	1,69	99,11
4	"	(,24)	0	(,19)	0	54,52	,41	40,38	0	(,68)	(,65)	,87	(1,68)	,47	,96	99,13
5	"	,50	0	0	0	54,40	,35	40,29	(,31)	(,55)	(,55)	,45	(,80)	,30	,48	98,02
6	"	(,19)	0	(,19)	,32	54,85	,56	41,64	(,11)	,79	(,75)	,87	(,33)	,43	,38	100,65
7	13/7	,39	na	na	(,17)	54,08	,46	39,72	(,60)	(,62)	(,37)	,90	4,10	,32	1,95	99,78
8	"	(,18)	na	na	,25	55,49	,38	40,82	0	(,22)	(,32)	,84	(2,60)	,43	1,33	100,20
9	"	,29	na	na	(,11)	55,42	,38	41,46	0	,92	,76	,84	(2,53)	,37	1,29	101,79
10	25/5	na	(,10)	0	(,19)	55,14	,44	39,95	na	0	na	na	5,35	na	2,25	98,92
11	"	na	(,10)	0	0	55,44	,36	39,53	na	(,21)	na	na	(1,66)	na	,70	96,60
12	"	na	0	0	0	55,51	,46	40,65	na	(,33)	na	na	(1,09)	na	,46	97,58
13	"	na	0	(,21)	,26	54,62	,35	39,74	na	(,16)	na	na	2,89	na	1,22	97,01
14	"	na	0	(,17)	0	55,38	,36	40,09	na	0	na	na	(1,81)	na	,76	97,05
Mean		,29	0	,10	,10	54,88	,39	40,47	,14	,42	,49	,80	2,38	,39	1,15	99,70
St. dev.		,11		,10	,12	,54	,10	,67	,21	,29	,24	,14	1,34	,06	,57	
Recommended2)	1	,34	,07	,05	,01	54,02	,23	40,78				,45	3,53	,41	1,66	98,40

Table - 2c

ANALYSIS

Anal. no.	Date	SiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	P_2O_5	Y_2O_3	Ce_2O_3	La_2O_3	SO_4^{2-}	F^-	Cl^-	$O=^{1)}$	SUM
1	14/7	1,44	0	(,19)	0	53,24	,32	37,64	(,34)	1,34	(,44)	1,14	4,18	0	1,95	98,02
2	"	1,23	0	0	0	53,87	,26	37,78	0	1,28	(,20)	1,08	3,10	0	1,49	97,31
3	"	1,07	0	0	0	53,14	(,13)	37,60	0	1,06	(,43)	1,11	3,49	0	1,65	96,38
4	13/7	1,07	na	na	(,10)	53,95	(,12)	37,44	1,02	1,41	,81	,81	(2,12)	0	1,02	97,83
Mean		1,20	0	0	0	53,55	,21	37,62	,34	1,27	,47	1,04	3,22	0	1,53	97,39
St. dev.		,18				,42	,10	,14	,48	,15	,25	,15	,86		,39	
Reccommended2)		1,75	na	,12	na	53,66	,28	38,08	,15	1,22	,44	,87	3,90	na	1,73	99,91

Sample No.		Point	Nb_2O_5	Ta_2O_5	TiO_2	UO_3	Al_2O_3	Ce_2O_3	FeO	MnO	MgO	CaO	Na_2O	F^-	Sum
TH-1	3.95 m	1.1	69.1	0	4.1	0	0	0	0	0	tr	19.2	7.0	8.0	99.4
"	"	1.2	67.5	0	3.8	0	tr	0	0	0	tr	18.7	6.4	6.5	96.4
"	"	1.3	67.6	0	3.1	0	tr	tr	0	0	tr	17.5	7.3	5.0	95.5
"	"	1.12	67.2	tr	3.6	tr	0	0	tr	0	tr	18.8	6.3	8.7	95.9
"	"	3/4	57.6	2.3	3.6	0	.3	0	2.6	0	tr	21.8	tr	3.8	88.2
TH-1	3.95 m	1.4	63.6	.5	4.2	0	.3	0	.8	0	.3	16.6	6.3	5.9	92.6
		1.5	68.6	0	3.4	0	0	0	0	tr	0	19.1	6.2	6.3	97.3

Table 3. Selected microprobe analysis of pyrochlores from biotite- apatite rock (lamprophyre).
Sums do not include F^-.
"tr" = traces

that of the associated columbite. It is crowded with included phases, quartz and pyrite are registered. Preliminary data on the chemistry indicate that this m dification is high in V (~5 % wt) and Ta (~10 % wt), and are to a certain extent in accordance with the Ca-pyrochlores reported by Mariano (1980).

The "lamprophyre - pyrochlores" are already described in Ch. 3cl, Fig. 15. They are characteristically colourless to light brown, and exhibit very strong internal reflections. The grain size varies from 0.001 to 0.05 mm. The chemistry is rather uniform, as shown by selected analysis listed in table 3. They are characterized by relatively high contents of Ti, Ca, Na, and F^-, hereas Ta, V and Fe are low or virtually absent. Noteworthy are the possitive correlation between Ta and Fe enrichments and Nb and Na depletions.

4b2 Columbite. This orthorombic mineral is the most widely distributed Nb-mineral, reported from søvites, lamprophyres and rauhaugites. It is always opaque, and anisotropic with a grey colour in reflected light. The mineral's ideal formula is XZ_2O_6 where the X-position most commonly are occupied by Fe and Mn, and the Z-position by Nb and Ta. However, chemistry, as well as size and textural relations to adjacent phases are highly variable.

Columbite in "Søvite III" occur as anhedral, often rounded grains, with size less than 2 mm. Chemical analyses of two grains indicate high Fe and low Ti and Ta relative to the other modifications (Table 4).

Columbite in "Søvite IV" are intimately intergrown with pyrochlore in zoned, euhedral, up to 0.1 mm crystals. They are rounded with very finegrained inclusion of pyrite and a silica phase (according to chemical indications). The columbite crystals are chemically inhomogeneous, but generally lower in Nb and higher in Ta than average (Table 4).

Columbite is a subordinate phase in biotite-apatite rock where it occur closely assosiated with and probably in a replacement relation to fersmite, it is not easily separated optically from the latter despite its higher reflectivity. Very fine grained inclusions in fersmite fulfil this requirement (Fig. 15), but are unfortunately too finegrained to be identified by use of microprobe. Analysis of definite grains are given in Table 4. They show the lowest Mn-values and are also relatively low in Ta.

Columbite is, however, the major Nb-phase in magnetite-biotite-apatite rock.

Sample		Point	Rock Type	Nb_2O_5	Ta_2O_5	TiO_2	Al_2O_3	Sc_2O_3	Y_2O_3	Ce_2O_3	FeO	MnO	MgO	CaO	Na_2O	UO_3	Σ
				Analysis													
TH-3	58.40	1 B	Søvite III	76.1	0	2.1	tr			0	20.3	1.2	tr	.3	tr	tr	100.0
TH-3	58.40	1 C	Søvite III	73.6	0	2.6	0			0	19.7	.9	0	1.8	tr	0	98.6
TH-4	64.50	2 B	Søvite IV	69.0	5.6	4.2	tr			0	19.0	1.5	tr	.2	0	0	99.5
TH-4	64.50	2 D	Søvite IV	66.4	4.2	4.4	.4			.9	17.9	1.3	.3	.8	tr	0	95.8
TH-1	3.95	1.7	Bi-ap-rock	72.6	.4	5.8	0			0	18.7	.4	.6	1.9	0	0	100.4
TH-1	3.95	7.4	Bi-ap-rock	74.5	0	4.5	0			0	18.4	.8	.7	.9	0	0	99.8
TH-1	9.60	1.3	Bi-ap-rock	68.7	1.5	7.8	.3			0	18.5	.9	.9	.5	tr	0	99.1
TH-4	16.70	1 B	Mgt-bi-ap-rock	63.9	8.3	4.0	1.1			.9	16.7	1.2	2.5	.9	tr	0	99.5
TH-4	16.70	1 D	Mgt-bi-ap-rock	73.0	.4	5.8				tr	19.8	1.3	.3	.3	tr	0	100.9
TH-11	20.10	1 A/B	Ap-rock	73.3	2.4	2.8	tr			0	19.0	1.1	.3	.7	0	0	99.6
TH-11	20.10	1 C	Ap-rock	67.4	2.7	2.5	.2			0	17.1	1.2	tr	5.3	0	0	96.4
TH-11	20.10	1 D/E	Ap-rock	73.7	2.6	3.3	0			0	19.5	.9	.3	.7	tr	0	101.0
FV-23		1	Rauhaugite II	71.69		6.16		.67	.94		20.55	2.99		<0.5			103.00
FV-23		2	Rauhaugite II	65.91		6.05		1.32	.66		20.14	3.25		<0.5			97.33
FV-23		3	Rauhaugite II	69.77		5.50		.38	.73		19.76	3.45		<0.5			99.59
FV-23		4	Rauhaugite II	69.89		5.84		.64	.90		20.59	2.84		<0.5			100.70
FV-23		5	Rauhaugite II	68.69		6.23		1.12	1.30		19.72	3.00		<0.5			100.06
FV-28		6	Rauhaugite II	71.40		5.74		2.74	.65		17.49			<0.5			98.02
FV-28		7	Rauhaugite II	71.78		5.16		.73	.46		20.67			<0.5			98.80

Table 4. Microprobe analysis of columbite from different rocktypes from the Tuftehavna area, and for comparison from rauhaugite II W of Fensgruvene (Åmli, 1974, samples FV-23 and FV-28, Wavelength dispersive analysis).

"tr" = traces
Blank = not analyzed

Optically the mineral is homogeneous with no sign of zoning or included or exsolved opaque phases. However, the mineral is crowded with non-opaque phases, of which one is identified as a thorium-silicate, probably thorite. Analysis of the columbite, listed in Table 4, show variable, but significant contents of Ta and Ce, and a positive correlation between these elements and Mg and Al.

Columbite is also the major ore mineral in apatite-rock, where it occur as mm-sized subhedral, rounded crystals, poicilitically enclosing medium to fine-grained subhedral apatite. The chemistry varies somewhat indicating thourough inhomogenities The high Ca (CaO = 5.3 %) in pt. 1c, a rim position in the analyzed grains, may be due to interference from included fersmite not registred optically, or possibly a solid solution between the two structurally closely related minerals. The Ta-contents are noteworthy above 2 % (wt % Ta_2O_5).

Columbite in rauhaugites has not been studied by the present author. Åmli (1974) has analyzed columbites from rauhaugite II sampled west of Fens-gruvene. His analyses (see Table 4) show strong enrichment in Mn, Sc and Y. The two latter elements have not been found in significicant amounts in any columbites analyzed during the cource of the present study.

4b3 Fersmite. Fersmite is an orthorombig mineral with ideal formula XZ_2 (O, OH, F)$_6$ where X is represented by Ca, Ce, Na and Z by Nb, Ti, Fe, Al according to Phillips & Griffin (1981). Briefly speaking this means that fersmite is chemically related to columbite by exchanging Fe with Ca in the X-position. The charge effect of other substitutions is balanced by substitution of OH^- and F^- for O^{2-}.

The firm existence of this mineral in Norway has not yet been published. V. d. Veen (1960) suggests that the phase "intermediate between koppite and columbite" described by Sørum (1955) from Søve is actually fersmite. Mariano (1980) reports extensive zoning in pyrochlores from the Hydro Quarry by Søve. Some of these zone segments consists mostly of Ca and Nb (eg. figs 5b and 6b, Mariano, 1980), but by containing virtually no Na they are not resembling known Ca-pyrochlores from the Fen Complex. On the other hand these spectra seems identifical with the one presented in fig. 10b (from the Vipeto area), which is identified as a fersmite, although not "isostructural with pyrochlore" as claimed on p. 20 (Mariano 1980), but with columbite. However, as no analysis corresponding to these spectra are recorded in his tables, no stoechiometrics calculation can be carried out to control the identity.

In the Tuftehavna material fersmite is only registred in the biotite-apatite, there being the major Nb-oxide. The general node of occurance is described in Ch. 3 (C.f. Figs. 12,14 and 16). I will therefore turn directly to the chemical data available.

In Table 5 analysis of fersmites from five split cores from TH-1 are listed. The major elements are Ca, Nb and Ti whereas the mineral is generally low in Ta and REE. The F-contents are generally below detection limit, but still listed (in "( )") for the purpose of calculating of structural formulas, which are based on (6 oxygens ÷ F^-) in the unit cell. These calculations verify the dominance of Ca in X-position and Nb in Z-position in the structure.

The fersmites are earlier (in Ch. 3) shown to be extremely heterogeneous. This is generally not reflected in chemical data, which suggests that the heterogeneities are chemically closely related to the host. An example would be the suggested columbite inclusion, which specifically could account for the observed variations in Fe-contents.

4b4 Ta-mineral. An unidentified Ta-rich mineral is observed occationally in biotite- apatite-rock. It is usually euhedral, strongly zoned and "contaminated" by silicates (Fig. 13). Grainsize is usually less than 0.1 mm. The mineral appear to be isotropic, but optically heterogeneous: Partly translucent with light brown colour, partly metamictized. It has a greyish colour in reflected light.

Preliminary chemical data on the core, which are the most Ta-rich, give appx. 45 % Ta_2O_5, 25 % Nb_2O_5 and between 8 and 0.4 % of Ca, Ti, Al, U, Fe, Na and Mg -oxides listed in downward order, summing to 91.5 %.

4b5 Magnetite. The magnetites are not studied in any detail, and just qualitative data are obtained. These include the general observation of ilmenite exsolution lamellaes. Furthermore these seem to be a general feature that the magnetites from søvites are enriched in V. Tom Andersen (per.comm.) have obtained up to 1.15 % V_2O_3 by microprobe analysis. On the other hand magnetites from magnetite- biotite- apatite-rock are virtually free from vanadium.

4c Apatite chemistry

Microprobe analysis have been carried out on apatites from the major rock types within the area. In addition on the routine energy-despersionbased

						Analysis							
Sample	Point	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	Nb_2O_5	Ta_2O_5	Ce_2O_3	UO_3	F^-	Σ
TH-1 7.9	1	2.5	n.a.	tr	tr	n.a	17.0	n.a	78.2	.4	n.a	tr	n.a	99.1
	2	2.2	n.a	tr	0	n.a	18.0	n.a	78.2	1.5	n.a	tr	n.a	99.7
	3	3.0	n.a	0	0	n.a	15.0	n.a	75.1	tr	n.a	.7	n.a	94.0
	8	3.9	n.a	0	0	n.a	16.0	n.a	75.7	tr	n.a	..6	n.a	96.6
TH-1 3.95	1.4	3.3	0	tr	0	0	17.2	tr	78.3	.4	0	0	(2.6)	98.3
	1.5	3.7	0	0	tr	tr	17.0	0	79.7	0	0	0	(1.4)	100.4
	1.6	2.0	tr	tr	0	0	17.8	0	77.4	.5	0	0	(2.1)	98.6
	1.8	1.0	0	0	0	tr	16.6	tr	78.5	.5	tr	0	(1.0)	97.7
	1.9	7.4	0	1.3	tr	0	16.2	0	74.5	.3	tr	0	(1.2)	99.7
	1.10	2.7	0	0	0	tr	17.0	0	78.6	.6	tr	0	(.9)	98.9
	1.11	2.5	0	.5	0	0	17.1	0	78.0	.8	0	0	(.6)	99.7
	1.13	3.7	0	tr	0	0	16.5	0	76.5	.5	1.0	0	(.8)	98.0
	1.14	2.2	tr	0	0	tr	17.6	tr	76.3	tr	1.0	0	0	97.1
	1.15	3.3	tr	.5	0	tr	17.4	0	77.6	.9	tr	tr	(2.0)	99.7
	1.16	2.3	.2	.4	0	tr	17.2	0	80.4	tr	0	0	(1.0)	100.5
	1.17	2.3	0	tr	0	0	17.3	0	80.5	tr	0	0	0	100.1
	3.2	3.4	.2	tr	0	.3	17.4	tr	76.1	1.0	1.1	0	(1.1)	99.5
	3.3	3.2	0	tr	tr	0	17.6	0	78.6	tr	0	0	0	99.6
	3/4	4.1	tr	.6	tr	0	20.1	0	70.4	1.1	.8	0	(.5)	97.1
	6	2.2	.5	0	tr	.8	16.6	0	77.2	1.3	tr	0	(1.3)	98.9
TH-1 4.40	1.2	1.0	0	1.6	0	tr	15.5	tr	78.0	3.9	.9	0	4.2	99.5
	1.3	2.0	.3	1.9	0	.2	15.5	tr	74.0	3.7	tr	0	4.1	98.5
TH-1 6.25	1.1	9.0	0	0	0	0	15.9	0	72.0	.5	0	0	3.0	99.1
	1.2	2.4	0	tr	tr	tr	17.2	.3	78.2	.5	0	0	0	98.6
	1.3	2.7	0	0	tr	0	17.4	tr	79.1	.7	0	0	(1.0)	99.9
	1.6	3.0	0	tr	0	0	17.3	tr	75.3	.4	0	0	(.5)	96.0
	1.7	2.4	0	.5	0	0	17.3	tr	77.6	.6	0	tr	(1.9)	98.4
TH-1 9.60	1.1	2.3	0	0	0	tr	17.7	0	78.4	tr	tr	0	(.3)	97.4
	1.2	2.2	.4	8.1	0	.5	12.0	tr	73.7	1.3	tr	0	3.1	96.6
	1.4	2.3	1.0	1.1	tr	1.7	10.0	tr	72.5	4.3	1.4	0	(2.0)	98.2
	1.5	3.2	.5	1.7	0	.7	16.1	0	75.9	1.6	.9	0	0	99.6
	1.7	4.4	.2	.8	0	tr	16.4	tr	72.4	1.5	.9	0	0.0	95.6
	1.8	3.4	.2	1.5	0	.5	16.4	tr	73.7	.6	0	0	(.4)	96.5
	1.10	2.7	0	tr	0	0	16.1	0	78.9	0	tr	0	2.2	98.7

Table 5. Microprobe analysis of fersmites from biotite- apatite rocks, TH-1 Tufteshavna.

Analysers: Sample 7.90 m: Ragnar Hagen, A/S Sydvaranger
Others : E.G.

						Structural formula.						
Sample	Point	Ti	Al	Fe	Mn	Mg	Ca	Na	Nb	Ta	Ce	U	F
TH-1 3.95	1.4	.10					1.04		1.88	.01			.46
	1.5	.15					.97		1.82				.27
	1.6	.12					1.05		1.93	.01			.36
	1.8	.07					..98		1.95	.01			.17
	1.9	.30		.06			.92		1.70	.01			.20
	1.10	.11					.98		1.93	.01			.15
	1.11	.10		.02			.99		1.91	.01			.10
	1.13	.15					.96		1.86	.01	.04		.14
	1.14	.08					1.03		1.89		.02		-
	1.15	.14		.02			1.01		1.91	.01			.34
	1.16	.08	.01	.02			1.02		1.96				.30
	1.17	.08					.98		1.93				.02
	3.2	.14	.01			.02	1.01		1.87	.01	.02		.19
	3.3	.13					1.01		1.87				
	3/4	.17		.03			1.19		1.76	.02	.02		.09
	6	.09	.03			.06	.97		1.90	.02			.23
TH-1 4.40	1.2	.08		.08			.96		1.99	.07	.02		.70
	1.3	.12	.02	.09		.02	.96		1.93	.06			.74
TH-1 6.25	1.1	.37		.04			.93		1.80	.01			.52
	1.2	.10					.98		1.90				-
	1.3	.11					1.01		1.94	.01			.30
	1.6	.12					1.03		1.89	.01			.09
	1.7	.10		.02			1.04		1.95	.01			.34
TH-1 9.60	1.1	.12					1.03		1.88				.06
	1.2	.14	.02	.25		.04	.76		1.94	.01			.57
	1.4	.10	.07	.06		.14	.89		1.83	.08	.03		.36
	1.5	.08	.03	.06		.06	.88		1.88	.02	.03		-
	1.7	.10	.01	.04			.93		1.83	.02	.02		.14
	1.8	.14	.01	.07		.03	.96		1.04	.01			.07
	1.10	.15					1.08		1.93				.36

full analysis, more careful individual analysis are carried out for Mg, Cl and F^- to fix these constituents' variations relative to specific industrial wants.

As is shown in Table 6, the variations are generally small. Charachteristic are:

CaO: 54-56 wt %
Na_2O: 0.2-0.4 wt %
P_2O_5: 40.3-41.3 wt %
F^- : 2.5-4.0 wt %
Cl^- : 0.04-0.12 wt % (Av. 0.07 %) and
MgO 0.10 wt %

Contents of SiO_2, Al_2O_3, FeO, Ce_2O_3 and La_2O_3 are low and irregular. The only traces of chemical zoning are exhibited by Cl which is significantly enriched along grain boundaries (cf. TH-1, 9.60 m 1C vz. 1D, Table 6). Whether this is a general phenomenon or is restricted to certain rocktypes, samples or structural features is not yet ascertained.

The calculated structural formulaes indicate a deficiency in the P-position suggesting a significant substitution of C (in the form of $(CO_3OH)^{3-}$?) for PO_4^{3-}. Taking this, as well as the substitutions of OH^- for F^- and Cl^-, into account the probable full composition of the analyzed apatites may be expressed as

$$(Ca_{4.90-4.98}Al_{0-0.02}\,Mg_{0-0.01}Na_{0.02-0.07})\,(P_{2.84-2.92}Si_{0-0.4}$$

$$S_{0-0.01}C_{0.05-0.16})\,O_{12}\,(F_{0.70-1.00}Cl_{0-0.2}OH_{0-0.28})$$

The indicated content of C is comparable to CO_2-contents between 0.4 and 1.4 wt %. This parameter, if confirmed by later direct analysis, seem to be the most critical when considering the Fen apatites as possible source of industrial production of fertilizers. The other quality requirements outlined by Lenning (1982) are met with as far as the apatite itself is concerned. Complications arising from impurities in a concentrate are outside the scope of the discussions in this chapter.

SAMPLE	No POINT	REF	METHOD	ROCK TYPE	SiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	P_2O_5	Y_2O_3	Ce_2O_3	La_2O_3	SO_4^{2-}	F^-	Cl^-	O=[1)]	SUM
									ANALYSIS										
TH-1 3.95 m	1	25/5	EDX	Bi ap-rock	na	0	0	0	54.5	,2	39,8	na	tr	na	na	tr(2.4)	na	,9	96,0
	1	14/7	"	"	,3	tr	0	tr	55.0	,3	40,7	0	tr	0	,2	3.0	0	1,4	97,8
		"	spectr	"				0								3.5	,04	1,6	98,1
	2	25/5	EDX	"	na	,2	0	,2	54.6	,3	40,4	na	0	na	na	tr(1.8)	na	,8	96,7
	2	14/7	"	"	,3	,2	0	tr	55,4	,2	41,3	tr	tr	0	tr	tr(2.6)	0	1,1	98,9
		"	spectr	"				0								3.3	,05	1,4	99,4
	4	25/5	EDX	"	na	,2	tr	tr	na	tr	41,0	na	tr	na	na	tr(1,9)	na	,8	98,0
TH-1 8,35 m	1	25/5	"	Bi ap-rock	na	0	0	tr	55,9	,2	40,9	na	0	na	na	tr(2.4)	na	1,8	98,4
		15/7	spectr	"				0								3.5	,05	1,5	99,1
	2	"	EDX	"	tr	tr	0	tr	55,0	,4	40,8	0	tr	tr	tr	4.3	0	1,8	98,3
		"	spectr	"				0								4.2	,05	1,8	98,3
TH-1 9,60 m	1A	14/7	EDX	Bi ap-rock	,3	tr	0	0	56,4	,3	40,9	0	0	0	,3	0	,12	,1	98,2
		"	spectr	"				0								4.0	,12	1,8	100,5
	1B	"	EDX	"	tr	0	0	0	55,9	,2	41,3	0	tr	tr	tr	2.8	0	1,2	99,0
		"	spectr	"				0								2.8	,08	1,2	99,1
	1C	"	EDX	"	,4	0	0	0	56,4	,4	42,0	0	tr	tr	tr	tr(2,0)	0	,8	100,2
		"	spectr	"				0								3.0	,11	1,3	100,8
	1D	"	EDX	"	tr	0	0	tr	55,9	,4	41,7	0	tr	0	tr	tr(1,8)	0	,8	99,0
		"	spectr	"				0								3.4	,08	1,4	100,1
	3	25/5	EDX	"	na	0	0	,3	55,7	,4	41,0	na	tr	na	na	0(,9)	na	,4	97,9
TH-1 4,40 m	1	25/5	EDX	søvite	na	tr	0	0	56,1	,3	40,8	na	0	na	na	tr(1,4)	na	,6	98,0
	1	14/7	"		,2	0	0	0	54,8	,3	40,3	0	0	0	tr	tr(2,3)	0	,9	96,9
		"	spectr	"				0								3.3	,07	1,4	97,6
TH-3 12,70 m	1	15/7	EDX	Mgt-bi-ap-rock	,5	0	tr	,2	54,3	,2	40,4	0	0	0	tr	tr(2,3)	0	1,0	96,9
		"	spectr	"				0								3.0	,06	1,3	97,4
	2	"	EDX	"	tr	tr	tr	,2	54,0	tr	40,1	tr	0	0	tr	tr(,9)	0	,4	94,8
			spectr	"				0								2.9	,05	1,2	96,1
	3	"	EDX	"	,3	,2	0	tr	55,0	tr	40,8	0	tr	0	,4	tr(1,7)	0	,8	97,6
		"	spectr	"				0								3.0	,05	1,4	98,4
TH-3 38,25	1	"	EDX	Ap-vein	tr	0	,4	,3	54,4	,4	40,6	0	0	0	tr	2.6	0	1,1	97,6
		"	spectr	"				0								2.6	,08	1,1	97,7
	2+3	"	EDX	"	,3	0	0	0	54,3	,2	40,4	0	tr	0	,3	3,6	tr	1,6	97,5
		"	spectr	"				0								3,4	,11	1,5	97,5

Table 6. Microprobe analysis of apatite from Tuftehavna, Fen. EDX= Energy-dispersive measurements; Spectr.: "Wave-length-despersive" measurements made on separate manual spectrometers, tr= traces; na= not analyzed; O= (F^-+Cl^-+SO_4^{2-}).

Table 6 contd.

Structural formula, based on 25 O+2(OH, F, Cl)

			Si	Al	Fe	Mg	Ca	Na	P	Y	Ce	La	S	F	Cl
TH-1	3,95	1					9,93	,07	5,77					1,22	
		1					9,86	,13	5,78				0,02	1,59	
														1,86	,01
		2		,02		,03	9,86	,09	5,76					,98	
		2	,05	,03			9,92	,08	5,85					1,37	
														1,74	,01
		4					9,93	,07	5,78					1,01	
TH-1	8,35	1					9,92	,08	5,73					1,26	
														1,83	,01
		2					9,87	,13	5,77					2,27	
														2,22	,01
TH-1	9,60	1A	,05				9,89	,11	5,67				,08	-	,04
														1,46	,04
		1B					9,92	,08	5,80					1,50	
														1,50	,02
		1C	,07				9,88	,12	5,81					1,05	
														1,59	,03
		1D					9,87	,13	5,81					,96	
														1,81	,02
		3				,07	9,81	,12	5,70					,44	
TH-1	4,40	1					9,92	,08	5,72					,53	
		1	,03				9,92	,08	5,73					1,20	
														1,80	,02
TH-3	12,70	1	,08			,05	9,89	,06	5,82					1,22	
														1,59	,02
		2					9,94	,06	5,83					,51	
														1,64	,02
		3	,05	,04			9,96		5,84				,02	,92	
														1,62	,01
TH-3	38,25	1				,06	9,75	,13	5,75					1,39	
														1,39	,03
		2/3				,07	9,93	,07	5,82				,03	1,96	
														1,85	,03

4d Silicates

The silicates occuring in rocks from the Tuftehavna area have not received the attention deserved. For petrogenetic and metallogenetic purposes, the intention was originally to "map" the chemical variations for the most widely distributed silicates and correlate such data with those of related phases, oxides, carbonates, phosphates and sulfides. This program is not fulfilled, and the sole data presented here are on biotites from the lamprophyric rocks: biotite-apatite rocks and magnetite- biotite- apatite rocks.

The biotite-phenochryst of these rocks are zoned, often cyclically. The zoning pattern in biotites from biotite- apatite-rocks are described in Ch. 3. The underlying data (Table 7) show that they are magnesian (Mg/Fe-ratios are between 6 and 9) although not as magnesian as the one analysis from a søvite (pers.comm. S. Olmore). Qualitative data on biotites from a magnetite-biotite- apatite- rock show a similar Mg-rich core, but a much stronger Fe-enrichment towards the deep brown rim.

All listed biotites are charachteristically low in Ti, contrary to the biotites from damtjernites reported by Griffin & Taylor (1975) with 3-6 wt % TiO_2.

Routine fluorine-analysis would normally be of limited value in a Fe-rich phase, because of the overlap between the employed F K-lines and Fe L-lines. However, the expected proportionality between apparent F and Fe detections have not shown up. From Fig. 11 it can be seen that the two parameters are partly inverse proportional suggesting that for some reason these F-values are conditionally reliable.

Sample		Point		SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	F^-	Σ
TH-1	3.95	1 A	core	40.2	0.3	11.5	4.4	tr	25.3	0	.3	10.2	2.4	94.6
TH-1	3.95	1 B		40.7	0.5	10.8	6.0	0	24.6	0	tr	10.4	3.9	96.9
TH-1	3.95	1 C	rim	40.7	0.6	11.7	6.6	0	23.4	tr	.3	11.0	5.4	99.7
TH-1	8.35	1 A	core	40.3	0.5	12.5	4.9	tr	25.0	0	.5	10.2	3.0	96.9
TH-1	8.35	1 B		40.3	0.5	12.8	4.7	0	25.2	0	.4	10.3	3.4	97.6
TH-1	8.35	1 C		41.2	0.6	11.5	7.5	tr	23.0	0	0	10.8	3.5	98.1
TH-1	8.35	1 D		41.4	0.4	11.8	5.5	0	25.4	0	0	11.0	5.2	100.7
TH-1	8.35	1 E		41.7	0.8	11.3	7.0	0	23.3	0	0	10.4	4.0	98.5
TH-1	8.35	1 F	rim	42.5	0.5	11.8	6.8	tr	23.9	tr	tr	10.7	4.7	100.9
TH-1	8.35	1 G	core	40.0	0.5	12.5	4.9	tr	25.3	0	.4	9.9	5.0	98.5
TH-1	8.35	1 H		40.5	0.5	11.6	6.6	0	23.8	0	tr	10.6	5.0	98.6
TH-1	8.35	1 I	rim	41.9	0.5	12.2	6.0	0	24.0	0	tr	10.7	3.8	99.1
TH-1	9.60	1 A		40.8	0.3	10.5	5.9	0	24.8	0	0	10.6	4.2	97.1
F-0014				41.33	.27	11.15	2.7	n.a	27.86	1.33	n.a	9.93	1.94	99.92

Table 7. Microprobe analysis of biotites from biotite- apatite rock from Tuftehavna (TH-1 -samples analyst H.Q.), and from Søvite (?) from the Hydro Quarry (F-0014, analyst A.I. Gunow, Colorado).

Sums include F^- but are not adjusted for $F^- \equiv O^{2-}$.

Sums of sample F-0014 also includes calculated H_2O^+ = 3.72 % (by Gunow, pers. comm. Olmore).

5. CHEMISTRY.

A general chemical assay program for selected elements has been carried out on the split drill cores. The complete TH-1 has been analyzed for Nb, Y, Th, Ce and Ta by Sentralinstitutt for industriell forskning (SI) and on selected segments for P by either SI or Institutt for energiteknikk (IFE). The cores of TH-3 through TH-12 are analyzed partly or completely for Nb, Ta, U and P by IFE.

The chemical data are earlier presented by Hultin (1982). As they are obtained from two different laboratories knowledge of the correlation between the two as well as the accuracy of the data is essential.
For this purpose the upper ten meters (2.35 - 12.0 m) of TH-1 have been reanalyzed by Louviers' Laboratories, Colorado, USA (Olmore 1982) and by IFE for some of the elements discussed in the present report: Loviers, Nb & Ta; IFE: Nb, Ta and U. No countercheck is made on P.
The results are listed in Table 8. These show that there exist rather essential divergences between the values from the different laboratories. However, for most of the elements these divergences seem to be of a systematic character. E.g. for Nb and U IFE's analysis are always significantly lower than the two other laboratories, whereas their Ta-values generally are higher. Louviers' are low in Y and high in Ce relative to SI (these elements are not analysed by IFE). The correlation between Th-values from Louviers' and SI is better. This suggests that the major problem is one of calibration.

No further control of analytical results or interlaboratory correlation has been carried out. With basis in petrographic observations I do however, regard the given results as being of reasonable quality, thereby taking into account analytical problems related to the elements involved, the "unusual" bulk chemistry and the methods employed.

Table 8

Depth (m)	Lab.	Nb_2O_5	Ta_2O_5	Y_2O_3	ThO_2	CeO_2	U_3O_8
2.35 - 3	SI	6.15	.062	.014	.024	.18	.032
	Louviers	6.93	.054	.008	.018	.230	.18
	IFE	5.0	.107				.022
3 - 4	SI	3.86	.028	.015	.012	.14	.025
	Louviers	2.95	.024	.009	.010	.213	.13
	IFE	2.6	.038				.017
4 - 5	SI	4.00	.032	.010		.10	.017
	Louviers	3.07	.021	.006	.006	.135	.005
	IFE	2.8	.037				.008
5 - 6	SI	3.43	.010	.011		.11	.008
	Louviers	2.92	.012	.007	.006	.197	.005
	IFE	2.2	.013				< .006
6 - 7	SI	5.43	.039	.011	.006	.14	.024
	Louviers	5.61	.038	.007	.012	.141	.011
	IFE	4.4	.057				.015
7 - 8	SI	4.43	.033	.011		.14	.018
	Louviers	3.82	.022	.006	.005	.177	.008
	IFE						
8 - 9	SI	6.29	.053	.010	.030	.16	.032
	Louviers	7.96	.057	.009	.038	.223	.016
	IFE	5.3	.069				.021
9 - 10	SI	4.72	.049	.017	.038	.16	.032
	Louviers	4.67	.041	.007	.032	.204	.017
	IFE	3.3	.063				.021
10 - 11	SI	2.00	.049	.015	.051	.09	.026
	Louviers	1.47	.034	.009	.047	.146	.014
	IFE	1.3	.050				.017
11 - 12	SI	1.43	.027	.016	.027	.12	.020
	Louviers						
	IFE	.7	.024				.011

Table 8. Chemical analysis of samples from TH-1, 2.35 - 12.0 m by three independant laboratories.

SI: Sentralinstitutt for industriell forskning (XRF).

5a Correlations of main oxides

Plate 5 - 8 present the results for Nb_2O_5, Ta_2O_5, P_2O_5 and U_3O_3 respectively. These plates are transparent overlays designed to fit directly onto each other, the lithological drill-logs (Plate 2), or the geophysical core date (Plate 9 and 10), thereby making the conditions favourable for the reader to make her/his own conclusions. I will therefore confirm the discussion to make some comments on the illustrations and the relations between them.

Plate 5. Nb_2O_5 show major enrichments through the lamprophyric rocks, mainly biotite-apatite rocks, but also related to magnetite-rich varieties, as in TH-4 and TH-12. The large volumes of Nb-enrichment are represented by biotite-calcite fels and fenitic rocks in TH-1. However, this enrichment is not strong enough to be of economical interest.

The major Nb-depletion is shown by the søvites containing blue amphibole.

Plate 6. Ta_2O_5 is enriched in the biotite- apatite- rocks and to some extent in rauhaugite I and apatite-rich søvites. The enrichment related to fenitic rocks etc. is not as pronounced as for Nb. E.g. in TH-1, there is some Ta-rich zones between 125 and 165 m partly related to biotite-calcite fels, but the Ta-content decreases further downwards.

Plate 7. P_2O_5 is of course reflecting the apatite contents in the rocks and are therefore enriched in søvites, lamprophyric rocks and other "late segregations" and apatite veinlets. Relative low P-contents is found in rauhaugites and fenitic rocks.

Plate 8. The higher U_3O_8-contents are found well distributed between the different rock types. On the other hand moderate enrichment is specifically related to biotite- apatite rocks, whereas the other major rocktypes do not show any distinct pattern in this respect.

5b Chemical correlation.

The correlation between Nb (Plate 5) and Ta (Plate 6) is very good and generally independant of rock type. The correlation with P (Plate 7) is also good, althrough the latter element show a much wider distribution of enrichment, especially in søvite rocks. Correlation with U (Plate 8) is not so well pronounced, with a wide range of rock types contributing to the higher values.

The correlation between Ta and P is generally good. Most sections enriched in Ta are also enriched in P, but the opposite is not always the case, e.g. in apatite veins in TH-7, ad in the blue amphibole- magnetite- apatite segregations. The correlation between Ta and U is very good and generally independant of rocktypes.

The correlation between P and U is not very good, illustrating the lack of enrichment of U in apatite-rich rocks.

6. GEOPHYSICAL SURVEY.

A careful review of the geophysical survey in Tuftehavna and adjacent areas is given by Carstens (1982). I will therefore here just add some comments to the possible correlations between lithologies and geophysical parameter, as measured on the drill cores. I will also include an evaluation of gravimetry as a possible tool for detecting mineralized lamprophyres within the Fen Complex.

6a Magnetic Susceptibility

When measured directly on undisturbed drill cores, magnetic susceptibility give a (semi-) quantitative measure for the content of ferromagnetic minerals, i.e. here mostly magnetite.
Plate 9 presents the results of these measurements from Tuftehavna cores.

It should be noted at this stage that the data used in this presentation are obtained by several workers, utilizing not exactly the same techniques. However, the general approach has been to make a member of measurements (usually three) over a distance of 1 m and average to obtained values before plotting. Still there may be inhomogeneities "escaping" measurements resulting in inconsistencies like the one demonstrated by TH-12, 127.5 m: an occurrence of magnetite - blue amphibole - apatite segregations, but no magnetite detected !

From Plate 9 it is seen that the søvites have a highly variable magnetite content. Among the enriched varieties are blue amphibole bearing. The biotite-apatite rock has no magnetite at all (e.g. see top of TH-1), as is also the case with most fenites and biotite- calcite fels (lower part of TH-1) and the rauhaugites.

6b Gamma-ray measurements

The γ -ray measurements are plottet in Plate 10. Large values show uniform low or intermediate values. The anomalous high values are confined mostly to occurences of apatite rich søvites, biotite- apatite rocks, magnetite-blue amphibole apatite segregations and rauhaugite II.

6c Geophysical comparison

As expected the correlation between γ -ray measurements and magnetic susceptibility is not very good. For the major Nb-enrichments represented by biotite- apatite rocks the correlation is negative. The highest correlation is exhibited by the magnetite-bearing segregation, og which some are also Nb-enriched. (TH-4, 16.5 m and TH-12, 45.5 m).

There is no indication that søvites adjacent to strongly mineralized biotite-apatite rocks are low in magnetite. Rather on the contrary, these mineralisations show a definite affinity for the blue amphibole (and often magnetite-rich) søvites, as is also indicated on Plate 1, the geological map.

6d Geophysical-geochemical correlation

Low magnetic susceptibility and high γ -ray detections are the undisputed guides to strongly mineralized biotite-apatite rock. Lower grade mineralized rocks of this type, do also emit less intense γ-radiation (TH-5 and TH-7). On the other hand the mineralizations magnetite- blue amphibole biotite rock may also be of economic importance.

Relatively good correlation is shown between γ-ray intensity and P-contents (Plate 7), possibly relating the γ -rays to the amount of apatite present.

The last relation to be mentioned here, is the one between γ -ray intensities and U (Plate 8). The correlation is relatively good, suggesting that U are contributing strongly to the total γ -radiation from the rocks.

6e Gravimetric studies

The gravity anomalies across the Fen Complex are known from the work of Ramberg (1964, 1973). The regional gravity high suggest a dominance at depth of denser rock types, like damtjernite or vipetoite whereas the higher carbonates dominates at surface level.

The "pure" varieties of the major rock types exhibit distinct density contrasts. Due to extensive compositional overlap these contrasts are in variable degree reduced, but should still be sufficient for detecting a 3-dimentional distributional pattern.

6e1 Density data on the major rock types at Tuftehavna. For this purpose density data on important rock types appearing locally at Tuftehavna as well as on major rock types occuring regionally within the Fen Complex are compiled in Table 9, together with their compositional charachteristics.

The anticipated densities are calculated on the basis of rough petrographic data, variations in modal composition and reference data on mineral densities. (Phillips & Griffen 1981, Deer, Howie & Zussmann 1963).

Despite the obvious uncertainties involved in these data, they clearly indicate that the apatite, magnetite and/or Nb-rich rock-types are among the densest occuring in the Fen Complex and the densest within the restricted area.

A series of measurements carried out at the Mineralogical-geological museum on split core segments from Drillholes 1 and 3 give densities between 3.06 and 3.21 g/cm^3 (Table 10) on lamprophyric rocks. The intension is that this sampling should cover a reasonable large range of textural and compositional variations exhibited by this rock type. However, none of the samples contained substantial amounts of magnetite, which will increase the densities.

This tentative survey suggests that detailed gravity studies do certainly represent an attractive exploration method for localizing new Nb-mineralization.

Table 9

	Rock type	Major phases (falling order of importance)	Aniticipated density range	Data from Ramberg 1973 Mean density	Density range
Tuftehavna	Søvite	Cc-bi-blue amph-mgt-ap		2.80	2.73-2.90
	Magnetite-segregation (Mgt>50%)	Mgt-blue amph-ap-bi-Cc	4.0-5.2		
	Blue amph (b.a.>50%)	Blue amph-mgt-ap-bi-Cc	3.0-3.5		
	Biotite-apatite rock	Bi-ap-Nb-oxides +/-mgt	2.87-3.16 Measured: 3.06-3.21		
	Rauhaugite I	Ank-dol-Cc-ap-Cb		2.91	2.81-2.99
	Rauhaugite II	Ank-dol-Cc-chl			
	Apatite	Ap-dol	2.86-3.2		
	Rødberg	Cc-hm		2.95	2.86-3.06
	Biotite-calcite fels) Holla te/Kåsenite etc.	Bi-Cc-px-chl-ap-ab- -blue amph-sph		2.88	2.83-2.96
Regional	Fenite	Alk.fsp.-px-amph-ap-sph-zr-py		2.71	2.68-2.77
	Damkjernite	Bi-amph-px-ol		3.08	3.05-3.09
	Damkjernite breccia	" + country rock		2.94	2.78-3.12
	Vipetoite	Px-amph-vi		3.11	2.92-3.26
	Melteigite	Px-Ne		3.13	3.02-3.18
	Ijolite	Px-Ne		2.92	2.80-2.99
	Urtite	Ne-px-bi		2.64	-
	Tinguaite	Alk.fsp.-Ne-px		2.78	2.76-2.84

Drillhole no.	m	Density g/cm^3
1	3,95	3,17
	6,75	3,06
	8,35	3,12
	9,60	3,15
	9,70	3,12
	11,15	2,99
3	34,15	3,21
	35,80	3,08

Table 10 Density determinations on split core segments of lamprophyric rocks from Tuftehavna. Drillhole no. 1; 11.15 m is impure, by containing appx. 50% søvite.

7. METALLOGENETIC CONSIDERATIONS

The rock types occuring in the Tuftehavna area represent a sequence of magnetic and metasomatic events, more or less well-defined and separated. Most of these events are related to different types of Nb-mineralizations, as described in preceding chapters. No thorough account on the metallogeny of all these types can be given at present. I will instead just sum up the vain characteristic for the type of mineralization which have attrachted most attention during the last period of exploration in Tuftehavna: the lamprophyric biotite- apatite rocks.

The biotite- apatite rocks are strongly related to the søvites. Partly they occur interlayered, partly the biotite- apatite rock crosscut the søvite there by postdating it. All the major phases, probably also including the ore minerals found in the biotite- apatite rock do also appear in mineralized søvites. These include biotite, apatite, pyrochlore, columbite and probably also fersmite.

The rauhaugites on the other hand are, whenever the relations can be observed, later than the biotite- apatite rocks, and exhibit quite a different mineral paragenesis: They are generally low in apatite and biotite, and the predominant Nb-mineral is columbite.

It is therefore concluded that the biotite- apatite rocks are genetically related to the søvites, in which they are emplaced. It is suggested that they represent late magmatic differentiates from the søvitic magma, and that they have suffered from syn to post magmatic mobilization leading to the commonly observered crosscutting relationship.

The Nb-minerals are regarded as generall having a primary origin. The pyrochlores occur as perfect euhedral crystal, showing no textural or chemical sign of pseudomorphism. The primary origin of the fersmite is for internal textural reasons somewhat obscure. It is here referred to the numerous partly unidentified phases included or intergrown with the fersmite. However, the crystal forms, as well as the coexistence with unaltered pyrochlore exclude the possibility of pseudomorphism from pyrochlore. Pseudomorphism from columbite is also regarded as hardly probable, with reference to the considerable amount of Fe which then would have had to be moved away from the system considered. It is therefore concluded that the included minerals either are primary inclusions or exsolved postmagmatically from the primary fersmite.

8. RECOMMANDATION

In the Tuftehavna area we have had the possibility to study the only known occurence within the Fen Complex of strongly mineralized lamprophyric rocks. Consequently there is not the faintest statistical reason to suggest that this is a typical occurence of these important rocktypes. With this strong reservation in mind, the Tuftehavna story points towards søvitic domains. The distance to enclosing country rock is small, but that is probably not diagnostic as the distance would never be very large in this wedge-shoped part of the søvite body (see key map, Plate 1). Magnetic properties are diognostic, as magnetite is either lacking completely or very abundant in the mineralized rock types. γ -radiation may be diagnostic in søvitic terrains where the lamprophyres would be among the most radioactive, comparable with rødberg and massive rauhaugites. Specific gravity is diagnostic separating mineralized lamprophyres from fenites, søvite and rauhaugites, but not from rødberg or not-mineralized lamprophyres like the damkjernites.

My recommendation would therefore be to concentrate the efforts to søvitic bodies, which exhibit high γ -radiation, magnetic high or low, and gravity high.

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Fig. 11 Biotite in biotite- apatite rock.

a. Modified from Fig. 3A, Olmore 1982. Biotite phenocrysts from TH-1, 8.35 m. Horiz. width 3 mm, parallel nicols.

b. Semicontinous profiles, A-F and G-I, through the two adjacent phenochrysts. Analysis are recalculated to 100 % on volatile-free basis. For F^- the original values are used. Full analysis are listed in Table 7.

Fig. 12 Fersmite (black) and pyrochlore (translucent, euhedral) in biotite-apatite rock. TH-1, 3.95 m. Horiz. width 0.54 mm. Parallel nicols.

Fig. 13 Euhedral Ta-mineral included in biotite in biotite- apatite rock. TH-1, 3.95 m. Reflected light, parallel nicols. Horiz. width o.54 mm.

Fig. 14 Radial aggregates of fersmite needles in biotite- apatite rock. TH-1, 3.95 m. Horiz. width 0.36 mm.

a. Reflected light, parallel nicols.
b. Transmitted light, parallel nicols.

Fig. 15 Octahedral zoned pyrochlore crystals in apatite in biotite- apatite-rock. TH-1, 3.95 m.
Parallel nicols, oil immersion. Horiz width 0.06 mm.

a. Transmitted light.
b. Reflected light.

Fig. 16 Fersmite in biotite- apatite rock.

a. Inhomogeneous dark brown to black colour.
TH-1, 3.95 m.
Transmitted light, parallel nicols.
Horiz width 0.18 mm.

b. Included high-reflectivity (relatively) phases in fersmite.
One of these are probably columbite (see text for discussion).
TH-1, 3.95 m.
Reflected light, parallel nicols, oil immersion.
Horiz. width 0.06 mm.

Fig. 17 Segragations of magnetite, blue amphibole and finegrained interstitial apatite.
TH-3, 88.80 m.

Fig. 18 Rauhaugite I

a. Cutting foliated søvite.
TH-8, 7.40 m.

b. With xenoliths of biotite- calcite fels.
TH-8, 108.25 m.

Fig. 11 Biotite in biotite- apatite rock.

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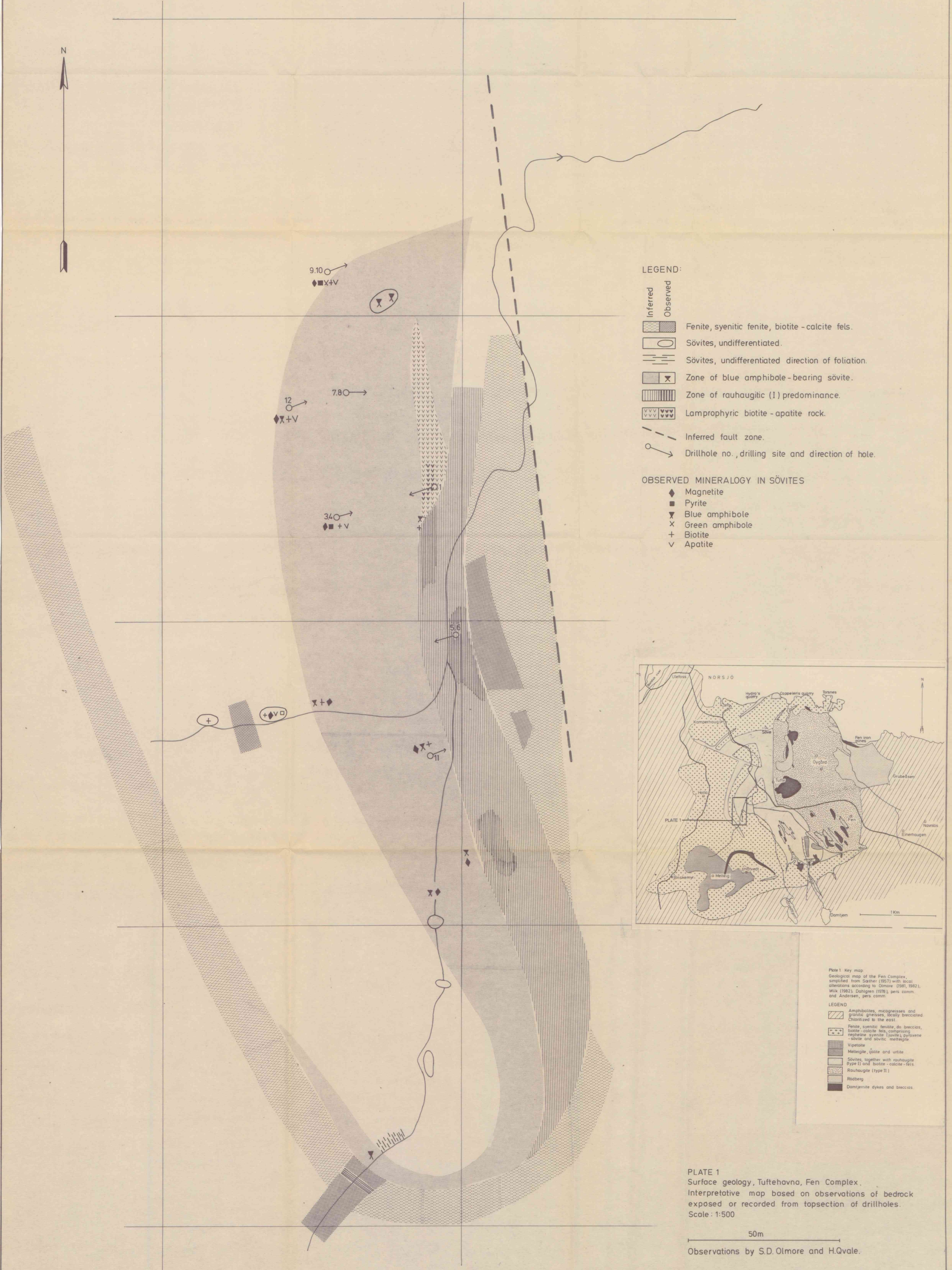
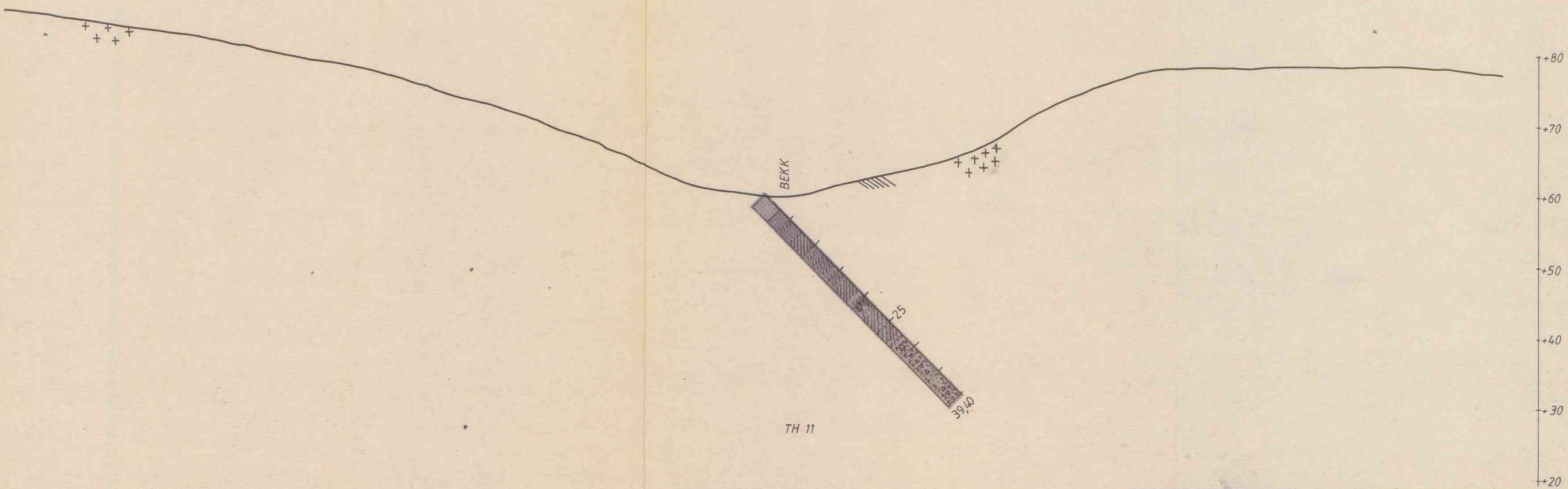


PLATE 1
Surface geology, Tuftehovna, Fen Complex.
Interpretative map based on observations of bedrock exposed or recorded from topsection of drillholes.
Scale: 1:500

50m

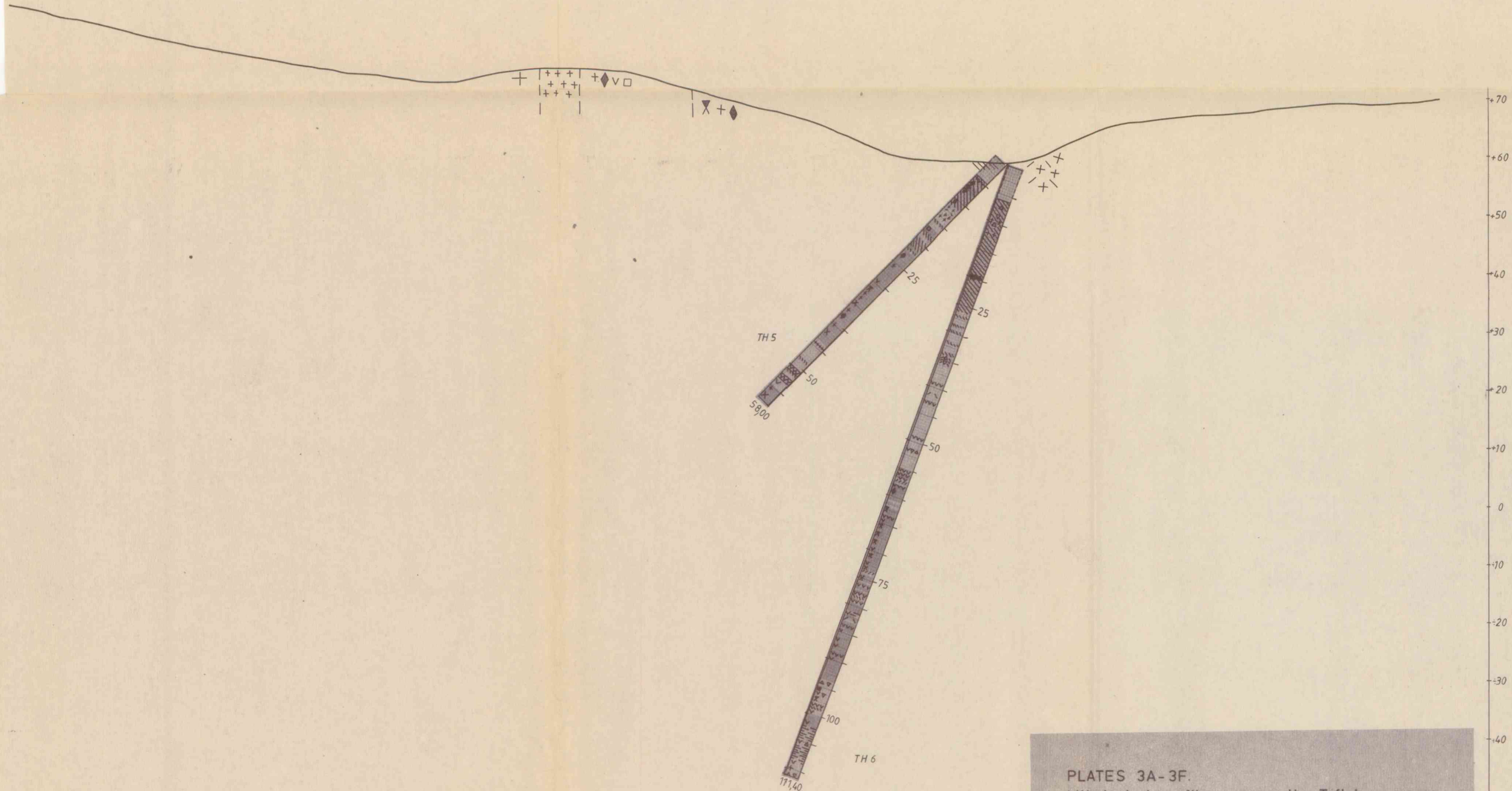
Observations by S.D. Olmore and H.Qvale.

H.Q. 1982



PLATES 3A-3F.
Lithological profiles across the Tuftehavna area, Fen Complex.
Compiled from plates 1and 2.
Scale 1:500
Legend as for Plate 2.

H.Q 1982

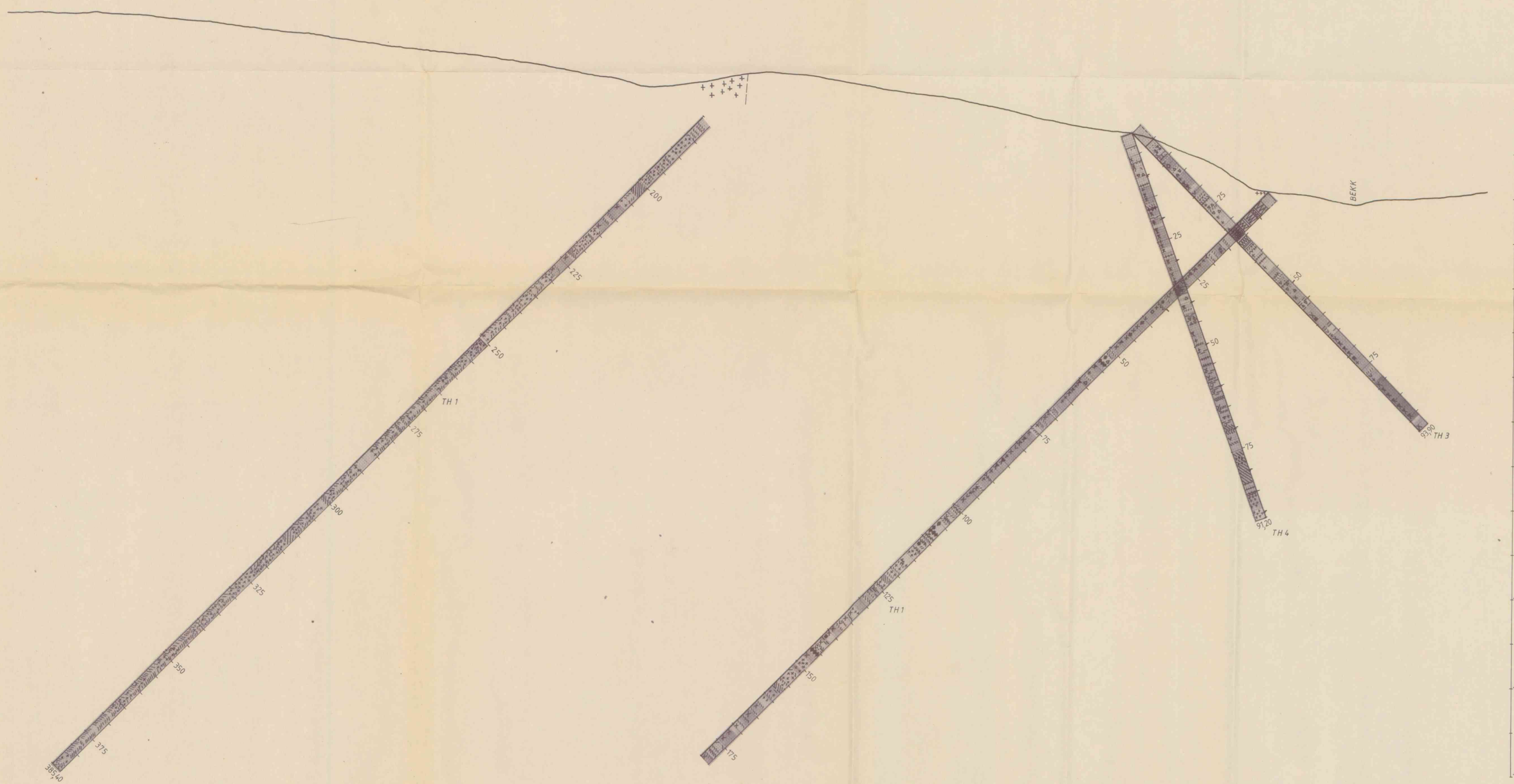


PLATES 3A-3F.
Lithological profiles across the Tuftehavna area, Fen Complex.
Compiled from plates 1and 2.
Scale 1:500
Legend as for Plate 2.

3B

H.Q 1982

3C



PLATES 3A-3F.
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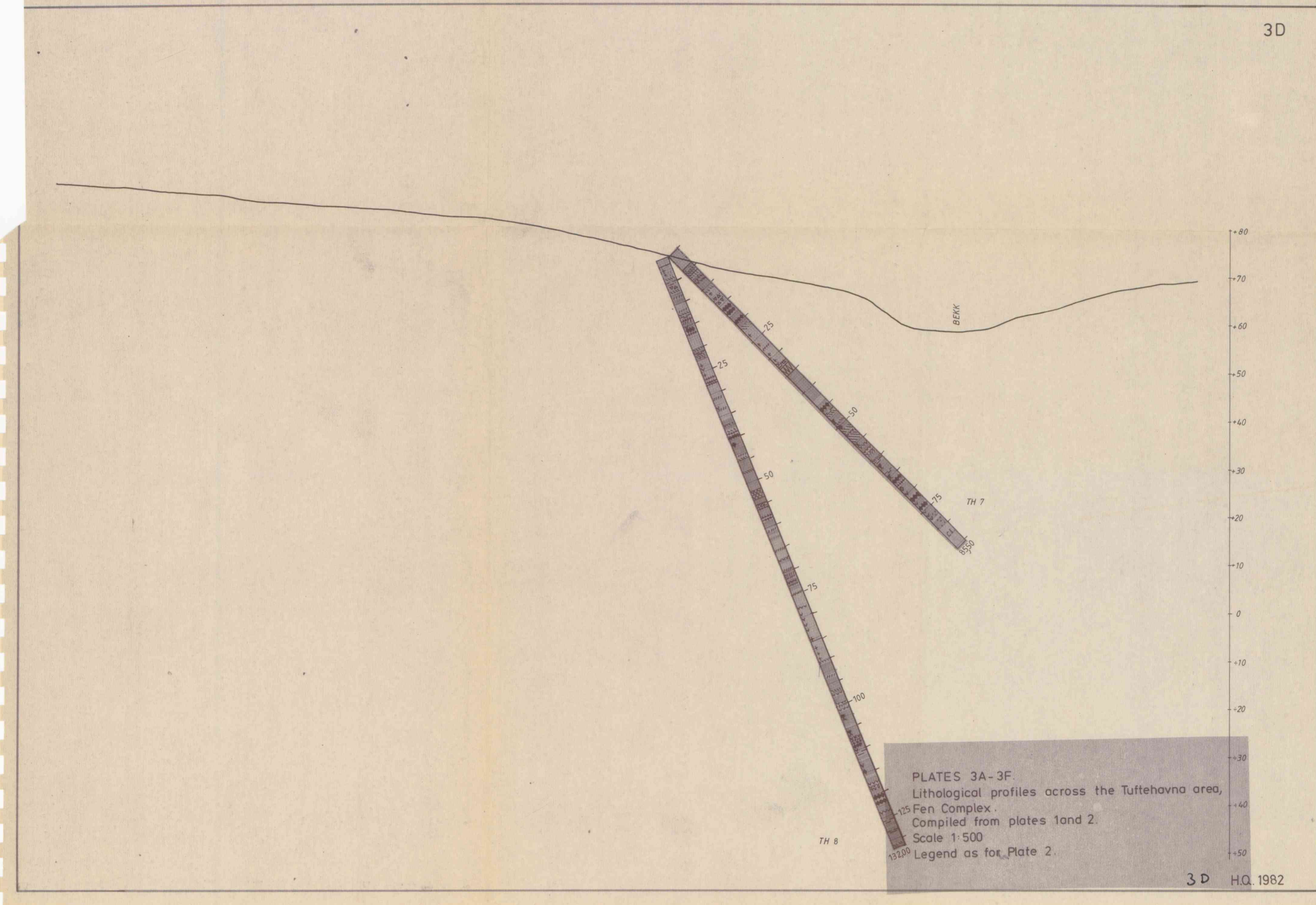
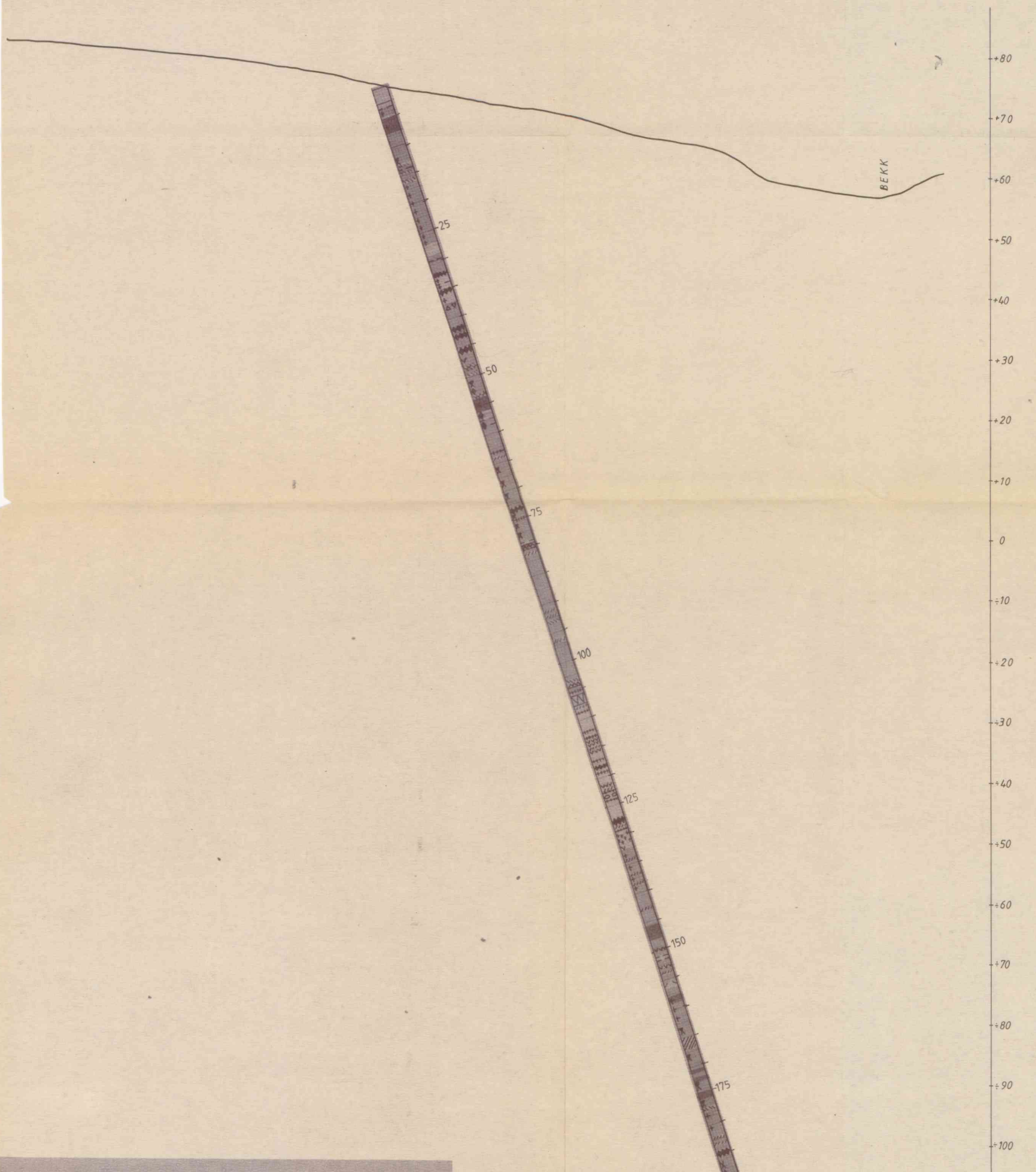
Scale 1:500
Legend as for Plate 2.

H.Q. 1982



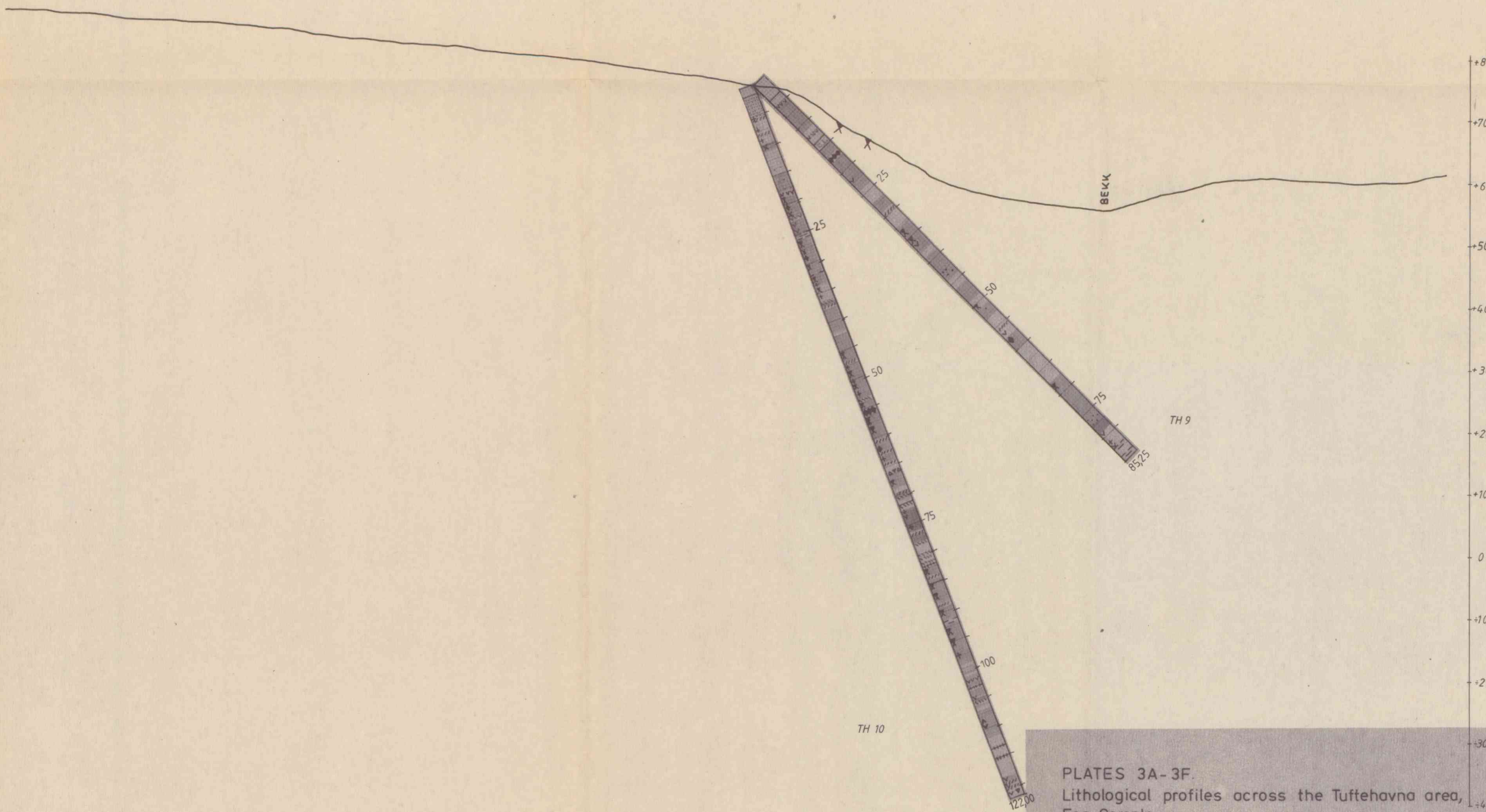
PLATES 3A-3F.
Lithological profiles across the Tuftehavna area, Fen Complex.
Compiled from plates 1and 2.
Scale 1:500
Legend as for Plate 2.

3 D H.Q. 1982



PLATES 3A - 3F.
Lithological profiles across the Tuftehavna area, Fen Complex.
Compiled from plates 1and 2.
Scale 1:500
Legend as for Plate 2.

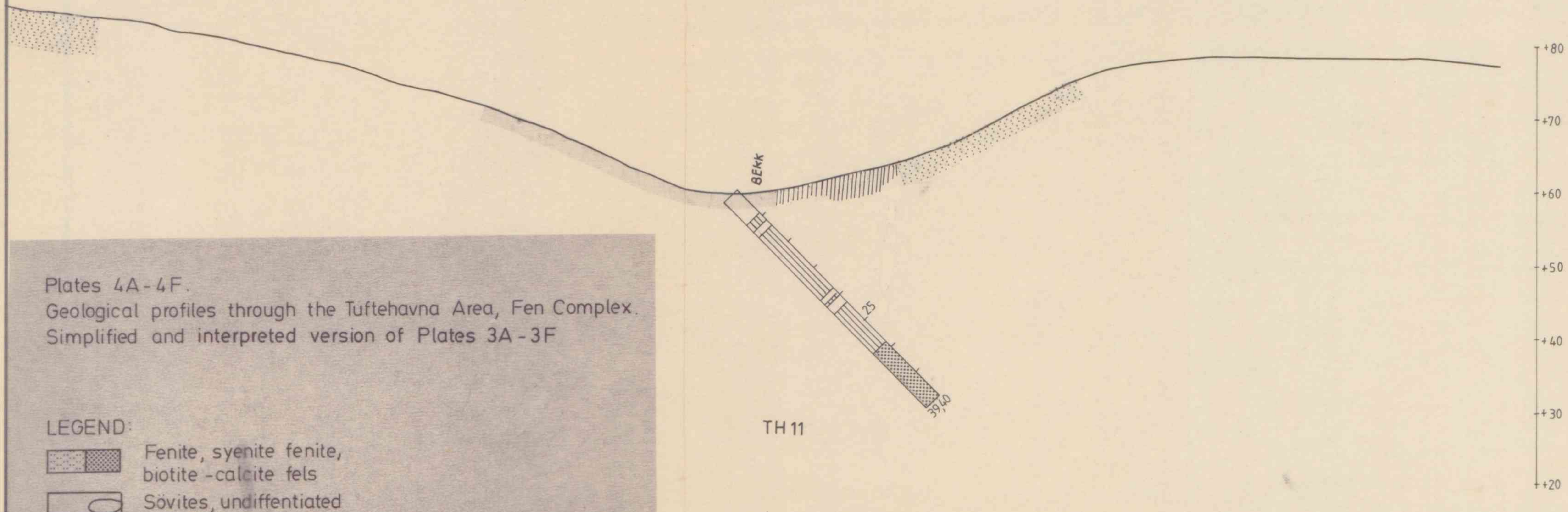
H.Q.1982



PLATES 3A-3F.
Lithological profiles across the Tuftehavna area, Fen Complex.
Compiled from plates 1and 2.
Scale 1:500
Legend as for Plate 2.

3F H.Q. 1982

4A



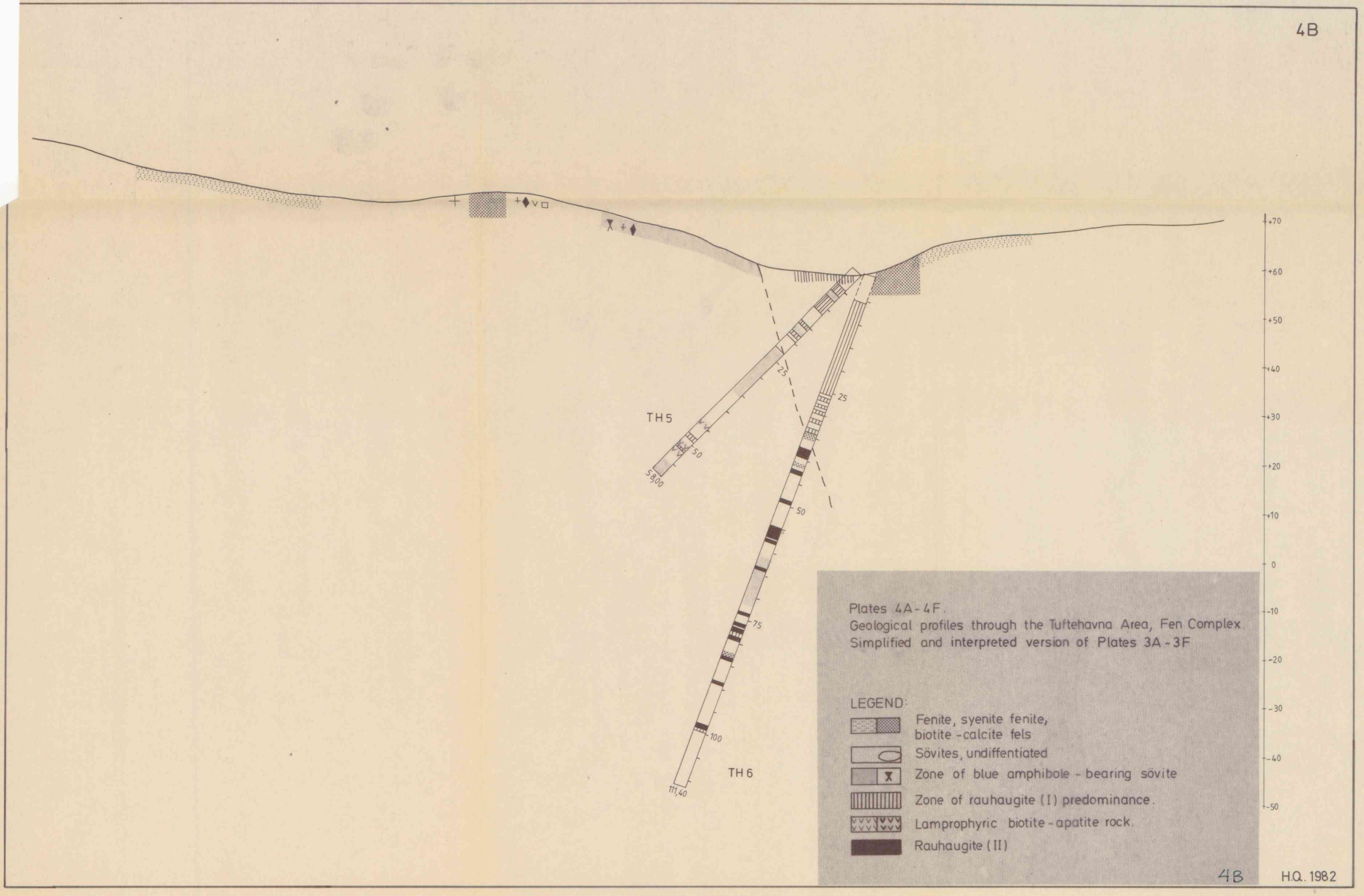
Plates 4A-4F.
Geological profiles through the Tuftehavna Area, Fen Complex.
Simplified and interpreted version of Plates 3A-3F

LEGEND:

- Fenite, syenite fenite, biotite-calcite fels
- Sövites, undiffentiated
- Zone of blue amphibole-bearing sövite
- Zone of rauhaugite (I) predominance.
- Lamprophyric biotite-apatite rock.
- Rauhaugite (II)

H.Q. 1982

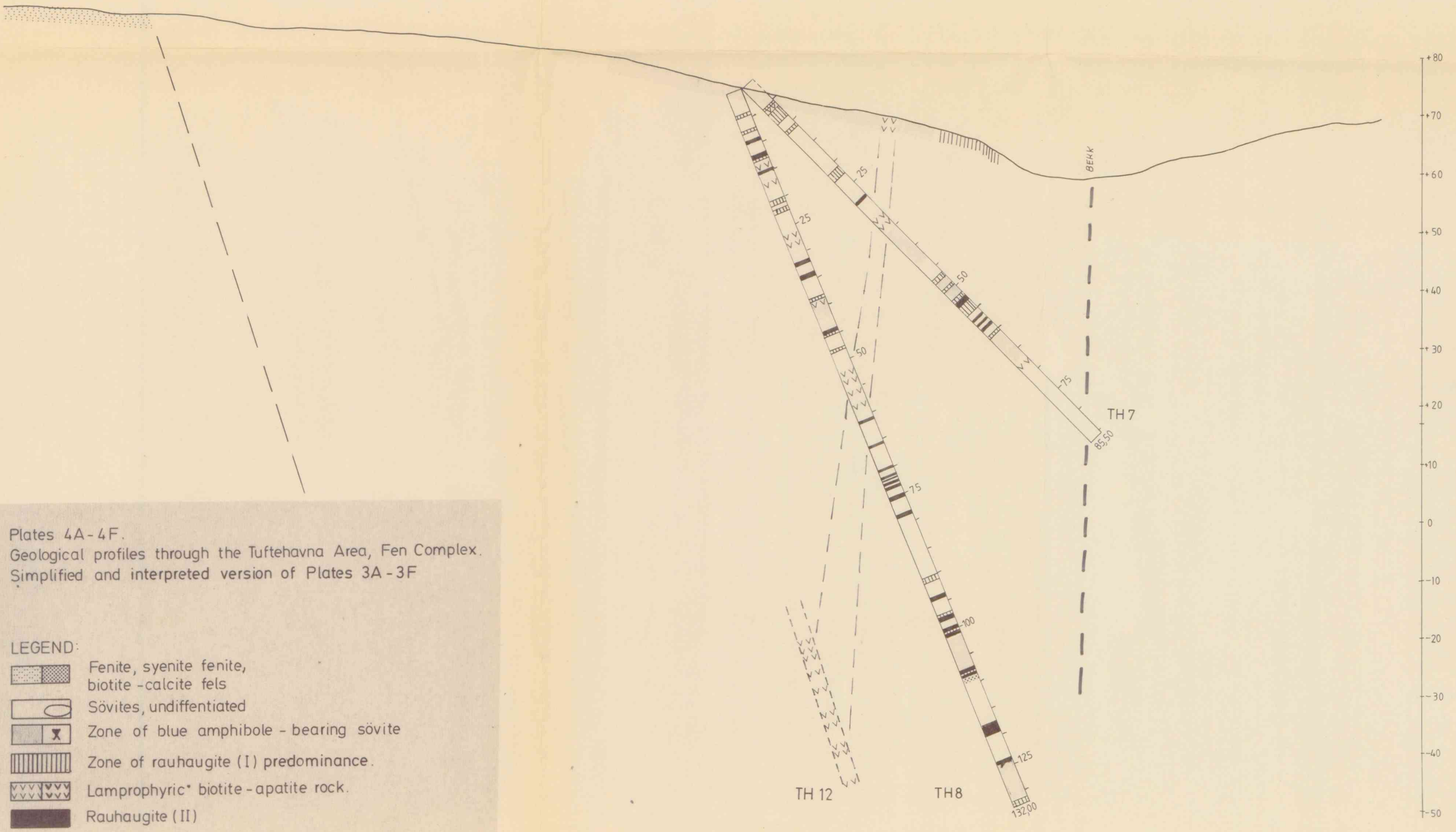
4B



Plates 4A-4F.
Geological profiles through the Tuftehavna Area, Fen Complex.
Simplified and interpreted version of Plates 3A-3F

Plates 4A - 4F.
Geological profiles through the Tuftehavna Area, Fen Complex.
Simplified and interpreted version of Plates 3A - 3F

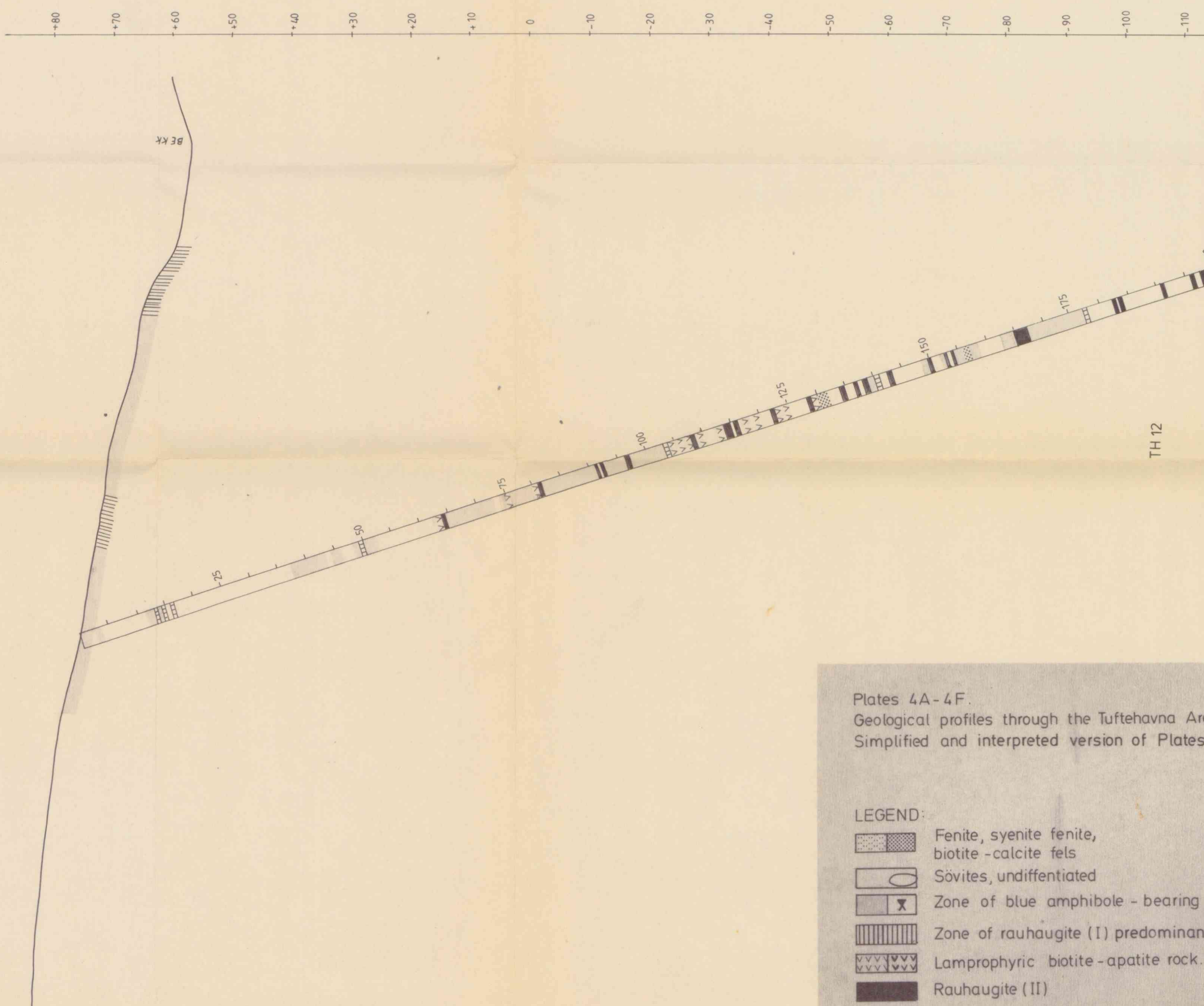
H.O. 1982



Plates 4A - 4F.
Geological profiles through the Tuftehavna Area, Fen Complex.
Simplified and interpreted version of Plates 3A - 3F

4D H.Q. 1982

4E

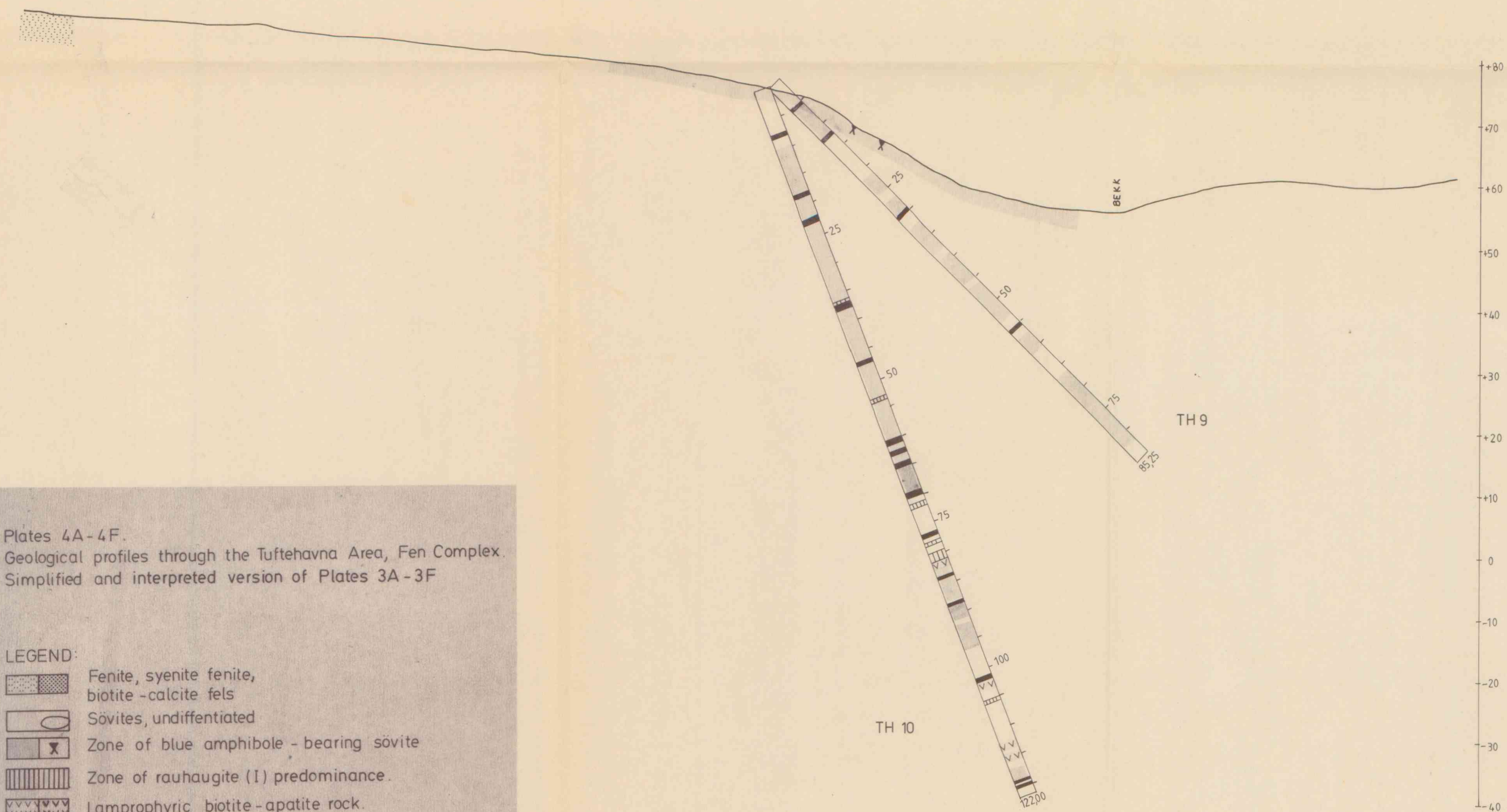


Plates 4A - 4F.
Geological profiles through the Tuftehavna Area, Fen Complex.
Simplified and interpreted version of Plates 3A - 3F

LEGEND:

- Fenite, syenite fenite, biotite - calcite fels
- Sövites, undiffentiated
- Zone of blue amphibole - bearing sövite
- Zone of rauhaugite (I) predominance.
- Lamprophyric biotite - apatite rock.
- Rauhaugite (II)

H.Q. 1982



Plates 4A - 4F.
Geological profiles through the Tuftehavna Area, Fen Complex.
Simplified and interpreted version of Plates 3A - 3F

LEGEND:

- Fenite, syenite fenite, biotite - calcite fels
- Sövites, undiffentiated
- Zone of blue amphibole - bearing sövite
- Zone of rauhaugite (I) predominance.
- Lamprophyric biotite - apatite rock.
- Rauhaugite (II)

4F H.Q. 1982

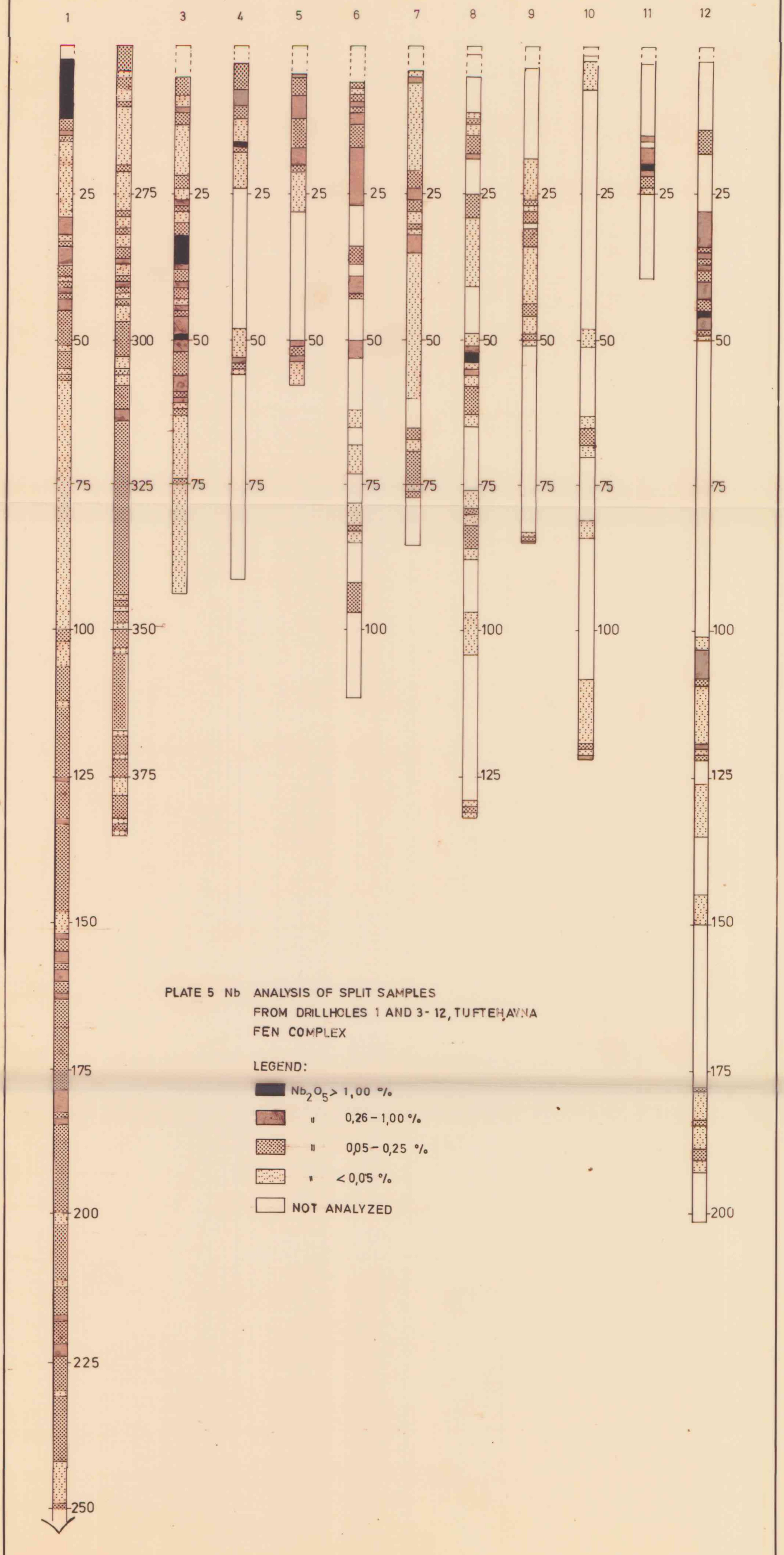


PLATE 5 Nb ANALYSIS OF SPLIT SAMPLES
FROM DRILLHOLES 1 AND 3-12, TUFTEHAVNA
FEN COMPLEX

LEGEND:

Nb_2O_5 > 1,00 %
" 0,26 – 1,00 %
" 0,05 – 0,25 %
" < 0,05 %
NOT ANALYZED

SYDVARANGER Rap. nr. 1354 H.Q. 1982

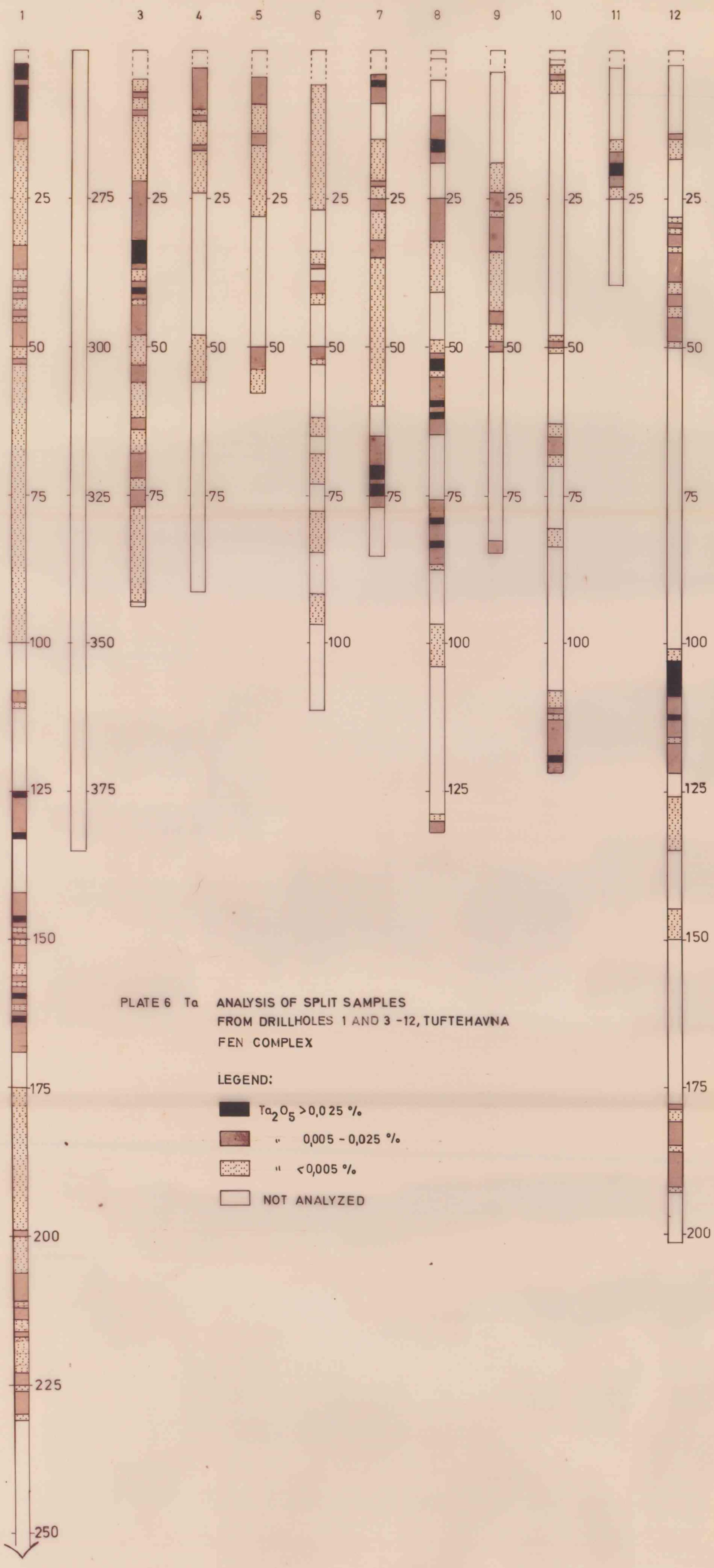


PLATE 6 Ta ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3 -12, TUFTEHAVNA FEN COMPLEX

LEGEND:

Ta_2O_5 > 0,025 %

" 0,005 - 0,025 %

" < 0,005 %

NOT ANALYZED

SYDVARANGER Rap. nr. 1354 H.Q. 1982

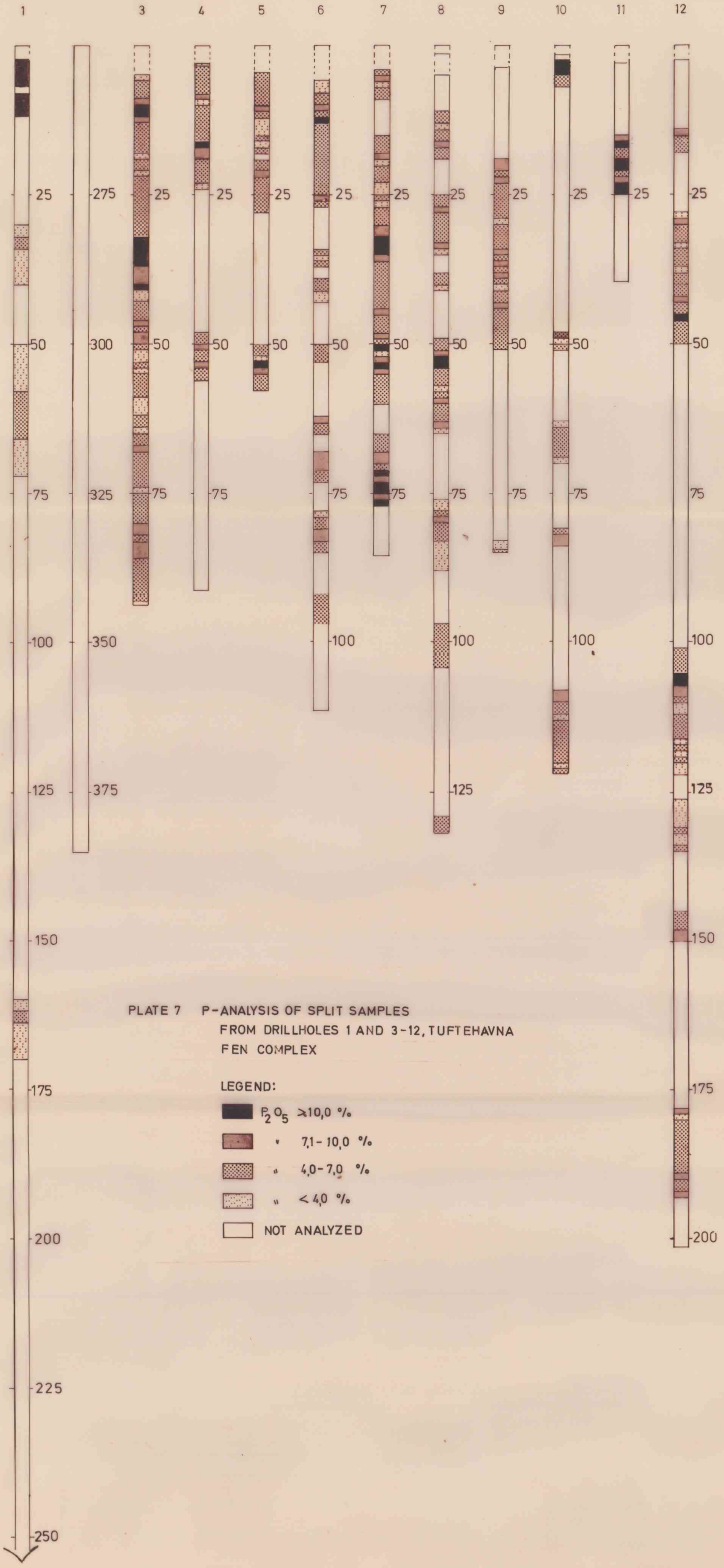


PLATE 7 P-ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3-12, TUFTEHAVNA FEN COMPLEX

LEGEND:

- P_2O_5 ≥10,0 %
- " 7,1 - 10,0 %
- " 4,0 - 7,0 %
- " < 4,0 %
- NOT ANALYZED

SYDVARANGER Rap. nr. 1354 HQ 1982

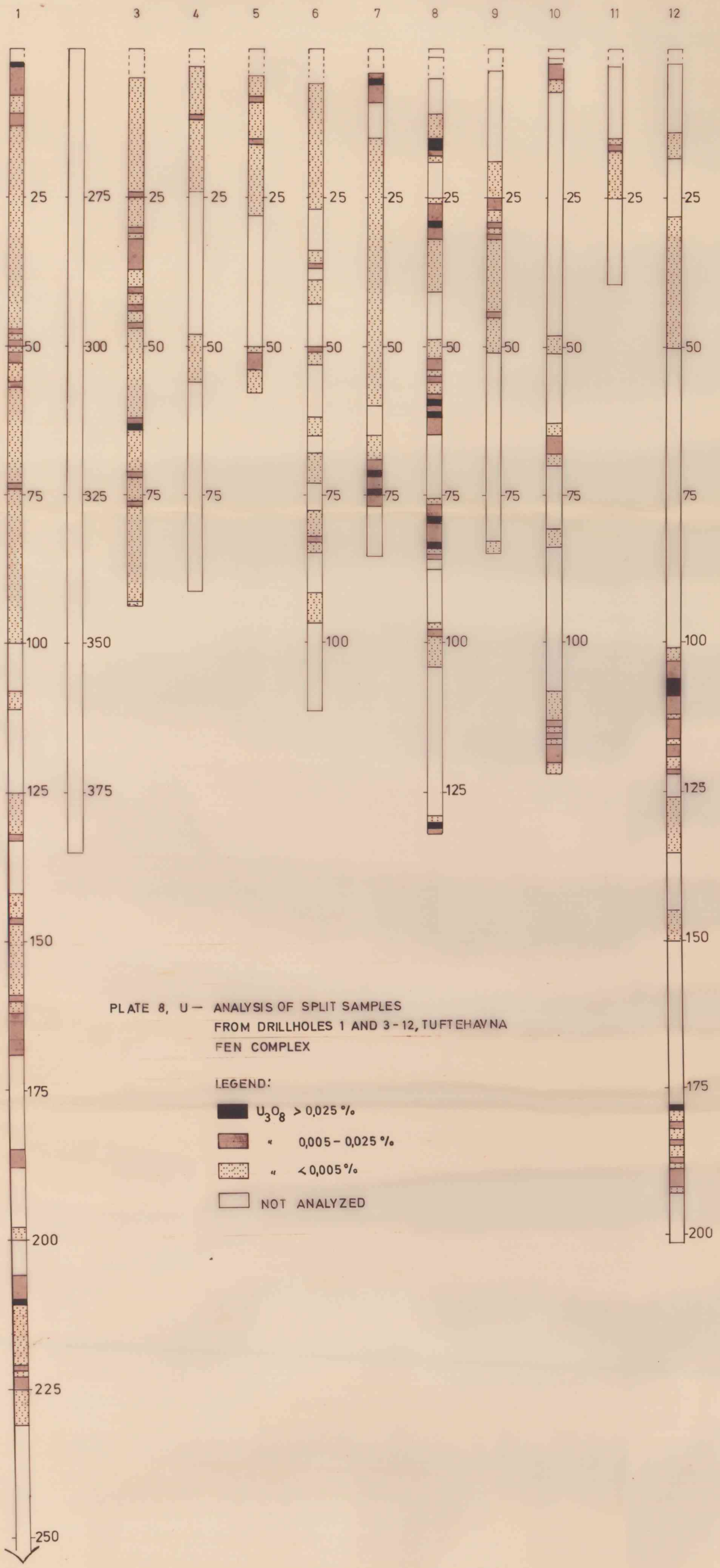


PLATE 8, U – ANALYSIS OF SPLIT SAMPLES
FROM DRILLHOLES 1 AND 3 - 12, TUFTEHAVNA
FEN COMPLEX

SYDVARANGER Rap. nr. 1354 H.Q. 1982

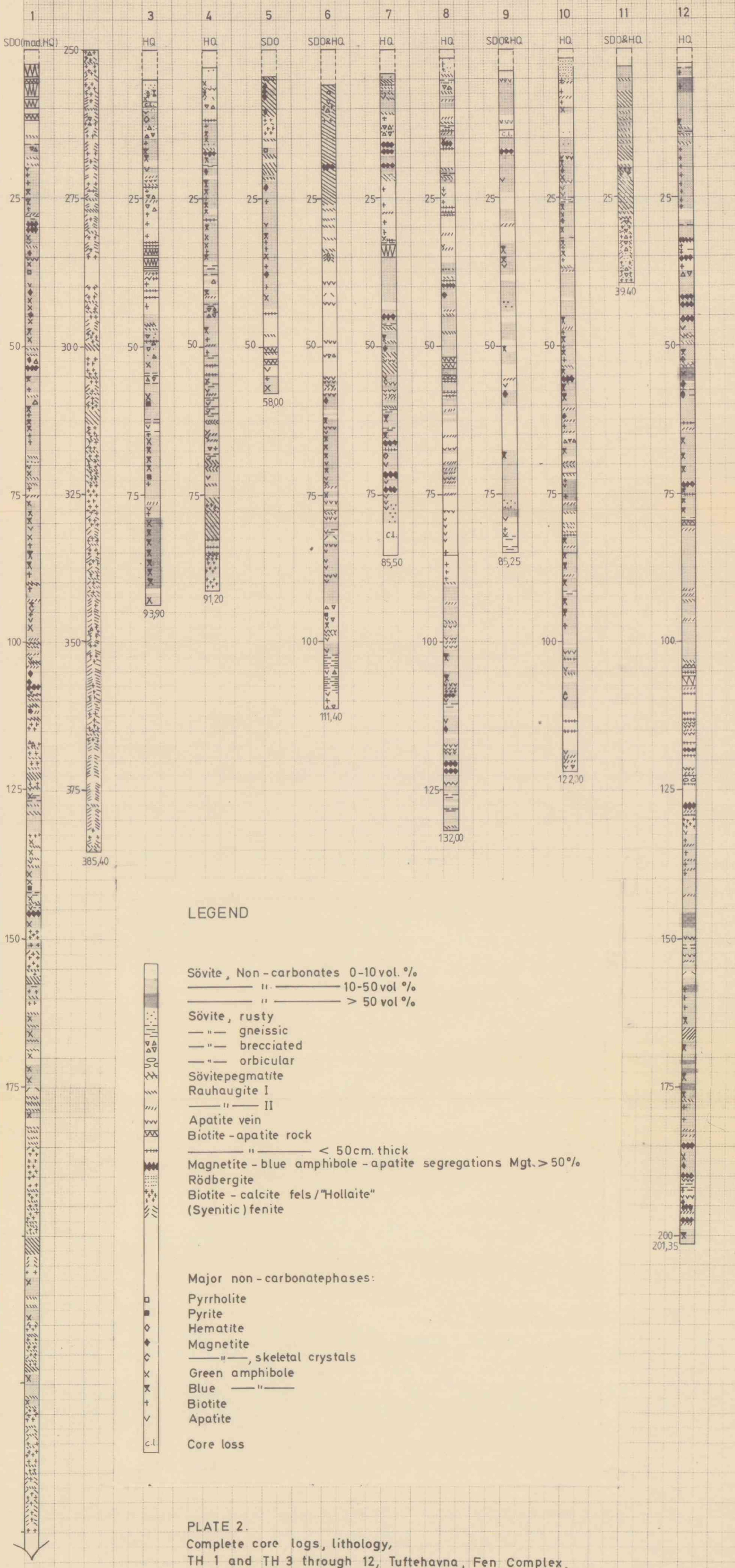


PLATE 2.
Complete core logs, lithology,
TH 1 and TH 3 through 12, Tuftehavna, Fen Complex.
Observations by S.D. Olmore (SDO) and H. Qvale (HQ)
Scale: 1:500
1982

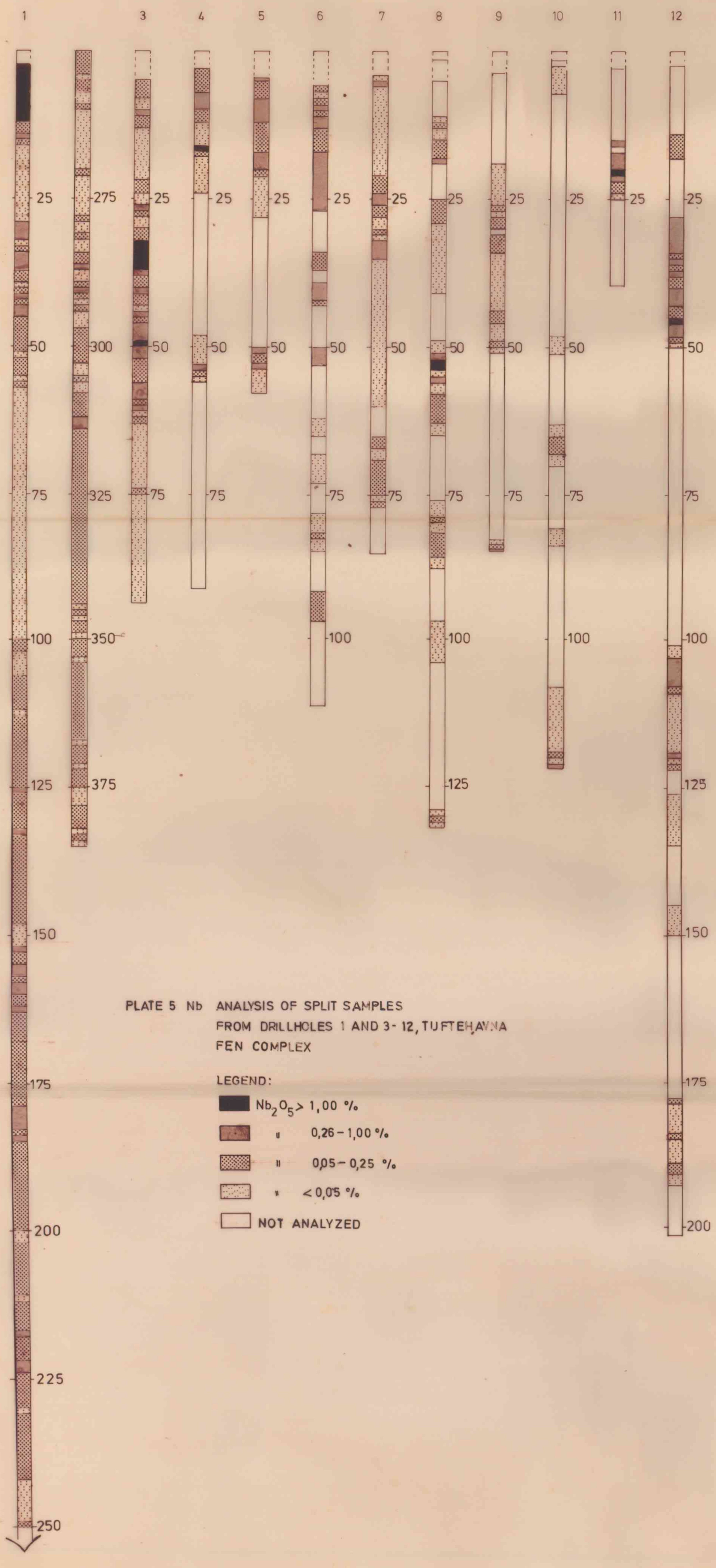


PLATE 5 Nb ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3 - 12, TUFTEHAVNA FEN COMPLEX

SYDVARANGER Rap. nr. 1354 H.O. 1982

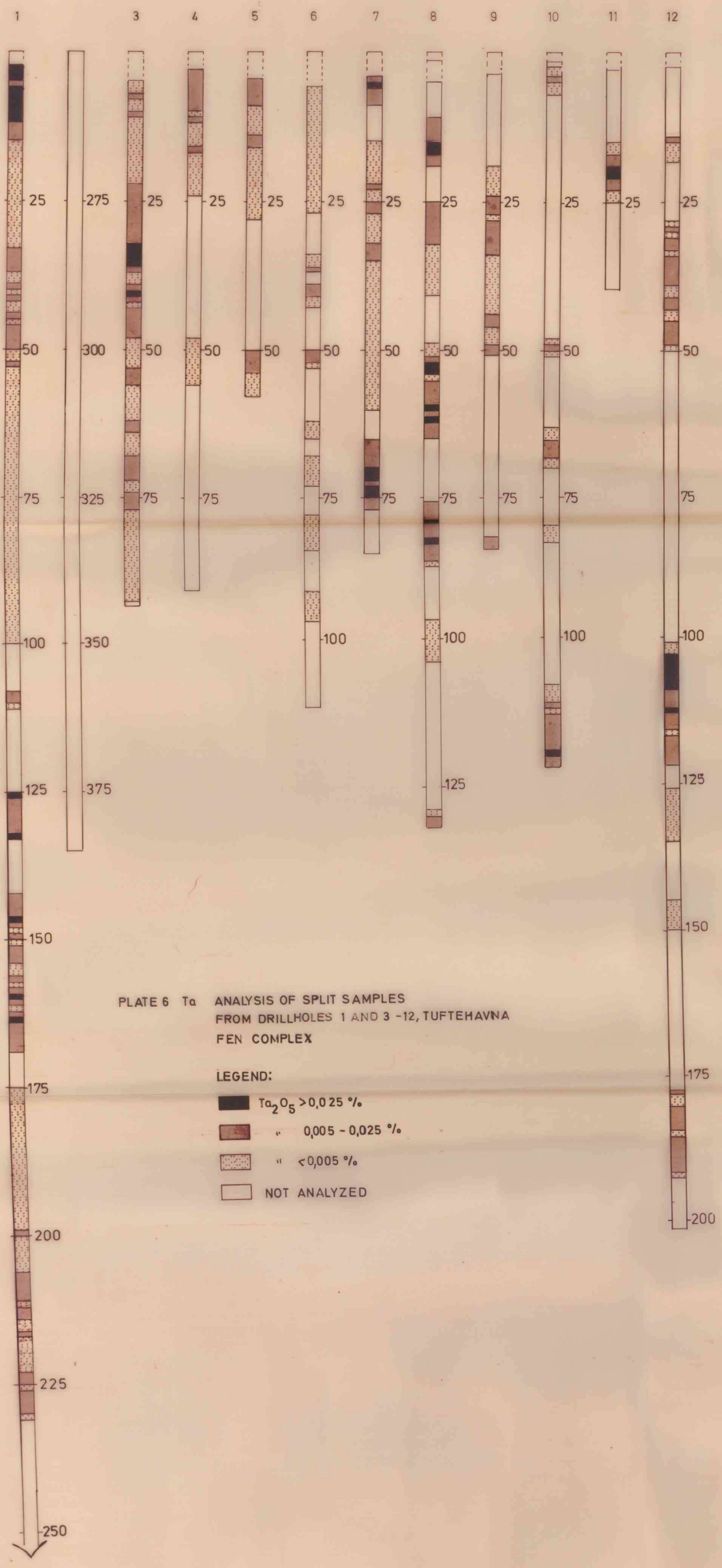


PLATE 6 Ta ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3 -12, TUFTEHAVNA FEN COMPLEX

LEGEND:

- Ta_2O_5 > 0,025 %
- " 0,005 - 0,025 %
- " < 0,005 %
- NOT ANALYZED

SYDVARANGER Rap. nr. 1354 H.Q. 1982

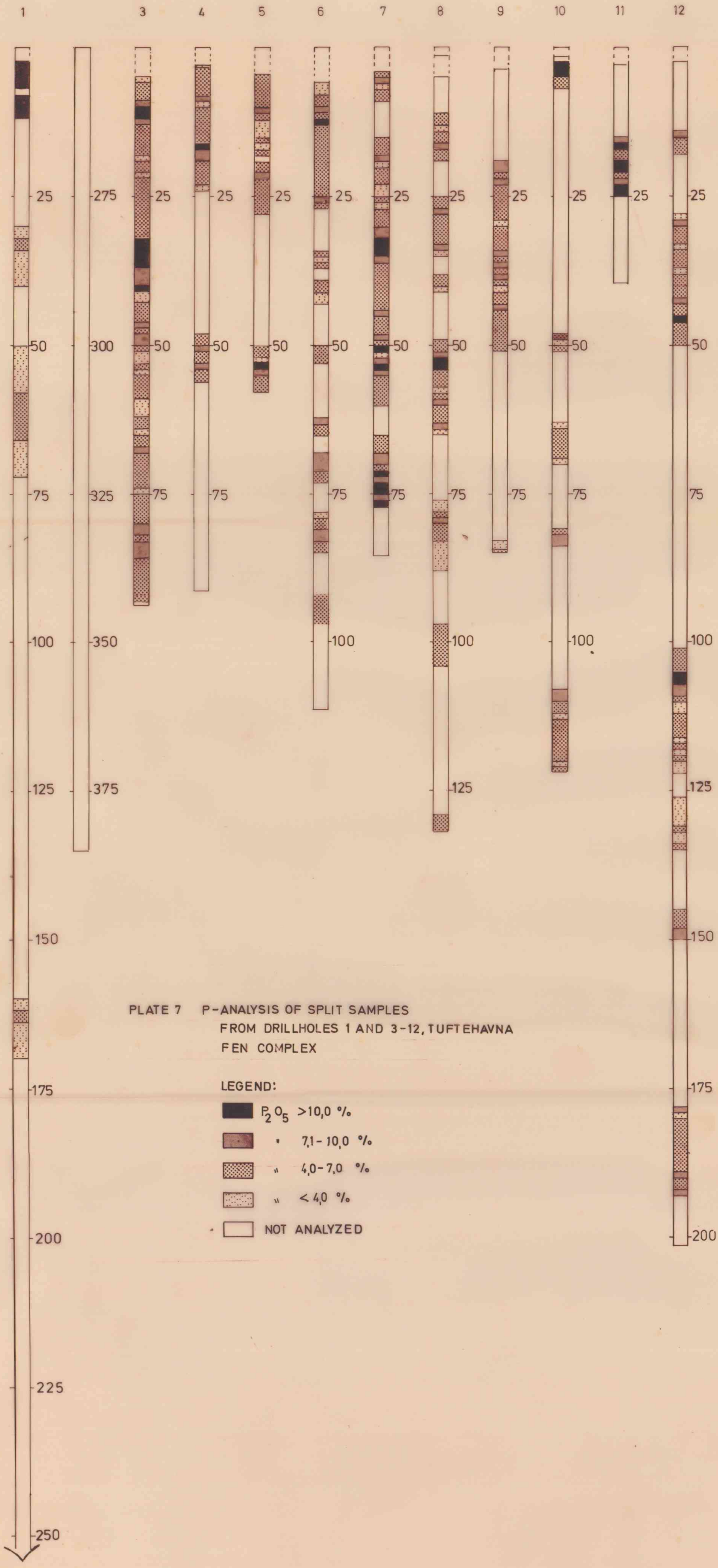


PLATE 7 P-ANALYSIS OF SPLIT SAMPLES
FROM DRILLHOLES 1 AND 3-12, TUFTEHAVNA
FEN COMPLEX

LEGEND:

P_2O_5 >10,0 %

" 7,1 - 10,0 %

" 4,0 - 7,0 %

" < 4,0 %

NOT ANALYZED

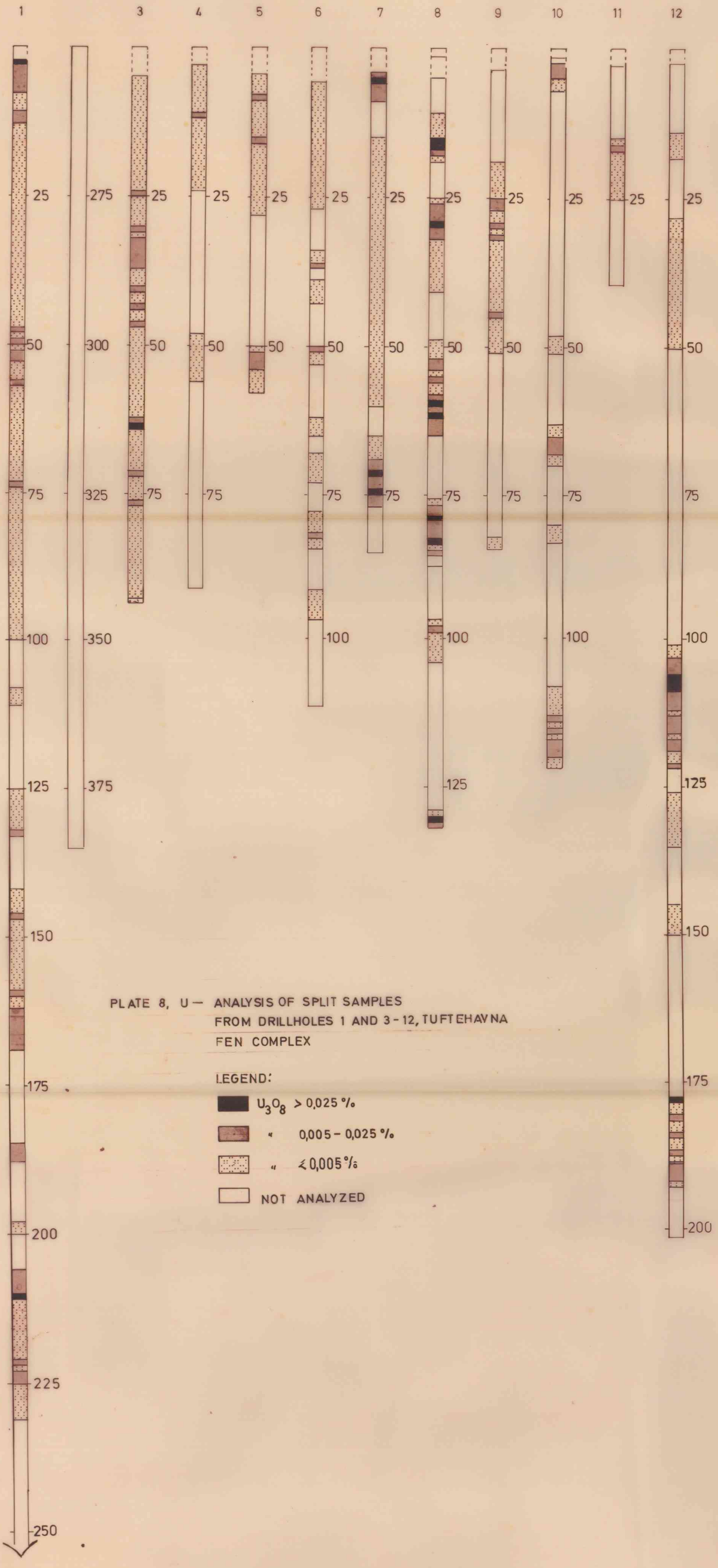


PLATE 8, U — ANALYSIS OF SPLIT SAMPLES
FROM DRILLHOLES 1 AND 3 - 12, TUFTEHAVNA
FEN COMPLEX

LEGEND:

U_3O_8 > 0,025 %

" 0,005 – 0,025 %

" ≤ 0,005 %

NOT ANALYZED

SYDVARANGER Rap. nr. 1354 H.Q. 1982

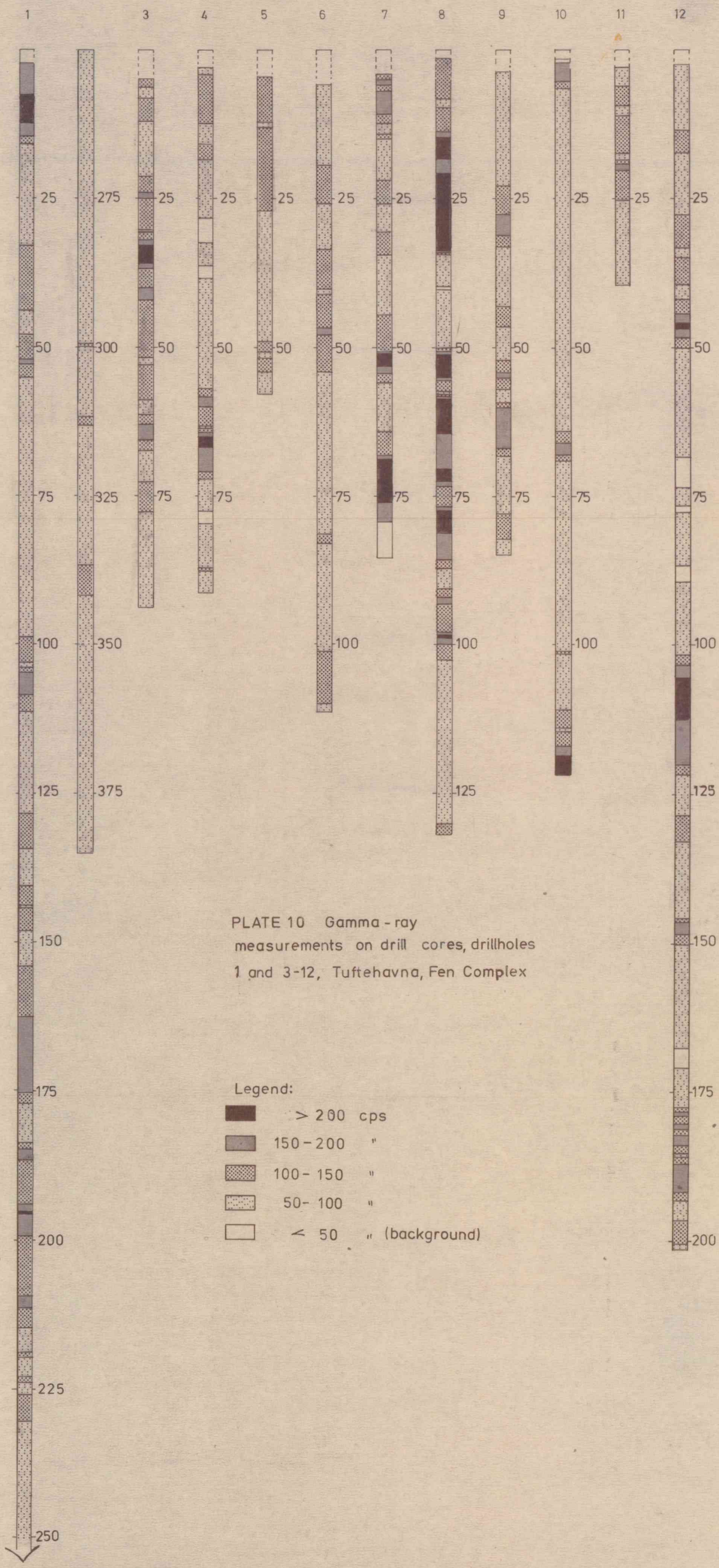


PLATE 10 Gamma - ray measurements on drill cores, drillholes 1 and 3-12, Tuftehavna, Fen Complex

Legend:
> 200 cps
150 - 200 "
100 - 150 "
50 - 100 "
< 50 " (background)

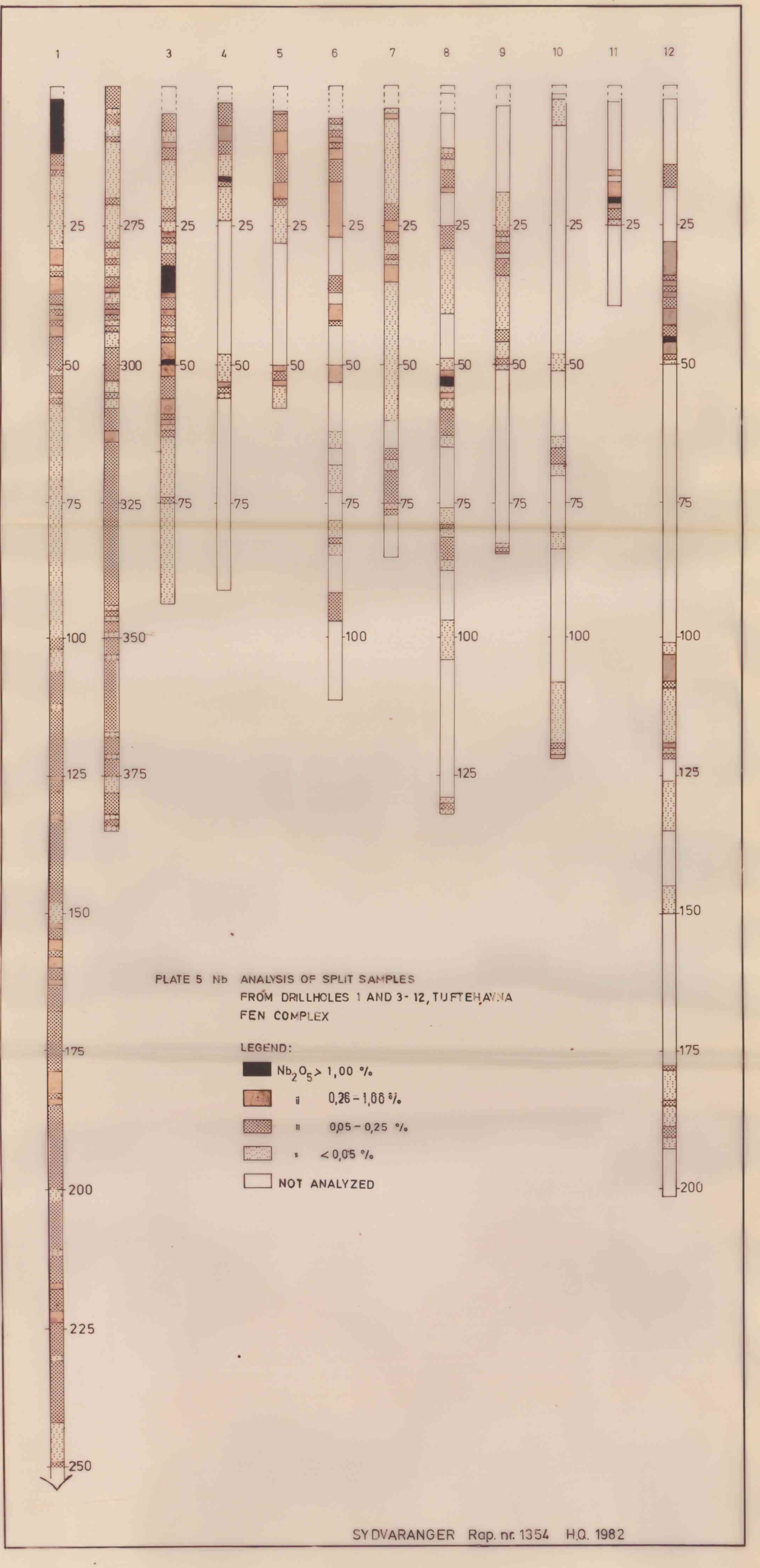


PLATE 5 Nb ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3-12, TUFTEHAVNA FEN COMPLEX

SYDVARANGER Rap. nr. 1354 H.Q. 1982

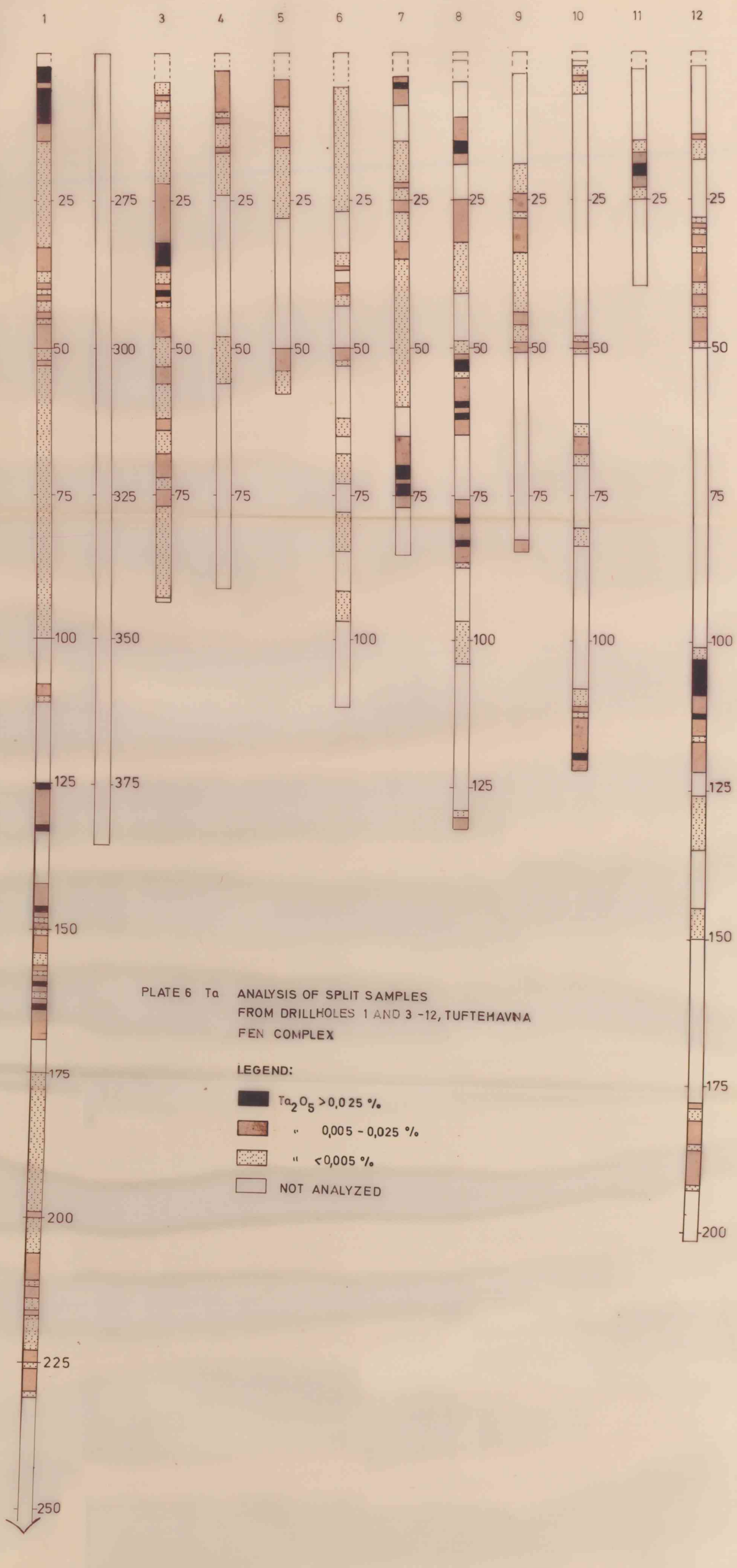


PLATE 6 Ta ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3 -12, TUFTEHAVNA FEN COMPLEX

LEGEND:

Ta_2O_5 > 0,025 %

" 0,005 - 0,025 %

" < 0,005 %

NOT ANALYZED

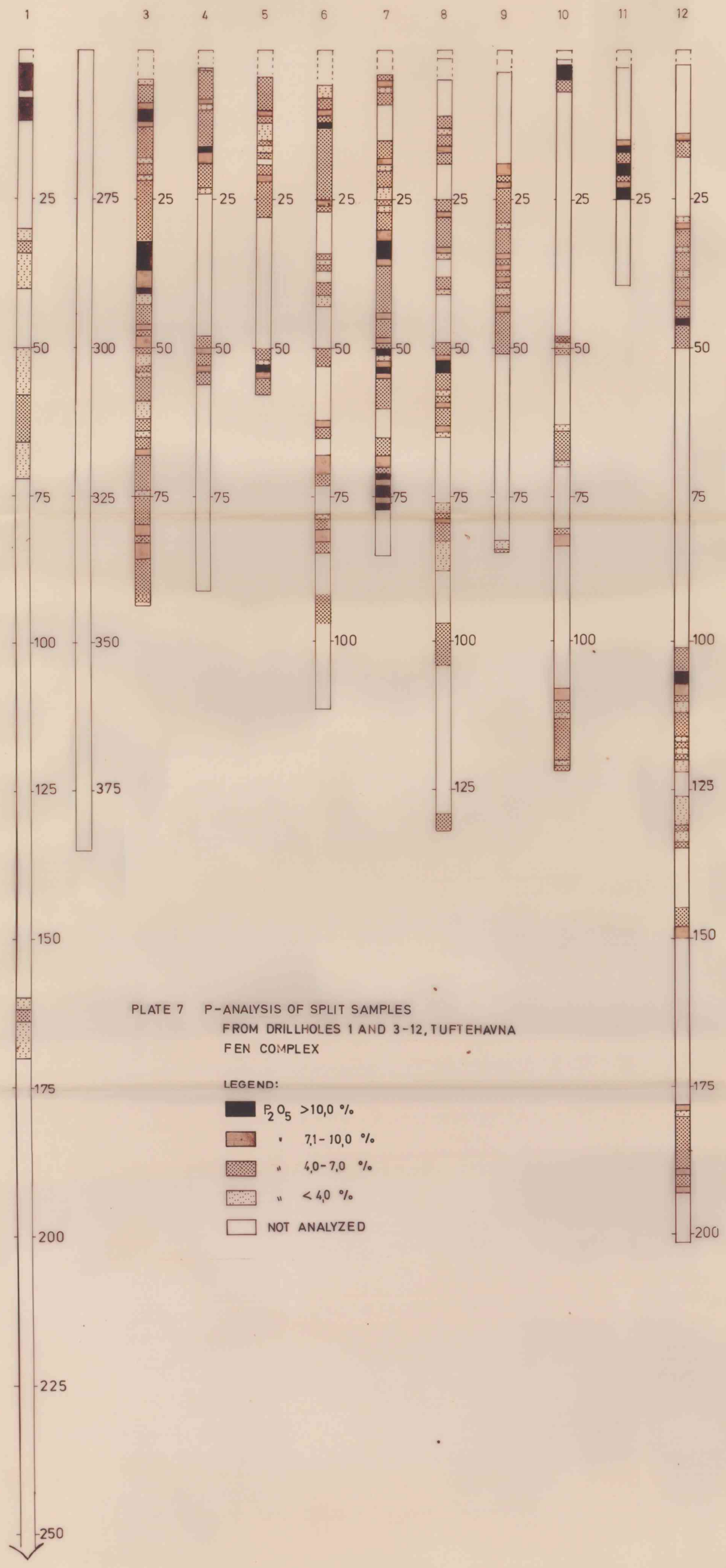


PLATE 7 P-ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3-12, TUFTEHAVNA FEN COMPLEX

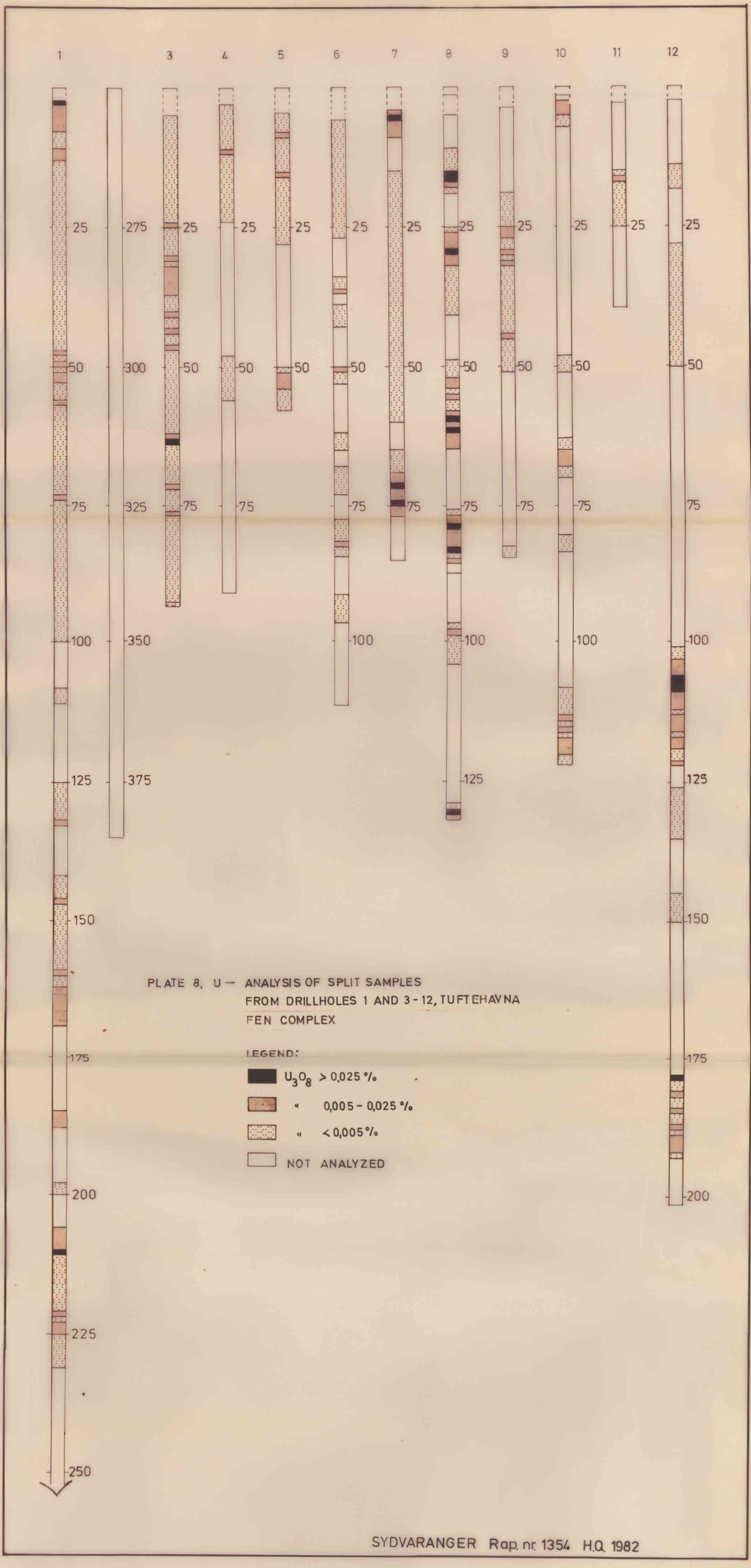


PLATE 8, U – ANALYSIS OF SPLIT SAMPLES FROM DRILLHOLES 1 AND 3 - 12, TUFTEHAVNA FEN COMPLEX

SYDVARANGER Rap. nr. 1354 H.Q. 1982

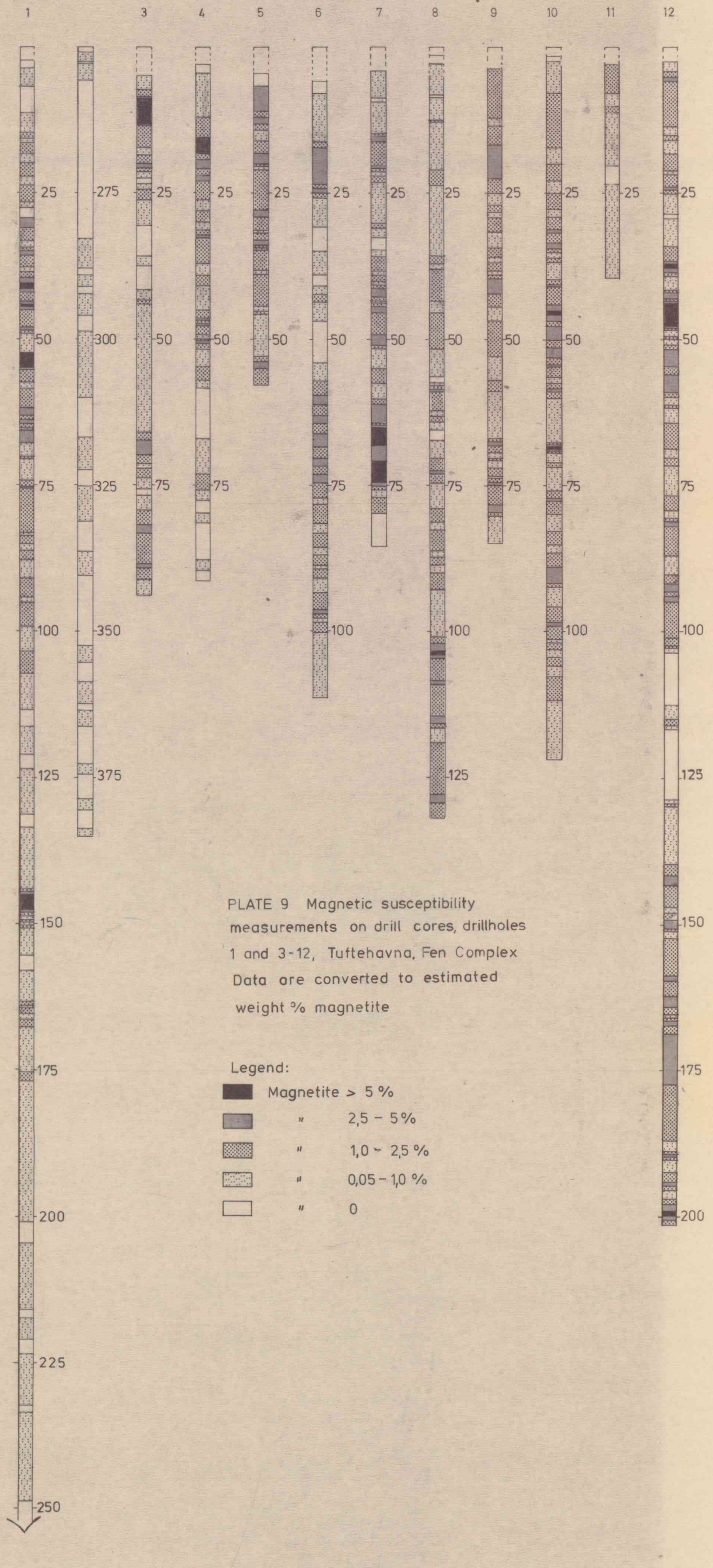


PLATE 9 Magnetic susceptibility measurements on drill cores, drillholes 1 and 3-12, Tuftehavna, Fen Complex
Data are converted to estimated weight % magnetite

Appendix

Diamond drill hole logs: TH-3 → TH-12

DIAMANTBORING Tuftehavna 1982.

Kjerneobservasjoner.

Borhull nr. TH-3 Profil 1

Koordinator: Y 50960 X 141.534

Påsatt i høyde ~ 70 m.o.h. m.

" i retning 80^g

" med helning -45^o

Borhullets lengde 93.00 m

Boret meter	Bergart		Kjerne-mangel	Skifrighet	Bergart prøve
0 - 5.10	Overburden				
6.80	Grey søvite, partly rusty, med. gr.				
	chlorite vein	5.10		20^o	
	Dol. veinlets	6.00		8^o	
	Bands of BT + CHL	6.40		35^o	
	Brecc. with BT + CHL ?	6.60			
10.60	Søvite, white, massive, med. gr.				
	Slickenside	7.00		75^o	
	Brecciated	7.20			
	PY-rich along fault	8.40		20^o	
	Rusty with euh. MT.	8.70-9.90			
12.85	Søvite, grey, MT-rich	12.10			
	Interst. noncarb. finegr.				
	phase with grey-green col.				
	BT+PH cryst. 1-10 mm				
13.15	Søvite, white w/MT				
15.80	Søvite, white to grey, partly brec. text.				
	Relict, exsolved MT-cryst.				
	CHL-joints	15.50			
23.20	Søvite, with bluish/violet subh. relict				
	cryst. of MT.				
	Greenksh-grey dol. dike	21.35			
	Dessim. PHY foliation	21.90		50^o	
	AP-dike	22.20			
	late rauh. dike cuts fol.	22.45-22.60			
	and mineralization				
	BT+AP-dike	22.86-22.90			
23.70	Søvite, pink to grey, fine gr. fol.			50^o	
25.00	Søvite, fine grained with large euh.				
	BT-flakes + MT.				
32.00	Søvite, as above partly pink and brecciated.				
	Late dol. veins	25.85-25.90			
	Brecciated with grey dol.	26.00			
	MT-phenocryst, BT < 10 %	27.70			
	With PY+AP+MT+BT	29.20			
	Mafic veins	29.30-30.00			
	With olivine, dark veinlet				
	sub. parall. to e:a	30.00-31.00		10^o	
	Cut fol.			70^o	

1000-9-74. FS 0030. A 4. H. C.

Ark 2 Bh. nr. TH-3 Profil 1

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
32.90	Søvite, Foliated with patches and stringers of BT+AP -rock at 32.40-32.60 Dykelet at 32.60 with 50° to c.a. Crosscutting dike of BT+AP -rock 32.95-32.90		50°	
33.10	Massive BT+AP -rock, banding crosscutting some foliation in søvite		50°	
33.60	Søvite, with patches of pink occasional large (< 2 mm) PHYCL cryst.			
34.60	Massive AP+BT -rock			
34.80	Søvite, locally w/AP -dike/ veinlets loaded with PHYCL. Pink decolouration. Banded AP+BT -rock, bands Med./fine gr. CHL -joints and probably also chloritizised BT.		60°	
36.80	Søvite			
36.95	BT+AP -rock, fine gr. well demonstrated "dissolved søvite".			
37.50	Søvite			
37.80	Late dol (?) veinlets sub parall. to c.a. cut BT+AP -rock which cuts foliation in søvite at		75°	
40.20	Søvite, complex cutting relationships 38.30 1) Weakly foliation søvite cut by 2) BT+AP -rock cut by 7 cm 3) Appearantly gneissic apatite or dolomite veins < 2 cm, cut by 4) Greenish veins/joints filled with dol./ankeritic carb. causing alteration of søvite as well (Rauh. II)			
40.50	Massive AP+BT -rock.			
79.20	Søvite, usually weakly fol. but also small gneisic relics 41.45, 41.60 and 41.90 patches and stringers with BT+AP. Impure 46.00-46.30 Pegmatite of søvite 46.30 Dol. veinlets 46.75 Brecciated 48.30 CHL. -veinlets 52.50 Impure 53.00-54.20 Impure, gneissic and brecciated 54.20-56.40 Massive impure sulphide rich 56.40-62.10			

Ark 3 Bh. nr. TH-3 Profil 1

Boret meter	Bergart		Kjerne-mangel	Skifrighet	Bergart prøve
	Gneissic	62.10-62.90			
	Homogenous, massive BT-rich	62.90-65.15			
	Gneissified vein	64.75			
	Mainly massive homogenous, silico-søvite with large amount of blue amph.	65.15-70.60			
	Without amph., but with clusters of mafics + PY	70.60-73.60			
	Impure, some PY + conc. along dolo (?) veins	74.00-79.20			
91.30	Silico -søvite Large MT -cryst./ clusters + PY + PO ?	88.20-88.80			
91.90	Søvite				
93.80	Søvite, impure, alternating with silico-søvite. All med. gr.				
	Stop at 93.00 m.				

1000-9-74. FS 0031. A 4. H. C.

DIAMANTBORING Tuftehavna 1982.

Kjerneobservasjoner.

Borhull nr. TH-4 Profil 1.

Koordinator: Y 50959 X 141.534

Påsatt i høyde ∼ 70 m.o.h. m.

" i retning 80^g

" med helning -67.5^o

Borhullets lengde 91.35

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
0 - 2.75	Overburden			
3.80	Søvite, fine gr., rusty			
5.90	Søvite, w/ diss. euh. MT + PY/PO.			
6.00	Søvite, deep weathered.			
7.50	Søvite, fine gr. white/pink Apatite veinlet 6.20-6.40 Occ. MT -emp. <0.7 cm.			
8.20	Silico? søvite, dark grey Brecciated appearance. AP or DOL -rich patches floating in $CaCo_3$ -rich matrix			
9.25	Søvite, white/pink fine gr.			
9.75	Søvite, brecciated w/ dolomite (?) matrix cutting c.a.		$45-75^o$	
11.45	Søvite, med.gr. white to grey. w/ ∼ 1 mm BT -grains and agg. of PO. Decolouration (to pink) along veinlets ∼ 1 mm thick CHL.			
11.60	Søvite, with euh. MT -cryst. ∼2 mm and PO -agg.			
12.25	Søvite, white impure w/stringers/ patches of mica.			
12.40	Silico-søvite, w/ large BT and MT- empt. Graduation to more finegr. rock with larger fraction of blue amph.(?)			
15.85	Søvite, impure. Impurities are concentrated in irregular patches and agg. Joint w/ rusty weathering at 15.75		70^o	
16.05	Søvite, interlayered with pure søvite.			
16.55	AP or Dol. dominated rock w/ gneissic appearance. Frequent <1 cm MT -cryst. (euh) + 5 % PY.			
17.45	Søvite			
17.48	MT + BT + AP -rock.			

Ark 2 Bh. nr. TH-4 Profil 2.

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
17.70	Søvite, grey impure silico. med.gr.			
17.85	Søvite, coarse gr. with w/ MT + blue am.			
17.90	Søvite			
18.15	Søvite, coarse gr. silico. w/euh. MT and blue am.			
19.25	Søvite, impure.			
19.35	Søvite, gneissic			
19.70	Søvite, Impure w/ occ. MT -cryst.			
20.95	Silicosøvite, coarse gr. w/MT ~ 1 cm conc. betw. 19.70-20.10			
21.20	Søvite, pure w/ PY -agg. < 1 cm long lensoide			
22.15	Silicosøvite, w/ patches of PO at 21.50			
22.30	Søvite, impure			
23.00	Silicosøvite			
25.50	Søvite, impure, MT-enrichment at 23.30 and 23.70			
26.50	Silicosøvite, massive			
27.40	Søvite, rel. pure, doloritizised (?) veinlet			
28.00	Silicosøvite			
28.20	Søvite			
28.45	Silicosøvite			
28.55	MICA + AP + PY -rock, 5 cm, encl. in søv.			
31.30	Silicosøcite			
31.85	Søvite, impure			
42.25	Silicosøvite, w/dess. sulph. (PY + PO?) and MT at 32.00-32.50 Zones of gneissification and decolouration ~ 1 cm thick ~ 10 cm zone at 32.50-32.70 blue am. disapp. at 33.25 blue am. increases at 33.90 w/ numerous stringers at 34.40 and veinlets < 1 mm thick irreg. Traces often parall. c.a. at 35.10 Significant, but variable MT -content. Gneissified zones at 36.25-36.30 Gneissified and coarse brecciated søvite/silicosøv. at 37.60-37.90 Granular silicosøvite w/euh. MT grad. disapp. at 37.90-38.15 grey coarse gr. calc. dom. rock (silico?) søvite? at 38.15-38.65		90°	

Ark 3 Bh. nr. TH-4 Profil 1.

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Brecciated søvite 38.65-38.85 BT+MT -bearing søv.probably also am. -bearing 38.85-40.60 W/ BT+AM+ acc. MT 40.60-42.25 Dark wein w/wide metasomatic halo. Dark calc. (Rauh. II?) 41.30-42.25			
42.35	Søvite, fine gr.			
42.55	Søvite, increasing dark min. Brecciated, gneissic, metasomatically decolourizised. Dark grey colour dominates.			
45.05	Søvite, white areas dominate			
45.65	Silicosøvite, spinifex text.			
48.00	Søvite			
	Søvite, (silico), "spinifex" dominates, patches/areas of more pure søv.			
48.60	Søvite, BT + AP -enriched			
48.85	Søvite, BT + MT -enrich			
48.90	Søvite, BT -enrich			
49.00	Søvite			
49.65	Silicosøvite, with BT			
49.68	Rauhaugite-vein		45^{o}	
50.15	Silicosøvite, partly spinifex			
50.60	Søvite, impure, interlayered by silicate dominated silicosøvite AM. dom.			
50.95	Silicosøvite, spinifex.			
51.05	Søvite			
52.60	Silicosøvite, partly spinifex, gneissic and- or - decolourized pink.			
52.95	Layered AP + BT -rich			
53.20	Søvite, impure w/ minor am.			
56.00	Søvite/silicosøvite, impure w/loc. spinifex and am. as maj. phase.			
56.10	Layered gneissic søvite			
56.45	Søvite, impure w/ BT + MT, partly gneissic, partly homog.			
56.60	Søvite, (silico ?) dark grey homog.			
56.82	Søvite, impure as above			
56.87	Søvite			
57.40	Søvite/silicosøvite, alternating			
57.50	Søvite			
66.25	Søvite, impure w/ generally gneissic appearance.			

1000-9-74. FS 0031. A 4. H. C.

Ark 4 Bh. nr. TH-4 Profil 1.

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	DOL(?) +/- CHL -veinlets at 57.20-57.90, 62.50, 64.70-66.20 Mafic patches and stringers at 59.20-63.50 Impregnation of sulphides at 58.70 Veins with metasomatic lateral alteration at 62.05, 7 cm which crosscutting foliation in søvite.			
66.75	Søvite, med. gr.			
67.15	Søvite, sulphide rich, mostly granular impure søvite, foliated brecciated fragments of hollaite (?).			
67.45	Søvite			
67.55	Søvite, sulphide rich			
69.20	Søvite, impure with sulphiderich zones. Well foliated, often gneissic.			
70.30	Rauh. (?), dolomite dominated impure well fol. with gneissic carbonatite.		45°	
70.40	Mafic dike			
71.00	As 69.20-70.30			
75.55	Søvite, impure Dolomitic carb. rauh. 72.93-73.25			
76.30	Rauh. dolomitic			
77.22	Hollaite (?), massive brecc. dense, black rock.			
77.80	Rauh. w/ minor calc.			
78.10	Hollaite			
78.45	Rauh. impure, sul. -rich mafic stringers.			
82.45	Rauh. rel. pure.			
82.52	Carbonatite, impure calc. dom.			
82.90	Hollaite (?) sul. -rich			
83.25	Søvite, impure interlayered w/ holl.			
84.10	Søvite			
84.35	Hollaite			
84.42	Søvite, impure			
85.30	Hollaite			
85.60	Søvite, pegmatitic			
85.80	Hollaite			
86.80	Søvite, impure as hollaite and agg. of sulphides (PY /~ 1/2 - 2 cm long)			
87.40	Hollaite			

Ark 5 Bh. nr. TH-4 Profil 1.

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
88.10	Søvite/Hollaite, heterogenous, interlayered.			
88.50	Hollaite, massive, partly coarse gr.			
89.25	Søvite, impure, layered			
89.97	Mafic rock, porphyric with crosscutting søvite (zoned) veinlets.			
91.35	Søvite, w/ large patches of hollaite. The latter is PY -rich.			
	Stop at 91.35 m			

1 000-9-74. FS 0031. A 4. H. C.

DIAMANTBORING Tuftehavna 1982.

Kjerneobservasjoner.

Borhull nr. TH-5 Profil 2

Koordinator: Y 50998 X 141.495

Påsatt i høyde ~ 60 m.o.h.

" i retning 280^g

" med helning -45^o

Borhullets lengde 58.75 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	See appendix			

1000-9-74. FS 0030. A 4. H. C.

TH5 … 5TO W TOTAL DEPTH 58M. S. D. OLMORE

COMPLETED - MAY 12, 1982

Nb, Cs

1
2 0-4.62 NO RECOVERY OVERBURDEN
3
4 Gsg 20, Ds 80 S∅ IS LT GRY, CRSE GRND. — DIKE W ABD GRN AP SEGS CRSE M… IN S∅ BLOTCHES OF AP
5 Gsg 100 W AP-MAG SEGS.
6 Ds 30 Gsg 70 BIOT & MAG IN GYG ZONES, S∅ PK, BLEACHED — PY, TR BLU AM, PK DISCOLORED S∅
7 Gsg GRN-GRY AA W/ FEW PINK PATCHES, FOL.
8 Gsg (GRN GRY) AA DISS MAG, DISS BIOT
9 Gsg (GRN GRY) W/ ZNES OF PK S∅ — TH 5 8.7 TS
10 Gsg (GRN GRY) W/ LOC DENSE MAG MINERAL, DISS .5MM GRAINS
11 Gsg-40 Ds-10 CH 50 CH DRK GRN W/ PATCHES OF PK K FELD. PATCH PK K FELD AT 98, ABD SULFIDES. — Gsg DEFINITELY CUTS Ds AT 30 ABD MAG AND AP IN Gsg. FLOW BANDED.
12 CH-100 DRK GRN-BLACK, LOC K FELD PATCHES, VNTS S∅
13 CH-100 AA
14 CH-50, Ds 48, Gsg 2 VNTS OF GRN WHITE S∅ — DISS FINE MAG IN S∅, FINE MICA.
15 Ds 95 Gsg 5 FEW DIKELETS ~~Gsg~~ W/ MAG, BIOT.
16 Ds 100 GRAY-WHITE S∅ W TR PY, DISS BRN MICA — LOC WHITE, CLEAN W/OUT BIOT AND MAG.
17 Ds-75 Gsg GRN GR DIKE CUTS FOL IN S∅ AT 75CM. — Gsg LOADED W/ AP MAG F.G., Ds CRSE W. BLU AM, MAG, BT.
18 Ds, Gsg MIXED DOM FG, GRN-GRY W/ FEW PK PATCHES .42
19 Gsg, FG, DENSE, SCARCE MAG .28
20 Gsg 80, Ds 20 MIXED ZONE, WELL FOL @ 60° .38
21 Gsg 60, Ds 40 MIXED AA S∅ CRSE W/ BLU AM, MAG — LEAFY INTERGROWTHS OF CALCITE, BLU AM, BIOT, MAG. CORRELATES W/ …
22 Ds 100 CRSE W/ BLU GRN AM, BIOT — AA WELL DEV BRIM MAG TEXTURES. V2
23 AA "LEAFY" TEXT OF AM & BT. — AA
24 AA AA — AA
25 AA CRSE GRAIN — AA
26 AA AA — AA
27 AA AA
28 AA AA CRSE MAG →
29 AA AA
30 AA AA — LOCAL ZONES RICH IN APATITE
31 AA FOL AT 25° HIGH CONTENT OF BLU AM SILKATE RICH — AA
32 AA PERC 30% SILICATES. — AA
33 AA BANDS @ 60° TO CA — AA
34 AA — AA
35 AA — AA
36 Ds 100, CRSE SILICATE-MAG RICH ROCK, PRIM MAG TEXTURES LOC PATCHES OF GRN AP. — AA
37 Ds-100 AA
38 AA
39 AA
40 AA W/ RADIAL AGGREGATES OF GRN AM
41 AA — TH-5, 40.4 TS
42 AA
43 AA
44 Ds-100 FINER GRAINED FOL SUB ∥ TO CA. — 44.3 2 CM DIKE OF LAMP
45 F.G. SOVITE FEW WHITE PATCHES
46 F.G. S∅ W/ WHITE PATCHES W/OUT MANY SILICATES
47 WHITE GRY FINE GRND
48 AA SM DIKE Gsgy →
49 AA
50 AA
51 ← THIN 2 CM Gsg DIKE.
52 Ds 85, LAMP 15 BANDED AM-MAG RICH APATITE CONTACT AT 40° TO CA AT 52.85
53 LAMP 70, Ds-30 CONTACT AT 53.7 AT 60° TO CA — MINERALIZED DIKE FOL AND E IS INDETERMINATE — TH-5, 52.95 TS Photos @ 53.3 & 53.6 TH-5, 53.4 M TS
54 TYPICAL CRSE MAG RICH S∅ W/ ABD AP — ← AP RICH ZONE, HIGH MAG
55 Ds-100 CRSE, DRK BT FLAKES, AND MAG, AP
56 Ds-100 AA
57 Ds-100 AA
58 Ds-100% AA — BANDS AT 50° TO CA
59

DIAMANTBORING Tuftehavna 1982.

Kjerneobservasjoner.

Borhull nr. TH-6 Profil 2

Koordinator: Y 50999 X 141.495

Påsatt i høyde ~60 m. o.h.

« i retning 280^g

« med helning -70^o

Borhullets lengde 111.50 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	See appendix			

DDH TH-6   S.O. OLMORE   26/5/82   MAG   .3K CPS SCIN

0-6 NO RECOVERY

	MAG	SCIN	
G+ Tufte-type, RH, S+ MIXED, F.G. GRAY			
AA	0	75	HEALED, BROKEN ZONE 6-10.5M
AA	0	65	
AA	.02	65	
AA PATCH OF CH 9.7-10.3M	0.24	70	DISS FG MAG
AA	0.27	70	LGE MAG PHENOS @ 10.8
AA CH 11.5-12M	0.16	60	TRCS OF CH COM.
AA	0.31	70	FOL SUB II TO CA; DISS BLK SPECKS CB
AA	0.12	60	
G+ TUFTE TYPE GRY TO GRN GRY, F.G. CALCITE & DOLOMITE	0.81	65	
AA	0.27	70	
AA	1.08	85	AP-MAG SEGS, DISS P.O.
AA	3.44	90	ZONE COULD CORRELATE W/ TH-5
AA	8.51	80	FOL @10° TO CA; DISS MAG IN 5MM GRAINS
AA EXTREMELY MAG RICH	7.3	70	FOL @10° TH-6, 19.9M - CHECK FOR CB.
AA	7.5	115	DISS BRN P; 20-26 LOADED W/ DISS MAGNETITE
AA	6.8	125	COULD BE LOADED W/ BLK CB SPECKS.
AA	6.5	130	
AA	6.3	130	
AA RELICT PATCHES OF FX SØVITE	4.7	135	V HIGH @ 24.5M @ 170CPS. SAME RELS AS IN TUFTESTOLLEN TH.6,24.58
AA	5.8	130	FOL MIXED SUB II TO CA.
AA	1.6	100	
G+ AA w/ black specks, cuts Ds (søvite) yellowish, crse grnd.	.1	85	
	.1	60	RHOIKE @ 40° TO CA. DISS CB MINL
Do, G+ MIXED GRN GRY TO YEL GRY, CALCITE RICH	.24	80	DISS PY-CB THROUGHOUT, TR MAG, WK FOL. GRN AP.
	.92	80	
Ds? YEL GRY CRSE POSS DISS CB	0	75	
Ds? - PROBABLY ALT W/ G+ ABD AP. DISS BLK SPECKS. ?	.07	80	ATYPICAL SØVITE; DISS CB-BLK SPECKS IN RH
YEL-GREY CRSE SØVITE OR POL (RECRYSTALLIZED?) at DIKE @ 37.3 W/ YEL-PK MINERAL	.05	70	DIKE SHOWS HIGH RAD LEVEL
Rauh. I Fine gr.	.06	105	
Søv. Brecc	.08	115	140 cps at 35.4
∠30° C.A. 30°	2.06	110	
	0.13	110	
Søv	1.9	105	
	0.0	110	
Søv. fine gr. fol. 37,75 - 40° AP-vein	0.0	100	
Boudinage - 39,30 38,50 - 20° 39,85 - 28°	0.17	85	
Brecc, 25°	0.49	105	
Brecciated AP-rock w/ coronitic	3.64	120	
alteration textures and relict features	0.7	125	
cut by sövite veins:	2.0	125	
	0.16	140	
½ → 2 cm at 25° c.a. 25°	0.0	150	
	0.0	150	210 CPS AT 48.5
	0.0	105	
	0.0	120	
Brecciated AP enrich. søv. VEIN-syst 51.90 ∠35° 35°	0.0	140	180 CPS AT 51,3
	0.04	130	
Søv. fine gr. partly fol.	0.0	120	
Fol. 52,75 - 10°	0.0	100	
53,50 - 0° PY	0.7	90	
54,80 - 25° 20°	0.8	75	
Søv. impure MT-bearing, med. gr. AP	2.0	75	
AP/DOL-VEIN, PY-rich at 55,20 ∠20° c.a	2.2	60	
AP-VEINS 2-10mm 55.60-55,70 ∠55° c.a	3.2	60	
Zoned AP/DOL-vein 56,05-56,75 ∠65° c.a	6.3	60	
Rauh. II at 56.80° ∠50° c.a.	6.0	60	
	3.0	60	
	4.6	60	
Søvite, impure, massive w/ blue am. Weakly	6.8	60	
developed fol. at 63.40 ∠40° c.a. 62°	4.0	60	
cut by rauh + AP-vein ∠65°	4.2	60	
Not confirmed AP-enrichment	8.7	60	
around 64.50. Vein at 66.70 ∠62°	7.6	60	
Do. but significant AP-enrichment and	2.9	60	
less blue am. Rauh II veinlet at 69.40 ∠40°	4.7	70	
Do. blue am. rich. AP	6.7	70	
	4.9	75	100 cps at 72,10
Søv. impure, gen. blue am. M = 20-40 % PY	4.9	60	
AP-enrichment at 72.25 - 72.40	6.5	60	
PY rich rauh. 93.80 ∠55° 65°	4.2	60	
	2.9	70	
Do. alternating w/ rel pure søv. PY-rich AP 28°	2.5	75	
Occ. well fol. AP RAH 35°	1.2	80	[illegible] cps at 78,20 and 78,80
at 75,90 ∠65° AP 45°	4.5	75	
cut by num. Rauh. - AP vein			

DARK GREY AP+RICH, GNEISSIC FOL. 70° AP
Do. as 71.05 - 75.50 m, Brecc. AP-rock
AP + DOL-vein 35° DOL
MOSTLY PURE WHITE SØV. CUTTING AP-rich GNEISSE SØV
DO. as 71.05 - 75,50 m. AP

AP
30° AP

Homogeneous and massive søv. med/coarse gr. PY+MT
partly blue am. BT-cryst 1-4 mm AP
and AP-rich in upper part. Impure

AP 57°
Sharp upper contact of gneissic dol (+/AP) rock + rauh. Ap 45°
gradual trans. toward massive imp. søv. as AP-rich.
93,30 - 98,50 AP-PY-enrichm. 101.60 - 101,75

10°
Sövite, fine gr. gneissic. Variable amount
of BT + PHL - impl. 0 - 2 % < 3mm 20° AP
High PY-content. AP-breccia 105,15 - 105,70 90°

fd 35°
AP+MT
40

søv. med. gr. weakly fol.
søv. dark grey brecci.

[illegible] 24/4-83

DIAMANTBORING Tuftehavna 1982.

Kjerneobservasjoner.

Borhull nr. TH-7 Profil 3

Koordinator: Y 50963 X 141.575

Påsatt i høyde ~ 71 m.

" i retning 100°

" med helning -45°

Borhullets lengde 85.50 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
0- 4.05	Overburden			
4.85	Søvite, rusty impure, well fol. at 4.60		60°	
6.50	Rauh. I, with patches of BT+AP-rock. Massive between 5.60-5.95			
7.00	Søvite, rusty, rel. pure (rauh. I with much calcite).			
7.40	Rauh. I,			
7.65	Rauh. I, rich with calcite.			
7.85	Søvite, impure and AP-rich.			
8.10	Rauh. I, Lower contact		50°	
10.45	Søvite, impure.			
10.83	Rauh. I.			
12.35	Søvite, with MT+BT phenocryst.			
14.95	Søvite, rauhaugized, strongly brec. Dark grey, patchy, well fol. Rusty between 12.85-13.85 Fol. at 13.90		35°	
15.65	Søvite, MT-rich, massive, coarse/med.gr. MT => 1 - 5 cm.			
15.90	Søvite, MT-rich, phenocryst. 1-10 mm. + / - AP and BT. Fol. at 15.70		90°	
20.95	Søvite, impure, w/ grey silicates occational MT - phenocryst. Weak fol. Coarse to med.gr. 1 - 5 cm thick MT + AP - BT rock dikes at 16.70, 16.95, 17.05, 17.20 and 19.40. Pure søvite-dikes (?) at 16.02-16.07 16.62-16.70 16.80-16.93 17.10-17.16 Fol. at 17.50 Py-vein, 2 mm thick at 18.20.		80° 10°	
21.80	Søvite, veins with cal. rich rauh. veins.			
27.50	Søvite, med.gr. with BT-phenocryst. 2 mm. Well fol. at 24.15-24.75 24.20 24.60		85° 55°	

1000-9-74. FS 0030. A 4. H. C.

Ark 2 Bh. nr. TH-7 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Pure søvite at 24.75-24.95			
	Well fol. at 27.32-27.50, 27.90		60°	
	Rauh. vein at 27.40°		0°	
31.70	Søvite, coarse gr. with fine grained cross-cutting gneissic grey søvite. Increasing amount of BT-phenocryst. < 15 mm. Fol. at 29.40.			
32.05	Søvite, fine gr. impure grey and AP-rich.			
32.17	BT + AP-rock, coarse gr.			
32.45	Søvite, fine gr. grey, gneissic. Fol. at 32.40.		75°	
34.90	BT + AP-rock, very coarse to coarse, partly fol. at 34.50		50°	
35.00	Søvite, BT + AP-rich			
43.15	Søvite, coarse gr., patchy AP-decreasing BT-phenocryst variable. Blue am. variable.			
	Occ. weak fol. at 39.50		60°	
	40.60		85°	
	41.60		40°	
43.80	Søvite, coarse, pure w/sharp contacts.			
48.10	Søvite, coarse and impure with veinlike bodies of MT + AP-vein BT-silicate rocks.			
	Locally gneissic fol. at 46.20		80°	
	Rauh. I at 46.90-47.00			
48.80	Søvite, coarse gr. impure w/blue am.			
49.10	Rauhaugite, Calc.-rich fine gr. grey with AP-vein (Søv. or Rauh.?)			
49.60	Søvite, impure with blue am.			
50.15	Mt + BT + Py-concentration, coarsegr.			
50.25	Rauhaugite I, fine grained with grey AP.			
50.80	Søvite, impure med. gr.			
54.45	Rauhaugite, fine grained, grey with AP.			
	Fol. AP-dikes at 52.30 and generally sub-parallel at 53.15-54.45		5°	
	Patches of søvite.			
56.00	Søvite, patchy and silicate rich and massive. Coarse gr. MT-grey silicate-AP (access.)			
56.05	Søvite, Impure, med.grained with BT-phenocryst 1-3 mm. Gneissic appearance at 56.40-56.55.			
	Fol. at. 57.50		40°	
59.85	"Silicate-søvite", w/grey silicate MT-agg. (< 3 cm) anh, euh. BT (< 1 cm)-minor PY or PO.			
	AP-vein at 57.30		15°	
	58.15		45°	
	Rauh.-vein II 58.40-58.55		18°	

Ark 3 | Bh. nr. TH-7 | Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
60.00	Rauhaugite (?), massive, grey fine to med. grained. AP-bearing.			
68.50	"Silicate søvite", massive, coarse andpatchy, 20 % blue, green sil. am. 15 % MT, very coarse agg. or occationally euh. phenocryst. 5 % BT- phenocryst. euh/subh. Well fol. gneissic transection at 60.45 64.05-64.30 w/strong PY-min.		 35° 50°	
	MT + BT + CALC -rock, very coarse grained at 65.80-66.15 BT + AP -enrichment at 67.50-67.60 MT -enrichment 67.60-68.10			
70.95	Søvites, variable types, generally coarse to med. gr. AP-rich. BT + MT -content ~10 %. either as fine/med. grained anh. grains, or very coarse euh. phenocryst. Weakly foliated at 69.30		 35°	
71.85	MT + AP-rock, massive No BT			
73.55	Søvite, massive, coarse/med. gr. AP + MT, w/minor BT.			
74.45	MT + AP -rock, massive, No BT. Coarse grained.			
76.65	Søvite, AP + MT w/minor BT. Weakly for., at 74.90 Numerous rusty dolo.stringers.		 80°	
76.70	Core loss			
77.60	Søvite, AP + MT as above. Extremely rusty. 1-3 mm euh. MT-cryst.			
77.85	Søvite, rel. pure and massive w/euh. MT-phenocryst.			
80.00	Søvite, impure, rusty and foliated. Significant dolo. stringers < 5 mm thick fol. < 1 cm euh. MT-phenocryst. The søvite less thoroughly weathered. 79.65-79.95 pure søvite, strongly weathered.			
85.50	Søvite, BT-rich, impure Great core loss. 40 cm. recovered.			

T.H. 24/1-83

1000-9-74. FS 0031. A 4. H. C.

DIAMANTBORING Tuftehavna 1982

Kjerneobservasjoner.

Borhull nr. TH-8 Profil 3

Koordinator: Y 50.962 X 141.575

Påsatt i høyde ~ 71 m.

« i retning 100^g

« med helning -68°

Borhullets lengde 132.00 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
0- 1.60	Overburden			
2.05	Core loss. Rusty rel. pure søvite.			
3.60	BT-søvite. BT - 5-10 %. White rel. homogenous			
	BT- PH- agg. 1-3 cm.			
	Chlorite filled joints at 2.50		40°-60°	
	3.20		10°	
4.15	Do. heavily weathered and rusty.			
	Rusty joints 3.75-4.10		0°	
4.80	Interlayered søvite and rauh. veins, all rusty			
	Rauh. veins 4.15-4.18		35°	
	4.25-4.35		80°	
	4.75		50°	
5.85	Rusty søvite w/ gneissic appearance.			
	Fol. at 5.70.		85°	
7.00	Brecciated søvite. Interstitial rauh. in subordinate amounts.			
7.90	Do. but rauh. dikes at ~ 30 % of total in irregular patches and along joints.			
	Fol. in søvite at 7.50		65°	
	Joint at 7.60		35°	
	The rauh. clearly cuts the fol. in søvite.			
9.20	Impure søvite w/ irreg. stringers and patches of mafic concentrations.			
	Rauh. vein at 9.10		60°	
9.55	Do. but mafics min. make up > 25 % incl. PY + MT + BT.			
10.05	Søvite w/ irreg. patches rich in MT + PY.			
12.45	Weakly fol. søvite w/ 5-10 % M.			
	Fol. at 10.60		75°	
	Rauh. vein 11.75		30°	
12.65	Massive rauh. dikes interlayered w/ gneissic fine grained søvite. PY-rich (5 - 10 %)			
	Fol. at 12.55		45°	
12.85	Gneissic søvite as above.			
18.00	Impure søvite, massive to well foliated medium to coarse grained.			

Ark 2 Bh. nr. TH-8 Profil 3

Boret meter	Bergart		Kjerne-mangel	Skifrighet	Bergart prøve
	Rusty weathered	13.40-13.70			
	BT + AP -stringers	13.85-14.05		20°	
	Rauh. vein 1 cm	14.33		50°	
	AP -rich gneiss	15.20-15.22		25°	
	BT+AP+MT enriched søvite	15.22-15.80			
	BT+AP -enrich/BT+AP -rock	16.00-16.30			
	Numerous mm-thick rauh. veinets at	15.80-16.00 16.50			
	Fol. in søvite at	17.50		50°	
20.20	Do. Med. to fine grained. Well foliated, locally PY -enriched at	19.90-20.00			
	Fol. at	18.70		50°	
	Cross cutting søvite dikes 1 and 3 cm thick at and	20.05 20.12			
20.40	Rauh. dike small fraction of søvite.				
20.90	Well foliated, gneissic impure søvite.				
	Fol. at	20.65		50°	
	Joint at	20.90		35°	
22.70	Med. grained impure søvite. Weakly fol.				
	Rauh. dike 2 cm at	21.50		25°	
	Deeply weather and rusty at	22.30-22.70			
24.20	Coarse grained BT-søvite. BT + PH cryst. <1 cm, PY + AP enriched locally at	23.75			
	Fol. at	23.20		60°	
24.55	Massive fine grained banded white and grey (AP ?) søvite				
	Banding / foliation at	24.30		25°	
25.10	Coarse grained BT -søvite as above.				
25.60	Mostly fine grained banded søvite as above, interlayered w/ coarse BT -søvite.				
	Fol. at	25.50		35°	
	(This fol. seems to be secondary in rel. to a compositional banding).				
26.65	Coarse BT -søvite.				
27.00	Massive BT + AP -søvite.				
27.90	Very coarse, 5 cm, relict patches of (BT) + AP -rock w/ interstitial søvite.				
	Fol. at	27.20,		90°	
	cut by gneissic søvite-veins at, or rauh. (II ?).			5°	
35.55	Coarse BT -søvite, amounts of BT + PH -cryst, highly variable 0 - 15 % per 10 cm core. Occational cm -sized euh. MT -cryst. Large num. of rauh. veinlets				
	especially at	31.00-31.50 33.50-33.85		10°-50° 10°-90°	
	BT+AP -enriched søvite at	33.40-33.50			

Ark 3 Bh. nr. BH-8 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
35.90	MT -søvite. Starting in a coarse grained skeletal texture gradually turning to banded fine grained plastically deformed (?) texture. Fol. varies from 90° to < 10° along lower contact.			
40.65	Impure søvite, generally well foliated pure søvite dikes at 37.25-37.30		85°	
	38.70-38.85		90°	
	and between 39.60-39.80		45°	
	The latter is seperated in several zones by mafic layers of MT + tremolite (?) + AP (?) -rock. The tremolite appears as radial aggr. 5 mm.			
	BT + AP -rock at 39.27-39.32		60°	
	cutting fol. in adjacent søvite		45°	
	Paches containing blue amph. agg. locally at 40.35			
	Fol. søvite at 40.60		30°	
	41.90		47°	
42.85	MT, grey silicate søvite cyt by rauh. veinlets.			
44.00	Impure massive søvite w/ 5 - 10 % M.			
44.40	Veins of rauh. and veinlets intercalated with søvite.			
51.75	Impure søvite.			
	Rauh. at 44.60-44.70			
	48.95-49.05		50°	
	Fol. at 47.45		35°	
	50.35		40°	
52.85	Massive BT+AP -rock of grain size varying from fine to very coarse calcite bearing. Upper contact		50°	
53.10	Impure foliated søvite.			
53.85	Fine grained BT + AP -rock.			
61.10	Impure foliated søvite w/ patches and stringers of BT + AP -rock up to 5 cm.			
	wide at: 55.00-55.50			
	55.95-56.35 with		50°	
	at lower contact (sub) parallel in søvite 57.90-58.00			
	58.45			
	Fol. at 59.40		30°	
	Rauh. and dol. vein at 61.10			
63.10	Alternate pure white søvite and dark grey impure søvite, AP -rich.			
	Fol. in mafic patches 62.35		55°	
64.05	Dark grey well foliated impure søvite w/ some pure søvite bands.			
	Fol. at 63.20		50°	
68.85	Rel. pure søvite w/ dark grey patches and numerous rauh. II veins crisscrossing especially at 65.30-65.80, also cut by mm. thick bracciating chlorite veins.			

Ark 4 Bh. nr. TH-8 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Fol. at 65.30		53°	
	Rauh. w/ AP -vein at 67.60		50°	
	Dark grey impure søvite at 67.65-67.75			
69.95	Same but pink.			
	Rauh. II 69.90-69.70		20°	
74.15	Med. grained MT -søvite well foliated M > 20 %.			
	Pure søvite at 70.45-48.00		40°	
	Thin rauh. at 70.70 + AP			
	71.40		20°	
	71.60 + AP		80°	
	72.55 + AP -vein			
	73.70			
	Fol. at 71.25		75°	
75.85	BT -søvite (BT < 5 %) massive without distinct foliation. BT as < 3 mm phenocryst.			
	Rauh. II at 75.15			
78.60	Søvite as above w/minor irreg. patches / stringers of AP -rich.			
	Minor BT in both rock types.			
	AP -vein at 78.55		90°	
	Weak fol. in søvite at 78.20		75°	
83.65	Same, but AP -rocks are major constituents (~ 40 %). Coarse grained. Occasional MT -phenocryst.			
	Fol. 80.25		50°	
85.25	Impure søvite fine to medium grained MT -rich => grain size 1-2 mm.			
	Weak fol. at 83.75		80°	
90.10	Rel. pure søvite, weakly foliated w/ occational BT and MT -phenocryst.			
	Rauh. I -dike, 3 cm at 88.60		37°	
	Mm -thick rauh. II veins at 88.70		25°	
90.20	Pure søvite dike		45°	
91.25	Well foliated silicate rich søvite. MT -phenocryst 2 % i 1-3 mm			
	Fol. at 90.40		60°	
	90.30		65°	
96.20	Impure med./fine grained søvite. No distinct fol.			
96.45	Rauh. I dike tangential e.a.			
102.25	Impure søvite distinct fol. Med. grained.			
	1 cm rauh. I -dike at 96.80		60°	
	cutting rauh. II veins		15°	
	AP -veinlet at 97.50		75°	
	Fol. at 98.50		25°	
	AP -dike at 99.50-99.70		15°	
	99.75 cutting (?)		20°	
	Rauh. II at right angle			
	AP -dike 5 cm at 100.05		20°	
	AP -dike 1 cm at 100.95		25°	

Ark 5 Bh. nr. TH-8 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
103.45	Coarse gr. silicate MT -søvite, blue amph., Anh. MT. Grain size 3-15 mm.			
104.55	Impure søvite.			
104.75	Pure søvite			
107.65	Impure søvite, coarse / med.gr., partly blue amph. -bearing. MT -usually occur at anh. skeletal aggr. < 3 cm, last 5 cm of section shows enriched euh. MT -cryst. 5-15 mm. 3 mm thick AP-vein at 107.50		40°	
107.75	5 cm pure med. gr. søvite			
107.90	Impure coarse søvite as above, dominantly cut by composite dol. + AP -dike.		25°	
108.00	Pure søvite			
108.15	Impure coarse søvite as above			
108.30	Composite dol./ AP -dike w/ rounded fragments of rødbergite (?) related to damtjernite phase of intrusion (accord. to S.P.O.)			
123.70	Impure coarse grained søvite. AP - MT (euh.) enrichment at 108.80-109.05 AP - enriched, BT bearing at 109.95-110.40 Gneissic development at 110.60-110.70 110.95-111.00 Pure med. gr. søvite at 111.40-111.55 112.25-112.60 AP -enrichment at 113.30-113.90 Pure med. gr. søvite 113.90-114.00 MT + AP + BT -enrichment at 114.00-114.35 MT -euh. 1-5 mm, BT subh. < 3 mm. Pure søvite 116.25-116.45 AP -enrichment / AP -rock at 117.00-118.30 Do. 118.50-118.70 MT (euh.) (0.5 - 1.5 cm) + AP -enrichment at 120.70-120.90 Do. 121.60-121.80		70°	
125.40	Med.gr. impure BT, grey-blue amph. søvite. AP -veinlet at 123.80		20°	
26.40	Coarse gr. rel. pure søvite w/blue amph. < 1 cm. Gneissic at 126.00, fol.		75°	
127.00	Do, but higher fractions of dark mineral.			
127.30	As from 125.40-126.40			
128.90	As from 126.40-127.00 with max. M at 127.00-127.20 Fol. gneissic rock at 128.60		60°	
130.07	Alternating pure søvite and very coarse blue amph.- and AP -bearing søvite.			
131.15	Fine / med. gr. fol. impure søvite- Euh. MT-cryst. and PYCHL - emp. Fol. at 130.85		55°	

Ark 6 Bh. nr. TH-8 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
131.30	Gneissic AP- and dol. rich søvite (?) or rauh (?)			
132.00	Fol. impure søvite as above, but lightly variable fol. Fol. at 131.40		40°	
	Stop at 132.00.			

G.H 24/4-83

DIAMANTBORING Tuftehavna 19 82

Kjerneobservasjoner.

Borhull nr. TH-9 Profil 4

Koordinator: Y 50957 X 141.65

Påsatt i høyde ~ 71 m.

« i retning 80g

« med helning -45°

Borhullets lengde 85.30 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Se vedlegg.			

1000-9-74. FS 0030. A 4. H. C.

By:
S.D. Olivo
J.E. Wanil
H. Quale
I. Hutti

Depth	Description				Remarks
2					
3					
4	Ds sd w/few pink patches, com py, am, ap.		1.5	70	
5	Ds sd, crse grnd w/ ap. tr biot mag, am		2.9	75	
6	Ds sd, w/10cm ap dike @ 30-40cm.	AP	4.4	90	
7	AA patchy white & green sd. pk alkali fs @ 50cm.		2.9	80	FeOx zones 60-100
8	AA mag-ap-blu am sd; blotches & bands, segregations.		3.5	80	graphic mag
9	AA AA AA		2.5	75	AA
10	AA AA AA		2.6	75	AA
11	AA AA		3.3	70	AA
12	Ds crs bladed calcite, graphic mag, blotchy ap.	AP	4.6	75	AA
13	AA apatite rich 2 cm dike @ 30cm.		1.5	97	rel high rad.
14	AA		2.0	70	
	core missing → 13.75-15.1				
15			—	—	
16	Ds loaded w/ diss 2mm euh mag, biot, patches of blu am.		4.5	70	tr sulfides.
17	AA but finer grained.		4.0	65	
18	AA crudely banded, blotchy textured, crse grnd. graphic mag		8.5	65	mag-ap rich zone @ 17.15.
19	AA		5.8	75	
20	Ds crse mag-ap-biot-am rich.		6.5	70	
21	AA w/ streaks of red mineral @ ~40cm.		7.4	70	TH-20.4 TS
22	Ds crse AA		6.5	70	
23	Ds AA v High in apatite.		5.3	90	
24	Ds AA- blu am, mag, biot, ap crse		4.5	110	
25	Ds AA grades to finer grained white barren sd w/ f.g. mag & poss cb		4.5	130	180 cps @ 24.9
26	Ds fine grnd, white, diss sm specks of mag, cb?		.5	130	
27	*Ds fine grnd, white, AA		.3	120	
28	Ds- crse fol @ 40° streaks of ap-blu-am crse biot		3.4	110	red streaks.
29	Ds-crse AA		1.8	200	
30	Ds-both f.g. sd gray diss mag & cb? specks biot		2.0	170	late dol or ap vn w/ rad along core axis.
31	AA AA		2.6	170	
32	AA f.g. sd AA		2.7	150	
33	AA AA		.5	120	
34	Ds both f.g. & crse grnd, blu am rich. mixed		.7	90	
35	AA		2.4	70	
36	Ds crse w/ blotches of blu am 1cm in dia		3.2	70	
37	Ds AA w/ ap rich zone 36.5 → 37		.8	70	
38	Ds w/ near massive blu amphibole seg. also mag & ap		5.3	70	
39	Ds near barren, sulfide rich white, loc ap pods.		1.2	80	
40	Ds patches & orbs of blu am, graphic mag, crse biot		4.9	170	
41	Ds AA w/ special orbicular blu am patches		9.76	70	special red brown mineral?
42	Ds AA		6.68	70	
43	Ds AA streaks of blue am tr ap, graphic mag		4.8	70	
44	Ds AA streaked blu am. FeOx stn.		2.1	120	
45	Ds crse → f.g. pink sd w/ poss diss cb, tr biot, mag.		2.3	150	
46	Ds white, med → f.g. barren		1.0	130	
47	Ds graphic mag, ap, blu am med grnd.		1.5	100	
48	Ds AA		2.8	80	
49	Ds AA 48.6 crse xtals mag intergrowths of mag & ap		4.2	85	
50	Ds white → lt gray f.g. wk fol.		2.1	90	
51	Ds AA w/ streaks of blu am towards base		4.3	80	
52	Ds med → f.g. gray → white blu am graphic mag		4.5	80	
53	Ds AA- white-gray to pk sd, locally bladed calcite		2.6	110	
54	Ds f.g. gry well fol sdv.		1.2	110	
55	AA f.g. gray → pk sd.		1.4	170	
56	AA w/ poss dol dike @ 60 cm also @ 95cm.	AP	0.7	140	
57	AA pk-wh- med-f.g. sd. ap seg @ 90cm.		1.2	110	
58	Ds loc crse bladed calcite w/ mag & ap. & blu am		3.3	80	
59	Ds variable text ap, blu am, mag, banded.		2.5	80	
60	Ds AA, "leafy" texture		1.7	110	
61	Ds white, & pink med → f.g.		0.2	180	
62	AA local segregations of mag.		0.7	200	
63	AA w/ poss diss cb minz		0.3	160	
64	AA		0.1	170	
65	AA		0.1	180	
66	AA w/ poss gray dolomitization adj. fracts		0.2	180	
67	AA		0.1	170	
68	Ds - gray → grn-gry streaked blu am.		0.8	120	
69	Ds loaded w/ blu am, biot, mag. mag is euhedral.		3.9	90	loc patches red brown min.
70	Ds mixed- low content of blu am & silicates some graphic mag		1.3	80	
71	AA		2.3	70	
72	AA w/ streaked blu am & mag.	AP	1.1	70	
73	AA w/ pods of blu am, ap & mag.		3.5	65	
74	AA		2.1	70	
75	Ds w/ loc segs of blu am, mag, ap.		6.0	70	
76	Ds weakly fol. 75.35 ⇒ 60°, sc bl. Am.				
77	Ds Very coarse				
78	Ds ful. fine gr. Rusty, fol. 77,50 ⇒ 56° 78,15 ⇒ 35°	AP			
79	Ds Massive coarse gr. M ≥ 50%				
80	Pure søvite	Py			
81	Ds. M < 10%	Py+BT			
82		Py+AP			
83	Søv. fine gr. fol. 83.40 ⇒ 75° 85.15 ⇒ 46°				
84		Py			
85					

DIAMANTBORING TUFTEHAVNA - FEN 19 82.

Kjerneobservasjoner. H. Qvale.

Borhull nr. TH-10 Profil 4

Koordinator: Y 50956 X 141.615

Påsatt i høyde 70.5 m.o.h.

" i retning 80^g

" med helning -70^g

Borhullets lengde 122.00 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
0 - 2.50	Overburden			
	Rødbergite, red to grey, fine to med.gr. w/relict unaltered søvite blocks <10 cm. No appearent foli.			
5.65	Med.gr. bi.- søvite cut at by rauhaugite II - veinlets		90°	
5.70	AP-rich rauhaugite II - dike.			
6.50	Rel. pure søvite crossed by rauhaugite-veinlets		90°	
9.75	Patchy med.grained bi-søvite. Numerous mm-thick veinlets of chl/ap/dol (?) Mostly sub parallel to foliation.			
10.80	Coarse gr. impure massive, blue amphibole bearing søvite, rel. rich in AP at 10.50.			
14.95	Coarse gr./alternating med.gr. bi-søvite and coarser almost (?) pegmatitic pure søvite veinlets (1-2 cm). Variable AP-content, although never exeptional.			
	12.05-12.45 med.gr. pure søvite			
	14.15-14.40 oxidizing alteration			
	along joints.		40°	
29.95	Massive impure søvite w/blue amf., skeletal bi + MT with occational euh. MT-clusters. Med. to coarse gr. rødbergitition at			
	16.10-16.30		40°	
	17.40-17.80		35°	
	along joints.			

1000-9-74. FS 0030. A 4. H. C.

Ark 2 Bh. nr. TH-10 Profil 4

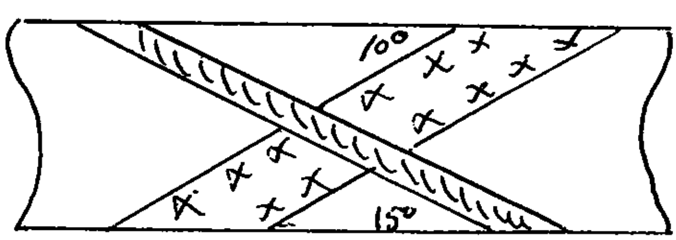
Boret meter	Bergart		Kjerne-mangel	Skifrighet	Bergart prøve
	AP- vein at	18.40		55°	
	AP + DOL-vein at	22.70-22.75		30°	
	AP - enrichment at	23.35-23.65			
	AP - enrichment at	24.35-24.60			
	Gneissification / well foliated locally with AP and PY-rich at	25.05-25.75			
	Foliated at	25.30		70°	
33.50	Same, but coarse / very coarse and dominated by blue amp. Other major phases anh. bi, anh.skeletal or enh. MT.				
	Well fol./gneissic	32.10-32.25		70°	
34.00	Same, but low in blue amp. and euh. MT.				
34.95	As from	29.95-33.50			
37.05	Rauhaugite (?) I at	36.70-36.80			
	Med./coarse grained grey/green skeletal MT.				
	Rauhaugite II at 37.50 (5 cm).			10°	
44.70	Med./coarse grained massive søvite, impure w/grey/green silicates, AP + /- bi + /- MT (both the latters mostly as relict skeletal				
	in alteration	42.00-42.50			
	with rel. pure søvite.				
45.15	Impure well foliated søvite. This section shows zoning around pure søvite	44.90-44.98			
	and increasing mag. to both sides. Foliation at 44.90.				
47.20	Coarse impure, mostly blue amphibole bearing massiv søvite. Extrusive zoned, ph, blue amph. Rauhaugite II (1 cm) at lower contact.			80°	

Ark 3 Bh. nr. TH-10 Profil 4

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
47.50	Med. grained rel. pure søvite, no distinct fol.			
48.00	Some but high in mag. ≈ 40 %,			
	dominated by MT + BT. Minor blue amph.			
50.05	Coarse - very coarse grained blue amph. + MT +			
	BT + AP and impure søvite.			
	MT enhed. < 2 cm.			
	Blue amph. anh. < 2 cm.			
	Massive blue amph. + MT + BT + AP rock alt.			
	no/pure søvite from 49.50-49.85.			
50.50	Med. grained BT + MT søvite			
	M = 50-10 %.			
51.50	Massive coarse blue amph. + MT + BT -rock.			
	No foliation.			
	Blue amph. content and grain size decreases.			
	M = 5-50 %.			
	Chlorite filled joint at 51.10		10°	
53.63	Fine/med. grained impure BT + MT -grey silicate			
	søvite.			
53.75	Foliated rauhaug II.		90°	
60.00	Massive or weakly fol. impure coarse søvite			
	dominated by blue amph. + MT and BT.			
	Foliated at 54.40.			
	MT + blue amph. segr. 55.55-55.65		45°	
61.20	Impure grey/green amph. (?) + BT + AP -søvite.			
	Massive but cut by numerous veinlets			
	(rauh. II ?) at 60.60.		10°	
62.10	Alternating pure søvite and clusters of			
	AP + MT -grey silicates + BT.			
	Cut by rauh. II (1 cm) 61.50°		7°	
	rauh. II (3 cm) 61.80°		70°	
62.95	Rel. pure søvite with relict skeletal BT, to			
	some extent elongated at 62.85 m.		70°	
	Coarse grained rauh. II (1/2 cm)			
	parall. at ca. 62.40-62.85 m.			
64.95	Well foliated impure søvite. As above, but			
	with additional fine/med. gr. MT.			

Ark 4 Bh. nr. TH-10 Profil 4

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	(M 20 % in plain søvite) but cut by MT +			
	silicate segr. at 63.30 (4 cm thick)		25°	
	(II foliation).			
	Rauh. II vein (2 cm) at 64.60		15°	
	Foliation at 64.95		55°	
66.55	Weakly foliated fine- med. grained MT + BT			
	-søvite.			
	Foliation 65.75		70°	
	Veinlets (Rauh. II ?) 65.15		20°	
	and at 65.70-66.00		10°	
	Rusty weathered rauh. II at 66.55 parall.			
	foliation.		40°	
69.00	Coarse bl e amph. + MT + BT + AP -søvite.			
	Between 68.40-68.85 CC < 20 %.			
	Weakly fol. at 68.50		40°	
71.65	Coarse søvite, M ~ 5 % exept 69.95-70.35			
	where M ~ 10-15 %.			
	Weakly fol. at 69.70		45°	
	Rauh. II (1 cm + 2 x 1 mm) 69.50		85°	
	Rauh. I 70.15		25°	
	cut by rauh. II-veinlets.		15°	



Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
77.15	Coarse massive blue amph. + BT + MT + AP -søvite.			
	M ~ 50 %. Gneissic rauh. I 72.18-72.32		35°	
	with desiminated columbite		90°	
	AP-enrichment, gneissic 73.45-73.55			
	Rauh. II veinlets at 76.85		10°	
	Fol. at 74.75		35°	
78.80	Same, well foliated fine- med. grained, fol.			
	77.80		70°	
	78.55		40°	
	Dol. dom. at 78.55-78.70			
	Rauh. I - gneiss.			

1000-9-74. FS 0031. A 4. H. C.

Ark 5 Bh. nr. BH-10 Profil 4

Boret meter	Bergart		Kjerne-mangel	Skifrighet	Bergart prøve
81.95	Coarse grained as to	77.15			
	but M ~ 10 %, and concent. in				
	bands/patches, and cut by several				
	irregular dikes at rauh. I at	80.15-80.45			
		80.60-80.80			
		80.95-81.10			
		81.50-81.80			
91.90	Same, but higher M : 10-75 %				
	mostly dom. by blue amph.				
	agg. ~ 1-5 cm.				
	Euh. MT is com. At 81.95 BT +				Sample
	AP -rock (82.05-82.13) is cut			25°	
	by rauh. I. Rauh. II at	84.20		30°	
		89.10		10°	
		88.45		50°	
	Fol.	86.85		70°	
		88.80		80°	
	Gneissified at	91.80-91.90			
	Corona text. around blu amph. at	91.80			Sample
96.55	Med.grained, blue (/green)				
	amph. still present, but only as				
	single grain or smaller agg. without.				
	prefered orientation.				
99.15	Alternating rock as above, but with				
	well developed foliation and banded				
	fine grained BT-søvite.				
	Foliation	96.35		65°	
		97.70		0°	
		98.80		20°	
99.30	Pure søvite.				
111.25	Med./ fine grained impure søvite				
	with occational zones of pure				
	søvite mostly at	100.10		90°	
		100.50			
		101.10			
		103.05			
		104.85			

Ark 6 Bh. nr. BH-10 Profil 4

Boret meter	Bergart		Kjerne-mangel	Skifrighet	Bergart prøve
	AP. zones at	102.15		80°	
	AP + BT segregation along pure				
	søvite at	103.05			
	AP-enrichment at	104.80		55°	
	Rauh. I (3 cm) enclosed in gneissic				
	fine grained søvite (impure) rich				
	in py.				
	Foliated at	105.25-105.50		20°	
	Pure søvite at	106.25,		50°	
	foliated.				
	Spenifex looking texture at	108.10-109.65			
		110.50-110.80			
	Irregular foliation pattern				
	generally			90°	
118.05	Real pure søvite weakly foliated.				
	BT+AP+MT-segregation in				
	coarse søvite	113.15-113.40			
	Minute BT + AP -segr. at	115.30			
		117.05			
	Pure søvite at	116.20-116.35			
	Foliated at	118.05		80°	
118.50	Pure søvite				
119.00	Very coarse AP + blue amph. +				
	BT segregation in pure søvite.				
	Inhomogeneous AP-rich impure søvite				
	patches of grey-green silicates,				
	AP; brecciated segregation of				
	these and pure søvite				
	Rauh. II (1 cm)	119.50		5°	
		120.25		45°	

YH. 24/4-82

DIAMANTBORING Tuftehavna 1982

Kjerneobservasjoner.

Borhull nr. TH-11 Profil 5

Koordinator: Y 50.989 X 141.456

Påsatt i høyde 61 m.

" i retning 79^{g}

" med helning -45^{o}

Borhullets lengde 39.50 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
0- 3.15	Overburden			
7.20	Coarse impure søvite Massive partly skeletal. No distinct fol. BT + MT + green amph. M < 25 %			
10.05	Rauhaugite, fine grained M 10 %, gneissic, locally well foliated M < 50 - 70 %.		$50-70^{o}$	
17.00	Coarse /med. gr. impure søvite as 3.15-7.20 Foliated. Rauh. I at 10.95-11.00			
18.95	Med. gr. pure søvite.			
21.60	Intercalated foliated pure søvite, impure med. gr. søvite and mafic bodies of hollaite ?			
29.50	Oxydized - rusty carbonatite			
39.40	Oxydized synitic rock (MT + FSP) and hollaite.			

1000-9-74. FS 0030. A 4. H. C.

GH 24/4-83

DIAMANTBORING Tuftehavna 1982.

Kjerneobservasjoner.

Borhull nr. TH-12 Profil 3

Koordinator: Y 50942 X 141.569

Påsatt i høyde ~ 72 m.o.h.

" i retning 80^g

" med helning - 72°

Borhullets lengde 201.35 m

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
0 - 2.30	Overburden			
2.95	Med. -coarse grained pure Søvite. -patches of BT and radial amph. aggregates (blue-green amph.).			
3.05	Gneissified rusty søvite as above. Foliated		55°	
4.75	Impure med. gr. søvite. Massive homog. subhedr. BT + AP -bearing M 20 %.			
7.50	Søvite, do. but M 50 %. MT-bearing, often euhedral.			
12.30	Med/fine - gr. greenish grey impure søvite M 50 %. Homog. massive.			sample
14.55	Coarse blue amph./BT/ +/- MT +/- AP impure søvite. Gneissic zones 13.95-14.05 Rauhaug. I gneissic 13.30 14.15-14.25		 65° 20° 43°	
15.65	Med./fine gr. impure grey green søvite. No apparent. blue amph.			
16.15	Gneissic rauhaugite I. Foliated at 15.95		63°	
24.25	Coarse massive patchy impure søvite w/BT + green min. (amph ?) and AP. Chlorite bearing streaks at 19.00-19.20 and 23.50.			
27.00	Fine gr. often well foliated impure. M ~ 30 % - BT - dominating. Fol. (≡ contact to former rock type) at 24.30 25.30		 25° 65°	
32.30	Rel. pure patchy søvite coarse/med. gr. increasing M = 5 - 50 %. Usually week or no foliation. Gneissic at 29.40 32.20 Cutting band at		 80° 70° 15°	
32.45	BT + AP + MT + PY -rock cutting (?) søvite coarse grained. Euh. MT.			
37.65	Homogenous BT + PY +/- MT søvite.			

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Ark 2 Bh. nr. TH-12 Profil 3.

Boret meter	Bergart	Kjernemangel	Skifrighet	Bergart prøve
	Rel. pure M ~ 5 - 15 %. No foliation.			
	Gneissic AP-rich at 33.60-33.65		90°	
	PO + MT at 33.90			
	Weakly foliated at 36.60		45°	
	37.35		48°	
	MT + AP -rock 35.60-35.85			
44.80	Patchy inhomog. impure coarse gr. søvite, rich in PO and +/- BT + blue amph. M ~ 5-50 %.			
	Brecciated near upper MT + AP -rock at 41.80-42.00			
	BT + AP - MT -rock transfering to very fine grained massive dark grey/black rock. (similar to hollaite ?) and to MT + AP -rock 42.70-43.10			
46.30	MT-rock. Dominantly massive coarse to very fine grained locally enriched in AP + PY + BT and with enclosed søvite "blocks" near lower end.			
	Contact sample at upper end. Foliation in søvite at 44.80		70°	
49.00	Fine grained weakly fol. and banded impure AP + BT -søvite. at 46.60			
	banding with,		20°	
	is cut by fol.		50°	
	M 5 - 25 %.			
	Søvite pegmatite at 48.70 along with gneissification and numerous rauh. II veins < 5 cm wide to 48.90.			
51.60	Coarse gr. blue amph. bearing impure søvite.			
	Rauh. II vein 0.5 cm thick at 49.90 reacts on HCl.			
	Weakly foliated, contains blue amph. + BT + MT + AP. M = 5 - > 50 %.			
52.20	As 51.60, but blue amph. out and MT in as dominant phase.			
55.90	Finegrained impure søvite w/ M ~ 50 %, green amph. + BT +/- AP +/- MT.			
	1 cm thick søvite pegmatite at 53.60		35°	
102.95	As 51.60, coarse grained cutting (?) pure søvite at 55.90-56.30. Irregular gneissification common between 57.40 and 57.80. MT -dominant			
	M - phase from 55.90-58.00			
	58.45-59.10			
	Thereafter mostly skeletal.			
	Blue amph. generally apparent or dominant, the latter continously from 65.80-73.20			
	and 74.40-79.00			
	Gneissic fol. at 58.40		80°	
	Rauh. II (?) at 64.08-64.15		90°	
	64.33-64.34		20°	
	Numerous CHL and -or PY-veinlets criss-crossing from 62.00-65.60			

1000-9-74. FS 0031. A 4. H. C.

Ark 3 Bh. nr. TH-12 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Patches and veinlets of			
	BT + AP -rock at 63.15			
	(2 - 3 cm)		70°	
	and BT + AP + MT -rock at 73.55-73.80			
	Pure søvite 73.20-73.55			
	coarse gr.			
	1 cm. veinlet BT + AP at 75.30			
	Weak fol. at 76.15		30°	
	Gneissic fol. at 79.20		45°	
	Very inhomogenous between 79.15-81.60.			
	BT + AP -rock stringers			
	and patches 79.75-79.50			
	and 80.05-80.15			
	Dark grey fine grained/very fine grained rock			
	(BT + AP ?) at 80.13-80.75			
	and rauh. II (?) vein at 81.55-81.58		15°	
	Weak fol. at 83.60		70°	
	88.95		65°	
	89.35		5°	
	Rauh. II (?) at 91.55-91.60			
	Fol. at 90.95		90°	
	Rauh. II (?) at 92.10-92.15			
	Rauh. I at 93.25-93.35, fol.		45°	
	Blue amph. dominanting 92.40-94.80			
	Rauh. II (?) at 96.55		15°	
	Fol. at 98.95		30°	
	100.40		40°	
105.40	Impure foliated søvite, fine grained and mostly gneissic, intercalated with other rock types.			
	Rauh. I at 103.02-103.40			
	BT + AP -rock at 103.60-104.20			
	with Rauh. I.			
	Cut by unfoliated søvite 104.20-104.70			
	w/ BT + AP -rock at 104.60 (3 cm)			
	Rauh. I at 104.70-104.95			
	BT + AP -rock at 104.95-105.30			
	Foliated at 103.25		20°	
107.20	Foliated BT + AP -rock			
	(AP - dominant) fol. at 105.50		30°	
129.35	Rel. pure fine/med. grained søvite. Weak or no fol. Grain size usually between 0.5 - 3.0 mm occasionally.			
	Rauh. II veinlets at 107.45		90°	
	Chlorite at 107.20-108.40,			
	crisscrossing			
	BT + A+ -rock at 108.50-108.75			
	Patches of BT + AP at 111.80-111.95			
	at 112.85-112.90			
	BT+AP+MT -enrichment at 113.15-113.30			
	AP -enrichment at 113.50-113.70			
	AP -vein at 114.20-114.25		50°	
	114.30-114.33		65°	
	Rauh. II at 114.95 (1 cm)		80°	
	AP -vein at 115.00-115.08			
	BT+AP+MT -enrichment at 115.20-115.35			

Ark 4 Bh. nr. TH-12 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Coarse grained. Euh. BT + MT.			
	BT+AP-patch 2x 1/2 cm at 116.90			
	MT-enrichment 117.90 (1/2 cm)			
	BT + AP -rock 118.70-118.75			
	Foliation at 118.50		65°	
	Finegrained BT+AP -rock 120.98-121.45 interlayered with søvite.			
	Fol. 121.10		60°	
	Rauh. II at 121.70 (2 cm)		70°	
	BT+AP-rock at 122.23-122.32			
	Spherical AP-søvite 122.55-123.15			
	cut by rauh. II at 122.70 (2 cm)		90°	
	BT+AP -rock 123.12-123.40			
	Fol. at 123.50		20°	
	BT+AP -rock 123.75-123.92			
	Patches of BT+AP -rock 123.97-124.35			
	BT+MT+AP -rock in patches / stringers at 127.40-217.70			
	Do. 127.90-127.95			
	Numerous rauh. II and/or AP-veins 128.20-128.70 crisscrossing			
	BT+AP -rock/patch at 128.75			
	Foliated at 128.75		45°	
131.40	Hollaite or AP -rich rock. Massive, no fol. Crisscrossed by chlorite veins, or rauh. II. It shows veinlike extensions down-wards cutting AP -rich søvite at		90°	
132.10	AP -rich søvite dominating. Massive or with irregularity directed structural elements.			
139.75	Med./ coarse grained søvite. M = 5 - 20 %, dominantly BT. Cut by numerous rauh. II - veinlets up to 1 cm, all the way from top to bottom. Blue amph. and PY occur locally near bottom.			
140.65	Well foliated rauh. I in white and grey fine grained versions interlayered w/fine grained white søvite (?).			
145.70	Coarse grained impure søvite dominated by MT + BT and- or greenish amph. Occational rauh. II -veinlets. No distinct foliation.			
148.10	Do, but PY -rich and w/ M > 50 % => mafic rock.			
157.80	Coarse grained impure søvite w/ BT, MT and blue amph. as dominanting phases.			
	AP -enrichment at 149.75-149.85			
	150.05-150.10			
	Gneissic and PY -enriched at 150.90-151.10			
	Foliated at 150.90		80°	
	BT -porphyroblasts ?			

Ark 5 Bh. nr. TH-12 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Gneissic at 151.70-151.85 Fol.		35°	
	AP - dike/vein 152.85-152.95		60°	
	Two rauh. II generations? at 153.80-153.90			
	2-5 cm MT and blue grey zoned rounded silicate aggregates.			
158.70	Impure fine/med. gr. AP -rich søvite. M ≈ 50 %. BT, green amph, MT.			
177.50	Coarse gr. impure søvite. Near top dominant by BT, MT and green amph. and variable M ≈ 10 - 50 %.			
	From 162.00 to app. 170.00 increasing calcite and blue amph. becoming the dominant phase. Visible AP.			
	Rauh. II veins with strongly altered contacts parall. to subparall. 155.05-167.00			
	Foliation at 168.60		65°	
	M > 50 % at 171.10-171.40			
	172.20-172.45			
	174.25-175.15			
	175.25-175.60			
	Gneissic rauh. I 177.10-177.17			
	Foliation		50°	
178.90	Med. grained impure søvite M = BT + MT and rich in AP. M = 40 %. No dist. fol.			
184.90	Med. grained rel. purer søvite (M =10-20 %) with distinct foliation developet locally BT +/- green amph. +/- MT dominated, often in skeletal texture.			
	Fol. at 179.70		40°	
	182.05		35°	
	Thin (< 1/2 cm) rauh. II. veinlets sub. parall. at 181.70-183.00			
	Rauh. II 183.18-183.26			
	PY-veinlet - 2 mm thick 184.65		70°	
	MT -(rusty rims) + AP enrichment at 184.75-184.90			
191.20	Impure med/coarse gr. søvite w/amph. in a sphene tex/skeletal texture + euh. MT as major M. Interrupted by zones of rel. pure søvite as above.			
	Weakly foliated.			
	The skeletal texture gradually dissappear, but the rock retains its greyish tint caused by the amph. and a substantial AO -content.			
	AP + MT euh. 189.05-190.05			
	AP -veinlet (?) 190.05 (3 cm)		80°	
198.35	Heterogenous rel. pure med. grained søvite with gneissic well fol. zoned M∼10 % BT -major phase. Local large MT, but MT always present in small quantity.			
	Gneissic at 191.30-191.50		65°	
	AP-veins w/ MT at 193.40-193.50		90°	

Ark 6 Bh. nr. TH-12 Profil 3

Boret meter	Bergart	Kjerne-mangel	Skifrighet	Bergart prøve
	Euh. coarse MT at 194.20-194.60 Rauh. II veinlets (1/2 cm) at 195.10 195.30-195.50 196.10 196.20-196.35 197.65 PY + MT + AP euh. 197.35-197.50			
198.80	As above, but AP -rich			
201.35	Coarse / very coarse impure. søvite w/ blue amph., euh. MT and BT, and AP. Blue amph. aggreg. are often zoned and rounded.			

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