SKB TECHNICAL REPORT 86-06

Geological and tectonic description of the Klipperås study site

Andrzej Olkiewicz
Vladislav Stejskal
Swedish Geological Company

Uppsala, October 1986

SVENSK KÄRNBRÄNSLEHANTERING AB
SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT CO
BOX 5864 S-102 48 STOCKHOLM
TEL 08-665 28 00 TELEX 13108-SKB

GEOLOGICAL AND TECTONIC DESCRIPTION OF THE KLIPPERÅS STUDY SITE

Andrzej Olkiewicz, Vladislav Stejskal
Swedish Geological Company, Uppsala, Sweden

October 1986

A list of other reports published in this series during 1986 is attached at the end of this report. Information on KBS technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01) and 1985 (TR 85-20) is available through SKB.

Geological and Tectonic Description of the Klipperås Study Site

Andrzej Olkiewicz
Vladislav Stejskal

Swedish Geological Co.
Uppsala, Sweden

October 1986

ABSTRACT

The Klipperås study site is situated 45 km WNW of Kalmar in south-eastern Sweden. The site is situated between two regional NW-SE oriented lineaments. The site itself does not show any distinct lineaments. The site is flat, covered by till and with few outcrops. The precambrian rocks of this area are thought to be postorogenic in relation to the svecokarelien orogeny.
Almost all knowledge on the bedrock is obtained from 14 drill cores and from geophysical surface measurements. According to the statistics based upon the cores, the bedrock consists of 85 % granites, 7 % greenstones, 5.5 % porphyries, 1.5 % mafic dykes and 1 % aplites.
The granites are normally grey-red, medium grained and massive. They are, in a tectonically undisturbet condition, strongly magnetic.
Closely associated with the granites are aplite dykes.
The greenstones are schistos and represent a number of originally different rocks. Some of them are xenolithes, others are dykes. The latter are often associated with dyke porphyries in composite dykes.
The dyke porphyries have variable chemical compositions. Their width is usually 10 m and the directions group between W-WNW.
The youngest rocks comprise a number of different, rather well-preserved mafic dykes. Their direction varies from N to NE. Their width varies from ca 1 m to 10 m.
The geophysical surface measurements display many discontinuities of variable intensity. They are oriented in two main directions, N-S and NE-SW. The boreholes confirm the existence of discontinuities either as fracture zones or dykes. The dip of the fracture zones and the dykes vary from steep to 75^{o}.
The horizontal fracture zone at the depth of 780 m is an exception.The widest investigated fracture zone has a width of 30 m.
Most of the fracture zones are associated with greenstones and most of the elastic deformations and joints have a vertical orientation.
The zones have moved several times. At least four generations of fractures occur. The tectonic movements have affected the bedrock far beyond the zones.The bedrock is divided into blocks of different sizes which are displaced relative to each other.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Background

Investigations for the siting of a final repository for high level radioactive waste are currently being conducted in crystalline rock formations in Sweden.

A repository is planned to be located at a depth of about 500 metres, and investigations are being carried out in boreholes below that level.

A standard program has been established for the site investigations, comprising a number of phases (Ahlbom et al 1983), which are as follows:

* General reconnaissance for selection of study site.
* Detailed investigation on the ground surface.
* Depth investigations in boreholes.
* Evaluation and modelling

In the Klipperås area, the investigations started in 1982 with reconnaissance studies for the selection of the site and geological mapping of the area. During 1982-83 a tentative surface geophysical investigations were performed within an area of 14 km^2. The depth investigations were started in April 1983 with the first cored and percussion borehole. During 1984 a detailed ground surface geophysical investigation was conducted. From the results of this investigation, an area of aproximatly 4-8 km^2 was selected. From June to April 1985 13 cored boreholes and 13 percussion boreholes were drilled. The boreholes were investigated geophysically and hydrogeologically.

This report deals with the geology and the tectonics within the Klipperås study site and its immediate surroundings. All significant information from the aerial photographs, surface mapping, drillings, core logging and geophysical investigations at the surface and in the boreholes has been used for the geological and the tectonic interpretation of the Klipperås study site.

Other investigations are reported separately. These are as follows:

- Geophysical investigations at the Klipperås study site.
  SKB Technical Report TR 86.07.
  S. Sehlstedt and L. Stenberg.
  Swedish Geological Co, 1986.

- Hydrogeological investigations at the Klipperås study site.
  SKB Technical Report TR 86-08.
  B. Gentzschein.
  Swedish Geological Co, 1986.

- Geophysical laboratory investigations on core samples from the Klipperås study site.
  SKB Technical Report TR 86-09.
  L. Stenberg.
  Swedish Geological Co, 1985

- Fissure fillings from the Klipperås study site.
  SKB Technical Report TR 86-10.
  E-L. Tullborg.
  Swedish Geological Co, 1986.

1.2 Description of the area

The Klipperås study site is situated in the south east part of Sweden,on the topographic mapsheet 4F Lessebo NE, about 5 km WNW of Orrefors, Figure 1.1.

The differences in altitude in the area are relatively small, Figures 1.2 and 1.3. The relief within the site is low. The lowest point of the site is found on the west boundary, c.166 metres above sea level. The highest point c. 206 metres above sea level is situated on a vaguely hill in the west part of the site.

The area is situated above the highest coastline and consequently the moraine is not wavewashed, and exposures are few. The overburden is composed mostly of till of 0.5 to 11 metres thickness, which is partly covered by organic sediments, peat bogs and former lakes. In the western part of the site, moraine with large boulders dominates. The bouldersize decreases towards the central part and in the east the moraine consists primarily of small boulders and gravel. Exposed bedrock forms only some promille of the surface of the investigation area and consists exclusively of granite. Outcrop size rarely exceeds 20 m^2. The area of exposed bedrock in the surrounding area is variable. The outcrops are clustered 2 km north of the site around Stibbetorp and occur frequently along sections of the main roads. In outcrops north of the area, volcanites dominate. The locations of the outcrops in the investigation area and its immediate surroundings is shown in Figure 2.1 page 17.

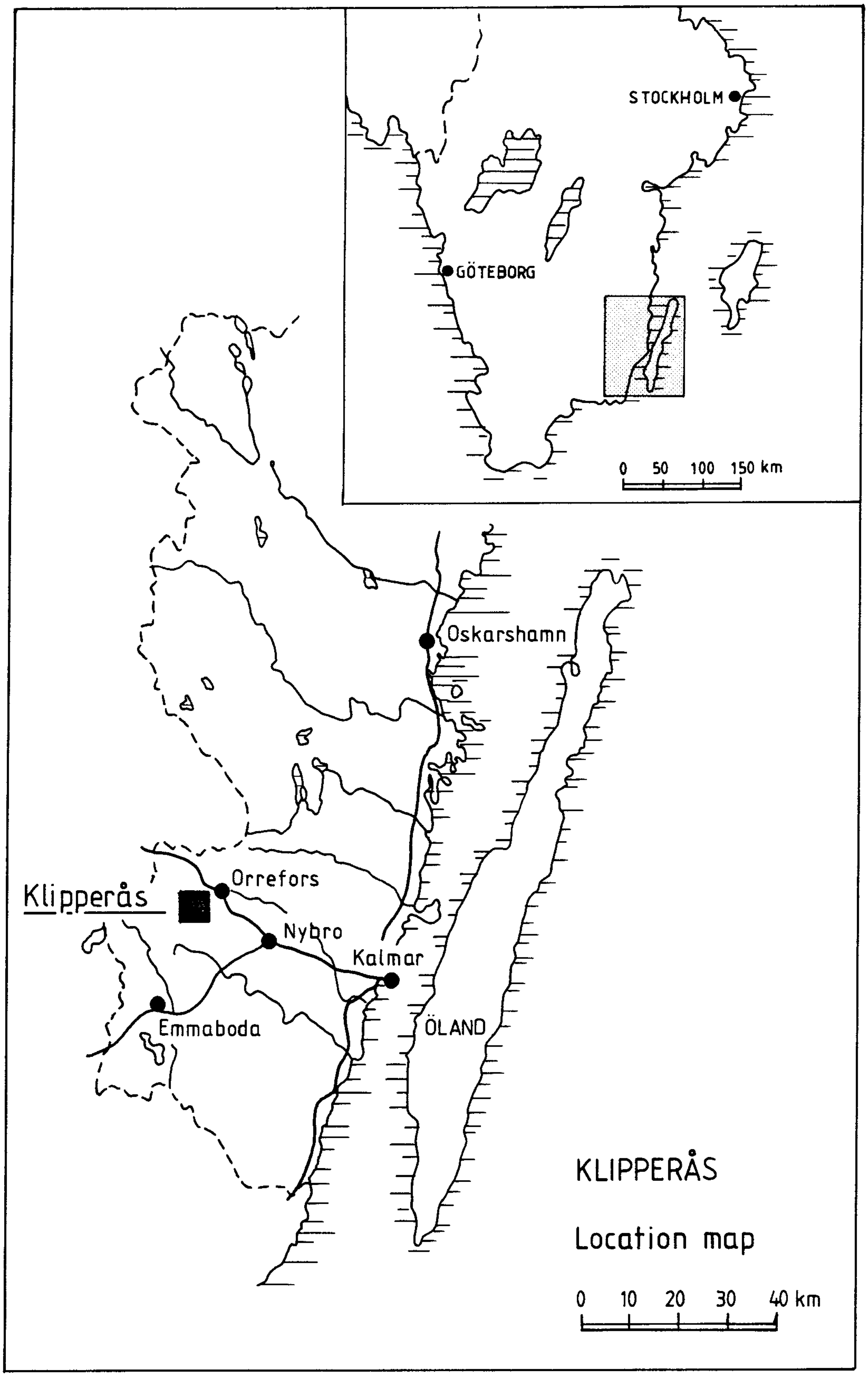


Figure 1.1 Location of the Klipperås study site.

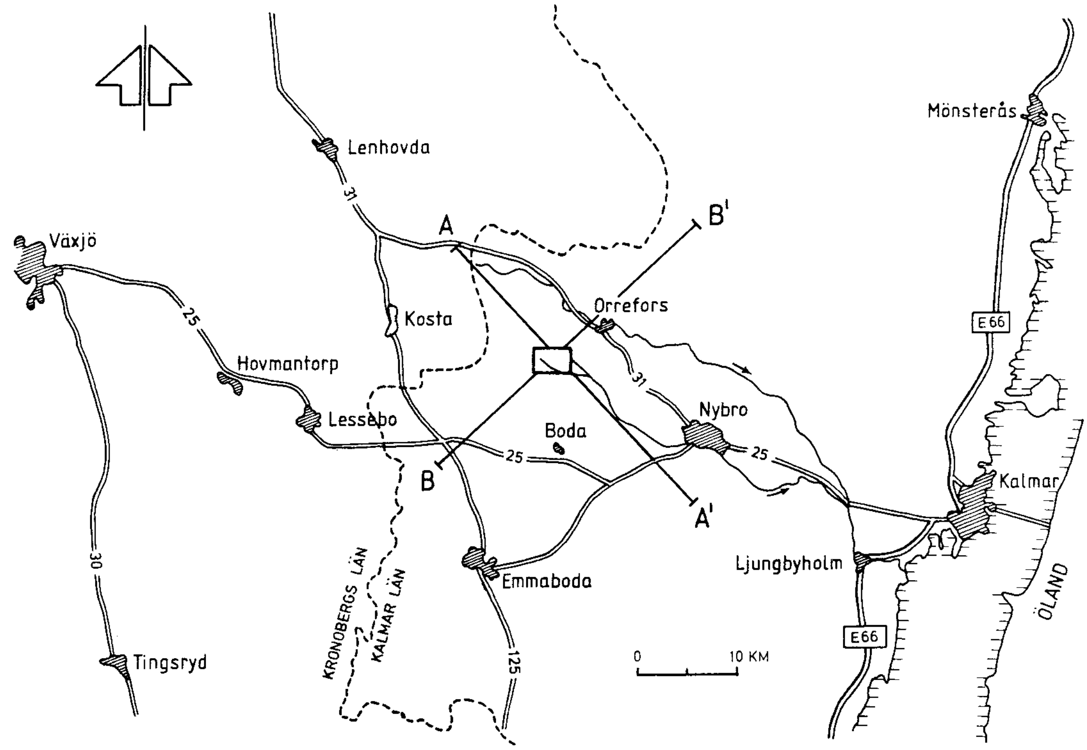


Figure 1.2 Map of the S-E part of Småland showing the location of the Klipperås site and lines of physiographic profiles.

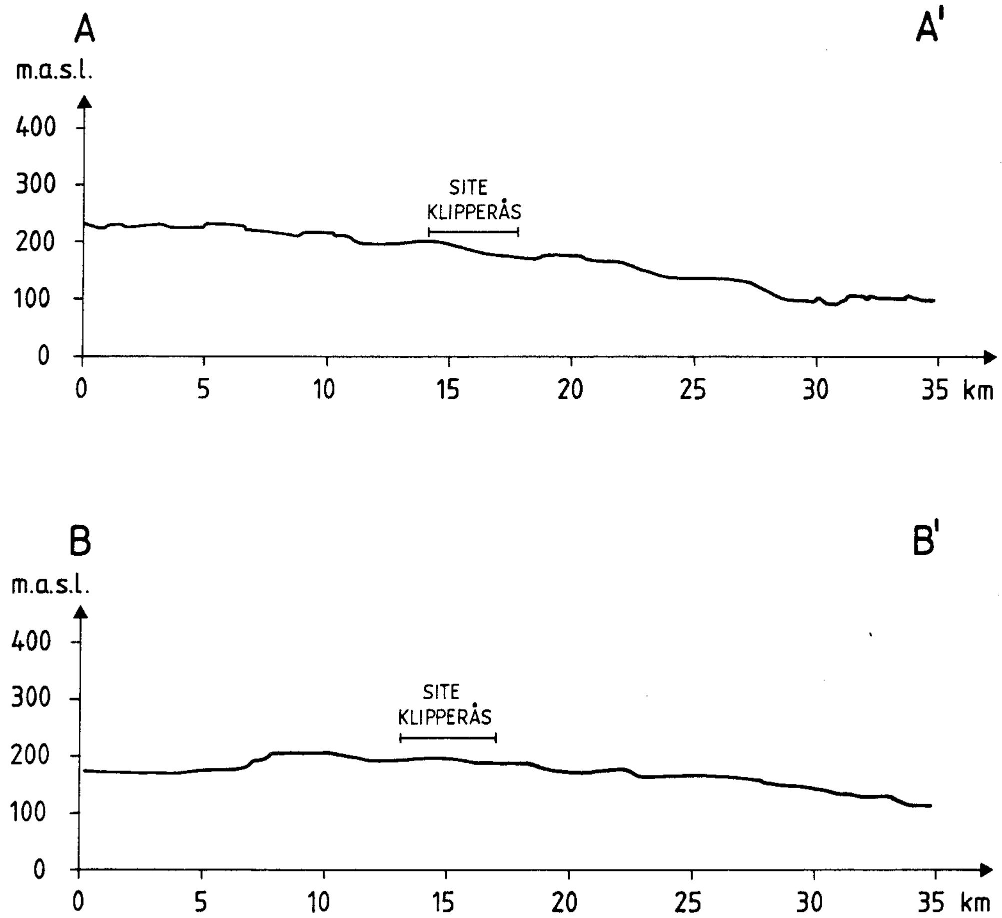


Figure 1.3 Physiographic profiles of a part of S-E Småland.

1.3 Regional geology

The oldest known rocks from this region (2 500 - 2 000 m.y.) comprise strongly metamorphosed Svecocarelian metasediments, metavolcanics and early granitoids, Table 1.1 and Figure 1.4. A continuity of the granite terrain of SE Sweden is locally interrupted by belts of other rocks.

The suite of Småland granites which compose the main part of the bedrock in SE Sweden, occupies an intermediate position in the scheme of the precambrian rocks in the region.

One belt consists of foliated granitoids which extend in the east west direction approximately from Oskarshamn to Vetlanda. The granitoids intruded contemporarily with the Svecocarelian orogeny, 1800-1950 m.y.

Other belts, which occur rather frequently, are the Småland volcanites. They are genetically closely linked with the postorogenic Smålands granites. The volcanites are preserved on the tops of granitic intrusions as flat lying plates or raised to more or less steeply dipping zones striking E-W to NW-SE.

Minor constituents of the Precambrian in the area include rocks of various ages. They compose a genetically heterogeneous group of massif forming rocks and hypabyssal bodies of basalt, dolerite and porphyries.

Granites younger than Småland granite are represented by Karlshamn and Götemar granites.

The precambrian evolution of the crystalline rocks was generally accomplished after formation of Jotnian sediments(Almesåkra complex, 1000 m.y. old) which are not metamorphosed. To a large extent they are undeformed.

The youngest group of rocks in this region consists of mafic dykes which intruded the older rocks less than 1000 m.y. ago.

Rock unit or geological event	age (milion years)
Dolerite (in part)	900
Almesåkra complex (Jotnian sediments)	1300-1100
Karlshamn and Götemar granite	1400
Hypabyssal porphyry and metabasite dykes	1620
Småland granites and Småland volcanites (Postorogenic intrusions)	1650-1690
Svecokarelian orogenesy	1800-1950
Gneissic granitoides in a belt from Vetlanda to Oskarshamn (Prim- or synorogenic intrusions)	1800-1950
Metavolcanites and metasedimentary rock and gneisses in Blekinge and Västervik areas (Svecokarelian supra-crustal complex)	2500-2000

Table 1.1 Chronological scheme of the geological evolution in SE Sweden.

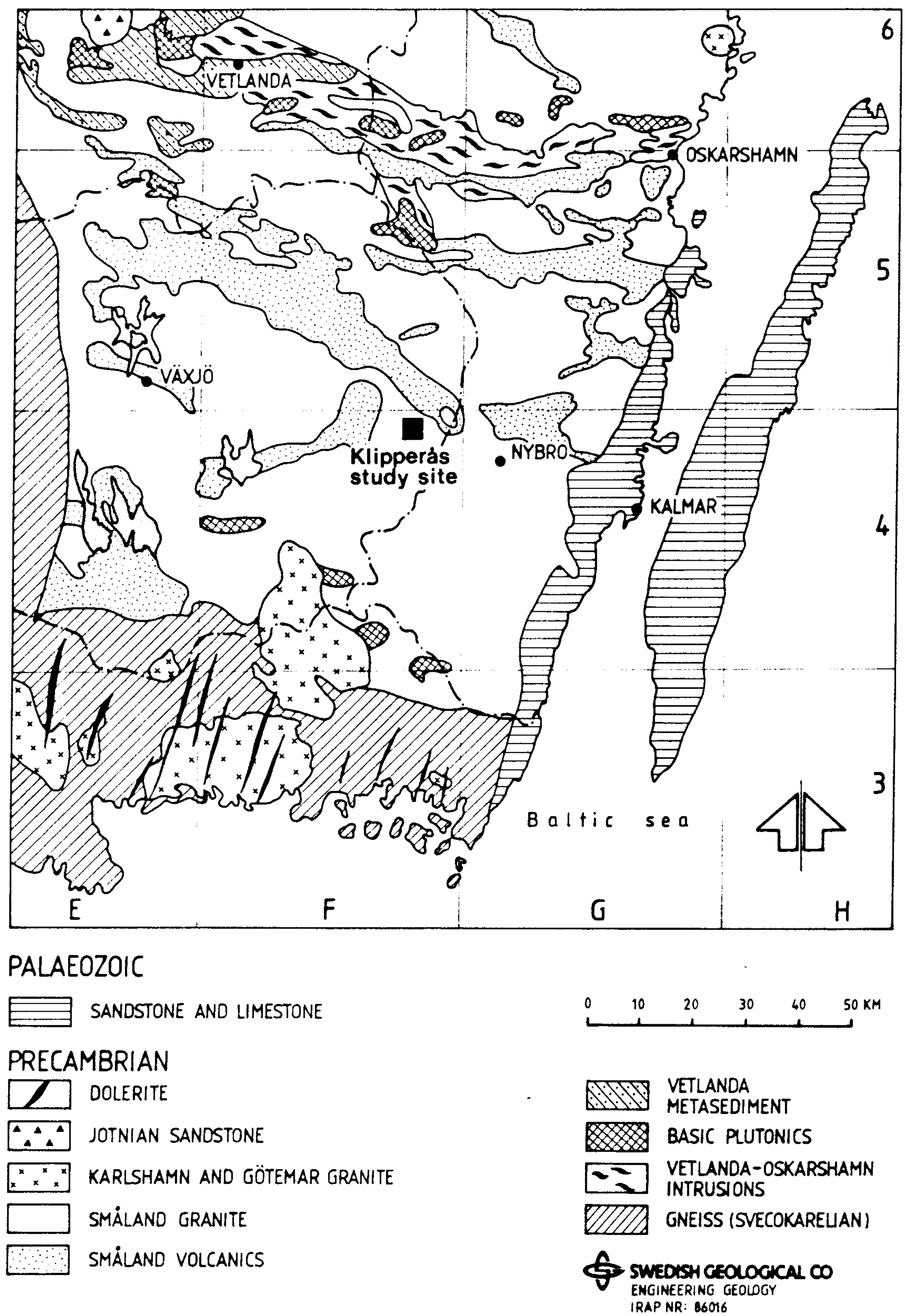


Figure 1.4 Regional geology

1.4 Previous investigations

Most of the published information on the broad geological environment of Klipperås study site dates from the late 19th century. The results of this general survey of Småland were presented in combined Quaternary and Petrological maps 1:200 000 (SGU, Ser Ab) together with a description. The Klipperås study site is located on map sheet Lessebo (No 4) mapped by Holst 1879. According to his description, the bedrock in the area of the map sheet consists of Växjö (Småland) granite, dense gneiss ("hälleflinta") and dykes of porphyry and dolerite. The maping on adjoining sheets to the north and west has been carried out by Hummel (1877), Stolpe (1892) and Holst (1885, 1893).

Further investigations were made in the coast region of Småland and resulted in maps 1:100 000 (SGU, Ser Ac) together with a description. (Svedmark, 1904), (Munthe and Hedström 1904).

Additionally, there is a Petrologic map at a scale of 1:200 000 together with a description (SGU, Ser Aa No 5) which includes, among other maps, the Lessebo sheet (Hedström and Wiman 1906).

The bedrock geology, with emphasis on geological aspects of dyke rocks in Småland was treated by Nordenskjöld (1893) and Eichstädt (1894).

Later compilation can be found in Magnusson et al. (1960) and in Lundegårdh et al. (1985).

Detailed examination of the relationship between plutonic rocks and Småland volcanics were described by Persson (1974).

The radiometric age determinations of plutonic and volcanic rocks from Småland were conducted by Åberg (1972, 1978), and Åberg and Persson (1984).

The results of geological mapping comprising different plutonic and supracrustal complexes on map sheets 1:50 000 Vetlanda, Småland are being prepared for publication by SGU (L. Persson, Ser Af No 150 and 151).

A comparative study of rare earth and other trace elements in rock, soil, peat and plant samples within the Klipperås study site was made recently by Landström, Sundblad and Olkiewicz (1986).

1.4 Research methods

In the construction and description of the geological and tectonic maps of the Klipperås area, the following work was conducted.

A local coordinate system in N-S and E-W directions were established. All data concerning inclination and declination are given in the 360^0 system.

Two independent studies of lineaments was performed:

1. Over the area of 625 km^2 with the study site Klipperås as an approximate centre.

2. Over the study site of Klipperås, 14 km^2.

The interpretation was made from aerial photographs at a scale of 1:30 000 with a stereoinstrument Topcon. The results are presented as maps and diagrams.

The criteria used for the interpretation of the lineaments from the aerial photographs are as follows: the topographic level differences and the biotop differences. In the area of Klipperås is difficult to use both these criteria. The area is exceptionally flat and covered by till. The vegetation equalizes the irregulaties and the weak relief of the area was discernible only on the forest clearings.

The continuity of the lineaments on the aerial photographs is in most cases not as clear as on the presented map. Very often, many short, sometimes indistinct indications in the picture are approximated to one line.

To discover the outcrops, profiles every 50 m through the 14 km^2 area were checked. The adjacent area, within a distance of 3 to 4 km from the boundary line, was investigated for the outcrops. The surveying was performed by car, along existing roads. A short, geological description of the adjacent area is included in this report.

Geophysical surface measurements, electrical conductivity and magnetization measurements, were performed to obtain information on the physical properties of the bedrock, to the boundaries and distribution of rock types, the presence of ore minerals and to locate fracture zones.

14 diamond boreholes, Ø 56 mm, of a combined total length 6933 m, and 14 percussion boreholes, of a combined total length 1420 m were drilled. The diamond boreholes were drilled at inclinations from 50^o to 80^o. The percussion boreholes were inclined at 50^o to the vertical. No orientations of the drill cores were made. The logging of the core considered changes of the rock type, colour and grain size. The computer system for the core mapping was utilized for recording the depth and type of fracturing, mineralogy of filling, slickensiding, the orientation of the fractures relative to the bore-hole axis, the distribution of zones of dense fracturing and the features of extreme crushing of the core. The connotation of different transitive features, grade of cataclasis, inclusions and narrow veins are also recorded. Colour slides and photos were taken after the logging.

34 rock samples were collected from the cores. Thin sections were produced. Semiquantitative and on one thin section quantitative (700 points) mineralogical determination was performed.

A chemical analysis was performed at the SGAB laboratory in Luleå on 13 samples. The major and trace elements are detected with XRF-analysis. The results have a possible error of ± 5 %. H_2O^+, CO_2 and F are detected by the wet chemical method.

The results of the mineralogical determinations and the chemical analysis are presented in tables and diagrams.

The rocks are classified according to IUGS, Subcommision of the Systematics of Igneous Rocks (1973).

In the description of the rocks the grainsize is classified as follows:

< 0,05 mm	aphanitic
0,05 - 0,5 mm	very fine grained
0,5 - 1,0 mm	fine grained
1,0 - 1,5 mm	fine medium grained
1,5 - 3,0 mm	medium grained
3,0 - 5,0 mm	coarse-medium grained
> 5,0 mm	coarse grained

In this rapport, the length mesurements denote distances along the core, not the "true depth", unless stated otherwise. The comment "vertical depth" will be given whenever this is appropriate.

The results of the geological and tectonic surface and deep interpretations are presented as maps at scale of 1:20 000.

All relevant information from other investigations; borehole geophysics and hydrological investigations were utilized for the purpose of geological and tectonic interpretation of the Klipperås site.

The geophysical logging includes three resistivity methods, natural gamma, susceptibility, spontaneous potential and temperature, resistivity and salinity of the borehole fluid. Geophysical measurements are also made on core samples in the laboratory.

The hydrualic measurements include the following: measurements of hydraulic conductivity by single-hole and cross-hole testing, determination of the hydraulic fracture frequency and determination of groundwater head at different levels in the bedrock.

The single-hole hydraulic tests are performed in 20 m sections as transient tests with injection and fall-off phases. The hydraulic head is calculated from Horner plots and from direct measurement over a long period.

The hydraulic conductivity values obtained are used in descriptive hydraulic models based on geologic-tectonic models of each site under consideration. In the hydraulic models, the bedrock is subdivided into diffferent hydraulic units. The conductivity values obtained in each unit are used to describe the frequency distribution of the conductivity and to calculate an effective hydraulic conductivity versus depth to be used in further numerical groundwater model calculations.

2. GEOLOGY

2.1 General description

The material in Table 2.1 and Figures 2.1 and 2.2 is relavent to this chapter.

The exposed bedrock, which forms only a promille of the surface of the Klipperås study site consists exclusively of granite. The lack of outcrops makes the description of the bedrock almost totally dependent on information obtained from the 14 drillcores. Accoring to the statistics made upon them, the bedrock of the site consists of 85 % granites, 7 % greenstones, 5,5 % porphyries, 1,5 % mafic dykes and finally 1 % of aplites.

In direct connection to the study site occurs an area occupied by acid volcanites. Small xenolithes of these rocks have been found in the granite outcrops within the study site. The volcanites are the oldest rocks within the area of investigation.

The granites, called Småland granites, dominate the area. They intruded and brecciated the older rocks in several cycles. The granites are normally grey-red, medium-grained and massive. In a few cases, a weak schistosity in the E-W direction was observed. If undisturbed tectonically, the granites are strongly magnetic.

Besides the granites, the greenstones are the most commonly occuring rocks within the study site. They have variable chemical compositions and represent a number of originally differenet rocks. Despite their strong alteration and schistosity in some cases, their previous origin could be deduced. Some of the greenstones occur as xenolithes in granites i.e. they are older than the granite. Others have intruded the granites as dykes and are accordingly younger than the granites. Some of the older greenstones are of extrusive origin i.e. belong to the mafic variants of volcanites. Due to the small volume of the core it is impossible to determine whether the greenstone is a xenolithe or dyke.

Greenstones which occur as dykes within the granites are often associated with dyke porphyries in the so-called composite dykes. The greenstone dykes are younger than dyke porphyries.

The dyke porphyries are hypabyssal rocks with variable chemical composition. They are usually red with phenocrysts of feldspars, sometimes also of quartz in a very fine-grained groundmass. Their widths are normally around 10 m and it is common that they are in contact on one or both sides with the above mentioned greenstone dykes whose width is a few meters.The direction of these dykes groups between E-W and WNW-ESE. They dip steeply to the south.

Among the dykes within the site the aplites are the oldest ones. Generally they appear as narrow dykes whose width is about 0.5 metre.

The youngest rocks in the area comprise a number of different mafic dykes. They have relatively well-preserved textures and magnetic properties. Their width varies from some meters to almost 10 m. An exception is one dyke detected by geophysical measurements, but not controlled by drillings. The width of this dyke is estimated to be 100 m. The directions of the mafic dykes vary from N-S to NE-SW. They dip steeply.

The dominating fracture filling minerals are chlorite, epidote, hematite, calcite, muscovite/illite, quartz, adularia and pyrite. In the metabasites and the dolerites, smectites have also been identified together with calcite (Tullborg,1986).

The precambrian rocks of the area described above are considered as postorogenic relative to the Svecokarelian orogeny. The age of all rocks, except the mafic dykes, varies from 1645 m.y. for volcanic rocks, to 1620 m.y. for Småland dyke porphyries (Åberg, 1978). The mafic dykes intruded later and their age is considered to be 960-980 m.y. (Lundqvist, 1980).

MAFIC DYKES	relatively well-preserved
GREENSTONES DYKES	Often as composite dykes
DYKE PORPHYRIES	
APLITE DYKES	
SMÅLAND GRANITES	
MAFIC INTRUSIVE ROCKS ? altered to greenstones	as xenolithes
VOLCANIC ROCKS Acid rocks and mafic rocks altered to greenstones	as xenolithes

Table 2.1 Rocks of the Klipperås study site.
Relatively younger rocks upwards.

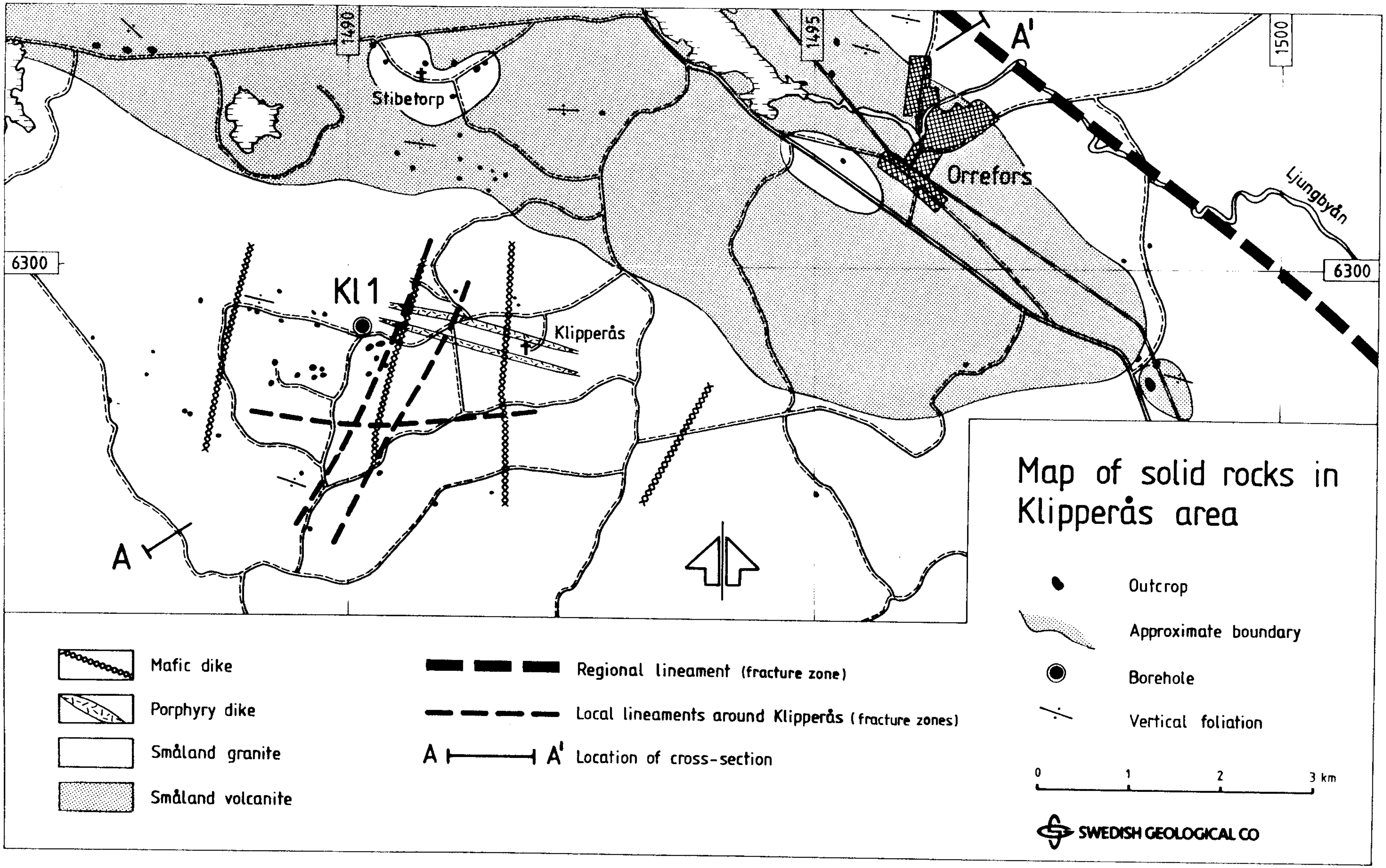


Figure 2.1 Map of solid rocks in the Klipperås study site and surroundings

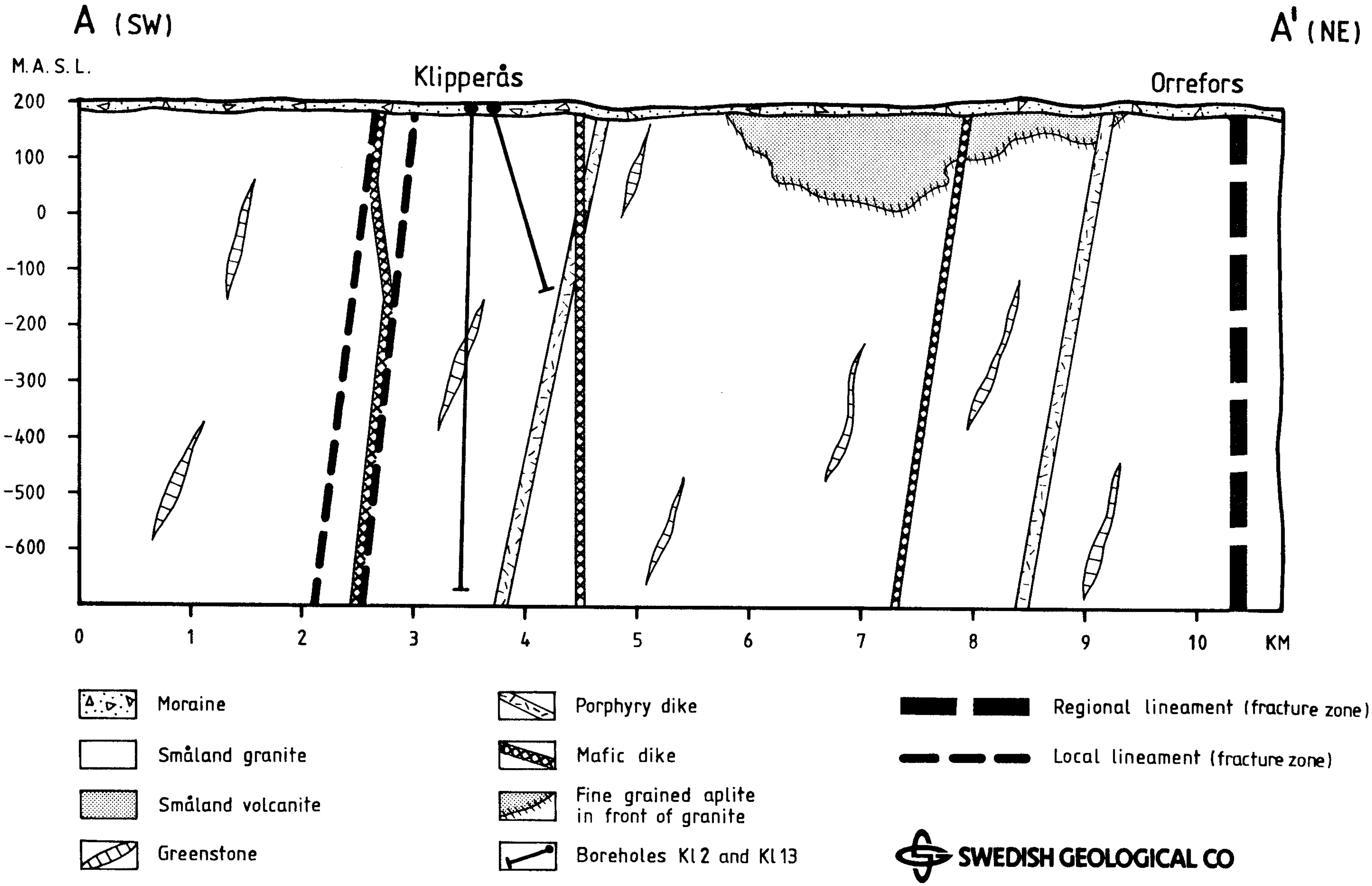


Figure 2.2 Schematic vertical cross section of the Klipperås study site and surrondings.

2.2 Rock type description

2.2.1 Volcanic rocks

North and east of the study site there are a number of outcrops consisting of volcanic rocks, Figures 2.1 and 2.2. According to the old map from 1905 (Hedström and Wiman), the contact between granite and volcanic rocks runs immediately north of the Klipperås area in the direction WNW-ESE. This line of contact is approximate since no direct contact could be found in the field.

Although no outcrops of volcanic rocks occur within the investigation area, their existance beneath till cover cannot be excluded. Small, isolated, sharply bordered angular fragments of porphyry have been observed in granite within the investigation area.

The main variety among the volcanic rocks are reddish or grey, fine grained quartz porphyries and plagioclase porphyries with rather well-preserved structure. This primary structure comprises homogeneous porphyritic or pseudo-fluvial and fragmental types.

Immediately NW of Orrefors, fine grained tuffites occur. In some localities, they turn into coarse volcanic conglomerates.

Recrystallized types of quartz porphyries were observed along the intrusive contacts of granite where the original rock tranforms first to an aplite-like porphyry or fine grained granite, and finally to coarser Småland granite. Isolated, sharply bordered angular fragments of porphyry in granite can be abundant locally.

Tectonic deformation of Småland volcanics is most clearly demonstrated by schistose tuffitic rocks and strongly flattened fragments of volcanic conglomerates. Finely grained porphyritic rocks display a distingtly compressed texture under the microscope.

2.2.2 Granites

All of the small number of exposed outcrops within the Klipperås study site consist of granites. The granites, generally called Småland granites (Växjö variant), are usually grey-red, but red and grey varianties also occur. Mediumgrained to coarse medium-grained granites are the most common types. Fine-grained and coarsegrained granites occur sporadically. The granites are massive, but in a few cases a weak schistosity in east-west direction was observed.

The granites are hypidiomorphic, inequigranular with maximum grain variations from 2 to 9 mm. Occasionally, they are slightly porphyritic. This is common with zoned feldspar crystals and in some less degree blue colored quartz.

Distinct contacts between differenet kinds of granites have been observed in the drill cores, which means that the rocks intruded over several cycles.

The granites in the drill cores exhibit the same variations as on the surface.

Studies of 6 thin sections show that the granites are mineralogically rather uniform. See Table 2.3. The normal composition consists of quartz, plagioclase, potassium feldspar and some biotite which is often altered to chlorite. Accessory minerals are muscovite, epidote, titanite and pyrite and/or magnetite. Fluorite was found as an accessory in only one thin section. The main minerals are usually subhedrally shaped. Quartz demonstrates undulatory extinction. This is common with secondarily formed grains. The plagioclase is usually replaced by soussurite. Perthite exsolution occurs in K-feldspars.

The chemical analysis of one granite sample shows 77 weight per cent of SiO_2, see Tables 2.6 and 2.7 (sample no 1).

With the help of the computer program BENORM, the normative q:or:ab+an (quartz : k-feltspar : plagioclase) composition is

presented in a triangle diagram, Figure 2.3a.
The contacts between the granites and other rocks are always sharp.

The granites of Klipperås are strongly magnetic. The values vary between 2 x 10^{-4} and 1 x 10^{-2} SI-units (Stenberg, 1986). The magnetic properties vary considerably over short distances, depending on the degree of tectonization. In some very strongly tectonized sequences of the core, the oxidation of the magnetite caused deposition of hematite on the surfaces of fractures.

Tectonic affects on the granite varies considerably. The most characteristic for the Klipperås granites is the microfracturing, which influences the feldspars. Long sequences of the core are interwoven by epidote healed fractures. Breccia and narrow belts of mylonite occur frequently too. The tectonization on a microscopic scale is seen under a microscope as deformed twins of plagioclase,grains of secondarily grown quartz, undulatory extinction of quartz, epidote and quartz healed microbreccia.

2.2.3 Aplites

The aplites are light red, fine grained, equigranular dyke rocks with a granitic composition. They occur in almost all drill cores. Generally they appear as narrow roughly 50 cm width dykes. The widest one, about 7 m width, is found in borehole Kl 10. The contacts are usually sharp.

The aplites are contemporary with the granites since they intruded as residual products in cracks within the solidifying granites.

2.2.4 Greenstones

The rock type designated "greenstone" comprises in this report, fine grained, green or grey green rocks rich in chlorite and epidote. Their original minerlogy and textures suffered intensive alteration and their primary contact relationship to the wall rock is completely obscure.

The above mentioned observations can be conveniently used in the macroscopic description of the core to separate them from other better preserved mafic rocks of similar chemical composition.

Besides the granites, the greenstones are the most common rocks in the Klipperås site.

The studies of 13 thin sections shows that chlorite, plagioclase, quartz and epidote dominates the greenstones. In some samples quartz is lacking, and in such cases uralitized pyroxene can occur. Accessory minerals are mica, ore minerals and sometimes calcite. Plagioclase grains vary in size between 1 and 10 mm. The plagioclase are corrodet and in most cases altered to saussurite. See Table 2.4.

The chemical analysis of three greenstone samples shows that the SiO_2 content can vary between 50 and 54 weight per cent. The remaining elements show relatively small variations. See Tables 2.6 and 2.7 (samples no 7-8).

With the help of the computer program BENORM the normative q:or:ab+an composition is presented in a triangle diagram, Figure 2.3b. According to Streckeisen (1967), one of the greenstones has granodioritic and two others have monzodioritic-gabbroitic compositon.

Most of the greenstones from the drill cores are more or less schistose.

In spite of alteration and schistosity, it is possible in many cases to discern the primery structures. In several thin sections the plagioclase grains or the remaining parts of them, are arranged in a configuration which resembles an ophitic structure. Other thin sections show porphyric structures with plagioclase as phenocrists. Amygdales filled with epidote, quartz and chlorite or calcite also occur. Some structures can be seen to be fluidal.

In most cases the greenstones are non-magnetic. The magnetite in the rock is almost always altered to leucoxene.

The contacts between greenstones and other rocks are always sharp. The greenstones close to the contacts are almost always strong schistose which causes difficulties in the interpretation of the character of the contacts. The core section also encloses too small an area to make a definite interpretation of the relative age of the rocks. In spite of this, however, it can be noted that in the core from Kl 4, the greenstone brecciated the granite, and in Kl 2 the granite brecciated the greenstone.

Summing up, it can be said, that the greenstones within the Klipperås site have different ages and differenet origins. Some of the greenstones are xenolites in the granites i.e. they are older than the granites. In other cases, the greenstones have intruded the granites as dykes and are accordingly younger than the granites. An example of the last case are the narrow greenstones, which accompany the porphyry dykes in the composite dykes, see the next chapter. Greenstones with the ophitic structure are presumably previous dolerite dykes or mafic crystalline rocks. The amygdales and the fluidale structures provide evidence that other greenstones were formed as extrusive lavas on the surface.

2.2.5 Dyke porphyries

To form an opinion on the relative age of the rocks, it is necessary to examine their mutual relationship. The lack of uncovered bedrock within the study site does not give an oportunity for such studies. Examination of drill cores is not always reliable in these particular cases. The question of whether a rock represents a dyke or a xenolithe is very important from the point of view of the repository.

The fact is that the dykes can have a considerable extension both in length and in depth. This makes them important both as potential weaknes zones and as potential water transporters. The xenolithes on the countrary, usually have limited extension and are therfore not so important as the dykes. However, from the point of view of their water chemistry, also their number, volume, mineralogy and chemical composition are also, of course of considerable importance.

Porphyries exist in all cores, except in Kl 3, 7 and 8. In all cases except two, these rocks are on one or both sides in contact with greenstones. In two cases greenstones occur within the porphyries. The contacts between these rocks are always sharp and often tectonically disturbed. In Kl 6 a clear intrusive contact of the porphyry against the granite can be seen. The contacts between the porphyries and the greenstones give contradictory information. In one case, in Kl 9, xenolites of greenstones in red porphyry occurs. In the next case, Kl 6, angular fragments of porphyry in greenstone occurs.

Several authors, among them Eichstädt (1884), Persson (1973 and 1974) described dykes with a very special appearance from northern Småland. These are the granite porphyry dykes, which are in contact on one, or on both sides with uralite dolerites. They call them "composite dykes". Persson (1974) states that the uralite dolerites are the younger of these two, because they "cut the dyke porphyries".

The many cases of consequent joint appearance of porphyry and greenstones in Klipperås leads us to belive that they represent "composite dykes".

Of course, this does not exclude the possibility that some of the pophyries do not represent dykes, but are xenolithes of older volcanites. During the mapping of the outcrops, some small fragments of volcanites were found in granites. But, to solve problems of this type requires a more extensive investigation than the one described here.

The porphyries from the Klipperås drill cores are very fine-grained phenocrysts containing rocks. They are usually red, but brown and grey-black varieties also occur. The phenocrysts consist of rectangular plagioclase and microcline crystals, sometimes also of angular or oval quartz grains. The size of the phenocrysts vary from 1 to 12 mm. The quartz and plagioclase are never bigger then 4 mm in size. The crystals of microcline are perthitic. Both, the microcline and plagioclase are, to different extents, altered to sericite. The groundmass consists of quartz and feldspar (granophyric texture). Chlorite, epidote, ore minerals and apatite are accessory minerals.
8 sections of porphyry were examined, see Table 2.3.

The content of SiO_2 varies; of the five porphyry samples examined, four contain ca 70 weight per cent and one 58 weight per cent SiO_2, see Tables 2.6 and 2.7 (samples no 2-6). According to the q:or:ab+an composition, three samples are of granitic composition, one of granodioritic and one of monzonite composition. See the triangle diagram Figure 2.3a

In most cases the porphyries are strongly magnetic, values up to 1-6 x 10^{-2} SI-units were measured (Stenberg, 1986).

With the help of geological and geophysical similarities, it was in some cases possible to connect porphyry dykes between different bore-holes: Kl 5 and 10, Figure 3.27, Kl 6 and 13,Figures 3.27 and 3.23, Kl 11 and 14, Figure 3.22. The directions of these dykes group between E-W and N70W - S70 E and dip 80^{o} steeply to the south. The width of these dykes is usually around 10 m.

The ground magnetic measurement shows narrow, E-W to ESE-WNW directed anomalies. Some of these anomalies are identified in bore-hole Kl 12 as porphyry dykes. The dykes dip 75^{o} to the south, see Figures 3.1 and 3.24.

The determination of the dyke directions in the Klipperås site correspond to the directions measured by Persson (1974) in north-eastern Småland.

2.2.6 Mafic dykes

There is a widespread occurrence of mafic dykes which penetrate the precambrian bedrock in a broad surrounding of the study site and are mentioned by Holst (1893) and Eichstädt (1884).

During the initial stages of the survey performed in the study site area, magnetic mafic dykes were localised geophysically. Unfortunately these dykes have not been observed exposed anywhere in the area around Orrefors and Klipperås, Figure 2.1. All the information on the orientation, mineralogy and character of the mafic dykes was obtained by combining the geophysical measurements and investigations of samples from drilling.

Mafic dykes, which show relatively well-preserved primary textures, or structures of hypabyssal dykes, will be described in this chapter. Due to increased intensity of alteration or tectonisation, many of them were converted to fine grained or schistose greenstones, which is most evident at strongly altered mafic dykes following the margins of porphyry dykes (composite dykes).

The different dykes of mafic rock found in the study site show different characters both geophysically (Sehlstedt and Stenberg, 1986) and petrographically. Three types of dykes will be described below.

Type 1

A strongly magnetic (Sehlstedt and Stenberg, 1986) dolerite dyke (microgabbro) is intersected by Kl 4, Kl 9 and Hkl 10, Figures 2.4, 3.19 and 3.20 and Table 2.2. It is about 10 m thick and is oriented NNE-SSW, with a vertical dip.

A dyke of the same type as described above, probably either a displaced continuation of this, or an apophyse occurs in Kl 2, Figure 3.26 and Table 2.2.

Table 2.2 Data from boreholes intersecting a dolerite dyke

Borehole	Dolerite sect	Vertical depth	Strike/Dip
Kl 4	19- 29 m	21 m	N-S/90^{o}
Kl 9	356-373 m	316 m	N25^{o}E/65^{o}
Hkl 10	52- 63 m	50 m	
Kl 2	943-953 m	745 m	

The original mineral composition and the ophitic texture of the dolerite is fairly well preserved. The rock is greyish black, fine grained. Microscopically it is composed mainly of lathe-shaped plagioclase (labradorite). Augite, and occasionally olivine occurs between the plagioclase individuals. The principal accessory mineral is magnetite. The relative mineral composition of the dolerite in boreholes Hkl 10 and Kl2 is shown in Table 2.5 and their classification according to the normative composition is shown in Figure 2.3a.The result of the chemical analysis is shown in Tables 2.6 and 2.7 (sample no 12).

Type 2

Dykes of uralitized dolerite which cut the granite in the study site are represented in boreholes Kl 11 and Kl 14, Figures 2.4 and 3.22 and Table 2.3. They are supposed to have a direction of NE-SW and a vertical dip. These dykes are not identified on geophysical maps. The dyke in Kl 11 is strongly magnetic while the dykes in Kl 14 are magnetic in places.

Table 2.3 Data from boreholes intersecting uralised dolerite dykes.

Borehole	Dolerite sect.	Vertical depth	Strike/Dip
Kl 11	139-148 m	120	N55E/Steep
Kl 14	169-200 m	160	N50E/Steep
	520-527 m	430	
	571-575 m	470	

The dyke is dark grey or greenish, dense at the contacts and coarsening inwards towards the dyke where it clearly displays the ophitic groundmass. The chief constituents are plagioclase (labradorite) which is ususally clouded by secondary minerals. Grains of pyroxene are almost completely converted to uralite (amphibole). In addition, there occur some biotite, and, as alteration products of the primary minerals, small quanitities of chlorite, epidote, quartz and hematite.

The relative mineral composition of samples from borehole Kl 14 is shown in Table 2.5 and its classification according to the normative composition in Figure 2.3a. The results of the chemical analysis are shown in Tables 2.6 and 2.7 (samples no 10 and 11).

Type 3

An intrusive dyke of strongly magnetic alkaline basalt with well preserved primary mineralogy and structure. Due to reversed magnetization of the dyke in relation to present earths magnetic field, it was not detected by magnetic surface measurements (Sehlstedt and Stenberg,1986).

The dyke is around 5 m thick, strikes N-S and dips steeply. The dyke is documented in four boreholes, Kl 5, Kl 6, Kl 10 and Hkl 3. In two of the boreholes the rock types divide into more than one section. In Kl 5 there are two sections and in Kl 6 there are eight sections. See Figures 2.4, 3.27 and Table 2.4.

Table 2.4 Data from boreholes intersecting a basalt dyke

Borehole	Basalt sect.	Vertical depth	Strike/Dip	True width
Kl 5	19- 29 m	20.8 m	N-S/90^o	5 m
Kl 6	339-371 m	307.2 m	N-S/90^o	17 m
Kl 10	88-100 m	72.0 m	N-S/90^o	8 m
Hkl 3	90- 96 m	71.2 m	N-S/90^o	>5 m
Hkl 4	(not measured)			

The dyke rock has black to greenish black colour and is very fine-grained. Macroscopically visible are olivine grains up to 5 mm in size and pyroxene prisms 1-2 mm in length. In some parts of the dyke there occur scanty, subrounded pinky phenocrysts about 1 cm in size, resembling ortoclase.

Microscopically the main components are pyroxenes, altered olivine, biotite and accessorally, magnetite, set in a cryptocrystalline or glassy groundmass, see Table 2.5. The large grains of olivine are altered to fibrose aggregates of chlorite, serpentine and talc. The idiomorphose phenocrysts of pyroxene (augite) are fresh, zoned and occasionally clustered into bushy aggregates.

The chemical composition of the basalt differs from the other mafic dykes in the study site in their conspicuosly high content of K_2O and low SiO_2 ratio expressed by the feltspatoides in the triangle diagram, Figure 2.3a. See Tables 2.6 and 2.7 (sample no 13).

In addition to the above described mafic dykes, numerous similar well preserved dykes exist. But these are very small and of unknown extension. They were mapped in drill cores from the study site.

Besides the above described mafic dykes, two others were detected by geophysical measurements, but were not controlled by drillings. Both of these dykes have approximately NNE-SSW directions. The westernmost dips steeply to the west and has a width of about 100 m. The second one is situated to the east of the definitive area selected. These mafic dyke is considerably smaller and dip steeply. See Figure 2.1.

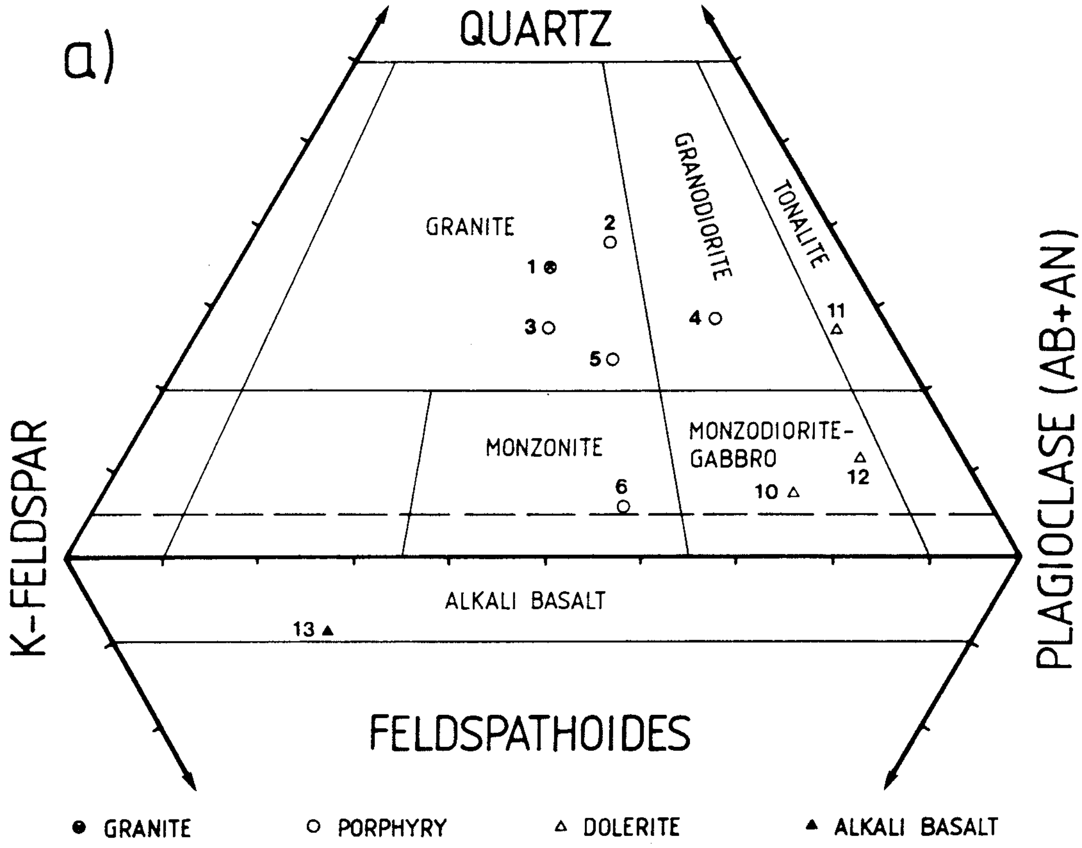


Figure 2.3A Normative composition of the Klipperås granite, porphyry dykes and mafic dykes.

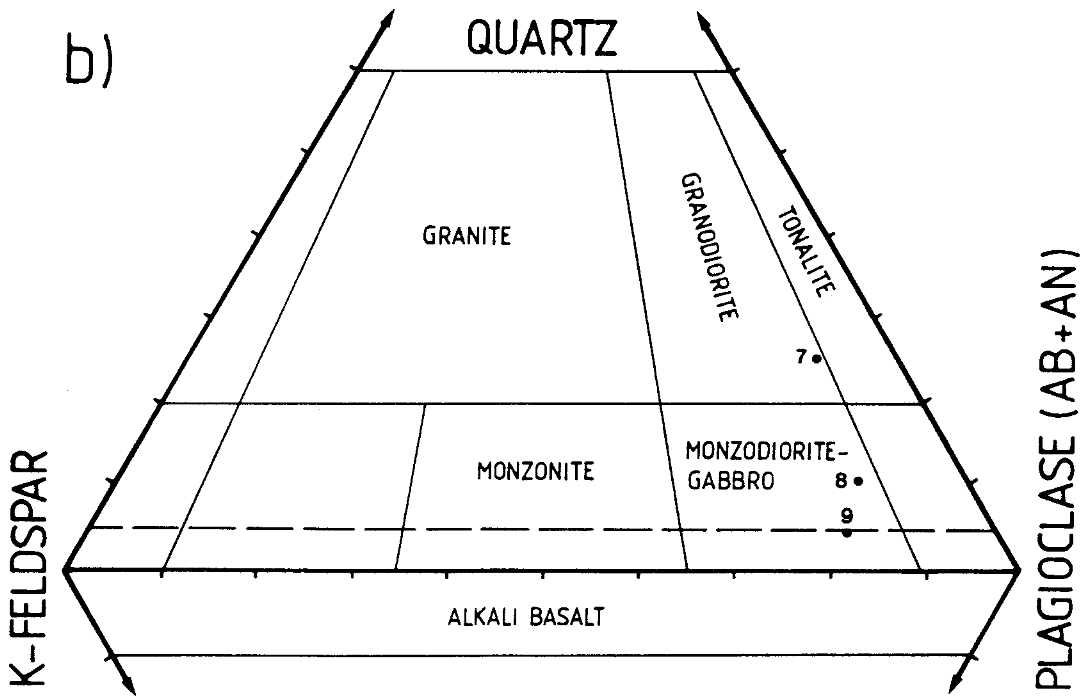


Figure 2.3B Normative composition of the Klipperås greenstones.

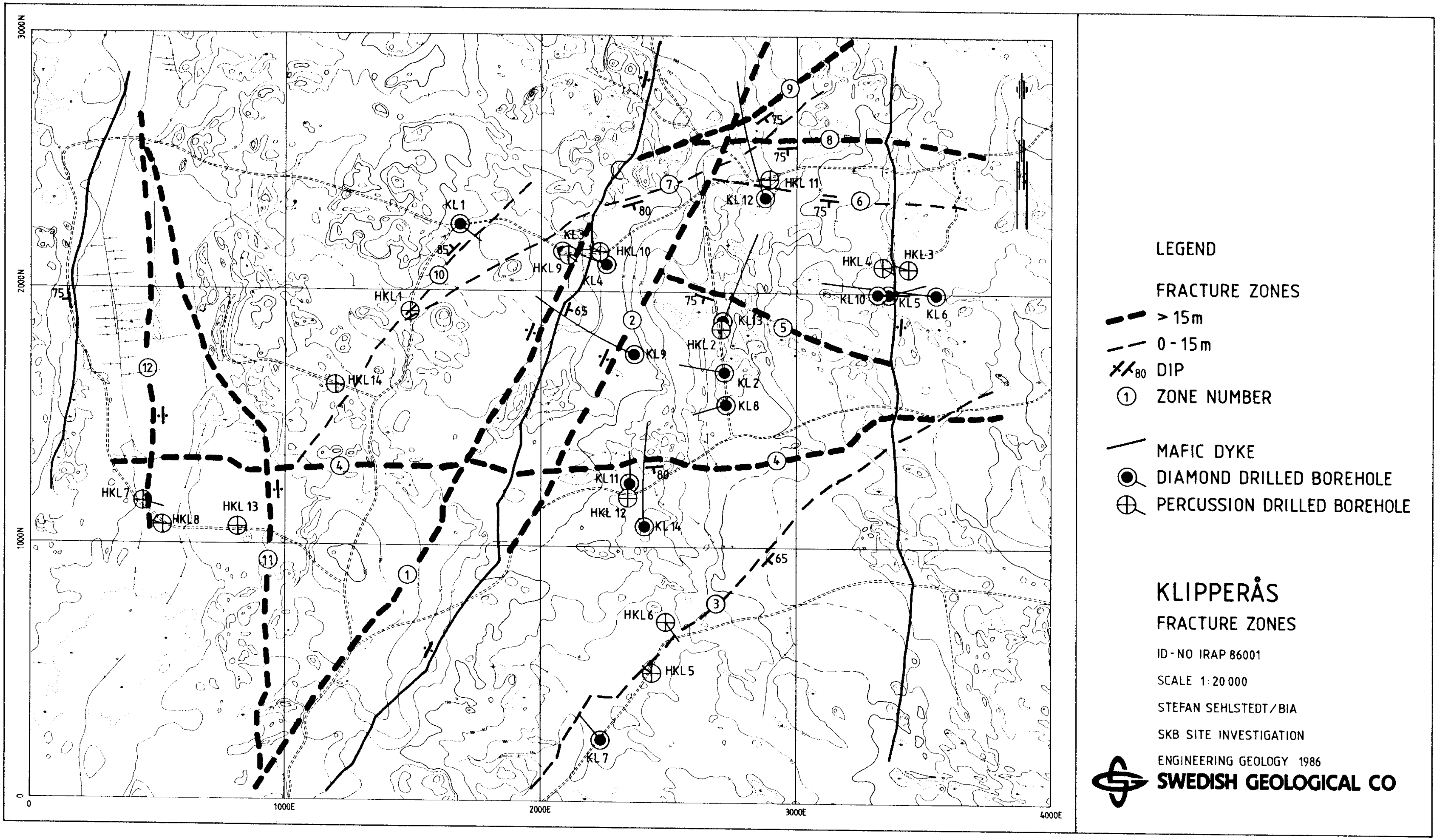


Figure 2.4 Fracture zones and dykes within the Klipperås study site (Sehlstedt, Stenberg, 1986)

	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL
Sample	01002	02001	02002	02003	02005	12001	14001	14005	09003	02004	11002	06001	06004
Rock	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*
Bore-hole	Kl 1	Kl 2	Kl 2	Kl 2	Kl 2	Kl 12	Kl 14	Kl 14	Kl 9	Kl 12	Kl 11	Kl 6	Kl 6
Deep (m)	178,15	100,15	365,50	491,00	886,80	507,20	127,90	363,50	539,25	610,00	117,00	264,00	417,75
Chlorite	xxx	xx	xx	xxx	xx	xx	xx	xx	xx	xx	(x)	xx	xx
Quartz	xx	xx	xx	x	xx	xx	xx	+	xx	-	+	-	-
Plagioclase	xx	x	x	-	x	xx	xx	xx	xx	xx	xxx	xx	xx
Epidote minerals	xx	x	xx	xx	xx	xx	x	xx	xx	x	xx	x	x
Micas	+	x	+	+	+	-	x	+	-	+	+	+	-
Calcite	+	-	+	-	-	+	-	-	-	-	-	-	-
Ore minerals	+	+	-	+	+	-	+	+	+	+	+	x	+
Amfibole	-	-	-	+	-	-	-	-	-	x	-	x	x
Unknown	-	-	-	-	-	+	-	-	-	-	-	-	-

* Gs = Greenstone

Table 2.3 Relative mineral composition of the rocks from the Klipperås study site.

	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL
Sample	01002	02001	02002	02003	02005	12001	14001	14005	09003	02004	11002	06001	06004
Rock	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*	Gs*
Bore-hole	Kl 1	Kl 2	Kl 2	Kl 2	Kl 2	Kl 12	Kl 14	Kl 14	Kl 9	Kl 12	Kl 11	Kl 6	Kl 6
Deep (m)	178,15	100,15	365,50	491,00	886,80	507,20	127,90	363,50	539,25	610,00	117,00	264,00	417,75
Chlorite	xxx	xx	xx	xxx	xx	xx	xx	xx	xx	xx	(x)	xx	xx
Quartz	xx	xx	xx	x	xx	xx	xx	+	xx	-	+	-	-
Plagioclase	xx	x	x	-	x	xx	xx	xx	xx	xx	xxx	xx	xx
Epidote minerals	xx	x	xx	xx	xx	xx	x	xx	xx	x	xx	x	x
Micas	+	x	+	+	+	-	x	+	-	+	+	+	-
Calcite	+	-	+	-	-	+	-	-	-	-	-	-	-
Ore minerals	+	+	-	+	+	-	+	+	+	+	+	x	+
Amfibole	-	-	-	+	-	-	-	-	-	x	-	x	x
Unknown	-	-	-	-	-	+	-	-	-	-	-	-	-

* Gs = Greenstone

Table 2.4 Relative mineral composition of the rocks from the Klipperås study site.

	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL	AKKL
Sample	10001	02006	14002	14007	14006	10001	06002	05001
Rock	Md*	Md*	Md*	Md*	Md*	Md**	Md**	Md**
Bore-hole	HKL 10	KKL 2	KKL 14	KKL 14	KKL 14	KKL 10	KKl 6	KKL 5
Deep (m)	55	952,55	180,05	522,20	572,00	92,10	396,10	13.50
Plagioclase	xxx	xxx	xxx	xxx	xxx	-	-	-
Pyroxene	xx	(x)	xx	xx	+	xx	xx	xx
Chlorite	xx	-	x	xx	xxx	+	+	+
Olivine/ serpentine	+	-	-	-	-	xx	xx	xx
Ore minerals	+	+	+	+	+	+	+	x
Mica	+	-	+	-	+	-	-	-
Amfibole	-	-	x	xx	x	-	-	-
Hematite	-	-	+	-	+	-	-	-
Epidote	-	-	-	xx	x	-	-	-
Quartz	-	-	-	+	-	-	-	+
Zircone	-	-	-	-	+	-	-	-
Biotite	-	-	-	-	-	+	x	+
Calcite	-	-	-	-	-	-	-	+
Undefined groundmass	-	xxx	-	-	-	xx	xx	xxx

* Md = Mafic dyke (dolerite)
** Md = " " (alkali-olivine basalt)

Table 2.5 Relative mineral composition of the rocks from the Klipperås study site.

Chemical analyses of rocks from Klipperås. Major element in weight %

	1	2	3	4	5	6	7	8	9	10	11	12	13
Id number	AKKL 01001	AKKL 14003	AKKL 14004	AKKL 01003	AKKL 05002	AKKL 09004	AKKL 01002	AKKL 02004	AKKL 06001	AKKL 14006	AKKL 14002	AHKL 10001	AKKL 06002
SiO	77.0	76.0	72.8	69.7	71.5	57.9	53.8	50.3	49.9	53.9	59.2	52.6	46.2
TiO	0.2	0.4	0.4	0.7	0.4	1.1	0.9	1.6	1.3	0.7	0.7	2.7	1.9
Al O	12.7	12.1	13.7	13.8	14.2	17.9	14.4	15.1	15.8	13.6	14.5	16.9	11.0
Fe O	1.2	2.4	2.4	4.7	2.7	6.8	0.1	2.7	1.5	8.0	7.5	10.5	11.3
MnO	<0.1	<0.1	<0.1	0.1	<0.1	0.1	0.2	0.2	0.2	0.2	0.13	0.16	0.15
CaO	0.8	1.6	1.1	2.8	1.9	5.2	9.5	8.6	8.8	9.5	8.0	7.2	8.5
MgO	0.3	1.0	0.5	1.3	1.2	1.9	8.6	8.4	9.3	10.2	8.1	5.3	15.1
Na O	3.5	3.5	3.9	4.7	4.1	3.8	1.7	2.5	2.4	2.6	2.0	3.6	0.8
K O	4.8	3.8	5.6	2.6	4.5	5.6	0.9	1.1	1.6	1.8	0.7	1.4	5.4
P O	0.03	0.15	0.07	0.23	0.16	0.38	0.33	0.30	0.24	0.25	0.18	0.67	0.50
S	<0.01	0.02	0.02	0.05	0.01	<0.01	0.07	0.02	0.09	0.07	0.08	0.15	0.11
BaO	0.04	0.1	0.05	0.09	0.12	0.15	0.05	0.05	0.07	0.06	0.03	0.05	0.15
Sum	100.7	101.1	100.5	100.8	100.8	100.9	100.6	100.9	101.2	101.0	101.1	101.2	101.1
H O>105	0.1	0.4	0.4	0.8	0.6	1.2	3.8	3.4	3.0	2.1	3.1	1.3	2.2
CO	0.1	<0.1	0.5	0.1	0.1	0.1	2.2	0.1	0.1	0.1	0.2	0.1	0.2
F	0.06	0.11	0.10	0.08	0.11	0.08	0.05	0.05	0.05	0.12	0.02	0.05	0.12
Sum	0.26	0.61	1.00	0.98	0.81	1.38	6.05	3.55	3.15	2.32	3.32	1.45	2.52

Table 2.6 XRF analysis (major elements) and wet chemical method analysis (H_2O, CO_2, F) of the rocktypes from the Klipperås study site.

	Analysis weight %	V	Cr	Co	Ni	Cu	Zn	Mo	Ba	W	Pb	Th	U	Cl	As	Rb	Sr	Y	Zr	Nb	Sn
1	AKKL 01001	0.002	<0.001	0.014	0.0011	<0.001	0.004	0.03	0.04	0.24	0.002	<0.001	<0.002	0.02	0.002	0.015	0.009	<0.001	0.016	0.003	<0.01
2	AKKL 14003	0.004	<0.001	0.014	<0.001	<0.001	0.007	0.05	0.09	0.18	<0.002	<0.001	0.004	<0.01	<0.001	0.008	0.030	<0.001	0.034	0.002	<0.01
3	AKKL 14004	0.002	<0.001	0.012	0.001	<0.001	0.007	0.08	0.05	0.18	<0.002	<0.001	<0.002	0.01	0.002	0.012	0.007	0.004	0.051	0.004	<0.01
4	AKKL 01003	0.006	<0.001	0.013	<0.001	0.003	0.055	0.06	0.08	0.17	0.013	<0.001	<0.002	0.02	0.002	0.007	0.030	0.003	0.046	0.003	<0.01
5	AKKL 05002	0.005	<0.001	0.011	<0.001	<0.001	0.009	0.04	0.11	0.16	<0.002	<0.001	0.003	0.02	0.001	0.010	0.037	<0.001	0.030	0.003	<0.01
6	AKKL 09004	0.007	<0.001	0.012	<0.001	0.002	0.014	0.06	0.14	0.13	0.004	<0.001	<0.002	0.02	0.001	0.008	0.063	0.005	0.054	0.003	0.01
7	AKKL 01002	0.018	<0.0185	0.012	0.006	0.010	0.010	<0.001	0.05	0.12	0.006	0.004	<0.002	0.02	0.003	0.007	0.092	0.004	0.020	0.003	<0.01
8	AKKL 02004	0.025	<0.0031	0.013	0.008	0.008	0.021	0.002	0.04	0.09	0.008	0.003	<0.002	0.02	0.002	0.009	0.062	0.004	0.025	0.002	<0.01
9	AKKL 06001	0.020	<0.0042	0.013	0.013	0.007	0.011	0.002	0.06	0.09	<0.002	<0.001	0.002	0.02	0.001	0.008	0.059	0.002	0.020	0.002	0.01
10	AKKL 14006	0.012	<0.0362	0.011	0.010	0.003	0.084	0.002	0.05	0.09	0.012	<0.001	0.003	0.02	0.001	0.009	0.073	0.002	0.022	<0.001	<0.01
11	AKKL 14002	0.014	<0.0037	0.012	0.015	0.006	0.006	0.003	0.03	0.10	<0.002	<0.001	<0.002	0.01	0.002	0.004	0.042	0.002	0.030	0.001	<0.01
12	AHKL 10001	0.017	<0.0030	0.013	0.007	0.007	0.118	0.003	0.05	0.10	0.006	<0.001	0.003	0.02	0.001	0.002	0.050	0.002	0.029	0.002	0.01
13	AKKL 06002	0.014	<0.0310	0.011	0.035	0.006	0.013	0.003	0.14	0.06	<0.002	0.001	0.002	0.01	<0.001	0.023	0.105	0.003	0.031	0.004	0.01

Table 2.7 XRF analysis of rocks from the Klipperås study site. Trace element.

3. TECTONICS

3.1 General description

According to the interpretation of the aerophotographs, two large regional NW-SE oriented lineaments run about 5 km north east, and 9 km south west from the Klipperås area. Within the study area, only a few, morphological weakly marked lineaments occur,Figure 3.6. This is due to the fact that the Klipperås study site is situated on the precambrian peneplane, which is extremly flat and completely covered by till.

The geophysical surface investigations and the drillings present a much more complicated and differenciated tectonic picture of the bedrock. The area of Klipperås is crossed and recrossed by a number of discontinuities, Figures 3.1 and 3.2. Directions N-S and a wide section around NE-SW represent the main orientations. These directions correspond to the results from measurements of lineaments within and around the Klipperås site as well as with the general trends in SE Sweden. Some of the discontinuities are open with high hydraulic conductivity, others are sealed by secondary minerals or by dykes of different rock compositions. Fourteen boreholes were drilled within the Klipperås area. All of those directed towards the discontinuities have confirmed their existence, either as fracture zones or as dykes.

Due to the geophysical data and the result of the drilling it is calculated that all discontinuities with the direction around N-S dip steeply, and all in the wide sector around E-W dip 75-80° to the S. Two fracture zones with the direction NE-SW turn out to have a different dip, one; 85° to the NW, the other; 65° to the SE. One zone at the level of 750 m is suggested to have a horizontal or sub-horizontal extension.

The width of the fracture zones vary. Generally, it can be stated that the width of 50 % of the investigated fracture zones are between 20 and 30 m and the width of the remaining fracture zones lie between 10 and 15 m. The width of the fracture zones vary also within the same zone, which is normal due to the undulation of the zones.

The fracture zones are generally recognized in the cores due to the increased fracture frequency, crushed rock, clay alteration and hematization of the feldspars.

All of the investigated fracture zones, except three, are associated with greenstones. In four cases, porphyry dykes and greenstones (composite dykes) are present.

The sections of the cores within and outside of the zones, sometimes for many tens of meters, consist of breccia, bands of mylonite and of increased frequency of seald fractures. Schistosity occurs mostly within the greenstones. These traces of deformation reveal that the fracture zones are situated within areas which were previously displaced, probably several times. At least four generations of fracturing occur. (Tullborg, 1986). One zone, zone 3, is suspected to be late reactivated - reflections of possibly neotectonic movement are mentioned.

Magnetic investigations also prove that tectonic affects on the bedrock are not only confined to the zone. The magnetic map of Klipperås shows large areas with low magnetization, see Figure 2.4. They follow both sides of the fracture zones. One example is the demagnitized area between zones 1 and 2, i.e. highly affected by tectonic movements. This is proved in borehole Kl 9.

The geophysical and the borehole investigations gave many indications of block displacements within the bedrock of Klipperås. It is suggested that high magnetic intensity in the area west of zone 1 represents a different part of the bedrock than the eastern area, with a low magnetic intensity. The magnitude and direction of the vertical movement is uncertain, (Sehlstedt, Stenberg, 1986). A horizontal displacement demonstrates a number of magnetic porphyry dykes in the north-eastern part of the area. The dykes are cut off by zone 2 and rotated by about 15^{o} from their original direction. An example of vertical movement is seen from borehole Kl 1. It is assumed that the area SE of the zone 10 represents a deeper, uplifted part of the bedrock than the area NW of the zone.

The geophysical interpretation of the fracturing within the Klipperås area indicates that all fracture zones and dykes are cut into pieces and have undergone variable displacements, see Figure 2.5.

Slickensides are common, but indistinctly formed. They dominate in vertical fractures, showing that the largest principal stresses within this region were released verticaly.

All of the rocks are more or less affected by tectonization. Most characteristic for the bedrock of Klipperås is the microfracturing of the granite, the rock which dominates the area. The most highly fractured parts are concentrated in the greenstones and the contacts between granites and greenstones. Generally, the granite shows the lowest fracture frequency, the greenstone the highest. See Table 3.1.

Table 3.1 Relative composition of the bedrock in the study site Klipperås and their fracture frequency.

Rock	% of the bedrock	Fractures/m
Granite	85	4,3
Greenstone	7	10,0
Porphyry dykes	5,5	7,5
Mafic dykes (dolerite)	1,4	6,4
" " (basalt)	0,1	18,7
Aplite	1	7,4
	100	

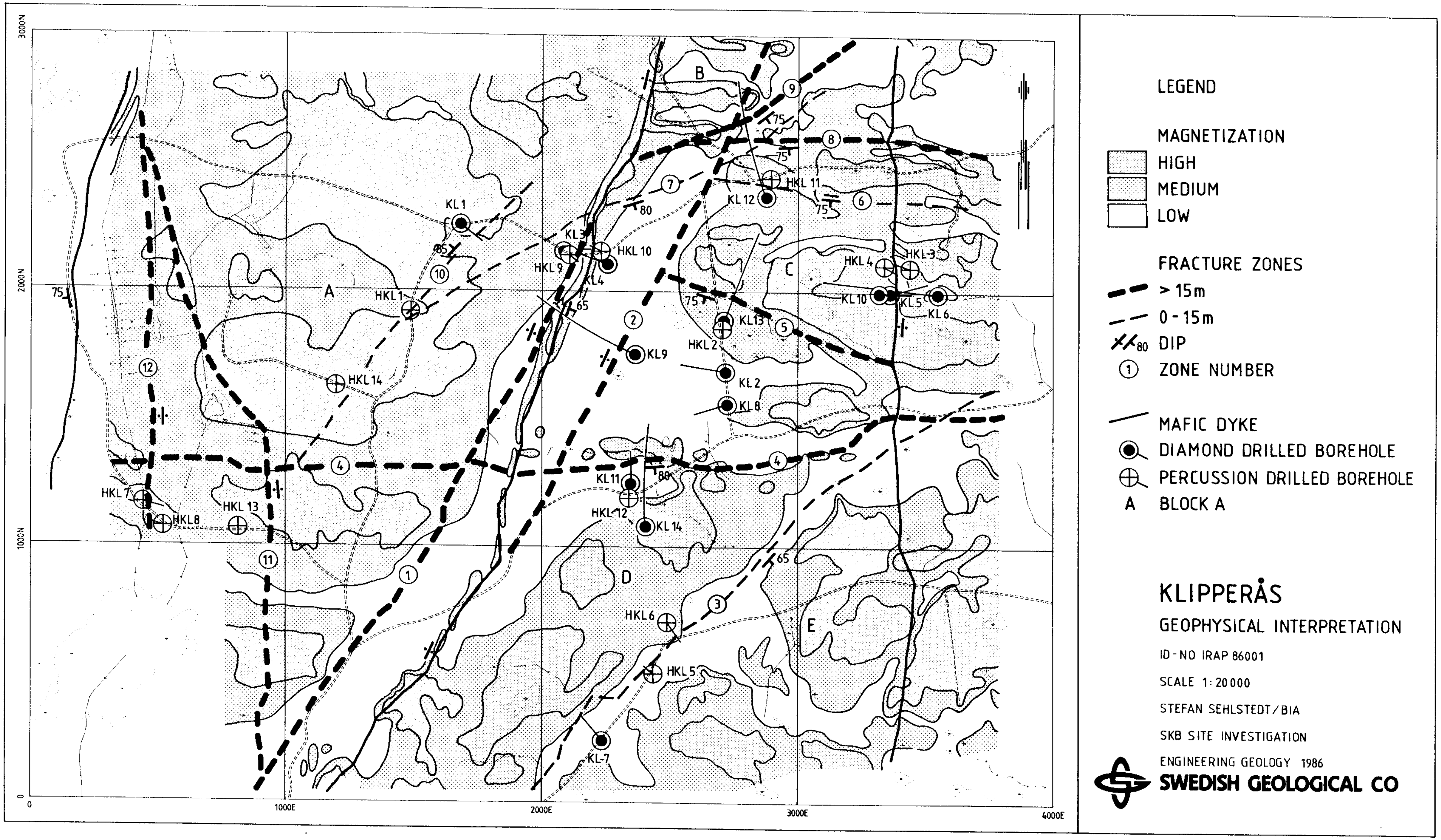


Figure 3.1 Interpretation of the magnetic and electromagnetic measurements of the Klipperås study site (Sehlstedt, Stenberg, 1986).

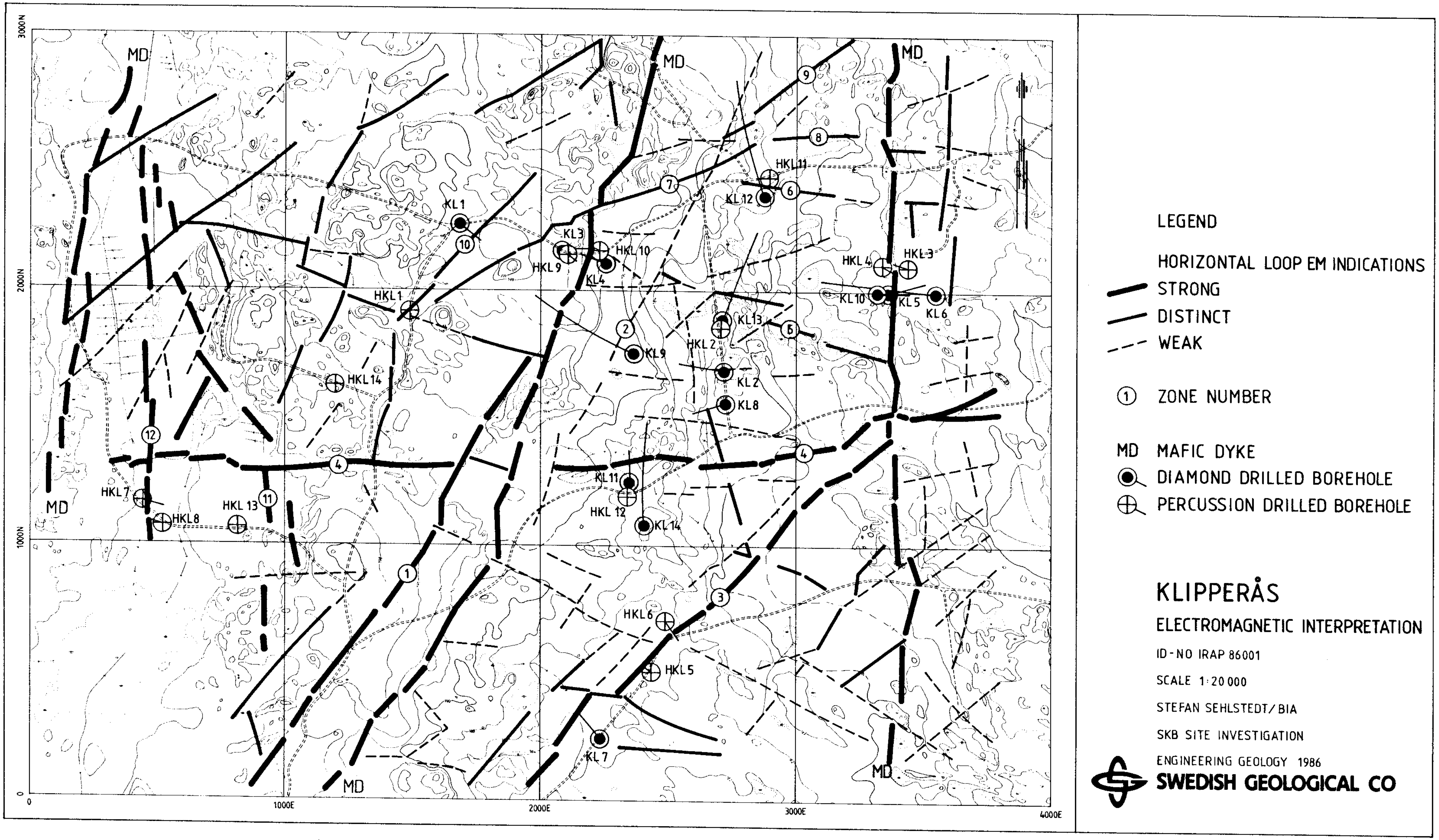


Figure 3.2 Electromagnetic interpretation of horizontal loop EM measurements (Sehlstedt, Stenberg, 1986).

3.2 Lineaments

3.2.1 Regional interpretation of lineaments

The morphological lineaments visible on aerial photographs were classified as (i) distinct lineaments and (ii) weak lineaments.

In the area analysed, Figure 3.3, two major tectonic zones can be seen, oriented approximately NW-SE. These seperate the NE and SW cornes from the middle part. These zones are made up of closely arranged sets of long lineaments, and are considered to be of regional importance.

The existence of the northern regional lineament was confirmed during the general survey of the area, Figure 2.1. The scattered outcrops along this line consist of strongly mylonitized and linearly structured granite.

The resulting picture in the middle part of area is formed by a complicated pattern where several directions are represented as short and distinct lineaments. In the diagram of lineament length distribution, Figure 3.5, it is shown that the lengths of over 60 % of the lineaments do not exceed 3 km.

The prevailing concentration of lineaments in the NW sector, Figure 3.4, depends largely on ice erosion. The second important direction of lineaments is oriented almost perpendicularly to the ice movement. These lineaments are weakly defined but form persistent lines. They have E and NE directions.

3.2.2 Interpretation of lineaments within the Klipperås study site

Within the Klipperås study site, only morphologically very weak marked lineaments occur. In most cases the interpretation is uncertain. The western part of the area exhibits the highest frequency of lineaments. The central part, where all of the boreholes are located, is practically without lineaments. The length of the lineaments never exceeds one kilometer. Most of them are shorter than 500 m in length.

After control in the field, only 6 of 53 aerial photo interpretated lineaments could be recognized within the site, Figure 3.6.

The distribution of directions is presented in an azimuth frequency diagram, Figure 3.7. This diagram shows five well developed trends of directions:

1. dominant trend, oriented approximately N-S
2. oriented about N25°W
3. " " N55°W
4. " " N25°E
5. " " N55°E

3.2.3 A comparison between different interpetation methods.

In spite of the uncertainity of the mapping the lineaments within the Klipperås site and in spite of the small number of lineaments discovered, the diagram in Figure 3.7 corresponds rather well with the statistics made over the area of 625 km^2 around the Klipperås, Figure 3.4. The only discrepancy which can be seen appears around the E-W directions, where lineaments are absent within the investigation area for this case.

If we compare the results of the aerially investigated lineaments in Figures 3.4 and 3.7 with the statistics made on the geophysically indicated discontinuities, Figure 3.8 from the map in Figure 3.2, we can see that a discrepancy occurs. If we exclude the influence of the glaciation, two dominant trends remain,- one around N-S, and a second within a wider sector around N45°E.

This results corresponds well with the observationes made within SE Sweden by Rösshoff and Lagerlund (1977). The tectonic pattern there has main direction in N, NW and WNW.

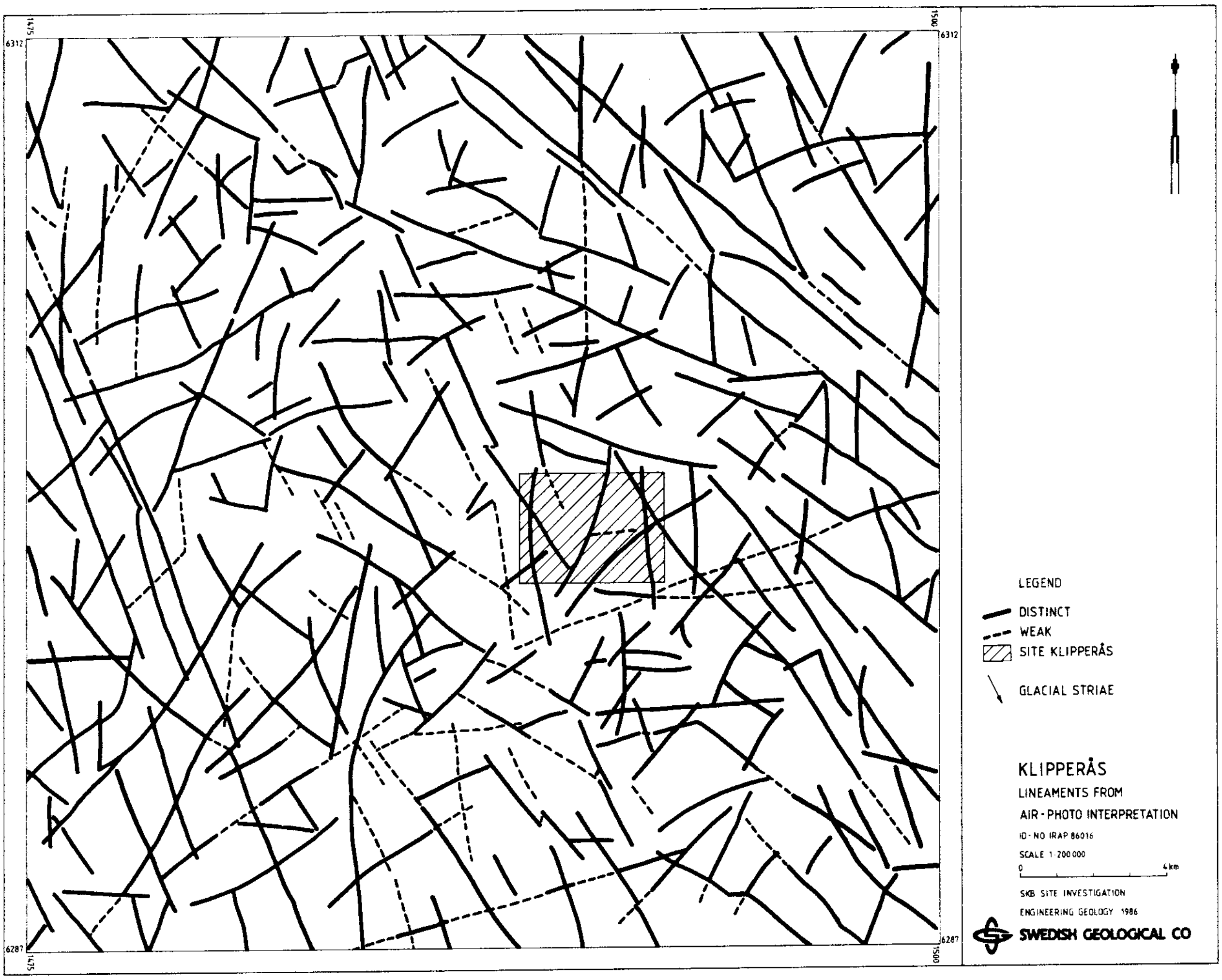


Figure 3.3 Lineament interpretation map over an area of 625 km^2.

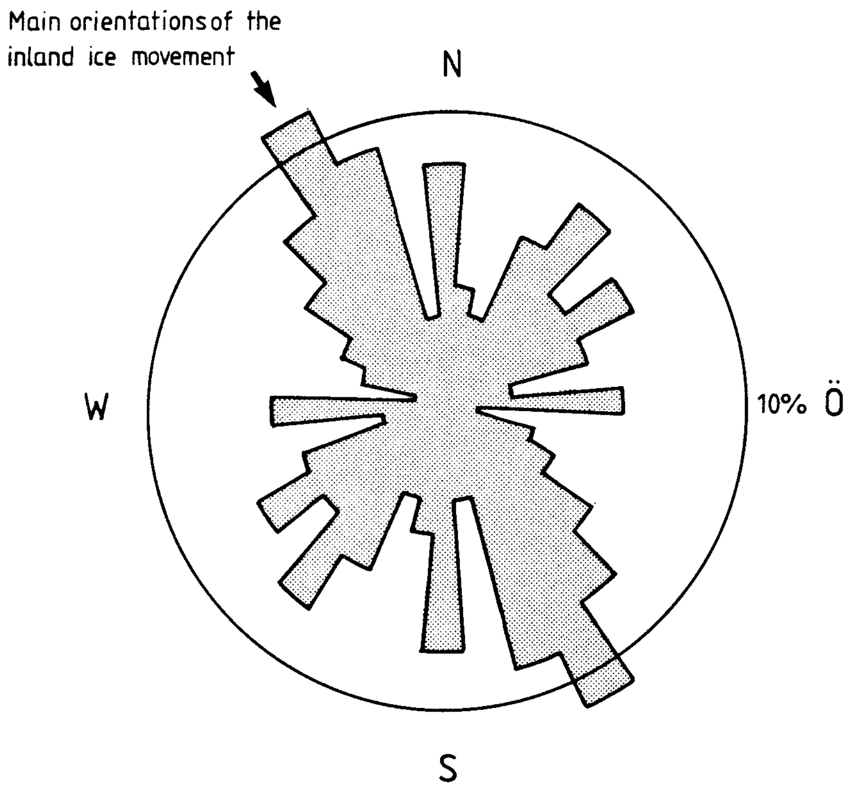


Figure 3.4 Azimuth frequency diagram for lineaments from Figure 3.3. Number of mapped lineaments are 262.

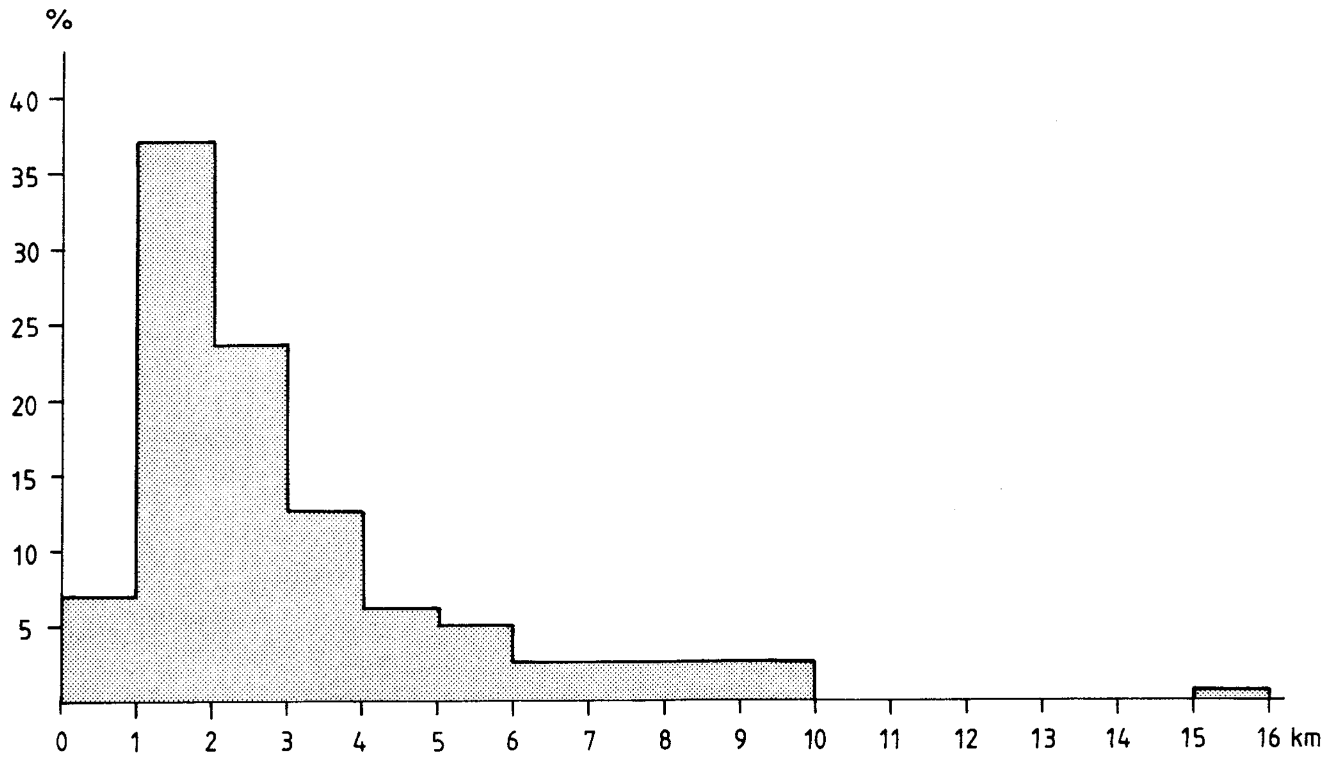


Figure 3.5 Length distribution histogram for lineaments from Figure 3.3. Number of mapped lineaments are 262.

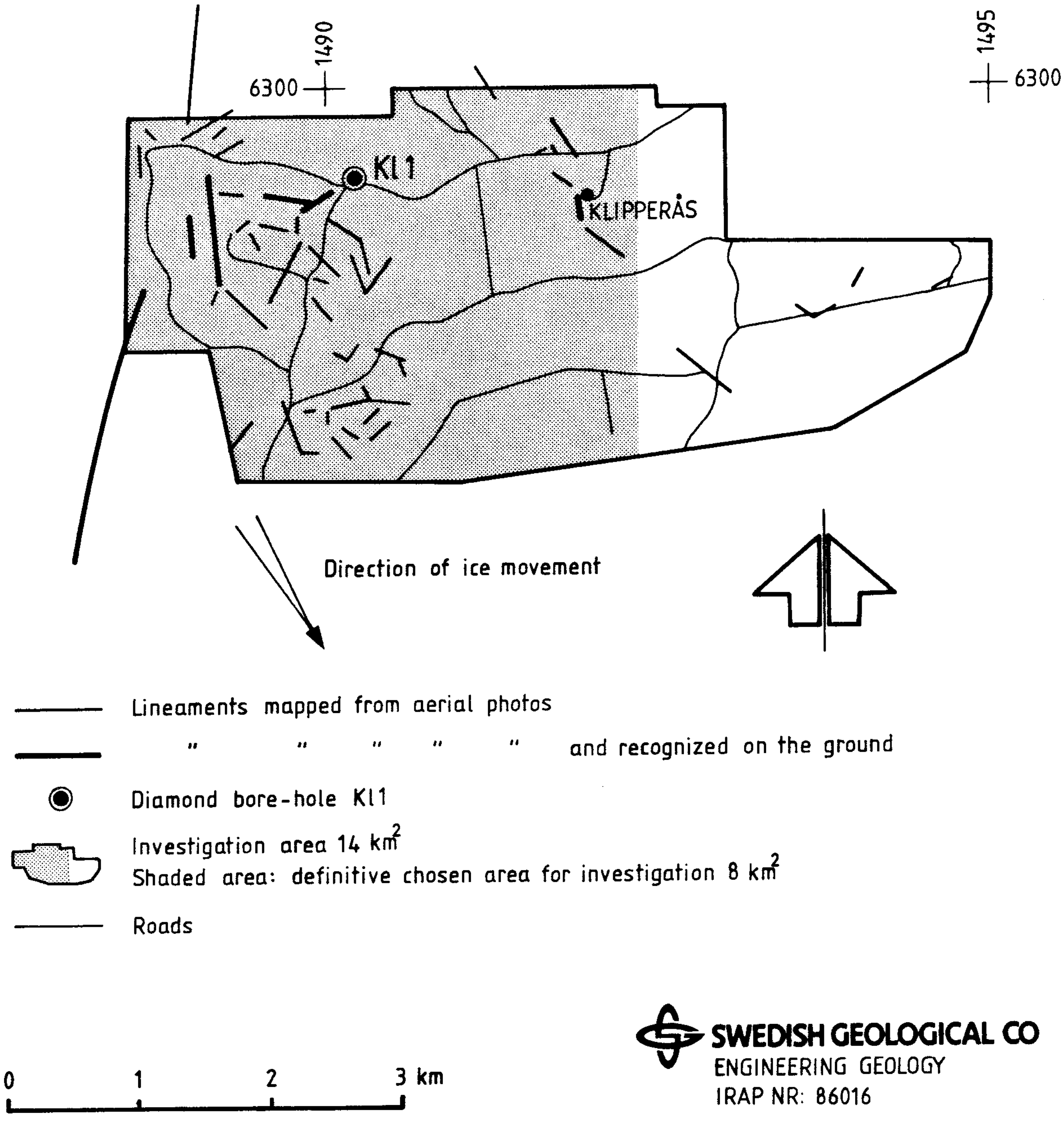


Figure 3.6 Lineament interpetation of the Klipperås study site.

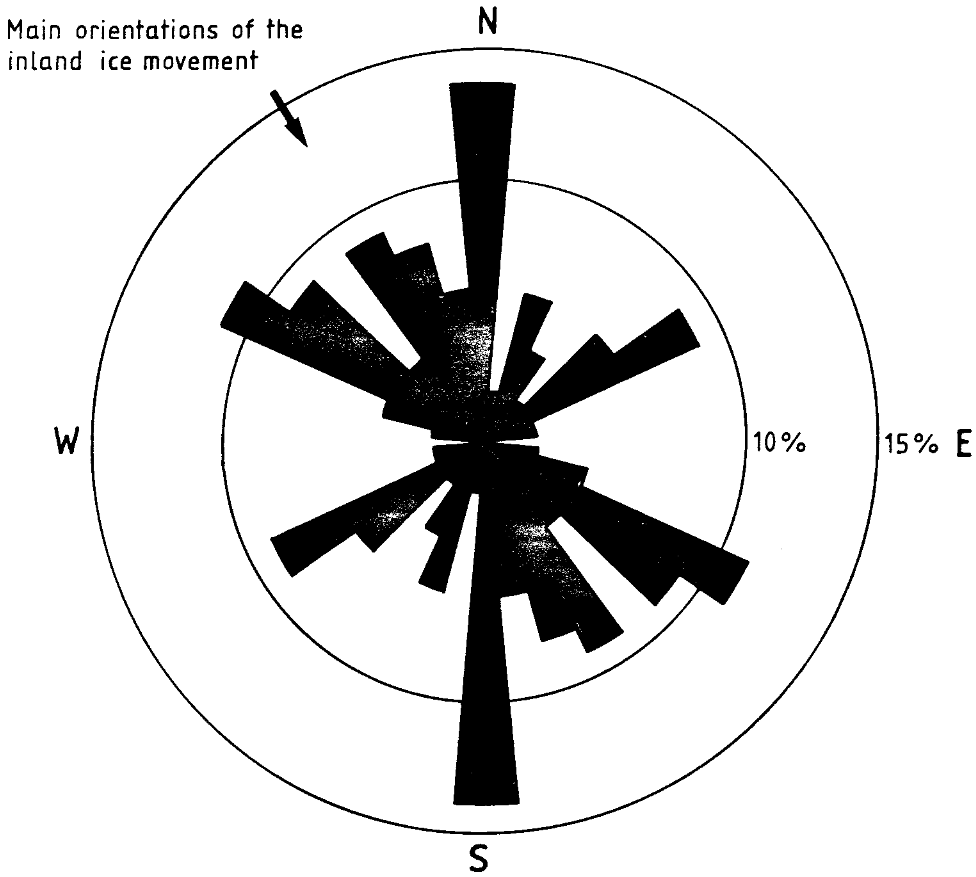


Figure 3.7 Azimuth frequency diagram for lineaments within Klipperås study site interpetated from areial photographs.

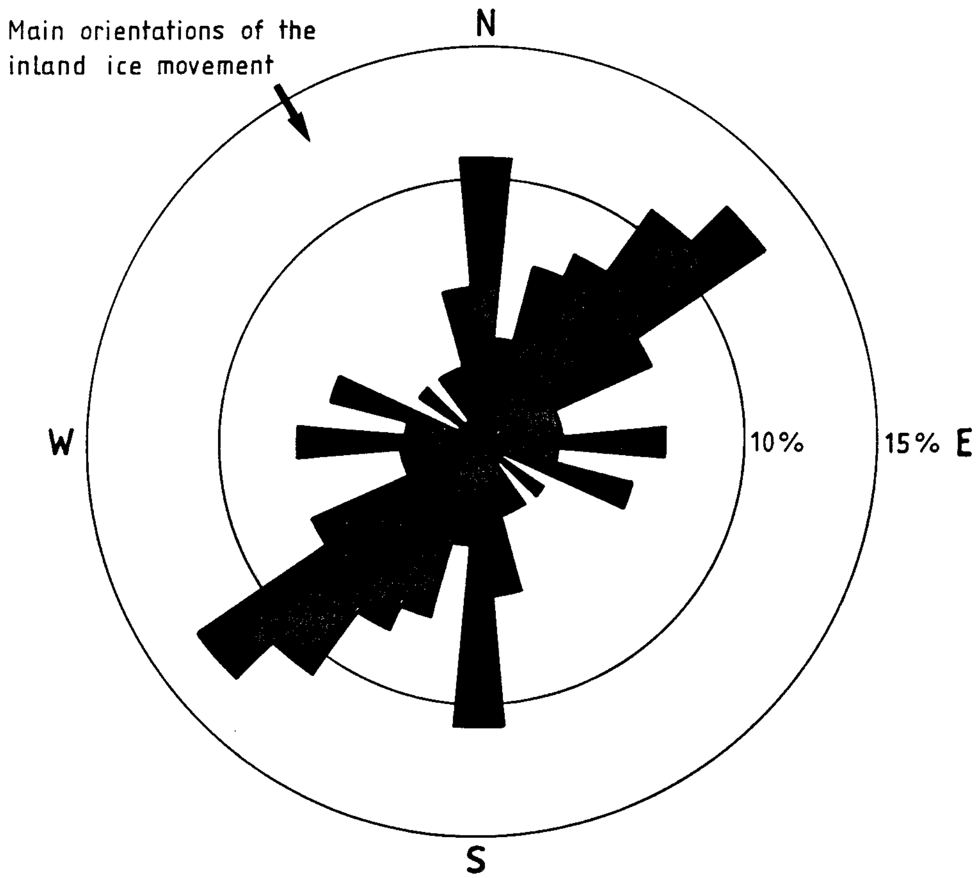


Figure 3.8 Azimuth frequency diagram for lineaments interpetated from electromagnetic measurements.

3.3 Description of the fracture zones at the Klipperås study site.

Regarding the directions of the zones discussed below, it must be said that due to the later movements of the rock mass, no fracture zone has a completely continuous extension, but is in shorter or longer sections faulted by other fracture zones. Some of the zones change direction slighty, but the main strike direction maintained. See Figure 3.1 and 3.2.

3.3.1 Zone 1

Zone 1 has been intersected by three boreholes, Kl 3, Kl 4 and Kl 9, Figures 3.2, 3.19 and 3.20. The principal direction of the zone is N25^{o}E and it has a vertical dip. The average width is 30 m. Data from each borehole intersecting the zone is presented in Table 3.2. According to the geophysical surface measurements, the northen part of the zone is intruded by a mafic dyke, whose width is approximately 10 m.

Table 3.2 Data from boreholes intersecting zone 1

Borehole	Zone sec. Resistiv.	Zone sec. Frac.freq.	Vert.depth	Strike/Dip	True width
Kl 3	140-195 m	140-190 m	145.1 m	N-S/90^{o}	28 m
Kl 4	110-180 m	122-180 m	125.6 m	N20^{o}E/90^{o}	36 m
Kl 9	615-665 m	610-662 m	554.3 m	N30^{o}E/90^{o}	29 m

Fractions of normal, fractured and crushed rock within the zones from each borehole are presented in Figure 3.9.

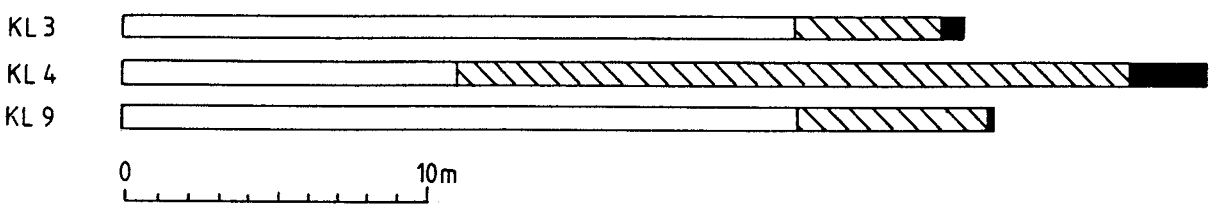


Figure 3.9 Precentage of crushed (black), highly fractured (striped) and slightly fractured bedrock (non coloured) in the fracture zone 1 at Klipperås.

All rock types within the fracture zones are strongly brecciated, mylonitized with fissures sealed by quartz, epidote or calcite.

Two percussion boreholes (HKl 9 and HKl 10) were directed towards zone 1. HKl 9 intersects zone 1 giving a water flow of 20000 l/h. HKl 10 did not intersect zone 1 and only produced less than 6000 l/h water flow.

3.3.2 Zone 2

Zone 2 has been intersected by two boreholes, Kl 9 and Kl 12, Figures 3.20 and 3.24. The principal direction of the zone is N25^{o}E and it has a vertical dip. The average width is 20 m. Data from each borehole intersecting the zone is presented in Table 3.3. According to the geophysical surface measurements is the southernmost part of the zone is intruded by a mafic dyke whose width is approximately 10 m.

Table 3.3 Data from boreholes intersecting zone 2

Borehole	Zone sec. Resistiv.	Zone sec. Frac.freq.	Vert. depth	Strike/Dip	True width
Kl 9	120-160 m	125-153 m	121.2 m	N30^{o}E/90^{o}	22 m
Kl 12	595-630 m	595-630 m	501.7 m	N15^{o}E/85^{o}E	13 m

Fractions of normal, fractured and crushed rock within the zones from each borehole are presented in Figure 3.10.

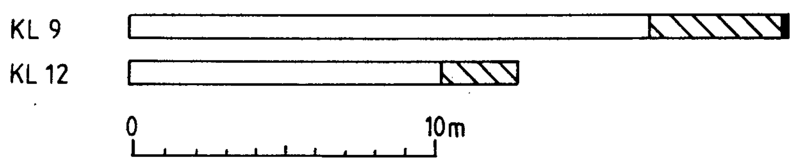


Figure 3.10 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 2 at Klipperås.

In Kl 9 in the middle of the zone, a gouge, 1.5 cm in width, can be found. Long sections of the core are altered. Quartz and calcite are the most common minerals sealing the fractures. Quartz fillings in particular can be rather broad. Several are 5 cm in width, one is 60 cm in width. A 5 m length section of the core is brecciated and partly mylonitized.

The zone in Kl 12 is brecciated, mylonitized and foliated in shorter and longer sections. The core is interwoven by many epidote and quartz sealed fractures.

3.3.3 Zone 3

Zone 3 has been intersected by borehole Kl 7, Figures 3.2 and 3.21. The principal direction of the zone is N35^{o}E and it has a dip of 65^{o} to the east. The width is 12 m. Data from the borehole intersecting the zone is presented in Table 3.4.

Table 3.4 Data from boreholes intersecting zone 3

Borehole	Zone section	Vert.depth	Strike/Dip	True width
Kl 7	115-130 m	106.1 m	N35^{o}E/65^{o}E	12 m

Fractions of normal, fractured and crushed rock within the zone from the borehole are presented in Figure 3.11.

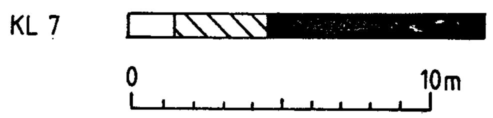


Figure 3.11 Percentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 3 at Klipperås.

The core section from 107 to 137 m is exceptionally disturbed. Between 116 to 127 m, most of the rock is crushed and one meter of this section consists of grey-yellow sand. A microscopy study shows also that the sand is a product of crushing. The sharp edged, 0.1-1 mm grains, consist of small rock fragments: granite, greenstone and porphyry. The clay alteration of the fragments is very thin. This indicates that the reactivation of an older, probably composite dyke containing zone 3 is of a younger date (Tullborg,1986). Does the zone 3 represent a result of neotectonic movement? According to Rösshoff and Lagerlund (1977), traces of some weak neotectonic movements are observed within SE Sweden, but extensive marked neotectonism is unknown.

Generally, the bedrock within the zone and below it shows old breccias, mylonites and quartz and epidote filled fractures. This zone has therefore been displaced earlier, probably several times.

The two percussion boreholes HKl 5 and HKl 6, Figure 3.2, were drilled towards zone 3. The sinking speed diagram of HKl 5 shows that the bedrock in this area is fractured and crushed. HKl 5 gave a water flow of 6600 l/h at 69 m and at 90 m depth respectively. The borehole HKl 6 never reached the zone, but confirms the information from the core of Kl 7 that the NW side of the zone is also strongly fractured. At 141 m in HKl 6, water was produced of a rate of 1500 l/h, and at 146 m at a rate 2000 l/h.

3.3.4 Zone 4

Zone 4 has been intersected by two boreholes, Kl 11 and Kl 14, Figures 3.2 and 3.22. The principal direction of the zone is E-W and it has a dip of 80^{o} to the south. The average width is 25 m. Data from each borehole intersecting the zone is presented in Table 3.5.

Table 3.5 Data from boreholes intersecting zone 4

Borehole	Zone sec. Resistiv.	Zone sec. Frac.freq.	Vert.depth	Strike/Dip	True width
Kl 11	108-148 m	108-148 m	98 m	N75^{o}E/90^{o}	23 m
Kl 14	368-410 m	368-410 m	337 m	N85^{o}E/80^{o}	27 m

Fractions of normal, fractured and crushed rock in zone 4 from each borehole are presented in Figure 3.12.

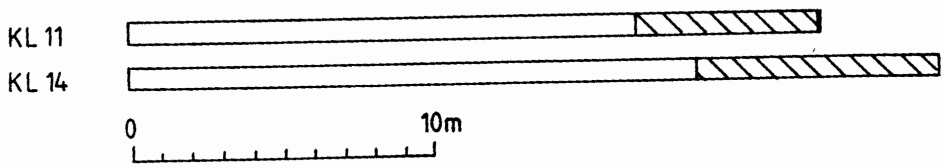


Figure 3.12 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 4 at Klipperås.

It can bee seen from Table 3.5 that zone 4 has different widths in Kl 11 and Kl 14, section 108-148 (40 m) and section 368-410 (42 m) respectively. The cause of this discrepancy is uncertain. One explanation can be that the disturbed section in Kl 14 is a section of intersection for two or more minor fracture zones. The electric surface mesurements display a very weak WNW oriented discontinuity crossing the zone 4 above this section, see Figure 3.22. The undulation within the zone could be another explanation.

The fracture frequency in Kl 11 is high. It has three crushed sections. These represent a minor part of the core. Hematitsation is common and clay alteration occurs in two sections, of 5 cm and 2 cm thickness. Drill water losses were recorded at four differnt depths. Old tectonic structures, such as breccia and sealed fractures occur mainly within and very close to the fracture zone.The sealing material consists mostly of epidote quartz and calcite.

The drill core from Kl 14 shows traces of earlier tectonic movements, not only witin the zone, but also ca 70 m on both sides of the zone. Shistosity, breccia, mylonite and many epidote sealed fractures characterize this section of the core. The fracture frequency is very high, but only a small part of the core is crushed. Alteration is common and in two places clay alterations occur in the rock. In one place, a 40 cm long section is clay altred. Drill water losses have been observed within the zone.

3.3.5 Zone 5

Zone 5 has been intersected by Kl 13, Figures 3.2 and 3.23. The principal direction of the zone is N80^{o}W and it has a dip of 75^{o} to the south. The width is 23 m. Data from the borehole intersecting the zone is presented in Table 3.6.

Table 3.6 Data from the borehole intersecting zone 5

Borehole	Zone section	Vert. depth	Strike/Dip	True width
Kl 13	152-188 m	147.2 m	N80^{o}W/75^{o}S	23 m

Fractions of normal, fractured and crushed rock within the zone from borehole is presented in Figure 3.13.

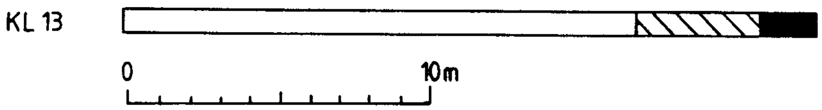


Figure 3.13 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 5 at Klipperås.

Drill water losses were observed at 173.0 m, 174.2 m and 175.3 m. Hematization, alteration and clay alteration occur. The rock within the zone is brecciated, mylonitized and interwoven by epidote sealed fractures.

3.3.6 Zone 6

Zone 6 has been intersected by the borehole Kl 12, Figure 3.2 and 3.24. The principal direction of the zone is N75^{0}W and it has a dip of 75^{0} to the south. The width is 12 m. Data from the borehole intersecting the zone is presented in Table 3.7.

Table 3.7 Data from boreholes intersecting zone 6

Borehole	Zone section	Vert. depth	Strike/Dip	True width
Kl 12	70- 88 m	64.7 m	N75^{0}W/75^{0}S	12.5 m

Fractions of normal, fractured and crushed rock within the section from the borehole are presented in Figure 3.14.

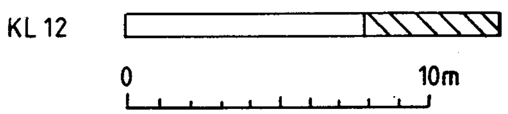


Figure 3.14 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 6 at Klipperås.

Hkl 11 which is 100 m long and located close to zone 6 has a water production of 3000 l/h recorded at 30 m depth which corresponds well with Kl 12. Kl 12 shows several water losses and a high fracture frequency. The sinking speed diagram of Hkl 11 indicates a rather uniform bedrock not having larger changes in quality. This contradiction in the results obtained may have its origin in single water bearing fractures.

The core shows tectonic influences such as brecciation, mylonitization, foliation and sealed fractures. Even below zone 6, in the direction of zone 7, many narrow sequences of mylonitization and foliation can be found.

3.3.7 Zones 7, 8 and 9

The 288-384 m section in drill core Kl 12 has a high fracture frequency, which is in accordance with the borehole logging (Sehlstedt and Stenberg, 1986). Nevertheless,it is possible to select within this disturbed section three distinct fracture zones: 7, 8 and 9, Figures 3.2 and 3.24. The core shows also that the area within, between and outside the zones from 230 to 400 m, was previously, and probably at several times, tectonized. All of this section of the core is highly brecciated, mylonitized and shows a large number of epidote sealed fractures and also a smaller number of quartz sealed fractures.

Zone 7

Zone 7 has been intersected by Kl 12, Figure 3.24. The principal direction of the zone is N65°E and it has a dip of 80° to the south. The width is 13.5 m. Data from the borehole intersecting the zone is presented in Table 3.8.

Table 3.8 Data from the borehole intersecting zone 7

Borehole	Zone section	Vert. depth	Strike/Dip	True width
Kl 12	288-306 m	257.2 m	N65°E/80°S	13.5 m

Fractions of normal, fractured and crushed rock within the zone from borehole is presented in Figure 3.15.

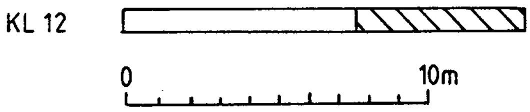


Figure 3.15 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 7 at Klipperås.

Zone 8

Zone 8 has been intersected by borehole Kl 12, Figure 3.24. The principal direction of the zone is N85^{o}W and has a dip of 75^{o} to the south. The width is 28 m. Data from the borehole intersecting the zone is presented in Table 3.9.

Table 3.9 Data from boreholes intersecting zone 8

Borehole	Zone section	Vert. depth	Strike/Dip	True width
Kl 12	312-347 m	285.4 m	N85^{o}W/90^{o}	28 m

Fractions of normal, fractured and crushed rock within the zone from borehole is presented in Figure 3.16.

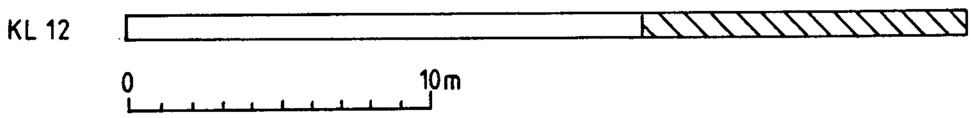


Figure 3.16 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 8 at Klipperås.

Zone 9

Zone 9 has been intersected by boreholes Kl 12, Figure 3.24. The principal direction of the zone is N60^{o}E and it has a 75 dip to the south. The width is 17.5 m. Data from the borehole intersecting the zone is presented in Table 3.10.

Table 3.10 Data from borehole intersecting zone 9

Borehole	Zone section	Vert. depth	Strike/Dip	True width
Kl 12	362-384 m	323.0 m	N60^{o}E/75^{o}S	17.5 m

Fractions of normal, fractured and crushed rock within the zone from the borehole are presented in Figure 3.17.

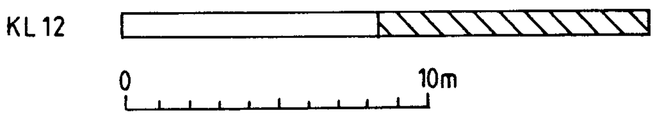


Figure 3.17 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 9 at Klipperås.

3.3.8 Zone 10

Zone 10 has been intersected by the borehole, Kl 1, Figures 3.2 and 3.25. The principal direction of the zone is N45^{o} E and dips 85^{o} to the NW. The width is 10.5 m. Data from the borehole intersecting the zone is presented in Table 3.11.

Table 3.11 Data from borehole intersecting zone 10

Borehole	Zone sec. Resistiv.	Zone sec. Frac.freq.	Vert.depth	Strike/Dip	True width
Kl 1	280-310 m	284-305 m	290.5 m	N45^{o}E/85^{o}NW	10.5m

Fractions of normal, fractured and crushed rock within the zone from the borehole are presented in Figure 3.18.

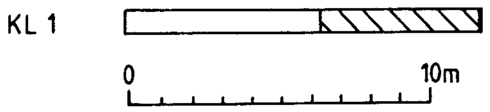


Figure 3.18 Precentage of crushed, highly fractured and slightly fractured bedrock in the fracture zone 10 at Klipperås.

A long section, 280-330m, partly within the zone, shows signs of tectonic stress, breccia, mylonite and foliation.

Within the zone, at 289 m, drill water losses were registered.

According to the results of analysis of the core and to the hydrogeological and geophisical mesurements in the borehole it is assumed that a vertical displacement had occured along zone 10. This assumption is based on the different character of the two blocks on either side of zone 10. The upper part is dominated by horizontal and subhorizontal fractures, while the fractures in the lower block are nearly all vertical. There is also a difference in the physical and hydrogeological properties. The upper part has lower resistivity and very high hydraulic conductivity. In the lower part the properties are reversed, a high resistivity and a hydraulic conductivity below detection limit. Water analyses from the lower part (406 m) also reveal water with long residence time (Smellie at al,1985). It is sugested that the lower part,SE of the fracture zone 10, represents a deeper, uplifted part of the bedrock.

3.3.9 Zones 11 and 12

According to the geophysical measurements, three strong anomalous indications occur in the western part of the area. No diamond drilling was performed in these areas. See Figure 3.2.

Two of them, 11 and 12, are supposed to be fracture zones.

Their width and dip is unknown.

The westernmost,third one, is assumed to be a dolerite dyke. It strikes in the direction N15^{o}E, dips steeply to the west and has a width of about 100 m.

3.3.10 Zone H1

A twelve meter lenght section, from 792 to 804 m of the borehole Kl 2 has lower resistivity values, Figure 3.26. Due the technical difficulties a long section of the core within and in vicinity of the zone is not available. The remaining part of the core, related to this zone (8 m), consists of highly fractured granite mixed with compressed greenstone. Crushed rock comprises 50 cm of the core. The rocks are slightly altered and hydrate Fe oxides cover fracture surfaces. Water transport has therefore occurred within the fractures. In one place, within the zone, at 802 m, flush water loses were noted. The rocks within the above mentioned part of the core consist of epidote and calcite healed breccia.

All calculations to correlate these fracture zones with surface indications or with some existing fracture zones in other boreholes were unsuccessful. A horizontal or subhorizontal position of the zone H1 is therefore the most probable. A preliminary interpretation of the data from borehole radar investigations confirms the existence of a fracture zone; it starts at 765 m and has an inclination of about 30^{o} to the horizontal plane.

3.3.11 The area between zones 1 and 2

The zones 1 and 2 are two zones which extend almost parallel, right through the investigated area. The distance between them varies from about 250 m in the south to about 350 m in the north.

The magnetic measurements on the surface show that the area between these two zones has an anomalously low magnetization, Figure 3.1, page 41. The probable explanation of this divergence is that zones 1 and 2 have moved against each other and caused strong fracturing of the block lying between them. The deformation associated with the fracturing provided routes for the hydrothermal solutions, which oxidized the magnetite existing in the rocks, and hence caused demagnatisation of the bedrock. The drillcores from the borehole Kl 9 and 4 confirms this explanation. The borehole Kl 9, penetrating this interzonal block, shows a number of strongly fractured sequences, Figure 3.20. In addtion, during the drilling of Kl 9 in this section, four places with flush water looses were discovered.

The drillcore also shows traces after old and now sealed brecciations and mylonitizations. This implies that the area between zones 1 and 2 had probably been fractured in several earlier tectonic movements. The borehole Kl 4, most of which was drilled inside the interzonal block, shows the same picture.

Within the area between zones 1 and 2 in the north ther exist several narrow, E-W directed, highly magnetic belts, see Figures 3.1 and 3.24. These are supposed to be porphyry dykes. The magnetic structures continue on the eastern side of the zone 2, but in the direction of WNW. The abrupt change of direction must mean that the interzonal block moved along zone 1 to the south, and along zone 2 to the north.

A narrow, very strong magnetic belt runs along the low magnetic anomaly. It is a dolerite dyke which intruded the northern part of zone 1, the southern part of zone 2 and connected these two zones obliquely across the anomaly. We can assume that at the time of the dolerite intrusion, only these parts of the vertical zones 1 and 2 had been opened and the conduction was formed a discharging fracture, dipping by approximately 60^{o} to the E.

3.3.12 The tectonic picture of the area around the mafic dyke shown by boreholes Kl 5, 6 and 10.

The mafic dyke has been intersected by three boreholes, Kl 5, Kl 6 and Kl 10, Figure 3.27. Drilling showed that the mafic dyke is fractured but the hydrological investigation showed no increase in conductivity within the dyke. The principal direction of the dyke is N-S and it has a vertical dip. The average width is 10 m. Data from each borehole intersecting the dyke is presented in Table 3.12.

Table 3.12 Data from boreholes intersecting a mafic dyke

Borehole	Zone sec. Resistiv.	Zone sec. Frac.freq.	Vert.depth	Strike/Dip	True width
Kl 5	19- 29 m	12- 34 m	20.8 m	N-S/90^{o}	5 m
Kl 6	338-372 m	351-370 m	307.2 m	N-S/90^{o}	17 m
Kl 10	88-100 m	87-105 m	72.0 m	N-S/90^{o}	8 m
Hkl 3	90- 96 m	-	71.2 m	N-S/90^{o}	>5 m

Parts of the mafic dyke which occur within the fractured section are clay altered. In boreholes Kl 5 and 10, where the mafic dyke is in contact with a porphyry dyke, this porphyry also shows a high fracture frequency. In Kl 6 the highest fracture frequency is limited to the mafic dyke. In contrast to the porphyry , the surrounding granite has a low fracture frequency. Whether this phenomenon is due to the different competece of the rocks, or whether the fracturing in the porphyry dike is associated with this rock and follows its geographical extension, cannot be answered.

About 100 m to the north, two percussion holes, HKl 3 and 4, were drilled towards the mafic dyke. The sinking speed diagram of HKl 4 shows an increasing sinking speed in section 22 to 50 m. The rock there is probably highly fractured and crushed. This highly fractured sequence is situated directly to the west of the mafic dyke. The dyke itself shows a slowly decreasing sinking speed.

The increased sinking speed is probably caused by a tectonized porphyry dyke which is indicated there by the geophysical surface measurements.

According to experience from earlier drilling, we can suppose that the mafic dyke is rather tough for the percussion drill.

The borehole gives, at 40 m depth ca 3600 l/h and at 60 m ca 4200 l/h water.

The second percussion hole HKl 3 was drilled from the opposite side of the dyke. According to the geophysics the hole reaches the dyke, but does not go through it. Here, the sinking speed diagram indicates a decreasing speed, except in some few short sequences. The borehole produces only ca 1500 l/h.

Note:

Parallel to the mafic dyke, about 40 m to the east runs a N-S going lineament. It is an offset with a difference of ca 2,5 m between the levels. The offset in the morain is equivalent in the bedrock. Here,the difference is ca 5 m.
In the beginning off the investigations it was considerent that this lineament represents a fracture zone. The drillings show that this is not the case. No continuation beneath the lineament exists.The probable explanation is that a large plate of the granite was transported away by the glacier.

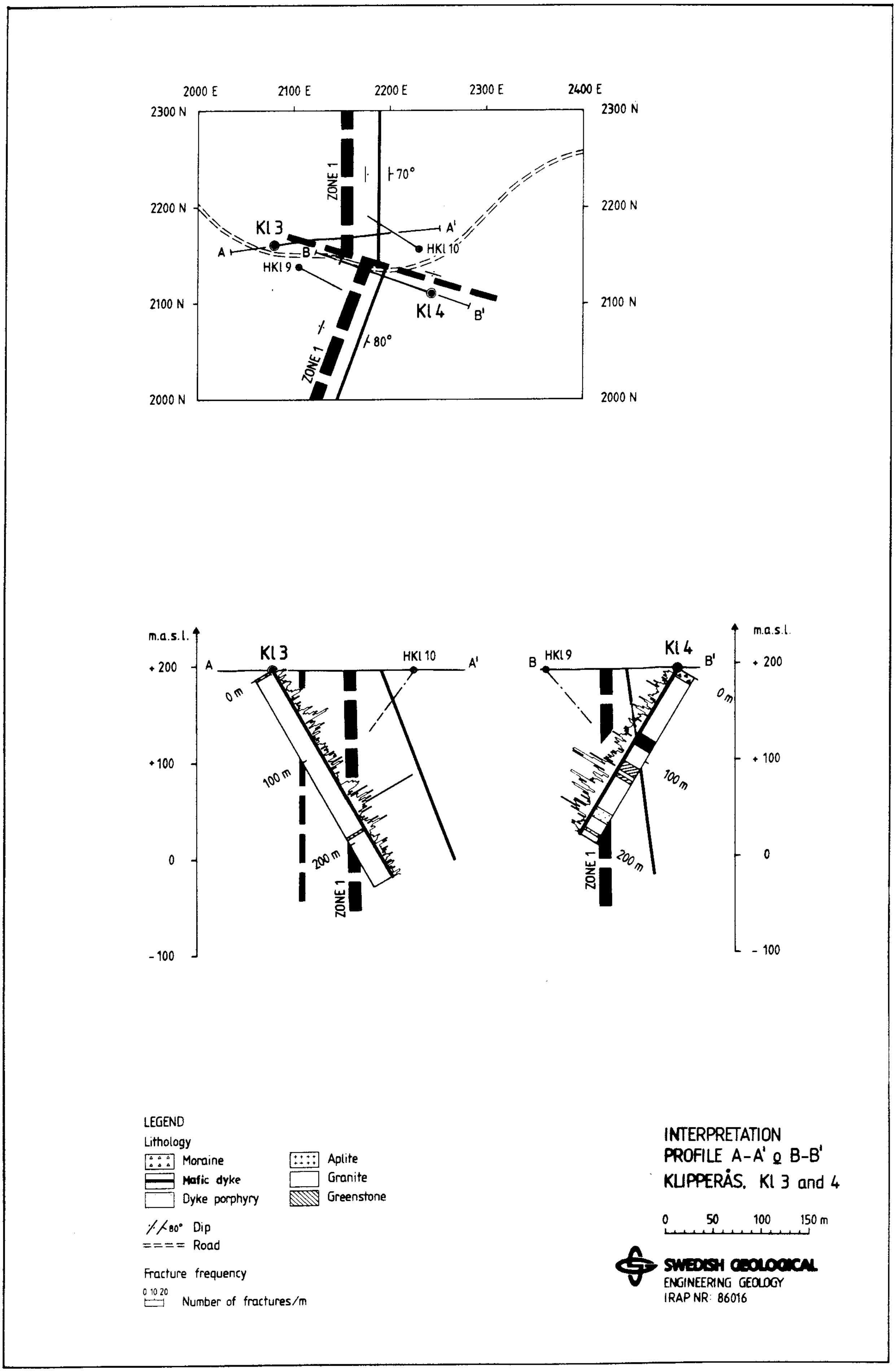


Figure 3.19 Schematic lithology and fracture frequency with interpretation of the boreholes Kl 3 and Kl 4.

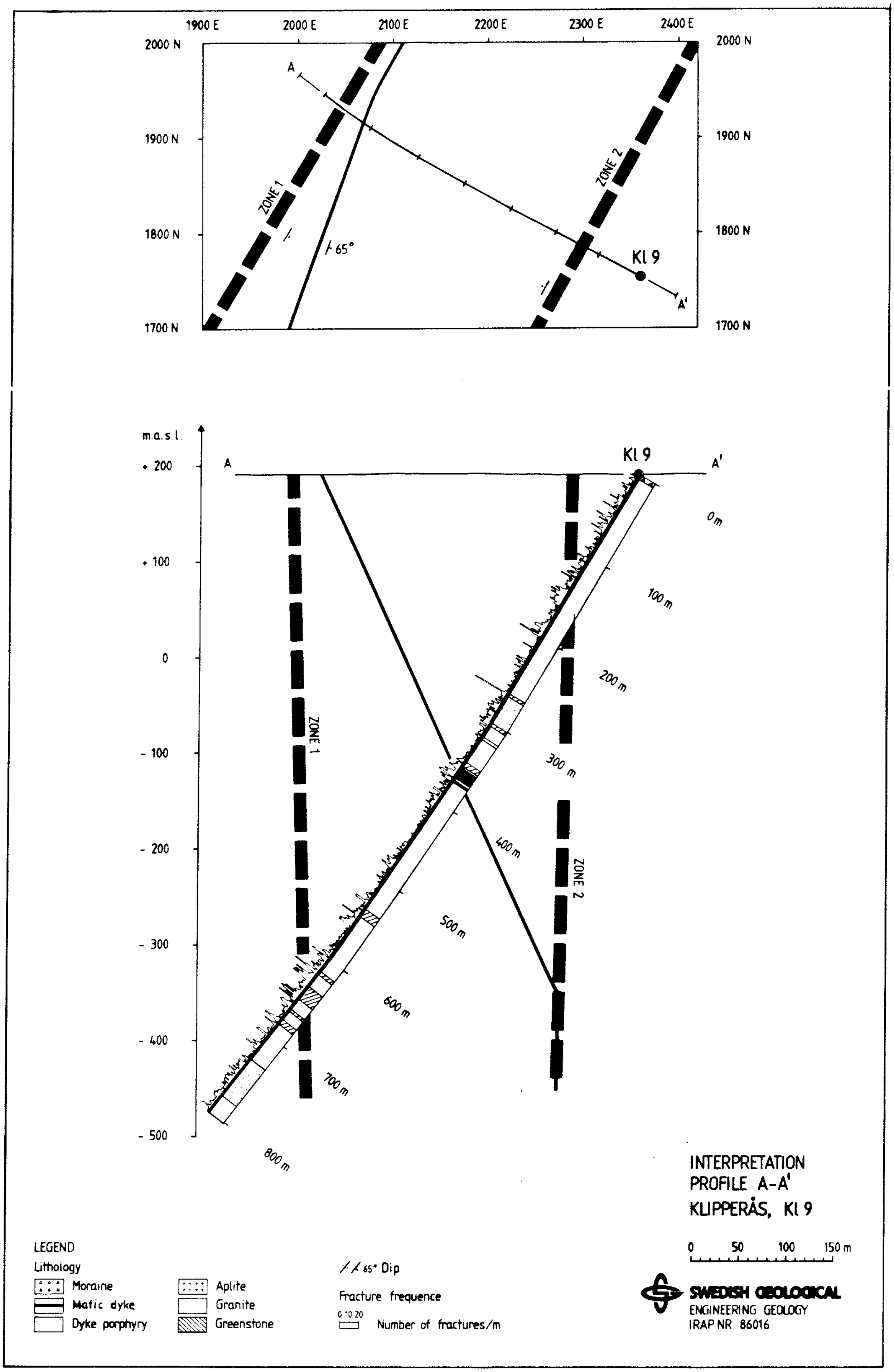


Figure 3.20 Schematic lithology and fracture frequency with interpretation of the borehole Kl 9.

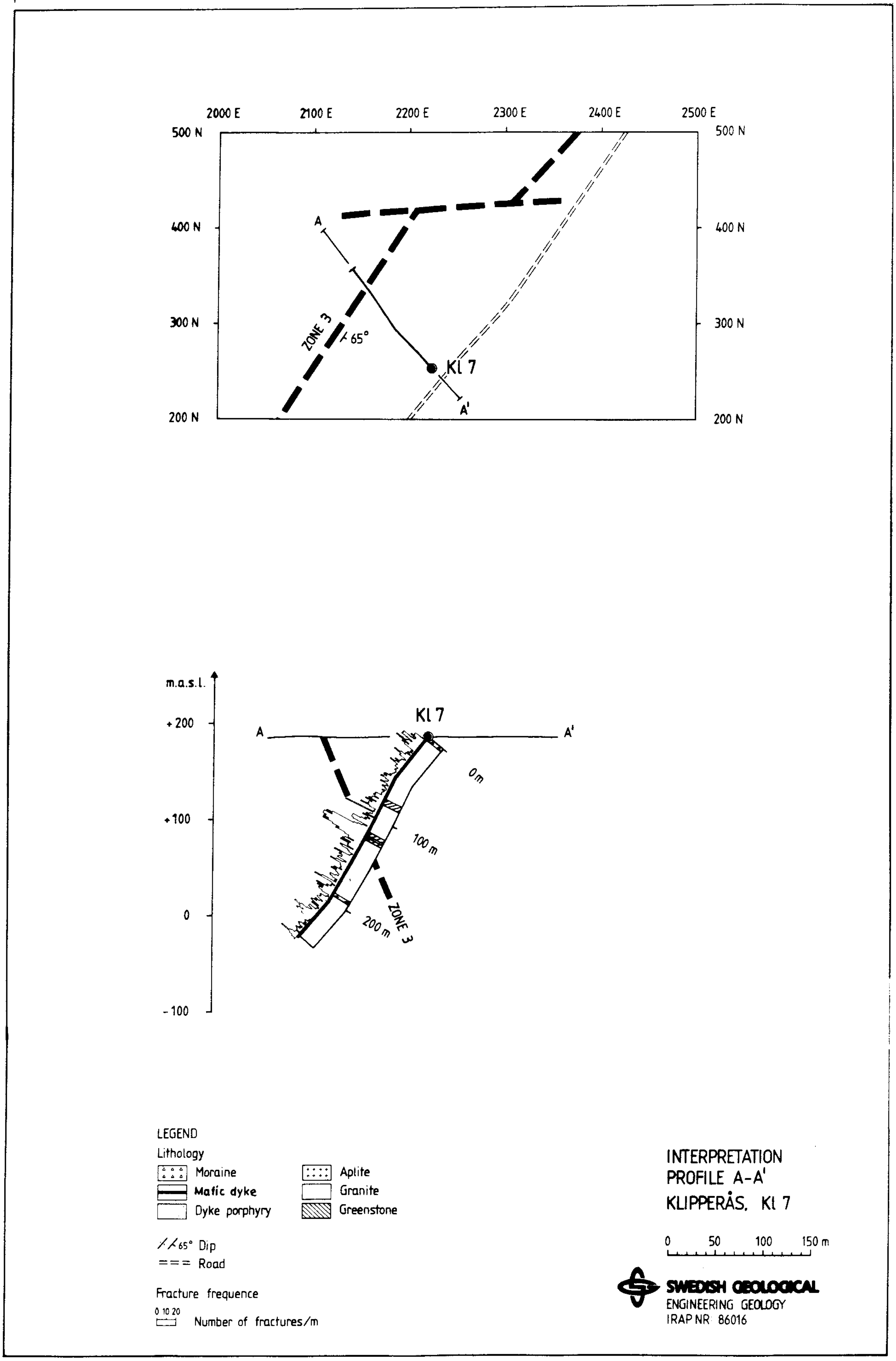


Figure 3.21 Schematic lithology and fracture frequency with interpetation of the borehole Kl 7.

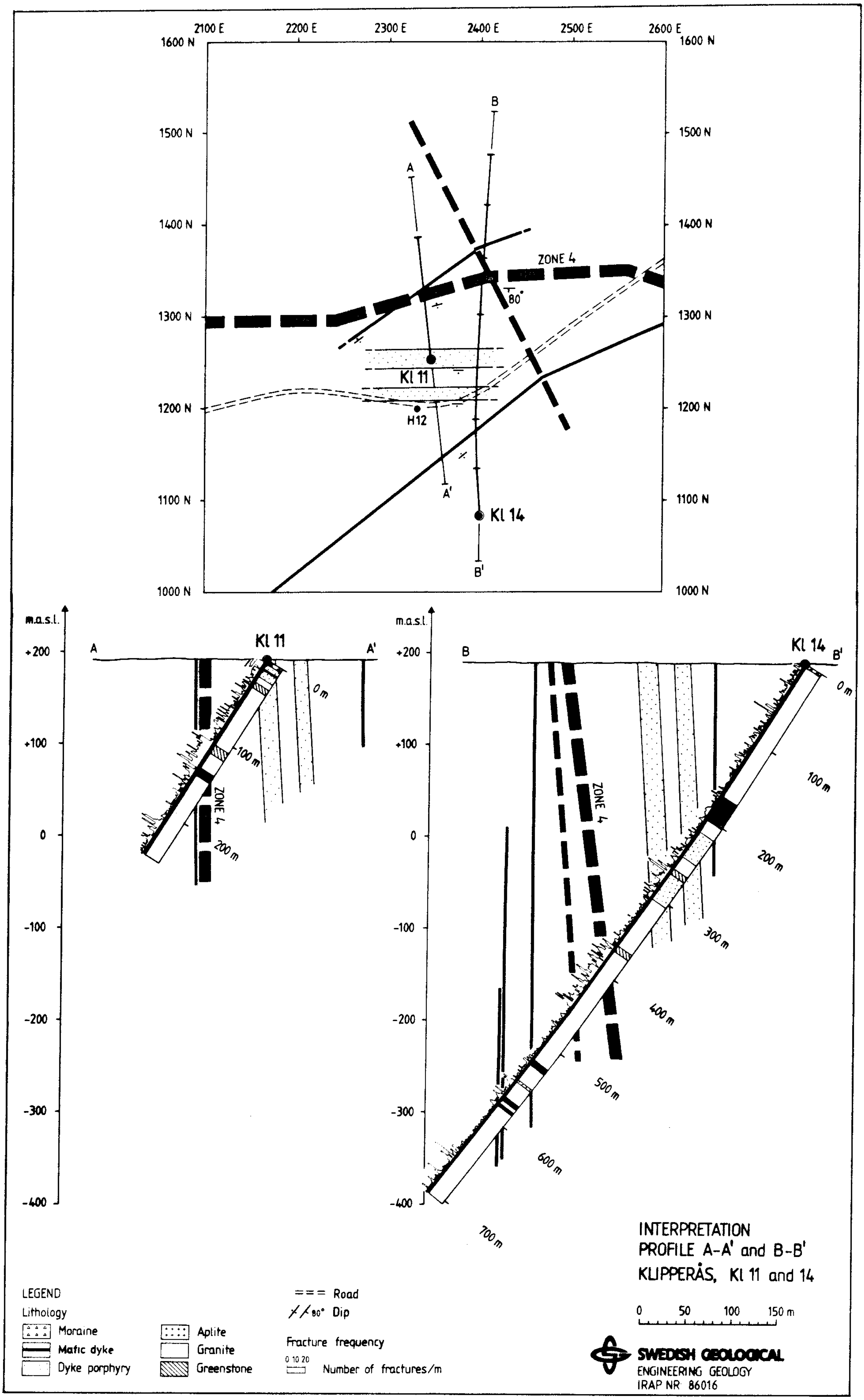


Figure 3.22 Schematic lithology and fracture frequency with interpretation of the boreholes Kl 11 and Kl 14.

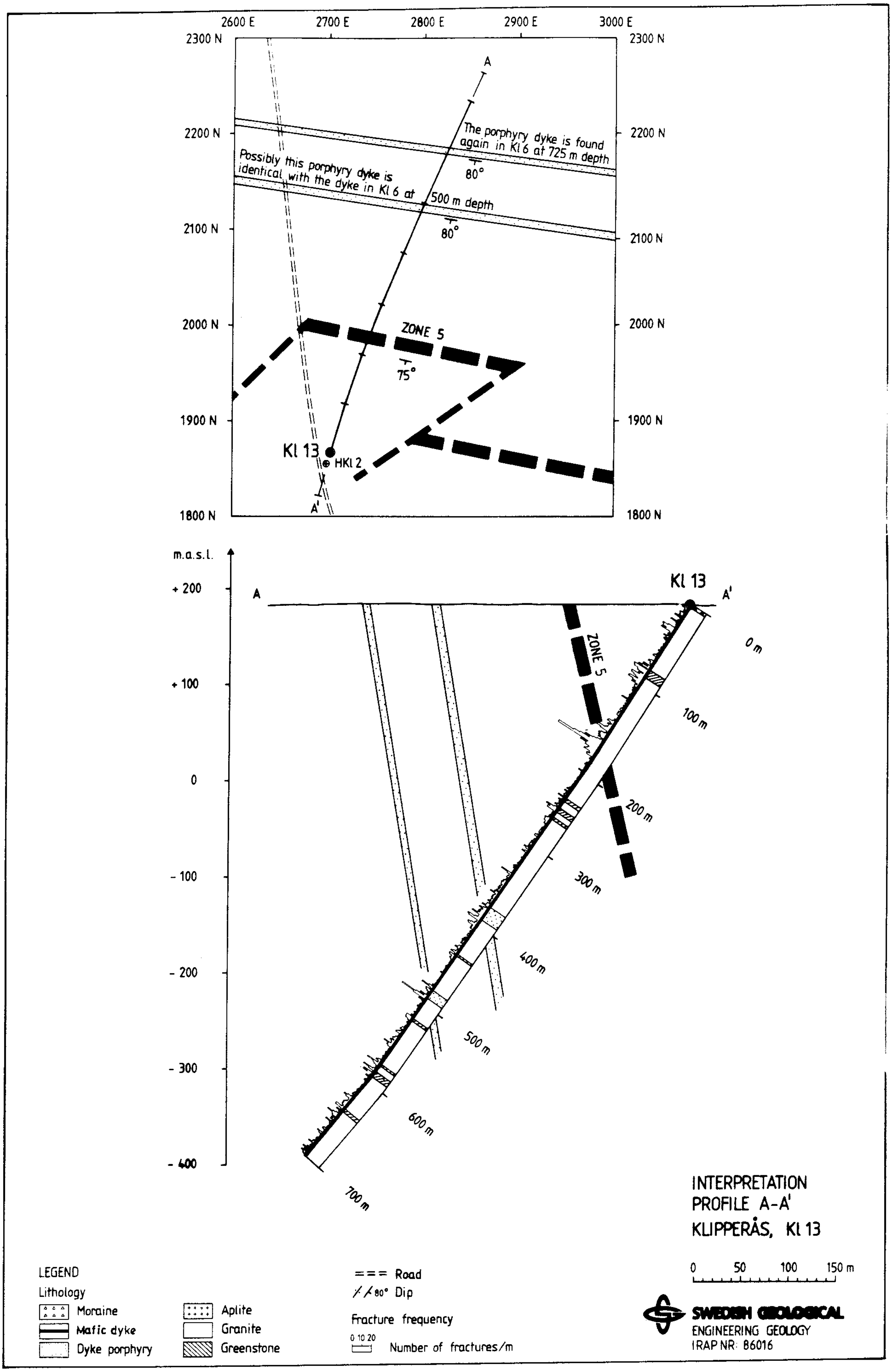


Figure 3.23 Schematic lithology and fracture frequency with interpretation of the borehole Kl 13.

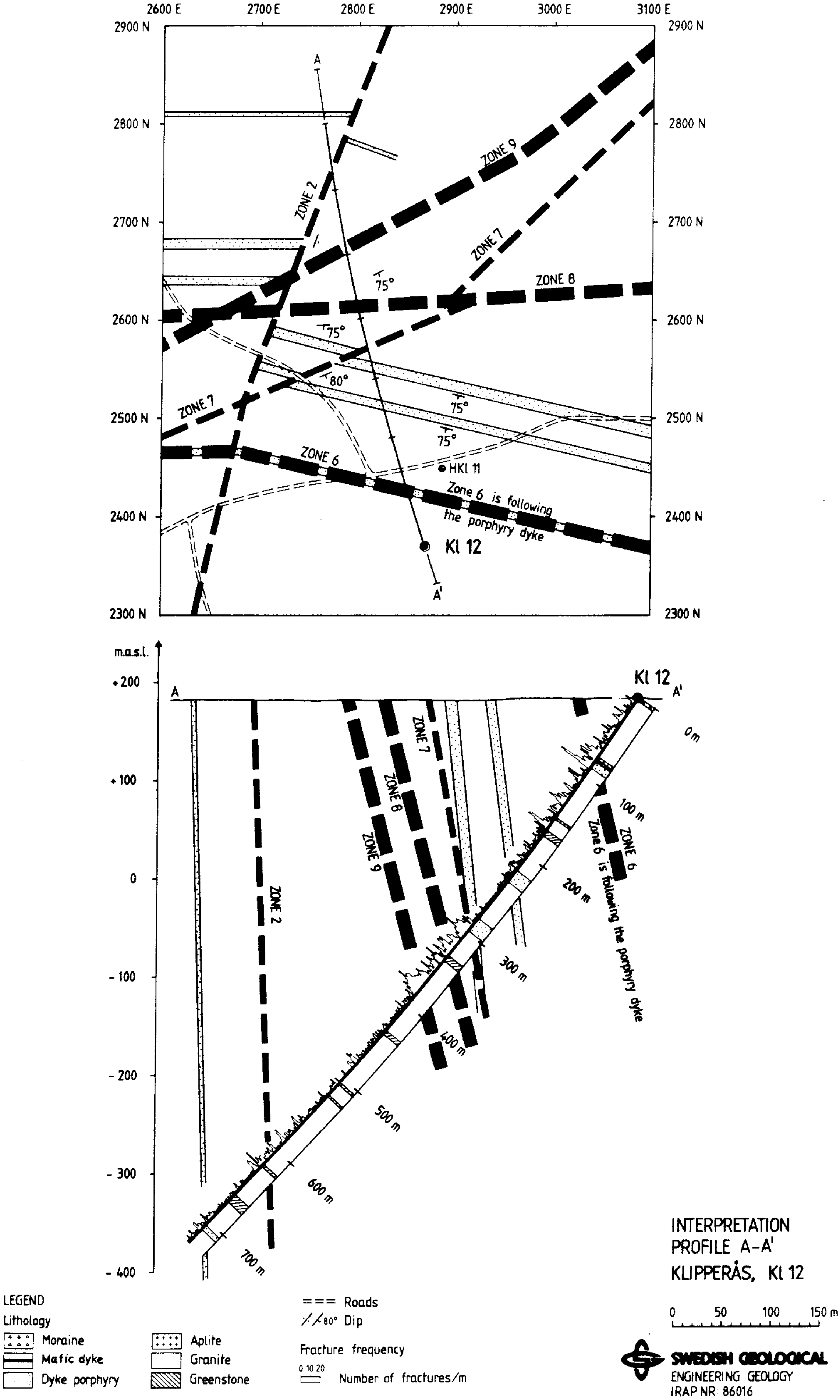


Figure 3.24 Schematic lithology and fracture frequency with interpretation of the borehole Kl 12.

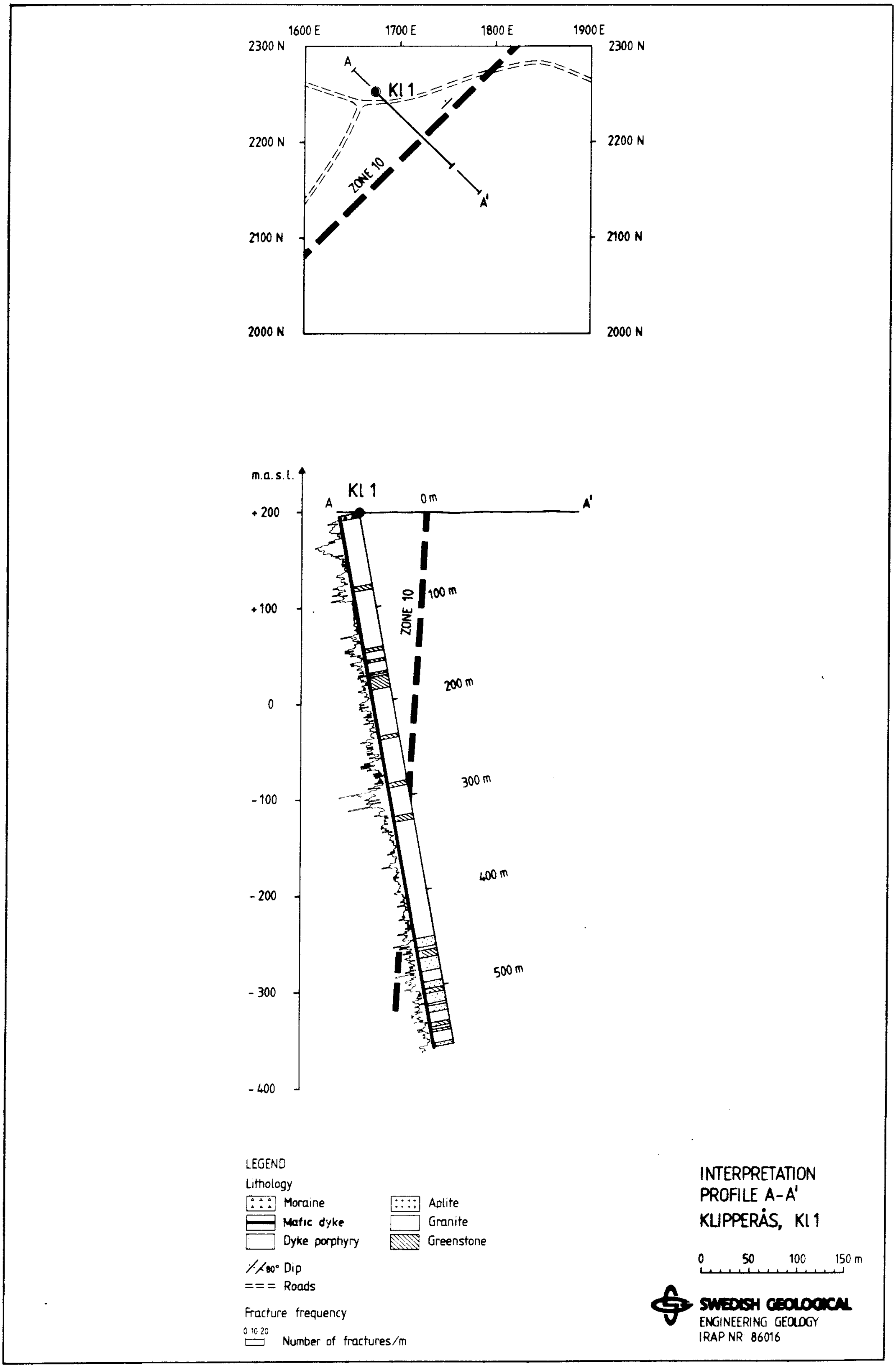


Figure 3.25 Schematic lithology and fracture frequency with interpretation of the borehole Kl 1.

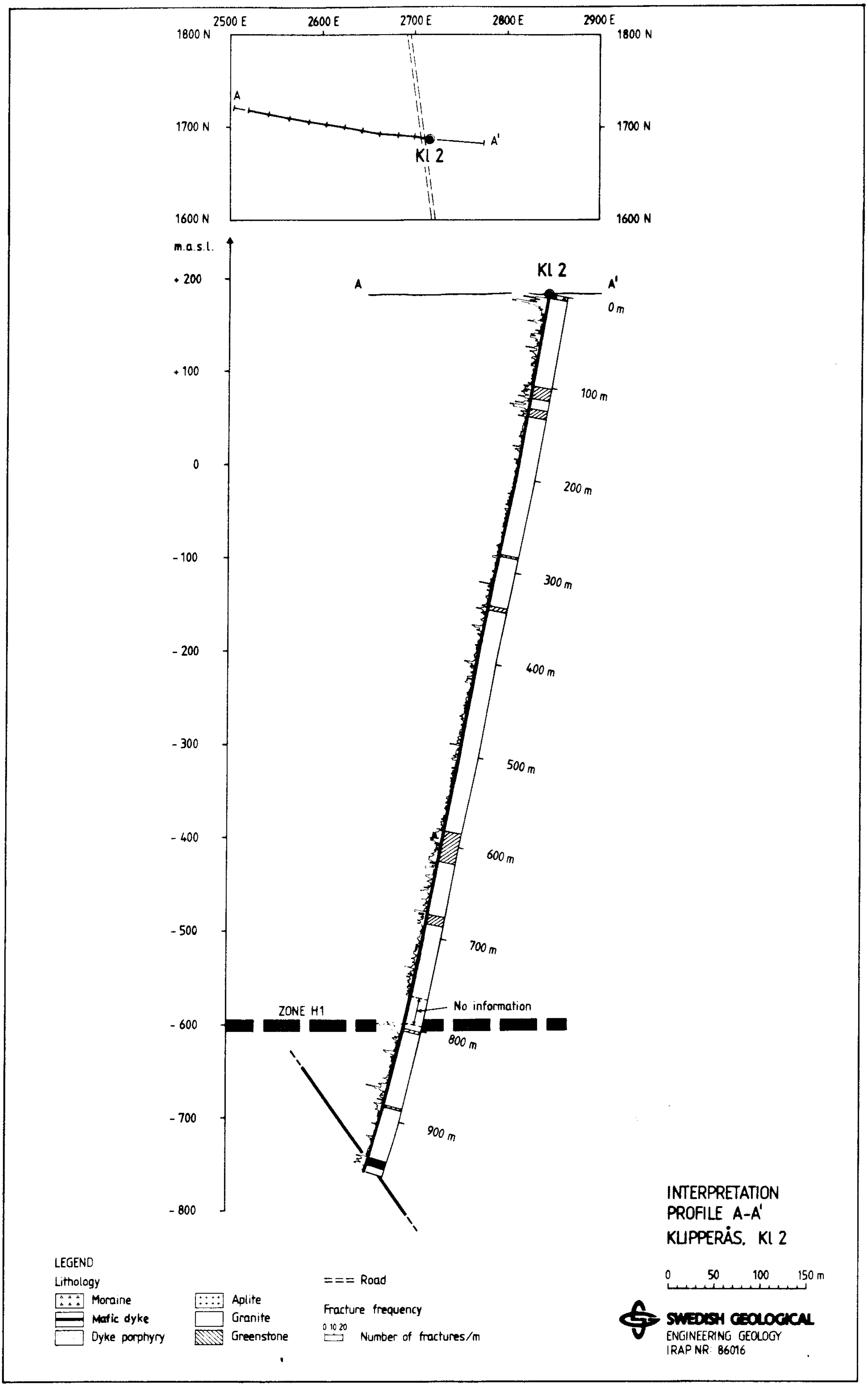


Figure 3.26 Schematic lithology and fracture frequency with interpretation of the borehole Kl 2.

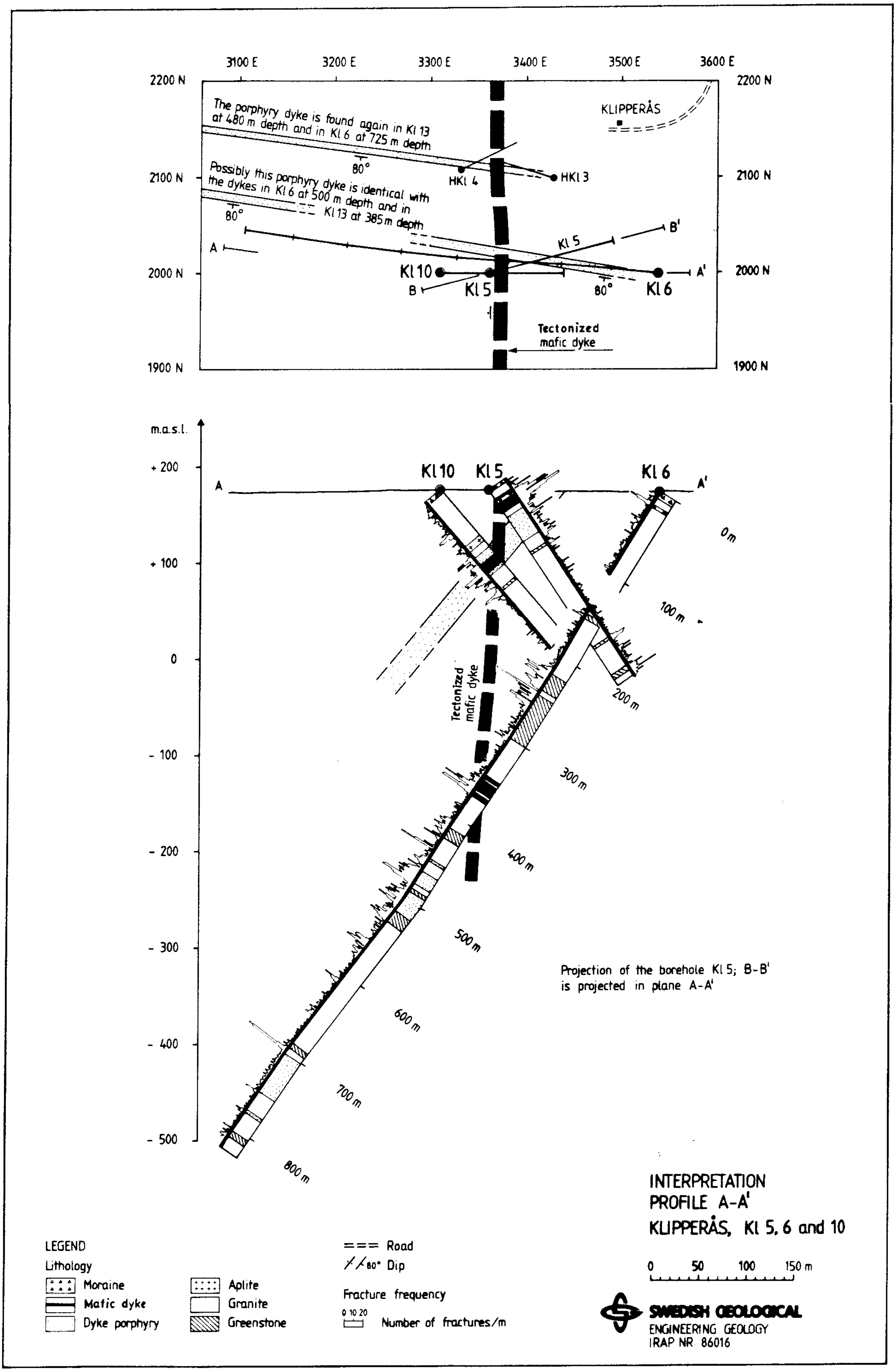


Figure 3.27 Schematic lithology and fracture frequency with interpretation of the bore holes Kl 5, Kl 6 and Kl 10.

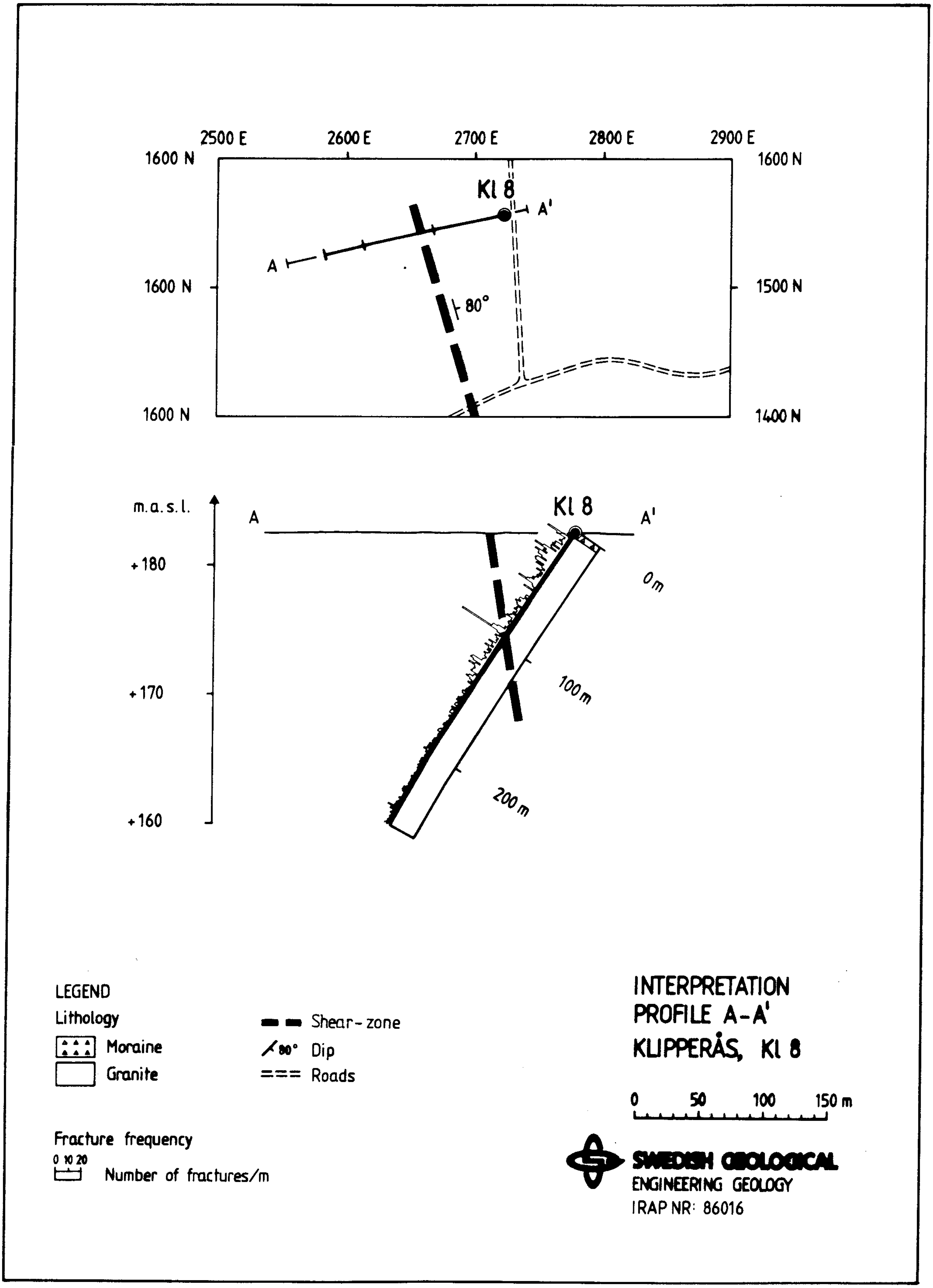


Figure 3.28 Schematic lithology and fracture frequency with interpretation of the bore hole Kl 8.

4. REFERENCES

Åberg, G. 1972: An Rb/Sr Age of the Småland Porphyries. GFF 94, pp 311-319.

Åberg, G. 1978: Precambrian Geochronology of south-eastern Sweden. GFF 100, pp 125-154.

Ahlbom, K., Carlsson, L., Olsson, O. 1983: Final disposal of spent nuclear fuel - geological , hydrogeological and geophysical methods for site characterization. KBS TR 83-43.

Egerth,T., 1986: Compilation of geological and technical borehole data from the Klipperås study site. SKB AR 86-10.

Eichstädt, F., 1884: Om Uralitdiabas, en följeslagare till gångformigt uppträdande småländska kvartsporfyrer. GFF 6, pp 709-716.

Gentzschein, B., 1986: Hydrogeological investigation at the Klipperås study site. SKB TR 86-08.

Hedström, H., och Wiman, C., 1906: Berggrundskarta i skala 1:200 000 med beskrivning omfattande de topografiska kartbladen Lessebo, Kalmar, Karlskrona, Ottenby. SGU Ser A_1a 5.

Holst, N.O., 1876: Bladet Lessebo. Beskrivning och karta. SGU Ser Ab 4.

Holst, N.O., 1893: Bladet Lenhofda. Beskrivning och karta. SGU Ser Ab 15.

Landström, O., Sundblad, B., Olkiewicz, A., 1986: A comperative study of rare earths and other trace elements in rock, soil and plant samples. Studsvik /NP-86/15.

Lundegårdh, P.H. et al., 1985: Beskrivning till provisoriska översiktliga berggrundskartan Oskarshamn. Med en karta 1:250 000. SGU Ser Ba 34.

Lundqvist,T., 1979: The Precambrian of Sweden. SGU Ser C 768.

Magnusson, N.H., et al., 1960: Description to accompany the Map of the Pre-Quaternary rocks of Sweden. With tone map in the scale 1:1 000 000. SGU Ser Ba 16.

Nordenskjöld, O., 1893: Ueber Archaeische Ergussgesteine aus Småland. SGU Ser C 135.

Persson, L. 1974: Precambrian rocks and Tectonic Structures of an area in northeastern Småland, southern Sweden. SGU Ser C 703.

Persson, L., in prep.: Beskrivning till berggrundskartorna Vetlanda NV och NO. SGU Ser Af 150 och 151.

Persson, K.L., Administrativa borrhålsdata från typområdet Klipperås. SKB AR 86-11.

Rösshoff, K., Lagerlund, E. 1977: Tektonisk analys av södra Sverige, Vättern - Norra Skåne. KBS TR 20.

Smellie, J., Larsson, N-Å., Wikberg,P., Carlsson, L. 1985: Hydrochemical investigation in crystalline bedrock in relation to existing hydraulic conditions: Experiece from SKB test - sites in Sweden. SKB TR 85-11.

Streckeisen, A.L. 1967: Classification and Nomenclature of Igneous Rocks. N. Jb. Miner. Abh. 107, pp 144-240.

Sehlstedt, S., Stenberg, L. 1986: Geophysical investigations at the Klipperås study site. SKB TR 86-07.

Stenberg, L., 1985: Geophysical laboratory investigations on core samples from the Klipperås study site. SKB TR 86-09.

Tullborg, E-L., 1986: Fissure fillings from the Klipperås study site, SKB TR 86-10.

A P E N D I X

DRILL CORE DESCRIPTION Page

DRILL CORE DESCRIPTION

1. General description

14 diamond boreholes were drilled within the study site Klipperås. The positions are shown in Figure A 1. Seven of them have a length between 200 and 265 m, six from 700 to 960 m, one is 565 m long. A combined total length of 6933 m was drilled. The inclination of the boreholes vary from 50^{o} to 80^{o}. Greatest vertical depth reached was 943 m.

The drillcores shows that granite is the dominat rock type, 85 %, see Table 3.1,page 40. Every drill core contains no less then 70 % of granite. In all cores except one, other rock types are present. The quantity and distributions vary from one borehole to another.

In most cases the boreholes have been directed towards geophysically indicated discontinuities. The boreholes have confirmed their existence at depth as fracture zones or dykes.

The granite has the lowest fracture frequency throughout all drill cores, see Table 3.1. In general, the greenstones have the highest fracture frequency, but occasionally in some cores other rock types can be more highly fractured than the greenstones.

Detailed geological logs and fracture logs, descriptive and plotted, are collected with other adequate technical data and presented in internal reports SKB AR 86-10, "Compilation of geological and technical borehole data from the Klipperås study site", T. Egerth, and SKB AR 86-11, "Administrativa borrhålsdata från typområdet Klipperås, K.L. Persson.

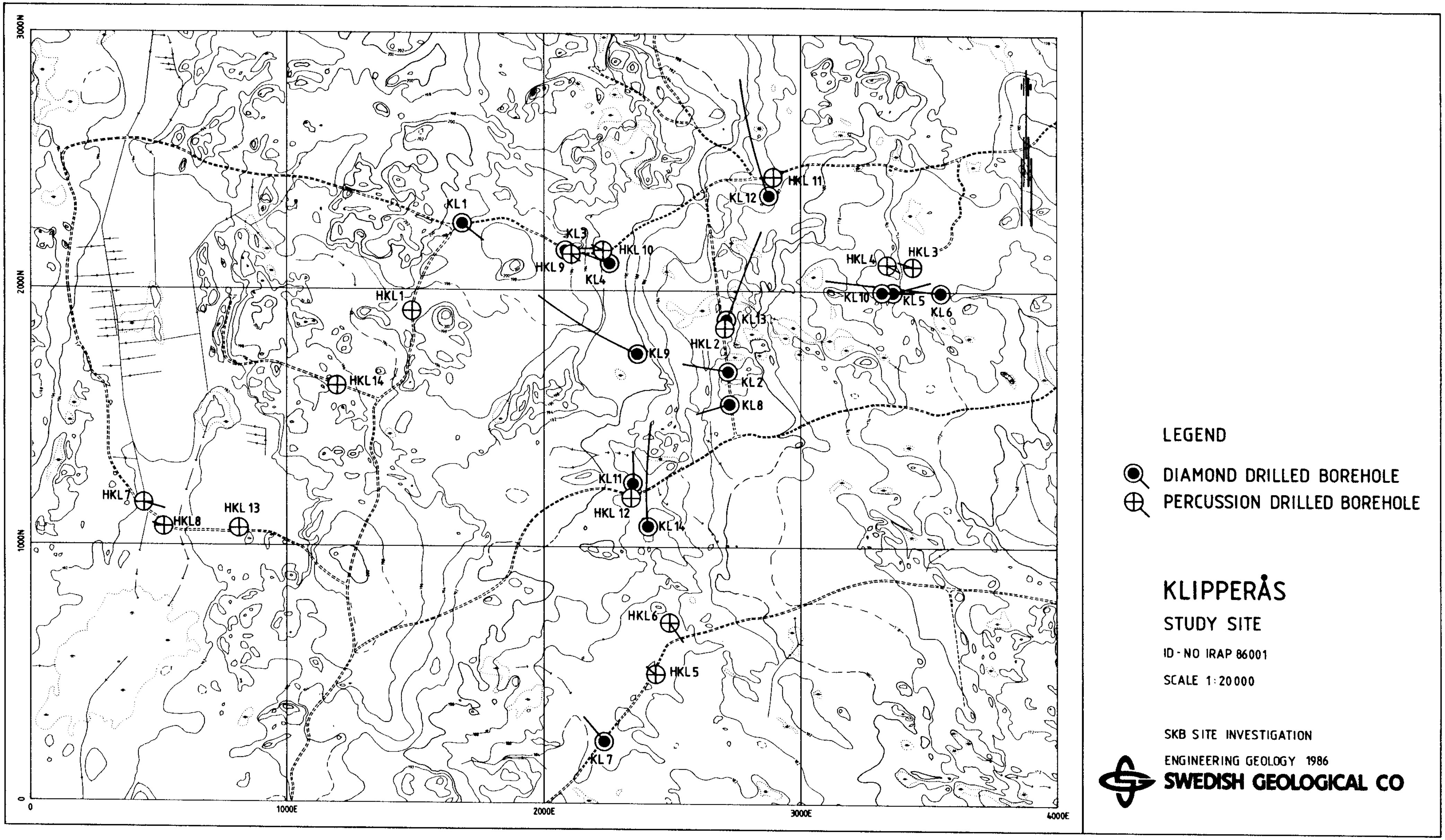


Figure A. 1 Klipperås study site with borehole locations.

1.1 Borehole Kl 1

Local coordinates: 2253 N/ 1674 E
Declination: 134°
Inclination: 80°
Drilling length: 563.95 m

Purpose of drilling: Reconnaissance drilling for estimation of bedrock condition in the Klipperås area.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.70		
granite	414.80	73.86	83.8
Greenstone	86.95	15.52	16.8
Porphyry	53.60	9.75	14.0
Aplite	4.90	0.87	2.4
Total	563.95	100	

Table A. 1 Distribution of rock types in Kl 1

The bedrock is dominated by reddish-grey medium grained massive granite, rich in microcline. The granite matrix is intensively penetrated by a network of hairline cracks sealed by epidote and sericite.

A strong alignment of the mineral aggregates or mylonitic textures are confined to the shearing zones. Intensive shearing commonly appears along porphyry or greenstone contacts. The fracturing and crushing in the core, which forms zone 10, depends strongly on compressed bands of greenstone intercalated with granite.

A cataclastically deformed dyke of porphyry associated with schistose greenstone is probably concordant to the nearly E-W magnetic anomalies at the surface.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	2728	6.58
Greenstone	640	7.36
Porphyry	456	8.51
Aplite	17	3.47
Total fractures	3841	6.86

Table A. 2 Fracture frequencies related to rock types in Kl 1

The mean fracture density in the core is 6.8 fractures/m. The distribution of the fracturing related to the different rock types is summarized in Table A. 2.

The variation of fracture frequency along the borehole is illustrated in Figures A 2 and 3.25. A significant increase in fracturing frequency is limited to the near surface fracture zone at 28 m, which probably represents a flat lying structure. An increased fracturing frequency adjacent to the contacts of greenstones and porphyries to granite, forms an overall trend through the bedrock.

Description of the borehole

The uppermost and largely permeable part of the granitic bedrock contains many fractures affected by alteration and coated by hydrate iron oxides. The core section between 25-40 m represents a highly fractured and partly brecciated granite which is locally crushed and clay altered.

Bands of greenstone in the granite cause a higher fracturing, frequency, e.g. in the sections between 70-85 m and 140-190 m.

Longer sections of undisturbed sparsely fractured granitic bedrock occur at 90-140 m, 190-270 m and 330-440 m.

At 280-310 m the borehole intersects zone 10. The core shows a marked schistosity oriented subparallel to the core. Most of the core consists of strongly mylonitic and highly fractured granite. A 2 metre section of crushed rock is located in greenstone. A total of 4 metres of crushed rock was registered in zone 10. Fracture fillings are formed by epidote, chlorite and calcite. Some limited effects of alteration were registered as coatings of hydrate iron oxides.

Between 440-540 m, the borehole intersects the marginal part of a steeply dipping porphyry dyke which is oriented almost parallel to the borehole. Cataclastic to mylonite deformation is characteristic for all rock types involved, including even a thin, schistose greenstone, which follows the contact of a porphyry dyke.

1.2 Borehole Kl 2

Local coordinates: 1687 N/ 2717 E
Declination: 278^{o}
Inclination: 78^{o}
Drilling length: 958.60 m

Purpose of drilling: Penetrate the homogeneous bedrock in continuation of a weak electromagnetic anomaly.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.85		
Granite	825.45	86.46	152.30
Greenstone	87.15	9.13	31.35
Mafic dyke (Dolerite)	9.15	0.96	9.15
Aplite	0.80	<0.1	0.60
Unknown (764.30-796.50)	32.20	3.37	
Total	958.60		

Table A. 3 Distribution of the rock types in Kl 2.

The bedrock is dominated by grey or reddish medium to coarse grained granite, with very subordinate aplite dykes. The inclusions in granite are formed wholy by greenstone and a dyke of dolerite and amounts to about 10 % of the rock mass.

The granite is homogeneous and massive, apart from local narrow zones of cataclasis and bands of mylonite. Fracturing is limited, and sections of disturbed rock are partly well compacted.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	1907	2.31
Greenstone	583	6.70
Mafic dyke (Dolerite)	80	8.74
Aplite	2	2.50
Total fractures	2572	2.79

Table A. 4 Fracture frequencies related to rock types in Kl 2

The mean fracture density in the core is 2.79 fractures/ m. The 764.30-796.5 m section is not included in the calculation of the fracture frequency because the boxes containing the core from this section are missing. In Table A. 4 the distribution of the fracture frequency in Kl 2 is summarized and in Figures A. 3 and 3.26, the variation along the borehole is shown.

The granite generally shows low,irregulary distributed jointing along the borehole. In places, there are unfractured sections up to 4 m in length. The fracture frequency always increases adjacent to the inclusions of greenstones. The average fracture frequency in the dolerite is higher than in the surrounding rock.

Description of the borehole

The shallow part of the subsurface is apparently more affected by alteration. About 1 m of crushed and partly clay altered granite occurs at 12 m. Thin coatings of hydrate Fe oxides, alteration phenomena and locally thin clay alterations on fracture surfaces extend down to 48 m.

Most of the subsurface is distinguished by slightly fissured granitic bedrock. Granite is occasionally cut by narrow zones of fracturing associated locally with cataclastic texture.

Greenstones often occur as steeply dipping slabs in the granite. They are irregularly distributed along the borehole and range from decimetres to metres in width. Prominent greenstones occur at 100-130 m, 586-618 m and at 680 m. Macroscopically, the greenstones are massive or slightly schistose, whilst contacts to the granite always show a strong schistosity.

The zone H1 was intersected at 792-804 m and is supposed to be nearly horizontal. Unfortunately, the core from the upper part of the zone and the adjacent portion of rock mass is missing.

The zone has been identified geophysically and is also manifested by a high hydraulic conductivity. The remaining portion of the core, related to zone H1, consists of highly fractured granite intermingled with compressed greenstone. Crushed rock comprises 50 cm of the core and a slight alteration is combined with hydrate irone oxides covering fracture surfaces.

Some main features in the lowermost part of the borehole have influenced the rate of fracturing. These are a shear zone, at 866 m, a band of greenstone at 885 m, and a dolerite dyke at 945 m. The sheared granite is strongly schistose and includes 10 cm of crushed, reddish and partly clay altered granite. The dolerite occurs as a steeply dipping dyke about 5 m thick. Its continuation to the surface could not be established.

1.3 Borehole Kl 3

Local coordinates: 2160 N/ 2079 E
Declination: 85^{o}
Inclination: 60^{o}
Drilling length: 249,95 m

Purpose of drilling: Penetrate zone 1

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of the same rock type(m)
Moraine	2.35		
Granite	246.40	99.50	134.00
Greenstone	0.80	0.30	0.80
Aplite	0.40	0.20	0.35
Total	249.95	100	

Table A. 4 Distribution of the rock types in Kl 3

The drillhole penetrates granitic bedrock with only minor aplite dykes and a small inclusion of greenstone. The granite is reddish-grey, medium grained, with non-uniform grain size and massive structure. Locally, the granite is transformed from massive to cataclastic, schistose or brecciated, and sealed by secondary quartz. An extensive tectonization of granite is concentrated in zone 1.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	1672	6.79
Greenstone	640	11.25
Total fractures	1681	6.79

Table A. 5 Fracture frequencies related to rock types in Kl 3

The mean fracture density in the core is 6.79 fractures/m. The distribution of the fracturing related to the different rock types is summarized in Table A. 5.

The variation of the fracture frequency along the borehole is illustrated in Figure A. 4 and 3.19.

Description of the borehole

Increased fracturing in granite affected by near surface alteration occurs at several levels in the uppermost part of the borehole. A continunous section of slightly fissured granite was noted between 118-138 meters.

Between 140-195 m, the core exhibits a highly fractured and extensively tectonized granite which forms zone 1. The zone includes short sections of crushed granite with a total core length of 1.4 m. Alteration occurs at some fracture surfaces and slickensides were registred only adjacent to the inclusion of greenstone at 194 m.

Down to the bottom of the borehole, the tectonisation decreases progressively. Locally small shear zones occur which are accompanied by zones, decimeters in width, which consist of crushed and subordinate clay alterations in the granite.

The most common fracture filling minerals are chlorite, calcite and epidote. Coatings of hydrate Fe-oxides occur throughout the borehole.

1.4 Borehole Kl 4

Local coordinates: 2110 N/ 2243 E
Declination: 289^{o}
Inclination: 59^{o}
Drilling length: 200.00 m

Purpose of drilling: Investigation of the relationship between a dolerite and zone 1.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	8.45		
Granite	136.05	71.03	69.75
Greenstone	29.55	15.43	20.75
Mafic dyke (Dolerite)	13.25	6.91	13.25
Porphyry	12.70	6.91	13.25
Total	200.00	100.00	

Table A. 6 Distribution of the rock types in Kl 4

The uppermost part of the bedrock penetrated by the borehole consists wholy of reddish grey, medium grained massive granite. Subordinate, widely spaced mylonitic bands are irregulary arranged along the core.

The granite is intruded by a dolerite dyke which has a northerly strike and dips towards SE. Part of this dyke follows zone 1 and part follows zone 2. The dolerite is about 10 m wide and is characterized by a well preserved structure and by dense, chilled margins against the granite.

A strong tectonic disturbance occuring in the lower part of the borehole belongs to zone 1. Granite contains numerous inclusions of greenstone, quartz veins and quartz-healed breccia.

Intrusive porphyry dykes which intersect the granite in the lowermost part of the borehole, range in thickness up to about 5 m. Strongly sheared greenstones occur at their margins.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	1468	10.79
Greenstone	382	12.93
Mafic dyke (Dolerite)	158	11.92
Porphyry	162	12.76
Total fractures	2170	10.85

Table A. 7 Fracture frequencies related to rock types in Kl 4

The mean fracture density in the core is 10.85 fractures/m, reflecting the presence of disturbed rock within zone 1. In addition, the fracture frequency increases adjacent to the dolerite dyke.

The distribution of fracture frequency in Kl 4 is summarized in Table A. 7 and its variation along the borehole is shown in Figures A. 4 and 3.19.

Description of the borehole

The granitic bedrock in the shallow part of the subsurface is densely fractured. This may depend on the proximity of a prominent dolertie dyke. Sections of increased tectonisation are indicated by microbrecciation and movements along fracture planes are indicated by slickensides. Altered fracture surfaces coated with hydrate irone oxides are commonly present.

The dolerite dyke between 78 to 92 m is intensely fractured. Fracture surfaces in dolerite are altered and slickensides were frequently noted. Fracture fillings are often black, very fine grained mineral aggregates of secondary alteration minerals of the dolerite, among which chlorite and illite are the most important.

The section of the borehole passing through zone 1 runs from 110 m to 180 m depth. The beginning of the zone is marked by bands of deformed greenstone intercalated with granite. Extensive crushing is correlated with the greenstones (3.85 m of the core). Below 135 m, zone 1 consists dominantly of tectonically disturbed and densely fractured granite which, locally, is clay altered. The thickness of the crushed rock section is 0.7 m. Secondary quartz occurs as veins and a groundmass of brecciated granite. Small cavities and open spaces along fracture planes are filled by minute crystals of quartz.

The intrusive dykes of porphyries at the lowermost part of borehole are more intensively fractured than the surrounding granite.

1.5 Boreholes Kl 5 and Kl 10

Borehole Kl 5

Local coordinates: 2000 N/ 3361 E
Declination: 76^{o}
Inclination: 56^{o}
Drilling length: 246.45 m

Borehole Kl 10

Local coordinates: 2000 N/ 3310 E
Declination: 90^{o}
Inclination: 49^{o}
Drilling length: 202.90 m

Purpose of drilling: Control of relationship of granite bedrock and intrusive dykes.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.35		
Granite	185.60	76.35	120.5
Porphyry	32.35	13.31	31.70
Mafic dyke (Basalt)	11.50	4.73	10.20
Greenstone	10.85	4.56	5.90
Aplite	2.80	1.15	2.10
Total	246.45	100.00	

Table A. 8 Distribution of the rock types in Kl 5

The bedrock penetrated by boreholes Kl 5 and Kl 10 consist mainly of medium to coarse grained, reddish granite accompanied by numerous dykes of aplite. Evidence of tectonisation is scarce. Massive, unstrained granite dominates the bedrock.

Prominent dykes of plagioclase porphyry and alkali-olivine basalt cut granite which also includes a sheet-like body of greenstone which is probably concordant to the porphyry. A dyke of alkali-olivine basalt is strongly indicated geophysically, and extends N-S across the entire width of the investigated area.

An oportunity to establish the geometry of intrusive bodies in subsurface is provided by the proximity of borehole Kl 10. This was drilled parallel to Kl 5, at a distance of about 50 m, from Kl 5.

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Glacial drift	4.90		
Granite	157.10	79.34	79.05
Porphyry	15.75	7.95	10.45
Mafic dyke (Basalt)	11.40	5.76	11.40
Greenstone	4.55	2.30	2.90
Aplite	9.20	4.65	7.35
Total	202.90	100.00	

Table A. 9 Distribution of the rock types in Kl 10

The most notable observation from borehole Kl 10 is the chilled contacts of the basalt dyke against plagioclase porphyry. This provides evidence that porphyries have intruded prior to the dyke of basalt.

The dip of the porphyry dyke found in Kl 5 and Kl 10 is 80^{o}. Its strike is assumed to follow the main magnetic features of the area WNW-ESE. It is not intersected by Kl 6, due to its dip and strike. The true width of the dyke is about 5 m.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	546	2.94
Porphyry	286	8.84
Mafic dyke (Basalt)	321	27.91
Greenstone	130	11.98
Porphyry	456	8.51
Aplite	43	15.36
Total fractures	1326	5.45

Table A. 10 Fracture frequencies related to rock types in Kl 5

The mean fracture density in the borehole Kl 5 is 5.45 fractures/m. The distribution of the fracturing related to the diffrent rock types is summerized in Table A. 10.

The variation in fracture frequency along the borehole is illustrated in Figures A. 5 and 3.27. Intense fracturing and alteration is limited to the basalt dyke situated near the surface. Porphyry and greenstone are usualy more densely fractured than granite, which shows slight to moderate fracturing.

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	442	2.82
Porphyry	149	9.46
Mafic dyke (Basalt)	162	14.21
Greenstone	62	13.63
Aplite	17	3.47
Total fractures	879	4.44

Table A. 11 Fracture frequencies related to rock types in Kl10

The mean fracture density in the borehole Kl 10 is 4.44 fractures/m. The distribution of the fracturing related to the different rock types is summarized in Table A. 11.

The variation in fracture frequency along the borehole is illustrated in Figures A. 5 and 3.27. The intensity of fracturing is greatest in the basaltic dyke and decreases successively on both sides through porphyry into granite. A low fracture frequency is noted for the granite.

Description of the boreholes

Drilling confirmed that the expected fracture zone in Kl 5 was an intrusive dyke of alkaline-olivine basalt, occuring at between 19-29 metres borehole length. Clay alteration commonly occur in this densely fractured dyke.

The following plagioclase porphyry dyke is well preserved. It shows only a moderate increase in fracture frequency and schistose margins with thin, compressed greenstone. Granite, down to the bottom of the borehole, is sparsely fractured.

In Kl 10, the expected fracture zone was indentified as a basalt dyke identical to the one confirmed in Kl 5. The state of preservation of the basaltic dyke is much better when compared with borehole Kl 5, owing to its more deeply seated position in borhole Kl 10, even if the fracturing is dense. The section includes a total of 0.8 metres of crushed rock.

The basalt is surrounded by plagioclase porphyry into which the basalt has intruded. Porphyry represents a continuation of the dyke mentioned above in Kl 5. Even the fracturing characteristics are similar for porphyry and the surrounding granite in both Kl 5 and Kl 10.

Fracture filling minerals are calcite, chlorite and iron oxide. A clay altered shear zone of about 1 m width occurs in the granite at 45 m depth.

1.6 Borehole Kl 6

Local coordinates: 2000 N/ 3539 E
Declination: 276^{o}
Inclination: 56^{o}
Drilling length: 808.00 m

Purpose of the drilling: Investigation of fracturing in vicinity of basaltic dyke.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	7.85		
Granite	568.65	71.07	164.90
Greenstone	118.90	14.86	54.60
Porphyry	92.95	11.62	47.80
Mafic dyke (Basalt)	16.05	2.00	7.70
Aplite	3.60	0.45	3.20
Total	808.00	100.00	

Table A. 12 Distribution of the rock types in Kl 6

The crystalline bedrock occuring in the eastern part of the area investigated consists mainly of medium-grained,reddish-grey,uneven grained granite. Dyke rocks that accompany granite are porphyry and very subordinate aplite. Strongly altered basalts (greenstones) have a widespread occurence in granitic masses and are frequently found associated with intrusive dykes of porphyries. Both porphyry and greenstone form sheet like bodies inclined at a small angle to the borehole axis, giving long sections, even for rather thin bodies.

The above mentioned older rocks are cut by a dyke of alkali-olivin basalt which intruded along a vertical, N-S trending fissure.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	2038	8.58
Greenstone	1015	8.54
Porphyry	753	8.10
Mafic dyke (Basalt)	244	15.20
Aplite	58	16.11
Total fractures	4108	5.13

Table A. 13 Fracture frequencies related to rock types in Kl 6

The mean fracture density in the core is 5.13 fractures/m. The distribution of fracturing related to the differtent rock types is summarized in Table A. 13.

The variation in fracture frequency along the borehole is illustrated in Figure A. 6 and 3.27. Increased fracture frequency is stronly correlated with tectonically disturbed boundaries of intrusive dykes and inclusions in granite.

Description of the borehole

Reddish-grey medium grained to coarse grained granite, tectonically undisturbed and slightly fractured, form the upper part of the borehole. Weathering is sometimes found and is limited to detached fractures or rock boundaries. Down to 184 m, iron oxide is commonly found as a coating on fracture surfaces.

Greenstone occurs as an extensive inclusion in granite between 240-300 m. Crushed rock is related essentially to greenstone and occupies 2.7 m of the core.

The parallel set of mafic dykes (alkali-olivine basalt) in granite was intersected at 338-372m. Their dip is vertical. Their thickness varies from 0.1 m to 5 m and the walls are sharp. Increased fracturing is associated with the dyke rock and even includes 1.5 m of crushed core, partly affected by alteration. The fracture fillings consist of calcite, chlorite and iron oxide.

Most of the granite below 372 m is markedly undisturbed and stronger tectonization is restricted to a few shearing zones and to the boundaries to porphyry dykes. The most prominent of them were found between 490-524 m and 700-750 m. The boundaries of the dykes are strongly sheared whilst the interiors are generally well preserved. Foliated greenstones are always present at the margins. Crushed rock was noted only in a few dm-wide zones at 439 m and 478 m. At 696 m there is a 1.5 m long crushed section which appears mainly due to schistosity oriented parallel to the core.

1.7 Borehole Kl 7

Local coordinates: 253 N/ 2225 E
Declination: 320^{o}
Inclination: 57^{o}
Drilling length: 250.30 m

Purpose of drilling: Penetrating zone 3

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.95		
Granite	230.50	93.57	95.50
Greenstone	10.65	4.23	7.10
Aplite	5.20	2.11	3.90
Total	250.30	100	

Table A. 14 Distribution of the rock types in Kl 7

The bedrock is dominated by reddish, medium grained, microcline rich granite with sparse, small aggregates of mafic minerals. The granite shows tectonic deformation of variable strength which is represented mainly by hairline, sealed fracturing in a granitic matrix or sometimes as elongated mineral aggregates.

The granitic basement is cut by two narrow dykes of aplite and a more significant band of greenstone occurs between 77-90 m. Frequently occuring slices, fragments and narrow bands of greenstone are densely arranged between 116-127 m and thus coincide partly with zone 3. The true width and orientation of greenstones and aplites could not be estimated.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	2546	11.05
Greenstone	159	14.93
Aplite	83	15.96
Total fractures	2788	11.32

Table A. 15 Fracture frequencies related to rock types in Kl 7

The mean fracture density in the core is 11.32 fractures/m. The distribution of fracturing related to the different rock types is summarized in Table A. 15.

The variation of fracture frequency along the borehole is illustrated in Figures A. 7 and 3.21.

The frequency of fracturing in the core is high, compared with other boreholes in the area, and the frequency of occurence of unfractured portions of granite is low.

Description of the borehole

The bedrock is highly fractured and strongly affected by close to surface alteration down to 20 m. Thereafter a relatively unfractured granite follows, which extends down to 108 m.

The portion of granitic bedrock with frequent inclusions of greenston bands adjacent to, or within zone 3 (which occupies section from 115 to 130 m in the borehole) is intensively tectonized and fractured. This is indicated by a highly disintegrated drill core, which, in extreme cases consists of a loose, sandy material between 125-126 m. The combined total length of the crushed rock section occupies 9.05 m of 15 m of the drilled length of zone 3.

The intensity of tectonic crushing combined with wethering gives long sections of incohesive rocks in borehole. Coatings of hydrate iron oxides and slickensides were frequently observed in the core.

From the lower boundary of zone 3, and down to the bottom of the borehole several sections of fracturing occur. More widespread sections of foliation with characteristic mylonitic border zones and crushed rock also occur. Altered fracture surfaces coated by hydrate iron oxides occur between 224-228 m.

1.8 Borehole Kl 8

Local coordinates: 1557 N/ 2722 E
Declination: 283°
Inclination: 58°
Drilling length: 266.11 m

Purpose of drilling: Investigation of a distinct electro-magnetic anomaly.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.85		
Granite	262.25		
Totaly	266.15	100.00	

Table A. 16 Distribution of the rock types in Kl 8

The borehole was drilled in a medium reddish-grey massive granite containing only very small mafic xenolithes. The granitic structure is massive,unaffected by tectonic processes. Locally, the granite is cut by a network of quartz-epidote sealed microfractures or by detached fractures (cm thick)filled with quartz-epidote which are widely scattered through the granite. The other products of tectonization are usualy small bands of mylonite or compacted brecciation and crushed rock.

Distribution of the fractures

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	926	3.53

Table A. 17 Fracture frequency in the granite in Kl 8

The mean value for the fracture density in the core is 3.53 fractures/m. Table A. 17.

The variation of the fracture frequency along the borehole is illustrated in Figure A. 7 and 3.28. There is a marked decrease in fracture frequency below 130 m.

Description of the borehole

The uppermost part of the granitic bedrock, down to 35 m, is cut repeatedly by zones of fracturing and is relatively strongly affected by alteration. Most of the fractures are covered by iron oxides and 0.25 m of the core is crushed.

The NNW directed electromagnetic anomaly at the surface was drilled through between 91-95 m of core length. Most of it is marked by an increased frequency of fracturing and only about 1 m of the core reveals strongly sheared granite accompanied by crushing. Slickensides and thin films of iron oxides and clay minerals occur commonly on the fracture surfaces. Slightly fractured granite prevails in the drilled section below 95 m.

1.9 Borehole Kl 9

Local coordinates: 1754 N/ 2360 E
Declination: 300^{o}
Inclination: 56^{o}
Drilling length: 801.03 m

Purpose of drilling: Penetrate the granitic bedrock limited by the zones 1 and 2.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	4.70		
Granite	646.75	81.22	141.50
Porphyry	79.65	10.00	48.55
Greenstone	53.20	6.68	7.00
Mafic dyke (Dolerite)	14.75	1.85	12.20
Aplite	2.00	0.25	0.90
Total	801.05	100.00	

Table A. 18 Distribution of the rock types in Kl 9

The bedrock consists principally of medium grained, massive and homogenous microcline granite. The shifting appearance of the granite is due mainly to the presence of microfracturing or compression in the structure. Numerous bands of greenstone of variable thickness occur in the granite. Their orientaion is unknown. In addition, narrow dykes of aplite and quartz veins are very subordinate.

The granite is intruded by a dolerite dyke which has a NNE strike and dips towards E. The dolerite has retained its primary ophitic texture and forms a strong feature on the magnetic map.

Two porphyry dykes, traversing the granite have a somewhat different macroscopic appearance.The porphyry at 280 m are reddish -brown with phenocrysts of quartz and feldspar, and at 750 m, dark-grey plagioclase porphyry occurs. Their orientation is possibly reflected by a slight, WNW-ESE directed magnetic anomaly at the surface.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	2598	4.02
Porphyry	420	5.27
Greenstone	457	8.59
Mafic dyke (Dolerite)	92	6.24
Aplite	18	9.00
Total fractures	3585	4.50

Table A. 19 Fracture frequencies related to rock types in Kl 9

The mean fracture density in the borehole Kl 9 is 4.50 fractures/m. The distribution of the fracturing related to the diffrent rock types is summerized in Table A. 19.

The variation of fracture frequency along the borehole gives an impression of regular alternation of moderately and densely fractured bedrock, see Figures A. 8 and 3.20.

Description of the borehole Kl 9

Weathered fracture surfaces and coatings with iron-oxides are common down to 65 m. Tectonically disturbed granite within zone 2 was drilled through between 120-160 m of core length. The beginning of the zone is marked by an increased fracture frequency and a 0.2 m wide crushed granite section. Repeated zones of fracturing and an 0.1 m wide section of crushed granite characterize zone 2, between 142 m to 156 m. The most common fracture filling minerals are chlorite, calcite and quartz. Minute crystals of calcite and quartz occur in voids along the fracture planes.

The section 615-665 m in borehole Kl 9, represents zone 1 which is characterized by schistose greenstone and deformed granite. In some places, the rocks are compressed into each other, and brecciation occurs along the contacts. Both rock types are traversed by numerous fractured sections. 15 cm of the core within the zone is crushed and 1 cm wide clay alteration occurs at 622 m. Thin films of clay minerals and iron oxides are commonly found as cmatings on the fracture surfaces.

Due to the strain concentration in the contacts between porphyry and granite, schistose margins, accentuated by compressed greenstones between them are typical for core sections traversed by the contacts eg. at 535 m. Increased mylonitisation in the granite was registered from 760 m down to the bottom of the borehole.

1.10 Borehole Kl 11

Local coordinates: 1252 N/ 2347 E
Declination: 353^{o}
Inclination: 57^{o}
Drilling length: 250.82 m

Purpose of drilling: Penetration of zone 4

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	4.70		
Granite	200.00	81.27	68.50
Greenstone	19.75	8.03	7.85
Porphyry	17.30	7.03	9.70
Mafic dyke (Dolerite)	9.05	3.67	9.05
Total	250.80	100.00	

Table A. 20 Distribution of the rock types in Kl 11

The characteristics of a segment of bedrock described below are based on the boreholes Kl 11 and Kl 14. Reddish grey, medium to coarse grained massive microcline granite predominates in the boreholes.

The granitic bedrock is cut by several dykes of uralitized dolerite. The largest of them penetrated by borehole Kl 14 reaches a thickness of about 12 m. The dyke has a vertical dip and a NE trend, indicated by a boundary between magnetic and demagnetized granite.

The dyke of quartz porphyry which occurs in the uppermost part of borehole Kl 11 is identical to that in Kl 14. Its strike is WNW with a vertical dip. In addition to above mentioned rock types, there are bands of greenstones in the granite whose thickness varies considerably. Their structural orientation, as well as those of the aplite and quartz veins, are unknown.

Large portions of bedrock have a weak tectonization and are interrupted by only narrow, irregularly spaced shearing zones. Granite and other rock types are extensively tectonized within zone 4.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	1114	5.57
Greenstone	217	10.99
Porphyry	196	11.33
Mafic dyke (Dolerite)	72	9.05
Total fractures	1599	6.50

Table A. 21 Fracture frequencies related to rock types in K 11

The mean fracture density in the core is 6.50 fractures/m. The distribution of fracturing related to the differtent rock types is summarized in Table A. 21.

The variation of the fracture frequency along the borehole is illustrated in FigureS A. 9 and 3.22.

Description of the borehole

The dyke rock in the uppermost part of the borehole is formed by a phenocryst rich quartz porphyry.

The granite in the upper part of the subsurface is only slightly influenced by tectonic processes and moderatly fractured. There are small sections of densely fractured granite with an irregular distribution.

A strong tectonic disturbance is concentrated in the section between 104-148 m which represents zone 4. In the beginning of the zone, a deformed dyke of uralitizised dolerite can be found, which runs parallel to the zone. Other rocks involved are cataclastic granite, schistose greenstone and a small compressed dyke of porphyry. Rock contacts are often fractured or brecciated due to shear displacements. In the section 104 m to 148 m (core length) only 0.35 m of chrushed and 0.15 m of clay altred core can be found. Alteration and iron oxide coatings of fracture surfaces are scarce. Fracture fillings are formed mainly by calcite, chlorite and epidote.

Apart from a 10 m long densely fractured section (211 - 221 m) containing 0,3 m of crushed rock and with frequent traces of alteration on the fracture surfaces,below 148 m of core length in Kl 11, the granitic bedrock has a low fracture frequency.

1.11 Borehole Kl 12

Local coordinates: 2370 N/ 2870 E
Declination: 346^{o}
Inclination: 50^{o}
Drilling length: 730.14 m

Purpose of drilling: To assess the intrusive dykes and dislocations in the bedrock revealed by geophysical measurements.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.55		
Granite	618.20	85.08	94.80
Greenstone	55.50	7.64	10.05
Porphyry	47.50	6.54	16.20
Aplite	5.40	0.74	2.25
Total	730.15	100.00	

Table A. 22 Distribution of the rock types in Kl 12

The borehole was directed towards some magnetic and electromagnetic anomalies which can be refered to as dykes of porphyry and prominent shearing and mylonitization zones.

The bedrock is formed mainly by reddish-grey medium grained microcline granite. Intrusive dykes intersect the granite at several levels. They appear partly as narrow, fine grained aplite or granite and pegmatite, partly as prominent dykes of quartz porphyry. The directions of the non-magnetic aplites and pegmatites are unknown, whilst porphyry dykes generate distinct magnetic anomalies with a WNW strike. Small and subordinate inclusions of greenstone are widely scattered throughout the borehole.

To the north of the drilling site, the bedrock is passed by five major zones. The deformation generated numerous shear zones in which the granite is highly mylonitized and fractured.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	2805	4.53
Greenstone	329	5.93
Porphyry	444	9.45
Aplite	18	9.00
Total fractures	3638	5.00

Table A. 23 Fracture frequencies pelated to rock types in Kl12

The mean fracture density in the borehole Kl 12 is 5.00 fractures/m. The distribution of the fracturing related to the different rock types is summarised in Table A. 23.

The variation of fracture frequency along the borehole is illustrated in Figures A. 10 and 3.24.

Description of the borehole Kl 12

Large portions of bedrock penetrated by the borehole have undergone intense cataclasis and mylonitization, which is reflected both by the cataclastic textures and a high density of fracturing.

Reddish grey medium to coarse grained microcline granite forms the dominat component of the bedrock.

Discontinuities in the upper part (down to approx. 290 m in the borehole) are clustered in sections with tectonically influenced granite,and along shearing planes, compressed contacts of dyke rocks and foliated inclusions of greenstone. Weathered fracture surfaces and thin films of hydrate Fe oxides are widely scattered throughout the rock mass. Fractures from surface to a depth of 100 m are calcite depleted. Most common fracture filling minerals are chlorite, epidote and sericite.

Zone 6 is encountered in the borehole between 70-88 m as a structurally conformable line of disturbance to a prominent porphyry dyke which is mylonitised. The most intense shearing, brecciation and fracturing occurs at the dyke margins as well as in some dm wide zones of crushing. Granite adjacent to the dyke is strongly schistose. The fracture filling minerals are chlorite epidote and sometimes also pyrite and quartz. Alteration is very common.

The section 200-290 m is well preserved and moderately fractured despite the 10 m wide dyke of porphyry and the surrounding foliated granite.

The section between 288-384 m in the borehole Kl 12 is occupied by the closely arranged zones 7, 8 and 9. They are separated by portions of schistose and less intensely fractured granite. Their connection with the electro-magnetic structures at the surface are somewhat tentative, based on the assumption of their vertical dip. Their descriptions are given below.

Zone 7 (288-306 m): The beginning of the zone is transected diagonally by a quartz porphyry dyke which includes a schistose contact against granite. The granite itself is, in some places strongly cataclastic,mylonitizied or cut by sealed fissures. The structure of the granite is extensively aligned and contains reddened feldspar grains, 2 dm of crushed and partly clay altered granite occurs at 303 m. Fracture fillings are formed besides chlorite, calcite and epidote also by pyrite and sericite. Weathered fractures are common and in certain places there are thin coatings of iron oxides and clay minerals.

Zone 8 (312-347 m): Deformation within the zone has at least resulted in alingment of the granitic structure. Large portions of the rock mass display a granite which is microbrecciated, strongly schistose, mylonitic and reddened. Dense fracturing occurs adjacent to major shearing planes. Alteration and slickensides commonly occur, and fractures are filled by calcite, chlorite, epidote and iron oxide.

Zone 9 (362-384 m): The intense deformation in the granite is even more concentrated than in the zones described above. Most of the rock is microbrecciated, schistose, mylonitic and highly fractured. The section from 368 m to 380 m appears to be dissected by parallel sets of shear fractures to which the schistosity of the granite is conformably arranged.

Fracture surfaces are altered and the principal mineral fillings consist of chlorite, calcite and epidote. Quartz, iron oxides and clay minerals are also common.

Zone 9 transforms with depth to a predominantly massive, low to moderately fractured granite. Compacted bands of mylonitized granite and greenstone occur. The interrupting zone of densely fractured granite with alteration along the fracture planes appears between 471-479 m.

Zone 2 (595-630 m) which is penetrated by the borehole is inclined at a small angle to the core axis. The granite has an aligned texture and is cut by a network of sealed microcracks and encloses minor greenstones. Moderate density fracturing predominates and zones of dense fracturing are absent. Alteration, slickensides and thin films of hydrate Fe oxides occur in addition to calcite, chlorite, sericite, epidote coatings on fracture surfaces.

Greenstones and porphyry dyke in granite occur in the lowermost part of the borehole (689-712 m).

1.12 Borehole Kl 13

Local coordinates: 1866 N/ 2703 E
Declination: 22^{o}
Inclination: 55^{o}
Drilling length: 700.06 m

Purpose of drilling: Penetration of zone 5.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	2.95		
Granite	627.50	90.02	80.50
Greenstone	44.85	6.43	8.90
Porphyry	27.75	3.55	15.65
Total	700.05	100.00	

Table A. 24 Distribution of the rock types in Kl 13

The rock mass in the upper part of the borehole consists principally of reddish-grey, medium grained microcline granite which encloses a band of greenstone of variable width and two intrusive dykes of porphyry. The granitic bedrock is largely undisturbed, except for the 23 m wide zone 5 and locally, scarce and narrow zones of shearing.

Two prominent greenstones and a number of thin slices of greenstone were drilled through. Their orientation is unknown and their macroscopic appearance varies, mainly due to the degree of schistositiy, metamorphic banding, occurrence of relics of primary feldspar grains in a dense chlorite-rich matrix, and, in one case, a hornfels-like borders in the contact with the granite.

Greenstones occuring at the margins of the intrusive porphyries are usually strongly sheared. It is assumed that the porphyry dykes are penetrated by drilling perpendicularly to their strike, as indicated at the surface by narrow, WNW trending magnetic anomalies. The calculated thickness for the vertically dipping dykes varies between 5 and 9 m.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	1862	2.97
Greenstone	362	8.07
Porphyry	147	5.94
Total fractures	2371	3.40

Table A. 25 Fracture frequencies related to rock types in K 13

The mean fracture density in the core is 3.4 fractures/ m. The distribution of fracturing related to the different rock types are summarized in Table A. 25.

The variation of fracture frequency along the borehole is illustrated in Figures A. 11 and 3.23. This figure shows a pronounced concentration of fracturing in zone 5 and the margins of dykes and inclusions in the granite.Same sections of the core, extending from 50 - 100 m in length, are formed by a slightly jointed massive granite.

Description of the borehole

The granitic bedrock in the uppermost part of the borehole is undisturbed and characterized by an uneven distribution of fractures. Fracture filling minerals are calcite, chlorite and frequently, hydrate Fe oxides. The following sections contain

weathered fracture surfaces: 29-35 m; 71-75 m; 85-90 m.
A progressive increase in fracture frequency occurs at the beginning of zone 5 (from 145 m), and there occur bands of cataclastic or mylonitized granite.

1.13 Borehole Kl 14

Local coordinates: 1084 N/ 2400 E
Declination: 02^{o}
Inclination: 55^{o}
Drilling length: 705.22 m

Purpose of drilling: Investigation of the bedrock adjacent to the zone 4.

Bedrock geology

Rock type	Total length (m)	%	Longest sequence of a given rock type (m)
Moraine	3.20		
Granite	560.90	79.90	124.30
Porphyry	69.65	9.92	34.25
Mafic dyke (Dolerite)	45.35	6.46	31.45
Greenstone	25.10	3.58	6.95
Aplite	1.00	0.14	0.80
Total	705.20	100.00	

Table A. 26 Distribution of the rock types in Kl 14

The condition preveiling in the subsurface around the boreholes Kl 14 and Kl 11 were described in chapter 1.10. The granitic bedrock, penetreted by borehole Kl 14 at a deeper level than that documented by Kl 11, is much the same, containing narrow bands of greenstone and dissected by minor dykes of porphyry and dolerite. Zones of shearing and mylonitization are relatively frequent.

Distribution of the fracturing

Rock type	Number of coated fractures	Fracture frequency per 1 m
Granite	2023	3.62
Porphyry	341	4.90
Mafic dyke (Dolerite)	183	4.04
Greenstone	316	12.59
Aplite	5	5.00
Total fractures	2868	4.09

Table A. 27 Fracture frequencies related to rock types in K114

The mean fracture density in the borehole Kl 14 is 4.09 fractures/m. The distribution of the fracturing related to the different rock types is summarized in Table A. 27.

The variation of fracture frequency along the borehole is illustrated in Figures A. 12 and 3.22. There is a pronounced increase in fracture frequency at the margins of intrusive dykes and inclusions of greenstone owing to the considerable shear displacements along the contacts.

Description of the borehole Kl 14

Reddish-grey, medium grained, massive microcline granite dominates the borehole. Large portions of undisturbed granite alternate with rather subordinate sections of cataclastic or schistose granite.

Two dykes of uralitized dolerite occur at drilling lengths of 174 m and 517 m and have vertical thicknesses of 15 and 2.5 m respectively. These dykes have chilled margins and a coarsening grain size towards their interiors.

The porphypy dominates the borehole between 205-305 m. Macroscopically, the porphyry in section 214.50-247.85 m differs from other known porphyry dykes in the area; texturally resembling fine grained porphyric granite. The contacts towards the surrounding medium grained granite are diffuse. The primary structure is largely undisturbed.

The porphyry dyke at 270.75-305.00 m is formed by a red-brown microcrystalline groundmass, rich in phenocrysts of euhedral feldspar grains about 1 mm in size and smaller, and rounded grains of quartz. The dyke has distinct contacts to the schistose greenstone which occurs at the margins. In the interior of the porphyry dyke there occur only subordinate bands of mylonite. Crushed greenstone (0.8 m width) and some clay alteration is localised to this section.

The E-W oriented zone 4 was penetrated by Kl 14 between 368-410 m. At the beginning of the zone, a conforming dyke of schistose, uralitised dolerite occurs with an adjacent, strongly cataclastically deformed granite. The granitic bedrock and inclusion of greenstone are densely fractured. The most intensive deformation follows the rock contacts. In some places there are 2-3 cm wide clay alterations.

The zone encloses a portion of moderately fractured and weakly tectonized granite between 420-425 m. The rate of deformation in the granite decreases progressively towards 450 m drilling length.

Apart from portions in the bedrock having an exceptionally low fracture frequency, alteration phenomena commonly occur along the fracture surfaces and are very frequent within zone 4. Below the drilling length of 450 m, only minor alteration occurs.

Fracture fillings are calcite, chlorite, epidote, hydrate Fe oxides and in some places, pyrite.

In the granitic bedrock below 450 m, there are widely spaced minor dykes of porphyry and amfibolitic- or greenstone-like metabasites. Strong compression and shearing are usually concentrated at the contacts. The mylonitic effects in granite have been documented frequently. Sometimes, sections up to 50 m in length can show little evidence of jointing.

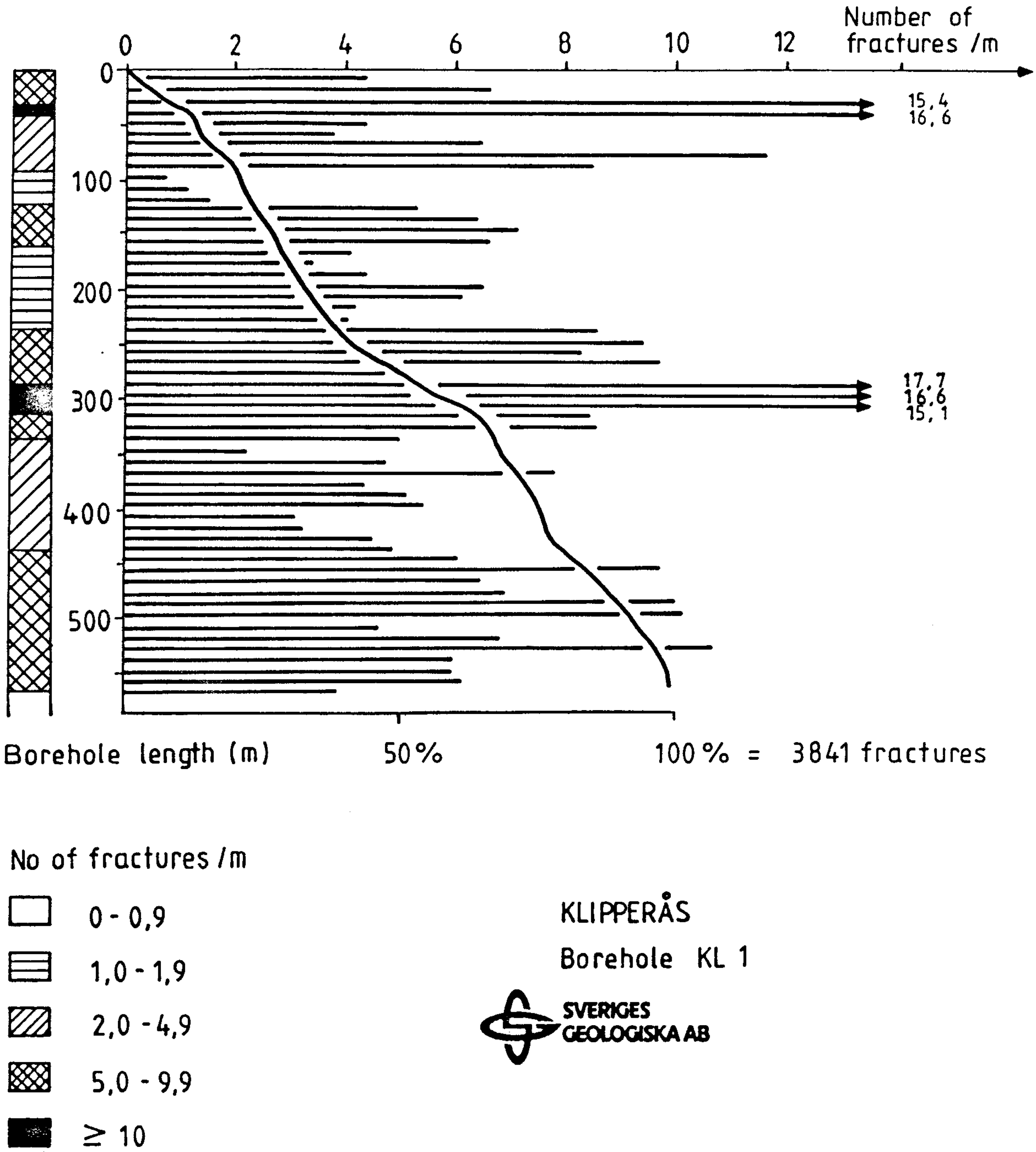


Figure A 2. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 1.

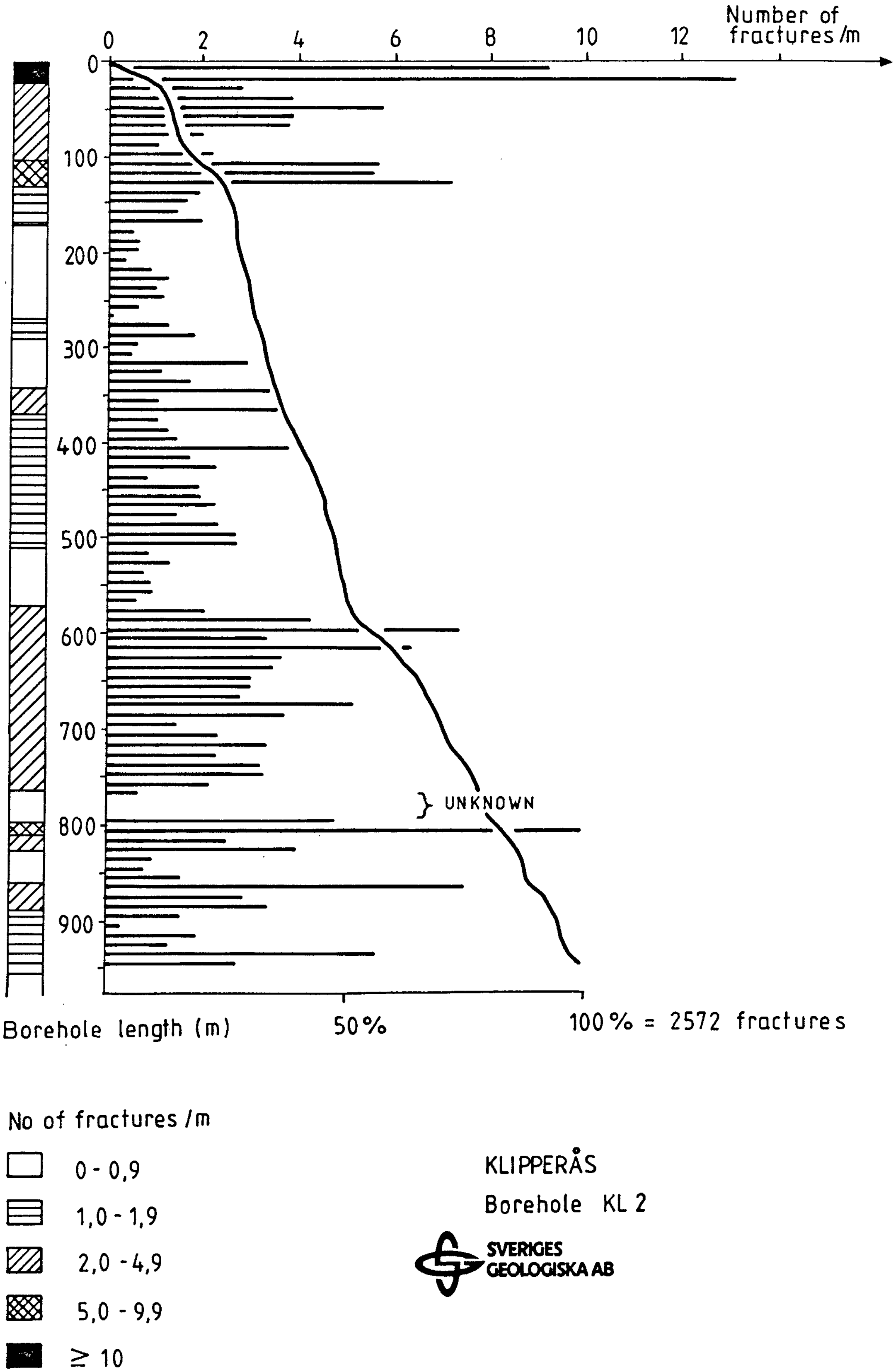


Figure A 3. Fracture frequency in 10 m sections and cumultative number of fracture. in borehole Kl 3 and Kl 4.

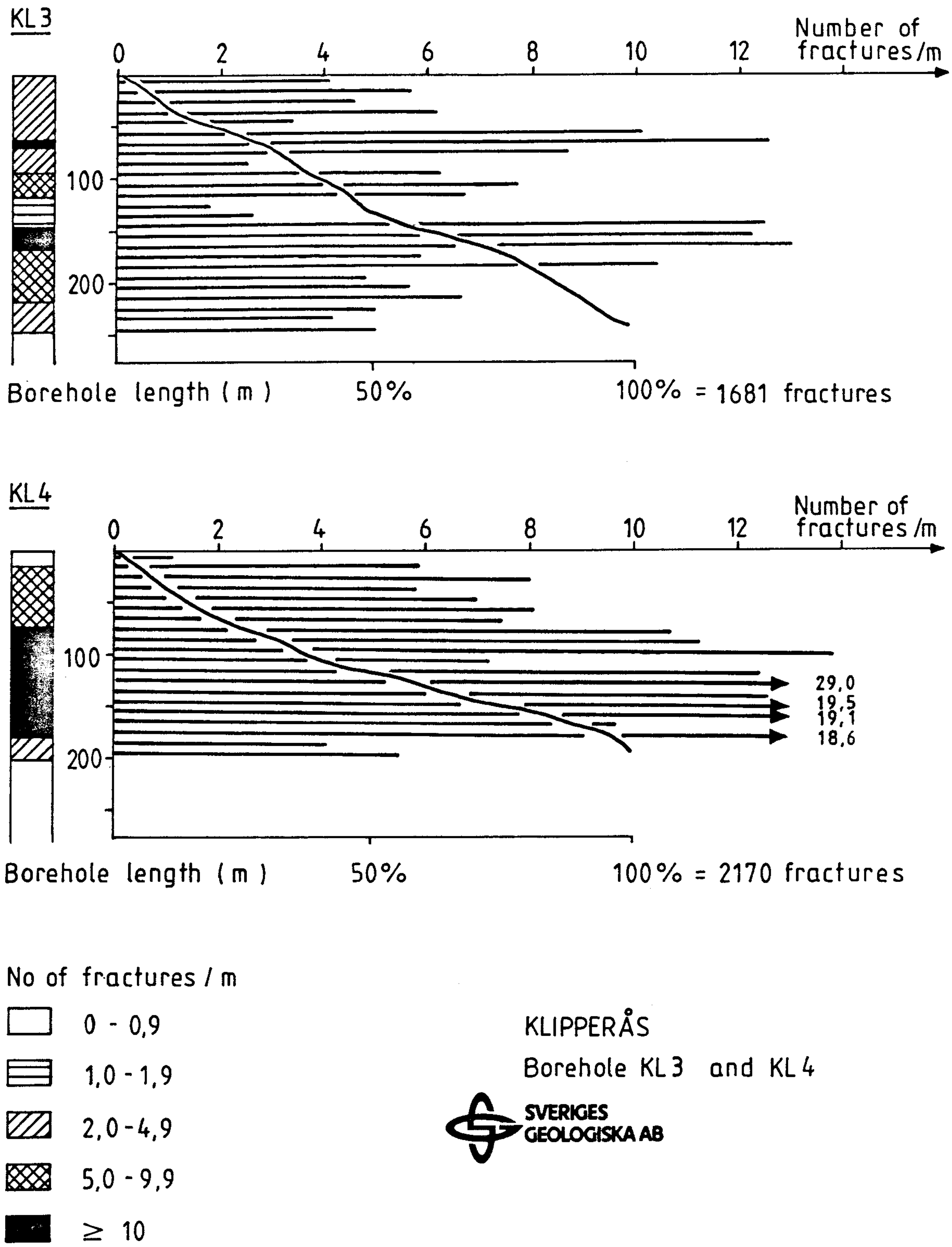


Figure A 4. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 3 and Kl 4.

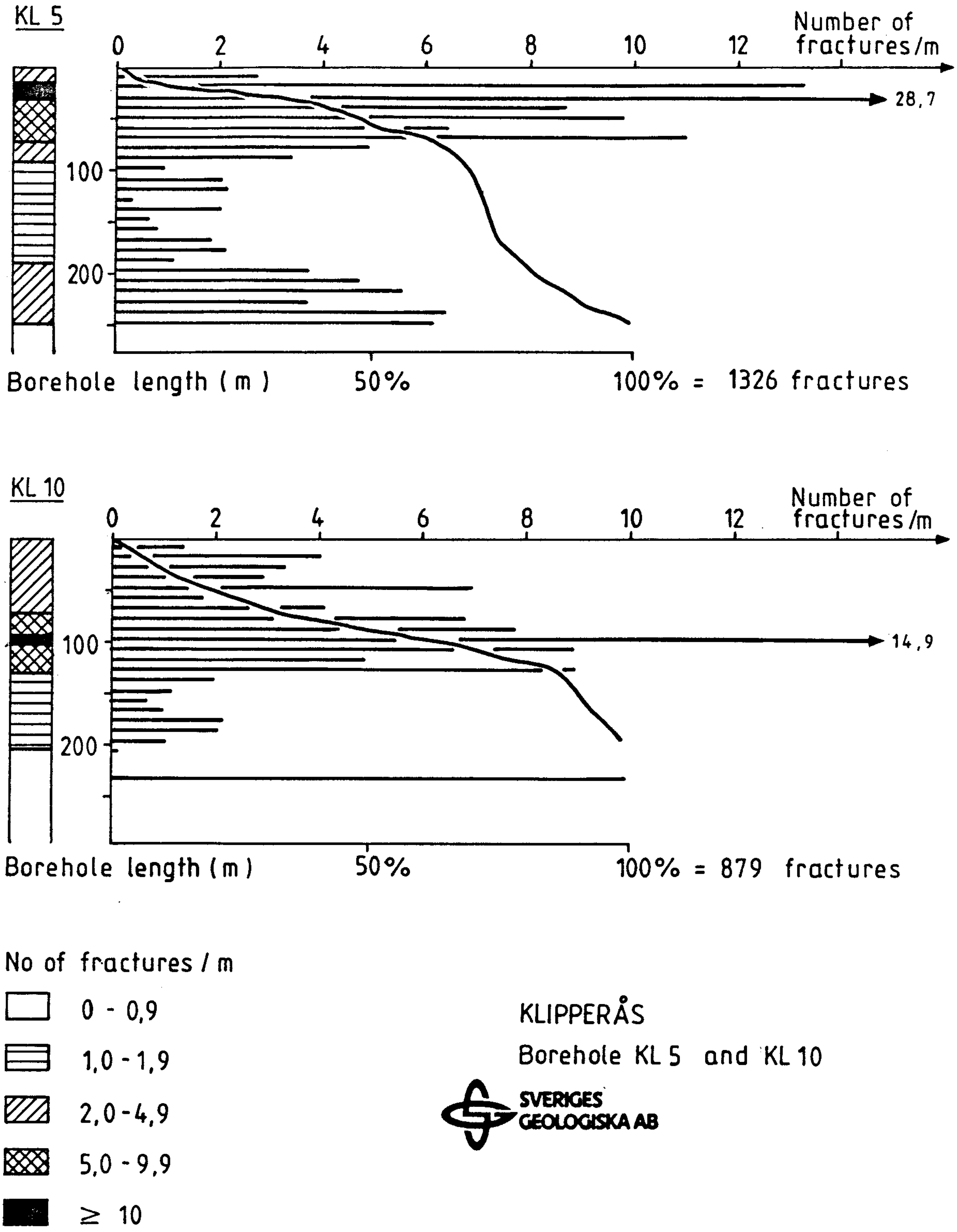


Figure A 5. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 5 and Kl 10.

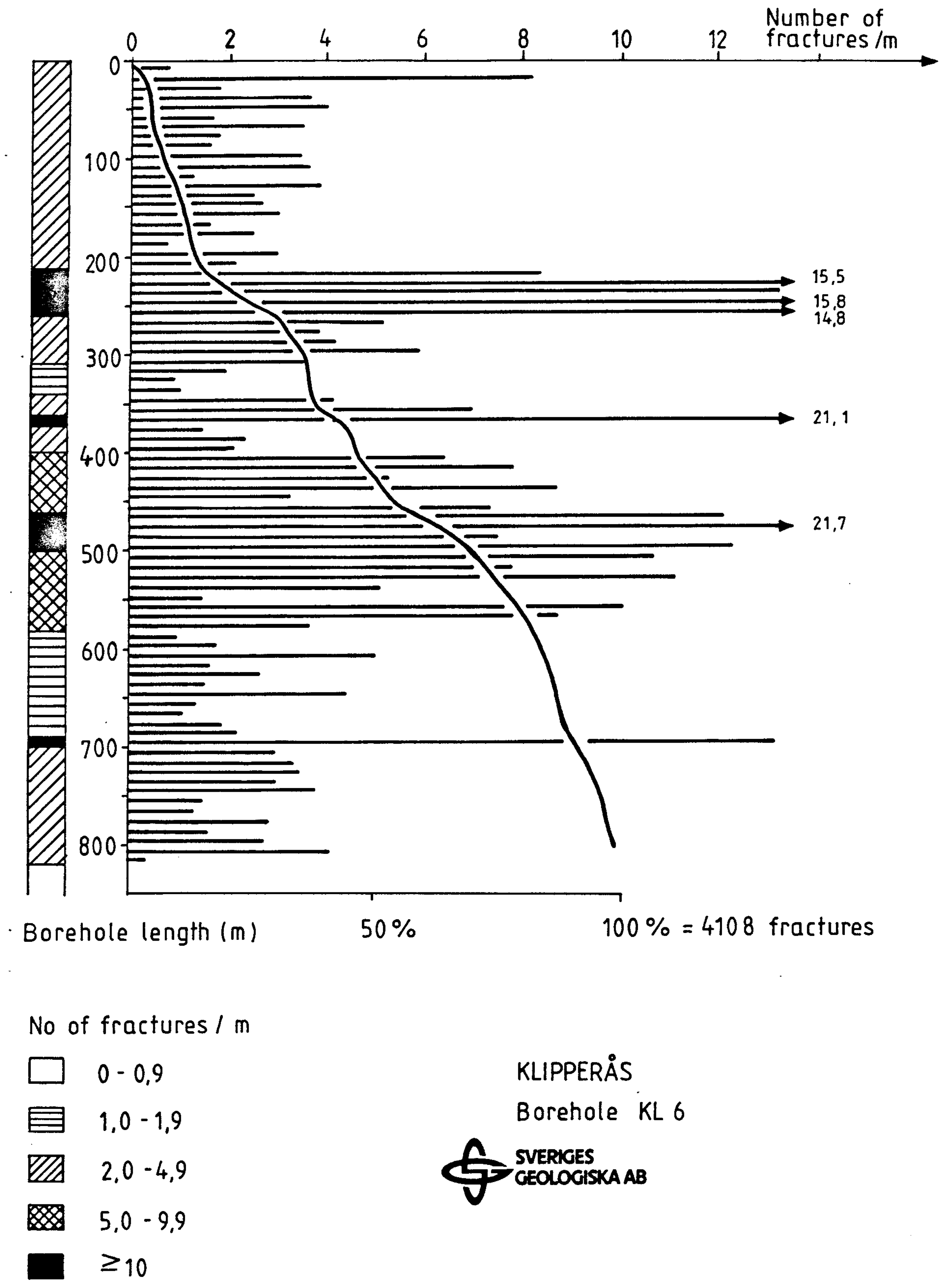


Figure A 6. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 6.

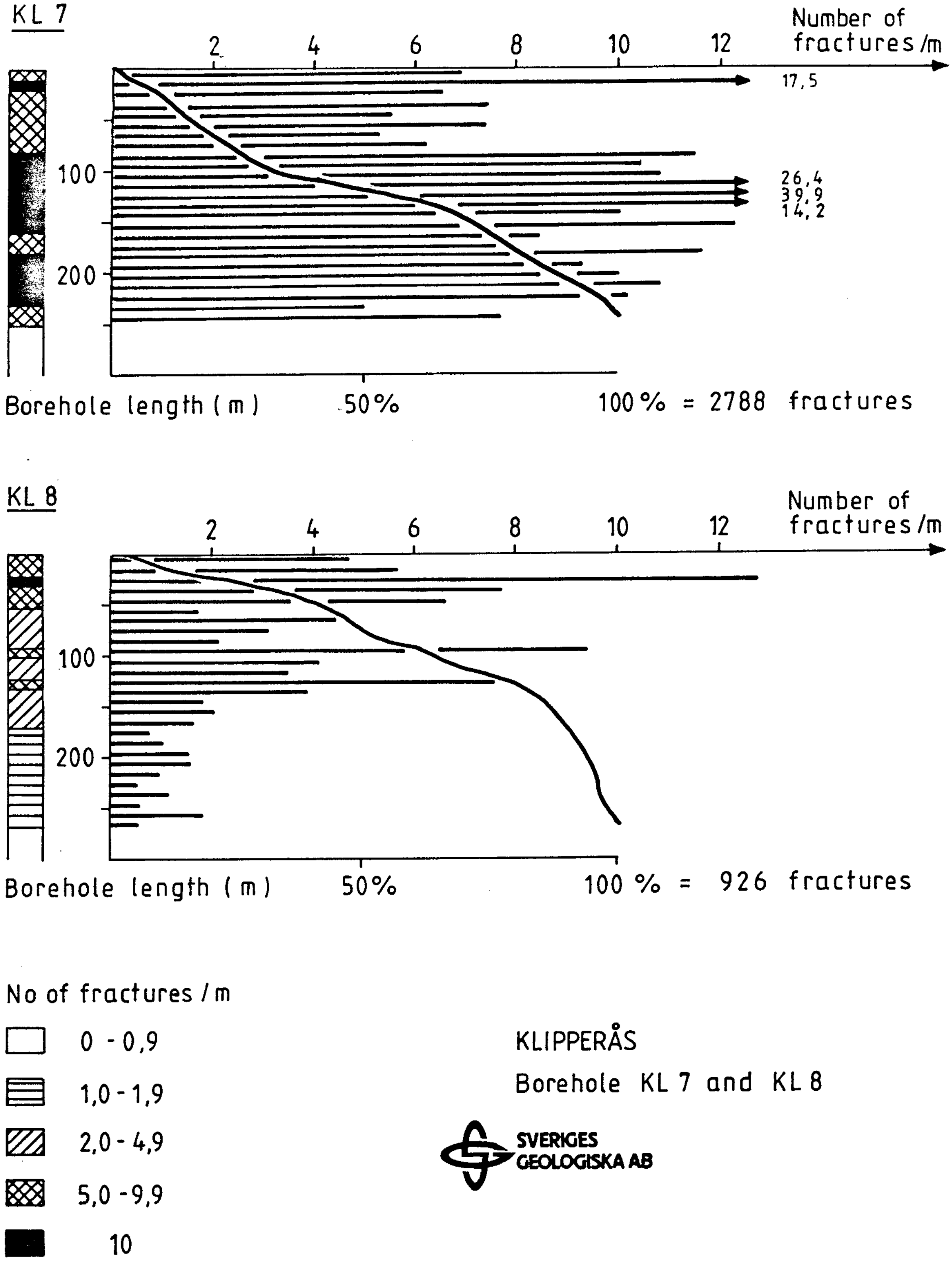


Figure A 7. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 7 and Kl 8.

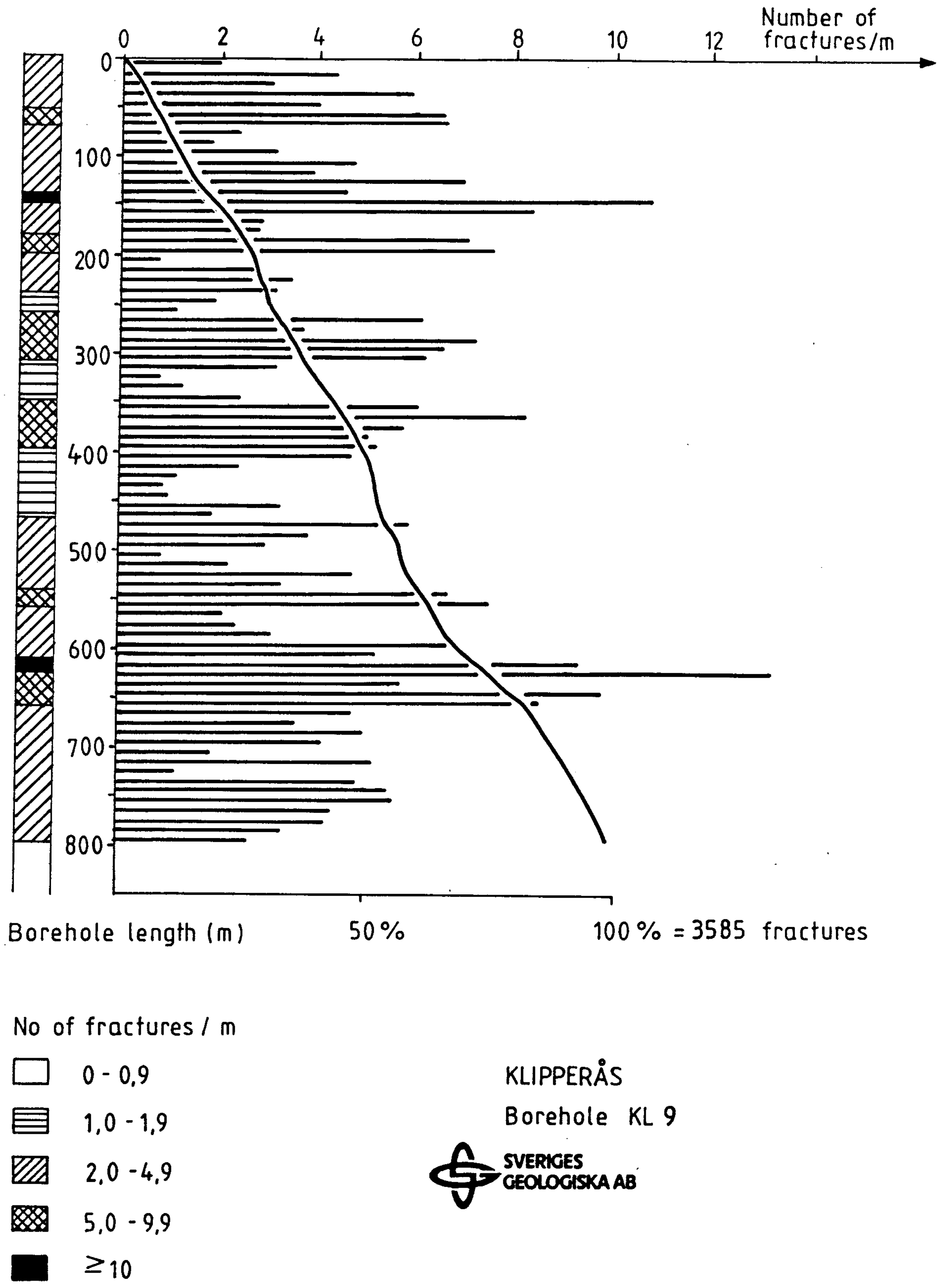
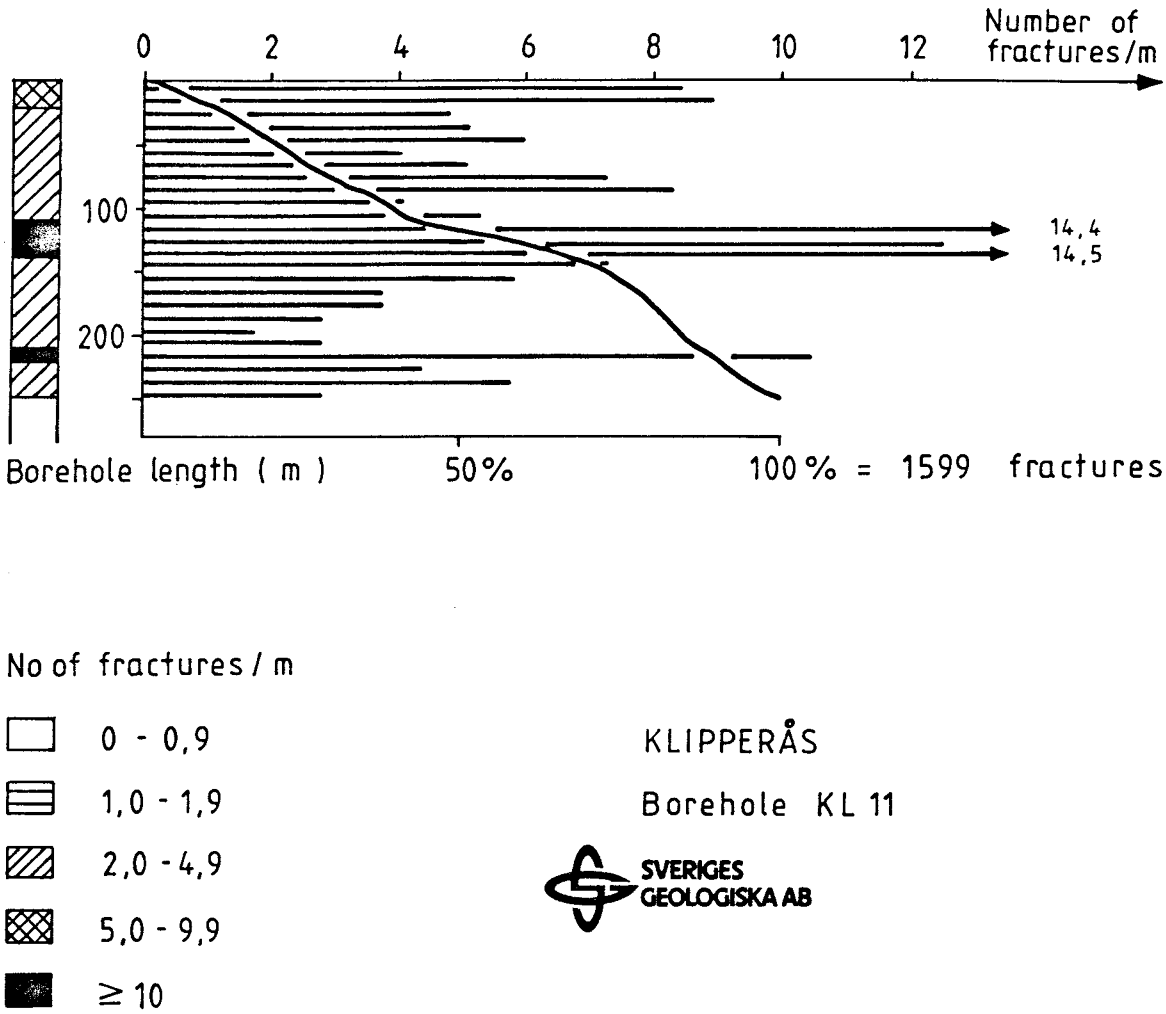


Figure A 8. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 9.



KLIPPERÅS

Borehole KL 11

SVERIGES GEOLOGISKA AB

Figure A 9. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 11.

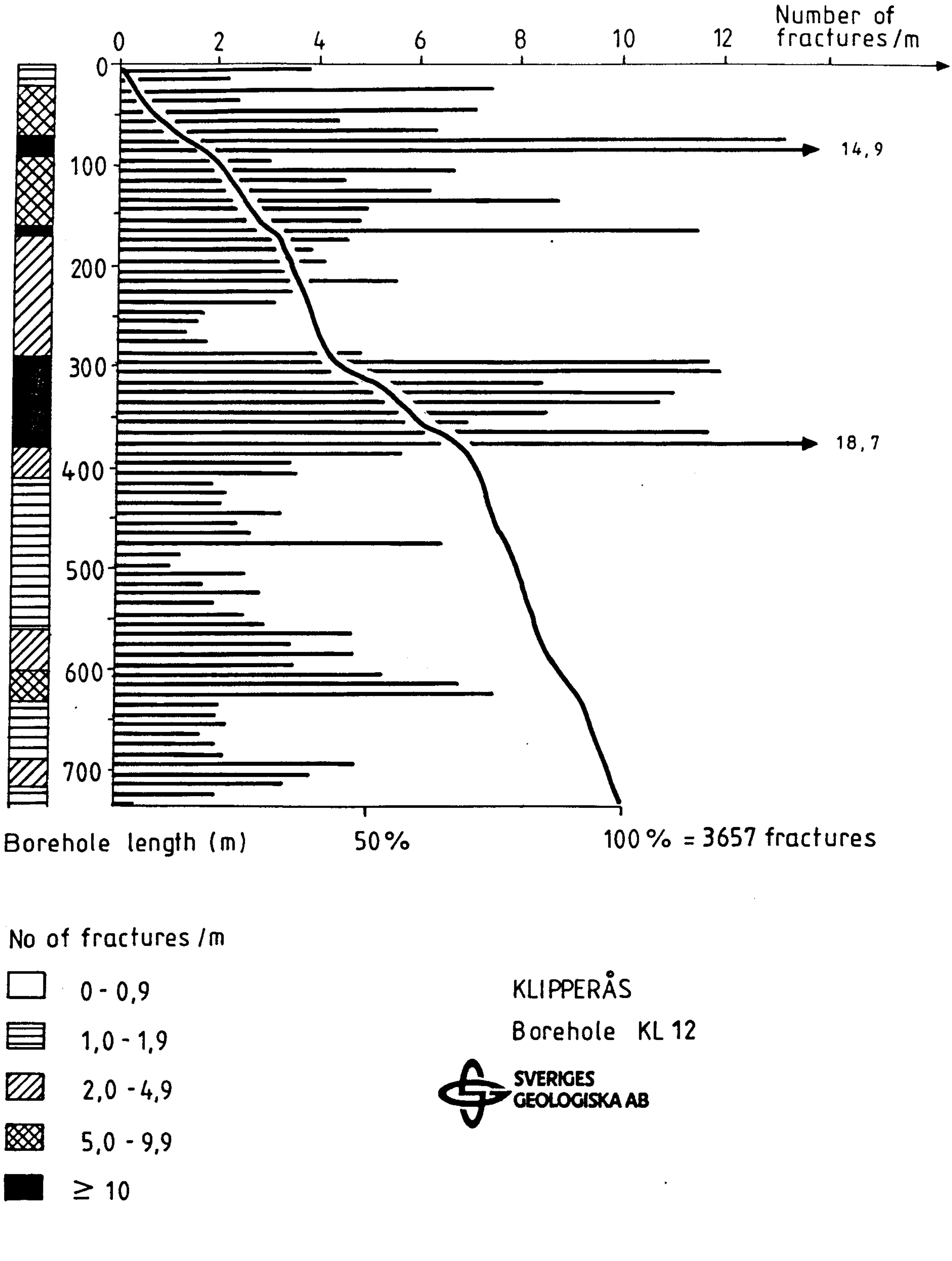
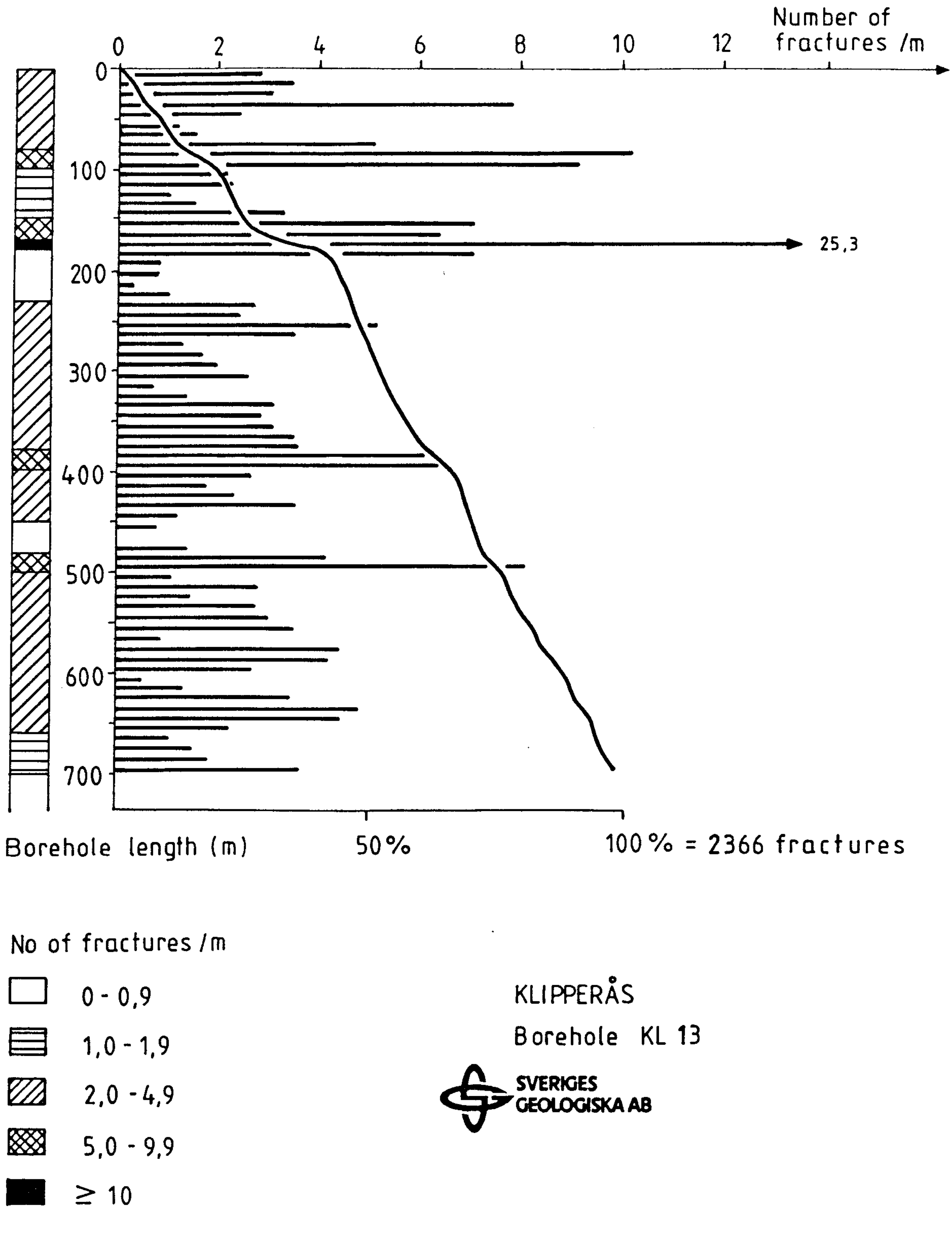


Figure A 10. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 12.



SVERIGES GEOLOGISKA AB

Figure A 11. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 13.

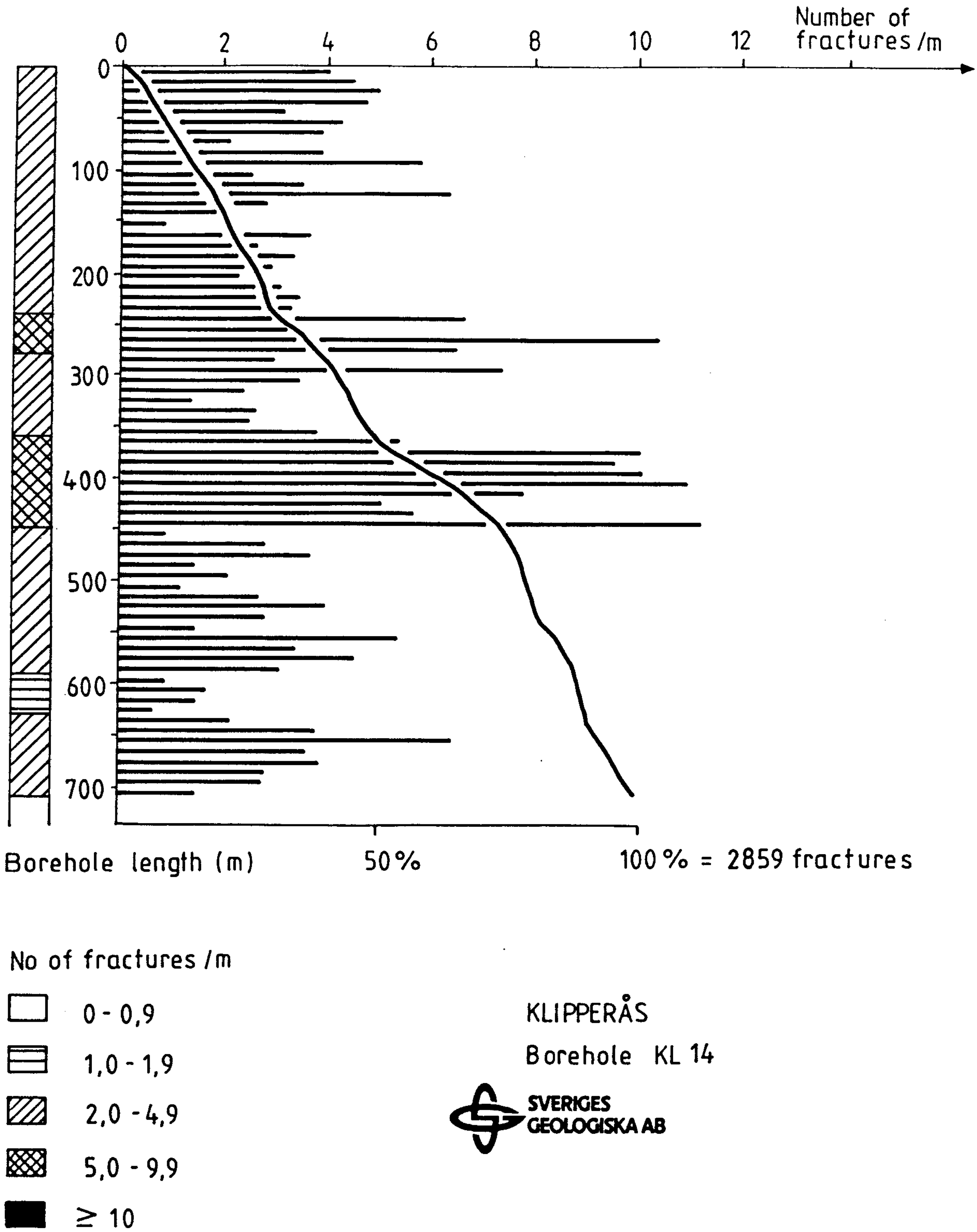


Figure A 12. Fracture frequency in 10 m sections and cumultative number of fractures in borehole Kl 14.

List of SKB reports

Annual Reports

1977–78
TR 121
KBS Technical Reports 1 – 120.
Summaries. Stockholm, May 1979.

1979
TR 79–28
The KBS Annual Report 1979.
KBS Technical Reports 79-01 – 79-27.
Summaries. Stockholm, March 1980.

1980
TR 80–26
The KBS Annual Report 1980.
KBS Technical Reports 80-01 – 80-25.
Summaries. Stockholm, March 1981.

1981
TR 81–17
The KBS Annual Report 1981.
KBS Technical Reports 81-01 – 81-16.
Summaries. Stockholm, April 1982.

1982
TR 82–28
The KBS Annual Report 1982.
KBS Technical Reports 82-01 – 82-27.
Summaries. Stockholm, July 1983.

1983
TR 83–77
The KBS Annual Report 1983.
KBS Technical Reports 83-01 – 83-76
Summaries. Stockholm, June 1984.

1984
TR 85–01
Annual Research and Development Report 1984
Including Summaries of Technical Reports Issued during 1984. (Technical Reports 84-01– 84-19)
Stockholm June 1985.

1985
TR 85-20
Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01-85-19)
Stockholm May 1986.

Technical Reports

1986

TR 86-01
I: An analogue validation study of natural radionuclide migration in crystalline rock using uranium-series disequilibrium studies
II: A comparison of neutron activation and alpha spectroscopy analyses of thorium in crystalline rocks
J A T Smellie, Swedish Geological Co, A B MacKenzie and R D Scott, Scottish Universities Research Reactor Centre
February 1986

TR 86-02
Formation and transport of americium pseudocolloids in aqueous systems
U Olofsson
Chalmers University of Technology, Gothenburg, Sweden
B Allard
University of Linköping, Sweden
March 26, 1986

TR 86-03
Redox chemistry of deep groundwaters in Sweden
D Kirk Nordstrom
US Geological Survey, Menlo Park, USA
Ignasi Puigdomenech
Royal Institute of Technology, Stockholm, Sweden
April 1, 1986

TR 86-04
Hydrogen production in alpha-irradiated bentonite
Trygve Eriksen
Royal Institute of Technology, Stockholm, Sweden
Hilbert Christensen
Studsvik Energiteknik AB, Nyköping, Sweden
Erling Bjergbakke
Risö National Laboratory, Roskilde, Denmark
March 1986

TR 86-05
Preliminary investigations of fracture zones in the Brändan area, Finnsjön study site
Kaj Ahlbom, Peter Andersson, Lennart Ekman, Erik Gustafsson, John Smellie, Swedish Geological Co, Uppsala
Eva-Lena Tullborg, Swedish Geological Co, Göteborg
February 1986