# TECHNICAL REPORT

85-09

## Concentration and distribution of natural radionuclides at Klipperåsen and Bjulebo, Sweden

Björn Sundblad, Ove Landström, Rune Axelsson
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# CONCENTRATION AND DISTRIBUTION OF NATURAL RADIONUCLIDES AT KLIPPERÅSEN AND BJULEBO, SWEDEN

## ABSTRACT

The recipient areas Klipperåsen and Bjulebo are completely different. Bjulebo is a coastal site at the Baltic where two types of recipients are identified: a brackish bay and a lake. Klipperåsen on the other hand is an inland site where the recipients are bogs. One of these is the rest of a former lake and situated above a marked fracture zone in the bedrock.

Gamma ray surveys, which covered representative soil types, gave average exposure rate values of about 18 μR/h for both sites. This corresponds to a radiation dose of about 1.5 mSv/y.

Concentrations of Th and U were determined in rock, soil and plant samples and activities of Ra-226, Ra-228, Th-228, Cs-137 and K-40 in soil and plant samples. Average concentrations in Klipperåsen samples are for granite (dominating rock) 20.7 ppm, Th and 6.6 ppm U, for soil (upper zone) 5.6 ppm Th and 2.9 ppm U and for peat 1.8 ppm Th and 2.4 ppm U (dry weight). Fairly high concentrations were observed in some organic soil samples, 11.5 ppm Th and 13.1 ppm U. The nuclides in the U and Th decay chains are usually in disequilibrium, indicating different migration patterns for the radium, uranium and thorium isotopes. A much higher root uptake of radium isotopes as compared to uranium and thorium isotopes was observed.

The water quality and the content of U, Ra-226 and Rn-222 in ground and surface water samples were determined. The Ra-226/U-238 activity ratio is in average 0.1 for the Bjulebo and 3.1 for the Klipperåsen water samples, i e the uranium content is roughly the same whereas the Ra-226 content is very low in the Bjulebo water samples.

TABLE OF CONTENTS

# 1 INTRODUCTION

Knowledge of concentrations and migration patterns of natural radioactive elements in the hydro- and biosphere of repository sites are valuable for:

- estimation of the "background" dose level due to natural radioactivity.
- calculation and estimation of "superimposed" doses due to release of similar (Ra-226, U) or analogous to radionuclides from a repository.

The aim of this project was twofold; to study the natural radiation environment and to describe the recipient areas of two potential repository sites; Bjulebo and Klipperåsen in the district of Småland, Sweden. Similar projects have been performed within the SKB research areas of Fjällveden, Voxna, Gideå and Kamlungekölen, Sundblad, Bergström (1983), Evans et al (1982).

The study comprised important nuclides in the U- and Th-decay chains (U-238, Ra-226, Rn-222, Th-232, Ra-228, Th-228), K-40 and Cs-137. Natural ("background") levels of these radionuclides were determined in samples of ground- and surface water, sediment, soil, rock and vegetation.

# 2 NATURAL RADIONUCLIDES AND THEIR DISTRIBUTION

## 2.1 Geology and experimental

### 2.1.1 Geology

The geology has been investigated by SGAB (Olkiewicz, SKB-report in preparation).

The Bjulebo area is characterized by outcropping rocks (granite) and with a fairly thin overburden.

Outcrops are on the other hand very rare at Klipperåsen and the soil thickness is here in the order of 4 meters (observations at the drilling sites). The dominating rock is granite (approx 85 %), the rest constituting greenstone and volcanic rocks in about equal amounts. Dikes of diabase also occur.

The Klipperåsen area is situated above the highest shoreline and the overburden is thus mostly composed of till, which partly is covered with organic sediment, peat bogs and former lakes. The till is rich in boulders, especially in the north western part where boulders, sizing up to 100 $m^3$ occur. The boulders which are mainly granites have probably local origin.

The topography of the Klipperåsen area is very flat, implying small hydraulic gradients.

### 2.1.2 Sampling methods

An estimate of the natural external dose to man requires knowledge of the concentration and distribution of the natural radioactive elements in rocks and soils. Especially in the Klipperåsen area, the boulder-rich and heterogeneous till renders the representative sampling for laboratory analyses a difficult problem. To overcome this, the natural exposure rate was measured in the field. The results of this gamma ray survey was then utilized in the planning of sampling sites.

The soil samples were taken from the uppermost 30-40 cm and were thoroughly mixed to obtain a homogeneous sample. About three kilogram of vegetation were cut for each sample. The soil and vegetation samples were dried and ashed before the analyses.

The size of water samples was five litres for the uranium-radium analysis. The samples were acidified by $HNO_3$. To determine the water quality one litre samples were taken. These samples were taken from surface and ground water.

General features of the samples are described in Tables 1 - 2.

### 2.1.3 Analytical methods

The following methods were applied in the laboratory:

Th: Rock, soil and plant samples (in ashed form) were analyzed with INAA (Instrumental Neutron Activation Analysis). The Th-232 activity (Bq/kg) was calculated from the obtained ppm values.

U: Rock, soil, plant (in ashed form) and water samples were anlyzed with DNA (Delayed Neutron Analysis). The U-238 activity (Bq/kg) was calculated from the obtained ppm values.

Ra-226, Ra-228, Th-228 and K-40 activities were determined with gamma ray spectrometry measurements of ashed samples of soil and plant.

The Ra-226 concentration in water samples was analyzed with a technique based on alpha measurements.

Rn-222 in water samples was determined with gamma ray spectrometry measurements of gammaemitting daughter products.

The following methods were applied in the field:

Ground gamma ray survey was carried out with scintillometers which were calibrated in μR/h.

Rn-222 in soil air was measured with an instrument based on electrostatic collection of radon daughters followed by α-spectrometry measurements of Po-218. The detector was usually placed at a depth of 70 cm.

For measurements of Rn-222 exhalation from the ground surface the same equipment was used. The detector was placed inside a cap, whose side was airtight against the ground. The field radon measurements were carried out by C Stenquist and are separately reported in the Studsvik Technical Note NW-84/866, see Appendix.

## 2.2 Natural gamma radiation

The natural gamma radiation was measured along lines with a distance of roughly 100 meters between the measuring points and at a height of 1 meter above the ground. The total length of the lines was 15 to 20 km for each site, covering different types of soil. The total number of measuring points was

130 to 150 for each site. The results are presented in tables below.

The samples are close to normal distribution according to $\chi^2$-tests.

Natural gamma radiation in Bjulebo, May 1984

| Soil type | Mean (μR/h) | Standard-deviation | Coefficient of variation |
|---|---|---|---|
| Till | 16.9 | 2.9 | 0.17 |
| Outcrops | 22.0 | 4.9 | 0.22 |
| Arable land | 16.4 | 2.9 | 0.25 |
| Peat | 5.5 | 1.5 | 0.27 |
| Swamp | 11.5 | 4.3 | 0.38 |
| Total | 18.1 | 5.6 | 0.31 |

Natural gamma radiation in Klipperåsen, May 1984

| Soil type | Mean (μR/h) | Standard-deviation | Coefficient of variation |
|---|---|---|---|
| Till | 17.4 | 2.6 | 0.15 |
| Boulder-rich till | 18.6 | 2.6 | 0.14 |
| Till with large boulders | 21.3 | 2.2 | 0.10 |
| Large boulders (granite) | 22.6 | 2.2 | 0.10 |
| Arable land | 15.0 | 1.0 | 0.07 |
| Peat | 4.1 | 0.3 | 0.08 |
| Swamp | 12.6 | 4.1 | 0.32 |
| Total | 17.6 | 3.7 | 0.21 |

The total mean for the two sites are almost identical: 18.1 μR/h in Bjulebo and 17.6 μR/h in Klipperåsen. However, in the Bjulebo area the range of values are wider and the coefficient of variation is 0.10 higher.

The till values are about the same for the two areas. This is also valid for the rock, peat and arable land.

An analysis of variance of the gamma measurements for Bjulebo showed that the means of the soil types are different at the 1 % level of significance, see table below. However, this is valid for the whole datamaterial. If one for example compares the different till types at Klipperåsen one will see that they are not significantly different.

Analysis of variance, Bjulebo

| | Sum of squares | Degrees of freedom | Mean square | F ratio |
|---|---|---|---|---|
| Treatments | 2 072 | 4 | 518 | 30.5 |
| Error | 2 306 | 135 | 17 | |
| Total | 4 378 | 139 | | |

F ratio (1 % level) = 3.4

The result of the analysis of variance of Klipperåsen is roughly the same, see table below.

Analysis of variance, Klipperåsen

| | Sum of squares | Degrees of freedom | Mean square | F ratio |
|---|---|---|---|---|
| Treatments | 740 | 5 | 148 | 18.3 |
| Error | 941 | 116 | 8 | |
| Total | 1 681 | 121 | | |

F ratio (1 % level) = 3.2.

The calculated F ratios (30.5 and 18.3, respectively) exceed the theoretical value of 3.4 and 3.2 respectively, i.e. the ground gamma radiation value of the soils are significantly different.

Two gamma ray profiles (W-E and N-S) in Klipperåsen are shown i Figures 5 and 6, respectively. The former lake can easily be seen as a marked dip in Figure 5.

## 2.3 Radionuclide distribution including radon

Th, U and the radionuclides Ra-226, Ra-228, Th-228, K-40 and Cs-137 were determined in soil, peat and vegetation samples. The sampling sites are shown in Figures 2 and 4.

The different analyses were made on material taken from the same bulk sample material (in ashed form). Analyzed sample sizes were about 200-800 mg for the Th-analysis, 3-6 g for the U-analysis and from 5 (plants) to 70 g for the Ra-226, Ra-228, Th-228, K-40 and Cs-137 analyses. Due to the relatively small samples for the Th analysis, error in the activity ratios caused by inhomogeneity cannot be excluded.

Th and U concentration values, Th/U ratio, Ra-226, Ra-228, Th-228, K-40 and Cs-137 activity and activity ratios are shown in Table 4. The Th-232 and U-238 activity values were calulated from the specific activities:

Th-232: $3.93 \cdot 10^{3}$ Bq/g Th

U-238: $1.24 \cdot 10^{4}$ Bq/g U

For comparison, some Th and U analyses were made of core samples of drillhole B9 which are representative for the bedrock in the area. The results are presented in Table 5.

The concentration of Ra-226, U and the activity ratio Ra-226/U-238 in water samples are shown in Table 6.

The Rn-222 concentration was measured at five sites (Figure 2 and 7). At two sites measurements of Rn-222 exhalation were also made. The results are shown in Table 7, which also includes values for Rn-222 in artesian seeping water from borehole 8 and surface water.

## 2.4 Water quality

Conductivity, pH and major constituents as Na, K, Mg, Ca, $HCO_3$, $SO_4$ and Cl were determined for surface and ground water. Besides $KMnO_4$, $NH_4$, $NO_2$, F, Mn, Fe and Al for some sites were analyzed. All values are shown in Table 3.

Four types of recipients are represented in Bjulebo, well, creek, lake and sea. The sur- face waters, sampled in May 1984, is slightly increased in Na, Cl and $SO_4$ as compared to standard composition, Hutchinson (1957). On the other hand there is a deficiency of K and Ca. The major constituents of sea water follow the standard composition of Baltic water with the exception of $SO_4$ (+25 %), Voipio (1981). Of the trace metals, Al and Fe are higher as compared to the Baltic standard.
The pH and buffer capacity are both low in the two creeks.

All the water samples from Klipperåsen, with the exception of a borehole sample are surface water. The Klipperåsen data, presented in Table 3 are from two sampling occasions, the first one in May 1984 and the other one in September 1984. The first five samples (VKL1-VKL5) represent the spring period and the last four (VA5-VA10) the autumn period. There are small differences between spring and autumn values, (cf. VKL2-VA9 and VKL3-VA8). Only $KMnO_4$ has increased by a factor 2.

The pH and the buffer capacity values are generally low in Klipperåsen.

There are no great differences in water quality between the two research areas. The pattern is the same concerning the excess or deficiency of the constituents in the water.

## 2.5 Runoff

During September survey in Klipperåsen the water discharge was measured in connection with the water sampling. However,this is only a point measurement and will not give the transport of different constituents.

The mean runoff in Klipperåsen is around 8 $l/s \cdot km^2$, see Chapter 3. Expected average highwater for these small catchments is in the range of 100-150 $l/s \cdot km^2$. The average lowwater is in the order of 0.1 - 1 $l/s \cdot km^2$, Melin (1970). In September the measured runoff varied between 12-30 $l/s \cdot km^2$.

## 2.6 Discussion

Average values of Th and U for the mineral soil samples JKL1 - JO11 are 5.8 ppm and 2.9 ppm resp, i.e. considerable lower than the averages of the granite which dominates the bedrock (cf. Table 5). This difference is partly explained by the fact that the "radioactive" granite boulders are not represented in the analyzed soil samples. The depth distribution of Th and U was not investigated. However, the samples Bj2 and Bj3 (A2 and B horizons) from the Bjulebo area indicate increasing values with depth.

Average Th, U and Th/U values for the peat samples (J01 - J03) are 1.8 and 2.4 ppm and 0.74 respectively. The corresponding average values for the organic soil samples (Jo6-Jk12) are 11.5 ppm, 13.1 ppm and 0.88, respectively. A low Th/U ratio is thus characteristic for the organic soils and considerably lower than for mineral soils and rocks.

The fact that the ashed fraction of these organic samples is rather enriched in Th and U (up to 60 and 70 ppm, respectively) speaks in favour of sorption or precipitation from soil solution prior to sedimentation of clay or mineral particles. Also the lantanides are enriched in the ashed samples (e.g. 1 000 ppm La in sample J08 as compared to about 10-15 ppm in the mineral soils).

The Th and U content of the plant samples are low, Th being below the detection limit and U showing an average of 10 ppb.

For the Th-232 decay chain, equilibrium is established within 30-40 years whereas up to 1 million years are required for the U-238 decay chain. In Table 4, most of the samples are not in radioactive equilibrium, as regard Ra-226-U-238 and Ra-228-Th-232.

Average Ra-226/U-238 ratios are for vegetation 348, peat 2.8, "organic soil" 0.36 and mineral soil 1.80. The corresponding values for Ra-228/ /Th-232 are >370, 2.8, 1.06 and 1.47 respectively. Different processes can cause such a disequilibrium, e g leakage of uranium isotopes. The high activity ratios for the plant samples indicate much higher uptake of both Ra-226 and Ra-228 as compared to U-238 and Th-232. Such a Ra migration could explain the high activity ratios of the upper soil zone.

A comparison of the water activity between the Bjulebo and Klipperåsen area, Table 6, shows as general much lower values of Ra-226 from Bjulebo, whereas the uranium content is about the same.

The higher Ra-226 values at Klipperåsen are concentrated to creeks and streams draining peat bogs and their Ra-226/U-238 activity ratios are about 4-5. An interesting exception is VA5 (which drains the area with peatlike organic matter) which shows the same low ratio value as the soil.

The borehole is characterized by a high Ra-226/ /U-238 activity ratio.

# 3 DESCRIPTION OF THE RECIPIENT AREAS

## 3.1 The Klipperåsen area

### 3.1.1 General description

The Klipperåsen area, 56°47'N, 15°40'E, is situated 5 km south-west of Orrefors, Småland, see Figure 1.

#### 3.1.1.1 Climate

According to the Köppen classification, the area belongs to the cold snow-forest zone, Dbf.

The annual mean air-temperature in Växjö is 6.5°C.

The mean precipitation (1931-60) is 645 mm (uncorrected). The correction for Eastern Småland is +18 %, i.e. the corrected precipitation is 760 mm.

#### 3.1.1.2 Hydrology

The average annual runoff in this part of the country is around 8 $l/s \cdot km^2$, Tryselius (1971). Calculated evapostranspiration is 475 mm/year, Eriksson (1980).

#### 3.1.1.3 Vegetation

The whole country is divided into different vegetational zones. The Småland area belongs to the boreo-nemoral zone, Abrahamsen (1977).

### 3.1.2 Recipients

There are no lakes within the research area except bogs. The only large lake close to Klipperåsen is Orranäsasjön within the drainage area of Ljungbyån. A small lake, Sibbetorpasjön, is situated north of the research area.

There are lots of small bogs within the main part of the area. Besides these small bogs we have found a relatively large bog area in the western parts of the area. It is a former lake area of about 0.4 $km^2$, in this report referred to as Långesjön. There are only small pools left telling about the existence of a former lake. This area is situated above a marked fracture zone. Because of that this area has been chosen as a probable primary recipient.

#### 3.1.2.1 Drainage areas, lakes and discharge

About 75 % of the research area is drained by Granöbäcken, a tributary of Ljungbyån. The western part is drained by Hermantorpabäcken, a tributary of Hagebyån. This western area is equivalent to some 10 % of the total area.

In table 3.1 two alternatives of recipients are summarized. The first one is a bog in the center of the research area belonging to catchment area of Granöbäcken. The second one is the western one with the former lake and the recent pools, called Långesjön.

Catchments - Klipperåsen

| Catchment | Area (km$^2$) | Lake Percentage |
|---|---|---|
| Primary bog | 0.015 | 0 |
| Granöbäcken | 0.17 | 0 |
| Madesjön above | | |
| Nybroån | 106 | 0.8 |
| Ljungbyån | 750 | 0.8 |
| | | |
| Långesjön | 2.8 | 2.5 |
| Bodasjön | 70 | 0.7 |
| Hagbyån | 447 | 3.6 |

The lake percentage is very low within the catchments as can be seen from table above. This is typical for south-eastern part of Sweden.

Discharge values of Ljungbyån are presented in the table below.

Characteristic values of discharge and runoff in Ljungbyån, Källstorp 1922-75

| | m$^3$/s | l/s · km$^2$ |
|---|---|---|
| Highest highwater flow | 35 | 102 |
| Average highwater flow | 15.9 | 46 |
| Highest annual flow | 4.5 | 13.1 |
| Longterm average flow | 2.6 | 7.6 |
| Lowest annual flow | 1.0 | 2.9 |
| Average lowwater flow | 0.15 | 0.43 |
| Lowest lowwater flow | 0.01 | 0.03 |

### 3.1.3 Land use

The different kind of land in Kalmar county is presented in tables below.

Types of land in Kalmar county

| Type | Area ($km^2$) | Percentage |
|---|---|---|
| Forest land | 7 170 | 64.2 |
| Arable land and pasture | 2 630 | 23.5 |
| Swamp | 360 | 3.2 |
| Rock surface | 830 | 7.4 |
| Other land | 180 | 1.6 |

Source: SCB (1981)

Use of arable land in Kalmar county 1981

| Crop | Area ($km^2$) |
|---|---|
| Cereals | 453 |
| Fodder | 589 |
| Oleiferous | 31 |
| Potatoes | 16 |
| Horticultural plants | 8.5 |

### 3.1.4 Yield form arable and horticultural land in Kalmar county 1981

The yield of cereals, ley, potatoes are shown in tables below.

Yield of cereals, ley and potatoes in Kalmar county 1981

| | Yield ($kg/m^2$) |
|---|---|
| Wheat and rye | 0.46 |
| Barley and oats | 0.38 |
| Ley | 0.66 |
| Potatoes | 3.26 |

Source: SCB

### 3.1.5 Classification

The type of classification of the area is the same as chosen for e.g. Fjällveden, Sundblad (1983). The hydrological region is "Rivers of Southern Sweden - Eastern Rivers - Fa", Gottschalk (1975). In this region the snowmelt or a combination of rain and snowmelt form the main runoff in the spring.

The physical geographic region, according to Abrahamsson (1977) is - "The plains of south-eastern Småland with woods and lakes. (12a)".

The terrain is flat and most of area is above the marine border. This means that area is covered by moraine with a frequence of bare rock and very little of fine sediments.

## 3.2 The Bjulebo area

### 3.2.1 General description

The Bjulebo area, 57°38' N and 16°32' E, is situated 15 km south-west of Västervik, see Figure 3.

#### 3.2.1.1 Climate

The climate zone is the same as Klipperåsen i.e. cold snow-forest zone, Dbf.

The annual mean air temperature in Västervik is 6.9°C.

The mean precipitation (1931-60) is 542 mm (uncorrected). The corrected value is 640 mm.

3.2.1.2 Hydrology

The average annual runoff in this area is around 7 l/s · $km^2$, Tryselius (1971). Calculated evapotranspiration is 500 mm/year, Eriksson (1980).

3.2.1.3 Vegetation

The vegetation zone is the same as Klipperåsen, i.e. boreo-nemoral zone.

## 3.2.2 Recipients

There are two types of recipients, a bay Slingsviken in the south-west and a lake Ålsjön north of the research area.

The main part of the area is drained to Ålsjön, see Figure 4. Within this drainage area there is a bog Gåsmossen with the only surface water in the vicinity.

There is a small tarn in the southern part called the Annelundsgölen.

3.2.2.1 Drainage areas, lakes and discharge

The drainage area of Slingsviken is about 8 $km^2$. The surface of the 3.5 km long and narrow bay is 0.8 $km^2$, and its volume about $3 \cdot 10^6$ $m^3$. The mean depth of the bay becomes 3.5 m.

The lakes Maren, Ålsjön and Toven constitute the lowest part of Botorpströmmen drainage basin. At the outlet of Ålsjön the drainage area is 999 $km^2$ and at the outlet in the Baltic it is 1 004 $km^2$. The lake percentage is 11.3.

Characteristic discharge values for Botorpströmmen at Yxern is found in table below. The drainage area at this point is 326 $km^2$, i.e. is only one third of the total area. However, it gives the character of the whole area because the lake percentage is about the same.

Characteristic values for discharge and runoff in Botorpströmmen 1922-45

| | $m^3/s$ | $l/s \cdot km^2$ |
|---|---|---|
| Highest highwater flow | 11.2 | 34 |
| Average highwater flow | 6.5 | 19.9 |
| Highest annual flow | 3.7 | 11.3 |
| Longterm average flow | 2.0 | 6.1 |
| Lowest annual flow | 0.70 | 2.1 |
| Average lowwater flow | 0.39 | 1.2 |
| Lowest lowwater flow | 0.07 | 0.21 |

Concerning land use and yield, see sections 3.1.3 and 3.1.4.

### 3.2.3 Classification

The hydrological region is the same for Bjulebo as for Klipperåsen i.e. "Southern Sweden - Eastern Rivers - Fa".

The physical geographic region is "The coasts and archipelagoes of the Baltic Sea (25c)". It is characterized by the fissure valley landscape. The mainland forests are dominated by pine or bare rock. The climate is dry especially in spring and the beginning of the summer. The vegetation period is around 180 days.

## 4 CONCLUSIONS

In Klipperåsen and Bjulebo investigations have been made, aiming to measure level and dose from natural radioactivity and to find migration patterns of interesting radionuclides (i.e. radium and uranium) in these particular areas.

Introductory gamma ray surveys gave average exposure rate values of 18.1 μR/h and 17.6 μR/h for Bjulebo and Klipperåsen respectively, which correspond to radiation doses of about 1.5 mSv/y.

The soil (upper 40 cm and excluding boulders) at Klipperåsen have averages of 6 ppm Th and 3 ppm U. Neither Ra-226 nor Ra-228 are in equilibrium with U-238 and Th-232; in those cases about 50 % enrichment of radium isotopes. One explanation of this disequilibrium can be the observed high uptake in plants of the two radium isotopes relative to uranium and thorium; i.e. the nutrient cycle of plants causes an enrichment in the upper soil horizon of radium.

Average thorium and uranium values are for peat 1.8 ppm and 2.4 ppm and for some organic soil 11.5 ppm and 13.1 ppm, respectively. The ratio Th/U is on an average 0.8 in the Klipperåsen peat deposits, compared to 2-3 in the soil and rocks; i.e. uranium is enriched relative thorium. The different bogs exhibit characteristic isotope ratios (ranging from 0.3 to 5.0 for Ra-226/U-238), which may depend on type and age of peat deposit, hydrology, changing of chemical environment during the history of the bog, drainage.

In general, the water that drains the peat deposits have high Ra-226/U-238 values, about 4-5. However, one creek which drains an area with organic soils has the same low Ra-226/U-238 value, 0.3, as the drained organic soil.

The water samples from Bjulebo have much lower Ra-226/Ra-228 activity ratios than the Klipperåsen samples.

Potential recipients in the two research sites have been defined. In Bjulebo two types, a lake and a brackish bay, are identified. The primary recipients in Klipperåsen are bogs. One is a small bog with a small catchment. The other one is a wide bog area. It is a former lake situated above a marked fracture zone. The greatest interest has been put on this area, where most of the sampling has been carried out.

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Table 1 The general features of the sampling sites at Bjulebo

| Sampling site | Type | Land-use | Dominating soil |
|---|---|---|---|
| WATER | | | |
| VBj1 Annelund | Drilled well | Forest | Bedrock |
| VBj2 Annelundsgölen | Creek | Forest | Till |
| VBj3 Centralbäcken | Creek | Arable land | Clay |
| VBj5 Ålsjön | Oligotropic lake | Forest | Till |
| VBj4 Slingsviken | Brackish bay | - | - |
| SOIL | | | |
| JBj1 Bjulebo | Pasture ground | | Clay |
| JBj2 Strängenäs | Forest | | Till - A2 horizon |
| JBj3 Strängenäs | Forest | | Till - B horizon |

Table 2 The general features of the sampling sites at Klipperåsen

| Nr | Sampling site | Type | Land-use | Dominating soil |
|---|---|---|---|---|
| | WATER | | | |
| VKL1 | Granöbäcken | Creek | Forest | Till |
| VKL2 | Mossen | Creek | " | Peat |
| VKL3 | Deragård | Stream | " | Till |
| VKL4 | Norrbäcken | Creek | " | " |
| VKL5 | Stibbetorpasjön | Stream | " | " |
| | | | | |
| VA1 | Stamphult | Creek | Forest | Till |
| VA2 | Borrhål 8 | Artesian borehole | - | - |
| VA3 | Sammanflödet | Creek | Bog | Peat |
| VA4 | Rundegöl | " | " | " |
| VA5 | Bäck väster | " | Forest clear-cut | Till |
| VA6 | Långegöl | " | Bog | Peat |
| VA7 | Storemosse | " | Forest/bog | Till/peat |
| VA8 | Deragård | " | Forest | Till |
| VA9 | Mossen | " | " | Peat |
| VA10 | Mörkerås | " | " | Till |
| | | | | |
| | VEGETATION | | | |
| VE1 | Långegöl | Grass | Bog | |
| VE2 | Deragård | Grass | Pasturage | |
| VE3 | RN-2 | Fern | Forest | |
| | | | | |
| | SOIL | | | |
| JKL1 | | Forest | | Till |
| JKL2 | | Clearing | | Organic |
| JKL3 | | Forest | | Till/boulder |
| JKL4 | | Clearing | | Till |
| | | | | |
| JO1 | | Bog | | Peat |
| JO2 | | " | | " |
| JO3 | | " | | " |
| JO4 | | Pasture ground | | Sandy clay |
| JO5 | | Forest | | Till |
| JO6 | | Clearing | | Organic |
| JO7 | | " | | " |
| JO8 | | " | | " |
| JO9 | | " | | Till |
| JO10 | | " | | Organic |
| JO11 | | " | | Till |

Table 3 Water quality data for Bjulebo and Klipperåsen
Unit: mg/l

| Sample no | Type | pH | Cond mS/m | $KMnO_4$ | $HCO_3$ | $NH_4$ | $NO_2$ $NO_3$ | $SO_4$ | F | Cl | Na | Mg | K | Ca | Mn | Fe | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BJULEBO | | | | | | | | | | | | | | | | | |
| VBJ1 | Well | 7.9 | 25.3 | 2 | 152.0 | <0.010 | <0.005 | 11 | 1.40 | 4.6 | 10.1 | 2.6 | 0.74 | 43.0 | 0.130 | 0.16 | - |
| VBJ2 | Creek | 5.2 | 4.8 | 123 | 2.9 | 0.096 | <0.005 | 5 | 0.22 | 5.0 | 3.9 | 1.3 | 0.62 | 2.9 | 0.030 | 0.32 | - |
| VBJ3 | Creek | 5.4 | 7.0 | 107 | 4.9 | 0.120 | 0.045 | 10 | 0.20 | 7.3 | 4.2 | 2.0 | 0.69 | 6.0 | 0.074 | 1.50 | 0.70 |
| VBJ5 | Lake | 7.0 | 11.8 | 19 | 31.0 | 0.087 | 0.051 | 19 | 0.28 | 10.0 | 5.6 | 2.9 | 1.90 | 13.2 | 0.038 | 0.08 | 0.04 |
| VBJ4 | Sea | 7.6 | 1090.0 | 32 | 88.0 | 0.023 | <0.005 | 680 | 1.60 | 3850.0 | 1910.0 | 246.0 | 76.00 | 92.0 | 0.017 | 0.13 | 0.20 |
| KLIPPERÅSEN | | | | | | | | | | | | | | | | | |
| VKL1 | Creek | 4.8 | 6.9 | 63 | 0.7 | 0.016 | 0.047 | 17 | 0.15 | 8.2 | 4.5 | 1.8 | 0.82 | 3.7 | 0.17 | 0.73 | 0.52 |
| VKL2 | Creek | 4.2 | 7.9 | 76 | - | 0.076 | 0.049 | 16 | 0.18 | 7.6 | 4.9 | 1.6 | 0.53 | 4.1 | 0.05 | 0.65 | 0.91 |
| VKL3 | Stream | 4.7 | 7.6 | 41 | - | 0.012 | 0.038 | 16 | 0.24 | 8.4 | 4.8 | 1.8 | 0.83 | 4.1 | 0.15 | 0.59 | 0.64 |
| VKL4 | Creek | 5.2 | 6.4 | 107 | 2.7 | 0.018 | 0.082 | 11 | 0.15 | 7.0 | 4.3 | 1.8 | 0.85 | 4.0 | 0.08 | 0.65 | 0.50 |
| VKL5 | Stream | 5.5 | 7.3 | 28 | 2.7 | 0.064 | 0.011 | 15 | 0.40 | 9.5 | 4.6 | 1.7 | 0.65 | 4.7 | 0.15 | 3.00 | 0.37 |
| VA2 | Borehole | 7.3 | 44.5 | 31 | 273 | 0.2 | <2.0 | <1 | 1.20 | 4.0 | 20.6 | - | 3.15 | 83.0 | 0.44 | 0.23 | - |
| VA3 | Stream | 4.2 | 7.9 | 167 | <1.0 | 0.1 | <2.0 | 11 | 0.30 | 5.0 | 4.5 | - | 0.45 | 4.0 | 0.10 | 1.88 | - |
| VA5 | Creek | 4.2 | 7.5 | 169 | <1.0 | 0.1 | <2.0 | 8 | 0.30 | 5.0 | 4.2 | - | 0.42 | 4.0 | 0.13 | 2.69 | - |
| VA8 | Creek | 4.7 | 7.9 | 97 | <1.0 | <0.1 | <2.0 | 10 | 0.30 | 5.0 | 4.5 | - | 0.90 | 5.0 | 0.12 | 1.09 | - |
| VA9 | Creek | 4.1 | 9.8 | 144 | <1.0 | <0.1 | <2.0 | 14 | 0.20 | 5.0 | 4.7 | - | 0.45 | 5.0 | <0.05 | 0.60 | - |
| VA10 | Creek | 4.3 | 7.8 | 126 | <1.0 | <0.1 | <2.0 | 12 | 0.20 | 5.0 | 4.4 | - | 0.45 | 5.0 | 0.07 | 1.26 | - |

Table 4 Concentration and activity of radionuclides in soil and vegetation (on dry weight base)

| Sample nr | Type | Percentage ash(of dry weight) | Th ppm | U ppm | Th/U | Concentrations Bq/kg U * | Ra-226 | Ra-228 | Th-228 | K-40 | Cs-137 | Activity ratios Ra-226/U-238 | Ra-228/Th-232 | Th-228/Th-232 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KLIPPERÅSEN | | | | | | | | | | | | | | |
| VE-1 | Vegetation | 3.5 | <0.015 | 0.006 | <2.5 | 0.2 | 20 | 7 | 6 | 254 | 118 | 277 | >117 | > 97 |
| VE-2 | " | 5.6 | <0.015 | 0.020 | <2.5 | 0.5 | 10 | 4 | 8 | 271 | 209 | 38 | > 67 | >130 |
| VE-3 | " | 10.0 | <0.015 | 0.008 | <2.5 | 0.2 | 67 | 55 | - | 691 | 687 | 728 | >920 | - |
| JO-1 | Peat | 12.6 | 2.8 | 3.4 | 0.8 | 87 | 49 | 14 | 24 | 38 | 10 | 1.2 | 1.2 | 1.2 |
| JO-2 | " | 9.8 | 0.9 | 1.7 | 0.5 | 44 | 120 | 21 | 31 | 12 | 63 | 5.6 | 5.9 | 8.5 |
| JO-3 | " | 6.5 | 1.7 | 1.9 | 0.9 | 49 | 37 | 10 | 11 | 15 | 36 | 1.5 | 1.4 | 1.6 |
| JO-6 | Organic | 24.2 | 11.2 | 11.4 | 1.0 | 289 | 85 | 43 | 57 | - | 35 | 0.6 | 1.0 | 1.3 |
| JO-7 | Soil " | 23.7 | 8.9 | 11.8 | 0.8 | 300 | 39 | 43 | 56 | 60 | 57 | 0.3 | 1.2 | 1.6 |
| JO-8 | " | 23.1 | 15.9 | 18.1 | 0.9 | 460 | 66 | 73 | 96 | - | 27 | 0.3 | 1.2 | 1.5 |
| JO-10 | " | 16.4 | 9.7 | 12.4 | 0.8 | 316 | 44 | 32 | 43 | - | 27 | 0.3 | 0.8 | 1.1 |
| JKL-2 | " | 20.2 | 11.8 | 11.7 | 1.0 | 299 | 40 | 49 | 66 | 43 | 26 | 0.3 | 1.1 | 1.4 |
| JKL-1 | Till | 96.1 | - | 2.8 | - | 70 | 54 | 35 | 46 | 809 | 8 | 1.6 | - | - |
| JKL-3 | " | 94.1 | 6.7 | 3.8 | 1.8 | 97 | 77 | 41 | 61 | 746 | - | 1.6 | 1.6 | 2.3 |
| JKL-4 | " | 94.6 | 6.9 | 3.1 | 2.2 | 79 | 76 | 40 | 44 | 689 | 8 | 2.0 | 1.5 | 1.6 |
| JO-4 | " | 92.7 | 3.8 | 2.7 | 1.4 | 69 | 53 | 22 | 20 | 717 | 11 | 1.6 | 1.5 | 1.3 |
| JO-5 | " | 93.4 | 5.7 | 2.4 | 2.4 | 62 | 43 | 19 | 35 | 740 | - | 1.4 | 0.9 | 1.6 |
| JO-9 | " | 89.3 | 7.1 | 3.3 | 2.2 | 84 | 86 | 62 | 79 | 661 | 53 | 2.1 | 2.2 | 2.8 |
| JO-11 | " | 92.2 | 4.8 | 2.4 | 2.0 | 61 | 67 | 21 | 35 | 692 | 18 | 2.3 | 1.1 | 1.8 |
| BJULEBO | | | | | | | | | | | | | | |
| JBJ-1 | Pasture | 94.1 | 12.0 | 3.4 | 3.5 | 87 | 67 | 47 | | 889 | 8 | 1.6 | 1.0 | 1.4 |
| JBJ-2 | Till | 95.6 | 4.7 | 2.0 | 2.4 | 51 | 40 | 29 | | 738 | 19 | 1.6 | 1.6 | 1.7 |
| JBJ-3 | " | 95.9 | 13.0 | 9.3 | 1.4 | 236 | 98 | 55 | | 726 | 8 | 0.9 | 1.1 | 1.6 |

* Inlcudes U-238, U-234 and U-235

Table 5 Th and U concentrations in rock samples from Bh 9, Klipperåsen

| Rock type | Core level | Th,ppm | U,ppm | Th/U |
|---|---|---|---|---|
| Granite | 20.15 m | 20.3 | 7.8 | 2.6 |
| " | 119.40 " | 18.7 | 7.5 | 2.5 |
| " | 159.80 | 28.8 | 10.6 | 2.7 |
| " | 221.10 | 21.7 | 4.6 | 4.7 |
| " | 320.90 | 18.0 | 4.9 | 3.7 |
| " | 525.35 | 14.7 | 4.2 | 3.5 |
| " | 720.90 | 22.5 | 7.8 | 2.9 |
| Quartsporphyry | 282.35 | 26.8 | 11.0 | 2.4 |
| Greenstone | 353.0 | 1.4 | 0.87 | 1.6 |
| Diabase | 366.40 | 1.9 | 0.57 | 3.3 |
| Granite, mean | | 20.7 | 6.8 | 3.2 |

Table 6 Concentration of Ra-226 and uranium in water samples from Bjulebo and Klipperåsen

| Sample | Radium-226 $Bq/m^3$ | Uranium $Bq/m^3$ | Activity ratio Ra-226/U-238 |
|---|---|---|---|
| BJULEBO | | | |
| VBj1 | 2 | 36 | 0.1 |
| VBj2 | <2 | 8 | <0.3 |
| VBj3 | <1 | 17 | <0.1 |
| VBj4 | 2 | 21 | 0.2 |
| VBj5 | <2 | 9 | <0.4 |
| | | | |
| KLIPPERÅSEN | | | |
| VKL1 | 9 | 19 | 1.0 |
| VKL2 | 28 | 13 | 4.3 |
| VKL3 | 29 | 11 | 5.3 |
| VKL4 | 5 | 16 | 0.6 |
| VKL5 | 15 | 5 | 6.0 |
| | | | |
| VA1 | 8 | 7 | 2.3 |
| VA2 | 15 | <5 | >6.0 |
| VA3 | 15 | 7 | 4.3 |
| VA4 | 20 | 10 | 4.0 |
| VA5 | 4 | 34 | 0.2 |
| VA6 | 17 | 8 | 4.3 |
| VA7 | 9 | 11 | 1.6 |
| VA8 | 13 | 12 | 2.2 |
| VA9 | 27 | 11 | 4.9 |
| VA10 | 13 | 11 | 2.4 |

Table 7 Concentration of Rn-222 in soil and water

| Sampling site | Rn-222 $Bq/m^3$ | Rn-222 exhalation $mBq/m^2$ s |
|---|---|---|
| 1 Soil air | 2 500 | 2.1*) |
| 2 " | 15 000 | |
| 3 " | 7 000 | |
| 4 " | 2 500 | 3.2 |
| 5 " | 3 000 | |
| 6 Groundwater from borehole 8 | 260 000 | |
| 7 Surface water VA3 | 3 200 | |

*) Average of four measurements

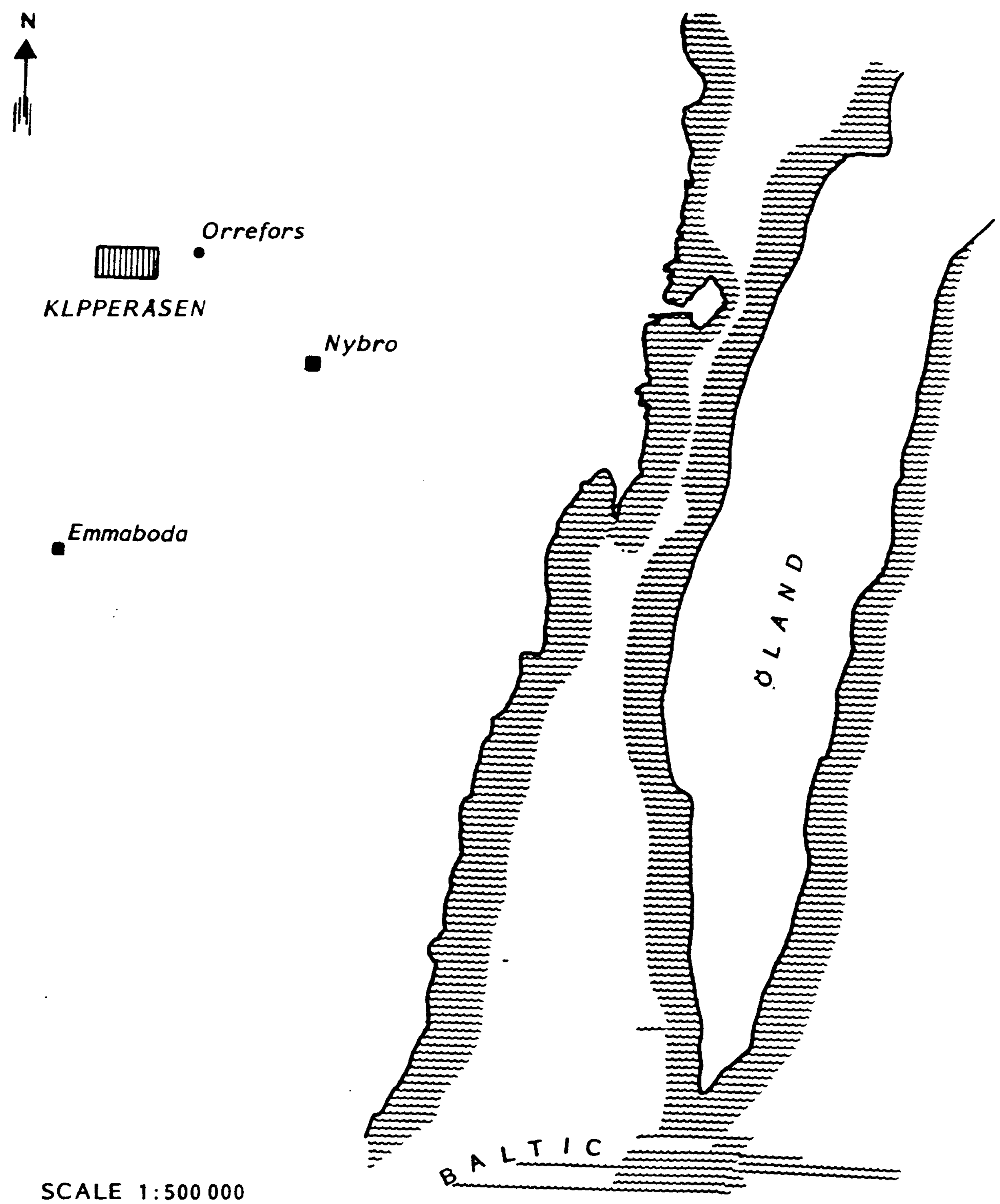



Figure 1 GENERAL MAP OF KLIPPERASEN

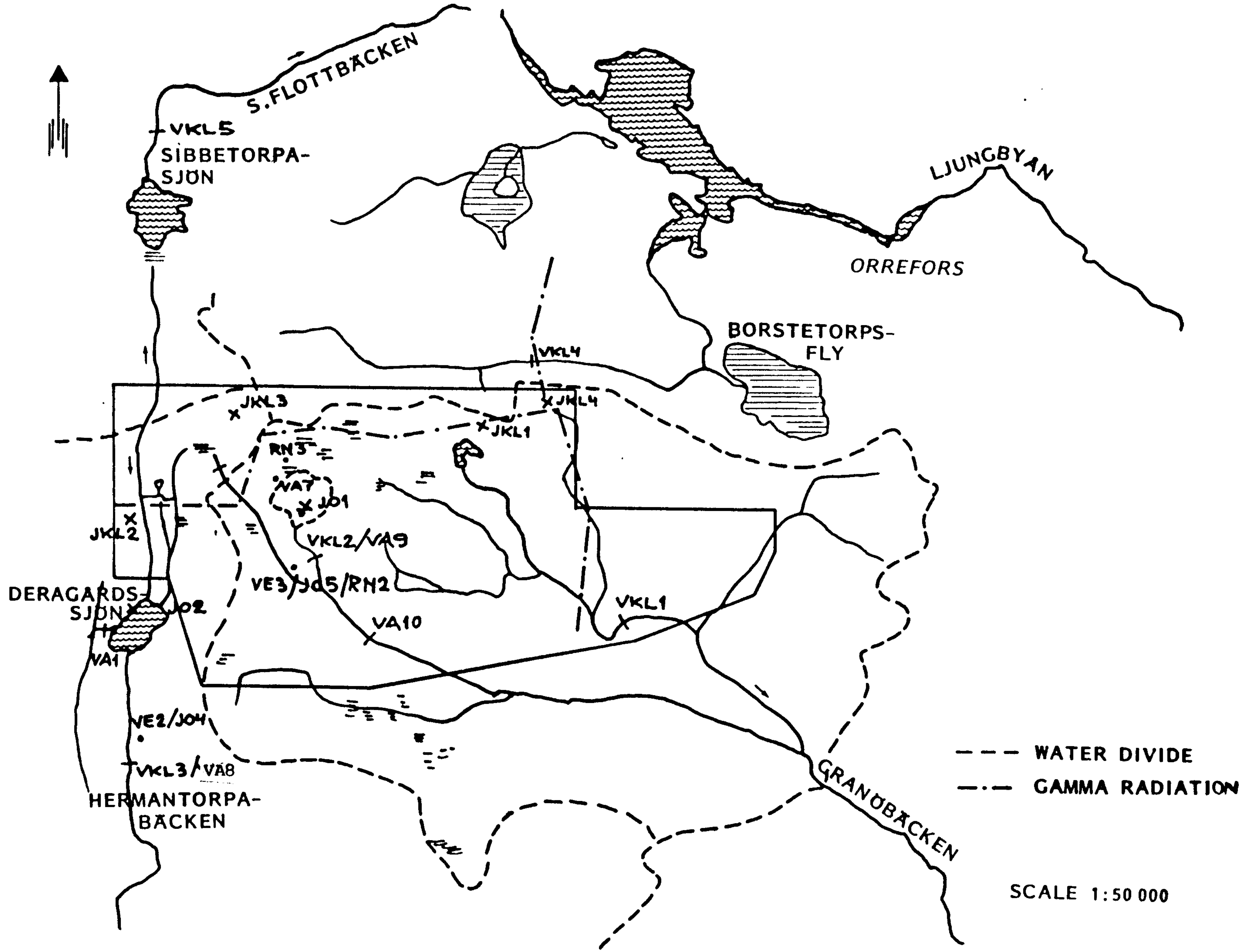



Figure 2 KLIPPERASEN

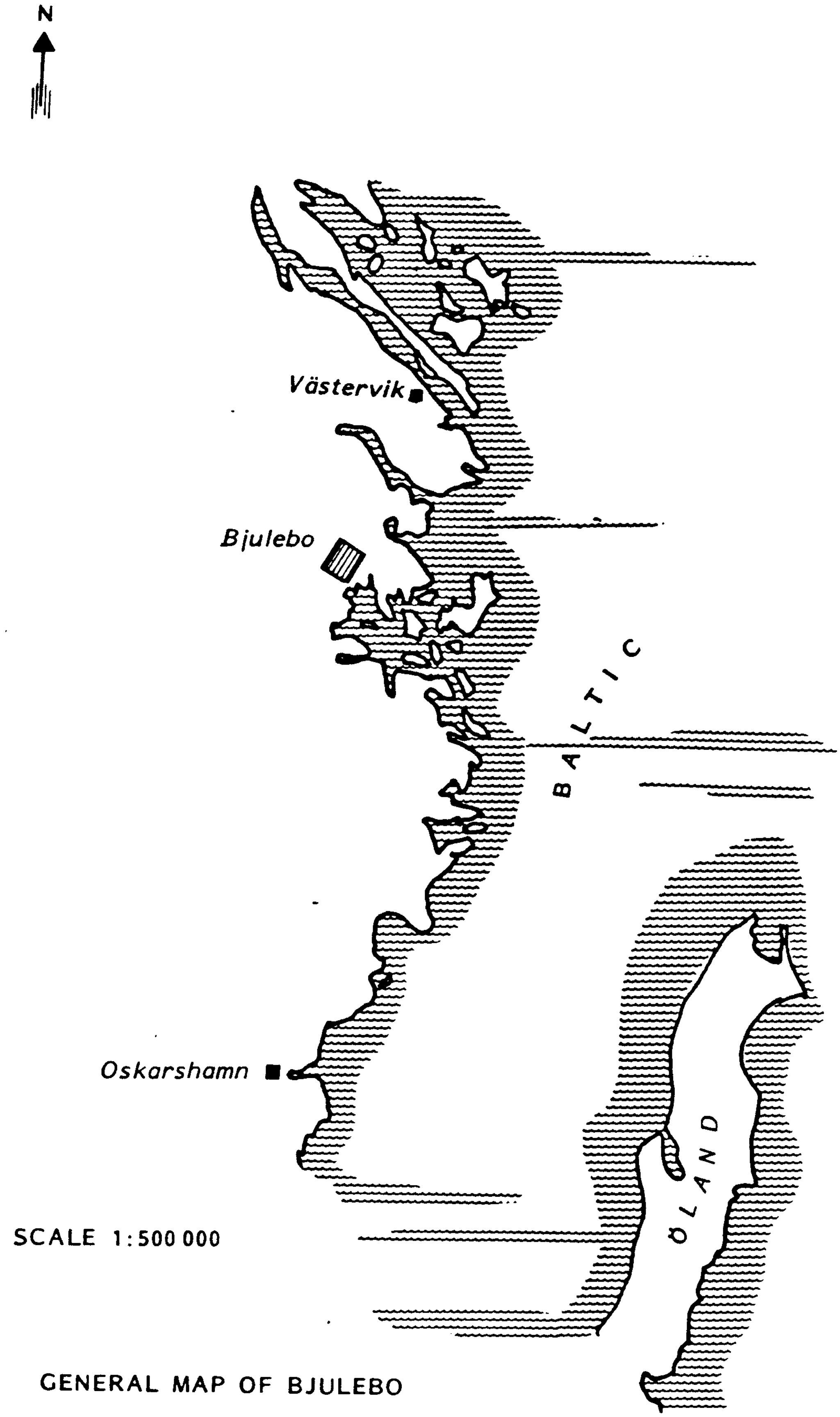
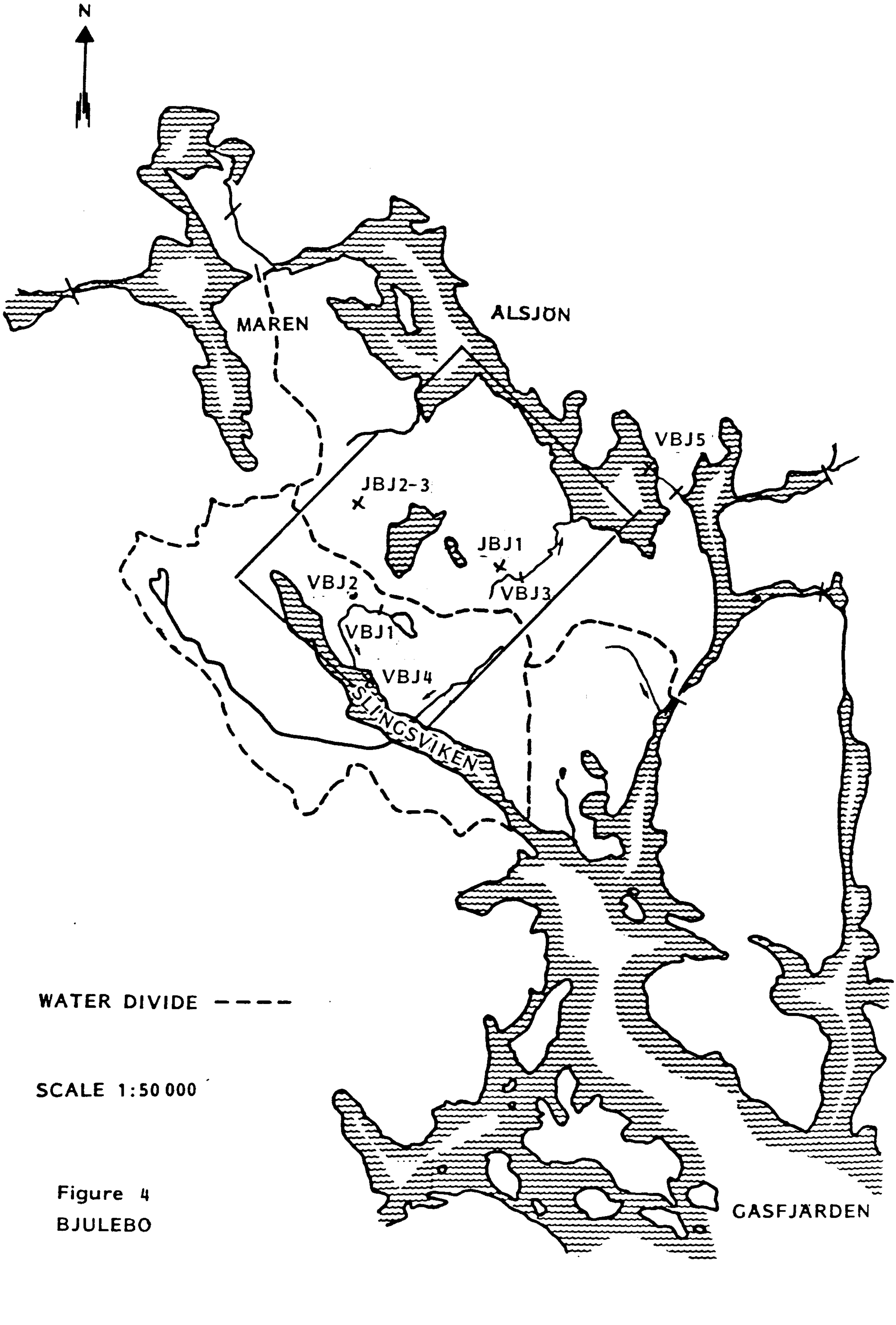



Figure 3 GENERAL MAP OF BJULEBO

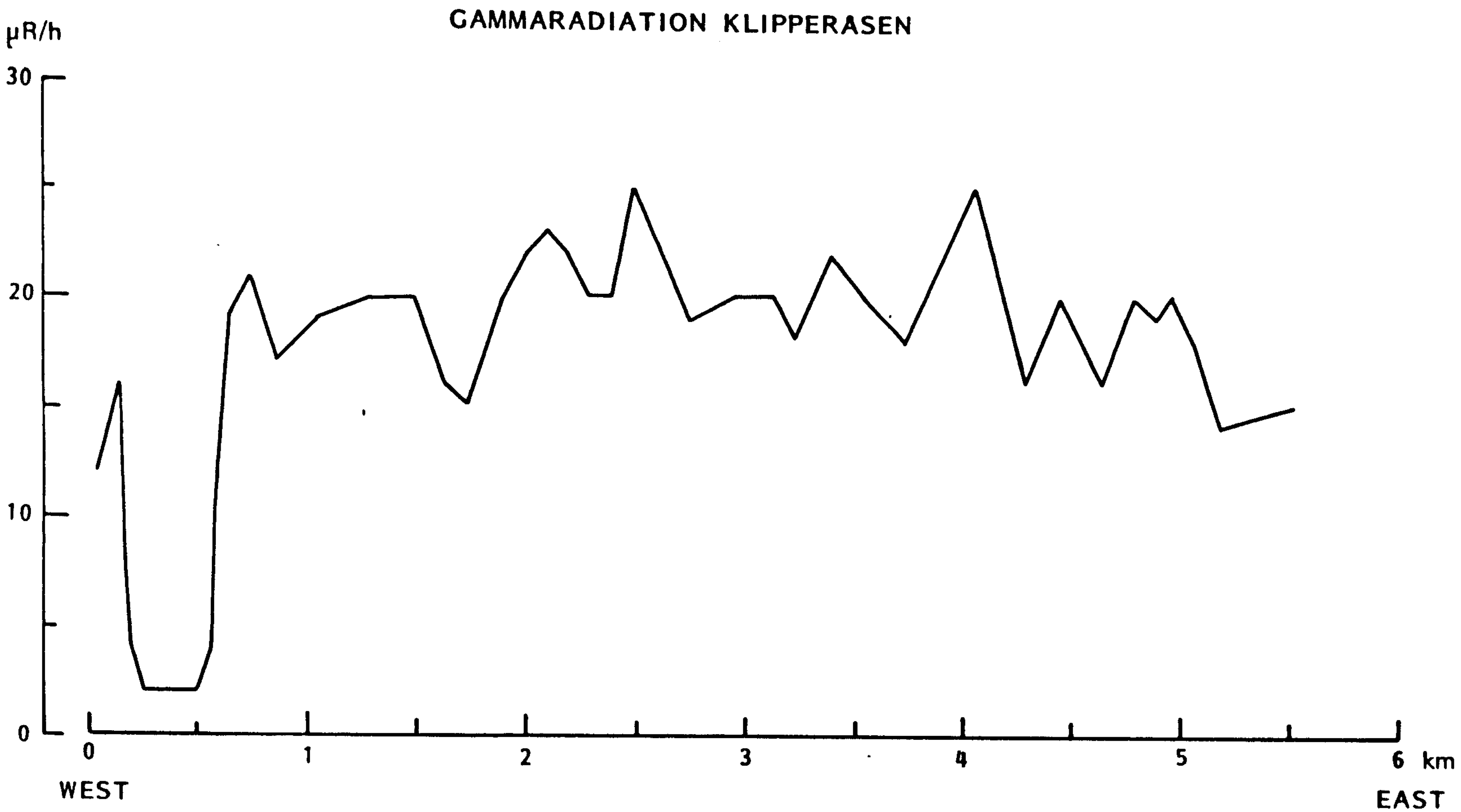



WATER DIVIDE - - - -

SCALE 1:50 000

Figure 4
BJULEBO

Figure 5


GAMMARADIATION KLIPPERASEN
µR/h
30
20
10
0
0
1
2
3
4
5
6 km
WEST
EAST

GAMMARADIATION KLIPPERASEN

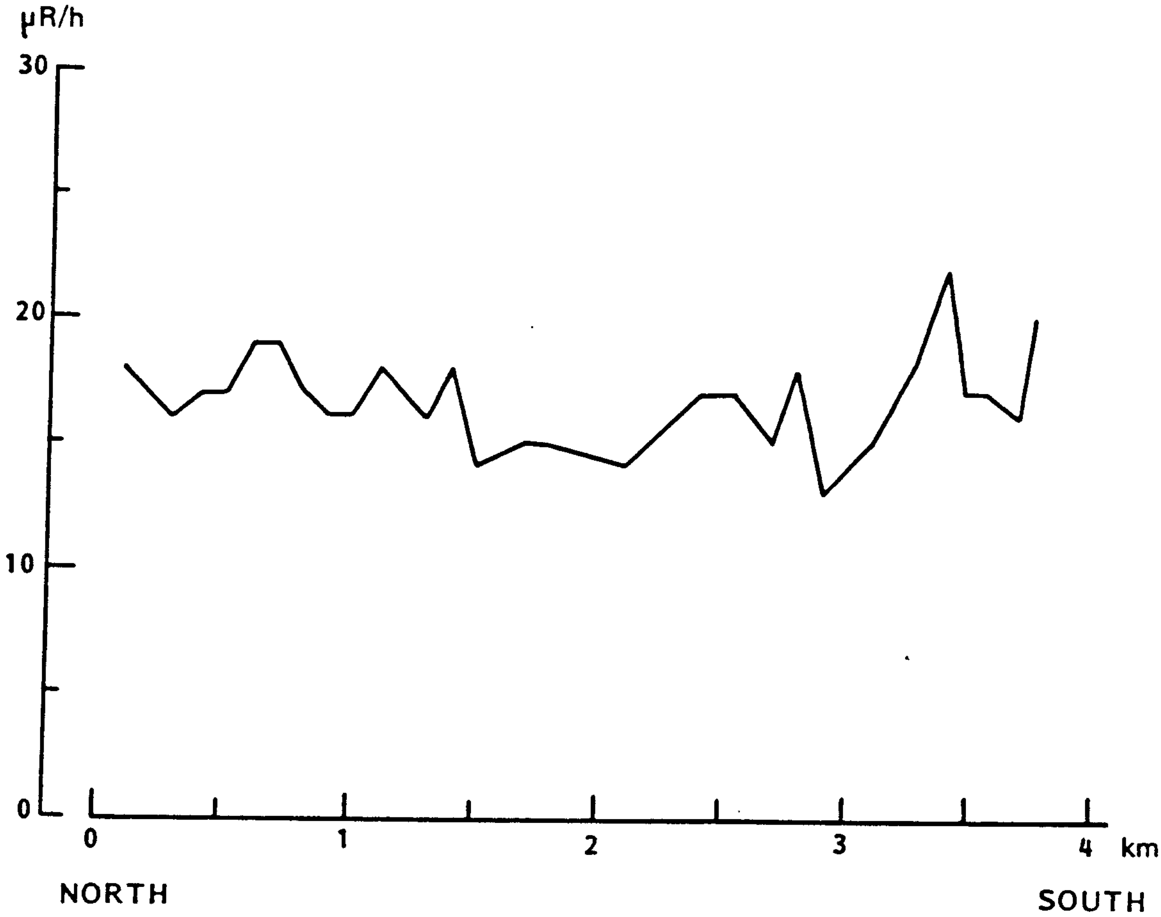



Figure 6

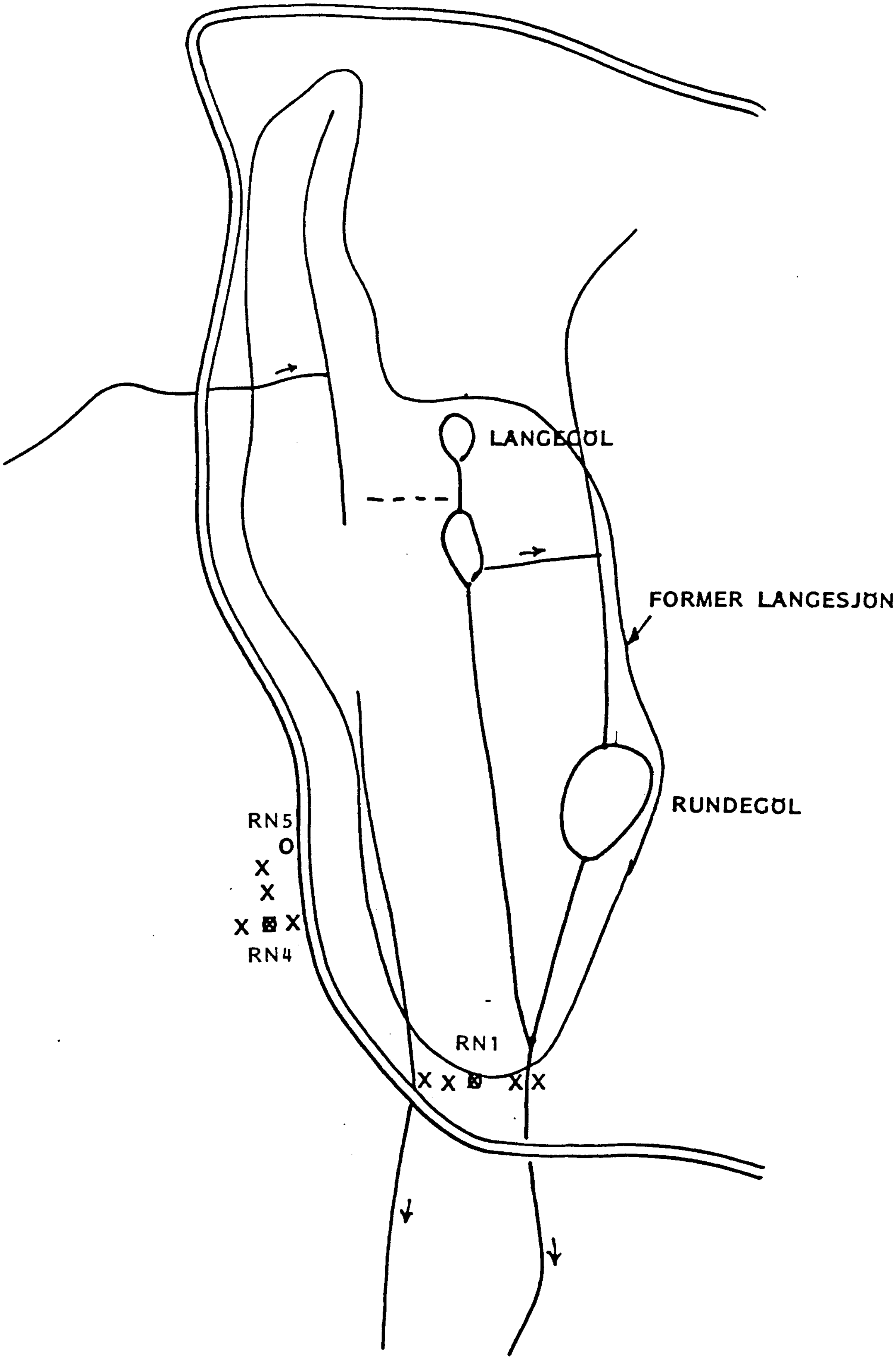



Figure 7 RADON SAMPLING SITES, KLIPPERASEN WEST
SCALE 1:7500 X:Rn exhalation O: Rn in soil

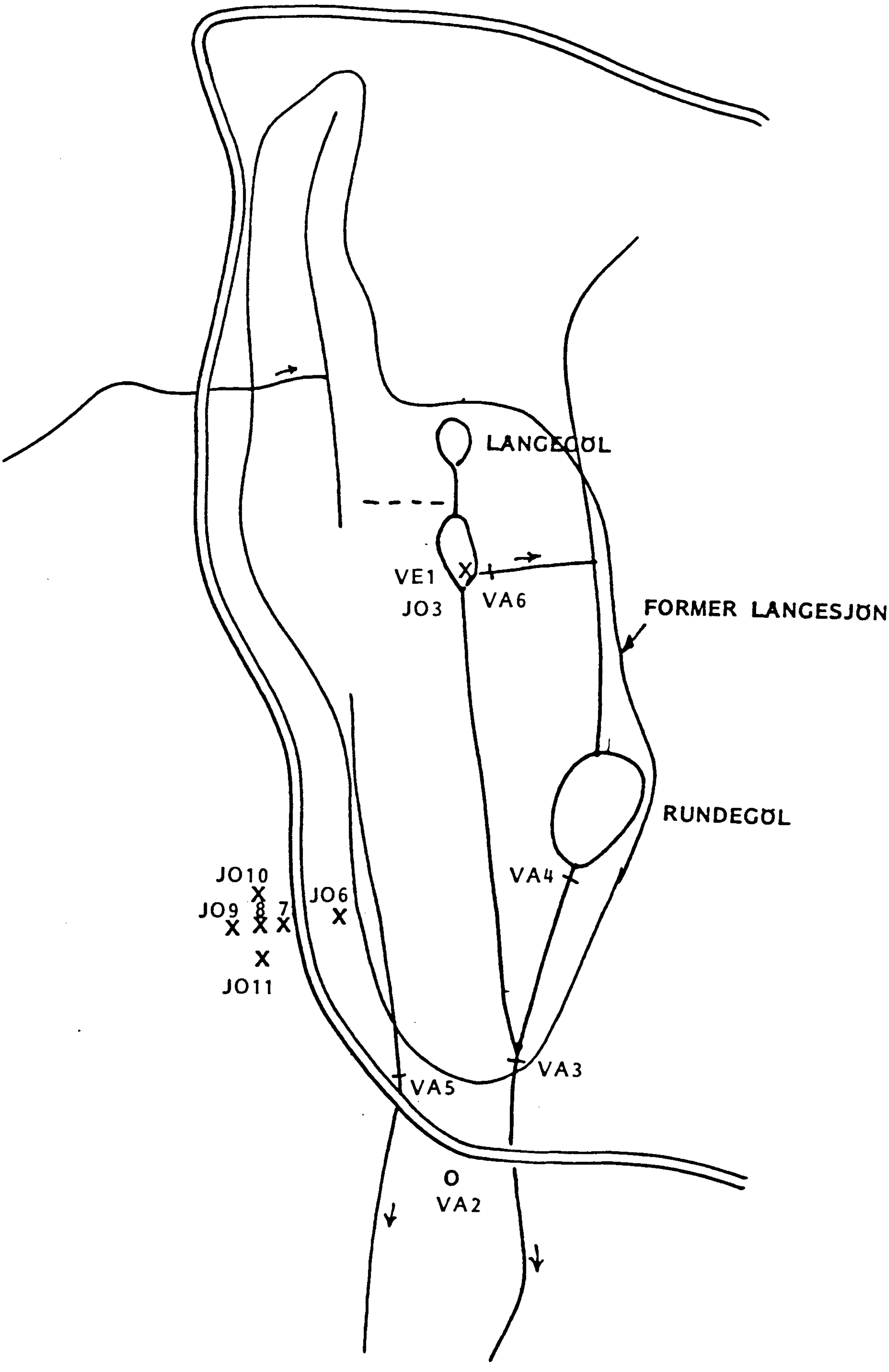



Figure 8 SAMPLING SITES, KLIPPERASEN WEST

# MEASUREMENT OF RADON AT KLIPPERÅSEN

Curt Stenquist

## SUMMARY

Within a SKB project, measurements of Radon from the soil have been carried out at KLIPPERÅSEN, Småland.

The results, when referred to the adopted classification of Radon concentration in the ground, indicate that the level is within the range from "Low" to "Normal" values.

## 1 INTRODUCTION

Within the SKB project, Concentration and distribution of natural radionuclides at Klipperåsen and Bjulebo, Sweden, a limited measurement of Radon concentration and Radon exhalation from the soil have been made respectively.

The measurements were performed september 26 - 28, 1984.

The measuring points were chosen specifically, so that the crack zones and diabase sweeps within the west part of the area, were encircled 1). During the measuring process, the air pressure, wind speed, temperature and relative humidity were noted. These parameters have special significance for Radon exhalation.

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1) the points in detail are shown in the report

## 2 MEASUREMENT AND RESULT

For the measurements, a modified Radon meter of STUDSVIK RM-1 type was used. The concept of measuring is based on a electrostatical collection of Radon daughters on an aluminium foil. In the first test the meter was placed in the ground at a dept of about 0.7 meter to register the Radon concentration. In the second test the meter was placed inside a tight bucket, which was then pressed firmly against the ground surface. By an alpha detector, the electrostatical foil inside the meter, mesured the radiation consisting of RaA (Po-218) at a steady rate (15 minutes) and by that, the total Radon quantity could be determined. The measurements were repeated in intervals during a period of one to two hours.

During the testing period (September 25 - 28) no heavy variations of the air pressure occured (SMHI).

The results are shown, in the Table 1 below.

## 3 CONCLUSIONS

As mentioned in the introduction there are several parameters which govern the Radon concentration in the ground. Besides the weather conditions, one must be aware of the measuring depth, ground permeability and ground water proportion. These are of a great importance to the Radon concentration.

The suitable measuring period, if one is not sure about the condition of the ground, is September to November. Preliminary limit values for measuring depth is stated to 0.5 - 1 meter.

Regarding the different types of soil, the following classification can be made for Radon concentration in the ground ($Bq/m^3$ on a depth of 0.5 meter)

| | Gravel | Sand | Silt | Clay |
|---|---|---|---|---|
| High | > 25000 | > 25000 | (<10000) | > 50000 |
| Normal | 6000-25000 | 6000-25000 | (<10000) | 15000-50000 |
| Low | < 6000 | <6000 | (<10000) | 15000 |

Accomplished measurements at KLIPPERÅSEN, compared with the table values above, indicate concentration from "Low" to "Normal" value. It is especially in the point 2 and 3 that one finds the higher values.

When comparing the exhalation rate of Radon to the measuring concentration in soil, the accordance is good. Topical value is in the magnitude of 10 $mBq/m^2 \times s$.

Table 1 Conclusion of radon measurements at KLIPPERÅSEN

| Measuring point | Radon in ground ($Bq/m^3$) | Radon removal ($mBq/m^2.s$) | Relative humidity (%) | Air pressure (mbar) | Temperature ($^oC$) |
|---|---|---|---|---|---|
| 1 | 1000-5000 | 2 | 75 | 1006 | 10 |
| 50 m east | | 1 | 78 | 1006 | 10 |
| 50 m west | | 3 | 80 | 1006 | 10 |
| 100 m east | | 0.3 | 85 | 1006 | 10 |
| 100 m west | | 4 | 76 | 1006 | 12 |
| 2 | 10000-25000 | | 75 | 1006 | 11 |
| 3 | 3000-10000 | | 75 | 1006 | 12 |
| 4 | 1000-5000 | 4 | 78 | 1006 | 12 |
| 50 m east | | 6 | 78 | 1014 | 8 |
| 50 m west | | 1 | 80 | 1014 | 8 |
| 100 m north | | 0.6 | 79 | 1014 | 8 |
| 100 m north | | 1 | 83 | 1014 | 7 |
| 5 | 1000-5000 | | 77 | 1010 | 9 |

Windspeed < 4 m/s

# List of Technical Reports

*1977–78*
TR 121
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Summaries. Stockholm, May 1979.

*1979*
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*1985*
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Stockholm June 1985.

TR 85–02
**The Taavinunnanen gabbro massif.**
**A compilation of results from geological, geophysical and hydrogeological investigations.**
Bengt Gentzschein
Eva-Lena Tullborg
Swedish Geological Company
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**Porosities and diffusivities of some non-sorbing species in crystalline rocks.**
Kristina Skagius
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Department of Chemical Engineering
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TR 85–04
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David B. Curtis
New Mexico, USA, March 1985

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Kristina Skagius
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TR 85-06
**Mechanical properties of granitic rocks from Gideå, Sweden**
Christer Ljunggren
Ove Stephansson
Ove Alm
Hossein Hakami
Ulf Mattila
Div of Rock Mechanics
University of Luleå
Luleå, Sweden, October 1985

TR 85-07
**Complex forming properties of natural occurring fulvic acids**
**Part 1. Complexes with cadmium, copper and calcium**
Jacob A. Marinsky,
A. Mathuthu,
M. Bicking and
J. Ephraim
State University of New York at Buffalo
Buffalo, New York 14214,
July 1985

TR 85-08
**In situ one-year burial experiments with simulated nuclear waste glasses**
Larry L Hench, Derek Spilman and T Buonaquisti
College of Engineering, Univ. of Florida, Gainesville, USA
Alexander Lodding
Chalmers Univ. of Technology, Gothenburg, Sweden
Lars Werme
SKB, Stockholm, Sweden