SKB

TECHNICAL REPORT

95-16

Temperature conditions in the SKB study sites

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TEMPERATURE CONDITIONS IN THE SKB STUDY SITES

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

Information on SKB technical reports from1977-1978 (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), 1985 (TR 85-20), 1986 (TR 86-31), 1987 (TR 87-33), 1988 (TR 88-32), 1989 (TR 89-40), 1990 (TR 90-46), 1991 (TR 91-64), 1992 (TR 92-46), 1993 (TR 93-34) and 1994 (TR 94-33) is available through SKB.

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

ABSTRACT (English)

This report is intended to serve as a basis for estimation of the range of ambient temperatures likely to be encountered in the final repository for spent fuel. In this report the borehole measurements from the SKB study sites, total 11 sites including Äspö Hard Rock Laboratory, are presented.

It is reasonable to assume that the SKB study sites constitute a representative range of bedrock temperature conditions likely to be encountered at the repository site. This is because of the geographical spread of the study sites, as well as the spread in rock types. The temperature at 500 m depth below the ground levels varies between 5.5 to 14.5 °C between the various sites, while the temperature gradient varies between 9.5-15.5 °C/km. If also those granite areas of anomalous high radiogenic heat production are included the plausible range of temperature gradient might be extended up to say 18 °C/km.

ABSTRACT (Swedish)

Denna rapport redovisar borrhålsmätningar av temperaturer och beräknade temperaturgradienter i SKB:s typområden, inklusive Äspölaboratoriet. Totalt redovisas data från 11 områden. Syftet är att uppskatta vilka temperaturförhållanden som kan tänkas råda i berggrunden på en kanditatplats för ett djupförvar för använt kärnbränsle.

Typområdena är förmodligen representativa för de naturliga temperaturförhållanden som kan tänkas råda i berggrunden kring ett framtida djupförvar. Detta baseras på att SKB:s typområden är spridda över Sverige och representerar skilda bergarter.

Medeltemperaturen på 500 m djup varierar mellan 5,5 till 14,5 °C mellan de olika typområdena medan temperaturgradienten varierar mellan 9,5 till 15,5 °C/km. Temperaturgradienten kan möjligen vara något högre, kanske upp till 18 °C/km, om även granitområden beaktas där värmeproduktionen i berggrunden är hög på grund av högre halter av radioaktiva ämnen än normalt.

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1 INTRODUCTION

This report is intended to serve as a basis for estimating the range of ambient temperatures likely to be encountered in the final repository for spent fuel. To do so borehole temperature measurements from the SKB study sites are presented along with estimated temperature gradients. In order to discuss the representativity of the study sites for assessing the general range of temperatures found in the crystalline bedrock of Sweden some other temperature gradients from other areas of Sweden are also presented.

2 TEMPERATURE GRADIENTS

The temperature in a water filled borehole will in most cases represent the temperature of the surrounding bedrock. However, if groundwater flow occurs along the borehole heat will be transported along the borehole and the measured temperature will not be representative of the depth at which it was measured. Generally, if water is transported upwards the measured temperature will be higher than the rock temperature and if water is flowing downward it will be lower. Irrespective of if the flow is directed upward or downward such a flow results in a decrease in the thermal gradient.

Other changes in the thermal gradients are caused by seasonal variations of surface temperatures or changes in the thermal conductivity of the rock. In both cases the borehole measurements represent the thermal conditions in the surrounding rock. According to Landström et al., (1979) seasonal variations in the surface temperatures reach a depth in the crystalline bedrock of about 50 m, while surface temperature variations taking place over hundreds of years reach a depth of 150 m. Below this depth the bedrock temperatures are only influenced by surface temperature variations taking place over thousands of years or longer. For example, the bedrock temperatures are influenced (reduced) by the last glaciation down to a depth of approximately 2500 m.

The peak temperatures in the bedrock surrounding the canisters is reached after less than 100 years from repository closure (Thunvik and Braester, 1991). Referring to the discussion above, the 500 m repository depth implies that no changes in surface temperatures will affect the bedrock temperatures under such short time period.

This report does not include thermal conductivity data. Such data are available from some of the SKB study sites, notably Äspö (Sundberg, 1991) and Fjällveden, Gideå, Kamlunge, Svartboberget (Ahlbom and Karawacki, 1983). A general account of thermal properties of Swedish crystalline rocks is presented by Sundberg (1988 and 1995).

3 TEMPERATURE CONDITIONS IN THE STUDY SITES

3.1 General

The SKB program for radioactive waste disposal includes characterization of study sites. Extensive site characterization have been carried out on eight such sites for assessing their potential as repository sites for spent nuclear fuel. The sites are located in the Precambrian crystalline basement and are distributed from the north to the south of Sweden. The locations of the study sites are shown in Figure 1.

Within the site characterization program diamond drilled core boreholes were drilled down to depths of 600-1000 meters. The boreholes were logged with different geophysical tools, including thermistors, and the hydraulic conductivity of the bedrock were tested in 2-25 m sections. A detailed discussion of the methods used is presented in Ahlbom, Carlsson and Olsson (1983).

Borehole water temperatures are measured with a thermistor with an relative accuracy of 0.01 C. Distance between the measured points in most boreholes were 5 m. To avoid disturbance from the heating caused by the drilling activity the temperature surveys were made at a minimum of 2 weeks after drilling was completed and before any other downhole tools were run.

To determine the average temperature at a depth of 500 m below ground the temperature logs from a number of deep boreholes at each site have been plotted as a function of vertical depth below ground. When available, borehole deviation log data were used to obtain the vertical depth. In other cases the estimated plunge of the borehole has been used. For each site the depth below ground for all boreholes is given relative to a common datum given in Table 1.

For each borehole the temperature gradient has been estimated through least squares fitting of a straight line to a 100 m long segment of the temperature curve centered on the measurement point. This procedure will effectively remove small scale variations in the temperature gradient due to flow in the borehole and limited measurement accuracy.

As is evidenced from the data presented below the greatest uncertainty in the data is due to groundwater flow within the boreholes. Boreholes where temperature logs are significantly disturbed by groundwater flow have been removed from the data sets presented below. Still, there is a spread in temperature and gradient values which varies from site to site. To some extent the variability represents the heterogeneity of the flow system at a site as new flow paths are opened by the boreholes. It should be recognized that sites with few boreholes most likely have the same uncertainty in temperature and gradient as sites with many boreholes even if data appear to indicate otherwise.

For each study site data is presented in two plots where one presents the temperature as a function of depth below ground and the other presents the temperature gradient as a function of depth. Based on these plots the average temperature and temperature gradient at a depth of 500 m have been estimated. It should be noted that the temperature gradient data from the first few hundred meters below ground are often disturbed by groundwater flow in the boreholes.

The values presented in this report deviate somewhat from data presented in earlier reports summarizing the results from the study sites. The discrepancy in temperature at 500 m depth depends on the different number of boreholes included in the analysis and the lack of a precise definition of the depth at which a representative temperature was estimated. In this report an attempt has been made to estimate the temperature gradient at a depth of 500 m. Earlier reports often give temperature gradients based on the entire temperature curve leading to a value representative for 200-700 m below ground.

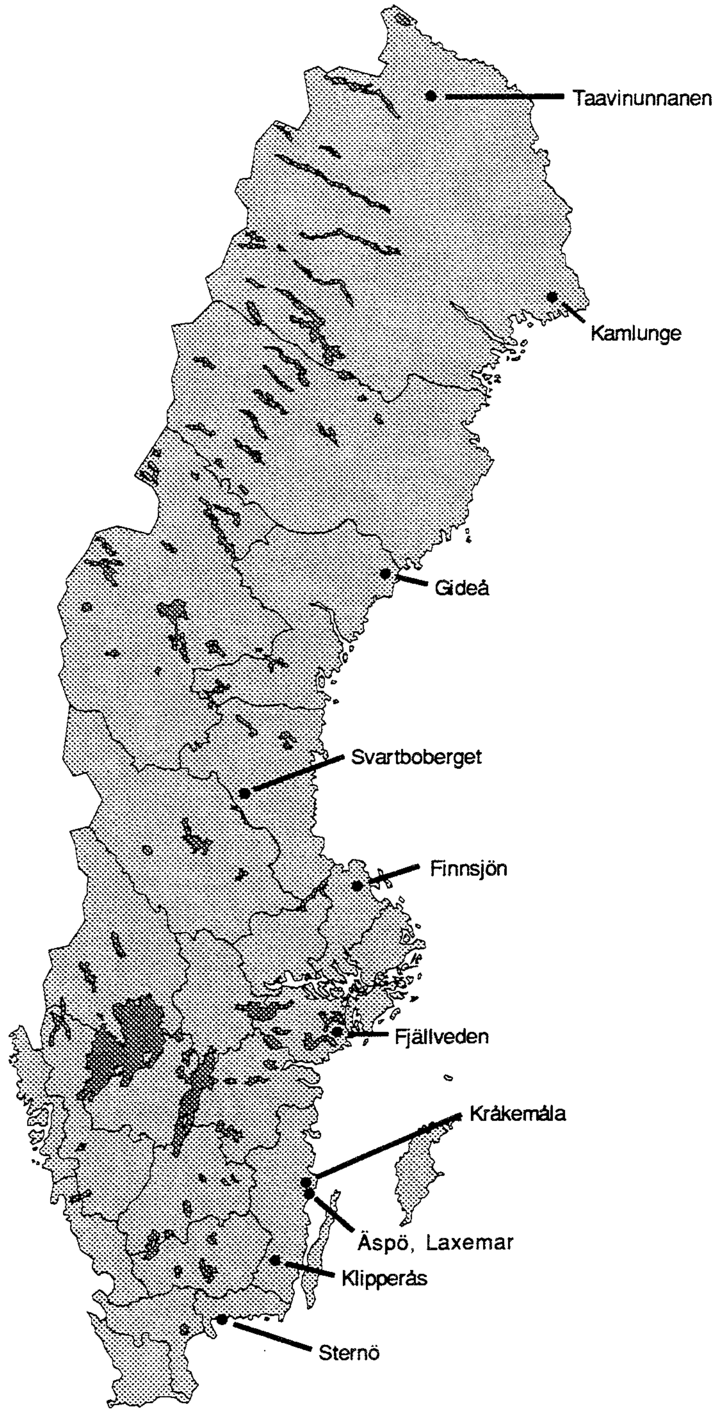

Figure 1. Location of the SKB study sites.

3.2 Sternö

The bedrock at the upper part of the site consists of gneiss (the Coastal Gneiss). At several hundred meters depth the main rock type is changed to Karlshamn granite. In borehole KKA01 (which is the only borehole where temperatures has been measured) this occurs at 585 m depth. Unfortunately, temperature measurements are only available down to 500 m depth. An possible explanation for the gradual change in the temperature gradient, Figure 2, might be a change in bulk thermal conductivity caused by an increasing amount of granitic inlyers. The mean temperature at 500 m depth is 13.4 °C, and the mean temperature gradient is estimated to 12.5 °C/km.

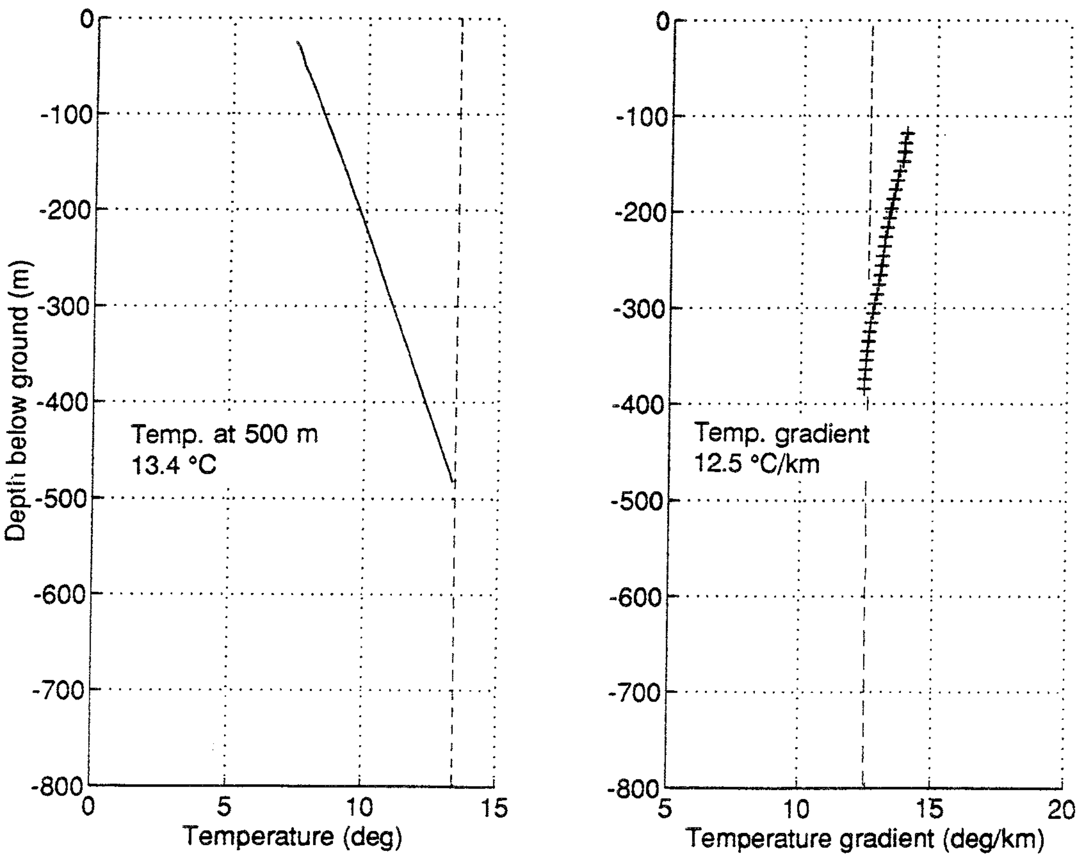

Figure 2. Temperatures (left) and temperature gradients (right) in the borehole KKA01 at Sternö study site.

3.3 Klipperås

This site is dominated by reddish granite, the so-called Småland granite. In addition, there are some minor occurrences of volcanic rock, as well as dykes of doleritic, aplitic and porphyritic compositions. Figure 3 displays temperature measurements from borehole KKL01. (This was the only borehole where digital data was available at the time of reporting. A visual check of data from the other boreholes indicate that KKL01 gives representative values.) The mean temperature at 500 m depth is 13.4 °C, and the mean temperature gradient is estimated to 13.7 °C/km.

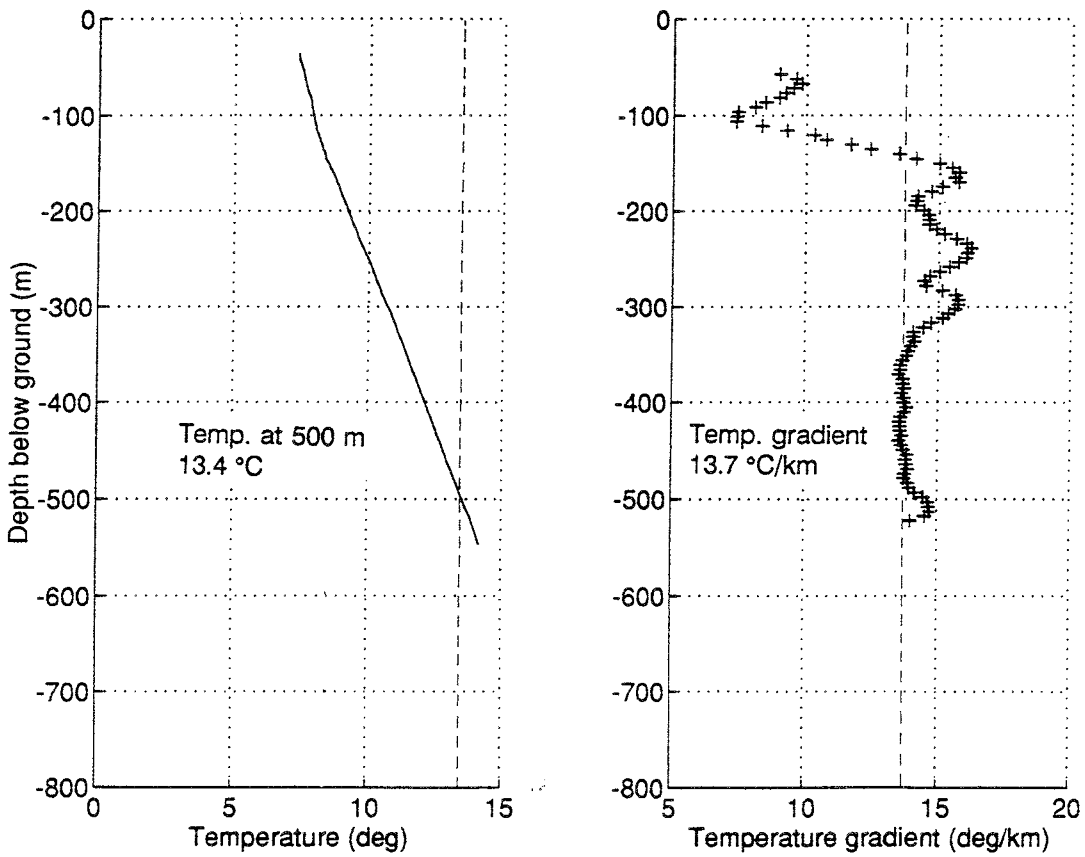

Figure 3. Temperatures (left) and temperature gradients (right) in boreholes at the Klipperås study site.

3.4 Kråkemåla

This site consists of a post-tectonic "young" granite, the Götemar granite. The granite has an anomalous high radiogenic heat production. Three boreholes have been drilled and temperature logged. However, due to strong disturbance in the temperatures by groundwater flow only results from two boreholes are displayed in Figure 4. The mean temperature at 500 m depth is 14.4 °C, and the mean temperature gradient is estimated to 13.7 °C/km.

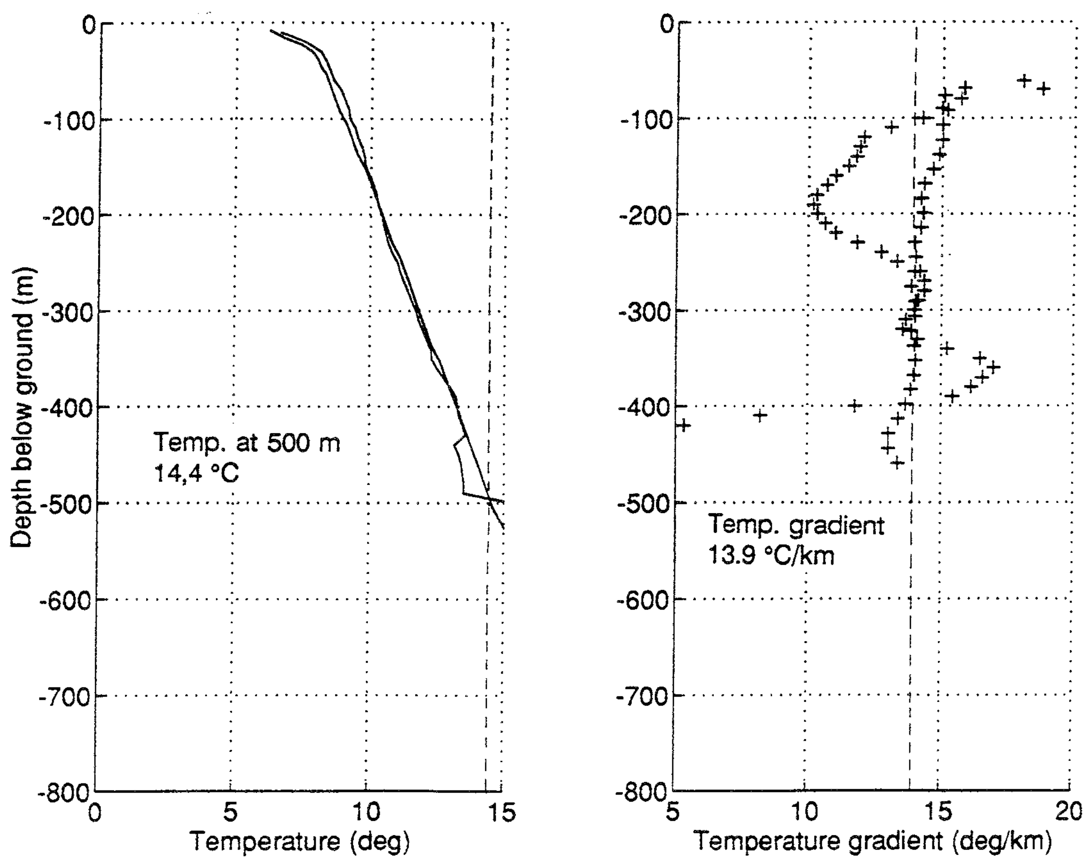

Figure 4. Temperatures (left) and temperature gradients (right) in boreholes at the Kråkemåla study site.

3.5 Fjällveden

Dominating rock type is veined gneiss. Vertical dykes of granite gneiss also occur to some minor extent. Figure 5 shows that the mean temperature at 500 m depth is 13.2 °C. The mean temperature gradient is estimated to 15.0 °C/km. There is a slight decrease in temperature gradient with depth.

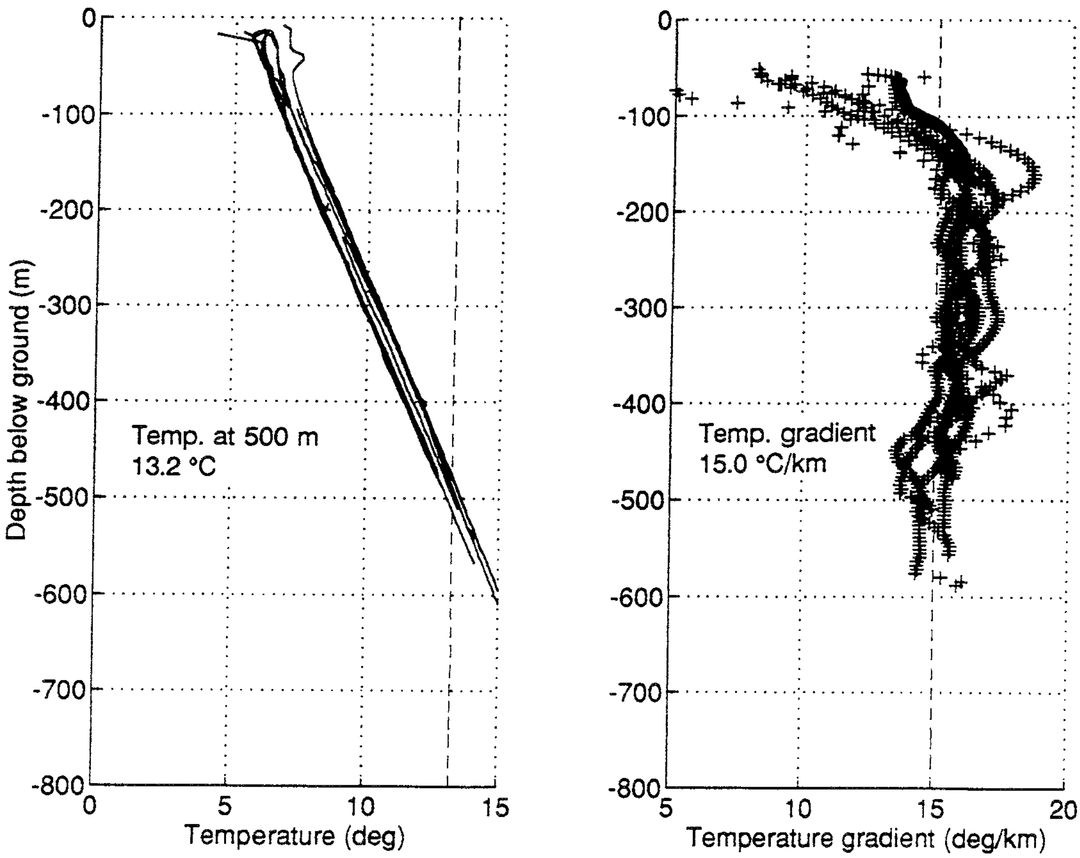

Figure 5. Temperatures (left) and temperature gradients (right) in boreholes at the Fjällveden study site.

3.6 Finnsjön

The bedrock at the Finnsjön study site consists of granodiorite. In spite of a large number of boreholes there are only temperature logs from 3 deep boreholes. The mean temperature at 500 m depth below ground is 11.6 °C/km, Figure 6. The mean temperature gradient is estimated to 12.7 °C/km.

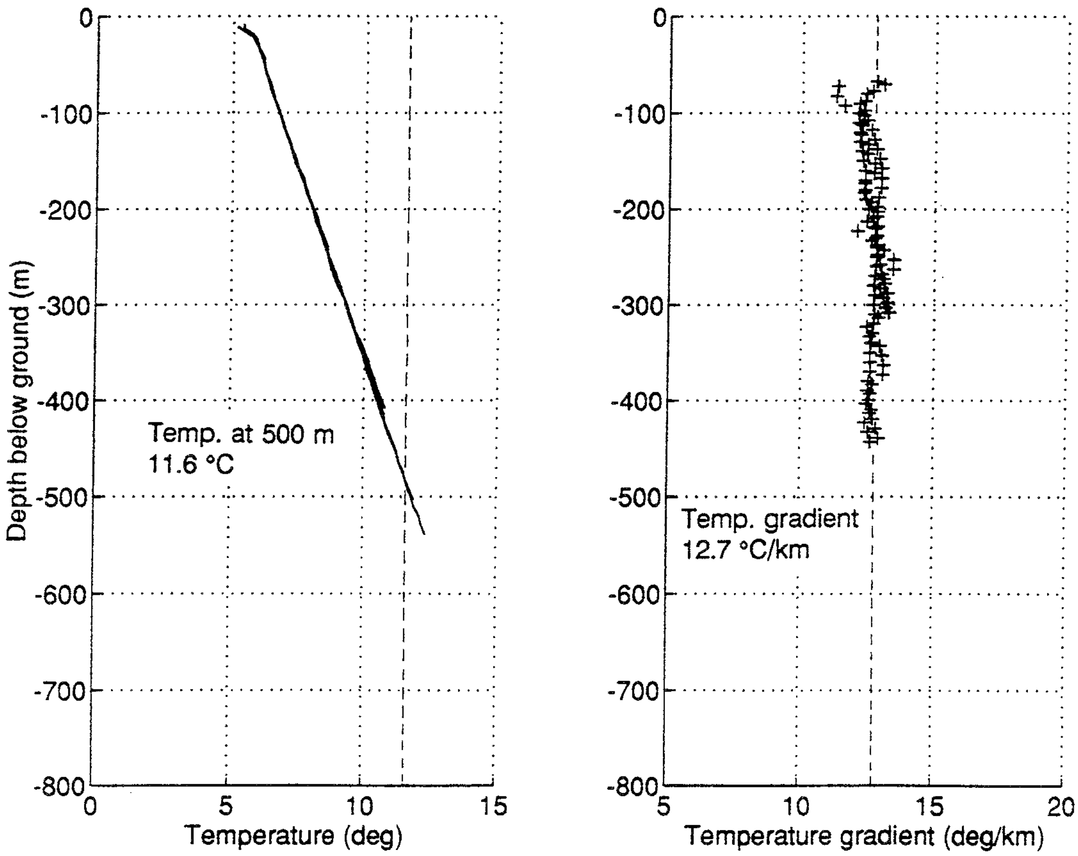

Figure 6. Temperatures (left) and temperature gradients (right) in boreholes at the Finnsjön study site.

3.7 Svartboberget

Migmatitic gneiss dominates the bedrock at Svartboberget. The mean temperature at 500 m depth is 10.0 °C, and the mean temperature gradient is estimated to 13.2 °C/km, Figure 7. The data from this site is disturbed by groundwater flow in the boreholes.

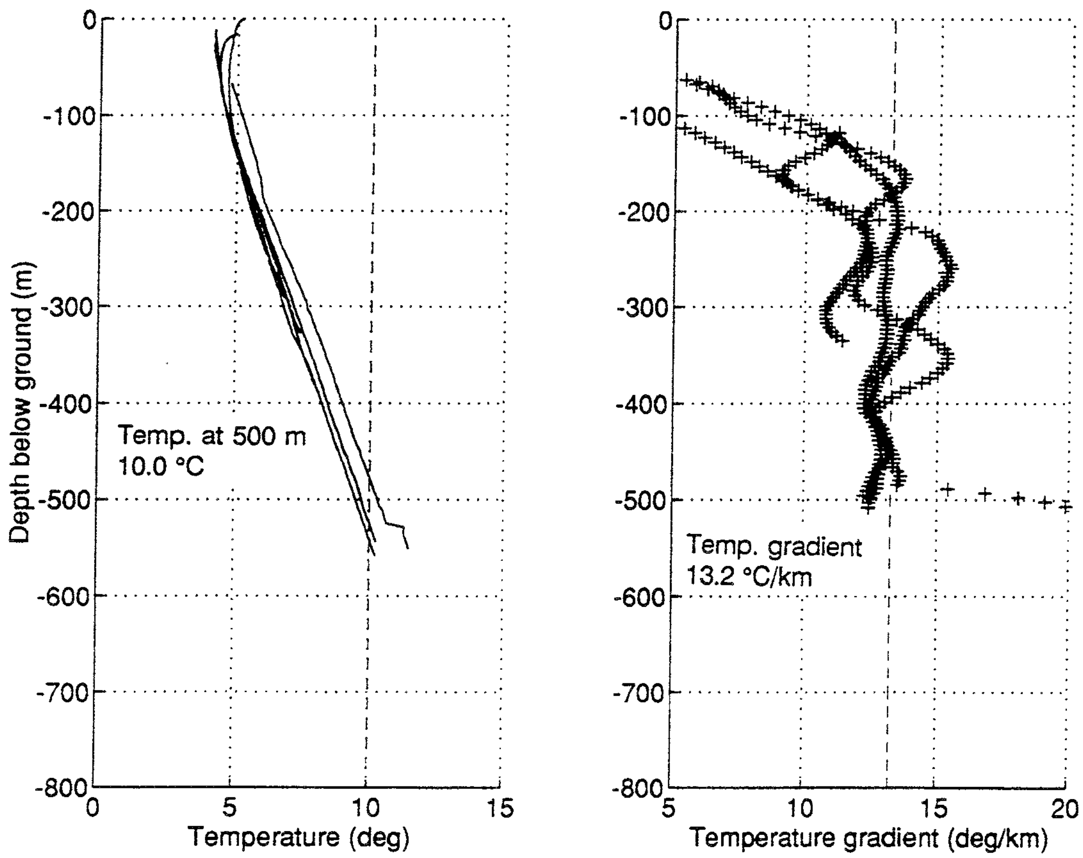

Figure 7. Temperatures (left) and temperature gradients (right) in boreholes at the Svartboberget study site.

3.8 Gideå

Dominating rock type is veined gneiss. Horizontal dykes of granite gneiss also occur to some minor extent. Figure 8 shows that the mean temperature at 500 m depth is 10.9 °C. The mean temperature gradient is estimated to 15.5 °C/km.

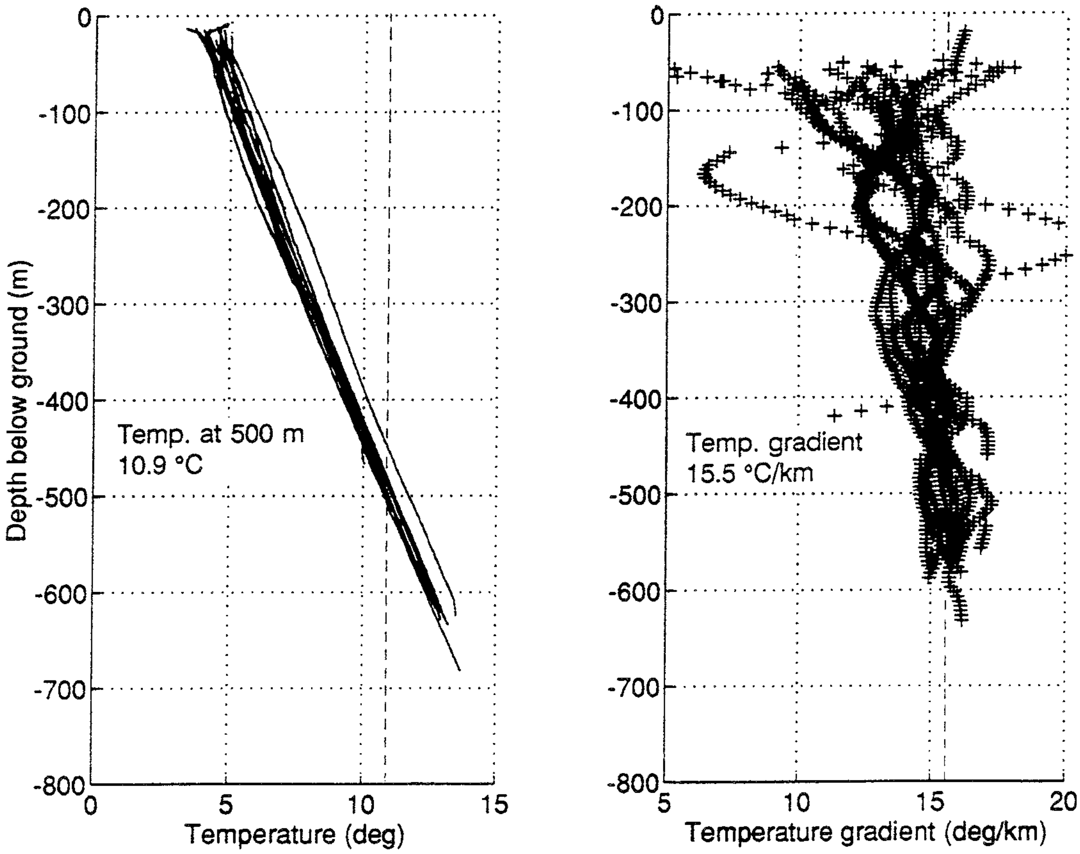

Figure 8. Temperatures (left) and temperature gradients (right) in boreholes at the Gideå study site.

3.9 Kamlunge

Kamlunge study site consists of several rock types, including high heat conducting quartzite to low heat conducting greenstone. The dominating rock types are however granite and gneiss. Kamlunge constitutes a plateau elevated 100 m above the surrounding valleys. The mean temperature at 500 m depth is 8.7 °C. Estimated mean temperature gradient is to 11.6 °C/km, Figure 9. The data is somewhat disturbed by groundwater flow in the boreholes. The temperature gradient seems to increase slightly with depth.

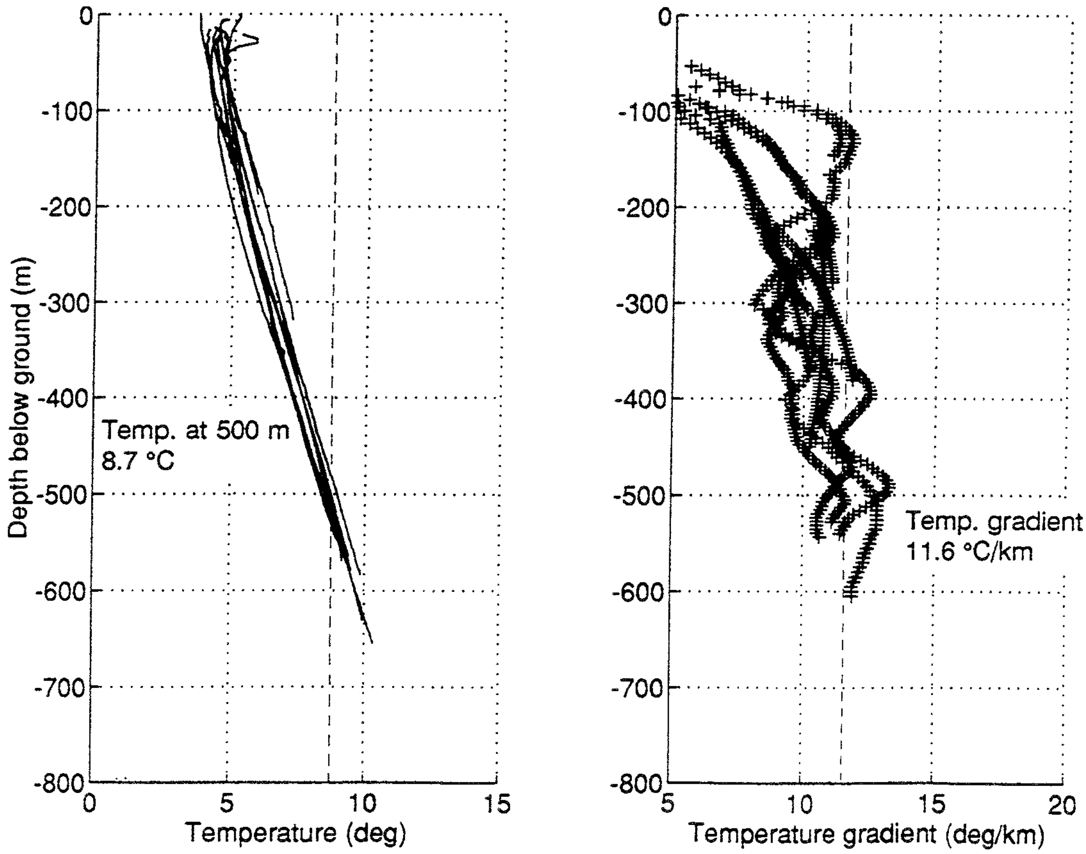

Figure 9. Temperatures (left) and temperature gradients (right) in boreholes at the Kamlunge study site.

3.10 Taavinunnanen

Gabbro is the dominating rock type at Taavinunnanen. To some minor extent also granite dykes occurs. Only one borehole exist at this site. The low temperatures measured in this borehole is somewhat surprising since the low thermal conductivity of gabbro should increase the thermal gradient with 30 % compared with granitic bedrock. To some extent the low thermal gradient might be caused by the lack of radiogenic heat production in gabbro. The mean temperature at 500 m depth is 5.5 °C. Estimated mean temperature gradient is 9.5 °C/km, Figure 10.

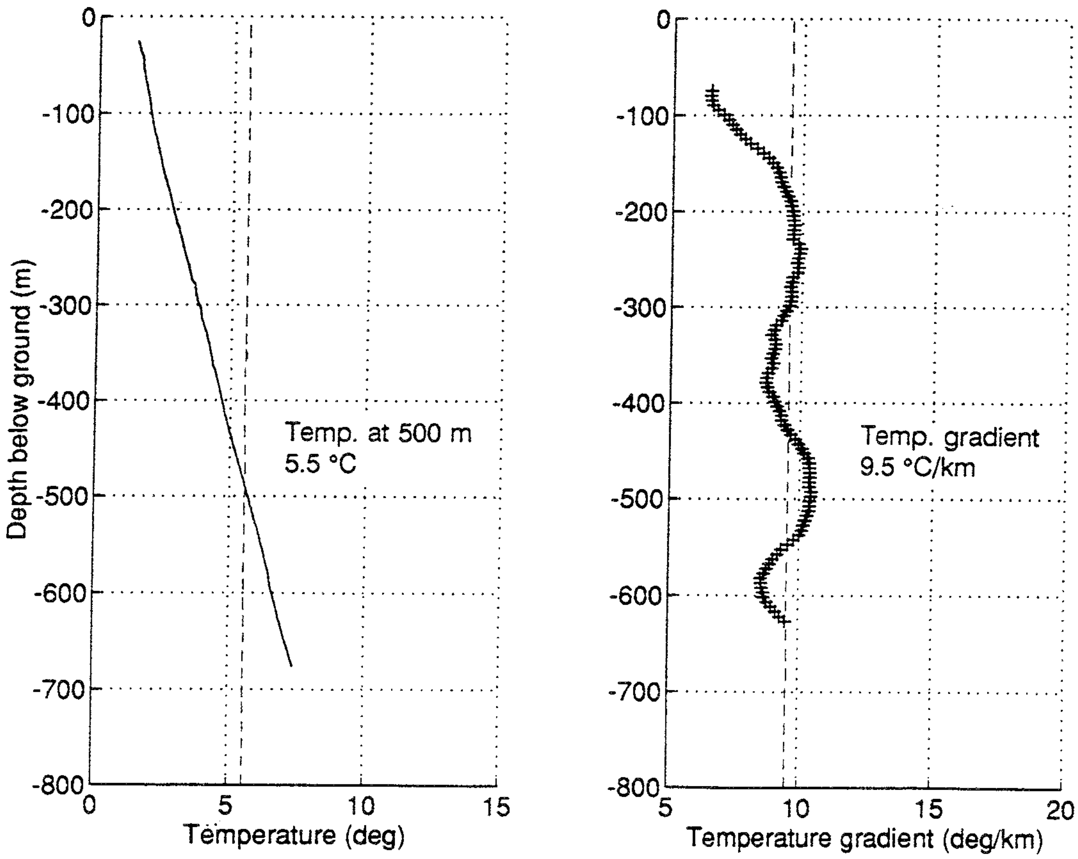

Figure 10. Temperatures (left) and temperature gradients (right) in the borehole KTA01 at the Taavinunnanen study site.

3.11 Äspö

Several rock types occurs at Äspö. Diorite and Småland granite are the dominating rock types, but fine-grained granite and greenstone also occurs. The mean temperature at 500 m depth is 14.6 °C. Estimated mean temperature gradient is 15.0 °C/km, Figure 11. The data is somewhat disturbed by groundwater flow in the boreholes. The temperature gradient seems to increase slightly with depth.

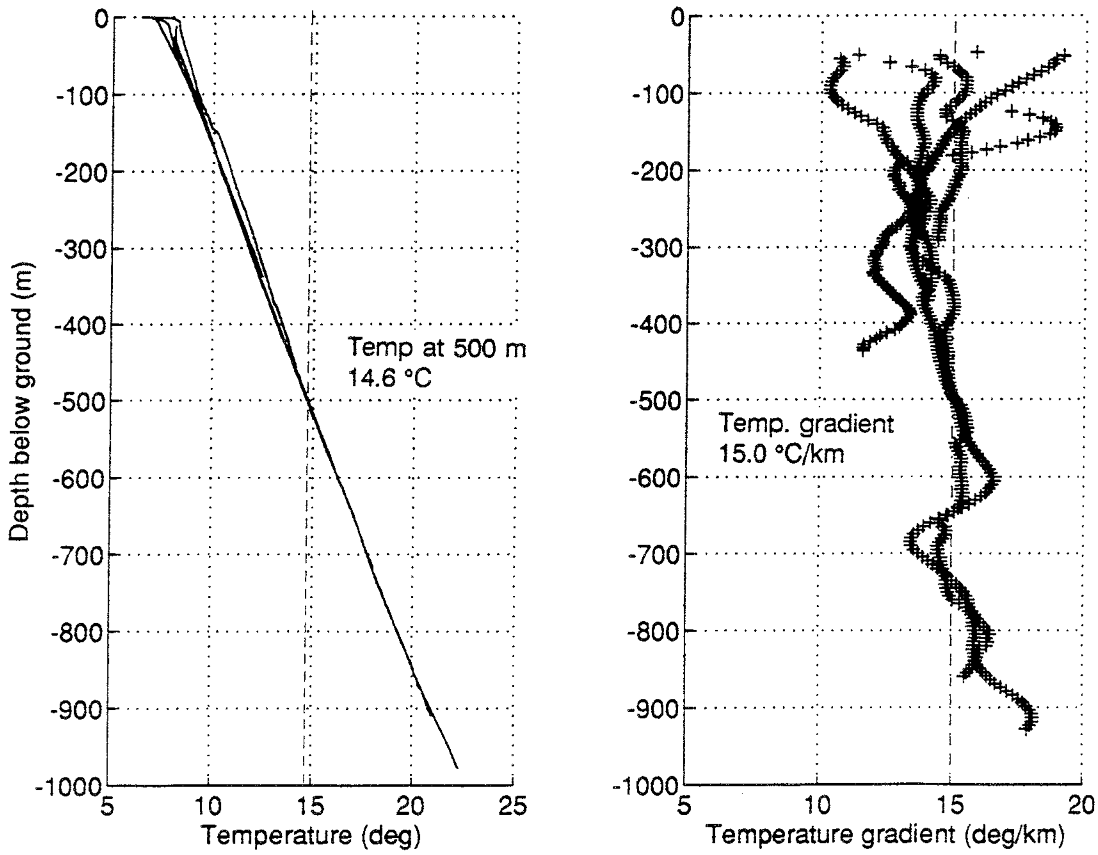

Figure 11. Temperatures (left) and temperature gradients (right) in boreholes at the Äspö island.

3.12 Laxemar

The bedrock consists of the same rock types as at Äspö. The mean temperature at 500 m depth is 14.4 °C. Estimated mean temperature gradient is 15.2 °C/km, Figure 12. A surprisingly high difference in temperature between the two boreholes is noted. No plausible explanation to this has been presented yet. Both measurements are considered to be correct.

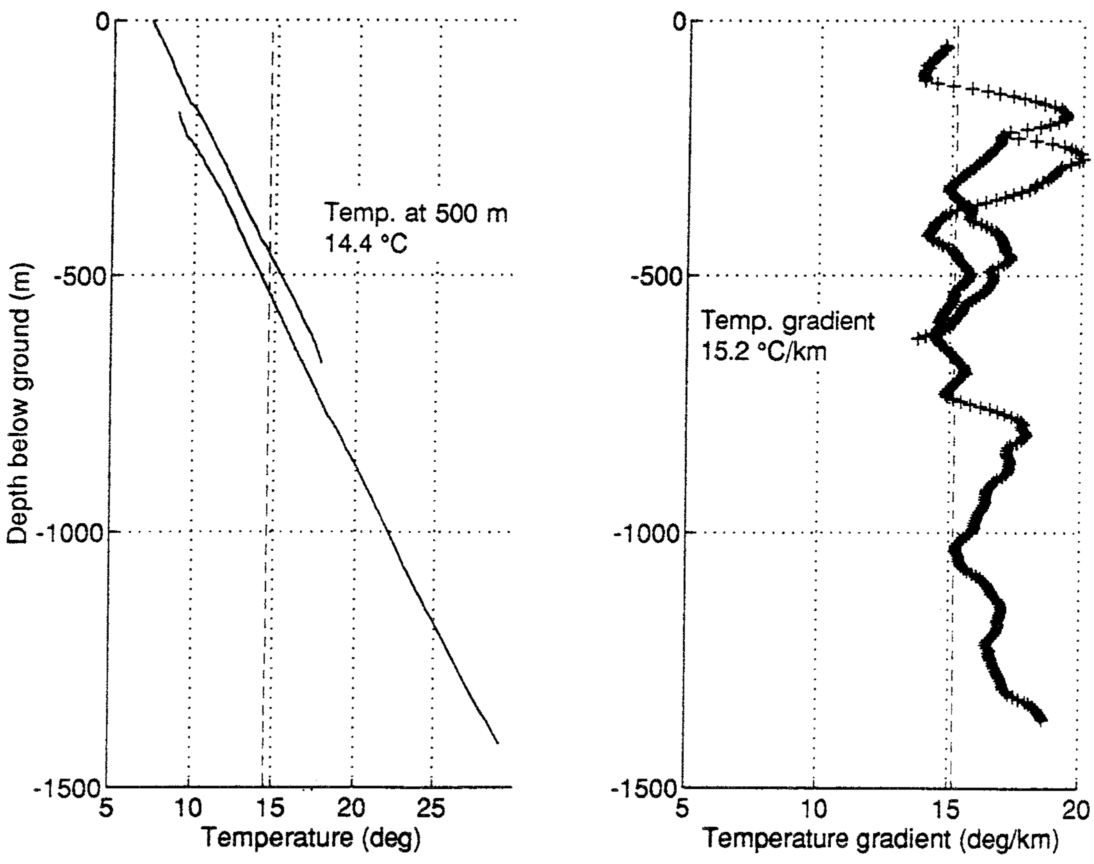

Figure 12. Temperatures (left) and temperature gradients (right) in boreholes at the Laxemar study site.

4 AREAS WITH ANOMALOUS TEMPERATURE GRADIENTS

During the seventies a considerable amount of prospecting activities were made for locating areas with anomalous high temperature gradients in order to utilize them for extraction of geothermal energy (Landström et al., 1979). The most apparent of these areas were those covered by thick formations of sedimentary rock. For example, the Ljunghusen 1 borehole located in Skåne and reaching a depth of 2300 m, show a temperature gradient of 35°C/km (Eriksson et al., 1979).

Crystalline Precambrian rocks constitute the main part of Sweden. The prospecting for "hot regions" in this part has been focused on rock massif, mainly granites, which display high radiogenic heat production. Figure 11 shows the location of the most promising of these granites. However, in spite of proven high radiogenic heat production no strong increase in temperature gradients were found in boreholes. For example, the Bohus granite showed a mean gradient of about 16°C/km, while a borehole in the central part of the Malingsbo granite showed a gradient of about 18 °C/km. It is interesting to note that the SKB study site Kråkemåla represent such a radiogenic granite. No anomalous high temperature gradient is however observed for this site.

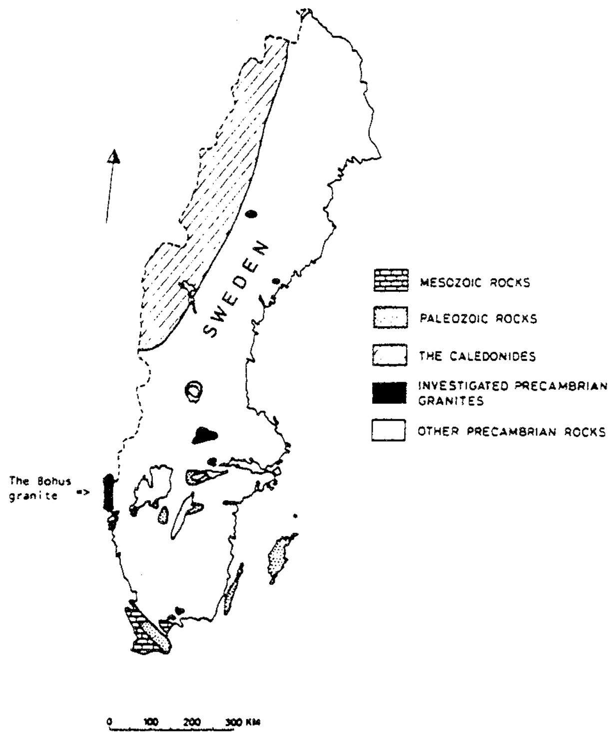

Figure 13. Location of areas with sedimentary rocks and some of the larger granite massifs displaying high radiogenic heat production (black on the map). From Eriksson et al., 1979.

5. CONCLUSIONS

The estimated borehole temperatures and borehole temperature gradients for each of the study sites are shown in Figure 14.

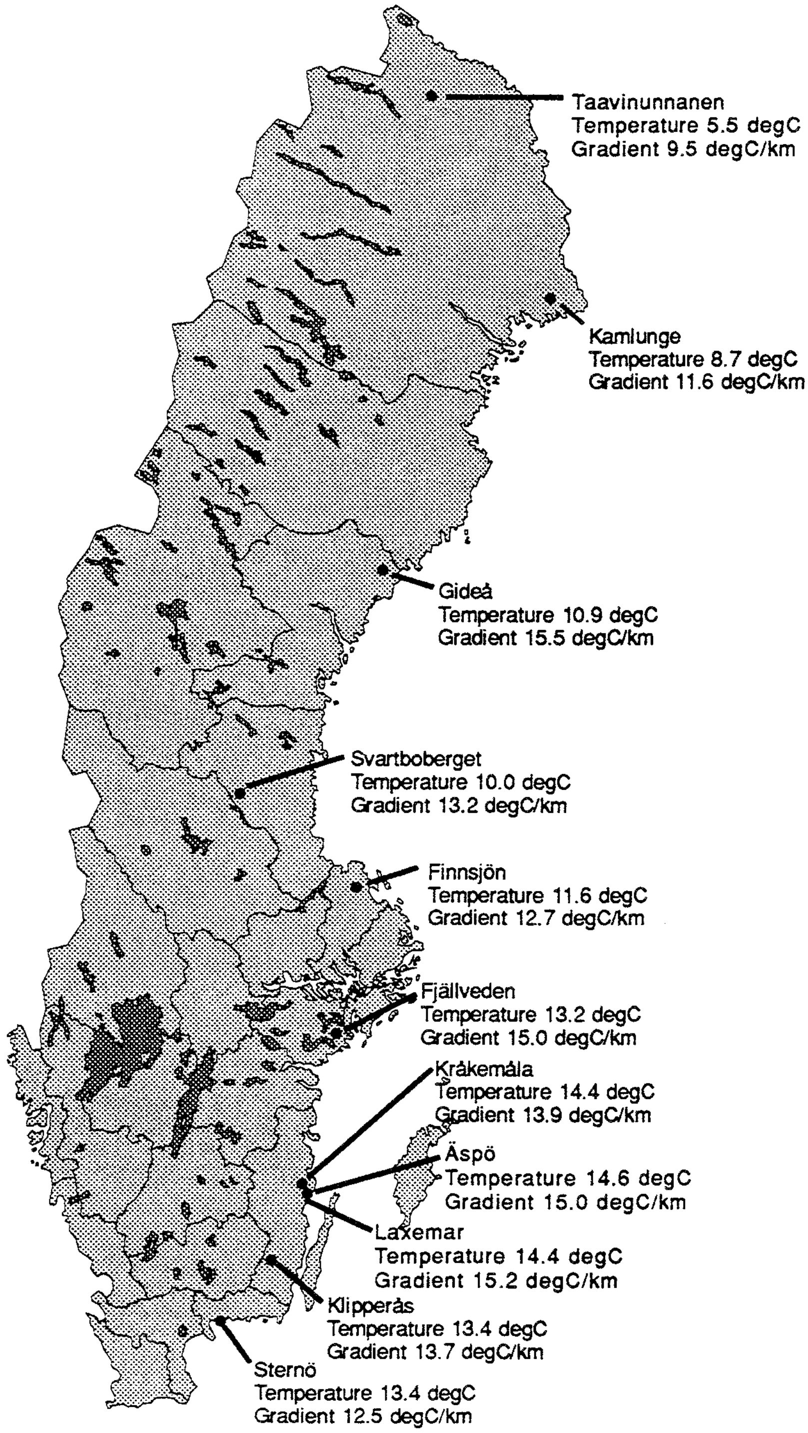

Figure 14. Estimated temperatures at 500 m depth and estimated temperature gradients for SKB study sites.

It is reasonable to assume that the SKB study sites constitute a representative range of bedrock temperature conditions likely to be encountered at the repository site. This is because of the geographical spread of the study sites, as well as the spread in rock types encountered in the boreholes. Table 1 shows a summary of temperature conditions at all sites. The temperatures at 500 m depth below the ground level varies between 5.5-14.4°C, while the temperature gradient varies between 9.5-15.5 °C/km. If also those granitic areas of anomalous high radiogenic heat production are included the plausible range of temperature gradients might be extended up to say 18 °C/km. As noted above the values given in Table 1 differ slightly (< 1 °C and < 1.5 °C/km) from values presented in reports summarizing results from the study sites. The values given in Table 1 are believed to be more representative of the conditions 500 m below ground than previously presented values.

Table 1. Temperatures and temperature gradients at 500 m depth for the SKB study sites.

Site	Approximate elevation (m)	Temperature at 500 m level (°C)	Temperature gradient (°C/km)
Sternö	23	13.4 ± 0.3	12.5 ± 0.5
Klipperås	200	13.4 ± 0.5	13.7 ± 0.5
Kråkemåla	15	14.4 ± 0.3	13.9 ± 0.5
Fjällveden	60	13.2 ± 0.5	15.0 ± 0.5
Finnsjön	33	11.6 ± 0.3	12.7 ± 0.3
Svartboberget	290	10.0 ± 1.0	13.2 ± 0.6
Gideå	115	10.9 ± 0.5	15.5 ± 0.6
Kamlunge	150	8.7 ± 0.5	11.6 ± 1.0
Taavinunnanen	675	5.5 ± 0.5	9.5 ± 1.0
Laxemar	18	14.4 ± 0.7	15.2 ± 0.5
Äspö	7	14.6 ± 0.3	15.0 ± 0.3

REFERENCES

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

Ahlbom K. and Karawacki E., 1983: Thermal properties measured on core samples from Fjällveden, Gideå, Kamlunge and Svartboberget. SKBF/KBS AR 83-36.

Eriksson K.G., Ahlbom K., Landström O., Larson S-Å., Lind G. and Malmqvist D., 1979: Investigations for geothermal energy in Sweden. Pure and Applied Geophysics. Vol. 117, Nos 1/2. Birkhäuser Verlag Basel.

Landström O., Larson S-Å., Lind G. and Malmqvist D., 1979: Värmeflöde i berg. Geologiska inst. Publ. B137. Chalmers Tekniska Högskola/Göteborgs Universitet.

Sundberg J., 1988: Thermal properties of soils and rocks. Geologiska institutionen, Publ. A 57, Göteborgs Universitet/Chalmers Tekniska Högskola.

Sundberg J., 1991: Thermal properties of the rocks on Äspö island. Thermal conductivity, heat capacity, geothermal gradient and heat flow. SKB HRL Progress Report 25-91-09.

Sundberg J., 1995: Termiska egenskaper för kristallint berg i Sverige. Kartor över värmekonduktiviteter, värmeflöde och temperatur på 500 m djup. (I manus.)

Thunvik R. and Braester C., 1991: Heat propagation from a radioactive waste repository. SKB AR 91-17. Stockholm.

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

1981
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The KBS Annual Report 1982
KBS Technical Reports 82-01 – 82-27
Summaries
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KBS Technical Reports 83-01 – 83-76
Summaries
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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

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Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01 – 85-19)
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SKB Annual Report 1987
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List of SKB Technical Reports 1995

TR 95-01

Biotite and chlorite weathering at 25°C. The dependence of pH and (bi) carbonate on weathering kinetics, dissolution stoichiometry, and solubility; and the relation to redox conditions in granitic aquifers

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[3] MBT Tecnología Ambiental, Cerdanyola, Spain

January 1995

TR 95-02

Copper canister with cast inner component. Amendment to project on Alternative Systems Study (PASS), SKB TR 93-04

Lars Werme, Joachim Eriksson

Swedish Nuclear Fuel and Waste Management Co, Stockholm, Sweden

March 1995

TR 95-03

Prestudy of final disposal of long-lived low and intermediate level waste

Marie Wiborgh (ed.)

Kemakta Konsult AB, Stockholm, Sweden

January 1995

TR 95-04

Spent nuclear fuel corrosion: The application of ICP-MS to direct actinide analysis

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March 1995

TR 95-06

Palaeohydrological implications in the Baltic area and its relation to the groundwater at Äspö, south-eastern Sweden – A literature study

Bill Wallin

Geokema AB, Lidingö, Sweden

March, 1995

TR 95-07

Äspö Hard Rock Laboratory Annual Report 1994

SKB

April 1995

TR 95-08

Feasibility study for siting of a deep repository within the Storuman municipality

Swedish Nuclear Fuel and Waste Management Co., Stockholm

January 1995

TR 95-09

A thermodynamic data base for Tc to calculate equilibrium solubilities at temperatures up to 300°C

Ignasi Puigdomènech[1], Jordi Bruno[2]

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April 1995

TR 95-10

Investigations of subterranean microorganisms. Their importance for performance assessment of radioactive waste disposal

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June 1995

TR 95-11

Solute transport in fractured media – The important mechanisms for performance assessment

Luis Moreno, Björn Gylling, Ivars Neretnieks

Department of Chemical Engineering and Technology, Royal Institute of Technology, Stockholm, Sweden

June 1995

TR 95-12
Literature survey of matrix diffusion theory and of experiments and data including natural analogues
Yvonne Ohlsson, Ivars Neretnieks
Department of Chemical Engineering and Technology, Royal Institute of Technology, Stockholm, Sweden
August 1995

TR 95-13
Interactions of trace elements with fracture filling minerals from the Äspö Hard Rock Laboratory
Ove Landström[1], Eva-Lena Tullborg[2]
[1] Studsvik Eco & Safety AB
[2] Terralogica AB
June 1995

TR 95-14
Consequences of using crushed crystalline rock as ballast in KBS-3 tunnels instead of rounded quartz particles
Roland Pusch
Clay Technology AB
February 1995

TR 95-15
Estimation of effective block conductivities based on discrete network analyses using data from the Äspö site
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