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Testing of Borehole Gamma-ray Spectrometry
Method in the North Calotte Region

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<p>Summary: Test measurements with a borehole gamma-ray spectrometer have been carried out in the North Calotte region. This was a rented commercial instrument from IFG Corporation, Canada. The investigated sites were Biggejavre (Sc/REE), Fidnajokka (postglacial fault) and Bidjovagge (Au, Cu) in Finnmark and Bleikvassli (Zn,Pb,Cu) in Nordland. The results from the test measurements were to be compared with results from a new instrument developed by the Finnish company Astrook Oy.</p> <p>Calibration of the instrument and stripping ratio calculations have been carried out at NGU. Because of too short measuring time and the small crystal in the probe, the calculated stripping ratios were poor. From these ratios and the calculated calibration constants, the concentration of K, U and Th can be estimated. Calibration measurements were taken on pads used for ground and airborne instruments which will not give the same condition as in a borehole. A correction was made for the difference in shape between the flat pads and a borehole and this is a source of some inaccuracy.</p> <p>Another problem was the energy drift of recorded borehole spectra probably caused by temperature changes. Consequently, the recorded spectra had to be translated with respect to energy. In some cases this was difficult because no clear peaks were observed in the spectra.</p> <p>The results show in some cases good correlation between the calculated concentrations and chemical analyses. The calculated K content in the gneisses and mica schists in Bleikvassli is a little low compared to the chemical analyses. The calculated U and Th concentrations in those investigated boreholes are consistent with known U and Th content, while the calculated K content in Biggejavre is obviously wrong because of poor stripping ratios. Detailed correlation calculations were not performed because the lack of detailed chemical analyses.</p> <p>Deposit name and grid-reference : Biggejavre 34W 5958 76957 Fidnajokka 34W 5967 76875 Bidjovagge 34W 5586 76884 Bleikvassli 33W 4470 73105</p>			
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1. INTRODUCTION

The project is a co-operation between the Finnish company Astrock OY and the Geological Survey of Norway (NGU). The project is sponsored from *North Calotte Interreg II*, by 50 % of total cost. Astrock OY has developed a new gamma ray spectrometer based on new innovative technology which is expected to be easier and more reliable to use than traditional instruments. The geological background of the gamma-ray method is well known, but there is a lack of comprehensive reference data to profoundly study the borehole gamma-ray spectrum method in Norway (Nordic countries).

The aim of the project is to create base for a new geological and geophysical research method for further actions in the field of business development in the North Calotte Region. The new method may increase the efficiency of mineral prospecting by, for example, reducing the need for the chemical analysis of rock samples. In mineral exploration and mining it means lower exploration and production costs. With the help of the new method it may be possible to find new mineralization zones of economic importance.

To get a good understanding of the spectrometer data NGU and Astrock wanted to investigate several areas in Norway and Finland that differ from each other in rock age and rock type. NGU's part in the project has been to carry out measurements with a commercial gamma-ray spectrometer at different sites in Norway. This has been done by using a gamma-ray borehole spectrometer from the Canadian company *Instruments for Geophysics (IFG)*. The sites investigated in Norway were Biggejavre (Sc), Bidjovagge (Cu, Au), Fidnajokka (postglacial fault) in Finnmark and Bleikvassli mine (Pb, Zn, Cu) in Nordland. The results from these measurements will be used in testing the Finnish instrument. Planned investigations in Harelifjell (U) and Høgtuva (Be, U) were not carried out because of the quite heavy equipment. The field work was carried out in September 1997 by Harald Elvebakk and Jan S. Rønning.

2. BACKGROUND OF THE PROJECT

Gamma-ray spectrum measurements are widely used in airborne geophysics to map out the Uranium, Thorium and Potassium content in the ground for the needs of environmental monitoring, mineral exploration etc. NGU has long experience in doing such measurements. In detailed research the gamma-ray spectrum measurements have been used to classify rock types, minimize ore dilution etc. Gamma-ray spectrometers are based on the photomultiplier tube system. However, instruments based on this system can be very sensitive to vibration and

temperature changes which makes them troublesome and unreliable to use. For that reason, until now the use of gamma-ray spectrometers in drillholes has been limited, mainly due to low response from a small crystal detector.

Astrock Oy is a Finnish geophysical service company located in Sodankylä. This company has recently developed a gamma-ray spectrometer based on new technology. This technology is expected to perform better during temperature changes, and get higher spectral resolution and counting efficiency using another crystal. The quality of data is expected to be better than the data measured with the old technique. Therefore, there would be many new applications possible for this method, but there is a lack of comprehensive reference data to test the method.

The geological background of the gamma-ray method is well-known. Therefore, with a reasonable probability, the possible applications of the borehole logging gamma-ray method can be evaluated. The new method is known to increase the knowledge of mineralogy of rocks. It can be utilized in mineral exploration and the mining industry for example in replacing some of the chemical analyses with borehole spectrum measurements. The chemical analyses are expensive, time consuming and, in some cases, an environmentally risky method. Especially in production drilling the long waiting time for analyses makes the optimum drilling difficult and therefore creates extra costs. For these reasons chemical analyses should be avoided if possible. By gamma-ray spectrum measurements, when the method is fully developed, in situ measurements can be performed, and prospecting costs will be considerably reduced.

3. INSTRUMENT

The commercial instrument with the traditional photomultiplier tube system used in NGUs part of the project was rented from the Canadian company IFG Corporation. The name of this Gamma-ray spectrometer is BSG-01.

3.1 Description of the Gamma-ray spectrometer BSG-01

The BSG-01 is a fully digital borehole spectral gamma instrument which samples 256 channels of natural gamma radiation in the energy range of 0 keV to 3000 keV at a rate of one complete spectrum per second. The system is designed for use in slimline boreholes (diameter 46 mm). The standard detector used is a 25 mm by 76 mm NaI crystal. The detector is

optically coupled to a photo cathode and a photo multiplier tube (PMT). When a gamma ray strikes the detector, it emits a flash of light (or photon) which is detected by the PMT and converted into an electric voltage. The amplitude of this voltage is proportional to the energy of the photon which produced the light flash.

The probe is connected to the IFG logging cable (6 mm) which is stored on a winch equipped with a manual drive which also can be powered by an electric drill. The length of the cable used is 500 m. On the winch there is a depth wheel controlling the logging positions in the borehole. The IFG surface electronics consist of a single interface console that supplies power to the probe and converts data received from the probe. From the interface console the data are transferred to the portable PC where they are stored.

3.2 Energy range and window channels

Using gamma ray spectrometry, γ -rays from the following isotopes are used to map the natural radio element Potassium, Uranium, Thorium and the man made Cesium.

Element	Gamma Ray Emitter	Peak Energy (keV)	Comment
Potassium	^{40}K	1470	Radiation from isotope itself
Uranium	^{214}Bi	1760	Daughter of ^{238}U
Thorium	^{208}Tl	2615	Daughter of ^{232}Th
Cesium	^{137}Cs	662	Radiation from isotope itself

For the system used, the energy range of 0 to 3000 keV is divided up into 256 channels numbered 0 to 255. Each channel is 11.719 keV wide. Gamma rays from each element are detected in a ranged channels, called windows, centered on the element's peak energy. The windows used in the present investigation are described below:

Window name	Symbol	Peak energy	Energy window (keV)	Channel no.
Total count 1	TC1		0100 - 3000	008 - 255
Total count 2	TC2		0400 - 3000	034 - 255
K (^{40}K)	K	1470	1370 - 1570	116 - 133
U (^{214}Bi)	U	1760	1660 - 1860	141 - 158
Th (^{208}Tl)	Th	2615	2400 - 2800	204 - 238
Cs (^{137}Cs)	Cs	662	650 - 674	55 - 57

These energy windows are set as default in the acquisition software.

3.3 Data acquisition and processing

The data acquisition is controlled by a software, named G256 (IFG Corporation 1994 a), run on a portable PC. The data records transmitted by the IFG surface interface console are sent to the PC, which acts as the data acquisition unit. The data are received, displayed and permanently stored for later processing. Measurements can be carried out in continuous mode (logging with constant speed taking measurements every second) or in incremental mode (taking measurements at specific depths for a fixed time interval). During logging the total counts in each window are shown on the PC screen.

Due to temperature changes in the detector, the channel numbers of the spectra will not usually line up with the expected corresponding energy values. To adjust for this, a calibration file has to be made. This file is made by taking measurements near a calibration source of known spectral characteristics. For this purpose a ^{137}Cs source was used. The process is described in detail in the IFG reference manual.

The data processing is done by a software called S256 (IFG Corporation 1994 b). S256 is designed for processing and display of binary data from the IFG spectral gamma probe. Further, the S256 converts the binary raw data files into ASCII files which means that any software may be used to display the data. Using the S256, spectra from any place in the borehole can be studied. There is an option for summing and plotting of spectra from specified positions in the borehole. Another option is creating window files which can be plotted in the same manner as other geophysical borehole logs. During the project some bugs in this sum up of spectra option were discovered and it was not possible to get the summed values of total counts in each channel. NGU therefore had to make new software for these purposes. In this software, routines for stripping and calculations of concentration were included (Mauring 1998), see later.

4. CALIBRATION OF BSG-01

In gamma-ray spectrometry, it is a drawback that high energy radiation is absorbed and registered in low energy windows. To find the right number of counts caused by one element in its window, the effect of other elements has to be stripped off. In order to use the method to calculate the concentration of the natural radio elements, the sensitivity of the crystal or calibration factor have to be known.

To calculate stripping ratios and calibration factors, measurements have to be taken on calibration pads (Grasty et. al. 1991). NGU has such pads for calibration of ground and

airborne gamma-ray spectrometers. Each set consists of a low radioactivity background pad, and three radio element pads of potassium, uranium and thorium which provide almost pure gamma-ray spectra. The size of each pad is 1 m x 1 m x 0.3 m. Some uncertainty in the measurements were expected because of uncertainty in geometric correction between the flat surface of the pad and the situation in a borehole. This means that there was no mass surrounding the entire probe like the situation in a borehole.

Measurements were taken on each pad for 10 minutes. After each measurement on the radio element pad, measurements were taken on the background pad. The pads were placed exactly at the same place for each measurement. Because of drift in the spectra the summed spectra had to be adjusted for each pad measurement. Figure 1 and 2 show the summed spectra from the pad measurements before adjusting. Both for the Th and U spectrum it is difficult to identify the peak of Th and U. The reason is too short measuring time. The counts in the U and Th window should be much higher to get reasonable stripping ratios. To get an error less than 1 % in the Th (U, K) calibration factor, the number of counts in the Th (U, K) window on the Th (U, K) pad should be higher than 10,000. In our calibration the count rates were in the range of 900 to 1,400. The measuring time should have been about 1 hour to get an error of 1 - 2 %. Unfortunately the authors became aware of this after the instrument was returned to Canada. The poor stripping ratios will then influence on the concentration calculations in the test of the instrument.

4.1 Calculation of stripping ratios

Before calculating the stripping ratios the summed spectra were adjusted in this way

The K-peak, ch 117, was moved to energy level 1470 keV (center of K-window)

The U-peak, ch 141, was moved to energy level 1760 keV (center of U-window)

The Th-peak, ch 205, was moved to energy level 2600 keV (center of Th-window)

Total counts in each window after drift correction are shown in table 1. B_x means counts on background pad before measurements on x-pad

Table 1. Data from calibration pad measurements

Pad	TC1	K	U	Th
B _K	16461	405	101	101
K	35570	1427	180	77
B _U	16050	373	86	93
U	120455	1700	989	143
B _{Th}	14880	362	93	75
Th	114638	1417	964	927

The data in Table 1 are total counts in 10 minutes. From this data, the stripping ratios can be calculated from background corrected values:

$$\alpha = \text{count rate in U window} / \text{count rate in Th window} \quad - \quad \text{on Th pad}$$

$$\beta = \text{count rate in K window} / \text{count rate in Th window} \quad - \quad \text{on Th pad}$$

$$\gamma = \text{count rate in K window} / \text{count rate in U window} \quad - \quad \text{on U pad}$$

$$a = \text{count rate in Th window} / \text{count rate in U window} \quad - \quad \text{on U pad}$$

$$b = \text{count rate in Th window} / \text{count rate in K window} \quad - \quad \text{on K pad}$$

$$g = \text{count rate in U window} / \text{count rate in K window} \quad - \quad \text{on K pad}$$

The calculated stripping ratios for this crystal will then be (Grasty 1977):

$$\alpha = (964 - 93) / (927 - 75) = 1.022$$

$$\beta = (1417 - 362) / (927 - 75) = 1.238$$

$$\gamma = (1700 - 373) / (989 - 86) = 1.470$$

$$a = (143 - 93) / (989 - 86) = 0.055$$

$$b = (77 - 101) / (1427 - 405) = -0.023$$

$$g = (180 - 101) / (1427 - 405) = 0.077$$

4.2 Calculation of concentration factors

The stripped data $n_{K,K}$, $n_{U,U}$ and $n_{Th,Th}$ can then be found by using the following stripping equations ($n_{x,x}$ is the number of counts in window x caused by element x) :

$$\begin{aligned} n_{K,K} &= (n_{Th}(\alpha\gamma - \beta) + n_U(a\beta - \gamma) + n_K(1 - a\alpha)) / A t && \text{(on K-pad)} \\ n_{U,U} &= (n_{Th}(g\beta - \alpha) + n_U(1 - b\beta) + n_K(b\alpha - g)) / A t && \text{(on U-pad)} \\ n_{Th,Th} &= (n_{Th}(1 - g\gamma) + n_U(b\gamma - a) + n_K(ag - b)) / A t && \text{(on Th-pad)} \end{aligned}$$

where A is given by

$$\begin{aligned} A &= 1 - g\gamma - a(\gamma - g\beta) - b(\beta - \alpha\gamma) \\ t &= 600 \text{ sec} \end{aligned}$$

n_K , n_U and n_{Th} are the background corrected counts over 600 seconds in the three windows from the pad measurements. By running the stripping program (Grasty 1977) the number of counts pr. second from element x in window x are found to be

$$\begin{aligned} n_{K,K} &= 1.75 \text{ counts/sec} && \text{(on K-pad)} \\ n_{U,U} &= 1.54 \text{ counts/sec} && \text{(on U-pad)} \\ n_{Th,Th} &= 1.46 \text{ counts/sec} && \text{(on Th-pad)} \end{aligned}$$

To transform the stripped count rates on the pads into a borhole measurement situation the data have to be multiplied with a geometric factor. This factor is estimated to be 2.1 for all three windows.

$$\begin{aligned} n_{K,K} &= 1.75 * 2.1 = 3.68 \text{ counts/sec} \\ n_{U,U} &= 1.54 * 2.1 = 3.23 \text{ counts/sec} \\ n_{Th,Th} &= 1.46 * 2.1 = 3.06 \text{ counts/sec} \end{aligned}$$

Each calibration pad has a known content of K, U and Th as shown below:

	K (%)	U (ppm)	Th (ppm)	Background corrected
BLANK	1.34	0.98	2.28	
K-PAD	7.98	0.46	1.82	6.64 (%)
U-PAD	1.25	53.33	3.20	52.35 (ppm)
Th-PAD	1.34	2.31	110.0	107.72 (ppm)

By using the concentrations, the geometric factor and the stripped count rates in each window, a concentration factor can be calculated transferring the stripped data to real concentration. The concentrations used are the background corrected values for each pad. The K, U and Th concentration in the background pad are subtracted from the concentration in the respective K, U and Th pad. The background count rates were subtracted in the same way and represent a common procedure in the calibration calculations.

$$K_{\text{FACTOR}} = 6.64 / 3.68 = 1.80 \text{ (\% K/counts/sec)}$$

$$U_{\text{FACTOR}} = 52.35 / 3.23 = 16.21 \text{ (ppm U/counts/sec)}$$

$$Th_{\text{FACTOR}} = 107.72 / 3.06 = 35.20 \text{ (ppm Th/counts/sec)}$$

In the new program made at NGU (Mauring 1998), the counts in each window are summed up at every position in the borehole. Further, this program calculates the stripped count rates using the above calculated stripping ratios and stripping equations. Finally the K, U and Th concentrations are calculated by multiplying the stripped values by the concentration factors.

5. INVESTIGATED SITES IN NORWAY

Four sites in the North Calotte Region have been investigated: Biggejavre, Bidjovagge, Fidnajákka and Bleikvassli. The field work was carried out in September 1997.

5.1 Biggejavre

Biggejavre is a scandium - Rare Earth Element (REE) deposit located some 40 km north of Kautokeino in Finnmark (Sandstad 1989). The area is shown on the location map no 98.091-02. The deposit was discovered using airborne gamma-ray spectrometry, AGRS (Håbrekke 1983). A Norwegian mining company has investigated the deposit by mapping and drilling. The deposit was never put into production. The Sc-bearing rock is an albitite consisting more than 90 % albite. The main scandium mineral in the deposit is davidite which also consists Y, U, Cr, Ti, Fe, V and REE. The average analyses are 120 ppm Sc, 230 ppm Y, 830 ppm U, 4080 ppm Cr. The deposit is about 40,000 tons.

Three boreholes were investigated by gamma-ray spectrometry. Figure 3 shows a cross section of the central part of the deposit. Borehole 83-03, 83-04 and 83-09 were investigated. Boreholes 83-03 and 83-04 cut the main albitite zone, while borhole 83-09 is outside the albitite. Borehole 83-05 was blocked.

5.2 Bidjovagge

The Bidjovagge copper-gold deposit is located 40 km northwest of Kautokeino in Finnmark (map -03 and -04). The deposit was mined from 1975 to 1979 as a copper mine. New investigations on the gold distribution led to a re-opening of the mine in 1985. The mine was closed in 1992. The main minerals of economic significance were chalcopyrite and gold. Other minerals in the deposit are pyrite, pyrrhotite, magnetite, ilmenite, hematite, tellurides, rutile, sphalerite, galena, davidite and pentlandite. The gold occurrence is often associated with weak uranium mineralization caused by davidite (Bjørlykke et al. 1987).

In 1996 the deposit and the surroundings were investigated (drilling) again, now looking for gold rich parts close to the mining area (Geologiske Tjenester A/S 1996). All together there were drilled about 2700 m (28 boreholes). Some of these holes were to be investigated by gamma-ray spectrometry. However, almost every hole was blocked or buried under

overburden. The upper 10 m of borehole B96-18 and borehole B96-19 were measured. These holes were not the most interesting for gold mineralization and correlation analysis between gamma-rays and gold content.

5.3 Fidnajåkka

In the Fidnajåkka area, 30 km north of Kautokeino (map -02), the Stuuragurra Fault was discovered as an active fault in 1983 (Olesen et al. 1992a). The Stuuragurra Fault is a postglacial fault and can be observed on the surface as a fault scarp (up to 7 m high). The length is about 80 km. Geological and geophysical investigations have been carried out for several years (Olesen et al. 1992b). The fault has been drilled, and in one of the boreholes, DH 6, gamma-ray spectrometry was carried out. The borehole was blocked at 37 m (total length 135 m). The rock types under 12 - 13 m overburden are a redish grey quartzite (with some K-feldspar) and a dark banded quartzite. The main element of interest for gamma ray spectrometry was Potassium.

5.4 Bleikvassli

The Bleikvassli Zn-Pb-Cu deposit is located about 50 km south of Mo i Rana in Nordland (map -05). The deposit occurs in the Uppermost Allochthon in the North Norwegian Caledonides (Ramberg 1967). The Bleikvassli mine was opened in the early 1950s. The Mine sequence consists mainly of mica schists and kyanite schists, and in the mine area it contains the Bleikvassli Zn-Pb-Cu ore body and associated siliceous and feldspathic rocks. The average grades of the ore body are 8 % Zn, 3 % Pb and 0.4 % Cu. The ore zone is underlaid by a microcline gneiss in the footwall with a high K₂O content (up to 11.6 %). The ore zone quartz-muscovite schist has a K₂O content of 4 - 5 % (Skauli 1992). The average content of U is 5 - 10 ppm (peaks of 20 - 30) and Th 30 - 50 ppm. Two boreholes were investigated in the mining area Bh 05-86 and Bh 30-95. The most interesting part of the investigations in Bleikvassli was to study the K content in the microcline gneiss.

Close to the mining area, 1.5 km to the south, Bh 01-97 was investigated in the Brunesebeken area. Disseminated sulfides were hit at 100 m depth with 1.5 - 1.6 % Cu and Zn (Bjerkgård 1998). There is no microcline gneiss in this area and the K content is in general lower than in the mining area. The main rock is amphibolite with low content of K.

6. RESULTS

The results from the borehole measurements are presented in borehole logs showing the calculated concentrations of K, U and Th. In most of the cases geological logs and chemical analyses are also shown. Detailed chemical analyses are missing. Therefore, it is not possible to do accurate correlations between calculated concentrations from the gamma ray spectrometry measurements and chemical analyses.

6.1 Energy stabilization of spectra from the borehole measurements

At each borhole a reference spectrum was obtained by taking measurements close to a calibration source, ^{137}Cs , with known spectral characteristics. It was intended that the relation between the ^{137}Cs peak in this reference spectrum and the spectrometer channels could be used to correct for temperature dependent instrument drift. However, when starting processing the data, these reference spectra could not be used to adjust the spectra from the borehole measurements. The reason was that the reference spectrum from the ^{137}Cs source on the ground only had a small energy drift while the borehole spectra indicated a drift of several channel numbers. The big energy drift in the borehole spectra was probably caused by the temperature difference between the ground and the borehole (up to 15°C). Instead of using the reference spectra, which gave no correction, known peaks of K and U observed in the borehole spectra were used for energy drift adjustment. In some cases it is difficult or almost impossible to locate clear peaks. This will make the energy adjustment inaccurate. The energy peaks used are shown in table 2.

Table 2. Energy peaks used in energy adjustment of borehole spectra.

Borehole	Depth (m)	Observed K peak (Ch. No.)	Observed U peak (Ch. No.)	Observed Cs peak (Ch. No.)	Adjusted to K peak (Ch. No.)	Adjusted to U peak (Ch.no.)	Adjusted to Cs peak (Ch.no.)
Big 03-83	5		140	51		150	56
Big 04-83	7		140	51		150	56
Big 09-83	12		140	51		150	56
Bidjo 18-96	3	121			123		
Bidjo 19-96	85.5, 58		137	51		150	56
Stuo 06	24.5	113		53	123		56
Bleik 30-95	53		136	51		150	56
Bleik 05-86	190	116		51	123		56
Brun 01-97	130	114			123		

Figure 4 - 11 show sum-up spectra at selected positions from the investigated boreholes. These spectra are not adjusted. The measuring time, 120 sec at each position, is in some boreholes, much too short to obtain clear peaks which can be used in the energy adjustment. However, if the concentration of radio elements is low, it is impossible to use the borehole spectra in energy adjustment whatever the measuring time is. The summed spectra were calculated by the software made by NGU because the IFG software could not handle the big files recorded in the boreholes. Adjustment of the borehole spectra was made by the S256 processing software from IFG.

On the spectra from borehole 03-83 and 04-83, Figure 4, in Biggejavre, two peaks can be observed. The main peak of interest in the U spectrum is at ch. 150 (1760 keV) which can be observed at ch. 140 (1600 keV) in Figure 4. Another peak is observed at ca ch. 90 (1020 keV) which is also a peak in the U spectrum (1120 keV). Figure 4 a. shows the gamma-ray spectra of K, U, Th and granite-gneiss (Telford 1976), and the peaks in the Uranium spectrum at 610 keV, 1120 keV, 1380 keV, 1760 keV, 2190 keV and 2400 keV.

6.2 Results from Biggejavre

Figure 3 shows a cross section of the deposit and the positions of the investigated boreholes. The two boreholes 83-03 and 83-04 cut the albitite zone which contains the Sc/U mineral davidite. Borehole 83-09 is outside the deposit and is free of radioactive minerals. Measurements were taken every 0.25 m in the albitite and the measuring time was 120 seconds. Outside the albitite the measuring intervall was increased to 0.5 and 1 m. Figure 12, 13 and 14 show the results from borehole 83-03, 83-04 and 83-09 together with chemical analyses of U_3O_8 , Zn and Cu and a geological log. For a detailed study of the result see the appendix where a listing of stripped values (c/s) and calculated concentrations at every position in the boreholes are shown.

Bh 83-03

Figure 12 shows the results from borehole 83-03. The radiation from the albitite is in some positions very strong. The chemical analyses indicates an average U_3O_8 content of 0.17 % (1700 ppm) at 6 - 7 m depth. At the same position the Pb content is 260 ppm and the Zn content 10 ppm. Pb and Zn are mentioned to see if there is any correlation between the γ -radiation (radioactive minerals) and Pb, Zn content. The average K_2O content in the albitite is 0.26 % (in the whole deposit).

The calculated U concentration is 1000 - 1800 ppm (see appendix) at 5.8 - 6.5 m. The chemical analyses indicates 1440 ppm U at 6 - 7 m. In spite of the bad calibration of the instrument the correlation between calculated concentrations and chemical analyses is quite good. For the rest of the hole (outside the albitite) the calculated U concentrations are 20 - 40 ppm. No chemical data exist from this part of the hole.

The calculated Th content varies from 5 to 42 ppm in the albitite zone, with an average between 3.5 to 6.5 m of approximately 15 ppm. Chemical analyses from the albitite show an average Th content of 17.5 ppm and a maximum value of 23.1 ppm. The calculated and the analysed concentrations seems to be in the same order, but differ in detail. For the rest of the hole the calculated Th content is very low (<1ppm) and there are no chemical analyses.

The gamma-ray spectrum measurements comes up with a K content of 16 % at position 6 - 7 m while the the average K₂O content in the albitite is 0.26 %. This is obviously wrong and can be explained by poor stripping ratios and great influence from U-radiation. Another influence on the high K content is the possibility of Radon in the borehole which is not stripped away. This will not be discussed further in this report.

The highest Pb content is observed in the albitite zone with the highest uranium content (6 - 7 m).

Bh 83-04

Figure 13 shows the results from Bh 83-04. The results are almost similar to the results of Bh 83-03. The borehole cuts the albitite in three levels. The chemical analyses indicates an average U content of 0.22 % (2200 ppm) at 7 - 8 m depth, 0.19 % at 17 - 18 m and 0.18 % at 24 - 26 m. Maximum Pb content at 25 - 27 m is 580 ppm and maximum Zn at 59 - 60 m is 140 ppm.

The calculated U content is 0.23 % (2362 ppm) at 7.5 m , 0.16 % (1659 ppm) at 17.5 m and 0.18 % (1837 ppm) at 26 m which is close to the chemical analyses. Figure A shows the correlation between the calculated U content and the chemical analyses in Bh 83-04. The chemical analyses give the average U content at one meter intervalls while the gamma-ray measurements were taken every 0.5 or 1.0 m. This might cause some uncertainty. The calculated values will not refer exactly to the same position in the borehole as the chemical analyses. Another problem related to the correlation is the influence area round the probe (the crystal) in the borehole. However, the correlation in this borehole is acceptable. The calculated correlation factor is 0.92.

The equation for the best fitting curve is $Y = 0.93 X + 28.2$

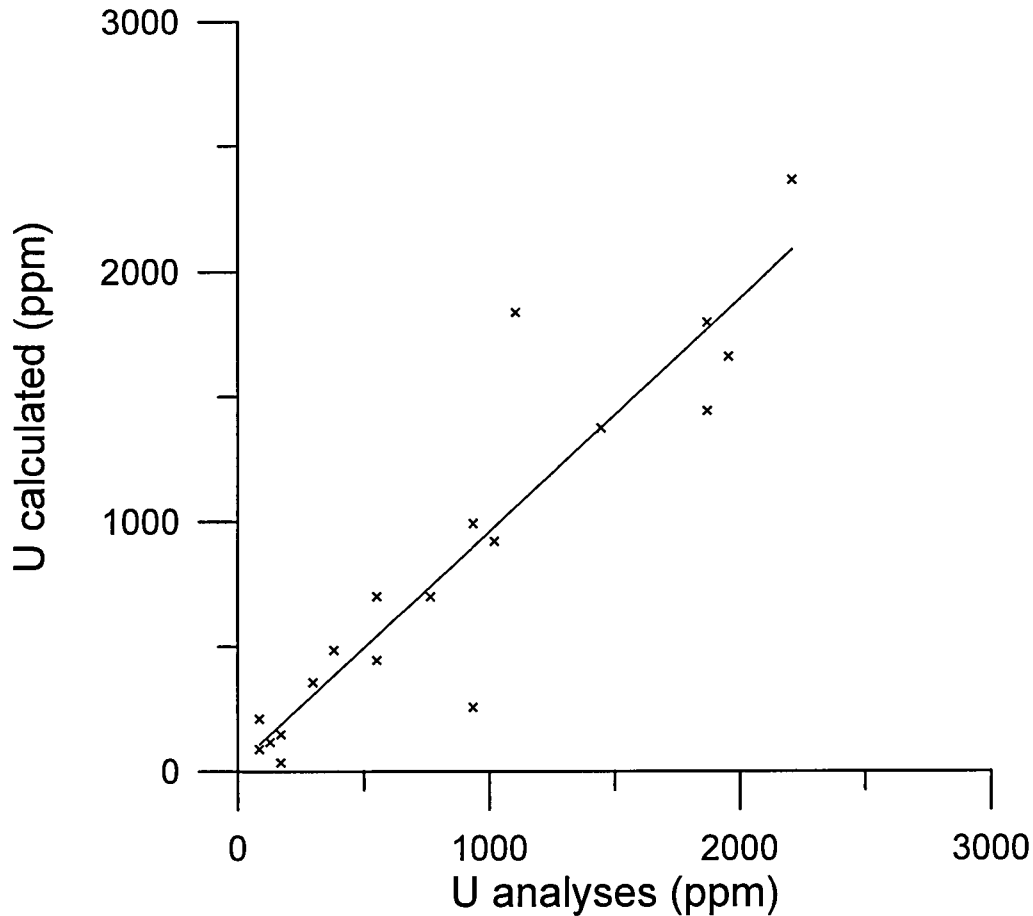


Figure A , Correlation between calculated U content and chemical analyses in Bh 83-04

The calculated Th content is 12 - 51 ppm at 7 - 8 m depth, 12 ppm at 17.5 m. This is in the same order as the chemical analyses which is 17.5 ppm (average). Outside the albitite the concentrations of K, U and Th are the same as in Bh 83-03.

Also in this borehole the calculated K concentrations in the albitite zone are obviously wrong. The calculated K content in the albitite is 10 - 20 % (maximum values), while the real content is 0.26 % K₂O (average).

Bh 83-09

Figure 14 presents the result from Bh 83-03. This borehole is 50 m away from the outcrop of the albitite and consists no albite . The results from this hole will be background values for the amfibolites and chlorite schists which are the main rock types in the area.

The K content is in the range 0 - 2.1 % which is reasonable values for such rocks. The U and Th content is mostly below 1 ppm and this explains better estimation of the K content since erroneous stripping ratios has less effect when U and Th content is low. Chemical analyses on these elements do not exist from the area. The U content is 15 - 40 ppm lower than the values in the same rocks in Bh 83-03 and 83-04 which is closer to the albitite and there might be some mud consisting albite in these boreholes.

6.3 Results from Fidnajåkka

In the Fidnajåkka area one borehole, Dh 6, was investigated by the gamma-ray spectrometry method. The borehole cuts through the Stuoragurra Fault which is a postglacial fault discovered in 1983. The measuring intervall was 0.5 m. No chemical analyses exists from this borehole, only a geological log.

The result from Dh 6 is shown in Figure 15. The variation in K content depends on the rock type. The upper 13 m of the borhole is overburden with a steel casing. The calculated K content is 0 - 2.8 %. The two rock types below 13 m are a redish-grey quartzite and a dark banded quartzite. The redish-grey quartzite contains microcline feldspar (K-feldspar). The gamma-ray spectrometry measurements clearly differ between the K-rich quartzite and the dark banded quartzite. The calculated K concentration in the redish-grey quartzite is 1.5 - 6 % (max value 6.06 %). In parts of the dark banded quartzite the K content is less than 1 %. Average content in sandstone is 0.6-0.7 % (Parasnins 1973).

The calculated U concentrations are 0 - 5.4 ppm while the Th concentrations are 0 - 5.6 ppm. Average content in sandstones are 0.45 ppm U and 1.7 ppm Th. Despite of low concentrations and bad stripping ratios, the calculated concentrations in Dh 6 seem reasonable, but in absence of chemical analyses the correlations can not be quantified.

6.4 Results from Bidjovagge

In the Bidjovagge mining area Bh 96-18 and 96-19 just south of the B-ore (B-malmi) were investigated, see location map 98.091-05. The new drilling investigation in 1996 was looking for gold in the rocks surrounding the mined deposits. Unfortunately the most interesting boreholes were blocked or burried of overburden. In Bidjovagge it was interesting to study the correlation between the gold mineralization and the gamma-radiation (U content).

Bh 96-18

Bh 96-18 was blocked at 11 m, but because of the gold content of 4.56 g.p.t. from 2 to 6 m the borehole was measured with the gamma-ray spectrometer. Measurements were taken every 0.25 m. The result is shown in Figure 16.

Only the gold bearing part (2 - 6 m) has been analysed. The calculated K content is low (mostly below 1 %). The calculated U content in the gold bearing zone (2 - 6 m) is 10.2 ppm, (5.2 - 14.4). In the rest of the hole the U content is 4.6 ppm. The U content in the gold bearing part is more than twice as in the rest of the investigated hole. It is known that the gold occurrence in Bidjovagge often is associated with weak Uranium mineralization (davidite, Bjørlykke et al. 1987). The calculated Th content is also some higher in gold bearing part of the borehole. In this part the Th content is 5 - 10 ppm and the rest of the hole 1 - 4 ppm.

Bh 96-19

The gold bearing parts in Bh 96-19 are located at 56 -88 m (0.29 g.p.t.). The best part in this section is from 82 to 88 m (1.13 g.p.t.). The result from the gamma-ray spectrometry is shown in Figure 17. From 82 - 85.5 m the U content is 13 - 27 ppm with a peak on 67 ppm at 85.5 m while the background values are 2 - 7 ppm. This is in the best gold bearing part of the borehole. The U content is twice the background at 59 - 64 m with a peak on 44 ppm. The K content is below 1 %. At 83.5 - 86 there is an increase in the K content to 2.7 % with a peak of 11 % at 85.5 m. This peak correlates exactly with the peak in calculated U content, and seems to be a result of bad stripping ratio. However this explanation does not fit the situation at 60 m depth where the uranium content increases while the Potassium log is not influenced. To study this in detail, it is necessary to do chemical analyses of the core samples.

6.5 Results from Bleikvassli

Two boreholes were investigated by the gamma-ray spectrometry method in the Bleikvassli mine area. Bh 30-95 was located underground in the mine and Bh 05-86 was drilled outside the mine to hit the deeper part of the ore formation. There was no ore mineralization in this borehole. However, the most interesting subject was to study the K content in the microcline gneiss underlying the ore zone. Few boreholes were available and the typical microcline gneiss was missing in two of the boreholes. In the Brunebekken area, 1.5 km south of the mine, a newly discovered disseminated deposit was investigated in Bh 1-97.

Bh 30-95

Bh 30-95 was drilled in the mine and cut a part of the ore body at 57.3 - 59.3 m. In this part the ore contains 5.78 % Zn, 3.13 % Pb and 0.24 % Cu. Another ore zone was found at 45.15 - 46.20 m with 3.66% Zn, 3.09 % Pb and 0.16 % Cu. There was no typical microcline gneiss in this hole, but the muscovite/biotite gneisses/schists have a K content of 4 - 5 % K_2O (3.3 - 4.1 % K). The measuring interval was 3 m above the ore zone. Close to the ore zone it was reduced to 1 and 0.5 m and even 0.25 m in the ore zone.

The results from the gamma-ray measurements are shown in Figure 18. The geological settings are different types of muscovite/biotite gneisses/schists with variable K concentration. The calculated K content is in the range of 1.5 - 5 % which in some parts is close to the real K content in this type of gneisses in the mine. The K content is lowest in the ore zone and can be seen as a series of minima on the K-curve. No detailed K analyses exists. Based on the Potassium log it seems possible to do a more detailed classification of the different rock types than is observed on the geological log.

The calculated U content is 10 - 30 ppm. Detailed analyses from other drill holes in the mine indicate a little lower background U content (5 - 10 ppm), but locally 20-30 ppm U is not unusual (Moralev et al. 1996).

The calculated Th content is in the range of 20 - 50 ppm which correlates better with the detailed chemical analyses from other boreholes which have a Th content in the same range.

There does not seem to be any correlation between the K, U, Th content and the content of Zn, Pb and Cu in the ore zone except that both the K, U, and Th-curves comes up with minima when crossing the ore zone. However, this is result from just one hole, and detailed investigations might come up with more reliable results. Radioactive minerals may occur together with sulfides, but because of the relative high K, U and Th content in the rocks surrounding the ore zone, it is difficult to observe correlations between the sulfides and radioactive minerals if they occur close to the sulfides.

Bh 05-86

This hole was 320 m deep and measurements were taken every ten meters. No chemical analyses were available. The upper 22 m of the borehole was marble, from 22 m muscovite/biotite gneisses with quartzite and graphite occur in different thickness and with variable content of K-feldspar. Microcline gneiss occurs at 170 - 174 m and from 304 m. The microcline gneiss is a K-rich gneiss which usually underlies the ore formation. The measurement intervals should have been at least 1 m when crossing the microcline gneiss. Because of some misunderstanding the operator got the geological log for another borehole which was deeper, and where the ore zone and the underlying microcline gneiss occurred in a deeper part in the hole than in Bh 05-86.

The result is shown in Figure 19. The gamma-ray measurements clearly differ between the marble and the gneisses, and the calculated K content is close to 0 in the marble. In the muscovite/biotite gneisses the K content is calculated to 2 - 5 % and 5 - 6 % in the microcline gneiss. Both these results are about 75 % of the known K content in the gneisses in Bleikvassli (Skauli 1992). The K-log clearly indicates the microcline gneiss at 170 m (5.98 % K) and from 280 m the K content is increasing indicating the microcline gneiss, 5.89 % K at 310 m. The K peak (6.18 % K) at 25 m does not indicate microcline gneiss. In the geological log this part of the borehole is described as biotite gneiss with garnet and some graphite. Even if the calculated K content seems to be too low, the variations in the K content seem to correlate well with the rock types. Better calibration procedure and smaller measuring intervals might have given a better result. The microcline gneiss in this borehole is often mixed with muscovite/biotite gneisses.

The gamma-ray measurements also differ between the marble and the gneisses regarding the calculated U and Th content. The U content is 0.2 - 2 ppm in the marble and 6 - 27 ppm in the gneisses. The marble contains no Th, while the Th content in the gneisses is calculated to 15 - 50 ppm. Both these results seem reasonable but there are some uncertainty if the variation along the borehole is reliable.

Bh 1-97

1.5 km south of the Bleikvassli mine a disseminated Cu, Zn deposit was found by EM ground measurements (Elvebakk & Dalsegg 1996) and drilling in 1997 (Bjerkgård 1998). In one of the boreholes, Bh 1-97, gamma-ray spectrometry measurements were carried out. Measurements were taken every 2 m outside the Cu, Zn mineralization, and every 0.25 m inside the ore zone. This area, Brunesebeken, is outside the Mine Sequence and the underlying microcline gneiss does not occur. The result from the measurements are shown in figure 20 which also includes a geological log and chemical analyses of Cu, Zn and Pb in the ore zone.

The calculated K content is low in the amphibolite, below 1 %. In the mica schists the K content is 3 - 6 %. The highest value, 6.32 %, is observed at 79 m in a muscovite schist. In the ore zone the K-content decreases. The calculated K content seems reasonable (no chemical analyses from this area), and the variations in K content correlates well with the different rock types along the borehole.

The U content is low, mostly below 1 ppm, in the upper 120 m of the borehole. The U content increases to 27 ppm in a graphite schist at 125 - 130 m. In the sulfide bearing garnet/amfibolite biotite schist at 135 - 150 m the U content is 3 - 8 ppm with some higher values, 15 - 25 ppm, at 140 m and 150 m (kyanite/garnet mica schist).

The calculated Th content is mostly below 15 ppm except at 149.5 - 150.5 m with a peak value of 51.1 ppm. This position is just below the richest Cu, Zn mineralization. No chemical analyses of K, U, Th can confirm the calculated concentrations, but due to the general K, U, Th content in amphibolites and mica schists (Bleikvassli mine), the calculated concentrations seem reasonable. The combination of K-, U- and Th-logs seems to give more detailed information than is shown on the geological log.

7. DISCUSSION

Testing of a borehole gamma-ray spectrometer, IFG Corporation, Canada, has been carried out at different sites in Norway. The instrument has been calibrated at NGU by taking measurements on calibration pads with known concentration of K, U and Th. Some problems with the calibration and energy adjustment of spectra are discussed. These problems will influence the calculated concentrations of K, U and Th. In situ measurements of K, U and Th concentrations is the main reason for doing gamma-ray spectrometry. The question is whether borehole spectrometer measurements can replace some of the expensive and time consuming chemical analyses.

7.1 Calibration and stripping

Calibration of the IFG gamma-ray borehole spectrometer on calibration pads at NGU was not successful. Because of the small crystal in the probe the measuring time on each pad was much too short to obtain clear peaks in the spectra from the U and Th pad measurements. Total counts in the K, U and Th window were in the range 900 - 1,400 by using 10 minutes measuring time. Total counts should be in the range of 10,000 to get an error of 1% in calibration factor. This will require at least one hour measuring. From the above, the stripping ratios were poor and led to large uncertainty in stripping the borehole data. Errors in calibration factors are estimated to be in the order of 10 % based on the too short measuring time.

Another problem with the calibration of the instrument was the location of the probe on the top of the flat pads. This will not be the situation in a borehole with rock surrounding the entire probe. To correct for this difference the stripped data were multiplied by a geometric factor. This factor was estimated to be 2.1. The size of this factor is also an uncertainty which will influence on the concentration calculations. It is obvious that the factor is greater than 2.0 (double mass). A better result could have been obtained by drilling holes in the pads and

doing the calibration measurements in a real borehole situation. However, the error in geometric effect is not the most serious one in the calibrating procedure.

7.2 Energy adjustment of spectra

There were great problems with temperature dependent instrument drift. To do energy adjustment of borehole spectra a reference spectrum was measured close to a calibration source, ^{137}Cs , on the ground by the borehole. However, this reference spectrum showed no drift in the Cs-peak, and could therefore not be used to adjust the spectra measured in the drillhole, spectra which obviously had temperature drift. The temperature difference between the surface and the boreholes was up to 15°C (see also chapter 6.1). To avoid this problem, the calibration source should be implemented in the probe with automatic adjustment of the borehole spectra. Instead of using the reference spectrum, energy peaks in the borehole spectra were used for energy adjustments. However, in most of the recorded spectra K, U and Th energy peaks were noisy and difficult to characterise, except in the Biggejavre spectra.

7.3 Correlation to chemical analyses

In spite of the problems described in sections 7.1 and 7.2 the calculated content of K, U and Th in some cases seem reasonable. Except Bh 83-04 at Biggejavre it is not possible to do quantitative correlation analyses because detailed chemical analyses are missing. At Biggejavre the correlation factor for calculated U content and chemical analyses is 0.92 which is acceptable. The best correlation between calculated concentrations and chemical analyses is obtained in Biggejavre (see chapter 6.2, Figure A). The calculated K content, however, is obviously wrong probably caused by poor stripping ratios (U in K window?).

The increasing U content in the gold bearing zones in Bidjovagge is interesting in gold prospecting. The chemical analyses from Bidjovagge indicates the average Au content for several meters. Because of this, variations in the calculated U content can not be correlated to the real Au content. In Bh 96-18 the calculated U_{mean} content (10.2 ppm) in the gold bearing part (4.56 g.p.t), is more than twice the calculated U_{mean} content (4.6 ppm) outside the gold zone. No gold analyses exists outside the gold zone. Detailed investigations might have found the real correlation between U and Au at the Bidjovagge deposit.

Gamma ray spectrometry could be used in gold prospecting if there is any correlation between gold content and gamma-radiation (U content). This correlation should be found at the specific deposit to be investigated.

In Fidnajokka the calculated K content clearly differs between the K-rich and the K-poor quartzites. To differ between the two rock types is not very important, but it shows that the method is reliable and with good calibration factors the K content could have been calculated in situ. Correlation with chemical analyses is not possible because such analyses are not available.

In Bleikvassli the K content in the microcline gneiss is important to investigate (mining for K). The calculated K content in the microcline gneiss and the mica schists is up to 25 % lower than the chemical analyses from these rocks. K analyses do not exist from the investigated boreholes. The analyses refer to other boreholes in the mine (not available for measuring). Better stripping ratios should make the result more reliable. However, the variation in K content due to the different rocks seems reasonable. This is clearly shown in Brunsebekken where the low K content (< 1 %) indicates the amphibolite and the higher K content indicates the mica schists (3 - 6 %). There are no chemical analyses on K from this borehole. Chemical analyses from selected parts in Bh 1-97 will make correlation to the calculated K content possible.

Is it possible that the borehole gamma-ray spectrum method can replace chemical analyses in prospecting for minerals? This should be tested out further, but in some cases the test measurements show reasonable correlations between calculated concentrations and chemical analyses. As mentioned, the U correlation factor at Biggejavre is acceptable (0.92).

7.4 Improvements, further plans

The main goal for this project, to compare the result from a commercial instrument and the results from a new developed Finnish instrument from Astrock Oy, is not discussed in this report. The Canadian instrument, IFG Corporation, might be well suited for measuring total gamma radiation and unstripped K, U and Th window channels. For in situ concentration measurements the test has shown that both the testing procedure and the instrument need some improvements.

- Improve the calibration

The stripping ratios were poor and should be improved by much longer measuring time on the calibration pads to get window counts in the order of 10,000.

- Longer measuring time

Also the measuring time in the boreholes should be longer in areas with low amount of radio elements. In the test two minutes were used in every hole. In Biggejavre two minutes were enough to reach more than 10,000 counts in the U-rich albitite.

- In situ spectra stabilization

This means that a calibration source should be implemented in the probe with automatic energy adjustment of borehole spectra. The test showed large energy drift in the borehole spectra probably caused by temperature changes.

- More sensitive crystal

A more sensitive (bigger) crystal will increase the count rate (count/sec.) and the measuring time can be reduced, but a longer crystal will also reduce the down-hole resolution.

According to the plans, two sites were not investigated in the 1997 test measurements, Harelifjell (U) and Høgtuva (Be, U) in Nordland. The authors opinion is that measurements in these areas will not get any new information, and since the access to these areas is troublesome, no investigation will take place. It is a better idea to rent the equipment again, do more accurate calibration and redo some of the borehole logging already done.

Radon in groundwater from wells in bedrock (drinking water supplies) is a problem in Norway. Investigation on such wells regarding the radon content is another subject that the gamma-ray spectrum method should be tested on.

Further chemical analyses on cores from some of the investigated sites would make a better correlation between the calculated concentrations and the chemical analyses. The plan is to get K-analyses from Bh 1-97 in Brunesebeken.

8. CONCLUSION

NGU has carried out test measurements using a borehole gamma-ray spectrometer from IFG Corporation at different sites in the North Calotte Region. The results should be compared with the results from a new borehole gamma-ray probe developed by the Finnish company Astrock OY. The instrument was calibrated by doing measurements on calibration pads with known concentrations of K, U and Th.

The calibration of the instrument was not successful because of too short measuring time on the pads. The small crystal as in the borehole probe requires measuring time of at least one hour to get an error of 1 % in calibration factor. Consequently, the calculated stripping ratios seems bad and the calibration should be done again. A geometric factor (2.1) was estimated to correct for the difference between the flat surface on the pads and the borehole situation with rock surrounding the entire probe. The error in this estimation is expected to be much less than the error caused by too short measuring time during calibration.

Another problem was energy drift in the borehole spectra caused by temperature changes. Reference spectrum from a Cs 137 source on the surface close to the borehole could not be used to adjust the borehole spectra because it had much less drift than these spectra. Therefore, known peaks in the borehole spectra was used for energy adjustment. This problem can be solved by implementing a calibration source in the probe and do automatic adjustment of spectra while measuring.

Longer measuring time at each position in the borehole is required in areas with low amounts of radio elements to increase the count rate (c/s). Using a larger crystal will also increase the count rate.

In spite of the problems with stripping and energy adjustments the results in some cases seem reasonable. Correlation between calculated U content and chemical analyses gives a correlation factor of 0.92 in the albitite at Biggejavre U-deposit which is acceptable. Increased U content in gold bearing zones in Bidjovagge was indicated. In Bleikvassli variations in K content are clearly indicated, but the level of the calculated K content seems to be up to 25 % too low regarding the average content in the mica schists and microcline gneiss. However, the calculated K content cannot be confirmed by chemical analyses and none of the boreholes cut through a typical microcline gneiss. Except of U in Biggejavre, correlation analyses between calculated concentrations of K, U and Th and chemical analyses have not been done because detailed chemical analyses are not available. The plan is to get analyses of K from Bh 1-97 at Brunesebeken in the Bleikvassli area.

The main conclusion of the project is that a better calibration and some improvements of the instrument could make the gamma-ray spectrometry method suitable for in situ calculation of K, U and Th concentrations. In such cases the method will reduce the need for expensive chemical analyses.

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APPENDIX

Listing of stripped K, U and Th window count rates and calculated K, U and Th concentrations.

Big03.stp

BIGGEJAVRE Bh 83-03

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.00	1.99	0.92	0.18	3.58	14.93	6.42
1.20	1.33	1.26	0.05	2.39	20.49	1.92
1.50	2.28	1.16	0.04	4.10	18.87	1.39
1.70	2.16	0.79	0.18	3.89	12.74	6.22
2.00	1.93	0.70	0.06	3.47	11.28	2.01
2.30	0.66	0.75	0.05	1.19	12.15	1.78
2.50	0.69	0.98	0.00	1.25	15.91	0.00
2.80	0.97	0.95	0.07	1.74	15.41	2.54
3.00	1.72	1.15	0.02	3.09	18.67	0.66
3.20	1.47	2.69	0.00	2.65	43.64	0.00
3.50	2.12	6.70	0.16	3.82	108.65	5.53
3.80	2.24	43.39	0.33	4.03	703.32	11.65
4.00	3.62	50.68	0.50	6.52	821.56	17.54
4.30	4.88	58.94	0.35	8.78	955.49	12.45
4.50	3.04	19.04	0.03	5.48	308.60	0.99
4.70	5.24	37.17	0.33	9.43	602.47	11.74
5.00	6.07	45.55	0.22	10.92	738.29	7.58
5.20	4.02	46.48	0.21	7.24	753.49	7.41
5.50	2.05	34.00	0.00	3.68	551.17	0.00
5.80	5.99	97.93	1.11	10.79	1587.51	39.21
6.00	8.91	113.20	1.20	16.03	1834.95	42.30
6.20	8.25	88.30	0.69	14.85	1431.27	24.32
6.50	2.88	61.74	0.00	5.19	1000.75	0.00
6.80	3.83	8.12	0.04	6.89	131.63	1.47
7.00	3.31	4.96	0.04	5.95	80.37	1.47
7.20	3.21	2.54	0.02	5.77	41.10	0.69
7.50	1.72	2.76	0.00	3.10	44.69	0.00
7.80	2.94	1.48	0.05	5.30	24.01	1.91
8.00	1.63	1.37	0.02	2.94	22.17	0.77
8.30	0.59	1.37	0.05	1.07	22.20	1.73
8.50	0.52	1.56	0.00	0.94	25.27	0.00
8.80	0.17	1.64	0.00	0.31	26.61	0.00
9.00	1.07	1.36	0.01	1.93	22.11	0.33
9.50	0.35	1.62	0.00	0.64	26.27	0.15
10.00	0.51	1.98	0.03	0.91	32.14	1.07
10.50	0.25	2.20	0.02	0.45	35.65	0.74
11.00	1.19	1.56	0.00	2.14	25.28	0.00
11.50	0.77	1.61	0.00	1.38	26.15	0.00
12.00	1.38	1.86	0.00	2.48	30.08	0.00
12.50	0.89	1.74	0.00	1.61	28.27	0.04
13.00	1.12	1.81	0.00	2.01	29.35	0.00
13.50	0.86	1.81	0.00	1.55	29.35	0.00
14.00	0.18	2.69	0.00	0.32	43.55	0.00
14.50	0.00	2.38	0.00	0.00	38.55	0.00
15.00	0.86	1.57	0.00	1.55	25.42	0.00
15.50	0.50	1.70	0.00	0.89	27.64	0.10
16.00	0.10	1.95	0.00	0.17	31.55	0.00
17.00	1.09	2.35	0.00	1.97	38.02	0.00
17.50	1.55	1.70	0.01	2.79	27.58	0.36
18.00	1.34	7.15	0.00	2.42	115.89	0.00
18.50	1.17	2.83	0.00	2.11	45.92	0.00
19.00	0.32	2.93	0.00	0.58	47.54	0.00
20.00	0.54	2.25	0.01	0.97	36.47	0.28
21.00	0.35	1.99	0.00	0.64	32.27	0.00
22.00	0.00	2.17	0.00	0.00	35.23	0.00
23.00	0.94	1.49	0.00	1.69	24.10	0.00
25.00	0.18	2.05	0.00	0.32	33.17	0.00
27.00	0.20	2.40	0.00	0.36	38.84	0.00
29.00	0.59	1.98	0.00	1.07	32.16	0.00
31.00	0.99	2.46	0.03	1.78	39.93	1.13
32.00	3.40	1.77	0.05	6.13	28.77	1.72
33.00	0.84	2.17	0.00	1.52	35.25	0.00
35.00	1.31	2.14	0.00	2.36	34.72	0.00
37.00	0.77	1.78	0.04	1.39	28.90	1.37
38.00	0.50	2.24	0.00	0.90	36.26	0.00
39.00	1.02	3.19	0.01	1.84	51.72	0.35

Big03.stp						
40.00	0.54	1.82	0.00	0.97	29.48	0.00
41.00	1.06	1.20	0.03	1.91	19.50	0.93
43.00	0.97	1.06	0.01	1.75	17.18	0.23
45.00	0.50	0.72	0.02	0.91	11.69	0.81
47.00	0.52	0.63	0.03	0.94	10.20	1.00
49.00	0.38	0.60	0.02	0.69	9.71	0.65
51.00	0.16	0.77	0.00	0.28	12.45	0.00

Big04.dat

BIGGEJAVRE Bh 83-04

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.50	0.49	1.09	0.06	0.88	17.69	2.18
2.00	1.34	1.57	0.00	2.41	25.46	0.14
2.50	0.14	1.24	0.05	0.26	20.04	1.92
3.00	0.22	1.16	0.04	0.40	18.74	1.24
3.50	0.68	1.29	0.08	1.23	20.86	2.86
4.00	1.78	0.75	0.12	3.21	12.24	4.18
4.50	1.76	0.77	0.08	3.16	12.44	2.94
5.00	1.90	1.06	0.10	3.42	17.15	3.69
5.50	2.79	1.12	0.16	5.02	18.09	5.79
6.00	2.53	3.41	0.08	4.55	55.24	2.94
6.50	2.39	9.15	0.11	4.31	148.39	3.70
7.00	3.08	64.67	0.36	5.54	1048.28	12.81
7.50	9.68	145.76	1.46	17.42	2362.71	51.55
8.00	5.41	89.82	0.20	9.74	1456.05	7.07
8.50	1.97	15.81	0.00	3.54	256.35	0.00
9.00	2.18	7.44	0.00	3.93	120.62	0.00
9.50	0.97	13.01	0.03	1.75	210.90	1.08
10.00	3.17	7.77	0.11	5.70	126.02	3.70
11.50	2.46	22.00	0.00	4.43	356.54	0.00
12.50	1.76	5.49	0.00	3.17	89.05	0.00
13.00	1.33	6.33	0.02	2.39	102.61	0.81
14.00	3.30	43.24	0.00	5.93	700.93	0.00
14.75	4.25	17.84	0.00	7.65	289.21	0.00
15.50	7.03	61.25	0.00	12.66	992.78	0.00
16.00	6.39	41.00	0.00	11.51	664.65	0.00
17.00	8.68	84.59	0.00	15.62	1371.25	0.00
17.50	11.64	102.38	0.34	20.95	1659.50	12.10
18.00	7.89	72.02	0.00	14.20	1167.38	0.00
19.00	3.92	2.18	0.12	7.05	35.31	4.35
19.50	3.16	2.59	0.05	5.69	42.04	1.74
20.00	2.45	2.11	0.10	4.40	34.19	3.59
20.50	1.33	27.45	0.10	2.40	445.04	3.39
21.00	6.67	40.52	0.13	12.01	656.78	4.61
22.00	3.76	29.95	0.00	6.77	485.54	0.00
23.00	4.28	43.25	0.00	7.70	701.12	0.00
24.00	8.68	110.81	0.00	15.63	1796.17	0.00
24.50	7.23	48.48	0.00	13.01	785.86	0.00
25.00	8.06	66.38	0.00	14.51	1076.00	0.00
25.50	9.98	88.89	0.00	17.97	1440.84	0.00
26.00	9.95	113.37	0.00	17.90	1837.77	0.00
26.50	4.83	24.50	0.05	8.70	397.12	1.76
27.00	3.88	3.52	0.02	6.98	57.04	0.82
27.50	5.68	14.20	0.07	10.23	230.13	2.60
28.00	11.11	56.87	0.00	20.00	921.85	0.00
29.00	3.23	4.14	0.02	5.82	67.06	0.60
29.50	1.80	0.98	0.07	3.24	15.88	2.56
30.00	1.69	2.51	0.00	3.05	40.65	0.00
30.50	1.73	7.23	0.00	3.11	117.18	0.00
31.00	1.51	3.12	0.03	2.72	50.57	1.18
31.50	1.25	1.73	0.00	2.25	27.96	0.00
32.00	1.32	1.05	0.01	2.37	17.02	0.23
32.50	1.67	0.99	0.00	3.00	15.99	0.04
33.00	1.62	1.02	0.07	2.91	16.49	2.34
33.50	1.06	1.13	0.02	1.91	18.33	0.77
34.00	1.34	1.23	0.01	2.41	19.91	0.50
34.50	1.39	1.12	0.02	2.50	18.21	0.75
35.00	2.25	0.94	0.03	4.04	15.28	0.89
36.00	2.38	10.69	0.00	4.28	173.36	0.00
37.00	2.49	1.04	0.03	4.48	16.90	1.19
38.00	2.00	2.01	0.02	3.59	32.66	0.71
39.00	0.81	0.93	0.00	1.45	15.12	0.05
40.00	0.81	0.86	0.04	1.45	13.94	1.39
41.00	1.06	0.94	0.01	1.91	15.27	0.23
42.00	0.39	1.14	0.00	0.71	18.47	0.00
43.00	1.00	1.09	0.00	1.80	17.73	0.00
45.00	0.35	1.07	0.00	0.62	17.39	0.00

Big04.dat						
47.00	0.64	0.96	0.05	1.14	15.55	1.66
49.00	0.61	0.98	0.00	1.09	15.92	0.00
51.00	0.40	1.05	0.00	0.72	17.00	0.00
53.00	0.00	1.15	0.00	0.00	18.66	0.00
55.00	0.47	0.86	0.00	0.84	13.96	0.00
57.00	0.12	0.93	0.00	0.21	15.01	0.00
59.00	1.51	1.14	0.00	2.71	18.46	0.00
61.00	1.13	3.42	0.00	2.03	55.50	0.00
63.00	2.79	2.72	0.00	5.02	44.02	0.00
65.00	1.86	1.75	0.01	3.34	28.37	0.51
67.00	0.57	0.72	0.03	1.02	11.73	1.16
69.00	0.25	0.86	0.00	0.45	13.90	0.00
71.00	0.00	1.08	0.00	0.00	17.54	0.00
73.00	0.20	0.82	0.00	0.36	13.24	0.08
75.00	0.00	1.16	0.00	0.00	18.80	0.00
77.00	0.10	0.93	0.01	0.18	15.02	0.38
79.00	0.13	0.90	0.00	0.24	14.53	0.17
81.00	0.27	0.95	0.00	0.48	15.32	0.00
82.40	1.21	1.39	0.00	2.17	22.48	0.00

Big09.stp

BIGGEJAVRE Bh 83-09

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.00	0.08	0.23	0.02	0.15	3.65	0.83
2.00	0.03	0.02	0.06	0.05	0.36	2.08
3.00	0.03	0.08	0.04	0.05	1.26	1.37
4.00	0.00	0.54	0.00	0.00	8.80	0.00
5.00	0.10	0.06	0.00	0.18	1.00	0.00
6.00	0.05	0.05	0.00	0.09	0.79	0.00
7.00	0.08	0.01	0.04	0.14	0.14	1.25
8.00	0.09	0.07	0.01	0.16	1.16	0.24
8.00	0.01	0.11	0.00	0.02	1.74	0.00
10.00	0.60	0.04	0.01	1.08	0.72	0.40
11.00	0.54	0.00	0.04	0.98	0.00	1.36
12.00	0.99	0.00	0.04	1.78	0.00	1.41
13.00	1.07	0.00	0.03	1.93	0.05	1.16
14.00	0.11	0.05	0.01	0.20	0.83	0.29
15.00	0.37	0.04	0.01	0.67	0.67	0.22
16.00	0.86	0.00	0.02	1.55	0.00	0.74
17.00	0.37	0.02	0.01	0.67	0.38	0.26
18.00	0.49	0.00	0.03	0.88	0.02	0.99
19.00	0.88	0.00	0.02	1.58	0.00	0.77
20.00	0.42	0.06	0.01	0.75	1.03	0.22
22.00	0.12	0.02	0.01	0.22	0.37	0.36
24.00	0.16	0.01	0.00	0.29	0.16	0.11
26.00	1.21	0.00	0.03	2.17	0.00	1.00
28.00	0.21	0.00	0.01	0.38	0.00	0.48
28.80	0.75	0.24	0.01	1.35	3.97	0.43

FIDNAJÄKKA Bh 06

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.00	0.51	0.22	0.12	0.93	3.60	4.18
1.50	0.70	0.20	0.06	1.26	3.30	2.27
2.00	0.72	0.18	0.13	1.29	2.96	4.42
2.50	0.98	0.13	0.08	1.76	2.09	2.94
3.00	0.55	0.24	0.16	0.99	3.97	5.67
3.50	0.73	0.18	0.07	1.31	2.96	2.64
4.00	0.49	0.13	0.13	0.88	2.18	4.64
4.50	0.48	0.19	0.04	0.87	3.10	1.52
5.00	0.49	0.25	0.07	0.88	4.10	2.61
5.50	0.80	0.00	0.15	1.45	0.03	5.15
6.00	0.55	0.09	0.14	0.99	1.49	4.76
6.50	0.63	0.18	0.11	1.13	2.97	3.75
7.00	0.74	0.16	0.07	1.33	2.65	2.38
7.50	0.88	0.17	0.07	1.58	2.71	2.49
8.00	0.69	0.13	0.13	1.24	2.13	4.50
8.50	0.62	0.16	0.07	1.12	2.56	2.30
9.00	0.50	0.09	0.05	0.89	1.47	1.73
9.50	0.23	0.10	0.05	0.42	1.63	1.79
10.00	0.00	0.22	0.03	0.00	3.64	1.00
10.50	0.00	0.18	0.05	0.00	2.85	1.71
11.00	0.06	0.19	0.03	0.11	3.10	0.88
11.50	0.19	0.20	0.04	0.34	3.17	1.27
12.00	1.58	0.20	0.08	2.84	3.25	2.69
12.50	0.29	0.25	0.03	0.53	4.02	0.96
13.00	0.52	0.30	0.01	0.94	4.80	0.45
13.50	2.02	0.08	0.08	3.63	1.33	2.67
14.00	2.44	0.01	0.12	4.39	0.15	4.06
14.50	2.41	0.09	0.14	4.34	1.51	5.07
15.00	2.35	0.16	0.06	4.22	2.67	2.18
15.50	0.14	0.34	0.00	0.26	5.45	0.06
16.00	2.55	0.09	0.10	4.60	1.43	3.40
16.50	1.37	0.03	0.09	2.47	0.53	3.15
17.00	0.87	0.10	0.06	1.57	1.55	2.02
17.50	2.27	0.14	0.07	4.08	2.22	2.47
18.00	2.91	0.10	0.11	5.24	1.69	3.95
18.50	2.68	0.01	0.09	4.82	0.20	3.04
19.00	1.24	0.13	0.10	2.23	2.07	3.46
19.50	1.32	0.15	0.07	2.38	2.38	2.58
20.00	0.83	0.18	0.04	1.49	2.94	1.52
20.50	1.75	0.24	0.10	3.14	3.83	3.66
21.00	2.14	0.16	0.08	3.86	2.58	2.93
21.50	2.19	0.20	0.06	3.94	3.23	2.29
22.00	2.00	0.17	0.13	3.61	2.80	4.59
22.50	1.38	0.24	0.06	2.48	3.90	2.15
23.00	1.73	0.19	0.11	3.12	3.13	3.73
23.50	1.76	0.24	0.06	3.17	3.97	2.15
24.00	1.58	0.16	0.10	2.85	2.65	3.36
24.50	3.37	0.05	0.13	6.06	0.75	4.74
25.00	2.03	0.11	0.08	3.65	1.75	2.93
25.50	0.04	0.33	0.01	0.08	5.33	0.30
26.00	0.00	0.21	0.03	0.00	3.35	1.10
26.50	0.04	0.17	0.04	0.08	2.68	1.51
27.00	0.26	0.18	0.02	0.47	2.90	0.77
27.50	0.18	0.12	0.01	0.33	2.02	0.21
28.00	0.46	0.23	0.04	0.84	3.72	1.43
28.50	1.74	0.17	0.08	3.14	2.68	2.89
29.00	0.86	0.18	0.04	1.55	2.89	1.25
29.50	1.94	0.14	0.10	3.49	2.19	3.41
30.00	1.95	0.16	0.10	3.51	2.60	3.67
30.50	2.54	0.00	0.10	4.58	0.00	3.59
31.00	2.24	0.05	0.07	4.03	0.81	2.61
31.50	2.04	0.12	0.09	3.68	1.87	3.23
32.00	1.41	0.11	0.09	2.54	1.79	3.03
32.50	2.11	0.07	0.12	3.80	1.15	4.27
33.00	2.16	0.05	0.07	3.89	0.79	2.56
33.50	0.77	0.04	0.04	1.39	0.71	1.44

Stu0609.stp						
34.00	0.77	0.19	0.04	1.39	3.04	1.46
34.50	0.01	0.06	0.07	0.02	0.98	2.29
35.00	0.03	0.16	0.03	0.06	2.56	1.22
35.50	0.22	0.05	0.05	0.40	0.77	1.59
36.00	1.45	0.08	0.07	2.60	1.29	2.52
36.50	1.71	0.03	0.11	3.08	0.53	4.02
37.00	0.71	0.17	0.07	1.28	2.70	2.35
37.50	2.06	0.20	0.05	3.71	3.31	1.87
38.00	1.85	0.15	0.08	3.32	2.36	2.71

Bidj018.stp

BIDJOVAGGE Bh 96-18

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.00	0.90	0.00	0.11	1.62	0.00	3.78
1.20	0.53	0.02	0.20	0.96	0.32	6.99
1.50	0.29	0.36	0.18	0.52	5.86	6.43
1.80	0.03	0.78	0.17	0.05	12.60	6.01
2.00	0.07	0.89	0.18	0.12	14.43	6.43
2.30	0.24	0.89	0.17	0.42	14.43	5.96
2.50	0.00	0.81	0.23	0.00	13.18	8.19
2.80	0.24	0.68	0.27	0.42	11.04	9.67
3.00	0.61	0.56	0.28	1.10	9.08	9.90
3.30	0.07	0.89	0.19	0.13	14.41	6.73
3.50	0.60	0.58	0.21	1.07	9.42	7.45
3.70	0.25	0.62	0.25	0.46	9.99	8.91
4.00	0.39	0.40	0.12	0.70	6.45	4.34
4.30	0.23	0.46	0.12	0.41	7.46	4.39
4.50	0.56	0.32	0.23	1.00	5.24	8.22
4.80	0.05	0.65	0.08	0.08	10.56	2.97
5.00	0.32	0.41	0.10	0.58	6.57	3.38
5.20	0.00	0.69	0.08	0.00	11.20	2.80
5.50	0.23	0.64	0.07	0.41	10.39	2.54
5.80	0.54	0.47	0.16	0.96	7.64	5.52
6.00	0.12	0.55	0.07	0.21	8.98	2.62
6.30	0.63	0.18	0.17	1.14	2.94	6.16
6.70	0.39	0.19	0.15	0.71	3.07	5.35
6.50	0.21	0.33	0.10	0.37	5.31	3.43
7.00	0.30	0.31	0.07	0.53	5.02	2.64
7.30	0.00	0.41	0.06	0.00	6.62	2.18
7.50	0.15	0.35	0.11	0.26	5.70	3.93
7.80	0.45	0.29	0.04	0.80	4.63	1.31
8.00	0.36	0.27	0.04	0.65	4.33	1.28
8.30	0.20	0.39	0.11	0.35	6.25	3.95
8.50	0.51	0.21	0.07	0.92	3.48	2.40
8.80	0.31	0.37	0.12	0.56	6.00	4.33
9.00	0.29	0.36	0.07	0.52	5.76	2.55
9.20	0.19	0.36	0.08	0.34	5.91	2.96
9.50	0.22	0.48	0.09	0.40	7.76	3.15
9.80	0.25	0.37	0.05	0.46	5.98	1.59
10.00	0.31	0.28	0.09	0.55	4.55	3.00
10.20	0.22	0.20	0.06	0.40	3.24	2.19
10.50	0.11	0.12	0.04	0.20	1.98	1.35
10.70	0.23	0.16	0.02	0.41	2.52	0.78
11.00	0.23	0.14	0.07	0.41	2.21	2.62
11.30	0.00	0.35	0.02	0.00	5.72	0.73
11.50	0.36	0.21	0.07	0.64	3.48	2.40
11.60	0.22	0.29	0.08	0.39	4.65	2.73

Bidjo19.stp

BIDJOVAGGE Bh 96-19

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.00	0.54	0.39	0.16	0.97	6.32	5.68
3.00	0.55	0.08	0.08	0.99	1.37	2.68
5.00	0.70	0.08	0.13	1.25	1.26	4.47
7.00	0.76	0.04	0.06	1.36	0.72	2.03
9.00	0.24	0.62	0.17	0.42	10.05	5.89
11.00	0.32	0.70	0.22	0.58	11.35	7.90
13.00	0.33	0.42	0.23	0.60	6.79	8.15
15.00	0.64	0.21	0.26	1.16	3.48	9.10
17.00	0.63	0.35	0.23	1.13	5.71	7.92
19.00	0.51	0.40	0.25	0.92	6.48	8.94
21.00	0.04	0.46	0.23	0.08	7.43	8.14
23.00	0.64	0.19	0.29	1.15	3.03	10.35
25.00	0.80	0.34	0.26	1.44	5.55	9.28
27.00	0.69	0.37	0.23	1.24	6.04	8.23
29.00	0.26	0.48	0.20	0.46	7.79	7.13
31.00	0.28	0.44	0.28	0.51	7.15	9.87
33.00	0.36	0.50	0.24	0.64	8.07	8.32
35.00	0.52	0.45	0.26	0.94	7.34	9.14
37.00	0.14	0.46	0.21	0.26	7.42	7.32
39.00	0.30	0.13	0.33	0.54	2.14	11.68
41.00	0.18	0.33	0.30	0.32	5.28	10.61
43.00	0.01	0.69	0.29	0.01	11.13	10.37
45.00	0.41	0.50	0.25	0.73	8.12	8.95
47.00	0.29	0.61	0.31	0.52	9.90	10.75
49.00	0.60	0.24	0.40	1.09	3.93	14.11
51.00	0.39	0.36	0.25	0.69	5.82	8.91
53.00	0.09	0.15	0.03	0.16	2.46	0.98
55.00	0.30	0.57	0.26	0.54	9.18	9.04
57.00	0.45	0.45	0.30	0.81	7.30	10.58
59.00	0.48	2.73	0.17	0.87	44.26	5.90
60.00	0.03	1.03	0.33	0.06	16.77	11.52
61.00	0.56	1.36	0.27	1.02	22.01	9.52
62.00	0.23	0.86	0.26	0.41	13.97	9.01
63.00	0.10	0.78	0.26	0.18	12.59	9.07
64.00	0.50	1.07	0.26	0.91	17.30	9.13
65.00	0.29	0.06	0.12	0.53	0.91	4.33
66.00	0.10	0.64	0.18	0.18	10.42	6.33
67.00	0.00	0.46	0.18	0.00	7.40	6.46
68.00	0.23	0.20	0.01	0.41	3.26	0.39
69.00	0.04	0.51	0.12	0.07	8.22	4.15
70.00	0.25	0.47	0.18	0.45	7.54	6.20
71.00	0.26	0.54	0.24	0.46	8.82	8.45
72.00	0.16	0.49	0.22	0.28	7.95	7.69
73.00	0.33	0.51	0.24	0.59	8.25	8.58
74.00	1.05	0.40	0.24	1.89	6.43	8.48
75.00	0.23	0.63	0.19	0.41	10.21	6.76
76.00	0.01	0.66	0.19	0.03	10.71	6.83
77.00	0.05	0.50	0.31	0.09	8.12	10.76
78.00	0.00	1.06	0.23	0.00	17.19	8.12
79.00	0.00	0.64	0.27	0.00	10.39	9.50
80.00	0.00	0.57	0.17	0.00	9.29	6.09
81.00	0.14	0.55	0.13	0.25	8.91	4.75
82.00	0.00	0.84	0.13	0.00	13.54	4.67
83.00	0.58	1.71	0.04	1.04	27.78	1.35
83.50	0.92	0.84	0.13	1.65	13.57	4.52
84.00	1.55	1.25	0.17	2.79	20.20	5.91
84.50	0.60	0.50	0.05	1.08	8.16	1.61
85.00	0.36	0.54	0.08	0.65	8.70	2.85
85.50	6.12	4.16	0.04	11.02	67.51	1.39
86.00	0.61	0.17	0.01	1.10	2.74	0.47
86.50	0.48	0.06	0.01	0.86	0.93	0.27
87.00	0.17	0.04	0.01	0.31	0.58	0.37
87.50	0.34	0.03	0.01	0.60	0.45	0.22
88.00	0.21	0.00	0.01	0.37	0.08	0.46

BLEIKVASSLI Bh 30-95

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
4.00	2.21	0.60	1.02	3.97	9.71	36.00
7.00	0.93	1.30	1.30	1.68	21.14	45.60
10.00	1.03	0.81	1.88	1.85	13.16	66.12
13.00	1.89	0.51	1.63	3.40	8.27	57.20
16.00	1.19	0.65	1.54	2.14	10.52	54.27
19.00	1.06	0.43	2.03	1.91	6.91	71.39
22.00	1.03	0.99	1.49	1.85	16.08	52.58
25.00	1.23	0.88	1.30	2.22	14.19	45.77
28.00	1.79	1.19	1.74	3.22	19.36	61.20
31.00	0.81	0.78	1.24	1.45	12.61	43.82
34.00	1.07	1.80	1.63	1.92	29.11	57.35
37.00	1.67	1.15	1.66	3.01	18.71	58.48
40.00	2.11	0.76	1.52	3.79	12.32	53.60
43.00	1.90	0.25	0.57	3.41	4.13	19.93
43.50	2.47	0.54	0.64	4.44	8.68	22.55
44.00	2.28	0.49	0.66	4.10	7.97	23.38
44.50	1.73	0.65	0.52	3.12	10.56	18.13
45.00	1.75	0.50	0.87	3.15	8.07	30.73
45.20	0.86	0.78	1.35	1.54	12.63	47.45
45.50	0.57	0.76	0.83	1.03	12.29	29.28
45.80	0.89	1.44	1.25	1.60	23.42	44.09
46.00	1.66	1.13	1.40	2.99	18.39	49.22
46.20	1.60	0.77	1.25	2.88	12.42	43.88
46.50	0.82	1.27	1.40	1.47	20.57	49.17
47.00	1.47	1.05	1.24	2.65	17.02	43.53
48.00	2.83	1.08	1.23	5.09	17.48	43.37
49.00	2.80	1.73	1.43	5.05	28.10	50.48
50.00	1.68	1.50	1.02	3.02	24.39	35.89
51.00	2.82	1.36	2.13	5.08	22.12	74.90
52.00	0.95	2.74	1.57	1.71	44.38	55.43
53.00	1.23	1.59	1.43	2.21	25.69	50.39
54.00	1.32	1.77	1.37	2.37	28.64	48.31
55.00	0.81	1.60	0.99	1.45	26.00	35.02
55.50	0.80	1.43	1.19	1.44	23.16	41.96
56.00	0.88	1.45	1.58	1.58	23.47	55.77
56.20	1.99	1.46	1.25	3.58	23.73	44.05
56.50	1.38	1.71	1.07	2.48	27.77	37.67
56.80	0.89	1.92	1.38	1.60	31.12	48.57
57.00	0.95	1.26	1.42	1.72	20.47	49.89
57.20	0.75	0.79	0.37	1.35	12.75	13.17
57.80	0.66	0.68	0.72	1.18	11.02	25.30
58.00	1.32	0.79	0.94	2.38	12.86	33.11
58.20	1.69	1.18	1.27	3.03	19.13	44.65
58.50	0.88	2.01	1.50	1.58	32.55	52.89
58.80	1.94	1.63	2.15	3.50	26.39	75.77
59.00	1.78	1.24	2.01	3.20	20.16	70.69
60.00	1.79	1.47	1.54	3.22	23.82	54.37
61.00	2.08	1.86	1.10	3.74	30.21	38.85
62.00	1.00	0.80	0.31	1.80	12.93	10.96
63.00	1.94	0.25	0.48	3.49	4.09	16.97
64.00	1.84	0.45	0.37	3.32	7.37	12.90

BLEIKVASSLI Bh 05-86

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
5.00	0.03	0.09	0.00	0.05	1.41	0.00
10.00	0.00	0.03	0.00	0.00	0.45	0.00
15.00	0.00	0.12	0.00	0.00	2.02	0.00
20.00	0.05	0.01	0.01	0.08	0.21	0.31
25.00	3.44	0.35	0.72	6.18	5.67	25.49
30.00	1.72	0.44	0.54	3.10	7.08	18.84
35.00	1.43	0.50	0.35	2.57	8.09	12.48
40.00	1.64	0.46	0.44	2.95	7.39	15.44
50.00	0.51	0.97	1.13	0.93	15.79	39.61
60.00	1.75	0.22	0.22	3.15	3.49	7.60
70.00	2.77	0.32	0.45	4.98	5.16	15.72
80.00	1.40	0.67	1.03	2.51	10.81	36.12
90.00	1.94	1.02	0.75	3.50	16.54	26.28
100.00	1.16	0.91	0.78	2.08	14.67	27.37
110.00	1.68	0.50	0.91	3.02	8.03	31.88
120.00	2.37	0.88	1.05	4.27	14.24	37.09
130.00	2.37	0.53	1.00	4.26	8.57	35.37
140.00	0.78	0.55	1.21	1.41	8.86	42.75
150.00	1.32	0.74	1.55	2.37	12.06	54.49
160.00	1.45	1.23	0.65	2.60	19.92	22.78
170.00	3.32	0.00	1.30	5.98	0.00	45.58
180.00	2.23	0.06	1.11	4.01	1.02	39.16
190.00	2.21	0.61	1.50	3.98	9.81	52.78
200.00	1.55	0.51	1.17	2.79	8.29	41.04
210.00	1.60	0.70	1.18	2.88	11.27	41.63
220.00	1.62	0.55	0.84	2.91	8.89	29.63
230.00	2.07	0.08	1.34	3.73	1.35	47.09
240.00	1.31	0.75	1.24	2.36	12.19	43.68
250.00	1.21	1.70	1.22	2.18	27.56	42.96
260.00	2.17	0.83	1.46	3.91	13.40	51.43
270.00	1.56	1.21	0.53	2.80	19.63	18.70
280.00	3.15	0.82	1.13	5.66	13.32	39.93
290.00	2.67	0.64	0.81	4.81	10.31	28.51
300.00	2.92	0.82	0.94	5.26	13.33	33.15
310.00	3.27	0.55	0.75	5.89	8.86	26.48
320.00	3.13	0.43	0.93	5.64	6.98	32.88

Bul-97.stp

BRUNESBEKKEN Bh 1-97

DEPTH	K (c/s)	U (c/s)	Th (c/s)	K (%)	U (ppm)	Th (ppm)
1.00	0.20	0.01	0.03	0.36	0.23	1.03
3.00	0.19	0.00	0.02	0.34	0.00	0.76
5.00	0.02	0.03	0.02	0.04	0.53	0.85
8.00	0.00	0.05	0.01	0.00	0.78	0.51
11.00	0.15	0.01	0.01	0.27	0.18	0.40
15.00	0.16	0.02	0.01	0.29	0.30	0.40
19.00	0.12	0.01	0.01	0.22	0.23	0.37
23.00	0.21	0.01	0.01	0.38	0.22	0.45
27.00	0.13	0.02	0.01	0.24	0.35	0.37
31.00	0.22	0.03	0.03	0.39	0.49	1.02
33.00	0.19	0.02	0.03	0.34	0.25	1.02
35.00	1.91	0.23	0.19	3.43	3.67	6.80
37.00	2.16	0.00	0.27	3.89	0.00	9.58
39.00	1.34	0.07	0.27	2.41	1.10	9.65
41.00	2.28	0.17	0.32	4.11	2.83	11.10
43.00	0.15	0.08	0.04	0.27	1.33	1.46
45.00	0.31	0.09	0.01	0.56	1.51	0.37
47.00	1.60	0.02	0.14	2.88	0.27	4.86
49.00	0.13	0.05	0.01	0.23	0.80	0.31
51.00	0.29	0.00	0.05	0.52	0.00	1.77
55.00	0.62	0.02	0.08	1.11	0.38	2.85
59.00	0.75	0.16	0.08	1.35	2.63	2.69
63.00	0.14	0.13	0.03	0.25	2.09	1.06
67.00	0.46	0.04	0.06	0.84	0.64	2.10
71.00	0.20	0.12	0.00	0.35	2.00	0.00
75.00	2.18	0.33	0.30	3.92	5.35	10.42
77.00	3.12	0.01	0.32	5.61	0.09	11.21
79.00	3.51	0.00	0.51	6.32	0.00	17.82
81.00	1.70	0.07	0.13	3.05	1.13	4.54
83.00	2.00	0.00	0.29	3.60	0.00	10.09
85.00	1.78	0.15	0.21	3.21	2.41	7.45
87.00	1.73	0.13	0.20	3.12	2.06	7.15
91.00	0.50	0.08	0.03	0.91	1.31	1.15
95.00	2.31	0.00	0.28	4.16	0.00	9.68
97.00	1.40	0.11	0.19	2.53	1.76	6.62
101.00	1.36	0.15	0.23	2.44	2.41	8.01
105.00	1.94	0.00	0.39	3.49	0.00	13.88
109.00	0.27	0.00	0.07	0.49	0.00	2.33
113.00	0.21	0.09	0.00	0.38	1.54	0.00
117.00	0.18	0.09	0.02	0.32	1.44	0.87
121.00	0.14	0.09	0.02	0.26	1.50	0.54
125.00	1.35	0.68	0.25	2.43	11.03	8.77
127.00	1.95	1.67	0.33	3.51	27.06	11.54
129.00	2.10	1.09	0.27	3.77	17.63	9.48
130.00	2.51	1.52	0.37	4.52	24.63	12.88
131.00	1.73	0.33	0.30	3.11	5.40	10.65
132.00	1.01	0.17	0.15	1.83	2.73	5.29
133.00	0.55	0.28	0.18	1.00	4.53	6.20
134.00	2.33	0.40	0.57	4.20	6.45	20.00
135.00	1.50	0.48	0.25	2.70	7.85	8.97
136.00	0.78	0.30	0.18	1.41	4.87	6.35
137.00	0.50	0.18	0.15	0.90	2.88	5.16
138.00	0.44	0.42	0.12	0.79	6.80	4.34
138.50	1.47	0.40	0.25	2.65	6.44	8.82
139.00	1.31	0.52	0.17	2.36	8.35	6.06
139.50	0.97	0.57	0.19	1.74	9.23	6.58
140.00	1.39	0.92	0.35	2.50	14.87	12.24
140.50	2.78	1.08	0.39	5.00	17.45	13.65
141.00	1.92	1.30	0.39	3.46	21.10	13.73
141.50	1.70	1.00	0.31	3.05	16.26	10.82
142.00	1.17	0.33	0.24	2.10	5.36	8.40
143.00	1.76	0.55	0.35	3.16	8.98	12.34
144.00	1.45	0.40	0.23	2.61	6.49	8.19
144.50	1.27	0.82	0.26	2.28	13.21	9.04
145.00	0.42	0.55	0.12	0.76	8.87	4.08
145.50	1.28	0.45	0.23	2.30	7.37	7.95

			Bul-97.stp			
146.00	0.73	0.24	0.19	1.31	3.94	6.71
146.50	0.70	0.34	0.06	1.26	5.50	2.01
146.80	0.64	0.37	0.11	1.16	6.01	4.00
147.00	1.13	0.16	0.22	2.03	2.66	7.79
147.30	0.87	0.50	0.11	1.57	8.10	3.94
147.50	0.97	0.44	0.29	1.75	7.14	10.13
147.70	1.00	0.46	0.15	1.79	7.44	5.31
148.00	1.63	0.87	0.27	2.93	14.06	9.53
148.50	1.26	0.48	0.25	2.28	7.82	8.78
149.00	2.36	0.74	0.48	4.25	11.98	16.97
149.50	1.88	1.08	1.13	3.38	17.53	39.60
150.00	2.14	1.12	1.45	3.84	18.14	51.13
150.50	2.26	1.09	1.13	4.07	17.60	39.91
151.00	2.27	1.58	0.44	4.08	25.60	15.57
151.50	2.53	0.28	0.41	4.55	4.57	14.39
152.00	2.96	0.29	0.42	5.32	4.71	14.72
152.50	2.48	0.53	0.38	4.47	8.60	13.28
153.00	2.61	0.25	0.43	4.70	4.12	15.11
153.50	2.63	0.46	0.42	4.73	7.46	14.73
154.00	2.42	0.23	0.47	4.36	3.70	16.51

Maps and figures.

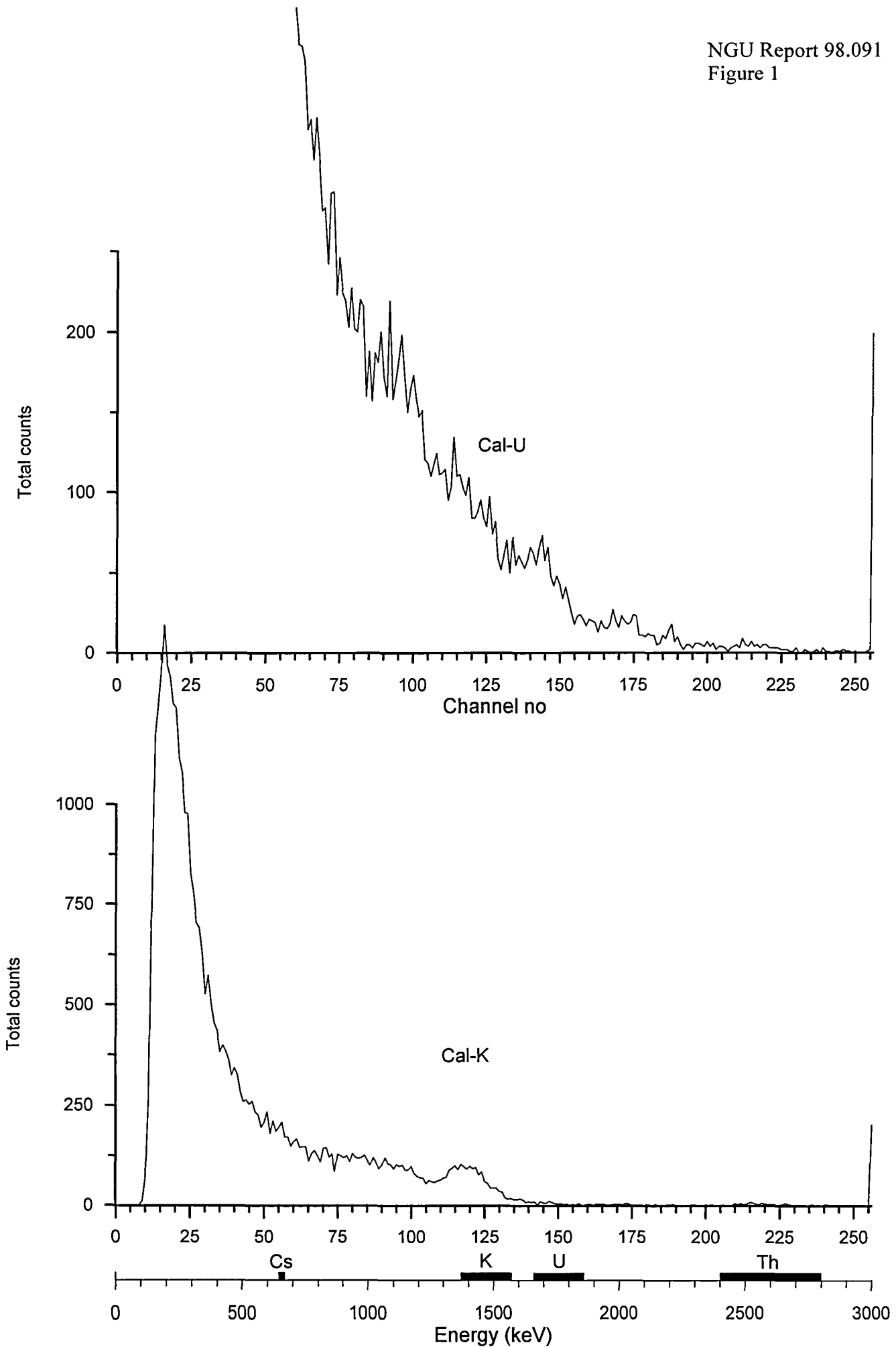


Figure 1, Summed spectra Pad measurements, U-pad (above), K-pad (below)

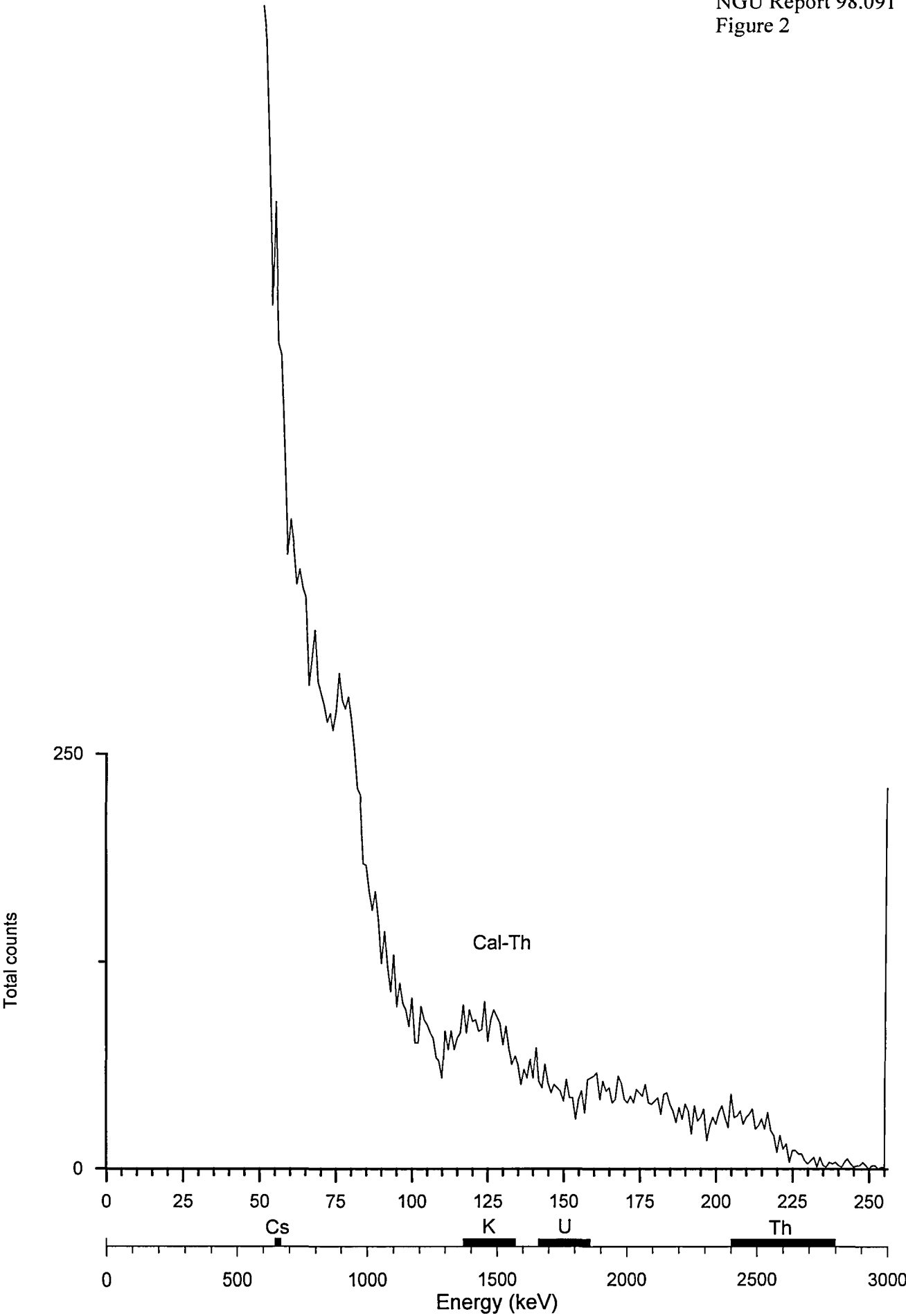


Figure 2, Summed spectra Pad measurements, Th-pad

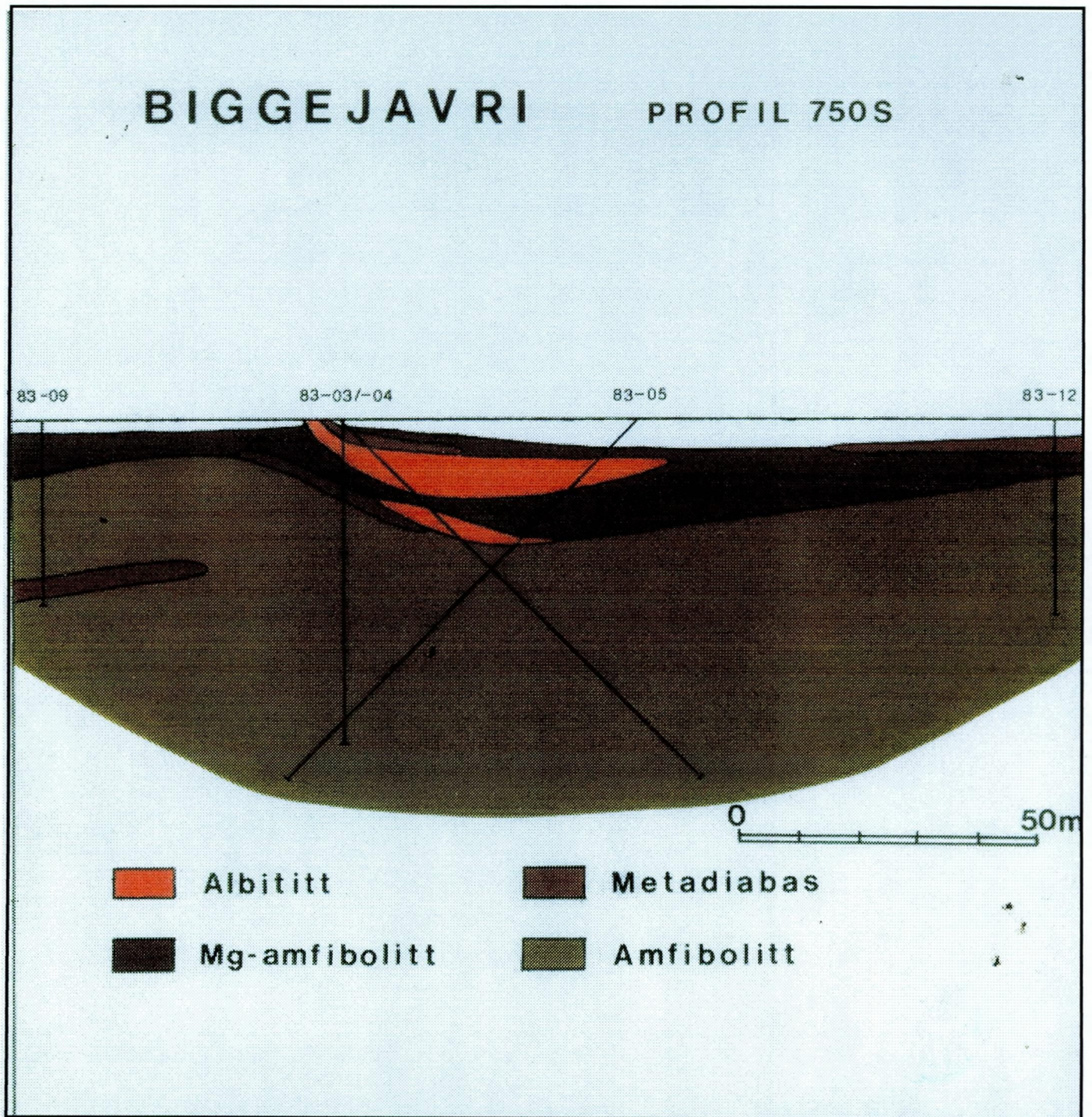


Figure 3. Biggejavre, crosssection of investigated Sc-deposit

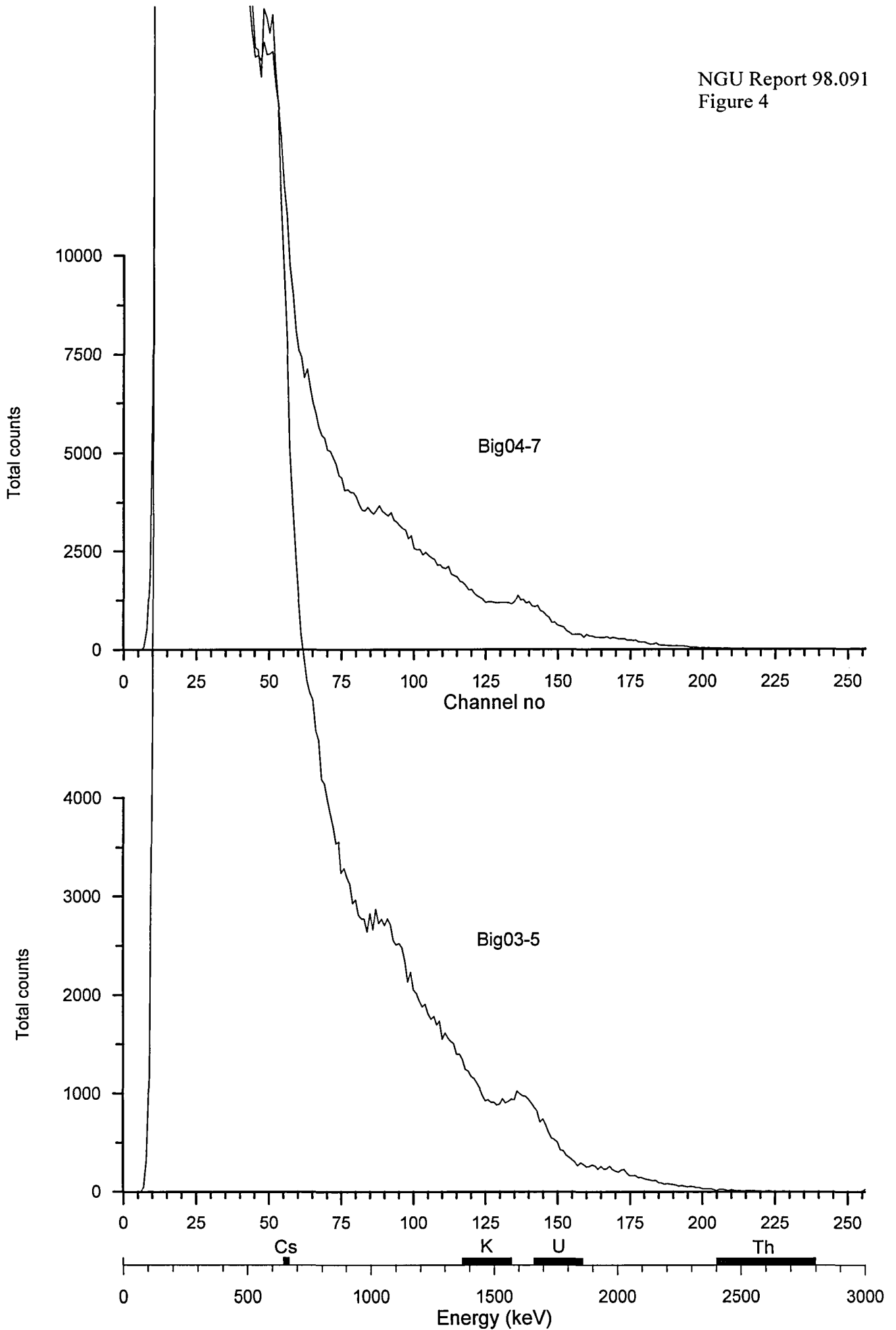


Figure 4, Biggejavre, Summed spectra of Bh 04-83 at 7 m depth (above) and Bh 03-83 at 5 m depth (below).

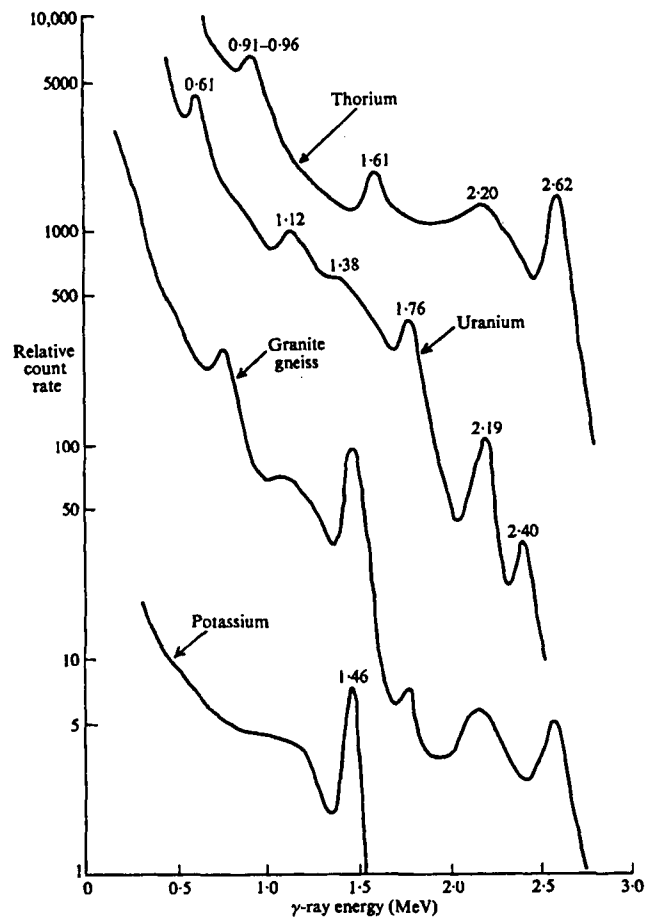


Figure 4 a. Gamma-ray spectra of K, U, Th and granite-gneiss

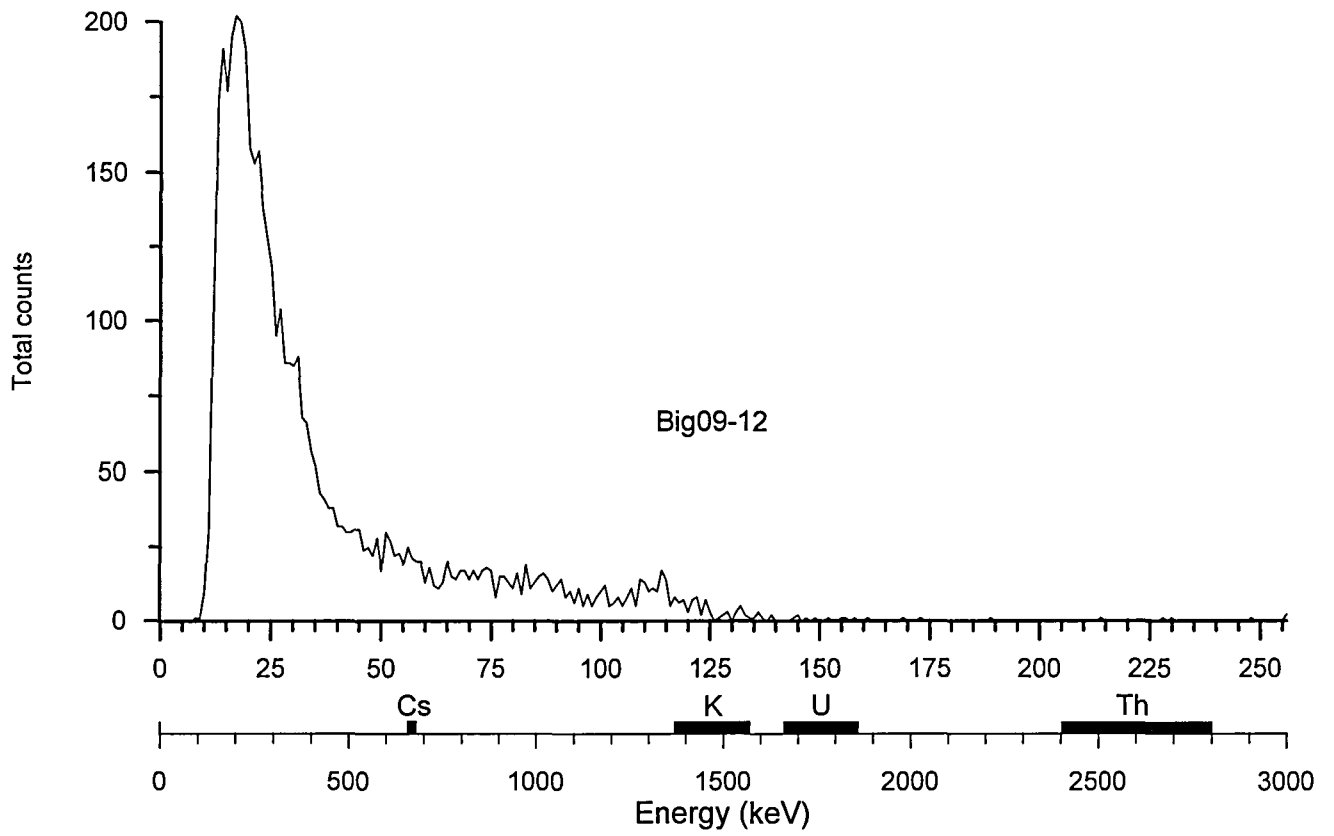


Figure 5, Biggejavre, Summed spectra of Bh 09-83 at 12 m depth.

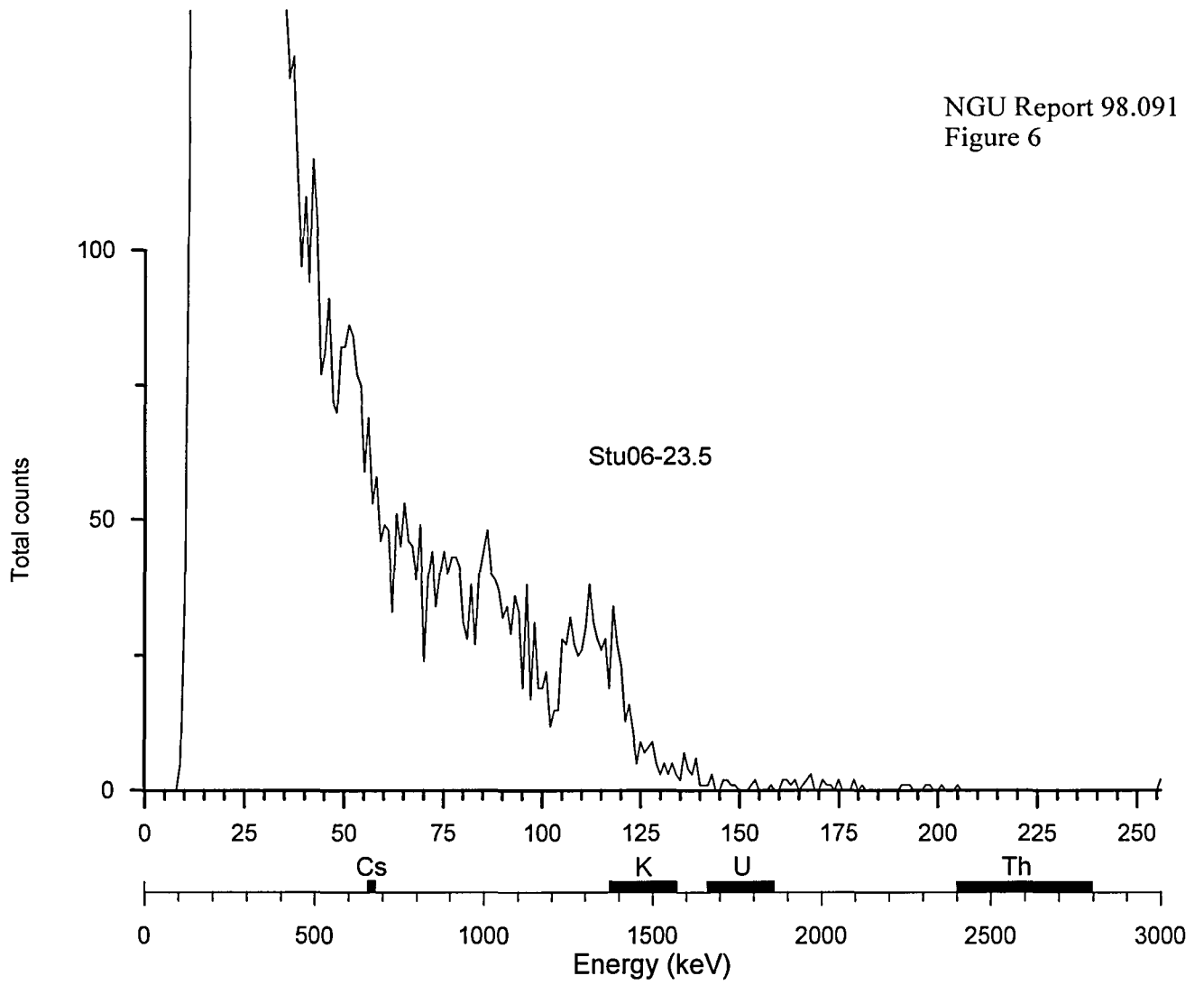


Figure 6, Fidnajokka, Summed spectra of Bh 06 at 24.5 m depth

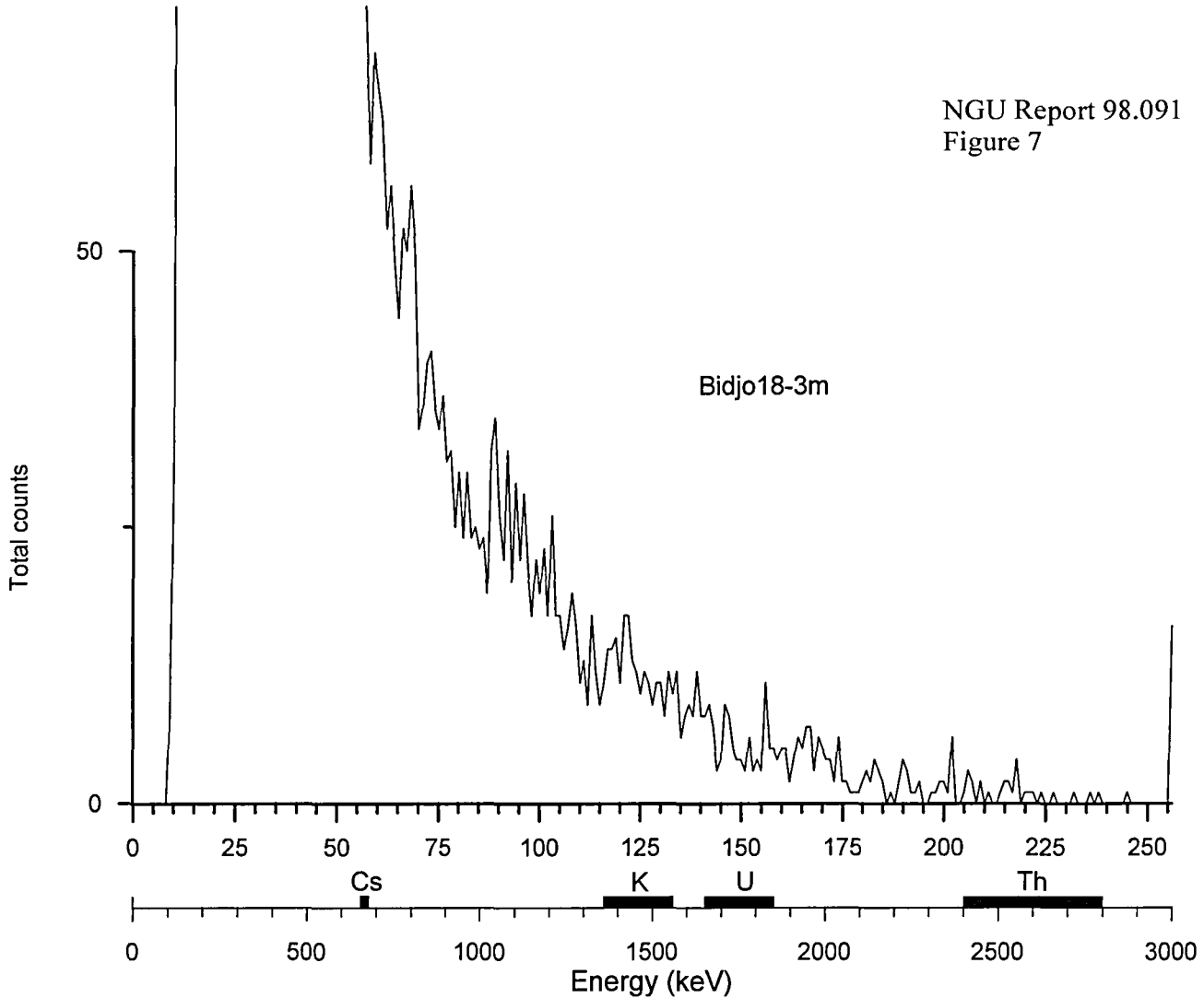


Figure 7, Bidjovagge, Summed spectra of Bh 96-18 at 3 m depth

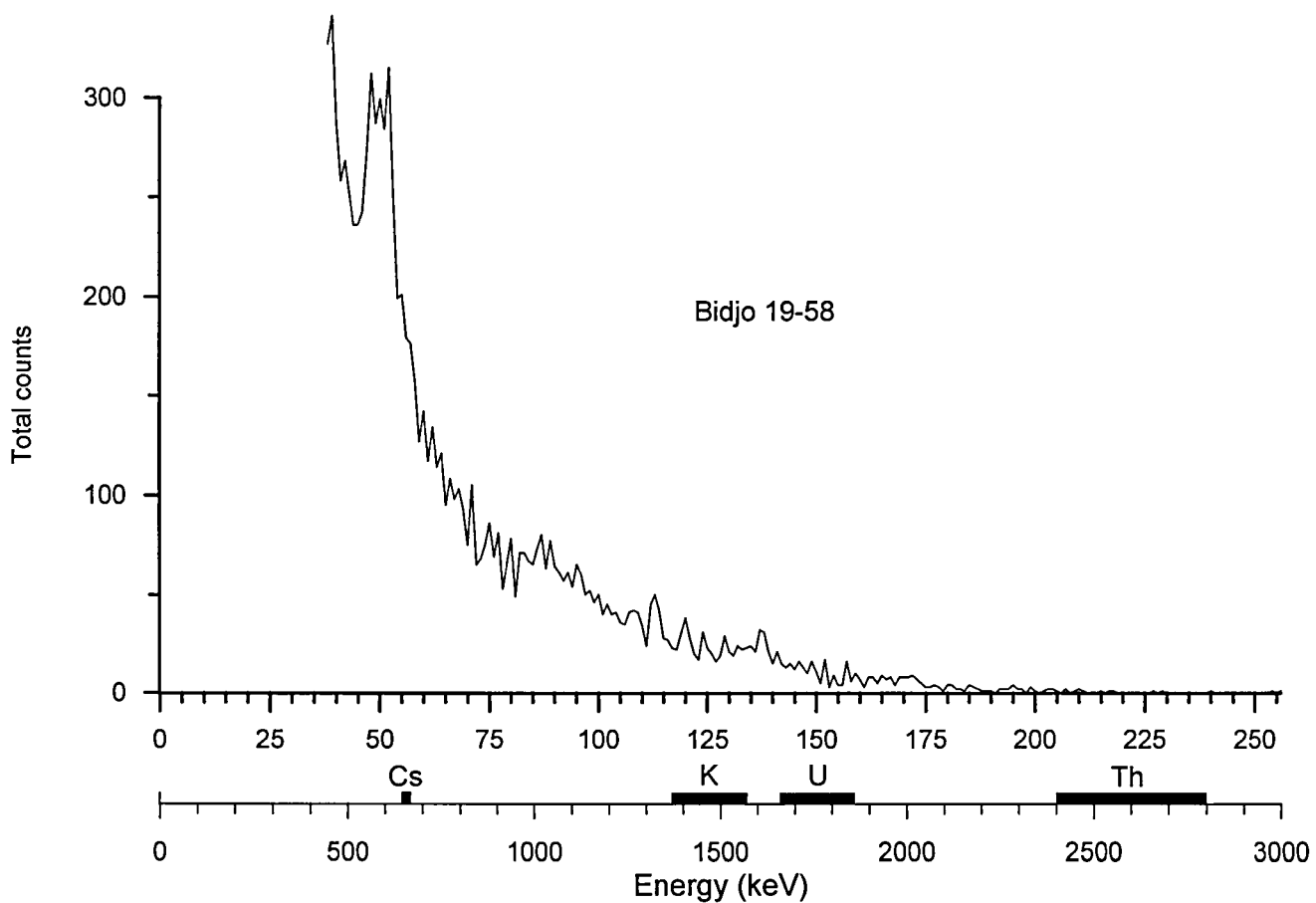
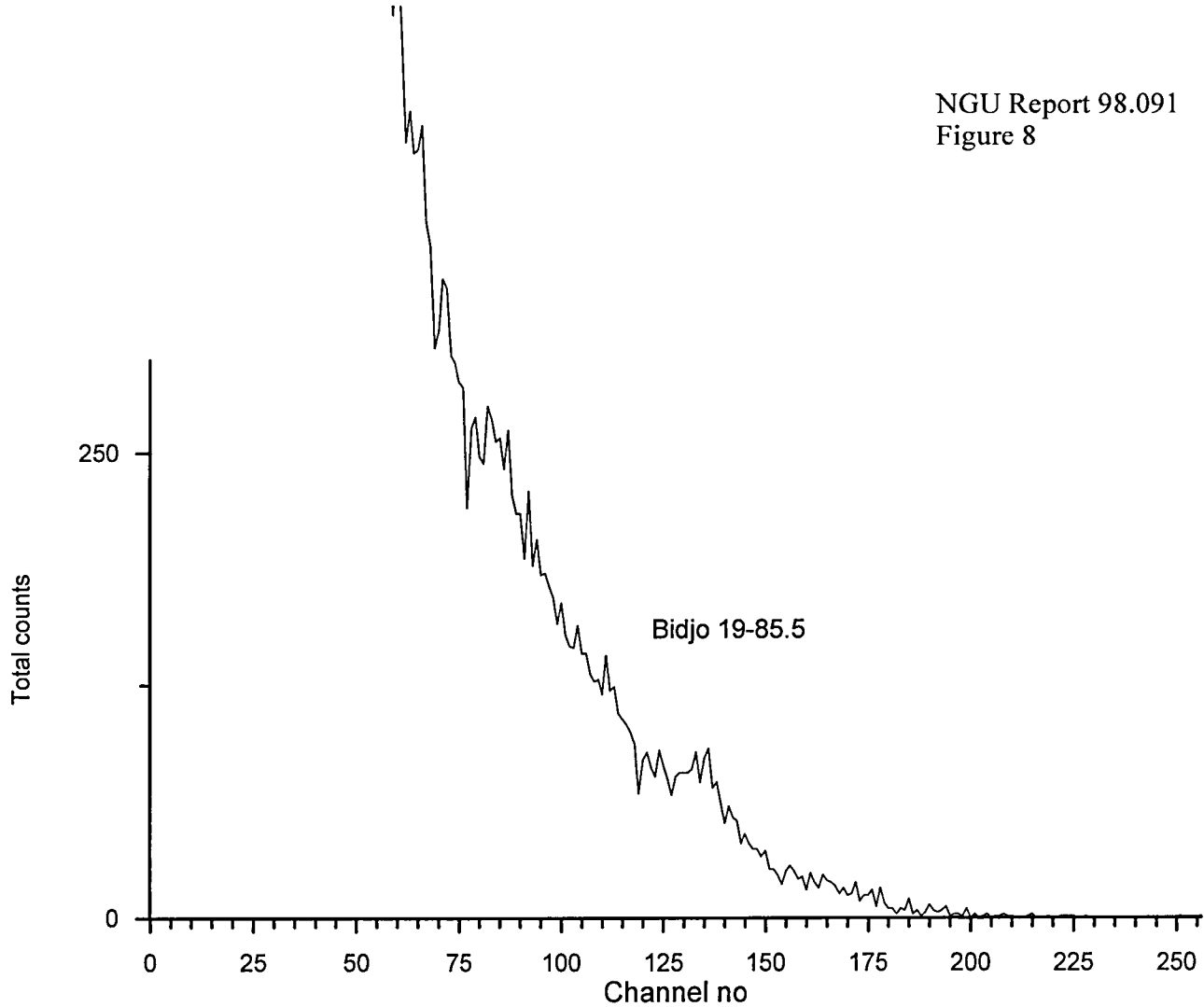


Figure 8, Bidjovagge, Summed spectra of Bh 96-19 at 85.5 m depth (above) and Bh 96-19 at 58 m depth (below)

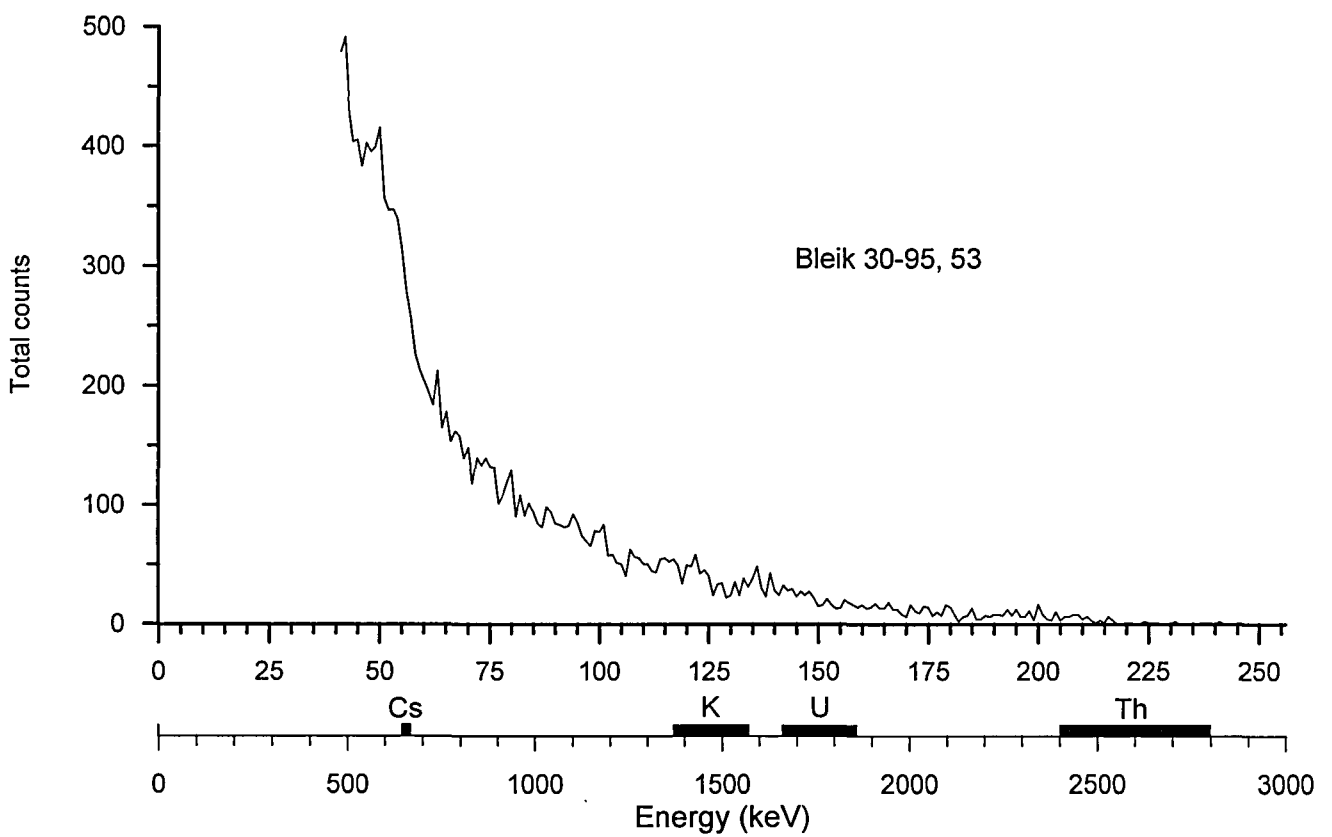
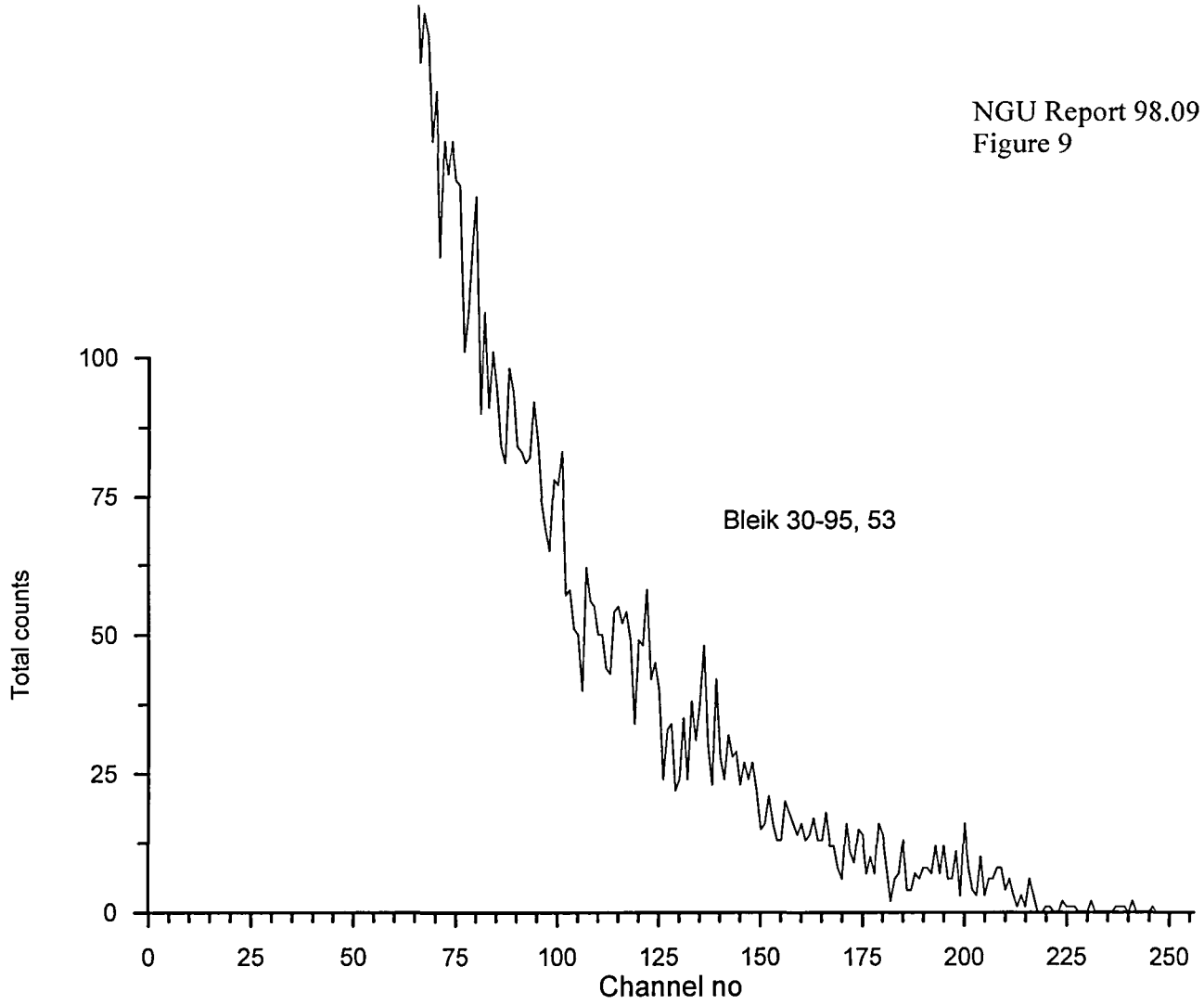


Figure 9, Bleikvassli, Summed spectra of Bh 30-95 at 53 m depth.

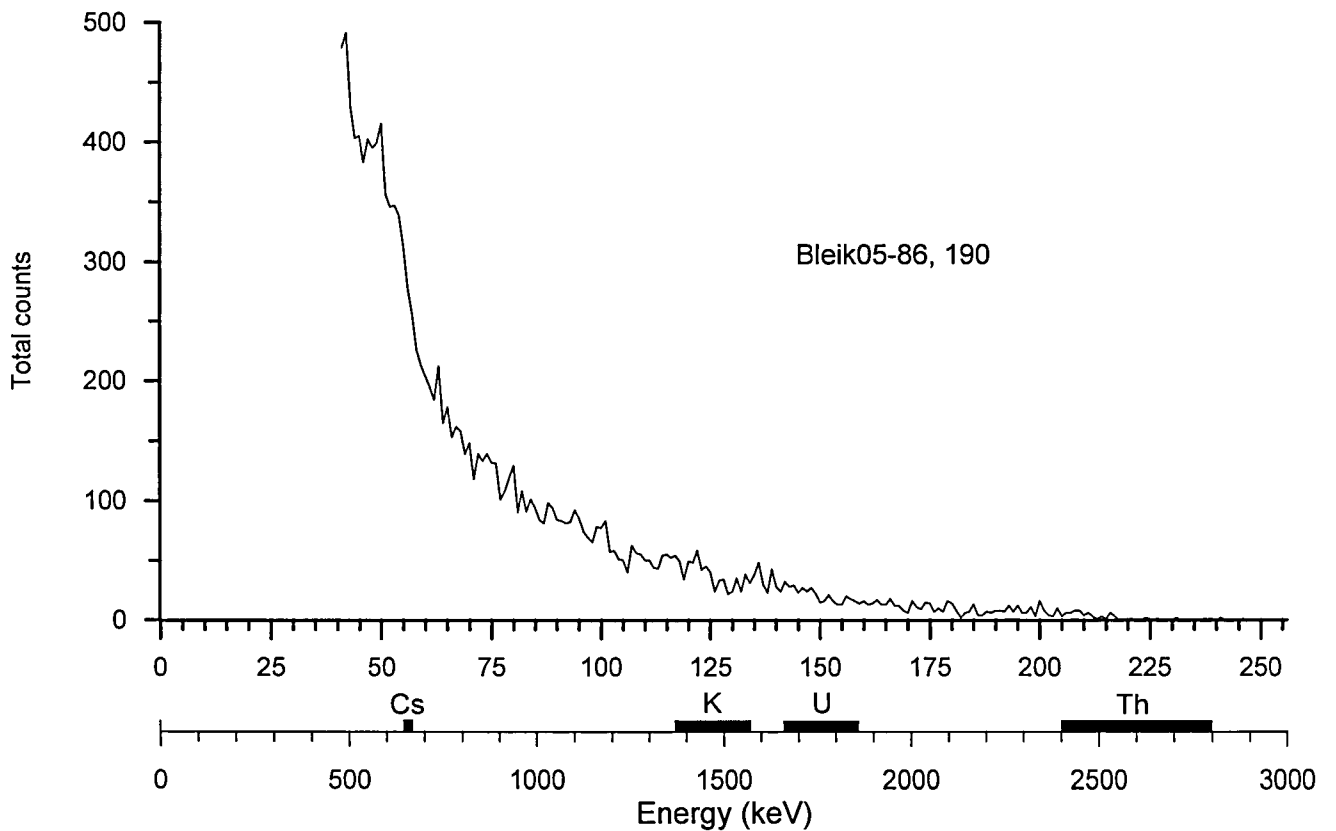
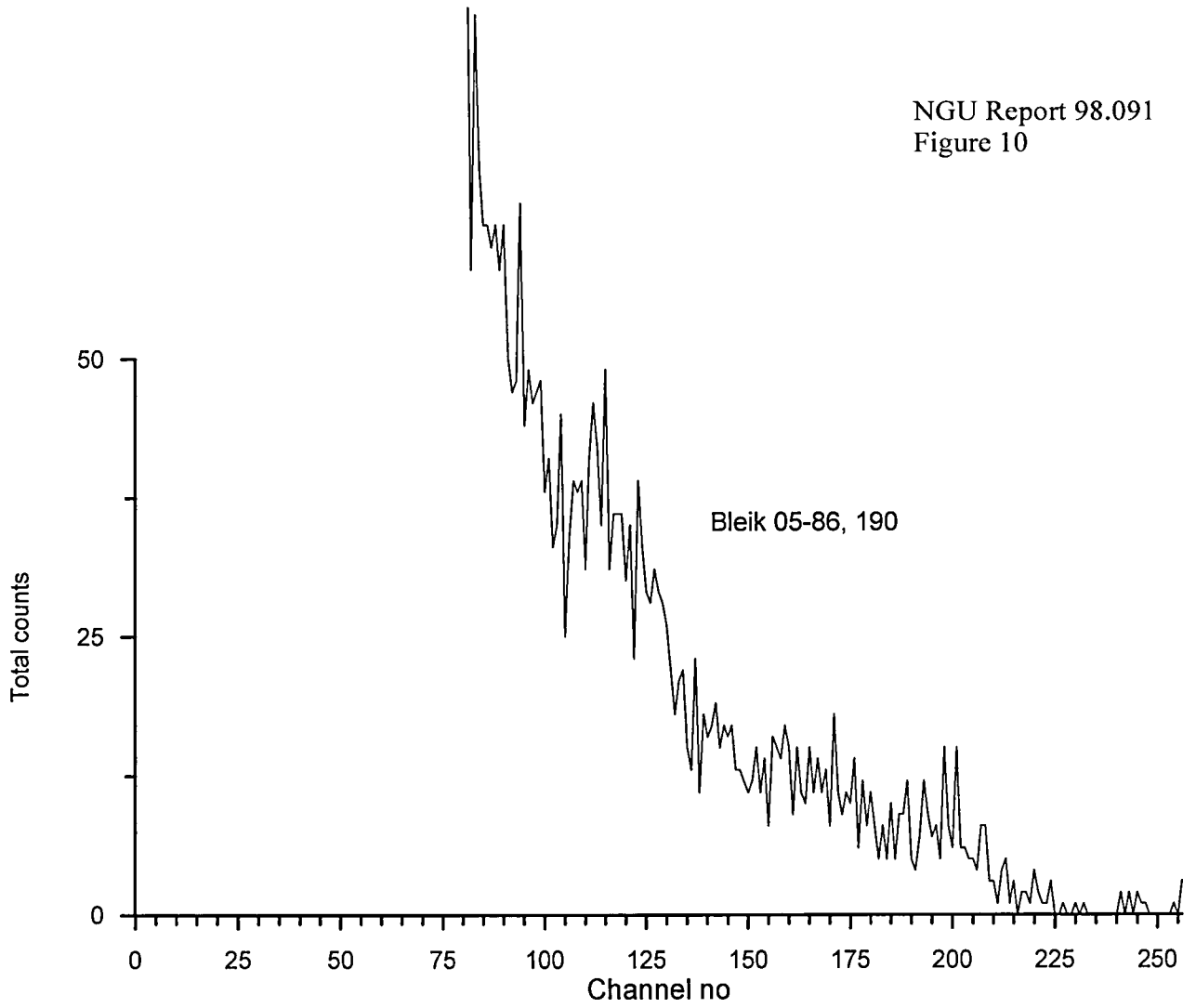


Figure 10, Bleikvassli, Summed spectra of Bh 05-86 at 190 m depth.

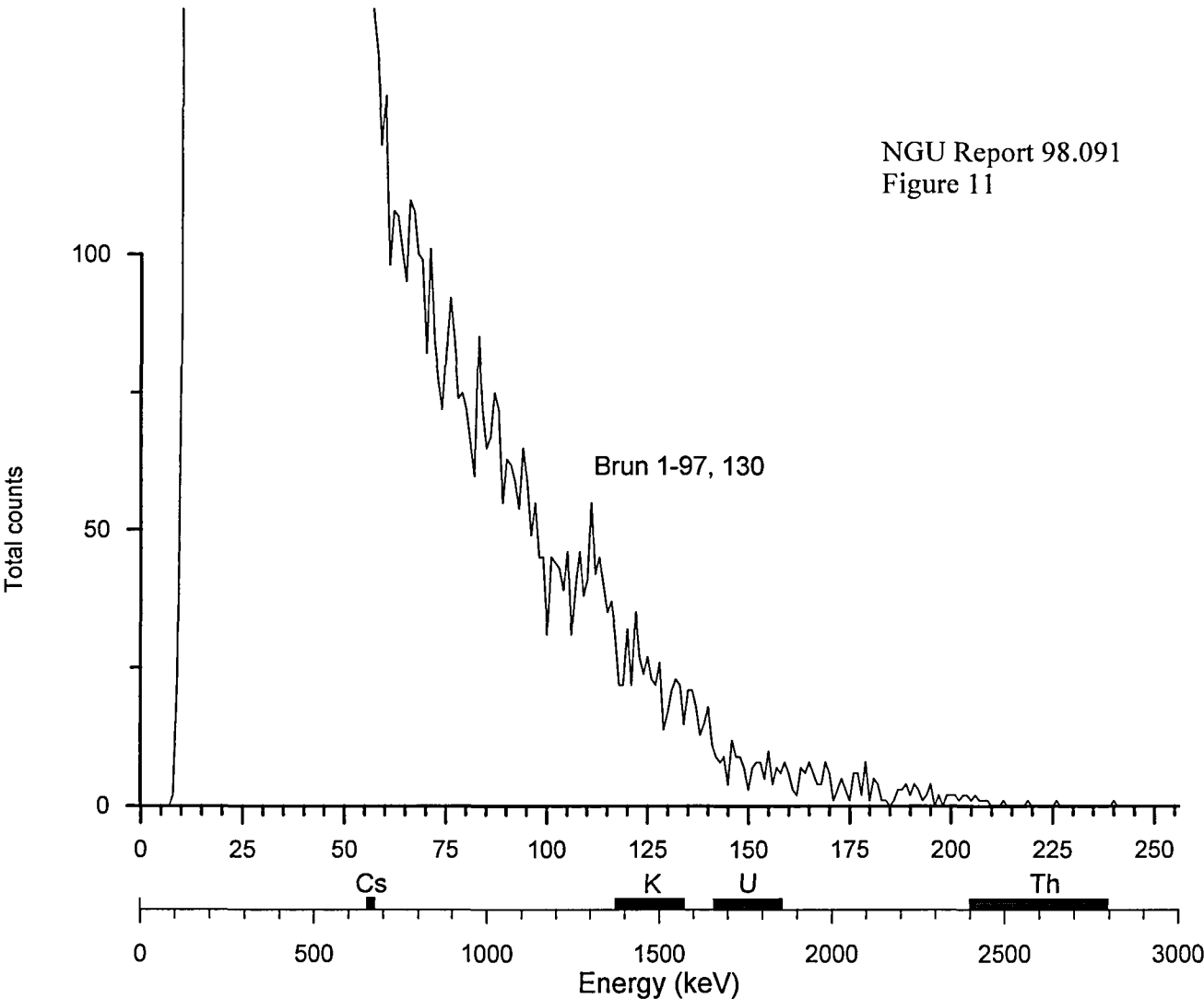
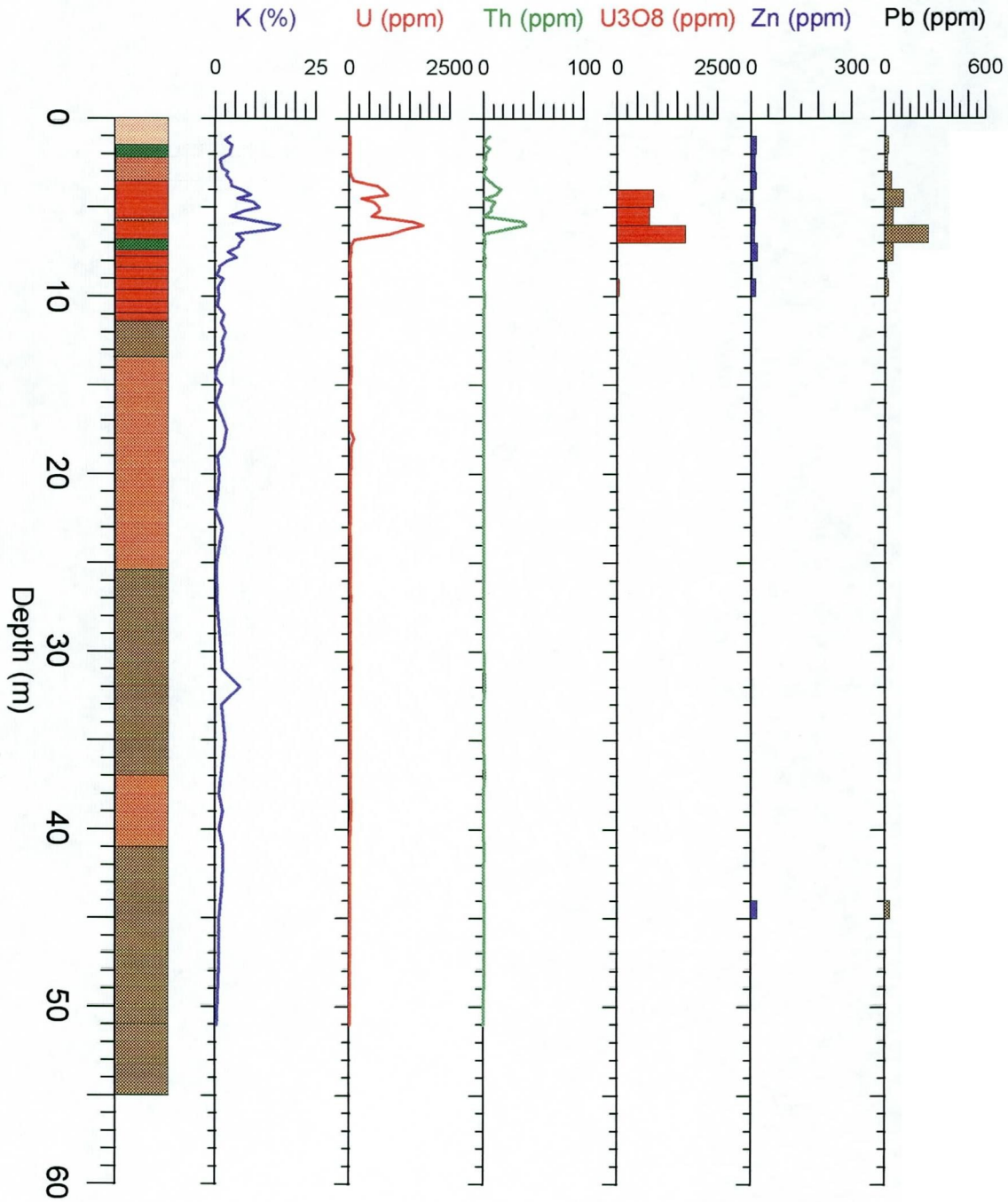


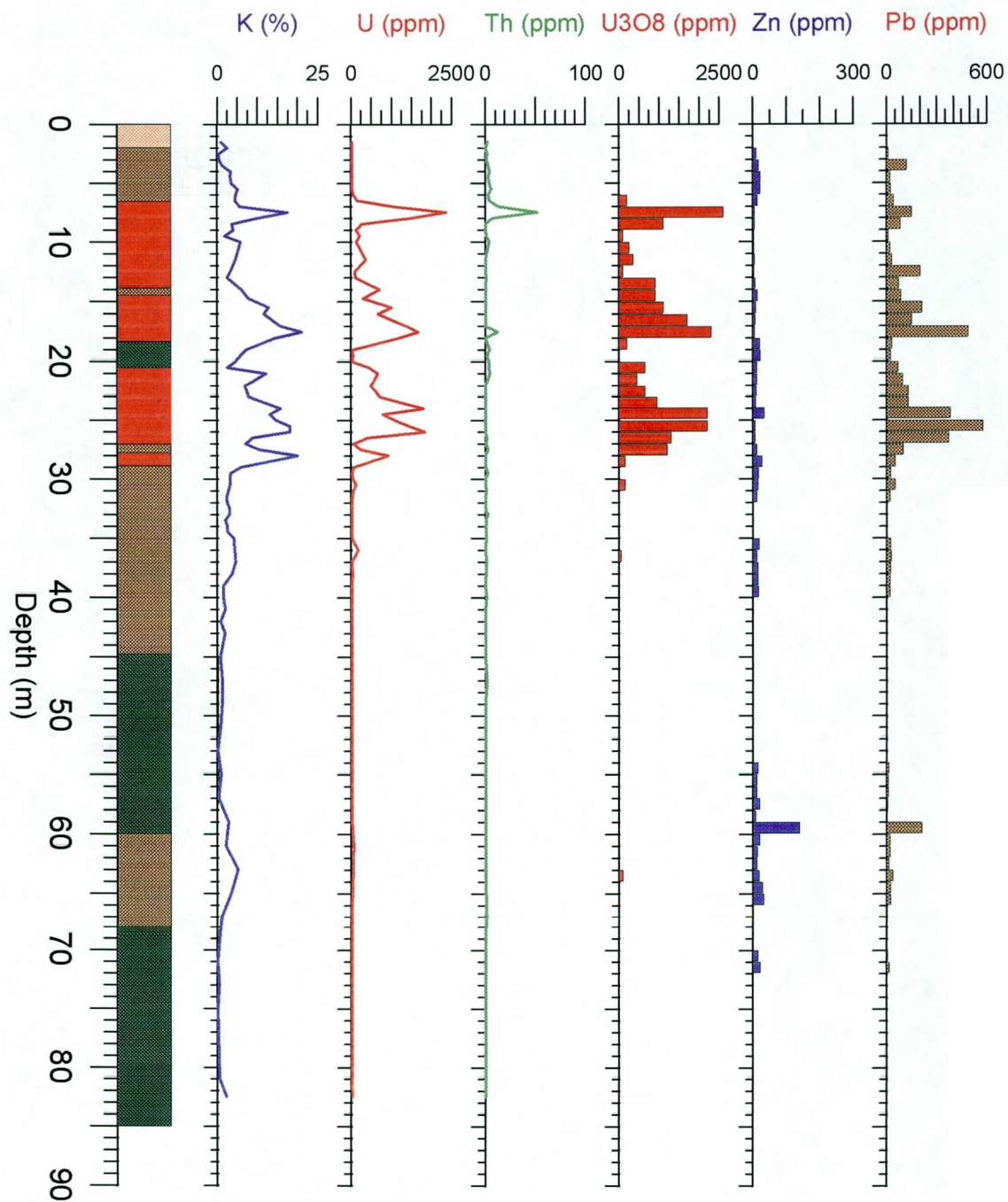
Figure 11, Brunesebeken, Summed spectra of Bh 1-97 at 130 m depth



LEGEND

- Overburden
- Chlorite schist
- Amfibolite with quartz, carbonates, biotite, chlorite
- Albitite
- Chlorite/amfibolite schist
- Amfibolite with chlorite

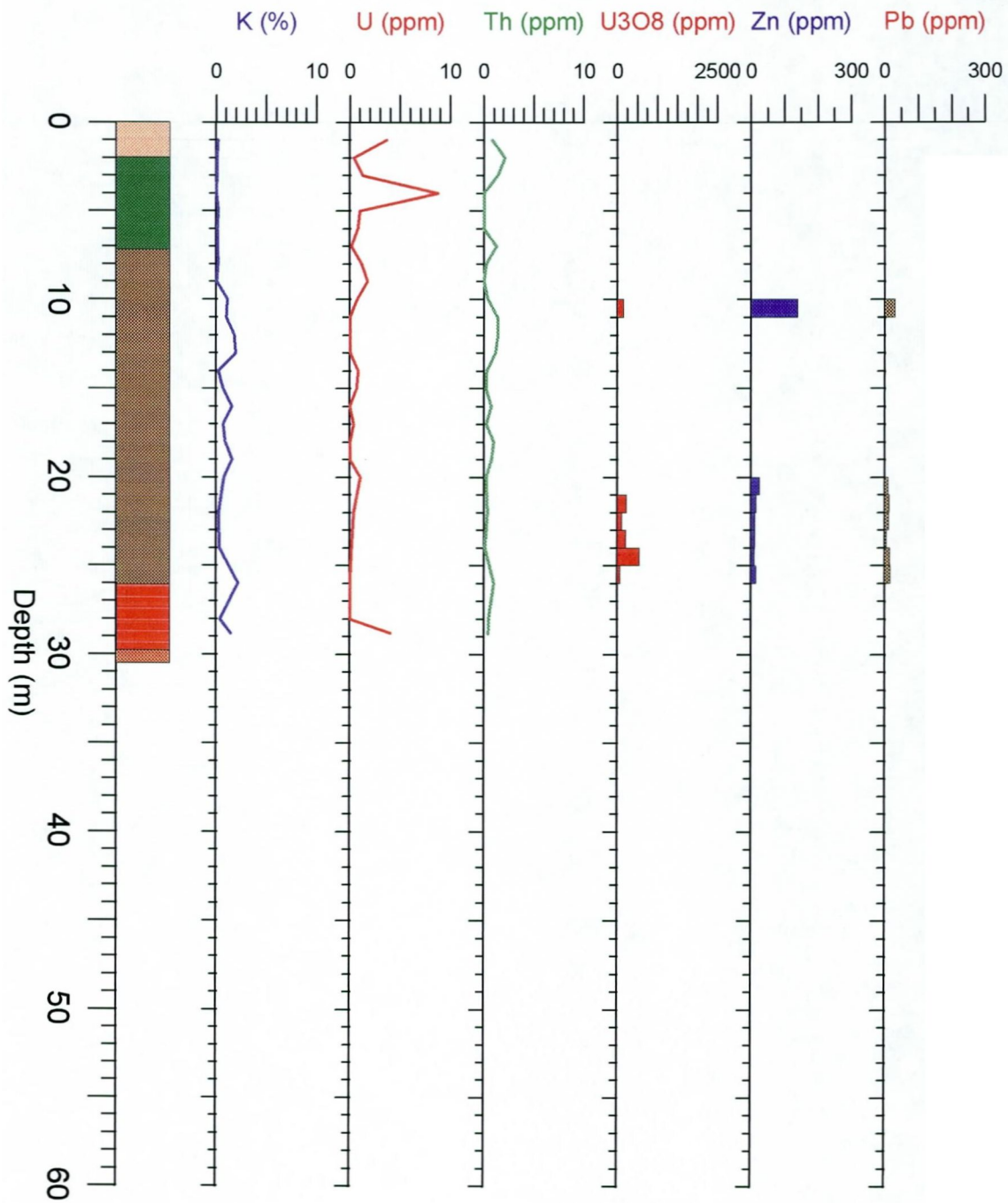
Figure 12. Biggejavre, Gamma-ray spectrometry, Bh 83-03
Calculated concentrations of K, U and Th
U3O8, Zn and Pb content.



LEGEND

- Overburden
- Amfibolite
- Albitite
- Green schist

Figure 13. Biggejavre, Gamma-ray spectrometry, Bh 83-04
Calculated concentrations of K, U and Th
U3O8, Zn and Pb content.



LEGEND

- Overburden
- Chlorite schist
- Amfibolite with chlorite
- Amfibolite with chlorite and diabas
- Amfibolite with quartz, carbonates, biotite

Figure 14. Biggejavre, Gamma-ray spectrometry, Bh 83-09
Calculated concentrations of K, U and Th
Cu, Zn and Pb content.

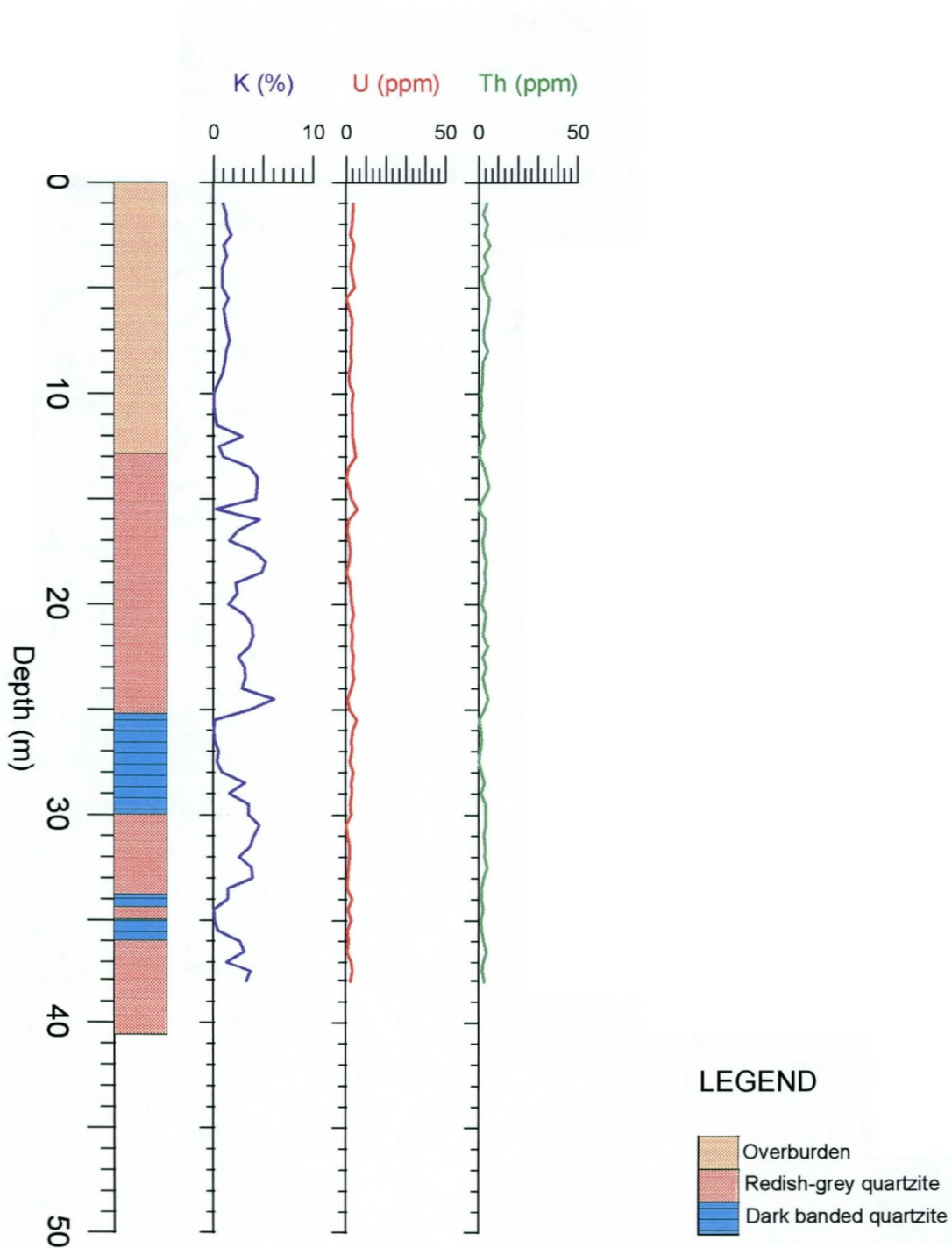


Figure 15. Fidnajokka, Gamma-ray spectrometry, Dh 6
Calculated concentrations of K, U and Th
Geological log of Dh 6.

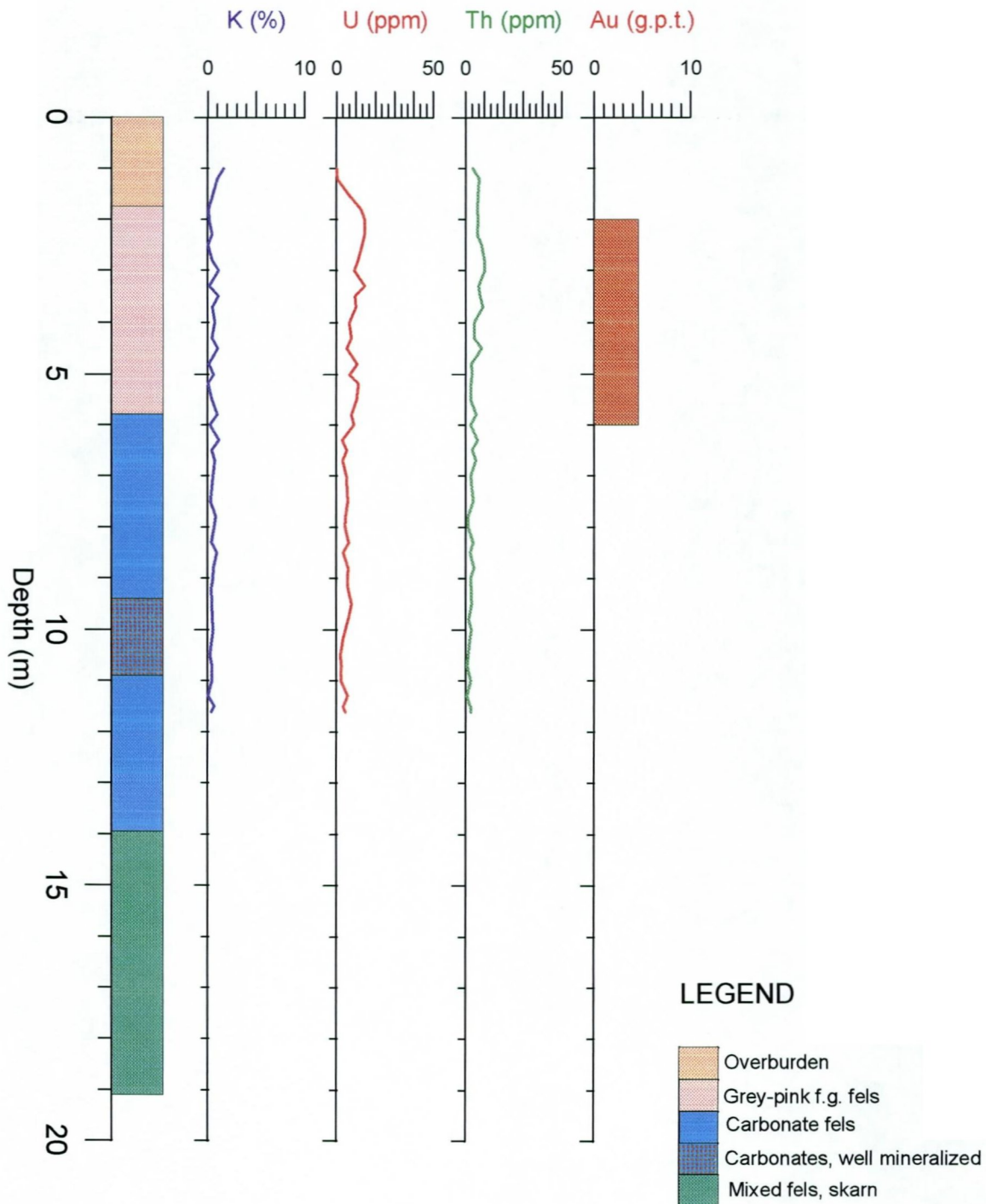


Figure 16. Bidjovagge, Gamma-ray spectrometry, Bh 96-18
Calculated concentrations of K, U and Th
Geological log and Au content.

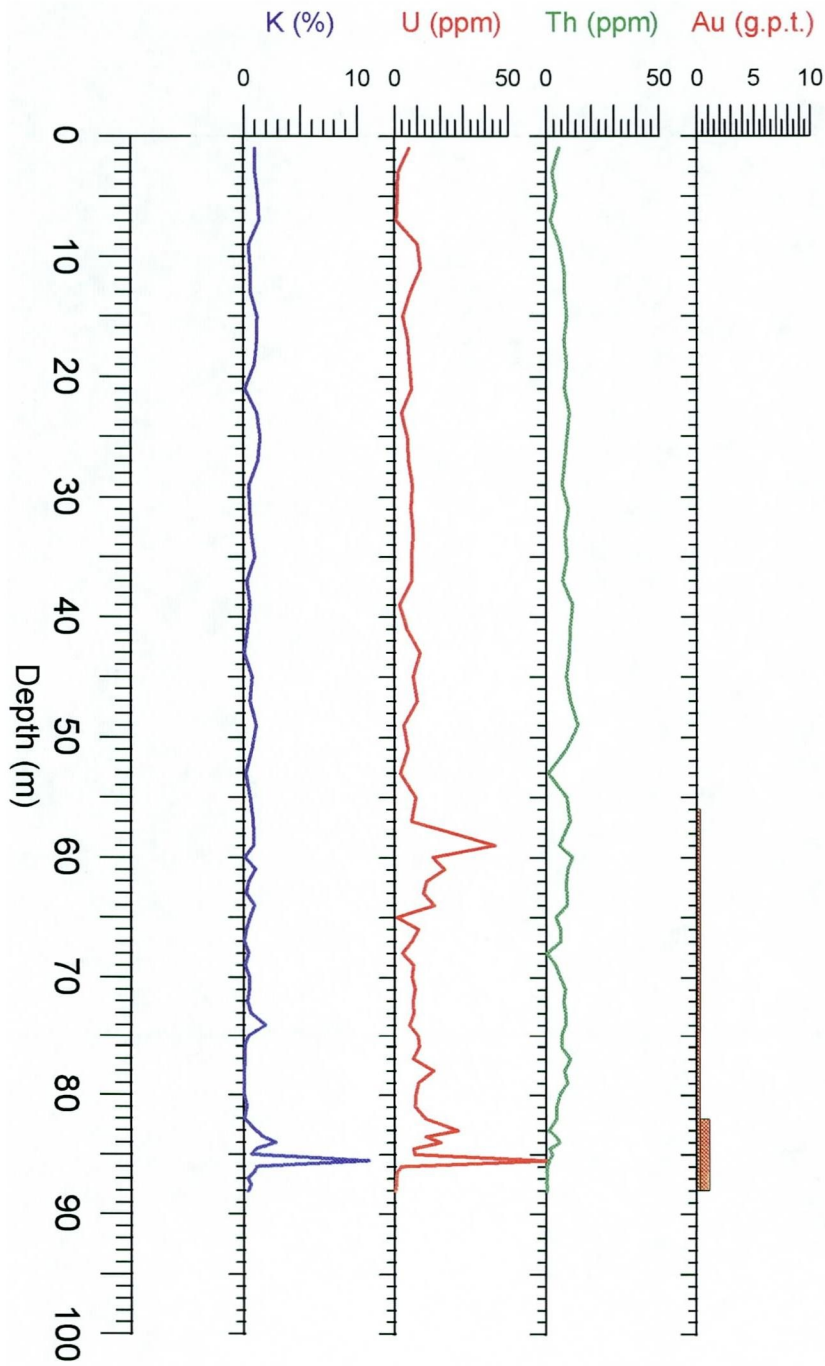
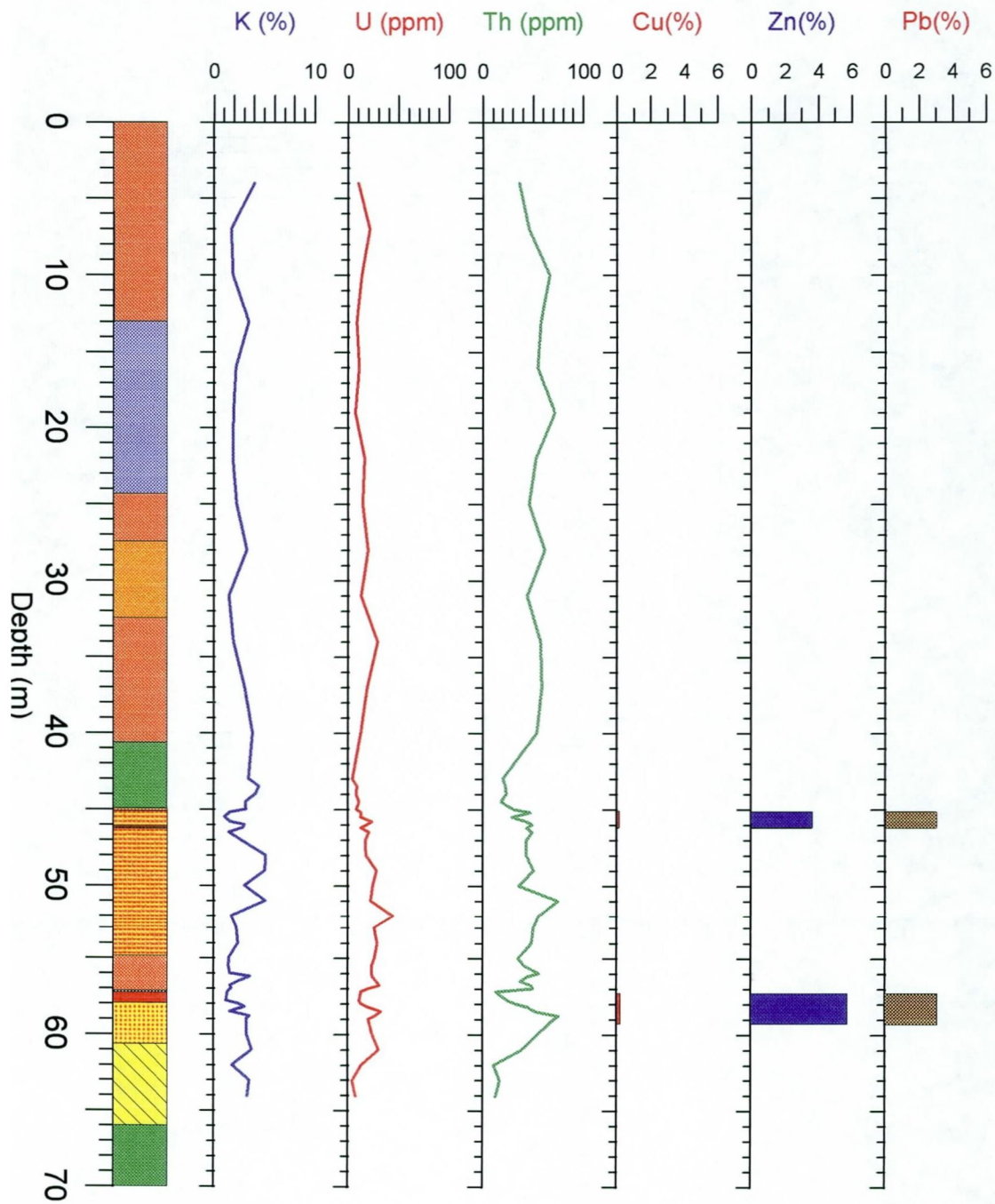


Figure 17. Bidjovagge, Gamma-ray spectrometry, Bh 96-19
Calculated concentrations of K, U and Th
Au content.



LEGEND

- Muscovite/biotite gneiss
- Kyanite gneiss
- Quartzite
- Garnet mica schist
- Muscovite gneiss with disseminated Po/Py
- Quartzitic musc. gneiss with disseminated Po
- Massive pyrite ore
- Musc./biotite gneiss with banded graphite and garnet

Figure 18. Bleikvassli mine, Gamma-ray spectrometry, Bh 30-95
Calculated concentrations of K, U and Th
Cu, Zn and Pb content in ore zone.

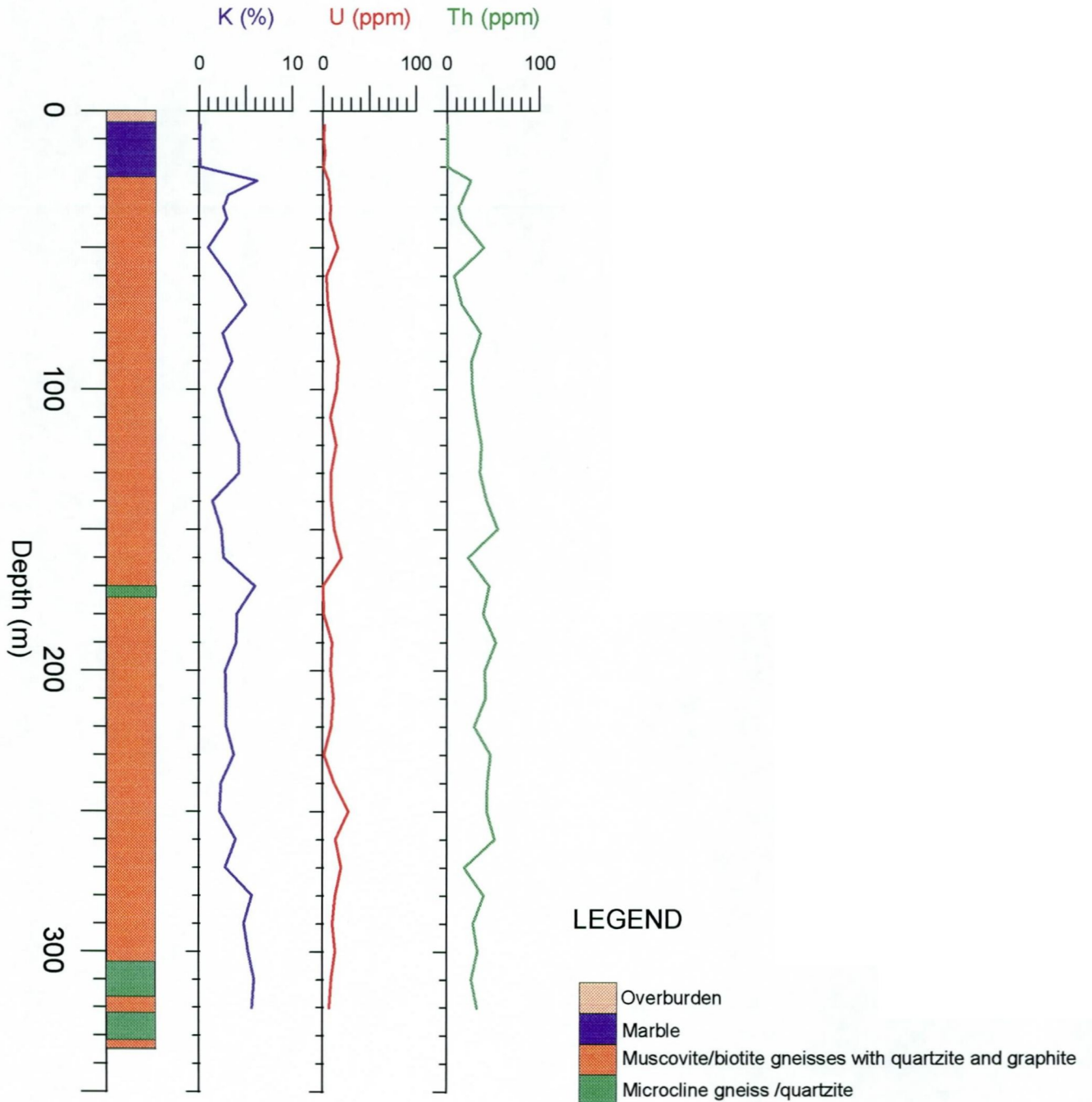
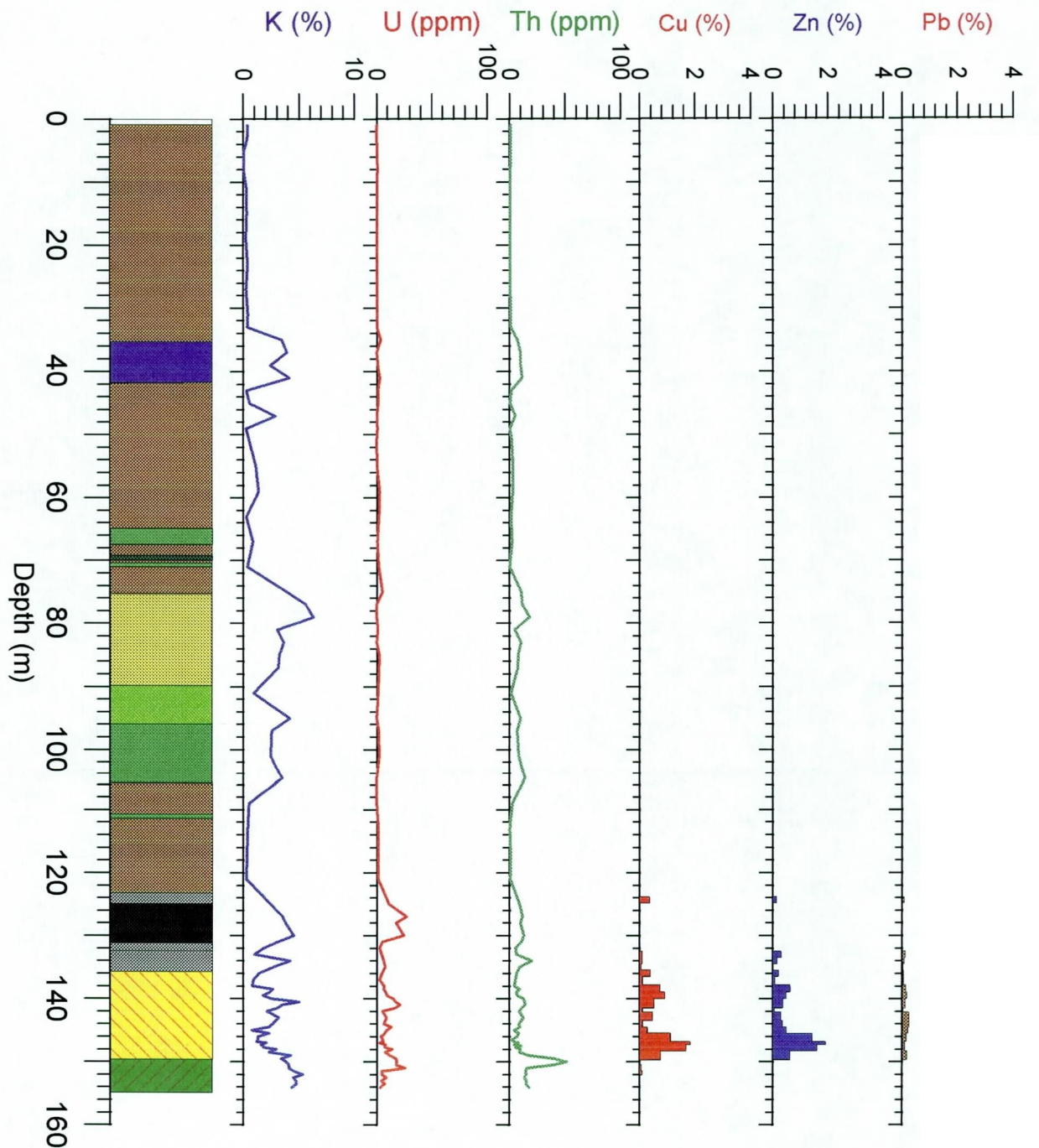


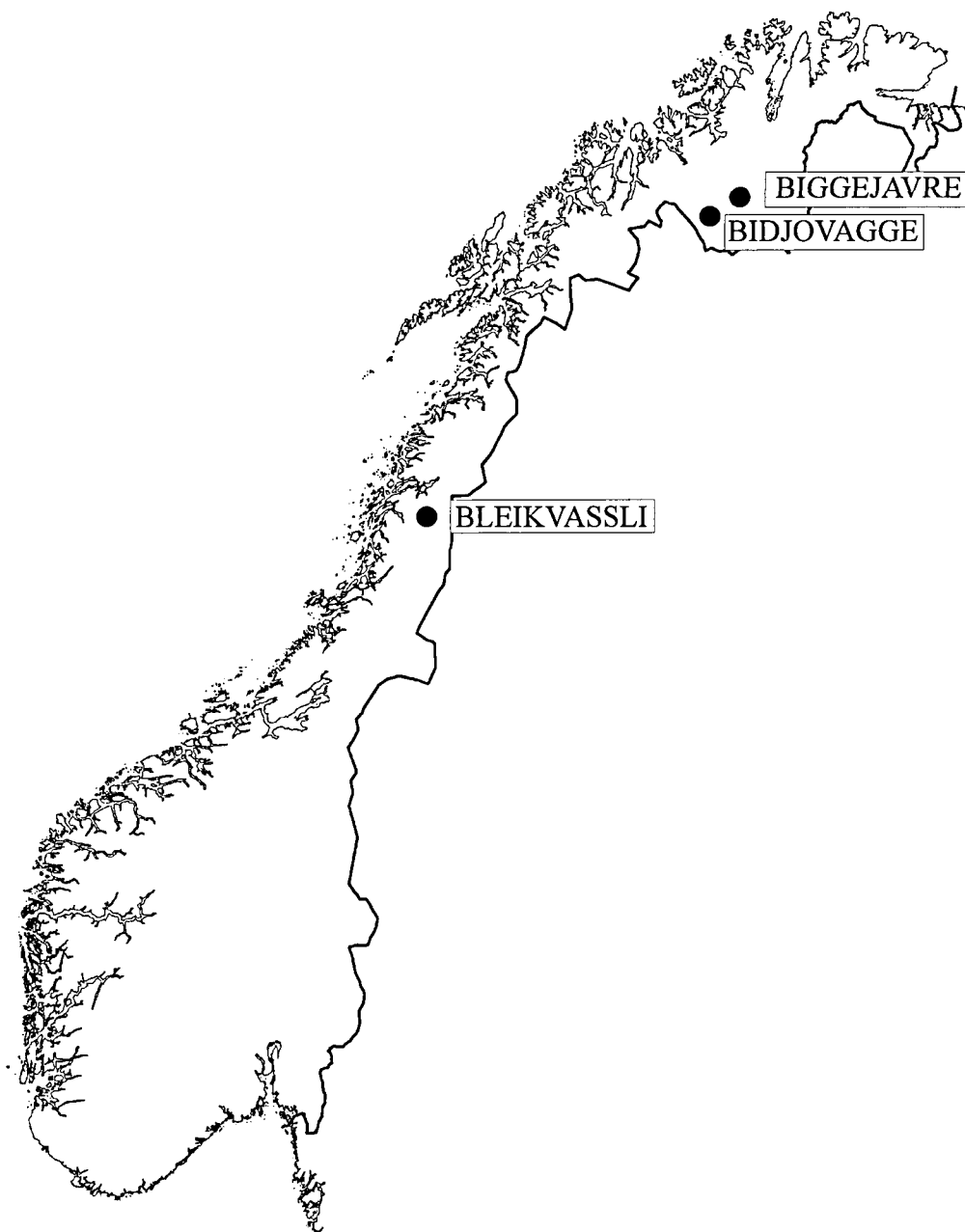
Figure 19. Bleikvassli, Gamma-ray spectrometry, Bh 05-86
Calculated concentrations of K, U and Th.



Legend

- Amphibolite
- Calcsilicate-banded mica schist
- Garnet-mica schist
- Mica schist
- Muscovite schist
- Epidot/amfibolite schist
- Biotite schist with graphite, garnet, amfibolite
- Graphite schist
- Garnet/amfibolite biotite schist with sulfides
- Kyanite/garnet mica schist

Figure 20. Brunesebeken, Gamma-ray spectrometry, borehole 1-97
Calculated concentrations of K, U and Th. Borehole log,
Cu, Zn and Pb content



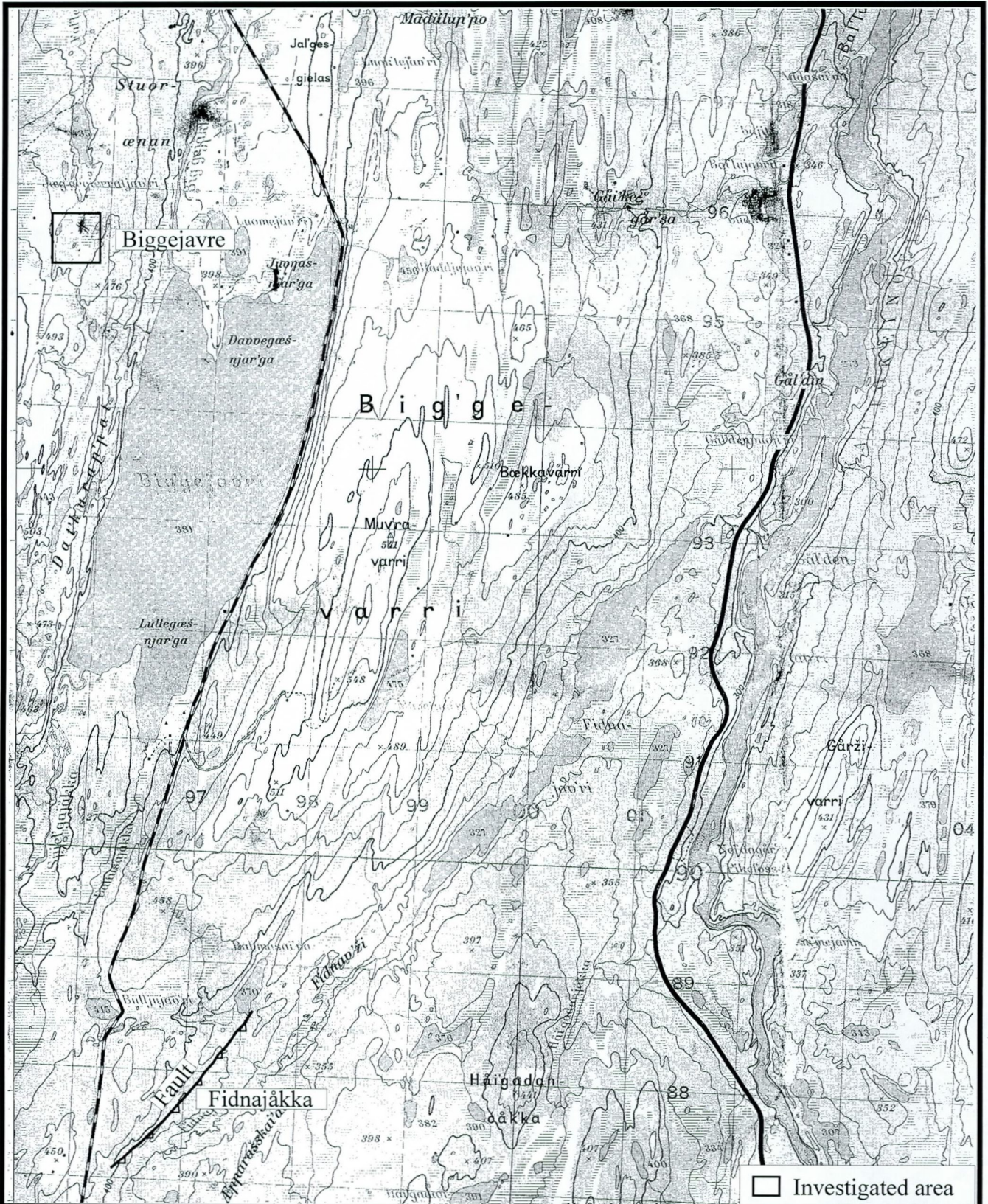
NGU
 LOCATION MAP
 NORWAY

SCALE	OPER HE/JSR	Sept. -97
	DRAW HE	Mai -97
	TRAC	

GEOLOGICAL SURVEY OF NORWAY
 TRONDHEIM

MAP NO.
 98.091-01

MAP 1:50 000



□ Investigated area

NGU
LOCATION MAP

BIGGEJAVRE

FINNMARK, NORWAY

GEOLOGICAL SURVEY OF NORWAY
TRONDHEIM

SCALE

1:50 000

OPER HE

DRAW HE

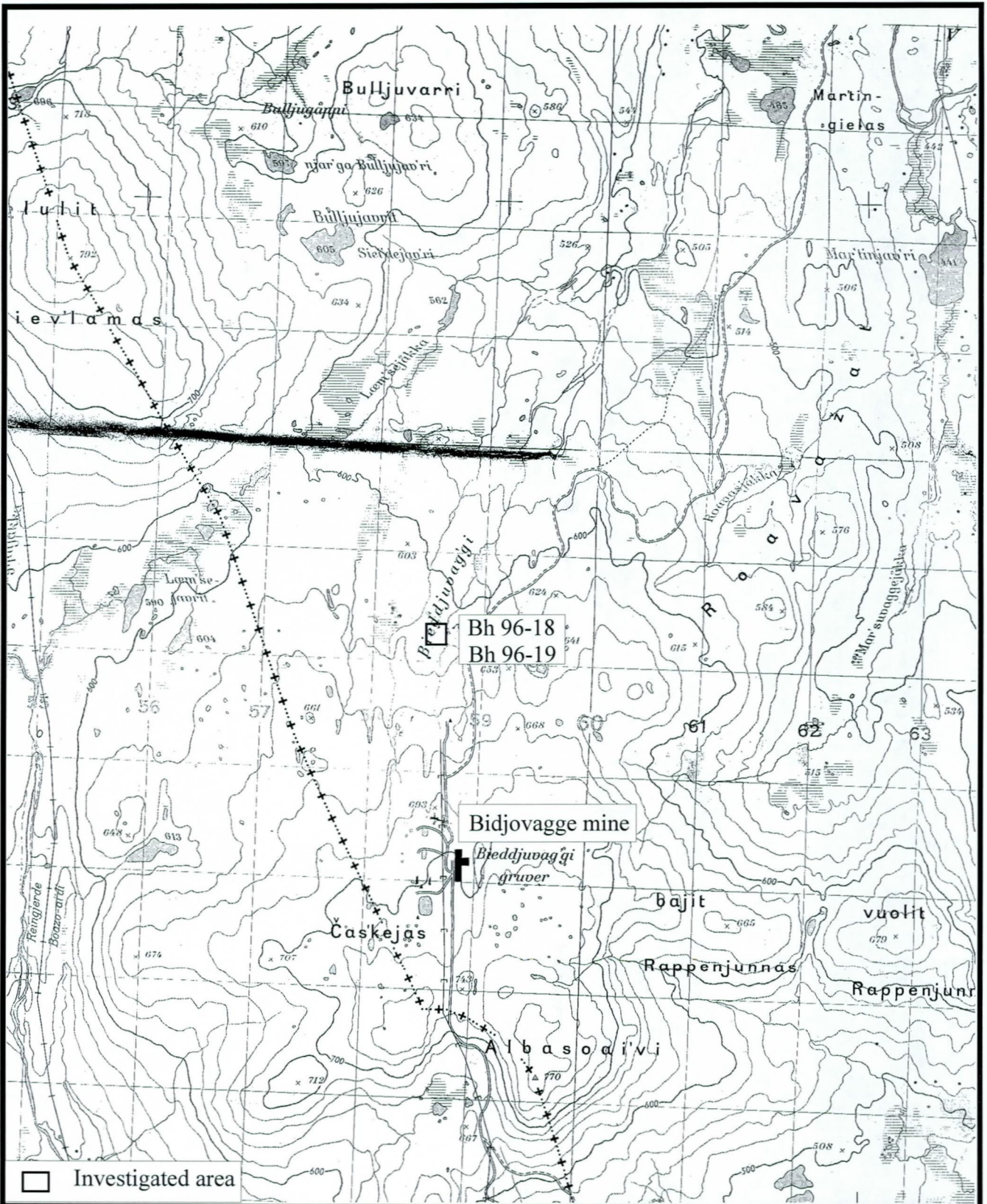
TRAC

Sept. - 97

May - 98

MAP NO.
98.091-02

MAP 1:50 000
1933 IV



NGU
LOCATION MAP

BIDJOVAGGE

FINNMARK, NORWAY

GEOLOGICAL SURVEY OF NORWAY
TRONDHEIM

SCALE

1:50 000

OPER HE

DRAW HE

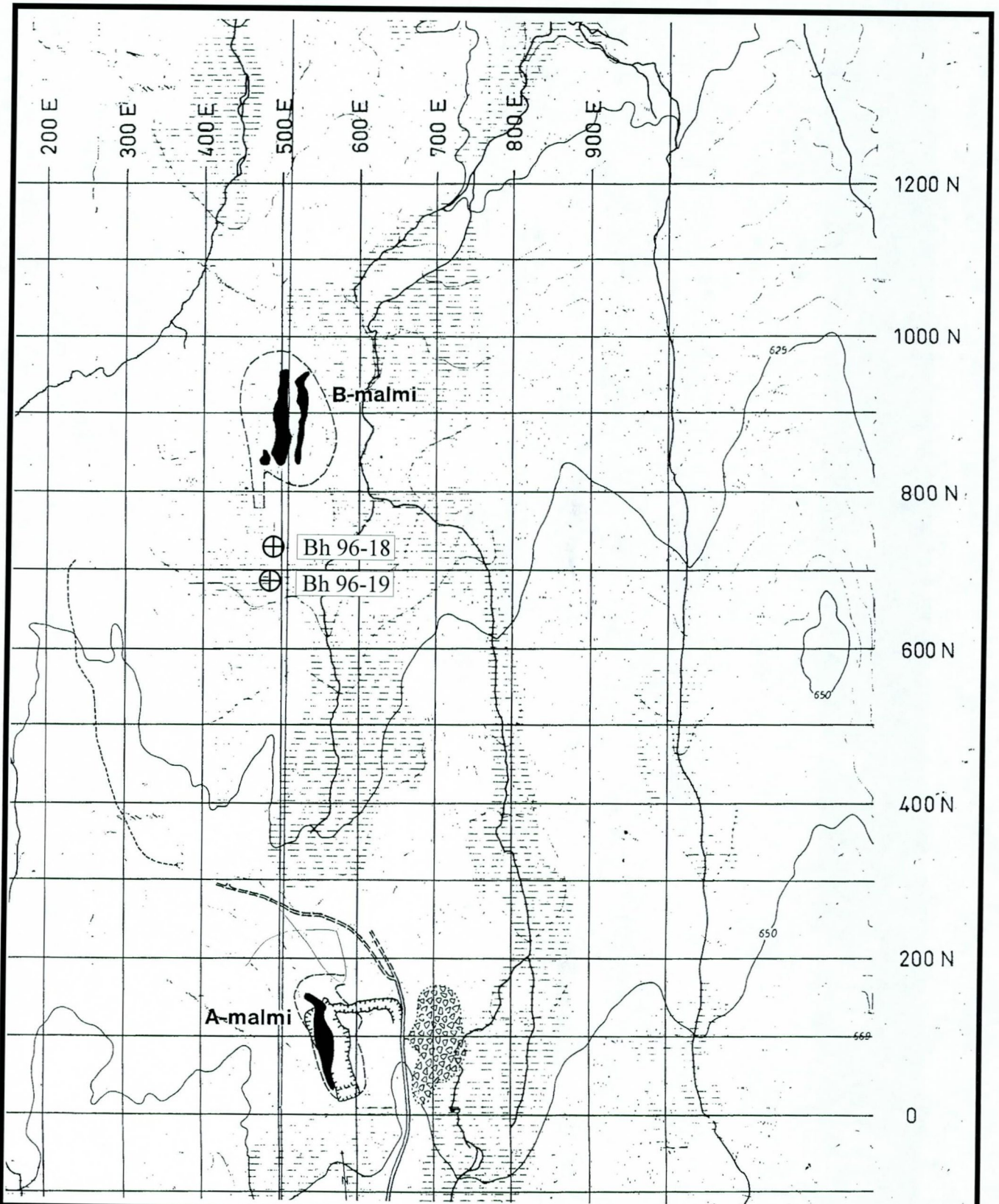
TRAC

Sept. - 97

May - 98

MAP NO.
98.091-03

MAP 1:50 000
1833 IV



NGU
LOCATION MAP

BIDJOVAGGE

FINNMARK, NORWAY

GEOLOGICAL SURVEY OF NORWAY
TRONDHEIM

SCALE

OPER HE

Sept. -97

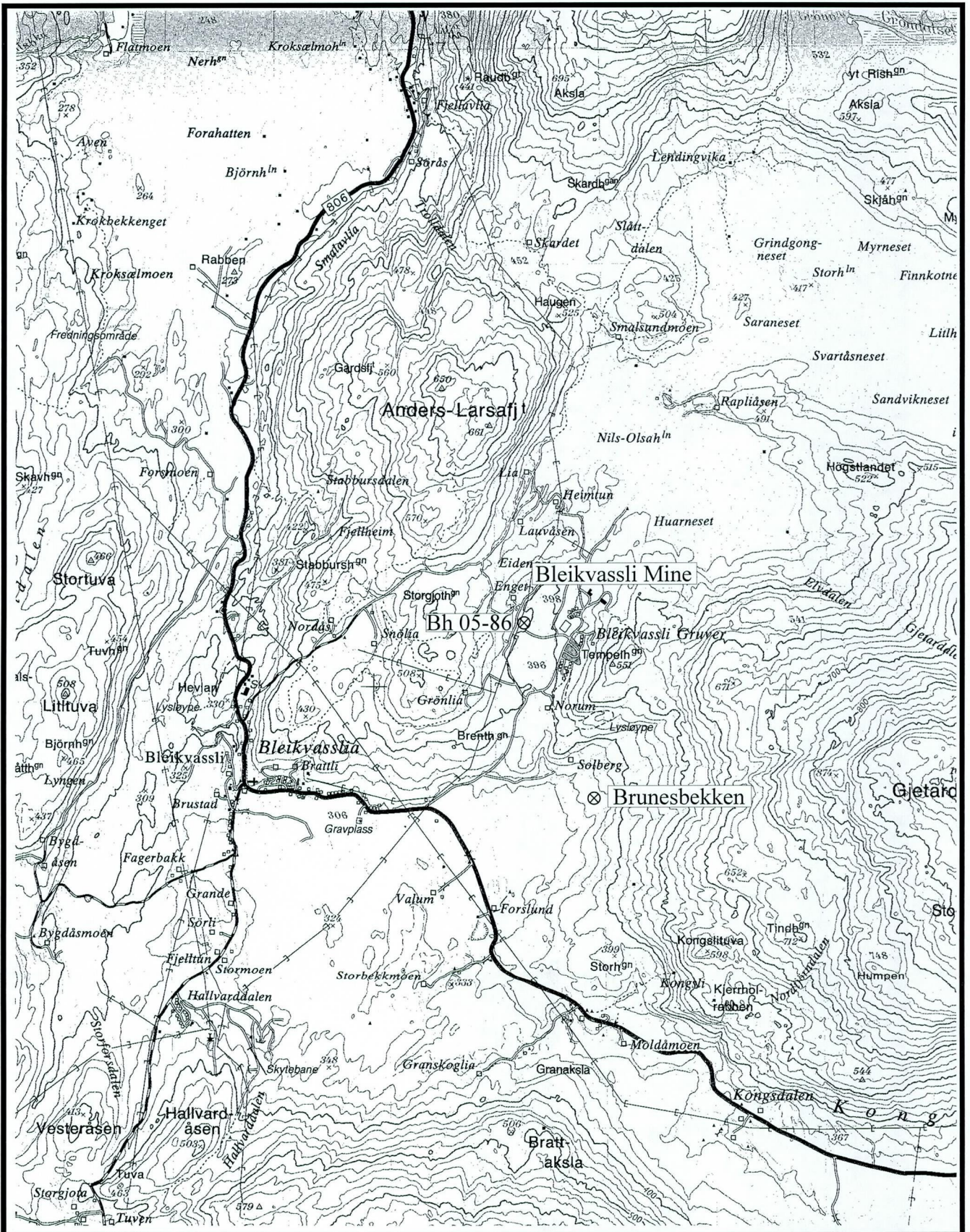
DRAW HE

May -98

TRAC

MAP NO.
98.091-04

MAP 1:50 000



NGU
LOCATION MAP

BLEIKVASSLI MINE

HEMNES KOMMUNE, NORDLAND

GEOLOGICAL SURVEY OF NORWAY
TRONDHEIM

SCALE

1:50 000

OPER HE	Sept. -97
DRAW HE	May -98
TRAC	

MAP NO.
98.091-05

KARTBLAD NR
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