SKBF TEKNISK
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82-22

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SVENSK KÄRNBRÄNSLEFÖRSÖRJNING AB / AVDELNING KBS

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STUDSVIK/NW--82/386

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ABSTRACT

An environmental sampling programme was performed in four potential areas suitable for the final storage of spent nuclear fuel. The background concentrations of uranium and radium in water, sediments, soils, peat and vegetation were determined. The values obtained for the different parts of the biosphere showed a close agreement with values recorded earlier in Sweden except for some vegetation samples. Thus the calculated plant-soil concentration factors for both uranium and radium showed somewhat higher values compared to earlier investigations of crops and soils in Sweden.

Approved by

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1. INTRODUCTION

In the current Swedish evaluations of future sites for the final storage of spent nuclear fuel, four areas have at present shown to be appropriate. These are Fjällveden, Voxna, Gideå and Kamlunge (Figure B.1). Within these areas, an environmental sampling programme was performed with the aim to determine the natural levels of uranium and radium in different biospheric recipients. The programme comprised collection of water, sediment, soil, peat and vegetation samples. General water quality data were also determined in order to obtain background information for the interpretation of the uranium and radium levels.

2. SAMPLING SITES

The sampling sites within the recipients were chosen with respect to the position of the main surface water divide. The general features of the sampling sites are shown in Table A.1 - A.4. The characteristics of the recipients are described earlier (1).

3. SAMPLING METHODS

Water samples were collected from the surface of the lakes and streams. Bottom sediments were collected with an Ekman grab sampler with a bottom area of 0.025 m^2. The grab penetrated the sediment down to about 5 cm depth.

The soil was considered more heterogenous than the other types of samples such as water and sediments. A classification of the soil was roughly made into pasture ground, arable land, and forest soil and peat. "Pasture ground" constituted samples collected in areas utilized by grazing cattle stocks, while "arable land" mainly comprised soil from cultivated fields. "Forest soil" represented samples collected in coniferous forest. From each sampling site, five samples from the upper 30 cm of the earth-layer were therefore pooled and thoroughly mixed before a subsample was taken. The same sampling procedure was performed for the peat samples.

The vegetation samples were mainly composed of grass from pasture grounds.

4. ANALYTICAL METHODS

4.1 Water

The uranium content in 1 l of water was determined with the delayed neutron activation technique (DNA).

Ra-226 was analyzed radiochemically. The sample volume was 3 l.

Conductivity and pH were determined in the field. A large number of chemical constituents were determined by the Geological Survey of Sweden (SGU).

- HCO_3 was determined by titration according to American National Standard ANSI/ASTM D513.
- F, Cl, NO_2, NO_3, NH_4, $KMnO_4$ and SO_4 were determined with an ion cromatograph, model DIONEX.
- Na, Mg, K, Ca, Mn, Zn, Fe and Cu were determined using an Image Dissector Echelle Spectrometer (IDES/ICP).

4.2 Solid material

Uranium in solid material was determined with the DNA technique.

Ra-226 was determined by enclosing the material for three weeks and measuring the radon and daughters in equilibrium with gamma spectroscopy.

5. RESULTS

The ambient concentrations of uranium and radium in water, sediment, soils, peat and vegetation for the areas Fjällveden, Voxna, Gideå and Kamlunge, respectively, are displayed in Tables A.5 - A.8 and in Figures B.2 - B.9. The results are expressed as Bq/volume or weight unit. For conversion to relative weight units the following relations can be used:

1 Bq radium = $3 \cdot 10^{-2}$ ppb
1 Bq uranium = 39.5 ppm

The water quality data are presented in Table A.9.

5.1 Fjällveden

The uranium values for the investigated surface waters varied between $1 \cdot 10^{-4}$ and $9 \cdot 10^{-3}$ Bq l^{-1}. The radium concentrations were all below the detection limit. The drilled well at Sågsjön (54 m depth) showed an increased content of uranium, compared to the surface waters, and also showed detectable amounts of radium (Table A.5, Figure B.2). Most of the constituents of the water were enhanced, too (Table A.9). The well situated at the farm Svista contained surprisingly high amounts of both uranium and radium, $4.16 \cdot 10^{-1}$ and $2.2 \cdot 10^{-2}$ Bq l^{-1}, respectively. The anions Cl, NO_3 and SO_4 and the major cations Na, Mg, K and Ca also showed increased values, implying that fertilizers from the surrounding fields are leached into the water.

The sediment samples collected from three lakes showed an uranium concentration around 150 - 200 Bq kg^{-1} (dry wt), and a radium value amounting to about 100 Bq kg^{-1} (Table A.5, Figure B.2).

The organic contents of the soil samples from the pasture and arable lands were mainly below 10 %. No correlation between the amount of organic matter in the soil and the contents of uranium and radium was found. The forest soil contained on the average 6 times less uranium and 2 times less radium, than the arable lands. For the peat samples, which had an organic content of 20 - 50 %, the concentrations of both uranium and radium were still lower (Table A.5, Figure B.3).

5.2 Voxna

The water samples contained an uranium concentration of $5 \cdot 10^{-3}$ - $1.3 \cdot 10^{-2}$ Bq l^{-1}. All radium values were below the detection limit (Table A.6, Figure B.4).

The sediments of lake Älmesjön and lake Norra Brynåssjön contained very high amounts of organic matter, 63 and 35 %, respectively; both the uranium and radium contents of the sediment from lake Älmesjön were low. However, the sediment from lake Norra Brynåssjön had an uranium concentration of about 200 Bq kg^{-1}, while the radium content was only 4 Bq kg^{-1}, the lowest of all values recorded in sediments in this investigation (Table A.6, Figure B.4).

The three peat samples consisted almost entirely of organic material, and both the uranium and radium values were low (Table A.6, Figure B.5).

5.3 Gideå

The water samples from the Gideå area showed uranium contents comparable to those of Fjällveden and Voxna. Both the uranium and radium values of the sediments were generally lower than those obtained in Fjällveden (Table A.7, Figure B.6).

The soil from Gideå mostly contained a low content of organic matter. The homogenity of the material was reflected in the uranium and radium contents, which both showed very small variations. For the peat samples, the organic content exceeded 95 %; their contents of both uranium and radium decreased about one order of magnitude (Table A.7, Figure B.7).

5.4 Kamlungekölen

The content of uranium in the water samples of Kamlunge was on the average $5 \cdot 10^{-3}$ Bq l^{-1}, which is somewhat lower than for the other areas (Table A.8, Figure B.8).

The soil samples collected on cultural lands contained about 7 % organic material, compared to 1 % for the forest soil samples. The contents of both uranium and radium in the cultural soil were about a factor 3 higher than in the forest soil.

One vegetation sample consisted of wildberry scrubs; the concentrations of uranium and radium were similar to those determined for pasture in the same area.

5.5 Plant-soil concentration factors (Cf)

The plant-soil concentration factors were calculated for the different recipient areas using the average concentrations of uranium and radium in arable lands and in pasture (Table A.11). For radium, the Cf values $(2 - 26)\cdot 10^{-2}$ were higher than the values $(3 - 75)\cdot 10^{-3}$ obtained for pasture in other areas (7,8,9,10), and also higher than those calculated for crops and soils in Sweden (11,12). Also for uranium, the pasture-soil concentration factor $(6 - 19)\cdot 10^{-3}$ obtained in this study was high compared to values from other areas (11,13). The enhanced Cf values will imply an increased exposure to man via the milk pathway.

6. SUMMARY

For uranium, the water samples collected in the lakes, rivers and streams of the four recipient areas showed a close resemblance. For 13 samples, the average uranium value ($\bar{x} \pm$ S D) was $(8 \pm 6)\cdot 10^{-3}$ Bq l^{-1}. The standard error only amounted to 20 % of the mean. The uranium values found are in agreement with values from other Swedish fresh water localities (2,3). The radium values were all below the detection limit.

The uranium contents of the water from the spring and the drilled well at Fjällveden (no 17 and 27, respectively) were raised a factor 3, compared to the content of the surface water, which is in agreement with findings in northern Sweden (4,5,6). The contaminated well at Svista farm had an uranium concentration comparable to that of the bog water at Masugnsbyn, northern Sweden (4). The water from the drilled well and the well at Svista also showed detectable amounts of radium.

The average uranium and radium contents of the bottom sediments in the four areas was 28 ± 38 and 77 ± 44 Bq kg^{-1} dry wt, respectively, which is in accordance with the values recorded for lake Finnsjön (2), and in lake Hornborgasjön and river Flian (3).

The uranium and radium values of the different kinds of soil in displayed in Figure B.10 and B.11. Generally, the content of uranium and radium in forest soil was a factor 4 and 2, respectively, below that of the pasture and arable soils. The concentrations of uranium and radium in arable soils are comparable to the average contents obtained from cultural lands in southwestern Sweden (7).

The average contents of uranium and radium of pasture was 1.21 ± 0.75 and 9.23 ± 8.36 Bq kg^{-1}, respectively. The pasture-soil concentration factors for both uranium and radium were somewhat higher than earlier obtained values for crops.

REFERENCES

1. SUNDBLAD, B and BERGSTRÖM, U
Description of recipient areas related to final storage of unprocessed spent nuclear fuel.
STUDSVIK/NW-82/351.

2. EVANS, S and BERGMAN, R
Uranium and radium in Finnsjön - an experimental approach for calculation of transfer factors.
STUDSVIK/NW-81/26.

3. AGNEDAL, P-O
Basundersökningar i recipienterna för Ranstadsverket 1961 - 1965.
AE-SSS-192, 1967.

4. ARMANDS, G
Geochemical prospecting of an uraniferous bog deposit at Masugnsbyn, northern Sweden.
AE-36, 1961.

5. EK, J, EVANS, S and LJUNGQVIST, L
Variation in radioactivity, uranium and radium-226 contents in three radioactive springs and along their out-flows, northern Sweden.
STUDSVIK/NW-82/177.

6. EK, J
Bearbetning av uranhaltsmätningar i vatten och bäcktorv från bäckar i Sverige.
SKBF/KBS tekn rapp 81-11.

7. GERA, F
Geochemical behaviour of long-lived radioactive wastes.
CNEN-ET/PROT (76)-5.

8. THOMPSON, R C
Neptunium - the neglected actinide: A review of the biological and environmental literature.
Rad Res 90, 1 - 32 1982.

9. MILLER, C W et al
Recommendations concerning models and parameters best suited to breeder reactor environmental radiological assessments.
ORNL-5529 1980.

10. KHADEMI, B, ALEMI, A A, NASSERI, A
Transfer of radium from soil to plants in an area of high natural radioactivity in Ramsar, Iran.
Int Symp on the natural radiation environment, Houston Texas CONF-780422, 1978.

11. ERIKSSON, Å and FREDRIKSSON, L
Naturlig radioaktivitet i mark och grödor.
SLU-IRB-52 (1981).

12. EVANS, S and ERIKSSON, Å
Uranium, thorium and radium in soil and crops - calculation of transfer factors.
STUDSVIK/NW-82/319.

13. CHARLES, T, GARTEN, Jr
A review of parameter values used to assess the transport of plutonium, uranium and thorium in terrestrial food chains.
Env Res 17, 437 - 452, 1978.

Table A.1

The general features of the sampling sites at Fjällveden

Sampling site	Type	Sediment	Land-use	Dominating soil
Water				
Lidsjön	eutrophic lake	minerogenic	mixed arable and forest land	till
Morpasjön	oligotrophic lake	organogenic	forest	till
Sågsjön	oligotrophic lake	minerogenic	forest	till
Glottran	mesotrophic lake		arable	clay
Fjällvedsbäcken	stream		forest	till
Tallmon	spring		forest	till
Sågsjön	drilled well		forest	clay
Svista	well		arable	clay
Soil				
Oppeby	pasture ground			
Tallmon	arable land			
Svista	pasture ground			
Fj-8	peat			
Sågsjön	forest soil			
Vegetation				
Oppeby	grass		pasturage	
Svista	grass		pasturage	

Table A.2

The general features of the sampling sites at Voxnan

Sampling site	Type	Sediment	Land-use	Dominating soil
Water				
N Brynåssjön	oligotrophic lake	organogenic	bog and forest	till
Älmessjön	oligotrophic lake	organogenic	bog and forest	till
Stream West*			forest	till
Stream East*			bog and forest	till
Soil				
Near stream W	forest			
Near stream E	peat			
Vegetation				
Near stream W	grass		forest	
Near stream E	"		forest	

* Stream west and east of the surface water divide

Table A.3

The general features of the sampling sites at Gideå

Sampling site	Type	Sediment	Land-use	Dominating soil
Water				
Gideå dam	obligotrophic	minerogenic	forest (arable)	till
Skademarkssjön	obligotrophic	minerogenic	arable land	clay
Stream West*	obligotrophic		forest	till
Stream East*	obligotrophic		clear-cut forest	till
Soil				
Gideåbruk	pasture			
Spångmyran	peat			
"Vägskälet"	forest			
Skademark	arable land			
Vegetation				
Gideåbruk	grass		pasturage	
Skademark	grass		arable land	

* Stream west and east of the surface water divide

Table A.4

The general features of the sampling sites at Kamlungekölen

Sampling site	Type	Sediment	Land-use	Dominating soil
Water				
Granträsket	oligotrophic	minerogenic	forest and arable land	till
Häggmanstjärn	oligotrophic	organogenic	forest	till
Storlappträsk	oligotrophic	minerogenic	forest	till
Idträskbäcken	oligotrophic		forest	till
Kalixälven	oligotrophic		forest	till
Sangisälven	oligotrophic		forest	till
Soil				
Granträsk	arable land			
Kölbäcken	peat			
Häggmanstjärn	forest sandy soil			
Vegetation				
Granträsk	grass		pasturage	
Häggmanstjärn	wildberry scrub		forest	

Table A.5

Ambient concentrations of uranium and radium in water (Bq l^{-1}), sediment, soil and pasture (Bq kg^{-1} dry wt) for the Fjällveden area

Sample no	Sample type		Uranium Bq l^{-1} ± SD	Radium Bq l^{-1} ± SD
001	Lake water		(9.2±2.9)E-3	<1.1 E-3
015	"-		(5.0±2.9)E-3	<4.0 E-3
026	"-		(1.3±0.4)E-2	<2.8 E-3
043	Stream water		(2.5±0.3)E-2	<2.0 E-3
017	Spring water		(2.0±0.3)E-2	<5.6 E-3
027	Well		(3.18±0.35)E-2	(2.57±0.18)E-2
035	"		(4.16±0.10)E-1	(2.22±0.12)E-2
			Bq kg^{-1} ± SD	Bq kg^{-1} ± SD
014	Sediment	8*	(2.17±0.05)E2	(1.12±0.05)E2
016	"	20	(2.05±0.05)E2	(1.09±0.05)E2
028	"	12	(1.55±0.05)E2	(6.14±0.25)E1
008	Pasture ground	2	(2.32±0.05)E2	(8.2±0.6)E1
009	"-	7	(2.32±0.05)E2	(1.02±0.06)E2
010	"-	7	(2.35±0.05)E2	(1.07±0.06)E2
018	Arable land	4	(6.90±0.05)E2	(1.20±0.09)E2
019	"-	4	(1.04±0.05)E3	(4.39±0.45)E1
020	"-	3	(5.48±0.05)E2	(4.99±0.41)E1
023	Peat	44	(4.40±0.09)E1	(2.10±0.33)E1
024	"	9	(6.83±0.13)E1	(4.51±0.44)E1
025	"	35	(4.08±0.08)E1	(2.51±0.32)E1
029	Forest soil	11	(7.61±0.14)E1	(4.37±0.46)E1
030	"-	<1	(8.07±0.15)E1	(5.09±0.48)E1
031	"-	22	(6.95±0.14)E1	(6.7±0.7)E1
032	"-	<1	(8.39±0.15)E1	(5.07±0.49)E1
036	Pasture ground	4	(1.27±0.05)E2	(7.6±0.5)E1
037	"-	8	(1.21±0.05)E2	(7.07±0.34)E1
038	"-	12	(1.14±0.05)E2	(7.18±0.20)E1
011	Pasture		1.22±0.11	2.2±2.4 <6.2
012	"		1.85±0.13	1.0±2.8 <5.6
039	"		1.11±0.09	5.5±2.0
040	"		(2.4±0.5)E-1	1.9±1.8 <4.9

* Content of organic matter (%)

Table A.6

Ambient concentrations of uranium and radium in water (Bq l^{-1}), sediment, soil and pasture (Bq kg^{-1} dry wt) for the Voxna area

Sample no	Sample type		Uranium Bq l^{-1} ± SD	Radium Bq l^{-1} ± SD
051	Lake water		<2.3 E-3	<1.2 E-3
053	"-		(5.0±3.1)E-3	<2.9 E-3
052	Stream water		(1.3±0.3)E-2	<8.3 E-4
054	"-		(5.1±3.2)E-3	<5.0 E-3
			Bq kg^{-1} ± SD	Bq kg^{-1} ± SD
063	Sediment	63*	(4.79±0.12)E1	(1.3±0.5)E1
064	"	35	(2.14±0.05)E2	3.8±1.4
057	Peat	98	2.34±0.07	1.4±0.4
058	"	96	3.02±0.11	3.8±2.0
059	"	98	1.00±0.05	1.2±0.3
060	Forest soil	4	(4.54±0.10)E1	(2.3±0.3)E1
061	"-	5	(4.71±0.11)E1	(3.75±0.32)E1
062	"-	6	(3.87±0.10)E1	(3.25±0.15)E1
055	Pasture		2.73±0.19	(1.74±0.22)E1
056	"		(3.5±0.7)E-1	7.1±1.8

* Content of organic matter (%)

Table A.7

Ambient concentrations of uranium and radium in water (Bq l^{-1}), sediment, soil and pasture (Bq kg^{-1} dry wt) for the Gideå area

Sample no	Sample type		Uranium Bq l^{-1} ± SD	Radium Bq l^{-1} ± SD
103	Lake water		(7.2±3.2)E-3	<8.4 E-4
101	River water		<5.5 E-3	<2.2 E-3
102	"-		(6.3±3.2)E-3	<4.3 E-3
104	"-		(5.9±3.2)E-3	<6.8 E-3
			Bq kg^{-1} ± SD	Bq kg^{-1} ± SD
119	Sediment	4*	(8.37±0.17)E1	(5.85±0.33)E1
120	"	15	(9.97±0.22)E1	(8.34±0.38)E1
107	Pasture ground	8	(6.98±0.15)E1	(4.5±0.5)E1
108	"-	7	(7.47±0.16)E1	(4.91±0.49)E1
109	"-	7	(7.66±0.15)E1	(4.65±0.48)E1
110	Arable land	11	(7.81±0.15)E1	(4.50±0.45)E1
111	"-	5	(6.87±0.14)E1	(3.68±0.39)E1
112	"-	5	(6.09±0.13)E1	(1.65±0.21)E1
113	Peat	97	8.30±0.17	3.07±0.45
114	"	97	6.96±0.17	2.11±0.34
115	"	97	8.58±0.17	3.30±0.45
116	Forest soil	5	(5.55±0.12)E1	(3.21±0.15)E1
117	"-	7	(6.19±0.13)E1	(2.90±0.12)E1
118	"-	9	(6.93±0.15)E1	(3.28±0.27)E1
105	Pasture		(7.7±0.7)E-1	9.5±1.8
106	"		(7.6±0.9)E-1	6.7±2.1

* Content of organic matter (%)

Table A.8

Ambient concentrations of uranium and radium in water (Bq l^{-1}), sediment, soil and pasture (Bq kg^{-1} dry wt) for the Kamlunge area

Sample no	Sample type		Uranium Bq l^{-1} ± SD	Radium Bq l^{-1} ± SD
151	Lake water		(4.1±3.1)E-3	<1.0 E-3
152	Stream water		(3.7±3.1)E-3	<2.4 E-3
153	Lake water		<2.9 E-3	<2.9 E-3
154	"-		(4.1±3.1)E-3	<1.1 E-3
155	River water		(6.7±3.2)E-3	<5.0 E-4
156	"-		(8.2±3.2)E-3	<3.3 E-3
		*	Bq kg^{-1} ± SD	Bq kg^{-1} ± SD
168	Sediment	12	(1.27±0.05)E2	(1.21±0.05)E2
169	"	13	(1.08±0.05)E2	(8.27±0.34)E1
159	Peat	30	(2.07±0.05)E2	(5.47±0.48)E1
160	"	15	(9.67±0.19)E1	(5.59±0.21)E1
161	"	35	(7.48±0.14)E1	(4.03±0.32)E1
162	Arable land	7	(7.95±0.15)E1	(4.46±0.16)E1
163	"-	5	(8.96±0.17)E1	(5.77±0.31)E1
164	"-	9	(9.02±0.17)E1	(4.79±0.16)E1
165	Sandy forest soil	1	(2.82±0.08)E1	(2.40±0.21)E1
166	"-	1	(2.94±0.08)E1	(1.70±0.12)E1
167	"-	1	(3.41±0.09)E1	(2.45±0.21)E1
157	Pasture		1.61±0.10	(1.30±0.07)E1
158	Wildberry scrub		1.51±0.06	(2.81±0.05)E1

* Content of organic matter (%)

Table A.9

Water quality data for the areas Fjällveden, Voxna, Gideå and Kamlunge.
Values in brackets should be rejected due to probable sampling error

Area	Sample no	Water type	pH	Conductivity (mS/m)	F	Cl	NO_3	SO_4	NH_4	NO_2	$kMnO_4$	HCO_3	Na	Mg	K	Ca	Mn	Fe	Cu	Zn
					ppm															
Fjällveden	001	lake	7.2	13.6	0.44	7.6	<0.1	23	<0.02	<0.005	21	37	6.5	4.7	2.6	12	<0.01	0.04	<0.005	<0.01
	002	well	5.1	9.9	0.34	7.4	<0.1	27	<0.02	<0.005	10	22	6.6	3.3	1.2	12	0.02	<0.01	<0.005	<0.01
	015	lake	7.0	9.2	0.44	3.8	<0.1	14	<0.02	<0.005	36	23	5.0	3.2	1.6	8.0	<0.01	0.02	<0.005	<0.01
	017	spring	4.3	3.9	0.47	1.2	<0.1	10	<0.02	<0.005	32	2	2.3	0.85	1.4	2.7	<0.06	<0.01	<0.005	0.02
	026	lake	5.6	5.2	0.36	2.6	≤0.1	11	<0.02	<0.005	77	6	2.5	1.6	0.89	4.9	<0.01	0.16	<0.005	<0.01
	027	well	7.5	24.9	2.5	6.6	<0.1	13	<0.02	<0.005	4	163	40	3.2	2.2	22	0.06	<0.01	<0.005	0.11
	033	lake	7.5	11.9	0.45	9.1	<0.1	16	0.02	<0.005	26	36	6.8	4.6	3.5	7.5	<0.01	<0.01	<0.005	<0.01
	035	well	6.6	45.8	0.94	41	2.8	51	0.02	<0.005	4	238	27	22	8.5	53	<0.01	0.01	<0.005	<0.01
	043	stream	6.9	11.6	0.55	4.3	<0.1	15	0.02	<0.005	79	46	7.4	5.0	1.3	13	<0.01	0.16	<0.005	0.01
Voxna	051	lake	6.8	3.5	0.41	0.9	<0.1	3.6	0.05	<0.005	37	9	1.8	0.90	0.78	3.5	<0.01	0.30	<0.005	<0.01
	052	stream	6.5	4.4	0.50	0.9	0.5	3.7	0.03	<0.005	41	16	1.7	0.80	0.70	6.0	<0.01	0.11	<0.005	<0.01
	053	lake	6.5	3.0	0.50	0.8	<0.1	3.1	0.04	<0.005	34	9	1.7	0.84	0.72	3.3	0.01	0.24	<0.005	<0.01
	054	stream	5.1	6.2	0.50	1.1	(21)	4.2	0.14	<0.005	47	2	2.0	2.2	0.59	6.9	0.01	0.11	<0.005	<0.01
Gideå	101	river	6.2	2.2	0.60	1.0	0.5	1.9	<0.02	(0.17)	32	7	1.4	1.2	0.78	2.7	<0.01	0.33	<0.005	<0.01
	102	stream	4.5	4.1	0.63	1.6	<0.1	11	<0.03	<0.005	98	2	3.0	1.6	0.95	3.7	0.05	0.60	<0.005	<0.01
	103	lake	6.2	3.5	0.60	2.2	0.5	9.3	0.05	<0.005	32	7	2.0	1.1	1.2	3.8	0.02	0.18	<0.005	<0.01
	104	stream	5.9	2.3	0.54	1.5	0.5	4.3	0.03	<0.05	70	6	2.3	0.92	0.96	3.0	0.02	0.17	<0.005	0.03
Kamlunge	151	lake	5.6	3.7	0.50	1.2	<0.1	4.7	<0.02	<0.005	36	10	1.8	1.0	0.92	2.5	0.09	1.0	<0.005	<0.01
	152	stream	4.4	3.1	0.44	0.9	<0.1	5.2	<0.02	<0.005	88	3	1.5	0.75	0.57	1.7	0.06	1.5	<0.005	<0.01
	153	lake	5.5	2.5	0.51	1.3	0.3	2.7	0.02	<0.005	21	6	1.4	0.79	0.56	1.7	0.02	0.25	<0.005	<0.01
	154	lake	5.9	3.2	0.42	1.1	<0.1	4.1	0.02	<0.005	21	8	1.8	0.80	0.96	2.2	0.02	0.23	<0.005	<0.01
	155	river	6.2	3.3	0.75	1.1	<0.1	2.3	<0.02	<0.005	21	12	1.2	0.82	0.54	3.3	0.02	0.50	<0.005	<0.01
	156	river	5.6	6.1	0.67	2.8	<0.1	14	0.02	<0.005	57	6	2.6	1.4	0.93	3.6	0.17	1.6	<0.005	<0.01

Table A.10

Average contents of uranium and radium in different kinds of soil samples from Fjällveden, Voxna, Gideå and Kamlunge, respectively, expressed as Bq kg^{-1} dry wt

	n	(%) organic content	Uranium $\bar{x}$±SD	Uranium ±95 % conf int	Radium $\bar{x}$±SD	Radium ±95 % conf int
Fjällveden						
Pasture ground	6	7	177± 62	62	85±16	16
Arable land	3	4	759±253	465	71±42	78
Forest soil	4	8	78± 6	9	53±10	14
Peat	3	29	51± 15	28	30±13	24
Voxna						
Forest soil	3	5	44± 4	8	31± 7	14
Peat	3	97	2± 1	2	2± 1	3
Gideå						
Pasture ground	3	7	74± 4	6	47± 2	4
Arable land	3	7	69± 9	16	33±15	27
Forest soil	3	7	62± 7	13	31± 2	4
Peat	3	97	8± 1	2	3± 1	1
Kamlunge						
Arable land	3	7	83± 6	11	50± 7	13
Sandy forest Soil	3	1	30± 3	6	22± 4	8
Peat	3	27	127±72	133	50± 9	16

Table A.11

Uranium and radium concentration factors (Bq plant material/ Bq kg^{-1} soil, dry wt) for the recipient areas Fjällveden, Gideå and Kamlunge. η = number of samples

Area	Soil type	Soil η	Pasture η	C_f Uranium	Radium
Fjällveden	pasture ground	3	2	$6.6 \cdot 10^{-3}$	$1.65 \cdot 10^{-2}$
"	arable land	3	2	$5.6 \cdot 10^{-3}$	$7.55 \cdot 10^{-2}$
Gideå	arable land	3	1	$1.0 \cdot 10^{-2}$	$2.05 \cdot 10^{-1}$
"	pasture ground	3	1	$1.04 \cdot 10^{-2}$	$2.03 \cdot 10^{-1}$
Kamlunge	arable land	3	1	$1.85 \cdot 10^{-2}$	$2.58 \cdot 10^{-1}$
				$\bar{x}$ $1.02 \cdot 10^{-2}$	$\bar{x}$ $1.52 \cdot 10^{-1}$

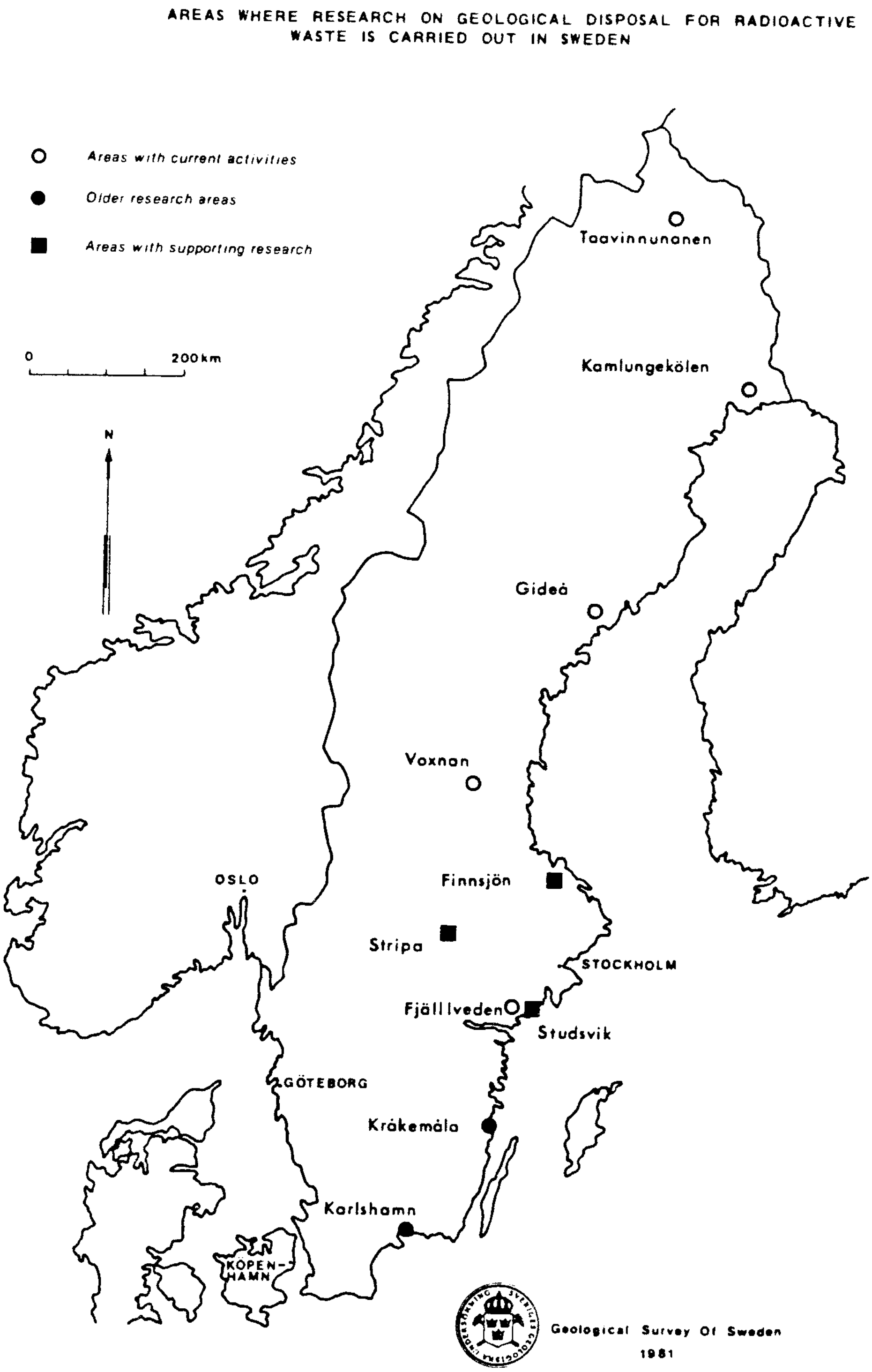

Figure B.1

(From Geological Disposal of Radioactive Waste, Research in the OECD Area 1982.)

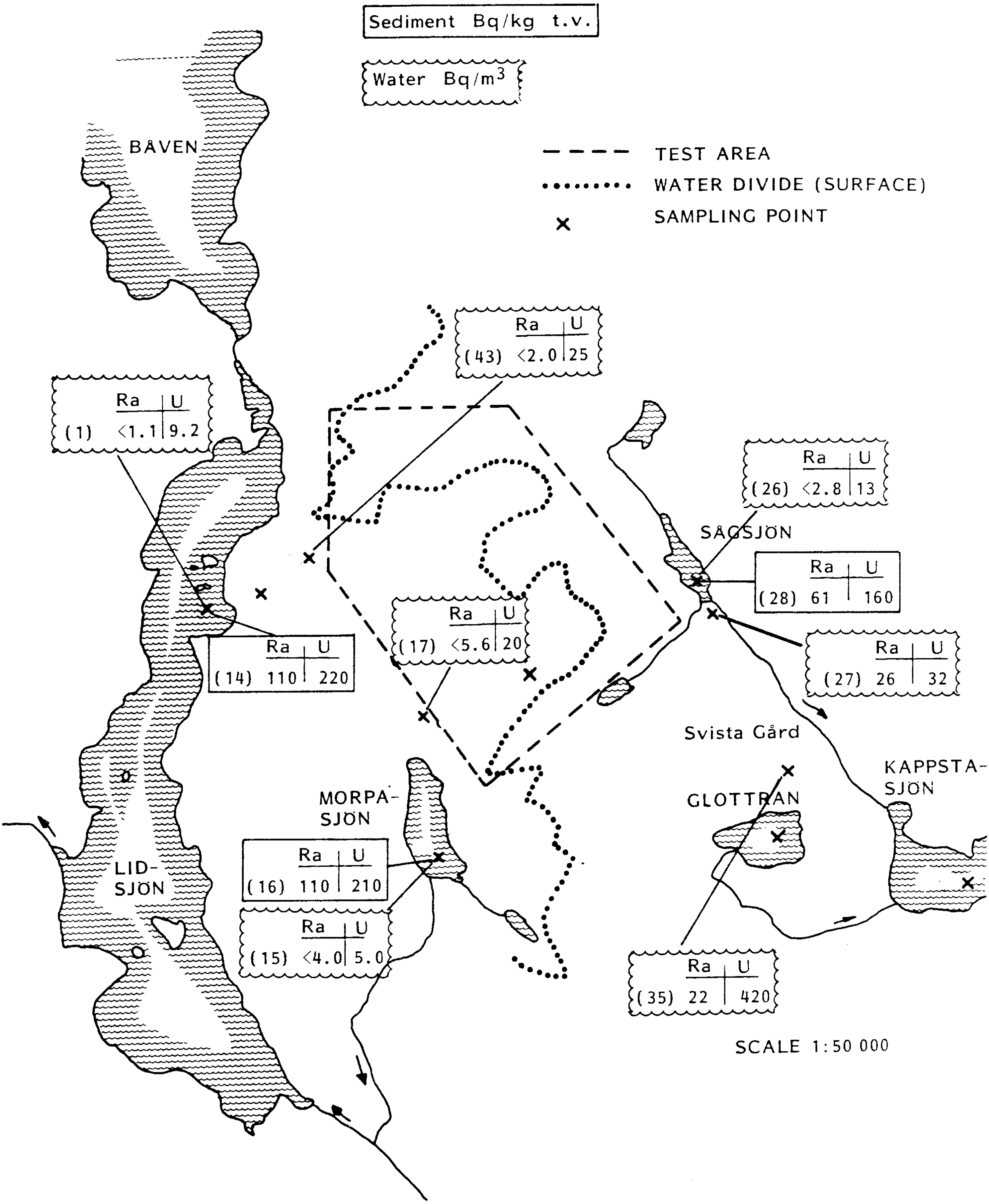

Figure B.2

The Fjällveden area.
Sampling sites and contents of radium and uranium in water and sediment.

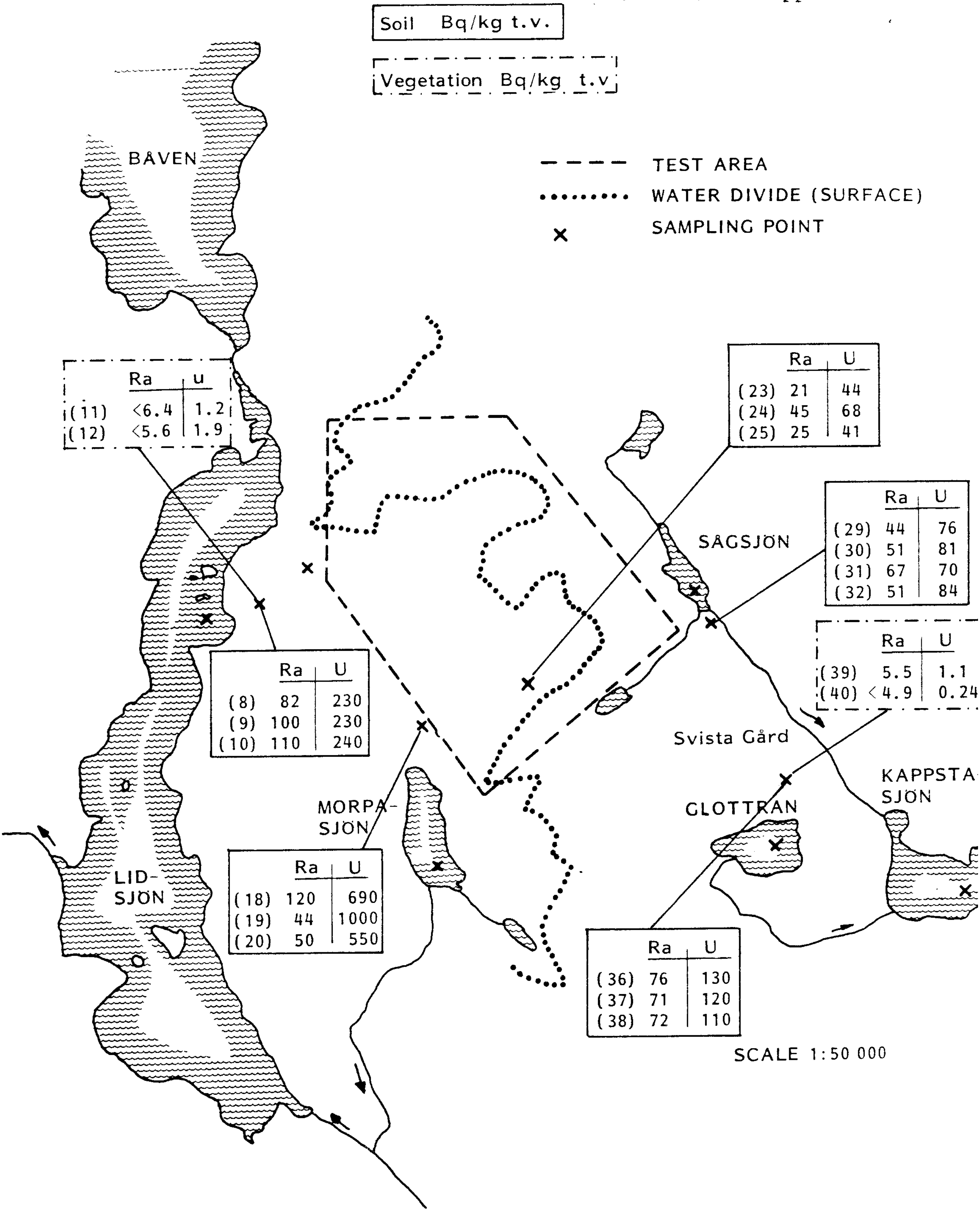

Figure B.3

The Fjällveden area.
Sampling sites and contents of radium and uranium in soil and vegetation.

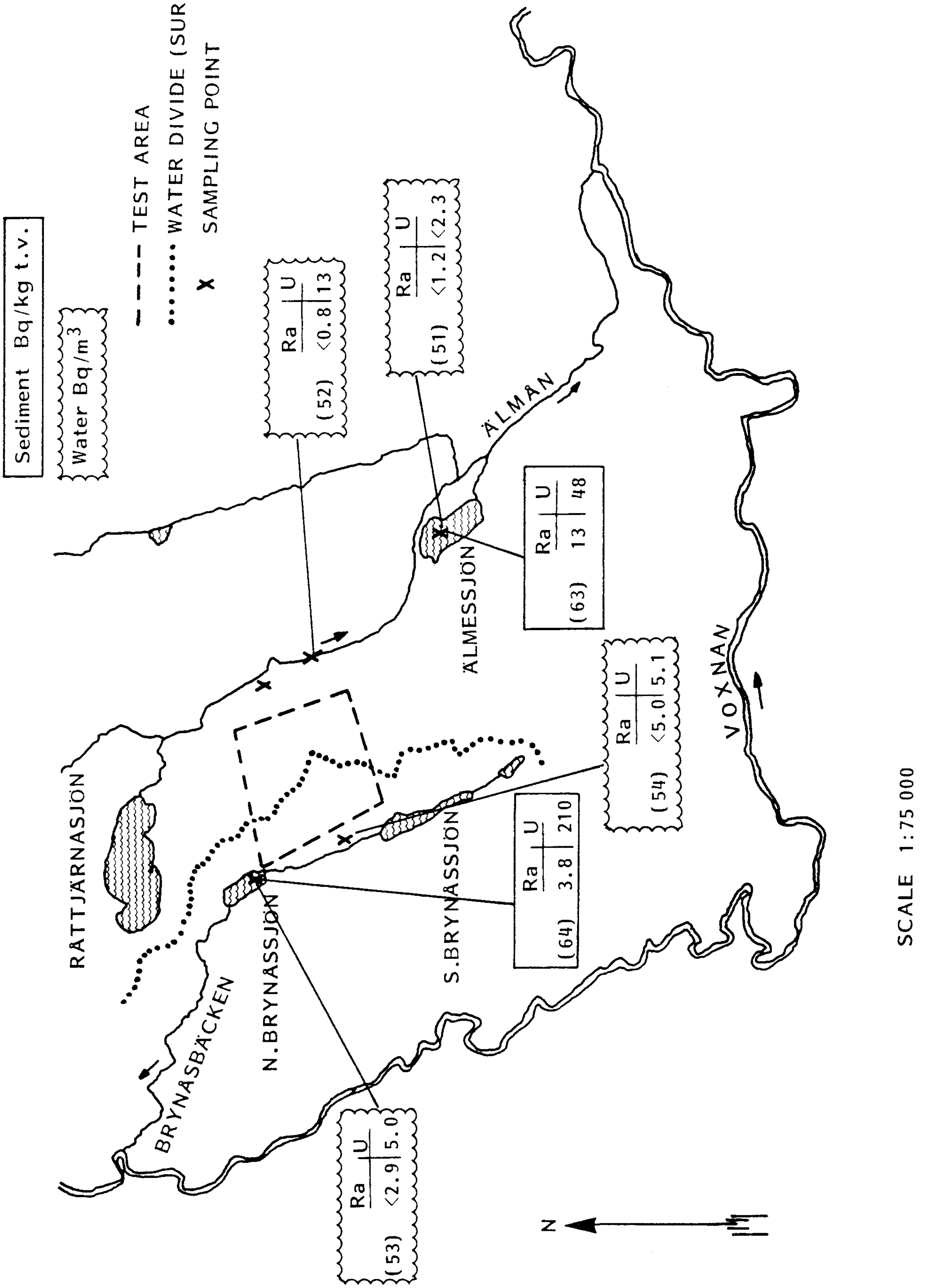

Figure B.4

The Voxnan area.
Sampling sites and contents of radium and uranium in water and sediment.

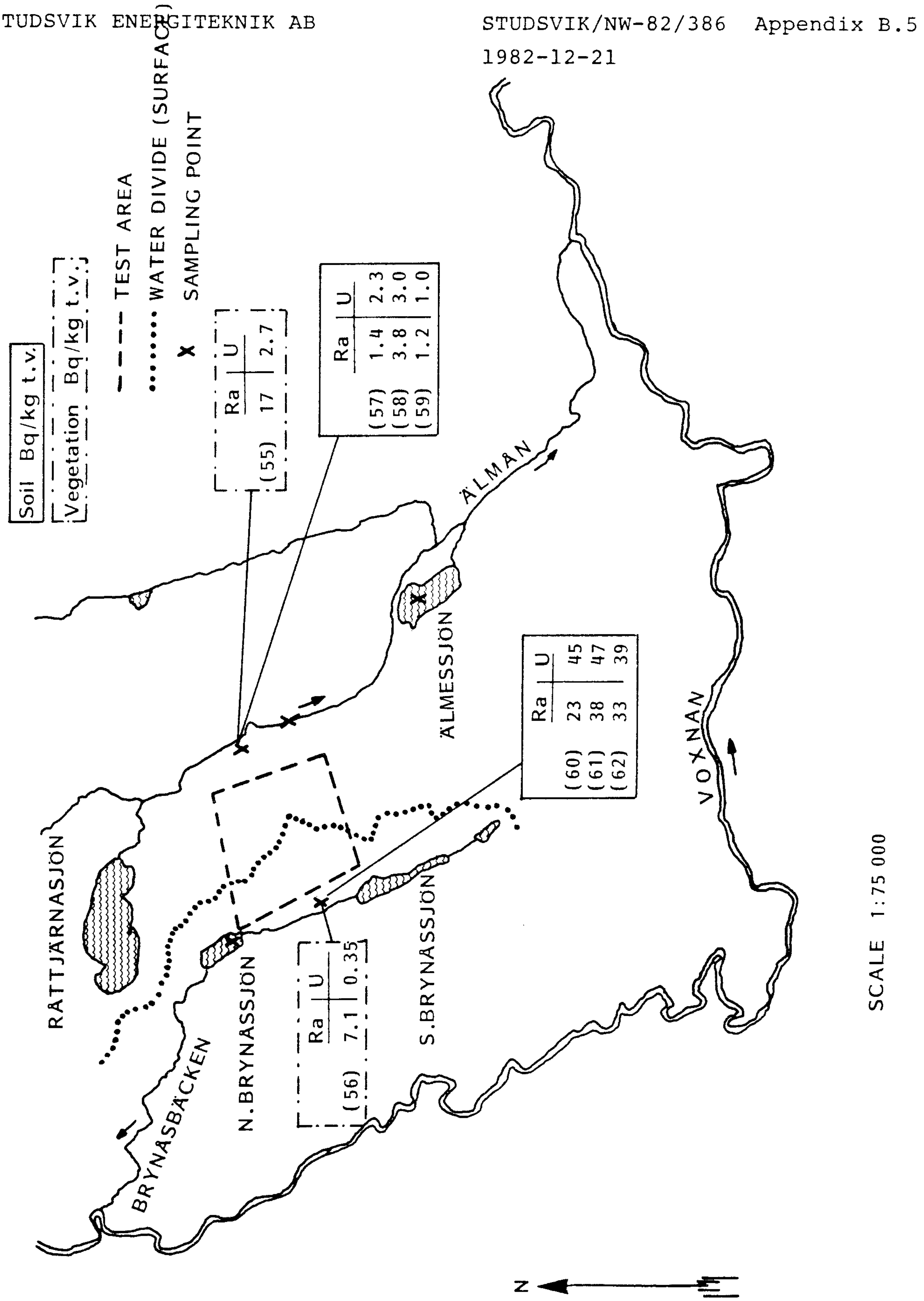

Figure B.5

The Voxnan area.
Sampling sites and contents of radium and uranium in soil and vegetation.

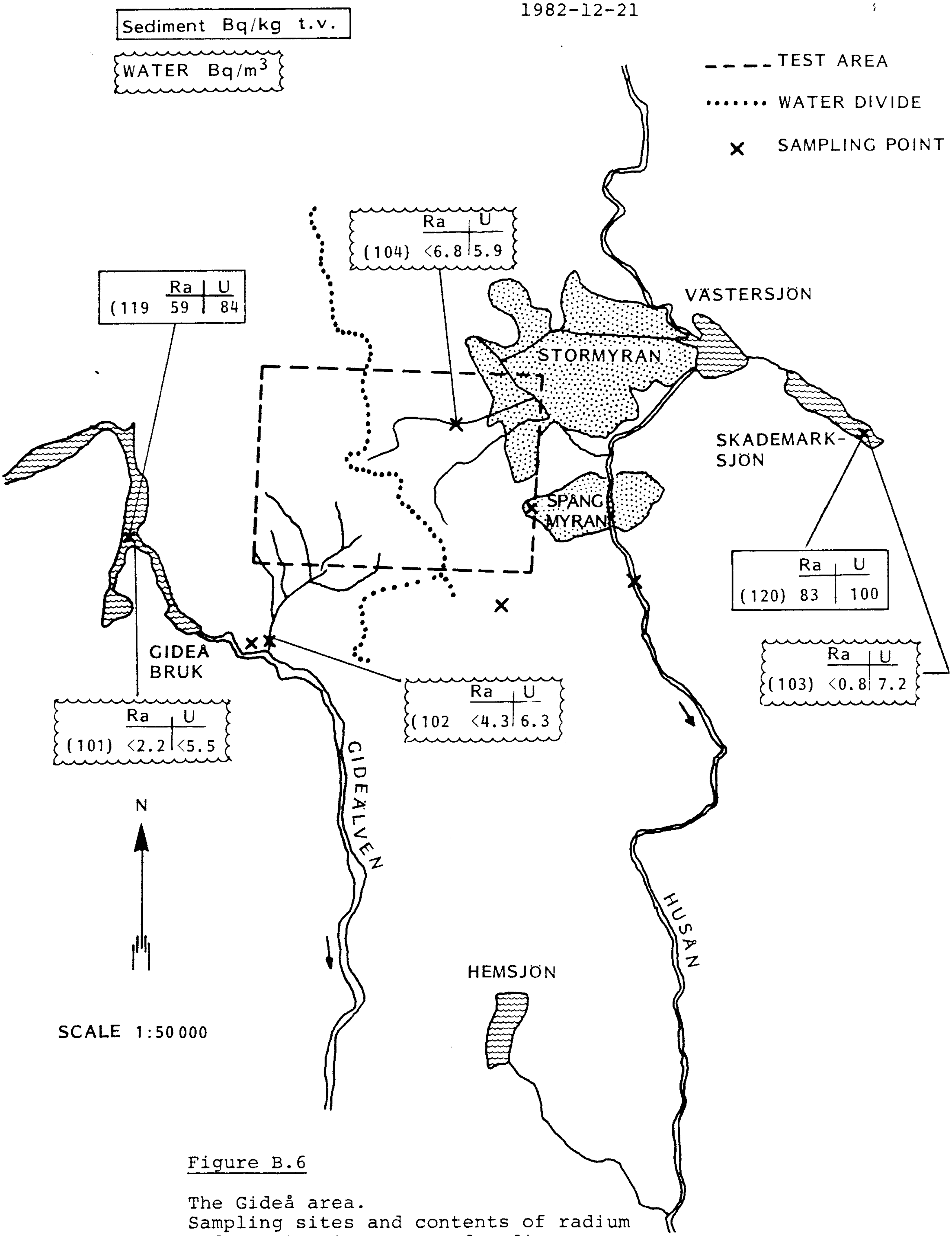

Figure B.6

The Gideå area.
Sampling sites and contents of radium and uranium in water and sediment.

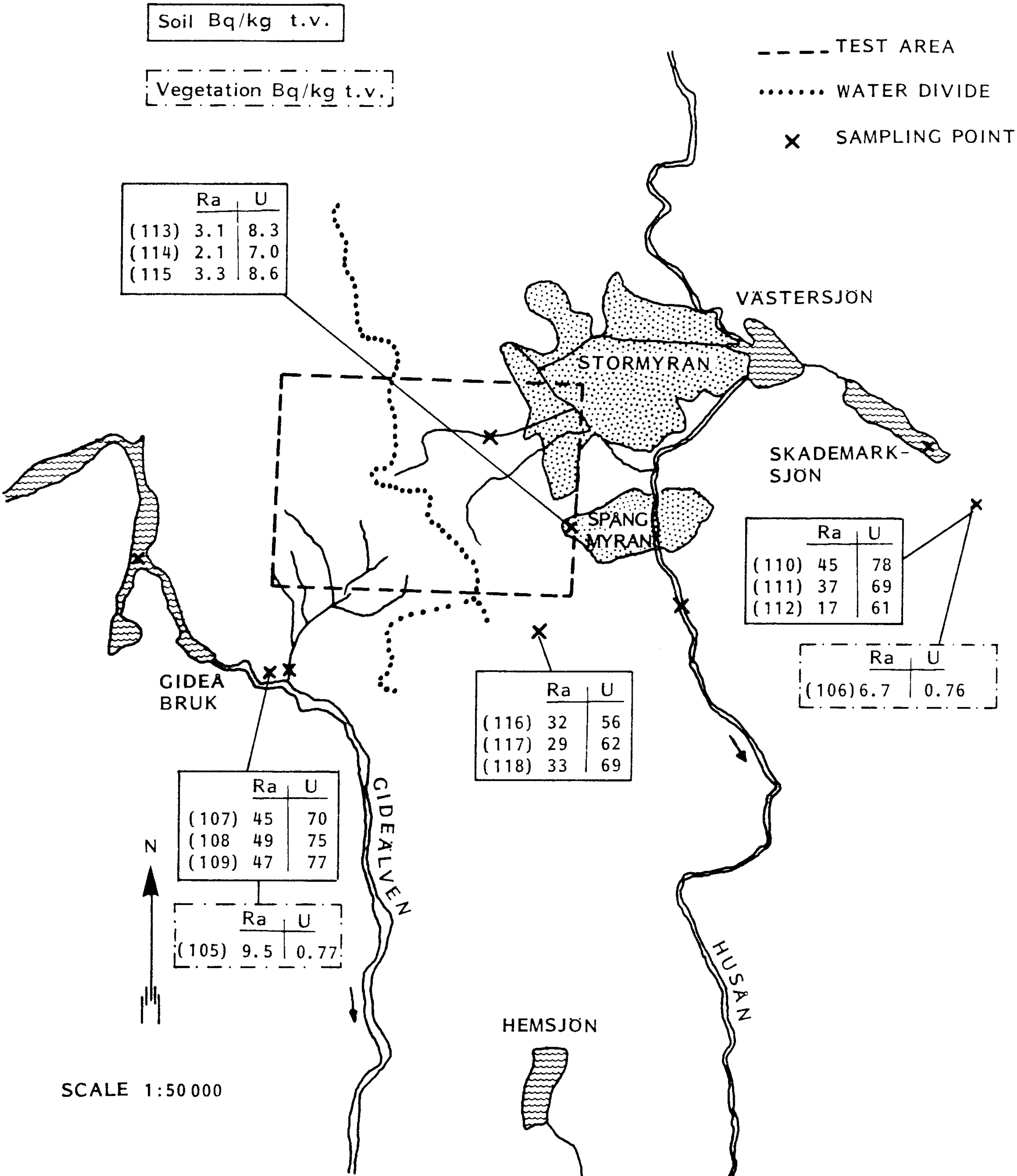

Figure B.7

The Gideå area.
Sampling sites and content of radium and uranium in soil and vegetation.

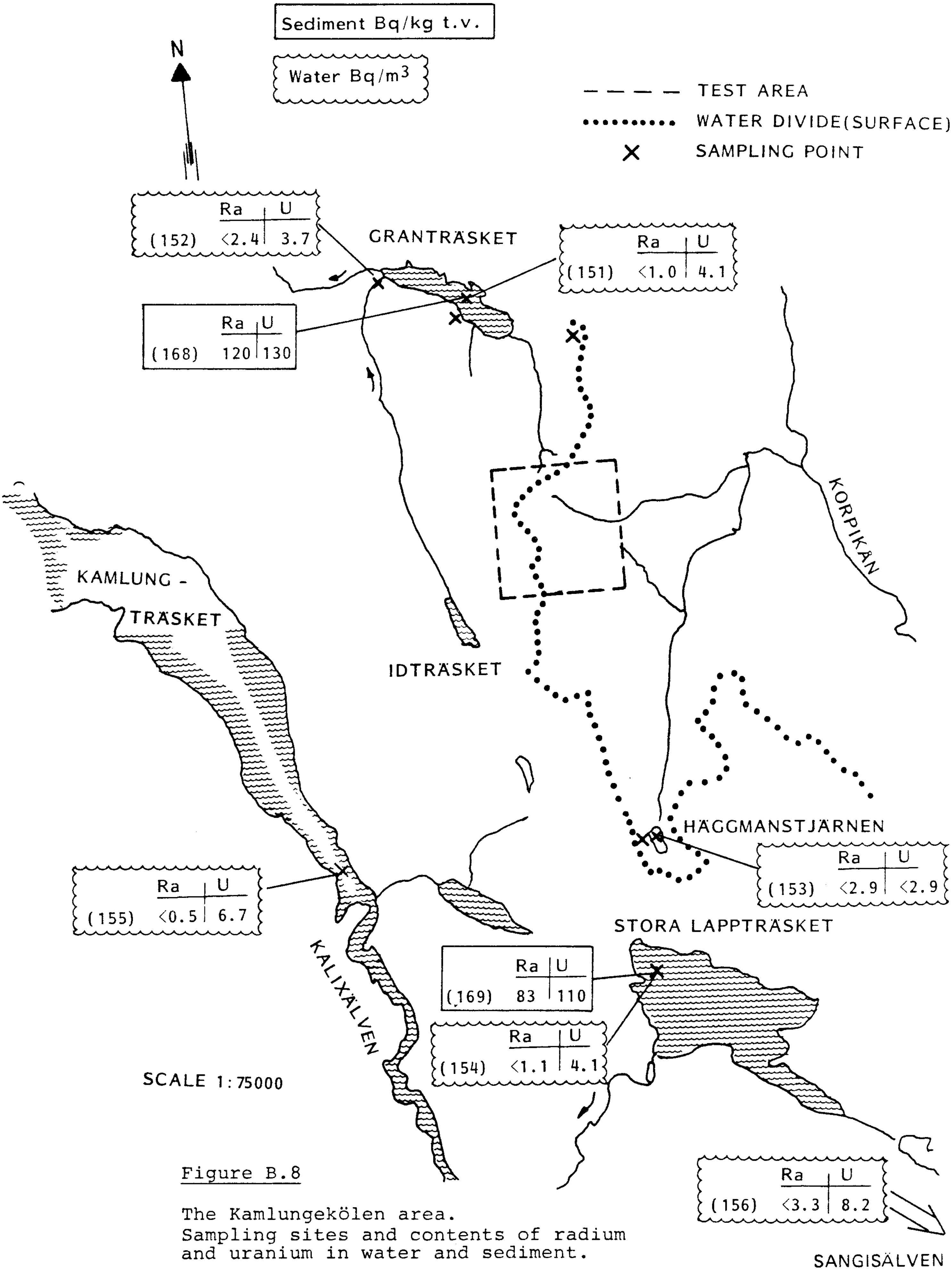

Figure B.8

The Kamlungekölen area.
Sampling sites and contents of radium and uranium in water and sediment.

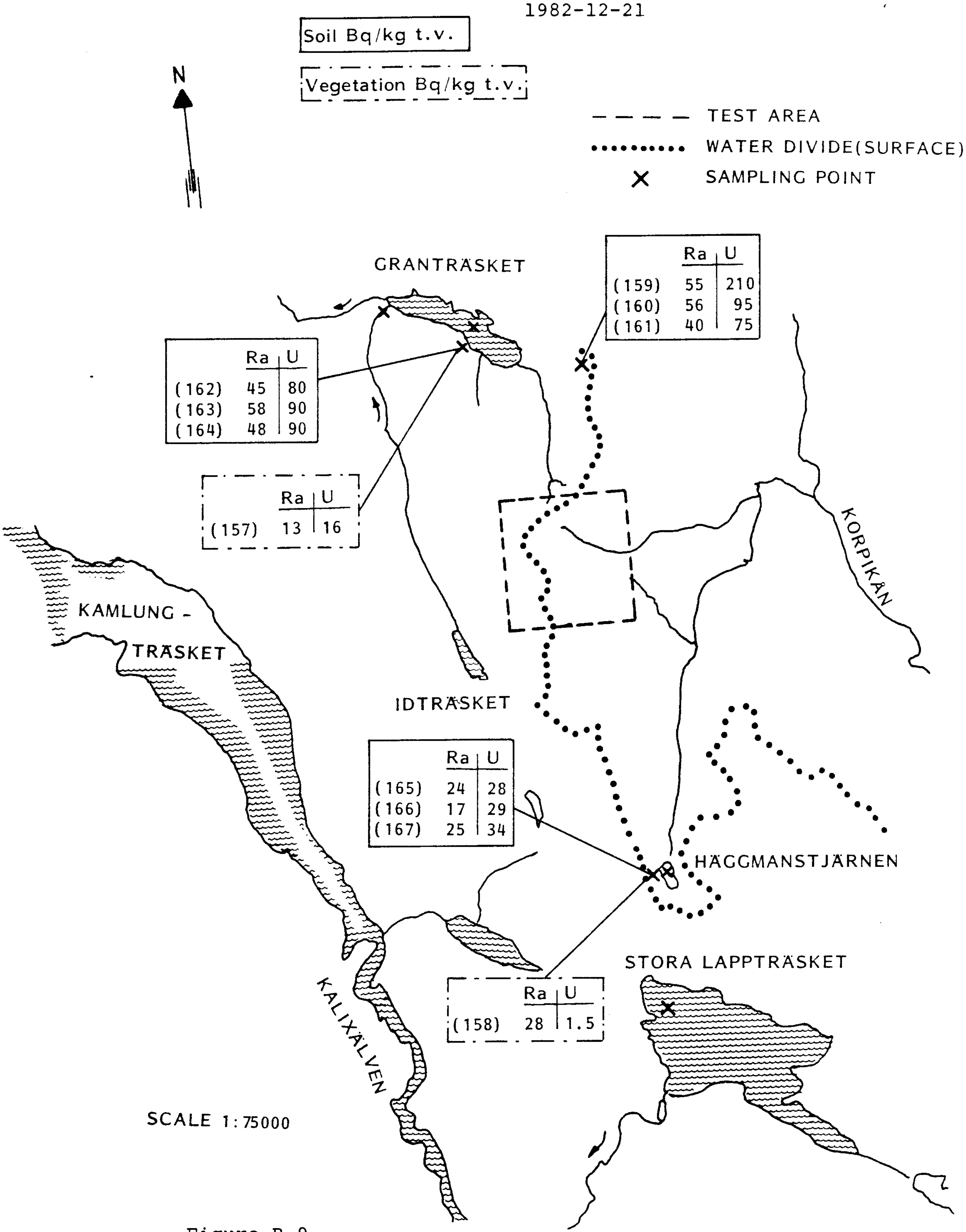

Figure B.9

The Kamlungekölen area.
Sampling sites and contents of radium and uranium in soil and vegetation.

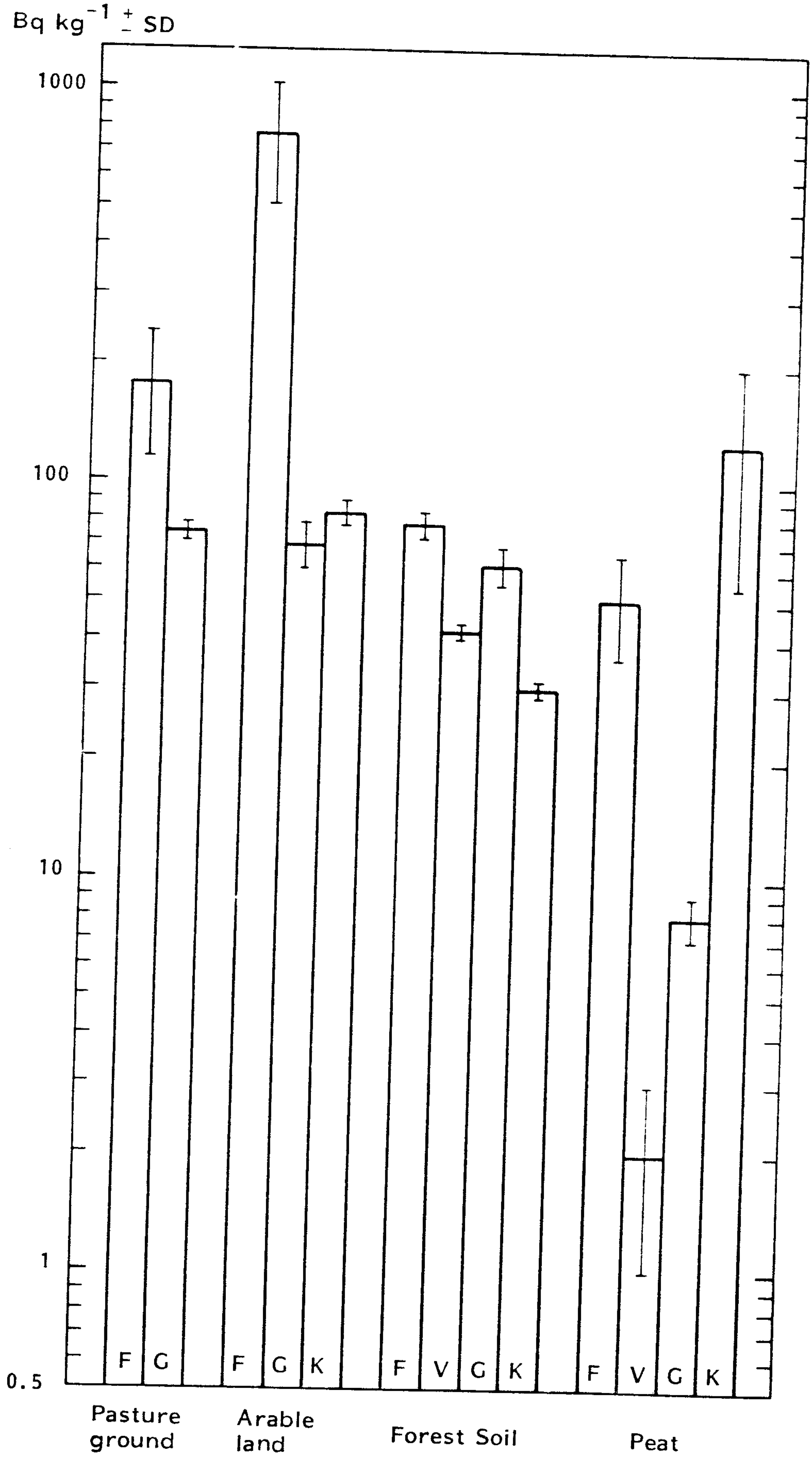

Figure B.10

Average contents of uranium in different kinds of soil, expressed as Bq kg^{-1} ± SD (dw).
F = Fjällveden, V = Voxna, G = Gideå, K = Kamlunge

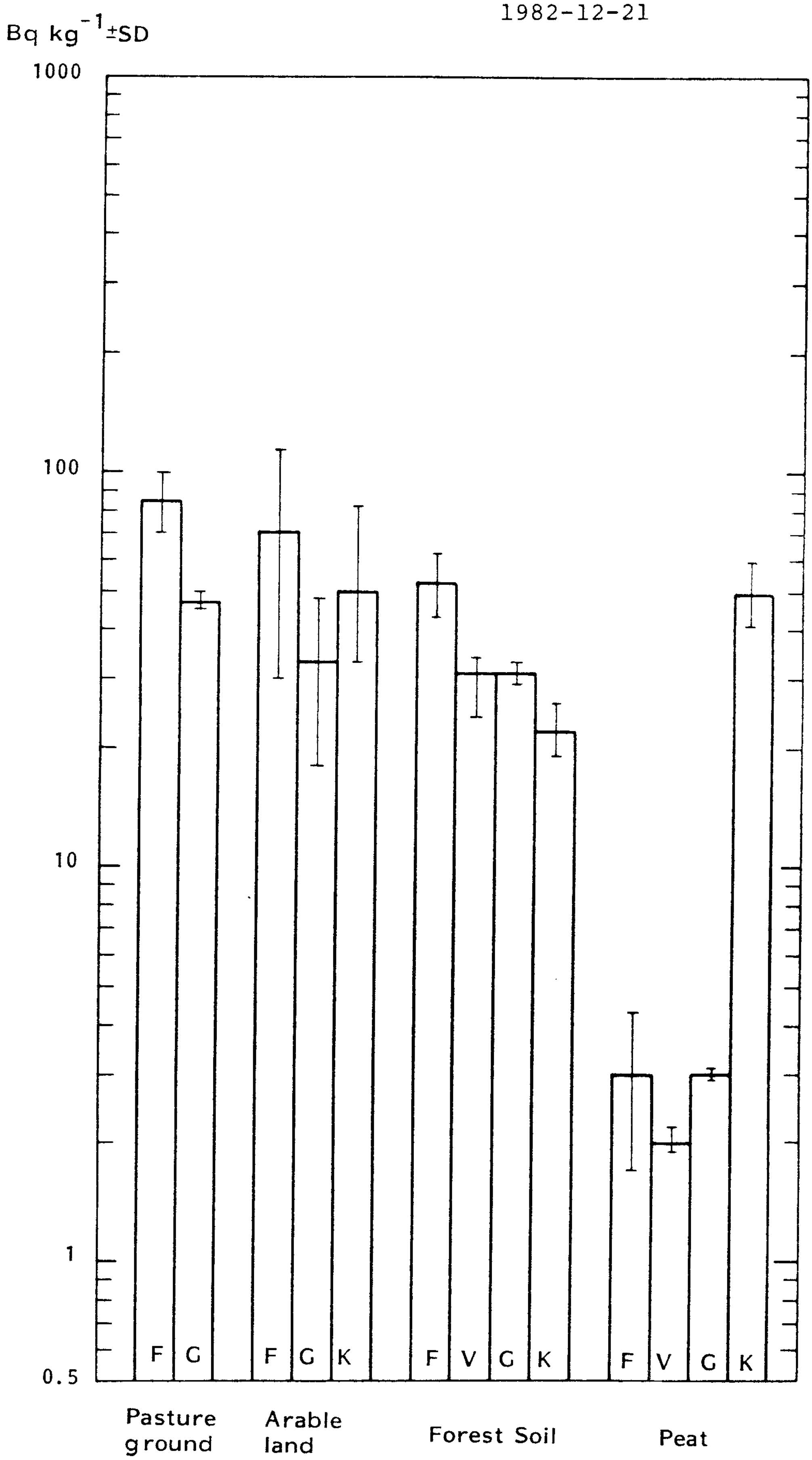

Figure B.11

Average contents of radium in different kinds of soil, expressed as Bq kg^{-1} ± SD (dw).
F = Fjällveden, V = Voxna, G = Gideå, K = Kamlunge

FÖRTECKNING ÖVER KBS TEKNISKA RAPPORTER

1977-78

TR 121 KBS Technical Reports 1 - 120.
Summaries. Stockholm, May 1979.

1979

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

1980

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

1981

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

1982

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December 1981

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

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PLAN 82
Part 1 General
Stockholm, June 1982

TR 82-09:2 Radioactive waste management plan
PLAN 82
Part 2 Facilities and costs
Stockholm, June 1982

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Sweden, April 1982

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Department of Chemical Engineering
Stockholm, Sweden, 1982-03-01

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Luleå, December 1982

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December 1982

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Stockholm, Sweden 1982-12-22

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T Ittner
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