Central Kola Survey Expedition
Murmanskaya Geological Research Expedition
Geological Survey of Finland
Geological Survey of Norway

REPORT ON JOINT ECOGEOCHEMICAL MAPPING AND MONITORING IN THE SCALE OF 1 : 1 MILLION IN THE WEST MURMANSK REGION AND THE CONTIGUOUS AREAS OF FINLAND AND NORWAY

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NGU Rapport 93.152

Monchegorsk - Apatity - Rovaniemi - Trondheim 1993

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REPORT

Report no. 93.152	ISSN 0800-3416	Grading: Open

Title:
Report on Joint Ecogeochemical Mapping and Monitoring in the Scale of 1:1Million in the West Murmansk Region and the Contiguous Areas of Finland and Norway

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County: Finnmark	Commune: Sør-Varanger
Map-sheet name (M=1:250.000) Kirkenes	Map-sheet no. and name (M=1:50.000)
Deposit name and grid-reference: -	Number of pages: 132 Price: 155 Map enclosures: -

Fieldwork carried out: July - September 1992	Date of report: 30.12.1993	Project no.: 63.2590.01	Person responsible:

Summary:

A series of meetings between the Central Kola Survey Expedition (CKSE), Geological Survey of Finland (GTK) and Geological Survey of Norway (NGU) in 1991-1992 led to the implementation of a pilot project of a joint ecogeochemical study of the impacts of industrial activities on the terrestrial systems of West Kola Peninsula and adjacent areas in Finland and Norway. The main aims of this pilot project were to harmonize methods of sampling, preparation, analysis, data treatment and interpretation, focusing on heavy metals and radionuclides. A small area (12,000km^2) in the tri-state area, including Nikel, Zapoljarny and Kirkenes was chosen as test territory. Experiences of the pilot project should form a base for planning a major project to cover some 170,000 km^2 in the three countries. Snow cover, terrestrial moss, A$_0$-horizon, A$_{0+2}$-horizon, C-horizon, stream water, stream sediments and overbank sediments were used as sampling medias, with 15 sites in each country. A data quality assessment was carried out, and maps of pollutant elements clearly delineate patterns similar to those found by other workers. There is no indication that C-horizon is affected, but results of overbank sediments indicate that there are abnormal conditions with regards to the sediment transport and chemistry in the "industrial desert". Results of ^{134,137}Cs determinations in the uppermost 5 cm of the soil profile show no alarming levels. An attempt at modelling the flux of contaminants is also done.

Keywords: Geokjemi	Analyse	Databehandling
Forurensning	Radioaktivitet	Tungmetall
Fagrapport		

TABLE OF CONTENS

TABLES

FIGURES

APPENDICES

1. INTRODUCTION

Visible damage to the environment in the Kola region is severe. The effects of industrial pollution on terrestrial and aquatic environments are, especially near the cities of Nikel, Zapoljarny and Monchegorsk, clearly expressed. The area affected is also expanding relatively fast. There are few such locations in Europe, if any, where the environmental damage is so dramatically evident.

For geochemists with experience in the regional geochemistry of surficial deposits, it is of great importance to address the question of environmental pollution with the knowledge of large scale natural fluctuations in mind. A program to assess the effects of anthropogenic activities on the natural environment, must also address the question of inherent geochemical characteristics. The natural process of ore formation (that made the operations in Nikel and Zapoljarny possible in the first place), is one of depletion and enrichment of metals relative to the earth's crust. For many metals, economically interesting mineralisations are the results of an enrichment of 1000 - 10000 times the crust's average. Needless to say, this must be taken into consideration when assessing the magnitude of anthropgenic pollution.

The following is a brief recapitulation of the events that lead to the "Joint Ecogeochemical Mapping in the Scale of 1:1 Million of the Western Kola Peninsula and Contiguous Areas in Norway and Finland", and major events in the project itself.

In May 28-31, 1991 a meeting was held in Rovaniemi with specialists of the Finnish Geological Survey (GTK) and the Russian Central Kola Survey Expedition (CKSE), concerning a proposal to carry out a cooperative ecogeochemical research near the border areas between Finland and Russia. The meeting was arranged according to the correspondence of O. Darkshevich CKSE, K. Kauranne and A. Silvennoinen GTK.

At a follow up meeting in Monchegorsk, October 1-5, 1991, where also the Geological Survey of Norway (NGU) participated, it was decided to start a pilot-project in a test area including Nikel-Zapoljarny localities and adjacent Norwegian and Finnish areas. The main purpose of this pilot project would be to compare and harmonize sampling techniques and analytical and data processing methods (memorandum I, Appendix N° 1). The sampling was to be carried out during 1992.

The meeting in Rovaniemi March 24-26 1992 aimed to make decisions in detail about the pilot project (memorandum II, Appendix N° 2). It was decided that sample materials should include: Snow cover, feather moss, A_0-horizon, $A_0 + A_2$-horizon (combined sample), unaltered (C-horizon) soil, minerogenic stream sediment, stream water and overbank sediments (top and bottom samples).

In the meeting in Neiden/Kirkenes on May 21-22 1992 (memorandum III, Appendix N° 3) details about field documentation and the field excursion in July 1992 were discussed.

During the three-country field excursion in July 1992, the code list for field documentation, principles for finding ideal sample sites and methods of analysis were defined (memorandum IV, Appendix N° 4). As a conclusion a corrected schedule of the project was decided. Each part should write a draft of the national report by the end of the year 1992.

In the meeting at Rovaniemi, October 8 1992 (memorandum V, Appendix N° 5), a small change in time schedule was decided due to difficulties in the international exchange of samples. The national reports should be delivered to other participants at the end of January 1993.

The team of authors greatfully acknowledge the support by their own institutions, and in Norway the financial support of the Ministry of Environment. Furthermore, we would like to honor the pioneering spirit and efforts of the people during the various phases of the pilot project:

-Field work: T E Finne NGU, A Misund NGU, V A Pavlov CKSE, E N Semenov CKSE, U Väisänen, M Äyräs and assistants GTK.
-Analytical work: M Ilmasti and E Kallio GTK, V F Lagunova MGRE, F P Mahanjkova MGRE, A Misund NGU, H Niskavaara GTK, M A Salihova MGRE, N V Solovjeva CKSE, T Volden, M Ødegård and assistants NGU, and L J Zotova MGRE.
-Computing: I V Bogatyrev MGRE, T E Finne NGU, R Pohjola GTK, and M Äyräs GTK.

2. METHODS

2.1. FIELD WORK.

Samples were collected from 45 localities (15 localities per country) within the pilot project area comprising some 12000 km^2. In addition to the samples from the 15 localities, each country collected field duplicates from 5 localities, distributed throughout the area. Field duplicates were collected a few hundred meters away from the original samples.

Sampling sites in Finland were choosen by first assigning sites in which overbank sediments should be taken. The overbank sediment sites are at outlets of the drainage areas; accordingly some of the overbank sites are quite near each other. Stream sediments and water samples were taken at the same site as the overbank sediments. The terrestrial samples - moss, humus, combined sample and unaltered soil sample - were taken as near the centre of the drainage area of the overbank sediment sample as possible. The network of snow sampling was quite regular. Similar logistics was applied in Russia, whereas in Norway both stream related samples and terrestrial samples were collected from approximately the same locations for a given site.

Sample sites were marked by field crews on maps in the scale 1:50000 - 1:200000, and transferred to common base map in the scale 1:500000. Coordinates (Easting, Northing and altitude) for the locations were calculated to UTM-zone 36. Sites of sampling points for snow, soil horizons, water, stream sediments, overbank sediments and moss are shown in figures N° 1-3.

Field documentation followed a comprehensive scheme. Appendix N° 6 contains a list of codes and terms used for field description during sampling of the various materials. An overview of the various items observed at each sampling site for moss, A_0-horizon, A_{0+2}-horizon, C-horizon, stream sediments and stream water is given in Appendix N° 7. For snow sampling, the scheme illustrated in Appendix N° 8 was followed, and the observations indicated in Appendix N° 9 (also used in the WEGS pilot project of a West European geochemical atlas of overbank sediments and stream sediments (Bølviken et. al. 1993)) were recorded for overbank sediments.

For all laboratories to have the required sample sizes agreed upon, each party collected a total of about 30 kg samples from each sample site, not counting the field duplicates. All together, about 150 kg samples were transported to the Finnish laboratory, 500 kg to the Russian and 1000 kg to the Norwegian. In addition to this, the Finns processed some 180 kg snow, and the Russians twice as much.

2.1.1. Snow

Snow cover in the spring is ideally an accumulation of last winter's precipitation. The snow cover will contain precipitated snow with its solute components and particles deposited along, but also blown in dust of local natural or anthropogenic origin, as well as reworked snow (snow once deposited elsewhere, and blown into its final position).

Snow sampling was carried out in March - April 1992 in order to collect as large amount of the winter's total snowfall as possible. Sites of sampling were preferrably selected in a level area (50x50m) with uniform snow depth. Each sample was made from three subsamples collected so that different situations were taken into consideration (open field - underneath trees). The distance between the three subsites was 10-15 m, forming an equilateral triangle. The entire thickness of the snow pack was sampled, with the exception of the lowest 5 cm to avoid mixing with local vegetation and soil.

Sampling tool in Finland was a colorless plastic tube used by the Finnish Water and Environmental District. A similar tool was used in Norway, according to spcifications given by Norwegian Institute of Air Research (NILU). The diameter of the tube is 10 cm and the length 80-100 cm. In Russia, a specially developed black plastic tube with metal knife and closure assembly at the base was used. Samples were stored in 10 l white plastic buckets with lid, and kept frozen until arrival at the laboratory. Weight of the snow sample was about 6-8 kg for analysis in Russia and 3 kg for analysis in Finland.

2.1.2. Terrestrial moss (*Hylocomium splendens*)

The terrestrial mosses, more specifically the *Hylocomium splendens* and the *Pleurozium schreberi* species, are vegetation that obtain all their nutrition by air and precipitation. Their attachment organs should rather be dubbed "hold fasts", as they do not fill the function in the plant's nutritional cycle. Hence, the mosses' chemical composition should reflect the precipitation in their area. However, it is recognized that also chemical composistion of the bedrock/surficial deposits to some extent is reflected in the mosses chemistry - this probably due to blown in dust of local origin, and the interaction of local soil chemistry and moss through high flow of surface water at periods of the year. The species used in this work grow annual shooth, providing an opportunity to investigate the chemical environment of the last 2-3 years.

Feather moss (*Hylocomium splendens*) was handpicked from an area of 50 x 50 m. Only the three-four latest annual shoots were taken. Every effort was being made to avoid mixing the sample with minerogenic matter. About 20-30 g dry weight (1 liter) of moss was placed in a bag of paper or polyethylene. In the rare event that there was no feather moss present, samples of a different species, *Pleurozium schreberi*, were taken in the same manner. One sample was collected for the Finnish laboratory.

2.1.3. Organic soil (A_0-horizon).

Organic soil or the humus layer, is the top layer of any soil with top vegetation. Ideally, the humus layer consists of only decayed organic material, but due to several physical processes, there is often a quite substantial minerogenic admixture in the organic layer. Hence, a sample of humus will to a varying degree reflect local geology and atmospheric deposition. The humus particles have a quite different affinity to solutes than minerogenic particles. In many respects, the humus layer can be pictured as the resin of an ion exchange coloumn. The organic fraction is thought to give a good long term (decades) integration of conditions regarding solute chemistry.

Organic soil samples were made up of five subsamples taken at the corners of a 20x20 m square and at its center. For each subsample a square of approximately 20x20 cm was collected for the entire thickness of the A_0-horizon. All vegetation and litter was removed, and the humus material was worked manually to enable removal of coarse fragments and roots. Samples were wrapped in bags made from woven cotton or fiber glass or from polyethylene (Russia, Norway and Finland, respectively).

At each location three parallell samples of each 1.5 kg were taken, allowing all three countries' laboratories material for analysis.

2.1.4. Combination soil sample (A_0+ A_2 horizon).

Atmospheric fall-out of radioactive isotopes after nuclear missile tests and as a results of regular or irregular emissions of nuclear reactors, will have the greatest influence in the food chain an by direct radiation when they are retained in the upper 5 cm of the soil. At greater depth, the radiation will be screened, giving much less direct exposure to animals and man. At the same time, grazing animals will be less affected through the food chain, their forage is most influenced by the upper part of the soil profile.

At the humus subsampling point where the humus cover was at its thickest, a combination soil sample was taken. Samples were taken from surface to the depth of 5 cm, hence they represent mixtures of A_0 and A_2 soil horizons in varying proportions. The size of the square sample pit was made to suit a sample weight of 2 kg. Combination samples were collected for analysis by the Russian party only.

2.1.5. Unaltered soil (C-horizon).

The origin of soils may be many; glacial, glacio-fluvial, fluvial, and so on. In large parts of Northern Fennoscandia (comprising Northern Norway, Finland and the Kola Peninsula), the most important soils areawise were generated in connection with the glaciations in the past. These soils have since experienced weathering, but in most locations throughout this area, unaltered soil is found at depth. The chemical composition of these unaltered soils is considered to represent the natural state of the geologic environment.

At the sampling sites of humus and combined soil, samples from unaltered soil were also taken. The samples were taken at a depth where no brown Fe-enrichment is shown (mainly about 50-80 cm). Five subsamples, four from the corners of 20 x 20 m square and from the centre of the square, were combined in field and stored in plastic bags (Finland), woven bags of cotton (Russia) and fiber glass (Norway). Weight of the sample was 2.0 kg, and there were collected separate samples from the same pits for each of the three parties.

2.1.6. Overbank sediments (top and bottom).

Overbank sediments, or flood plain sediments, are sediments deposited on the floodplains of rivers and streams during episodes of flood. When rivers flood, their suspended loads are derived from an increased number of erosion points, and their composition can more rightfully be said to represent the entire drainage basin than during normal flow. The sediments accumulated on the flood plains present themselves much as lake sediments; chronologic profiles that show little, if any soil profile development.

Overbank sediments were sampled on the floodplain of rivers with size of upstream drainage basins between 30 and 100 km^2. From one pit, a top sample was colllected, as well as a bottom sample. The thickness of top samples was 10 cm from the top of the profile. Weight of a top sample was 2-3 kg. A bottom sample was taken, containing material from the part of the deposit between its base (or ground water level) and the middle. Weight of a bottom sample was 5 kg. The samples of overbank sediments were only collected for the Norwegian laboratory.

2.1.7. Stream sediments.

Recent stream sediments are composed of mineral grains eroded by the stream further upstream, usually at a limited number of point sources. The chemical composistion of a stream sediment at a given location is initially a result of the mineralogy of the soil upstream, but with varying importance, also a result of solute chemistry in and aroud the stream channel. The results of stream sediment geochemical mapping can therefore in many cases be difficult to interpret.

Minerogenic stream sediments were collected from the same locations as the stream water. At each location five subsamples along 50 m of the stream bed were collected into a bucket for one assembly sample. The sample was set to sediment for five minutes in order to keep the fines, and the decanted. Two samples of each 3 kg for Norwegian and Russian parties were collected at each sample point, and kept in sturdy polyethylene bags for transport to the laboratory.

2.1.8. Stream water.

Stream water has a component of precipitation and of ground water. Chemistry of these waters are delicate balances, but nevertheless it portrays its environment quite well. During normal conditions, the ground water will show higher contents than precipitation for most chemical compounds, but when precipitation is influenced by industry or the sea, this picture will change. The ratio of precipitation to ground water hence is important when working with stream waters, as well as immaculate cleanliness when working with this really low concentration natural substance.

Two water samples were collected near the surface of streams, both for analysis in Finnish laboratories. The first sample (0.5 l) was stored untreated in a plastic bottle rinsed with local water. The other sample was filtered through 0.45 μm Millipore® disposable cellulose acetate filters directly into 100 ml polyethylene bottles and acidified with 0.5 ml of 65 % MERCK® suprapure nitric acid. The filters were stored in polyethylene bags. Conductivity and pH were measured in the laboratory. Samples were collected for the Finnish laboratory only.

2.2. ANALYTICAL WORK.

Analytical work in the pilot project had the following main aims:

- allow for intercalibration of the national preparation and analytical methods
- allow each country to employ their own methods and techniques for all samples in order to compare all analytical data and to choose the techniques yielding most valuable information

2.2.1. Intercalibration.

As the original samples sent from each country to the others in practice are duplicate samples, it was decided that for intercalibration purposes, the Russians were to deliver subsamples of the non-acidified as well as the filtered and acidified samples from their own snow water to Finland. These 20 subsamples of snow water and 20 subsamples of snow filters, 14 subsamples of humus (A_0-horizon) from a Monchegorsk locality outside the pilot project area, and 7 subsamples of state standand samples were sent to Finland to be analyzed at GTK.

2.2.2. Analytical methods and techniques of Russian party.

2.2.2.1. Snow samples.

The snow samples of about 6-8 kg from each sampling station were delivered and prepared at the Central Kola Expedition. The snow was melted in room temperature and filtered instantly through blue ribbon cellulose filterpaper. The volume of the water was registered. One part of the snow water (1-2 litres) was used for analysing the common constituents (main cations Ca, Mg, Na+K, Fe(III), NH_4, anions HCO_3, CO_3, SO_4, NO_3, NO_2, Cl, and also Al, H_2SiO_3, pH, and F) and calculation of residue after evaporation, sum of cations, carbonate- and noncarbonate hardness. The remainder of the snow water (about 4-6 litres) was acidified and delivered to the Chemical laboratory of MGRE to be analysed by AAS (instrument C-115) for Ni, Cu, Co, Pb, Zn, Mn, Al.

The filterpaper was weighed before and after filtration and drying. The filter residues were delivered to the Spectral laboratory of MGRE and ashed at 450 °C (slow heating for 12-15 hours). The ash of the snow filter was analysed by Quantitative Emission Spectral Analyses (arch of alternating current 220 V, 20 Ampéres, DFS-13 spectrometer) for 16 elements: Ni, Cu, Co, Cr, V, Mn, Ti, Pb, Zn, Sn, As, Ag, Be, Nb, Zr, P. Results were reported as concentrations in the dry ash.

2.2.2.2. Soil samples, A_0 horizon (humus).

The samples were dried, homogenized (< 1.0 mm.), weighed and ashed at 400-450 °C (slow heating during 12-15 hours). Then ashed samples were sieved through sieve 0.07 mm. Both fractions (<0.07 mm and >0.07 mm) were weighed. The organic rich material (grain size <0.07 mm) was sent to the laboratories of MGRE for analysing total concentration of main petrogenic elements: Ca, Mg, K, Na, P, Al, Fe and also for 16 ore and rare elements: Ni, Cu, Co, V, Cr, Mn, Ti, Pb, Sn, Zn, Ag, Be, Nb, Zr, Sr, Be.

The chemical laboratory of MGRE also performed a partial digestion of soil samples by 7M HNO_3 according to the procedures of NGU. Content of sulphur was determined by weight chemical (gravimetric) method in the laboratory of CKSE. This laboratory also determined pH and contents of F in water-extracts.

2.2.2.3. Soil samples, C horizon.

The samples were split to two parts and sieved to two fractions (grain size < 0.07 mm and < 2.0 mm). For the < 0.07 mm fraction, methods of analyses, techniques, laboratories and lists of elements were the same as for A_0-horizon samples. The < 2.0 mm fraction was subjected to the same treatment, but only the 16 ore/rare elements were analysed. No water-extraction was done on these samples, but the fine fraction samples were extracted by 7M HNO_3.

2.2.2.4. Soil samples, combination A_0+ A_2-horizons.

The sample preparation included drying and homogenization of all sampled material. The analyses of ^{137}Cs and ^{134}Cs were made by the Nucleus Physical Laboratory of Experimental Methodical Expedition of the State Geological Enterprise 'Sevzapgeologia' in St. Petersburg. Results were reported as Ci/kg.

2.2.2.5. Stream sediment samples.

The samples were dried and the size fraction <0.07 mm was sieved to be analysed. Total contents (digestion $HF+HCO_3+HNO_3$) of the main petrogenic elements were determined by AAS (Ca, Fe and Mg), flaming photometer (Na and K), or colormetric method (Al). The heavy metals and rare elements were analysed by ESA, list of elements was the same as in case of the soil samples.

Further characterictics used by Russian party methods are given in table N° 1.

2.2.3. Analytical methods and techniques of Finnish party.

2.2.3.1. Snow samples.

After sampling, the buckets containing snow were kept in cold storage. Daily 5 samples were left to melt in room temperature. Next day after melting pH and conductivity (GTK method 143R) were measured from these "raw samples". The melted sample was filtered through blue ribbon cellulose acetate filter using vacuum.

The filtrate was divided into two subsamples. The first subsample was used for potentiometric determination of F (GTK method 143I) and ionchromatographic determination of Br, Cl, NO_3 and SO_4 (GTK method 143R). The other subsample was acidified with suprapure nitric acid (0.5 ml/100ml sample) and used for analysis with ICP-MS (GTK method 140M) and ICP-AES (GTK method 140P).

From selected samples a subsample was sent to NERC Isotope Geosciences Laboratory (in cooperation with the British Geological Survey) for stable isotope analysis.

The filter paper was digested with 10 ml concentrated nitric acid in micro wave oven, diluted to 50 ml with water and analysed with ICP-AES (GTK method 503P). Results were recalculated to total volume of snow melt water.

2.2.3.2. Soil samples, A_0 horizon (humus).

Field samples were dried at room temperature, bigger roots and extraneous material was removed under visual inspectation. Samples were homogenized by milling with a domestic blender with blades made of non contaminating material. Samples were sieved to less than 2 mm. For comparison, a selection of samples were split and sieved to -0.5mm, and this fine fraction was coded Z.

For digestion, 0.500g of humus was mixed with 10 ml of concentrated nitric acid in a micro wave oven and diluted to 50 ml with water (US EPA standard 3051; GTK method 503). In addition an ammonium acetate leach at pH 4.5 (shaking for 2 hours) was carried out (GTK code 201).

The clear solutions were analysed with Thermo Jarrell Ash Polyscan 61E ICP-AES for 30 elements (GTK method 503P and 201P) and with Siex Elan 6000 Inductively coupled plasma mass spectrometer (ICP-MS) for 20 elements (GTK method 503M).

2.2.3.3. Soil samples, C horizon.

Samples were dried in original bags at 80 °C and hammered to break the agglomerates formed during drying. The sample was split with a riffle splitter to two equal splits. By use of nylon sieves, the sample splits were sieved to one fraction less than 0.063 mm and another fraction less than 2.0 mm, the latter coded Z.

An Aqua Regia digestion was performed adding 2.0g of the < 2 mm fraction to a mixture of 9 ml concentrated HCl and 3 ml concentrated HNO_3 in a borosilicate tube. It was left overnight at room temperature and then for 2 hours at 90 °C in an aluminium heat block. The digest was diluted to 60 ml with water, mixed thoroughly, decantated to polystyrene tubes and centrifuged (ISO standard 11 466; GTK method 511). In addition an ammonium acetate leach at pH 4.5 (shaking for 2 hours) was carried out (GTK code 201).

Similarly, 0.2 g of less than 0.063mm fraction was digested with 3 ml of Aqua Regia for two hours at 90 °C in an aluminium block, diluted to 15 ml with water, mixed thorougly, decanted to polystyrene tubes and centrifuged (GTK method 511). The fine fraction was not subjected to ammonium acetate leach.

The clear solutions were analysed with Thermo Jarrell Ash Polyscan 61E Inductively coupled plasma-atomic emission spectrometer (ICP-AES) for 31 elements (GTK methods 511P and 201P).

2.2.3.4. Terrestrial moss (*Hylocomium splendens*).

Field samples were dried in opened original bags in room temperature and homogenized by milling with a domestic blender with blades made of non contaminating material.

For digestion, 0.500g of moss was mixed with 10 ml of concentrated HNO_3 in a micro wave oven and diluted to 50 ml with water (US EPA standard 3051, GTK method 503).

The clear solution was analysed with Thermo Jarrell Ash Polyscan 61E ICP-AES for 30 elements (GTK method 503P) and with Siex Elan 6000 ICP-MS for 20 elements (GTK method 503M).

2.2.3.5. Stream water.

In the field two subsamples had been taken. From the unacidified sample determinations of pH and conductivity was performed, as well as analysis of F, Br, Cl, NO_3 and SO_4 (GTK methods 143R and 143I).

The acidified sample was analysed with ICP-AES (GTK method 140P) and ICP-MS (GTK method 140M).

2.2.4. Analytical methods and techniques of the Norwegian party.

A number of subsamples of stream water, moss, A_0-horison and C-horizon collected exclusively for the use of the British NERC Isotope Geosciences Laboratoy, were sent for stable isotope analysis (S and possibly N) after drying of soils and moss.

Prior to analysis in the NGU laboratory, all samples' numbers were shuffled to present the samples in random order for the instrument.

2.2.4.1. Overbank sediments top.

Upon arrival of the moist or already dry samples, they were left to dry at elevated room temperature. Samples were sieved through 0.125 mm nylon sieves, and 2 g were taken for determination of organic content by ashing at 480 °C. For analysis, 1.0 g material was digested with HNO_3 in autoclave (Norwegian Standard NS 4770), and analysed with an internal Y-standard by ICP-AES for 29 elements.

Splits of the prepared samples were also shipped to Finland for analysis at the laboratoy of GTK.

2.2.4.2. Overbank sediments bottom.

The moist samples were kept at elevated room temperature (35°C) until dry. Due to the large sample volumes (up to 10l), samples were split prior to sieving through 0.125 mm nylon sieves. Chemical analysis and determination of organic content was done as for overbank sediments top.

Splits of the prepared samples were also shipped to Finland for analysis at the laboratoy of GTK.

2.3. DATA PROCESSING AND MAP PRODUCTION.

The main tasks of data processing in the pilot project were:

- to elaborate and to test methods of data management and exchange of information between the three participants
- to compare analytical results of the various laboratories and to choose the best set of analytical methods and studied elements
- to check the traditional methods of geochemical data processing in application to environmental explorations
- to check the quality of sampling and analytical methods used in pilot project

Apart from exchanging data in formats described by memorandum III, it was also decided to store all analytical and field description data in the form of separate dBase III data files. Description of these files and their values are found in the field description schemes given in Appendix N° 7-9 together with the information in Table N° 1. Furthermore, it was decided that the official versions of these files should recide at NGU. The rationale for not constructing a sophisticated relational database to accomodate the results of the pilot project is simply the small number of data points compared to the amount of work needed to construct a comprehensive database structure.

2.3.1. Data processing in Russia.

The data base of Russian party was built in accordance with decisions of the meeting in Rovaniemi (memorandum N° 3 of 24-26.03.1992). It contains the field documentation for the 7 sampling medias (snow, organic A_0 horizon, mineral C-horizon, combination A_0+A_2 horizon, moss, and stream sediments) and analytical results for all these medias from Finnish and Russian laboratories. The coordinate system of UTM-zone 36 was used. The Norwegian party provided the computing program to change geographical coordinates to the UTM system, as well as digitized coast lines, border lines, large rivers and lakes of the test area.

The ANOVA algorithm was used to estimate the quality of sampling and analysing methods. The main samples were compared with their duplicates, and main analysis were compared with their analytical duplicates. Data processing was carried out at the Computing Centre of Murmanskaja Geological Research Expedition.

2.3.2. Data processing in Finland.

General statistic description (mean, standard deviation and range) of the analysed elements were calculated for water, moss, humus and C-horizon material.

A factor analysis (principal component analysis and varimax rotation) was carried out on the analytical results of moss and humus for elements which values were above the analytical detection limits (tables N° 2-3).

2.3.2. Data processing in Norway.

Locally derived analytical data were described with univariate statistical techniques, including estimates of minimum, maximum, arithmetic mean, median, standard deviation and cumulative distribution graphs. As a way of controlling quality of data, all field duplicates were checked using scatterplots as a visual control of calculated correlation coefficients.

Data of Finnish analysis on aqua-regia-digestions of overbank sediments prepared in Norway were compared to results of Norwegian nitric-acid-digests, employing the same techniques as for field duplicates.

All data files exchanged between the parties, containing field observations and analytical results in the form of ASCII-files and accompanying description files were transformed into .DBF-format (dBase III-standard) as agreed during meeting in Svanhovd March 1993. Files are also available in selfdescribed Lotus WK1-format.

2.3.4. Map production in Russia.

The data processing results were presented on a set of maps in scale 1:1000000. Two kinds of maps were made; point maps showing element concentrations of single samples, and isoline maps. The point maps employ filled circles with size increasing linearly as data values increase exponentially. For all point maps, Z-values were kept on scales 1 - 3 - 10 and multiples thereof for as many classes needed to cover the data range. Isolines were drawn on a regular grid of 10x10 km after applying an interpolation algorithm with inverse square distance weighting on the point information. The search radius was 20 km, and all maps have 10-12 isolines.

2.3.5. Map production in Finland.

Single-element symbol maps were made by GTK's Circmap program, in which the logarithmically increasing symbol size is calculated according to distribution of data values. First, the maps were drawn according to normal procedure by percentile values of 10 % (lower limit) and 99 % (upper limit). This procedure was used for all materials and all elements. As a second step, maps of selected materials and elements (enclosed in this report) were drawn so that the lower limit was mostly 5 % (in some cases 10 %) and the upper limit 90 % (in some cases 95 %).

2.3.6. Map production in Norway.

Maps were produced as combined point maps and iso-line maps. Circles were given same size, and shaded according to a scale of 14 grey shades following exponentially increasing data values. The Z-scale covered minimum value to 95 percentile. On the same map was drawn the results of a "moving median" gridding, where each 10x10 km grid cell is assigned the median of all data values falling within a 20 km search radius of the cell. The isolines refer to the same scaling used for the raw data in the point map.

3. RESULTS

3.1. COMPARISION AND QUALITY OF ANALYTICAL DATA.

3.1.1. Comparison between analytical results of the GTK, CKSE and MGRE laboratories.

Comparision of analytical data has been carried out by means of parallel analysis of melt water samples, snow filters, ash samples of A_0 soil horizon and Russian state standard samples.

Results of the Russian state standard sample analysis, made by GTK Laboratory (method 511P) are shown in table N° 4. These data show clearly that the method of partly digestion of samples by acid gives similar results for Zn, Cu, Ni, Co, P, As and for S (data only for sulphide ores). The other elements, especially those bound in the silicate minerals' structure (Si, Al, Na, K, Ca, Mg, Fe, Ti, V), cannot be compared. Table N° 5 illustrates the quality of analytical data of Russian laboratories and how they compare with results of GTK methods (for the first group of elements).

A pronounced decrease of Ni (by a factor of approximately 1.3) is observed for both the 140M and 511P methods compared to Russian methods. But Russian AAS and ESA methods give only a slight increase of Cu results compared with GTK methods.

No other elements show marked systematical variation. Random error of any of the methods are insignificant and are also considerably less than the natural dispersions of the elements.

This conclusion is confirmed by results of dispersion analysis which are given in table N° 6 according to Davis (1990).

Sulphur results for melt water samples are not compared. In CKSE Laboratory sulphur concentrations in melt water samples were determined by chemical weight (gravimetric) method. This method gives a total sulphur concentration, in contrast to method 140I of the GTK, giving only sulphate determination.

Sulphur in snow filters is not determined by Russian methods due to the low weight of filter residues.

It is neccessary to keep in mind that the Russian AAS method for analysis of water does have not the sufficient detection limits (table N° 1) for determination of background concentrations of Ni, Cu and especially Co, in spite of the rather big volume of samples.

3.1.2. Comparison between analytical results of the GTK and NGU laboratories.

A complete collection of dried and sieved top and bottom overbank sediment samples were sent from Norway to Finland for parallel analysis. The Finnish laboratory employed their Aqua Regia technique, as the Norwegian used nitric acid digestion. A total of 25 elements were determined by both laboratories, and their inter-laboratory reproducibility is illustrated by scatterplots in Appendix N° 10 and N° 11. Detection limit problems rid the results of Ag, B and Cd at either of the laboratories. Most other elements show good correlation, although Mo, Pb and Sc are somewhat poor. The erratic results of K are most likely due to the employed extractants' poor ability to bring the various silicate minerals into solution. For the major elements, the nitric acid extraction median values are between 1 and 2 times higher than for the aqua regia extraction. For the trace elements, median values of the two extraction methods vary only insignificantly.

3.1.3. Quality assessment of data sets.

A comprehensive scheme of quality assessment has been employed during sampling, preparation and analysing of the samples in order to locate sources of quality degradation in the material. For this report, we show only the most important series of control samples; the field duplicate level (Appendix N° 12) of the various media. For some elements/medias the field duplicates show poor results. Pollutant elements give generally good reproduceablity, but particularly for humus, the reproduceablity of major constituents is low. These are topics to be addressed in future work.

3.2. MAPPING OF GEOCHEMICAL STATUS IN THE TEST AREA.

Results of multimedia geochemical mapping are shown on figures N° 4-54.

3.2.1. Snow cover.

Due to the low concentrations of heavy metals and sulphur in snow, sample contamination is a serious problem. To evaluate the possibilities of contamination during the snow sampling, duplicate samples were taken both by Finnish plastic tube and by Russian sampling equipment at one (background) sampling site in Finland. The concentrations of heavy metals in snow samples taken by the Russian sampling equipment were much higher than those taken by the Finnish plastic tube, differences so high that they can not be due to sampling or analytical variation. A similar, but less pronounced difference is seen at adjacent sites on the border areas Finland/Kola and Norway/Kola. The contamination of samples taken by Russian equipment clearly seems to be due to the metal contents and/or painting of the equipments' reinforcement and closing mechanism. The relative seriousness of this problem, however, is lesser in the areas suffering the high industrial pollution impact than in more remote areas.

3.2.1.1. Melt water.

<u>SO4-ion.</u>
According to Finnish data (fig. N° 4) from IC-determination of SO_4-ion, concentration in the melt water varies from 0.3-0.5 ppm in the distance to 6-7 ppm near the Cu-Ni plants.

Russian data (fig. N° 5) give a rather different picture. These are obtained by precipitation of insoluble SO_4-salt following an oxidation of all available S to SO_4 in the melt water. For simplicity we use the term SO_4 also for these determinations in the further text and figures. Most of the high SO_4-ion concentrations are observed along the Barents Sea coast and the impact of SO_4-ions of technogenic origin does not show on this large gradient of total concentrations. Uncertainties about these data lead us treat them with care, and we will emphasize the results of ion chromatographic analysis for our later calculations. Nevertheless, to demonstrate the effects of marine influence, a recalculation of the primary Russian data of total SO_4-ion into two parts ($_{sea}SO_4$ and $_{techn}SO_4$) is attempted, using the common anion - cation composition of the melt water.

For this purporse the following formula was used: (Annual Handbook, 1989,1990,1991)

$dCl = Na + K + 0.09 - Cl - HCO_3 - NO_3$ (milli-equivalents)

0.09 (milli-equivalents) is the average value of (Ca + Mg) contents in melt water.

Furthermore:

If $dCl^- > 0$, then

$_{sea}Cl^- = Cl^- - dCl^-$ and $_{techn}Cl^- = dCl^-$,

$_{sea}SO_4^{2-} = 0$ and $_{techn}SO_4^{2-} = SO_4^{2-}$.

If $dCl^- = 0$ then

$_{sea}Cl^- = Cl^-$ and $_{techn}Cl^- = 0$,

$_{sea}SO_4^{2-} = 0$ and $_{techn}SO_4^{2-} = SO_4^{2-}$.

If $dCl^- < 0$ then

$_{sea}Cl^- = Cl^-$ and $_{techn}Cl^- = 0$,

$_{sea}SO_4^{2-} = -dCl$ and $_{techn}SO_4^{2-} = SO_4^{2-} + dCl^-$.

Results of these recalculations for SO_4 are shown in figures N° 6-7. Recalculated Russian data in fig. N° 6 are rather similar with the analysis of SO_4-ion by the Finnish laboratory. The reason for this apparent "coastal" phenomenon of increased S-content other than as SO_4 needs to be further investigated, however.

Content of SO_4^{2-} in the snow water according to Finnish analyses shows a broad region in which the snow has elevated levels. Combined with concentration of Cl^- and electric conductivity (not shown), the marine influence on the precipitation of the coastal zone becomes obvious.

pH

The values of pH in snow water show only limited fluctuation (fig. N° 8). The mean is approximately 4.5 and the range is from 4.3 to 6.7. The highest pH-values are at the locations near the towns of Nikel and Zapoljarny.

With the even and "normal" pH- and S-values in snow water, it seems clear that during winter 1991/1992, the transport of acidifying matter from the Kola Peninsula to Finland is rather small. In the snow research of the Lapland Forest Damage Project in 1991 (Derome et al., 1992) the results are much the same as in this study. The study of airborne pollution in Norway and Russia (Sivertsen et al 1992) shows that the highest summer and winter average concentrations were found within 20 to 30 km from the smelters and no elevated level in Finland.

Ni (fig. N° 9).

The analysis of both laboratories show an overall good correlation. The levels of high concentrations (30-300 ppb) in the Nikel - Zapoljarny industrial region are also similar. Data in the western part of the test area are less reliable due to insufficient detection limits of the Russian laboratory.

From the map it appears that in a sector from SW to NW, the deposition of Ni is not influenced by the industry in Nikel and Zapoljarny when the distance to these towns is more than 45 km. In the study of air pollution in the border areas of Norway and Russia (Sivertsen et al., 1992) it was found that Ni contents in snow decreased rapidly with distance from the smelters.

Cu (fig. N° 10).

As for Ni, there is a good resemblance of the anomalous levels of Cu contents (30-300 ppb) between the two labs. But in the concentration range 1-10 ppb Russian data are approximately three times higher than data of the Finnish laboratory.

Co (not shown)

Results show a very clear geochemical anomaly in the Nikel - Zapoljarny area, similar of that of e.g. Cu. (The range of Co is 0.01 - 10 ppb, a contrast of about 1000). As the Russian method has a rather high detection limit

(3 ppb), only the Finnish results are used.

Cr (fig. N° 11)
is given according to Finnish analysis. Cr is also known as one of the pollution elements, but the range of its concentrations is rather narrow (0.03-0.5 ppb).

Al (fig. N° 12)
is considered an indicator of acidification, and is also contributing to toxic effects on fish. In this survey, Al is high in the industrial area, presumably due to leaching of dust from the mining and ore dressing.

3.2.1.2. Snow filter.

Results of the ESA method employed by the Russian laboratory (total content) lend themselves for comparison with the results of analytical method 503P of the Finnish Laboratory (partial digestion).

Fe (not shown), S(fig. N° 13).
The concentration ranges of these two elements are very wide; 100 - 30000 ppb, and they are both identified as industrial pollutants in this area.

It is seen that sulphur concentration is high both around Nikel - Zapoljarny and in localities near Kirkenes, lake Inari and lakes Ala-Akkajarvi, Nyanamyarvi.

Ni (fig. N° 14), Cu (fig. N° 15), Co(not shown) and Cr(fig. N° 16).
Maps of all these elements give the same impression for either of the two analytical methods employed. All the elements show an extreme contrast (max/min-ratio of 1000 - 3000). The highest concentrations of these elements are observed in the Nikel - Zapoljarny industrial region. Moreover, contents of these elements increase in the southern part of test area.

Al (fig. N° 17)
shows much the same pattern as Al of snow water, but lacks the highs of east central Russian samples from areas of acidic rocks.

3.2.1.3. Snow pollution centers.

When calculated as filter/filter+melt water, the ratio for sulphur varies from 2.7 to 96.2 %. One method to locate pollution centres is, according to Djigalovskaja et al (1981) and Vasilenko et al (1985), to map the ratio of an element's concentration in snow filter to its concentration in melt water. Figure N° 18, showing the sulphur pollution centres, gives the same locations of centres as for Ni and Cu. There are two other local sulphur pollution centres in the localities of Kirkenes and lake Inari, but these show no heavy metal anomalies in the filter.

In a sector between SW to NW from Nikel, Cu and Ni deposition seizes at a distance of about 45 km, but as pointed out by Finne et al (1992), the site about 30 km NW of Nikel has less solid deposition of Ni and Cu than expected, when compared to its surroundings. These results coincide with those of Sivertsen et al (1992).

The patterns of Cu are very similar to those of Ni. It appears, however, that the ratio of filter/melt water for Cu is somewhat smaller in Norway than in Russia when compared to the ratio for Ni. The distribution of dry deposited Cu to the South and East of Nikel indicates elevated levels, also relative to the Ni content. Whether this is due to dry matter deposited from the industrial emissions or from locally derived dust cannot be determined from snow data.

3.2.2. Terrestrial materials.

Terrestrial material are moss (mostly *Hylocomium splendens*), humus and unaltered soil (till, sorted sediments, sea sediments), as well as combined soil.

3.2.2.1. Moss

In feather moss the contents of the heavy metals Ni, Cu, Co, As, Cd, and Cr and Se are highest in the surroundings of the towns Nikel and Zapoljarny, as shown on maps of the two first mentioned elements in fig N° 19-20. The pictures on the maps of these metals are in general the same. The high contents are spread according to the prevailing wind directions (SW to NE and SE to NW). The high contents reach the background at 30 to 50 km from the smelters. Elevated values are also found in Norway and Finland near the Russian border, but content in moss here is low compared to that of the Nikel vicinity. Somewhat elevated Co levels are found quite far to the West in Finland, but the Co contents here are near the analytical detection limit.

Niskavaara & Lehmuspelto (1992) give results similar to this study. The results of an environmental monitoring study in Northern Europe shows that the contents of Ni and Cu are very high in the Kola Peninsula and the border region in Northern Norway (Nord, 1992). The area of high contents in moss reaches the border region in Northern Finland, too.

The picture of sulphur contents in moss is quite simple (fig N° 21). The maximum contents are in the proximity of the town Nikel, with high values continuing to the North. Elevated contents are also found east of Zapoljarny and near Kirkenes, Norway. The contents reach background values (700-900ppm) at 25 to 30 km from the smelters. Slightly elevated contents of S are also found in the eastern parts of Finland.

The contents of Fe and V in moss are highest in the Nikel-Zapoljarny area as well (not shown).

The V contents can be due to industry and burning of oil. The Fe contents can also be due to industry, but also due to geology or dust from soil. The contents in southernmost site in Finland can be interpreted as dust contamination from soil. In this point also the contents of other metals, e.g. Al, Ba, Mn and Ti, are high. A little surprising is the quite low content of iron in moss near Kirkenes.

Phosphorous contents in moss is high almost everywhere in Norway; maximum values are near and to the west of Kirkenes. The reason for this is believed to be dust from the open pit iron mine at Björnevatn, although this iron ore is known to be low in P, but marine influence can not be excluded.

As a result of factor analysis six factors are given (table N° 2). Factor 1 is a combination of Cu, Ni, As, Co, S, Cd (and Fe). This factor reflects the anthropogenic effect, depending of pollution from the smelters of Nikel and Zapoljarny. Factor 2, Ti, Al, V and Sc, illustrates these elements dual origin; their content in moss partly originating from industry, partly from geology (local natural dust). The important elements of factors 3 (K, Mg, P) and 4 (Sr, Ca) are nutrients for mosses.

3.2.2.2. A_0 - horizon.

Soil horizon A_0 is a mixture of organic and minerogenic material in varying proportions. Calculating with a pure organic fraction is of great interest, and a method of arriving at such is described in Appendix N° 13.

Results of the Russian laboratories are arrived at using the mentioned technique, whereas Finnish result are reported on the base of wet ashing.

Reproduceablity of data is indicated by the scatterplots of Appendix N° 12. These indicate that some of elements, particularly S, are not stable. The maps of these elements should be read with great care.

The most pronounced Ni- and Cu- anomaly is observed in the Nikel - Zapoljarny industrial region, figures N° 22-23. The distribution of the contents of these metals are approximately in a NW-SE sector and the contents are at background level when the distance from industry area is about 30 km. In Finland the contents are mostly at background level, only a sligth elevation is shown. Co, not shown, bears much resemblance to the Ni and Cu patterns.

The contents of Fe (Fig N° 24), Cr (Fig N° 25) and V (not shown) are highest near Kirkenes, most likely due to the Bjørnevatn open pit iron mine and industry. Also the Nikel-Zapoljarny area show high concentrations and the areas of elevated content continue to the coast of Northern Norway. One exeptional site is in SW-part of Russian project area SE from river Pasvik, where the contents of Fe, Cr and V are elevated. The reason for this may be in local geology.

The highest contents of Pb (Fig N° 26) are near the roads, especially on the Finnish side (road from Kaamanen to Neiden) and Norwegian side. But the highest Pb content of this material is in Russia near Pasvik river; the same site where also Fe, Cr and V contents are elevated.

The elevated contents of S in humus form a broad and long zone from Zapoljarny via Norway to Northern Finland (fig. N° 27). The highest sulphur contents are near the town of Nikel and east of Zapoljarny. Because the distribution is approximately in accordance with prevailing wind directions, the high sulphur contents in humus can be interpreted as fartravelled pollution from smelters of Nikel and Zapoljarny. In Finland in the area of high sulphur contents in the humus the bedrock is basic rocks (gabbros, greenstones).

Maps of Cd (fig. N° 28) and Zn (fig. N° 29) show how the distribution of Cd coincide more or less with Ni, but only to a lesser extent for Zn and Pb.

A factor analysis of the humus material reveals that factor 1, with major components La, Y, U, Sc, Mn, Th, As, Al, Ba, (and Fe) (table N° 3), can mainly be ascribed to geology. Factor 2, a combination of P, K, Si, Na, V, Ti, B (and Mg and Fe) can be interpreted as a "nutrient factor". The combination of Ni, Cu, Cd, Co, Cr, As, S, Ca (and Mg) in factor 3 can be interpreted as anthropogenic effect. The combination of Zn and Pb (factor 5) can be interpreted as "ore prospecting factor", an indicator of possible mineralization.

3.2.2.3. Combination horizon A_0 + A_2.

Activites of radionuclides ^{137}Cs and ^{134}Cs have a fair correlation and show approximately the same levels. ^{137}Cs is shown as Ci/km^2 on fig. N° 30. The relation between Ci and Bq is given by the formula 1 Ci/km^2 = 37000 kBq/m^2. Maximum observed level is 0.006 Ci/km^2, or 2.6 kBq/m^2 for ^{137}Cs. These results show that within the test area there are no indications of pollutions by contemporary sources.

As for A_0-maps, the stability of this map is not the best. However, all figures of the analytical results indicate the same regional low level.

3.2.2.4. C-horizon.

Two size fractions (<0.07 mm and <2.0 mm) of C-horizon were used for analysing. This yielded results according to standards used by the international soil science society and by several environmental bodies (<2mm), as well as the vast records of the involved institutions in this survey (<0.07mm). Strong anomalies of individual pollution elements were not found in the test area.

Histograms of element concentrations in the fraction <0.07 mm are shown in Appendix N° 14. These data were used as an approximation of element background values in the minerogenic fraction of the A_0-horizon, as described in Appendix N° 13.

We can assume that the contents of elements in the unaltered soil material represents the natural, geological level. According to this material we have no reason to suppose any changes in element contents in C horizon due to anthropogenic input. It should be borne in mind that material named unaltered soil (C-horizon) does not have the same genesis throughout the test area (fig. N° 31), and only to a varying degree reflects the local bedrock. In Finland there is mostly till material, in Russia sorted sediments (glacio-fluvial) and in Norway there are also some sea sediments. In an environment study, the main concern with regard to C-horizon material is its mineralogical and chemical composition, regardless of the material's origin, as this material will be used to describe the original, natural conditions. Nevertheless, a lithological bedrock map would be the geochemist's first priority for input from the bedrock geology discipline.

The element contents in unaltered soil material (C horizon) can be roughly divided into two groups. The maps of Al, Ba, Ca, Co, Cr, Fe, K, Mg, Na, Ni, Sc, Sr, Ti, V and Zn are almost identical. In general, this group of elements show maximum values in Norway, east of the town of Kirkenes. The bedrock in this area are migmatitic volcanic gneisses, gabbros, Neiden granites and volcanites of Petsamo group (Nordkalott Project, 1987). The second group of elements is Cu, La, Li, Mn, P, Pb, S, Th and Y. The map pictures of these elements differ clearly from those of the first group and the individual maps differ from each other.

The maps of Pb, La and Th shows a distinct area of high contents in Finland near the border to Norway. The bedrock in this area is the Vainospää granite. Some elevated Pb contents are also in coastal area of Norway.

The contents of sulphur in soil material (fig. N° 32) is in general very low and shows no clear regional pattern.

The sampling site about 10 km south of Zapoljarny is noteworthy. At this point the contents of Co, Cu, La, Mn, Ni (fig. N° 33), S, V and Y are high, most of these show the maximum value. Also the contents of Cr, Fe and Sc are elevated. The bedrock in this area belongs to the Pechenga Complex.

In the unaltered soil material the southernmost sampling point in Russia is noteworthy, too. The contents of Al, Sc and S are very high in this site. Also the contents of Ba, Co, Cr, Fe, La, Ni, Pb, V and Y are elevated. The bedrock geology in this area is Lapland Granulite Belt.

Al contents (fig. N° 34) is high on the coast, where bedrock is acidic.

3.2.2.4. Stream sediments.

Multiplicative coefficients of main ore elements and sulphur contents in stream sediments (not shown) give only weak geochemical anomalies. Furthermore, their interpretation is rather complex. Due to the analytical techniques employed, and the dual nature of the stream sediments' chemistry (both clastic and hydromorphic) it is possible that the anomalies are connected with both industrial pollution and special geological features (Cu - Ni deposits).

3.2.2.5. Stream water

Water samples of Finland were taken in the period 18-26.08.1992, during and following a period of high precipitation and ground water level. Samples were taken in large rivers, rivers of 2.-3. order, and rivers of 1.-2. order (according to the code list). The speed of streams was estimated in sampling sites from 1 to 3 m/s, and the water temperature was 9.0 - 11.5 °C. There was no taste nor smell in any of the samples.

Water samples of Norway were taken between 26.08. and 06.09.1992, in large rivers, rivers of 2.-3. order, and rivers of 1.-2. order. Precipitation prior to and during this period was somewhat above normal, but only moderately affecting ground water level. Speed of stream varied from 0.2 to 2 m/s, and discharge from 50 l/s to 33 750 l/s. Water temperature was 6.3 - 9.6 °C. There was no taste nor smell in the samples, except swampy smell in one sample.

Water samples of Russia were taken in the end of summer 1992 in large rivers and in rivers of 2.-3. order. Precipitation was high throughout the summer. No smell or taste was found in samples, except the sample taken near Nikel (no. 4731). This sample had metallic taste and smell of H_2S.

Quality of water

Table N° 7 has minimum, maximum, mean values, and standard deviations of the measurements and analyses of elements and compounds.

All the water samples are somewhat acidic, pH values vary in Finland 6.5 - 6.8, in Norway 6.4 - 6.8 and in Russia 6.1 - 6.5. Electric conductivities were 2.1 - 3.3 mS/m in Finnish samples, 2.2 - 11.8 mS/m in Norwegian samples, and 2.6 - 36.2 mS/m in Russian samples.

According to the analytical results, contents of most of the elements are very low, especially for Ag, As, Be, Bi, Cd, Co, Cr, K, Li, Mo, Pb, Sb, Se, Th, Tl, V, and F. For most of the samples the levels of these elements were below the detection limit of the assay. For the other elements and compounds, levels were generally very low, too. Mean values of EC and Ca, Fe, K, Mg, Mn, Na and Cl contents are all lower than average values in surface water in all of Finland. Exceptions were Fe, Ni and SO_4 contents of some samples: They were found to be higher than recommended for drinking water in Finland.

The highest values for EC, B, Ba, Ca, Cd, Co, Cu, K, Li, Mo, Na, Ni, Sb, Si, Sr, V and SO_4 were found in sample number 4731, collected near Nikel. Maximum contents of Mg, Mn, NO_3 and Zn were found in sample no. 4729 situated east of Nikel.

Special attention is given to Ni (fig. N° 35) and Cu (fig. N° 36). These elements are well correlated, also with their counterparts of snow water. The map of SO_4 (fig. N° 37) is very much the same, and differs from that of snow water in that it seems to lack the marine influence. Al (fig. N° 38) has high values in areas where soil is composed mainly of acidic rocks. At Jarfjordfjellet, in the "acid rain" belt from Nikel, apparently the soils contain the required mafic minerals to buffer the precipitation's suspected acidity.

Distribution of pH-values in the area is shown in fig. N° 39. The mean pH of all the samples is 6.6, which is the same as mean pH of surface waters investigated throughout Finland. Generally, the most acidic waters are on the Russian side, but also in Finland and Norway near the Russian border. The difference betwen these and samples taken further from the industrial region is small, however, only a few tenths of a pH unit. From this low pH gradient it is not possible to be conclusive about acidification of surface water in the test area. Values of electrical conductivity are low, indicating only minor contents of electrolytes in the water samples.

The results of the S-isotope analysis of selected water samples done by NIGL indicates elevated $\delta^{34}S$-values in the proximity of Nikel (Spiro, pers. comm.).

3.2.2.6. Overbank sediments, top and bottom.

In general, impression from the maps of overbank sediments is much the same as from C-horizon. Both overbank sediments samples show the same geographic distribution, indicating that with the chosen thickness of the top sample (10cm), introduction of anthropogenically released material cannot be detected. The exception to this finding is the sample taken near Nikel. The bottom sample has even higher acid soluble contents of most elements than does the top sample. The vegetational conditions in (parts of) this drainage basin are exceptional, so also the volumes of fine grained industrial waste heaps. Such conditions induce special characteristics of the river flow and suspended load, causing rapid build up of flood plain sediments. Frequent channel shifts and erosion of flood plains are also characteristics of arid/semi-arid or glacial-front terrains - natures own versions of high sediment input regimes.

A parallel, detailed study of the chemical characteristics of an overbank sediment in Grense Jakobselv, border river Norway/Russia (Langedal and Ottesen, in prep.), clearly shows that layers in the top 10 cm of the deposit have a gradual (3-4 fold) increase in Ni-content. ^{210}Pb dating of these layers give ages of approximately 40 years at 15 cm.

Not counting the highly anomalous sample from the Nikel locality, the contrast of the element concentrations of top and bottom samples are far from dramatic. All in all, the chemical characteristics of the overbank sediments can be taken as a description of the natural situation of the area.

With this in mind, there is indication of an anomalous region of Mn and Mo in the southeastern half of the test area (Figures. N° 40-41). The influence of the elevated levels in the overbank sediments of these two elements on the pollution situation in the test area is presumably small, as neither of the elements are considered major components of the industrial emissions.

3.3 BASE CATIONS

Maps of base cations, indicating the buffering capacity of the soil, show varying conditions depending on which part of the soil profile is considered. In figures N° 42-43, the sum of ion equivalents of Ca + K + Mg + Na in the Aqua Regia extract of C-horizon and humus is shown, indicating that acid extractable is high in the C-horizons "downwind" from the smelters if only the distance is long enough. For humus, the situation in the industrial region of Nikel - Zapoljarny is characterized by high values, an indication of high emission of one or more of the base cations from the industrial processes. Similar results are seen in Fig N° 44, showing sum of ammonium aceatate extractable base cation equivalents of the A_0-horizon.

This base cation discharge of the industrial activities shows very clear also in the snow and water maps; with maximum values for Mg and Ca in the sample taken closest to the open pit mine area of Zapoljarny. It seems quite evident that the dusting affiliated with the mining and ore dressing in Zapoljarny is the cause of the high values of Mg and Ca on the surface in the Nikel - Zapoljarny region; the ore concentrate for the smelter contains some 20% MgO (Knut L. Sandvik, pers. comm.).

3.4. REMOTE SENSING

Related work in this area is carried out by Tømmervik et. al. (1992). In their work, based on several LANDSAT images for the period 1973 - 1988, they have found a decrease of the area classified as "Slight/no damage" from 8082 km^2 in 1973 to 3082 km^2 in 1988. Over the same period, the area classified as "Total damage" or "Severe damage" increased from 415 km^2 to 760 km^2. The soning of the 1988 images coincides very well with our findings of the most intense Ni-, Cu- and S-loadings.

4. CALCULATION OF LOADINGS

4.1. EVALUATION OF SEASONAL (WINTER) LOADINGS.

Finnish and Russian data for snow sampling were recalculated according to the following scheme:

a) Element concentrations in melt water and snow filter were added together.

b) Density of snow and reserves of moisture (snow water) were calculated for all sampling points. Field documentation and water mass after snow melting were used for calculation of snow density:

$$d(\text{kg/dm}^3) = \frac{\text{mass of water(kg)}}{\text{sum L of cores(dm)} * \text{D sampler(dm}^2\text{)}}$$

According to Russian and Norwegian field data (n=40) the average mean snow density was 0.34 kg/dm^3. Similar values are obtained using data about thickness and reserves of moisture from Ecologo (1992), there estimated snow density for this area is equal to 0.32 kg/dm^3 (n = 15, spring 1990). Finnish data were not used for calculation of average snow density because of unclearities in the field documentation.

Reserve of moisture in the snow cover, Q_{snow}, is expressed in millimeters. The mass of snow in kg for an area of 1 m^2 is then equal to 1 mm.

$$Q_{snow} = \text{H(dm)} * \text{d(kg/dm3)} * \text{100(dm2/m2)} = H * d * 100 \text{ (kg/m2)}$$

where H is thickness of the snow cover in dm.

c) Sulphur and heavy metal quantities per area of 1 km^2 (loading or surface density of accumulated precipitation during winter) were calculated and shown for some variables on the figures N° 45-48.

Sulphur
(fig. N° 45, Finnish data) shows a large area of high values in the Nikel - Zapoljarny industrial region and some smaller areas near Inari lake and Kirkenes. The loading of sulphur in the test area is not as high as may be expected. The most likely explanation to this is sulphur being transported even longer distances from the Cu-Ni plant than the extent of our investigated area.

Ni
loading (fig. N° 46) of snow cover reach levels of 100-200 kg/km^2 in the Nikel - Zapoljarny industrial region. Higher values are found near Zapoljarny in the Russian data, due to siliceous Ni from the open pit mining not being brought into solution by the Finish analytical procedure for snow filter. As for Fe, a rather strong gradient (5-10 times) is observed along the eastern side of Pasvik valley. In the southern part of the area, a slight rise in the loading (> 10 kg/km^2 according to Finnish and > 5 kg/km^2 according to Russian data) is noted. This may be explained by the local ore source near lake Alla - Akkajarvi, but it may also be due to influence of the Monchegorsk industrial region.

Cu
shows similar values for maximum loadings in Finnish and Russian data (fig. N° 47). But there are two exceptions: One rather prominent is observed in the southern part of the area; explained the same way as for Ni. In the western part of the area, the difference between the loading levels is about 2-3 times, and it is again likely that this reflects total and partly digested metal contents in snow water and filter of background level points.

Co and Cr
loadings (fig. N° 48, Cr not shown) show that Co and Cr densities are approximately 30 times lower than for Ni or Cu.

4.2. SEASONAL (SPRING) LOADINGS ON SOILS, SURFACE AND GROUND WATERS.

For calculation of seasonal (spring) loadings on soils, surface and ground waters, the test area was divided into drainage basins with areas of 500-1500 km^2 (fig. N° 49). In each of these, areas of similar conditions of melt water flow were determined.

Figure N° 50 and table N° 8 show the main characteristics of the territory. Mean coefficients of water flow and self cleaning capacity for various terrains are taken from published data (Nikonova, 1989). Although data are rather scarce, they give an opportunity for comparing terrains with regards to flow conditions of the pollution elements from the spring melt water.

Loadings on the drainage basins after snow cover melting in April - May 1992 were calculated and are given in table N° 9.

Nickel.

Total spring loading on the whole area is 239.7 tons according to Russian data or 280.2 tons according to Finnish data. Very high loadings are established for the drainage basins of river Vorjema and Jarfjorden of the Barents Sea coast, and also for Lower Pasvikelva (especially for its right tributaries). The highest loadings are found for river Pechenga. The most important discrepancies between Russian and Finnish data are observed for the drainage basins of rivers Pechenga and Vorjema (total sum of difference is about 40 tons). Again, this difference gives an estimate of the input from silicate bound Ni from the open pit mining and mineral dressing plant.

Hence, the total seasonal (winter) input of Ni to the snow cover amounts to 239.7 - 40 = 199.7 tons (Russian data), or 200.2 tons (Finnish data) within the pilot project area.

We will suppose that approximately 10% of this value (20 tons) is connected with sources other than the operations of Nikel - Zapoljarny, mainly in the southern part of the area (Alla - Akkajarvi Cu-Ni mine or Severonikel plants of Monchegorsk).

Then the seasonal Ni emission from Nikel - Zapoljarny plants can be estimated to 180 tons (within the period of 6 months from October 1991 to March 1992). Recalculated on an annual basis, taking the characeristics of winter precipitation as a guide for the entire year, the estimated annual Ni emission is 360 tons. According to data of Annual Handbook (1989, 1990, 1991) this average value is 303.7 tons for last three years (1989-1990).

The seasonal (spring) loading on soils in the test area is 80.8% of the total sum, the loading on water is 9.2% of total sum (7.8% for water of the river system and 1.4% for ground water of deep horizons).

Copper.

The total sum of loadings on the area is 151.1 tons (Russian data) or 189.3 tons (Finnish data). If the loading in the southern part of the area is connected with other pollution sources, the average mean (from Russian and Finnish data) for the Nikel - Zapoljarny industrial region is 151.5 tons. The estimated annual Cu emission from Nikel - Zapoljarny plants is about 303 tons. According to Annual Handbook (1989, 1990, 1991) this average mean is 182.4 tons.

The seasonal (spring) loadings on soils are 74-85% of the total sum, the loadings on waters are 15-26% (13-22% for waters of river systems and 2-4% for ground waters of deep horizons).

Cobolt (Finnish data).

The total seasonal loading in the test area is 7.5 tons (7.8% of this sum is the loading on waters). The estimate of an annual Co emissions from Nikel - Zapoljarny plants is 15 tons. The average mean is 11.4 tons for 1989-1990 years according to Annual Handbook (1989, 1990, 1991).

Sulphur.

The total seasonal technogenic sulphur loading on the area is 2331.2 tons (Finnish data), and 46.3% of this is connected with dry atmospheric falls (calculated from filter/filter + melt water ratio).

According to Krjuchkov and Makarova (1989), the ratio of S concentrations in atmospheric falls to snow cover is 2.7. With an annual precipitation of about 650 mm in this area and taking the average value of snow water reserve is 272 mm as a measure of the winter's proportion, the annual fall-out of sulphur with the wet deposition of the entire pilot study area is calculated using the figures from Table N° 9:

(1082.6 + 169.0) * 2.7 * (650/272) = 8075.6 tons.

Total annual S fall-out counting wet and dry phases is:

8075.6 + (1079.6 * (650/272)) = 10655.5 tons.

It is also known that the normal ratio of SO_4- to Cl-ions in sea water is 0.14. But along the coast of the test area this ratio is about 0.5 and higher (calculated from snow water). So almost all of the sulphur must be considered as of technogenic origin, which initially spread to the Barents Sea and then returned to the coastal zone.

The total sum of annual S deposition will be:

10655.5 + (2616.4 * (650/272)) = 16908 tons.

According to Annual Handbook (1989, 1990, 1991), the average mean of annual S emission from the Nikel - Zapoljarny plants is 132200 tons. Accordingly, only 12.8% of annual S emission fall out on the test area and the remainder (87%) is carried far distances from the emission source. These findings are similar to those of Krjuchkov and Makarova (1989).

Cr and Fe pollution loadings are also given in table N° 9. But as no official data about their emissions exist, a comparison with observed values of deposition cannot take place.

4.3. PERENNIAL TECHNOGENIC LOADINGS.

Results of the A_0 horizon sampling were used for determining the cumulative effect of the perennial loadings. They were recalculated to surface density of pollution (kg/km^2). According to Russian experience from heavily contaminated soils in the Monchegorsk region, accumulation in the soil profile of the pollutants in question is well described by applying the formula

$$Me = \frac{Me_{A0} * H_{A0} * 0.5}{13}$$

where

Me_{A0} is the metal content of the sampled humus

and

H_{A0} is the thickness of the sampled humus layer.

This approach may not seem to take into account the naturally derived fraction of the humus sample. But by applying preparation techniques of the Russian laboratories described above, one can do much to counter the influence of minerogenic constituents found in humus samples. However, a way to handle the fraction of the humus derived from solutes of natural, local origin, has not been found.

Iron (see fig N° 24)
A zone of high density is observed around Nikel and Zapoljarny and to the north-west and north-east of these towns.

Sulphur (fig. N° 51).
The highest loadings are found near Nikel and along the Barents Sea coast. The sum of loadings on the surface of the test area is 19677.3 tons. Taking into account that in this area the pollution diffuses to a depth of 0.3-0.5 m depending on local topography and character of soils, and that average thickness of sampled A_0-horizon is about 0.03 m, the sulphur mass in the soil horizons is about 131200 tons. Most likely, a majority of the sulphur fall-out is extracted and lead away by surface and ground water.

Heavy metals Ni, Cu, Co, Cr (fig. N° 52-54).
Distribution of heavy metals in the A_0-horizon is rather similar to that of the snow cover. The highest levels are again observed in the Nikel - Zapoljarny industrial region. There is a very strong gradient along the eastern side of the Pasvik valley.

The mass of Ni is 5110.6 tons on the surface of the test area and about 34000 tons in all soil horizons to the depth of 0.3-0.5 m. Similar estimates for Cu yield 4413 tons and 29420 tons for surface A_0-horizon and soil horizons to the depth of 0.3-0.5 m respectively. Parts of Ni and Cu were also extracted by surface and ground water.

5. CONCLUSION.

Harmonizing of methods and techniques in field, laboratory and interpretation has proved to be essential in the collaborative work undertaken, and we have identified the topics to be addressed for the main project.

Analysis intercalibration between Finnish and Russian laboratories/methods shows that the major difference in results is observed for elements (Ca, Mg, K, Na, Al, Fe, and others), which are bound in the structure of silicate minerals. Total and acid-digested concentrations of the important heavy metals (Ni, Cu, Co, Zn), S and P coincide fairly well.

The pollution status of the investigated area is given after analysis of a number of natural materials, including those found to be unaffected in the heart of the industrial region. The areas of high heavy metal loadings coincide with those that have impaired acid neutralizing capability. Some centres of Ni and Cu pollution are located bye use of snow dust/melt water ratio. Aside from the Nikel - Zapoljarny pollution centers one is found in the southern part of the investigated area; the Alla - Akkajarvi Cu-Ni mine or an extreme influence of Monchegorsk. For sulphur two other local pollution centres are foud; near Kirkenes and Inari lake. Beneficial to the environment in the industry "wasteland" is the large amounts of base cations discharged by the mining and ore dressing activities in Zapoljarny. Activities of ^{137}Cs and ^{134}Cs are generally low, with a maximum activity of 2.6 kBq/m^2.

Seasonal (spring) loadings are calculated from analysis of snow melt water and filter residue, and found to have intensities above 10 kg Ni/km^2 over an area covering 3000 km^2. For Cu the figures are similar, and the same 3000 km^2 show a S level of approximately 150 kg/km^2. In these areas, the natural contribution to the quoted levels is insignificant. Calculations of an annual emissions of Ni, Cu, S based on snow sampling are compared with official data and coincide rather well. The perennial loadings are given for soils to the depth of 0.3-0.5 m without taking into account extraction of elements by surface and ground water. Nevertheless the geochemical data of snow cover and A_0-horizon samples are very useful for evaluation of environmental pollution and give rather realistic results.

An evaluation of the various sampling medias' feasability for describing the natural and anthropological geochemical environment shows that

- snow sampling is the best medium for half-annual monitoring of wet and solid precipitation, and the results clearly delineates areas of high atmospheric deposition. Furthermore, the content of elements in the sonw pack at snow melting is important in describing the load on humus (and vegetation) at time of snow melting
- terrestrial moss is superior as a bioindicator covering a medium length time slice
- A_0-horizon is because of its dual origin (mix of local geology and anthropogenic input) more difficult to interpret, but very important for calculating locations and magnitude of chemical time bombs
- A_{0+2}-horizon is neccessary for the evaluation of radioactivity in the area
- C-horizon is one possible means of estimating the initial natural chemical characteristics
- overbank sediments, when available, provide an alternative for estimating initial natural characteristic, and are vital in describing chemical time bombs
- stream sediment is due to its dual nature (initial mineralogy and hydromorphically superimposed chemistry) difficult to interpret
- stream water delineates areas of high concentrations, but cannot be used alone for distinguishing between natural and anthropogenic phenomenas. The exceptional precipitation conditions during the summer of 1992 for some of the area impaired the water's ability to delineate geological features in background areas.

A sampling density of about 1 point per 300 km^2 gives sufficient information for mapping of air pollution effects in the scale of 1:1 mill. But for industrial centres and towns, it seems helpful to have more detailed sampling, perhaps 1 point per 100 km^2. The collected field documentation supplies data needed to make the various calculations for classification and interpretation.

Podsol soils could be a better monitoring media to study the effects of pollution to soil. The use of acid neutralization capacity method when analysing podsol soils, as well as weak leaches and pH measurements could give important additional information. More appropriate methodology than employed in the pilot project must be used for future work.

For snow sampling, particularly in the background areas, the possibilities of contaminating samples requires appropriate sampling techniques, and further work should be undertaken to deal with the mobillity of S species in the snow pack. The question of representativity of samples, particularly snow and humus, should be addressed to arrive at methodology yielding acceptable quality on the sampling.

Further work is needed to have a better integration of remote sensing and geochemistry. It seems also promising to develop models for delineating chemical time bombs as functions of chemical speciation of heavy metals, base cations, areas and volumes of deposits, and to ensue the possibilities of predicting their trigger mechanisms.

Finally, there is an apparent need for the development of a common database in the further work. At an early stage in the main project, vital questions about this data base should be addressed; its logical and physical structure, its international accessability and user classification criteria, and update policy and procedures, as well as maintenance resposibility. Critical stages of this database development should be accepted by a group representing its principal users.

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Table N° 1

ECO-GEOCHEMISTRY KOLA Pilot project Analytical program & detection limits

	Stream sediments		Organic soil A0								Mineral soil C						Terrestrial moss		Snow cover								Stream water		Overbank sediments top				Overbank sediments bottom				Comb. soil	
Material	01		02		02		02		02		05		05		05		08		09 Wate		09 Filter		09 Wate		09 Filter		10		11		11		12		12		13	
Lab/method	R		R total		R part		F noMW		F amac		R		F ar		F amac		F		R		R		F		F		F		N		F		N		F		R	
Element																																						
Ag	0.1	rf	0.1	rf			0.2	fd			0.1	rf	0.5	fa				fd			0.1	rf	0.001	ff			0.001	ff	1	na	0.5	fa	1	na	0.5	fa		
Al	100	ri	100	ri			0.2	fc		fb	100	ri		fa		fb		fc	0.002	rb*				ff		fc		ff	2	na		fa	2	na		fa		
As							0.3	fd	0.5	fb			3	fa	0.5	fb		fd					0.0002	ff	0.001	fc	0.0002	ff			3	fa			3	fa		
B							0.5	fd	0.1	fb					0.1	fb		fd					0.0002	ff		fc	0.0002	ff	1	na	3	fa	1	na	3	fa		
Ba							0.3	fc		fb				fa		fb		fc					0.0002	ff		fc	0.0002	ff	0.2	na		fa	0.2	na		fa		
Be	0.3	rf	0.3	rf			0.6	fd			0.3	rf						fd			0.3	rf	0.0001	ff			0.0001	ff	0.5	na			0.5	na				
Bi							0.2	fd										fd					4E-05	ff			4E-05	ff										
Br																								fk				fk										
Ca	0.002	rg	0.002	rg	0.002	rg	30	fc		fb	0.002	rg		fa		fb		fc	0.5	ra			0.02	ff		fc	0.02	ff	5	na		fa	5	na		fa		
Cd							0.06	fd		fb			0.3	fa	0.02	fb		fd					5E-06	ff	5E-05	fc	5E-06	ff	2	na	0.3	fa	2	na	0.3	fa		
Ce																													3	na			3	na				
Cl				rl															1	?				fk				fk										
Co	3	rf	3	rf	3	rf	0.06	fd		fb	3	rf		fa	0.02	fb		fd	0.5	re	3	rf		ff	0.0001	fc		ff	1	na		fa	1	na		fa		
Cr	10	rf	10	rf			0.4	fd	0.02	fb	10	rf		fa		fb		fd			10	rf		ff	0.0001	fc		ff	1	na		fa	1	na		fa		
Cs																		fd																				
Cs134																																					–	rk
Cs137																																					–	rk
Cu	10	rf	10	rf	10	rf	0.1	fd	0.02	fb	10	rf		fa		fb		fd	0.2	re	10	rf		ff		fc		ff	0.2	na		fa	0.2	na		fa		
EC																								fk				fk										
F				rl																			0.05	fi			0.05	fi										
Fe	0.002	rg	0.002	rg	0.002	rg	30	fc		fb	0.002	rg		fa		fb		fc	0.05	rb				ff		fc		ff	1	na		fa	1	na		fa		
Hg							0.02	fe										fe																				
K	10	rh	10	rh		rh	10	fc		fb	10	rh		fa	10	fb		fc	?	rc				ff	0.002	fc		ff	20	na	100	fa	20	na	100	fa		
La							1	fc	0.05	fb				fa		fb	0.8	fc							0.0001	fc			0.5	na		fa	0.5	na		fa		
Li							0.2	fc	0.02	fb				fa	0.02	fb	0.6	fc					0.0002	ff	0.0001	fc	0.0002	ff	0.5	na		fa	0.5	na		fa		
Mg	20	rg	20	rg	20	rg	1	fc		fb	20	rg		fa		fb		fc	0.5	ra				ff		fc		ff	5	na		fa	5	na		fa		
Mn	150	rf	150	rf			0.06	fc		fb	150	rf		fa		fb		fc	0.2	re	150	rf		ff		fc		ff	0.2	na		fa	0.2	na		fa		
Mo	2	rf	2	rf			0.1	fd	0.05	fb	2	rf	0.5	fa	0.05	fb		fd			2	rf		ff	0.0001	fc		ff	2	na	0.5	fa	2	na	0.5	fa		
NO3																			0.03	rb				fk				fk										
Na	10	rh	10	rh		rh	30	fc		fb	10	rh				fb		fc	?	rc				ff		fc		ff	1	na		fa	1	na		fa		
Nb	10	rf	10	rf							10	rf									10	rf																
Ni	10	rf	10	rf	10	rf	0.25	fd	0.05	fb	10	rf		fa	0.05	fb		fd	0.25	re	10	rf		ff		fc		ff	2	na		fa	2	na		fa		
P				?		?		fc		fb				fa		fb		fc								fc			10	na		fa	10	na		fa		
Pb	5	rf	5	rf			0.06	fd		fb	5	rf		fa		fb		fd	0.5	re	5	rf	0.0001	ff	0.0005	fc	0.0001	ff	5	na	3		5	na	3			
S	100	ri	100	ri	100	ri				fb	100	ri		fa		fb		fc								fc												
SO4																			0.1	ri				fk				fk										
Sb							0.2	fd	0.5	fb					0.5	fb		fd					5E-05	ff	0.001	fc	5E-05	ff			5				5			
Sc							0.1	fd	0.01	fb				fa		fb		fd							1E-05	fc			0.5	na			0.5	na				
Se							1	fd										fd						ff				ff										
Si							10	fc						fa				fc						ff		fc		ff	2	na			2	na				
Sn	3	rf	3	rf							3	rf									3	rf																
Sr	100	rf	100	rf			0.25	fc		fb	100	rf		fa		fb		fc	0.5	re	100	rf		ff		fc		ff	0.2	na			0.2	na				
Th							0.2	fd	0.1	fb			3	fa	0.1	fb		fd						ff	0.0005	fc		ff			3	fa			3	fa		
Ti	300	rf	300	rf			0.5	fc		fb	300	rf		fa		fb		fc			300	rf				fc			0.5	na		fa	0.5	na		fa		
Tl							0.2	fd										fd						ff				ff										
U							0.2	fd										fd						ff				ff										
V	10	rf	10	rf			0.2	fd		fb	10	rf		fa	0.01	fb		fd			10	rf		ff	0.0001	fc		ff	1	na		fa	1	na		fa		
Y							0.1	fc	0.01	fb				fa		fb	0.1	fc								fc						fa				fa		
Zn	30	rf	30	rf			0.2	fc		fb	30	rf		fa	0.02	fb		fc	0.2	re	30	rf		ff		fc		ff	0.2	na		fa	0.2	na		fa		
Zr	10	rf	10	rf							10	rf									10	rf							1	na			1	na				
alk																								fj				fj										
pH			–	rl															0.05	rd				fh				fh										

ra	Total content	Titrometry	CKSE	fa	Aqua Regia extract	511P ICP-AES
rb	Total content	Photocolorimetry	CKSE	fb	Amonium Acetate extract	201P ICP-AES
rc	Total content	Calculation	CKSE	fc	Nitric acid/micro-wave	503P ICP-AES
rd	Total content	pH 637M	CKSE	fd	Nitric acid/micro-wave	503M ICP-MS
re	Total content	AAS, equipment C-115	MGRE	fe	?	503H Hg (ICP-MS?)
rf	Total content	ESA, equipment DFS-13	MGRE	ff	Filtered, acidified (melt) water	140M ICP-MS
rg	HF+HClO4+HNO3-extract	AAS, equipment C-115	MGRE	fh	Filtered, acidified (melt) water	140P ICP-AES
rh	Total content	Flame photometry, PAG-2	MGRE	fi	Water/filtered melt water	143I Potentiometric
ri	Total content	Colorimetry	MGRE	fj	Water/filtered melt water	143T Alkalinity
rj	Total content	Gravimetry	CKSE	fk	Water/filtered melt water	143R Ion Chromatography/pH, Conductivity
rk	Total content	Gamma-spectrometry	EME/Sevzapgeologia			
rl	Water extract		CKSE	na	Nitric acid extract	ICP-AES

Table N° 2

MOSS
FACTOR ANALYSIS

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
Al	0.20051	*0.90652	-0.05931	0.09875	0.03729	0.14503
Ba	0.23454	0.15797	-0.66595	*0.50870	0.17534	-0.02961
Ca	0.42847	-0.02376	-0.36231	*0.76230	0.17150	-0.02962
Cu	*0.94089	0.20301	0.08418	0.19310	0.05710	-0.02871
Fe	*0.67943	*0.66402	0.06676	0.05406	-0.02366	0.06641
K	0.33532	-0.02045	*0.87474	0.15567	-0.05642	-0.02227
Mg	0.05438	0.18700	*0.72265	0.34596	0.02576	0.34494
Mn	-0.03024	-0.01215	-0.56028	-0.53803	*0.34747	0.19858
Na	0.09452	-0.23395	0.14344	0.07345	-0.65685	0.10571
Ni	*0.92734	0.26964	0.10977	0.11534	-0.05228	0.00051
P	0.23721	0.03062	*0.89992	-0.11615	0.18117	0.00110
S	*0.84865	0.18312	0.28656	0.22272	0.11962	0.14512
Si	0.18971	0.17742	0.23272	*0.68378	-0.02412	0.19345
Sr	0.16022	0.04699	-0.00007	*0.88823	-0.09664	0.00976
Ti	0.01451	*0.92126	0.04066	-0.04469	0.13373	0.05098
Zn	0.28010	0.01590	0.17757	0.12935	*0.75475	0.22714
B	0.49095	-0.05242	0.20012	*0.66275	0.25111	0.22060
Cd	*0.81326	-0.02072	0.05452	0.35094	0.11845	0.07704
Co	*0.87045	0.31371	0.13353	0.11199	-0.10337	0.07443
Cr	-0.02133	0.06821	0.15934	0.07698	0.06537	*0.81392
Pb	0.45552	0.14116	-0.26185	0.07258	-0.01689	*0.54387
V	0.51830	*0.80652	-0.06041	-0.02529	0.01851	0.16541
As	*0.92072	0.16263	0.03619	0.21685	0.13455	0.00932
Sc	0.30605	*0.70206	0.10922	0.21567	0.15945	-0.14144

1 FACTOR Cu,Ni,As,Co,S,Cd,(Fe)
2 FACTOR Ti,Al,V,Sc,(Fe)
3 FACTOR P,K,Mg
4 FACTOR Sr,Ca,Si,B,Ba
5 FACTOR Zn,Mn
6 FACTOR Cr,Pb

Table N° 3

HUMUS
FACTOR ANALYSIS

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
Al	*0.70341	0.64913	0.15894	0.00478	0.18315
Ba	*0.66631	0.12364	-0.03601	0.47243	0.11755
Ca	0.10704	0.42188	*0.55469	0.51136	0.07983
Cu	0.01273	0.09144	*0.96785	0.06880	0.08051
Fe	*0.64951	*0.62570	0.26300	0.20337	0.11235
K	0.02995	*0.83086	0.15244	-0.33678	0.15182
La	*0.96718	-0.07750	0.08519	-0.04608	-0.03215
Mg	0.31052	*0.62384	*0.54799	0.21828	0.24261
Mn	*0.84781	0.36509	0.04651	0.19013	0.01798
Na	0.25800	*0.77289	0.17469	0.08983	0.17375
Ni	-0.03404	0.10216	*0.97230	0.06917	0.09207
P	-0.07272	*0.90676	0.09881	0.05974	0.10185
S	-0.36102	0.01971	*0.59663	*0.59920	-0.05405
Si	0.23847	*0.80933	-0.01664	0.16269	-0.05819
Sr	0.00193	0.08926	0.15500	*0.82262	0.00260
Ti	0.50008	*0.68692	0.25009	-0.06790	0.13151
V	0.55903	*0.71498	0.20267	0.17783	0.12868
Y	*0.96688	-0.01625	0.12508	-0.03581	0.00244
Zn	-0.01760	0.06558	0.13223	0.08461	*0.95067
As	*0.71570	0.06345	*0.67180	0.01447	0.01601
B	0.04759	*0.67443	0.44343	0.30638	-0.05200
Cd	0.49552	0.14458	*0.77638	-0.03085	0.05596
Co	0.22349	0.47004	*0.77511	0.24752	0.08298
Cr	0.44662	0.45053	*0.70047	0.05353	0.16354
Mo	0.29177	0.08833	0.10168	0.37549	*0.48621
Pb	0.07049	0.39395	0.08367	-0.40461	*0.69717
Sc	*0.84876	0.39608	0.24002	-0.06201	0.18061
Th	*0.78480	0.33894	0.00726	-0.15422	0.33520
U	*0.87937	0.19642	0.05094	-0.01649	-0.08101

1 FACTOR La,Y,U,Sc,Mn,Th,As,Al,Ba,(Fe)
2 FACTOR P,K,Si,Na,V,Ti,B,(Mg),(Fe)
3 FACTOR Ni,Cu,Cd,Co,Cr,As,S,Ca,(Mg)
4 FACTOR Sr,(S)
5 FACTOR Zn,Pb,Mo

Table N° 4

ANALYSIS RESULTS OF THE RUSSIAN STANDARD SAMPLES
(method 511p,GTK,FINLAND)

	standard samples		ELEMENT CONTENTS																				
	N N	Composition	SI	AL	NA	K	CA	MG	MN	P	FE	S	BA	TI	V	SR	NI	CU	CO	CR	PB	ZN	AS
			%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	KPM	Control sample of moss ash	20.81 0.35	3.91 1.84	0.87 0.43	9.03 8.11	7.84 7.24	1.82 1.49	0.225 0.244	1.64 1.61	3.99 3.41	12700	730 405	1738 730	100 74.9	13.0 17.6	100 67.7	100.0 109.0	28.0 11.9	300 49.6	360 181	860 740	3>
2	LP-1	Control lithogeo-chemical sample	31.74 0.21	7.18 1.39	2.39 0.02	1.29 0.03	2.09 0.09	0.64 0.18	0.039 0.006	0.0349 0.0347	2.29 1.04	219	530 23.8	3000 629	19.3	4.0 7.9	24 9.4	17 13.3	<8 3.7	100 26.4	14 3>	25 18.3	3>
3	LP-2	Control lithogeo-chemical sample	31.91 0.09	1.44	2.26 0.03	1.36 0.06	1.84 0.13	1.00 0.43	0.037 0.014	0.048 0.050	2.65 1.46	90	600 50.8	3700 898	28.1	4.0 11.8	35 19.4	24 22.2	18 8.0	110 40.3	20 5	55 51.4	3>
4	CGH-3	State stadard sample of terrigene silt	25.30 0.06	8.71 2.28	1.19 0.03	2.02 0.15	0.29 0.23	0.97 0.84	0.101 0.108	0.057 0.080	6.13 6.33	284	570 106	5875 37.4	180 57.1	130 32.8	72 61.3	48 48.3	30 28.8	140 54.4	23 15	120 116	46
5	CGH-5	State standard sample of terrigene anomalens silt	28.45 0.07	7.62 1.27	1.73 0.06	2.95 0.27	2.11 1.48	1.53 1.29	0.067 0.060	0.079 0.072	3.81 3.48	1170	910 112	3717 494	110 41.7	280 45.6	36 27.1	190 203	13 12.4	88 43.3	58 49	90 87	480
6	CT-1A	State standard sample of trappean rock	22.95 0.11	7.53 3.29	1.85 0.60	0.58 0.16	7.29 2.33	3.46 1.31	0.163 0.075	0.092 0.089	10.65 6.70	400 441	230 52.7	11091 4420	191	270 96	90 48.7	220 217	46 28.5	140 36.5	5 3>	150 86.2	3
7	CNK-2	State standard sample of CU-NI ore	0.07	3.76 1.20	0.03	0.17	13.37 12.4	2.56 2.21	0.194 0.191	0.152	4.22 3.55	4100 3640	79.9	1918 109	45.3	59.2	15700 13900	3900 3900	11300 10800	20.5	92	390 403	57700 59300

20.81 above - certificated total contents of elements,
0.35 below - results of GTK laboratory

Table N° 5

QUALITY OF ANALYTICAL METHODS OF RUSSIAN PARTY AND THEIR COMPARISON WITH GTK METHODS

	Elements	Reproduction										Comparison											
		water		filter				ash of A0 horizon, mineral soil				ESA --- AAS Russian ash, A0		with methods of GTK									
		AAS		AAS		ESA		AAS		ESA				AAS 140M		AAS 511p ash,A0		AAS 503p filter		ESA 503p filter		Standard samples 511p	
-		n=13		n=22		n=16		n=29		n=14		n=37		n=18		n=14		n=20		n=12		n=7	
			e		e		e		e		e		e		e		e		e		e		e
1	NI	1.07	1.10	1.07	1.10	1.00	1.07	1.03	1.04	1.00	1.08	1.00	1.07	1.31	1.31	1.31	1.40	1.15	1.27	1.18	1.20	1.37	1.33
2	CU	0.95	1.13	1.02	1.08	0.96	1.08	0.99	1.04	1.07	1.16	0.99	1.08	1.24	1.17	1.15	1.06	1.25	1.17	1.31	1.27	1.05	1.09
3	CO	-	-	0.95	1.11	1.02	1.08	0.98	1.10	0.94	1.08	1.03	1.14	-	-	1.26	1.11	1.07	1.22	1.10	1.16	1.04	1.29
4	ZN	1.02	1.04	-	-	0.95	1.14	1.03	1.08	1.10	1.05	-	-	1.06	1.10	1.16	1.45	-	-	1.09	1.21	1.10	1.27
5	P	-	-	-	-	-	-	1.02	1.07	-	-	-	-	-	-	0.96	1.07	1.06	1.07	-	-	1.01	1.05
6	*) S	n=10 0.96	1.19	-	-	-	-	n=30 1.01	1.08	-	-	-	-	not to be compared		n=27 0.96	1.19	-	-	-	-	n=2 1.02	-

*) Sulfur was determined by chemical weight method

As was not compared because of insufficient detection limit (≈100ppm) of Russian methods

- relative systematic error,

e - ralative random error

Table N° 6

ANALYSIS OF NATIVE, SAMPLING AND ANALYTICAL VARIATIONS

	Elements	Ni				Cu				Co				Cr				S				Fe			
	Variations	Sampling		Analytical		Sampling		Analytical		Sampling		Analytical		Sampling		Analytical		Sampling		Analytical		Sampling		Analytical	
Media	Parameters	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n	Sum2	n
Snow water	Between groups	0.002	1	0.498	1	0.029	1	0.136	1																
	Within groups	66.255	28	9.958	18	48.211	28	4.028	18																
	Total	66.257	29	10.456	19	48.240	29	4.164	19																
	F-ratio	0.001		0.900		0.017		0.608																	
Snow filters	Between groups	.033	1	.001	1	.003	1	.002	1	.213	1	.007	1	0.172	1	.085	1								
	Within groups	66.132	28	1.218	4	31.010	28	.994	4	62.852	28	3.551	4	30.660	28	9.925	4								
	Total	66.165	29	1.219	5	31.013	29	.996	5	63.065	29	3.558	5	30.832	29	10.010	5								
	F-ratio	0.014		0.005		0.002		0.008		0.095		0.008		0.157		0.034									
A0 horizon	Between groups	0.249	1	2.495	1	0.120	1	2.029	1	.188	1	.435	1	0.001	1	.040	1	.001	1	.008	1	.009	1	.001	1
	Within groups	25.974	30	66.838	28	16.261	30	60.900	28	9.654	30	29.883	28	2.652	30	4.793	28	21.139	30	.564	10	2.031	30	5.722	18
	Total	26.223	31	69.333	29	16.381	31	62.929	29	9.842	31	30.318	29	2.653	31	4.833	29	21.140	31	.572	11	2.040	31	5.723	19
	F-ratio	0.288		1.045		0.221		0.933		0.585		0.407		0.010		0.235		0.000		0.149		0.138		0.004	
C horizon <0.07mm	Between groups	.194	1	.001	1	.017	1	.000	1	0.001	1	.041	1	.102	1	0.014	1	.039	1	.045	1	0.014	1	0.001	1
	Within groups	3.604	30	2.232	16	4.030	30	8.893	16	2.633	30	1.642	16	7.122	30	0.812	16	17.452	30	7.394	14	1.654	30	0.615	18
	Total	3.798	31	2.233	17	4.047	31	8.893	17	2.634	31	1.683	17	7.224	31	0.826	17	17.491	31	7.439	15	1.668	31	0.616	19
	F-ratio	1.617		0.009		0.124		0.000		0.010		0.405		0.431		0.277		0.067				0.246		0.016	
C horizon <2.0mm	Between groups	.103	1	.016	1	.030	1	.001	1	.384	1	.001	1	.070	1	.151	1								
	Within groups	2.880	30	2.387	16	2.216	30	1.950	16	5.209	30	2.568	16	3.386	30	.964	16								
	Total	2.983	31	2.403	17	2.246	31	1.951	17	5.593	31	2.569	17	3.456	31	1.115	17								
	F-ratio	1.069		0.105		0.411		0.002		2.213		0.000		0.618		2.511									

Sum2 - sum of deviation squares
n - number of freedom degrees

Table N° 7

Minimum, maximum, mean values, and standard deviation of pH, EC, and analysed elements and compounds (44 samples).

Variable	Min.	Maks.	Mean	Standard deviation
pH	6,1	6,8	6,5	0,19
EC mS/m 25°C	2,1	36,2	5,3	6,8
Ag ppb	0	0,01	0	0
Al ppb	11,7	154	44,81	29,43
As ppb	0,03	0,89	0,19	0,19
B ppb	0,91	25,90	3,35	4,30
Ba ppb	1,36	11,3	4,87	2,66
Be ppb	0	0,04	0,01	0,01
Bi ppb	0	0,01	0	0
Br ppm	0	0,02	0	0
Ca ppm	1,32	30,40	4,33	6,27
Cd ppb	0	0,07	0,01	0,01
Cl ppm	0,90	19,90	3,37	3,29
Co ppb	0,01	5,49	0,24	0,90
Cr ppb	0,11	0,62	0,25	0,09
Cu ppb	0,28	8,52	1,34	1,46
F ppm	0	0,40	0,05	0,07
Fe ppm	0,02	0,55	0,11	0,10
K ppm	0,20	2,53	0,46	0,39
Li ppb	0,11	2,86	0,38	0,42
Mg ppm	0,45	12,20	1,46	2,39
Mn ppb	0,46	75,30	8,35	14,03
Mo ppb	0,04	3,75	0,26	0,55
Na ppm	1,25	21,20	3,06	3,46
Ni ppb	0,18	477	16,31	73,61
Pb ppb	0,01	0,34	0,05	0,05
Sb ppb	0,004	0,14	0,03	0,03
Se ppb	0	0,83	0,13	0,22
Si ppm	0,78	3,66	1,80	0,64
Sr ppb	6,61	172	21,41	33,09
Th ppb	0,001	0,05	0,02	0,01
Tl ppb	0	0,01	0	0
U ppb	0,01	0,58	0,12	0,14
V ppb	0,05	0,62	0,14	0,10
Zn ppb	0,91	11,80	2,13	2,06
NO_3ppm	0	9,60	0,40	1,57
SO_4ppm	1,20	123	9,17	24,71

Table N° 8

CHARACTERISTICS OF REGION BY CONDITIONS OF MELT WATER FLOWING

Code square with similar conditions of flowing	Landscape-geomorfological conditions			Hydrogeological conditions		Coefficients of flowing			
	Hypsometrical level	Relief	Kind and composition of Q deposits	Ground freezeness degree	Thickness of airation zone	Underground water	River system		
							Total	including surface water	ground water
			I. MATERIC PART OF REGION						
n.1	75m (0 - 75m)	Valleis of big rivers	Marine less alluvial and lake deposits(>10m),clay silt,sand clay	max	<1m	0.00 - 0.10 0.05	0.90 - 1.00 0.95	0.90 - 1.00 0.95	
n.2	150m (75 - 150m)	Valleis of big rivers and lakes	Till,water-glasial deposits(5m),sand,sand clay	middle	1 - 3m	0.05 - 0.15 0.10	0.81 - 0.98 0.90	0.75 - 0.86 0.81	0.05 - 0.13 0.09
n.3	300m (150 - 300m)	Slopes of mountaines	Till(1.5-5m),sand with different grain size	middle	3 - 5m	0.10 - 0.20 0.15	0.76 - 0.94 0.85	0.61 - 0.75 0.68	0.15 - 0.19 0.17
n.4	>300m	Mountaine ranges(water-shed)	Bedrocks, elluvial-deluv. deposits(0.5-1.5m)granule round stone,gravel,sand	min	>5m	0.15 - 0.25 0.20	0.72 - 0.88 0.80	0.52 - 0.60 0.56	0.20 - 0.28 0.24
			II. COASTAL PART OF REGION						
n.1	150m (0 - 150 m)	SteepSlope valleis of rivers	Bedrocks,deluvial,shore deposits(1-3m),sand,gravel,granule round stone	middle	<1m	0.00 - 0.10 0.05	0.90 - 1.00 0.95	0.90 - 1.00 0.95	-
n.4	>150m	Flat summits	Bedrocks,elluvial-deluv. deposits(0.5-1.5m),sand, gravel,gran.round stone	min	>5m	0.15 - 0.25 0.20	0.72 - 0.88 0.80	0.52 - 0.60 0.56	0.20 - 0.28 0.24

*) n.1, where: n - code of drainage - basin, .1 - code of area with similar conditions of melt water flowing

**) 0.00 - 0.10 range of eschanging (up) and avearage mean (down)

0.05

Coefficient of ground water clearance itself - NI,CO,CR,FE - 0.1 1/day, CU - 0.6 1/day[6].

Table N° 9

ENVIRONMENTAL POLLUTION IN THE TEST REGION AFTER SNOW COVER MELTING (SPRING,1992)

Drainage - basins					NI(t)						CU (t)						S (t)						CD (kg)			CR (kg)			FE (t)		
	Name		Code	Area, (km2)	Soil		Surface water		Under ground water		Soil		Surface water		Under-ground water		Soil	Surface water	Under ground water	S total water surface and under-ground	including S techn.	including S sea	Soil	Surface water	Underground water	Soil	Surface water	Underground water	Soil	Surface water	Underground water
					R	F	R	F	R	F	R	F	R	F	R	F	F	F	F	R	R	R	F	F	F	F	F	F	F	F	F
Coast of the Barents sea	Bugor - fiorden		1	803	0.525	0.160	0.231	0.082	0.047	0.013	1.142	0.211	0.830	0.253	0.177	0.058	3.5	53.9	12.3	453.6	172.8	280.8	7.1	5.65	1.14	131.3	49.2	11.40	13.7	0.58	0.12
	Jarfiorden		2	654	10.240	7.440	0.647	0.768	0.139	0.178	2.990	5.330	1.505	1.215	0.321	0.275	65.4	75.3	11.5	547.9	24.6	523.2	276.3	23.90	1.00	847.0	19.0	4.00	344.0	4.50	1.00
	River Vorjema		3	487	15.190	11.460	0.522	0.530	0.140	0.135	5.670	4.550	1.000	0.948	0.279	0.278	41.2	50.7	10.9	311.2	35.1	276.2	419.0	22.00	6.00	1229.0	14.1	3.30	419.0	4.30	1.10
	River Pulmankijoki		4	720	0.206	0.034	0.151	0.019	0.040	0.005	0.705	0.124	0.591	0.136	0.159	0.037	3.6	43.7	3.9	92.2	72.0	20.2	5.2	0.85	0.22	29.6	2.5	0.60	3.4	0.39	0.11
		Sum		2664	26.954	19.094	1.551	1.399	0.365	0.331	10.597	10.215	3.926	2.552	0.936	0.648	113.7	223.6	43.6	1404.8	304.4	1100.4	703.6	62.40	8.40	2236.9	84.8	19.30	780.1	9.77	2.33
River Naatomojoki	Upperreaches and lake Jijarvi		5	784	0.244	0.080	0.232	0.021	0.053	0.005	0.796	0.141	0.674	0.155	0.160	0.037	6.3	36.8	6.9	156.8	9.6	147.2	5.8	1.37	0.32	24.5	2.3	0.50	4.7	0.48	0.11
	Lower reaches	Left tributaries	6	734	0.312	0.113	0.328	0.035	0.057	0.006	0.859	0.201	0.688	0.417	0.123	0.075	5.1	52.8	9.0	178.7	32.0	146.8	9.4	2.53	0.41	60.4	18.9	3.30	9.6	0.62	0.11
		Right tributaries	7	554	0.273	0.096	0.186	0.028	0.030	0.005	0.645	0.119	0.457	0.142	0.078	0.024	3.9	23.6	3.3	149.1	11.0	138.0	6.2	1.54	0.17	30.5	9.3	1.70	6.7	0.40	0.07
		Sum		2082	0.829	0.289	0.746	0.084	0.140	0.016	2.250	0.146	1.819	0.714	0.361	0.136	15.3	113.2	18.2	484.6	52.6	432.0	21.4	5.40	0.90	115.4	30.5	5.50	21.0	1.50	0.29
	River Munkelva		8	657	0.509	0.300	0.237	0.100	0.042	0.018	0.957	0.260	0.750	0.182	0.137	0.034	7.4	33.7	5.1	128.0	42.8	85.2	23.8	4.43	0.80	91.8	5.7	0.94	19.9	0.48	0.07
Lake Jnari	North - western part		9	1478	0.605	0.092	0.475	0.061	0.064	0.008	1.264	0.239	1.372	0.448	0.199	0.064	6.6	62.0	7.7	159.3	89.3	70.0	8.8	7.53	1.00	60.3	12.5	1.60	7.4	1.03	0.15
	North - eastern part		10	1475	0.442	0.325	0.410	0.097	0.052	0.012	1.120	0.320	1.044	0.340	0.125	0.040	134.0	53.3	5.7	266.9	76.0	191.0	19.5	6.10	0.70	72.1	13.2	1.50	13.3	0.92	0.10
	Eastern part		11	1356	2.539	0.585	0.738	0.144	0.113	0.026	2.234	0.566	1.280	0.409	0.202	0.077	133.4	57.0	7.8	344.4	153.2	191.2	33.1	7.40	1.20	418.3	15.3	2.50	26.7	1.78	0.32
		Sum		4310	3.586	1.002	1.623	0.302	0.229	0.046	4.618	1.125	3.696	1.197	0.526	0.181	274.0	172.3	21.2	770.6	318.4	452.2	61.4	21.00	2.90	550.7	41.0	5.60	47.4	3.73	0.57
River Pasvikelva	Upper reaches	Left tributariest	12	739	0.525	0.463	0.655	0.116	0.081	0.013	1.228	0.643	1.134	0.292	0.146	0.036	50.0	27.7	3.2	77.6	29.9	47.7	23.5	6.00	0.70	141.9	10.4	1.20	36.8	1.08	0.13
		Right tributaries	13	974	1.824	1.333	0.974	0.228	0.170	0.038	3.795	2.566	2.335	0.641	0.416	0.115	71.5	38.5	5.6	48.7	31.1	17.6	80.4	9.30	1.50	306.4	27.6	4.80	80.7	3.00	0.52
	Lower reaches	Left tributariest	14	915	9.417	10.299	1.258	1.121	0.091	0.085	4.490	7.727	2.500	1.392	0.213	0.098	38.4	65.6	6.0	215.9	107.3	108.6	533.0	36.3	2.70	990.0	18.3	1.60	212.8	3.60	0.57
		Right tributaries	15	1186	46.700	58.760	5.823	6.691	1.055	1.214	27.850	40.730	7.881	6.973	1.410	1.198	121.1	120.9	17.8	185.9	138.2	47.7	1825.0	120.0	20.00	2863.0	48.3	8.90	1113.0	10.90	1.90
		Sum		3814	58.557	70.855	8.710	8.156	1.397	1.350	37.363	51.666	13.85	9.298	2.185	1.447	281.0	252.7	32.6	528.1	306.5	221.6	2462.9	172.0	25.00	4301.3	104.6	16.50	1443.3	18.60	3.10
River Pechenga	Upper reaches		16	876	9.310	13.180	1.916	1.385	0.439	0.328	6.910	13.390	3.109	2.339	0.741	0.562	59.8	71.6	13.2	189.6	113.2	76.4	511.0	39.5	9.20	1441.0	30.8	6.90	611.1	6.84	1.54
	Lower reaches	Left tributaries	17	579	72.840	46.760	1.448	1.384	0.309	0.309	25.830	31.030	1.791	1.652	0.380	0.363	166.2	55.4	8.4	177.3	14.3	163.0	1758.0	40.8	8.20	4377.0	17.7	4.40	1839.0	7.22	1.29
		Right tributaries	18	520	32.991	17.210	0.976	0.908	0.170	0.163	11.770	14.510	1.360	1.065	0.249	0.190	93.5	59.8	8.9	84.0	39.8	44.2	832.0	31.2	5.40	2563.0	18.8	3.30	1129.0	6.30	1.10
		Sum		1975	112.441	77.150	4.340	3.677	0.917	0.800	45.510	59.930	6.260	5.095	1.370	1.115	319.5	186.8	30.5	450.9	167.3	283.6	3101.0	111.5	22.60	8381.0	67.3	14.60	3579.1	20.40	5.80
	Upper Titovka		19	603	6.470	9.400	1.064	0.852	0.225	0.180	4.040	6.660	1.635	1.161	0.359	0.264	23.8	51.2	9.1	121.6	97.5	28.6	251.0	29.8	6.30	1211.0	25.6	5.40	481.0	6.00	1.30
LakesAla-Akkajarvi,Nyanamyarvi			20	1284	2.039	4.040	0.541	0.903	0.116	0.193	5.620	31.700	1.921	3.492	0.424	0.770	44.9	49.1	8.7	64.2	45.4	12.8	392.0	31.64	6.75	650.0	35.9	7.70	194.0	4.50	0.76
Sum for all territory				17389	217.588	121.841	18.80	15.50	3.400	2.900	110.865	161.017	33.90	23.70	6.300	4.600	1079.6	1082.6	169.0	3957.3	1335.1	2616.4	7022.0	438.17	73.65	17538.1	395.4	75.54	6565.8	64.98	14.44
TOTAL SUM					R - 239.7 tons F - 200.2 tons						R - 151.1 tons F - 189.3 tons						R - S(techn) of water = 1335.1 tons F-2331.2t, S(techn) of water =1251.6 tons						F - 7.53 tons			F - 18.01 tons			F - 6645.2 tons		

R -Russian data, F - Finnish data

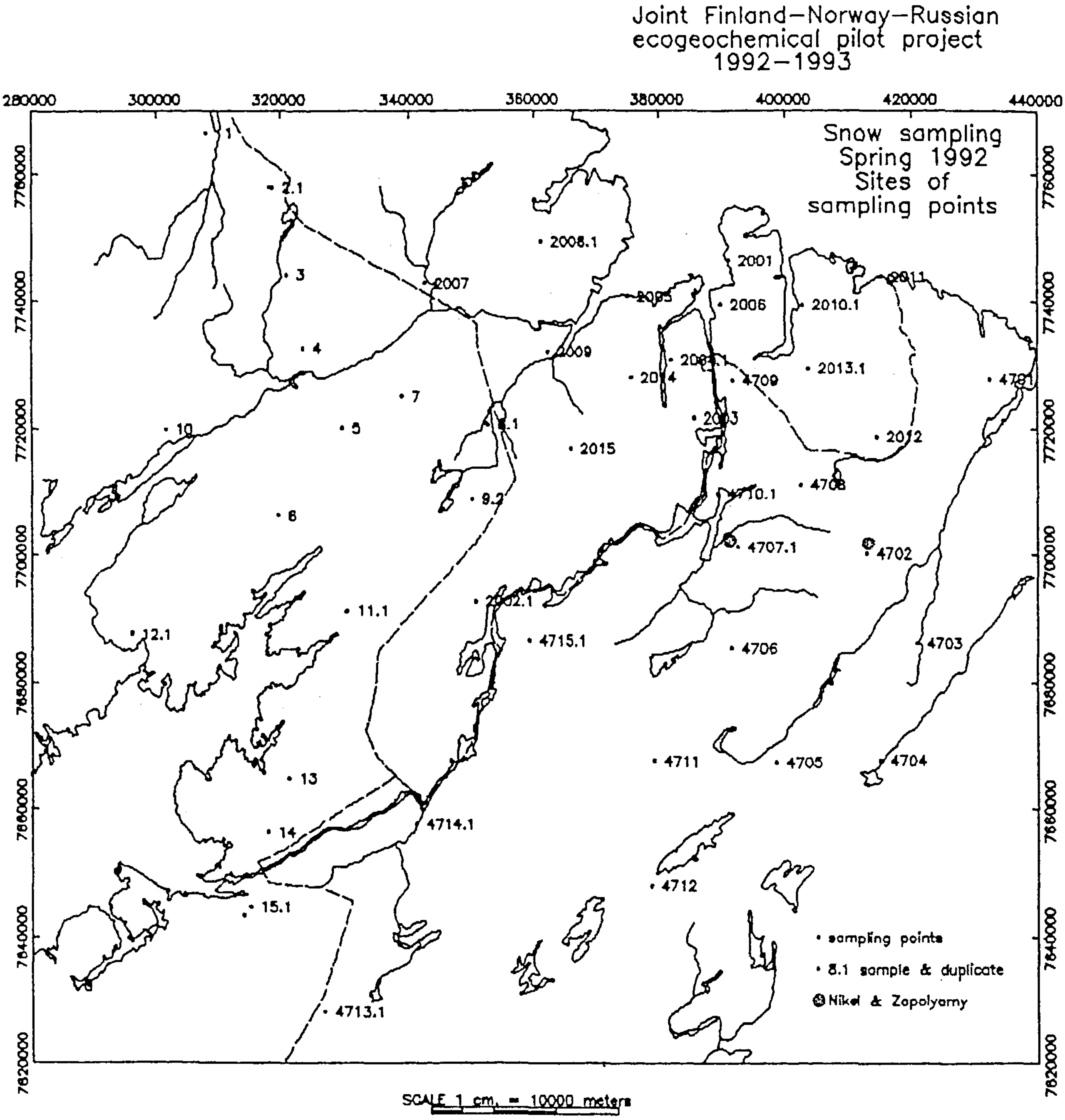

Joint Finland–Norway–Russian ecogeochemical pilot project 1992–1993
Snow sampling Spring 1992 Sites of sampling points
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
1
2.1
3
4
7
5
10
6
11.1
12.1
13
14
15.1
2007
2008.1
2005
2009
2014
2004.1
4709
2003
2015
9.1
9.2
2001
2006
2010.1
2011
2013.1
4701
2012
4708
4710.1
4707.1
4702
2002.1
4715.1
4706
4703
4711
4705
4704
4714.1
4712
4713.1
• sampling points
• 8.1 sample & duplicate
Nikel & Zapolyarny
SCALE 1 cm. = 10000 meters

Figure N° 1

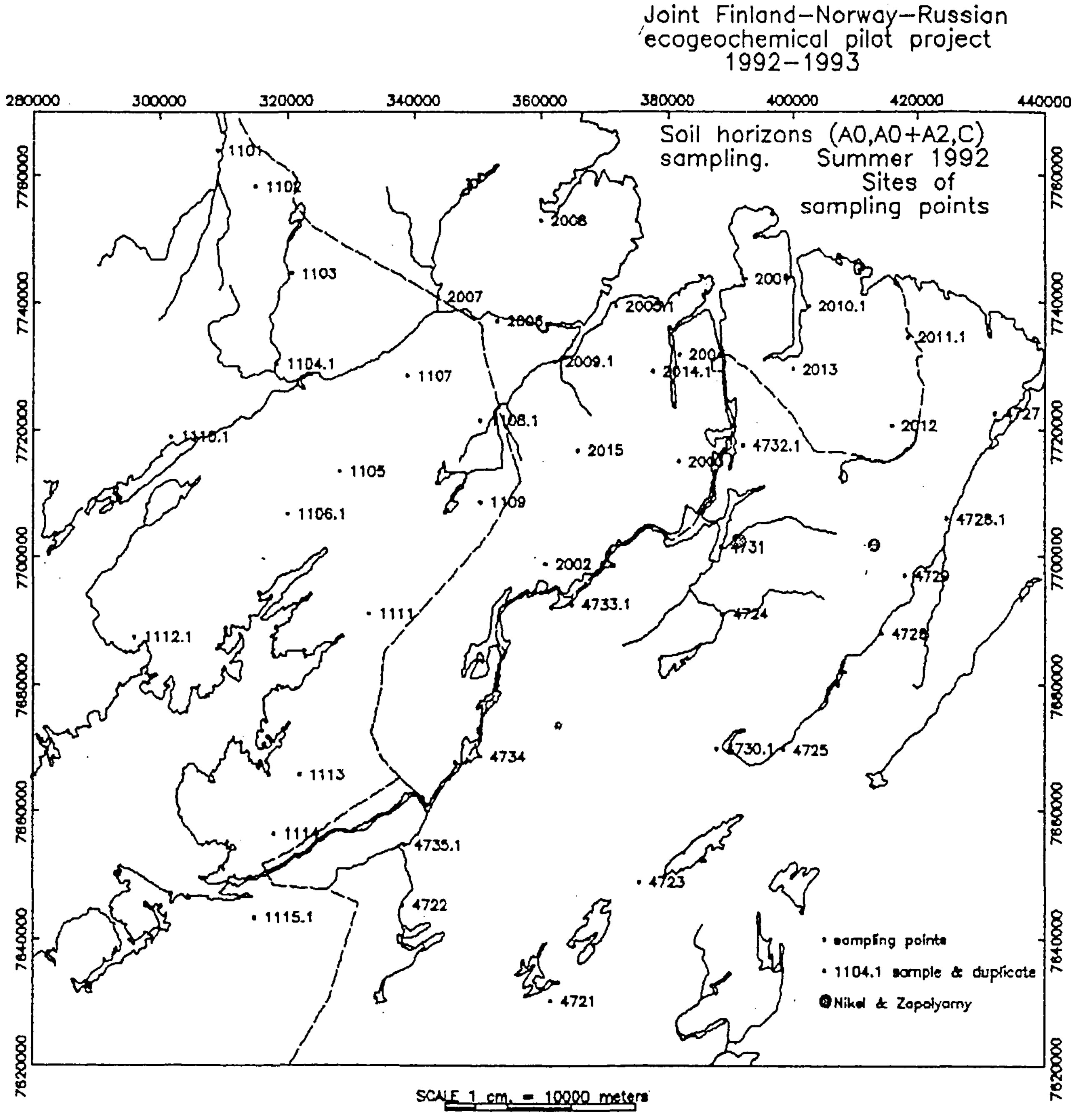

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Soil horizons (A0,A0+A2,C)
sampling. Summer 1992
Sites of
sampling points
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
1101
1102
1103
1104.1
1105
1106.1
1107
1108.1
1109
1110.1
1111
1112.1
1113
1114
1115.1
2001
2002
2003
2004
2005.1
2006
2007
2008
2009.1
2010.1
2011.1
2012
2013
2014.1
2015
4721
4722
4723
4724
4725
4727
4728
4728.1
4729
4730.1
4731
4732.1
4733.1
4734
4735.1
sampling points
1104.1 sample & duplicate
Nikel & Zapolyarny
SCALE 1 cm. = 10000 meters

Figure N° 2

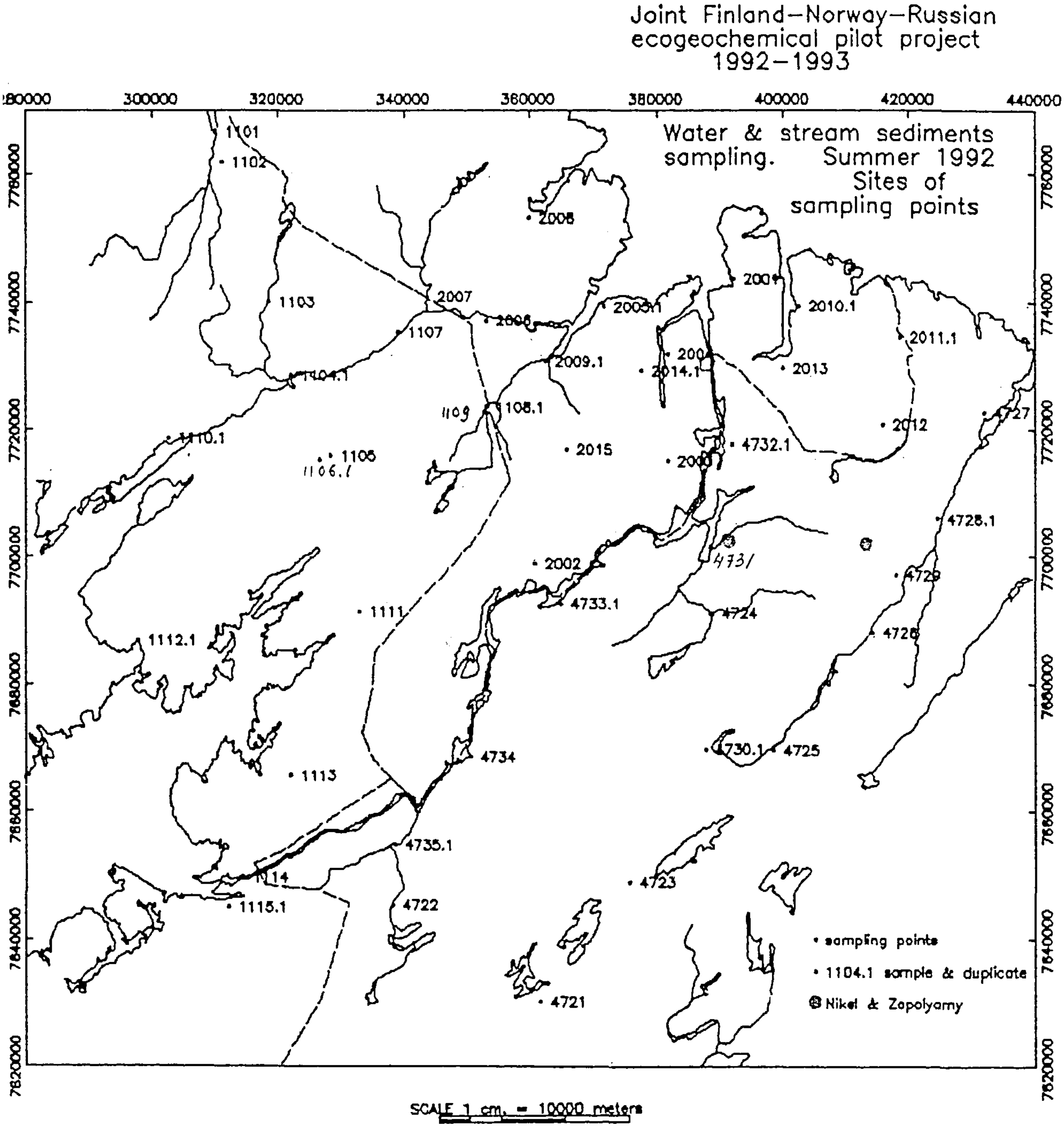

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Water & stream sediments
sampling. Summer 1992
Sites of
sampling points
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
1101
1102
1103
1104.1
1105
1106.1
1107
1108.1
1109
1110.1
1111
1112.1
1113
1114
1115.1
2002
2003
2004
2005.1
2006
2007
2008
2009
2009.1
2010.1
2011.1
2012
2013
2014.1
2015
4721
4722
4723
4724
4725
4726
4727
4728.1
4729
4730.1
4731
4732.1
4733.1
4734
4735.1
• sampling points
• 1104.1 sample & duplicate
Nikel & Zapolyarny
SCALE 1 cm. = 10000 meters

Figure N° 3

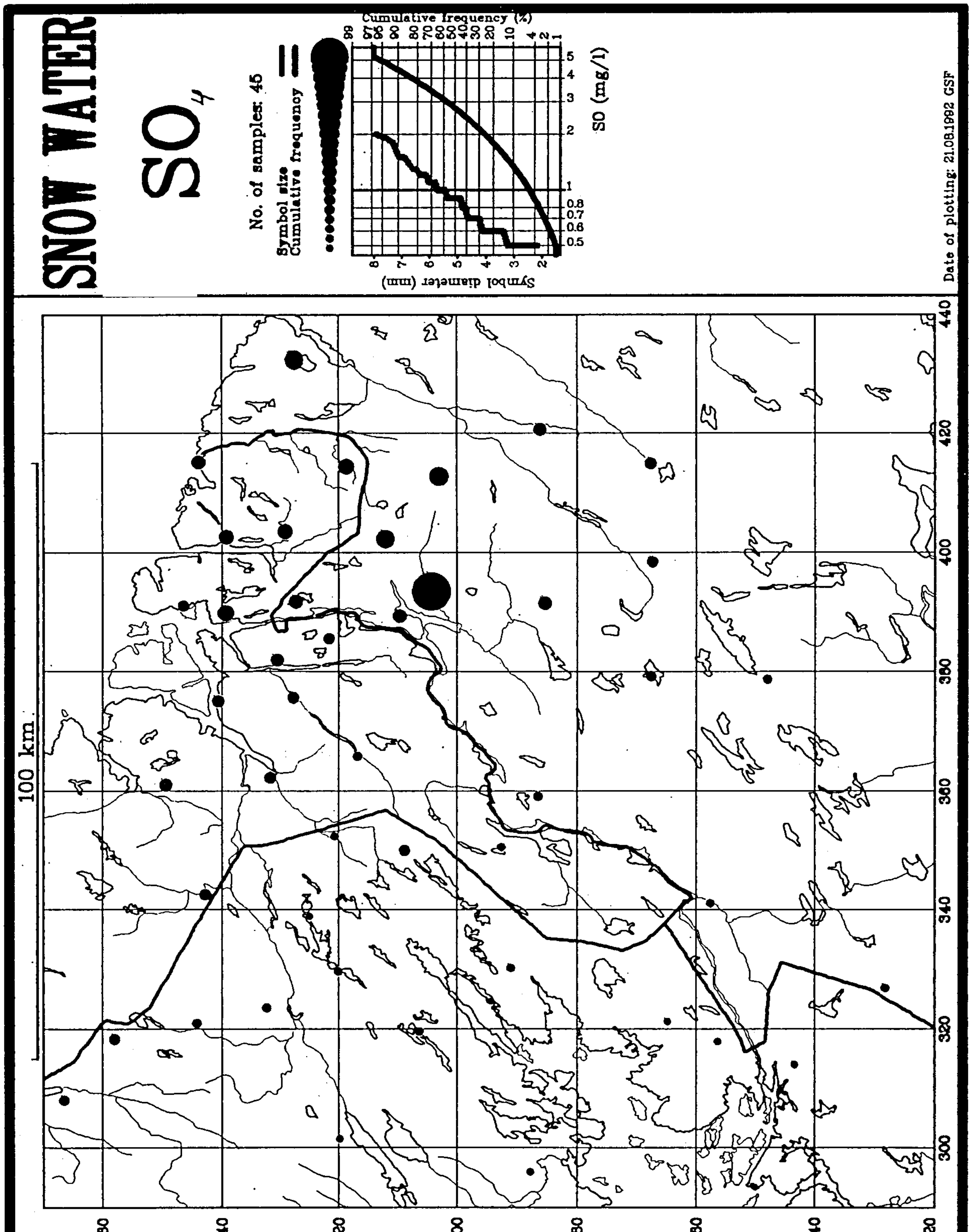

SNOW WATER
SO4
No. of samples: 45
Symbol size
Cumulative frequency
Cumulative frequency (%)
99 97 95 90 80 70 60 50 40 30 20 10 4 2 1
Symbol diameter (mm)
8 7 6 5 4 3 2
SO (mg/l)
0.5 0.6 0.7 0.8 1 2 3 4 5
Date of plotting: 21.08.1992 GSF
100 km
7760 7740 7720 7700 7680 7660 7640 7620
300 320 340 360 380 400 420 440

Figure N° 4

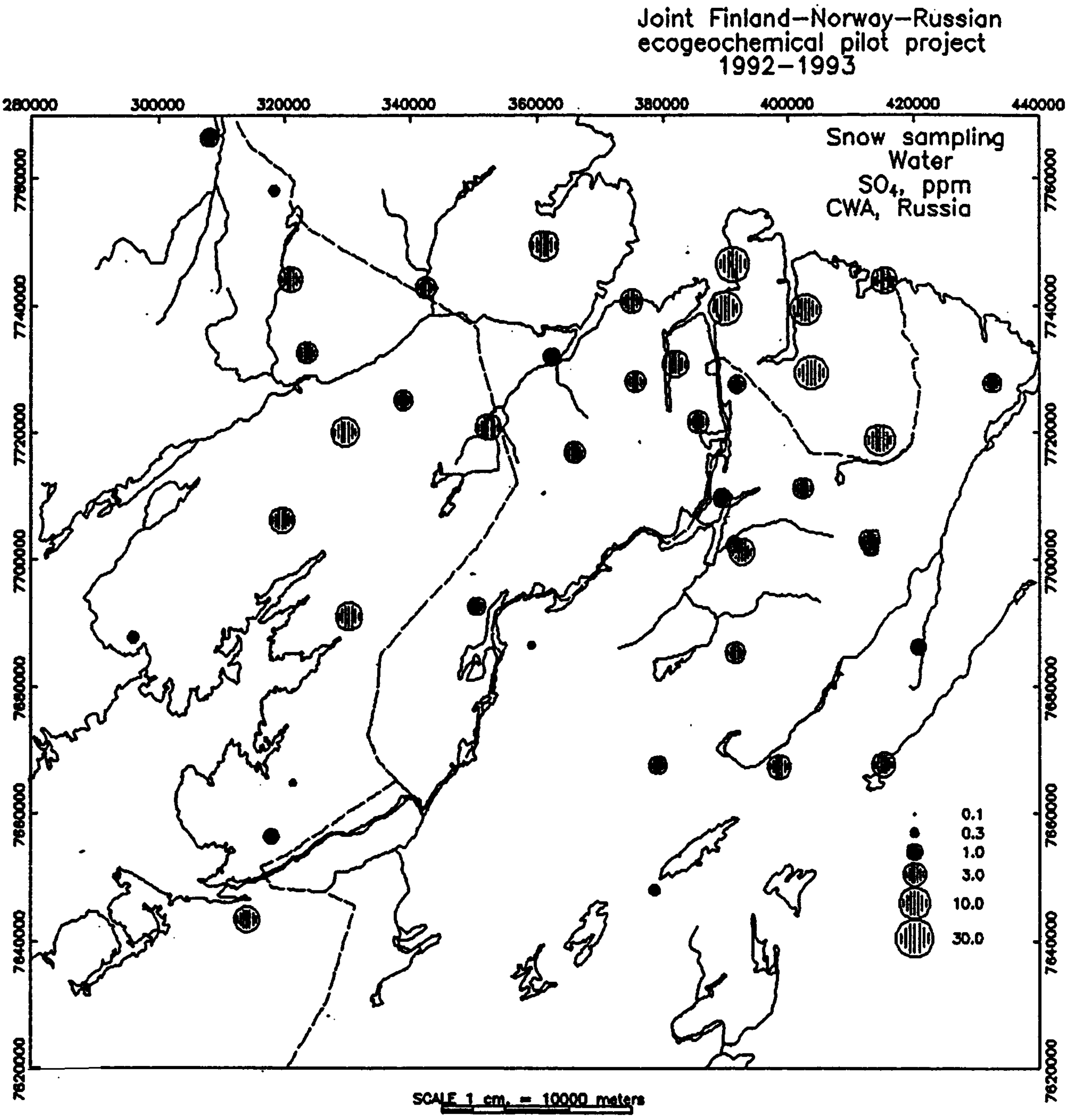

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7620000
7640000
7660000
7680000
7700000
7720000
7740000
7760000
Snow sampling
Water
SO4, ppm
CWA, Russia
0.1
0.3
1.0
3.0
10.0
30.0
SCALE 1 cm. = 10000 meters

Figure N° 5

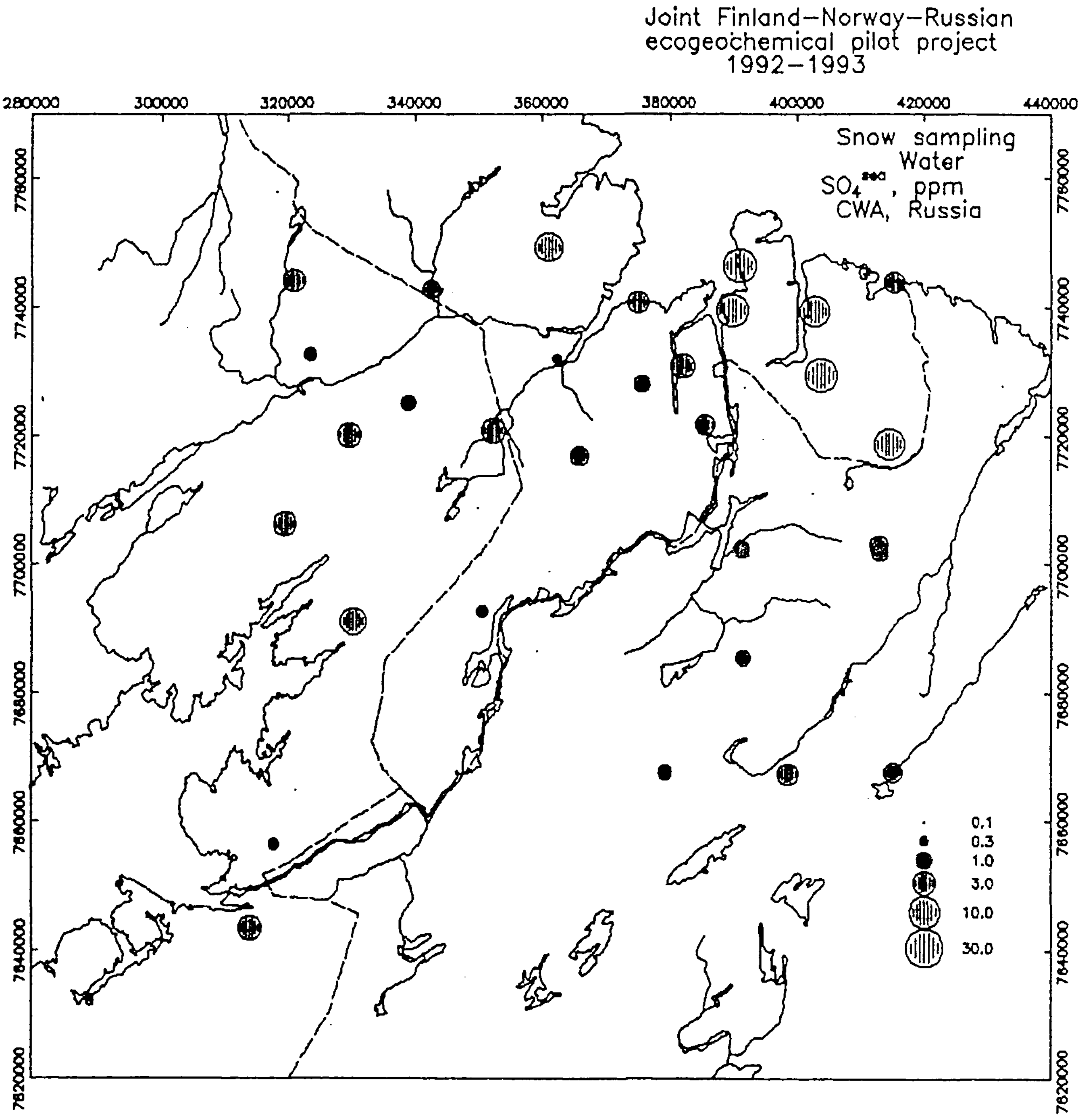

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow sampling
Water
SO_4^{sea}, ppm
CWA, Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
0.1
0.3
1.0
3.0
10.0
30.0

Figure N° 6

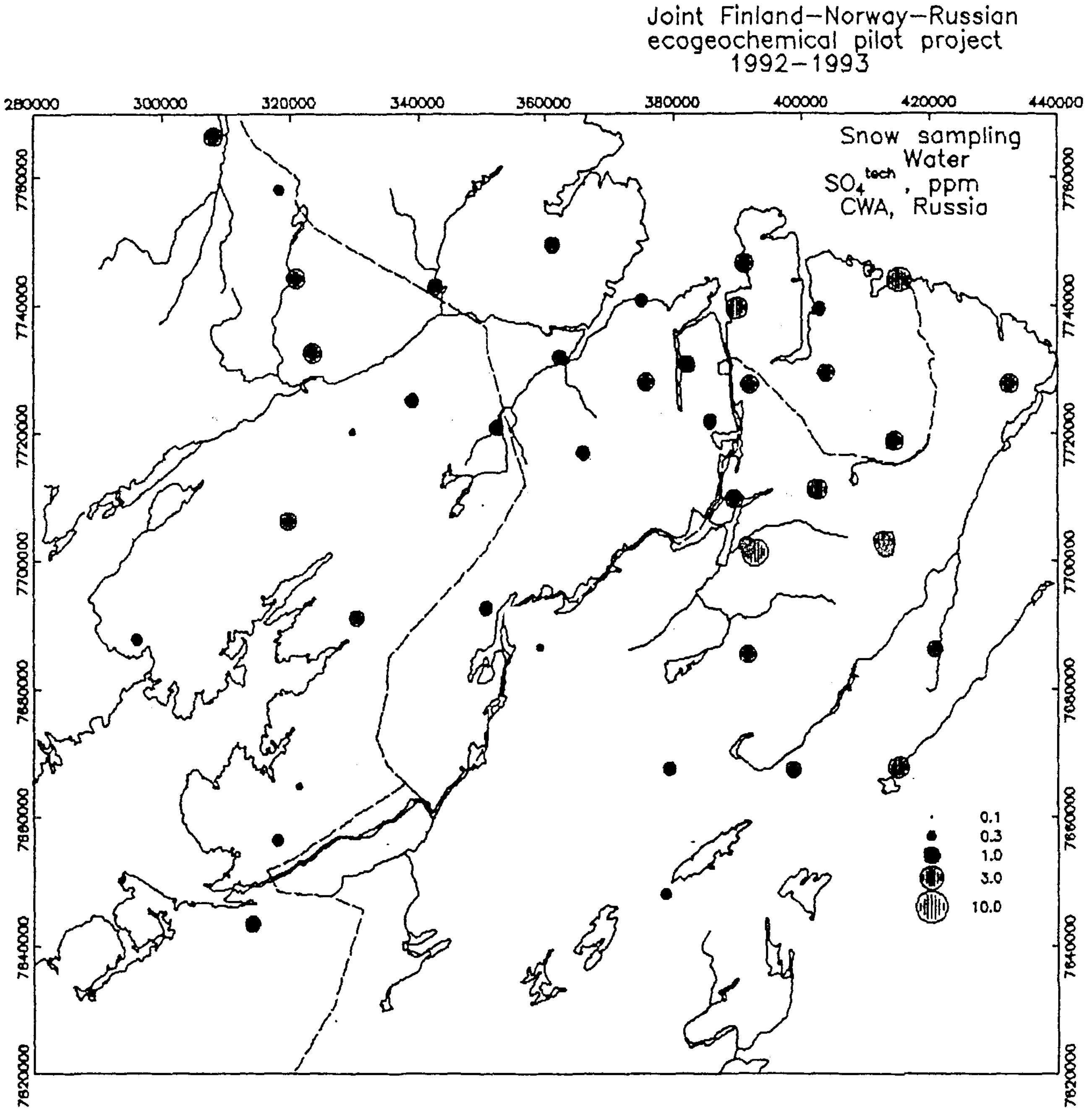

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow sampling
Water
SO_4^{tech}, ppm
CWA, Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
0.1
0.3
1.0
3.0
10.0

Figure N° 7

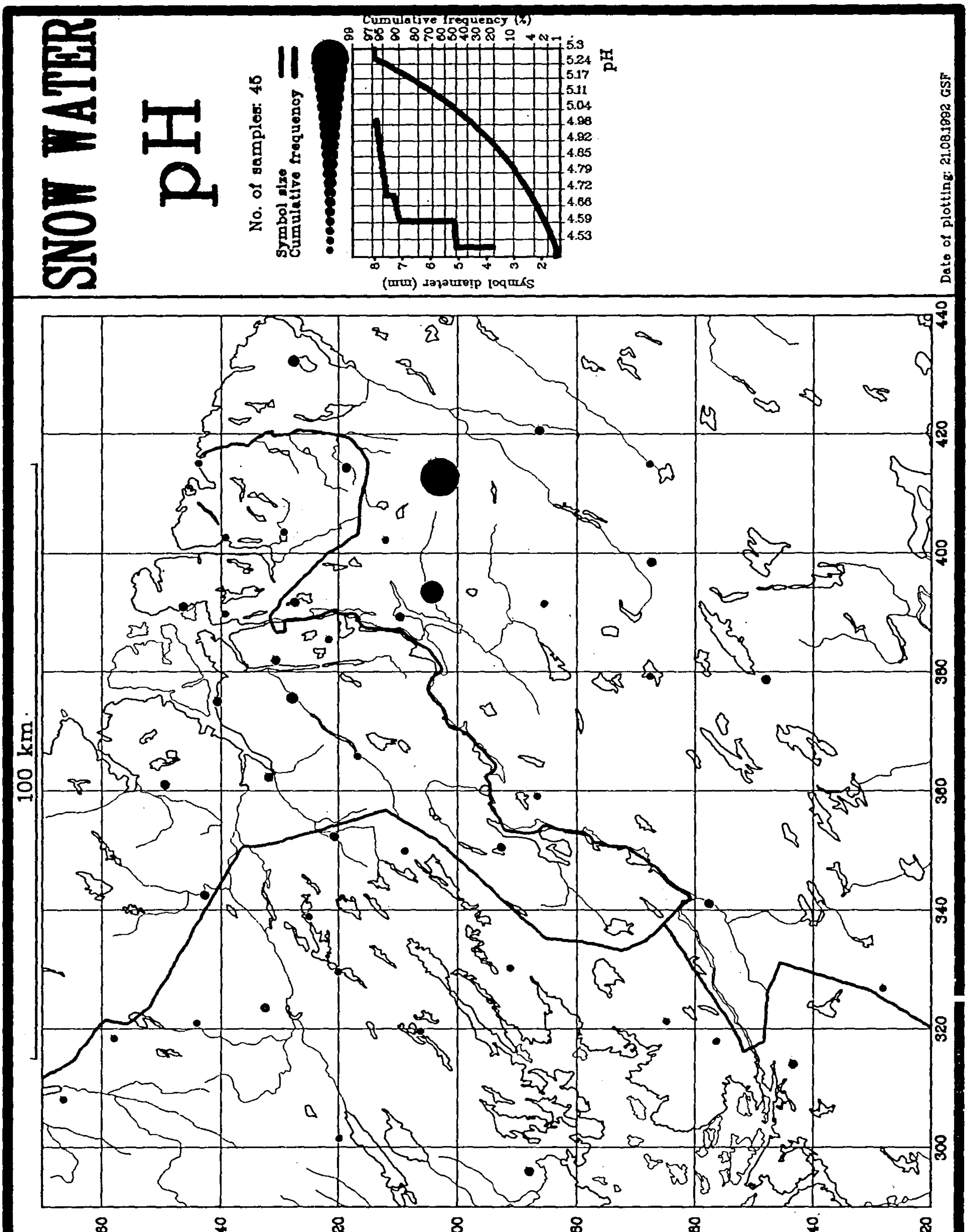

SNOW WATER
pH
No. of samples: 45
Symbol size
Cumulative frequency
Cumulative frequency (%)
99 97 95 90 80 70 60 50 40 30 20 10 4 2 1
5.3 5.24 5.17 5.11 5.04 4.98 4.92 4.85 4.79 4.72 4.66 4.59 4.53
pH
Symbol diameter (mm)
8 7 6 5 4 3 2
Date of plotting: 21.08.1992 GSF
100 km
300 320 340 360 380 400 420 440
7760 7740 7720 7700 7680 7660 7640 7620

Figure N° 8

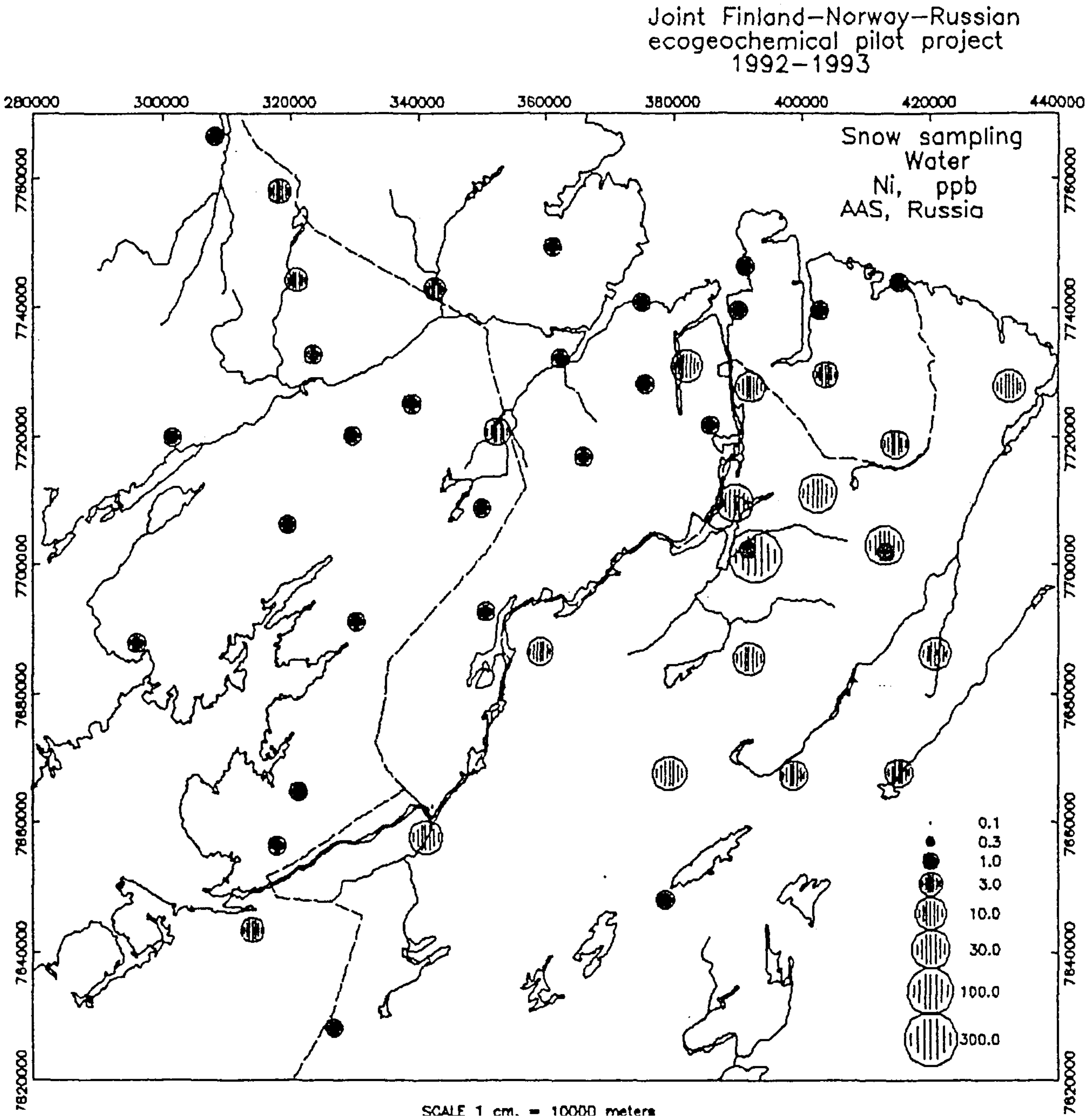

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Snow sampling
Water
Ni, ppb
AAS, Russia
0.1
0.3
1.0
3.0
10.0
30.0
100.0
300.0
SCALE 1 cm. = 10000 meters

Figure N° 9

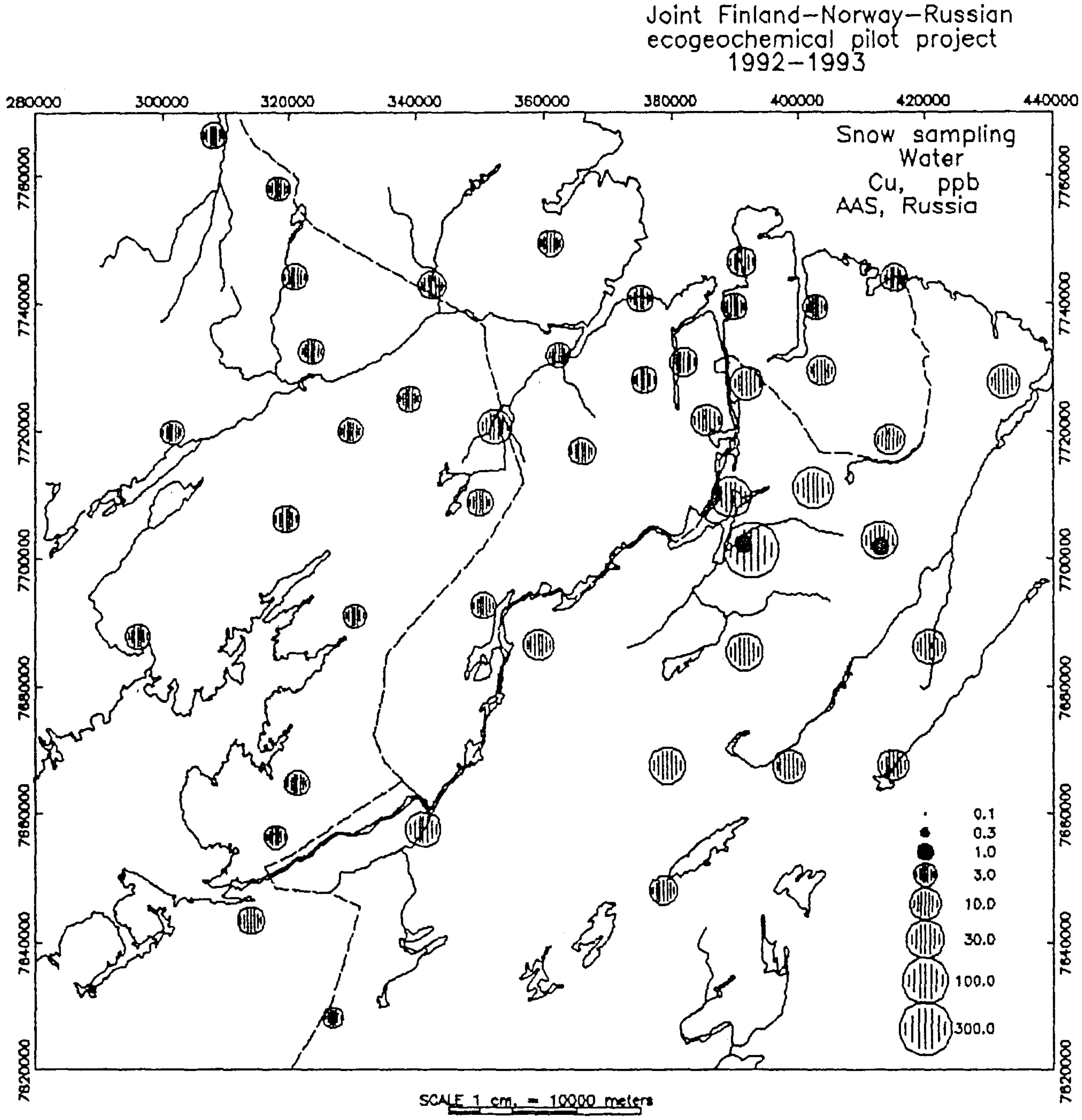

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Snow sampling
Water
Cu, ppb
AAS, Russia
0.1
0.3
1.0
3.0
10.0
30.0
100.0
300.0
SCALE 1 cm. = 10000 meters

Figure N° 10

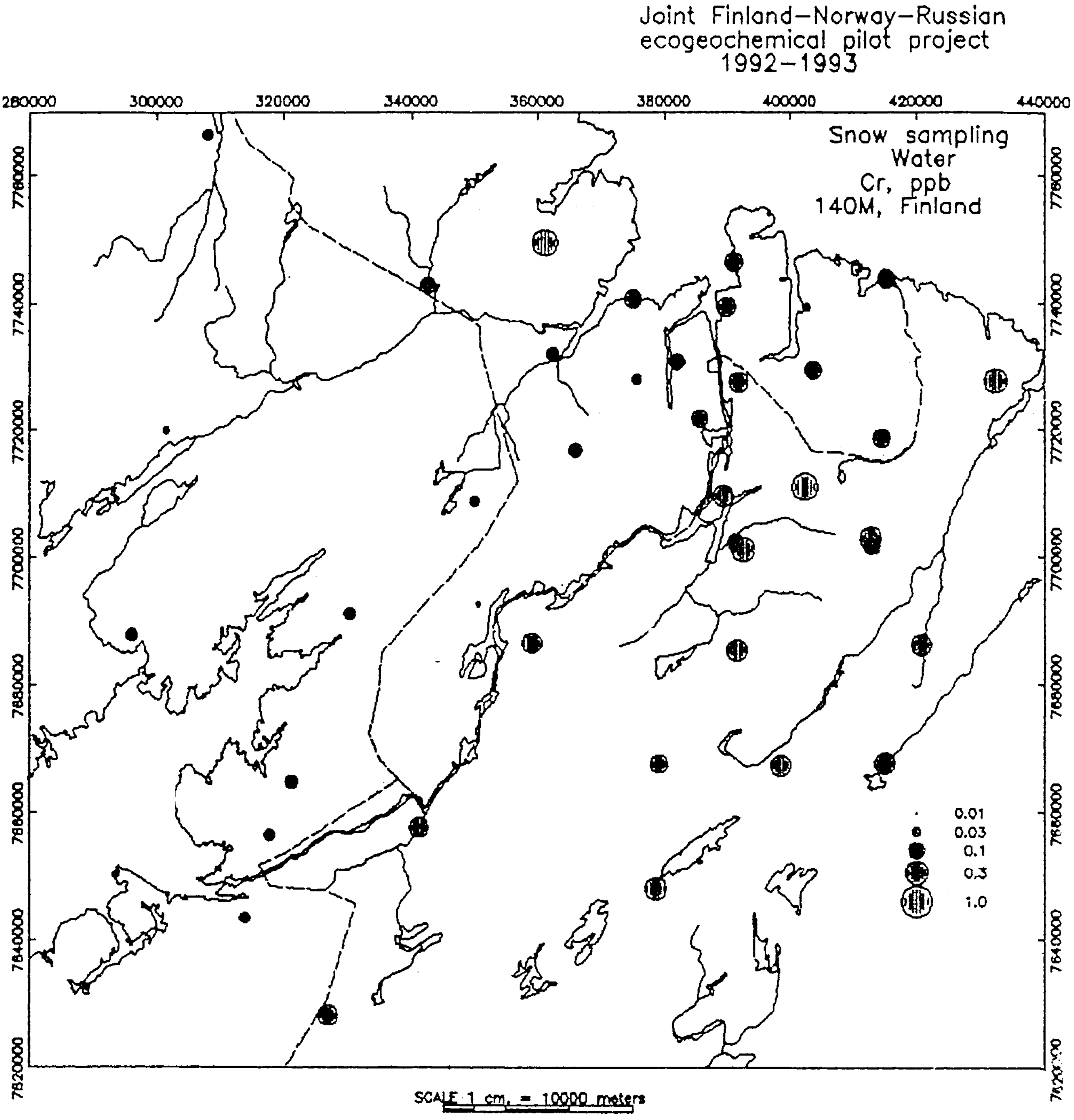

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Snow sampling
Water
Cr, ppb
140M, Finland
0.01
0.03
0.1
0.3
1.0
SCALE 1 cm. = 10000 meters

Figure N° 11

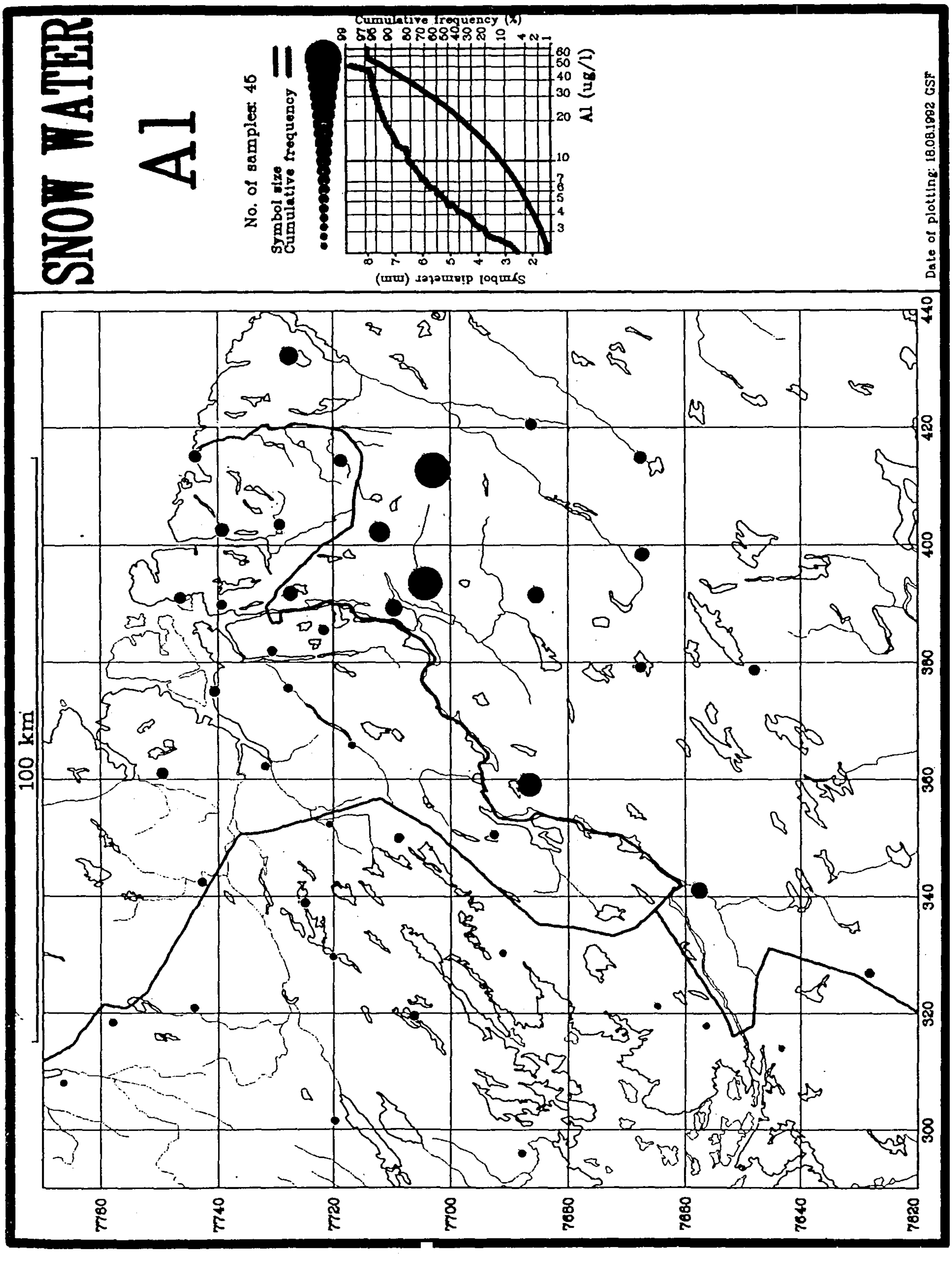

SNOW WATER
Al
No. of samples: 45
Symbol size
Cumulative frequency
Cumulative frequency (%)
99
97
95
90
80
70
60
50
40
30
20
10
4
2
1
Symbol diameter (mm)
8
7
6
5
4
3
2
60
50
40
30
20
10
7
6
5
4
3
Al (ug/l)
Date of plotting: 18.08.1992 GSF
100 km
7760
7740
7720
7700
7680
7660
7640
7620
300
320
340
360
380
400
420
440

Figure N° 12

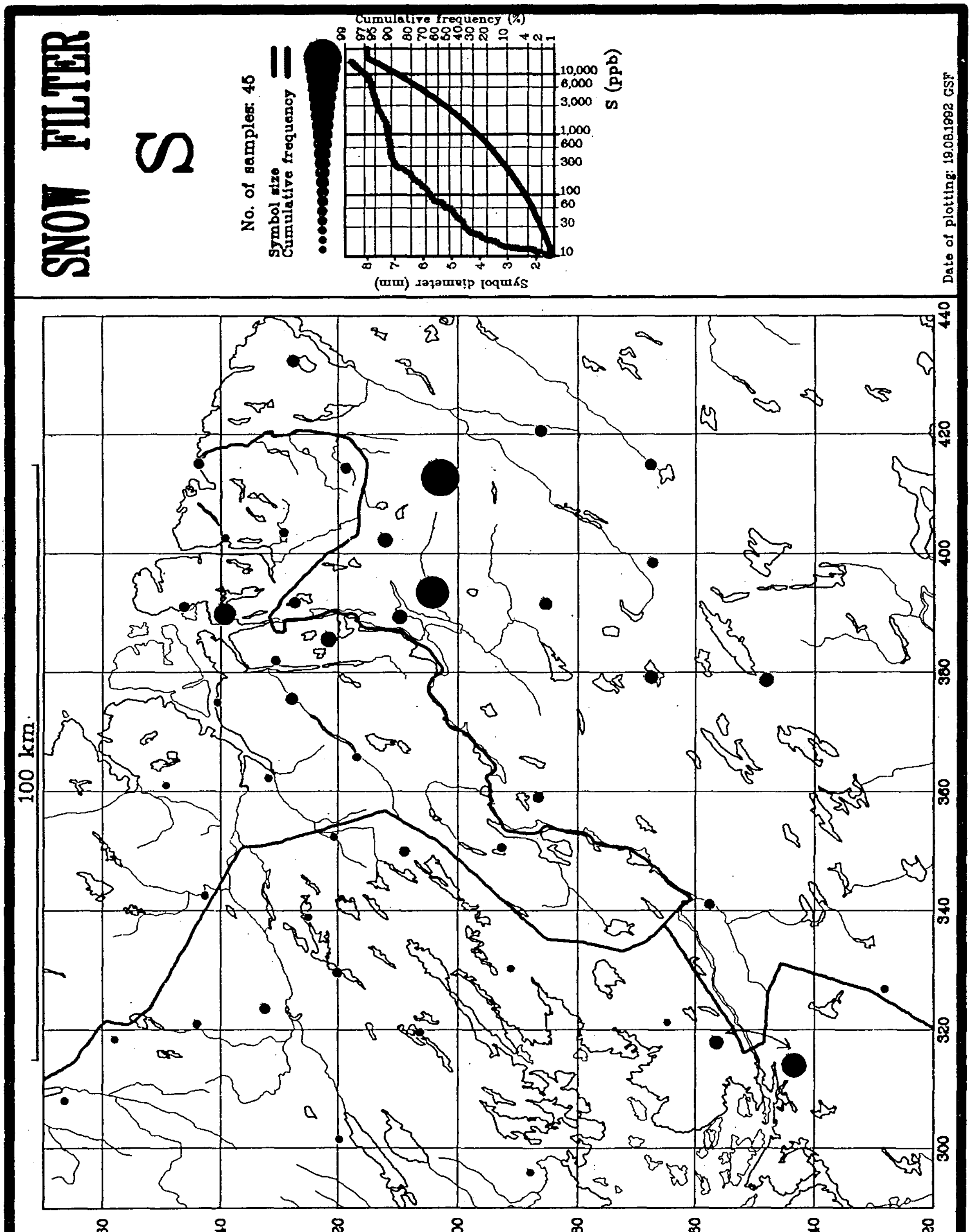

SNOW FILTER
S
No. of samples: 45
Symbol size
Cumulative frequency
Cumulative frequency (%)
S (ppb)
Symbol diameter (mm)
Date of plotting: 19.08.1992 GSF
100 km
7760
7740
7720
7700
7680
7660
7640
7620
300
320
340
360
380
400
420
440

Figure N° 13

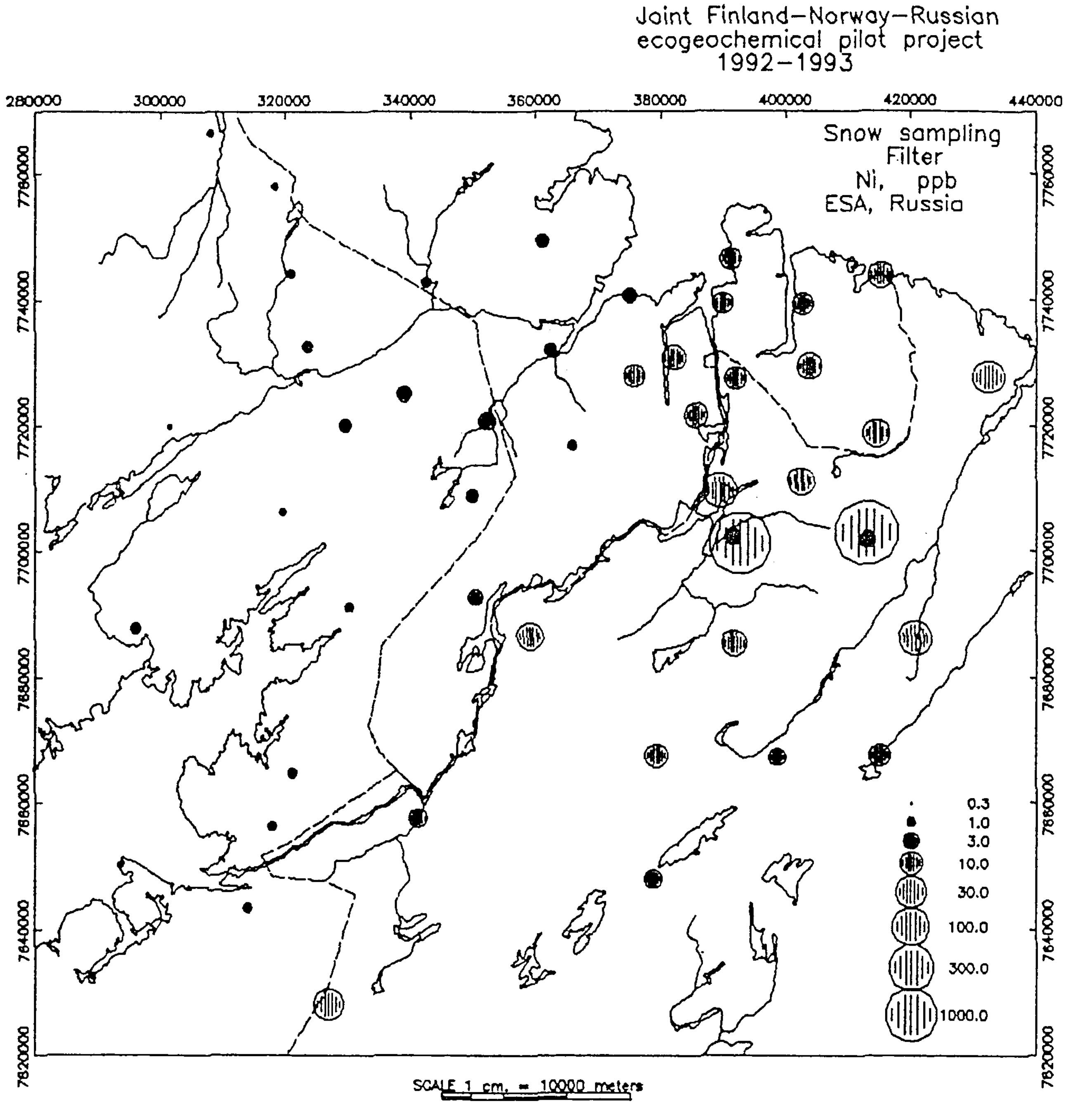

Joint Finland-Norway-Russian
ecogeochemical pilot project
1992-1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Snow sampling
Filter
Ni, ppb
ESA, Russia
0.3
1.0
3.0
10.0
30.0
100.0
300.0
1000.0
SCALE 1 cm. = 10000 meters

Figure N° 14

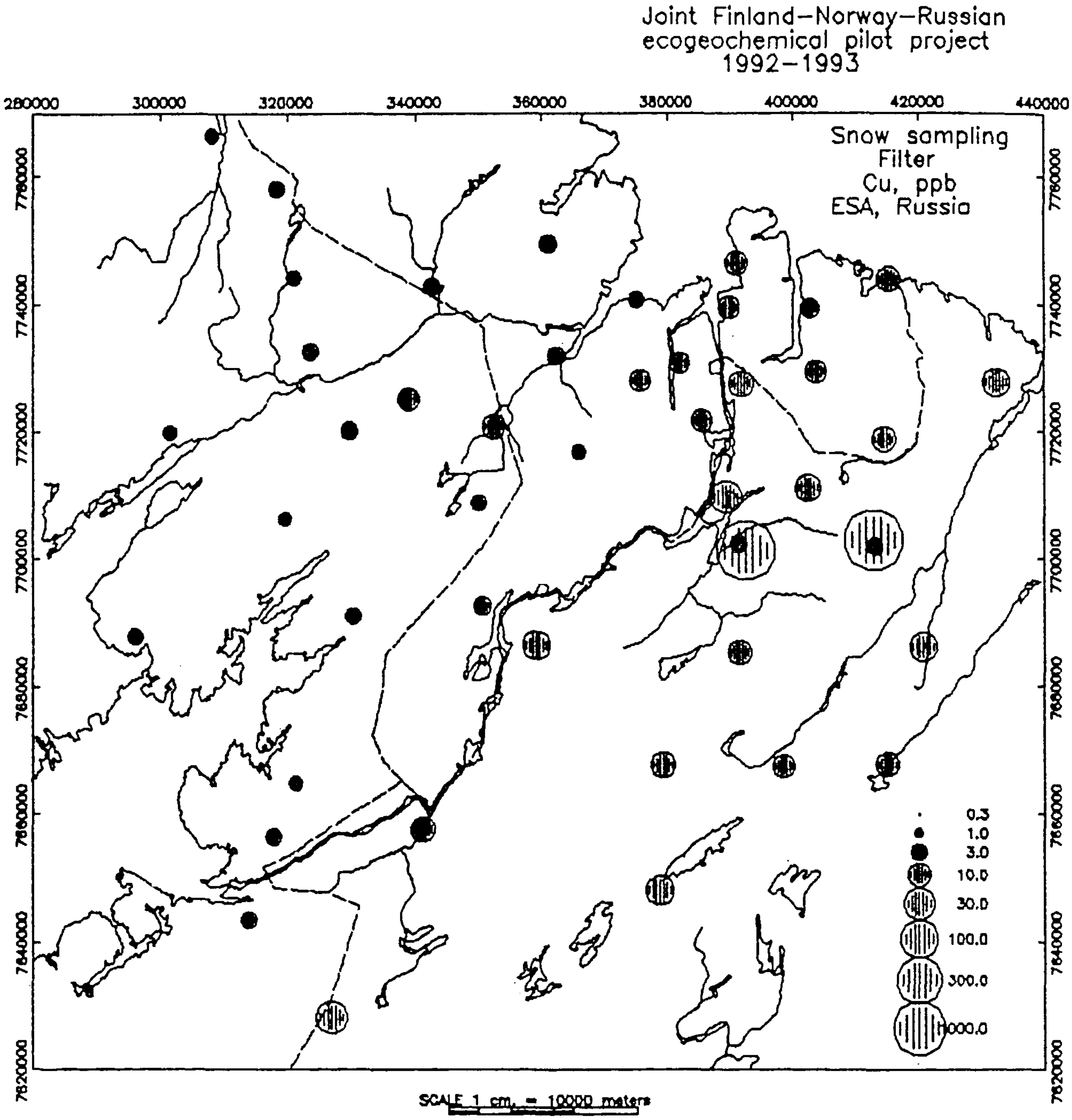

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow sampling
Filter
Cu, ppb
ESA, Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
0.3
1.0
3.0
10.0
30.0
100.0
300.0
1000.0
SCALE 1 cm. = 10000 meters

Figure N° 15

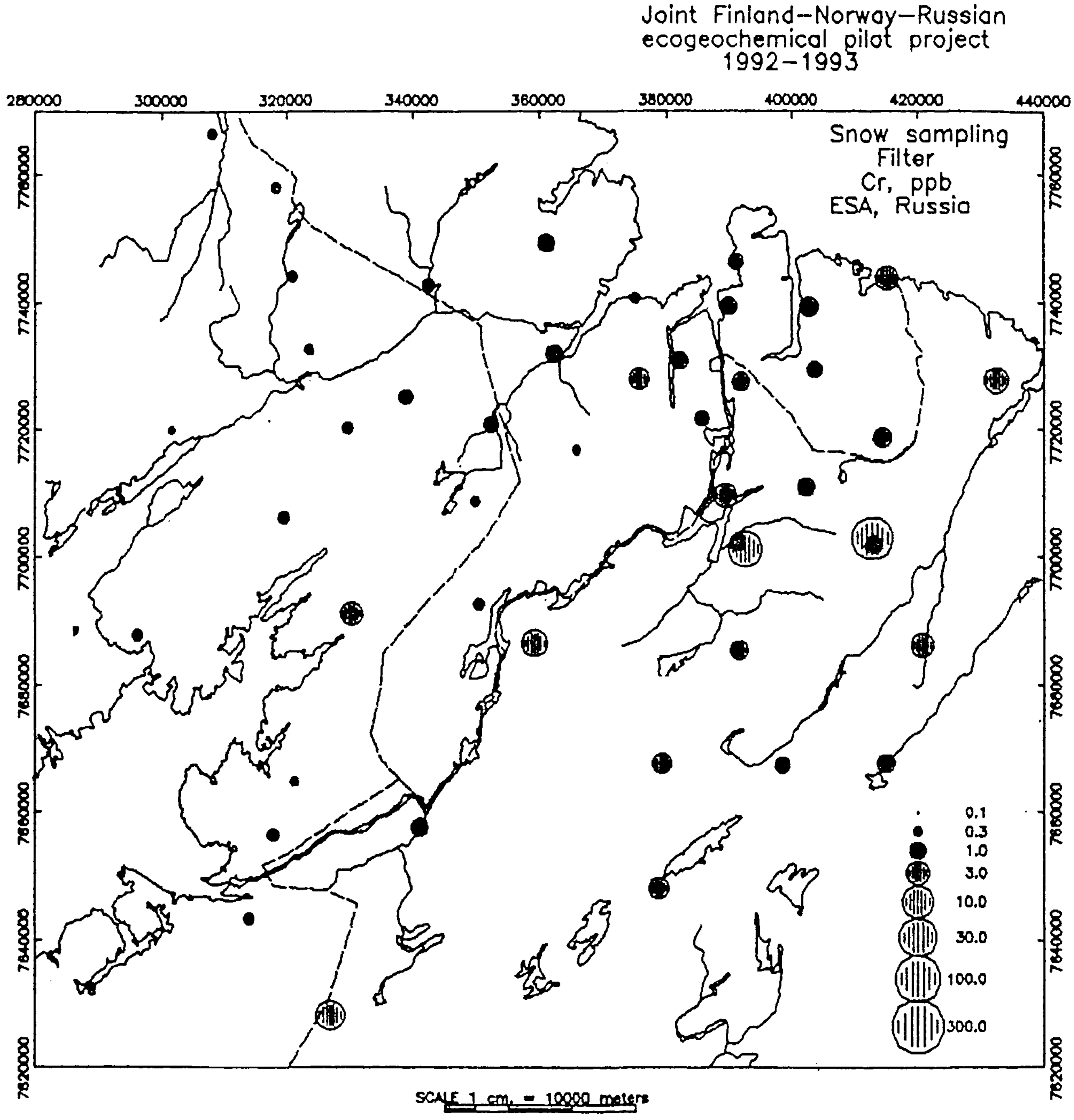

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow sampling
Filter
Cr, ppb
ESA, Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
0.1
0.3
1.0
3.0
10.0
30.0
100.0
300.0
SCALE 1 cm. = 10000 meters

Figure N° 16

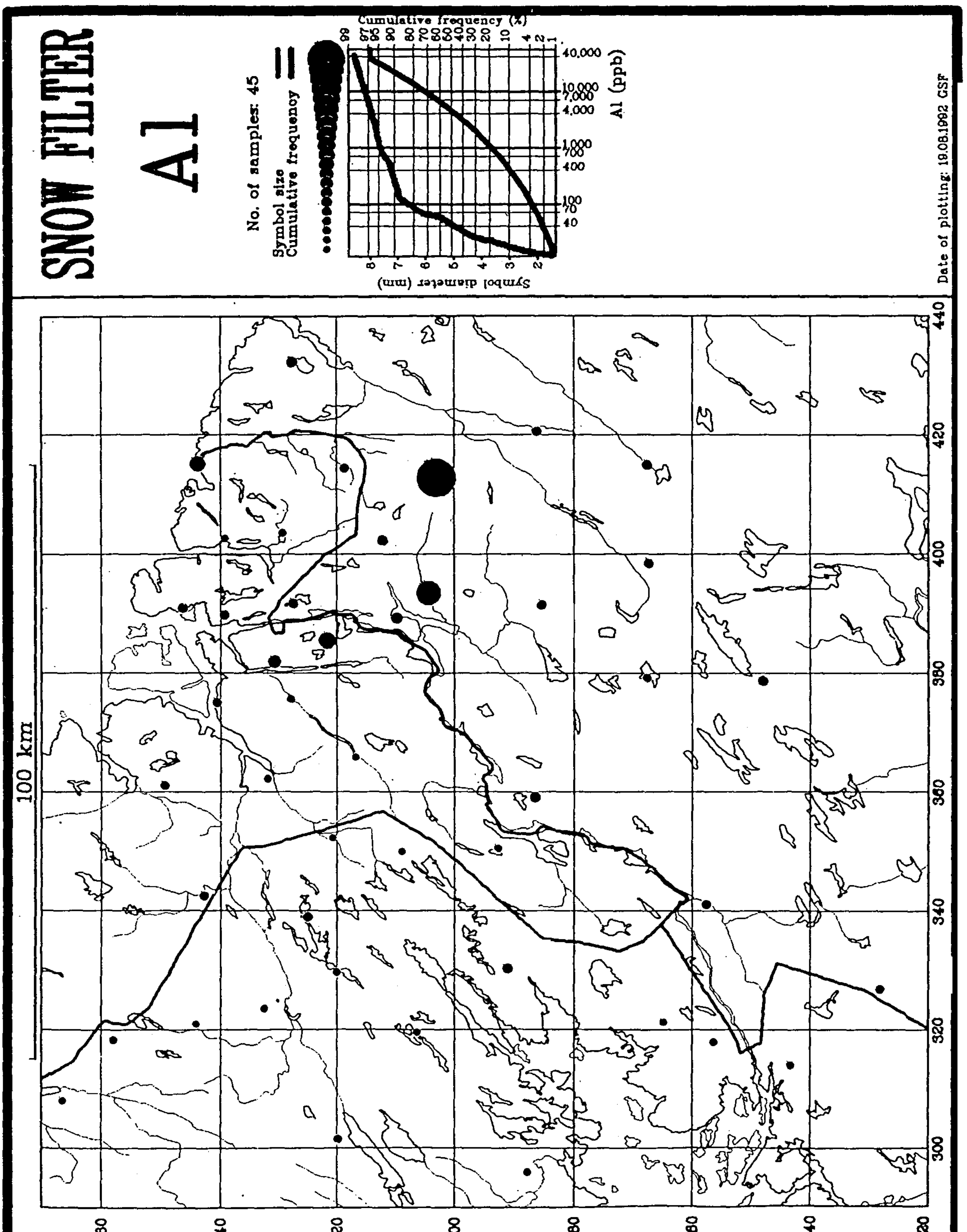

SNOW FILTER
Al
No. of samples: 45
Symbol size
Cumulative frequency
Cumulative frequency (%)
99
97
95
90
80
70
60
50
40
30
20
10
4
2
1
40,000
10,000
7,000
4,000
1,000
700
400
100
70
40
Al (ppb)
Symbol diameter (mm)
8
7
6
5
4
3
2
Date of plotting: 18.08.1992 GSF
100 km
7760
7740
7720
7700
7680
7660
7640
7620
300
320
340
360
380
400
420
440

Figure N° 17

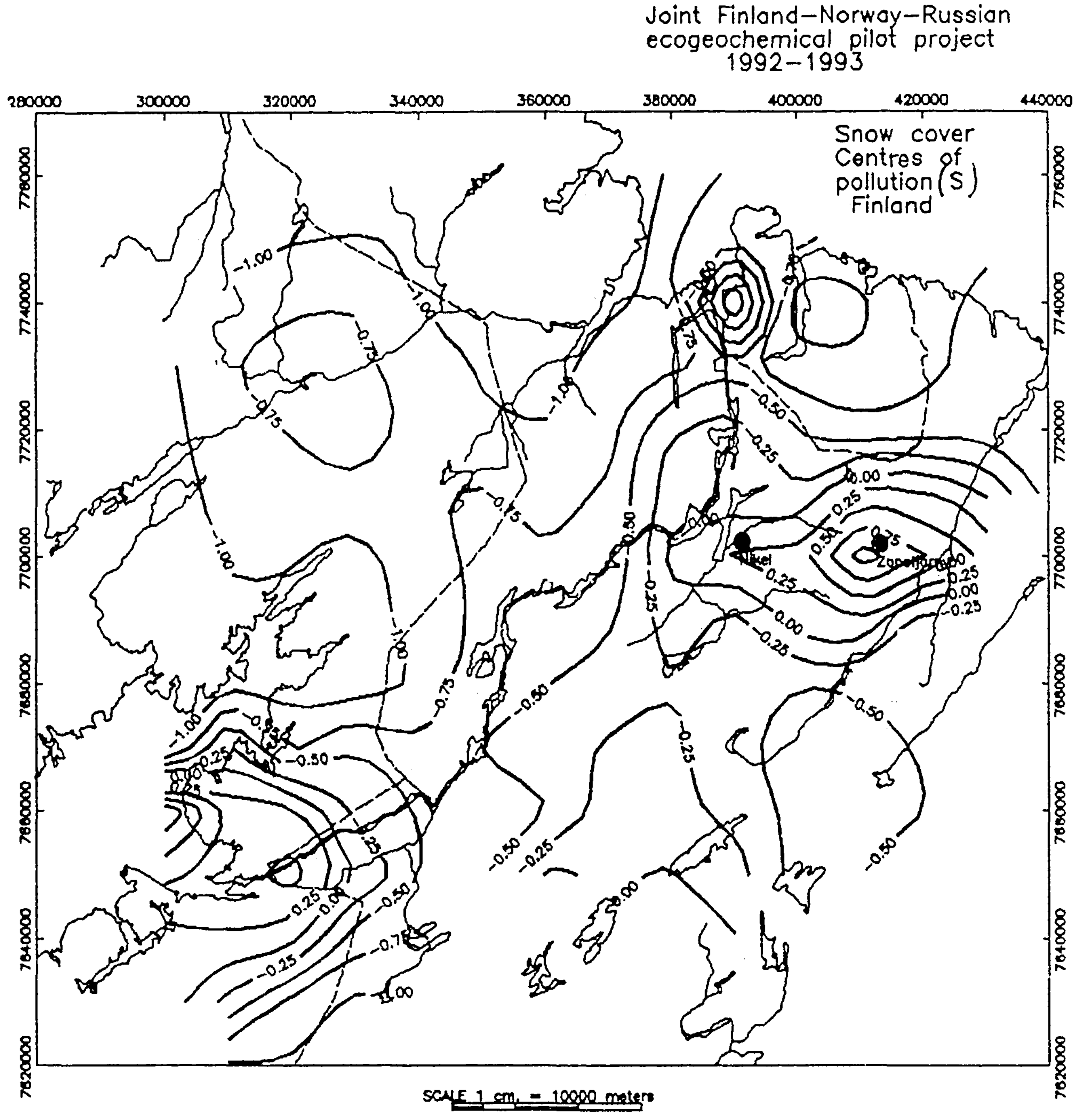

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow cover
Centres of
pollution (S)
Finland
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Nikel
Zapoljarnyj
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
SCALE 1 cm. = 10000 meters

Figure N° 18

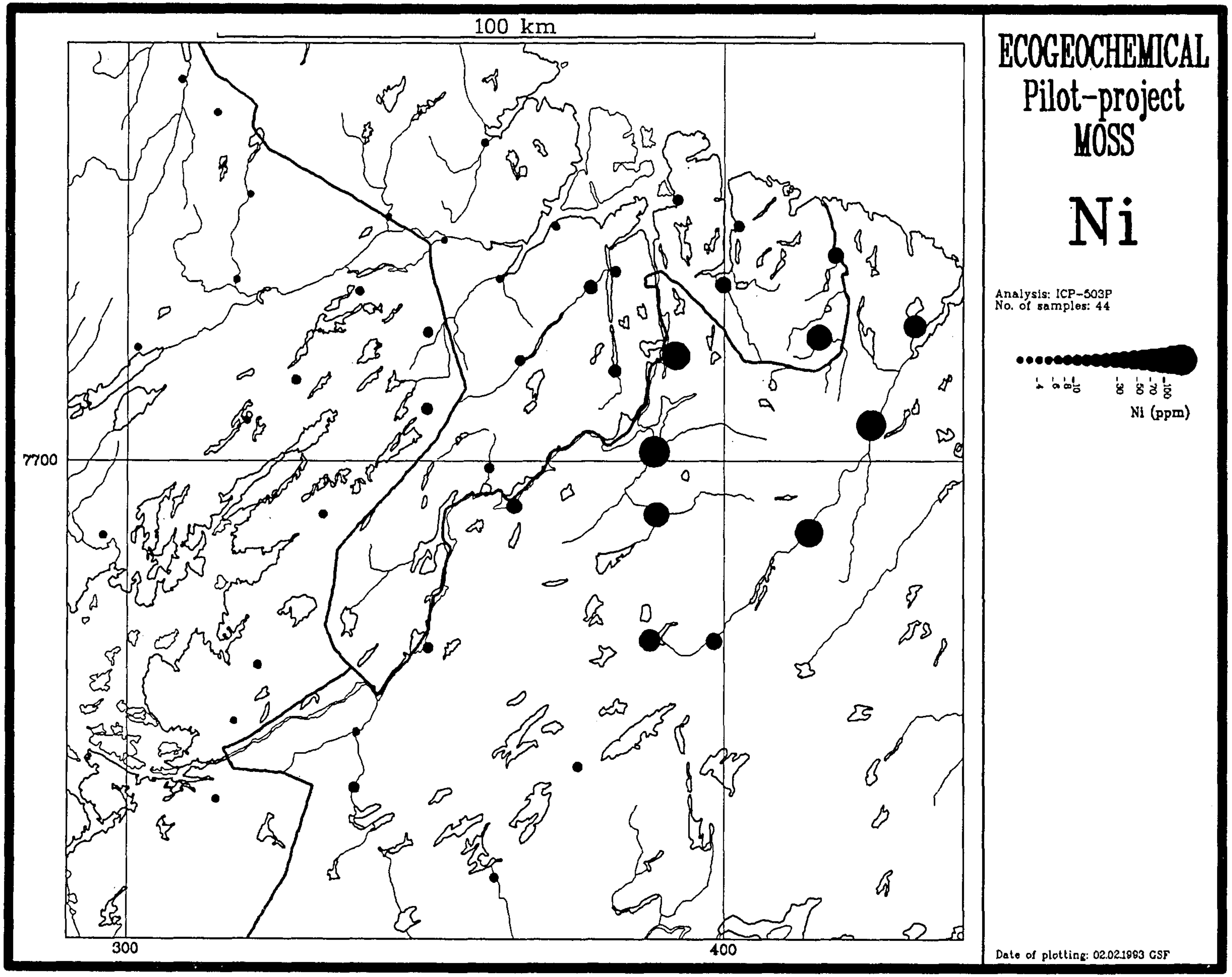

100 km
ECOGEOCHEMICAL
Pilot-project
MOSS
Ni
Analysis: ICP-503P
No. of samples: 44
4
6
8
10
30
50
70
100
Ni (ppm)
7700
300
400
Date of plotting: 02.02.1993 GSF

Figure N° 19

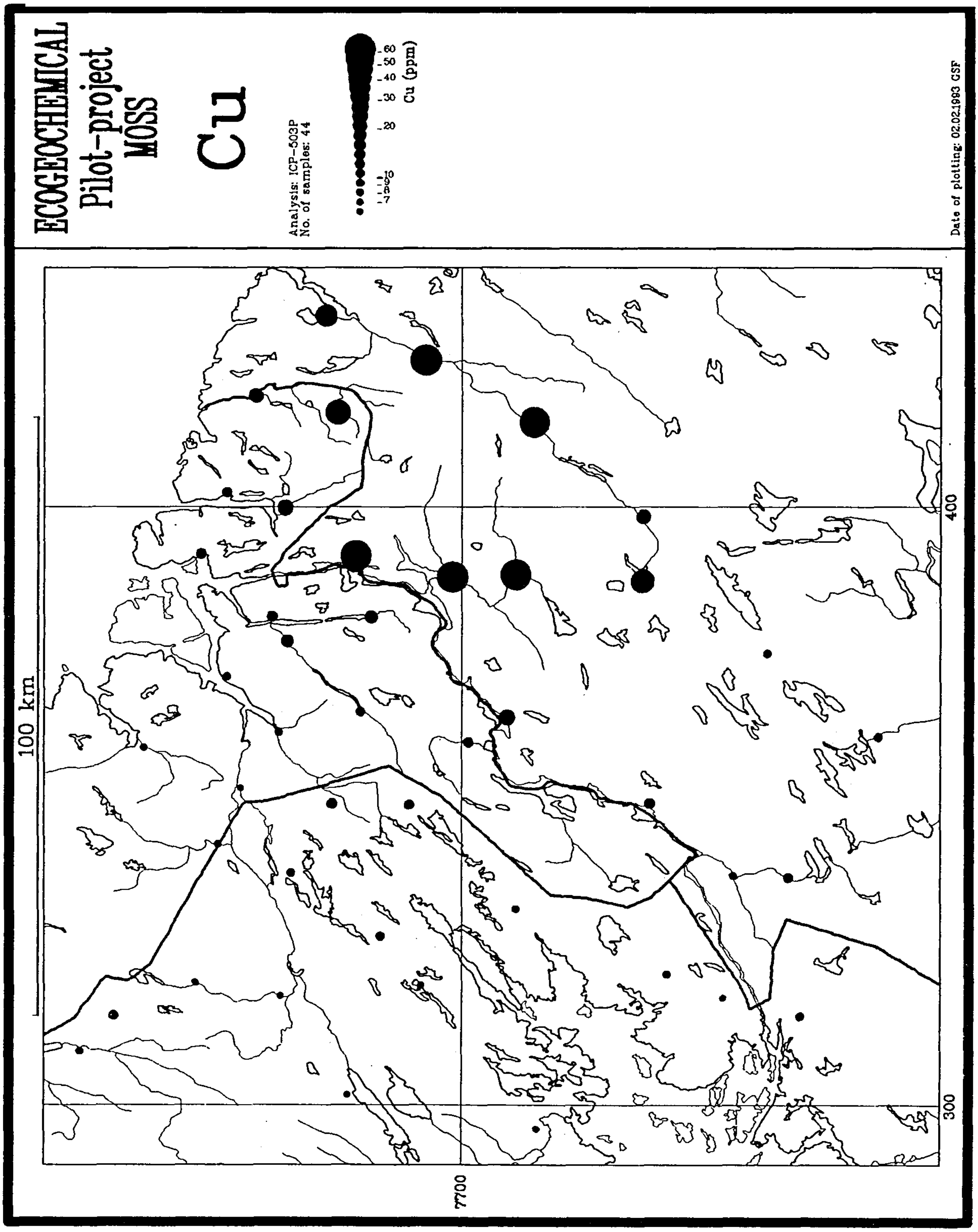

ECOGEOCHEMICAL
Pilot-project
MOSS
Cu
Analysis: ICP-503P
No. of samples: 44
60
50
40
30
20
10
9
8
7
Cu (ppm)
Date of plotting: 02.02.1993 GSF
100 km
7700
400
300

Figure N° 20

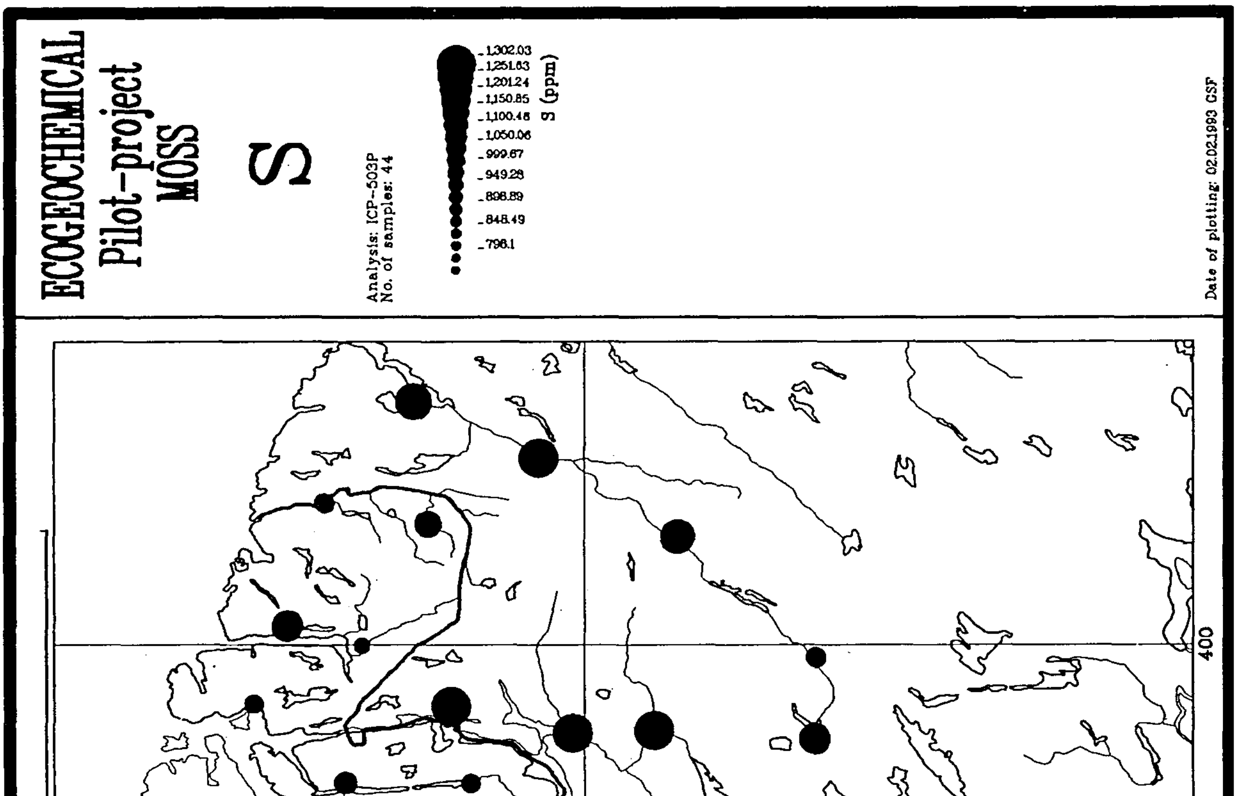

ECOGEOCHEMICAL
Pilot-project
MOSS
S
Analysis: ICP-503P
No. of samples: 44
1,302.03
1,251.63
1,201.24
1,150.85
1,100.46
1,050.06
999.67
949.28
898.89
848.49
798.1
S (ppm)
Date of plotting: 02.02.1993 GSF
100 km.
400
300
7700

Figure N° 21

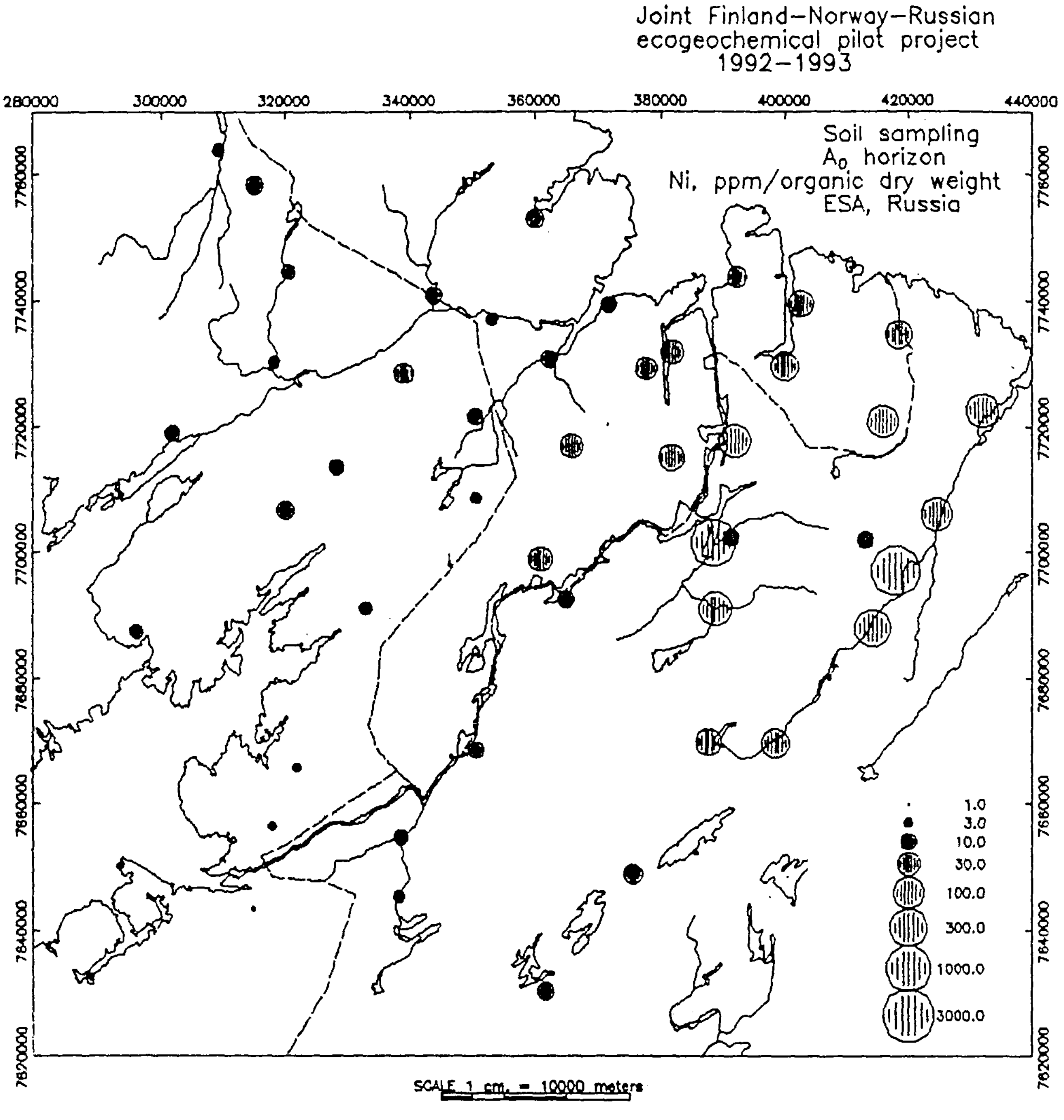

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Soil sampling
A0 horizon
Ni, ppm/organic dry weight
ESA, Russia
1.0
3.0
10.0
30.0
100.0
300.0
1000.0
3000.0
SCALE 1 cm. = 10000 meters

Figure N° 22

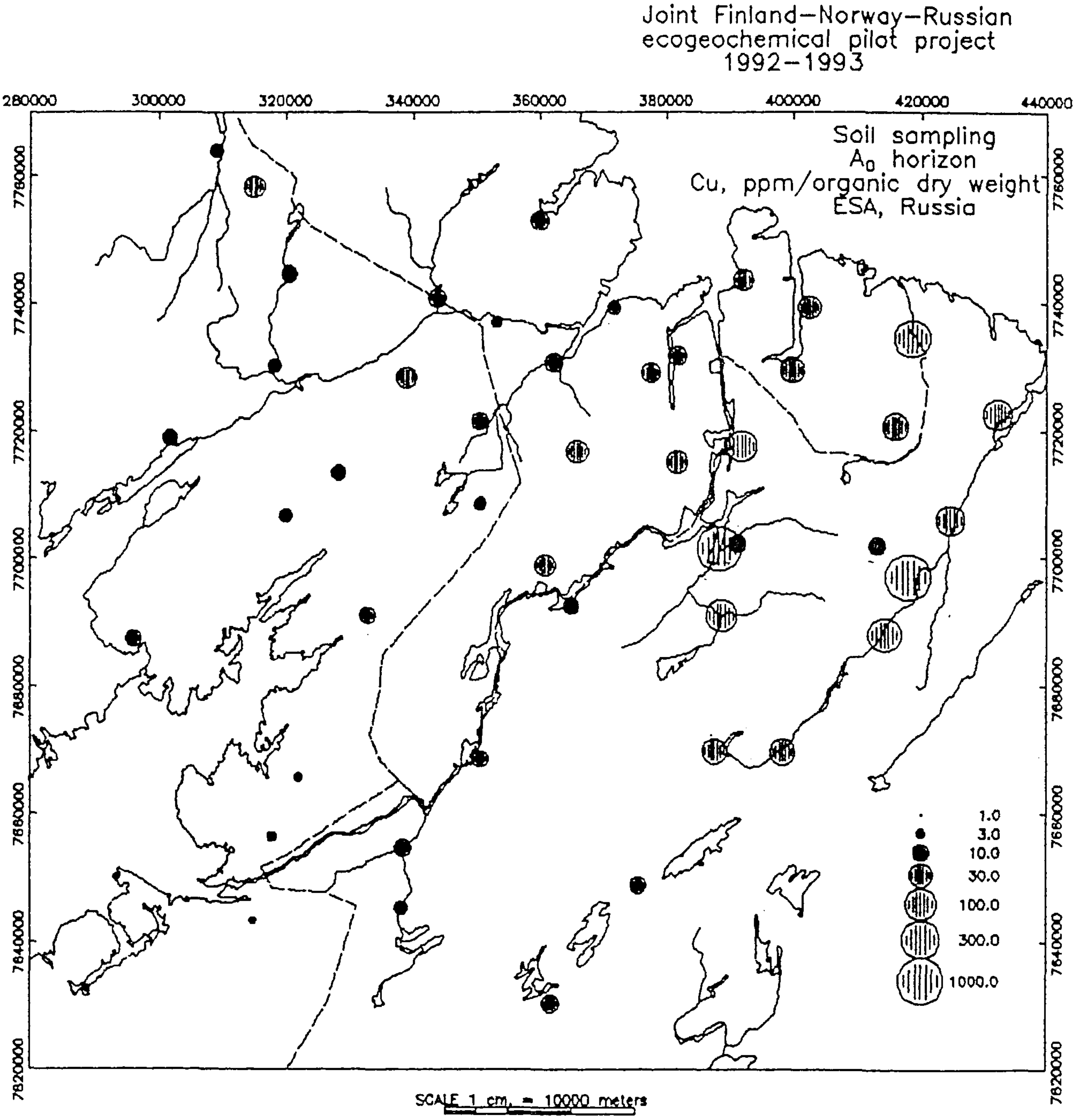

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Soil sampling
A0 horizon
Cu, ppm/organic dry weight
ESA, Russia
1.0
3.0
10.0
30.0
100.0
300.0
1000.0
SCALE 1 cm. = 10000 meters

Figure N° 23

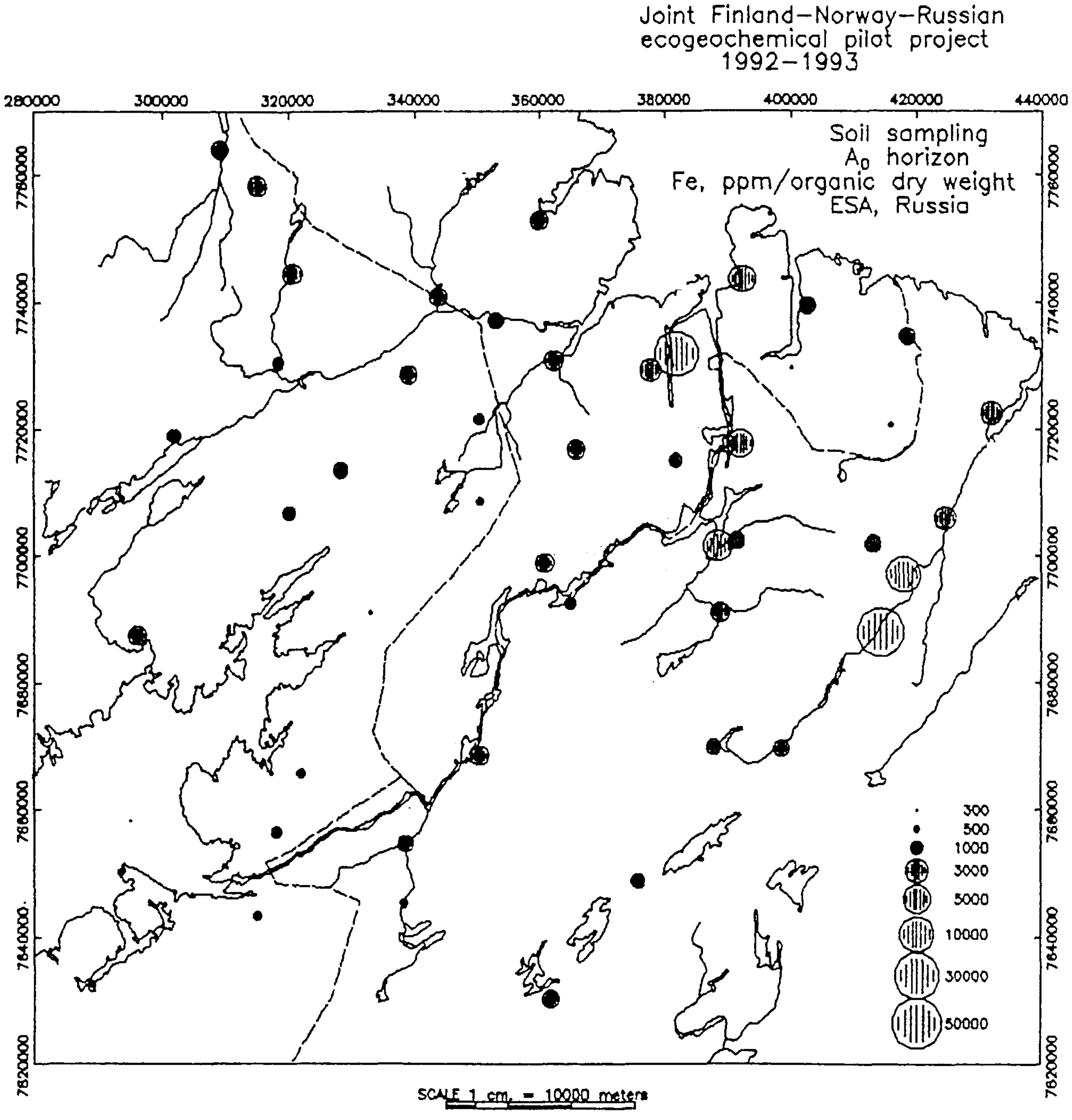

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Soil sampling
A0 horizon
Fe, ppm/organic dry weight
ESA, Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
300
500
1000
3000
5000
10000
30000
50000
SCALE 1 cm. = 10000 meters

Figure N° 24

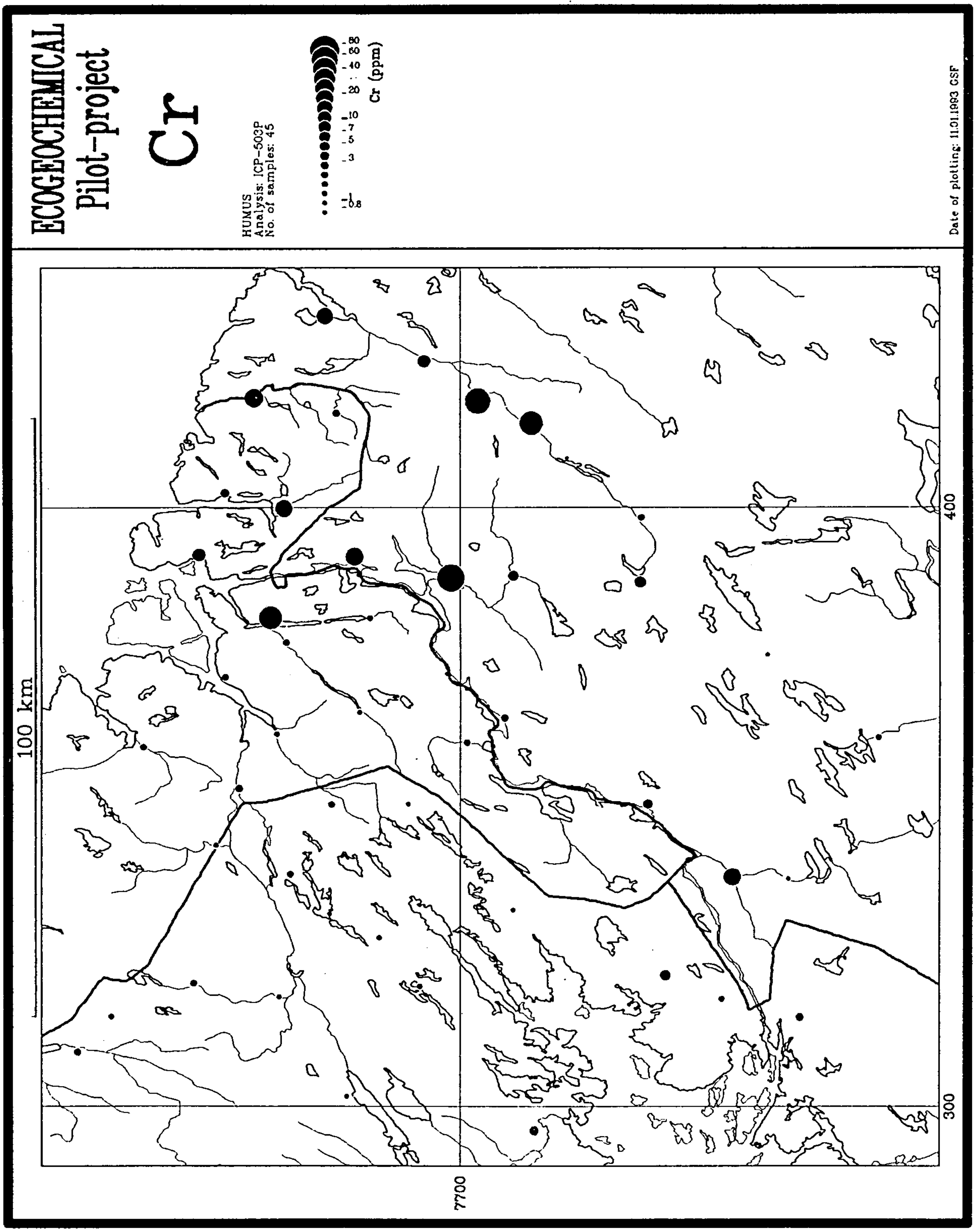

ECOGEOCHEMICAL
Pilot-project
Cr
HUMUS
Analysis: ICP-503P
No. of samples: 45
80
60
40
20
10
7
5
3
1
0.8
Cr (ppm)
Date of plotting: 11.01.1993 CSF
100 km
400
300
7700

Figure N° 25

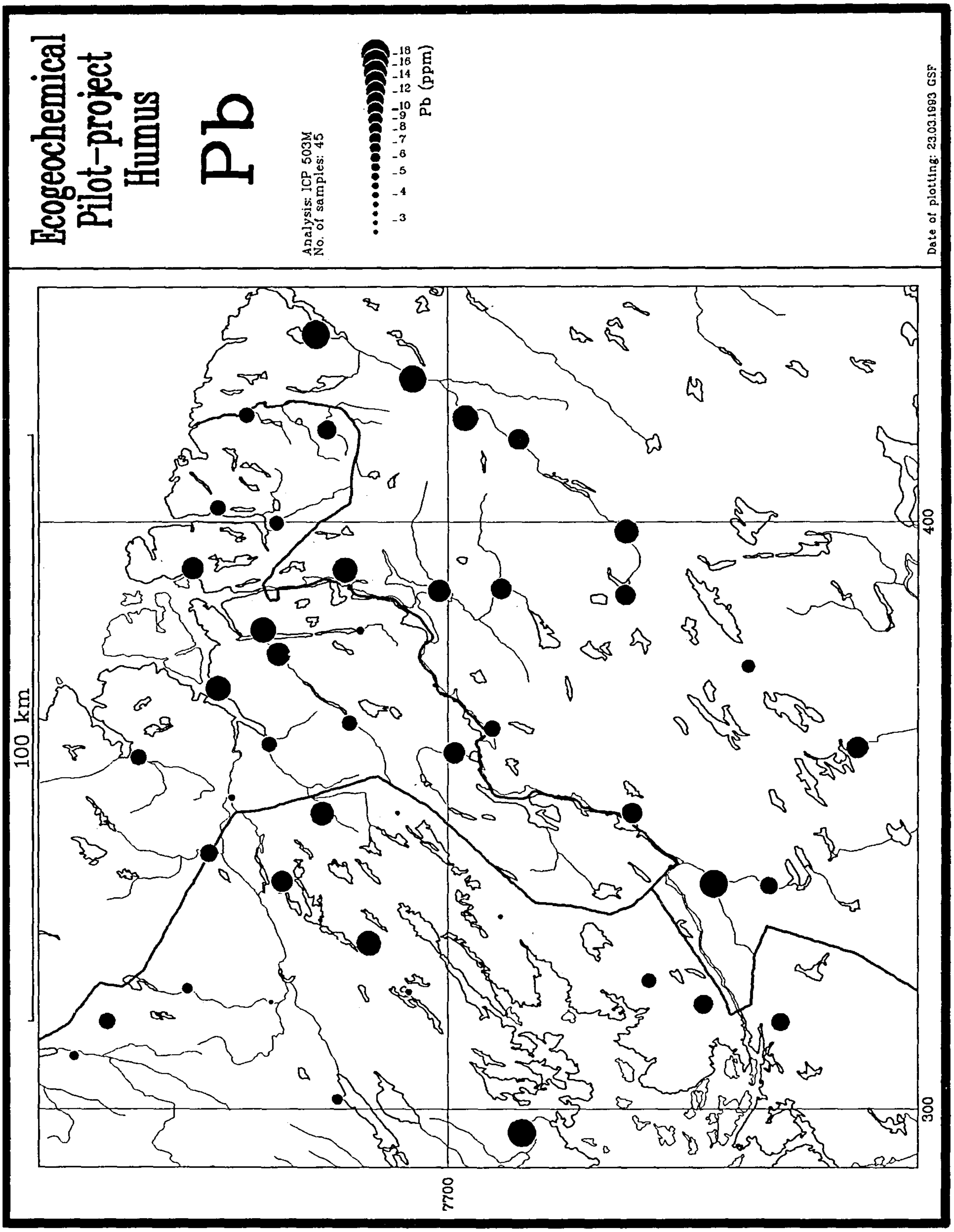

Ecogeochemical
Pilot-project
Humus
Pb
Analysis: ICP 503M
No. of samples: 45
3
4
5
6
7
8
9
10
12
14
16
18
Pb (ppm)
Date of plotting: 23.03.1993 GSF
100 km
400
300
7700

Figure N° 26

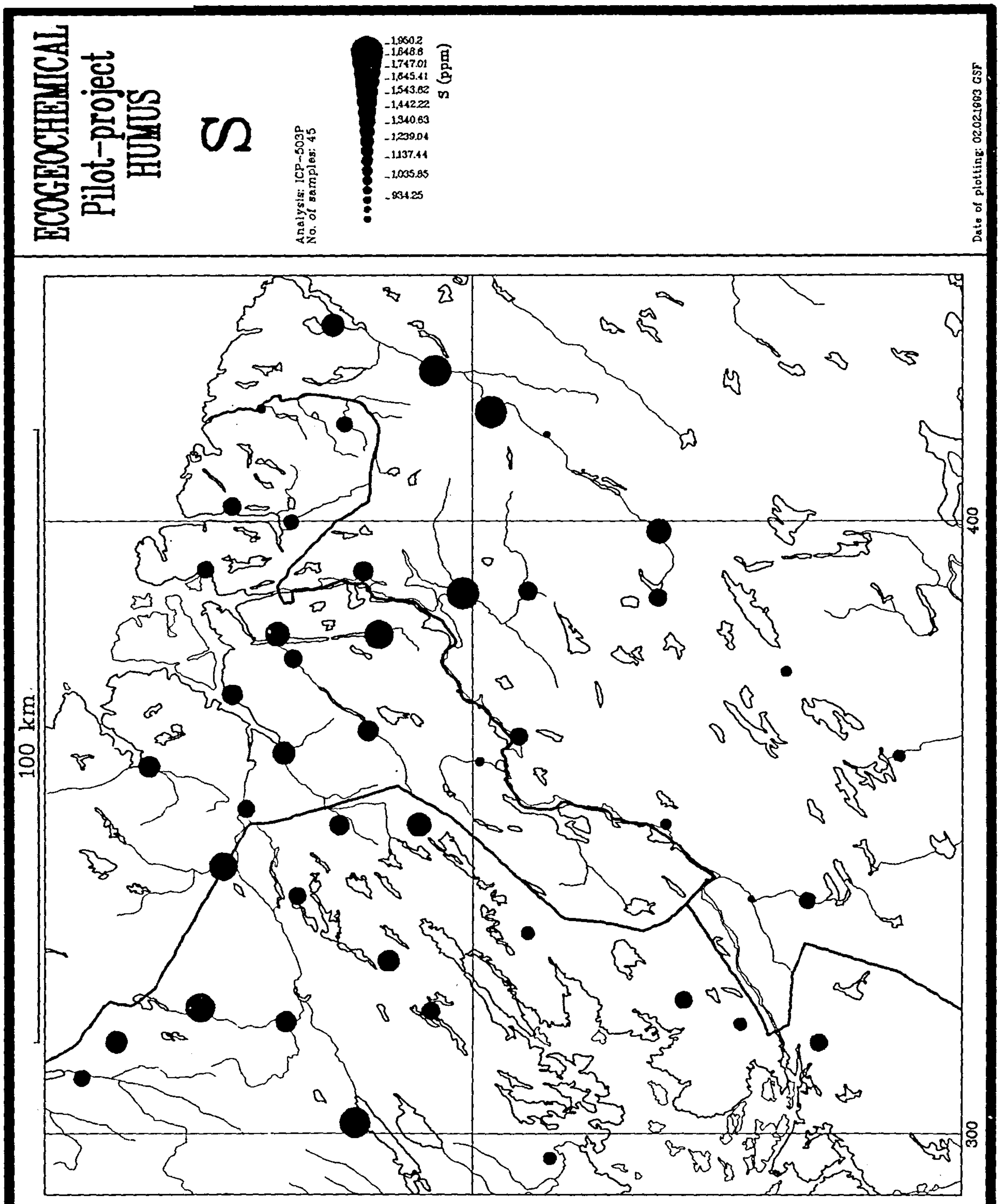

ECOGEOCHEMICAL
Pilot-project
HUMUS
S
Analysis: ICP-503P
No. of samples: 45
1,950.2
1,848.6
1,747.01
1,645.41
1,543.82
1,442.22
1,340.63
1,239.04
1,137.44
1,035.85
934.25
S (ppm)
Date of plotting: 02.02.1993 GSF
100 km
400
300
7700

Figure N° 27

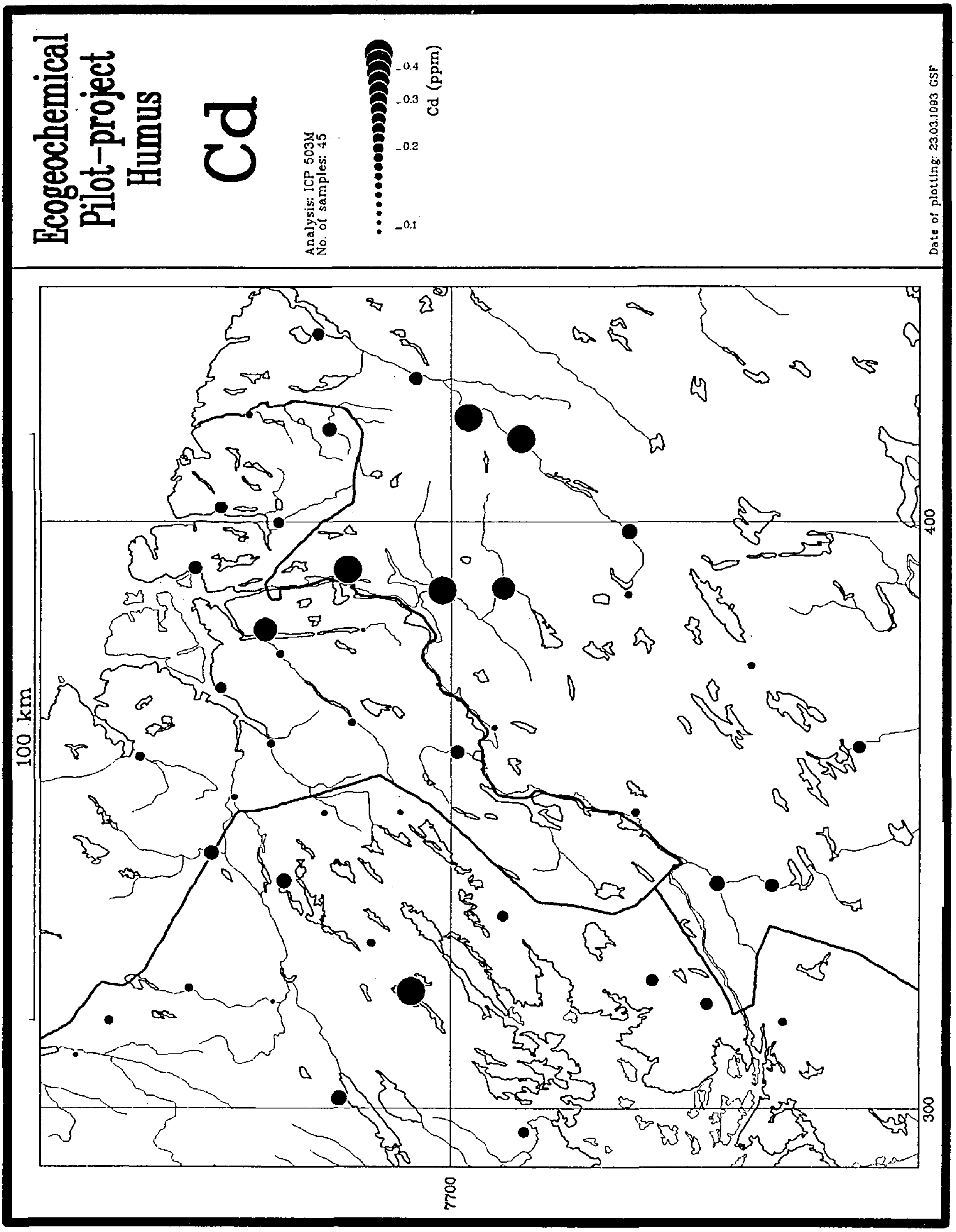

Ecogeochemical
Pilot-project
Humus
Cd
Analysis: ICP 503M
No. of samples: 45
0.1
0.2
0.3
0.4
Cd (ppm)
Date of plotting: 23.03.1993 GSF
100 km
400
300
7700

Figure N° 28

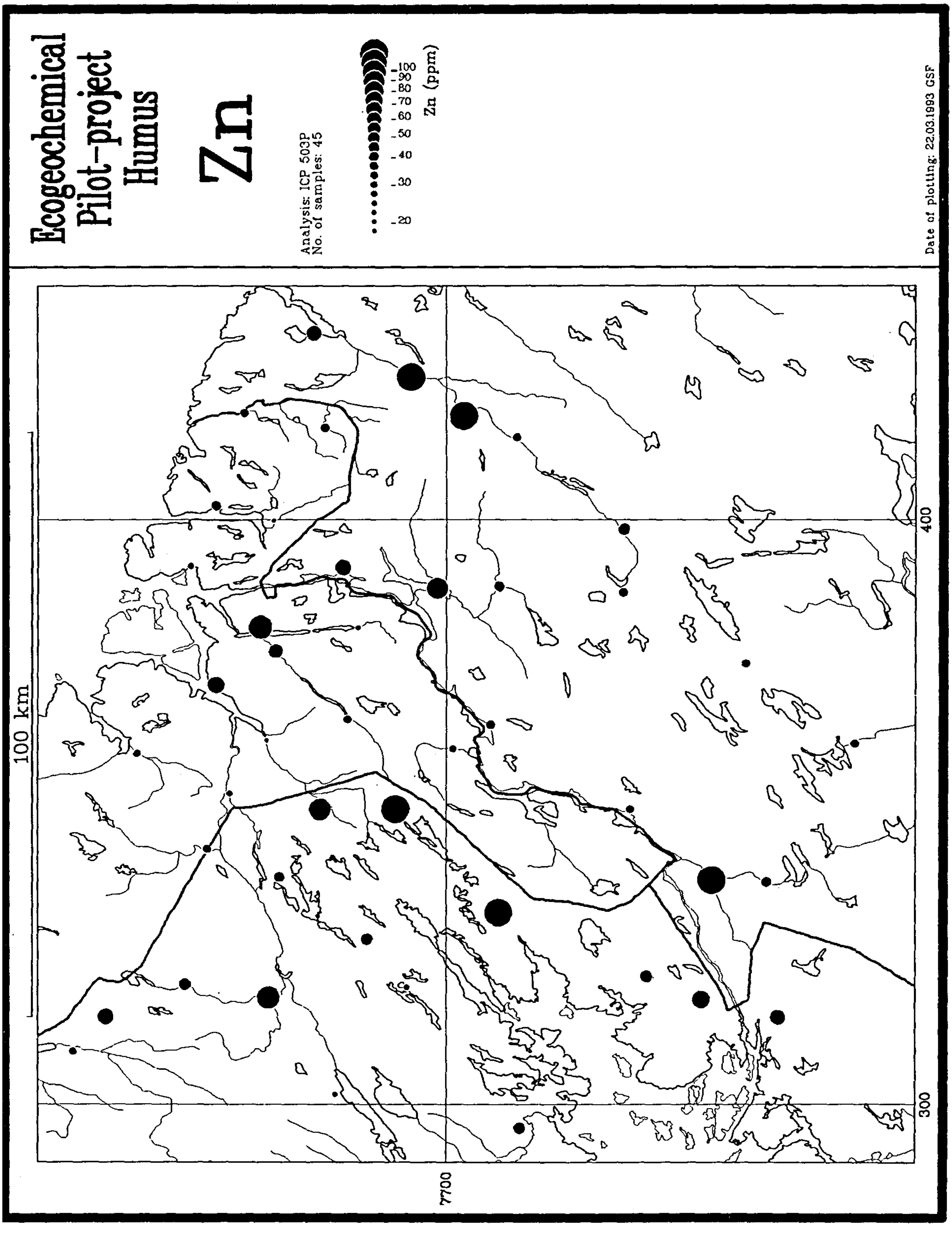

Ecogeochemical
Pilot-project
Humus
Zn
Analysis: ICP 503P
No. of samples: 45
20
30
40
50
60
70
80
90
100
Zn (ppm)
Date of plotting: 22.03.1993 GSF
100 km
400
300
7700

Figure N° 29

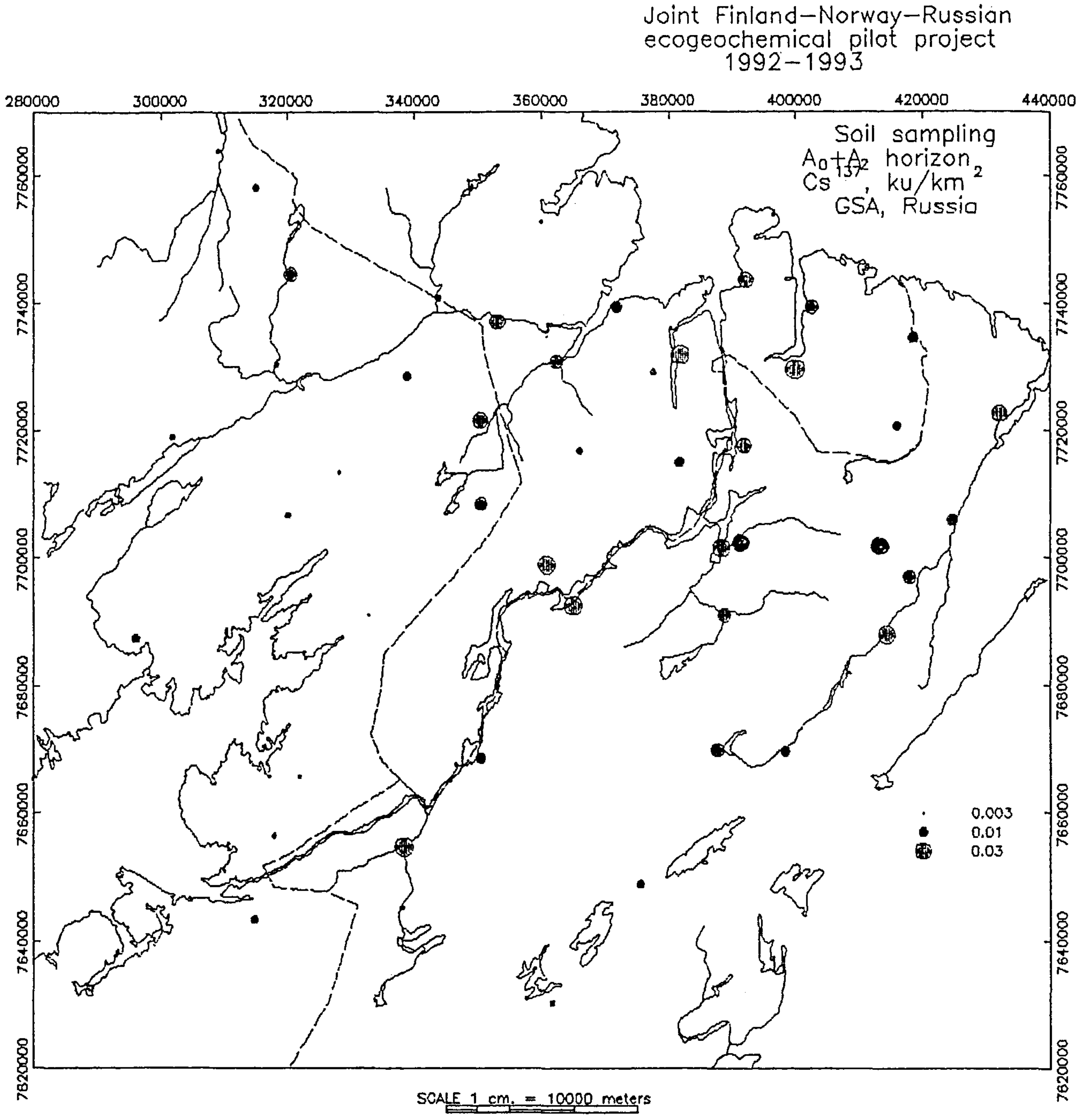

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Soil sampling
A_0+A_2 horizon
Cs^{137}, ku/km^2
GSA, Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
0.003
0.01
0.03
SCALE 1 cm. = 10000 meters

Figure N° 30

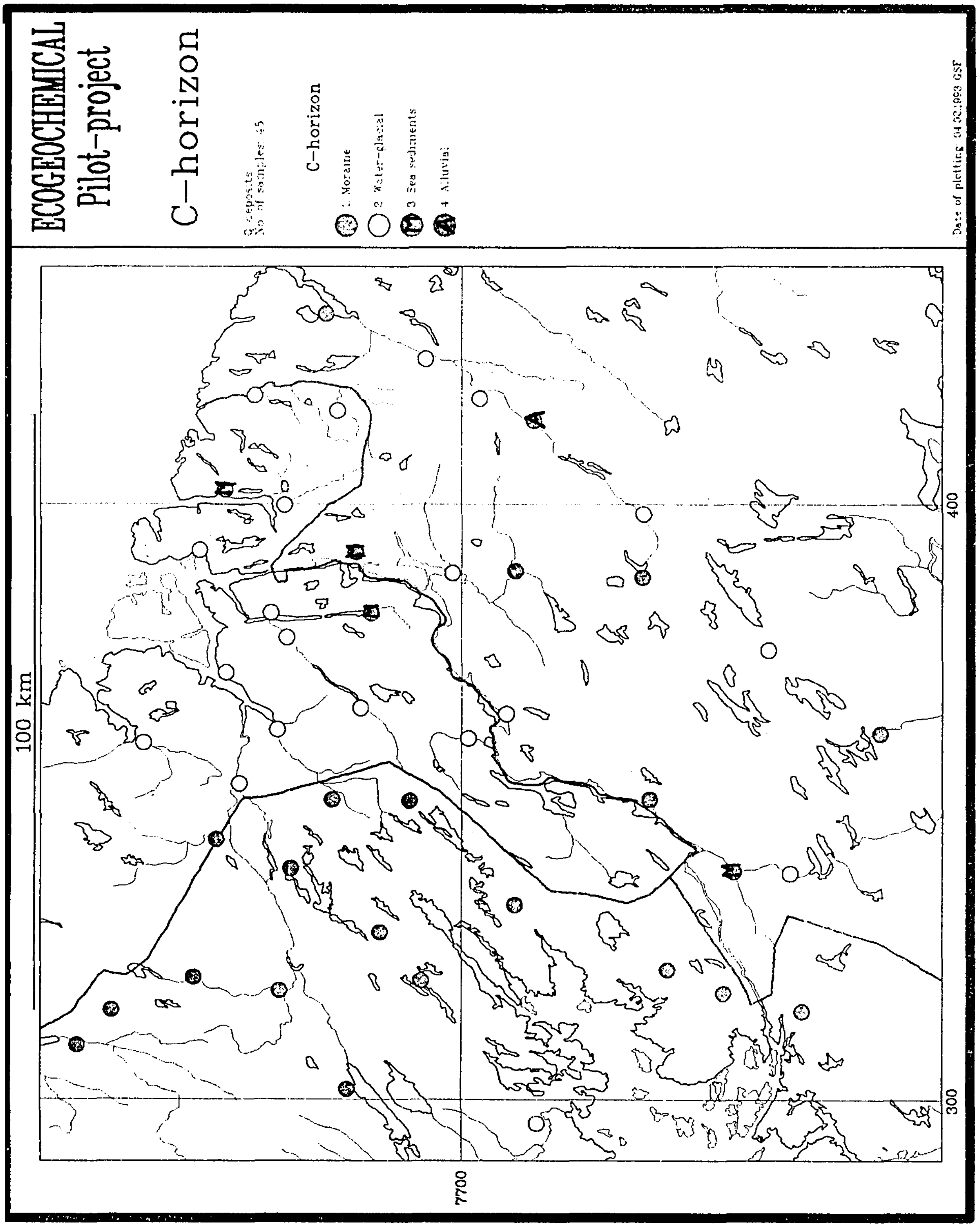

ECOGEOCHEMICAL
Pilot-project
C—horizon
Q-deposits
No of samples: 45
C—horizon
1 Moraine
2 Water-glacial
3 Sea sediments
4 Alluvial
Date of plotting 04.02.1993 GSF
100 km
400
300
7700
M
A

Figure N° 31

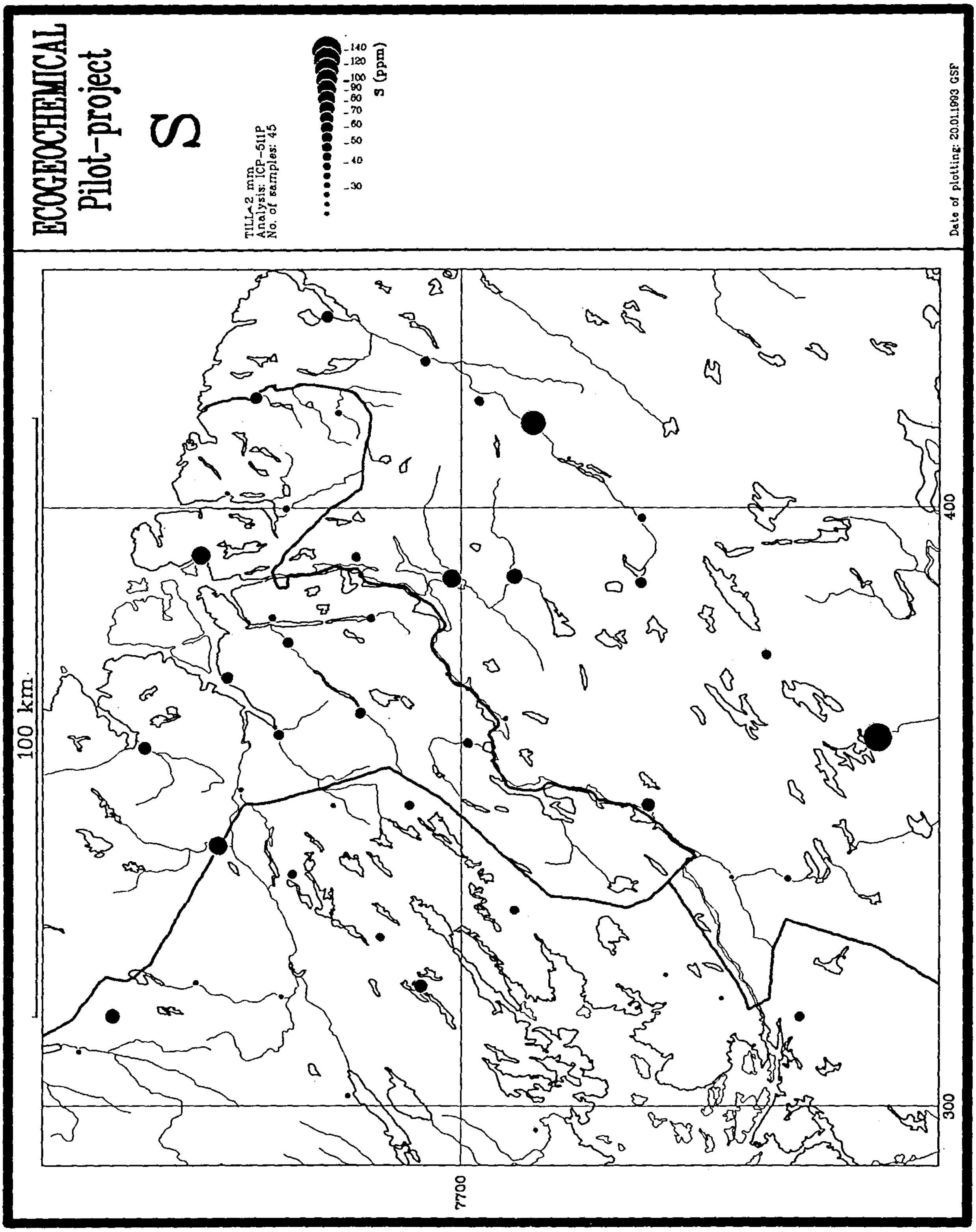

ECOGEOCHEMICAL
Pilot-project
S
TILL<2 mm
Analysis: ICP-511P
No. of samples: 45
-30
-40
-50
-60
-70
-80
-90
-100
-120
-140
S (ppm)
Date of plotting: 20.01.1993 GSF
100 km
7700
300
400

Figure N° 32

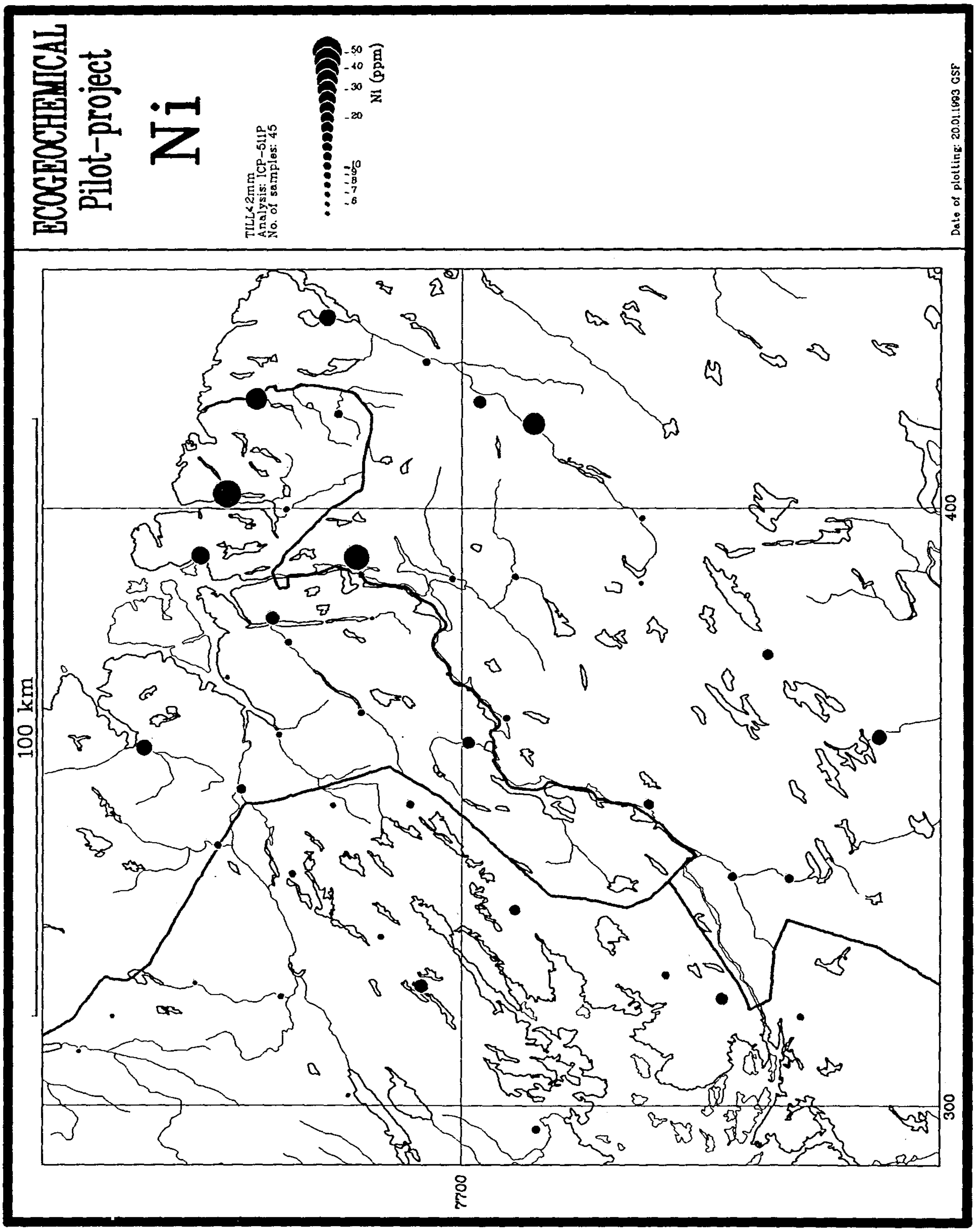

ECOGEOCHEMICAL
Pilot-project
Ni
TILL<2mm
Analysis: ICP-51IP
No. of samples: 45
6
7
8
9
10
20
30
40
50
Ni (ppm)
Date of plotting: 20.01.1993 GSF
100 km
7700
400
300

Figure N° 33

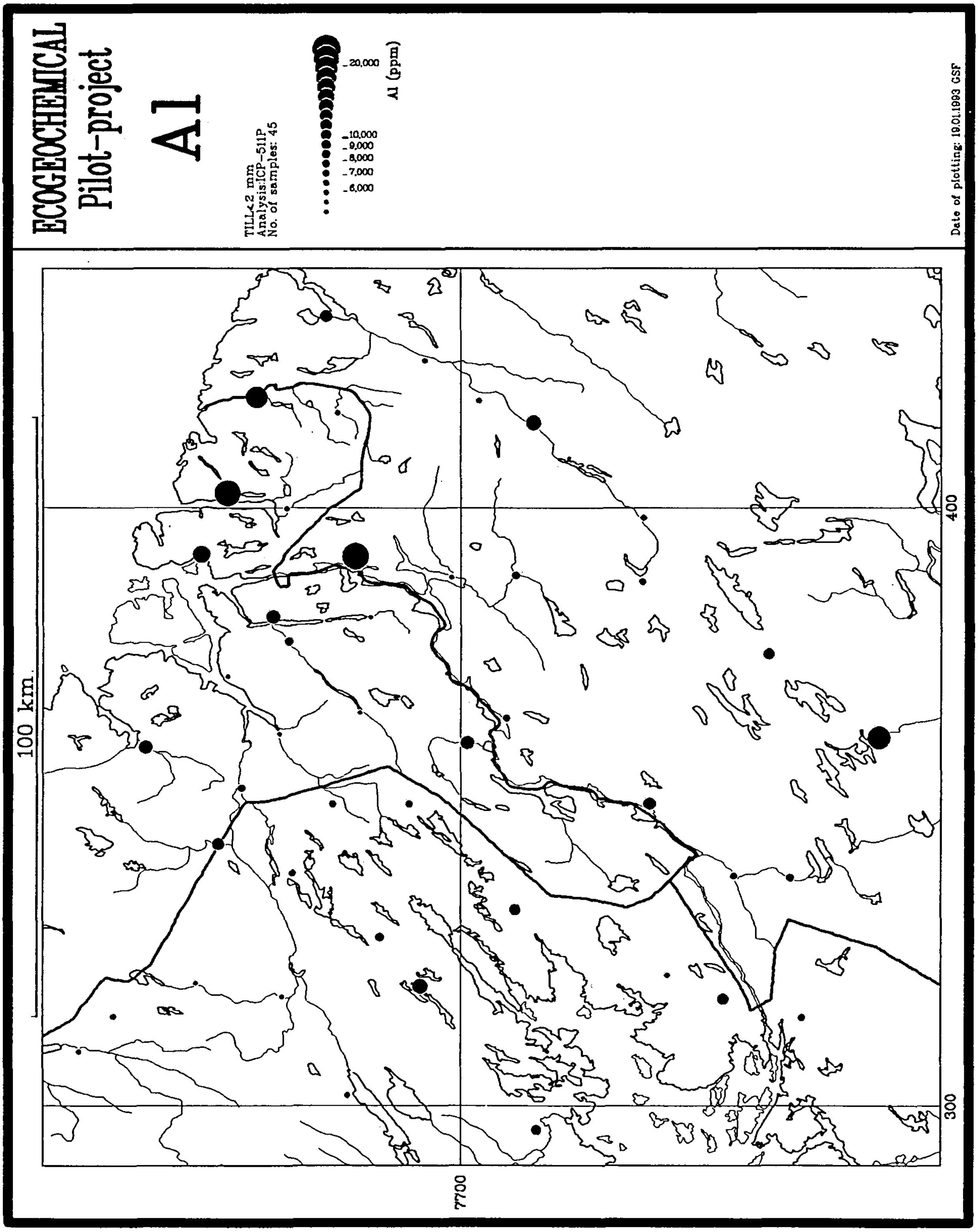

ECOGEOCHEMICAL
Pilot-project
Al
TILL<2 mm
Analysis:ICP-511P
No. of samples: 45
20,000
10,000
9,000
8,000
7,000
6,000
Al (ppm)
Date of plotting: 19.01.1993 GSF
100 km
400
300
7700

Figure N° 34

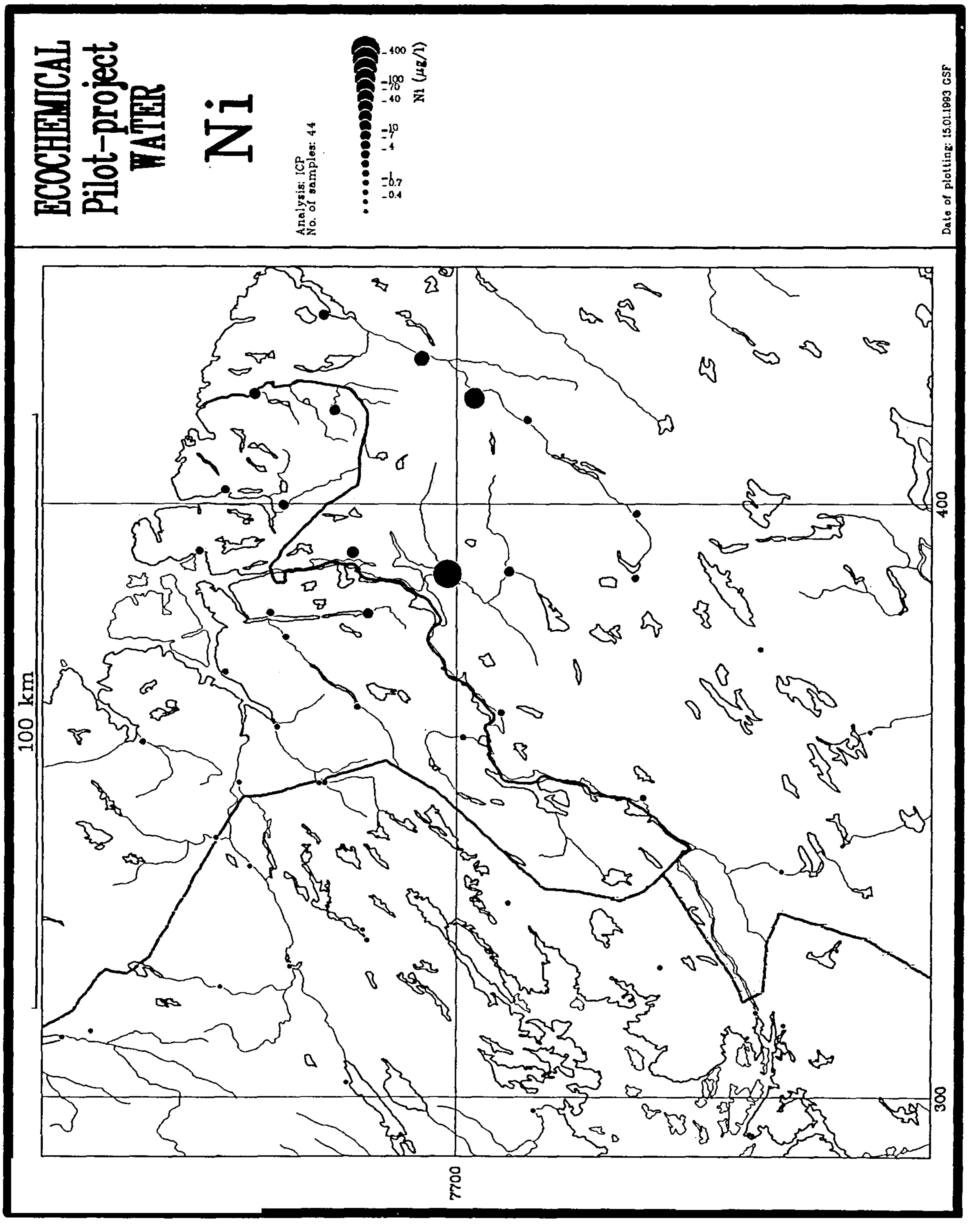

ECOCHEMICAL
Pilot-project
WATER
Ni
Analysis: ICP
No. of samples: 44
400
100
70
40
10
7
4
1
0.7
0.4
Ni (µg/l)
Date of plotting: 15.01.1993 GSF
100 km
7700
400
300

Figure N° 35

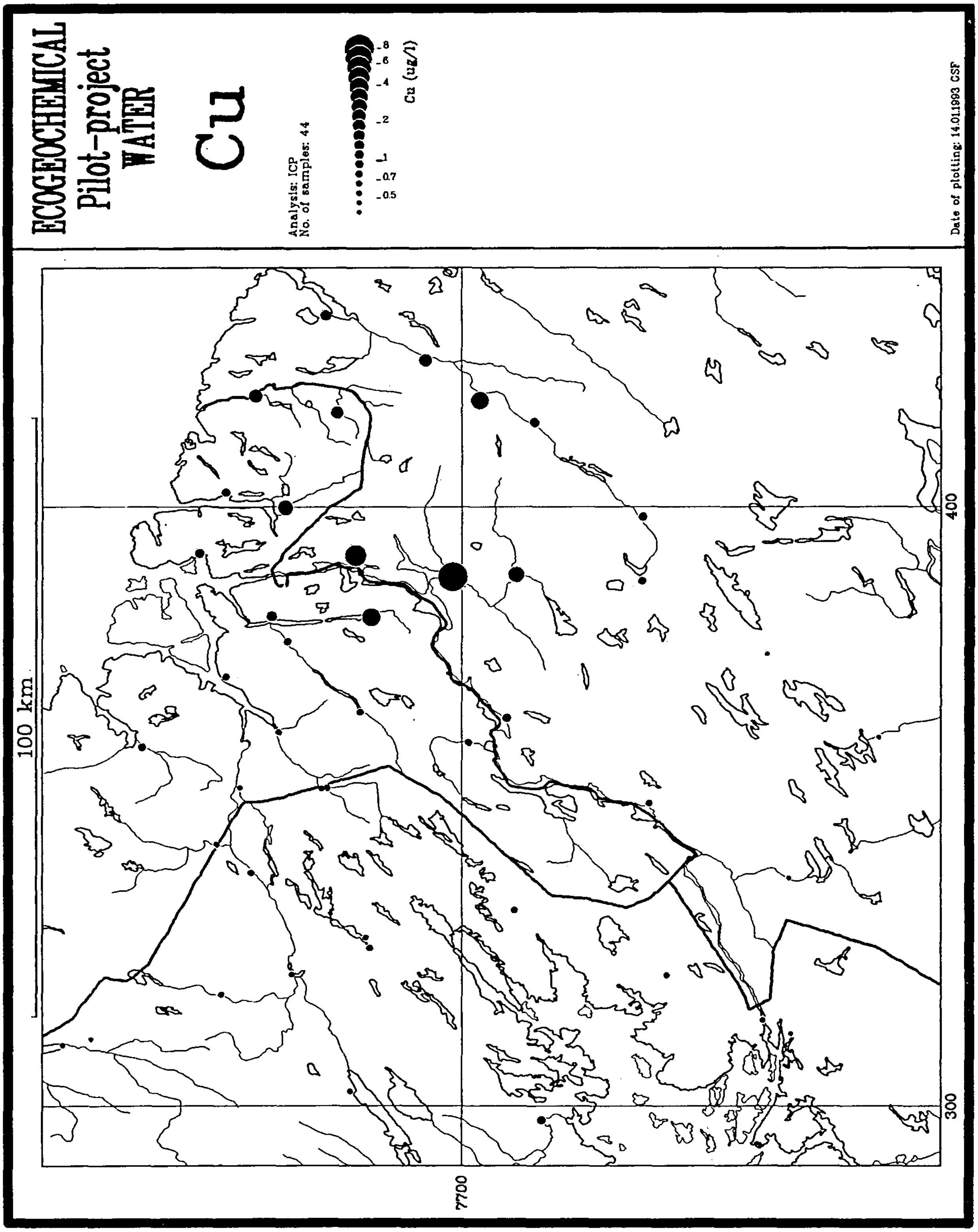

ECOGEOCHEMICAL
Pilot-project
WATER
Cu
Analysis: ICP
No. of samples: 44
8
6
4
2
1
0.7
0.5
Cu (ug/l)
Date of plotting: 14.01.1993 GSF
100 km
400
300
7700

Figure N° 36

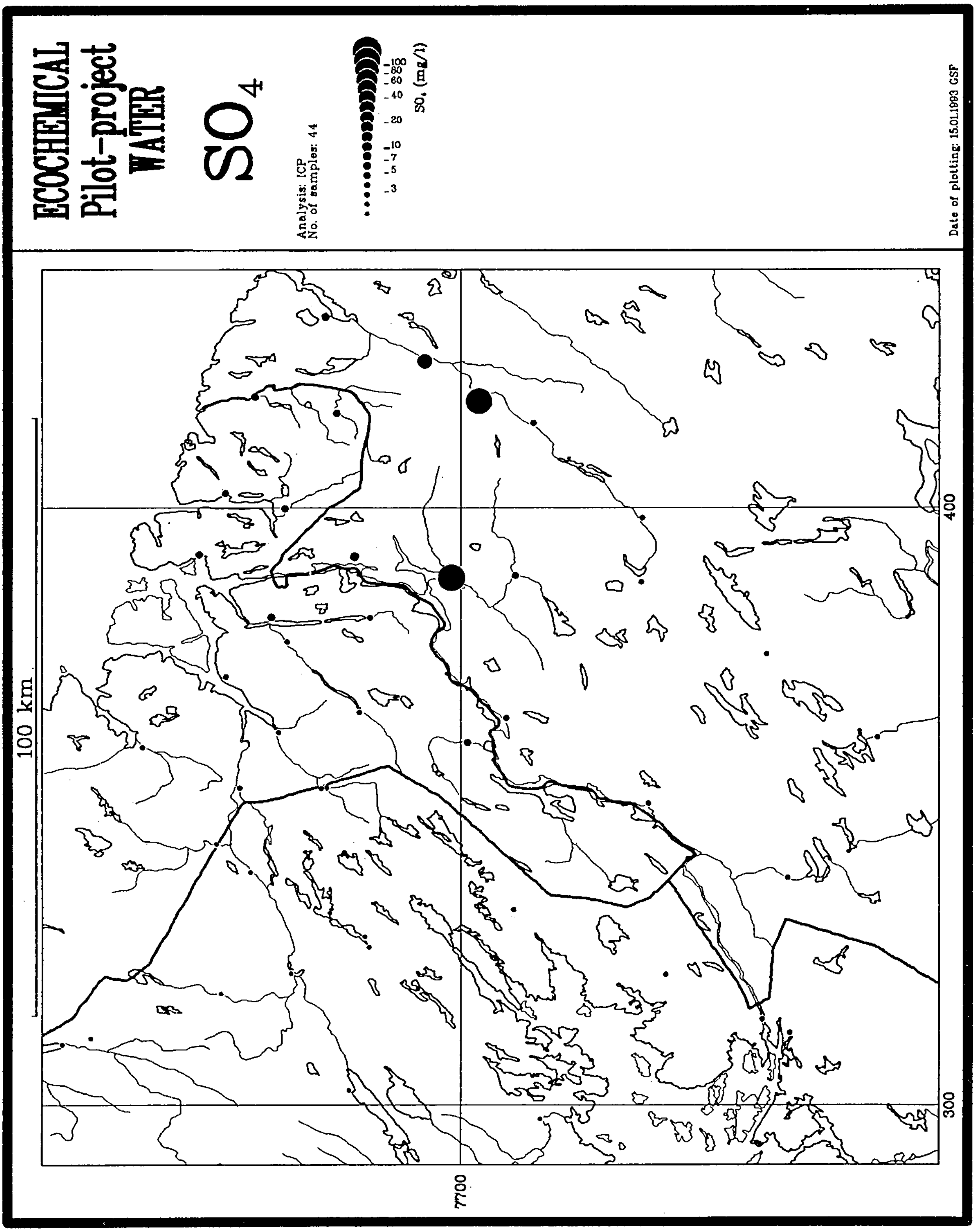

ECOCHEMICAL
Pilot-project
WATER
SO_4
Analysis: ICP
No. of samples: 44
100
80
60
40
20
10
7
5
3
SO_4 (mg/l)
Date of plotting: 15.01.1993 GSF
100 km
400
300
7700

Figure N° 37

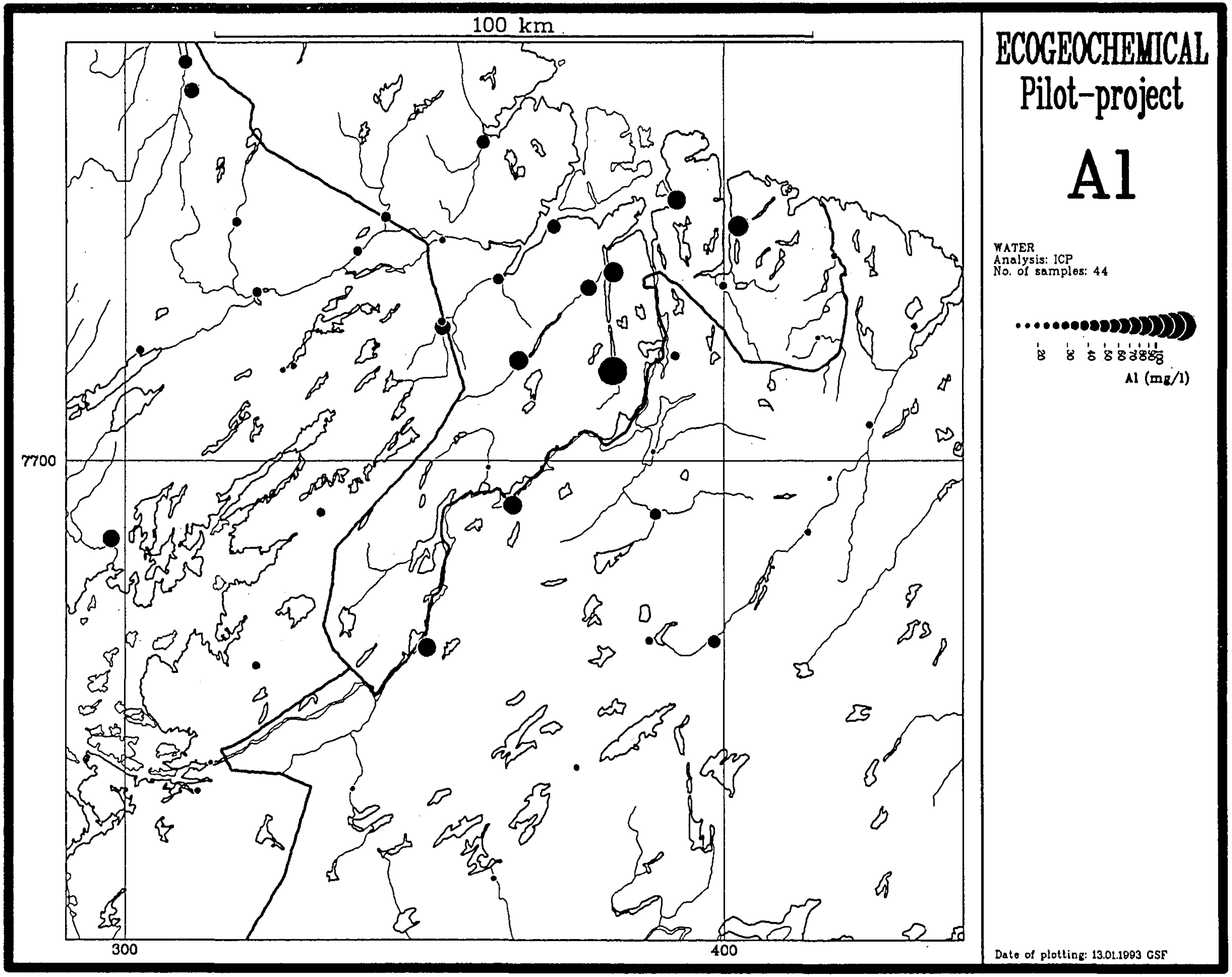

ECOGEOCHEMICAL
Pilot-project
Al
WATER
Analysis: ICP
No. of samples: 44
20
30
40
50
60
70
80
90
100
Al (mg/l)
100 km
7700
300
400
Date of plotting: 13.01.1993 GSF

Figure N° 38

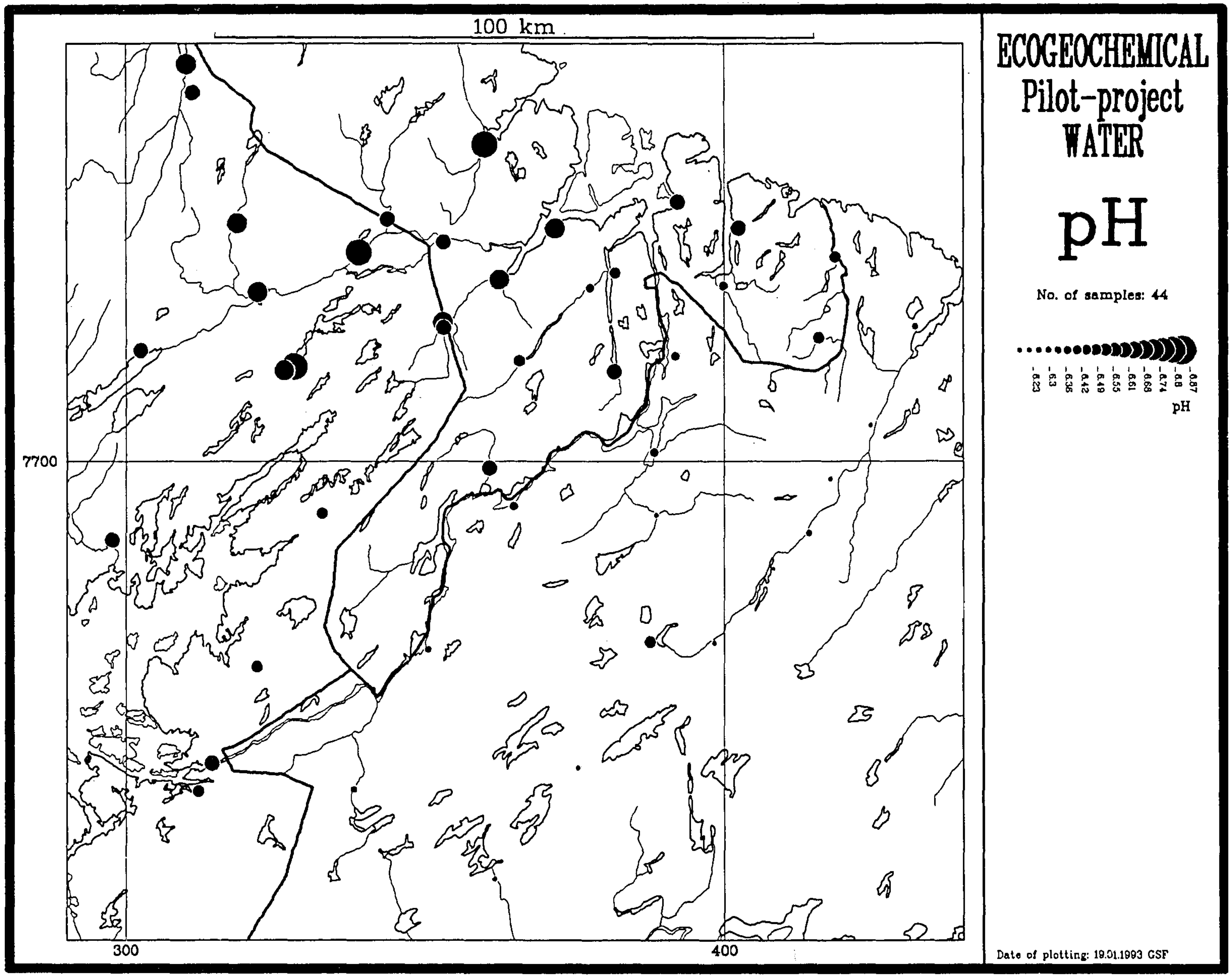
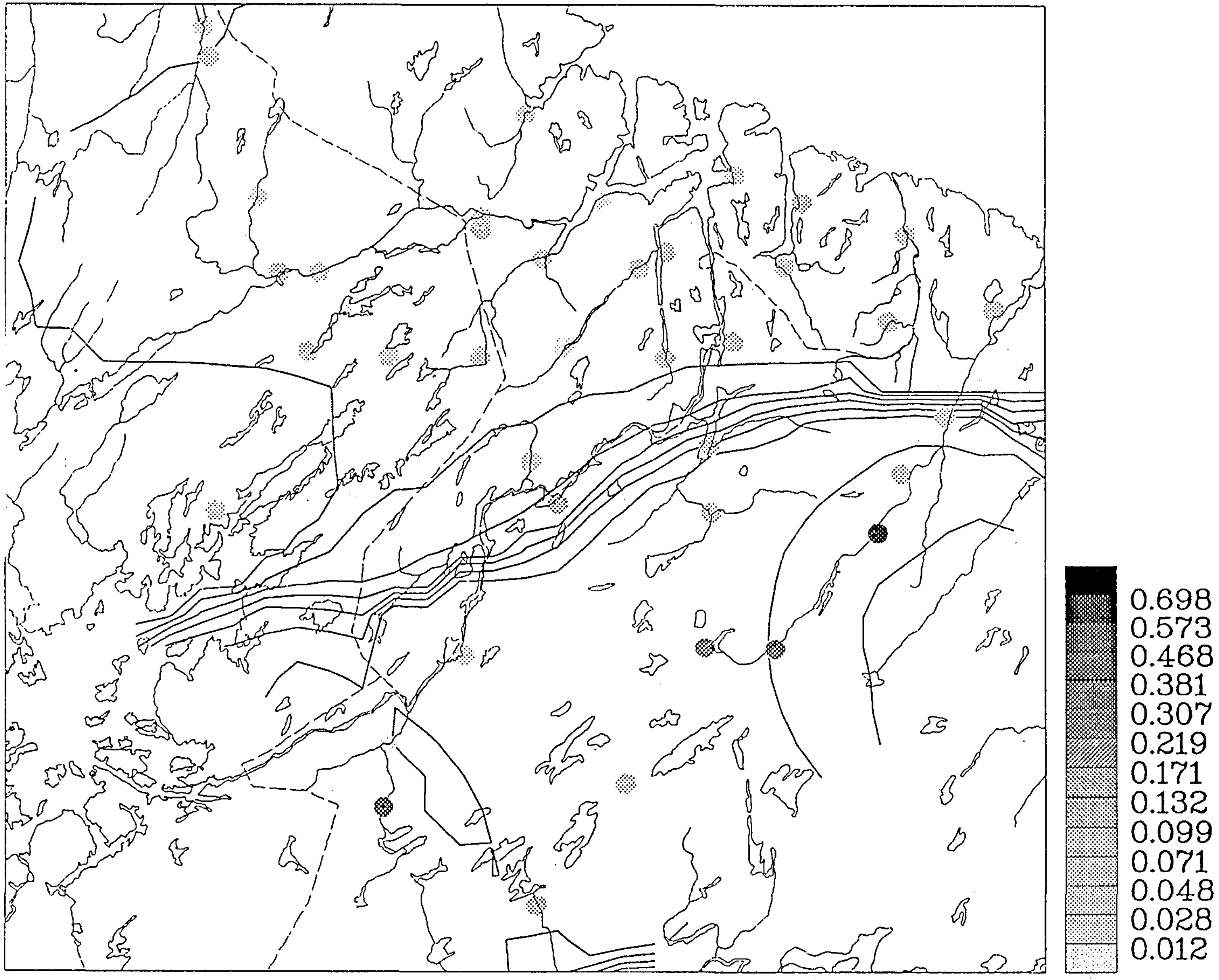

100 km
ECOGEOCHEMICAL
Pilot-project
WATER
pH
No. of samples: 44
6.23
6.3
6.36
6.42
6.49
6.55
6.61
6.68
6.74
6.8
6.87
pH
7700
300
400
Date of plotting: 19.01.1993 GSF

Figure N° 39

OVERBANK SEDIMENTS
BOTTOM -0.125mm

% Mn

HNO_3-extracted (NGU)



Joint ecogeochemical
pilot project 1992-93
Finland-Norway-Russia

50 km

Figure N° 40

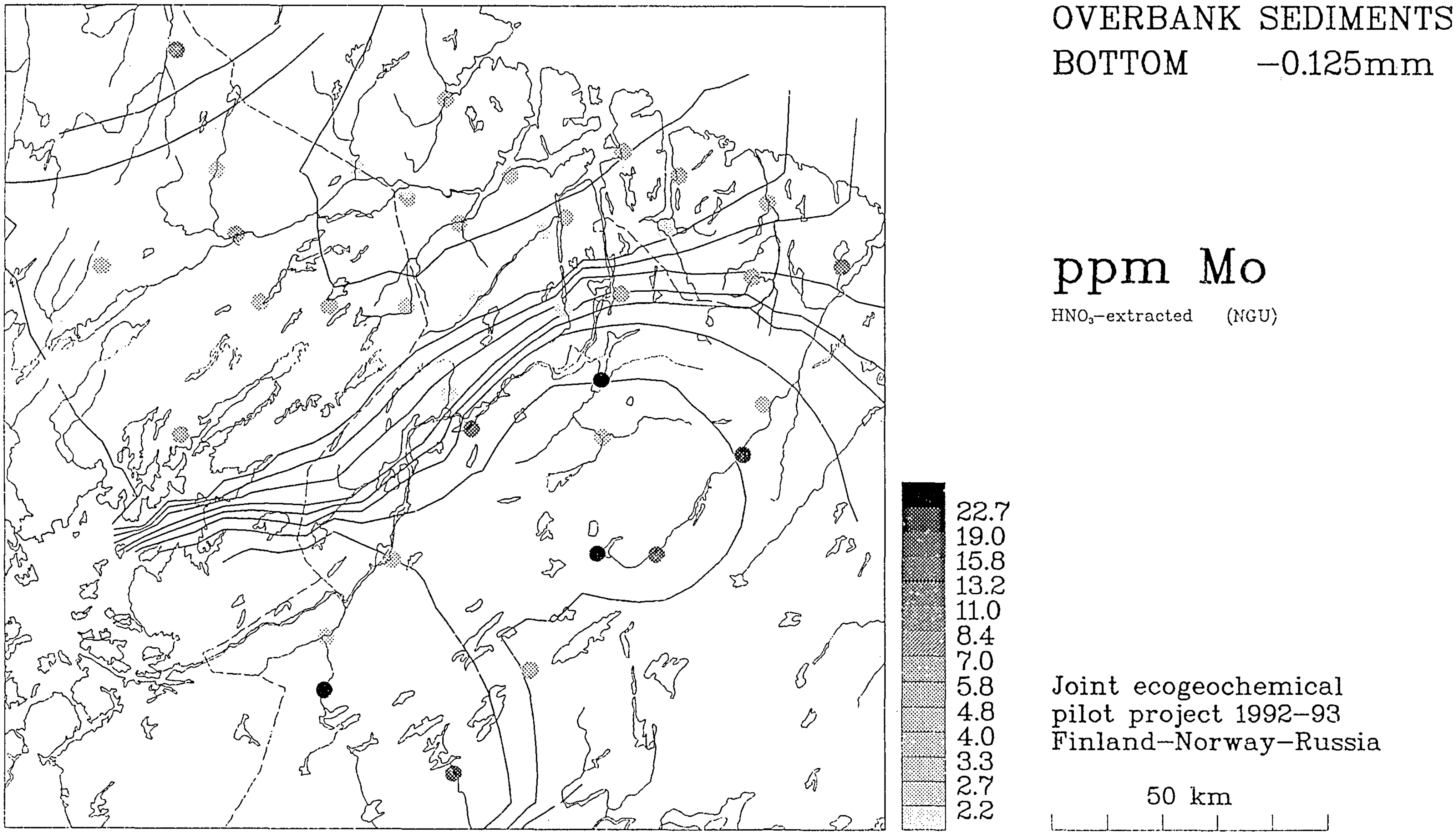

OVERBANK SEDIMENTS
BOTTOM −0.125mm
ppm Mo
HNO₃-extracted (NGU)
22.7
19.0
15.8
13.2
11.0
8.4
7.0
5.8
4.8
4.0
3.3
2.7
2.2
Joint ecogeochemical
pilot project 1992–93
Finland–Norway–Russia
50 km

Figure N° 41

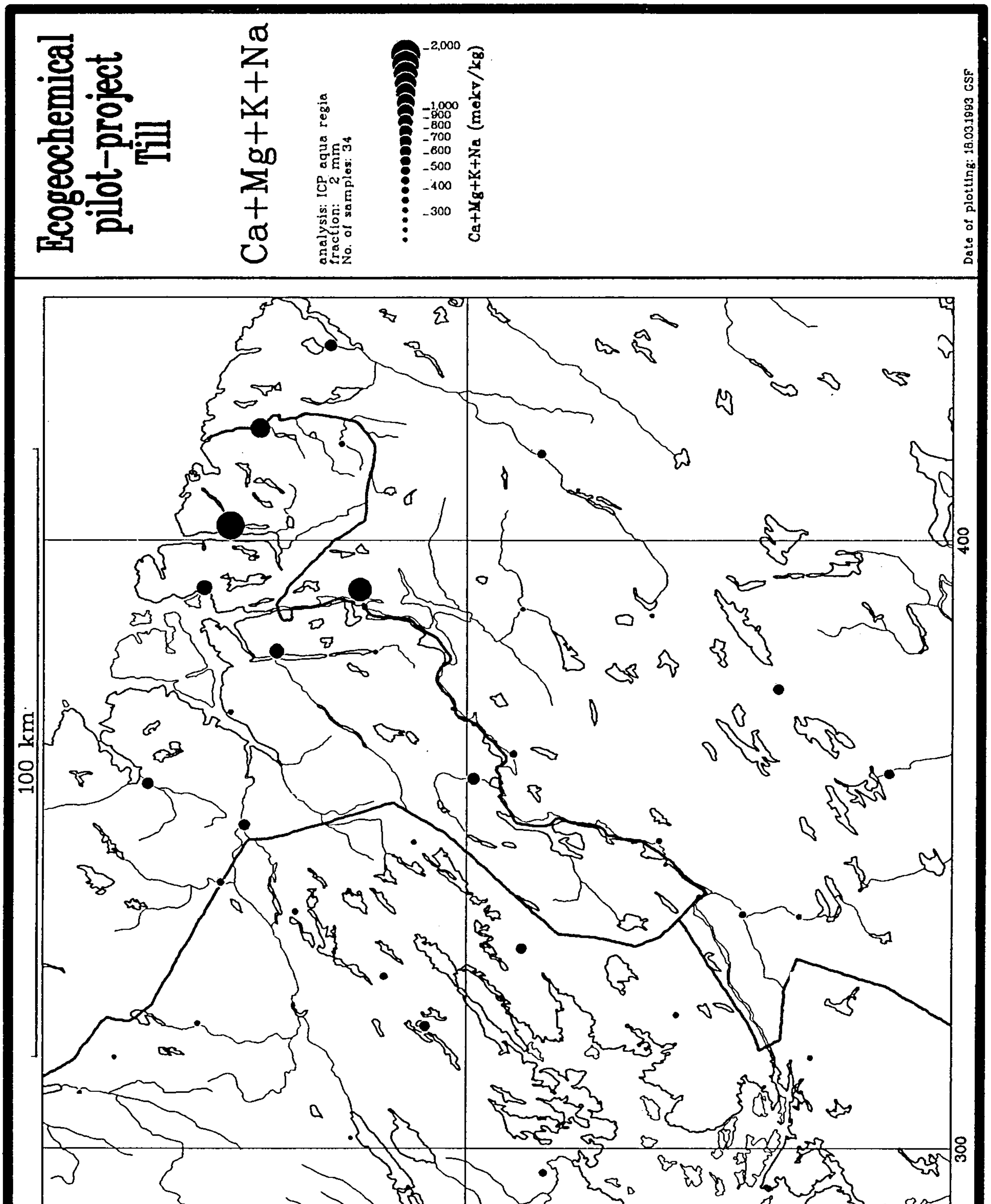

Ecogeochemical
pilot-project
Till
Ca+Mg+K+Na
analysis: ICP aqua regia
fraction: 2 mm
No. of samples: 34
2,000
1,000
900
800
700
600
500
400
300
Ca+Mg+K+Na (mekv/kg)
Date of plotting: 18.03.1993 GSF
100 km
400
300
7700

Figure N° 42

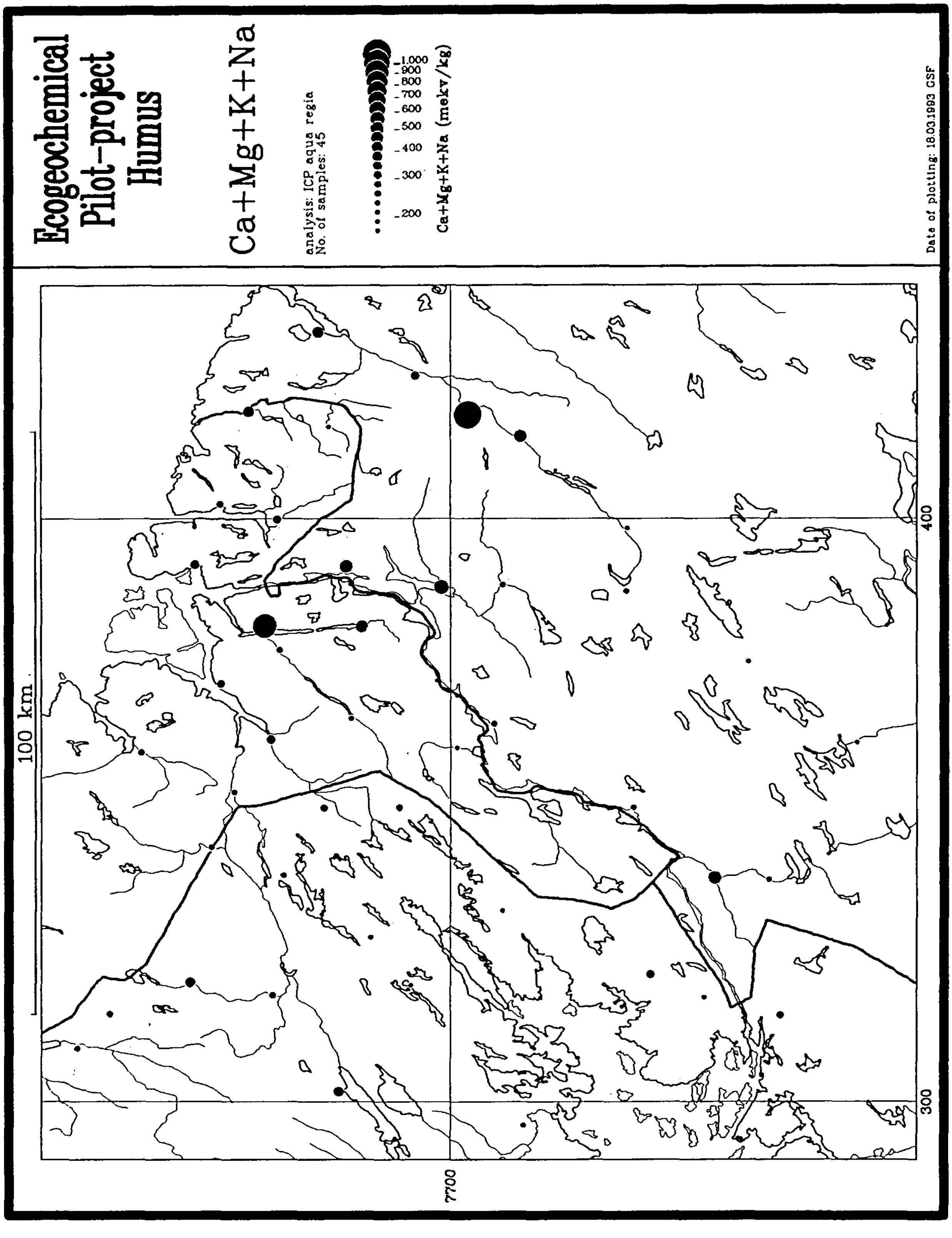

Ecogeochemical
Pilot-project
Humus
Ca+Mg+K+Na
analysis: ICP aqua regia
No. of samples: 45
1,000
900
800
700
600
500
400
300
200
Ca+Mg+K+Na (mekv/kg)
Date of plotting: 18.03.1993 GSF
100 km
7700
400
300

Figure N° 43

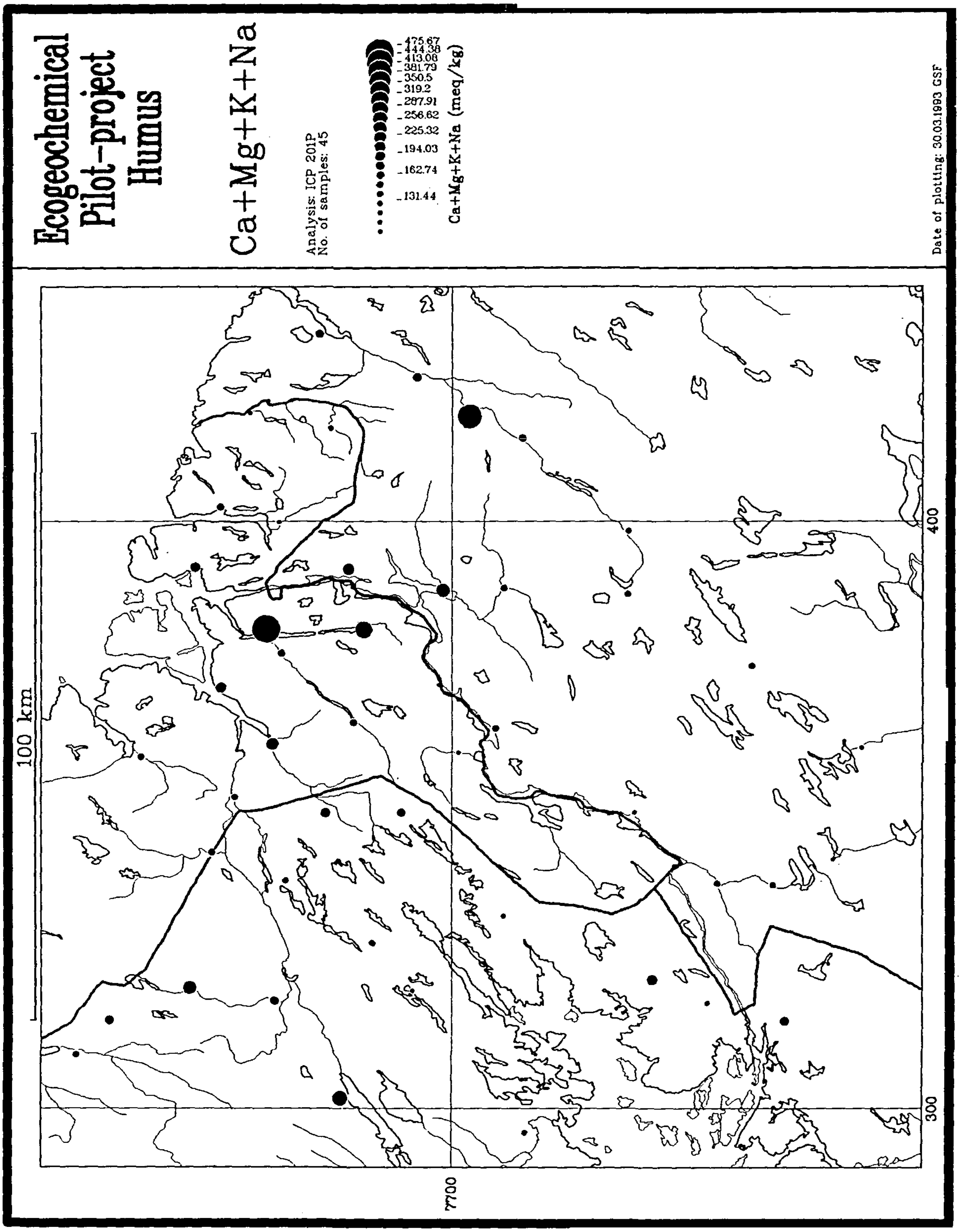

Ecogeochemical
Pilot-project
Humus
Ca+Mg+K+Na
Analysis: ICP 201P
No. of samples: 45
475.67
444.38
413.08
381.79
350.5
319.2
287.91
256.62
225.32
194.03
162.74
131.44
Ca+Mg+K+Na (meq/kg)
Date of plotting: 30.03.1993 GSF
100 km
400
300
7700

Figure N° 44

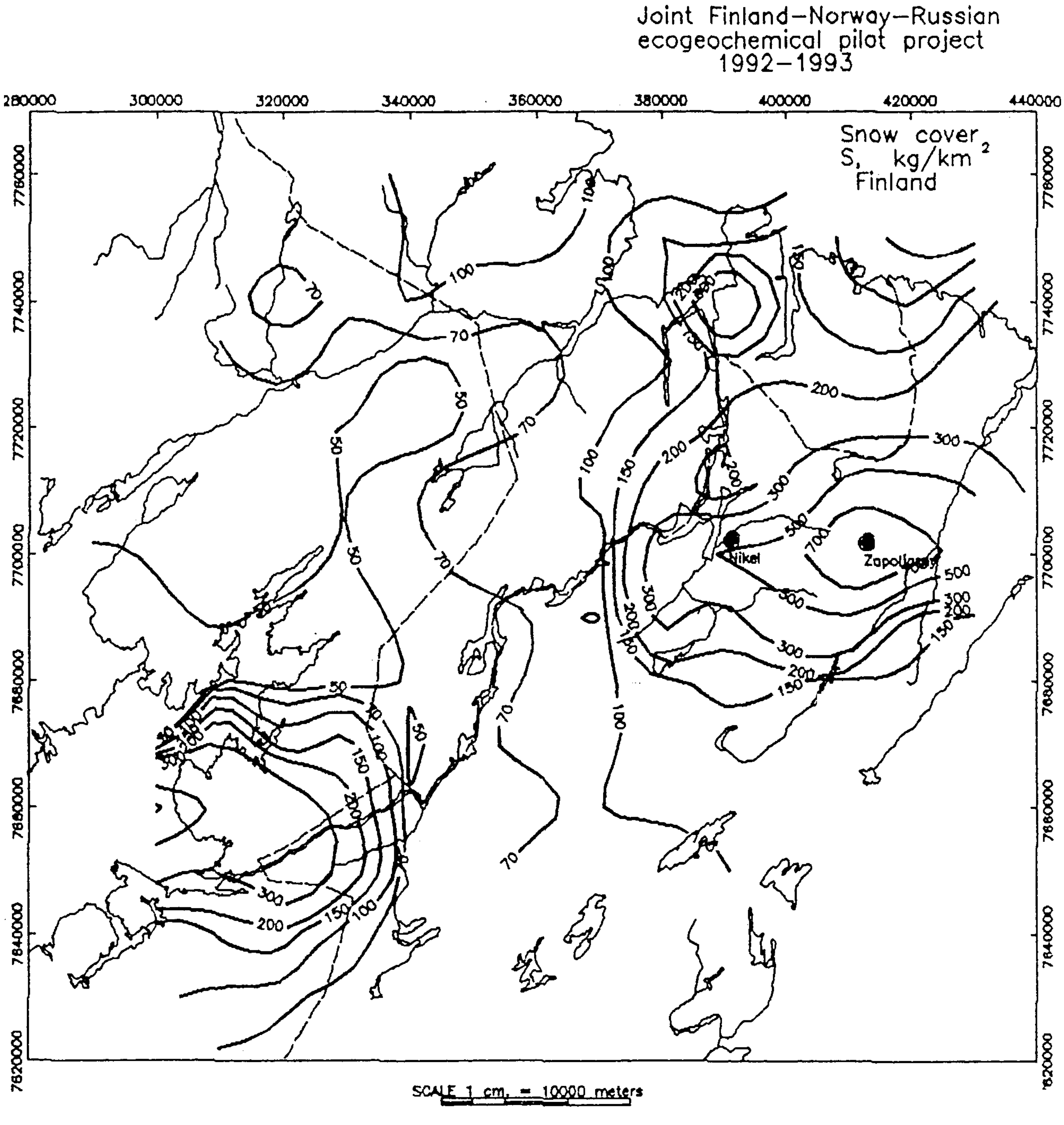

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow cover
S, kg/km²
Finland
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Nikel
Zapolyarny
70
100
50
150
200
300
500
700
SCALE 1 cm. = 10000 meters

Figure N° 45

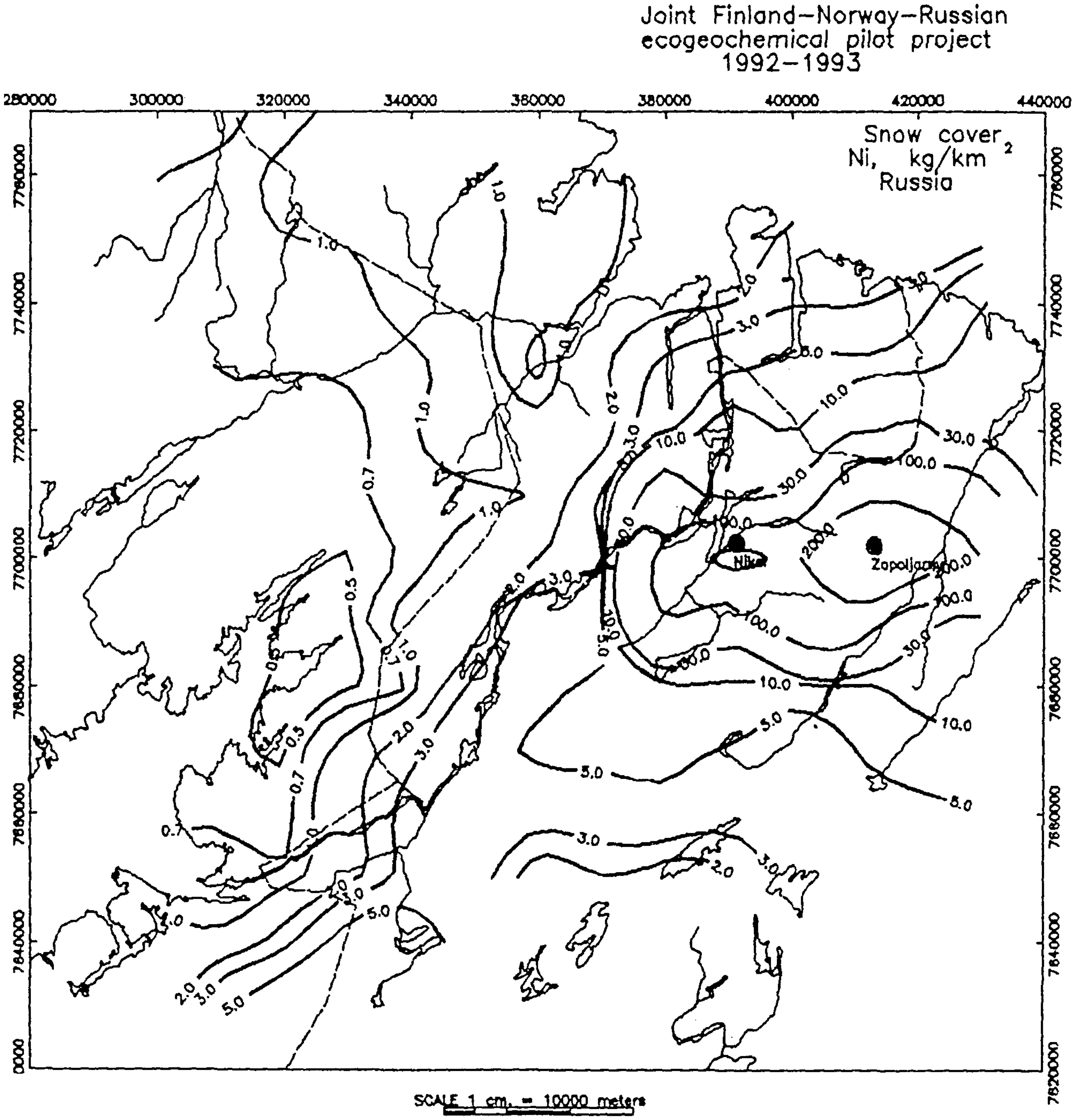

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow cover
Ni, kg/km²
Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Nikel
Zapoljarnyj
0.3
0.5
0.7
1.0
2.0
3.0
5.0
10.0
30.0
100.0
200.0
SCALE 1 cm. = 10000 meters

Figure N° 46

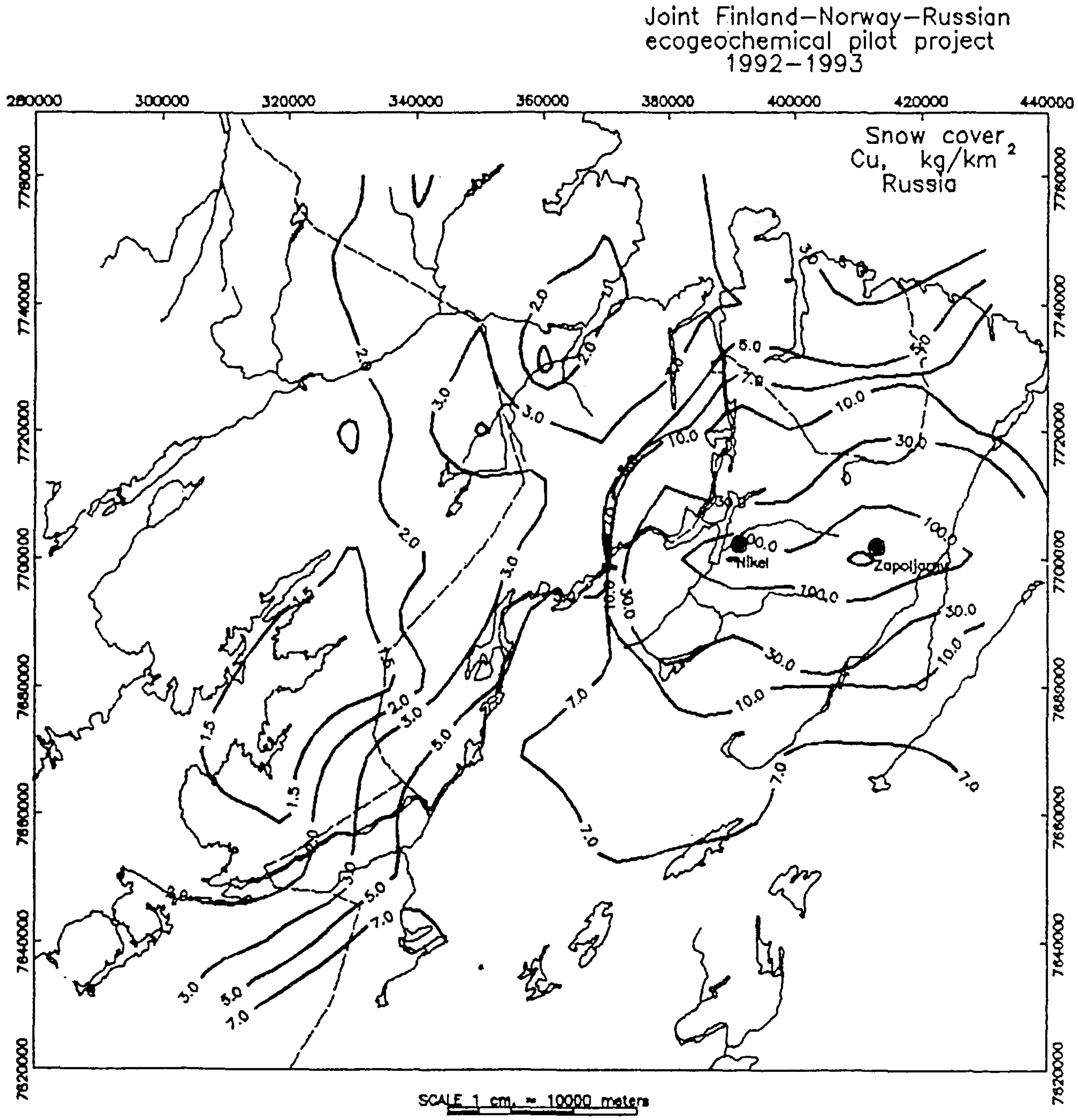

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Snow cover
Cu, kg/km²
Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
Nikel
Zapoljarny
1.5
2.0
3.0
5.0
7.0
10.0
30.0
100.0
SCALE 1 cm. = 10000 meters

Figure N° 47

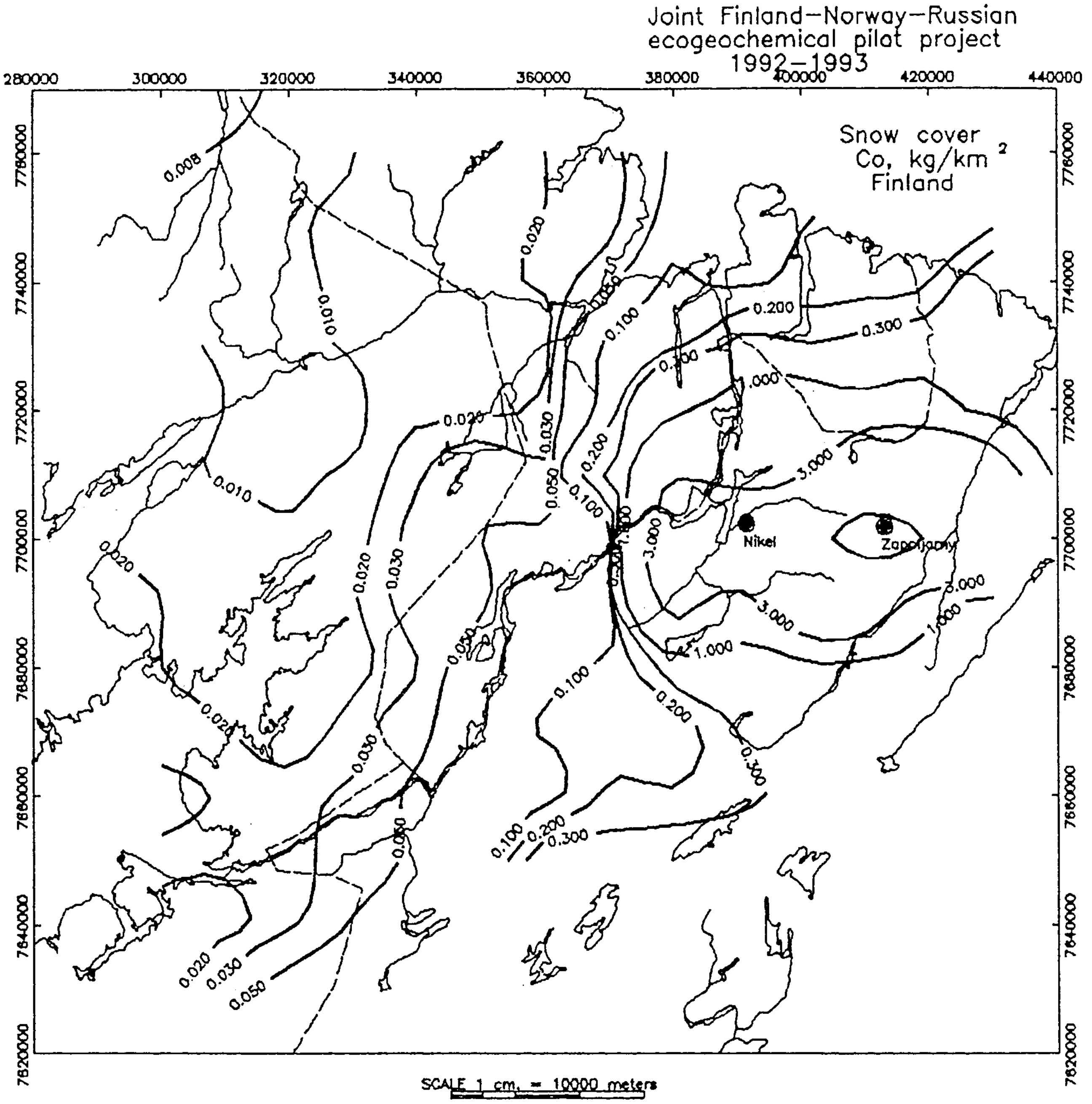
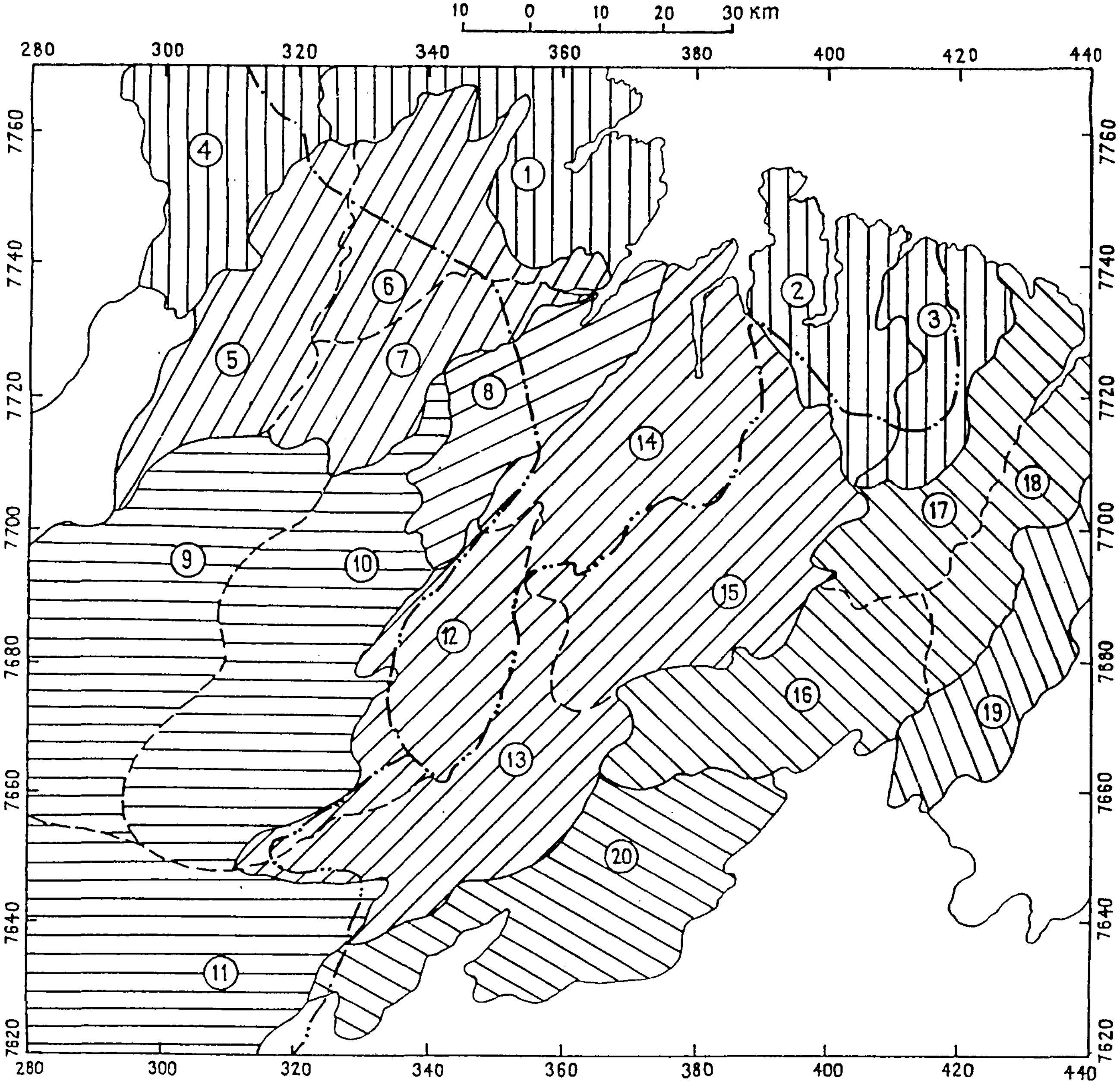

Joint Finland–Norway–Russian ecogeochemical pilot project 1992–1993
Snow cover
Co, kg/km²
Finland
280000
300000
320000
340000
360000
380000
400000
420000
440000
7780000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
0.008
0.010
0.020
0.030
0.050
0.100
0.200
0.300
1.000
3.000
Nikel
Zapoljarny
SCALE 1 cm. = 10000 meters

Figure N° 48

MAP OF DRAINAGE-BASINS



Dreanage-basins				
Shades	Name			Code
▥	Coast of the Barents sea	Bugöy-fiorden		1
		Jarfiorden		2
		River Vorjema		3
		River Pulmankijoki		4
▨	River Näätämo-joki	Upperreaches and lake Jijarvi		5
		Lower reaches	Left tributaries	6
			Right tributaries	7
▧	River Munkelva			8
▤	Lake Jnari	North-western part		9
		North-eastern part		10
		Eastern part		11
▨	River Pasvikelva	Upper reaches	Left tributaries	12
			Right tributaries	13
		Lower reaches	Left tributaries	14
			Right tributaries	15
▧	River Pechenga	Upper reaches		16
		Lower reaches	Left tributaries	17
			Right tributaries	18
▨	Upper Titovka			19
▧	Lakes Ala-Akkayarvi, Nyanamyarvi			20

Figure N° 49

MAP OF CONDITIONS OF MELT WATER FLOWING

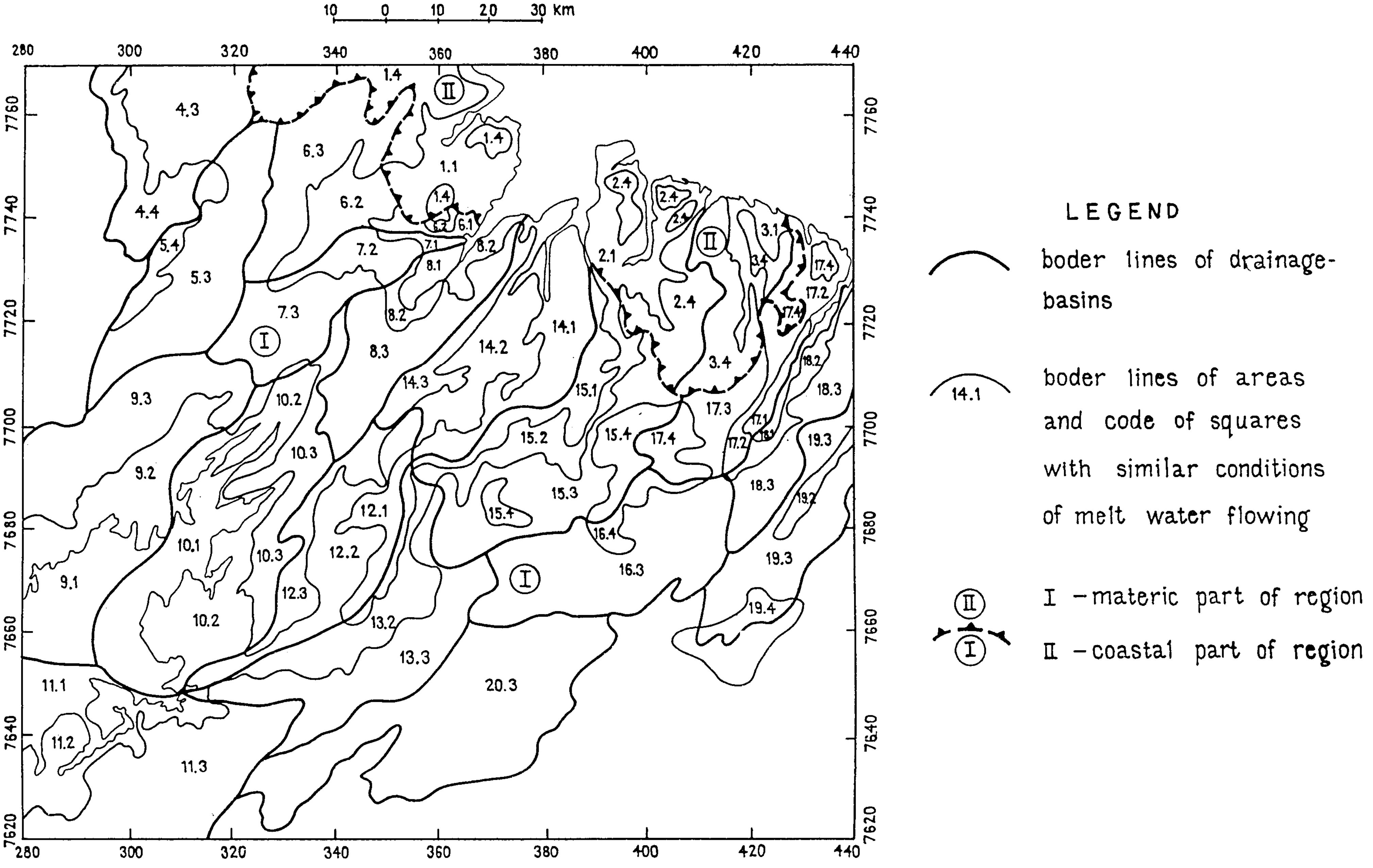


Figure N° 50
]

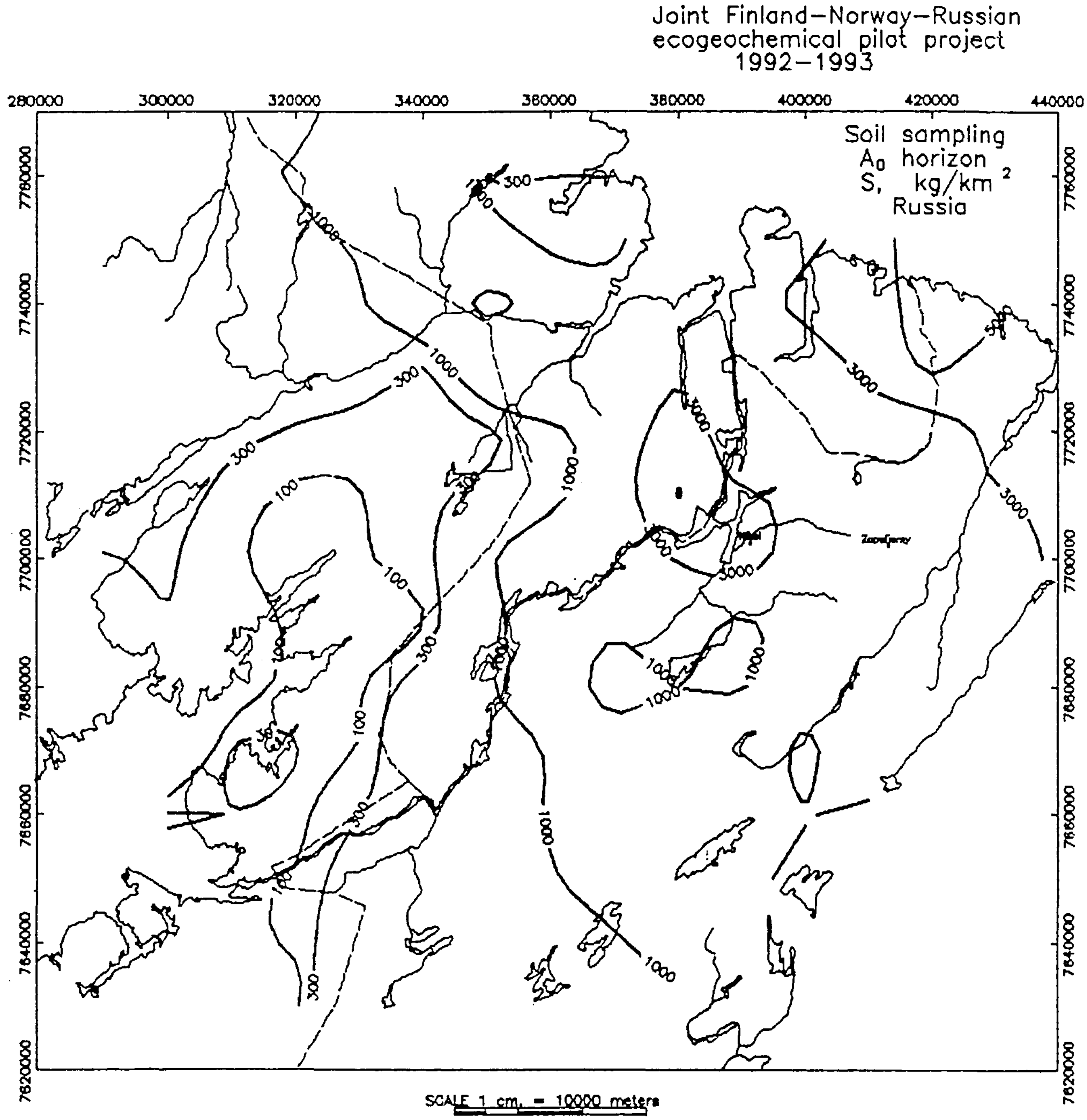

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Soil sampling
A_0 horizon
S, kg/km ^{2}
Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
100
300
1000
3000
Zapoljarny
SCALE 1 cm. = 10000 meters

Figure N° 51

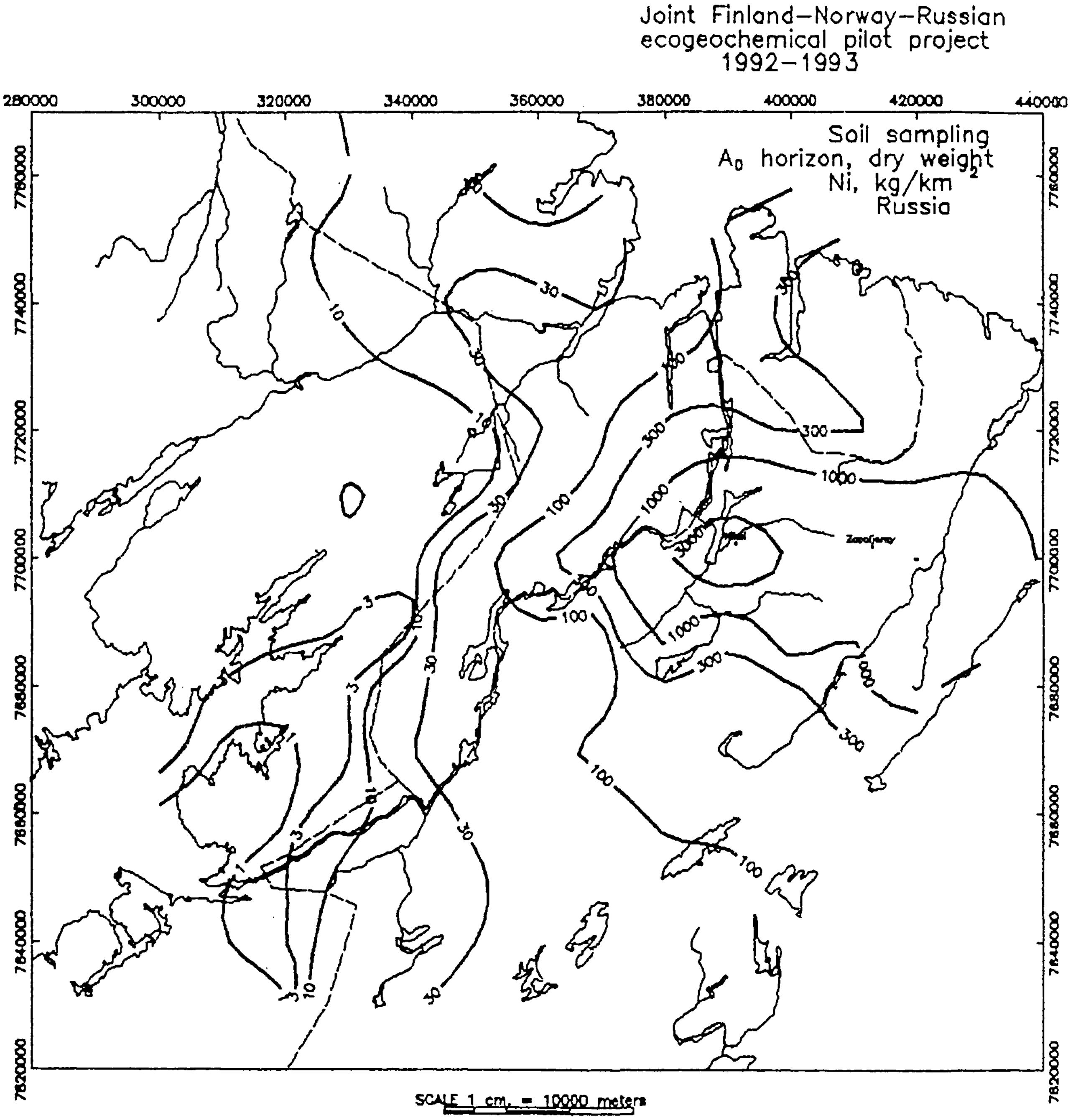

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993
Soil sampling
A0 horizon, dry weight
Ni, kg/km 2
Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
3
10
30
100
300
1000
3000
Zapoljarny
Nikel
SCALE 1 cm. = 10000 meters

Figure N° 52

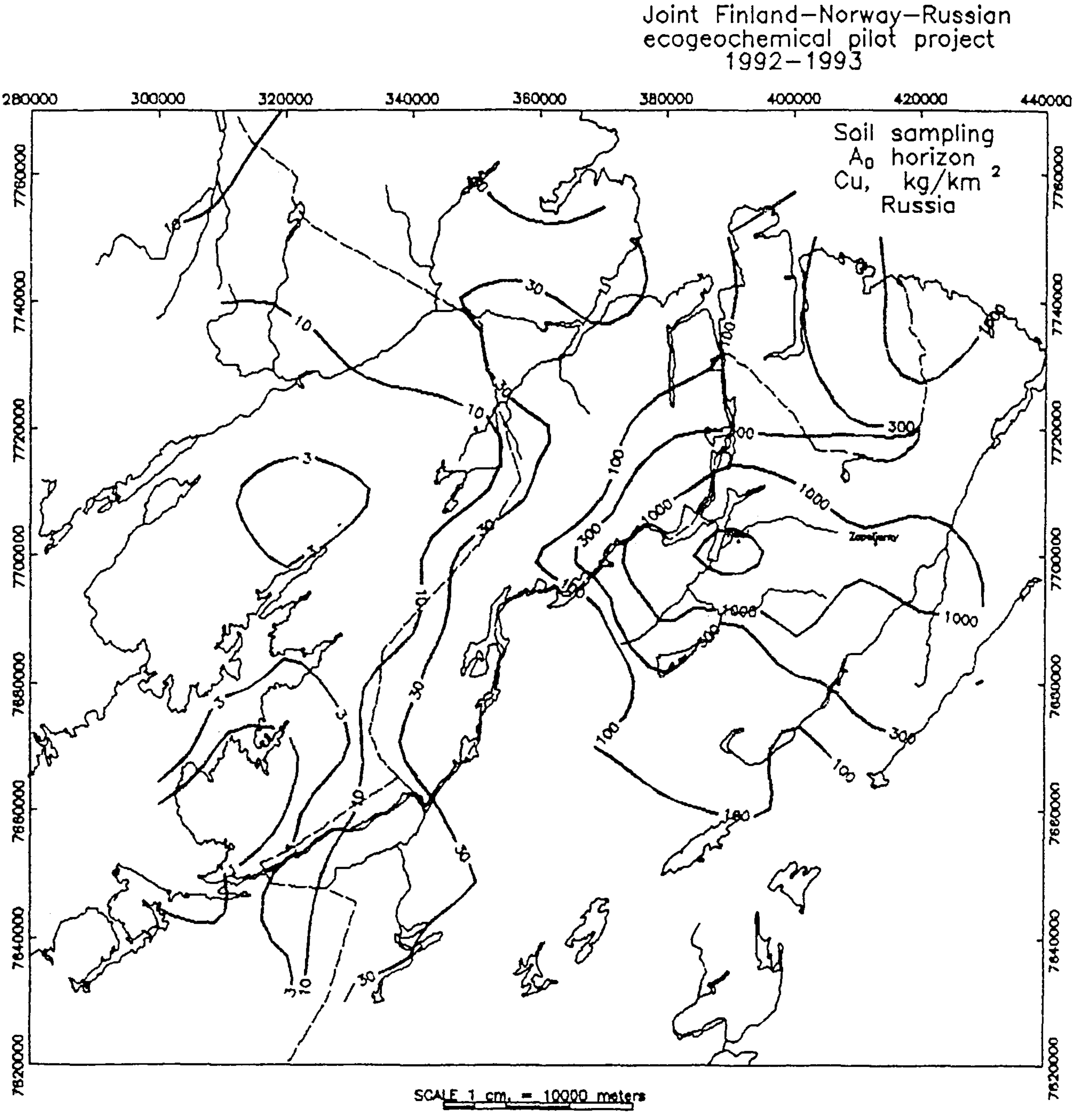

Joint Finland-Norway-Russian
ecogeochemical pilot project
1992-1993
Soil sampling
A₀ horizon
Cu, kg/km²
Russia
280000
300000
320000
340000
360000
380000
400000
420000
440000
7760000
7740000
7720000
7700000
7680000
7660000
7640000
7620000
3
10
30
100
300
1000
Zapolyarny
SCALE 1 cm. = 10000 meters

Figure N° 53

Joint Finland–Norway–Russian
ecogeochemical pilot project
1992–1993

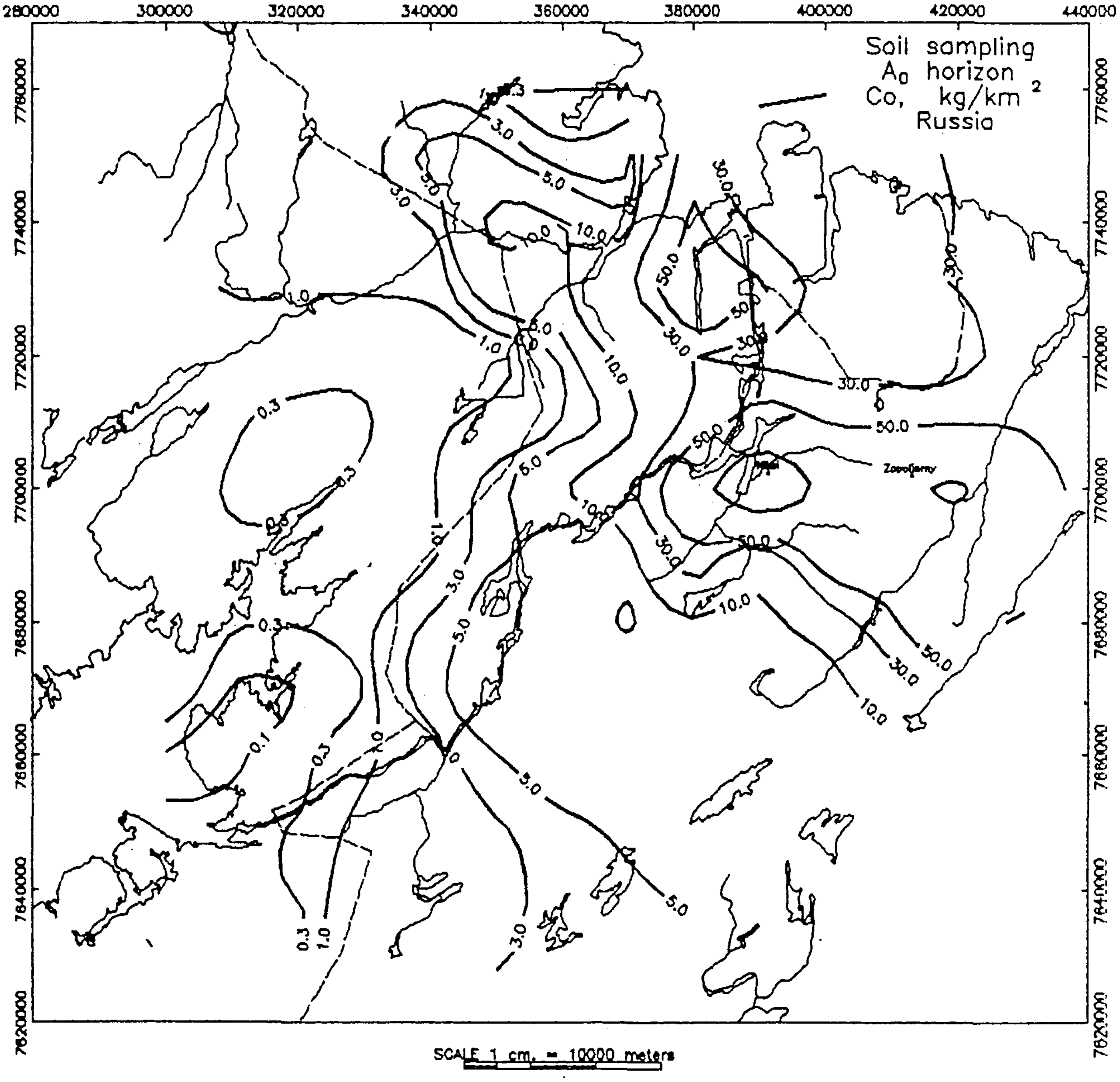


Figure N° 54

MEMORANDUM

of the meeting with Finnish-Norwegian delegation in Central Kola Expedition (CKSPE) of Sevzapgeologia Association (SZPGO), USSR.

Monchegorsk October 1-5, 1991

Participants:

- from Geological Survey of Finland (GTK): Matti Ayras, chief of geochemical mapping; Marja Liisa Raisanen, geologist; Heikki Niskavaara, laboratory manager;
- from Geological Survey of Norway (NGU): Rolf Tore Ottesen, program coordinator, section for geochemistry;
- from Sevzapgeologia Association (SZPGO): o.Darkshevich, chief of CKSPE; A.Lebedev, chief geologist; F.Gimatdinov, chief of the section; V.Chekushin, directing geochemist; V.Pavlov, chief of geochemical survey group; S.Latonin, geologist-geochemist; O.Kovyazina, chief of CKSPE laboratory; I.Berman, chief of integrated research group of Murmansk Geological Prospecting Expedition (MGRE); S.Mikhaelis, chief of MGRE laboratory; I.Bogatyrev, directing programmer of MGRE.

The meeting was arranged according to the Memorandum of GTK and CKSPE (Rovaniemi, May 28-31, 1991).
A fundamental goal of the meeting consisted in negotiating a possibility of cooperation in ecogeochemical survey which is being conducted presently in the Kola peninsula and contiguous areas of Finland and Norway.

In the Murmansk area ecogeochemical survey includes sampling of snow cover, vegetation substratum (A_0-horizon), mineral soils (horizons A,B,C), stream bottom sediments and vegetation (lichen). Sampling density is 1 sample/30-100 sq.km, and in a more close study in local areas - 1 sample/1-5 sq.km. Now and then underground and surface waters are sampled.

Samples are analyzed by chemical methods, AAS, OES, XRF and other techniques.

In Finland and Norway regional geochemical survey sampling is made on till, minerogenic stream bottom sediments, stream moss and water of superficial drainage system. Sampled is also feather moss (Hylocomium splendens) and podzol soil horizon. Sampling density - 1 sample/60-300 sq.km. Samples are analyzed by ICP, AAS, NAA, XRF and other methods.

The parties have stated that the following sample types, or media, are the same in all three countries, namely: vegetation substratum (A_0-horizon), mineral soil horizons (A_2,B,C), and stream bottom minerogenic sediments. Finnish and Norwegian parties highly appreciated the snow cover sampling method employed by the Soviet specialists. The Finnish specialists demonstrated the results of "Hylocomium splendens" moss sampling and soil acidification study which the Soviet specialists found very interesting. The Norwegian party presented information about the method of ecogeochemical mapping on scale 1/10 000 000 in the West Europe.

According to a common opinion, most important sample types (media) will be : snow, 'Hylocomium splendens' moss, A_0-horizon, horizons A_2, B and C, and stream bottom minerogenic sediments.

The Soviet party proposed a draft program of a joint project which will have the following goals:

1. To define a boundary-transgressive transportation of pollutants and their composition; to assess ecological state of border-line areas of Murmansk region (USSR), Finland and Norway.

2. To produce a set of ecogeochemical maps drawn to a scale 1/1000 000, covering a western part of Murmansk region and contiguous areas of Finland and Norway, and showing how these are contaminated with heavy metals, sulphur, radionuclides and other components.

3. To develop a procedure of regional monitoring over a dynamics of technological stresses; to set up a system of monitoring sites in the near-to-border areas of Murmansk region, Finland and Norway.

English text of the said program will be submitted to the Finnish and Norwegian parties by December 31 of 1991 at the latest.

The Finnish and Norwegian parties acknowledge a fact that, for lack of finances, they are not ready yet to participate in a joint ecogeochemical mapping of large territories on a scale 1/1000 000 in 1992. The parties have come to a conclusion that it will be reasonable to launch in 1992 a joint pilot project in a test area including Nickel-Zapoliarny localities and adjacent Norwegian and Finnish territories (total area 12-15 thou.sq.km, average sampling density 1 sample per 300 sq.km) in order to compare the sampling techniques, analytical and data processing methods.

Sample types (media) will be:

- snow cover (March 1992)
- feather moss (August 1992)
- stream bottom minerogenic sediments, soil horizons (A_0,A_2,B,C) and ~~stream~~ overbank ~~terrace bottom~~ sediments (September 1992)

When sampling the snow cover and river terraces the parties assist each other by way of showing the methodology.

Field records of snow cover sampling will include: sample number, sampling locality, geomorphological setting of a sampled locality, number of snow core samples and distance between them, description of forest vegetation.

Field record content for other sample types will be discussed during a meeting in Rovaniemi.

Analytical study for the pilot project in the test area will be made necessarily for the following elements:

- snow water: Ni, Cu, Co, Pb, Zn, Mn, Al, P, F, anion-cation composition analysis;
- filter precipitate: Ni, Cu, Co, Pb, As, Al, P, F, Sr;
- A_0-horizon, soil horizons, stream bottom minerogenic sediments: Ni, Cu, Co, Sr, As, S, Fe, Ca, Mg, P, F, Al_{total}, Na, K, $Al_{acid-soluble}$, water extracts for measuring 'pH', Cl, Al.

Feather moss samples ~~are~~ will be analyzed in a laboratory in Finland. The parties will decide in Rovaniemi, in March 1992, in which way and where the filter precipitates will be analyzed. All the samples of the rest types (media) will be analyzed for a specified minimal number of elements in the laboratories of three countries.

Processing of the data from the pilot project test area and reporting will include the following aspects:

- a study of methods and facilities to be used in creating a common database;
- database will be formed both on the automated data carriers and as composite tables on paper;
- raw-data maps will be produced by all three countries using their own methods.

As a result of such pilot project in the test area a joint report will be written by three parties, its content to be verified in Rovaniemi (March 1992).

Organization of the pilot project

A steering group is formed of 3 persons, each representing the participating side. The steering group nominates one project leader.

Each party forms a working group headed by a chief. Each working group will be manned with specialists in field sampling, analyses and automated data processing.

Time schedule

Planning	October 1991
Field	March 1992 - September 1992
Analyses	March 1992 - December 1992
Data processir	March 1992 - January 1993
Reporting	April 1992 - February 1993

Planning of the main project must be completed in ~~June~~ THE BEGINNING 199~~2~~3, in which case the results of snow cover sampling are to be presented in a final form in May of 199~~3~~2.

Meetings

Svanvik, Norway, 1st week of March 1992, 1-2 specialists from each party. The Soviet party renders assistance in conducting snow cover sampling procedure.

Rovaniemi, Finland, 4th week of March 1992, 4-5 persons from each side - specialists in analyses, automated data processing and geochemistry. Discussion of analytical problems, questions concerning data processing (formation of the database included) and planning of activities under the main project.

~~While~~ At the meeting in Rovaniemi, the parties will exchange the reference samples of standard composition, as well as the snow samples; organized there will be a meeting of the Soviet participants with the specialists of Meteorological Institute of Finland who will inform on airborne unnatural pollution simulation technique.

Joint field trips will be organized in three countries in the 1st week of August 1992 in order to be familiar with each other's sampling technique. The participants will be 2 specialists from each party.

Monchegorsk, USSR, February 1993. Making the joint report based on the pilot project results.

On behalf of the Soviet party

On behalf of the Finnish party

On behalf of the Norwegian party

MEMORANDUM

of the discussions in the Geological Survey of Finland, Regional Office of North Finland, in March 24 - 26, 1992

Participants:
Russian: **Chekuchin, Viktor**, leading geochemist, Central-Kola expedition (CKSPE),
Semenov, Evgeniy, geochemist, Central-Kola expedition,
Lagunova, Valentina, leading chemist, Murmansk expedition,
Bogatyrev, Igor, leading programmist, Murmansk expedition.
Norwegian: **Ottesen, Rolf Tore**, geochemist, Geological Survey of Norway (NGU),
Finne, Tor Erik, geologist, Geological Survey of Norway,
Misund, Arve, geologist, Geological Survey of Norway
Finnish: **Äyräs, Matti**, geologist, Geological Survey of Finland (GTK),
Niskavaara, Heikki, chemist, Geological Survey of Finland,
Tarvainen, Timo, senior system analyst, Geological Survey of Finland
British: **Heaton, Tim**, isotope geochemist, NERC Isotope Geosciences Laboratory, England, as observer and
Silvennoinen, Ahti, Head of Geological Survey of Finland, Regional Office of North Finland as cahairman in concluding discussion

The meeting was arranged according to the Memorandum of CKSPE, NGU and GTK ((Monchegorsk, October 1-5, 1991).

The aim of the meeting was to do the decisions in detail about pilot project; sampling methods, analytical methods and data processing as mentioned in Monchegorsk Memorandum.

The discussions in meeting were mainly in working groups, which were:

1. Field methods, field information and maps,
2. Analytical methods,
3. Data processing and
4. Financing

The reports of working groups were discussed by whole meeting group before decisions. The common reports of working groups are as appendices of this Memorandum.

In the final discussion it was decided:

1. Amount of materials:

A_o -horizon	1 - 1.5 kg
A_o + A_2 -horizon	1 - 1.5 kg
C -horizon	1.5 - 2 kg
Stream sediment sample	3 - 5 kg

Details will be decided in excursion in July 1992.

2. Adp

Each participant country uses their own systems. Field files will be send to others together with samples. Coordinates will be given using UTM orthogonal system, same coordinates in all countries. Norwegian participant will deliver the map in scale 1:500 000, to be used in pilot project. All countries can use also their own coordinates.

Adresses for sending the field files:

Igor Bogatyrev, Murmansk department of geological research, Fersmana st 26, 184200 Apatity, Russia

Tor Erik Finne, NGU, P.O.Box 3006, N-7002 Trondheim, Norge

Markku Pänttäjä, GTK, P.O.Box 77, SF-96101 Rovaniemi, Finland

3. Analysis

Chemist from each country will participate the excursion in July 1992. The results of snow analysis, analysis of other materials and common decisions about analysis of other materials than snow, will be discussed during the excursion.

4. Reporting

Each participating organization writes their own reports, from which the common report will be compiled at Monchegorsk meeting in February 1993. National reports with proposals for the common report will be delivered beforehand (if possible at the end of this year) to each participant. The Monchegorsk meeting may be delayed, if needed. Reports of snow material are ready before the environmental symposium held in Rovaniemi in October 1992. During this symposium also other ready results will be discussed.

5. Excursion in July 1992

Excursion starts at Boris Kleb border station 27 July at 14.00 afternoon Russian time.

27.7.	Nickel	accommodation in Russia
28.7.	Nickel area	" " " "
29.7.	Svanvik	accommodation in Norway
30.7.	Inari	accommodation in Finland
31.7.	Inari	departure via Lotta

Responsible persons for excursion: Evgeniy Semenov, Tor Erik Finne and Matti Äyräs. Each of them prepares and quides the program in his country.

Participants: two geologists and one chemist /each country. Names of participants will send to each other as soon as possible.

6. Symposium on the state of the environmnetal monitoring in Northern Fennoscandia and the Kola Peninsula

Geological Survey of Finland, Regional Office of North Finland has invited Dr. Alexei V. Lebedev to participate in the symposium and asked him to give an oral presentation on our mutual ecogeological pilot-project. Through him another researcher from Kola was invited to participate and to give an oral presentation on snow-studies in the surrounding of Monchegorsk.

Viktor Chekushin   Rolf Tore Ottesen   Matti Äyräs

FIELD METHODS /AM

Appendix 1

The following media will be sampled at a minimum sampling density of 1 sample per 300 square km (a total of 15 locations per country)

09	Snow cover
02	Organic soil (A0-horizon)
05	Mineral soil (C-horizon)
13	Combination soil sample (A0+A2)
08	Terrestrial moss (Hylocomium splendens or)
01	Stream sediments
10	Stream water
11	Overbank sediments top ("present day")
12	Overbank sediments bottom ("pre-industrial")

In the above table, sample type numeric code is given prior to each sample type name.

In addition to the 15 locations, each country will collect field duplicates from 5 locations, preferrably distributed throughout the area. Field duplicates should be collected a few houndred meters away from the original sample.

Location numbering is done by four digits where the following number series are given to the three countries:

0001-1999	Finland	For example:
2001-3999	Norway	09 2001
4001-9999	Russia	means snow sample from first location in Norway

Location numbers are not used continously within each sample series, but in a manner so that sample types coming from the same approximate location are given the same location number. This means, for instance, that if there is no terrestrial moss to be found where other medias are sampled, that location number will not be used for the moss.

Localities are marked by field crews on maps of their own choice, and afterwords transferred to map in the scale 1:500,000. Each country calculates coordinates (Easting, Northing and altitude; unit meters) for their locations, referring to UTM-zone 36.

Snow cover.

Selection of sample site: Preferrably a level area (50x50 m) with uniform snow depth. Subsamples should be taken so that different situations are covered (open field, underneath trees). Samples are collected with plastic tube of internal diameter 10 cm, and stored in water tight, non-contaminating plastic containers. For analysis in Russia, 5 kg is needed; for analysis in Finland, 2 kg. At each location field observations are recorded according to list given by Russian party with these additions/corrections to the following points:

3	Description of the surrounding 300 square km
6&7	Length in dm
9	Weight of snow sample with 0.1 kg accuracy
new	always take note whether sample is "normal" or fiel duplicate

Overbank sediments - top.
Selection of sample site: Overbank sediments should be sampled on the floodplain of rivers from drainage basins between 30 and 100 km^2 (see illustration). The sample should be taken from the uppermost 10 cm of the minerogenic part of the profile; no subsampling. Required sample size is 10 kg for each of the three parties involved. Sieving at 0.125 mm must be done as dry-sieving. At all locations, field descriptions are recorded as described by the Norwegians.

Overbank sediments - bottom.
Sample should be taken from the same hole as the overbank sediment - top sample. "Bottoms"-sample should contain material from the bottom half of the profile. Sample size (and sieving); see "top"-sample. At all locations, field descriptions are recorded as described by the Norwegians.

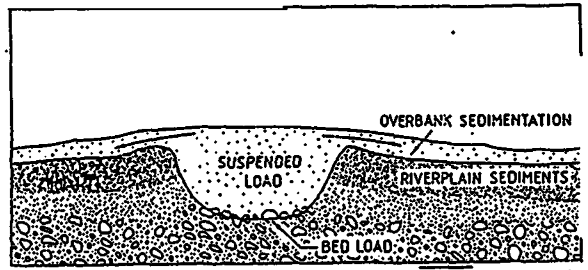
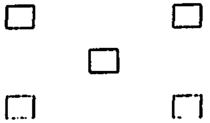


Fig. 7. Water discharge of a river during a major flood. Overbank sedimentation takes place on t river plain.

Figure 1.
Principle of overbank sediment deposition.

Organic soil (A_0).
Selection of sample site: Preferrably a level area as outlined below; with 5 subsamples.



Each subsample square is 20x20 cm.

Distance between subsamples 10-15 m.

At each location, <u>three</u> samples of each 1.5 kg will be collected, allowing all three parties material for analysis. Samples will preferrably be collected in bags that allow breathing in order to avoid decomposition and unwanted organic activity. At each location, field description will be carried out as described by Russians.

Mineral soil (C-horizon).
Procedure as for organic soils.

Combination soil sample (A_0 and A_2-horizons).
Selection of sample site; see other soil samples. Subsamples are 20x20x5 cm, and the number of subsamples is 3 in triangle of 10-15 m side. If applicable; 1 subsample underneath tree, 2 in open space. At each location, one sample of 1.5-2 kg will be collected for the Russian party. At each location, field description will be carried out as described by Russians.

Terrestrial moss.
Selection of sample site: Area 50x50 m, with 5 subsamples distributed within this area as for the organic soils. Only shoots from the last four years are to be sampled. At each location, one sample of approximately 2 liters will be collected in polyethylene bags for analysis by the Finish party. At each location, field description will be carried out as described by Russians.

Stream sediments.
Selection of sample site: Streams sampled should drain areas between 30 and 100 km^2. At each location, five subsamples along 50 m of the stream bed are to be collected. Three samples of each 3 - 5 kg are needed; one for each party's laboratory. At each location, field description will be carried out as described by Russians.

Stream water.
Selection of sample site: Stream water is to be collected from the same locations as the stream sediments. No subsampling is required. At all locations, pH and electrical conductivity should be measured by field crew. Two samples are needed for the Finnish lab; one 100 ml untreated and one 100 ml filtered (0.45 µm) and acidified (0.5 ml suprapure HNO_3). At all locations, field observations are recorded as described by the Russians.

Geological Survey of Finland
Chemical Laboratory
Joint Ecogeochemical Project
26.03.1992 /HN

Schema of analysis for different sample matrials

This schema is a draft version for chemical analysis of various sample materials included in the pilot project plan. It is a compilation of issues that were discussed during the meeting in Rovaniemi 23.- 26.03.1992. Only description of main digestion methods is given.

A.Snow

A.1 Snow water
A.2 Snow filter

-a separate more detailed paper has been compiled

B.Overbank sediment

- The norvegian part will do the preparation and analysis of this material
- size fraction <0.125mm
- amount of material ??
- amout of laboratory sample 100-200g

C.Feather moss (Hylocomium splendens)

- The finnish part will do the sample preparation and analysis of this material.
- the whole plant (3-4 yougest yearshoots)
- sample material about 2 litres (20-30g dryweight).
- for sampling a finnish standard SFS E206

D.Ao+A2 soil for radionuclide analysis

- The russian part will do the sample preparation and analysis of this material.
- sample material about 2kg.
- homogenized total sample.
- analysis of Cs137 and Cs134

E.Stream water

- The finnish part will do the analysis for the whole material. Each participant can take at the same time samples for analysis in own labs with own methods for intercalibration.

pH and electrical conductivity in field
- unacidified sample for ioncromatografic determinations (100ml polyethylene bottle)
- filtering (0.45µm) to 100ml polyethylene bottle and acidification with 0,5ml of suprapure HNO3 in the field for ICP and ICP-MS analysis.

F.Stream sediment

- size fraction <0.07 mm,
- each participant prepares and analyses its own samples and deliveres a subsample for other participants for intercalibration.
- at least 3 - 5kg of sample is required to get 100-200g of laboratory sample.
- digestion aqua regia (Finland and Norway) and HF-HCO4-HNO3 (Russia).
- weak leach (water, ammonium acetate)??

G.Soil profile

G.1 Ao (Humus)

- homogenized, ashed (450C) bulk sample.
- unashed subsample ? (for S and other volatiles).
- each participant prepares and analyses its own samples and deliveres a subsample to other partcipants for intercalibration.
- amount of sample material ??
- digestion aqua regia (Finland, Norway) and HF-HCO4-HNO3 (Russia).
- weak leach (water, ammonium acetate) ??

G,2 C (Mineral soil)

-two size fractions a) <0.07mm b) <2.0mm (ISO/DIN 11464)
- each participant prepares and analyses its own samples and deliveres a subsample for other participants for intercalibration.
- amount of material ??
- digestion aqua regia (Finland, Norway) and HF-HCO4-HNO3 (Russia).
- weak leach (water, ammonium acetate)??

Geological Survey of Finland
Chemical Laboratory
Joint Ecogeochemical Project
26.03.1992/HN

Analysis of snow samples

Samples: 15 samples will be taken in each country, five additional samples will be taken as field duplicates.

Totally 3 * 20 = 60 samples

From each sampling station 3 buckets of samples will be taken. One bucket will contain about 8 litres of snow (about 2-3 litres of water). One bucket from Norway, Russia and Finland will be delivered to Finnish Geological Survey and two buckets to Central Kola Expedition.

Analysis at GSF

Samples are delivered to Chemical Laboratory of Northern Finland preferably as snow (not melted). The bucket with snow is weighed in the field and again in laboratory.

The snow is let melt in room temperature. pH and electrical conductivity is measured instantly.

A 100ml subsample of original untreated sample is taken to a polyethylene bottle. Marked N (non-acidified) and delivered to Otaniemi for analysis of main componenets with ICP (method code 140P) and for IC - analysis for Br, Cl, F, NO_3, SO_4, (NH_4 ?) (method codes 143I and 143R).

The rest of the snow water is filtered through blue ribbon (S&S) cellulosa filterpaper. The volume of the water is registered. The filterpaper is weighed before the filtration and after filtration and drying.

A 100ml subsample from the filtrate is taken to a polyethylene bottle and acidified with 0,5ml of suprapure HNO_3, marked A (acidified) and delivered to Otaniemi for ICP and ICP-MS-analysis (codes 140P and 140M).

The filterpaper is rapped and put in sample ampoulle (marked F) and delivered to Kuopio laboratory. The sample is digested with microwaveoven with nitric acid (method 503) and delivered back to Rovaniemi for analysis with ICP (method 503P) and to Otaniemi for ICP-MS (method 503M).

A blank sample (a bucket with 3 litres of deionized water) will go through the whole procedure with 100ml of same deionized water in a polyethylene bottle.

INTERCALIBRATION

Because the original samples delivered to Finland and Russia are in practice duplicate samples, the russians will delivere also the non-acidified (marked N) and the filtered and acidified (marked A) subsamples of their own samples to Finland to be analyced at GSF. These samples should be deliverd in finns at the Kirkeness- meeting.

Russians will delivere the untreated filterpaper tney are using for filtration to be analysed at GSF together with other filterpapers (with precipitate).

DIFFERENCES IN PROCEDURES

The water samples are treated basicly with same procedures but the analyses are carried out totally with different methods due to differences in analytical instrumentation.

Russians preconcentrate the water samples by evaporating about 2000ml to 25ml and the analysis is done with flame atomic absorption spectrometer and potentiometric and colorimetric methods.
Finns dont use any preconcentration method and analyse the samples with ICP, ICP-MS and ioncromatography.

The filters are treated with different procedures. The russians ash at 600C the filter+precipitate and digest depending on the weight of the residue a part of the sample (about 0.1-0.2g). In addition emission spectrograph is used in the analysis.
Finns dont have so much experiencies on this kind of material but the intention is to dissolve the whole filter+precipitate with nitric acid in microwave oven and analyse the solution with ICP and ICP-MS.

Appendix 3

GEOLOGICAL SURVEY OF FINLAND
Timo Tarvainen

26.3.1992

FINNISH-NORWEGIAN-RUSSIAN ECOGEOCHEMICAL PILOT PROJECT

MEETING AT GTK, ROVANIEMI, 24.-26.3.1992

REPORT OF THE DATA PROCESSING GROUP

1. Databases

The pilot project will not make a common database for the field and analyse data. Each organization will use their own systems to store the data, but a common system to exchange the data will be needed.

2. Digital basic map

NGU will digitalize the coast lines, border lines, rivers and big lakes and provide this information to all participants.

3. Data exchange format

When the field work is done, all field observations are stored in a ASCII files, which can be read with a Fortran program. This file with a Alkemia type description file are stored on 5.25 inch diskettes and sent by post to other participants.

When analytical data is obtained, the analytical values will be added to the ASCII file, and the description of the new fields are added to the Alkemia type description file (ALD-file). These files are again stored on 5.25 inch diskettes and sent by post to the other participants.

The format of the ALD-file and the setup for naming of variables are presented in the appendix. This scheme will allow us export any parameter decided by the participants.

4. Coordinate systems

Each country may use their own coordinates during the field work. During the pilot project, all coordinates can be drawn on a common map to check the common coordinates, but later we will need transformation routines. When the data in exchanged in ASCII files, national coordinates MAY be included (SPSS-names xLocal and yLocal) and common coordinates MUST be included (SPSS-names x and y).

Each organization can change their national coordinates to geographical (degrees, minutes, seconds) coordinates. NGU will provide a Fortran program to change geographical coordinates to the common coordinate system. NGU will send the source of the Fortran progam to all participants after the meeting on a diskette.

5. Names of the analysed variables

The name of a analysed variable is combination of "element" name, fraction code, extraction+method code and laboratory code. The unit is shown in the 4th column of the Alkemia description file. The SPSS-name for the variable are the 8 first characters of the whole name.

The fractions are coded with numbers 1,2,3,... Fine fraction of soil samples is 1 etc.

The extraction and analytical method are coded with 4 characters. If the national code is shorter than 4 characters, leading zeroes will be added. If the national code is 3, 0003 will be used in the variable name.

The laboratory is coded with 1 character. Finnish labroratories are called A, B and C; Norwegian laboratories are D, ..., Z and Russian ones 1,2,..9.

Example

Cu analyzed from fine fraction (code 1) using Finnish method 511P in Otaniemi laboratory (code A) is

Cu1511PA

Cu analyzed from fine fraction (code 1) using Russian method 4 in second Russian laboratory (code 2) is

Cu100042

In most cases the whole name is the same as the SPSS-name of the variable. If the name of the "element" is longer than 2 characters (e.g. SO4), 8 first characters of the whole name (e.g. SO4+6+143T+B = SO46143TB) is used as SPSS-name.

6. Detection limits

The detection limit is marked as a comment in the Alkemia description file (ALD-file). For example:

```
Cu1511PAF Cu1511PA     ppm     T62,E9.3     ! DLimit=5
```

If the laboratory cannot give any value (the sample is lost...), -9999 should be given in the ASCII-file. If the laboratory informs only that the value is less than detection limit D, value D/2 should be written to the ASCII file and the detection limit should be marked in the description file. If the labroratory gives an non-negative value which is less than the detection limit, this value should be written to the ASCII-file, but the detection limit should be marked in the description file.

GEOLOGICAL SURVEY OF FINLAND
Timo Tarvainen 25.3.1992

ALKEMIA DESCRPTION FILES (ALD-FILES)

The Norwegian-Finnish-Russian ecogeochemical project will exchange field data and analytical data using ASCII-files. These ASCII-files are described using a Alkemia-type description file. One example of ASCII-files is included on this diskette (TESTDATA.ALK) with the description file (TESTDATA.ALD). This example is taken from the Finnish geochemical database and the content of the ASCII-file is not the same as the content of the files of our projects will be. However, the format of the description file will be seen from this example.

1. The first line of the description file tells the name of the ASCII-file.
2. The second line of the ALD-file tells the strategy of sampling using a 4-letter code. SAMR = soil samples, SAPS = stream sediments, SAKA = bedrock samples, SAJS = lake sediments, SALU = snow water, SALF = snow filter, SATS = overbank sediments, XXXX = something else
3. The third line is a free comment line max 80 characters
4. The fourth line tell the amount of Finnish map sheet codes which will be introduced on the following lines. ON OUR PROJECT THIS SHOULD BE 0 BECAUSE FINNISH MAP SHEET NUMBERING SYSTEM IS NOT USED. In the TESTDATA.ALD there are 2 map sheet numbers, which are shown on the next 2 lines. In our case, there will be no following map sheet code lines. Format I8.
5. The next line after the map sheet numbers (or in our project line number 5) tells the coordinate unit in meters. In this example, the coordinates are given in meters, and that is shown with 1 on this line. If the coordinates were given in kilometers, there would be 1000 in this line. Or if you present coordinates in yards or something very special, this tells how to change the coordinate unit to meters.
6. The next 4 lines tell the corner coordinates of the area. First Northing, then Easting on each line. Order: 1.South-West, 2.SE, 3.NE, 4.NW
7. Next line is a separator. Put 10 or more =-marks to this line. So it looks like this:

```
==================================
```

After the separator line we describe the fields. The fields are descibed on lines with 5 columns. COLUMNS:

COL 1. POSITIONS 1 - 8. The name of the variable for SPSS statistical program or a special code for coordinate fields. The Northing coordinate must be marked with x (really x not y) on this column. The Easting coordinate must be marked with y (really). All the other fields may have name of 1-8 characters including letters A, B, C...Z, digits 0,1,..,9 or special marks @, #, $ and _.

COL 2. POSITION 9. The type of the variable with the following codes, please use CAPITAL LETTERS:
A = Alphanumeric field
I = Integer
F = Real (floating point)

COL 3. POSITIONS 11-25. Name of the variable.

COL 4. POSITIONS 26-35. Unit (or empty).

COL 5. POSITIONS 36-50. Fortran format, e.g. T36,F8.3

COMMENTS STARTING WITH !-MARK POSITIONS 51-80. Put the detection limit here.

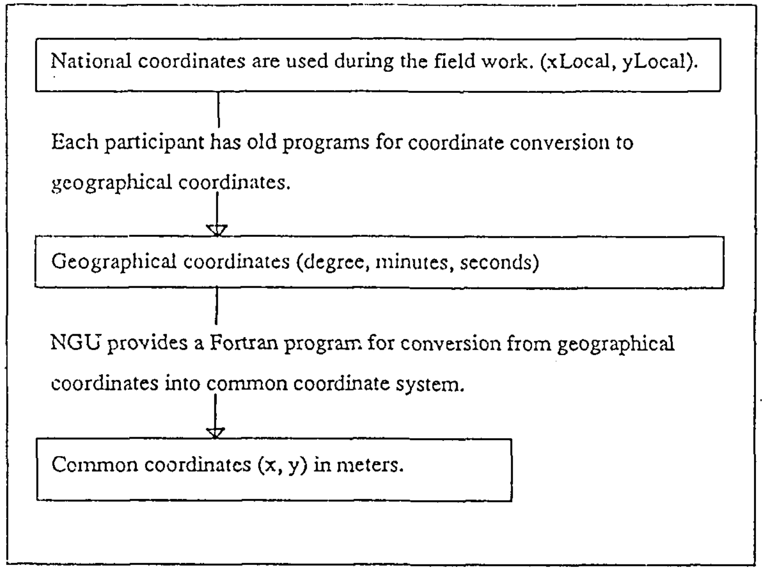
Example:

```
123456789 123456789 123456789 123456789 123456789 123456789 123456789
Cu       F Cu (ICP,Fin)   ppm       T62,E9.3       ! DLimit = 5
```

```
TESTDATA.ALK
SAMR
This is a line for comments
    2
4222
4224
    1
  6952915.        4430481.
  6952915.        4497201.
  6975257.        4497201.
  6975257.        4430481.
========================================
osasto  A Osaston lyhenne           T1,A1          ! Column 1 = name for SPSS
nimimerkA Nimimerkki .              T2,A4          ! Col 2 = type (A,I,F)
vuosi   A Näytteenottovuo           T6,A2          ! Col 3 = longer name for va
havtyyp A Havainnon tyypp           T8,A1          ! Col 4 = unit (m,ppm,%,..)
havnro  A Havaintonumero            T9,A6          ! Col 5 = Fortran-format
naytenroA Näytenumero               T15,A3
x       F Northing-coord m          T18,F8.0       ! In many countries called y
kaista  I Kaistanumero              T26,I1         ! but please put x and y lik
y       F Easting-coord  m          T27,F7.0       ! this in FIRST column
kl100   A Kartta100                 T34,A4
kl20    A Kartta20                  T38,A2
aines   A Aines                     T40,A2         ! Col 1 = Positions 1-8
maannos A Maannos                   T42,A1         ! Col 2 = Position 9
naytotinA Näytteenotin              T43,A1         ! Col 3 = Positions 11- 25
rinnayteA Rinnakkaisnäyte           T44,A1         ! Col 4 = Positions 26-35
yhdnayteA Yhdistetty näyt           T45,A1         ! Col 5 = Positions 36-50
lajite  A Lajite                    T46,A1         ! Comments pos 51..80
uusinta A Uusinta                   T47,A1
Pvm_511PA Anal. pvm 511P            T052,A8        ! comments start with !-mar
Cu_511P F Cu (511P)      ppm        T062,E9.3      ! DLimit=5 ppm
Cu_qual A Cu qualitycode            T71,A1         ! no qualitycodes in our files
Ni_511P F Ni (511P)      ppm        T074,E9.3      ! DLimit=5 ppm
Ni_qual A Ni qualitycode            T83,A1
```

APPENDIX

COORDINATE SYSTEM



National coordinates are used during the field work. (xLocal, yLocal).

Each participant has old programs for coordinate conversion to geographical coordinates.

Geographical coordinates (degree, minutes, seconds)

NGU provides a Fortran program for conversion from geographical coordinates into common coordinate system.

Common coordinates (x, y) in meters.

Appendix 4.

Geological Survey of Finland
Regional Office of North Finland
Joint Ecogeochemical Project
8.4.1992 /MÄ

The financing of the ecogeological joint project between Norway, Finland and Kola Peninsula (main project)

For applying financing for the main project, it was decided, that a preliminary project plan will be prepared.

The aim of the project is to map the ecogeological state in Northern areas in Norway, Finland and Kola Peninsula and after that to monitor the spreading of pollutants.

The project will be applied to be connected to Arctic Monitoring and Assessment Program (AMAP).

Rolf Tore Ottesen writes a project proposal: plan, organization and budget (total and cost/km^2). A letter, informing the decision in Russia to start the ecogeochemical mapping in the scale of 1:1 000 000 in Western Kola Peninsula area, will be appended.

Matti Äyräs collects the background materials for the project proposal: earlier maps, publications, papers to be published, memorandums and drafts, and writes a common text about those papers.

The project proposal and background material is delivered to par-

MEMORANDUM

of the discussion of the project for Joint Ecogeochemical Mapping and Monitoring in the West Murmansk Region and Contiguous Areas of Finland and Norway held at Neiden/Kirkenes, Norway on May 21-22 1992.

Participants.
Sergeij Sergeevich Latonin, Central Kola Expedition,
Vladimir Aleksandrovich Pavlov, Central Kola Expedition,
Matti Äyräs, Geological Survey of Finland, and
Tor Erik Finne, Geological Survey of Norway.

The meeting was arranged according to the Memorandum of meeting held in Rovaniemi March 24-26 1992, and later change of dates decided by telephone. The purpose of the meeting was to further discussions on details of field observations; plan for presentation at International symposium in Rovaniemi, October 1992, and clarification of details for international excursion in end of July. Prior to this meeting, there had been an exchange of snow samples at border station Boris Gleb, on 22 april 1992.

The following conclusions were made:

Exchange of materials: Russia provided 1.2Mb diskettes containing field observations (geographical coordinates) and analytical results for Russian snow water&filter samples. Finland provided 1.44Mb diskettes containing field observations (local coordinates) of Finish snow samples. Norway provided 1.2Mb diskettes containing field observations (common UTM 36 coordinates) of Norwegian snow samples, files giving coordinates for digitized base map, and Fortran routines converting geographical coordinates to UTM coordinates and vice versa. Also included were foil originals of the digitized base map, as well as color and black and white versions of the map sheet "Kirkenes 51 D" in the scale of 1:500000.

Oral presentation in Rovaniemi symposium on snow studies in the surroundings of Monchegorsk: The number of data sets at hand are to high to fit in the context of a single presentaion. Presentation should concentrate on essential data, and supplementary data should be given in an accompanying poster.

Details on international excursion in July: Tentative details of program include:

2707	Discussions
2807	Field demonstration of soil sampling/field description in Nikel area and Nikel-Zapolyarny area
2907	Early departure for Norway and field demonstration of overbank sediments and stream sediments
3007	Early departure for Finland and field demonstration of terrestrial moss sampling and stream water sampling.
3107	Conclusion and departure

It should be aimed to demonstrate selection of sample sites of all sampling media in all three countries.

Terminology of field description: A number of terms were described and discussed to increase a common understanding of the questions/answers contained in the field description documents. A number of terms still need clarification during the international excursion.

Size of field samples and export of materials: Clarification was done with regard to how much material and degree of preparation for export to analysing laboratory. The following table summarizes:

Sampling medium	Export to			Sum/site
	Finland	Norway	Russia	
(Snow	3 kg	0	5 kg	8 kg)
Terrestrial moss	2 l/ 30 g (dw)	0	0	0.1 kg
A_0 horizon	1.5 kg	1.5 kg	1.5 kg	4.5 kg
A_{0+2} horizon	0	0	2 kg	2 kg
C horizon	2 kg	2 kg	2 kg	6 kg
Stream water	100 ml untreated 100 ml treated	0	0	0.2 kg
Stream sediments	3 kg	3 kg	3 kg	9 kg
Overbank sediments top	0	10 kg	0	10 kg
Overbank sediments bottom	0	10 kg	0	10 kg
Sum/*20 samples	6.8/136	26.5/530	8.5/170	41.8/836

When nothing else is indicated, samples will be exported untreated, so that lab can do preparation uniformly for its own set of samples to be analyzed.
Terrestrial moss: Preferrably dried at maximum 40 °C
A_0 horizon: As above
A_{0+2} horizon: As above
Stream water: Keep cool. Treatment: Filter 0.45μm, 0.5ml suprapure HNO_3/100ml
Stream sediments: Remove rubble in field
Overbank sediments: Store in strong plastic sacks

Tor Erik Finne
Tor Erik Finne

Sergeij Latonin

Vladimir Pavlov

Matti Äyräs

MEMORANDUM

of the field excursion for the project "Joint Ecogeochemical Mapping and Monitoring in the Murmansk Region and Contiguous Areas of Finland and Norway", at Nikel area, Russia, Tårnet-Neiden area, Norway, and Sevettijärvi-Partakko area, Finland on July, 27-31, 1992.

Participants:
Tor Erik Finne, Geological Survey of Norway
Arve Misund, Geological Survey of Norway
Tore Volden, Geological Survey of Norway
Magne Ødegård, Geological Survey of Norway
Valentina Lagunova, Murmansk Expedition
Vladimir Pavlov, Central Kola Expedition
Evgeniy Semenov, Central Kola Expedition
Matti Äyräs, Geological Survey of Finland
Heikki Niskavaara, Geological Survey of Finland
Ulpu Väisänen, Geological Survey of Finland

The excursion was arranged according to the Memorandum of the meeting in Rovaniemi, May 21-22, 1992. The purpose of the excursion was to discuss details of the project, methods of sampling and analyses, and to demonstrate sampling in all three countries. Other aims were to discuss further stages of the project, as well the symposium in October 6-8, 1992, in Rovaniemi

Schedule of the excursion

July, 27	Meeting of all parties at Boris Gleb border station and travel to Nikel. Discussion in Nikel. Main topic: defining terminology.
July, 28.	Demonstration in the field at Nikel area. Sampling A_0, A_0+A_2, and C horizons. Visit to the surroundings of Nikel and Zapoljarny. Discussion in Nikel about sampling, terminology, and the code system.
July, 29.	Departure for Norway. Demonstration of sampling overbank sediments at Tårnet, Norway. Discussion in Neiden about problematic sample sites. Demonstration for finding ideal sample sites on topographic maps 1:50 000. Presentation of the results of snow sample analyses Watching video films made in the field by Norwegian colleagues.
July, 30.	Departure for Finland. A visit to a research station of monitoring air quality, at Sevettijärvi. Demonstration of sampling terrestrial moss, stream sediments, and stream water at Partakko. Discussion in Inari. Topics between geologists: sampling, progress of the project, and the schedule. Topics between chemists: analyses and the methods in the laboratory. Discussion of the results of snow sample analyses.
July, 31.	Conclusions of the field excursion. Departure.

Topics of discussions and conclusions in the field excursion

MOTTO: "You must think".

- defining the code list and terminology
- classification of vegetation zones in Norway, and its applicability to the Russian classification
- sampling, its problems, and finding ideal sample sites
- contamination in sampling
- methods of analyses
- use of western European data forms, especially for overbank sediments
- problems in changing information between countries

Conclusions:

- the final code system will be decided after the pilot project
- duplicate samples should be taken in the vicinity of the main sample, at the most in the distance of 100 m
- sampling A_0, $A_0 + A_2$, and C horizons: thickness of a sample (combination of five subsamples) is mean value of subsamples; at least one subsample should be taken under a tree
- sampling overbank sediments: thickness of top sample is 10 cm
- some changes in the weights and volumes of samples were made; changes are seen in the next table

Sampling medium	Finland	Export to Norway	Russia	Sum/site
(Snow	3 kg	0	5 kg	8 kg)
Terrestrial moss	20-30 g (dw)	0	0	0,1 kg
A_0 horizon	1.5 kg	1.5 kg	1.5 kg	4.5 kg
A_{0+2} horizon	0	0	2 kg	2 kg
C horizon	2 kg	2 kg	2 kg	6 kg
Stream water	500 ml untreated 100 ml treated	0	0	0.6 kg
Stream sediments	0	3 kg	3 kg	6 kg
Overbank sediments top	0	(2-)3 kg	0	(2-)3 kg
Overbank sediments bottom	0	5 kg	0	5 kg
Sum/*20 samples	4.2/82	14.5/290	8.5/170	27.2/544

Decisions for analyses

Samples of A_0 horizon:
- samples will be dried
- homogenized (<1 mm)
- ashing 450°C, slow heating 12-15 hours
- sieving <0.07 mm
- weighing a) grain size <0.07 mm
  b) grain size >0.07 mm (waste)
- grinding organic rich material, grain size <0.07 mm
- analysing a) $HF-HClO_4-HNO_3$ (Russia)
  b) 7M HNO_3 USEPA (Russia/Norway)
  c) analysing the total sample without ashing HNO_3, 3051, USEPA (503P) (Finland)

Samples of C horizon:
- split to two parts, sieving of both splits
  a) grain size <0.07 mm
  b) grain size <2 mm ISO standard
  Norway: 7M HNO_3
  Russia: $HF-HClO_4-HNO_3$
  7M HNO_3
  Finland: $HCl-HNO_3$

Schedule of the project

Sampling begins: Norway, August 25.
Russia, August 15.
Finland, August 17

Delivering the samples to the other parties Septempber 8. at 13.00 project (Finnish) time at Boris Gleb border station.

Discussions about the main project in Rovaniemi, October 6-8, at SYMPOSIUM ON THE STATE OF THE ENVIRONMENT AND ENVIRONMENTAL MONITORING IN NORTHERN FENNOSCANDIA AND THE KOLA PENINSULA.

A poster of snow sample analyses for the symposium will be made by Tor Erik Finne and Matti Äyräs.

Results of analyses will be recorded on the diskettes by the end of November, and will be mailed to all parties.

Reporting the pilot research: each party writes a draft by the end of the year 1992.

The common report will be compiled, and the presentation of the pilot project will be in February (6. week) 1993 either in Montshegorsk, Russia, or in Svanvik, Norway

Evgeniy Semenov Tor Erik Finne Matti Äyräs

Memorandum made by Ulpu Väisänen

MEMORANDUM

of the meeting of the project for Joint Ecogeochemical Mapping and Monitoring in the West Murmansk Region and Contiguous Areas of Finland and Norway held at GSF, Rovaniemi, Finland on October 8 1992.

Participants:

Brian Sturt, Tor Erik Finne, Arve Misund and Victor Melezhik, Geological Survey of Norway;

Alexey Lebedev, Murmansk District Committee for Geology and Sergei Latonin, Central Kola Expedition;

Reijo Salminen, as chairman and Matti Äyräs, as moderator, Geological Survey of Finland.

The discussions were held according to the list of topics, enclosed as appendix.

1. The aim of the main project

Possibilities of connecting the project to Inter-Nordic moss monitoring programme's next sampling in year 1995 were discussed. The connection is difficult due to the time schedule of the ecogeochemical project, but the preparation for connection will be continue. For the main project it was decided that the aims are: 1. environmental mapping and 2. monitoring using some material: e.g. snow, humus and remote sensing. More dense sampling is needed around the industrial areas, e.g. in Nickel, Kirkenes, Kemi-Tornio area etc. It was decided, for monitoring, that the humus samples of Nordkalott-project (1982-83) will be reanalysed in the density of 1 sample/300 km^2 in GSF's laboratory with financial support of Norway. Also the humus samples taken in cooperative work between Norway and Russia in Northern areas will be reanalysed. For connection to AMAP, Tor Erik Finne will contact the secretariat of AMAP and sends the information about AMAP to Monchegorsk Expedition/Darkschevich.

2. Decision about the main project

The financial support for the main project is not yet ready. The discussions for the financy will be continue. Details for the main project will be decided after the pilot-project reporting in spring 1993. It was decided, however, that the snow samples will be taken in the main project area during winter 1993; the exact sampling time will be decided in the meeting to be held in Svanvik (week 10, 1993). For the snow research each participant institution will mark the planned sampling points on maps and the details of the work will be discussed in Svanvik meeting.

3. Financing of the main project

Norwegians have leaved the application to the Norwegian Ministry of Environment, but they have not received any decision yet. Russians needs support for application of money. In Finland the financing will be partly GSF's own and partly external (not yet applicated). It was decided that the main project can start, however. The extend depends on the financing.

4. Organization of the main project

The participant delecations accepted the Norwegian proposal for organizing the project; steering group as mentioned in Norwegian application of financing. The leader of the project will nominated after the pilot project.

5. Sampling density and sampling area

The sampling density will be 1 sampling point/300 km^2; more dense around industrial areas. The extent of the main project area as decided earlier in Monchegorsk meeting, extending to the Kemi-Tornio area in Finland.

6. The materials of the main project

The sampling materials for main project will be decided after the reporting of pilot-project and according to results of pilot-project . The possible materials are for example: snow, humus and moss.

7. Contacts between participants

For contacts between participants the international E-mail will be used. In future the contacts will be better due to the works of telecommunication services in Norway and Finland. It is possible to use international transport services for sample delivering. Negotiations for the transport will be carried out both in Finland and Norway (Finne & Äyräs).

8. Reporting of the pilot-project

The report of the pilot-project will be "technical" one. A small change in time schedule was decided: the national reports will be delivered to every participantat the end of January 1993 and the common report will be prepared in three days meeting in Svanhovd, Svanvik, Norway in March (week 10) 1993. The common report will be delivered to all participating organizations.

. Randomization of samples

It was decided that the samples should be randomizized before analysing.

10. The common database

The participants accepted that the common database will be done as proposed in Norwegian financing application.
In each participant country all available data will be included in national databases.

On the behalf of the participanting organizations

Brian Sturt	Alexey Lebedev	Reijo Salminen
Norway	Russia	*Finland*

Appendix 6

Murmarsk & Central Cola Expeditions
Joint Ecogeochemical Project
20.04.1992

List of terms and codes for database

Code		Term
1		**Sampling media (kind of sampling)**
	1	Stream sediments
	2	Organic soil(A0-horizon)
	5	Mineral soil(C-horizon)
	8	Terrestrial moss (<u>Hylocomium splendens</u>)
	9	Snow cover
	10	Stream water
	11	Overbank sediments top ("present day")
	12	Overbank sediments bottom ("pre-industrial")
	13	*Combination of soil horizon A0+A2*
2		**Number of sample**
	0001..1999	Finland
	2001..3999	Norway
	4001..9999	Russia
3		**Field duplicate**
	0	Main sample
	1..9	Duplicate sample
4		**Northing coordinate X (m)**
		In common coordinate system transferred via geographical coordinates
5		**Easting coordinate Y (m)**
		Transferred like X -coordinate
6		**Coordinate Z (m)**
		Altitude
7		**Duplicate weighing**
	0	Main weighing
	1..9	Duplicate weighting
8		**Duplicate analysis**
	0	Main analysis
	1..9	Duplicate analysis
9		**Area relief (300 km^2)**~~The degree of [illegible]~~
	1	0..50 meters
	2	50..100 meters
	3	100..300 meters
	4	More than 300 meters
10		**Local topographic element** ~~Element of relief~~
	1	Top of hill
	2	Slope of hill
	3	Thalweg of hill slope
	4	River or lake terrace
	5	Flood - lands of river
	6	Shore of lake
	7	River - bed
	8	Shore of bog
	9	Swamp
11		**Density of forest**
	1	There is no forest
	2	A sparse wood
	3	A mean density of forest (the distance between trees is more than 10 m)
	4	A high density of forest (the distance between trees is less than 10 m)
12		**Snow depth (dm)**
13		**Sum of core lengths (dm)**
14		**Number of cores**
15		**Snow mass (kg)**
16		**Day of sampling**
17		**Month of sampling**
18		**Year of sampling**
19		**Vegetation zone**
	1	Arctic tundra
	2	Mountainous tundra
	3	Arctic forest -tundra
	4	Mountainous forest -tundra
	5	Northern taiga
	6	Mountainous northern taiga
	7	Upper swamp
	8	Transitional swamp
	9	Lower swamp
20		**Kind of relief**
	1	Plane, cutting, weakly cutting planes (sea,lake -aluvial, moraine) with relativ change of altitude to 20(50) meters.
	2	Weakly cutting accumulative planes (are characterised by spreading of low hill -ridge -circular, ozo -cam and accumulative moraine mezorelief).
	3	Middle cutting hill and hill -ridge plains, low varakas with absolute points to 200..300 meters and relative changes of altitude to 100..150 meters.
	4	Middle cutting hill planes and low varakas with hill -ridge mezorelief (are characterized by spreading hill -moraine and ozo -cam relief).
	5	Strong cutting relief (low mountains -tunturies and high varakas with absolute points more 300 meters and relative changes of altitude more 100..150 meters).
21		**Kind and thickness of Q cover**
	1	Monostratum section Q deposits(0..5 m).
	2	Small thickness (0..5 m).
	3	Great deposits with simple structure (thickness 10..20 m)
	4	Polystratum section Q deposits large thickness 20..40 m
22		**Geological position**
	1	Gneises of Central Kola block
	2	Laplandic granulate
	3	Pechenga greenstone belt
	4	Granitoides of Murmansk block

23		**Character of vegetation**
	1	Bushes tundra
	2	Lichen tundra
	3	Moss tudra
	4	Moss -grass tundra
	5	Birch thin forest
	6	Overgrown with willow
	7	Juniper thin forest with birch
	8	Northern taiga forest with fir
	9	Northern taiga forest with pine
	10	Northern taiga forest of mixed type (fir,pine,birch)
	11	Birch forest
	12	Grassy, moss -grassy swamps
	13	Bushes, moss -bushes swamps
	14	*Transitional(forest) swamps*
	15	Swamps with pine islands
	16	Swamps with fir islands
	17	Dry plane meadow
	18	Flooding meadow
	19	Agricultural fields
24		**Elementary landscape**
	1	Eluvial(autonomous)
	2	Transeluvial
	3	Superacvial
	4	Subacvial
	5	Accumulative eluvial
	6	Technogenic industrial
	7	Technogenic agricultural
	8	Technogenic of human life
25		**Type of moisture**
	1	Automorfic (airal, dry)
	2	Semihydromorfic (superacvial, moistureal)
	3	Hydromorfic(subacvial,saturated with water)
26		**Genetical type of Q deposits**
	0	Genesis is unknown
	1	Eluvial (ancient crust of wearthering)
	2	Moraine
	3	Water -glasial
	4	Sea sediments
	5	Deluvial (modern)
	6	Lake sediments
	7	Alluvial
	8	Swamp
27		**Soil horizon**
	1	Vegetation
	2	A0 -Vegetable badding
	3	A -Humus
	4	A1 -Mineral accumulative humus
	5	A2 -Podzole
	6	B -Illuvial
	7	G -horizon
	8	*C -Unalterated Q deposits*
	9	D -Bedding cristal rock
28		**Litological composition**
	1	Silt -clay
	2	Clay
	3	Sand -clay
	4	Clay -sand
	5	Thin grained sand
	6	Middle grained sand
	7	Large grained sand
	8	Gravel sand
	9	Various grained sand
	0	Peat
29		**Thickness of horizon (sm)**
30		**Moistureal**
	1	Dry
	2	Moistureal
	3	Saturated with water
31		**Depth (interval) of sampling (dm)**
32		**Contents of admixture (organic or mineral) %**
33		**Size of single pit for sampling (dm)**
34		**Number of pits for sampling**
35		**Distance between pits for sampling**
36		**Position in relief**
	1	Water -shed
	2	Slope
	3	Valley
	4	Terrace
37		**Kind of vegetation**
	9	Feather moss
38		**Vegetation part for sampling**
	8	Stems with leafs
39		**The percent of areal distribution (10 %)**
40		**Distribution of vegetation in society**
	1	Regular
	2	Spots with diffuse borders
	3	By groups
41		**Vegetation levels**
	1	Tree
	2	Bushes
	3	Grassy -bushes
	4	Moss - lichen

42 **Name of drainage basin**
1 Patsa -joki
2 Pechenga
3 Titovka
4 West Litza
10 Verchnetulomsky reservoir
11 Lotta

43 **Object of sampling**
1 Large rivers
2 Rivers of 2..3 orders
3 Rivers of 1..2 orders
4 Lakes

44 **Volume of water (liters)**

45 **Speed of stream (m / sec)**

46 Debit (l / sec)

47 Temperature (degree C)

48

49 Taste of water
1 No Taste
2 Bitter
3 Salty
4 Metallic

50 Smell of water
1 Without smell
2 H2S
3 Swampy
4 Rotten

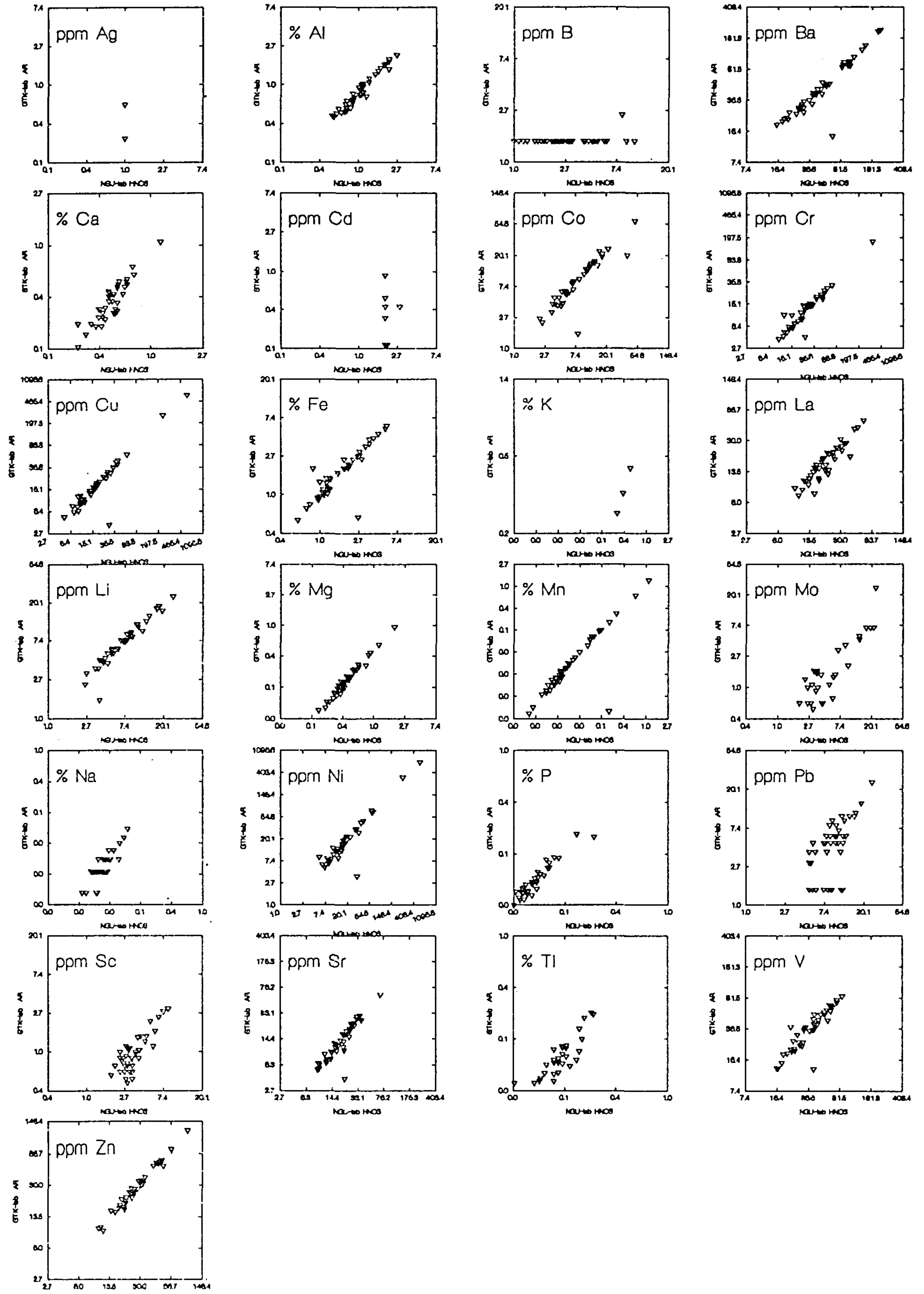
51 **Exposition of slope (degree)**

	NGU Project 63.2590.01	Stream sediment	Humus A0	Mineral C	Terrestial moss	Stream water	Comb.soil A0+2
2	Number of sample						
1	Sampling media (kind of sampling)	1	2	5	8	10	13
3	Field duplicate						
4	Northing coordinate X (m) UTM36						
5	Easting coordinate Y (m) UTM36						
6	Coordinate Z (m)						
7	Duplicate weighting						
8	Duplicate analyse						
9	300 km2 area relief	▨	▨	▨	▨	▨	▨
10	Local topographic element	▨	▨	▨		▨	▨
16	Day of sampling						
17	Month of sampling						
18	Year of sampling						
19	Vegetation zone						
20	Kind of relief						
21	Kind and thickness of Q cover						
22	Bedrock geology Geological position						
23	Character of vegetation ->41?						
24	Elementary landscape	▨				▨	
25	Type of moisture ?in the sample/area	▨			▨	▨	
26	Genetical classification of Q deposits						
27	Soil horizon	▨			▨	▨	
28	Grain size distrubution				▨	▨	
29	Thickness of sampled horizon (cm)	▨			▨	▨	
30	Moistureal in the sample/area	▨			▨	▨	
31	Depth of sampling (dm)				▨		
32	Contents of admixture (organic or mineral) %				▨	▨	
33	Size of single pit for sampling (dm)				▨	▨	
34	Number of pits for sampling/subsamples				▨	▨	
35	Distance between pits for sampling/subsample				▨	▨	
37	Vegetation species sampled	▨	▨	▨		▨	▨
39	Percentage of area sampled covered by specie	▨	▨	▨		▨	▨
40	Distribution of vegetation in socicty	▨	▨	▨		▨	▨
42	Name of drainage basin		▨	▨	▨		▨
43	Classification of water body		▨	▨	▨		▨
44	Volume of sampled water (liters)	▨	▨	▨	▨		▨
45	Speed of stream (m / sec)	▨	▨	▨	▨		▨
46	Water discharge (l/s)	▨	▨	▨	▨		▨
47	Temperature (grad C)	▨	▨	▨	▨		▨
48	Electric conductivity	▨	▨	▨	▨		▨
49	Taste of water	▨	▨	▨	▨		▨
50	Smell of water	▨	▨	▨	▨		▨
51	Exposition of slope (degree)?angle with horiz	▨	▨	▨		▨	▨

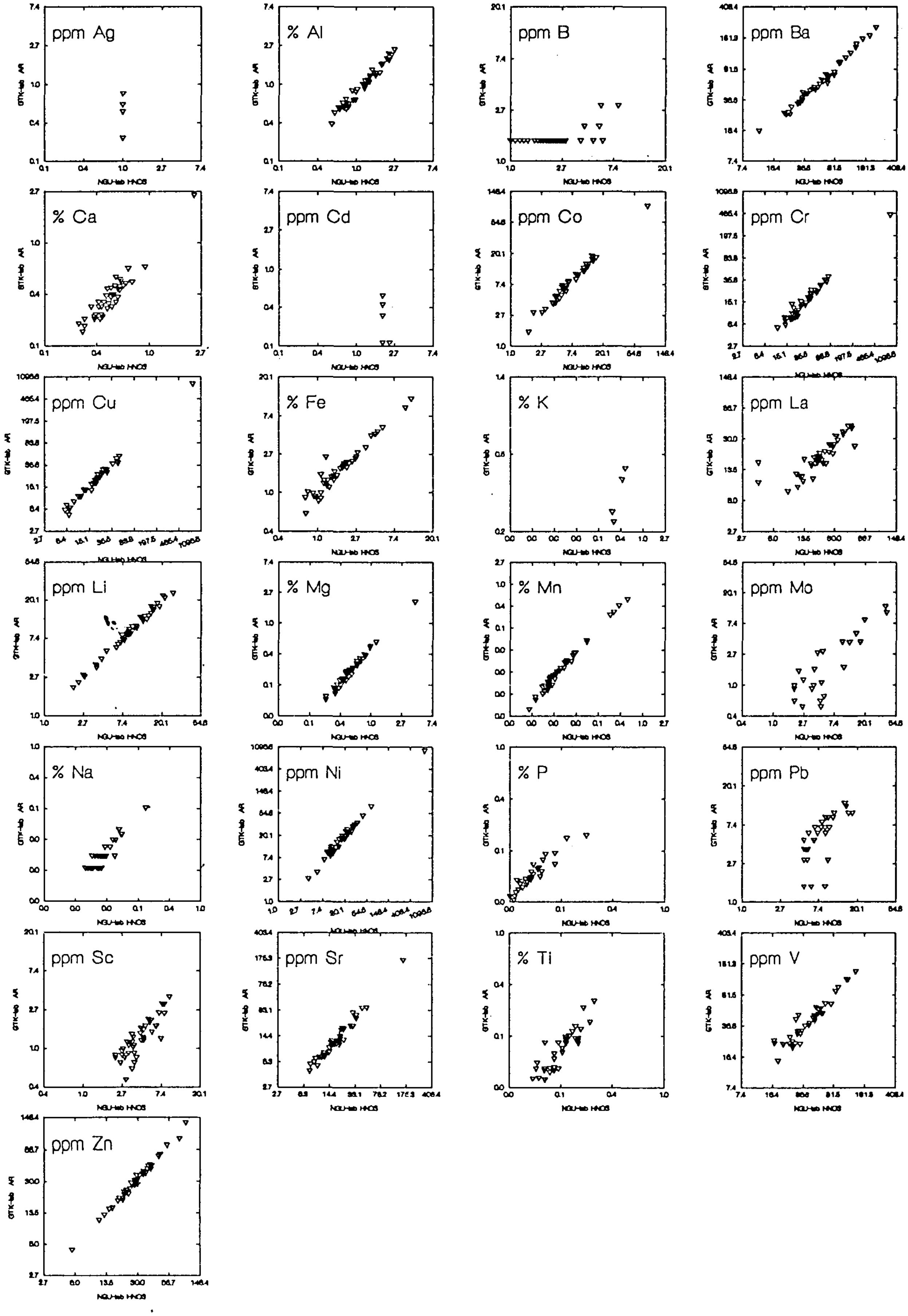
Code	Term	Observed
1	Sampling media (kind of sampling)	
2	Number of sample	
3	Field duplicate	
4	Northing coordinate X (m)	
5	Easting coorninate Y (m)	
6	Coordinate Z (m)	
7	Duplicate weighting	
8	Duplicate analyze	
9	The degree of relief dismemberment	
10	Element of relief	
11	Density of forest	
12	Snow depth (dm)	
13	Summary core length (dm)	
14	Number of cores	
15	Snow mass (kg)	
16	Day of sampling	
17	Month of sampling	
18	Year of sampling	

NUMBER SYSTEM	
Sample number (field)	
Random number (lab)	
Coordinates (UTM)	
PROFILE DESCRIPTION	
Samplin depth	
Sedimentary structures	Layering: Graided bedding: Organic material: Other:
Ground water	
Soil colour	
Hight of the deposit	
Objects for dating	
Type of material at the base of the deposit	
SITE DESCRIPTION	
Channel width	
Channel depth	
Channel type	Straight: Meandering: Braides: Fan:
Valley width	
Area of riverplain	
Terrasses	
River bed material	
DRAINAGE BASIN DESCRIPTION	
Geology	
Overburden	
Floods	
River regulations	
Major pollution sources	
ANNET	

Overbank sediments top NGU & GTK Lab

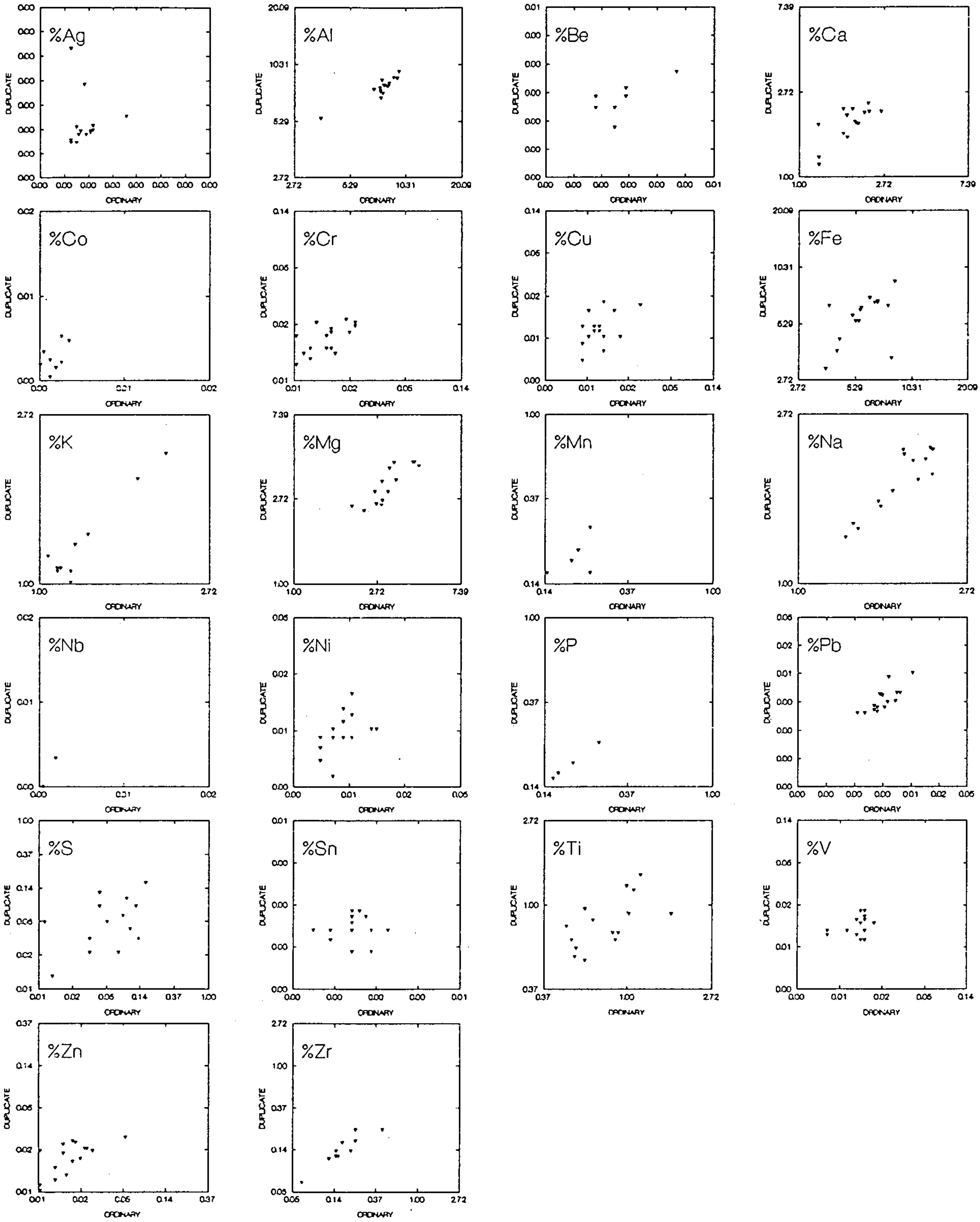


Overbank sediments bottom NGU & GTK Lab

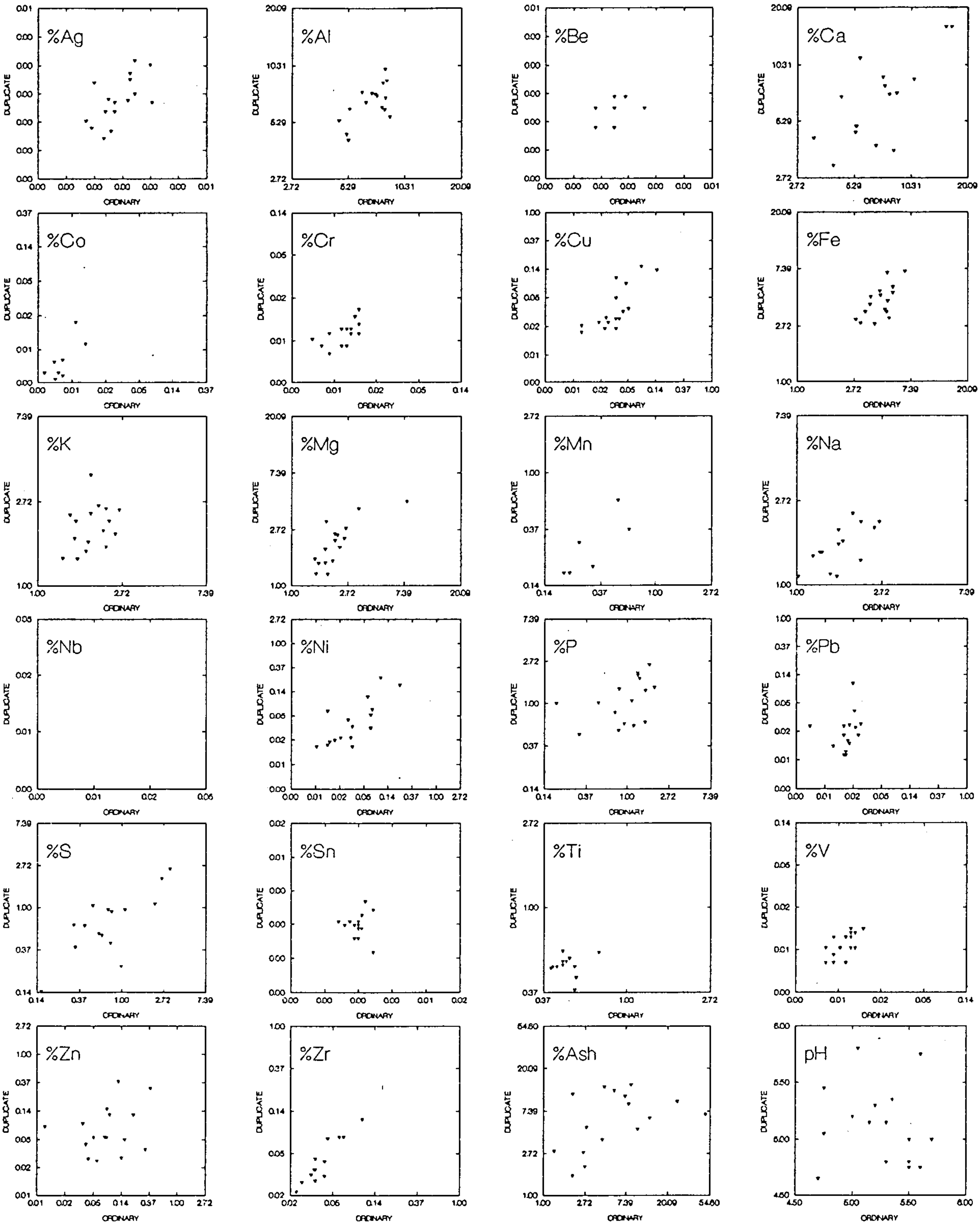


RUS: 01 Stream sediments

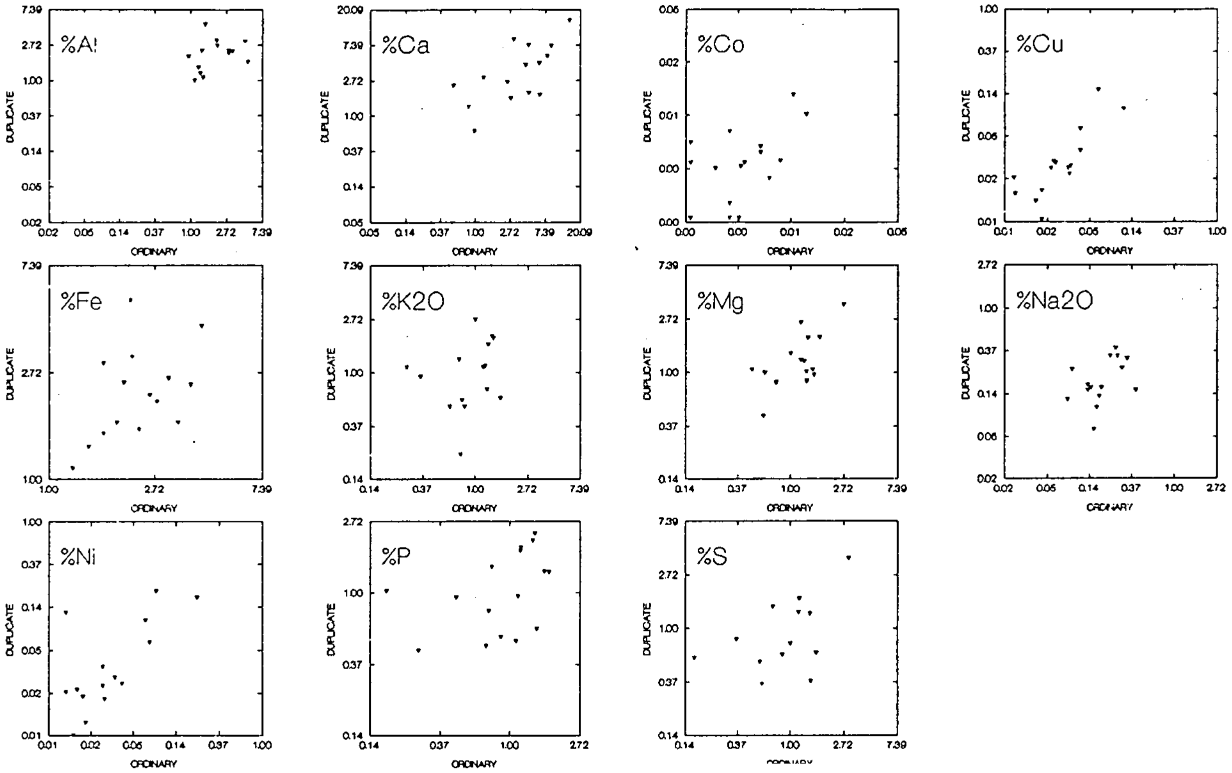
Field duplicates



RUS: 02 Humus Total **Filed duplicates**

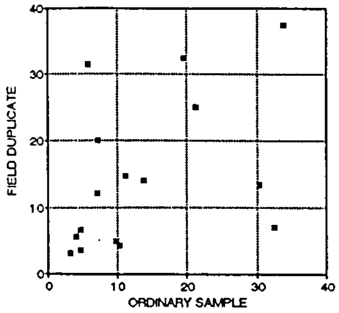


RUS: 02 Humus Partial Field duplicates

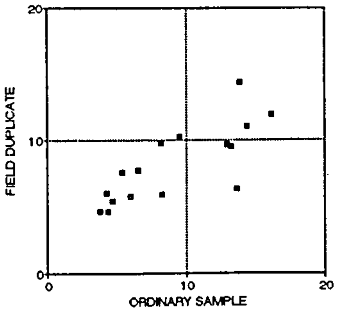


RUS: 13 Topsoil

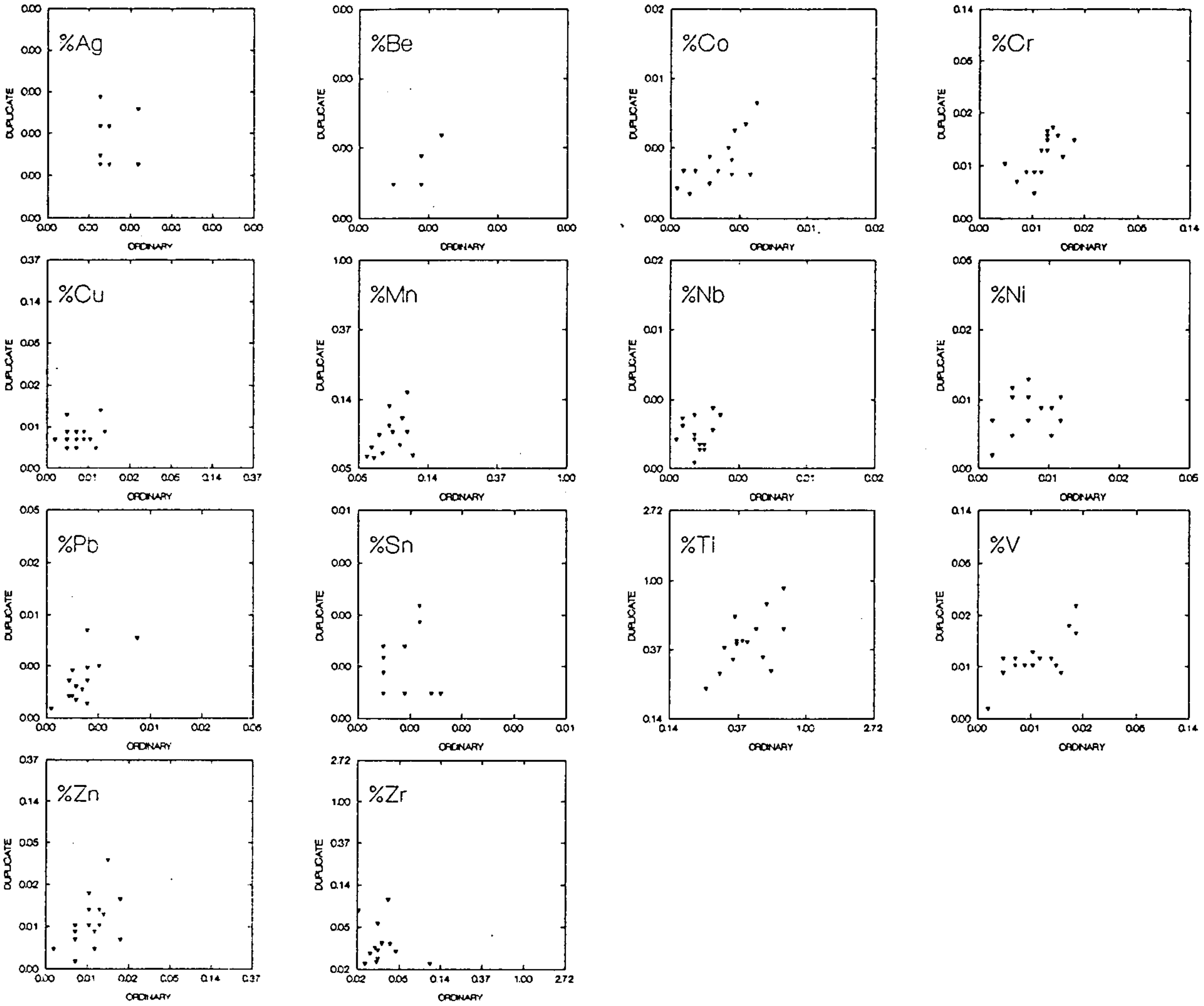
Cs 137 activity Ci/kg



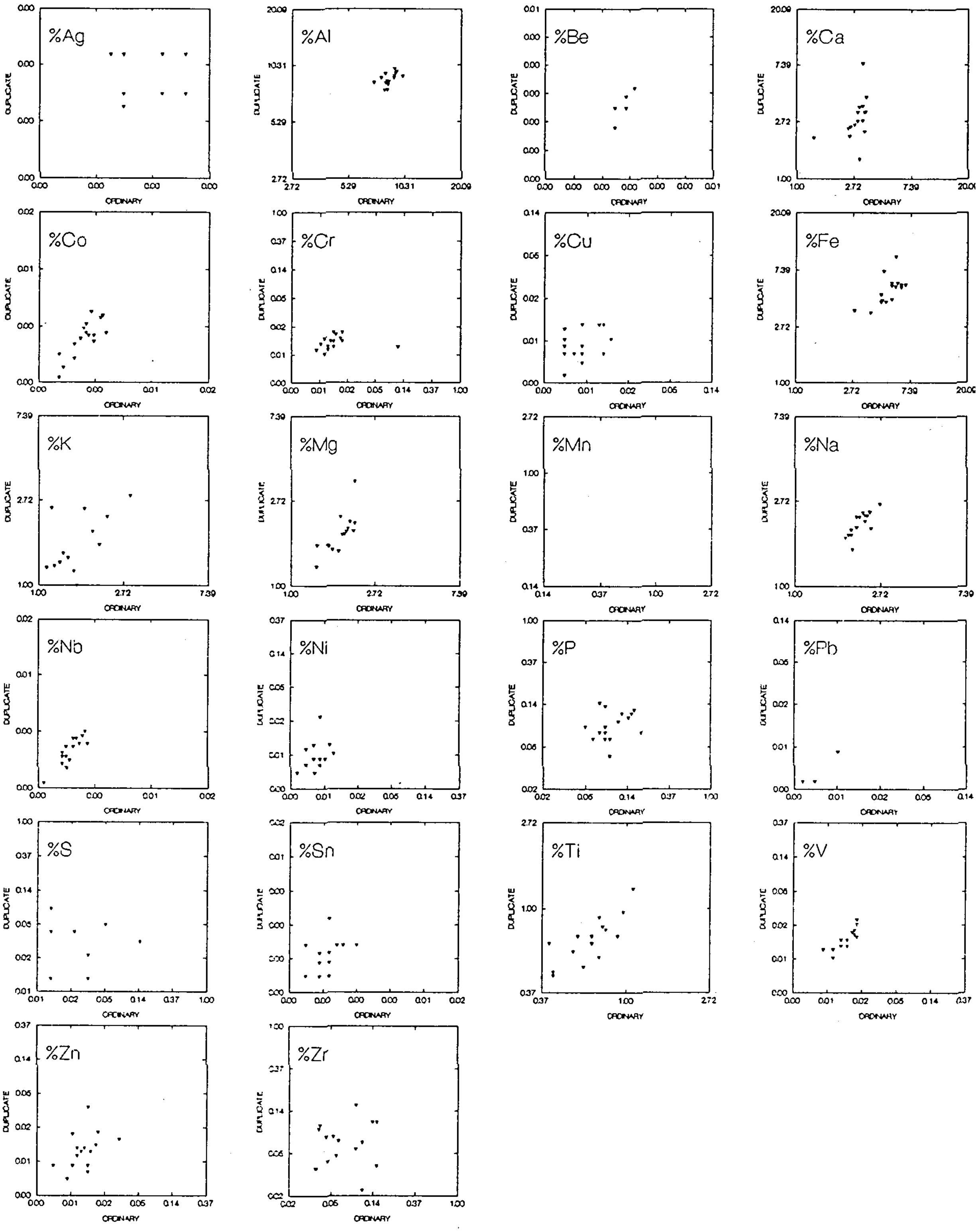
Cs 134 activity Ci/kg

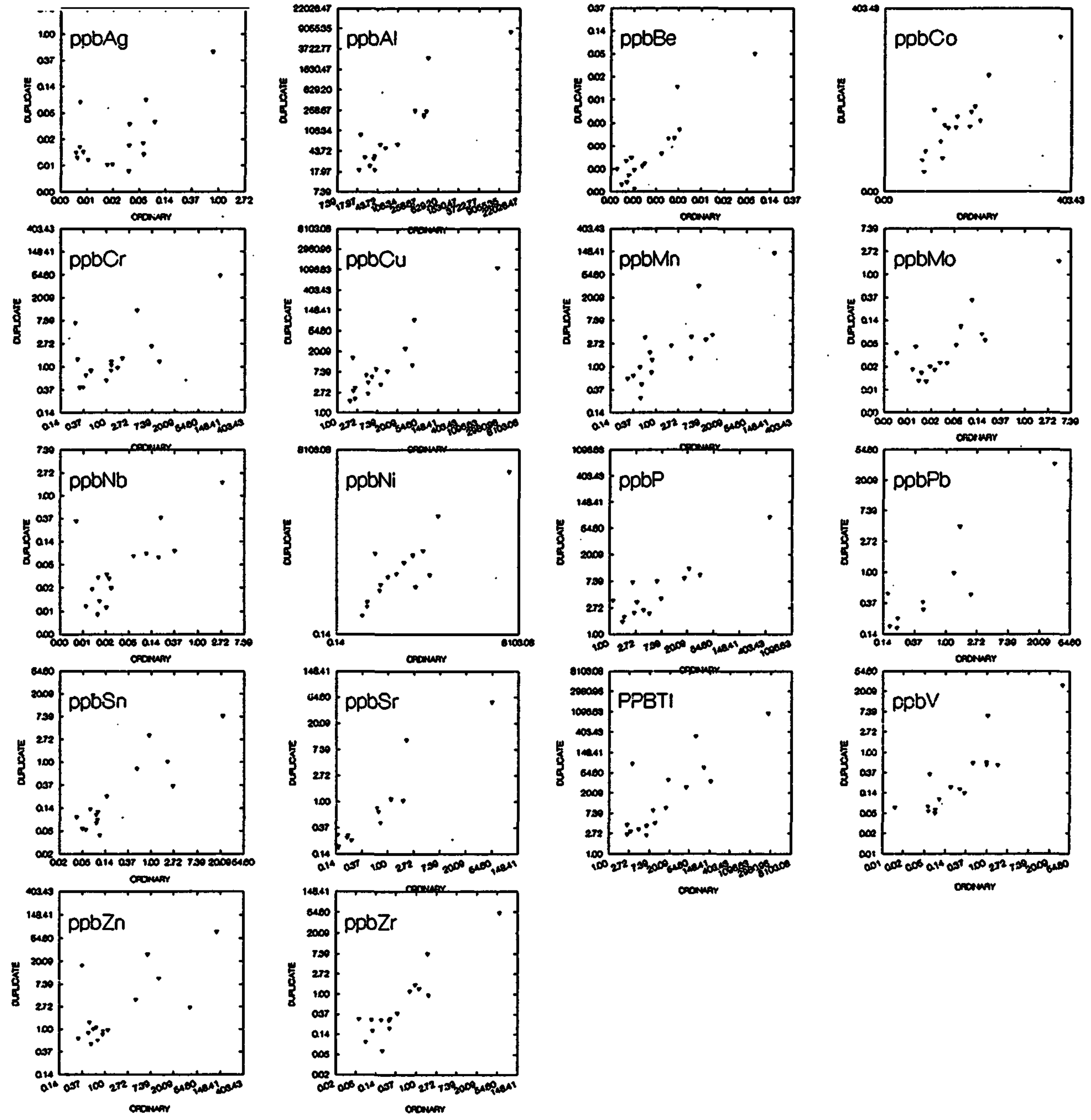


RUS: 05 C-soil <2mm Total Field duplicates



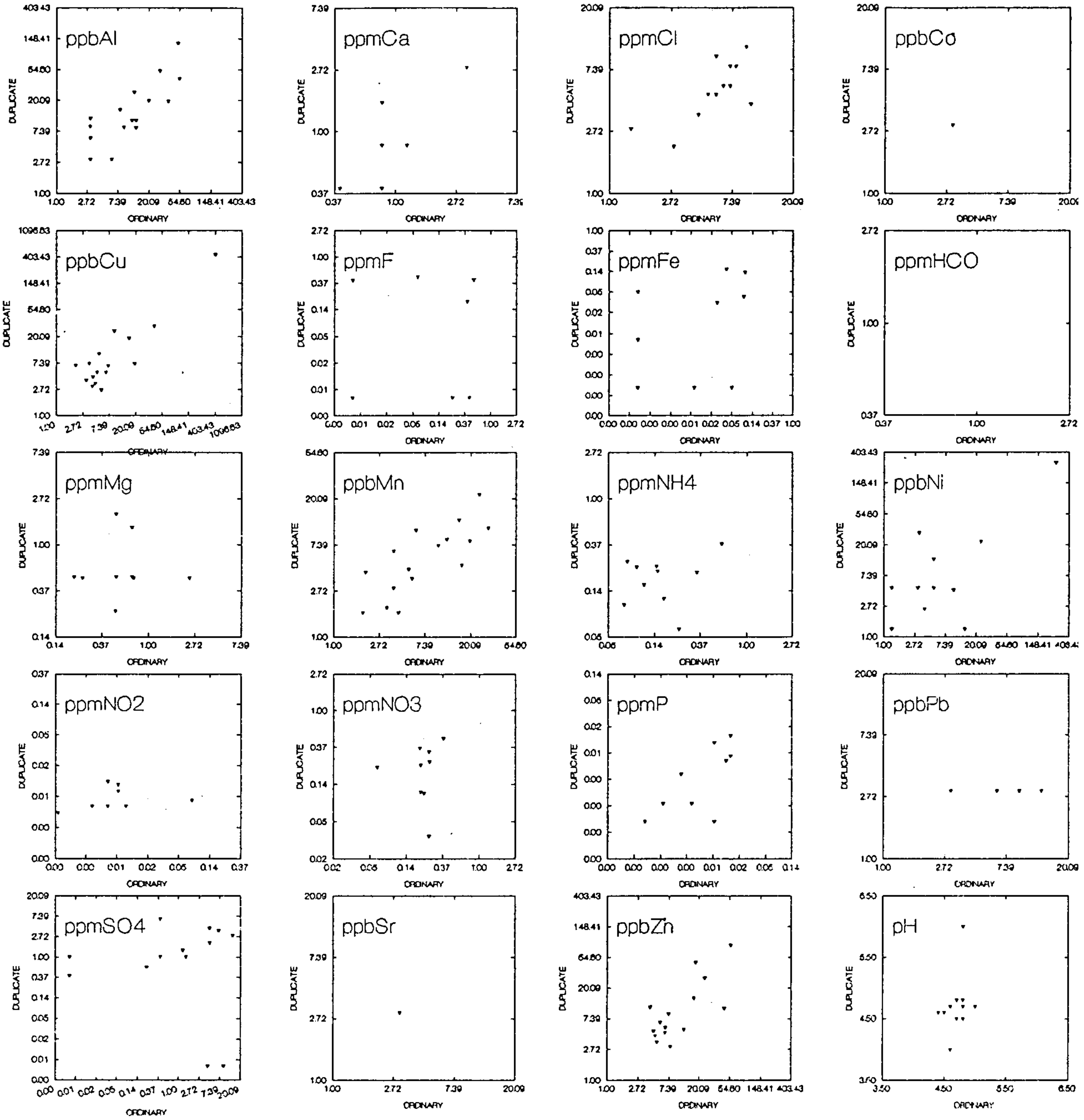
RUS: 05 C-soil -.07mm ~~Partial~~-Total Field duplicates




ppbAg
ppbAl
ppbBe
ppbCo
ppbCr
ppbCu
ppbMn
ppbMo
ppbNb
ppbNi
ppbP
ppbPb
ppbSn
ppbSr
PPBTI
ppbV
ppbZn
ppbZr
DUPLICATE
ORDINARY

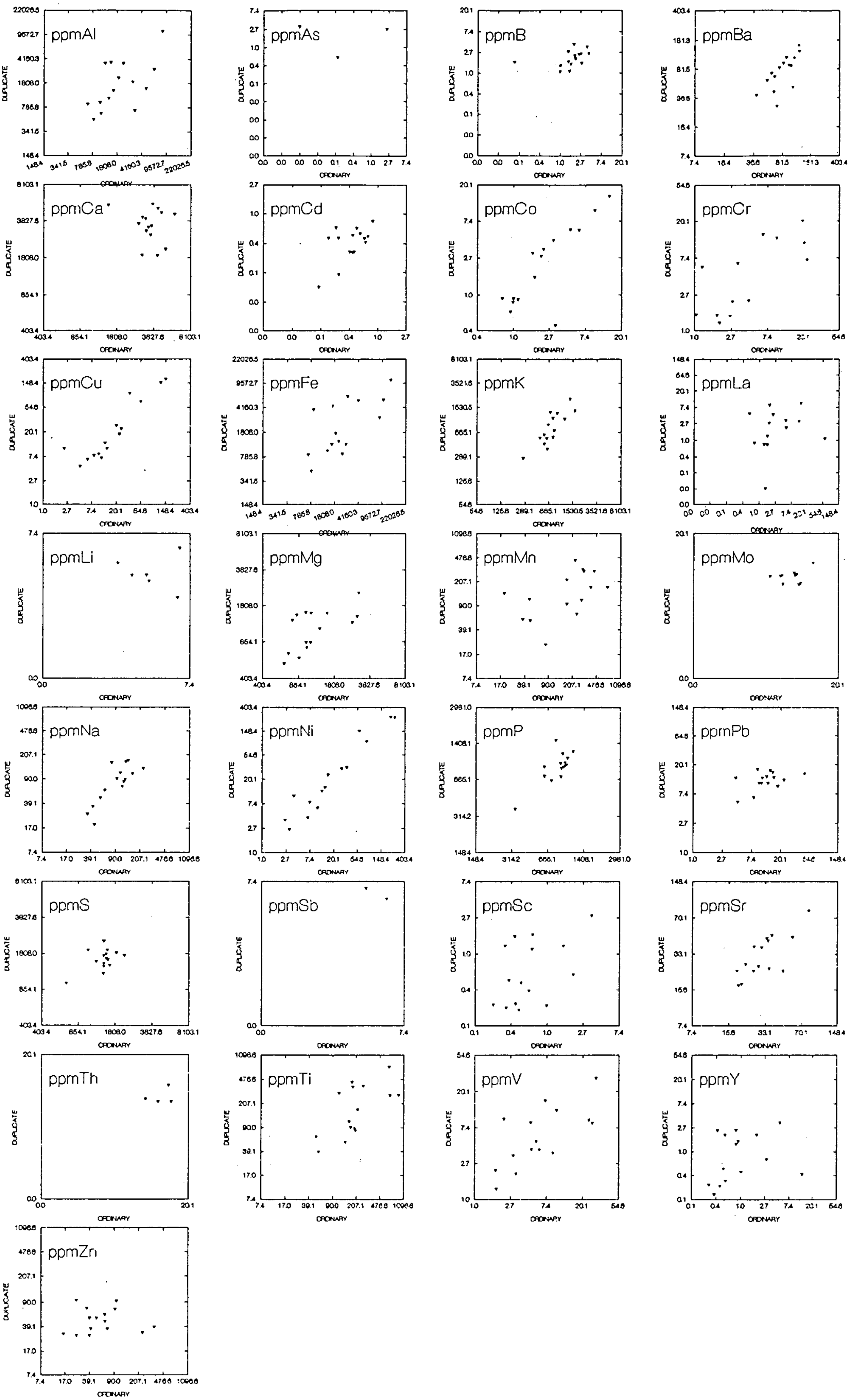
RUS: 09 Snow water

Field duplicates



FIN: 02 Humus HNO3/MicroWave Field duplicates

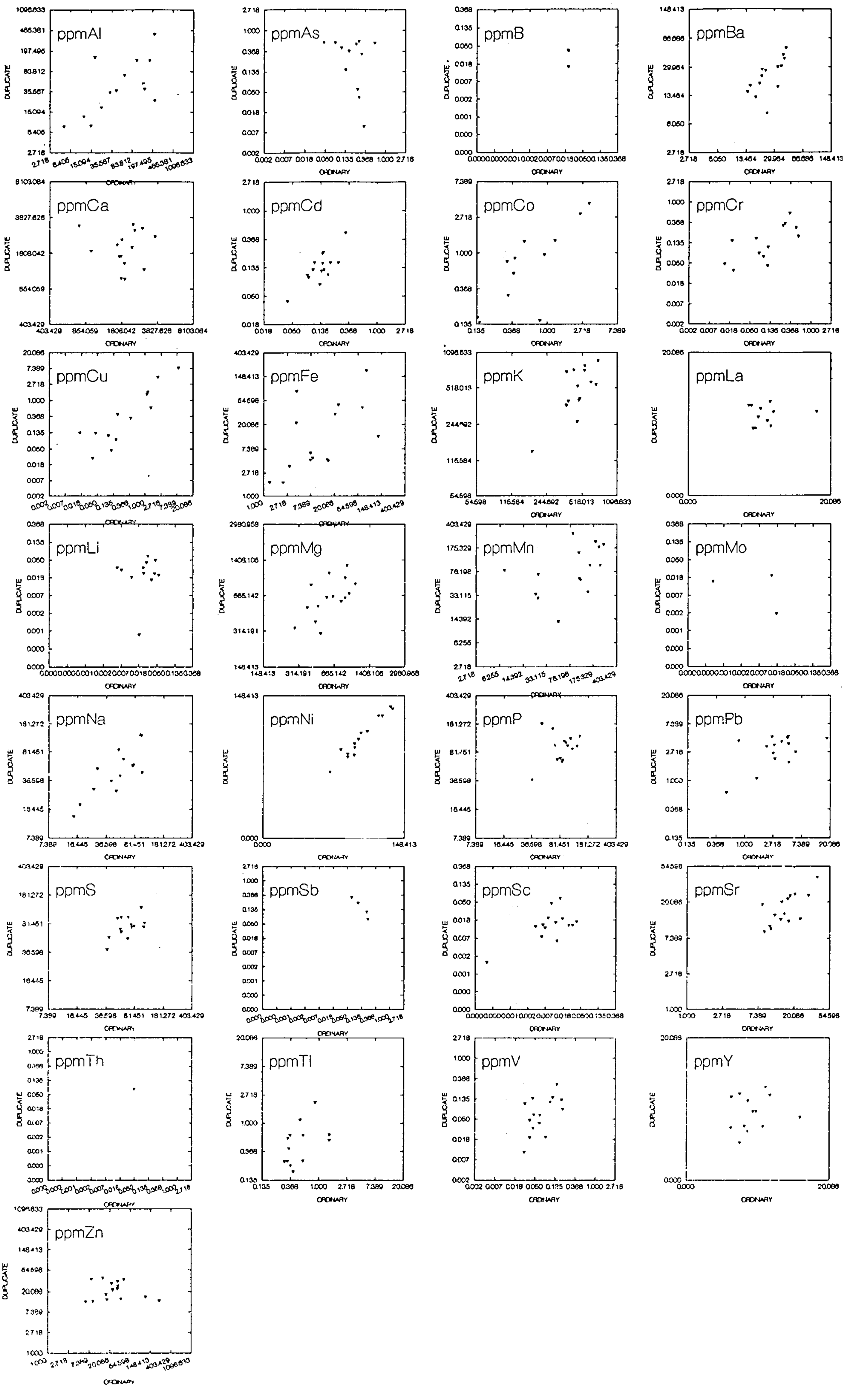
Appendix 12



FIN: 02 Humus Partial

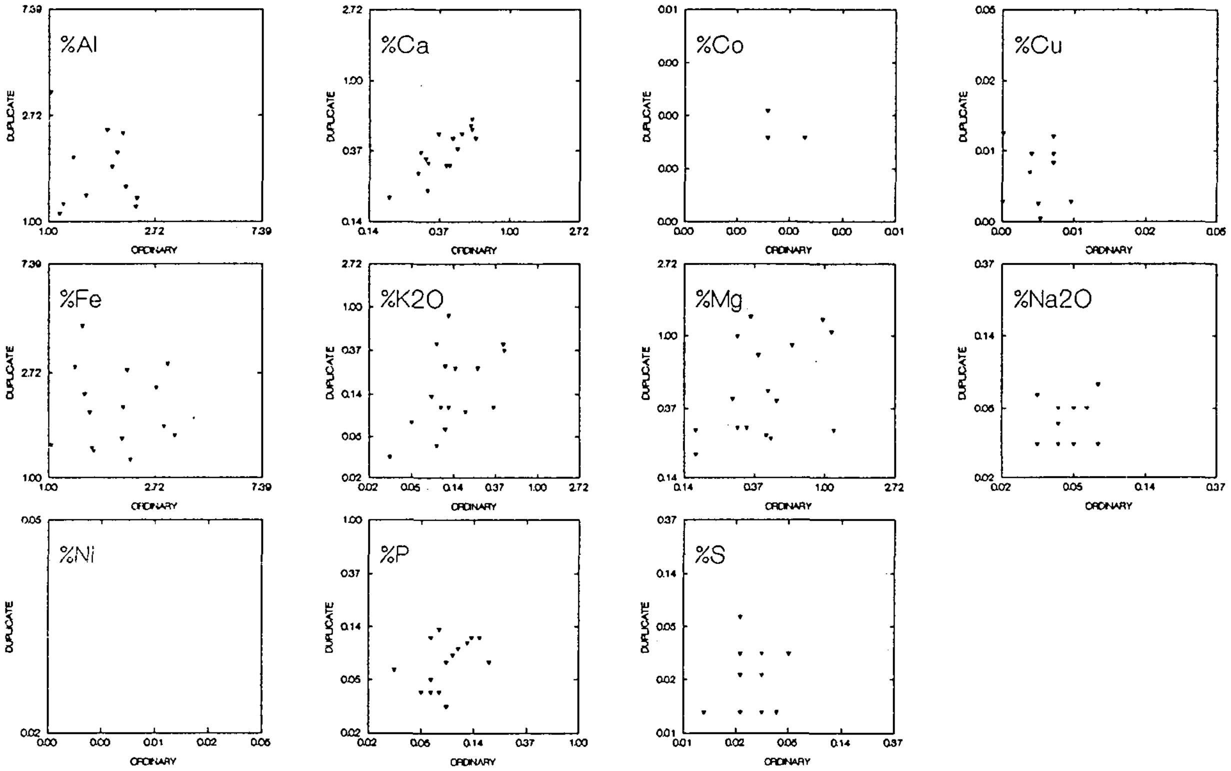
Field duplicates

Appendix 12

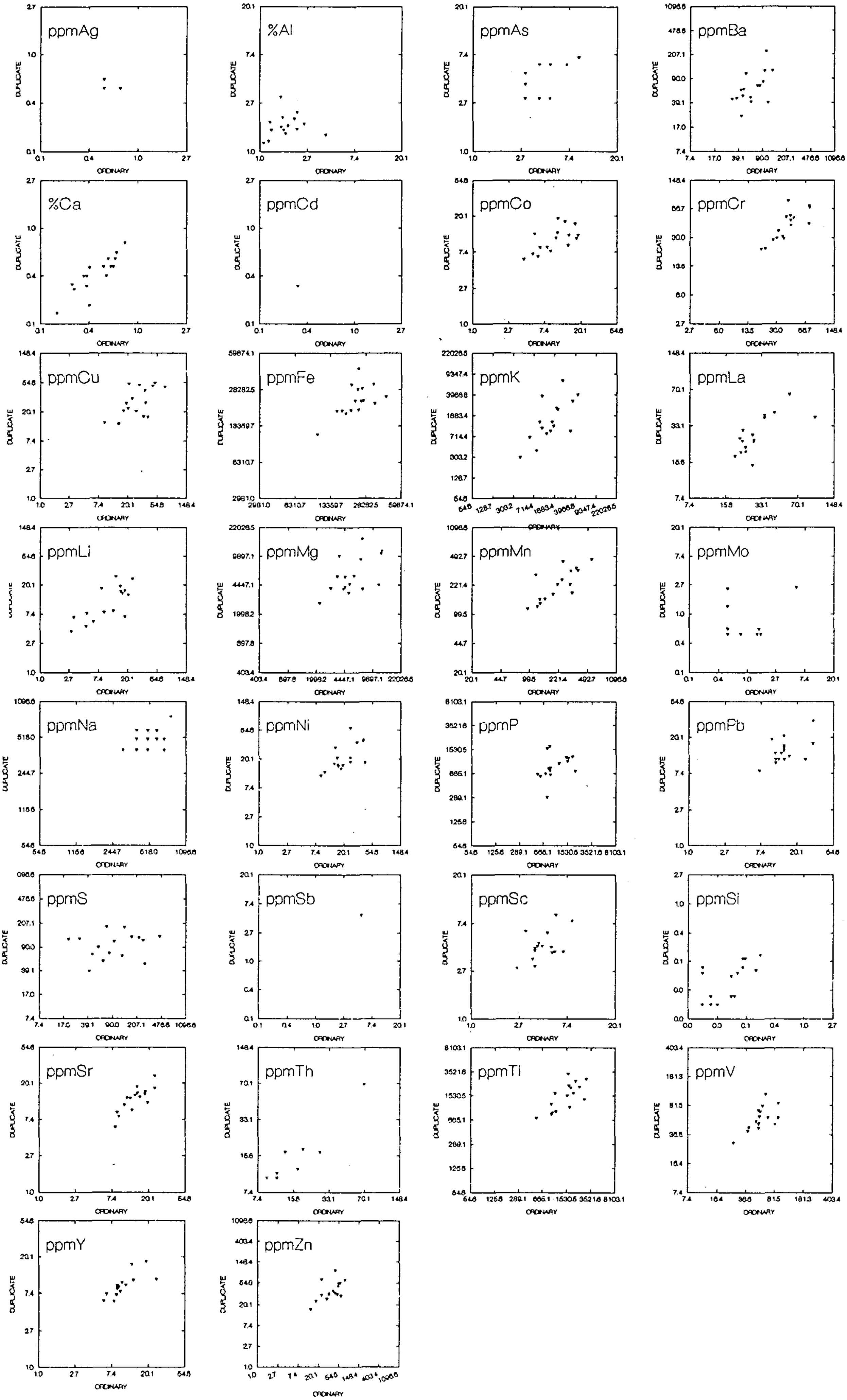


RUS: 05 C-soil -.07mm Partial Field duplicates

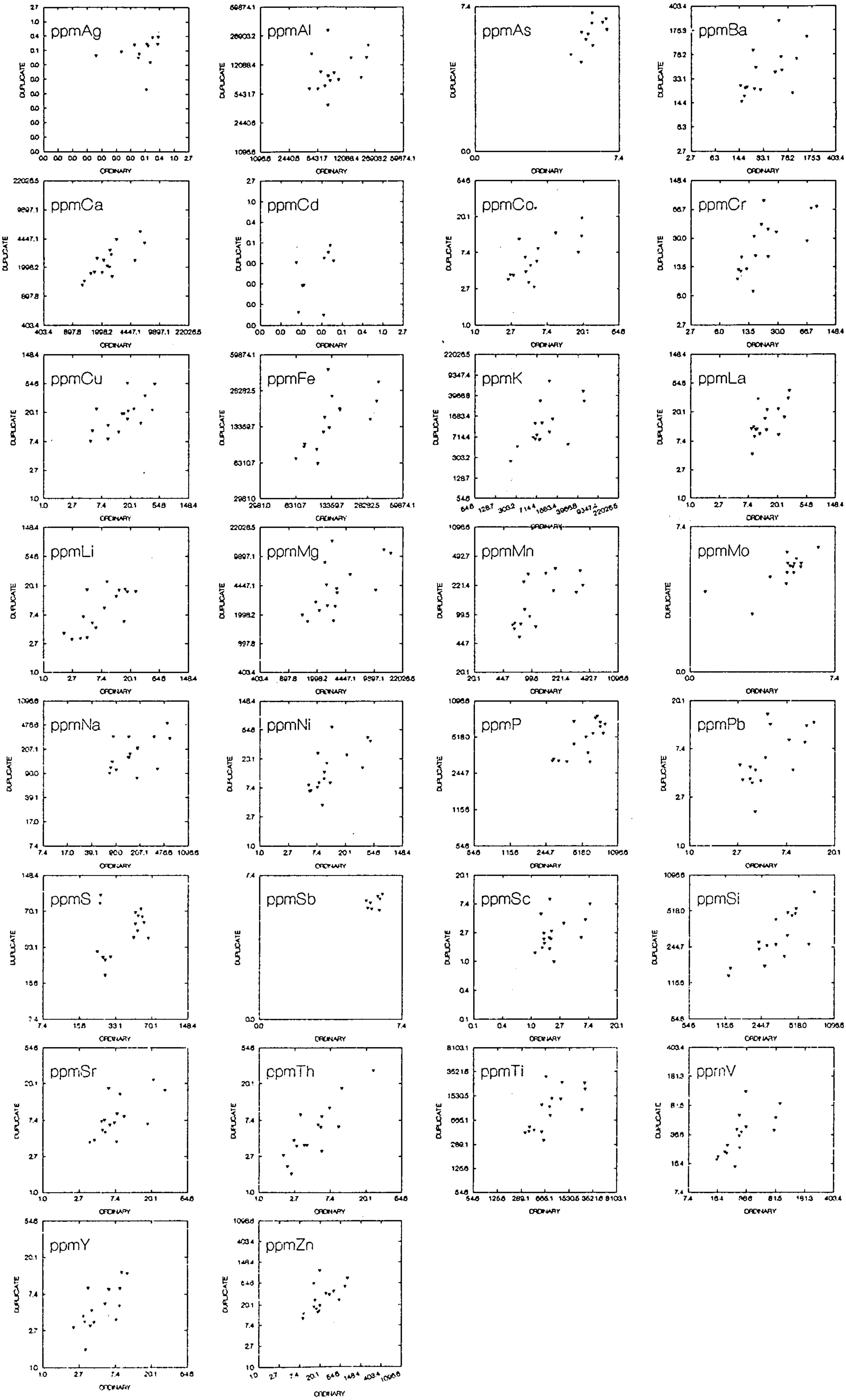
Appendix 12



FIN: 05 C-soil -.06mm AR Field duplicates

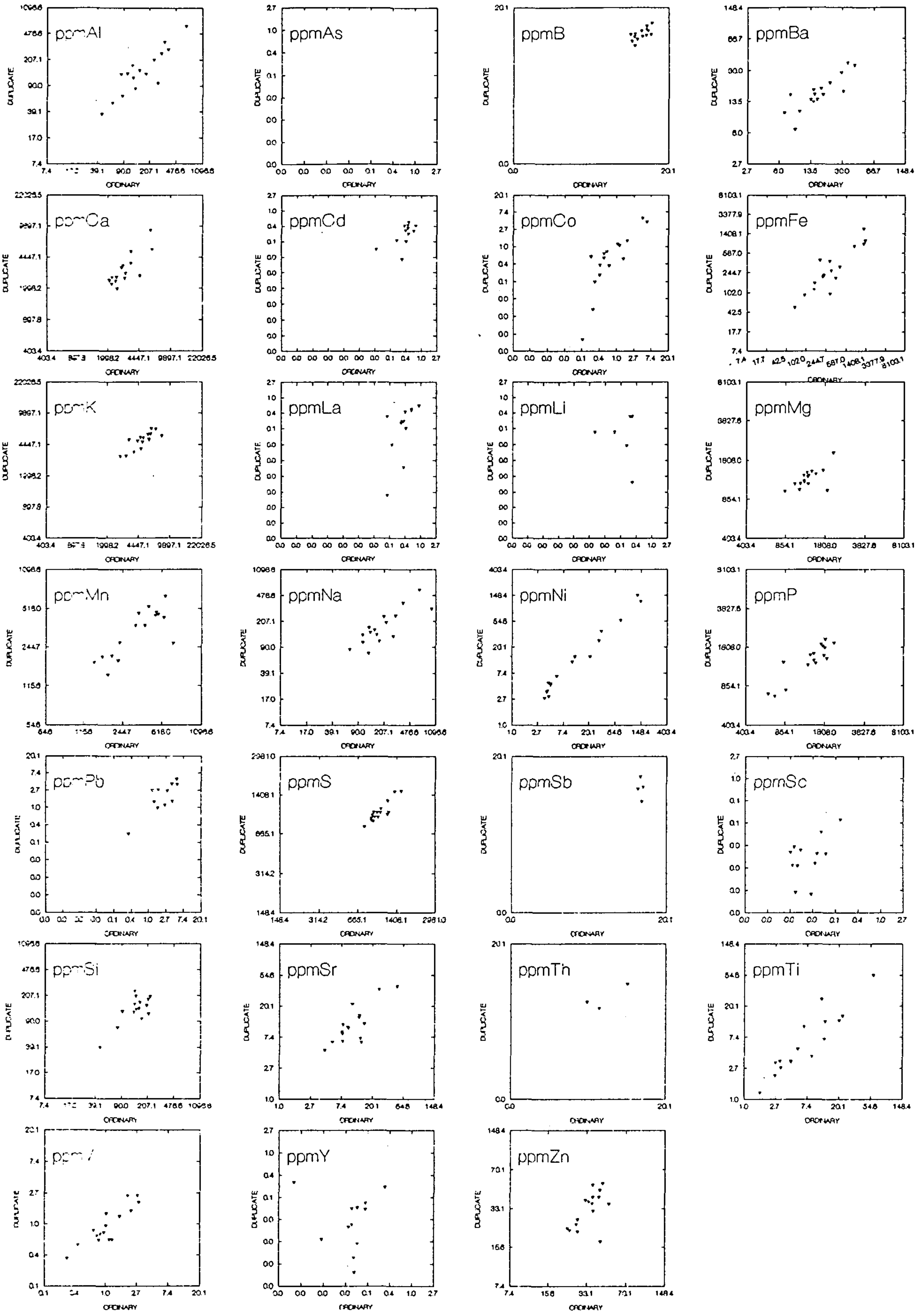


FIN: 05 C-soil -2mm Partial Field duplicates

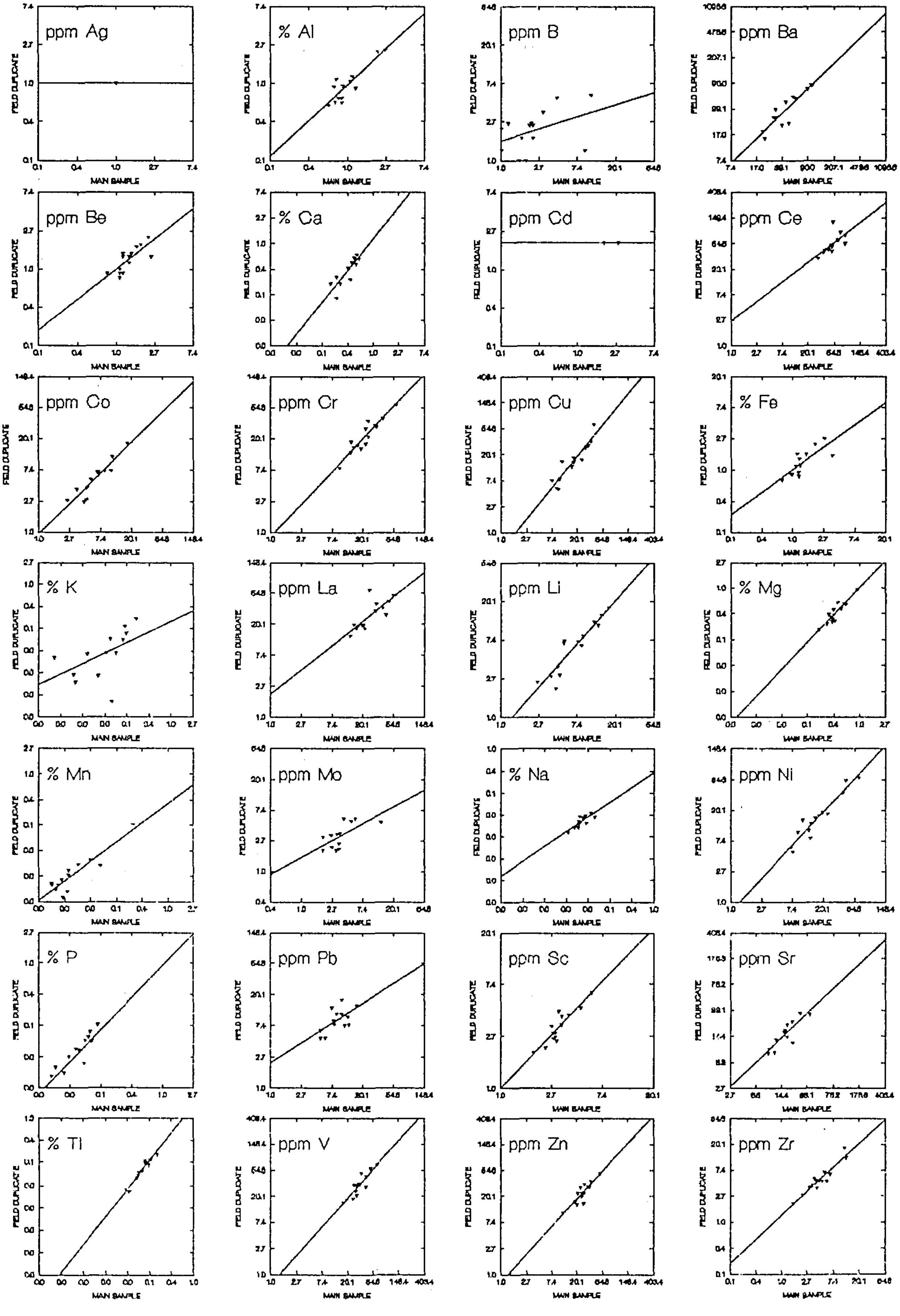


FIN: 08 Moss HNO3/Partial MicroWave Field duplicates

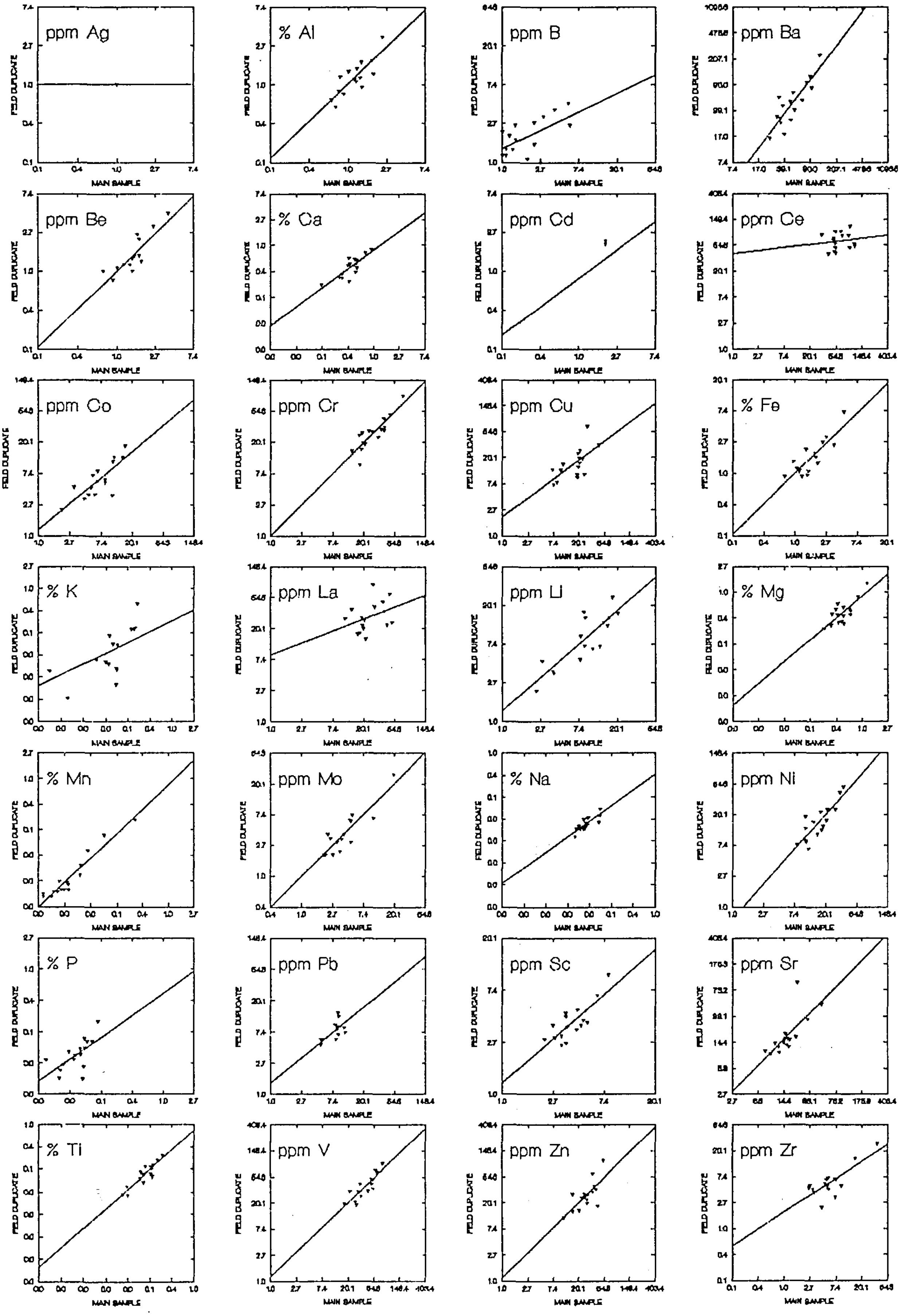
Appendix 12



NOR: Overbank sediments top Field duplicates



NOR: Overbank sediments bottom Field duplicates



For analysing humus, the <0.07mm fraction of ashed sample was used. Hence, there is a mixture of (organic) ash and minerogenic material <0.07 mm in any sample. Coefficient of ashing α was determined as the ratio of the primary weight P1 of sample (minus weight of fraction >0.07 mm) to weight of ashed sample P2 (also minus weight of fraction >0.07 mm).

$$P1 = P_{\text{dry weight}} - P_{>0.07},$$
$$P2 = P_{\text{ashed sample}} - P_{>0.07}.$$

$$\alpha = \frac{P1}{P2} = \frac{P_{org} + P_{<0.07}}{P_{ash} + P_{<0.07}} * 100\ (\%) \quad (1).$$

The analytical result of the ashed sample is:

$$C_{anal} = \frac{C_{ash} * P_{ash} + C_{<0.07} * P_{<0.07}}{P2} \quad (2).$$

where

C_{ash} is element content in organic ash

$C_{<0.07}$ is element content in minerogenic fraction <0.07 mm.

From this we have:

$$C_{ash} = \frac{C_{anal} * P2 - C_{<0.07} * P_{<0.07}}{P_{ash}} \quad (3).$$

It is neccessary to know $P_{<0.07}$, P_{ash} and $C_{<0.07}$. That is possible, if we know the composition of a "pure" sample of A_0 horizon. In theory $\alpha = \alpha_0 = (1\text{-}2\ \%)$ for such samples (constitutional ashing). But in practice, the empirical estimate of the average (modal) of α for our case is :

$$\alpha_0 = 3.5 \pm 1.5\ \% \quad (N=61 \text{ samples}).$$

We will use the value $\alpha_0 = 5\%$ as the top mean α_{0top} for "pure" samples. If of a sample is more than $\alpha_{0\text{-}top}$, it is neccessary to exclude the minerogenic part (<0.07 mm) from the results of the analysis. For this purpose a coefficient **K** is calculated as:

$$K = \frac{\alpha - \alpha_0}{100 - \alpha}$$

If $\alpha < \alpha_{0\text{-}top}$, then $\alpha_0 = \alpha$ (4)
else $\alpha_0 = \alpha_{0\text{-}top}$

and then:

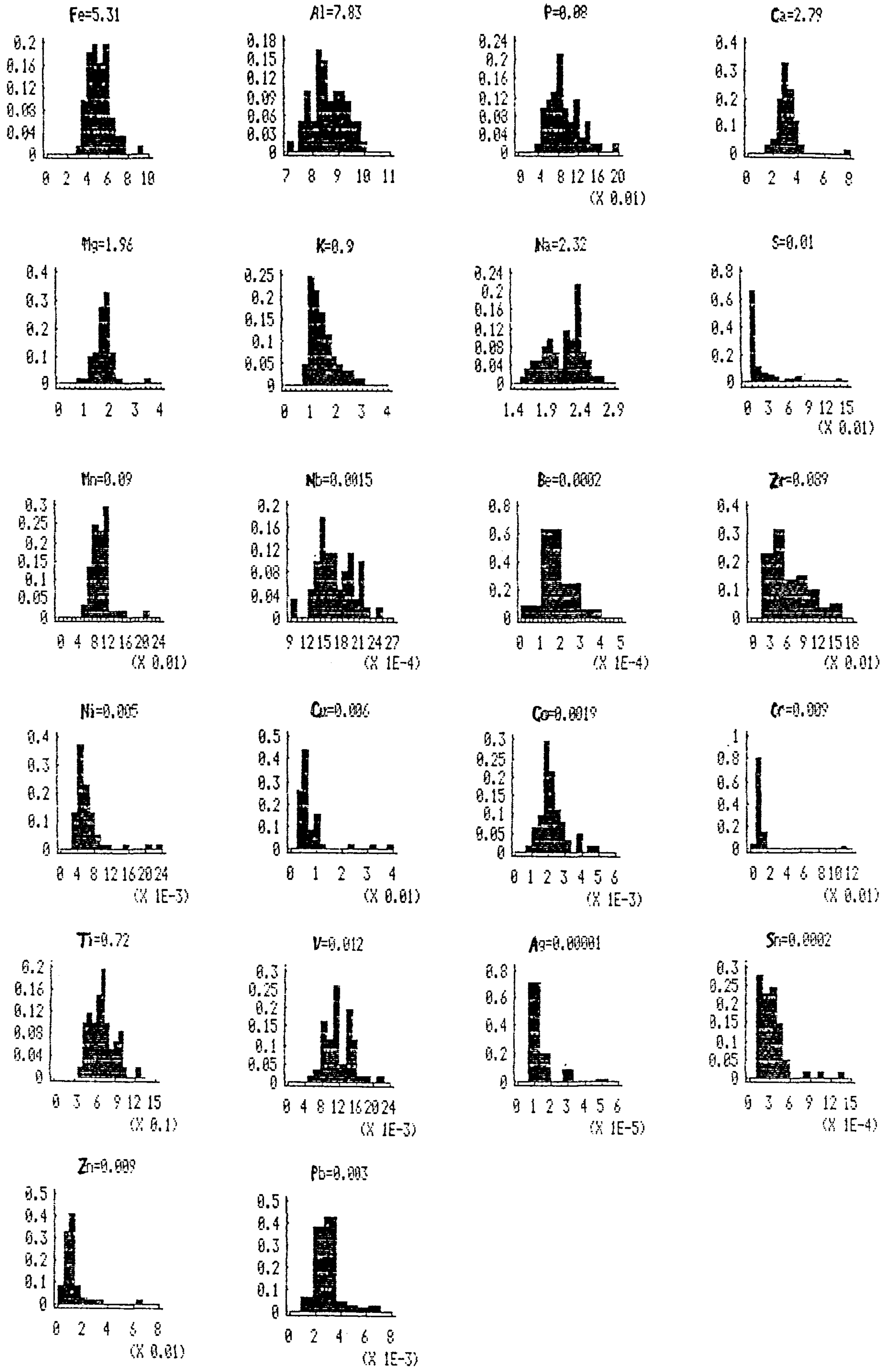
$$P_{org} = \frac{1}{1 + K} * P1;$$

$$P_{<0.07} = P1 - P_{org} \quad \text{and} \quad P_{ash} = P2 - P_{<0.07}.$$

The element contents in the minerogenic fraction <0.07 mm may be approximately equal to the element concentrations in fraction <0.07 mm of C-horizon. Then C_{ash} is calculated acording to (3) and

$C_{\text{dry organic weight}} = C_{ash} * \alpha_0$ with above mentioned conditions (4).

Appendix 14



Histograms of element contents (weight %) in soil horizon C (-0.07mm). Average (mode) values are shown for elements