NGU-rapport 88.147

Western European Geological Surveys (WEGS),

Working Group on Regional Geochemical Mapping

Project Proposal

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RAPPORT

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Forfatter: B. Bølviken, R. Hindel, R.T. Ottesen, O. Schermann, P. Simpson, T. Volden	Oppdragsgiver: WEGS

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Sammendrag: It is proposed to perform an orientation survey in three parts: (1) complete an inventory of the regional geochemical mapping thus far done in all WEGS countries (1988-89); (2) collect overbank sediments at various depths from 10-15 sample sites within the countries represented in the Working Group (1988); (3) repeat item (2) in all WEGS countries that want to participate (1989).

If the results of the orientation survey indicate that a joint regional geochemical mapping of Western Europe is warranted, the following tentative mapping programme is proposed: (1) sampling of overbank sediments at a spacing of 1 sample site per 500 km^2 in all participating countries. At each site two samples are taken, one natural, pristine sample at depth, and one sample influenced by pollution near the surface; (2) multielement chemical analysis for total contents, and acid soluble and plant extractable fractions; (3) statistical treatment of the data, prepartion of a data bank and maps of raw and interpreted data.

The main application of the results will be in the fields of:

(1) Environment. Examples of products: (a) maps of natural and anthropogenic distribution of heavy metals; (b) maps of susceptibility to acidification; (c) maps for the selection of pollution monitoring stations; (d) tables of municipal-, county- or nation-wise element contents for the use in geomedicine.

(2) Mineral exploration. Examples of products: (a) maps showing broad continental geological structures which may have ore potential; (b) maps of the distribution of elements such as Au, Pt, Pd, Os, Ir, Ru, Rh, REE.

Examples of other beneficial effects are: (a) promotion of cooperation between WEGS countries in the development of applied geochemistry; (b) contribution to the understanding of main geochemical processes in the crust and atmosphere; (c) contribution to world wide geochemical mapping.

Total cost if all WEGS countries participate is estimated to be of the order of DM 5 mill. Financial support in addition to institution fundings should be sought from European and international organizations.

Emneord	Antropogenic	Geochemistry
	Pollution	Acidification

WESTERN EUROPEAN GEOLOGICAL SURVEYS

Working Group on Regional Geochemical Mapping

Project proposal:

August 1988

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ABSTRACT

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INTRODUCTION

After J. Goni's retirement from B.R.G.M., B. Bølviken, NGU was asked to convene a meeting of the Working Group on Regional Geochemical Mapping consisting of members from Austria, France, F.R. Germany, Greece, Norway, Spain and United Kingdom (App. 1). A meeting in the Working Group was held in Trondheim May, 1986 (App. 2). The main conclusions from this meeting are (App. 3 and 4):

- only one of the geological surveys represented in the Working Group (BGR, Hannover) had completed geochemical mapping of the country (Fauth et al. 1985). The estimated years for completion were 1987 (Greece) and 2000 (U.K.), while other countries could not give such estimates.

- the most commonly used sampling material is stream sediment taken at a density in the order of 1 sample per 1-4 km^2, but details regarding, sampling and analytical methods vary from country to country.

- results of the Nordkalott project in Northern Scandinavia (Bølviken et al. 1986) show that (1) in large survey areas meaningful geochemical patterns can be obtained by less than 1 sample per 50 km^2; (2) multimedia and multielement geochemical surveys appear to be advantageous, and (3) preparation of joint maps including earlier obtained data from several surveys or countries does not seem to be feasible, because different sample types and the use of different field and laboratory methods have produced incompatible geochemical patterns.

- results from Norway show that it is possible to obtain significant geochemical patterns from overbank sediment (flood plain or levee sediments, alluvial soils) (Figs. 1 and 2) collected at a spacing of 1 sample per 500 km^2 (App. 5, Figs. 4 and 5).

Based on these considerations a new plan was proposed for geochemical mapping of Western Europe based upon the same types of samples and the same field and laboratory methods for the whole survey area. The plan specifies 5 different types of samples to be taken at a density of 1 sample station per 500 km^2.

This plan was presented for the WEGS directors in Uppsala August 1986. Although several comments were made by the directors, the idea met with general approval (App. 6).

In a Working Group meeting in Orleans, April 1987 (App. 2 and 7), the main topic of the discussions was the problem of sample types. The collection of several types of sample as in the Nordkalott project would be difficult to manage, and the project should employ a common sample type for all Europe. It was agreed to arrange an excursion in Norway in the autumn of 1987 to study Norwegian data from the use of overbank sediment as a sampling medium in regional geochemical mapping.

A progress report of the activities of the Working Group was presented at the WEGS meeting in Ankara, August 1987, and it was agreed that the Working Group should continue, and report to WEGS again in 1988 (App. 8).

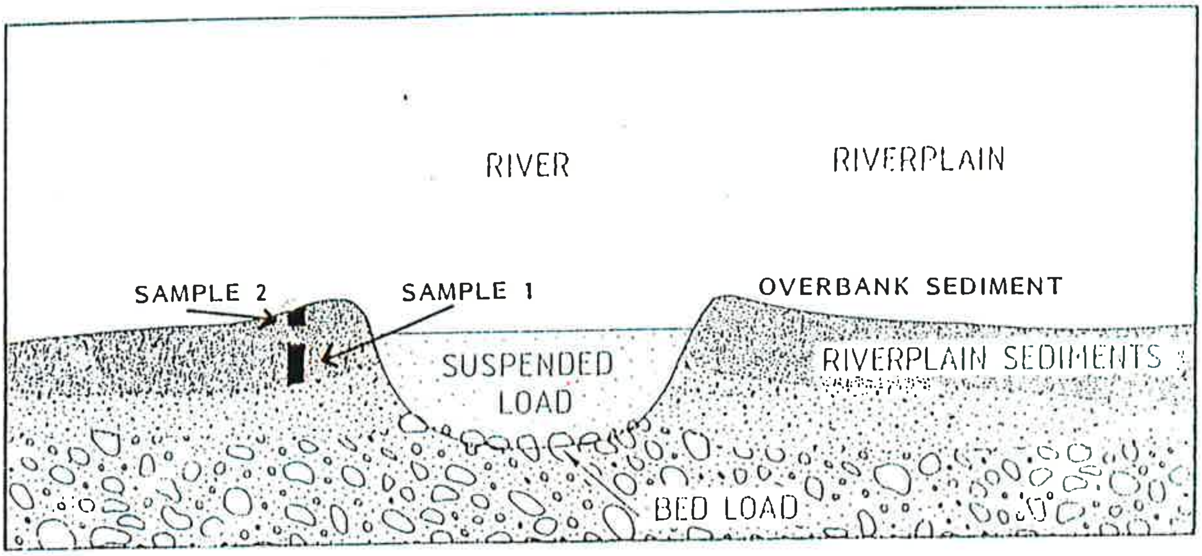


Fig. 1. Suggested sampling of overbank sediment.

Fig. 2. Overbank sediment from the river Jostedøla, Western Norway. The flood plain is in this case being eroded by the present day water flow in the river.

The Norwegian excursion was arranged in September 1987 (App. 2), and its main conclusions were (App. 5 and 9):

- Overbank sediment (o.s.) provides composite samples that represent large drainage areas and can be collected at widely scattered sample sites at low cost. O.s. is transported physically in water suspension during short periods and is less influenced by chemical processes than stream sediment, which may have coatings of secondary minerals. O.s. collected at shallow depths may reflect anthropogenic pollution, while o.s. taken deeper is pristine and may reflect natural conditions. Overbank sediment has been successfully applied in Norway. The Working Group recommends that a field trip be arranged in France and F.R. Germany in order to evaluate the use of o.s. in geochemical maping in other areas of Western Europe.

The proposed field trip in France and Germany was not realized, but during the meeting of the Working Group in Hannover, August 1988 (App. 2 and 10) an excursion was made along the Innerste River. This river system, which is heavily polluted by several hundred years of mining activities in the Harz Mountains, is included in a geochemical study of pollution of soils all over F.R. Germany. These conclusions can be drawn from the German data (App. 11):

- overbank sediment is common in German river systems.

- overbank sediment along the Innerste River is severely contaminated with heavy metals in the upper metre or so, but appears to be pristine at greater depths.

- analysis of overbank sediment from German rivers outside mining areas, for example at Bidergraben near Hausen (Tk 8012 Ehrenstetten), indicates that the upper few decimetres are contaminated while the deeper horizons are pristine.

The conclusion of the activities of the Working Group so far is the project proposal outlined in the following paragraphs.

PROJECT PROPOSAL

Orientation surveys

It is proposed that

(1) an inventory of the regional geochemical mapping thus fare done in the WEGS countries should be completed;

(2) the type of orientation survey, which is already done in F.R. Germany, should be carried out in Austria, France, Greece, Norway, Spain and U.K. The orientation survey should include the collection of overbank sediment at various depths (e.g. each dm) at a limited number of sites (e.g. 10-15) per country. The aim of the orientation survey is to study to which depth the effects of anthropogenic pollution can be traced in overbank sediment from various countries in order to decide upon sampling strategy and sampling methods.

(3) if the results of the orientation surveys under (2) above are favourable and conclusive, then similar orientation surveys should be carried out in those remaining WEGS countries that want to participate in a common geochemical mapping of W-Europe.

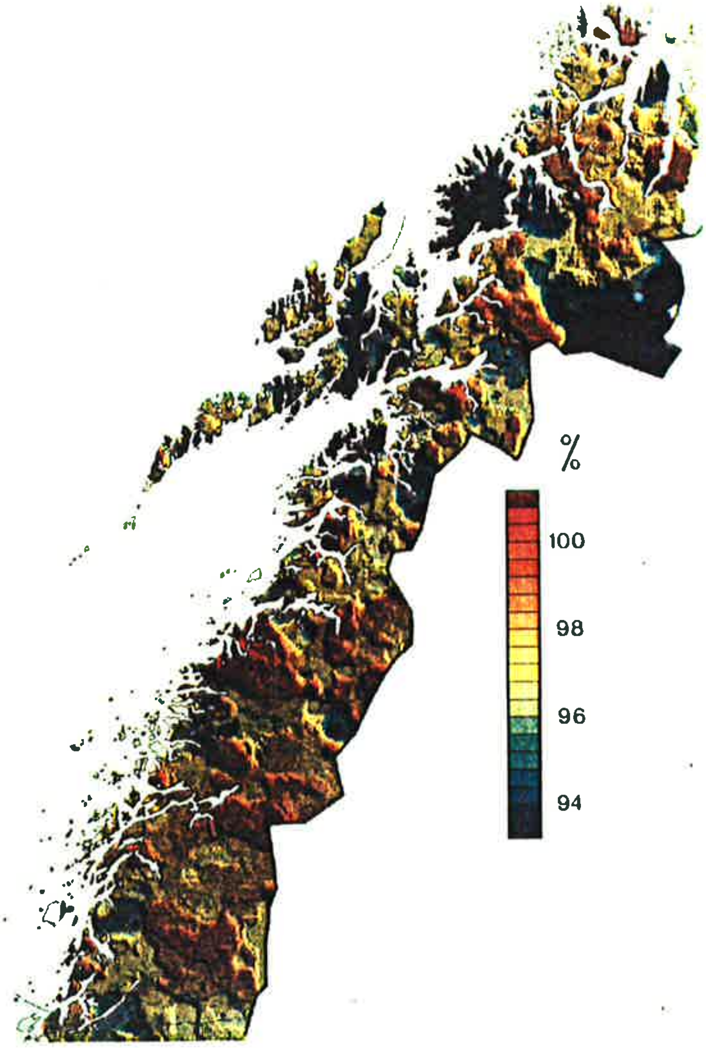


Fig. 3. Moving median (R=10 km) of the buffer percent of the <0.06 mm fraction of 932 samples of till taken at a depth of 60 cm within the Nordland and Troms district, Northern Norway. (64,000 km^2, 1 sample per 70 km^2)

$$\text{Buffer percent (B)} = \frac{[H+]_A - \Delta [H+]}{[H+]_A} \cdot 100$$

Where $[H+]_A$ is the amount of hydrogen ions added as H_2SO_4 to a suspension of a soil sample.

$\Delta [H+]$ is the difference in concentration of hydrogen as recorded by pH measurements after (pH_2) and before (pH_1) addition of acid to a soil suspension.

In this case pH_1 was measured after 2g soil were shaken with 10 ml of water. pH_2 was measured after the addition of 10 ml 0.005 N H_2SO_4 to the water suspension.

Main project

If the results of the orientation surveys indicate that common W-Europe regional geochemical mapping activities should continue, then the following project is tentatively suggested.

Samples of overbank sediment (alluvial soil, levee sediment) from 9293 sites (1 sample site per 500 km^2) should be collected all over Western Europe (Table 2).

A minimum of two large samples should be taken at each site, (1) a pristine sample at depth and (2) an anthropogenically polluted sample near the surface (Fig. 1).

The samples should be set in random order regardless of country of origin and analyzed for as many elements as possible including parameters such as:

- total contents of elements
- acid soluble contents of elements
- plant available contents of elements
- pH in water and acid suspensions

The obtained data are stored/made available as:

- a bank for storage and retrieval of digital data for map presentations, statistical treatments and interactive interpretations with other data;

- geochemical thematic maps such as natural and anthropogenic distribution patterns of elements, degree of pollution, susceptibility of soil to acidification, lime requirements of soil, release of Al and other elements from soil due to acid rain;

- progress reports, final reports and scientific publications.

A tentative working plan is indicated in Tables 1 and 2.

PURPOSE OF THE MAIN PROJECT

The purpose of the W-European geochemical survey can be divided into 4 groups:

1. Environment

- provide maps and data on the natural distribution of elements and the results of anthropogenic pollution of the overburden in Western Europe;

- map the susceptibility to acidification of the overburden in Western Europe (Fig. 3);

- provide basic geochemical data for establishing alert, warning and emergency criteria for action against past and present pollution of soils in Western Europe;

- provide background geochemical data for the planning of an appropriate number and locations for pollution monitoring stations in Europe;

- produce geochemical maps of the contents of harmful as well as essential elements in soils in order to provide basic background data in the planning of which areas should be used/not used for food production in Western Europe;

- provide general geochemical data for use in the general planning, for example contribute to the knowledge of which areas are suitable/not suitable for drinking water supplies or waste disposal;

- provide (nation-, province-, county-, municipality-wise) geochemical data for human and animal epidemiological research in Western Europe within the field of environmental geochemistry and health (geomedicine);

- contribute to the studies of global changes due to human activities in the environment.

Several of these points have been treated by Brundtland et al. (1987), while others warrant more attention than generally recognized.

2. Mineral exploration and geological modelling

- discover geochemical distribution patterns that may be important in exploration, but so broad-scaled that they cannot be recognized within individual countries when seen isolated;

- discover provinces and structures that point to the need for new approaches in the interpretation of regional geology (Fig. 4);

- find dispersion patterns of elements such as Pt, Pd, Os, Ir, Ru, Rh, Au, REE for which present information is limited because of high analytical costs (Fig. 5);

- develope methods for regional exploration in heavily contaminated areas.

3. International cooperation and foreign aid

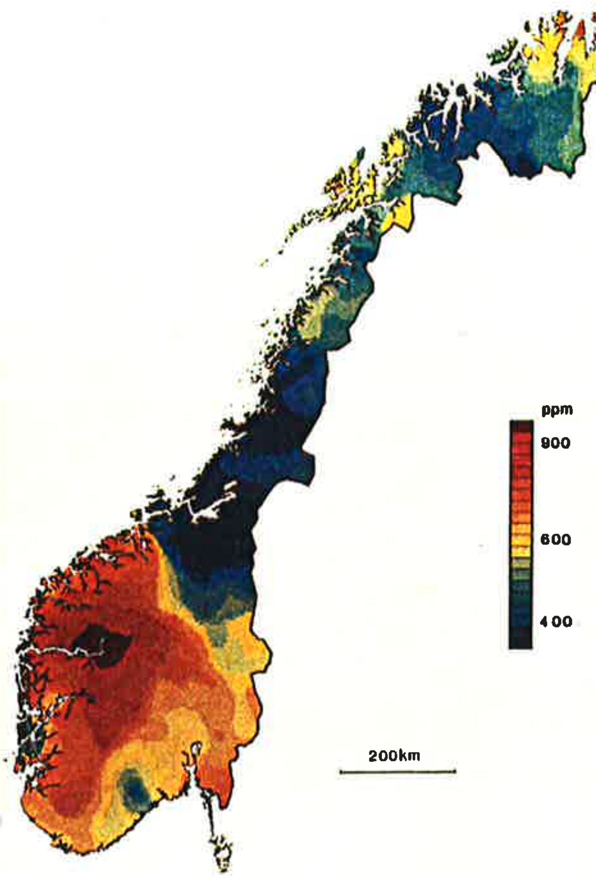
- The project will imply close cooperation between the geochemists of the WEGS institutions and will thereby have beneficial effects for the development of applied geochemistry in Western Europe.

- The experience gained during the preparation of a geochemical atlas of Europe can prove to be of great value for similar investigations in developing countries. In these countries the geology is often poorly known and the infrastructure does not permit the dense sampling normally used for a geochemical survey based on stream sediments. This situation can be counteracted by taking overbank sediments at widely spaced sample sites.

- The project will contribute to the IGCP project 289 "International Geochemical Mapping" (App. 12).

4. Geochemical research

The project will provide data that may throw light upon such problems as:
- interpretation of geochemical anomalies and provinces;
- establishing geochemical standards;
- how glaciation and various types of weathering affect the geochemistry of soils;
- how important airborne transportation from marine volcanic and other sources is in natural geological processes.



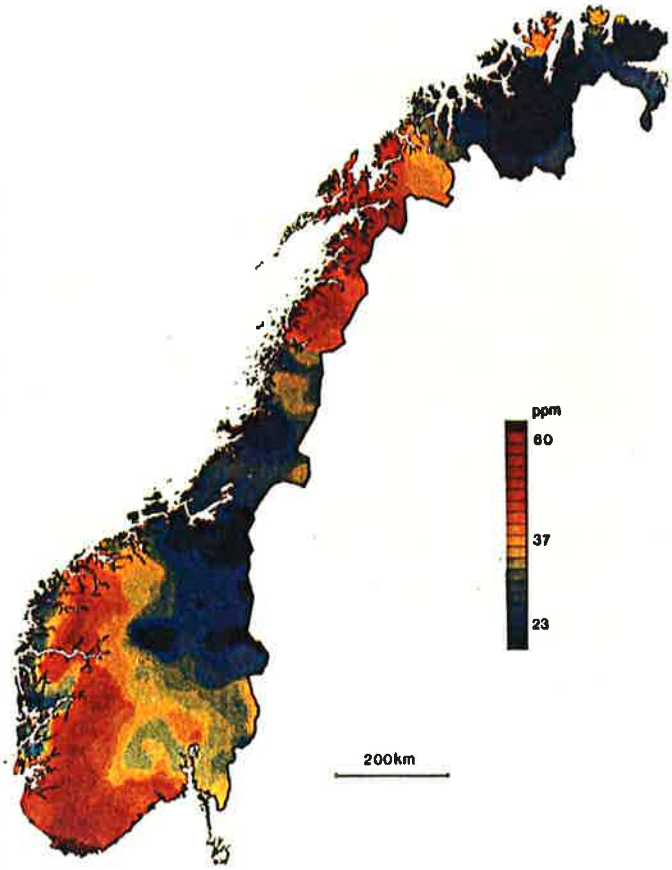


Fig. 4. Ba

Fig. 5. La

Total contents of Ba and La in overbank sediment, Norway. The maps are based on the analysis of 690 samples and show the rolling median within a window of diameter 100 km. The cartography is done at the Geological Survey of Finland.

USERS OF DATA

The project aims at the following target groups:

- environmental protection agencies in various countries.
- Western European organizations establishing standards for environmental protection and regulations in areal planning;
- health authorities and epidemiologists;
- agricultural authorities;
- mining industry and governmental exploration institutions;
- universities and schools;
- politicians;
- general public.

REFERENCES

Brundtland, G.Harlem et al. 1987. Our common future. World Commision on Environment and Development. Palais Wilson, 52, rue des Paquis, 1201 Genève. Oxford University Press.

Bølviken, B., Bergstrøm, J., Bjørklund, A., Kontio, M., Lehmuspelto, P., Lindholm, T., Magnusson, J., Ottesen, R.T., Steenfelt, A., Volden, T., 1986. Geochemical Atlas of Northern Fennoscandia, scale 1:4 mill. Geological Survey of Finland, Norway and Sweden. 20 p, 155 maps.

Fauth, H., Hindel, R., Siewers, U. and Zinner, J. 1985. Geochemischer Atlas Bundesrepublik Deutschland, Bundesanstalt für Geowissenschaften und Rohstoffe 13 p. 74 maps.

TABLE 1. PLANS OF ACTIVITIES IN REGIONAL GEOCHEMICAL MAPPING

Time period	Activity/subject	Estimated time or costs
1988 - 89	Inventory Orientation Survey in the Working Group countries Orientation survey in all WEGS-countries	2-3 man weeks per country
1990 - 91	Field work in the main project	DM 2.9 mill, see Table 2
1992 - 93	Analysis, preparation of data bases and maps	DM 2.0 mill
1994	Interpretation and reporting of the results	0.5 man year per country

TABLE 2. GEOCHEMICAL MAPPING OF WESTERN EUROPE.

AREAS, NUMBER OF SAMPLE SITES AND ESTIMATED COSTS OF FIELD WORK

	Area (km^2)	No. of sample sites	Estimated field costs (1000 DM)
Austria	83,853	168	53
Belgium	30,513	62	20
Cyprus	9,251	18	6
Denmark	43,069	86	27
Finland	337,009	674	210
France	547,026	1,094	344
F.R. Germany	248,687	498	160
Greece	131,944	246	80
Greenland (icefree)	341,700	682	215
Iceland	103,000	206	65
Ireland	70,283	140	44
Italy	301,262	602	190
Luxembourg	2,586	6	2
Netherlands	40,844	82	26
Norway	324,219	648	205
Portugal	92,082	184	60
Spain	504,782	1,008	320
Sweden	449,964	900	280
Switzerland	41,293	82	26
Turkey	780,576	1,401	440
U.K.	244,046	488	155
Total	4,727,989	9,293	2,929

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Appendix 1. WEGS meeting Reykjavik Sept. 1985. Item 4 of the Minutes.

MINUTES FROM THE WEGS MEETING IN REYKJAVIK, SEPTEMBER 1985

Item 4 Regional Geochemical Mapping

27. Dr. Goni introduced his report (Appendix 4). Papers provided by Greenland, the Federal Republic of Germany and the Netherlands were also distributed.

28. The following points were among those made during the discussion of this report:-

(a) There are still problems in persuading geologists to use the results of regional geochemical mapping, so that it is necessary to consider carefully how they should be presented. An example, developed in Finland, using different shades of grey was demonstrated, as were maps produced recently in Austria.
(b) An expert group should be established to make recommendations on this subject.
(c) Dr. Goni 's comprehensive report contained too many points for discussion by such a Group, which should therefore select those it considered to be the most important. It was stressed that the Group should not be concerned with routine operations, but rather with such problems as the relationship between geochemical data and mineralogy.

29. It was agreed that a Working Group, which should decide its objectives, should be convened by Dr. Goni. Dr Goni suggested the following terms of reference:-

(a) Main objectives:

(i) Interpretation of geochemical anomalies(in which form the elements really are in the samples).

(ii) The relationship between element distribution and human health.

(iii) Establishing geochemical and chemical standards (in water, soils, organic materials, gas, etc.).

(b) Subsidiary subjects:

(i) The chemical mobility of elements as a function of concentration, climatic regime, topography, etc.

(ii) Types of samples and density of sampling.

(iii) The interpretation and selection of geochemical anomalies, particularly on a "tactical" scale.

30. Initially, the Group should include representatives from the United Kingdom, the Federal Republic of Germany, Norway, Spain, Greece and Austria.

31. It was also agreed that Dr. Goni would distribute to all members the papers summarised in Appendix 4.

Appendix 2. WEGS Working Group on Regional Geochemical Mapping
Representatives and activities 1986 - 1988.

WEGS Working Group on Regional Geochemical Mapping

Report of activities 1986 - 1988

The directors of the Western European Geological Surveys (WEGS) have established a Working Group on Regional Geochemical Mapping with members from Austria, France, Great Britain, Greece, Norway, Spain and West Germany.

The Working Group held a meeting in Trondheim, Noway 21-22 May 1986, with attendance from Austria, France, Germany, Great Britain, Greece, and Norway (Appendices 1 and 2). A report of the activities was given at the meeting of the WEGS directors in Uppsala, Sweden 25 August 1986, and the directors asked the Group to prepare a draft proposal (Appendix 3). Members of the Group had informal discussions in Orleans 26 April 1987. A progress report was prepared for the WEGS meeting in Ankara 1987 (Appendix 4), and an excursion was arranged in Norway 10-14 September 1987 with participants from France, Germany and Norway (Appendix 5).

The next meeting of the WEGS directors will be held in Copenhagen 12 September 1988, where results of the Working Groups acitivities and a proposal for further work will be presented. A draft proposal (Appendix 6), will be discussed in Hannover 21-22 August 1988 (Appendix 7).

The activities of the WEGS Working Group on Regional Geochemical Mapping should be viewed in light of the great interest for internatinal geochemical mapping being demonstrated at the 12th International Geochemical Exploration Symposium in Orleans April 1987 (Appendix 8), and at the V.M. Goldschmidt Conference, in Baltimore May 1988 (Appendix 9). Overbank sediment is a sampling medium of great interest in connection with low density geochemical mapping (Appendix 10).

Geological Survey of Norway
Trondheim 29 July 1988

Bjørn Bølviken
Divisional Director

WEGS WORKING GROUP ON REGIONAL GEOCHEMICAL

MAPPING : REPRESENTATIVES AND ACTIVITIES 1986 - 1988

	Austria	France*	Germany	Greece	Norway°	Spain	U.K.*
Meeting Trondheim May 1986	R	R	R	R	R	NR	R
WEGS meeting Uppsala Aug.1986	NR	NR	NR	NR	R	NR	NR
Meeting Orleans April 1987	NR	R	R	NR	R	NR	R
Excursion Norway Sept.1987	NR	R	R	NR	R	NR	NR
Meeting Hannover Aug.1988	R	NR	R	NR	R	NR	R

* : The representative has changed during 1986-1988
o : Convener
R : Represented
NR : Not represented

Appendix 3. Working Group meeting Trondheim May 1986. Minutes.

Trondheim 30. May 1986

APPENDIX 3

WESTERN EUROPEAN GEOLOGICAL SURVEYS

Working Group on Regional Geochemical Mapping
meeting at the Geological Survey of Norway,
Trondheim 20 - 22 May 1986.

Minutes prepared by Bjørn Bølviken

Participants: Alain Bourgh, France
Bjørn Bølviken, Norway
Alec Demetriades, Greece
Roland Hindel, F.R. Germany
John Moore, England
Rolf Ottesen, Norway
Otmar Scherman, Austria

The representative from Instituto Geologico Minero de Espana was held up on other business.

1. Reports were given from each participant about geochemical mapping in the home country.

- Austria

A geochemical atlas based upon analysis of stream sediment samples is being printed at the scale of 1:1 million. The aim of the mapping is mineral prospecting.

- F.R. Germany

The geochemical atlas of the F.R.G. is published at a scale of 1:2 million. The atlas is based on analysis of samples of stream sediments and stream water. The main aim of the project is mineral prospecting.

- France

The work for a geochemical atlas over France is not completed. Approximately 15% of the area is sampled so far. Results are published on map sheets at a scale of 1:1 million. The aim of the mapping is mineral prospecting.

- Greece

A geochemical atlas over Greece is in progress. The work will be completed in 1987 and the data will be published on maps at a scale of 1:2 million. The aim of the mapping is mineral prospecting, environmental research and delineation of medium to large scale geochemical provinces.

- Great Britain

Publication of the geochemical atlas of the UK on the scale 1:250 000 began several years ago, and completion of the whole series is expected around the year 2000. Mapping is based on the analysis of stream sediment samples, collected at an average density of 1 per 1½ sq km, currently for 29 elements. The main application is in mineral surveys, and interpretation of the data in relation to bedrock geology for that and other purposes is proceeding.

- Norway

A Norwegian geochemical atlas based on analysis of overbank deposits is to be published in the near future. A geochemical atlas and a geochemical interpretation map for the northern part of Scandinavia will be published in 1986. The atlas is based on analysis of 6 sample types for up to 46 elements. A number of significant, not forseeable large scale patterns occur in the data.

2. Conclusions and plans for future work.

* - A geochemical atlas of western Europe should be made.
- The suggested sampling density is 1 sample station per 500 km^2. (Total no of samples 7000).

- At each station the following sample types should be collected:
    - overbank sediments (one sample near the surface and one at depth)
    - surface and ground waters
    - soil (1 sample of topsoil and possibly one sample at depth)
- The samples should be analysed for as many elements as possible.

* - The aim of the project would be
    - detection of large scale geochemical provinces
    - environmental research
    - establish baseline element concentration in order to evaluate present and future pollution
    - detection of transfrontier pollution trends

* - Benefits of the project will be:
    - extension of the knowledge base for each individual geological unit
    - improvement in professional interaction between European countries

* - Bjørn Bølviken will as soon as possible prepare a draft for a project proposal. The raw material group and the environmental group of the EEC will be contacted by John Moore, and Alain Bourgh and A. Demetriades in order to inquire about possibilities for financial support. Each country will make a list of the analytical facilities that are available and which elements can be determined. Each country tries to raise money.

Next meeting is planned in Orleans in April 1987 in connection with the AEG/ICGC symposium.

30 May 1986

APPENDIX 4

WESTERN EUROPEAN GEOLOGICAL SURVEYS

Working Group on Regional Geochemical Mapping

Project Proposal: Geochemical Mapping of Western Europe

A. Bourg, France

B. Bølviken, Norway

A. Demetriades, Greece

R. Hindel, W. Germany

P.J. Moore, United Kingdom

O. Schermann, Austria

INTRODUCTION

At a meeting of the WEGS Working Group on Regional Geochemical Mapping held in Trondheim 21 - 22 May 1986 it was agreed to propose a project for geochemical mapping of Western Europe.

The following account presents:

(1) examples of regional geochemical maps from Scandinavia as background data indicating the type of patterns that can be expected from a low sampling density European geochemical mapping programme.

(2) a sketch plan for geochemical mapping of Western Europe, and

(3) a summary of the possible advantages and applications of a European geochemical atlas.

BACKGROUND DATA

Three sets of background data are referred to.

In northern Fennoscandia the geological surveys of Finland, Norway and Sweden in cooperation (with the Geological Survey of Greenland as an associated project member) have been engaged in the "Nordkalott Project" since 1980. This project has collected geological, geophysical and geochemical data in the area north of 66°N.

Until now the geochemical subproject has (1) taken up to 7 different types of geochemical samples from ca. 7000 sites within a 250 000 km^2 survey area (1 site per 30-50 km^2), (2) analyzed fine and heavy fractions of 4 sample types for a number of elements and (3) produced 136 single element, geochemical raw data maps. Ten examples of these maps (Maps 1-10) are attached to this proposal.

In Norway three sets of geochemical samples have been collected througout the country.

(1) 500 samples of organic material from the upper 2-5 cm of the soil profiles.

(2) 286 samples from main water works.

(3) 700 samples of overbank sediments (catastrophic flood sediments) from drainage areas.

All sets have been analysed for a number of elements. Five examples of geochemical maps are attached (Maps 11-15).

In Finland till has been sampled from approximately 1000 sites, all over the country. The samples have been analysed for a number of elements. One example of the resulting maps is attached (Map 16).

Some brief comments to these maps are given in the following paragraphs.

(1) In large segments of the earth, such as Fennoscandia north of 66°N, there exist broad, extensive geochemical distribution patterns detectable through the analysis of a restricted number (order of magnitude 1000) of surface samples (Maps 2-16). Such patterns may apparently, in some cases, form parts of even larger patterns of continental scale (Maps 2-8 and 11-16).

(2) Large scale geochemical distribution patterns could be of combined genesis, from purely natural (Maps 2-10, 12-13 and 16) to predominantly anthropogenic (Map 11).
The natural patterns are combinations of (i) patterns apparently caused by the primary composition of the bedrock (Maps 3-6), (ii) patterns dominated by a marine component in atmospheric precipitation (Map 13) and (iii) patterns of unknown genesis, possibly being an effect of fluids or gases migrating through the bedrock (Maps 2, 7, 10,16). All of these types of natural patterns may cross over established geological units or boundaries.

(3) The distribution patterns of a certain element in different sampling media may in some cases be similar (Maps 7 and 10) and in others dissimilar (Maps 6 versus 8 and 14 versus 15). The distribution patterns of different elements in the same sampling medium may in some cases be similar (Maps 3 and 4), and in others dissimilar (Maps 8 and 9). Maps for various elements and samples types, therefore, completment each other.

(4) The sample treatment (fine or coarse grain size, heavy or light fraction, acid soluble parts or totals) strongly influences the geochemical patterns (Maps 6 versus 8 and 8 versus 16).

(5) The whole concentration range of the individual elements must be symbolized on the maps in order to detect existing patterns (Maps 3, 4 and 5).

PLAN FOR GEOCHEMICAL MAPPING OF WESTERN EUROPE

It is suggested that 5 sample types from 7192 sites (1 sample site per 500 km^2) be collected all over Western Europe, see Appendix 2.

The sample types should be

- surface water
- ground water
- surface soil (terrestrial organic material)
- soil c-horizon, (soil parent material)
- overbank drainage sediments

Fine and heavy fractions of the samples should be analysed for their total contents, as well as extractable parts of as many elements as possible. All the analytical results as well as their computed derivatives should be illustrated on maps.

The project should have a single leader of a team consisting of representatives from each participating country. Each geological survey should collect the samples from its own country according to common instructions.

For a particular method of analysis, all samples of a specific type should be analysed in one laboratory and in a random order regardless of country of origin.

A pilot project could be carried out during 1987/88. The main project could start 1988/1989 and be completed by 1995. Provisional maps would be produced througout the project period.

Financial support should be sought from:

(1) The participating institutions.

(2) The European Community.

POSSIBLE BENEFIT FROM A WESTERN EUROPEAN GEOCHEMICAL ATLAS

(1) The atlas will provide basic information about main geochemical provinces in Europe having potential for both traditional and unusual types of economic mineral deposits.

(2) The atlas will document features of the present status of contamination of the environment in Europe caused by long distant transported air and water-born pollutants.

(3) The atlas will provide data about the natural distribution of chemical elements in Europe as a baseline reference against which contamination of the environment can be judged.

(4) A common WEGS geochemical mapping programme will improve the science of applied geochemistry in Western Europe.

Examples of fields of use of a European geochemical altas:

- Disclosure of possible existing European provinces of Au, Pt and other precious and strategic metals.
- Planning of drinking water supplies and purification plants.

- Investigation of the distribution of health problems in human beings and domestic animals in Western Europe in relation to geochemistry.
- Contribution to the investigation of causes for and measures to be taken against death of forests in Europe.
- Provision of basic data for the elucidation of broad scale, transfrontier tectonic events.
- Providing of data for the natural distribution of I, Cs and Sr in order to be able to compute values for specific activity (e.g. Cs137/Cs133) in establishing how serious the effects of past and possible future pollution from nuclear energy plants could be.
- Establishing background data necessary for political decisions in connection with acid rain, contents of nitrogen in ground water, contents of lead in cultivated soil, addition of selenium to fertilizers, etc.

APPENDIX 1. ENCLOSED MAPS.

Map no.

Northern Fennoscandia

1	Simplified geology, bedrock
2	Br in till, fine fraction, total contents
3	Cr " " , " " , " "
4	Ni " " , " " , " "
5	Al " " , heavy " , " "
6	Ba " " , " " , " "
7	Mo " stream sediments, fine fraction, acid soluble
8	Ba " " " , heavy " , total contents
9	W " " " , " " , " "
10	Mo in ash of stream organic matter, total contents

Norway

11	Al in drinking water
12	Ba " " "
13	Br " " "
14	Pb " overbank sediments, acid soluble
15	Pb " soil terrestrial organic matter, acid soluble

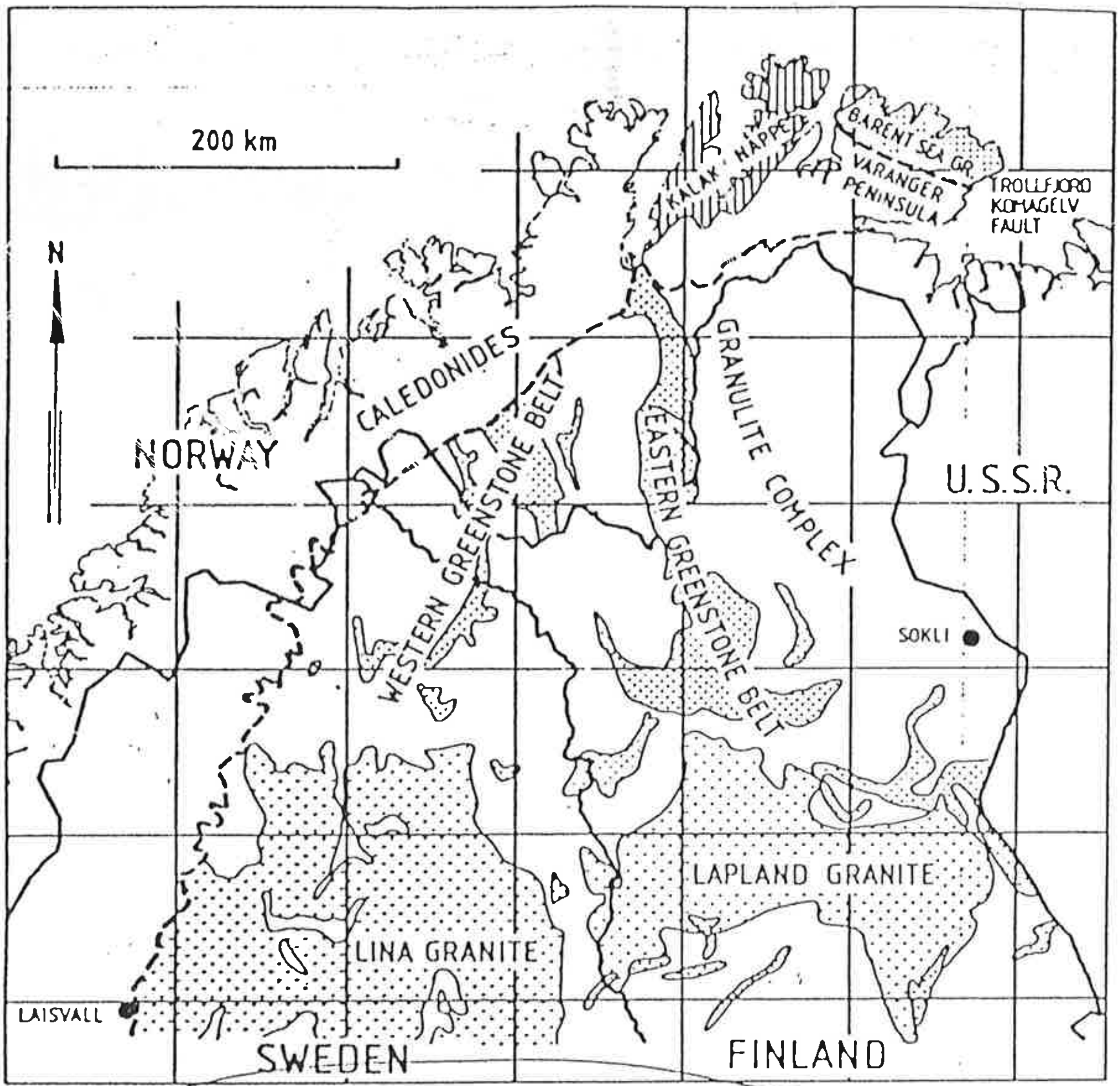
Finland

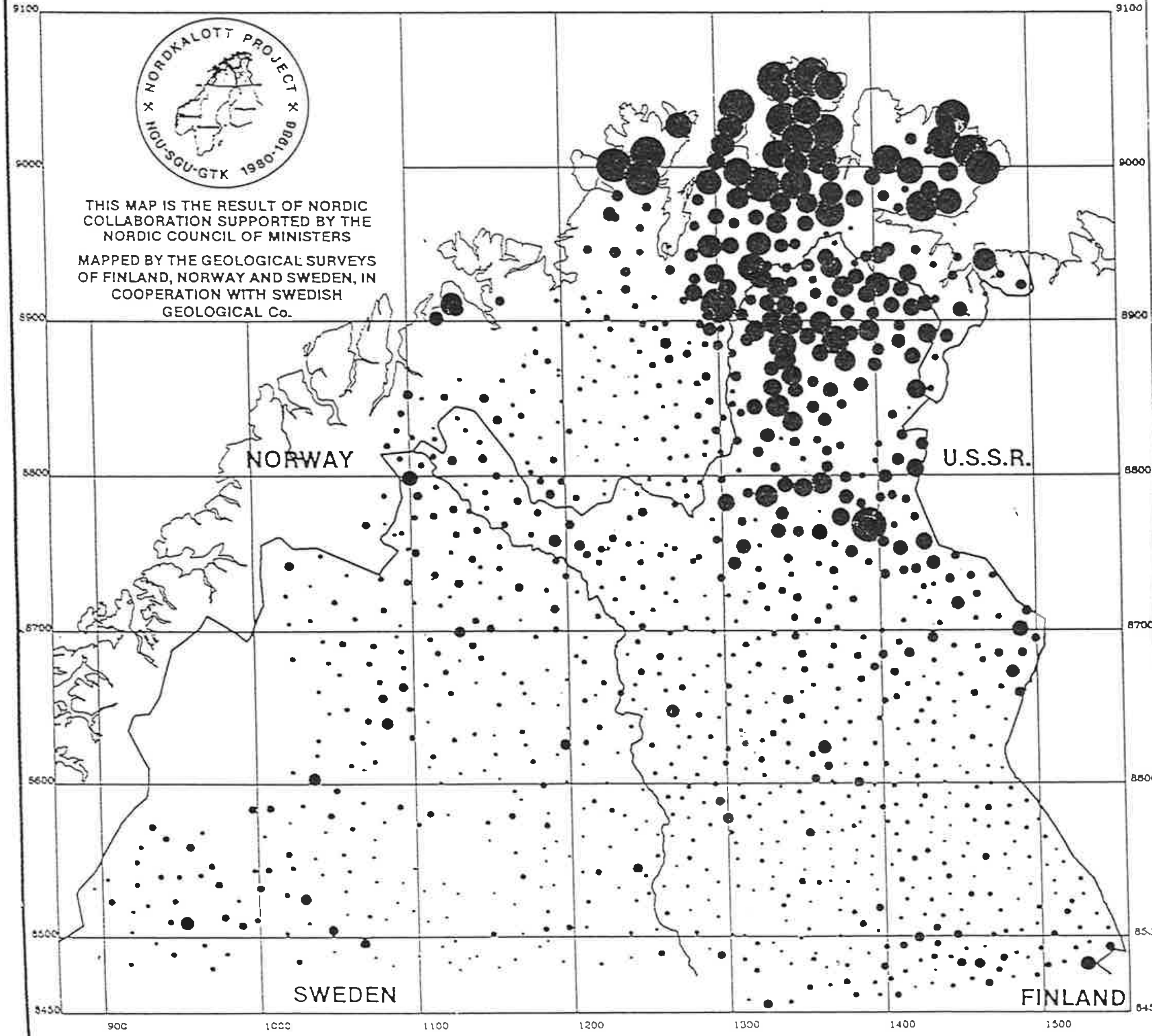
16	Ba in till, fine fraction, acid soluble

GEOCHEMICAL MAPPING OF WESTERN EUROPE.

AREAS, NUMBER OF SAMPLE SITES AND ESTIMATED COSTS OF FIELD WORK

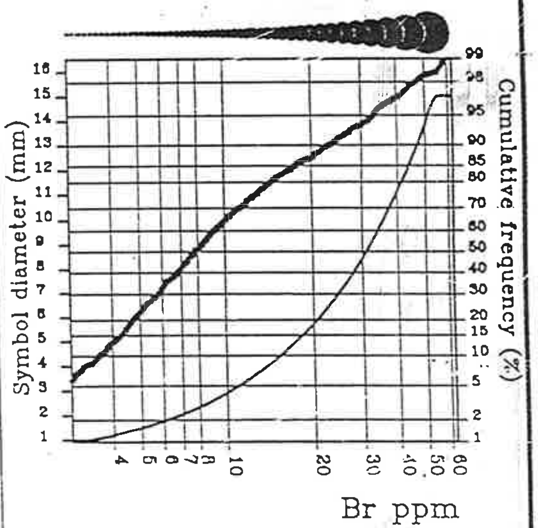
	Area (km^2)	No. of sample sites	Estimated field costs (1000 DM)
Austria	83,853	168	53
Belgium	30,513	62	20
Cyprus	9,251	18	6
Denmark	43,069	86	27
Finland	337,009	674	210
France	547,026	1,094	344
F.R. Germany	248,687	498	160
Greece	131,944	246	80
Greenland (icefree)	341,700	682	215
Iceland	103,000	206	65
Ireland	70,283	140	44
Italy	301,262	602	190
Luxembourg	2,586	6	2
Netherlands	40,844	82	26
Norway	324,219	648	205
Portugal	92,082	184	60
Spain	504,782	1,008	320
Sweden	449,964	900	280
Switzerland	41,293	82	26
Turkey	780,576	1,401	440
U.K.	244,046	488	155
Total	4,727,989	9,293	2,929


200 km
N
NORWAY
CALEDONIDES
KALAK
HAPPEL
BARENT SEA GR.
VARANGER PENINSULA
TROLLFJORD KOMAGELV FAULT
WESTERN GREENSTONE BELT
EASTERN GREENSTONE BELT
GRANULITE COMPLEX
U.S.S.R.
SOKLI
LAPLAND GRANITE
LINA GRANITE
LAISVALL
SWEDEN
FINLAND



Nordkalott project
Geochemistry
TILL
Br

Size fraction (μm): −62
Method of analysis: NAA
Laboratory: VTT/REA
No. of samples: 1040

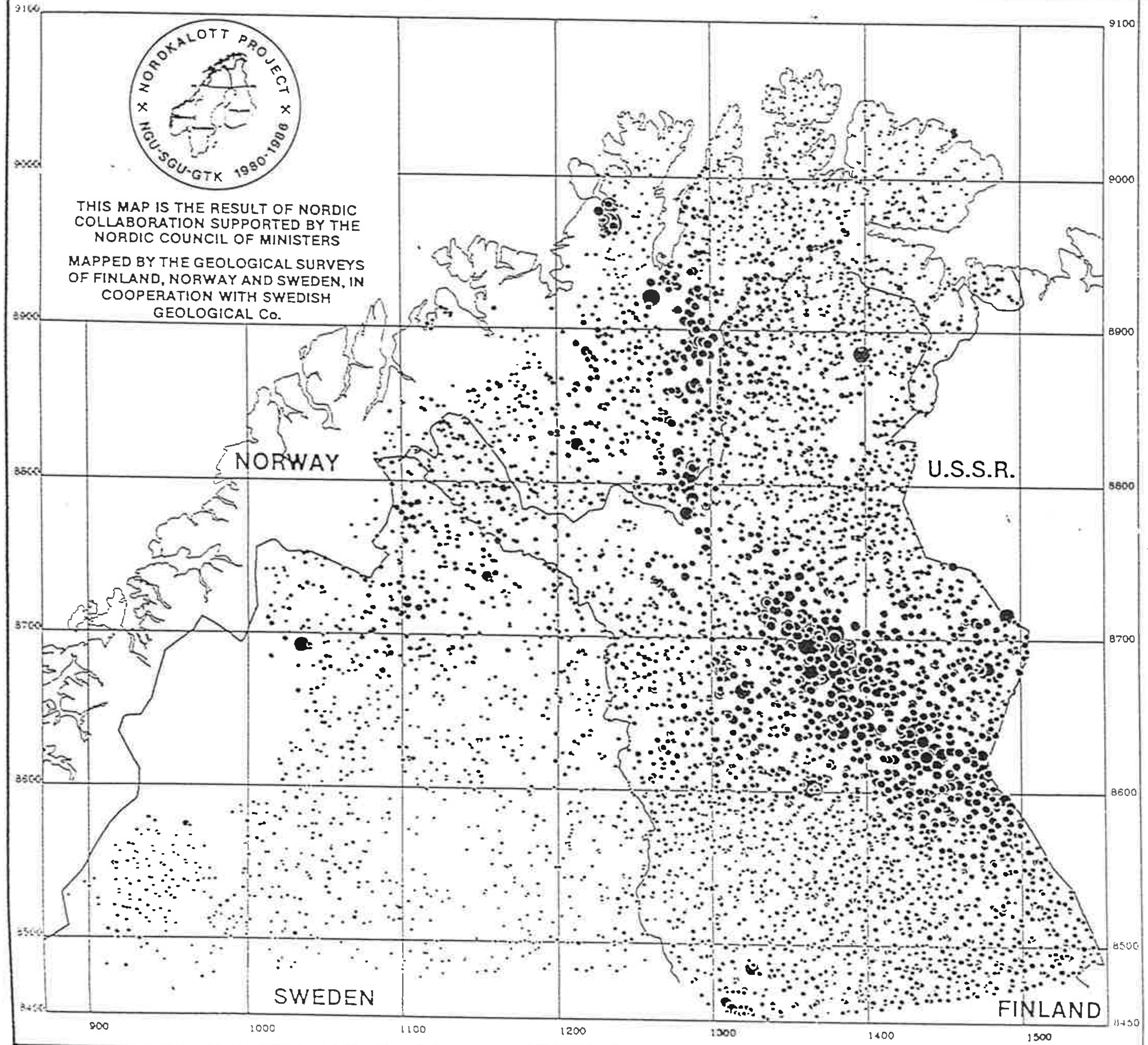


1: 4 000 000
100 km

Projection: Lambert conformal
Date of plotting: 25.03.1985

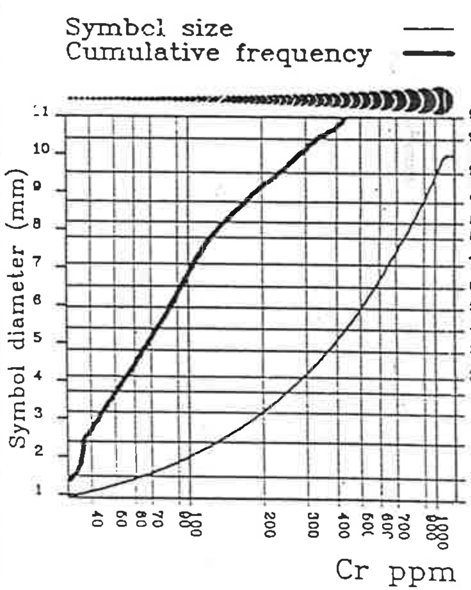
MAP 15

Compiled by: J. Bergstrom, A. Björklund, B. Bølviken, M. Kontio, P. Lehmuspelto, J. Magnusson, R.T. Ottesen, A. Steenfelt, and T. Volden. ISBN 91-7158-383-1



Nordkalott project
Geochemistry
TILL
Cr

Size fraction (µm): −62
Method of analysis: OES
Laboratory: GSF
No. of samples: 5399



1: 4 000 000

100 km

Projection: Lambert conformal
Date of plotting: 16.10.1984

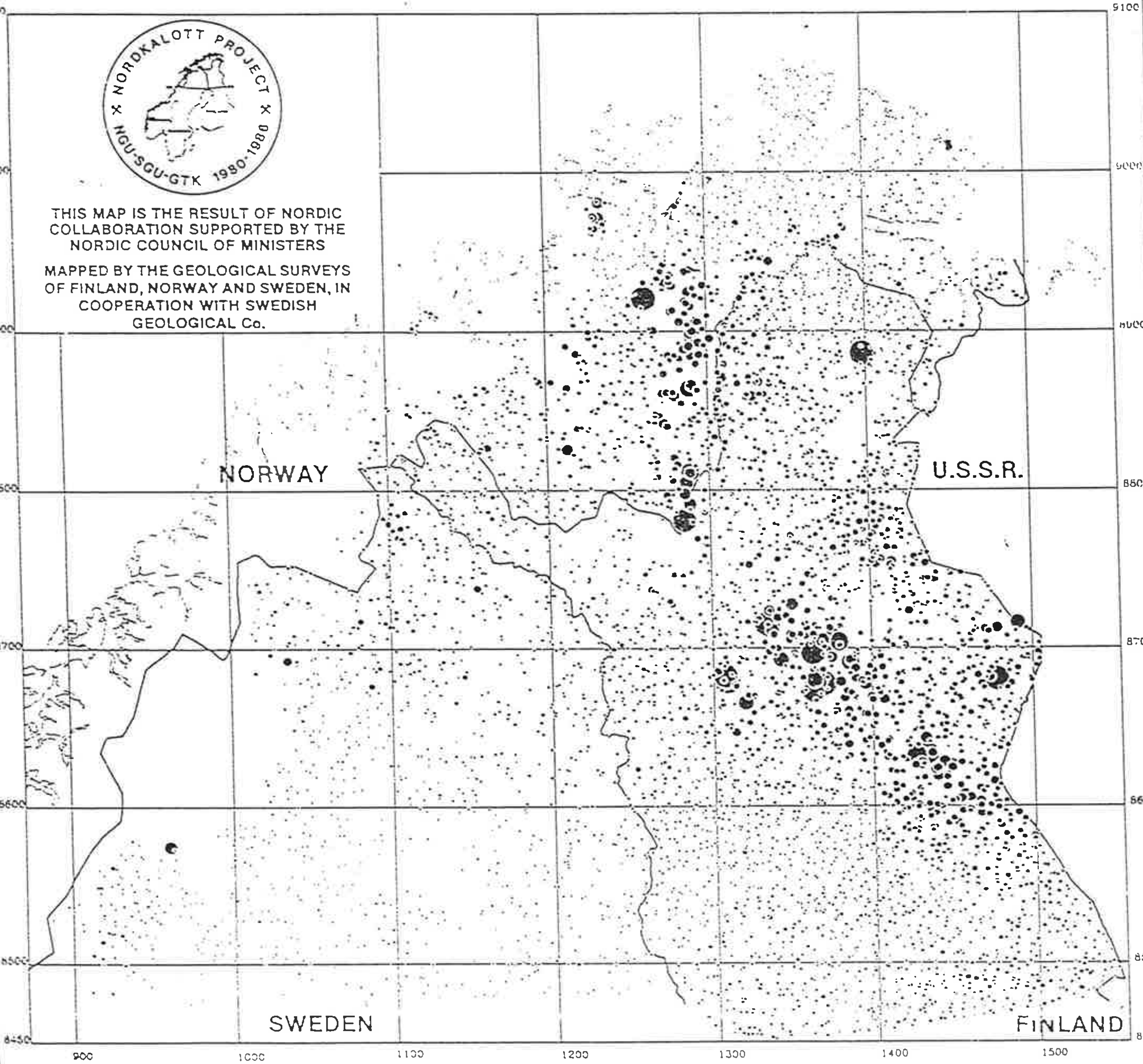
MAP 2

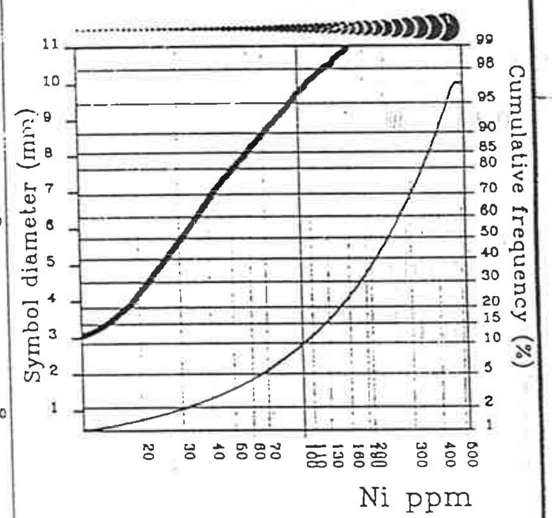
Compiled by: J. Bergström, A. Björklund, B. Bølviken, M. Kontio, P. Lehmuspelto, J. Magnusson, R.T. Ottesen, A. Steenfelt, and T. Volden.

ISBN 91-7158-383-1

Nordkalott project
Geochemistry
TILL
Ni

Size fraction (lm): −62
Method of analysis: OES
Laboratory: GSF
No. of samples: 5399





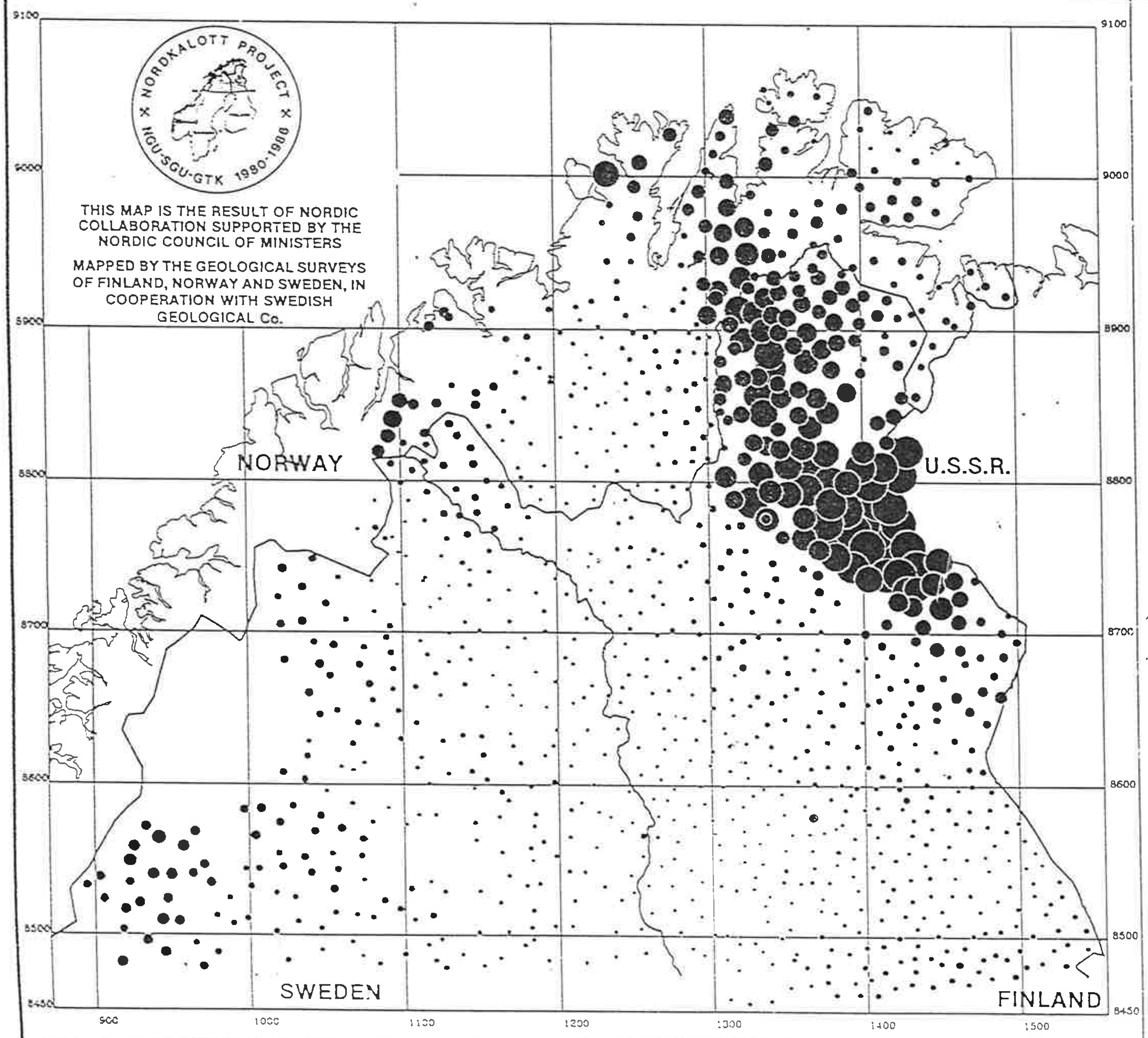
1: 4 000 000
100 km

Projection: Lambert conformal
Date of plotting: 04.02.1985

MAP 7

Compiled by: J. Bergström, A. Björklund, B. Bølviken, M. Kontio, P. Lehmuspelto, J. Magnusson, R.T. Ottesen, A. Steenfelt, and T. Volden.

ISBN 91-7158-383-1



Nordkalott project

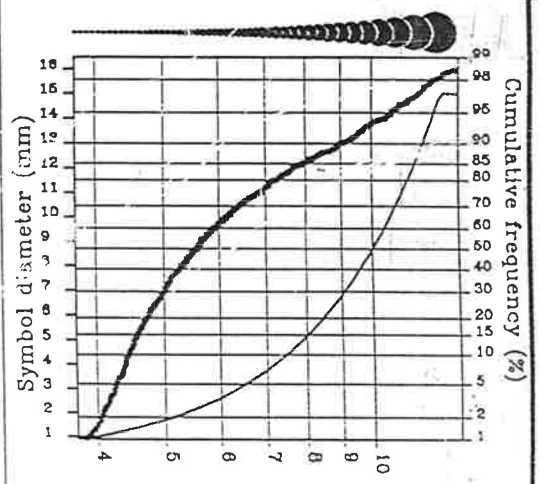
Geochemistry

TILL

Heavy minerals

Al

Size fraction (μm): 62...500
Heavier than 2.96 g/cm^3
Method of analysis: XRF
Laboratory: SGAB
No. of samples: 1034



1: 4 000 000
100 km

Projection: Lambert conformal
Date of plotting: 20.03.1985

MAP 28

Compiled by: J. Bergström, A. Björklund, B. Bølviken, M. Kontio, P. Lehmuspelto, J. Magnusson, R.T. Ottesen, A. Steenfelt, and T. Volden.

ISBN 91-7158-383-1

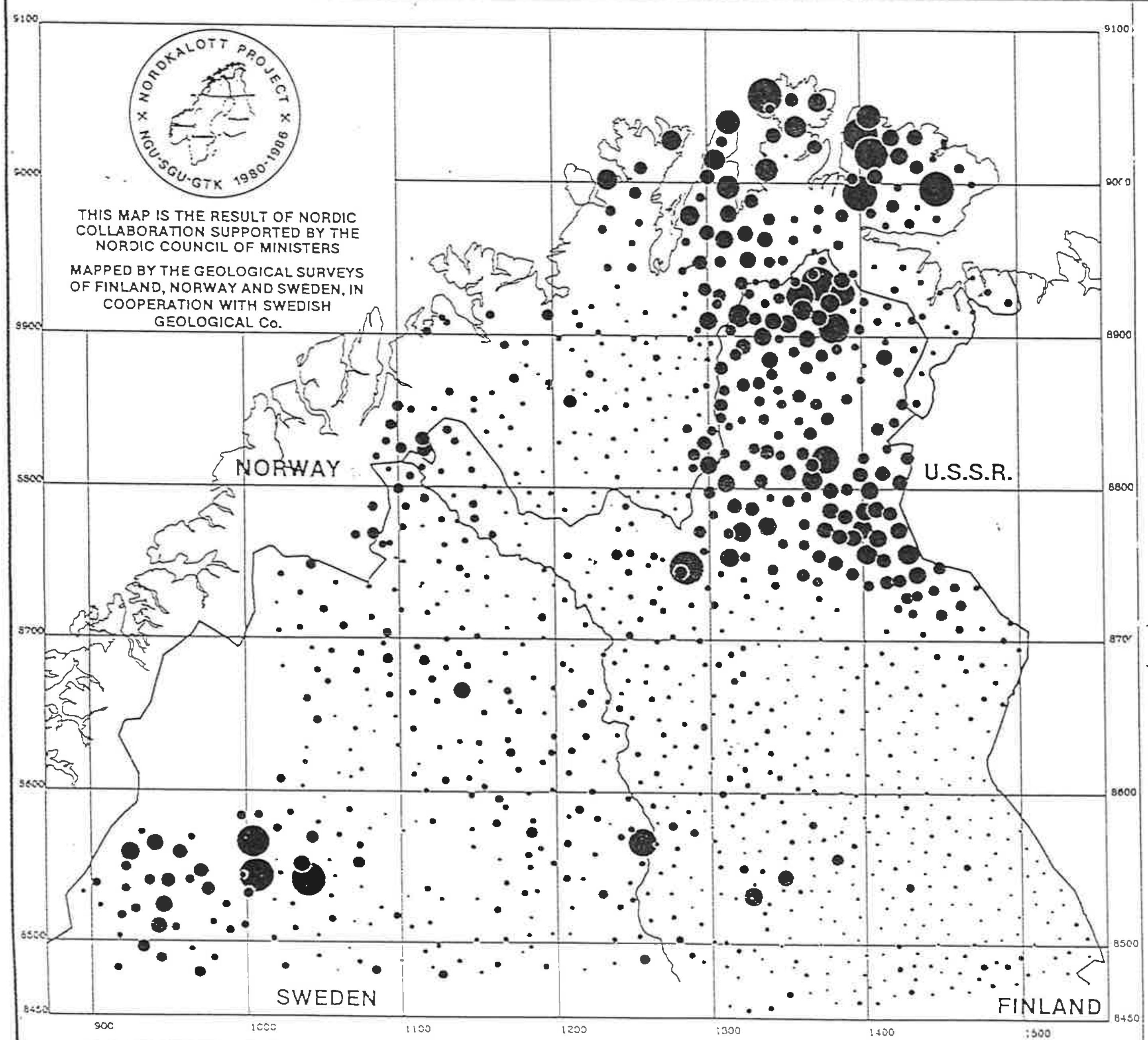
Nordkalott project

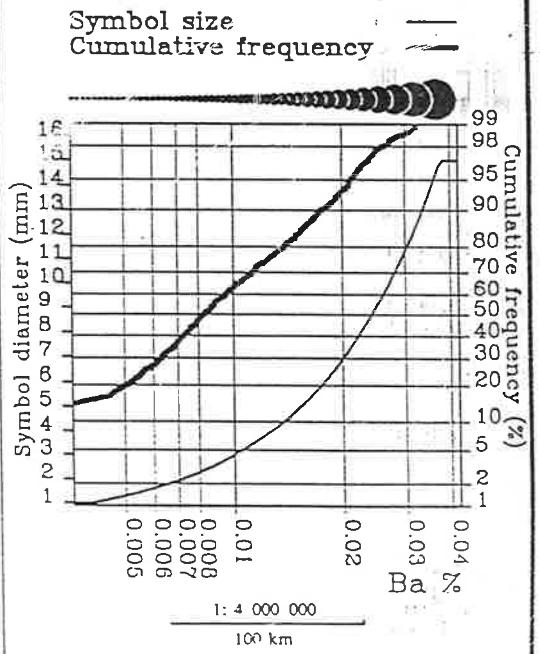
Geochemistry TILL

Heavy minerals

Ba

Size fraction (μm): 62...500
Heavier than 2.96 g/cm^3
Method of analysis: XRF
Laboratory: SGAB
No. of samples: 1034



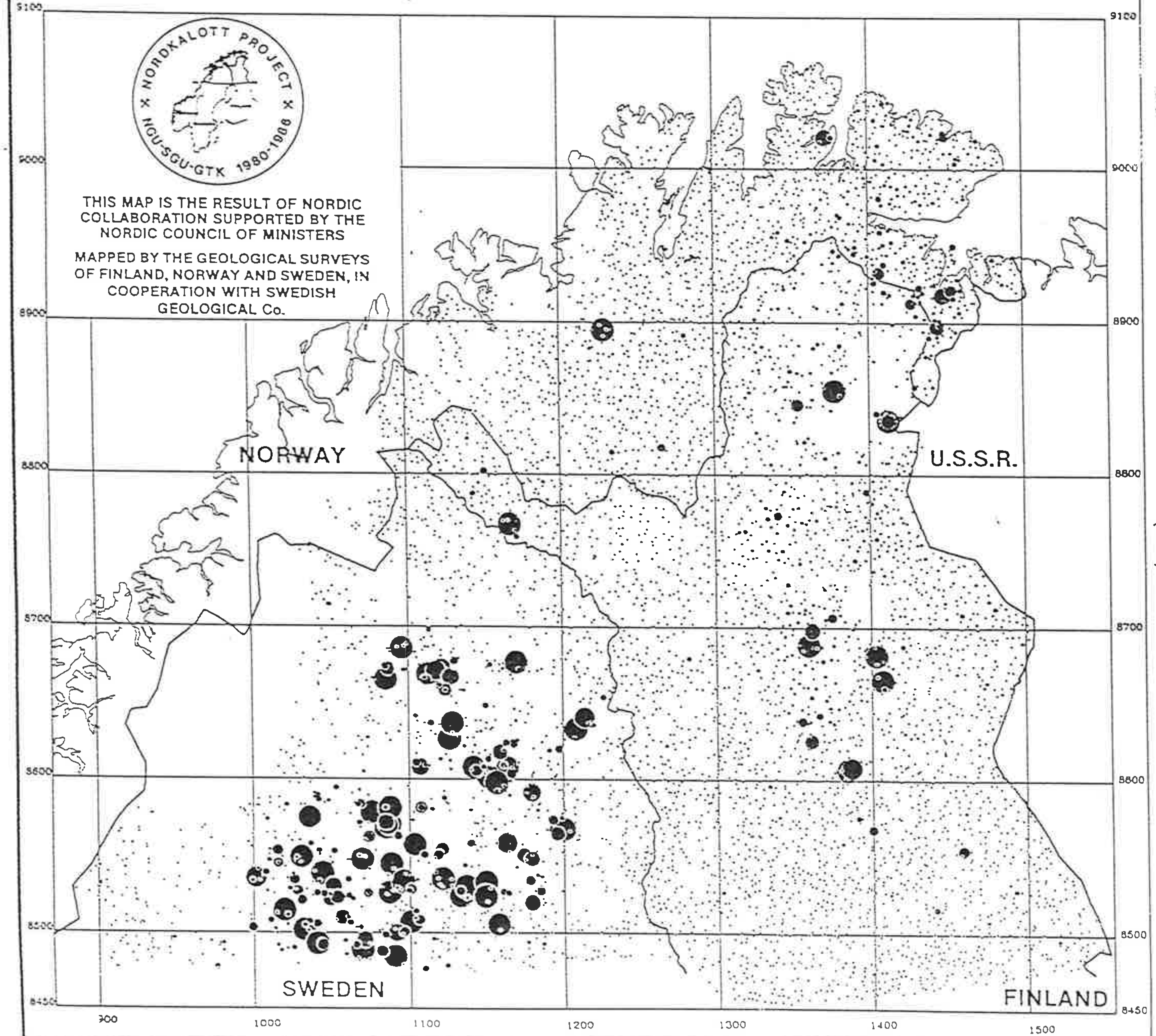


Projection: Lambert conformal
Date of plotting: 24.07.1985

MAP 29

Compiled by: J. Bergström, A. Björklund, B. Bølviken, M. Kontio, P. Lehmuspelto, J. Magnusson, R.T. Ottesen, A. Steenfelt, and T. Volden.

ISBN 91-7158-383-1

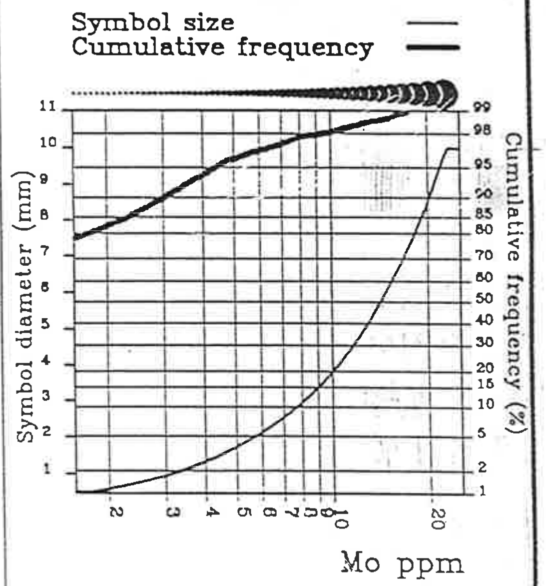


Nordkalott project

Geochemistry – STREAM SEDIMENT

Mo

Leaching: Hot 7M HNO_3
Method of analysis: ICP
Laboratory: NGU
No. of samples: 5773



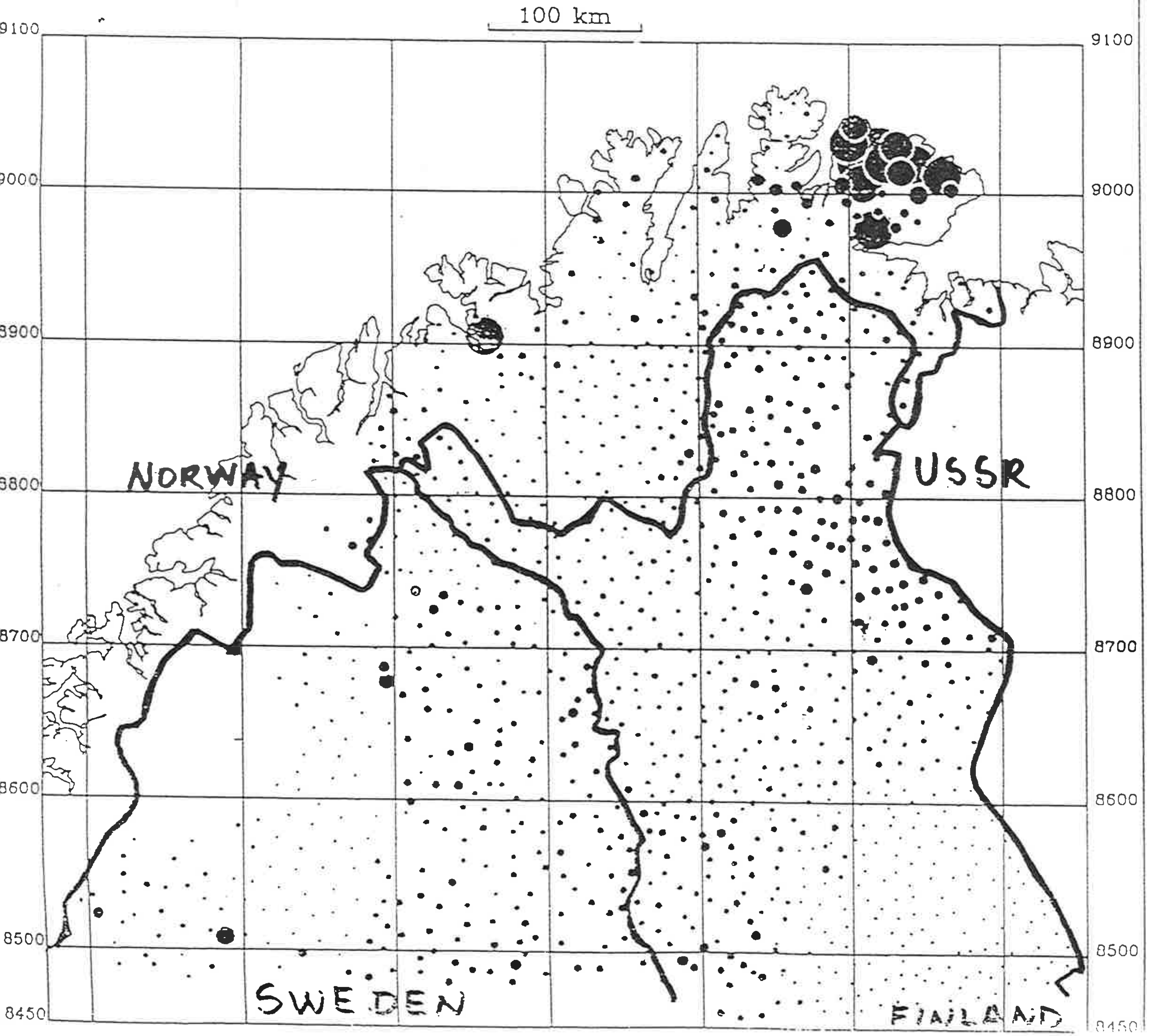
1: 4 000 000

100 km

Projection: Lambert conformal
Date of plotting: 18.03.1985

MAP 67

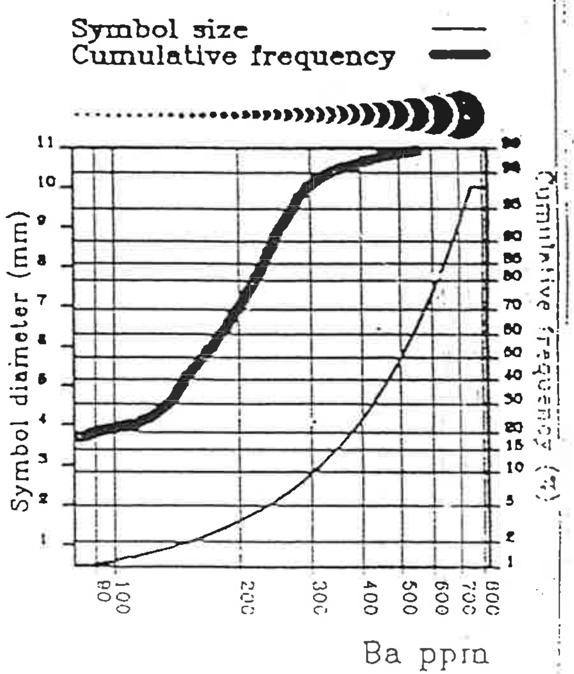
Compiled by: J. Bergström, A. Björklund, R. Bølviken, M. Kontio, P. Lehmuspelto, J. Magnusson, R.T. Ottesen, A. Steenfelt, and T. Volden,

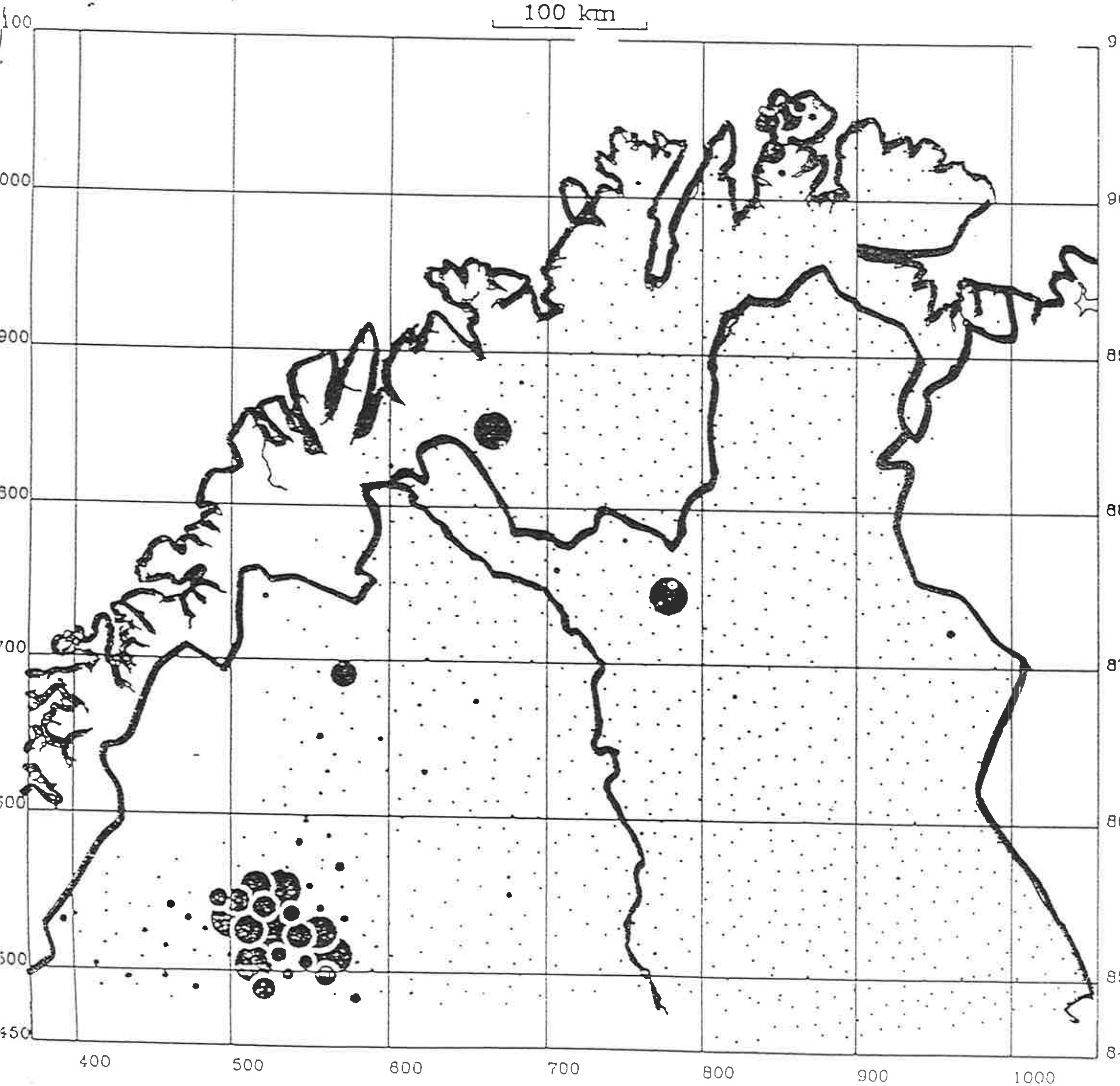


Nordkalott project

Geochemistry
STREAM SEDIMENT
Heavy minerals
Ba

Heavier than 2.96 g/cm³
Method of analysis: XRF
Laboratory: SGAB
No. of samples: 1056





Nordkalott project

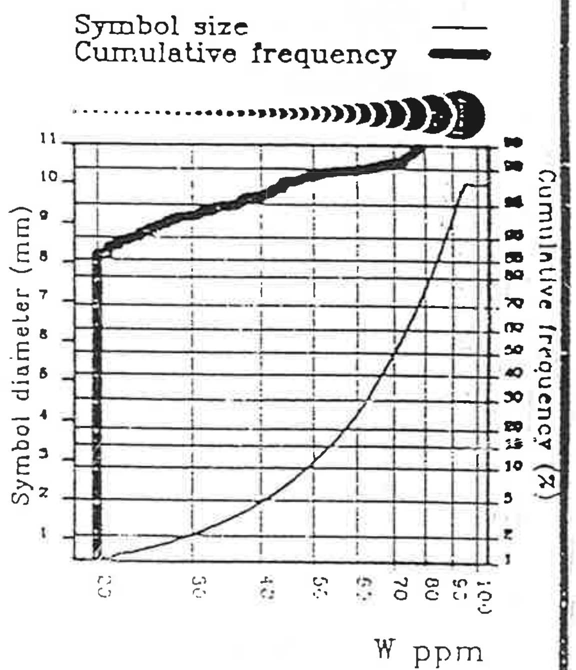
Geochemistry

STREAM SEDIMENT

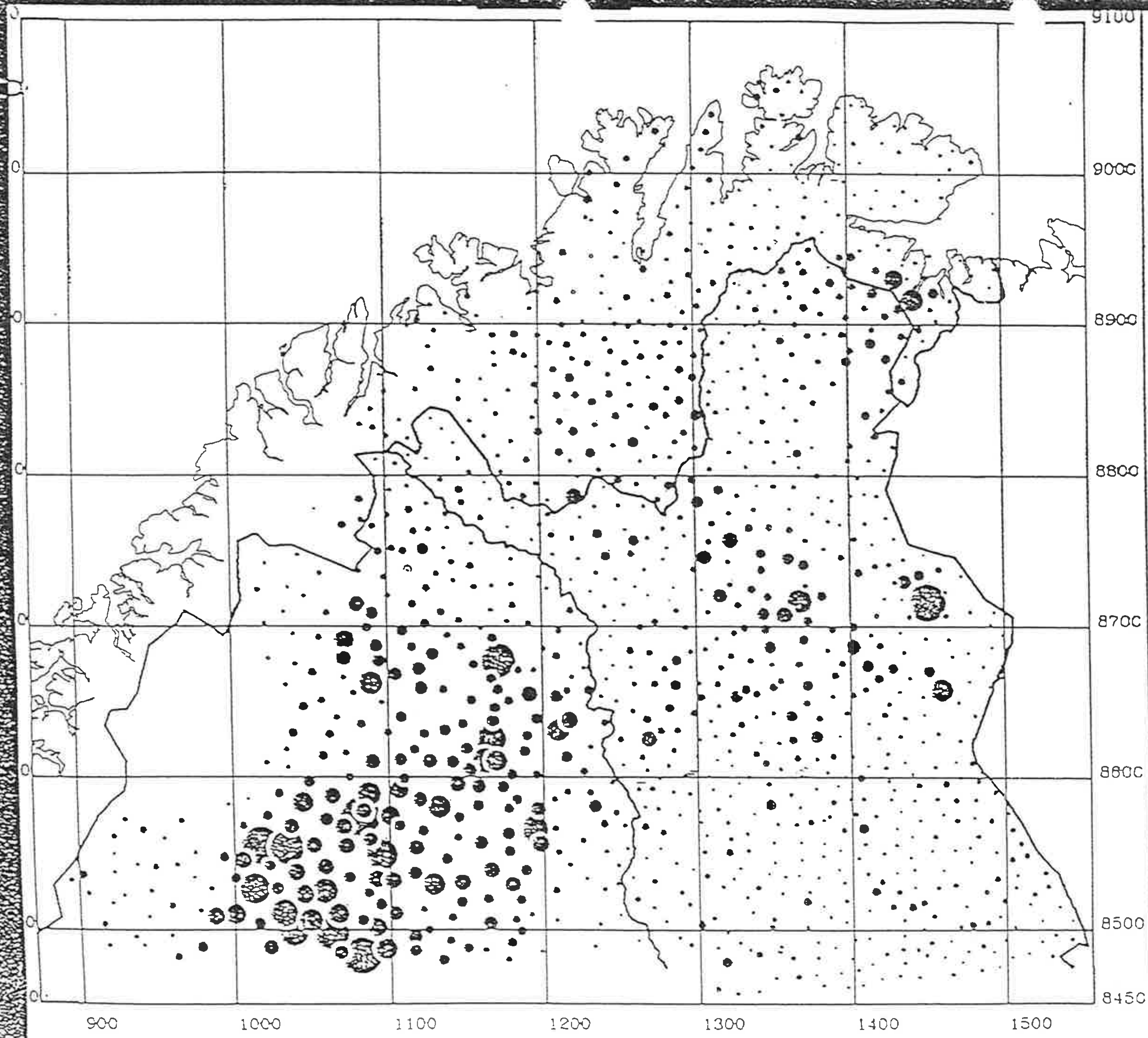
Heavy minerals

W

Heavier than 2.96 g/cm³
Method of analysis: XRF
Laboratory: SGAB
No. of samples: 1056



Projection: Lambert conformal

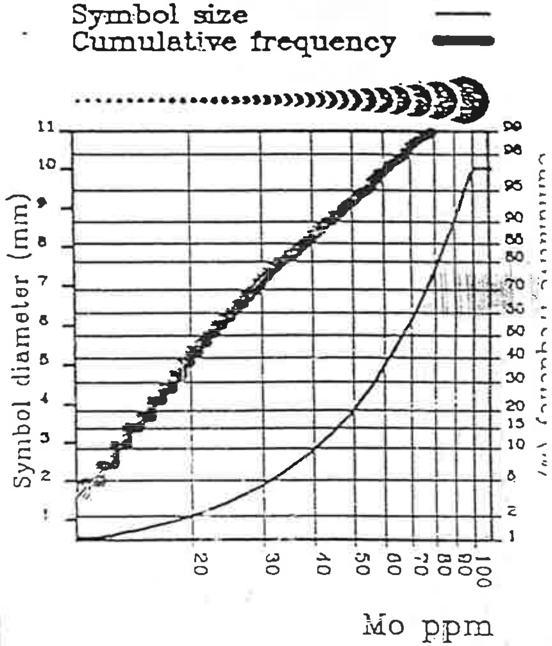


Geochemistry

STREAM ORGANIC MATTER

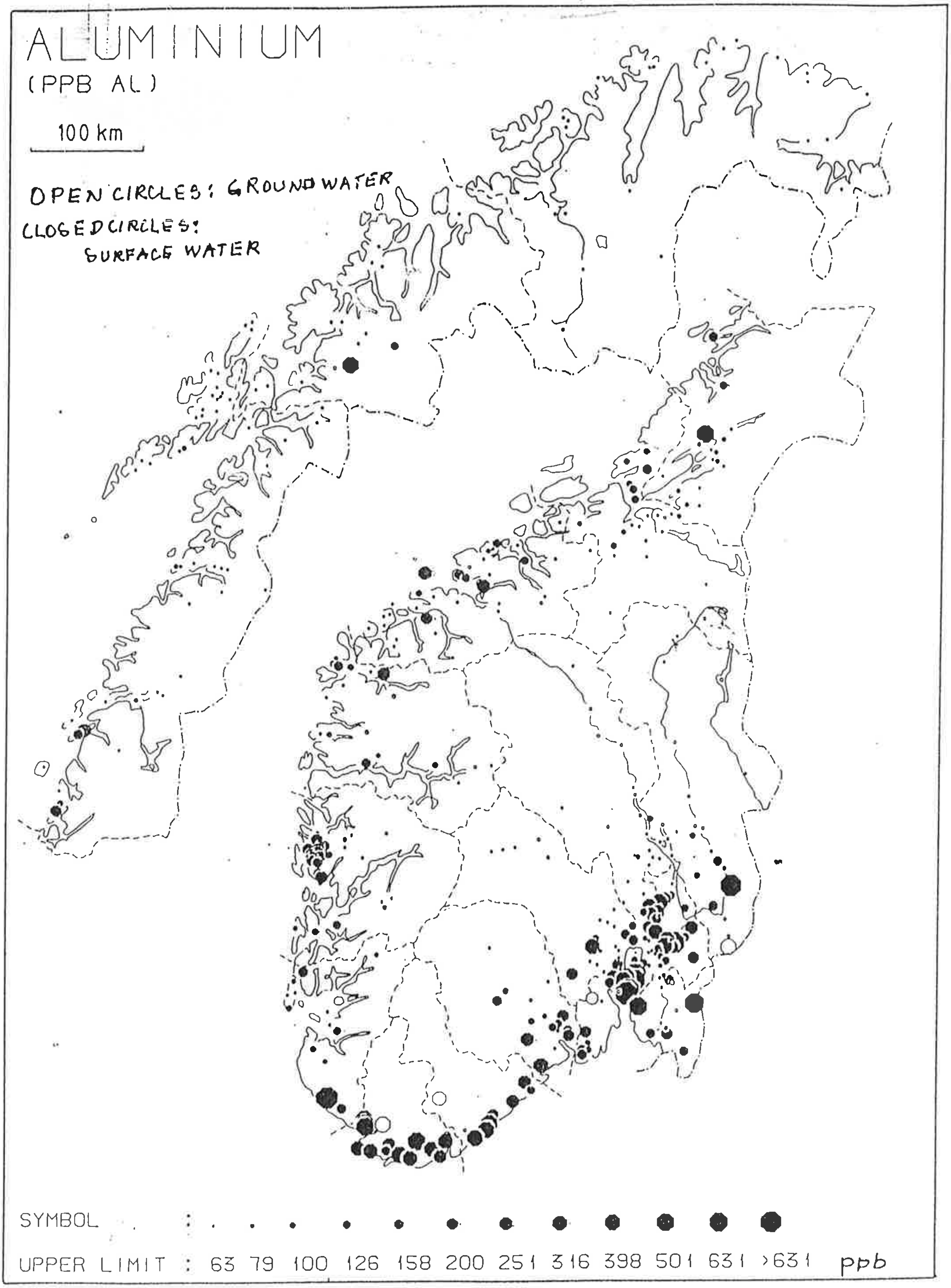
Mo

Content in ash
Method of analysis: XRF
Laboratory: SGAB
No. of samples: 1096

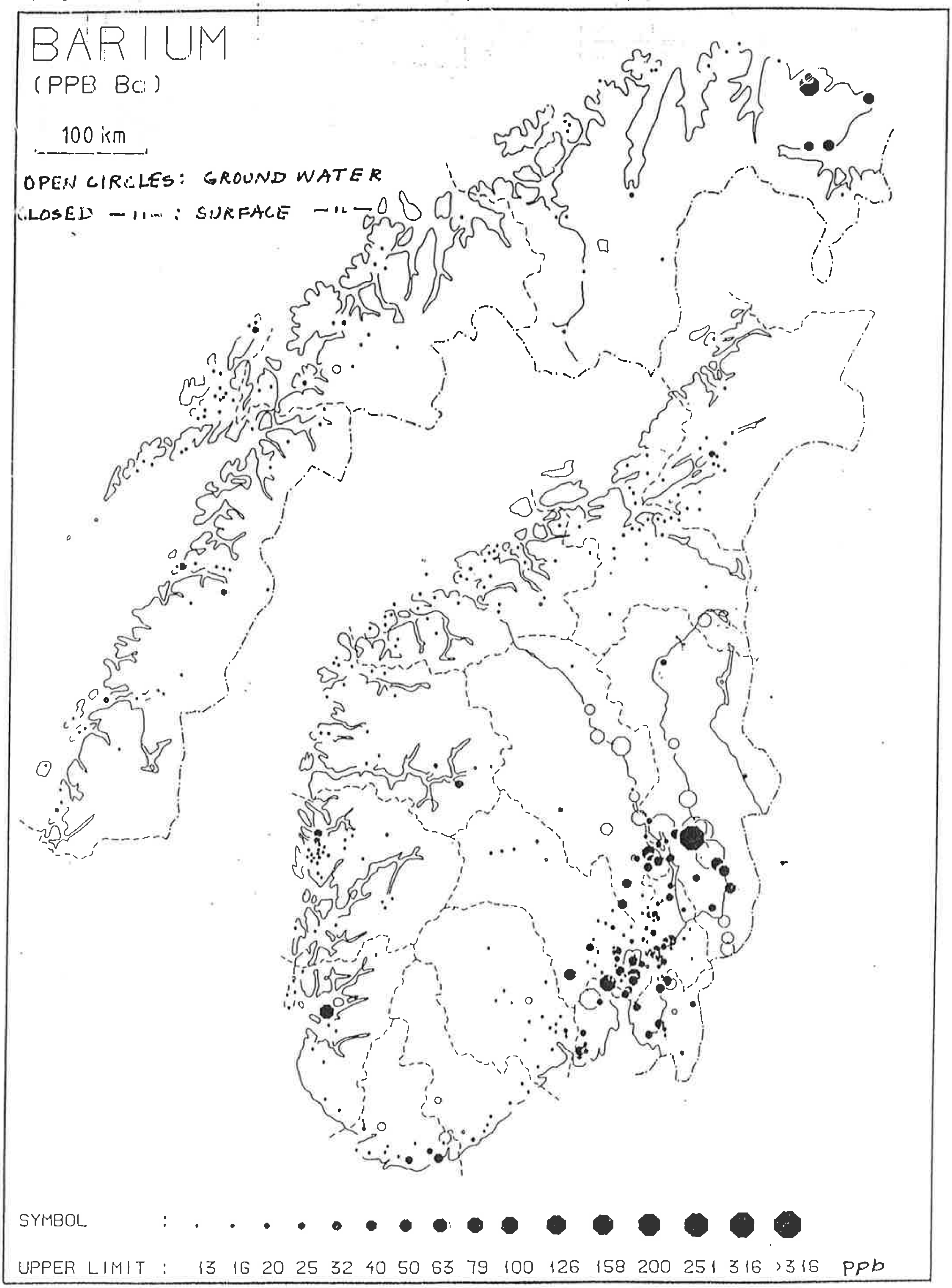


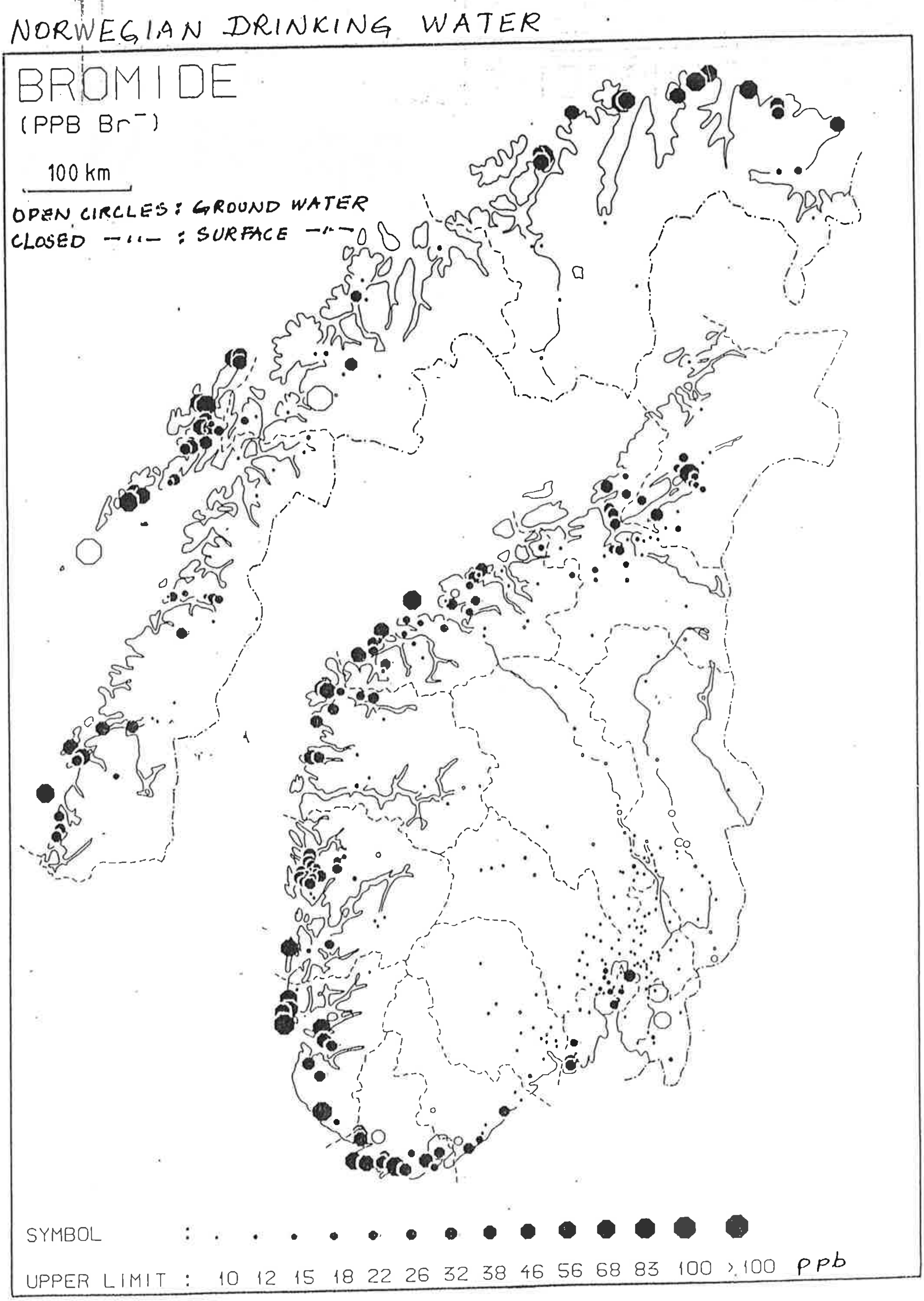
Projection: Lambert conformal
Date of plotting: 04.04.1985

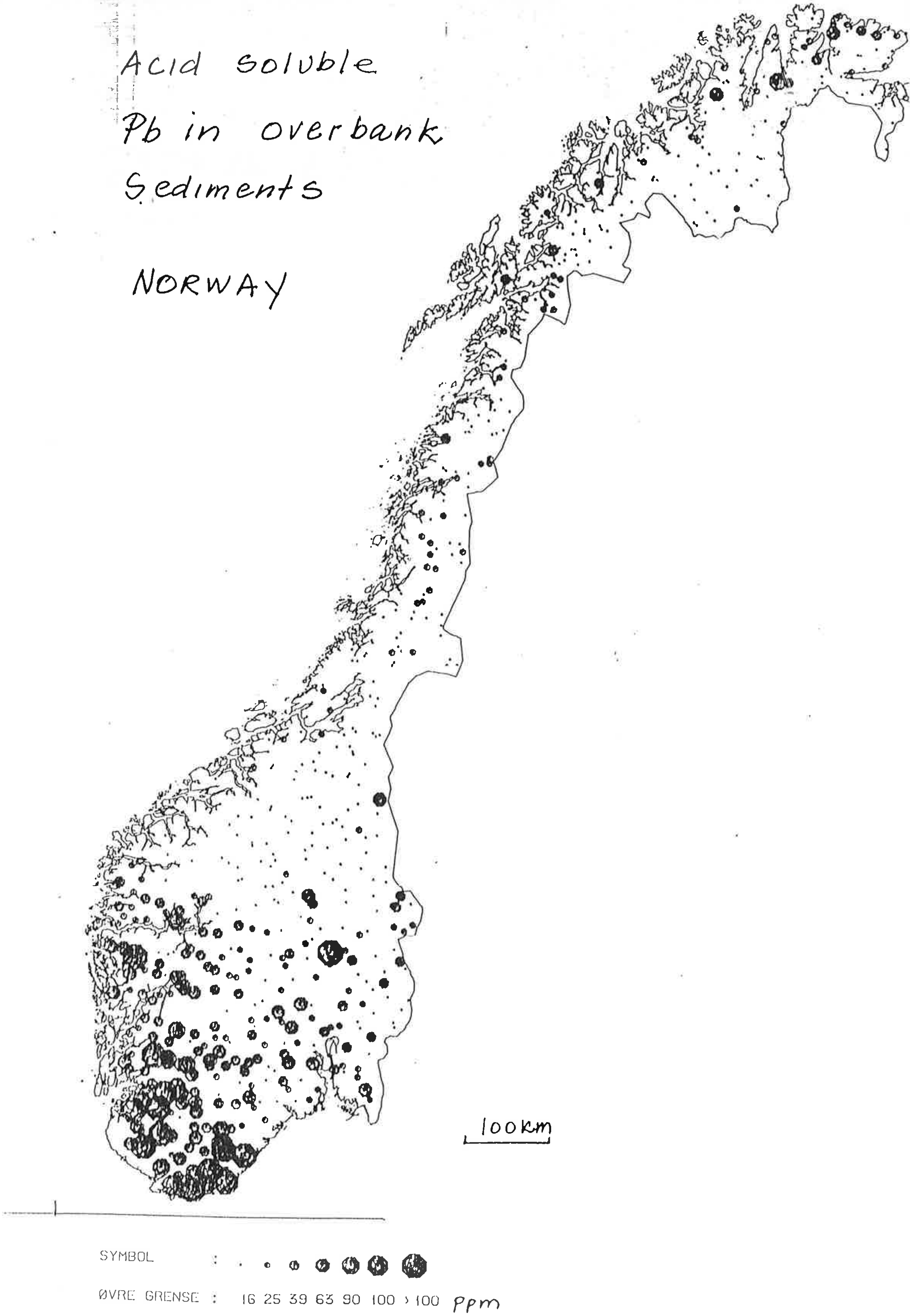
NORWEGIAN DRINKING WATER



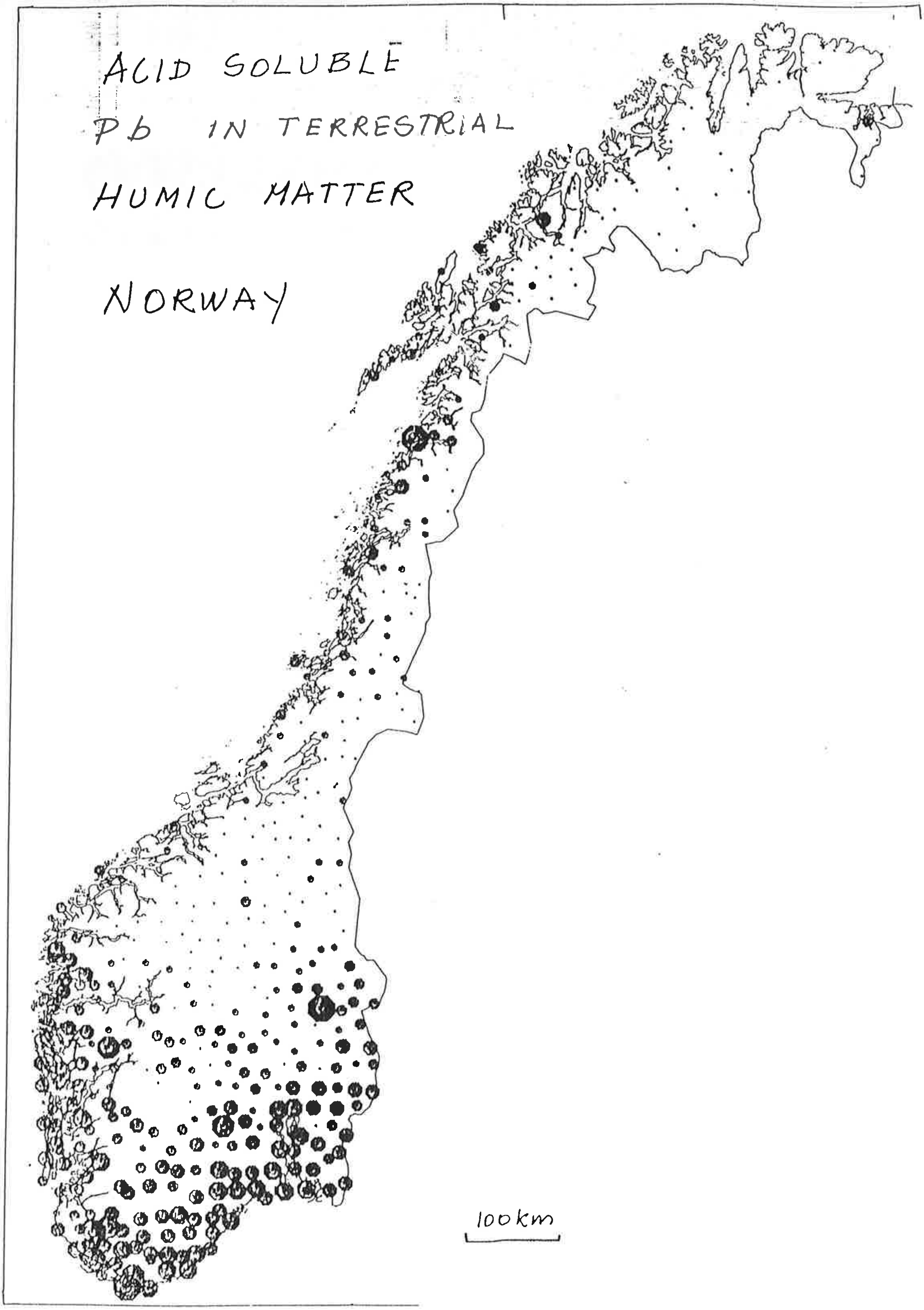
NORWEGIAN DRINKING WATER



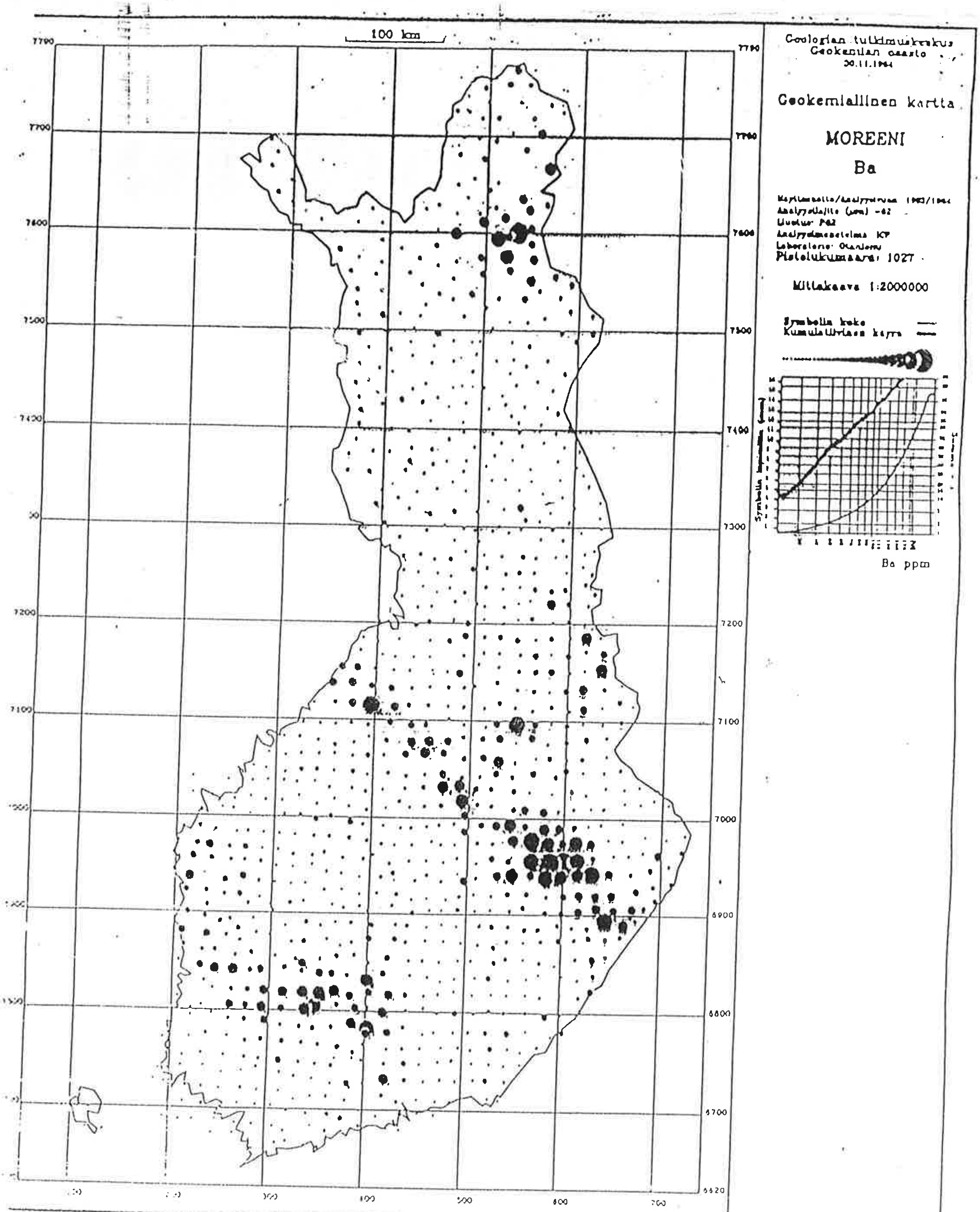

NORWEGIAN DRINKING WATER
BROMIDE
(PPB Br⁻)
100 km
OPEN CIRCLES: GROUND WATER
CLOSED —"— : SURFACE —"—
SYMBOL
UPPER LIMIT : 10 12 15 18 22 26 32 38 46 56 68 83 100 >100 ppb



Acid soluble
Pb in overbank
Sediments
NORWAY
100km
SYMBOL :
ØVRE GRENSE : 16 25 39 63 90 100 >100 ppm



SYMBOL



GLACIAL TILL, FINLAND
ACID SOLUBLE Ba. IN FINE FRACTION

Appendix 5. Overbank sediment: a representative sample medium for regional geochemical mapping.

APPENDIX 5

OVERBANK SEDIMENT:
A REPRESENTATIV SAMPLE MEDIUM
FOR REGIONAL GEOCHEMICAL MAPPING

by

R.T. Ottesen, J. Bogen, B. Bølviken and T. Volden

Manuscript submitted June 1988 to be printed in the Journal of Geochemical Exploration

OVERBANK SEDIMENT: A REPRESENTATIVE SAMPLE MEDIUM FOR REGIONAL GEOCHEMICAL MAPPING

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* Geological Survey of Norway, Trondheim, Norway
** Norwegian Water Resources and Water Administration, Oslo, Norway

Abstract

In Scandinavia, most fluvial erosion takes place in the Quaternary glacial overburden, at a restricted number of small source areas along individual drainage channels. As a consequence, a sample of active stream sediment is representative of only a very limited portion of the drainage area. This restriction makes stream sediment less reliable for regional exploration than generally expected. Overbank (levee or river plain) sediment produced during large floods is an alternative more representative sampling medium. The sediment suspended during a flood has a much more widespred origin, and when the load is deposited upon the flood plain, nearly horizontal strata are formed and preserved at levels above the ordinary stream channel. A composite sample through a vertical section of such strata, represents a great number of sediment sources that have been active at different times, and forms an integrated sample of the entire catchment area. Because young sediments overlay older, the uppermost layers will be contaminated by pollutants in industrialized regions, but those at depth may remain pristine and will to a greater extent reflect the natural preindustrial environment. In regional geochemical mapping, overbank sediment can be sampled at widely spaced sites, keeping costs per unit area low. Examples from Norway (1 sample station per 500 km^2) show that overbank sediment produces broad geochemical patterns with high contrasts reflecting the bedrock geochemistry. Some patterns agree with known geological units and metallogenic provinces, but hitherto unknown major structures have also been indicated. A large Mo-deposit missed by a traditional stream survey is readily detected in the overbank sediment. It is concluded that overbank sediment is a promising alternative sample medium which should be tested in other physiographic regions.

Introduction

Although stream sediment is a widely used sample medium for geochemical exploration, very few detailed descriptions exist in the literature. The information we have (Ottesen and Theobald, 1988) indicates that the term 'stream sediment' generally means active sediment from the stream bed in regular contact with the stream water. This material consists mainly of rock fragments and mineral grains with varying amounts of organic matter and secondary oxides (oxidates), all being subject to temporary deposition on the stream bed.

The application of active stream sediment as a sampling medium to geochemical mapping presupposes that its chemical composition generally reflects both the bedrock and overburden in the catchment area upstream from the sample point. This assumption is probably not always true, at least not in glaciated terrain in Fennoscandia.

Scandinavian research has shown that in Northern Europe the traditional model for denudation based on supply and removal of fresh weathering products (Holmes, 1965) fails to describe the overall denudation activity (Nilsson, 1972; Nordseth, 1976; Bogen, 1982, 1983, 1986 and 1987; Bogen and Huseby, 1982; Bogen and Nordseth, 1986). By applying the concept of sediment budget (Swanson et al., 1982) it becomes clear that the present day regional pattern of sediment yield closely coincides with the presence of Quaternary deposits available for erosion and transport (Fig. 1). Except around active glaciers, Fennoscandian fluvial sediment, consists mainly of mixtures from earlier formed glacial deposits.

True sheet erosion does not often occur. The major portion of the stream sediment originates from scattered small source areas along a drainage channel (Table 1, Figs. 2 and 3). These point sources develop during floods through channel shifting and gullying, and under normal water conditions when a stream undercuts an adjacent slope containing fine grained material, which induces mass movements when the water rises (Bogen, 1980), (Fig. 4).

Once a point source is established, the most significant process supplying sediment is gully erosion, channel erosion and mass movements including slump earth flows, debris slides and soil creep (Table 1).

Except for local source areas, erosion in most Scandinavian landscapes is generally minimal due to a complex of factors, of which the following 3 are thought to be the most important:

(1) The large amounts of sediments suspended in the stream water from an active, but restricted local source reduces the down stream erosion capacity of the stream and prevents homogenous erosion along the stream bed.
(2) Bed and bank are armoured by glacial debris, which limits both the general channel erosion and the effects of scouring (Fig. 5).
(3) In the nordic climate the vegetation provides an efficient protection against erosion by promoting infiltration and counteracting surface runoff (Fig. 2). However, if vegetation is lacking or the soil becomes water saturated during snowmelt or rain, then extensive erosion may take place (Figs. 3 and 4).

Due to the limited extent of the sediment sources, active inorganic stream sediment cannot represent whole catchment areas. Samples of active stream sediment taken at intervals along a drainage channel are often nothing but replicates of material from the same sediment source, producing little or no geochemical information in addition to what could be obtained from a few key samples.

Apart from water and various types of sample media rich in organic material (which are not discussed in this paper), inorganic lake sediment is an attractive alternative to stream sediment. However, a serious disadvantage in using lake sediment is that a sufficient density of adequate lakes will not exist in all types of landscapes. Other drawbacks include (1) the sediment cannot be inspected visually before sampling; (2) the deposition rate and the grain size of inorganic lake sediment supplied from inflowing rivers can be subject to large variations within short distances on the bottom causing corresponding variations in sample composition; (3) the genesis of inorganic lake sediment may occasionally be complicated due to slumping; (4) interpretation of data for the composition of lake sediment may be difficult due to varying contributions from organic matter and oxidates and; (5) certain strata of lake sediment are susceptible to contamination from anthropogenic sources.

In this publication we suggest overbank (floodplain, river plain or levee) sediment as an alternative drainage sample type devoid of some of the drawbacks of active stream sediment and inorganic lake sediment. Earlier accounts of the use of overbank sediment in geochemical mapping include those given by Ottesen et al. (1986), Ottesen (1987), Bølviken et al. (1988), Ottesen and Volden, (1988), and Ottesen and Bølviken (1988).

OVERBANK SEDIMENT

Overbank sediment is produced when major floods occur in a river system. During such floods the water discharge exceeds the quantity that can pass through the ordinary stream channel (bankful discharge). Even in streams of moderate size, the water level can reach several metres above normal, thereby covering large areas. At these times many new sediment sources open up (Figs. 2, 3 and 4), and the origin of the load suspended in the stream is manifold. Throughout the flood - and especially during its last phases - some of the load will be deposited on the flood plain at levels well above those of the ordinary stream channel (Figs. 6 and 7). In this way nearly horizontal strata of overbank sediment are built up over long periods of time. In Norway, the thickness of the layers from individual floods may vary from a few millimetres to several decimetres, while the total thickness of overbank sediment strata could be up to a few metres (Fig. 8).

A vertical section through overbank sediment reflects the history of sedimentation back through time, and a composite sample of such a section will give an integrated picture of the chemical and mineralogical conditions from a large number of sediment sources opened during many floods. As active sources eventually become paleosources (Fig. 9) due to exhaustion or shifts in the river channel or other conditions affecting erosion, it is possible to characterize a large drainage area with data from one sample.

It should again be noted, however, that the above discussions only deal with clastic transport. Chemical dispersion including e.g. precipitation and dissolution of secondary oxide coatings on grain surfaces complicates the picture.

EXPERIENCE USING OVERBANK SEDIMENT IN NORWAY

Overbank sediment has been collected from 690 sites uniformly scattered all over Norway (320 000 km^2), each site representing large drainage areas of 60-300 km^2. The sample stations were preselected by searching each of the 1:50 000 scale topographic map sheets of Norway for a suitable floodplain. In the field the samples were collected at distances of 2-200 m from the present day stream, depending on the circumstances. Sites close to the active channel were avoided in order to reduce the possibility of obtaining polluted samples. A vertical section through the sediment was cut with a spade, and after excluding the upper 5-10 cm, approximately 5 kg of bulk sample were taken from the rest of the section. In the laboratory the samples were dried and sieved to obtain a minus 0.062 mm fraction, which was analysed for total elements by X-ray Fluorescence (Faye and Ødegård, 1975), and acid soluble elements by Inductively Coupled Plasma Spectrometry (Ødegård 1981) and Atomic Absorption Spectrometry (Kuldvere 1988). The analytical results were plotted as single element dots or moving median maps, of which 3 examples are given in Figs. 10-12.

Some conclusions based on the results are summarized as the following 6 points, with reference to Figs. 10-16, Tables 2-4 and 7 numbered case histories.

(1) All elements, including several of economic interest, depict broad regional patterns with high contrasts (Figs. 10-12). Some of the provinces obtained may indicate new areas with potential for mineral deposits.

(2) The chemistry of overbank sediment reflect compositional features of the bedrock. (Case History 1).

(3) The regional geochemical patterns sometimes agree with known geological structures, in other cases they indicate features not known before. (Case History 2, 3 and 4).

(4) Well defined overbank sediment geochemical provinces coincide with metallogenic provinces. (Case History 5).

(5) Major mineral deposits missed by stream sediment surveys can be indicated by the analysis of overbank sediment. (Case History 6).

(6) Overbank sediment can be used as a sample medium in heavily polluted terrain. (Case History 7).

Case Histories

1. A total of 133 samples of granites from major massifs in southern Norway were collected. The samples were ground and analysed after nitric acid extraction for the contents of 28 elements using ICP spectrometry (Ødegård, 1981). The analytical data, when compared with corresponding values for the minus 0.062 mm fraction of overbank sediments, showed

there are significant correlations between the element content in the overbank sediments and those in the granites, La and Mo being given as examples in Table 2 and in Figs. 11-12 and 14-15.

2. The rocks of the Barents Sea Group north of the Trollfjord-Komagelv fault zone (Fig. 13) on the Varanger Peninsula have been described as a foreign element in the Caledonides of Northern Norway, supposedly being of a remote origin outside the Baltic Shield (Siedlecka, 1975; Kjøde et al., 1978; Roberts, 1985). Although the rock types are similar on both sides of the fault, the Barents Sea Group has been classified as the most distinct geochemical province found in the Nordkalott project (Ottesen et al., 1985, and Bølviken et al., 1986). Overbank sediment data also show significantly different element contents north and south of the fault, see examples in Table 3.

3. Geological mapping has revealed that the Precambrian rocks of southern Norway can be divided into two blocks by a large generally N-S running tectonic line (Sigmond, 1985), the Mandal-Ustaoset fault zone (see Fig. 13). Overbank sediment west of the Mandal-Ustaoset line has relatively high contents of Ba, and La, while those east of the line have relatively low Ba- and La-contents (Figs. 11-12).

4. Main structures in the bedrock in Scandinavia have been identified by airborne geophysics, see Fig. 16 taken from Eriksson and Henkel (1983).

   Overbank sediment data, show a distinct NW-trending discontinuity in the Ba contents through southern Norway (Fig. 10), coinciding with one of the geophysical lineaments ('Jan Mayen FZ' on Fig. 16). The south-eastern part of this structure ('the Mylonite Zone') is interpreted as a suture (Gaal, 1986), while the northwestern part is indicated as one Precambrian unit on the geological map (see Fig. 13). The coinciding geophysical and geochemical lineaments indicate that a revised interpretation of major geological events is warranted in the Pre-cambrian of Western Norway.

5. Several molydenite prospects and abandoned Mo-deposits including the Knaben mine, lie within a metallogenic province in south-western Norway (Bugge, 1983)

   The map of Mo in overbank sediment (Fig. 12) shows a geochemical province embracing this metallogenic province. However, the geochemical province also includes Mo-occurrences discovered more recently in the northern part of the Permian Oslo region (see Mo data on Fig. 13 taken from Juve and Gust (1984) and Case History 6).

6. A large Mo deposit was discovered at Nordli, in the drainage basin of the Høverelva River within the northern part of the Oslo region, southern Norway (Figs. 12 and 13). Geological prospecting, analysis of soil samples from a depth of 1-3 m, and diamond drilling delineated this rather large deposit of several tens of million of tonnes at a cut off grade of 0.05 % Mo (Dannow, 1987). However, active stream sediment failed to produce any Mo-anomaly in the Høverelva River although the

stream crosses a large outcrop area of the deposit, and numerous mineralized bolders are observed in the stream bed. Strong stream sediment Mo-anomalies were, nevertheless, obtained from minor Mo-occurrences elsewhere in the region. (Volden, 1979, 1980).

The lack of a traditional stream sediment anomaly in the Høverelva River may be explained by the long term variability of the sediment-producing processes within the drainage basin. The existance of a large floodplain and delta of the river shows that great amounts of sediment have been transported by the river during postglacial time. Quaternary sediment sources have been active at various localities during this period (Fig. 9). Some of these earlier sources have probably been enriched in Mo, and Mo-containing sediments have then moved through the river channel during the past millennia. At present, the stream channel in the mineralized area is armoured with large boulders (Fig. 5), and erosion is very limited. The only sediment sources now active are located further upstream, where the overburden has low contents of Mo. Toward the present time, any earlier Mo-containing sediments in the stream bed have, therefore, been replaced by sediments with low contents of Mo.

The above interpretation is corroborated by the analysis of overbank sediment and delta sediment taken at depths of 0.6-14m some 8 km downstream from the deposit. An average Mo-content of about 15 times higher than background was obtained (Fig. 12), while certain strata showed considerably higher values.

7. The Trondheim region (Cambro-Silurian rocks) is the most important copper district in Norway (Fig. 13), where mines have been in operation for the past 300 - 400 years. In some of the mining areas streams are heavily polluted by mine waste, and stream sediment data are of restricted value in exploration.

   At the outlet of the heavily polluted Orva River, which drains an area of Cu, Zn and Pb containing pyrite deposits at Røros, both active stream sediment and a vertical section of overbank sediment from polluted into more pristine material were sampled. The contents of Cu, Zn and Pb are anomalously high in the stream sediment and in the upper part of the overbank sediment, while high background values were found in the overbank sediment taken at depth. The contents of Ba, La, Li, Sr and Zr, which are not enriched in the ore bodies, show background values in both the stream sediment and in the overbank sediment (Table 4).

DISCUSSION AND CONCLUSION

A summary of some advantages and drawbacks in the use of stream, lake and overbank sediment as sampling media is given in Table 5. The application of the stream media are also illustrated in Fig. 17, which indicates that significant ore deposits may still remain undiscovered in Scandinavia and possibly elsewhere, even in areas where detailed stream sediments surveys have been conducted.

Other arguments in favour of sampling overbank sediment for regional geochemical mapping include:

- Overbank sediment can represent whole drainage areas, and large samples can be taken at low density and low cost per unit area. A small number of large samples facilitates the use of complex multielement chemical analysis.

- Overbank sediment seems to be present in all river systems with fluctuating water levels or occasional floods. Varying rainfall and drainoff occur in most places, and descriptions of the sedimentary environment in various parts of the world suggest that overbank sediment exists for example in Australia (Woodyer et al., 1979); Canada (Nanson, 1980; Deslodges and Church, 1987); Great Britain (Lewin et al., 1977) and USA (Baker, 1987). Overbank sediment should, therefore, be considered as a possible sample medium suitable for a geochemical atlas of the world.

- Overbank sediment may be sampled at depth, but still above the ground water level, in which case possible anthropogenic pollution is less of a problem than when using surface samples or sample types such as lake sediment that exist only below ground water level.

It is concluded that overbank sediment is a promising alternative sample medium for regional geochemical mapping, which should be carefully tested in other physiographic regions.

ACKNOWLEDGEMENT

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TABLE 1 Types of sediment sources in Fennoscndian streams in different environments.

(Sources: Nordseth, 1972, 1976; Bogen, 1980, 1984; Mansikkaniemi, 1982).

Environment,	Areal extent in Scandinavia	Sediment Source	Representativity of stream sediments for the drainage basin
Active glaciers	Small	Sheet erosion (?)	The whole drainage basin reflected
High alpine regions	Small	Sheet erosion (?)	The whole drainage basin reflected
Alpine regions	Large	Point sources in the overburden - undercutting of adjacent slopes - channel erosion in segments of streams	Small parts of drainage basins reflected
Forested till	Dominating	Point sources in the overburden - undercutting of adjacent slopes - channel erosion in segment of streams - farmfields	Small parts of drainage basins reflected
Marine terrace clays	Small	Point sources in the overburden - channel erosion in segments of streams - farmfields	Small parts of drainage basins reflected

TABLE 2 Contents of hot nitric acid soluble La and Mo in samples from 11 main granites in southern Norway and the corresponding values for overbank sediment sampled in streams draining the granites. (See also Figs. 13, 14 and 15)

	Bedrock (granites)			Overbank sediments		
Area	N	La	Mo	N	La	Mo
1. Tynset	7	27	2.5	3	25	1
2. Trysil	23	60	3.5	4	35	1.5
3. Odal	7	40	4.4	3	40	2.5
4. Oslo graben, north	8	84	7.2	5	70	6
5. Oslo graben, south	5	44	2.3	7	40	2.5
6. Vassfaret	11	74	4.0	2	70	4
7. Flå	12	57	3.7	4	60	3
8. Sætesdal	32	136	6.7	16	140	10
9. Odda	11	72	5.3	4	70	6
10. Karmøy - Stord	8	33	4.5	1	30	2.5
11. Sogn	3	73	3.6	2	65	2.5

Figures for La and Mo indicate arithmetic mean in N samples (in ppm.)

TABLE 3 Contents of total Ba, Cu, K and Y in overbank sediment collected north (metamorphosed sediments of the Barents Sea and Løkvikfjell Groups) and south (metamorphosed sediments of the Vadsø Tanafjord and Vestertana Groups) of the Trollfjord-Komagelv fault zone, Varanger Peninsula, Northern Norway.

	N	Ba (ppm)			Cu (ppm)			K (%)			Y (ppm)		
		M	x	SD	M	x	SD	M	x	SD	M	x	SD
North of fault	13	595	598	101	27	24	9.8	3.49	3.37	0.65	76	71	18.4
South of fault	12	478	499	112	14	17	9.1	2.44	2.39	0.60	52	56	8.2

N : number of samples
M : median
x : arithmetic mean
SD : Standard deviation

The arithmetic means of the two sets are different at $p < 0.001$ using student t test.

TABLE 4 Contents of hot nitric acid soluble elements in stream sediment, and in top and bottom layers of a handdug pit (60 cm deep) through overbank sediment at the polluted Orva River, Røros, southern Norway.

	Active stream sediment	Overbank sediment Top layer	Overbank sediment Bottom layer
Cu (ppm)	344	3800	41
Pb (ppm)	325	229	10
Zn (ppm)	404	1300	200
Ba (ppm)	69	48	37
La (ppm)	25	17	21
Li (ppm)	6	7	12
Sr (ppm)	14	6	10
Zr (ppm)	16	15	8

TABLE 5 Summary comments on the use of stream, lake and overbank sediment as sampling media in geochemical mapping in Scandinavian and similar landscapes.

	Stream sediment	Lake sediment	Overbank sediment
Origin, derivation	Mainly point sources in the catchment area	Major parts of the catchment area may be represented if vertical sections are sampled	As for lake sediment
Type of dispersion	Combinations of clastic and hydromorphous	As for stream sediments	Predominantly clastic
Availability to sampling	Varying depending on sediment production rate, see Table 1.	Large regions have insufficient density of lakes	Present in all drainage systems with a fluctuating water level
Problem of sampling	Often laborous to obtain sufficiently large samples of fine fraction	Sample sites cannot be inspected before sampling	Easy to obtain a large sample. Suitable sample sites can be selected from visual inspection
Susceptibility to pollution	Strongly polluted in industrialized areas	To a varying degree influenced by polluted ground- and surface waters	Surficial samples can be polluted, while samples at depth may be pristine
Problems of interpretation	Interpretation is complicated by varying presence of sediment sources, contents of hydrous oxides, organic material and pollution in the drainage area	As for stream sediments	Essentially clastic fluvial dispersion facilitate interpretation. Soil forming processes at sampling site may complicate the interpretation in drainage systems with rare flood events

Figure Captions

Fig. 1 Suspended sediments in Norwegian rivers. Unit: Tonnes yearly yield per km^2 drainage area.

Fig. 2. Fluvial erosion at a local source at the Karasjok River, Northern Norway. The river undercuts a slope containing glacial overburden. No visible erosion is taking place from the bank with vegetation cover on the far left side of the picture, which represents the normal conditions along the river.

Fig. 3. A sediment source opened up during spring flooding of the Lena River, southern Norway

Fig. 4. Sediment source opened up during a catastrophic rain storm in 1979 at the Jostedalen River, Western Norway.

Fig. 5. Bed and bank armouring of the Høverelva River, southern Norway.

Fig. 6. Water discharge of a river under ordinary conditions with normal amounts of water.

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

Fig. 8. A section through overbank sediment at the Atna River, southern Norway. Carbon 14 dating has indicated that the middle part of the section was deposited about 400 years ago.

Fig. 9. Paleosediment source at the Høverelva River, southern Norway. The sources are recognized by (1) the location near the present stream and (2) the inclination of the regular slope facing the river (exposed through logging) which corresponds to the angle of repose.

Fig. 10. Total contents of Ba in overbank sediments, Norway. The map is based on the analysis of 690 samples and shows the rolling median within a window of diameter 100 km. The cartography is done at the Geological Survey of Finland, (see also Bjørklund and Gustavsson, 1987).

Fig. 11. Hot nitric acid soluble La in overbank sediment, Norway. For explanation and references, see Fig. 10.

Fig. 12. Hot nitric acid soluble Mo in overbank sediment, Norway. An anomalous sample down stream from the Nordli deposit (see Case Histories 5 and 6, page 00 and 00) is indicated with an arrow.

Fig. 13. Bedrock Geology of Norway. (After Sigmond et al., 1983). Mo occurrences. (After Juve and Gust, 1984).

Fig. 14. Contents of hot nitric acid soluble La. Abscissa: data from 1) main granites in southern Norway (see Fig. 13) versus Ordinate: data from samples of overbank sediment taken in streams draining the granites. (See also Table 2.) N = 11, correlation coefficient (r) = 0.97.

Fig. 15. Contents of hot nitric acid soluble Mo. Abscissa: data from 11 main granites in southern Norway (see Fig. 13) versus ordinate: data from samples of overbank sediment taken in streams draining the granites. (See also Table 2). N = 11, correlation coefficient (r) = 0.83.

Fig. 16. Major lineaments in the bedrock in Scandinavia as interpreted from the aeromagnetic map by Eriksson and Henkel (1983).

Fig. 17. A diagramatic depiction of how geochemical dispersional patterns for active stream sediment and overbank sediment may be influenced by mineralizations and sediment sources. In the stream at the right hand side, the active stream sediment is dominated by sediment source No. 1, a reason why the anomaly can be detected only in the overbank sediment. This situation is analogous to that described in Case History 6 for the Høverelva River, see page 00.

In the middle river, where no active sediment sources exist in the upper part, a stream sediment anomaly has developed where the stream crosses the mineralization due to influence from paleosources and a presently small diffuse sediment production occurring along the stream bed. This anomaly is diluted by sediments from source 3.

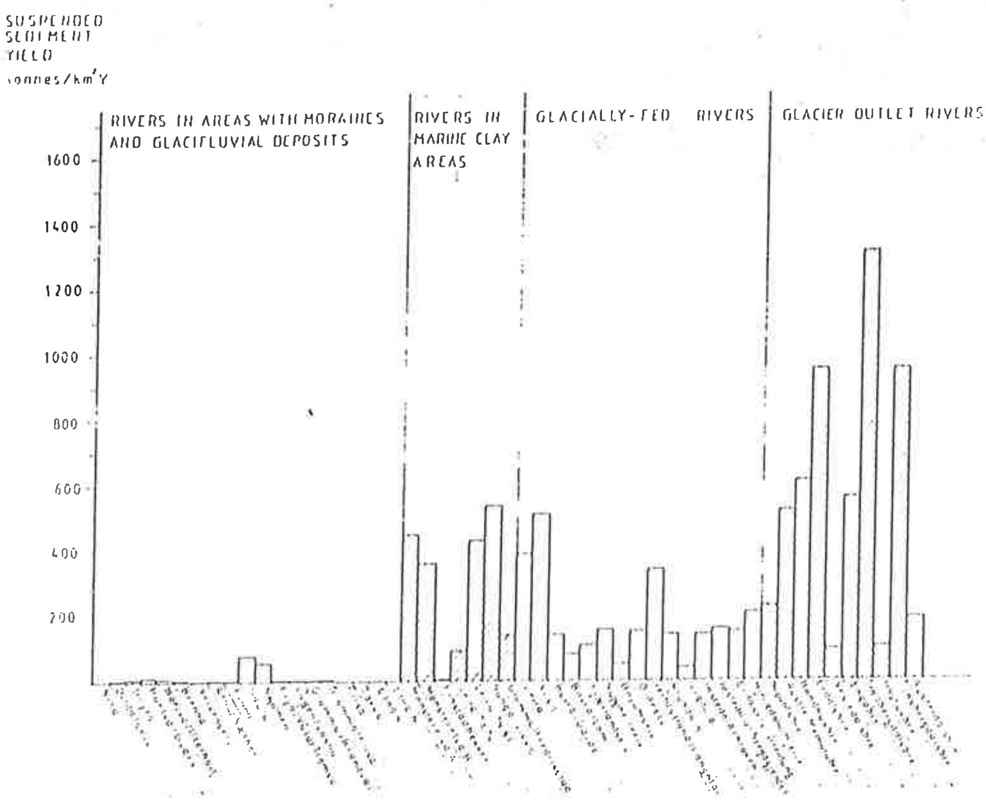
SUSPENDED SEDIMENT YIELD tonnes/km²Y
RIVERS IN AREAS WITH MORAINES AND GLACIFLUVIAL DEPOSITS
RIVERS IN MARINE CLAY AREAS
GLACIALLY-FED RIVERS
GLACIER OUTLET RIVERS
1600
1400
1200
1000
800
600
400
200

Fig. 1

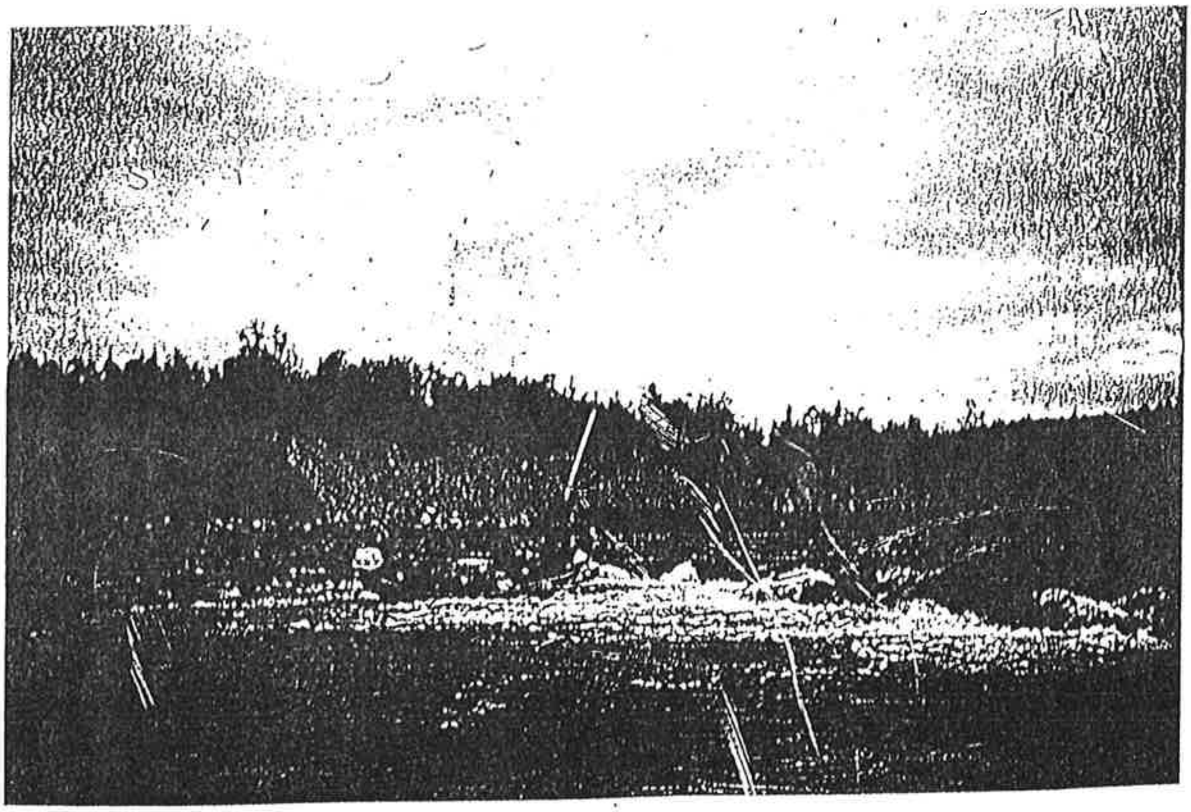

Fig. 2

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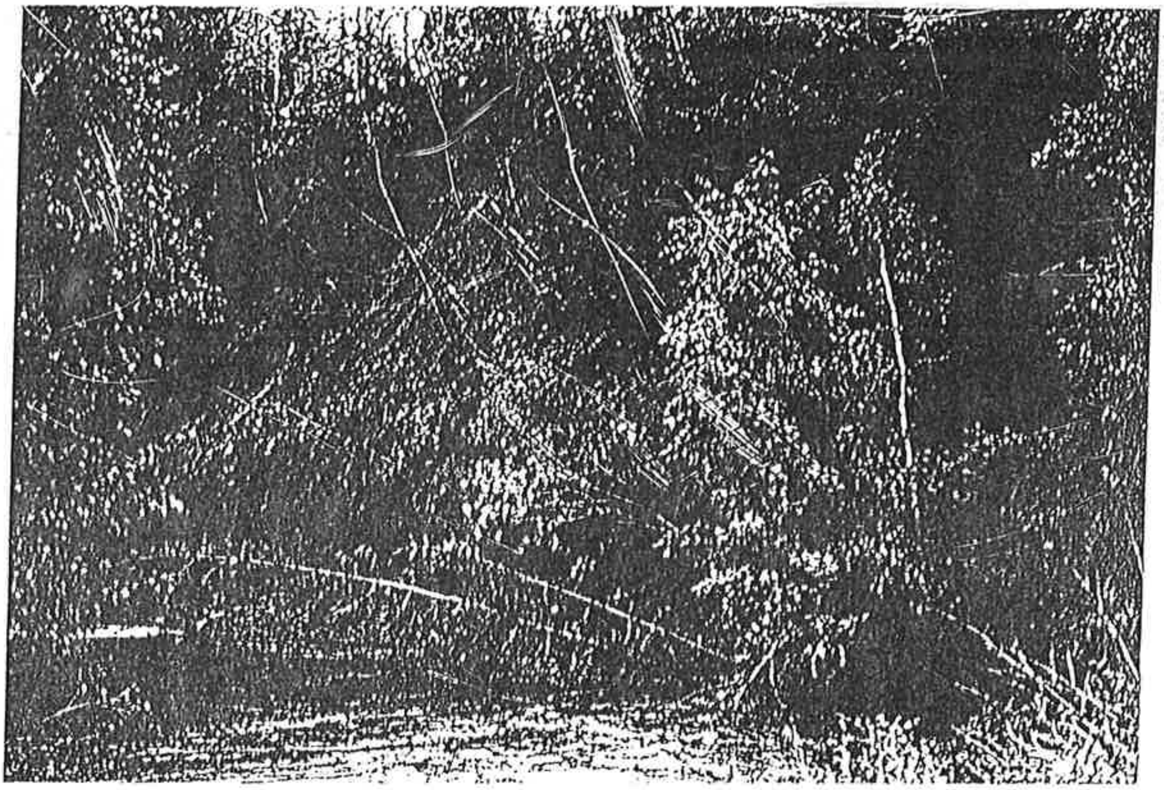

Fig. 3

Fig. 4

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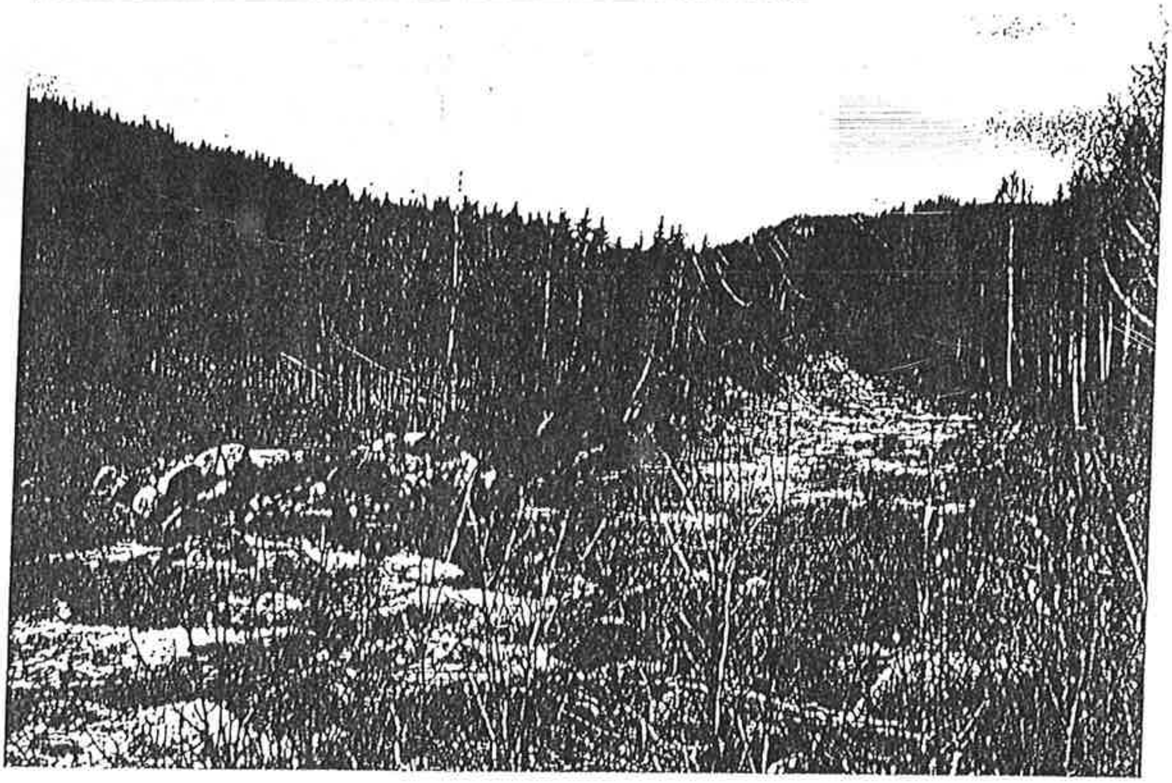

Fig. 5

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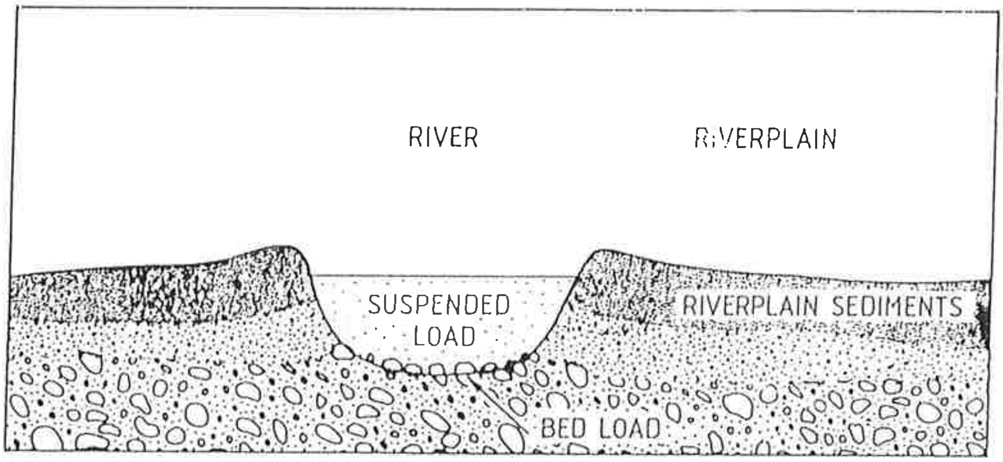

Fig. 6

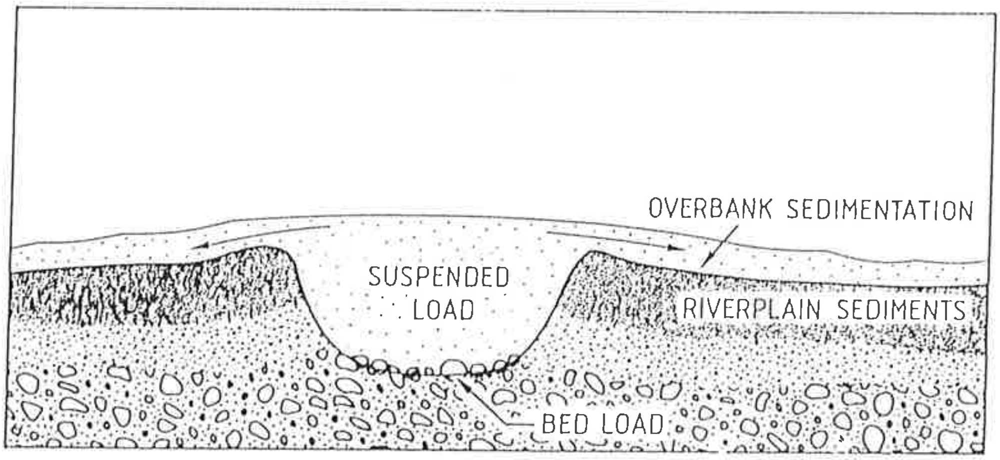

Fig. 7

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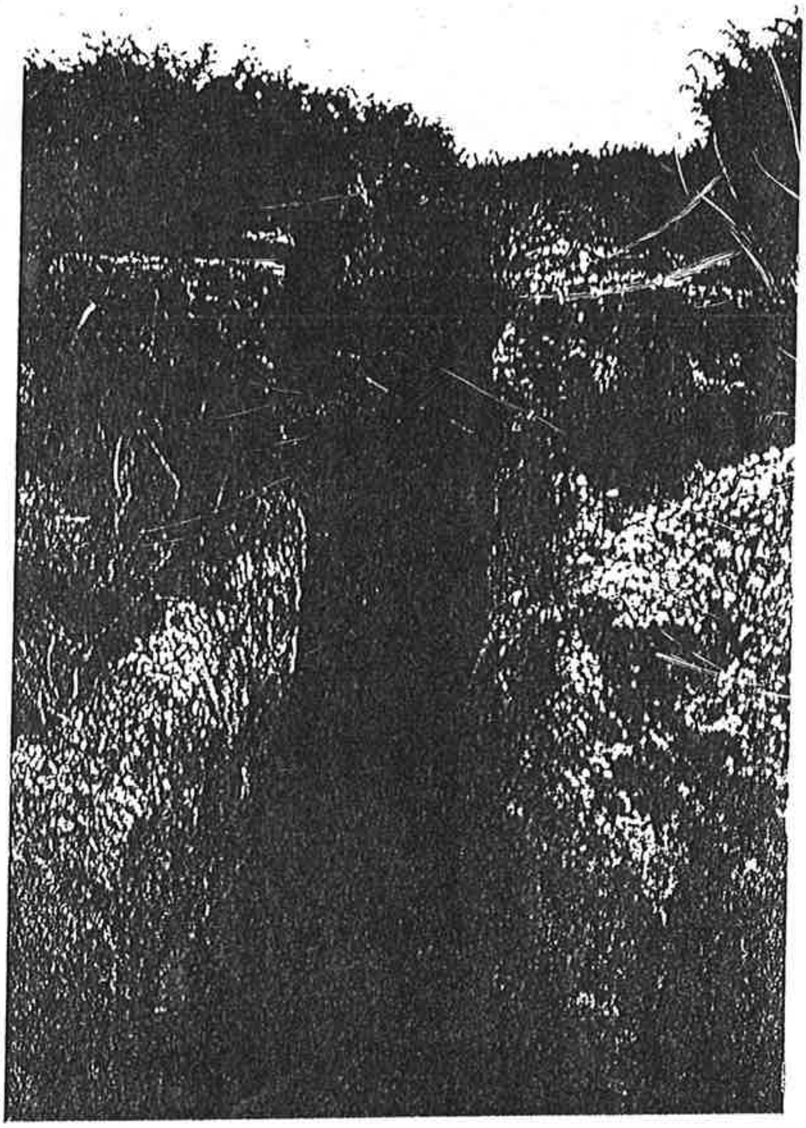

Fig 8.

Fig. 9

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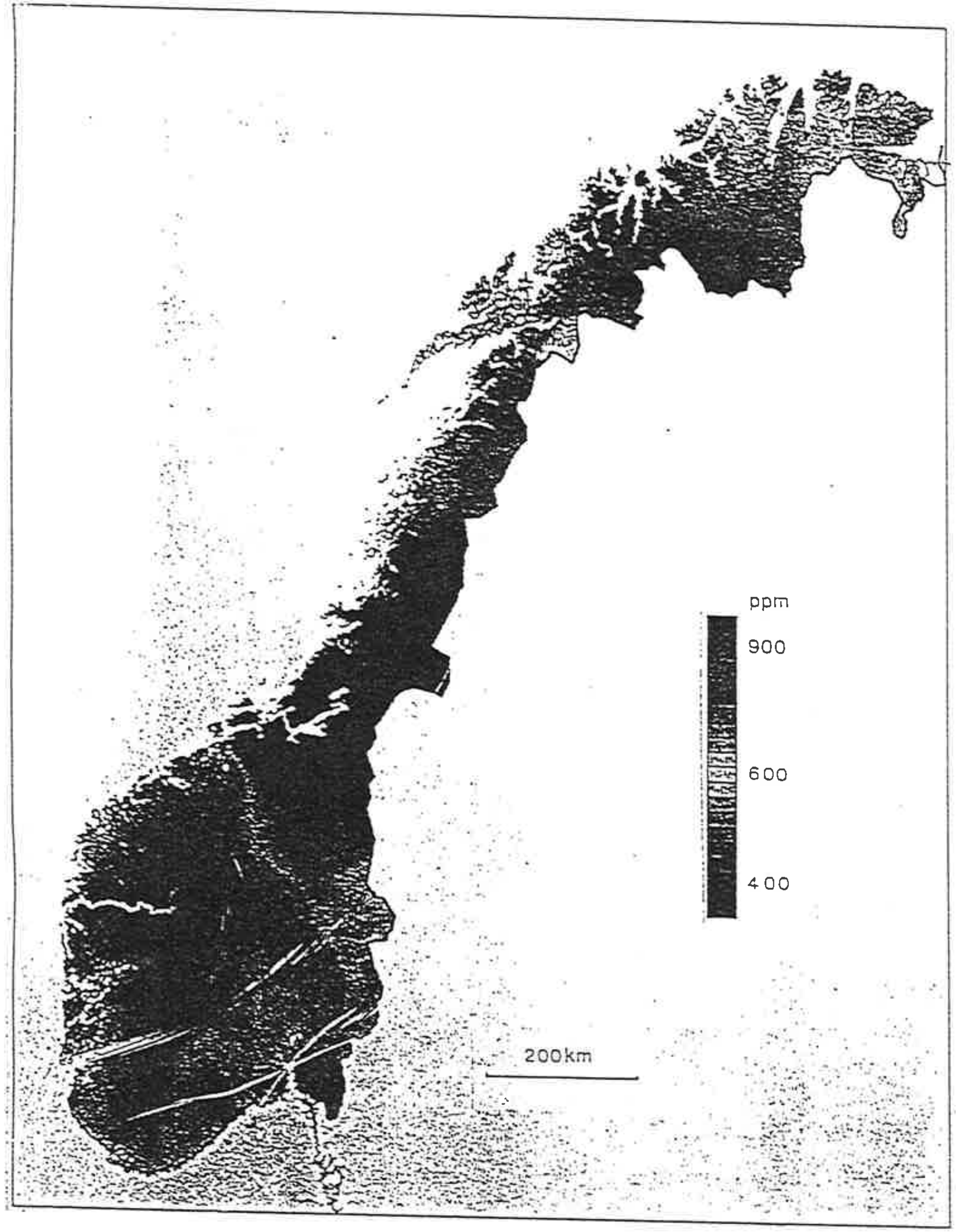

Fig. 10

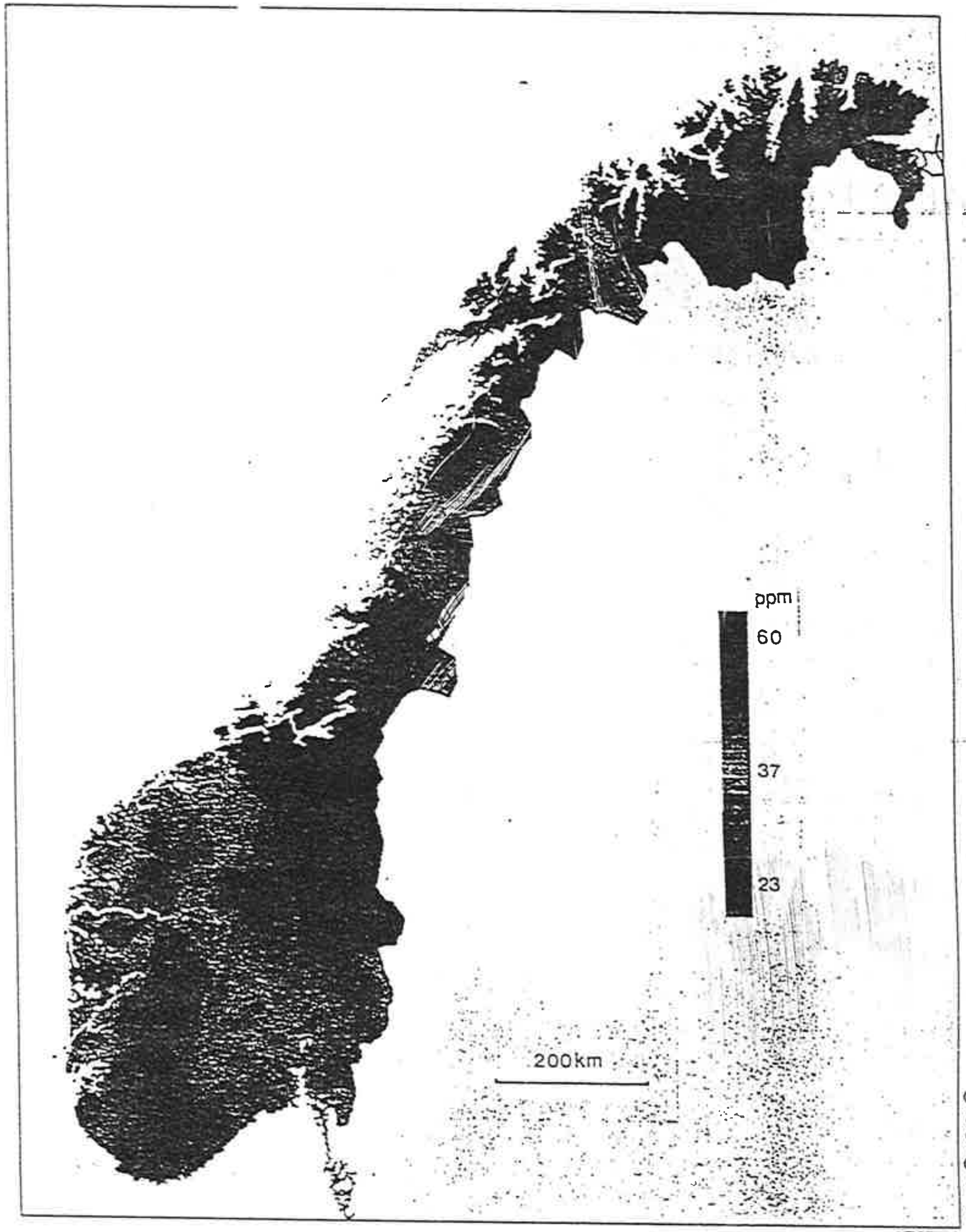

Fig. 11

Fig. 12.

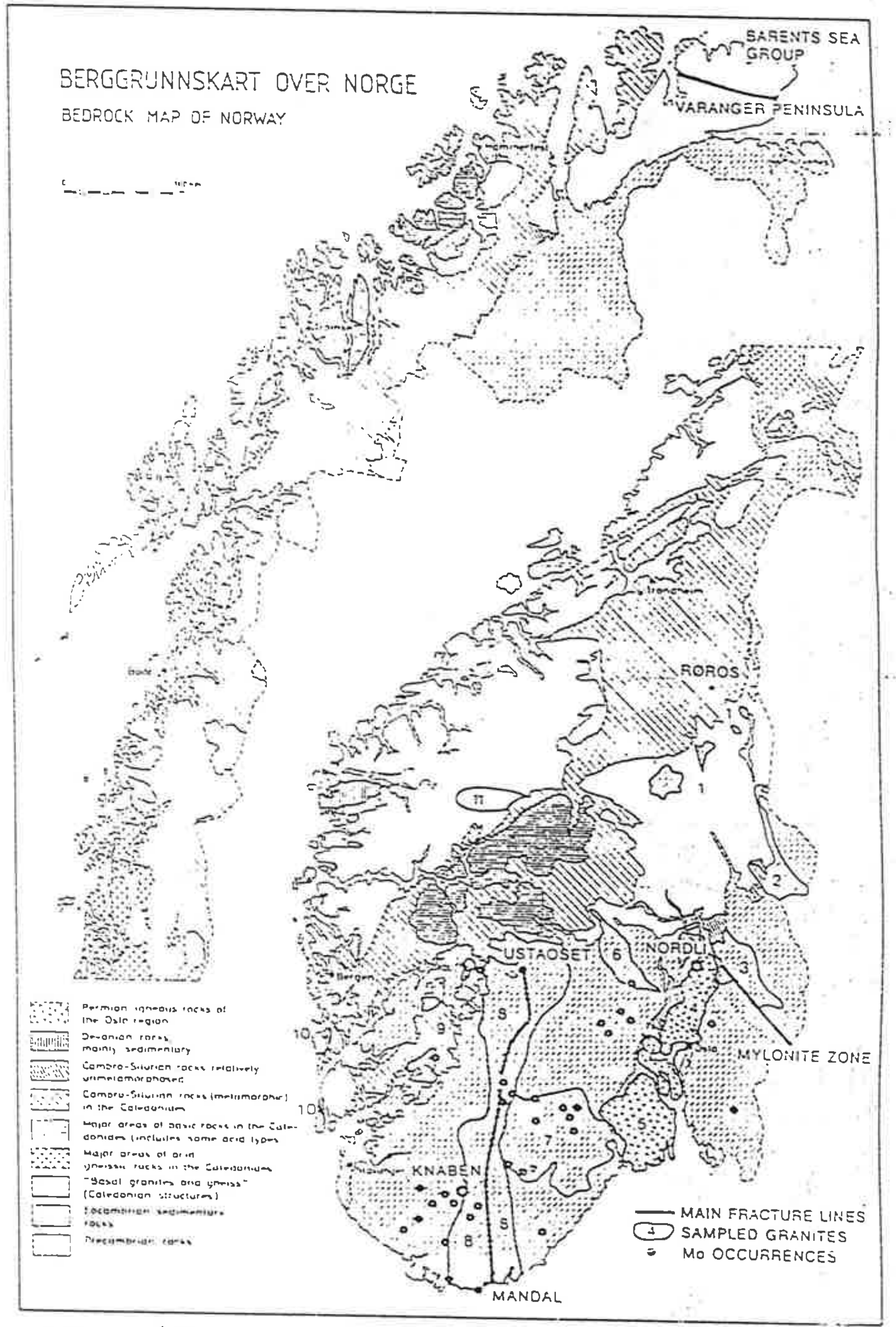

Fig. 13

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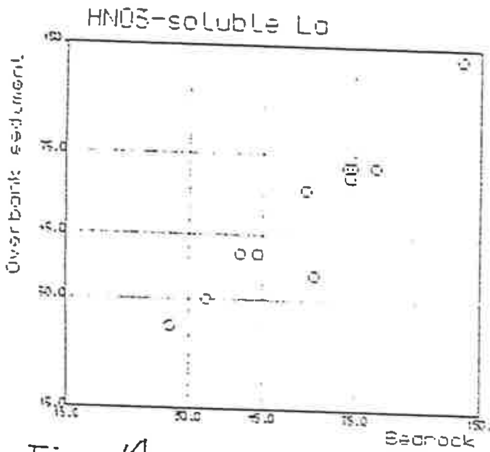

Fig. 14

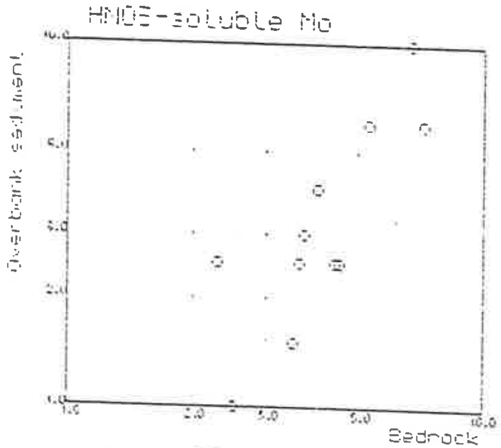

Fig. 15

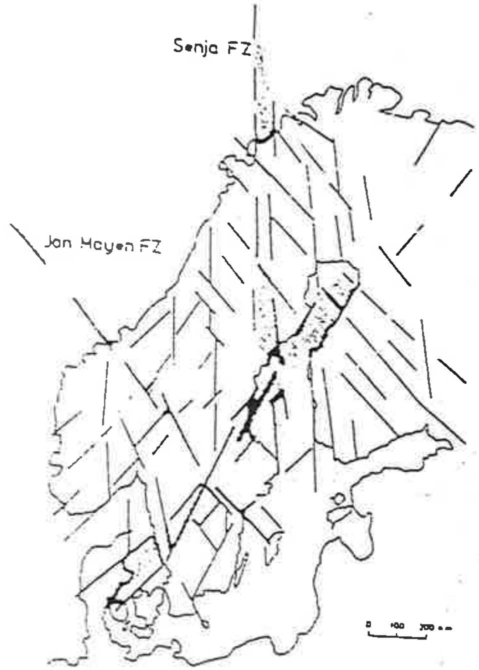

Fig. 16

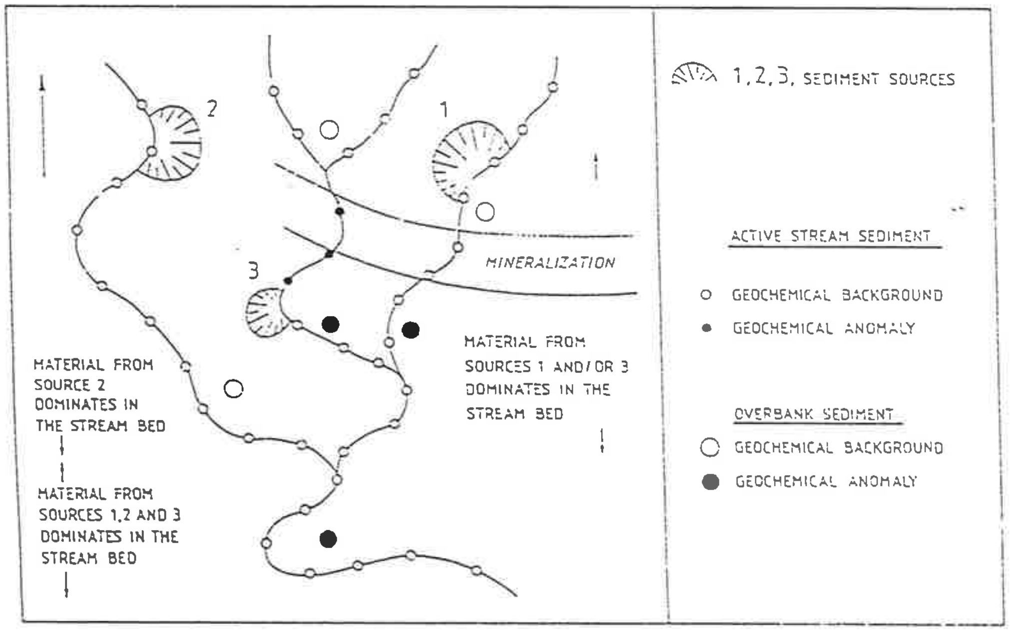

Fig. 17

Oddesen et al.

Appendix 6. WEGS meeting Uppsala August 1986. Item 5 of the minutes.

APPENDIX 6

EXTRACT FROM THE MINUTES OF THE
MEETING OF THE DIRECTORS OF
WESTERN EUROPEAN GEOLOGICAL SURVEYS 1986
SWEDEN 25-29 AUGUST

Item 5. Regional geochemical mapping

32. Dr Heier reported that he had agreed to be responsible for this item, following Dr Goni's retirement from the B.R.G.M.

33. Dr Bolviken then introduced the report of the working Group that had met in Trondheim in May. The Group proposed that a geochemical atlas of W. Europe should be produced, based on a very low density of sampling (1 composite sample per 500 km^2). Samples at each station to be from the soil, water and stream sediments, analysed for the maximum possible number of elements. It would be essential for the analyses of all the samples by a particular method to be done in one laboratory.

34. Some of the principes involved were illustrated by maps produced during the Nordkalott Project. Dr Bolviken demonstrated that major anomalies and distribution patterns, identified by close sampling (ca 1 per 30-50 km^2) were also reulated by much lower sampling densities (down to 1 per 500 km^2). There is some reason to believe that such patterns are present at all scales.

35. During the discussion of the Group's proposal, the points made included:

(a) It would be necessary to decide how many samples were to be integrated in each composite sample.

(b) The Nordkalott area may be particularly favourable for a low-density survey, being relatively free from human industrial activities.

(c) In W. Europe there are very large ranges in temperature, rainfall and contamination.

(d) There may be political objections to the preparation of such an atlas, bearing in mind for example, concern about airborne pollution.

(e) It might be necessary to monitor changes due to contamination by selecting a limited number of reference sites at which sampling is repeated at intervals.

(f) Some Surveys (for example the B.R.G.M.) may find that funds are more accessible for such monitoring, rather than for further geochemical mapping.

(g) A pilot project (see p 5 of the report) would be necesary because the experience gained during the Nordkalott Project may not be applicable to all of W. Europe.

(h) The costs would be split approximately equally between the field and laboratory work.

(i) Same Surveys might be able to bear the field work costs, but external funding would be necessary to cover all the analytical costs.

(j) The results would be of particular relevance to environmental problems (in the widest sense, including for example epedemiological problems.

36. It was agreed that the working Group should meet in Orleans in April 1987 in association with the AEG/ICGC meeting and that all Surveys should send representatives if they wish. All Surveys should send information about long-term reference sites to Dr. Bolviken.

37. The idea met with general approval and it was therefore agreed that the Group should prepare a draft proposal, taking account of all the points raised in the discussion. The proposal should indicate the costs of the sampling programme and of the analytical work. The proposal will be considered by WEGS in 1987.

38. It was also agreed that there should be informal contact with the E.E.C.

Appendix 7. Working Group on Regional Geochemical Mapping. Progress report July 1987.

APPENDIX 7

WESTERN EUROPEAN GEOLOGICAL SURVEYS

Working Group on Regional Geochemical Mapping

Progress Report per 1 July 1987

by

Bjørn Bølviken,
Geological Survey of Norway

Representatives for Austria, France, Greece, Norway, West Germany and United Kingdom had a meeting in Trondheim 21-22 May 1986. The participants of the meeting made a proposal for geochemical mapping of Western Europe based on 5 sample types collected at a density of 1 sample site per 500 km^2. The proposal was discussed at the WEGS-meeting in Uppsala, Sweden 25-29 August 1986 with the following conclusions:

(1) The idea met with general approval and the Group should prepare a draft proposal, taking account of the points raised in the discussions in Uppsala.

(2) The working Group should meet in Orleans in April 1987 in association with the AEG/ICGC-meeting.

The following representatives for the countries of the Working Group met in Orleans:

France: P. Lecomte, Lilliane Laville-Timset
Norway: B. Bølviken, R.T. Ottesen
United Kingdom: Jane Plant
West Germany: R. Hindel

The main topic of the Orleans discussions was the problem of sample types. It was agreed that an excursion be arranged for participants of the Working Group in Norway during August 1987. The objective of the excursion is to study possible sample media in order to arrive at common sample types and sampling techniques for all Western Europe. If the Norwegian excursion proves to be successfull, then similar field excursion should be arranged in midle and southern Europe during autumn 1987 or spring 1988. When these field studies are completed, then the Working Group will present a proposal for further work to the WEGS' directors.

The idea of world wide geochemical mapping was also discussed in Orleans independant of the WEGS Working Group.

A workshop on the subject was held, and the matter was also rised as a main topic during the general discussions on the last day of the symposium. The general impression is that a majority of the worlds geochemists is in favour of aiming at a world wide geochemical map. The idea is particularily well accepted in China.

A committee headed by Alf Bjørklund, Finland was established in order to work further with this idea. Canada, China, Denmark, Finland, Norway and U.S.S.R. are represented in the committee. The link between the committee and the WEGS' Working Group is secured through Bjørn Bølviken as the Norwegian representative.

The directors of the WEGS will be kept informed about the further developments in this matter. It is felt that the WEGS, if wanted, have a good possibility for taking the lead in establishing the guide lines for a world wide geochemical mapping programme.

Copy of telex sent to members of the Working Group

Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, Postfach 510153, D-3000 Hannover 51, F.R. Germany
Attn.: Roland Hindel

Bureau de Recherches,Géologique et Minéres (BRGM), P.B. 6009, F-45060 Orléans Cedex, France. Attn.: Ignace Salpeteur

British Geological Survey, 64 Gray's Inn road, London WC1X 8NG, England.

Geologische Bundesanstalt, Rasumofshygasse 23, A-1030 Wien, Austr
Attn.: Otmar Schermann

Geological Survey of Norway, P.O. Box 3006 Lade, N-7002 Trondheim Norway. Attn.: Bjørn Bølviken, and Rolf Tore Ottesen

Institute of Geology and Mineral Exploration, 70 messoghion Stree 115 27 Athens, Greece. Attn.: Alec Demetriades.

Instituto Geologico y Minero de Espana, Rios Rosas 23, 3003 Madri Spain. Attn.: Ramon Querol

July 28, 1988

WEGS Working Group on Regional Geochemical Mapping

The working group is asked to join in a meeting in Hannover, West Germany August 22-23, 1988.

Programme: 1) Summary of activities up to now. 2) Preparation of final proposal from the Working Group to be presented for the WEGS directors in Copenhagen 12 September 1988. 3) Possible visit to field locations with overbank sediments in the Hannover area.

Please send information about your attendance to
Dr. Roland Hindel, BGR, Stilleweg 2, Postfach 510153,
D-3000 Hannover 51, FR Germany
Telephone: 511 - 6430
Telex: 92 37 30 BFG (BGR) HAD

Roland will book hotell room according to your instructions. I suggest arrival 21 August in the afternoon. Please send me copy of your correspondance with Dr. Hindel. Further details will be mailed to you shortly.

My address is: Geological Survey of Norway, P.B. 3006 Lade,
N-7002 Trondheim, Norway.
Telephone: 47-7-92 16 11
Telex: 55 4 17 NGU N
Telefax: 47-7-92 16 20

Sincerely
Bjørn Bølviken
Divisional Director

Appendix 8. WEGS meeting Ankara August 1987. Item 5 of the Minutes.

MINUTES FROM THE WEGS MEETING IN ANKARA AUGUST 1987

Item 5. Regional Geochemical Mapping

31. Dr. Heier introduced the progress report of the Working Group on Regional Geochemical Mapping which had met in Orleans in April.

32. The first excursion in Norway mentioned in the report was now taking place. There would be another next Spring and it might be necessary, to ensure common sample types, to arrange an excursion in Southern Europe.

33. Dr. Heier went on to suggest that ample time is needed to allow the Group to develop a sound proposal. As mentioned in the report there is an increasing worldwide interest in the subject and a strong link between WEGS and this wider interest is assured by the participation of Dr. Bolviken in the work of a committee with much wider representation that is chaired by Dr. Bjorklund of Finland.

34. The following points were made in discussion : -

(a) The Working Group should not lose sight of the three main purposes of the project as they were outlined when it was initiated.

(b) The solution of practical problems should have a higher priority than the preparation of an atlas which would not necessarily be the best result.

(c) It was also pointed out, however, that an atlas may have many valuable applications.

(d) Referring to the last sentence of the report it was suggested that WEGS should concentrate its efforts on the solution of West European problems, although an incidental benefit might be to help to solve worldwide problems.

(e) It is necessary to ensure that the members of the Working Group maintain good contacts with other organisations, for example water authorities, that are involved with similar problems.

35. It was agreed that the Working Group should continue and report to WEGS again in 1988.

Appendix 9. Use of overbank sediments as a sampling medium in geochemical mapping. Report from excursion in Norway Sept. 1987.

NGU-rapport 88.026

Use of overbank sediments
as a sampling medium
in geochemical mapping

NGU
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RAPPORT

Rapport nr. 88.026

ISSN 0800-3416

Åpen/~~Fortrolig til~~

Tittel:
Use of overbank sediments as a sampling medium in geochemical mapping

Forfatter:
B. Bølviken, R. Hindel, I. Salpeteur
J. Bogen, R.T. Ottesen, T. Volden

Oppdragsgiver:
NGU

Fylke:

Kommune:

Kartbladnavn (M. 1:250 000)

Kartbladnr. og -navn (M. 1:50 000)

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Prosjektnr.:

Seksjonssjef:

Sammendrag:

An excursion was arranged in Norway 10.-14. September 1987 in order to study the use of overbank sediments as a sampling medium in geochemical mapping.

The conclusions of the excursion are:

Overbank sediments (o.s.) are composite samples that represent large drainage areas and can be collected at widely scattered sample sites at low cost. O.s. are transported physically in water suspension and are less influenced by chemical processes than stream sediments, which may have coatings of secondary minerals. O.s. collected at shallow depths may reflect anthropogenic pollution, while o.s. taken at depth may reflect natural conditions. Sampling and analysis of overbank sediments have been successfully applied in Norway and we recommend that an excursion is arranged in France and Western Germany in order to evaluate their use in geochemical mapping in other areas of Western Europe.

Emneord		
Geokjemi	Kartlegging	
Fagrapport	Vesteuropa	
Flomsedimenter		

15 March 1988

WESTERN EUROPEAN GEOLOGICAL SURVEYS

WORKING GROUP ON REGIONAL GEOCHEMICAL MAPPING

USE OF OVERBANK SEDIMENTS AS A SAMPLING MEDIUM IN GEOCHEMICAL MAPPING

B. Bølviken
NGU

R. Hindel
BGR

I. Salpeteur
BRGM

Working Group Members

With contributions by
J. Bogen*, R.T. Ottesen** and T. Volden**

* Norwegian Water Resources and Energy Administration
** Geological Survey of Norway

INTRODUCTION AND SUMMARY

An excursion was arranged in Norway 10.-14. September 1987 in order to study the use of overbank sediments as a sampling medium in geochemical mapping.

The participants of the excursion were the representatives in the Working Group from France (I. Salpeteur), Germany (R. Hindel) and Norway (B. Bølviken, with colleagues R.T. Ottesen and T. Volden). Individuals from GTK, Finland (P. Lestinen) and SGU, Sweden (S.Å. Ohlsson), took part due to the preparation of the Midtnorden Project. Jim Bogen of the Norwegian Water Resources and Energy Administration, was invited as a specialist in river erosion and sediment transport.

The conclusion of the excursion is that overbank sediments (o.s.) are an interesting sampling medium in large scale geochemical mapping owing to :

- O.s. are composite samples that represent large drainage areas, and can, therefore, be collected at widely scattered sample sites and at low costs to each country.
- O.s. are transported physically in water suspension and are less influenced by chemical processes than stream sediments, which may have coatings of secondary minerals. The interpretation of the dispersion patterns of element contents in o.s. may therefore be relatively simple.
- At a given sample site the age of o.s. increases with depth. By sampling at shallow depths the effects of anthropogenic pollution may be traced. Samples taken at greater depths may reflect the natural conditions that existed before the times of industrial pollution.

Overbank sediments have been applied successfully in Norway, and we think that they are also applicable further south in Europe. An excursion should be arranged during spring 1988 in order to study the use of overbank sediments as a sampling medium in middle Europe. The Norwegian excursion will be repeated 1988 for those members of the Working Group that could not take part in the 1987 excursion.

The following account presents:
- A definition of overbank sediments.
- Some advantages of overbank sediments over active stream sediments.
- Experiences from the use of overbank sediments in Norway.
- An overview of the possible uses of overbank sediment data in Europe.
- Some research recommendations.
- Examples of the costs involved in nation wide sampling of overbank sediments.

DEFINITION OF OVERBANK SEDIMENTS

Overbank sediments are products of major floods of river systems. During such floods the water discharge exceeds the quantities that can pass through the ordinary river channel (bankful discharge). Material suspended in the water of a flooding river will be deposited on river plains at higher levels than the normal stream channel (Fig. 1A and B). Such deposits of overbank sediments may later be eroded by stream water (Fig. 2), or — which is most often the case — overlain by more recent overbank sediments deposited during later floods. In this way nearly horizontal strata of young sediments above older are formed. The thickness of the layers may vary from a few millimetres to several decimetres (Fig. 3).

A vertical section through overbank sediments shows the sedimentation history back in time. A composite sample of such a section will give an intergrated picture of the chemical and mineralogical conditions in the whole drainage basin over a long period of time.

SOME ADVANTAGES OF OVERBANK SEDIMENTS OVER TRADITIONAL ACTIVE STREAM SEDIMENTS

The term stream sediments normally means active sediments from the stream bed in current contact with stream water. This sampling medium is widely used in geochemical mapping but suffers, nevertheless, from several drawbacks of which the most important are:

(1) During normal discharge conditions of a river only one or a few sources of limited areas may be exposed to erosion (Figs. 4 and 5). The major parts of the stream will approach an equilibrium with its surroundings, which means that erosion and deposition in most places are at a minimum. Consequently, as far as clastical (mechanical) sediment transport is concerned, active stream sediments reflect only limited parts of the drainage area.

(2) Active stream sediments are in most cases subject only to a temporary deposition. Active stream sediments, therefore, reflect the normal flow conditions of a river during a relatively short time interval.

(3) Active stream sediments may or may not have coatings of hydrous oxides and other secondary minerals. Such coatings often contain relatively large amounts of elements that normally occur as traces. The coatings therefore, influence the bulk compotition of stream sediments to a varying degree depending on the environmental factors.

(4) Active stream sediments are susceptible to contamination by mine wastes and other products of human activities in the drainage area. Geochemical maps based on the analysis of active stream sediments are, therefore, of limited value in the prospecting for new ore deposits in industrialized or densely populated areas.

Overbank sediments are advantageous for several reasons:

(1) The sediment sources of a river system may change through time. During catastrophic floods a number of sediment sources are opened up. A section of overbank sediments thus reflects large parts of a drainage basin.

(2) Overbank sediments do not have coatings of secondary minerals to the came degree as active stream sediments do.

(3) Since younger overbank sediments are deposited on top of older ones, overbank sediments of various ages can be sampled. By sampling the upper layers, the effects of anthropogenic pollution may be detected. By sampling lower layers pre-industrial natural dispersion patterns may be disclosed. Geochemical maps based on overbank sediments might therefore be very useful for the exploration of mineral deposits in populated areas.

EXPERIENCES FROM USING OVERBANK SEDIMENTS IN NORWAY

690 overbank sediments have been collected from 60-300 km^2 large drainage areas uniformly scattered all over Norway. The samples were sieved to minus 0.062 mm grain size and analysed for the acid soluble and total contents of a number of elements.

Map presentation of the analytical results show (see examples in Figs. 6 and 7).

- All elements included several of economic interest, depict large scale regional patterns.
- The patterns sometimes agree with known geological structures; in other cases they indicate features not known before.
- Different elements produce different patterns.

Visual interpretation indicate that the obtained geochemical dispersion patterns mainly reflect compositional differences in the bedrock. However, natural transportation of matter through air or water may also contribute to the obtained patterns. The effects of anthropogenic pollution on the dispersion patterns are thought to be small.

POSSIBLE USES OF OVERBANK SEDIMENT DATA FROM WESTERN EUROPE

Overbank sediments can be used as an aid in:

- Exploration
- Geological mapping
- Environmental research
- Geomedicine (Environmental health)
- Agriculture
- Areal planning
- Other fields

Exploration: Relatively few samples of overbank sediments are needed in order to find the main geochemical distribution patterns of a country. It will therefore, be feasible to analyse the sample collections for many more elements than usual in geochemical surveys. In this way geochemical provinces of rare elements (f.ex. Au or Pt) may be disclosed. Since o.s. may represent conditions prior to excessive human activities, the original natural geochemical patterns may be detected even in mining or otherwise industrialized areas.

Geological mapping: Experience has shown that overbank sediments may disclose provinces and structures that point to new approaches in the interpretation of the regional geology. The patterns may be so large that they are recognizable only through geochemical mapping in areas larger than countries.

Environmental research: Dispersion patterns of the element contents in o.s. can reflect natural conditions as well as effects of pollution. Both are fundamental in environmental research. Geochemical mapping of Western Europe will aquire various data of value for the investigation of the effects of acid rain and other pollutants for example maps showing the distribution of sulphur, lead and susceptibility to acidification (Fig. 8).

Geomedicine (Environmental geochemistry and health): The occurrence of a number of diseases, amongst them dental caries, fluorosis and goiter, are related to the natural environment. Common diseases such as heart diseases and cancer, are thought to be effects of the environment. Nationwide and international geochemical data are important in the research relating diseases and environment.

Agriculture: Geochemical maps show the distribution of elements of which some may be essential and others harmful for plants and animals. Regional geochemical maps can therefore, be used in the planning of food production as well as in forestry.

Areal planning: Regional geochemical maps can for example, provide data indicating which areas are suitable or not suitable for drinking water sources, waste disposal, mining, agriculture, recreation etc. from a geochemical point of view.

Other uses: Preparation of a joint geochemical map of Western Europe will promote the intersurvey cooperation and improve the art of applied geochemistry. The existing national geochemical data sets in Western Europe have been obtained by different techniques in each country, and cannot be compared. A consistent new set of geochemical data is important both scientifically and practically, and will throw light upon problems such as:

- Which are the main geochemical provinces in Western Europe?
- How do glaciation and various types of weathering affect the surface geochemistry?
- How important is airborne transportation from marine, volcanic and other sources as natural geological processes?
- The experience gained during the preparation of a geochemical atlas of Europe can prove to be of great value for similar investigations in developing countries. In these countries the geology is often poorly known and the infrastructure does not permit the dense sampling necessary for a geochemical survey based on stream sediments. This situation can be partially counteracted by taking overbank sediments; in this case one sample/100 km^2 - 500 km^2 is adequate.
- Would it be feasible to produce a Geochemical Atlas of the World?

CONCLUSIONS AND SOME RECOMMENDATIONS FOR RESEARCH

- We consider overbank sediments as a very interesting sampling medium in geochemical mapping and recomment that their application in Europe is further evaluated in an excursion in France and Western Germany during spring/early summer 1988.

- The depth of the anthropogenically contaminated upper part of the overbank sediments should be studied in various parts of Western Europe.

- Since the environmental conditions vary significantly throughout Western Europe, local orientation surveys are desirable in order to study to which extent precipitation and fluctuating ground water levels may have caused post-depositional chemical alterations of the composition of overbank sediments at depth.

- It is desirable to check the availability of overbank sediments in mountainous areas with a strongly rejuvenated relief (France) and in the mediterranean zone, where the average rain fall remained low during the late Quaternary.

- In middle Europe the representativity of overbank sediments should be studied in areas of well differentiated lithologies as well as in known mineralized districts, where a high density geochemical coverage already exists.

- Possible use of overbank sediments as a sampling medium for preparation of maps of succeptibility to acidification should be studied.

EXAMPLES OF EXTIMATED COSTS 1987 OF NATIONWIDE SAMPLING OF OVERBANK SEDIMENTS

France

Area: 547 000 km^2
Number of sample stations: 1094
Number of man-months for sampling: 14
Currency: F.F.

Net salary of sampling crew		630 784
Overhead		86 010
Total salary of sampling crew	FF	716 800
Field allowances etc.	"	103 600
Transportation	"	246 400
Sample bags etc.	"	10 000
Total cost of sampling (including overhead)	"	1 076 800
Cost per sample station (including overhead)	"	984
Cost of sampling, without overhead		990 784
Cost per sample station, without overhead		906

Germany

Area: 249 000 km^2
Number of sample stations: 498
Number of man-months for sampling: 6 (4-5 samples per day)
Currency: D.M.

Net salary of sampling crew		
Overhead		
Total salary of sampling crew	DM	111 000
Field allowances etc.	"	20 000
Transportation	"	25 000
Sample bags etc.	"	1 000
Total cost of sampling (including overhead)	"	157 000
Cost per sample station (including overhead)		315

Norway

Area: 324 000 km^2

Number of sample stations: 690

Number of man- months for sampling: 6.4 (5 samples per day)

Currency: Norwegian kroner

Net salary of sampling crew	NOK	120 000
Overhead	"	200 000
Total salary of sampling crew	"	320 000
Field allowances etc.	"	192 000
Transportation	"	150 000
Sample bags etc.	"	5 000
Total cost of sampling (including overhead)	"	670 000
Cost per sample station (including overhead)	"	966
Cost of sampling, without overhead	"	470 000
Cost per sample station, without overhead	"	680

For a given method all samples should be analysed in random order in the same laboratory regardless of country of origin. The costs per element determined will be comparable to the costs of analysis normally experienced in geochemical mapping. It is suggested that the samples are analysed for a greater number of elements than normal. The total costs of analyses may therefore be considerable. However, several geological surveys can take part in sample preparation as well as analysis, and cash flow between the surveys is probably not necessary.

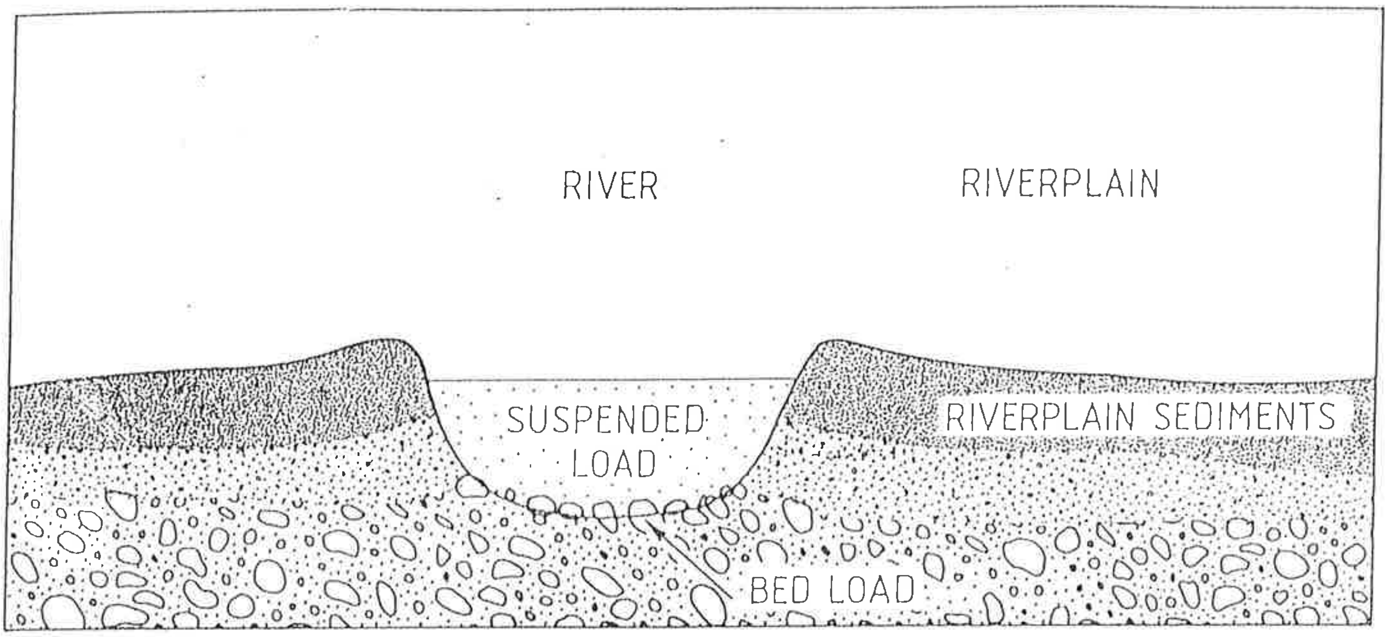

Fig. 1 Principle sketch of the water discharge of a river.

A. Water discharge of the river is less than bankfull discharge.

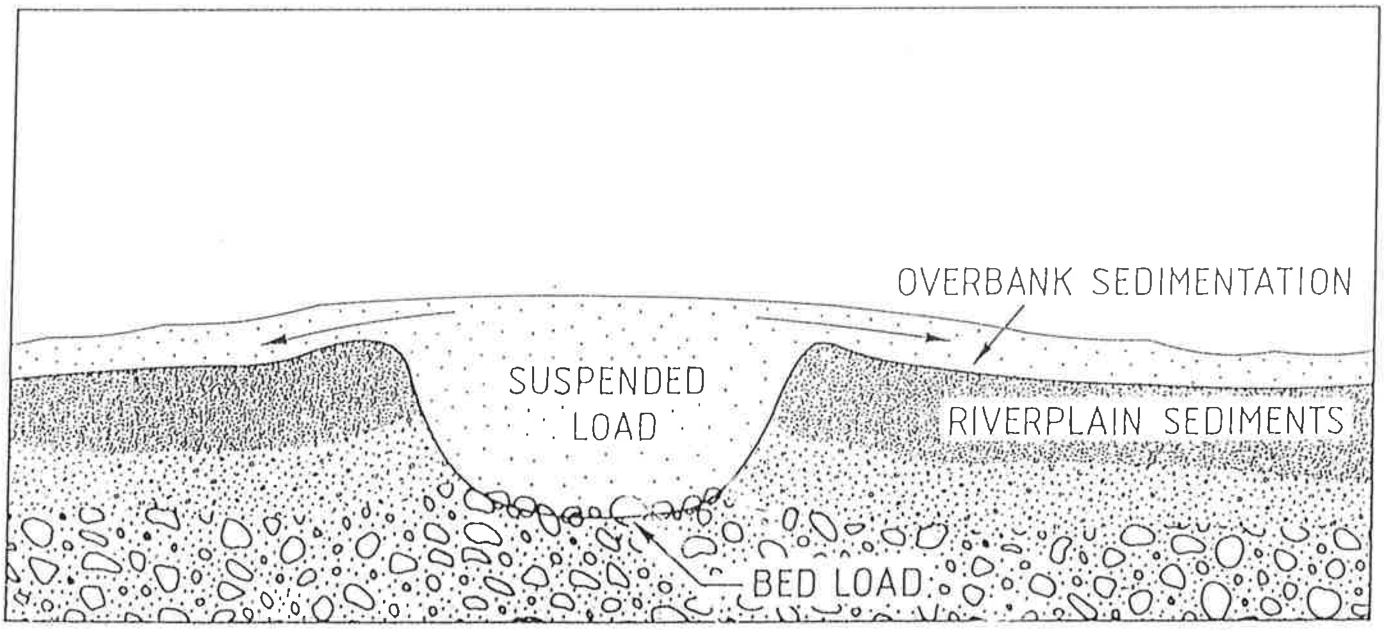

Fig. 1 Principle sketch of the water discharge of a river.

B. Water discharge of the river exceeding bankfull discharge during a large magnitude flood. Overbank sedimentation takes place on the riverplain.

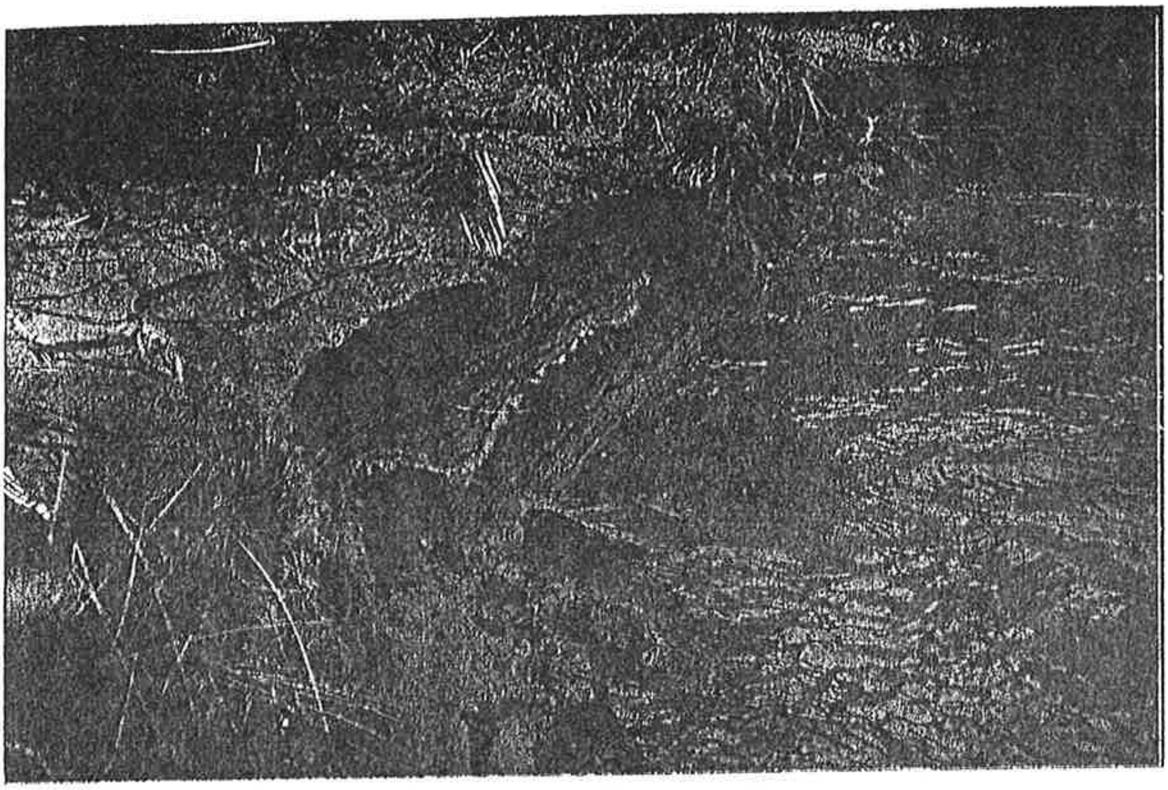

Fig. 2. Overbank sediments being eroded by the river in Jostedalen, Norway.

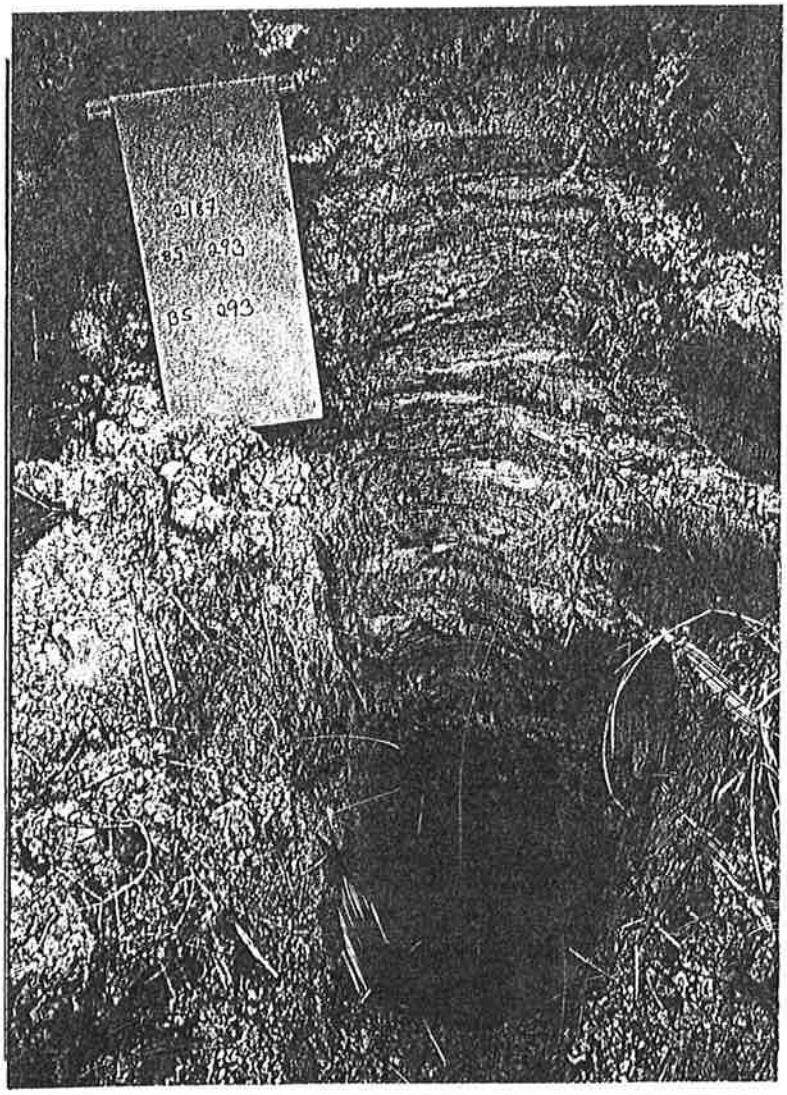

Fig. 3. A section through overbank sediments, Atna, Norway.

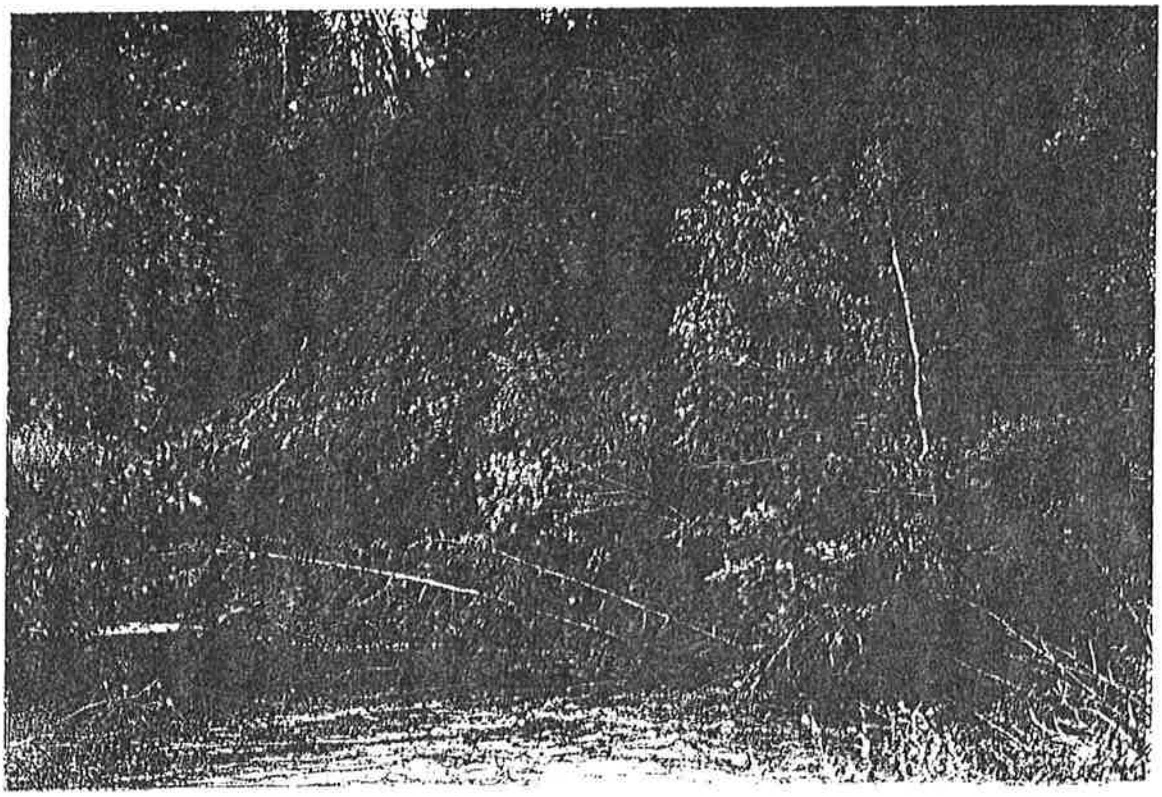

Fig. 4. Erosion at apoint source of the river Lena, Southern Norway.

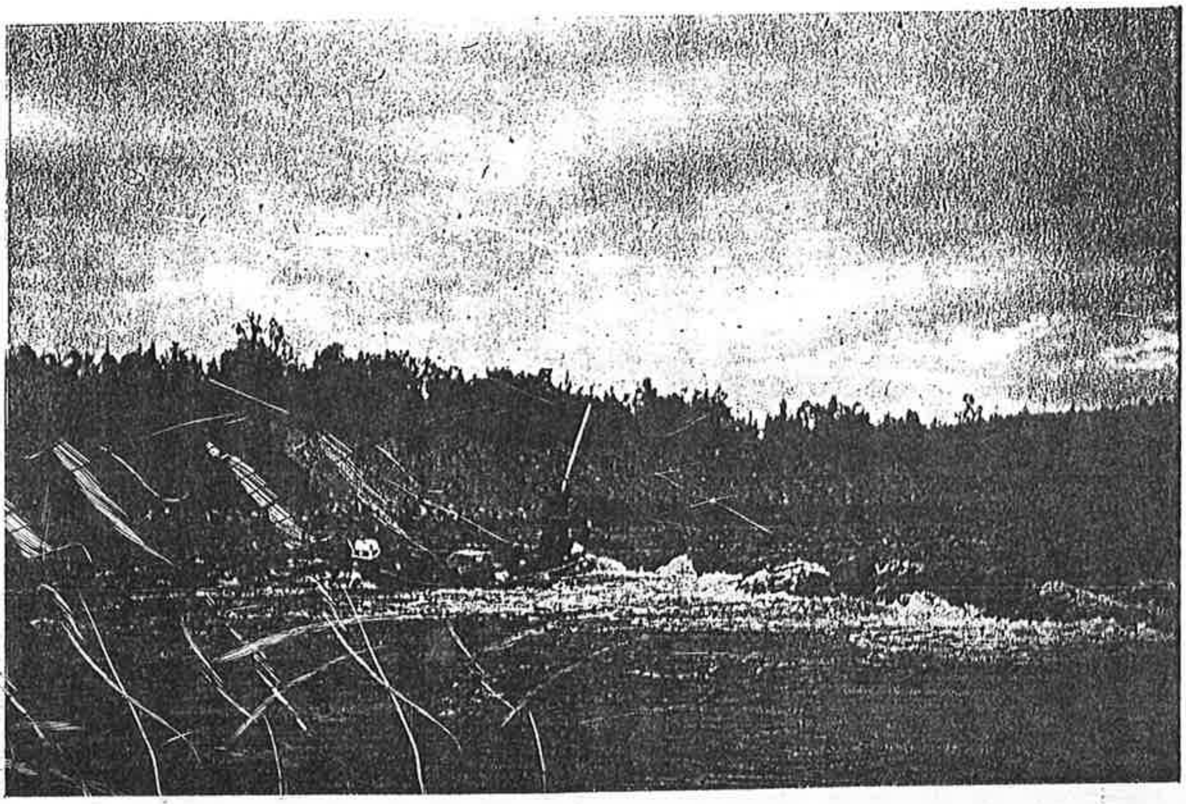

Fig. 5. Erosion at a point source of the river Karasjokka, Northern Norway. No erosion takes place of the bank at the far left side of the picture.

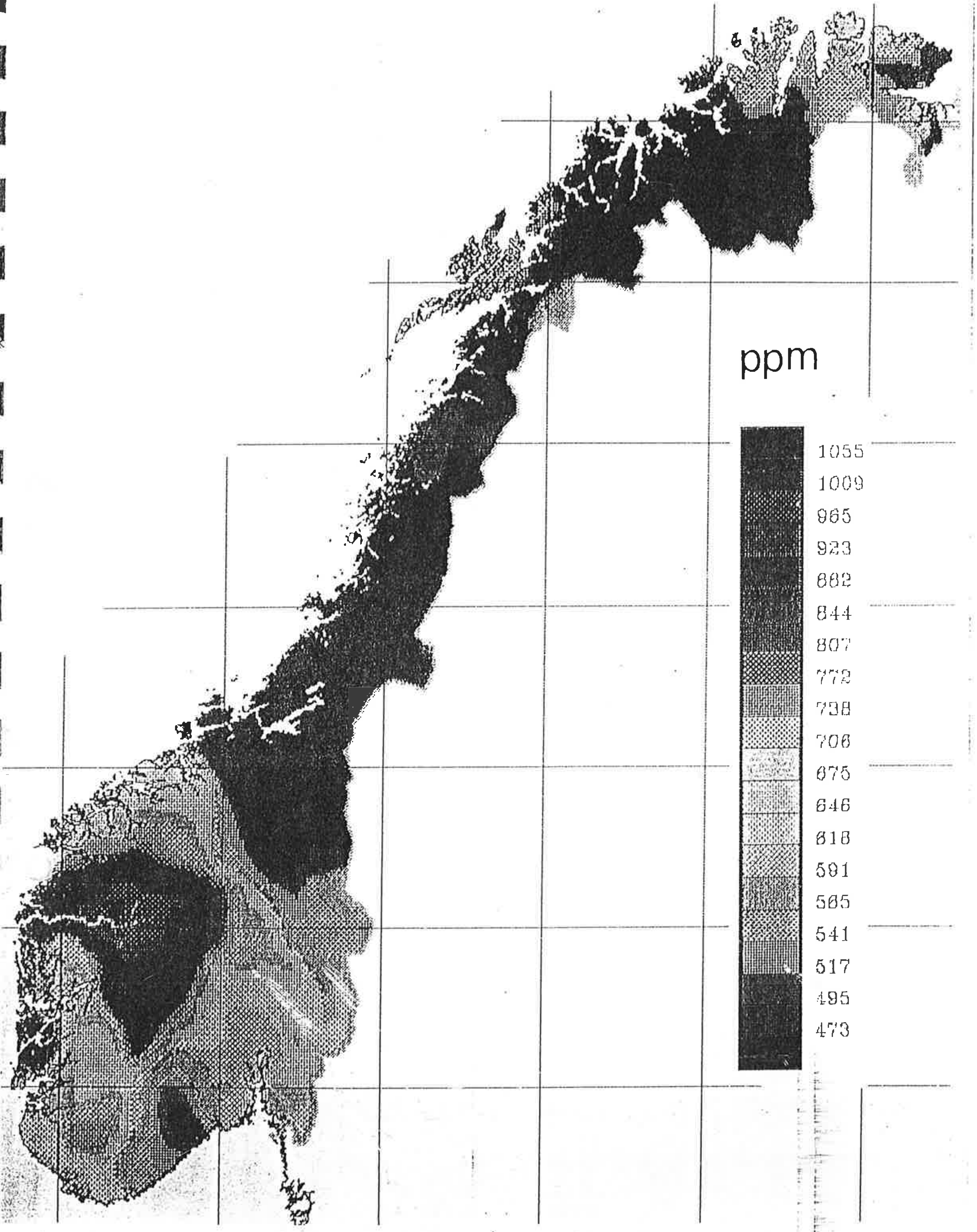

Fig. 6. Total barium in overbank sediments, Norway. The colours indicate the moving median (r=50 km) for 690 sample sites.

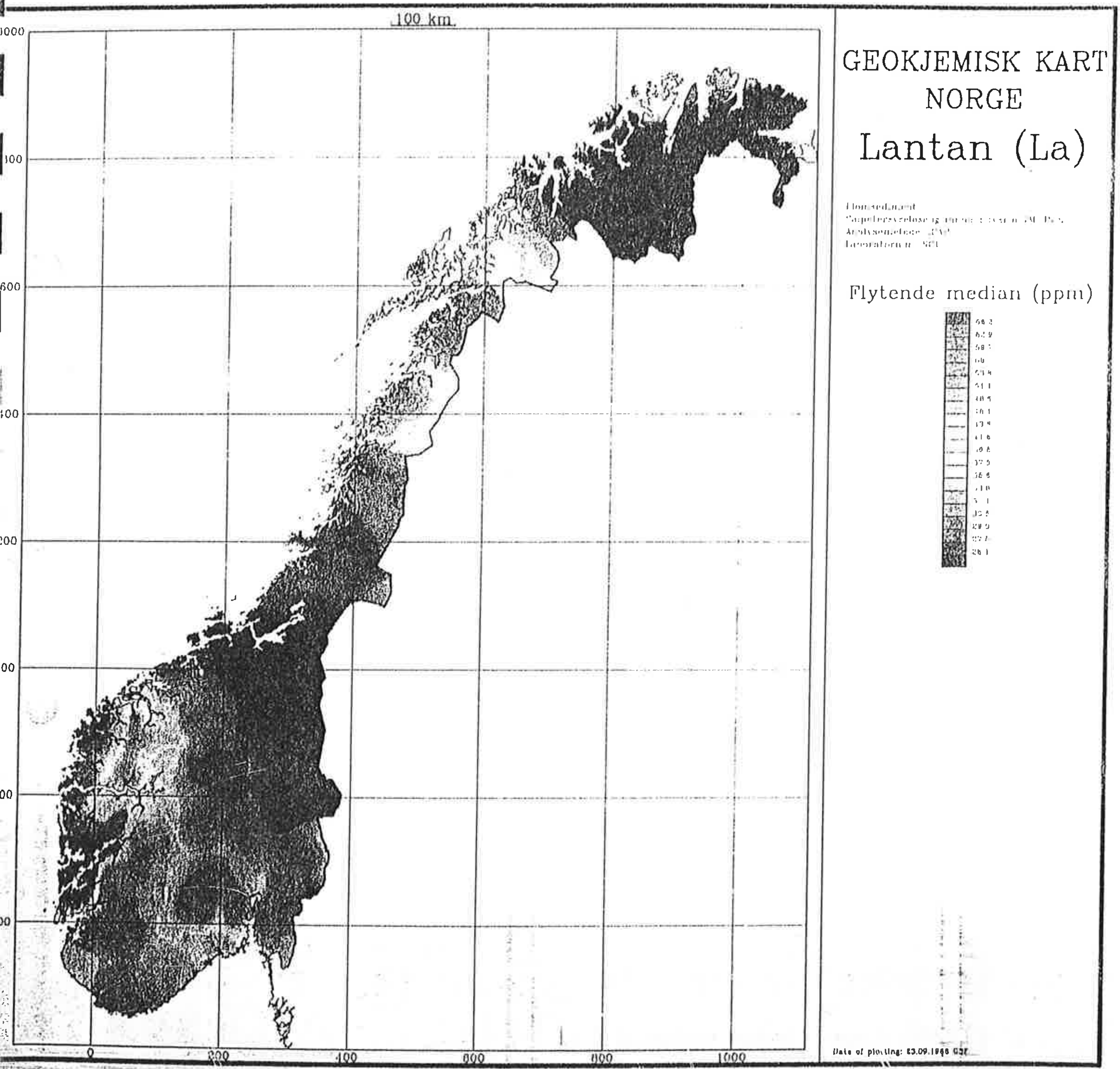

Fig. 7. Acid soluble lanthanum in overbank sediments, Norway. The colours indicate moving median (r=50 km) for 690 sample sites.

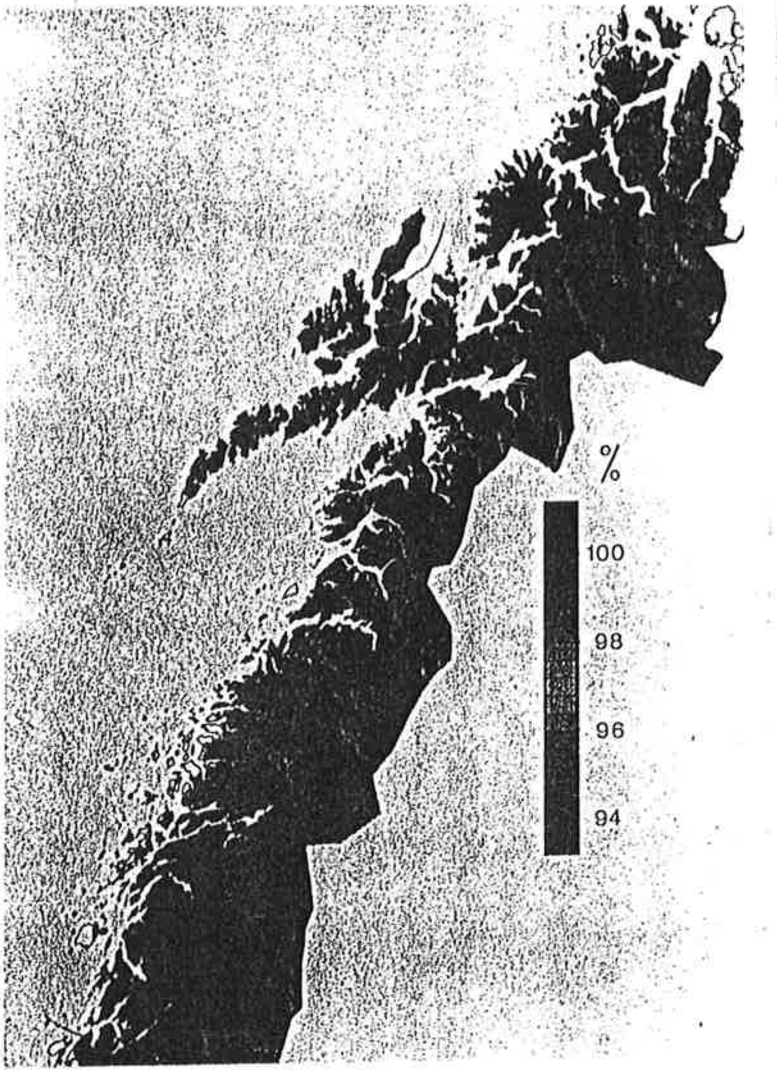

Fig. 8. Moving median (R=10 km) of the bufferpercent of the <0.06 mm fraction of 932 samples of till taken at a depth of 60 cm within the Nordland and Troms district, Northern Norway.

$$\text{Buffer percent (B)} = \frac{[H+]_A - \Delta[H+]}{[H+]_A} \cdot 100$$

Where $[H+]_A$ is the amount of hydrogen ions added normally as H_2SO_4 to a suspension of a soil sample.

Δ [H+] is the difference in concentration of hydrogen ions as recorded by pH measurements after (pH_2) and before (pH_1) addition of acid to a soil suspension.

In this case pH_1 was measured after 2g soil were shaken with 10 ml of water. pH_2 was measured after the addition of 10 ml 0.005 N H2SO4 to the water suspension.

Appendix 10. Working Group meeting Hannover Aug. 1988. Minutes.

WESTERN EUROPEAN GEOLOGICAL SURVEYS

Working Group on Regional Geochemical Mapping

meeting in BRG

Hannover August 22-23, 1988

Minutes prepared by Rolf Tore Ottesen

Participants:

Bjørn Bølviken, Norway
Roland Hindel, F.R. Germany
Rolf Tore Ottesen, Norway
Helmut Raschka, F.R. Germany
Peter Simpson, United Kingdom
Otmar Schermann, Austria
Tore Volden, Norway

The representatives from France Greece and Spain were held up on other business.

1. Dr. V.W. Stahl, BGR, opened the meeting.

2. Bjørn Bølviken gave a short review of the activities of the Working Group 1986-1988.

3. The letter of August 10, 1988 from Dr. C. Papavassiljon, ICCM to Mr. A. Archer was discussed. The Working Group agreed upon the following:

   - It is not desireable to create a new working group on Applied Geochemistry at this stage. Political questions such as the inclusion of Eastern European countries in WEGS project should not be treated by the Working Group, but by the WEGS directors.
   - The research suggested by Dr. J. Goni will be included in the project proposal that is being proposed by the Working Group.

4. Different geochemical themes were presented and discussed:

   - reproducibility of data
   - randomization of sample numbers before analysis
   - suceptibility of soils to acidification
   - lime requirements of soils
   - surplus of Al and heavy metals in soil water

5. A revised project proposal for the geochemical mapping of Western Europe was prepared. The plan is attached.

6. Further plans for work in the Working Group for the periode August 1988 to summer 1989 are indicated in the following table.

Subject	Deadline	Responsible
Final correction of the mapping plan	August 30, 1988	Bølviken Hindel Simpson Schermann
Destribution of the plan to the WEGS-directors	September 5, 1988	Bølviken

Subject	Deadline	Responsible
Presentation of the plan for the WEGS directors in Copenhagen	September 12, 1988	Bølviken
The Working Group will present a paper of its plans at the IGC in Washington. An abstract must be made before 15. September	September 15, 1988	Bølviken and coauthors
Results of the Copenhagen meeting to be reported to the Working Group members	October 21, 1988	Bølviken
Excursion in Austria, in terrain which includes most of the types of landscapes in W-Europe	Sept./Oct. 1988	Ottesen Schermann
Orientation surveys in Austria, France, Norway, and United Kingdom. - 10 sample localities from each country. - 10-15 samples per locality	fieldwork Oct. 1988 - Feb. 1989	Ottesen Salpeteur (?) Schermann Simpson
Meeting in Hannover to 1) Discuss results from the orientation surveys 2) Presentat a project plan to geochemists from all participating WEGS institutions	May 1989	Hindel Bølviken

Subject	Deadline	Responsible
Possible orientation surveys in the other participating WEGS countries	Summer 1989	?
Possible start of mapping project	Summer 1990	?
Project meeting in Hannover. Detailed planning.	Vinter 1989/90	?

7. An excursion was made along the river Innerste. The river drains the Harz 500 years old mining district. Data from overbank sediment were demonstrated. The sediment were heavily polluted in upper meter of the soil. Normal concentrat had been obtained at the lower part of the soil sections.

8. Next meeting in the working group is planned to be held at BGR in Hannover in may 1989. The members must be prepared to participate in two working group meetings during 1989.

Appendix 11. Heavy metals in alluvial soils, F.R. Germany and Norway.

VERTICAL DISTRIBUTION OF HEAVY METALS IN POLLUTED OVERBANK SEDIMENT IN F.R. GERMANY AND NORWAY

BGR, Hannover has determined the vertical distribution of heavy metals and other elements in soils taken from 500 sample sites from all over Germany. Some of these soils are classified as "alluvial soil" which is a term with the same meaning as "overbank sediment", "levee sediment" or "floodplain sediment".

Some of the sample stations are at the floodplain of the Innerste River, which drains the Harz Mountain ore fields. The mineralization is mainly Pb and Zn sulphides, and several mines have been in operation for at least 500 years.

Waste and tailings from the mines have been dispersed several tens of kilometres down the Innerste river and the active sediment in the river is strongly contaminated by heavy metals. Floods have occured frequently in the area during historical times, and fine grained anthropogenic material from the mines has been deposited on the flood plains of the Innerste river during these floods. Results from a typical section are given in Table 1.

TABLE 1. Vertical distribution of pH and metals in alluvial soils at Getter (Tk 3928 Salzgitter Bad), F.R. Germany

Depth cm	pH	Pb ppm	Cu ppm	Zn ppm	Cd ppm	Ni ppm	Co ppm	Li ppm	Fe ppm	Mn ppm	Hg ppb	Ag ppm	Sb ppm
+6 +5	4.7	6050	162	1395	7.8	23	11	42	22770	2090	2350	15	24.0
+5 0	5.8	13800	340	4190	20.5	28	15	82	43000	5600	7800	22	44.0
0 -8	7.0	19000	349	4620	21.0	28	15	89	48000	7000	8700	24	63.0
-8 -15	7.3	17300	262	3956	19.5	28	14	91	43000	5950	4600	22	60.0
-15 -24	7.5	15600	211	3582	14.6	27	13	96	41000	5200	4100	20	55.0
-24 -33	7.6	16500	219	3370	14.7	28	15	99	40000	5000	4700	20	57.0
-33 -40	7.5	14000	181	3283	10.6	28	16	99	34000	3700	3900	20	53.0
-40 -48	7.6	11800	229	3960	11.4	35	18	78	37000	3350	2150	16	41.0
-48 -53	7.5	3733	173	3739	11.4	38	20	54	32000	1600	700	12	19.0
-53 -75	7.6	3323	174	3112	8.6	38	22	49	32000	1510	670	11	15.0
-75 -80	7.5	3718	150	2559	5.5	39	22	56	35000	1850	940	12	16.0
-80 -85	7.5	1696	116	2123	6.0	48	20	54	39000	1620	550	10	8.0
-85 -95	7.1	617	57	1222	4.0	47	20	55	36000	1740	270	8	5.0
-95-100	6.9	314	42	810	2.5	41	19	49	33000	1430	210	7	3.5
-100-120	7.0	142	40	309	.7	51	17	43	37000	1230	145	7	2.3

A typical section outside areas with mine pollution is given in Table 2.

TABLE 2. Vertical distribution of pH and metals in alluvial soils at Bidergraben near Hausen (Tk 8012 Ehrenstetten) F.R. Germany

Depth cm	pH	Pb ppm	Cu ppm	Zn ppm	Cd ppm	Ni ppm	Co ppm	Li ppm	Fe ppm	Mn ppm	Hg ppb	Ag ppm	Sb ppm
0 -32	6.9	147	27	140	.7	31	12	75	27580	410	180	18	1.5
-32 -40	7.2	105	29	129	.5	46	17	95	30000	470	90	16	1.8
-40 -46	7.2	68	32	150	.5	53	21	114	29000	370	85	14	1.5
-46 -65	7.3	50	23	124	.4	39	17	94	26550	310	70	10	1.3
-65 -75	7.3	64	27	154	.5	45	20	96	32000	360	90	13	1.3
-75 -82	7.4	60	31	158	.6	51	23	95	42000	540	90	34	1.5
-82-104	7.3	60	36	144	.9	59	23	86	46000	850	90	70	2.0
-104-112	7.4	44	26	112	.7	57	22	63	41000	1030	140	65	1.8
-112-127	7.4	35	23	92	.5	52	18	61	32000	530	85	33	1.5
-127-150	7.4	40	25	94	.5	50	18	63	36000	720	65	40	1.5
-150-155	7.4	40	26	95	.4	51	17	67	36000	460	95	42	1.5
-155-162	7.4	34	21	74	.3	45	16	53	22880	290	55	12	1.0
-162-190	7.4	28	18	59	.5	40	14	41	18560	280	40	7	0.8
-190-200	7.7	24	11	41	.4	24	9	28	13020	310	30	8	0.5
-200-220	7.7	28	14	45	.4	29	11	23	13400	390	25	5	0.5

Tables 1 and 2 indicate that although the top layers of the overbank sediment in Germany may be polluted to a varying degree, it is possible to obtain pristine samples of overbank sediment at depth.

Analogous results have been obtained in one case in Norway. At the outlet of the heavily polluted Orva River, which drains an area of Cu, Zn and Pb containing pyrite deposits at Røros, both active stream sediment and a vertical section of overbank sediment from polluted into more pristine material were sampled. The contents of Cu, Zn and Pb are anomalously high in the stream sediment and in the upper part of the overbank sediment, while high background values were found in the overbank sediment taken at depth. The contents of Ba, La, Li, Sr and Zr, which are not enriched in the ore bodies, show background values in both the stream sediment and in the overbank sediment (Table 3).

TABLE 3 Contents of hot nitric acid soluble elements in stream sediment and in top and bottom layers in a handdug pit (60 cm) through overbank sediment at the polluted Orva River, Røros, southern Norway.

	Active stream sediment	Overbank sediment Top layer	Overbank sediment Bottom layer
Cu (ppm)	344	3800	41
Pb (ppm)	325	229	10
Zn (ppm)	404	1300	200
Ba (ppm)	69	48	37
La (ppm)	25	17	21
Li (ppm)	6	7	12
Sr (ppm)	14	6	10
Zr (ppm)	16	15	8

Appendix 12. Mapping the acid susceptibility of soils.

29.04.88

MAPPING THE ACID SUSCEPTIBILITY OF SOILS

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The natural sensitivity of soils to acidification can be obtained by measuring the pH in soil suspensions before and after addition of an acid. Tests using widely spaced samples of glacial overburden (1 sample per 70 km^2 taken at a depth of 60 cm), from the Nordland and Troms districts of Northern Norway show that the natural acid neutralizing capacity of the soil, varies in a systematical way and depicts broad patterns that cannot be foreseen from the interpretation of geological maps. Regional geochemical surveys of this type should be useful tools in predicting areas vulnerable to harmful effects of acid rain.

In a cooperative geochemical mapping programme carried out by the Geological Survey of Norway, soil samples were collected from 932 sites evenly distributed over the Nordland and Troms districts of Northern Norway (64 000 km^2). The samples were taken at the bottom of 60 cm deep pits dug by hand. The area has been glaciated, and the majority of the samples consists of till. After drying, the samples were sieved through a 0.6 mm nylon cloth. 2 g of the fine fraction were shaken (1/2 h) with 10 ml distilled water and left over night. The acidity (pH_1) of the suspensions were then measured with a glass electrode. 5 ml 0.005 N H_2SO_4 were subsequently added to the suspensions, which were again shaken (2 h) and left overnight. The final acidity of the suspension (pH_2) was then measured as before. The two sets of pH values were used to calculate the acid neutralizing capacity of each soil sample expressed as the 'buffer percent'.

The concept of buffer percent curves was introduced by J. Låg as early as 1945[1-3], and can for acid treatment be defined according to the formulae:

$$\text{Buffer percent (B)} = \frac{[H+]_A - [H+]}{[H+]_A} \cdot 100$$

where $[H+]_A$ is the concentration of hydrogen ions in an acid solution in which a soil sample is suspended.

$[H+] = [H+]_2 - [H+]_1$, which is the increase in concentration of hydrogen ions in suspensions of the soil as recorded by pH measurements before (pH_1) and after (pH_2) the soil has been suspended in solutions of successively increasing acidity.

For treatment with bases the formulae has an analogous form, $[H^+]$ being interchanged for $[OH^-]$.

The buffer percent describes the result of a number of different types of reactions between the soil and the acid of which neutralization is an important one. A comparison of bufferpercent values for soils is meaningfull only if all values are obtained empirically under standardized conditions. The formulae shows that if the addition of acid causes no change of pH in the soil suspension, the buffer percent will be 100. If the addition of acid leads to a decrease in pH, then the buffer percent will have some value less than 100.

According to our measurements the pH of the soil samples varies between the extremes 3.0 and 8.0, the mean value being 5.4. The buffer percent ranges from 74.8 to more than 100, with a mean value of 96.6%.

Rolling median maps for both the pH (Fig. 1) and the buffer percent (Fig. 2) yield well defined broad regional distribution patterns. The results of replicate analyses show that the patterns are reproducible.

As the survey region is sparsely populated (6.1 persons per km^2), with relatively little industrialization and quite remote from the main industrial areas in Europe, it is believed, that the principal patterns are natural. Analogous types of natural patterns very probably exist (or have existed) elsewhere in Norway and in other countries.

There are no obvious similarities between the patterns in Figs. 1 and 2. The geographical distribution of the buffer percent (Fig. 2) seem to be influenced by a complex combination of geological and geochemical factors such as: (1) The mineralogical composition of the bedrock. For Norway the bedrock and thereby the soils of the Nordland and Troms districts (Fig. 3) are rich in carbonates[4], promoting high pH and high acid neutralizing capasity of the soil in some areas. However, the contents of other minerals such as sulphides and silicates will also influence both the acidity of the soil and its recistance to acids[5-7]. (2) The clay content of the soil. The more clay there is in the soil, the higher the buffer capacity will be[5-7]. The amounts of clay in glacial soils vary with composition and texture of the bedrock, degree of preglacial weathering and the glacial history. (3) The contents of humus in the soil. Humus possesses ion exchange properties, and varying qualities and quantities of organic matter in the soil will affect both its pH and its buffer capacity[5-8]. (4) Secondary precipitates in the soil. Our raw data indicate (see also Fig. 2) that the buffer percent exeeds 100% in about 1/10 of the survey region. About 30 samples showed an increase in pH of one unit or more after the addition of acid. These apparently erroneous data (for which the buffer percent is not a suitable measure) are reproducible - and we think - correct. The results are thought to be caused by a dissolution and removal of secondary-mineral coatings on rock fragments and mineral grains in the soil during the acid treatment, by which carbonates or other acid-consuming primary minerals are exposed. (5) Other factors. There exist apparently unknown factors influencing the acid sensitivity of soils. A comparison of the distribution patterns of the buffer percent (Fig. 2) and that of Cl in the heavy mineral fraction of stream sediments (Fig. 4) reveals that high contents of chlorine in the heavy minerals in the stream sediments, are associated with low buffer percent in the soil, and vice versa.

The Cl-pattern in the stream sediments is thought to reflect that in the bedrock, but seems neither to be associated with the distribution of main rock types (Fig. 3) nor to be an effect of a dispersion from present marine sources along the western border of the survey area. The patterns appear rather to indicate a Pre-quaternary, but supposedly epigenetic supply of Cl to the bedrock in some areas. If this supply has been in the form of acid compounds, then metasomatic processes may have produced rock types - and as a concenquence soils - with a low acid neutralizing power. If sufficient amounts of chlorides are present, then an adsorption of Cl^- on soil particles at the expence of OH^- would also be a possible mechanism contributing to a low acid buffer capacity of the soil.

It is concluded that distribution patterns of the acid sensitivity of soils can be disclosed by measurements only, and should not be estimated by an interpretation of geological and other data as has been suggested by several authours[6,9].

Experience from regional geochemical mapping in glaciated terrain elsewhere in Scandinavia[10], indicates that the principal features of the geochemical dispersion patterns may be detected through the analysis of widely scattered soil samples. In the Nordland and Troms survey area a sampling density of 1 sample per 70 km^2 seems adequate for mapping the general trends in the acid sensitivity of soils. It appears that this type of maps would be of common interest in environmental research, since they may indicate areas vulnerable to harmful effects of acid rain.

Further work will imply a standardization of the methods and aim at a better understanding of the mechanisms controlling the acid susceptibility in various regions. We plan to continue the mapping in other areas of Norway including a determination of the buffer percent of surface soils and a study of the amounts of aluminium, magnesium and other elements that are released from the soil samples during the acid treatment. We also plan to obtain more complete buffer percent curves by analogous treatments of soils with bases. Thereby the time requirement of the soil can be mapped.

We thank the counties of Nordland and Troms represented by Gunnar Aker Johannesen and Ola Torsteinsen, county geologists, for financial support and professors J. Låg, I.Th. Rosenqvist, W.E. Sharp and E. Steinnes for valuable comments to an early draft of the paper.

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Bølviken et al. Figure captions

Fig. 1. Moving median[11] (window diameter 20 km) of pH in suspensions of 2g soil in 10 ml H_2O of 932 samples of the minus 0.6 mm fraction of soils at 60 cm depth (mainly till) from the Nordland and Troms districts, Northern Norway.

Fig. 2. Moving median[11] (window diameter 20 km) of the buffer percent[1,2,3] of 932 samples of the minus 0.6 mm fraction of soils at 60 cm depth (mainly till) from the Nordland and Troms districts, Northern Norway. 5 ml 0.005 N H_2SO_4 were added to a suspension of 2 g soil in 10 ml of water.

Fig. 3. Bedrock geology[12] of the Nordland and Troms districts, Northern Norway.

Fig. 4. Moving median[11] (window diameter 20 km) of the total contents of chlorine determined by XRF in 932 samples of the heavy mineral fraction of stream sediments (sp.gr. > 2.96 grain size 0.2-0.6 mm) from the Nordland and Troms districts, Northern Norway.

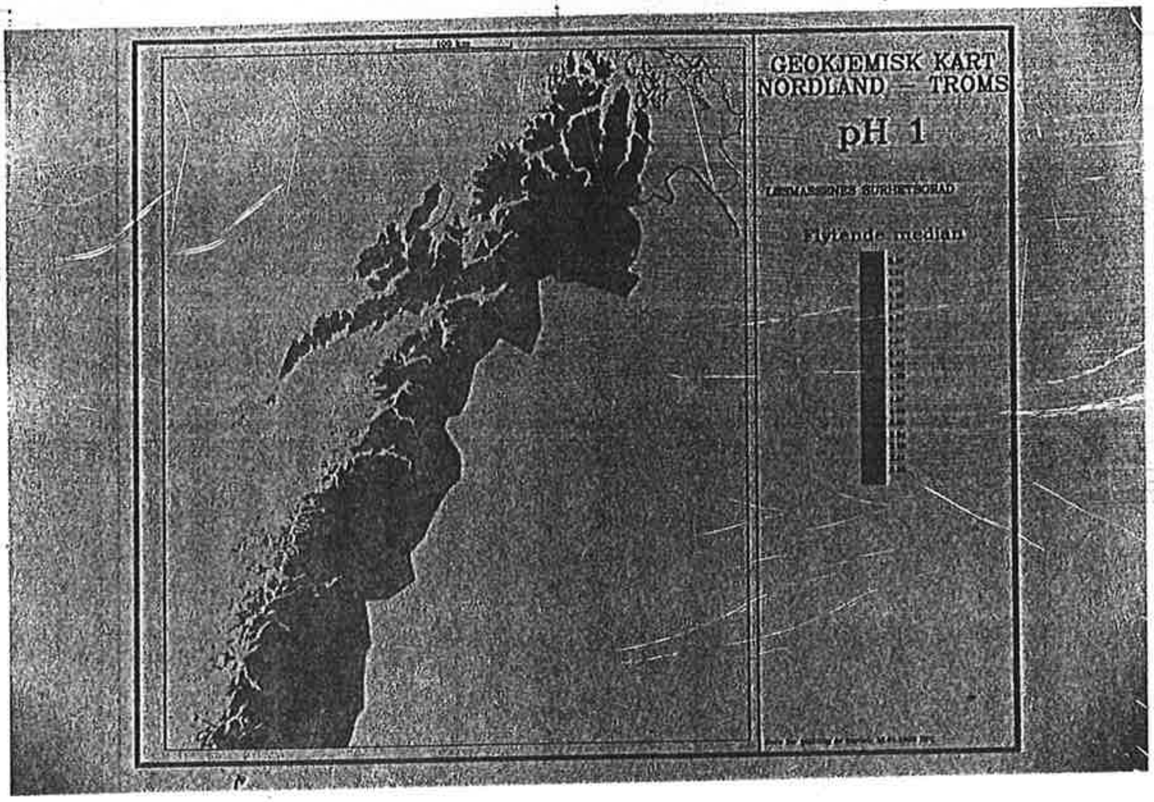

Fig. 1. Moving median[11] (window diameter 20 km) of pH in suspensions of 2g soil in 10 ml H_2O of 932 samples of the minus 0.6 mm fraction of C-horizon soils (mainly till) from the Nordland and Troms districts, Northern Norway.

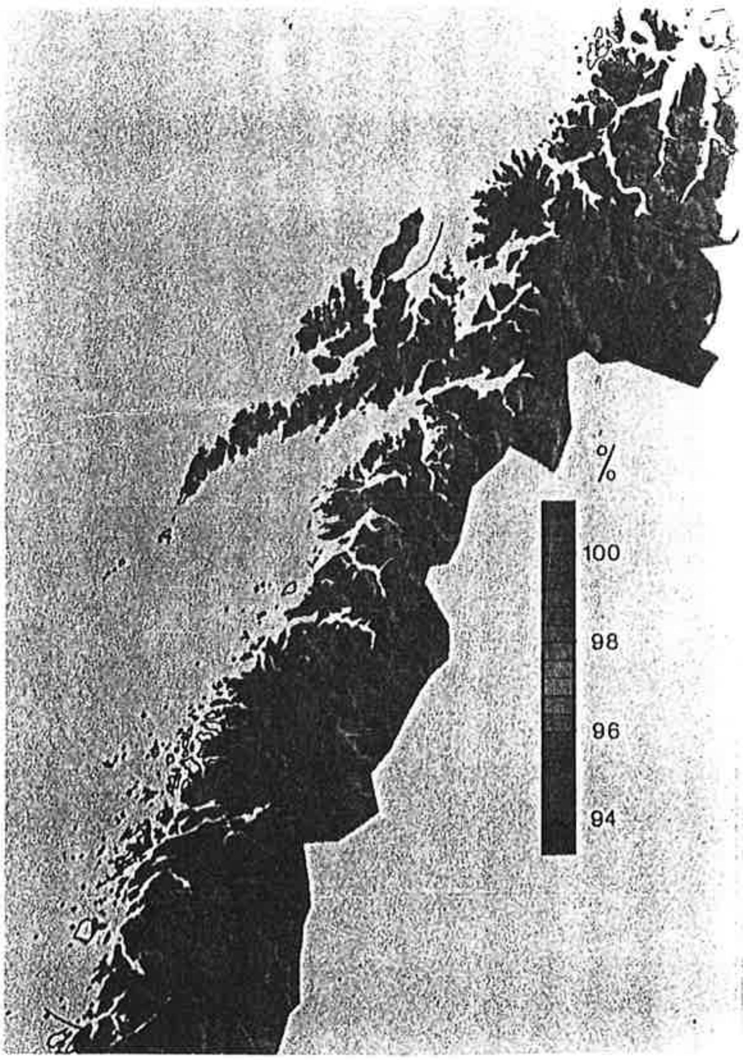

Fig. 2.

Moving median[11] (window diameter 20 km) of the buffer percent[1,2,3] of 932 samples of the minus 0.6 mm fraction of C-horizon soils (mainly till) from the Nordland and Troms districts, Northern Norway. 5 ml 0.005 N H_2SO_4 were added to a suspension of 2 g soil in 10 ml of water.

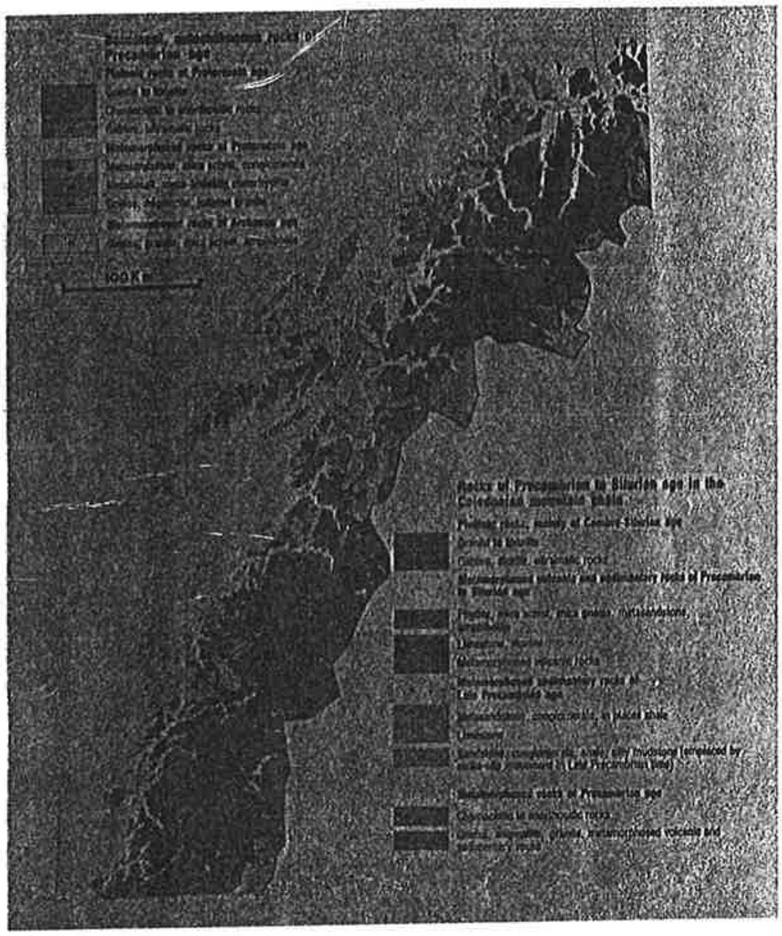

Fig. 3.

Bedrock geology[12] of the Nordland and Troms districts, Northern Norway.

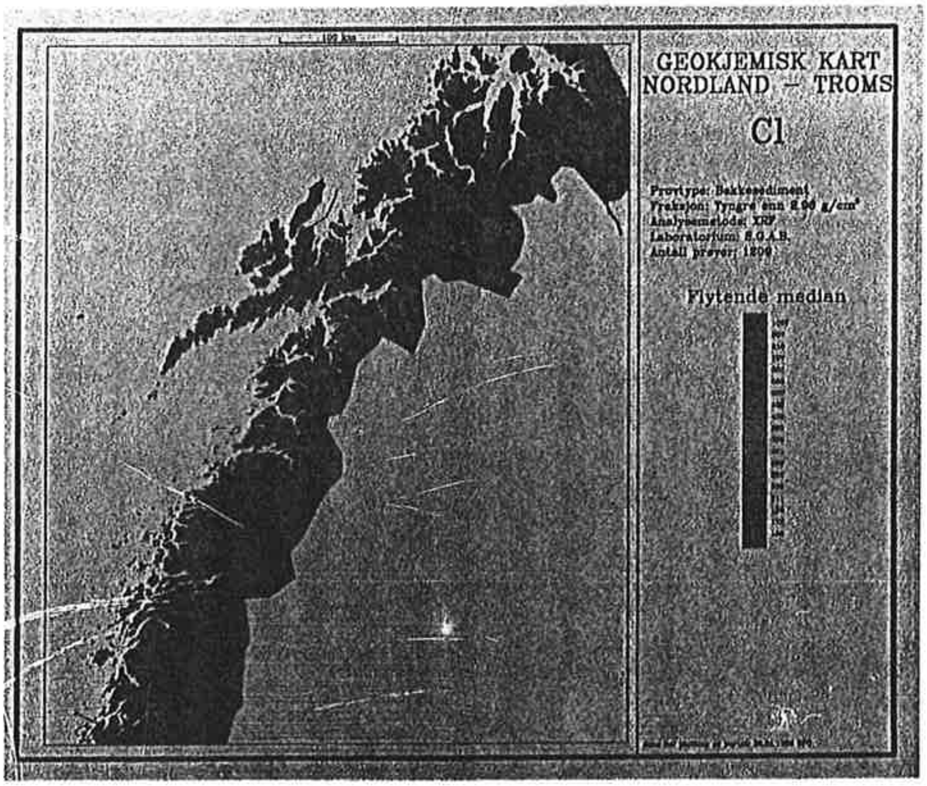

Fig. 4. Moving median[11] (window diameter 20 km) of the total contents of chlorine determined by XRF in 932 samples of the heavy mineral fraction (sp.gr. > 2.96 grain size 0.2-0.6 mm) from the Nordland and Troms districts, Northern Norway.

Appendix 13. International Geochemical Mapping.

APPENDIX 13

INTERNATIONAL GEOCHEMICAL MAPPING

IGCP PROJECT 259

SUMMARY REPORT OF MEETINGS at V.M. GOLDSCHMIDT CONFERENCE, BALTIMORE MAY 11-13, 1988

1.1 SCIENTIFIC PAPERS

A Session entitled International Geochemical Mapping was held on the first morning of the V.M. Goldschmidt Conference. The papers presented were:

B. Bolviken, The Nordkalott Project: a multi disciplinary mapping programme in Northern Fennoscandia.

----------, Plans for Geochemical Mapping of Western Europe.

A.G. Darnley, Geochemical mapping: a new international project.

J.S. Duval, Applications of modern gamma-ray techniques in geochemistry.

R.G. Garrett, Regional geochemical mapping by the Geological Survey of Canada.

J.M. McNeal, Geochemical mapping in the United States.

J.A. Plant, M.D. Forrest, P.M. Green, R.T. Smith, R.A.C. Williams, Regional geochemistry in the modelling of mineral deposits.

Xie Xuejing, Problems, strategical and tactical, in international geochemical mapping.

Arrangements are being made to have several of these papers published in a special issue of the Journal of Geochemical Exploration during 1989.

2. INAUGURAL BUSINESS MEETING

This was held from 17:00 to 19:15 on May 12, and 12:00 to 13:00 on May 13.

2.1 Election of Project Leader

Dr. M. Chaffee (USA), President of the Association of Exploration Geochemists, opened the business meeting. IUGS rules governing the establishment of IGCP Projects require that the Project

Leader be formally elected. Dr. Chaffee proposed Dr. A.G. Darnley (Canada); this was seconded by Dr. B. Bolviken (Norway) and Prof. Xie Xuejing (P.R.C.). There being no other nominations, the proposal was put to the vote and carried unanimously.

2.2 Project Organization

It was agreed that the project should be guided by a Steering Committee, composed of the leaders of geographically grouped Regional Committees, plus the leaders of 4 Technical Committees. The Project Leader will be chairman of the Steering committee. Each Technical Committee will deal with a specific group of problems on an international basis and should have a minimum of 5 members. The Project Leader will be an ex officio member of each Technical Committee.

2.3 Technical Committees

The Technical Committees will divide their responsibilities as follows (note that all aspects of radiometric survey work are covered by the Radiometric group):

1) Field Methods: to include all matters concerning selection of sample media; methods of sample collection; sample spacing, including ultra-wide spacing; sample mass; particle size(s) for analysis; collection of replicate samples; use of composite samples; selection and collection of material for reference standards; in-field sample processing, etc.

2) Analytical Methods: to include all matters concerning sample preparation and digestion; selection of analytical techniques; use and adoption of reference materials; provision of international inter-laboratory reference materials; expansion of analytical suites, etc.

3) Data Processing and Management: to include recommendations on the organization and contents of a world index of geochemical surveys; methodology for levelling/normalizing diverse data sets; development of standard formats for trans-border data-sets and map publication; evaluation of data interpretation methods for the principal user-groups, etc.

4) Radiometric Methods, to include all aspects of the collection, standardisation, compilation and interpretation of geochemical data obtained by airborne gamma-ray spectrometry. (Note that a working group has

already commenced work on methods for combining existing data, under the auspices of the International Atomic Energy Agency, Vienna, Organizer A.Y. Smith).

2.3.1 Nominations

Nominations for membership of the Technical Committees were solicited. These are to be sent to the Project Leader as soon as possible, and not later than September 15.

2.4 Regional Committees

The following Regional Committees were proposed on the basis of existing arrangements, arrangements made at the meeting, and previous correspondence; leaders are identified where known:

North America	(J. McNeal, USA)
China	(Xie Xuejing)
Eastern Europe	(F. Mrna, CSSR, to be confirmed)
Western Europe	(B. Bolviken, Norway)
USSR	(P.V. Koval, to be confirmed)

From discussion during the meeting it was indicated that there are good prospects for establishing in the near future Regional Committees to represent:

Latin America, Africa, and Australia.

In addition steps will be taken to investigate the best means to encourage the formation of Committees representing:

SE Asia, India, Japan, and the Middle East.

Assistance in this matter will be sought from UN and other International Agencies.

2.5 National Committees

It is expected that countries intending to take an active part in the International Geochemical Mapping Project and having geochemical data to contribute, or geochemical programs to arrange, may wish to establish a national committee for geochemical mapping. Clearly its size and structure will depend upon local circumstances. Whatever the arrangement, it is important that there should be a national representative who can participate in meetings of the relevant Regional Committee and contribute to the fulfillment of the project both nationally and internationally.

3. FUTURE MEETINGS

A number of forthcoming international Conferences were identified as providing suitable opportunities to promote the Project through:

1) presentation of papers and/or posters,
2) workshops to review specific problems.

These Conferences can also provide focal points for Technical Committee meetings.

<u>August 1988</u> IAGC Paris. (time is now short, but possibly an informal discussion concerning IGCP Project 259 could still be arranged if there is sufficient interest from persons in a position to speak for national organizations).

<u>July 1989</u> INTERNATIONAL GEOLOGICAL CONGRESS Washington.

A Theme Paper and Poster Session on International Geochemical Mapping is planned; in order to make this possible, ABSTRACTS MUST BE SUBMITTED TO THE IGM PROJECT OFFICE IN OTTAWA BEFORE 15th SEPTEMBER SO THAT THEY CAN BE EDITED AND ARRANGED AS A SELF-CONTAINED SESSION. THEY WILL THEN BE FORWARDED TO THE IGC ABSTRACT OFFICE TO MEET THE DEADLINE OF 1st OCTOBER. NOTE THAT ABSTRACTS ARE REQUIRED FOR BOTH POSTERS AND PAPERS. Abstracts for papers should be typed double-spaced, and may be up to 900 words in length, including title, and authors names and addresses. Contributions are invited on any major aspect of regional geochemical mapping, but those which demonstrate the application of such maps will be particularly appropriate for this occasion.

Note that the IGC Second Circular provides information about the Congress, including information about the Geohost Grant Program which is available to applicants from developing countries. The closing date for applications to arrive in Washington is August 1.

<u>October 1989</u> IGES Rio de Janeiro

<u>1990</u> IAGC Prague

<u>1991</u> (to be decided, suggestions invited)

<u>1992</u> IGC Japan

It is anticipated that, in addition to the main international meetings, Regional Committees will identify suitable events, conferences etc., within their own geographic regions where periodic IGM Regional Meetings can be held to plan and co-ordinate regional activities.

4. MATTERS ARISING IN DISCUSSION

The following points are recorded, in order that they can be considered and dealt with as necessary by the appropriate committees at future meetings.

1) In many countries, support for large-scale geochemical surveys seems to be increasing due to their environmental significance. The concept of "Global Change" is beginning to attract popular attention. Recognising that most existing geochemical surveys were conducted for geological/mineral exploration purposes, what additional steps could be taken in order to maximise the environmental usefulness of existing or new data? For example, could additional analyses of retained sample material be undertaken; how might the design of future surveys and analytical procedures be modified?

2) Given the desirability of expanding geochemical coverage of the world as rapidly as possible, there is an urgent need to establish the most satisfactory method of wide-spaced sampling. In this context, the question of single or composite samples is important. Stream (or river) sediments are generally considered to be the most universally available sampling media. On the basis of Norwegian experience, a strong case was made for "overbank" sampling, but questions were raised as to whether the technique can be applied in many other regions. Those present were asked to consider the suitability of the method for the areas they know.

3) Could the major river systems of the world be sampled by means of a few thousand samples in order to achieve world-wide coverage quickly? What would be the analytical requirements in order to detect significant regional differences? Could the material collected serve for control reference purposes?

4) There is a need to subdivide the world into physiographic-climatic zones within each of which geochemical methods can be optimised. It will be necessary to have overlap between the zones so that data can be normalized.

5) Should samples be totally or partially digested? For geological purposes the former is preferable; for mineral exploration applications some partial extractions are advantageous and this is more true for environmental interpretation. However, it is easier to obtain standardized data where total extractions are used.

6) A number of countries, for example, UK and France, hold considerable amounts of geochemical data pertaining to developing countries which are potentially suitable for incorporation in world maps. It will be necessary to obtain formal permission from the countries concerned before these data can be used for this purpose.

7) The inventory of existing world geochemical data should be compiled in digital form.

8) There is an international project (FAO funded?) concerned with the geochemistry of nutrients in the major world river systems. It was suggested that the possibility of co-operation should be investigated. There is also a project concerned with the geochemistry of the ocean floor. As a comment, the Chairman stressed the importance, particularly in the initial stages of an ambitious project such as this, of concentrating attention on the agreed objectives (see attachment). There was a danger of trying to go in too many directions at once.

9) All participants were asked to inform their colleagues about the project, and particularly any contacts they may have in developing countries, in order to encourage the widest possible involvement. It was stated that a very limited amount of funding will be available to assist a few participants from developing countries to attend specified meetings. More information will be available at a later date.

10) To facilitate the progress of the project, participants are requested to supply the Project Office in Ottawa (address below) with a complete postal address, and wherever available, telex, fax, and telephone numbers. Intercontinental mail usually takes a minimum of 1 week in each direction, and often much longer. In the interests of speedier communication, telex or fax communication is preferable.

5. PROJECT LEADER`S ADDRESS (PROJECT OFFICE).

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APPENDIX

IGCP PROJECT 259

International Geochemical Mapping

The development of methods for the international correlation of regional geochemical surveys

Objective:

The purpose of the project is to encourage and facilitate the compilation of an international series of systematic surficial geochemical maps by national and/or international organizations, based on the most appropriate types of sample material. The maps will show abundance levels, delineate regional trends and geochemical provinces, and permit the recognition of large scale anomalous features. They will complement existing international geological and geophysical map series, and will be published at scales suitable for direct comparison. To the greatest extent possible primary data will be stored in digital form to facilitate its reproduction at different scales in a variety of formats, for mineral resource, general geological and environmental studies.

The data will be related to bedrock geochemistry where possible.

A.G. Darnley
Geological Survey of Canada

IGCP PROJECT 259

APPENDIX TO SUMMARY REPORT

JUNE 1988

EXTRACT FROM LETTER SENT BY PROFESSOR BJORKLUND, ABO AKADEMI, FINLAND, DATED MARCH 29, 1988

"As I unfortunately can not attend the meeting on international mapping during the Goldschmidt Conference, I will give some comments which you may or not include as an appendix in the minutes to be di tributed after the conference.

1. The product of the proposed IGCP project will be regional maps of some well-studied areas of the continents. They will be of great value for exploration. However, the heterogeneous material and the varied ways of sample treatment and analysis over large regions will make it di ficult, probably impossible, to produce data of significance for ecological purposes. Geochemical data for detection of athropogen pollution and for mapping of the sensitivity of the environment to acidification with associated tendency to decline of forest, agricultural and water milieus are urgently needed. Therefore, I suggest that regions already covered with large numbers of samples of different media are resampled at a very low density in a niform way and that these samples after randomization are analyzed in a number of ways in one or a number of laboratories. A few hundred stations for the European region would probably be enough. By extrapolation this data could then be used to create environmentally oriented functions for the data of the heterogeneous material of the high-density grids of national origin.

2. The regional maps resulting from the proposed IGCP project will cover only a small part of the continents. The environmental problems are rapidly growing global, and are most probably already more global than we are aware of. There is an increasing number of reports on the first stages of forest decline in the northernmost parts of the globe. To understand the global geochemical processes of relevance for global ecology, we need

schematic maps of geochemical patterns on the continental scale. We will not get national data of reasonable continental coverage within a near future (10-15 years) to allow construction of continental-scale maps based on existing data. Therefore, it will be necessary to collect samples of super-high quality at super-low density (100-300 km spacing over the Eurasian continent) over previously unsampled areas. In this way the regional maps of the proposed IGCP project could be linked up into schematic maps of total coverage of continents. Technically this could be done by asking geochemists of the individual countries to organize sampling within their respective country according to procedures internationally agreed on. Then we perhaps could get organisations like UNESCO to finance sample preparation and analysis as well as data presentation.

3. We are in an urgent need to get a global monitoring network of the geochemistry of the secondary environment, because it is changing in a direction which is worrying from the ecological point of view. The continental-scale low-density sampling which I propose above could serve this purpose. Sampling could be well-documented and integrated with the "Global Change" program. All or part of the sampling stations could be used for regular monitoring in the future. Swedish geochemists have established such a monitoring network over Sweden several years ago.

The continental-scale geochemical mapping which I am suggesting is a difficult task. Selection of sampling material suitable for such a work will not be easy. I feel that this is a problem which can not be included in full in the proposed IGCP project. However, I think the issue could be dealt with as a low-priority subject within the proposed international geochemical mapping project. A group of 2-3 persons could be given the responsibility to make initial planning. After 2-3 years the emphasis could then gradually be shifted over from the compilation of regional maps to continental-scale mapping."

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IAEA AND INTERNATIONAL GEOCHEMICAL MAPPING

The International Atomic Energy Agency has been an active supporter of the International Geochemical Mapping project. As the UN agency charged with responsibility for uranium geology, exploration and development it has naturally had a long standing interest in the radioelements potassium, uranium and thorium as well as in geochemical exploration methods for uranium. As a result of the Chernobyl accident and the evident need it exposed for more reliable information on the natural radiation background, the Agency has begun a programme to establish methods and standards for the use of uranium exploration radiometric data for this purpose. Those surveys carried out using gamma spectrometric equipment contain basic data to permit mapping of radioelement concentrations on a regional scale at the same time.

The Agency's project on the Use of Radiometric Data to Define the Natural Radiation Environment was begun last year with the convening of a group of consultants to prepare a manual on standards and methods to make use of the data of uranium exploration surveys. Many of these data are from surveys where calibration was not carried out. In order to render the data acceptable a process of back calibration will be required. The requirements become more severe as use is made of spectrometric data to produce radioelement maps. Methods and procedures will be specified for carrying out this task. The preparation of this document is in hand and is expected to be completed later this year. In order to gather information on what radiometric survey data exists world-wide and to be able to make some estimate of their quality a questionnaire has been circulated to all 113 Member States of the I.A.E.A. Replies are begining to come in and the data will be compiled and published. With these data in hand an estimate can be made of additional coverage needed in order to complete the preparation of regional and continental background radiation and radioelement maps.

As far as geochemical exploration surveys for uranium are concerned the Agency has encouraged these for many years in its Technical Co-operation projects and training courses. A more or less standard methodology has developed over the years based on the determination of nitric acid extractable uranium by the fluorimetric method. It is, of course, recognized that while extractable, or labile, uranium may represent as little as 10 % of the total uranium content of a sample, it has been considered that this part is of more immediate interest for exploration purposes. It is doubtful, however, whether these data can or should be used for the purposes of international geochemical mapping. The Agency will, therefore, wish to participate in discussions on the specification of sample materials, sample densities and analytical methods to be used for the International Geochemical Mapping project, particularly in regard to its interest in uranium.

In connection with the acquisition of new radioelement data the Agency will convene later this year a consultants group to begin preparation of guidelines on instrumentation and procedures recommended for new gamma ray surveys. The Agency's Technical Reports nos.158 and 174 on "Recommended Instrumentation for Uranium and Thorium Exploration" and "Radiometric Reporting Methods and Calibration in Uranium Exploration" have had wide circulation but are now out of date. The new publication is intended to bring recommendations up-to-date with modern instrumentation and methods. At the same time the use of uranium exploration radiometric instruments and methods in nuclear emergency response situations, such as that following the Chernobyl accident, will be covered as well.