O-920964

WATER POLLUTION ABATEMENT PROGRAMME

THE CZECH REPUBLIC

PROJECT 3.4

Improvement of the Environment Deteriorated by Metal Mining Activity

Project Report for Phase I and

Programme of Work for Phase II

NIVA - REPORT

Norwegian Institute for Water Research NIVA

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Project 3.4 Improvement of the Environment Deteriorated by Metal Mining Activity

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Abstract:

The Zlaté Hory Mining District is the biggest mineral deposit of base metals in the Czech republic. The mining has been going on for many centuries and the water and ground is polluted by heavy metals from the mines. The concentrations of copper and zinc in the brooks draining the area is comparable to the concentrations found in Norwegian mine polluted rivers. The biology in the brooks is affected and in some parts of the river system there is no fish. The river through Zlaté Hory is a tributary to the River Odra in Poland.

To be able to compare the results from this area an intercalibration of methods for chemical analysis was performed. The results are given in this report.

4 keywords, Norwegian

1. Gruver
2. Tungmetaller
3. Avgang
4. Den Tsjekkiske republikk

4 keywords, English

1. Mining
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THE CZECH REPUBLIC

Project 3.4

Improvement of the Environment Deteriorated by Metal Mining Activity

Project Report for Phase I and
Programme of Work for Phase II

Oslo, Norway
February 1993

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Preface

The Governments of Norway and the Czechoslovak Federal Republic have signed a bilateral environmental protection agreement. As part of this agreement several collaborative projects have been identified. The Norwegian - Czechoslovak working group for the protection of the environment has discussed these projects and decided to contact Norwegian Institute for Water Research (NIVA) in co-operation with the Water Research Institute Prague (WRI) and the Institute of Industrial Landscape Ecology (ILE), Ostrava to execute several projects under the programme area "Abatement strategies in the River Odra catchment".

One of the projects is "Improvement of the Environment Deteriorated by Metal Mining Activity". The project proposal vas developed jointly by NIVA, WRI and ILE. During the mission to the Ostrava region in April 1992 the project proposal was discussed with the co-operating Czech institutions. It was agreed that the Mining University in Ostrava and Povodi Odry should be actively engaged in the project. The project is geographically related to the Zlaté Hory area in the north-eastern part of the Czech republic.

As part of the project, a group of scientists from the Czech republic visited Norway in October 1992. Norwegian methods of work with mine pollution were demonstrated during a short visit to the old mining town Røros.

During the discussions in Ostrava and Prague in April it was agreed to do an intercalibration of chemical analysis. This was done during the summer 1992.

This report is a simple presentation of the situation in the Zlaté Hory area and the results of the intercalibration. It has mainly been prepared by Rolf Tore Arnesen, but Konstantin Raclavsky, Helena Raclavska, Petr Brezina and Jiri Svrcula have all contributed to the information presented in the report.

Oslo, February 1993

Rolf Tore Arnesen
Senior Research Scientist

Table of contents

0. Summary

The Zlaté Hory Mining District is the biggest mineral deposit of base metals in the Czech republic. The mining which has been going on for many centuries have polluted the ground and the water around the mining operations. The most abundant mineral in the ore is pyrite and pyrrhotite. Other important minerals are sphalerite, chalcopyrite, and galena - sulphide minerals of iron, copper, zinc and lead.

The brooks draining the mining areas are polluted with metals, mainly copper and zinc. The concentrations are comparable to those found in Norwegian rivers in mining areas. The levels of copper and zinc are high, and in the brooks near the mines the biology is affected. The river from the area is entering Poland near the village of Zlaté Hory. It is a tributary to the Odra river.

To be able to compare chemical data derived at different laboratories, it is necessary to do intercalibration tests. As a preliminary test, synthetic samples were distributed to two Czech laboratories in Ostrava. Analysis on metals and parameters characterizing the general water quality were carried out. The samples had already been analysed by different Norwegian laboratories. The results were quite good, but there should be made some efforts to harmonize the analytical work.

1. Background

1.1 Water pollution from metal mines

Water and soil pollution from mining activities is an international problem, experienced in a great many industralized countries in most parts of the world. There are different types of water pollution from such activities depending upon the minerals being mined. The sulphide ore mines are known to give special problems due to their discharge of acid water, very often with high concentrations of the heavy metals iron, copper, zinc, lead and to some extent cadmium and other toxic trace metals.

In Norway NIVA have studied the pollution problems from sulphide ore mines since 1962, and in recent years the mine pollution problems have been gradually reduced by amendment measures in the most polluted areas. The total transport of heavy metals from mine sites to Norwegian rivers have really been reduced markedly during the last five years.

In this work NIVA has taken active part, quantifying the pollution loads, identifying the sources and suggesting possible measures to reduce the pollution loads to acceptable levels.

Our work have been divided into three different stages:

- **Describing the problem**

  Chemical, biological and physical description of the polluted area, with general information on: hydrology, impact on ecosystem, activities in the area, geographic position of waste rock dumps, mine water outlets, tailing ponds etc. In this stage existing data about the area are also processed and studied.

- **Quantifying transport of pollution**

  The most important sources of pollution are identified by very simple methods, e.g. visual inspection, analysis of a few samples of water from creeks or ground water wells. The information gathered in the first step is also used at this stage.

  From the above mentioned information a few sampling points are chosen for the next stage of the study. Stations for water sampling, and instrumentation for water flow registration are established. The main task is to range the different sources of pollution in the area according to their "polluting potential".

- **Abatement measures**

  From the results in step 2, possible abatement measures are described, giving the largest sources of pollution the highest priority. In this way it will be possible to make some recommendations on a pollution abatement policy based upon a simple cost/benefit discussion.

1.2 The Zlaté Hory area

The Zlaté Hory ore district covers and area of approximately 25 km^2. The northern border of the ore district touches the town of Zlaté Hory and in the south its boundary passes through the Hermanovice village. Geographically the area is situated in the northern part of Moravia in the Czech republic. The Mining District is the biggest mineral deposit of base metals in the former Czechoslovakia, and the areas of the most intensive exploitation of copper by underground mining.

The oldest written records of the Zlaté Hory mining village date from 1224. Presumably gold form placers have been washed even in the 12th century. Primary ores were mined from the end of the 13th century, but from the end of the 18th century there was no mining activity in the area for about 150 years. In 1951 the district was subject to geological exploration, which led to the opening of the Zlaté Hory-jih (South) main mine, exploiting copper ores. At present, other parts of the district are explored and the polymetallic deposits Zlaté Hory-východ (East) and Zlaté Hory-západ (west) are prepared for exploitation.

The most abundant mineral in the ores in the area is pyrite and/or pyrrhotite. Other important minerals are sphalerite, chalcopyrite and galena - sulphide minerals of iron, zinc, copper and lead. There may also be other less abundant elements of environmental significance e.g. arsenic, cadmium and mercury.

Two brooks are draining the present mining area in Zlaté Hory, Zámecký potok (Castle brook) and the Zlatý potok (Gold brook) (Figure 1). The two brooks are both tributaries to the river entering Poland near Zlaté Hory. This river is part of the river system running into the river Odra near Krapkowice in Poland.

There are significant environmental impacts to be seen in the area and the mining dumps and tailing ponds at Zlaté Hory were identified as an important problem by the screening study of environmental risk assessment in Project Silesia (1992). The mines may be closed down in the near future from economical reasons. The environmental impacts may then change, possibly to the worse.

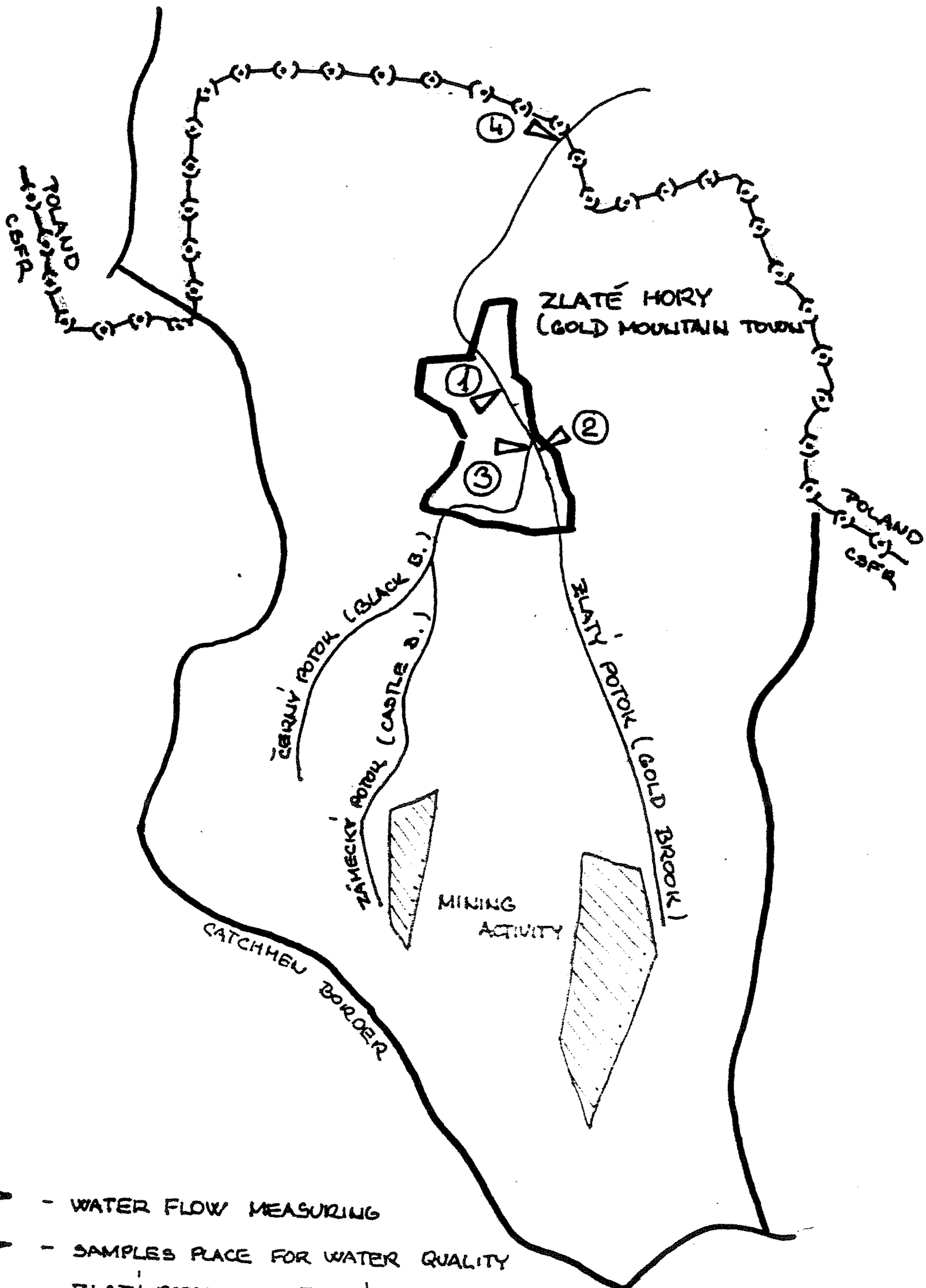
1.3 The Project

Based on NIVA's methods of work with metal mines in Norway (Section 1.1) it was suggested that the environmental problems in Zlaté Hory should be handled in a similar way. Therefore the main objectives of the project are:

- Assessment of the present environmental impact of metal mining effluents on water courses in the Zlaté Hory area.

- Identification and characterization of main sources of pollution, evaluation of the quality of surface and ground water, description of the impact of the mine pollution on the biology in the area.

- From a realistic description of the present situation, proposals for alternative measures for the abatement of the mine pollution in the Zlaté Hory area will be made.



① ▷ - WATER FLOW MEASURING

② ▷ - SAMPLES PLACE FOR WATER QUALITY
ZLATÝ POTOK NAD ČERNÝM POTOKEM

③ ▷ - ČERNÝ POTOK ÚSTÍ

④ ▷ - ZLATÝ POTOK - JARNOLTOWEK

Figure 1 Map showing the mine areas and the brooks with water sampling stations.

The short term objectives of the project which have been based mainly on the first part of the long term objectives are:

- Exchange of experiences between Czech and Norwegian experts on water pollution from mining activities.
- Evaluate existing data from the Zlaté Hory area
- Make plans for the future project (long-term objectives)

During 1992 the short term objectives for the project have been emphasized and the results obtained so far have been mainly to establish contacts, organize further work and to assess the situation in relation to NIVA's experience in this type of work. In the following chapter the results are briefly commented.

2. Work accomplished

2.1 Exchange of experiences

During the seminar in Ostrava K. Raclavsky and R. T. Arnesen visited the Zlaté Hory mining area. The situation was discussed and it was agreed upon an exchange of data and information on mine pollution. The mine "Mir" ("Peace") and the main mine site with flotation plant, tailings pond etc. seemed to be like similar mining operations in Norway.

During the visit of Czechs in Norway 6 - 10 October 1992 K. Raclavsky and H. Raclavska went to the Arvedalen/Kongens and the Storwartz mine at Røros, together with R. T. Arnesen and E. R. Iversen. The mines in Zlaté Hory are still in operation while the mines at Røros were abandoned some years ago. It was clearly demonstrated that the mines which have been closed for some time may be even more polluting than the ones in operation.

The methods used by NIVA to identify and quantify the main sources of pollution in a mining area were demonstrated and discussed at Røros. It was agreed that the application of similar methods in Zlaté Hory would give the information needed to propose cost efficient amendment measures in that area.

NIVAs methods to assess the chemical and biological influence of mine effluents on freshwater systems were also discussed. It was agreed that such methods would be a suitable supplement to the monitoring already going on.

It was agreed that NIVA and Institute for Industrial Landscape Ecology/Mining University - Ostrava (IILE/MUO) will start joint field studies in Zlaté Hory during May 1993. Before that time the Czech co-workers will investigate possibilities for establishing stations for water sampling and measurement of water flow, downstream identified pollution sources in the area.

2. 2 Evaluation of existing data

During the seminar in Ostrava in april it was agreed that NIVA should receive all existing relevant information from the Zlaté Hory area as soon as possible.

NIVA got data from Povody Odri (PO) in July 1992 and had communications with the Water Research Institute in Ostrava (WRI-O) in August. In January 1993 we received two reports from IILE/MUO). The data from PO have given much information about the water quality in the brooks polluted from the mining activities. From ILE/MUO the impact on the terrestrial system have been emphasized, but those reports have also important information about surface water chemistry and possible ground water pollution.

The data from Povody Odri (PO) represents samples taken every month at stations 1 and 2 (Fig. 1) and from station 4 twice a month. The samples have been analysed for many different parameters. To be able to compare the conditions in Zlaté Hory with mine polluted rivers in Norway, NIVA have to some extent processed the data. The yearly arithmetic mean is often used for such purposes and this was calculated for the most relevant parameters. This extract from the data from PO together with similar data from a mine polluted river at Røros in Norway is shown in table 1. It should be mentioned that the data from the river Orva in Norway represents the conditions before the amendment measures in this area were started.

Table 1 Water quality data from Zlate Hory, yearly arithmetic mean values
The Stations 2 - 4 represents different streams influenced by mining activity in Zlaté Hory
Station 5 represents the river Orva at Røros - Norway. Arithmetic mean of samples taken

Parameter	Unit	Station 2		Station 3		Station 4		Station 5
		1990	1991	1990	1991	1990	1991	1966 -92
Water flow	m^3/s	0.145	0.209	0.078	0.112	0.394	0.456	0.35
pH		7.48	7.53	7.46	7.35	7.50	7.52	4.4
Sulphate	$mgSO_4/l$	209	195	46	49	133	132	36
Calcium	mg Ca/l	79	83	27	27			7.2
Magnesium	mg Mg/l	7	6	4	4			2.1
Total iron	mg Fe/l	0.46	0.45	0.29	0.27	0.92	0.40	2.6
Zinc	µg Zn/l	100	112	570	1097	172	276	1500
Nickel	µg Ni/l	24	17	12	15	22	17	-
Copper	µg Cu/l	42.6	39.5	15.3	28.9	49.7	25.5	384
Mercury	µg Hg/l	0.56	0.21	0.27	0.20			-
Cadmium	µg Cd/l	3.50	4.83	4.00	6.58			2.1

The data from Røros are arithmetic means from about 15 samples taken randomly during the years 1966 - 1992. There has been no detectable change in the water quality during these years.

To present a detailed picture of the conditions in this water system, it will be necessary to use some more time on the chemical data. Many of the analysed parameters have not been used in this presentation, and the calculation of arithmetic means gives a simplified picture of the situation. Seasonal variations, interaction between the different chemical species etc. are poorly illustrated in this way. The biological effect of one parameter may be a function of many other parameters.

When joint fieldwork with Czech co-workers have been established, more detailed data processing should be done. There are some inconsistencies in the data from Zlaté Hory. This may be due to the measurement of water flow, or possibly to the chemical analysis of samples. Further investigations into this problem will be an important task during the fieldwork planned for 1993.

The report from ILE/MUO arrived at NIVA in January 1993. It emphasizes the impact on the terrestrial environment, and it is quite clear that the areas which have been studied, are markedly influenced by mining activity. The reported survey has been restricted to a relatively small area. It has not been enough time for any processing of the data presented in the report but the future work should emphasize to establish the geographical area of polluted ground, and to quantify the impact of the mine drainage in each part of the area.

The report from IILE/MUO also gives some data on the water quality in the brooks in the area. To some extent these data confirms the picture obtained from the data from PO. It will however be necessary to do some intercalibration between the laboratories to remove some discrepancies between them. This is best done by close co-operation between NIVA and the laboratories involved in the investigations in Zlaté Hory.

According to the data in Table 1 there are some similarities between a typical Norwegian "mine-rivers" and the rivers in Zlaté Hory. The concentrations of copper, zinc and iron are about the same or less than those found in Norwegian rivers of the same size. In relation to the copper- and zinc-values, mercury and cadmium are very much higher in Zlaté Hory. As mercury and cadmium are micro pollutants with great impact on biota, it is very important to assess reliable values of these heavy metals.

The values of mercury are very near the detection limit for the analytical methods used. It will therefore be of great importance to analyse mercury with more sensitive methods. The sampling and handling of samples for mercury analysis is important for the results.

2.3 Intercalibration of chemical analysis

2.3.1 Practical work

In September 1992 synthetic samples used for intercalibration of chemical analysis in Norway were distributed to the laboratory of Povodi Odry and to the Water Research Institute in Ostrava. The samples had been analysed by many different laboratories in Norway, and the "true values" were quite well established. Totally 8 samples were to be analysed on the following parameters: pH, conductivity, total phosphorus, total nitrogen, lead, iron, cadmium, copper, manganese, nickel, zinc, calcium, magnesium, sodium, potassium, chromium, an sulphate. For each parameter there were two different samples to be analysed. This made it possible to use Youden-plots[1] to evaluate the results. In the Youden-plots the Czech results are compared to the results obtained by Norwegian laboratories.

It should be mentioned that most of the Norwegian laboratories are using the same analytical methods. Generally the method used for an analysis have great influence on the result obtained. It is therefore difficult to point out the value which is "true" in a given case. To compare the results from different laboratoties in practical work, it is necessary to perform an intercalibration of methods between the laboratories involved.

In this first intercalibration, the results should be used by the participating laboratories to study their own methods and routines, and if necessary make corrections. The work should be carried on with new intercalibrations and the exchange of experience between NIVA and interested laboratories in the Czech republic should be increased.

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[1](Kateman, G. and Pijpers, F.W. 1981 Quality Control in Analytical Chemistry, John Wiley & Sons New York 1981

In Table 2 the "true values" and the results are listed. The two participating laboratories have already got the results of the intercalibration, and the laboratories are therefore kept anonymously and listed as Lab A and Lab B in the following text.

Table 2 Results of intercalibration between Norwegian laboratories and laboratories in Ostrava

Parameter	Samples/Values					
	"True" values		Lab A		Lab B	
	G	H	G	H	G	H
Total phosphorus (P)	0.64	0.56	0.82	0.61	0.66	0.58
Total nitrogen (N)	5.28	4.61	4.5		9.7	8.3
	K	L	K	L	K	L
Lead (Pb)	0.32	0.28	0.33	0.28	0.4	0.4
Iron (Fe)	0.32	0.4	0.31	0.4	0.28	0.35
Cadmium (Cd)	0.053	0.047	0.057	0.046	0.038	0.036
Copper (Cu)	0.16	0.14	0.17	0.15	0.16	0.16
Chromium (Cr)	0.32	0.267	0.3	0.24	0.3	0.26
Manganese (Mn)	0.48	0.40	0.5	0.41	0.44	0.4
Nickel (Ni)	0.288	0.36	0.29	0.36	0.24	0.28
Zinc (Zn)	0.192	0.24	0.18	0.23	0.16	0.19
	C	D	C	D	C	D
Calcium (Ca)	3.00	3.50	2.9	3.5	4	4
Magnesium (Mg)	0.84	0.70	0.82	0.68	0.61	0.85
Sodium (Na)	2.40	2.00	2.5	2.3	2.3	1.9
Potassium (K)	0.60	0.50	0.57	0.46	0.5	0.4
Chloride (Cl)	5.31	6.19	5.6	6.3	7.4	7.8
Sulphate (SO_4)	9.07	7.56	12.6	11.3	7.6	
	A	B	A	B	A	B
pH	7.4	7.16	7.5	7.2	7.4	7.2
Conductivity	299	282	305	278	261.6	247.2

In Appendix 1 you will find the Youden diagrams for the intercalibration. To help the laboratories in their efforts for better results some information about the Youden-diagram may be of interest:

A laboratory with mainly systematic errors will be represented by a point near to the 45 °-axis in the Youden-diagram. Points far from this axis indicate a component of random error in the results.

In the former case, the laboratory should examine their instruments, calibration routines, check volumetric and gravimetric equipment, or perhaps look for another analytical method.

In the latter case the laboratory should go through their analytical routines, cleaning methods, and the general way different tasks are performed in the laboratory.

The circle in the diagram indicates the interval of acceptable results. This circle is sometimes drawn on statistical criteria, sometimes on more subjective criteria depending on the nature of the analysis.

The results are discussed very briefly in the following text:

Total Nitrogen (Totalt nitrogeninnhold)

The results from Lab B are to high, and far outside the Youden diagram. Lab A did only analyse one sample which was much to low.

Total Phosphorus (Totalfosfor)

The results from Lab A are to high and outside the diagram. The results from Lab B are inside the circle that indicates that the results are acceptable.

Sulphate (Sulfat)

The Lab A is far to high on both samples and outside the diagram. The Lab B has only analysed one sample, which probably is to low. It is, however, a possibility that the marking of bottles have been mixed up in the report from the laboratory.

Chloride (Klorid)

Lab A is well inside the circle, while Lab B is to high along the 45 °-axis, which indicates mainly systematic error.

Magnesium (Magnesium)

Lab A is inside the circle, while Lab B seems to have a lot of random error in the results. One is to high and the other one is to low. It is a possibility that the samples have been interchanged during the analysis or in the reporting of results.

Calcium (Kalsium)

Lab A is inside the circle while Lab B is to high, mainly caused by systematic error.

Potassium (Kalium)

Lab A is inside the circle. Lab B is systematically a little to low.

Sodium (Natrium)

Lab A is to high on both samples, with components of both systematic and random error. Lab B is inside the circle.

Lead (Bly)

Lab A is well within the circle, while Lab B is systematically to high.

Iron (Jern) and Cadmium (Kadmium)

Lab A is within the circle, while both samples are to low for Lab B. The error seems to be mainly systematic.

Copper (Kobber)

Lab A is within the circle, but a little to high. The results from Lab B are outside the circle, but for this parameter the error seems to be mostly random.

Chromium (Krom) and Manganese (Mangan)

For these metals both laboratories are well within the circle for acceptable results.

Nickel (Nikkel)

Lab A has almost "true values" for both samples. Lab B is to low and the error is mainly systematic.

Zinc (Sink)

Lab A is within the circle, while Lab B is systematically to low.

2.3.2 Evaluation of results - intercalibration

The general impression of the results in this intercalibration is that values obtained by the Czech laboratories corresponds quite well with the "true values" for the samples. There are however some differences which should be diminished through further work.

Phosphorus and nitrogen are important parameters for the general characterization of water quality, and both laboratories should do some work on them. For the work with water pollution from mines, sulphate and heavy metals are important. Both laboratories should look into their methods for sulphate.

For most metals Lab A have made excellent work, but Lab B should check their methods and routines on these parameters.

The levels of cadmium found in the mine-polluted rivers in Zlaté Hory are much lower than those in this intercalibration. Mercury was not included in the test. It will be of great importance to do some work on these parameters in 1993. Parallel analysis of samples taken during the field work in 1993 is perhaps the best way to determine the environmental significance of these parameters in this area.

3. Conclusion

In 1992 the main work has been directed towards the short-term objectives. The study team has been organized. The future plans for the project have been discussed, and there have been an agreement on the methods to be applied in the work.

The exchange of experiences have been successful, and it seems that a frame of reference has been established for the people participating in the project.

The data received from Povodi Odry shows that brooks and rivers in Zlaté Hory are very polluted from mining. The concentrations of heavy metals are quite high, even though the concentrations of copper and zinc may be higher in Norwegian "mine rivers". The concentrations of cadmium and mercury are so high that they may give health problems if the water is used for drinking or if organisms from the rivers are eaten by people or animals. It has been reported that there is no fish in the rivers due to the high content of heavy metals. The ground near the mine wastes are markedly polluted and it should be done an investigation to establish the extent of ground pollution both concerning the geographical extent of impact and the degree of pollution.

Probably the ground water in the area is polluted from the mining activity. The transport of pollutants in the ground water should be assessed, and the possible influence on drinking water sources and influence on other user interests should be investigated.

4. Programme of work

4.1 Scope

The long-term objectives of the project can only be attained if the main part of the work is done by Czechoslovak scientists and authorities. To establish close contact between scientists in the two countries and create a mutually accepted frame of reference for this type of work, will be an important task at the present stage of the project.

The study will address the water quality problems caused by metal mining in the Zlaté Hory area, but it will be of interest to all areas in Czechoslovakia where metal mining affects water quality. Main emphasis will put on the studies necessary to do measures for the improvement of water quality in the main river Zlate Potok.

The study will involve the following tasks:

Task 1: Establishing a pollution budget for the area.
Sites for sampling and water flow measurements will be selected. This is important in order to get a more detailed picture of the pollution sources. Sampling will be done by Czech institutions and by NIVA. For inter laboratory calibration, samples will be split for analysis. This will be especially important for the metals cadmium and mercury. The data will be used for mass balance calculations.

To start the sampling program a team from NIVA will participate in field work together with Czech colleagues in spring 1993.

Task 2: Determine the impact of mine drainage on the environment

During the field work the team from NIVA will study water quality and the biology in a number of places within the area. Samples will be brought to NIVA for studies. Toxicity testing with fish or other organisms will be considered.

Task 3: Ground water quality

Studies of ground water pollution should be performed. The special local conditions makes it necessary that the practical part of this work is carried out by Czech experts.

As far as possible the work involved in each task will be executed by Czech institutions. The main task for NIVA will be to transfer our experience to the participating institutions, to ensure that the objectives are reached as soon as possible.

It should be mentioned that the local conditions are so different from those found in similar Norwegian areas, that the project can not be successfully carried out without the engagement from Czech colleagues.

To maintain the contact with the Czech institutions NIVA will visit the area twice in 1993.

4.2 Organization of the study

The project is executed jointly by Norwegian Institute for Water Research (NIVA), T.G. Masaryk Water Research Institute - Ostrava branch (WRI-O), Povodi Odry (PO), Institute of Industrial Landscape Ecology (IILE). Key staff responsible for the execution of the project are:

From Czechoslovakia:		
Helena Raclavská	MUO	(Main contact)
Jiri Svrcula	WRI-O	
Petr Brezina	PO	
Konstantin Raclavsky	IILE	
From Norway:		
Rolf Tore Arnesen	NIVA	(Main contact)

Other participants from NIVA involved in planning an execution of the project are Magne Grande and Eigil Rune Iversen.

NIVA will carry the overall responsibility and professional execution of the proposed study.

4.3 Work schedule

The study will be executed in 1993 and 1994. Final report will be submitted autumn 1994. A report summing up the results from 1993 will be prepared in February 1994.

APPENDIX

Youden-diagrams from the Intercalibration

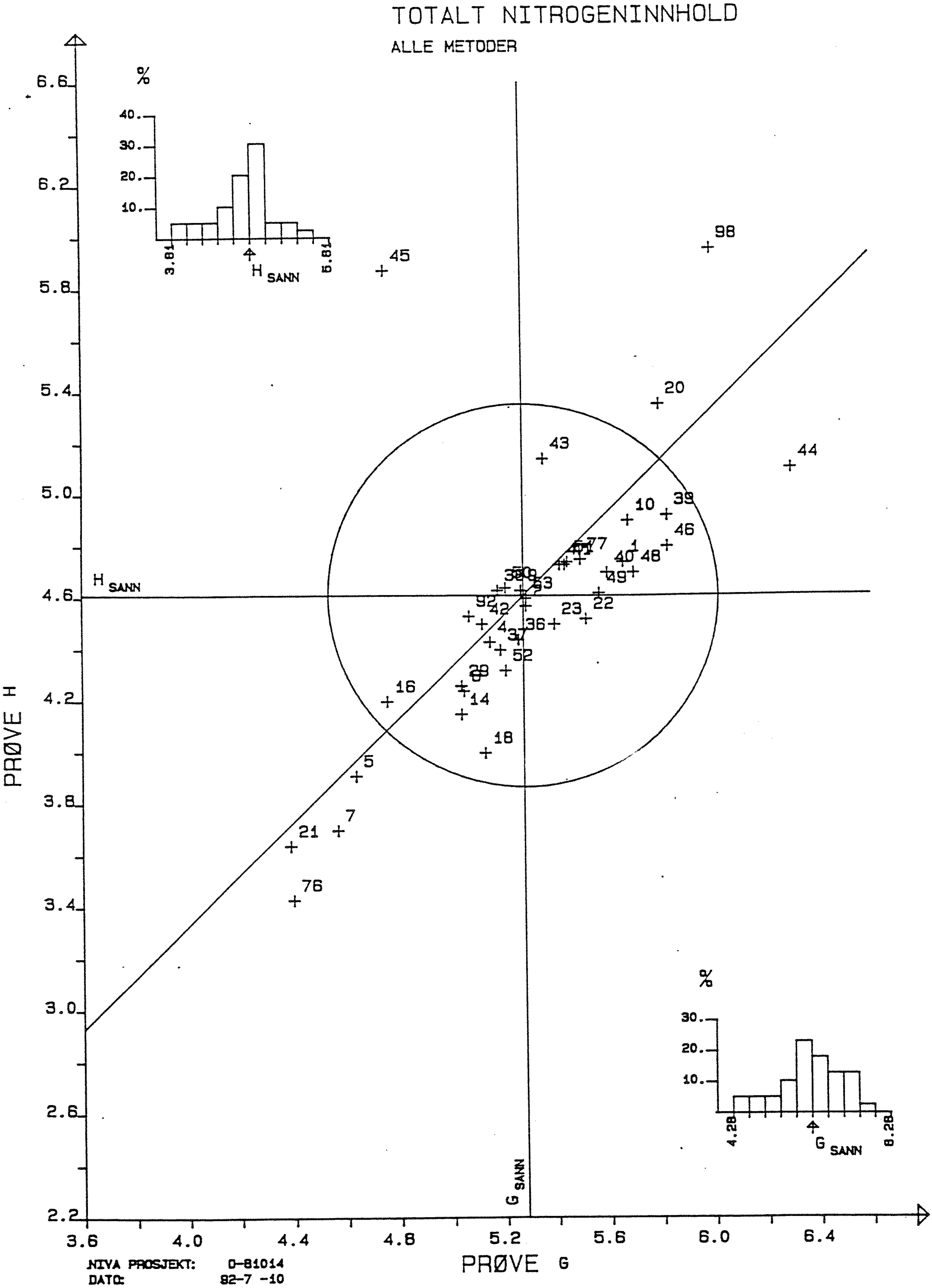

TOTALT NITROGENINNHOLD
ALLE METODER
PRØVE H
PRØVE G
H SANN
G SANN
%
NIVA PROSJEKT: 0-81014
DATO: 82-7 -10

FIG. 14 TOTALFOSFOR

ALLE METODER

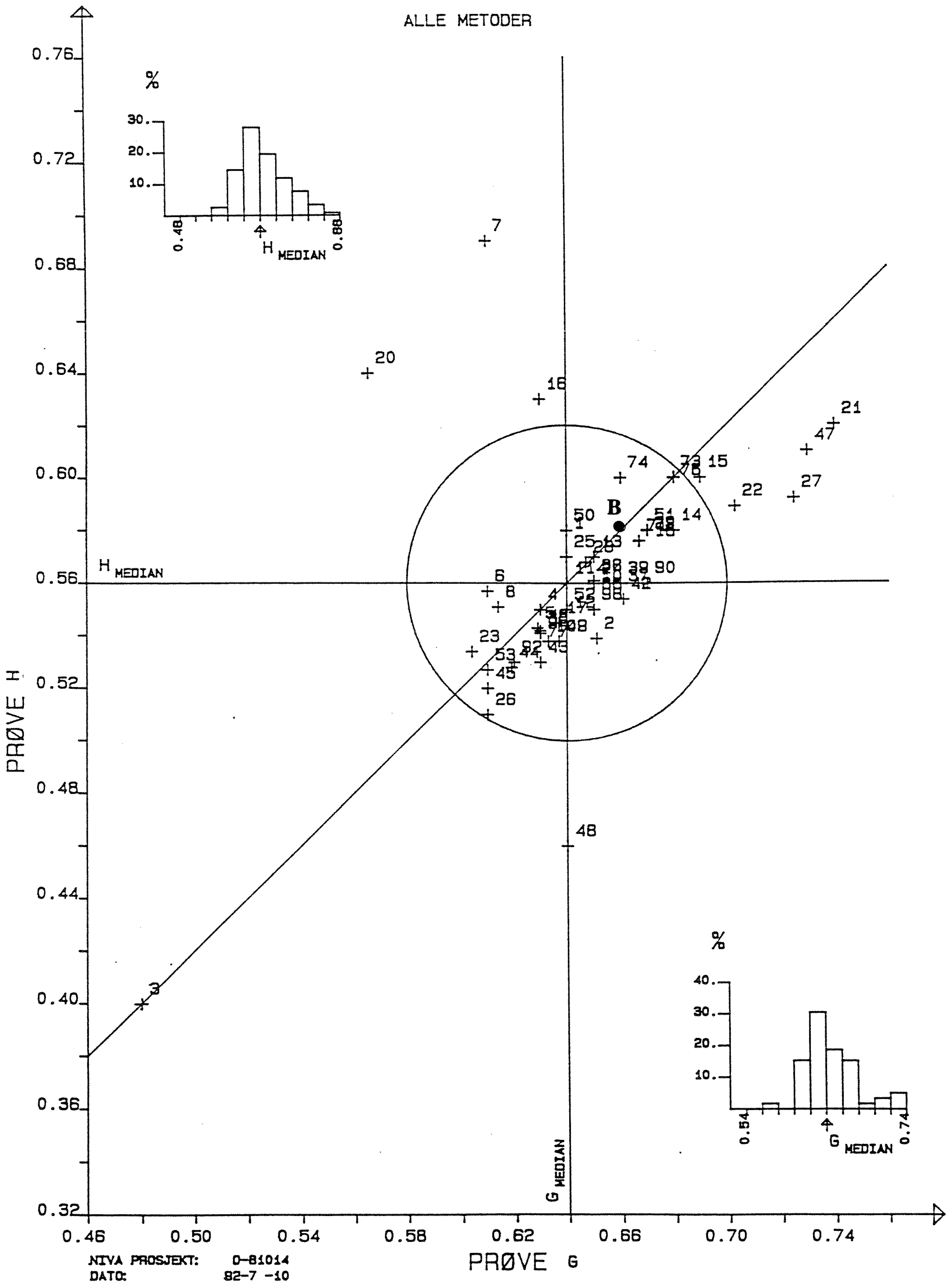


Fig. 12. Sulfat

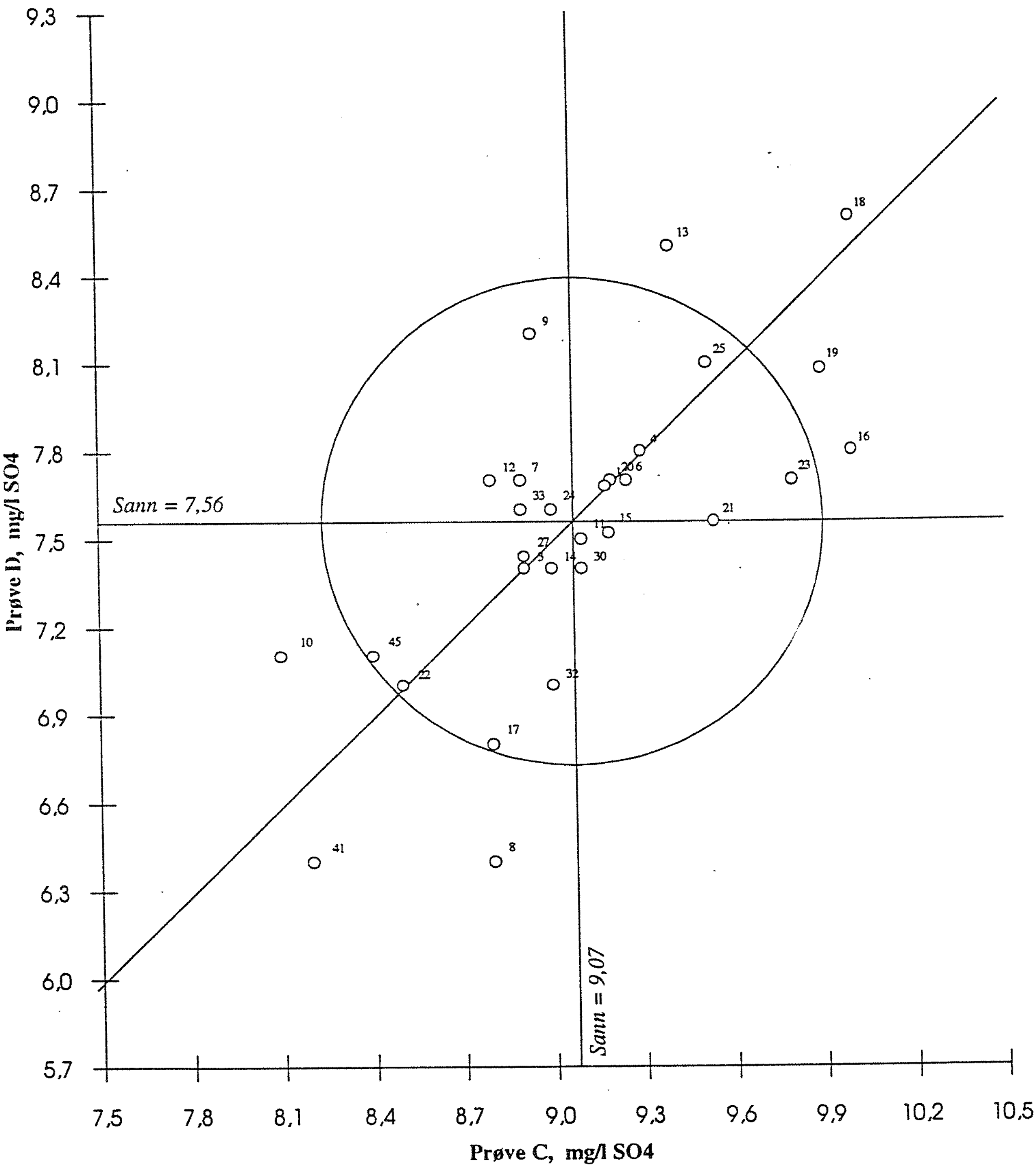


Fig. 10. Klorid

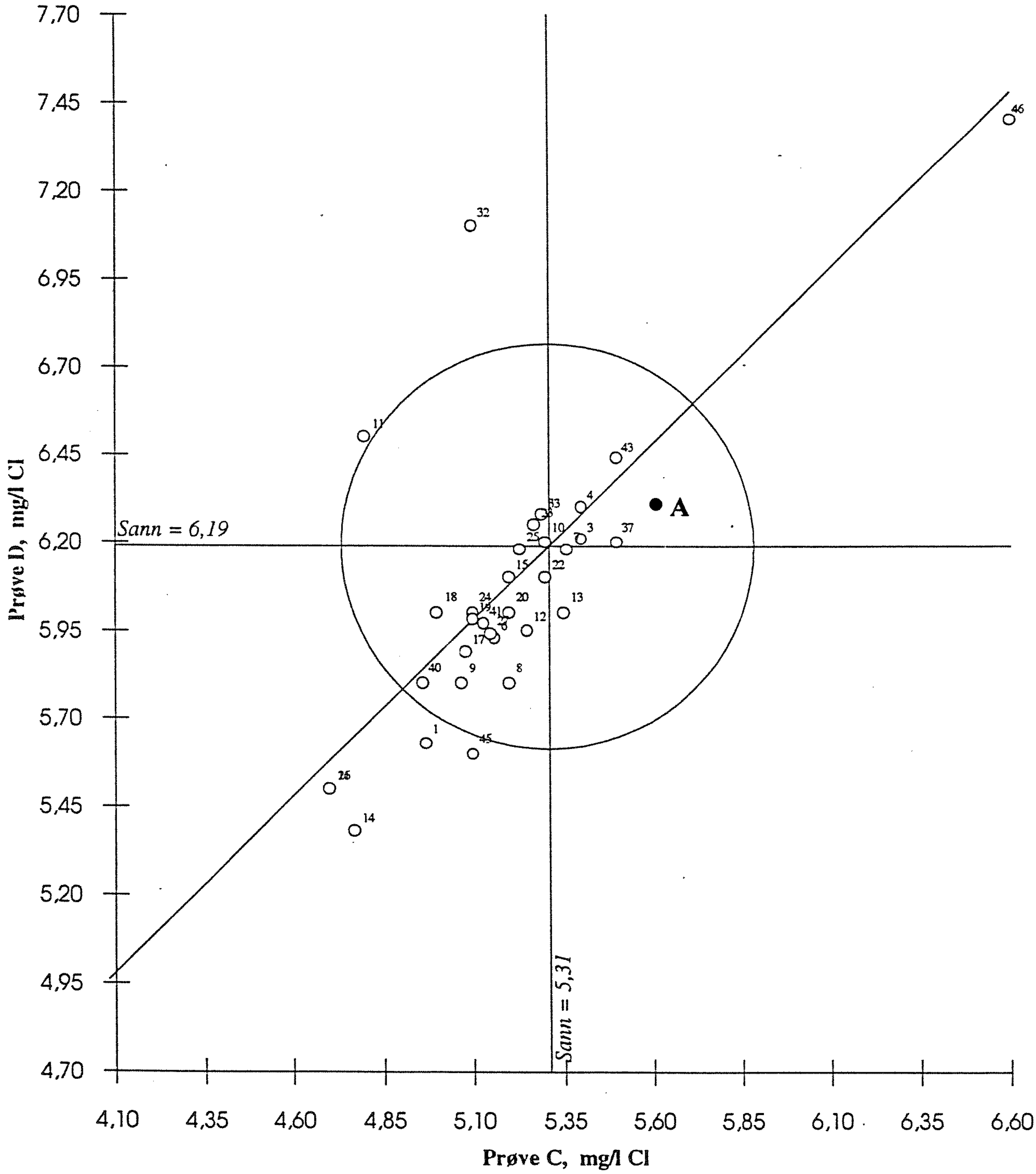


Fig. 8. Magnesium

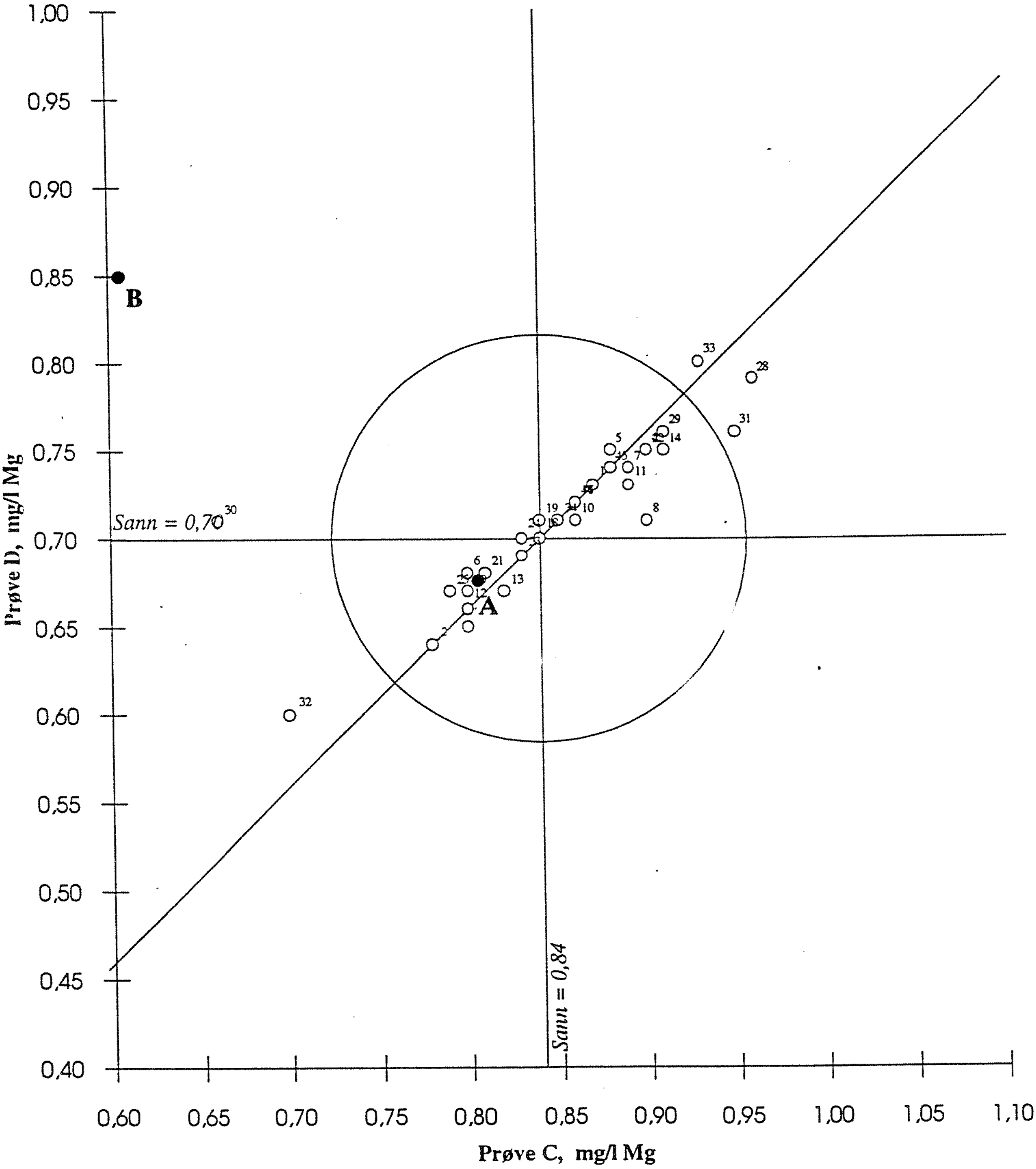


Fig. 6. Kalsium

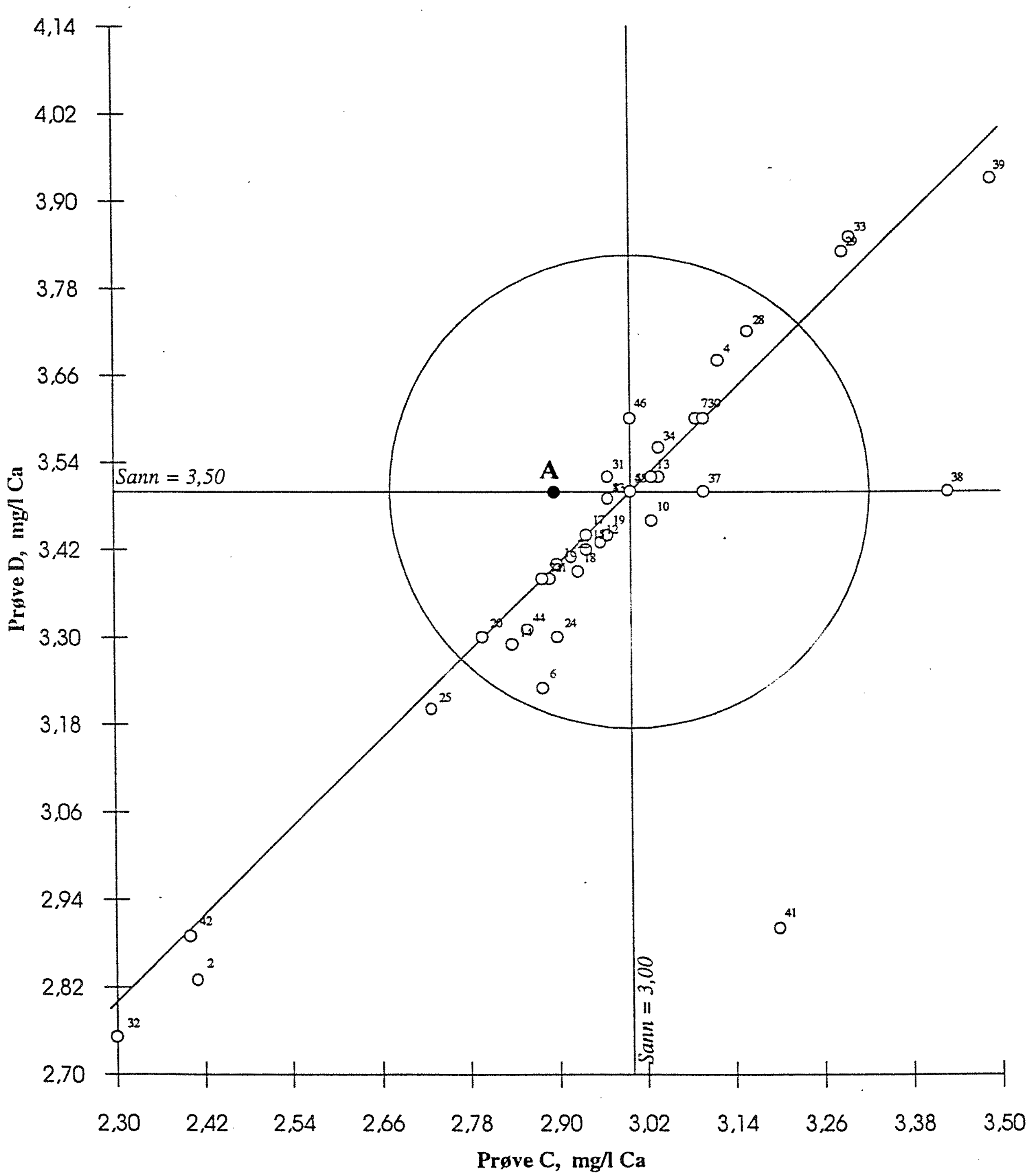
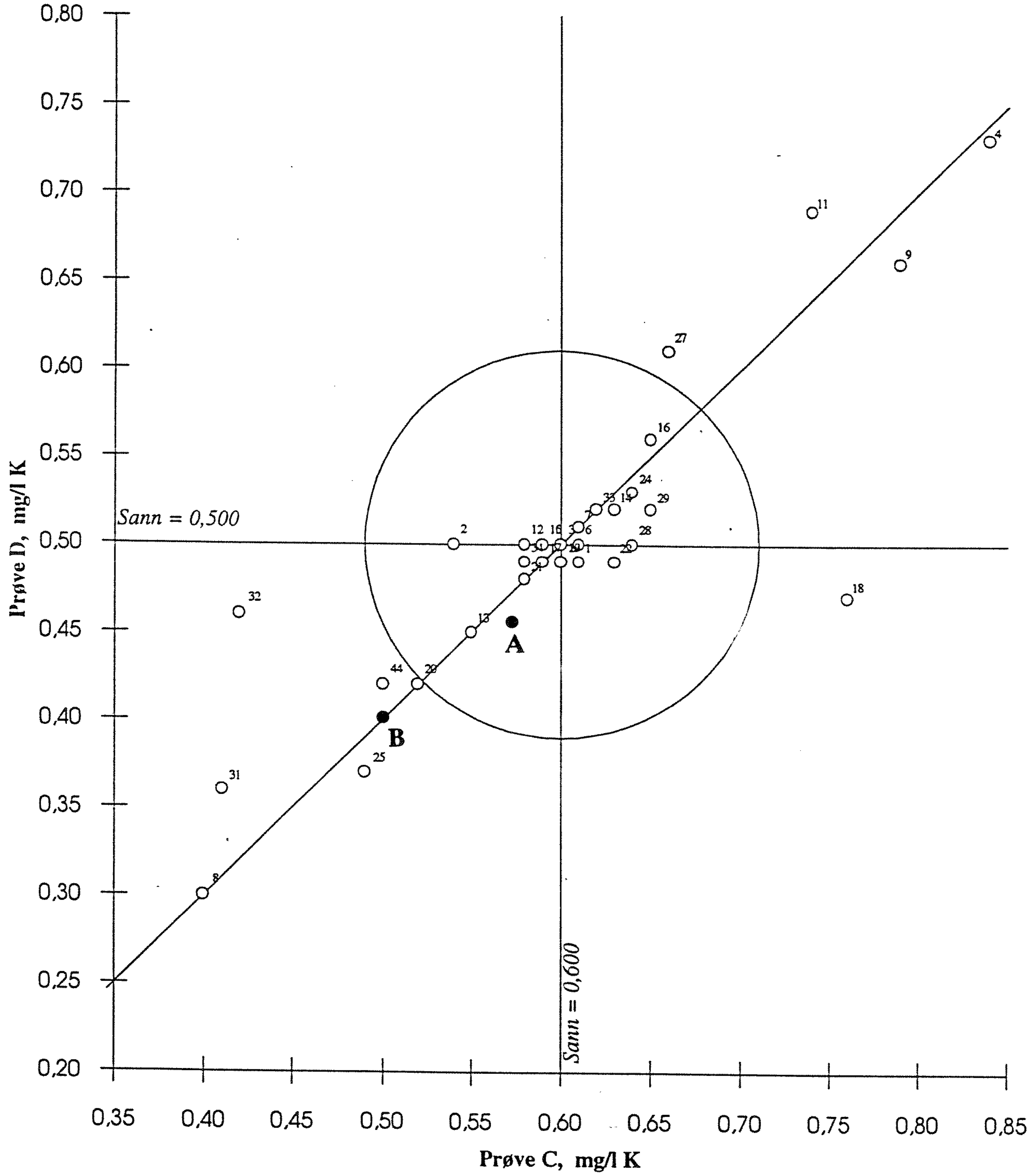


Fig. 4. Kalium



Prøve D, mg/l K
Prøve C, mg/l K
Sann = 0,500
Sann = 0,600
A
B
0,80
0,75
0,70
0,65
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,35
0,40
0,45
0,50
0,55
0,60
0,65
0,70
0,75
0,80
0,85

Fig. 2. Natrium

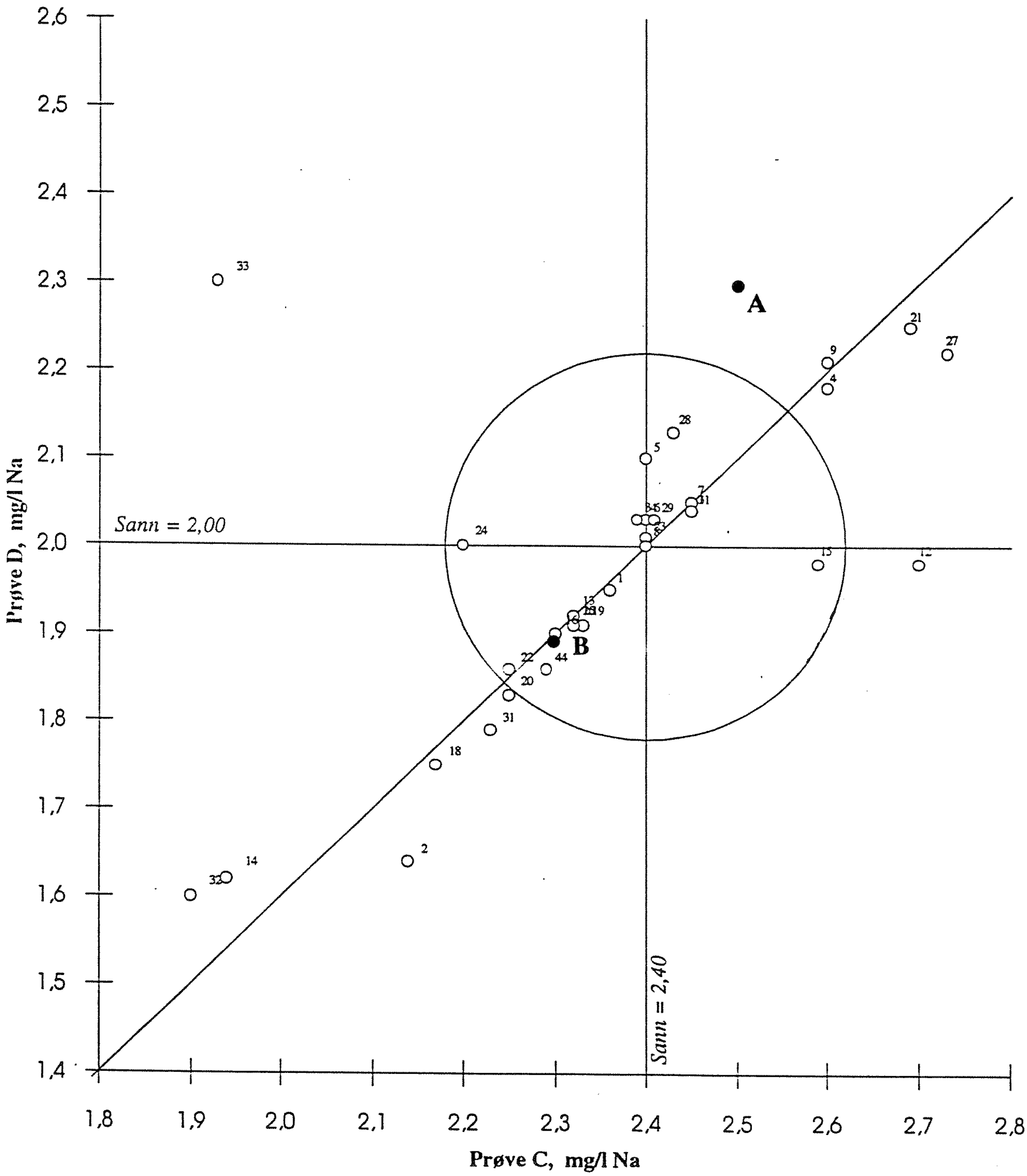


FIG. 18 BLY

ALLE METODER

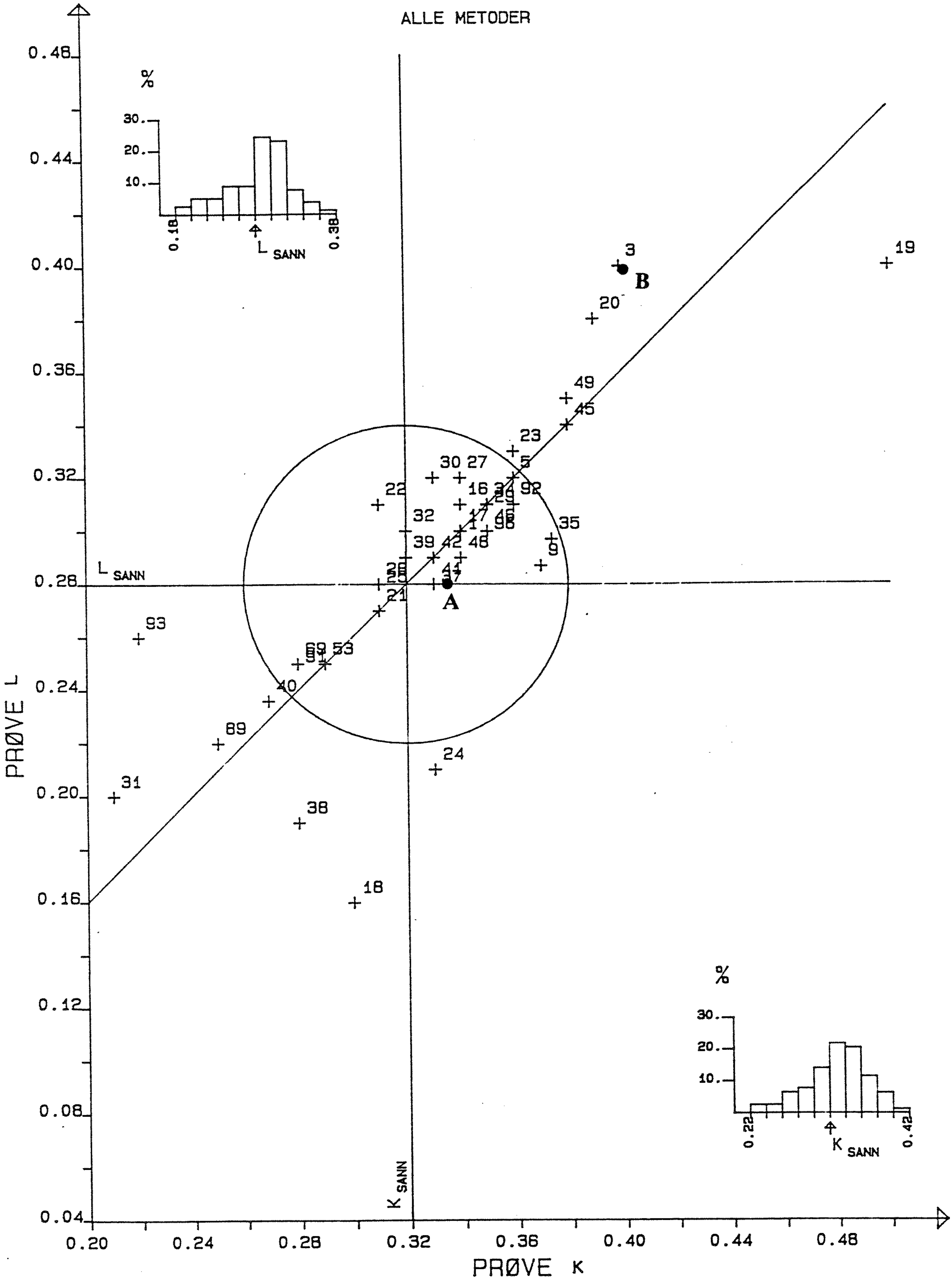
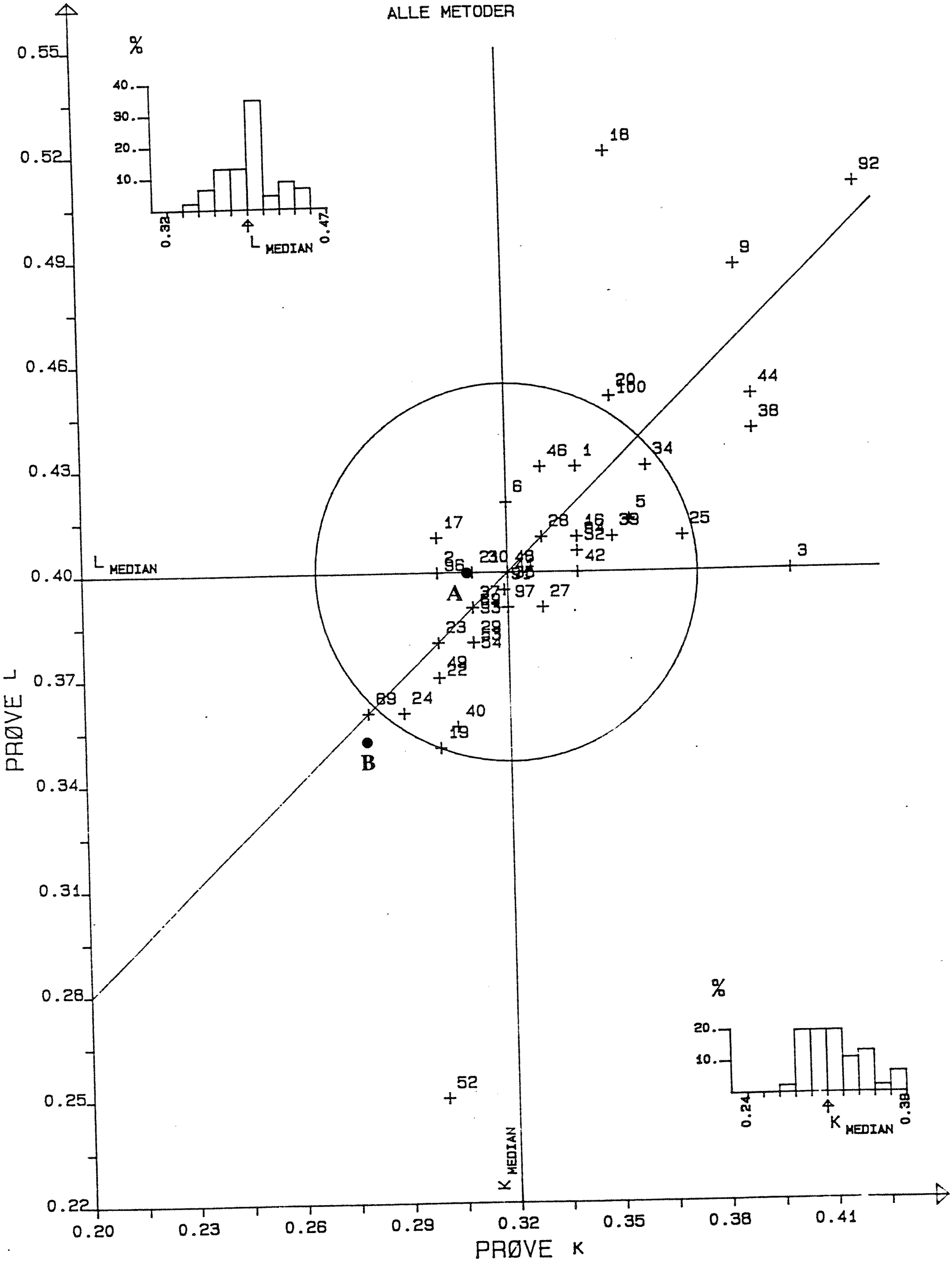
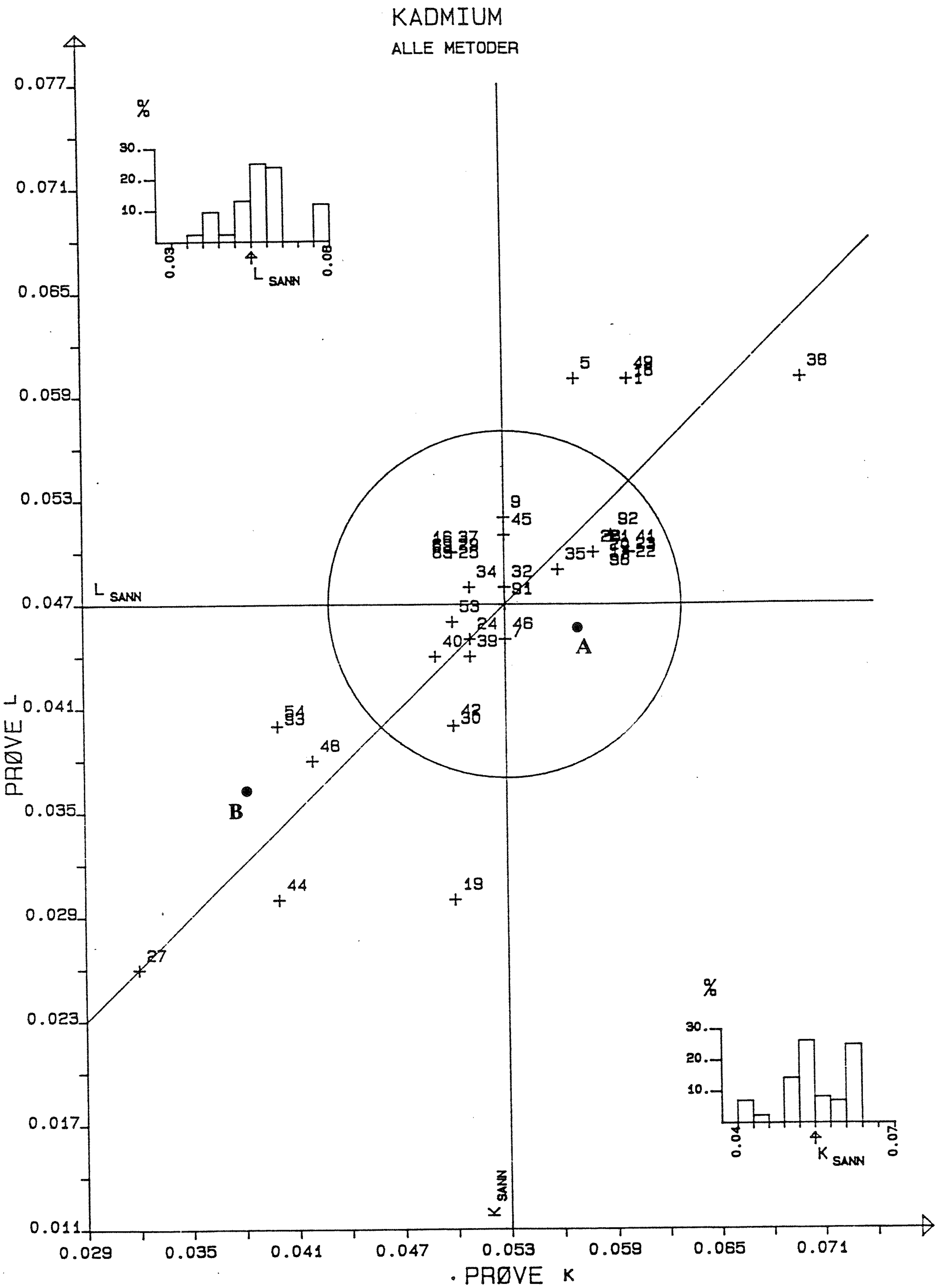
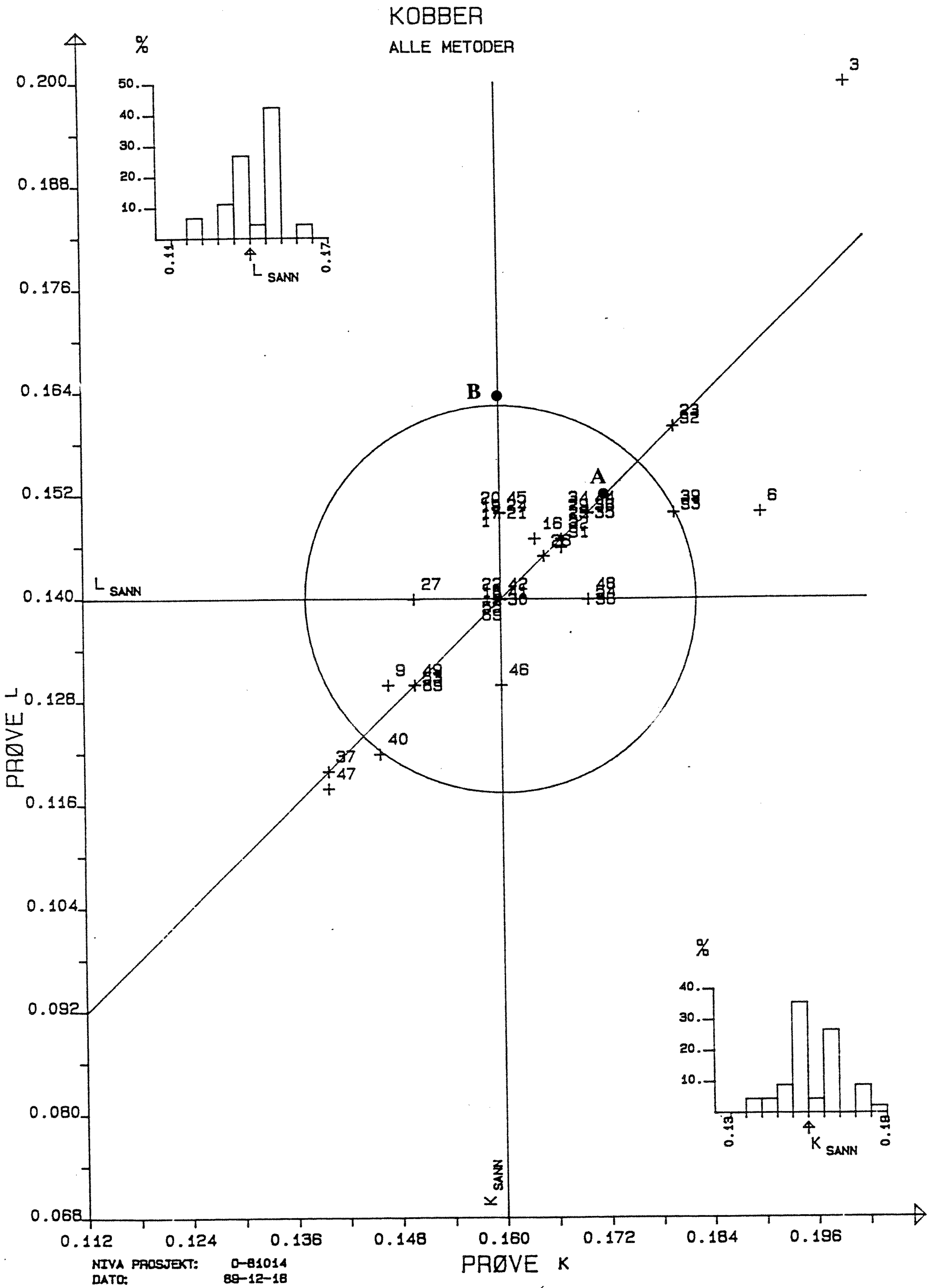


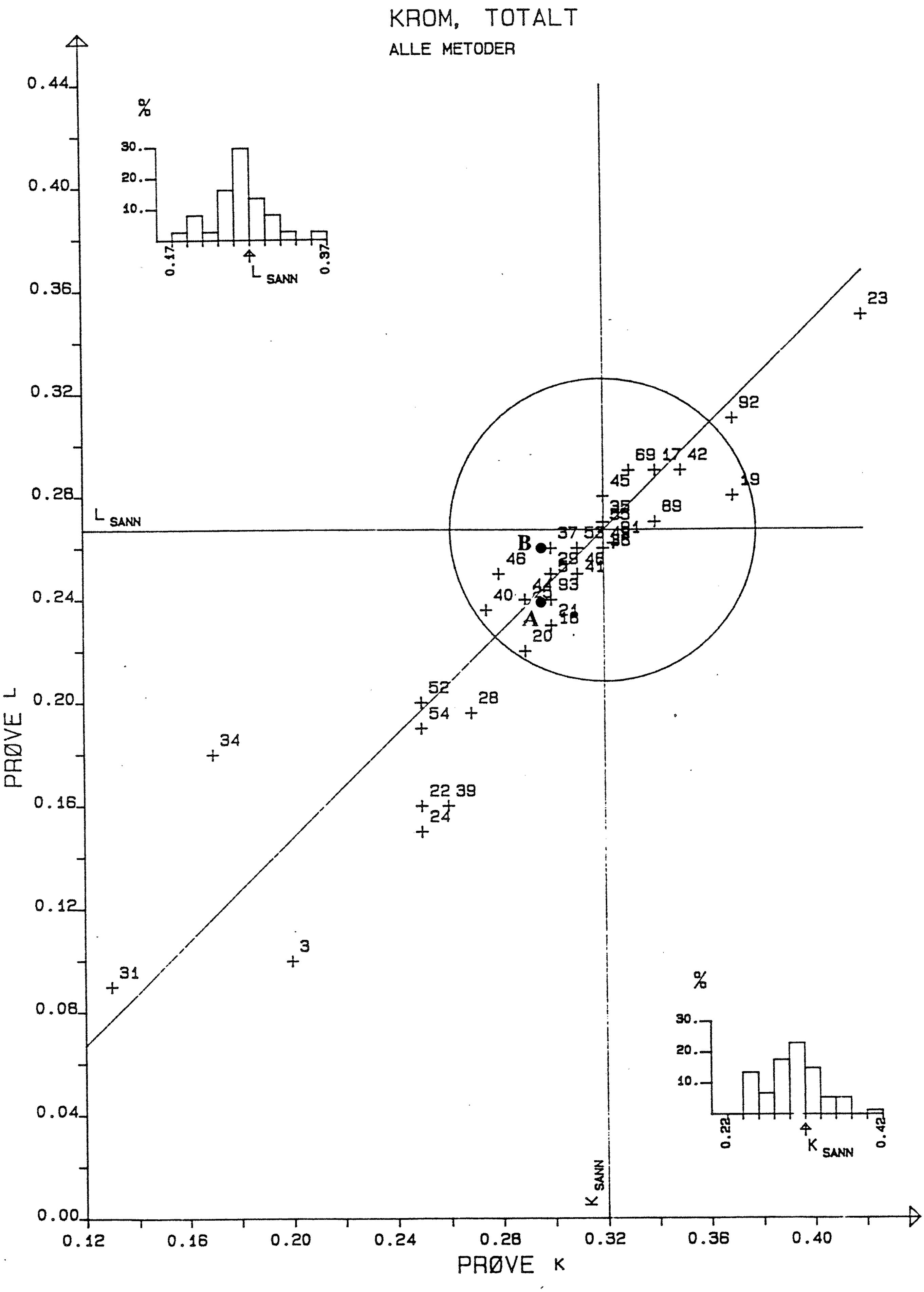
FIG. 20 JERN

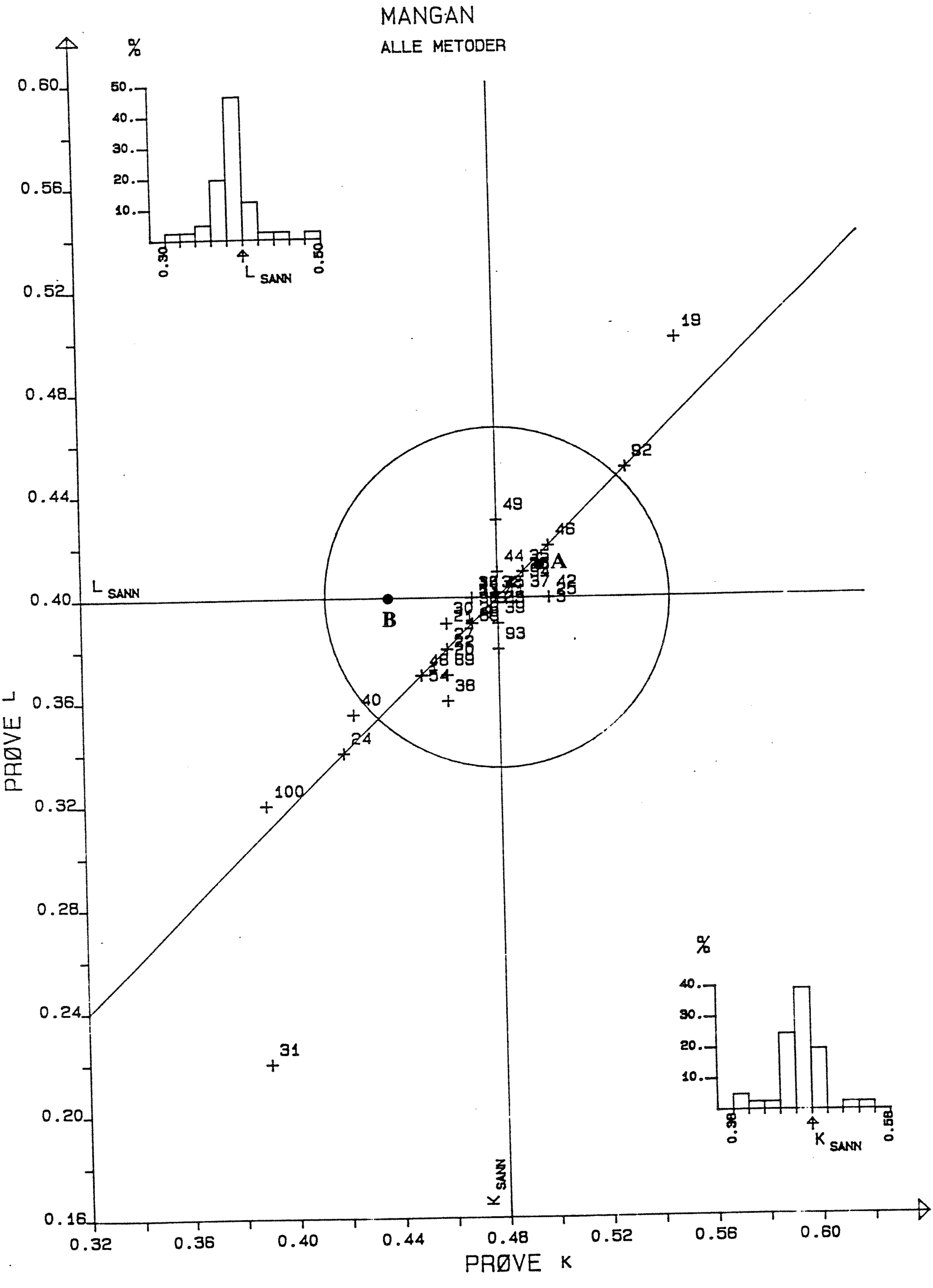
ALLE METODER

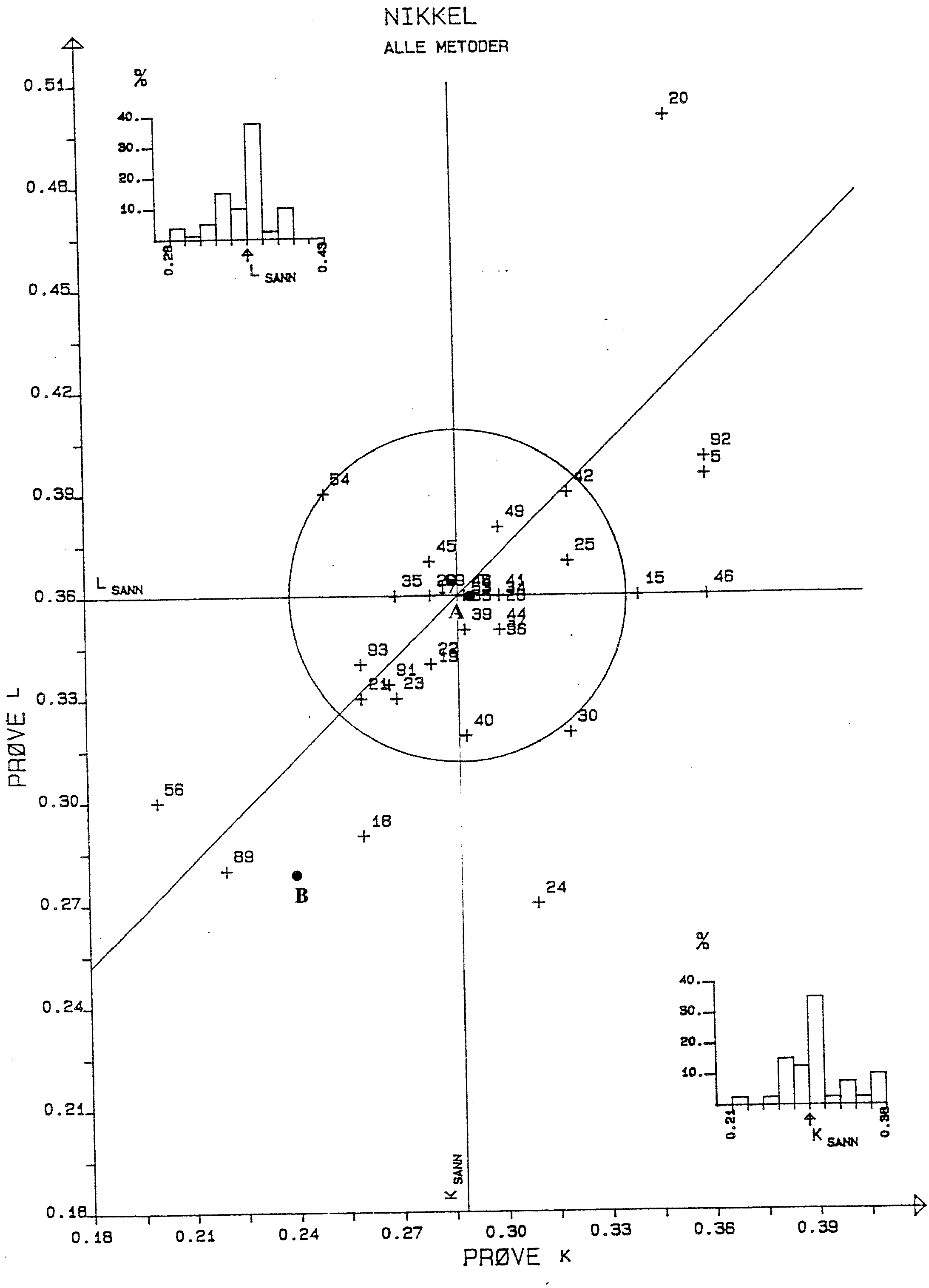


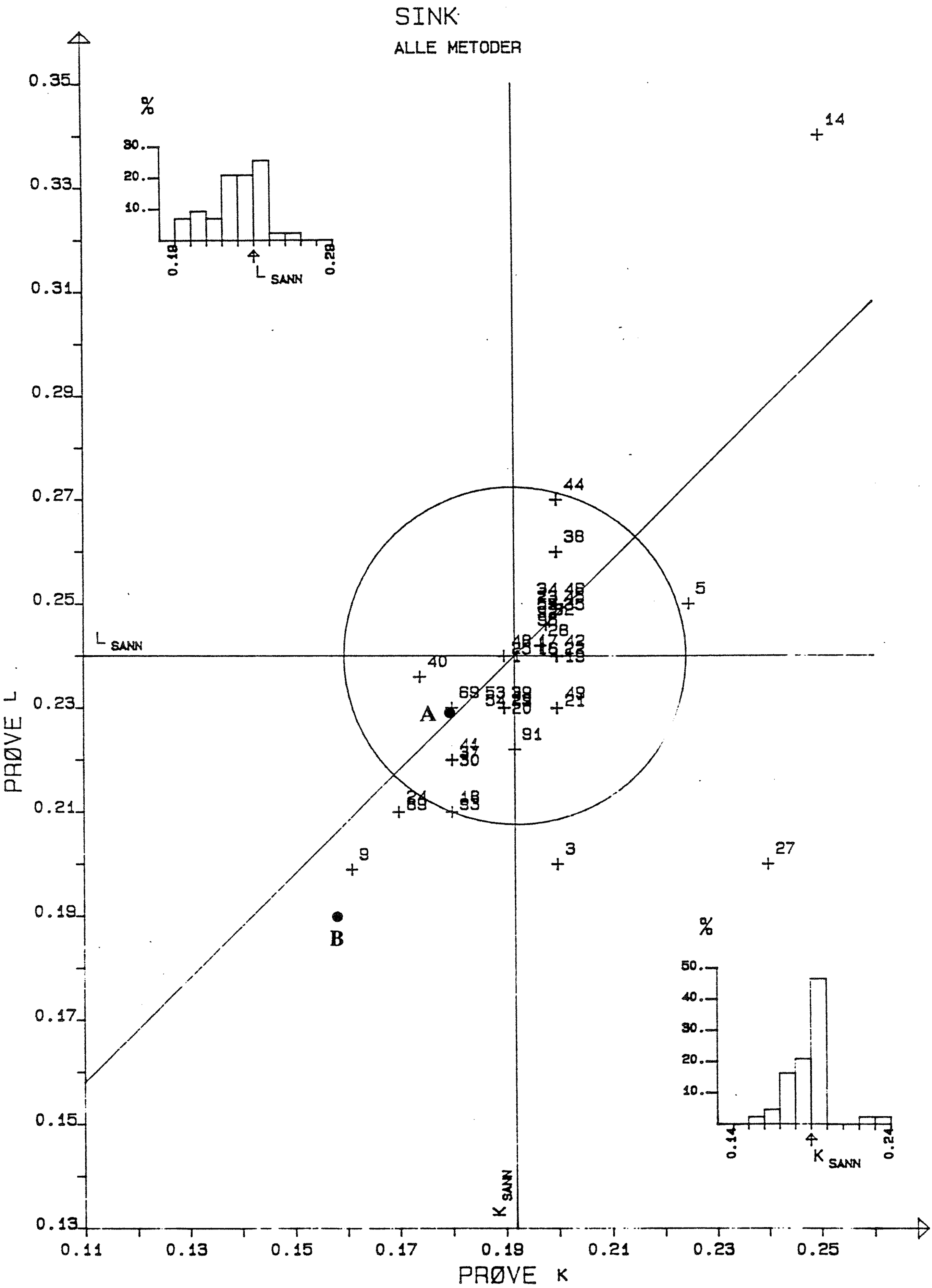

KADMIUM
ALLE METODER
%
L SANN
K SANN
PRØVE L
PRØVE K
A
B
0.077
0.071
0.065
0.059
0.053
0.047
0.041
0.035
0.029
0.023
0.017
0.011
0.029
0.035
0.041
0.047
0.053
0.059
0.065
0.071


KOBBER
ALLE METODER
%
PRØVE L
PRØVE K
L SANN
K SANN
A
B
0.200
0.188
0.176
0.164
0.152
0.140
0.128
0.116
0.104
0.092
0.080
0.068
0.112
0.124
0.136
0.148
0.160
0.172
0.184
0.196
NIVA PROSJEKT: O-81014
DATO: 89-12-18


KROM, TOTALT
ALLE METODER
PRØVE L
PRØVE K
L SANN
K SANN
%
30.
20.
10.
0.17
0.37
0.22
0.42
A
B
0.44
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40


MANGAN
ALLE METODER
PRØVE L
PRØVE K
L SANN
K SANN
%
A
B
0.16
0.20
0.24
0.28
0.32
0.36
0.40
0.44
0.48
0.52
0.56
0.60
0.32
0.36
0.40
0.44
0.48
0.52
0.56
0.60
19
92
49
46
44
35
37
42
55
39
30
93
38
40
24
54
100
31


NIKKEL
ALLE METODER
PRØVE L
PRØVE K
L SANN
K SANN
%
A
B


SINK
ALLE METODER
PRØVE L
PRØVE K
L SANN
K SANN
%
0.18
0.28
0.14
0.24
0.11
0.13
0.15
0.17
0.19
0.21
0.23
0.25
0.35
0.33
0.31
0.29
0.27
A
B

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