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The Hydrogeochemistry of the Altaiskii, Askizskii, Beiskii, Bogradskii, Shirinskii, Tashtipskii & Ust' Abakanskii Regions, Republic of Khakassia, Southern Siberia, Russian Federation - Data Report

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RAPPORT

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Sammendrag:
This report documents the geochemical and microbiological data on water samples collected during field expeditions during the summers of 1999 and 2000 to the Republic of Khakassia (Russian Federation) in southern Siberia. Data have been obtained from groundwater (boreholes, springs, wells), rivers and lakes and a preliminary interpretation suggests an evolutionary pathway from groundwater to surface waters and lakes involving up-concentration of highly soluble solutes (sodium, sulphate, chloride, boron, magnesium), and removal of silicon and calcium by precipitation of mineral phases. There is also a tendency to elevated pH and alkalinity in surface waters, which has yet to be satisfactorily understood. It is believed that this observation forms the key to understanding hydrochemical evolution in the study area and it will be the focus of subsequent interpretation. Mineral samples from lake / marsh areas have been analysed by XRD, which analyses confirm the formation of thin secondary evaporite crusts around lakes, comprising thenardite, calcite, dolomite and halite. In single cases, gypsum and mirabilite were detected. Analyses also suggest that groundwaters in villages have a tendency towards elevated nitrate levels and bacterial counts, possibly resulting from contamination from latrines. Analyses were also made of mine waters from coal mines in the Abakan-Chernogorsk syncline and from metalliferous mines at Abaza and Vershina Tyei. These mine waters had relatively high pH and low metals contents, due to the buffering nature of ambient groundwater and ore host rocks.

Emneord: Geokjemi	Hydrogeologi	Borebrønn
Fjell	Elvevann	Mikrobiologi
Grunnvannskvalitet	Innsjøer	Gruvevann

CONTENTS

1. INTRODUCTION

Tomsk State University (TGU) has long enjoyed fruitful collaboration in a number of scientific fields with the authorities of the Republic of Khakassia. During the period since 1996, TGU has been collaborating with the Khakassian State Committee for Environmental Protection (SCEP) to produce the geological section of an "Environmental Atlas of Khakassia" (Parnachev et al. 1998a,b, 2000). Personnel from the Geological Survey of Norway (NGU), the Norwegian University of Science and Technology (NTNU), URS Dames & Moore (UK) and Holymoor Consultancy (UK) have been fortunate enough to be invited to join this collaboration in the field of hydrochemical and hydrogeochemical mapping and have co-authored this report. The authors have been assisted greatly by the following persons during fieldwork:

- Ivan I. Vishnivyetskii, Chairman of the Khakassian SCEP
- Nikolai N. Kuznetsov, Vice-Chairman of the Khakassian SCEP
- Alexander A. Bulatov, Chairman of the Khakassian State Committee for Natural Resources
- Nikolai A. Gaevskii and Andrei G. Degermendzhii, Krasnoyarsk Institute of Biophysics
- Nikolai A. Makarenko, Hydrogeochemist, TGU
- Alexander Y. Berezovskii, doctorant, TGU

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- The British Council - Moscow
- Norwegian University of Science and Technology (NTNU) - Trondheim

Staff time has been provided to the project by:

- NTNU
- NGU
- URS Dames & Moore, London, UK
- Holymoor Consultancy, Chesterfield, UK

while NGU and the University of Kiel have supported the costs of water analyses.

Previous groundwater sampling was carried out in the Shira region of Khakassia during the period 16th - 21st August 1996, by David Banks (NGU), Prof. Valery Petrovich Parnachev (Dept. of Dynamic Geology, Tomsk State University) and Alexander Y. Berezovsky (Tomsk State University / Shira Regional Administration). Results of this sampling round are published by Banks et al. (1998a) and Parnachev et al. (1997a, 1999a).

This report deals with sampling carried out in the summers of 1999 and 2000

- **1999.** Sampling was carried out during the period 9th - 15th June 1999, by David Banks (Holymoor Consultancy), Prof. Valery Petrovich Parnachev (Dept. of Dynamic Geology, Tomsk State University), Bjørn Frengstad (NTNU/NGU) and Anatoly A. Vedernikov (Khakassian SCEP, Abakan office). During this sampling round, samples were mainly taken of lake waters and groundwaters from wells, boreholes and springs, in the vicinity of Abakan. Three samples of coal mine water were taken from the Abakan-Chernogorsk coal field. Lakes at Vlasyevo and Shira (Shirinskii region) were also sampled. During this period, samples were also taken of evaporite crusts around lakes and in spring areas for subsequent analysis by X-Ray Diffraction (XRD).

- **2000.** Sampling was carried out during the period 7th - 12th September 2000, by David Banks (Holymoor Consultancy), Prof. Valery Petrovich Parnachev (Dept. of Dynamic Geology, Tomsk State University), Wayne Holden (URS Dames & Moore, UK), Olga V. Karnachuk (Dept. of Plant Physiology and Biotechnology, Tomsk State University) and Anatoly A. Vedernikov (Khakassian SCEP, Abakan office). During this sampling round, samples were mainly taken of groundwaters from wells, boreholes and springs, and river/stream waters in the vicinity of Abaza, Askiz and Vershina Tyei. Samples of mine waters were taken from metalliferous mines at Abaza and Vershina Tyei. Samples of surface water along the length of the River Son were taken, and depth profiling and sampling was carried out in Lake Shira (Shirinskii region).

Alkalinity, pH, temperature (and Eh, where meaningful) were measured in the field, while filtered (0.45 μm) water samples were returned to NGU for analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Ion Chromatography (IC) methods. Evaporite samples were analysed by X-Ray Diffraction at NTNU, Trondheim. Bacteriological samples of unfiltered water were analysed by standard culture and plate counting procedures at TGU.

This report is intended to document the raw data produced during the study. This raw data report will form the documentation basis for scientific papers interpreting the data collected during the study.

The hydrochemistry of Khakassia has already been reported and published, to some extent, in the publications detailed in the "References" section.

2. INTRODUCTION TO THE STUDY AREA

Much basic physiographical data on the Republic of Khakassia can be found in the Atlas by Balakhchina et al. (1999).

2.1 Setting

2.1.1 Physiological Boundaries

Khakassia is situated in the central part of the Altai-Sayan Mountain region in southern Siberia, Russia (Fig. 4.1, 5.1). The western margins of the republic comprise the Kuznetsk Alatau mountains (rising to a maximum of 2178 m asl), while the southern fringes are dominated by the Western Sayan (highest peak 2930 m asl).

The lowland area in the east of the country (Shira, Askiz-Abakan) are Devonian-Carboniferous-Permian basin structures of the Minusinsk intermontane trough.

2.1.2 Political Boundaries

Politically, Khakassia shares borders in the west with Kemerovo Oblast', to the north and east with Krasnoyarsk Krai, to the south-east with the Republic of Tuva and to the south-west with the Altai Republic. The western and southern borders coincide with the Kuznetsk Alatau and Western Sayan mountain chains, respectively. The eastern border is largely formed by the River Yenisei.

2.1.3 Rivers

The major watercourse of the Republic is the River Abakan, rising in the south-western part of the country and flowing through Abaza and Askiz to its confluence with the Yenisei near Abakan city. In the northern part of the country, the Chulim River system dominates, rising in the hills south-west of Shira

The republic straddles a major natural watershed. The River Tom' (a major tributary of the Ob') rises in the mountains in the west of the country.

2.2 Climate

The Khakassian climate is highly continental and becomes more extreme towards the east. Figures 4.2 shows typical precipitation and temperature data for Abakan, which enjoys less than 400 mm precipitation per year. Winter minimum temperatures can fall to -50°C, while summer maxima rise to +36°C (Balakhchina et al. 1999).

Further west, precipitation amounts increase (Figure 4.3) and the temperature range becomes less extreme (Figure 4.4). In the mountainous south-west of the country, 1500 mm precipitation are recorded annually.

In general, Khakassia does not experience regional permafrost conditions.

2.3 Landscape and Vegetation

2.3.1 Lowland Areas

The lowland areas in the east of the country are characterised by the following:

- low rainfall
- extreme temperature
- tendency to salinisation of soils and groundwaters (see Fig. 14 in Balakhchina et al. 1999)
- steppe landscape
- presence of both freshwater and saline lakes

These areas coincide with the Devonian-Carboniferous geological basins. Thus, when considering groundwater quality in these formations, it is often unclear to what extent a feature, such as salinity, is due to geological factors (presence of palaeoevaporites) or modern climatic factors.

Limited agriculture takes places in these areas, although much of the steppe landscape is dedicated to cattle ranching.

2.3.2 Upland Areas

These are characterised by:

- pre-Devonian, erosionally resistant rocks
- elevated precipitation
- only slightly less extreme temperature fluctuations
- wooded, often taiga-like, vegetation
- freshwater lakes
- fresh groundwaters

The highest mountains are above the limit of forest.

2.4 Mining and Industry

Several different types of mining occur in Khakassia.

- Pyritiferous magnetite iron ores are worked at Abaza and Vershina Tyei
- Coals, of Permo-Carboniferous age, are worked in the Chernogorsk / Abakan syncline area
- Molybdenum is worked in a massive opencast mine at Sorsk, possibly the largest such mine in the former Soviet Union.
- Gold is worked at a number of locations including Kommunar and Priiskovii
- Other metals have been mined and processed in the Tu-im area.

Other major industries include:

- large-scale aluminium processing at Sayanogorsk.
- hydroelectric power generation south of Sayanogorsk
- forestry in the mountain areas
- chemical industry at Ust' Abakan.

2.5 Geology

The geology of Khakassia is described in detail in Appendix C.

3. ANALYTICAL RESULTS FROM SAMPLING OF 1999

The sampled sites are detailed in Appendices A and B.

3.1 Sampling and Analysis Routines

3.1.1 Groundwater Sampling

As in the previous sampling round, groundwater samples were taken, to the extent possible, from flowing sources (springs), artesian (flowing) boreholes or regularly-used wells and boreholes, to ensure that "fresh" groundwater was sampled. In the case of boreholes in use, the sample was typically taken from the nearest available tap to the well head. In a few cases, this would mean that the water had passed through a water tower or header tank prior to sampling. In one case, water was taken from a dug salt well which did not appear to be in especially regular use (sample Xa59). For each sample site the following samples were taken:

- 2 x 100 ml polyethene flasks, of water filtered at 0.45 µm, using a Millipore filter capsule and hand-held polypropene syringe. No acidification was carried out in the field.
- 1 x 10 ml sterile glass vial of unfiltered water for bacteriological analysis at TGU
- in the case of lakes, 1 x 10 ml sterile glass vial of lake sediments for bacteriological analysis at TGU.

3.1.2 Lake Water Sampling

Lake water samples were typically taken by wading into the lake to the extent that wading boots would allow (typically c. 70 cm water depth) and taken by submerging the sampling bottle to a depth of some 20-30 cm in water free of disturbed sediment.

3.1.3 Field Measurements

Field measurements of groundwater were taken either in the flowing water source or, if this was not possible, in a large (c. 15 l) bucket filled directly from the source. In lakes, the electrodes were submerged to maximum extent below the lake surface (c. 5-10 cm) for measurements to be taken. In the case of alkalinity, reaction vessels were filled either from the flowing source, or (e.g. in the case of lakes) from a large bucket filled with the water from the source. Field determinations included:

- determination of alkalinity (by average of multiple determinations, typically three determinations) using a AquaMerck 11109 alkalinity test kit, which employs titration against an acid solution with phenolphthalein (end-point pH=8.2) or mixed (end-point pH=4.3) indicators for p-alkalinity and t-alkalinity, respectively.
- pH, Eh (where turbulence and mixing with air were low enough to permit a sensible reading) using a Palintest Microcomputer 900 series instrument with pH, Eh, and temperature electrodes. These were calibrated at regular intervals (at least thrice daily) against solutions of known pH around 4, 7 or 10 (automatic temperature correction), as appropriate.
- Measurements of Eh in lake bottom sediments were simply taken by inserting the Eh electrode a short distance (1-2 cm) into the lake bed sediments.

3.1.4 Analysis at Norges Geologiske Undersøkelse

Samples (typically two samples of filtered water from each site) were transported by Bjørn Frengstad to the NGU analytical laboratory in Trondheim. Prior to analysis, samples were stored in a refrigerator at around 4°C, except for brief periods of transport. Upon arrival, the samples were stored in the NGU cool-room at 4°C. For analysis, the following procedure was followed:

1. One flask was used directly for ion-chromatography (Dionex 120 DX machine) analyses of anions.
2. The second flask was acidified with 0.5% concentrated Ultrapur HNO_3 *in the original flask*. This was done to hinder absorption / precipitation (and dissolve already sorbed/precipitated) of elements. This acidified quantum was used for ICP-AES (Thermo Jarrell Ash ICP 61 machine) and ICP-MS (Finnegan Mat machine with Meinhart Nebulizer CD-1) analyses.
3. In two cases (Xa57 and Xa58) alkalinity was so high that field measurements were uncertain. Additional 100 ml polyethene flasks of unfiltered water were collected for laboratory alkalinity analysis at NGU.

3.1.5 Sampling and Analysis of Evaporites

At some sites (lake shores, dry lakes, marsh areas) samples of very thin crusts of recent secondary evaporite mineralisation were collected in bags for analysis by X-Ray Diffraction. In most cases, the crusts were so thin that the sample also contained soil material. Non-quantitative analyses were performed at the Department of Geology and Mineral Resources Engineering, NTNU, Trondheim, using a PW1710 diffractometer. Peak positions were defined by minimum of 2nd derivative of peak.

3.1.6 Bacteriological Analysis at TGU

TGU analysed the glass sample vials of water for three groups of micro-organisms: aerobic saprophytes, anaerobic saprophytes and sulphate-reducing bacteria (SRB). The term saprophytes (saprophytic micro-organisms) is used for all heterotrophic micro-organisms that can grow on nutrient-rich organic media, either by fermentation or respiration. *E. coli* is, for example, a saprophyte. Plate Count Agar is a standard medium for enumerating this group, and it contains tryptone (protein), dextrose (sugar) and yeast extract (source of various organic substances including vitamins). Saprophytes are considered good indicators of the organic pollutant load an ecosystem, due to their high metabolic activity.

Environmental regulation authorities often have a prescribed procedure to analyse for saprophytic micro-organisms in water samples and a system for classifying water bodies accordingly. Generally speaking, a high number of aerobic saprophytes correlates with high contents of organic matter and biogenic compounds (e.g. dissolved inorganic nitrogen and phosphorus).

Aerobic saprophytes were analysed by the *most probable number* technique (MPN) on Plate Count Agar (Difco), a standard method prescribed by USA Drinking Water Regulations. The US standard places a limit of less than 500 cells/ml for potable water. Russian regulations employ similar standards (Guseva et al., 2000), but have differing limits for differing water use types:

Water class	Number of aerobic saprophytes, cells/ml
Very clean / Class 1	<500
Clean / Class 2	500-5,000
Moderately contaminated / Class 3	5,100-10,000
Contaminated / Class 4	10,100-50,000
Polluted / Class 5	50,100-100,000
Severely polluted / Class 6	>1,000,000

It should, however, be noted that Russian authorities tend to use another medium for running MPN technique than the US for saprophyte enumeration. The Russian method tends to underestimate cell numbers, compared to Plate Count Agar (Saava & Rinne, 1987).

Sulphate reducing bacteria (SRBs) were enumerated (by Tomsk State University) in completely filled glass tubes using a liquid modified basal Widdel medium containing (g/l distilled water): 1.0 NaCl; 0.4 $MgCl_2.6H_2O$; 0.15 $CaCl_2.2H_2O$; 4.0 Na_2SO4; 0.25 NH_4Cl; 0.2 KH_2PO_4 and 0.5 KCl. Trace element, vitamin, selenite-tungstate, $NaHCO_3$, and Na_2S solutions were added to the basal media as described by, e.g. Widdel & Bak (1992). Lactate (2 ml 40% lactic acid per l of medium) was used as the electron donor for sulphate reduction. Iron paper clips were placed in tubes as an additional reducing agent and Fe source for bacteria and as a solid surface for nucleating FeS precipitation and to signal sulphate reduction. Cultures were kept at 28°C for one month. Tubes were considered as positive for growth by visual assessment of black sulphide precipitate.

The analysed bacterial counts are much higher than one would expect for groundwater samples. Given the length of elapsed time between sampling in the remote Khakassian field area and analysis at TGU and, given that samples were not always able to be refrigerated in the field (although this was done, where facilities were available), it is possible that bacterial reproduction has occurred in the sampling vessels. It is thus possible that the analytical results do not reflect real bacterial counts "at source". However, we regard the analyses as probably giving some indication of the relative degree of bacterial population of the water samples (e.g. contaminated waters will have larger aerobic saprophyte bacterial populations at source and probably a higher content of nutrients to sustain bacterial reproduction *in vitro*, and will thus result in an elevated analytical aerobic saprophyte bacterial count.

3.2 Designation of Samples to Lithological and Land Use Classes

Sample no.	Location	Rock	Geology		Date	Source	Depth	Yield	Land Use
							m	l/s	
Xa34	Lake Kurinka		D3, C1		09/06/99	4			1
35	Marble quarry	Schists	R1, R2		09/06/99	1	60	6.94	1
36	Maina	Schists	K1		09/06/99	1	35		1
37	Bogoslovka	Ophiolite/Alluvium?	K1/Q?		09/06/99	1	45	2.78	3
38	Lake Utinoe		D3		09/06/99	4			1
39	Byeya Dairy	Carbonates	D2		09/06/99	1	40	1.39	3
40	Novotroitskaya		D3		09/06/99	1			3
41	Lake Chërnoe		C1+Q		09/06/99	4			1
42	Tumannii	Granite (Nordmarkite)	K2		10/06/99	2		0.63	1
43	Mount Amoga Spring	Carbonates	R3		10/06/99	3			1
44	Vershino-Bidzha Spring	Carbonates	R3		10/06/99	3		>1.0	1
45	SW of Moskovskii	Siltstone, tuff	C1		10/06/99	3			1
46	Khan Kul' borehole		D3		11/06/99	2	350 ?	0.07	3
47	Lake Solenoe		D3+C1		11/06/99	4			1
48	Lake Bulankul'	Nepheline-syenite	K-O		11/06/99	4			1
49	Sanatorium Bulankul'	Nepheline-syenite	K-O		11/06/99	1	45		3
50	E of Pulankul'	Basalt	D1		11/06/99	1	25?		2
51	Vtoroi Kluch	Basalt/syenite	K(-O)		11/06/99	3		0.40	1
52	Mount Timirtag	Limestone	D2		11/06/99	2		0.10	1
53	Kharasug Spring		D2 (K-O)		11/06/99	3		1.00	1
54	Charkov		D2/D3/?Q?		12/06/99	1			3
55	N of Charkov		D1		12/06/99	3			1
56	Ust' Kamisyak	Basal conglomerate	C1		12/06/99	3			1
57	Lake Ulugkol'		C1		12/06/99	4			1
58	Lake Uskol'		C1		12/06/99	4			1
59	Abakanskii 2 salt-well		D3		12/06/99	5			1
60	Moskovskii Sovkhoz	Carbonates	D2		12/06/99	1			3
61	Byelii yar opencast	Alluvium	Q		13/06/99	1	32		4
62	Izikskii 1 Opencast		P		13/06/99	6		61.11	4
63	Izikskii 2 Opencast		P		13/06/99	6		5.00	4
64	Khakasskaya mine		C3		13/06/99	6	140	13.89	4
65	Znamenka	Carbonates	D2		13/06/99	1			3
66	Polindeika	Basalt/sandstone	D1		13/06/99	1			3
67	Lake Vlasyevo		V-K/D1		15/06/99	4			1
68	Lake Shira (kurort)		D3		15/06/99	4			3

Source code: 1 = borehole (pumped)
2 = artesian borehole (overflows naturally)
3 = spring
4 = lake
5 = dug well
6 = mine water

Land Use Code: 1 = rural
2 = agricultural / cattle station
3 = urban / village
4 = coal mining

Geology: R = Riphean, V = Vendian, K = Cambrian, O = Ordovician, D1/D2/D3 = Lower/Middle/Upper Devonian, C = Carboniferous, P = Permian, Q = Quaternary

3.3 Field Analyses of Waters (pH, Temperature, Eh, Alkalinity)

Sample no.	Location	pH	Temp	Eh	Eh-sed	Alk_1	Alk_2	Alk_3	Alk_aver	H_2S
			°C	mV	mV	meq/l	meq/l	meq/l	meq/l	
Xa34	Lake Kurinka	10.11	20.0	[-15]	-420	35.3	36.1		35.7	2
35	Marble quarry	7.52	7.5	[+77]		3.6	3.7		3.7	0
36	Maina	7.55	8.0	[+40]		3.9	3.75	3.7	3.8	0
37	Bogoslovka	7.61	6.1	[+150]		5	5.2		5.1	0
38	Lake Utinoe	9.36	20.1	[+80-90]	<-200	14.1	14.3		14.2	1
39	Byeya Dairy	7.3	6.8	205		4.6	4.7		4.7	0
40	Novotroitskaya	8.09	6.1	[+155]		10.8	10.9		10.9	1
41	Lake Chёrnoe	9.13	18.1	[+150]	<-200	11	11.4		11.2	1
42	Tumannii	7.79	2.9	180		4.4	4.6		4.5	0
43	Mount Amoga Spring	7.35	9.6	210		6.1	6.3		6.2	0
44	Vershino-Bidzha Spring	7.39	7.8	215		5.6	5.6		5.6	0
45	SW of Moskovskii	8.35	11.5	< +100	<-400	10.9	10.6		10.8	1
46	Khan Kul' borehole	8.04	6.2	< +100		6.9	6.7		6.8	0
47	Lake Solenoe	9.01	14.1	[+80]	<-200	14.1	14.7	14.1	14.3	1
48	Lake Bulankul'	8.37	17.0	[+120-130]		3.7	3.8		3.8	0
49	Sanatorium Bulankul'	7.41	3.9	[+145]		6.8	6.5	6.3	6.5	0
50	E of Pulankul'	7.49	6.1	[+78]		4.3	4.4		4.4	0
51	Vtoroi Kluch	7.34	4.8	142		4.4	4.5		4.5	0
52	Mount Timirtag	7.5	6.0	-14		4	4.2		4.1	
53	Kharasug Spring	7.48	4.5	177		3.9	3.9		3.9	0
54	Charkov	7.51	6.3	68		5.2	5.2		5.2	0
55	N of Charkov	7.64	7.0	139		6.3	6.3		6.3	0
56	Ust' Kamisyak	7.38	7.3	190		6.6	6.4		6.5	0
57	Lake Ulugkol'	9.84	16.5	[+50]	<-400	>100			97.7	2
58	Lake Uskol'	9.93	15.8	[0-+50]	<-400	84			80.1	1
59	Abakanskii 2 salt-well	7.41	10.6	[<+100]		7.6	5.9	5.9	5.9	1
60	Moskovskii Sovkhoz	7.27	4.8	[+110]		7	6.9		7.0	0
61	Byelii yar opencast	7.92	10.1	[+130]		4.3	3.8	4.3	4.1	0
62	Izikskii 1 Opencast	8.39	8.6	[+140]		6.5	6.6		6.6	
63	Izikskii 2 Opencast	7.76	11.2	[+160]		22.7	27.4	22.9	24.3	
64	Khakasskaya mine	8.18	10.1	[+170]		22	22.2		22.1	0
65	Znamenka	7.59	5.0	[+127]		6.7	6.7		6.7	0
66	Polindeika	8.13	7.3	[+50]		2.8	3		2.9	0
67	Lake Vlasyevo	9.24	18.0	[+50]	-200 to -300	19.3	22.1	19.5	20.3	0
68	Lake Shira (kurort)	9.09	17.8	[+65]	> 0	16.6	16.8		16.7	0

Eh values are positive unless specified otherwise

Alk1, Alk2, Alk3 = field determinations of alkalinity. Alk_aver = average alkalinity (used in interpretation)

Note, for samples Xa57 and Xa58, the field measurements of alkalinity are given under Alk1, while lab determinations are given under Alk_aver

Eh values in square brackets [ ] indicate considerable uncertainty due to manner of measurement (pumping, turbulence, opportunities for aeration etc.)

Eh-sed = Eh value measured by placing Eh electrode in sediment at bottom of lake.

H_2S : 0 = no smell, 1 = some smell, 2 = strong smell

3.4 Analyses of Waters by ICP-AES at Norges Geologiske Undersøkelse

Sample no.	Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Xa34	<0.02	<0.02	0.0327	<0.005	83.7	18.4	7970	64.4	0.0119	3.82	<0.005	<0.002	<0.05	<0.02	<0.01	0.0118
35	8.23	<0.02	<0.01	<0.005	5.66	80.7	3.59	2.47	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
36	5.14	<0.02	0.0802	<0.005	8.38	60.2	5.41	<0.5	0.00147	<0.1	<0.005	0.00752	<0.05	<0.02	<0.01	<0.005
37	6.91	<0.02	<0.01	<0.005	29.4	52.7	5.88	0.888	0.00347	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
38	0.338	<0.02	<0.01	<0.005	240	43.6	2790	37.7	0.00681	0.136	<0.005	0.00421	<0.05	<0.02	<0.01	0.0113
39	6.05	<0.02	<0.01	<0.005	11.0	82.2	7.24	0.805	<0.001	<0.1	<0.005	0.0152	<0.05	<0.02	<0.01	<0.005
40	2.61	<0.02	0.0196	<0.005	20.3	19.1	662	2.33	<0.001	<0.1	0.0215	<0.002	<0.05	<0.02	<0.01	0.0272
41	1.45	0.0919	0.0933	<0.005	30.1	33.3	797	4.98	0.0101	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	0.00740
42	7.58	<0.02	<0.01	<0.005	21.2	47.6	16.0	1.03	0.330	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
43	3.71	<0.02	<0.01	<0.005	35.2	75.7	15.7	1.46	<0.001	<0.1	<0.005	0.00314	<0.05	<0.02	<0.01	<0.005
44	3.96	<0.02	<0.01	<0.005	33.3	68.6	15.2	1.37	<0.001	<0.1	<0.005	0.00520	<0.05	<0.02	<0.01	<0.005
45	3.80	<0.02	0.0916	<0.005	65.1	95.3	1320	3.84	0.320	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	0.00503
46	3.22	<0.02	<0.01	<0.005	82.0	87.7	553	3.59	0.00147	<0.1	0.00735	<0.002	<0.05	<0.02	<0.01	0.00770
47	0.380	<0.02	<0.01	<0.005	306	112	4130	15.4	0.0104	<0.1	<0.005	0.00323	<0.05	<0.02	<0.01	0.0139
48	0.395	<0.02	0.0164	<0.005	23.0	26.7	14.7	4.53	0.00214	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
49	7.00	<0.02	<0.01	<0.005	30.6	59.8	25.9	2.43	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
50	6.44	<0.02	0.0654	<0.005	13.8	69.7	18.3	1.18	0.0135	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
51	5.98	<0.02	<0.01	<0.005	21.3	63.6	27.9	1.57	0.00641	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
52	4.40	<0.02	<0.01	<0.005	21.1	93.2	19.4	1.89	0.00427	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
53	5.24	<0.02	<0.01	<0.005	10.2	67.6	13.5	1.58	0.00120	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
54	5.28	<0.02	0.0311	<0.005	33.1	63.8	32.1	2.82	0.00120	<0.1	<0.005	0.00242	<0.05	<0.02	<0.01	<0.005
55	5.65	<0.02	<0.01	<0.005	31.8	74.5	46.4	2.83	0.0183	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	0.00622
56	3.82	<0.02	<0.01	<0.005	28.7	64.6	26.9	1.21	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
57	0.0538	<0.02	0.0933	<0.005	178	4.21	11700	59.4	0.00254	0.193	<0.005	0.00259	<0.05	<0.02	<0.01	0.0152
58	0.584	0.0694	0.103	0.00754	15.7	4.48	7560	20.2	<0.001	0.139	<0.005	0.00223	<0.05	<0.02	<0.01	0.0265
59	1.63	<0.02	0.0196	0.00668	1990	963	31700	83.2	0.519	<0.1	<0.005	0.00923	<0.05	<0.02	<0.01	0.0400
60	5.55	<0.02	0.0131	<0.005	92.1	120	143	2.28	0.00200	<0.1	<0.005	0.0111	<0.05	<0.02	<0.01	0.00637
61	6.27	<0.02	<0.01	<0.005	27.8	49.1	67.5	1.68	0.00120	<0.1	<0.005	0.00457	<0.05	<0.02	<0.01	<0.005
62	4.99	<0.02	<0.01	<0.005	38.9	45.2	129	2.76	0.0129	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
63	4.04	<0.02	<0.01	<0.005	11.7	29.8	812	3.77	0.0184	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
64	3.49	<0.02	0.116	<0.005	132	69.6	858	10.8	0.00761	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
65	6.16	<0.02	<0.01	<0.005	80.4	126	79.7	3.12	0.00347	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
66	4.93	<0.02	0.0344	<0.005	13.1	53.1	133	<0.5	0.0101	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
67	<0.02	<0.02	<0.01	<0.005	309	21.9	626	31.8	0.00387	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	0.00948
68	0.744	<0.02	<0.01	<0.005	1110	52.4	3320	37.3	0.0115	<0.1	<0.005	0.00780	<0.05	<0.02	<0.01	0.0342

Sample no.	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Xa34	<0.01	<0.005	<0.01	0.0306	2.48	0.00613	<0.01	4.07	<0.001	0.100	<0.001	<0.05	<0.01	<0.001
35	<0.01	<0.005	<0.01	0.00242	0.168	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
36	<0.01	<0.005	<0.01	0.0978	0.317	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
37	<0.01	<0.005	<0.01	0.00636	0.225	<0.005	<0.01	0.0221	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
38	<0.01	<0.005	<0.01	0.0596	11.6	<0.005	<0.01	3.02	<0.001	0.237	<0.001	0.0775	<0.01	<0.001
39	<0.01	<0.005	<0.01	0.114	0.289	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
40	0.0165	<0.005	<0.01	0.0167	6.26	<0.005	<0.01	1.06	<0.001	0.0787	<0.001	<0.05	<0.01	<0.001
41	<0.01	<0.005	<0.01	0.0696	0.593	<0.005	<0.01	0.517	<0.001	0.00571	<0.001	<0.05	<0.01	<0.001
42	<0.01	<0.005	<0.01	0.0557	0.397	<0.005	<0.01	<0.02	<0.001	0.00635	<0.001	<0.05	<0.01	<0.001
43	<0.01	<0.005	<0.01	0.0369	0.559	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
44	<0.01	<0.005	<0.01	0.0318	0.550	<0.005	<0.01	0.0310	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
45	0.0166	<0.005	<0.01	0.0466	6.46	<0.005	<0.01	2.49	<0.001	0.136	<0.001	0.0760	<0.01	<0.001
46	0.107	<0.005	<0.01	0.00515	17.2	<0.005	<0.01	1.31	<0.001	0.135	<0.001	0.162	<0.01	<0.001
47	0.0146	<0.005	<0.01	0.0336	13.3	<0.005	<0.01	4.79	<0.001	0.601	<0.001	0.153	<0.01	<0.001
48	<0.01	<0.005	<0.01	0.0272	0.170	<0.005	<0.01	0.0310	<0.001	0.0102	<0.001	<0.05	<0.01	<0.001
49	<0.01	<0.005	<0.01	0.0182	0.361	<0.005	<0.01	0.0398	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
50	<0.01	<0.005	<0.01	0.0363	0.479	<0.005	<0.01	0.0376	<0.001	0.00952	<0.001	<0.05	<0.01	<0.001
51	0.0158	<0.005	<0.01	0.0460	0.553	<0.005	<0.01	0.0354	<0.001	0.00825	<0.001	<0.05	<0.01	<0.001
52	<0.01	<0.005	<0.01	0.0285	3.84	<0.005	<0.01	0.0885	<0.001	0.0267	<0.001	0.0935	<0.01	<0.001
53	0.0617	<0.005	<0.01	0.0448	1.02	<0.005	<0.01	0.0509	<0.001	0.0254	<0.001	0.0561	<0.01	<0.001
54	<0.01	<0.005	<0.01	0.0200	3.06	<0.005	<0.01	0.0442	<0.001	0.0171	<0.001	0.0727	<0.01	<0.001
55	<0.01	<0.005	<0.01	0.0321	0.692	<0.005	<0.01	0.0420	<0.001	0.0102	<0.001	0.0529	<0.01	<0.001
56	<0.01	<0.005	<0.01	0.0212	0.392	<0.005	<0.01	0.0243	<0.001	<0.005	<0.001	0.0539	<0.01	<0.001
57	<0.01	<0.005	<0.01	0.0230	0.312	0.0132	<0.01	3.47	<0.001	0.204	<0.001	<0.05	<0.01	<0.001
58	0.0268	<0.005	<0.01	0.0266	0.497	0.0559	<0.01	4.49	<0.001	0.140	<0.001	<0.05	<0.01	<0.001
59	0.337	<0.005	<0.01	0.0191	21.4	<0.005	<0.01	1.58	<0.001	5.38	<0.001	0.391	<0.01	<0.001
60	<0.01	<0.005	<0.01	0.0133	2.88	<0.005	<0.01	0.170	<0.001	0.0267	<0.001	0.0972	<0.01	<0.001
61	<0.01	<0.005	<0.01	0.0348	0.649	<0.005	<0.01	0.0376	<0.001	0.00889	<0.001	0.0550	<0.01	<0.001
62	<0.01	<0.005	<0.01	0.0254	1.22	<0.005	<0.01	0.0641	<0.001	0.0184	<0.001	<0.05	<0.01	<0.001
63	<0.01	<0.005	<0.01	0.0194	1.10	<0.005	<0.01	0.192	<0.001	0.114	<0.001	<0.05	<0.01	<0.001
64	<0.01	<0.005	<0.01	0.0233	3.95	<0.005	<0.01	0.257	<0.001	0.124	<0.001	<0.05	<0.01	<0.001
65	<0.01	<0.005	<0.01	0.0106	2.64	<0.005	<0.01	0.0929	<0.001	0.0146	<0.001	0.0536	<0.01	<0.001
66	<0.01	<0.005	<0.01	0.0203	1.27	<0.005	<0.01	0.0354	<0.001	0.0146	<0.001	<0.05	<0.01	<0.001
67	<0.01	<0.005	<0.01	0.0787	0.632	<0.005	<0.01	0.473	<0.001	0.0381	<0.001	<0.05	<0.01	<0.001
68	<0.01	<0.005	<0.01	0.00817	5.85	<0.005	<0.01	2.12	<0.001	0.201	<0.001	<0.05	<0.01	<0.001

3.5 Analyses of Waters by Ion Chromatography at Norges Geologiske Undersøkelse

(parentheses indicate analytical uncertainty due to possible interference at high salinity)

Sample no.	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Xa34	<2.0	5586	<4.0	31.73	<2.0	<4.0	8041
35	0.05	34.4	<0.05	<0.1	6.44	<0.2	5.29
36	0.18	0.69	<0.05	<0.1	4.50	<0.2	8.30
37	0.25	2.17	<0.05	<0.1	8.90	<0.2	5.61
38	1.33	1682	<2.0	13.38	<0.05	<8.0	4042
39	<0.05	7.05	<0.05	<0.1	10.11	<0.2	21.9
40	1.60	192	<0.8	0.78	212.36	<0.2	578
41	1.68	617	<0.8	4.37	<0.05	<0.2	530
42	0.98	1.95	0.07	<0.1	1.51	<0.2	14.5
43	0.61	5.13	<0.05	<0.1	4.89	<0.2	63.0
44	0.66	4.48	<0.05	<0.1	4.29	<0.2	49.7
45	1.43	747	<0.8	3.30	5.30	<3.2	1939
46	0.95	84.9	<0.05	0.88	24.58	<1.6	1418
47	3.21	1183	<0.8	10.00	<0.8	<3.2	8607
48	1.51	5.58	<0.05	<0.1	<0.05	<0.2	0.91
49	0.89	8.39	<0.05	<0.1	15.01	<0.2	11.9
50	0.79	7.75	<0.05	<0.1	7.28	<0.2	46.0
51	0.99	14.3	<0.05	<0.1	20.22	<0.2	41.5
52	0.69	6.27	<0.05	<0.1	6.51	<0.2	154
53	0.81	7.43	<0.05	<0.1	9.32	<0.2	41.4
54	0.94	16.7	<0.05	<0.1	6.24	<0.2	73.8
55	0.42	24.2	<0.05	0.20	11.28	<0.2	90.0
56	0.50	3.83	<0.05	<0.1	5.34	<0.2	40.2
57	<2.0	7645	<4.0	49.68	<2.0	<8.0	11052
58	18.70	3471	<2.0	15.72	<2.0	<8.0	10765
59	(300)	56325	<50	(200)	<50	<200	8372
60	0.60	124	<0.4	0.98	87.18	<0.2	456
61	0.58	54.3	<0.05	0.19	15.17	<0.2	88.5
62	0.54	92.5	<0.05	0.33	7.24	<0.2	115
63	0.11	305	0.48	0.49	7.14	<0.2	567
64	0.29	307	<0.05	0.82	2.78	<0.2	1135
65	0.66	96.8	<0.05	0.46	28.67	<0.2	331
66	0.65	128	<0.05	0.75	10.04	<0.2	143
67	1.09	387	<0.8	2.78	0.29	<0.2	1333
68	<2.0	2096	<2.0	12.97	0.16	<8.0	9765

Nitrite (NO_2^-) values regarded as invalid due to storage prior to analysis.

3.6 Analyses by ICP-MS at Norges Geologiske Undersøkelse (all analyses in µg/l)

Sample no.		Li_MS	Be_MS	B_MS	Rb_MS	Mo_MS	Cd_MS	La_MS	Ce_MS	Pb_MS	Al_MS	Cr_MS	Co_MS	Ni_MS
35	Xa35F	1.82	<0.1	<5	0.22	0.91	<0.01	<0.005	<0.005	0.048	<0.6	0.43	<0.03	<0.1
36	Xa36F	0.76	<0.1	6.36	0.08	0.51	<0.01	<0.005	<0.005	0.098	<0.6	0.14	<0.03	<0.1
37	Xa37F	<0.5	<0.1	39.86	0.19	1.1	<0.01	0.006	<0.005	0.022	<0.6	0.69	<0.03	<0.1
39	Xa39F	1.84	<0.1	24.21	0.26	0.4	0.013	0.01	<0.005	0.119	<0.6	0.17	<0.03	<0.1
40	Xa40F	ICP-AES	0.11	ICP-AES	0.88	33.2	0.023	<0.005	0.006	<0.02	<0.6	0.16	0.45	<0.1
41	Xa41F	9.14	0.12	ICP-AES	0.69	6.21	<0.01	0.028	0.056	0.079	28.66	0.16	0.457	0.65
42	Xa42F	7.16	0.12	46.6	0.1	13.34	<0.01	0.014	0.022	0.033	<0.6	<0.1	0.134	<0.1
43	Xa43F	3.22	<0.1	46.05	0.5	17.32	<0.01	<0.005	<0.005	<0.02	<0.6	0.5	<0.03	<0.1
44	Xa44F	5.33	<0.1	46.39	0.53	21.63	<0.01	<0.005	<0.005	0.054	<0.6	0.85	<0.03	<0.1
46	Xa46F	ICP-AES	0.11	ICP-AES	1.74	ICP-AES	0.233	0.006	<0.005	<0.02	<0.6	0.11	0.174	<0.1
48	Xa48F	12.72	0.11	65.72	1.1	7.9	<0.01	<0.005	0.006	0.035	<0.6	<0.1	<0.03	<0.1
49	Xa49F	6.63	<0.1	40.9	0.2	8.58	<0.01	<0.005	<0.005	0.046	<0.6	0.56	<0.03	<0.1
50	Xa50F	11.91	<0.1	54.09	0.31	31.32	0.092	<0.005	<0.005	0.063	<0.6	0.03	0.125	<0.1
51	Xa51F	7.73	<0.1	56.98	0.15	39.4	0.035	0.008	0.007	<0.02	<0.6	0.22	<0.03	<0.1
52	Xa52F	ICP-AES	<0.1	106.66	1.04	23.31	<0.01	<0.005	<0.005	<0.02	<0.6	<0.1	<0.03	<0.1
53	Xa53F	ICP-AES	<0.1	63.14	0.8	84.35	0.131	0.016	0.008	0.031	<0.6	<0.1	<0.03	<0.1
54	Xa54F	ICP-AES	<0.1	65.69	1.43	28.8	<0.01	<0.005	<0.005	<0.02	<0.6	<0.1	<0.03	<0.1
55	Xa55F	10.56	<0.1	58.92	0.68	3.56	<0.01	0.007	0.015	0.043	<0.6	0.55	0.05	<0.1
56	Xa56F	2.69	<0.1	53.21	0.36	7.22	<0.01	<0.005	<0.005	<0.02	<0.6	0.49	<0.03	<0.1
60	Xa60F	ICP-AES	<0.1	182.25	0.69	26.63	<0.01	<0.005	<0.005	0.052	0.61	0.17	0.065	<0.1
61	Xa61F	8.4	<0.1	56.56	0.36	3.55	<0.01	<0.005	<0.005	<0.02	<0.6	0.85	<0.03	<0.1
62	Xa62F	ICP-AES	<0.1	82.25	2.18	4.35	<0.01	<0.005	0.006	0.049	<0.6	0.12	0.336	7.23
63	Xa63F	ICP-AES	0.1	177.57	5.57	6.17	<0.01	0.049	0.114	0.048	6.07	<0.1	0.676	2.58
64	Xa64F	ICP-AES	0.12	245.8	5.83	1.14	<0.01	<0.005	0.017	0.026	1.29	0.16	0.106	1.33
65	Xa65F	ICP-AES	0.13	109.98	1.29	7.14	<0.01	<0.005	<0.005	<0.02	<0.6	<0.1	0.048	<0.1
66	XA66F	ICP-AES	0.13	67.24	0.27	4.01	<0.01	<0.005	<0.005	<0.02	<0.6	0.21	<0.03	<0.1

NB. No analyses performed on samples Xa34, 38, 45, 47, 57, 58, 59, 67 and 68 due to high salinity. ICP-AES=refer to Table 3.4 for ICPAES analysis

3.7 Bacterial Analyses, by Dr O.V. Karnachuk of Tomsk State University, Department of Plant Physiology and Biotechnology

Sample no.	Aerobic Saprophytes		Anaerobic Saprophytes		Sulphate Reducing Bacteria (SRB)	
	cells/ml		cells/ml		cells/ml	
Xa34	$28x10^{10}$	2.8E+11	$12x10^{6}$	1.2E+07	10^{7}	1E+07
35	$38x10^{7}$	3.8E+08	400	4.0E+02	0	0E+00
36	$32x10^{2}$	3.2E+03	500	5.0E+02	0	0E+00
37	$12x10^{5}$	1.2E+06	700	7.0E+02	10^{3}	1E+03
38	$70x10^{5}$	7.0E+06	$60x10^{4}$	6.0E+05	10^{7}	1E+07
39	$20x10^{5}$	2.0E+06	$20x10^{2}$	2.0E+03	10^{4}	1E+04
40	$45x10^{7}$	4.5E+08	$20x10^{2}$	2.0E+03	0	0E+00
41	$53x10^{8}$	5.3E+09	$20x10^{3}$	2.0E+04	10^{9}	1E+09
42	$14x10^{5}$	1.4E+06	200	2.0E+02	0	0E+00
43	$27x10^{3}$	2.7E+04	$32x10^{2}$	3.2E+03	10^{3}	1E+03
44	$72x10^{5}$	7.2E+06	100	1.0E+02	10^{2}	1E+02
45	$85x10^{2}$	8.5E+03	$50x10^{2}$	5.0E+03	1	1E+00
46	$21x10^{4}$	2.1E+05	$20x10^{4}$	2.0E+05	10^{4}	1E+04
47	$19x10^{3}$	1.9E+04	$40x10^{6}$	4.0E+07	10^{8}	1E+08
48	$94x10^{3}$	9.4E+04	$20x10^{4}$	2.0E+05	0	0E+00
49	$56x10^{3}$	5.6E+04	$2x10^{5}$	2.0E+05	10^{2}	1E+02
50	$61x10^{3}$	6.1E+04	$50x10^{3}$	5.0E+04	10^{4}	1E+04
51	$98x10^{3}$	9.8E+04	$12x10^{3}$	1.2E+04	10^{3}	1E+03
52	$30x10^{2}$	3.0E+03	1	1.0E+00	0	0E+00
53	$13x10^{6}$	1.3E+07	$2x10^{5}$	2.0E+05	10^{3}	1E+03
54	$88x10^{5}$	8.8E+06	$1x10^{4}$	1.0E+04	10^{4}	1E+04
55	$98x10^{3}$	9.8E+04	$4x10^{2}$	4.0E+02	0	0E+00
56	$66x10^{2}$	6.6E+03	21	2.1E+01	0	0E+00
57	nd	nd	$1x10^{5}$	1.0E+05	10^{4}	1E+04
58	nd	nd	$1x10^{3}$	1.0E+03	10^{3}	1E+03
59	30	3.0E+01	$6x10^{5}$	6.0E+05	0	0E+00
60	$87x10^{6}$	8.7E+07	$1x10^{4}$	1.0E+04	0	0E+00
61	$40x10^{2}$	4.0E+03	$18x10^{4}$	1.8E+05	0	0E+00
62	$14x10^{3}$	1.4E+04	5	5.0E+00	10	1E+01
63	$5x10^{2}$	5.0E+02	$12x10^{6}$	1.2E+07	0	0E+00
64	$71x10^{4}$	7.1E+05	$3x10^{4}$	3.0E+04	10	1E+01
65	$78x10^{2}$	7.8E+03	$1x10^{3}$	1.0E+03	0	0E+00
66	$27x10^{3}$	2.7E+04	$1x10^{5}$	1.0E+05	0	0E+00
67	$16x10^{2}$	1.6E+03	$2x10^{7}$	2.0E+07	10^{4}	1E+04
68	620	6.2E+02	$1x10^{7}$	1.0E+07	10^{4}	1E+04

nd = not determined

3.8 **Analyses of Evaporite Mineralisations by X-Ray Diffraction** (XRD) at NTNU, Trondheim

Sample No	Xa38	Xa41	Xa45	Xa47	Xa57	Xa58	Xa59
Locality	Lake Utinoe	Lake Chёrnoe	SW of Moskovskii	Lake Solenoe	Lake Ulugkol'	Lake Uskol'	Abakanskii 2 salt-well
Quartz	X	X	X	X	X	X	X
Plagioclase		X	X	X	X	X	X
K-feldspar		X	X	X	X	X	X
Thenardite	X	X	X	X	X	X	X
Mirabilite	X						
Calcite	X	X	X	X	X	X	X
Dolomite			X	X			
Mica		X	X				X
Gypsum							X
Halite				X	X	X	
Chlorite		X	X				
Kaolinite							X
Rozenite - $FeSO_4.4H_2O$ (?)						X	
Bernalite $Fe(OH)_3$ (?)							X
Ettringite (?)		X	X		X	X	

X = detection

3.9 Major Ion Chemistry

Sample no.	Mg	Ca	Na	K	Alkalinity	Cl^-	NO_3^-	SO_4^{2-}
	ppm	ppm	ppm	ppm	meq/l	mg/l	mg/l	mg/l
Xa34	83.7	18.4	7970	64.4	35.7	5586	<2.0	8041
35	5.66	80.7	3.59	2.47	3.7	34.4	6.44	5.29
36	8.38	60.2	5.41	<0.5	3.8	0.69	4.50	8.30
37	29.4	52.7	5.88	0.888	5.1	2.17	8.90	5.61
38	240	43.6	2790	37.7	14.2	1682	<0.05	4042
39	11.0	82.2	7.24	0.805	4.7	7.05	10.11	21.9
40	20.3	19.1	662	2.33	10.9	192	212.36	578
41	30.1	33.3	797	4.98	11.2	617	<0.05	530
42	21.2	47.6	16.0	1.03	4.5	1.95	1.51	14.5
43	35.2	75.7	15.7	1.46	6.2	5.13	4.89	63.0
44	33.3	68.6	15.2	1.37	5.6	4.48	4.29	49.7
45	65.1	95.3	1320	3.84	10.8	747	5.30	1939
46	82.0	87.7	553	3.59	6.8	84.9	24.58	1418
47	306	112	4130	15.4	14.3	1183	<0.8	8607
48	23.0	26.7	14.7	4.53	3.8	5.58	<0.05	0.91
49	30.6	59.8	25.9	2.43	6.5	8.39	15.01	11.9
50	13.8	69.7	18.3	1.18	4.4	7.75	7.28	46.0
51	21.3	63.6	27.9	1.57	4.5	14.3	20.22	41.5
52	21.1	93.2	19.4	1.89	4.1	6.27	6.51	154
53	10.2	67.6	13.5	1.58	3.9	7.43	9.32	41.4
54	33.1	63.8	32.1	2.82	5.2	16.7	6.24	73.8
55	31.8	74.5	46.4	2.83	6.3	24.2	11.28	90.0
56	28.7	64.6	26.9	1.21	6.5	3.83	5.34	40.2
57	178	4.21	11700	59.4	97.7	7645	<2.0	11052
58	15.7	4.48	7560	20.2	80.1	3471	<2.0	10765
59	1990	963	31700	83.2	5.9	56325	<50	8372
60	92.1	120	143	2.28	7.0	124	87.18	456
61	27.8	49.1	67.5	1.68	4.1	54.3	15.17	88.5
62	38.9	45.2	129	2.76	6.6	92.5	7.24	115
63	11.7	29.8	812	3.77	24.3	305	7.14	567
64	132	69.6	858	10.8	22.1	307	2.78	1135
65	80.4	126	79.7	3.12	6.7	96.8	28.67	331
66	13.1	53.1	133	<0.5	2.9	128	10.04	143
67	309	21.9	626	31.8	20.3	387	0.29	1333
68	1110	52.4	3320	37.3	16.7	2096	0.16	9765

3.10 Ion Balance / Quality Control

Sample no.	Location	Sum of anions (meq/l)	Sum of cations (meq/l)	Ion balance error (%)
34	Lake Kurinka	360.69	356.13	-0.64
35	Marble quarry	4.88	4.71	-1.79
36	Maina	4.06	3.93	-1.70
37	Bogoslovka	5.42	5.33	-0.87
38	Lake Utinoe	145.80	144.25	-0.54
39	Byeya Dairy	5.52	5.34	-1.61
40	Novotroitskaya	31.79	31.48	-0.49
41	Lake Chërnoe	39.65	38.93	-0.92
42	Tumannii	4.88	4.84	-0.40
43	Mount Amoga Spring	7.73	7.39	-2.25
44	Vershino-Bidzha Spring	6.83	6.86	0.22
45	SW of Moskovskii	72.34	67.63	-3.37
46	Khan Kul' borehole	39.11	35.27	-5.17
47	Lake Solenoe	226.87	210.81	-3.67
48	Lake Bulankul'	3.98	3.98	0.05
49	Sanatorium Bulankul'	7.23	6.69	-3.84
50	E of Pulankul'	5.69	5.44	-2.28
51	Vtoroi Kluch	6.09	6.18	0.71
52	Mount Timirtag	7.59	7.28	-2.08
53	Kharasug Spring	5.12	4.84	-2.82
54	Charkov	7.31	7.38	0.47
55	N of Charkov	9.04	8.43	-3.51
56	Ust' Kamisyak	7.53	6.79	-5.20
57	Lake Ulugkol'	543.50	525.30	-1.70
58	Lake Uskol'	402.10	330.87	-9.72
59	Abakanskii 2 salt-well	1769.07	1592.83	-5.24
60	Moskovskii Sovkhoz	21.38	19.85	-3.72
61	Byelii yar opencast	7.72	7.72	-0.02
62	Izikskii 1 Opencast	11.72	11.14	-2.56
63	Izikskii 2 Opencast	44.81	37.87	-8.40
64	Khakasskaya mine	54.44	51.93	-2.35
65	Znamenka	16.78	16.45	-0.99
66	Polindeika	9.65	9.51	-0.71
67	Lake Vlasyevo	58.96	54.57	-3.87
68	Lake Shira (kurort)	279.14	239.34	-7.68

Sum cations based on Na, Mg, Ca, K and pH
Sum anions based on $SO_4^{=}$, NO_3^-, Cl^- and alkalinity

4. ANALYTICAL RESULTS FROM SAMPLING OF 2000

4.1 Sampling and Analysis Routines

4.1.1 Water Sampling

As in the previous sampling round, water samples were taken, to the extent possible, from flowing sources (springs, rivers) or regularly-used wells and boreholes, to ensure that "fresh" groundwater was sampled. In the case of boreholes in use, the sample was typically taken from the nearest available tap to the well head. In a few cases, this would mean that the water had passed through a water tower or header tank prior to sampling. In one case, water was taken from a domestic dug well using a bucket (sample Xa76).

Field measurements were taken either in the flowing water source or, if this was not possible, in a large (c. 15 l) bucket filled directly from the source. Field determinations included:

- determination of alkalinity (by average of multiple determinations, typically three determinations) using a Hanna Instruments HI 3811 alkalinity kit. This employs titration using a 0.1% hydrochloric acid solution against 5 or 15 ml of water. A phenolphthalein indicator of turning point 8.3 is used to determine p-alkalinity, and a bromophenol blue indicator of turning point 4.5 to determine t-alkalinity
- pH using one or more of the following instruments: (a) Hanna HI 1280 Piccolo pH amplified electrode (only calibrated to pH 4 and 7) and (b) Hanna "pH Checker".
- Temperature using a Hanna "CheckTemp" thermistor-based electronic instrument. This suffered problems in the latter part of the sampling exercise, and the thermistor on an ELWRO Konduktometr N5721M was thereafter employed.

Samples for analysis at NGU were filtered at 0.45 µm, by a Millipore filter capsule and hand-held polypropylene syringe. One filtered sample of size c. 120 ml was taken in a polyethene screw-top bottle at each sampling location. No acidification was carried out in the field.

4.1.2 Sampling of Lake Shira

For sampling of lake water at Lake Shira, samples were taken at 2 m intervals, from 1 m to almost 19 m, using a double-barrel, weight activated, throughflow perspex depth sampler, belonging to the Krasnoyarsk Institute of Biophysics, from location N54°30.420' E90°12.384' (GPS reading) using a small motor-powered launch. The depth sampler was equipped with a mercury thermometer for temperature determinations, and taps at the bottom of the barrels for decanting of samples. These taps were used to take c. 120 ml filtered samples for analysis at NGU (as described below) for five of the depths sampled. At the same five depths, flasks of water were collected for immediate analysis of alkalinity when the boat came ashore, using the Hanna Instruments HI3811 kit.

Additionally, the following field analyses were made in the boat at every sample depth:

- temperature using the mercury thermometer in the depth sampler barrel
- pH using two pH meters

Olga V. Karnachuk of Tomsk State University's Department for Plant Physiology and Biotechnology also took a series of unfiltered samples in glass bottles from all sampled depths for the following analyses:

- for dissolved oxygen by the Winkler method. This was fixed immediately following sampling using alkaline manganese sulphate and potassium iodide. This fixes oxygen as manganese (III) hydroxide. Subsequent addition of acid generates iodine (I_2) in proportion to oxygen, which can be titrated with a solution of $Na_2S_2O_3$. Determinations were carried out on the day of sampling in the field lab of the Krasnoyarsk Institute of Biophysics at Lake Shira.
- for hydrogen sulphide (H_2S). This was fixed immediately following sampling, using zinc acetate. Sulphide was analysed in the lab at TGU within 3-4 days of sampling. Soluble sulphide was analysed using a methylene blue method, based on a colorimetric assay of dissolved H_2S and HS^-, using N,N-dimethyl-p-phenylenediamine (as dihydrochloride salt) as the chromophore (Cline 1969).
- in sterile glass bottles and vials for bacteriological analysis. These were kept in a refrigerator prior to analysis within no more than two weeks.

4.1.3 Analysis at Norges Geologiske Undersøkelse

Prior to analysis, samples were stored in a refrigerator at around 4°C, except for brief periods of transport. Samples were transported by David Banks to the NGU analytical laboratory in Trondheim, arriving on 2/10/00. Upon arrival, selected samples were subject to alkalinity determination, using the AquaMerck 11109 alkalinity titration kit (as a control of field measurements - see 4.3) and then the samples were stored in the NGU cool-room at 4°C. For analysis, the following procedure was followed:

- c. 10-20 ml water was taken from every flask and transferred to a separate flask. This non-acidified quantum was used for ion-chromatography (Dionex 120 DX machine) analyses of anions.
- The remaining volume ml was acidified with 0.5% concentrated Ultrapur HNO_3 *in the original flask*. This was done to hinder absorption / precipitation of (and dissolve already sorbed/precipitated) elements. This acidified quantum was used for ICP-AES

(Thermo Jarrell Ash ICP 61 machine) and ICP-MS (Finnegan Mat machine with Meinhart Nebulizer CD-1) analyses. Analyses were completed and reported by the end of November 2000.

4.1.4 Additional Analysis at Tomsk State University

Analytical determinations other than H_2S have been carried out on samples from Lake Shira at the Laboratory of Water Chemistry at the Institute of Civil Engineering at Tomsk. All compounds were determined by means of standard procedures prescribed by the Russian authorities for drinking water (GOST Voda pit'evaia 2874-82) on unfiltered samples within 2-3 days of sampling. All samples were kept in a refrigerator at 4°C prior to determinations. No fixing procedures were carried out on the samples.

- Sulphate was determined gravimetrically by precipitation as $BaSO_4$ (GOST 4389-72).
- Chloride was determined by titration with $Hg(NO_3)_2$ (GOST 4245-72).
- Photometric determinations have been performed for the following components:
  - orthophosphate with ammonium molybdate (ISO 6878/1-86);
  - ammonia with Nessler Reagent (ISO 7150/1-84);
  - nitrates with Na-salycilate (ISO 7890/3-88);
  - nitrites with Griess Reagent (ISO 6777-84).
- Total Fe was analysed photometrically with o-phenanthroline (ISO 6332-83) on unfiltered samples.
- Dry residue was analysed by drying in a water bath (GOST 18164-72)
- Mn permanganate oxidability was determined by titration with oxalic acid (ISO8467-86).

4.2 Designation of Samples to Lithological and Land Use Classes

Sample	Location	Type	Depth	Geology	H_2S	Land Use
			m		smell	
Xa70	Abaza mine	6	632	LPS	1	4
Xa71	Silver Spring II	3	0	LPS	0	2
Xa72	km 212	3	0	LPS	0	1
Xa73	Radon spring, km 223	3	0	LPS	0	1
Xa74	River Bolshoi On	7	0		0	1
Xa75	Matur borehole	1	90	D12	0	3
Xa76	Matur private well	5	6	Q	0	3
Xa77	River Matur	7	0	D12	0	2
Xa78	Baza DRSU Shepchul	1	35	D12	0	2
Xa79	River Bolshaya Syeya	7	0	D12	0	1
Xa80	Verkhnaya Syeya	1	30	D12	0	3
Xa81	Tashtip North	1	40	D12	0	3
Xa82	Imek North	1	100	D12	0	3
Xa83	River Tyeya	7	0	D3	0	1
Xa84	Vershina Tyei bore	1	35	LPS	0	1
Xa85	Mine stream, V. Tyei	6	0		0	4
Xa86	Mine water, V. Tyei	6	0		0	4
Xa87	Silver spring, Birikchul	3	0	C-O	0	1
Xa88	Kazanovka station	1	75	D12	0	3
Xa89	Askiz station	1	40	D3	0	3
Xa90	River Baza	7	0	D3	0	2
Xa91	River Son, Sonskii	7	0	LPV	0	2
Xa92	River Son, Katyushkino	7	0		0	1
Xa93	River Son, S. of Borets	7	0	D2	0	1
Xa94	River Son, d/s Borets	7	0	D2	0	1
Xa95	Oz. Shira, 0.05 m	4	0.05	D3	0	3
Xa96	Oz. Shira, 3 m	4	3	D3	0	3
Xa97	Oz. Shira, 9 m	4	9	D3	0	3
Xa98	Oz. Shira, 13 m	4	13	D3	2	3
Xa99	Oz. Shira, 18.4 m	4	18.4	D3	2	3

Type
1 = Pumped borehole
2 = Artesian borehole
3 = Spring
4 = Lake
5 = Dug Well
6 = Mine Water
7 = River / stream

Depth = depth of borehole / well or depth of sampling in mine or lake. Springs and rivers have depth set to 0 m.

Geology = dominant bedrock geological type
LPS = Precambrian or Lower Palaeozoic metasedimentary rocks
LPV = Lower Palaeozoic volcanics
C-O = Cambro-Ordovician granitoids

	D12 = Lower-Middle Devonian sedimentary rocks
	D3 = Upper Devonian Sedimentary rocks
	Q = well in Quaternary deposits
H_2S	0 = No obvious smell
	1 = Some H_2S smell
	2 = strong H_2S smell
Land Use	1 = rural
	2 = agriculture / cattle pasture or station
	3 = urban / periurban
	4 = mining

4.3 Field Analyses of Waters (pH, Temperature, Eh, Alkalinity)

Field alkalinity measurements using Hanna Instruments Alkalinity kit

Sample	Field alkalinity measurements using Hanna Instruments Alkalinity kit							
	t-Alk						p-Alk	
	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Average	Average		
	mg/l $CaCO_3$	mg/l $CaCO_3$	mg/l $CaCO_3$	mg/l $CaCO_3$	mg/l $CaCO_3$	meq/l	mg/l $CaCO_3$	meq/l
Xa70	27	21	20	22	21	0.4	0	0.0
Xa71	135	135	150		140	2.8		
Xa72	171	156	180		169	3.4		
Xa73	117	126	126		123	2.5		
Xa74	30	31	31		31	0.6		
Xa75	216	216			216	4.3		
Xa76	306	321	324		317	6.3		
Xa77	219	225	222		222	4.4	0	0.0
Xa78	276	270	270		272	5.4		
Xa79	192	183	189		188	3.8		
Xa80	246	234	246		242	4.8		
Xa81	270	270	279		273	5.5		
Xa82	264	258	258		260	5.2		
Xa83	123	132			128	2.5	9	0.2
Xa84	120	123	120		121	2.4		
Xa85	114	117	120		117	2.3		
Xa86	120	117	114		117	2.3		
Xa87	141	141	144		142	2.8		
Xa88	165	165	159		163	3.3		
Xa89	240	243	243		242	4.8		
Xa90	213	213	210		212	4.2		
Xa91	174	186	189	195	186	3.7		
Xa92	255	261	252		256	5.1		
Xa93	342	345			344	6.9		
Xa94	372	348	357		359	7.2		
Xa95	930	915	900		915	18.3	144	2.9
Xa96	885	891	882		886	17.7		
Xa97	990	1005			998	19.9		
Xa98	1035	1032	1017		1028	20.5		
Xa99	1065	1065			1065	21.3	144	2.9

Field measurements with Hanna HI 3811 alkalinity test kit, utilising a titration reaction between 0.1% HCl with 5 or 15 ml water, and a phenolphthalein indicator (end point pH 8.3) for p-alk, or a bromophenol blue indicator (end point pH 4.5) for t-alk.
Meas. 1, 2, 3, 4 = measurements 1, 2, 3, 4

Laboratory alkalinity determined using AquaMerck 11109 kit at Norges Geologiske Undersøkelse 2/10/00

	t-alkalinity measured in lab.			p-alkalinity measured in lab.		
	meq/l	meq/l	meq/l	meq/l	meq/l	meq/l
	Measurement 1	Measurement 2	Average	Measurement 1	Measurement 2	Average
Xa89F	5.0		5.0			
Xa90F	4.1		4.1			
Xa91F	3.9		3.9			
Xa92F	4.7		4.7			
Xa93F	6.8		6.8			
Xa94F	6.7		6.7			
Xa95F	17.1	16.9	17.0	2.9		2.9
Xa96F	17.5		17.5	4.1		4.1
Xa97F	19.5		19.5	3.9		3.9
Xa98F	20.2		20.2	3.9		3.9
Xa99F	19.3		19.3	3.8		3.8

Notes: these results are in general accordance with field measurements

These measurements with AquaMerck alkalinity kit 11109, using acid titration with 5 ml water, and phenolphthalein indicator (end point pH 8.2) for p-alk and mixed indicator (end point pH 4.3) for t-alk.

Analysed 2/10/00

Field pH and Temperature

Sample	Temp. (Hanna)	Temp. (ELWRO)	Temp. (thermom.)	pH (1)	pH (2)	pH (used)	Temp. (used)
	°C	°C					°C
Xa70	16.0			6.9	7.0	6.95	16.0
Xa71	8.3			7.25	7.4	7.33	8.3
Xa72	7.5			8.0	8.2	8.10	7.5
Xa73	4.1			7.75	7.76	7.76	4.1
Xa74	6.1			7.95	8.05	8.00	6.1
Xa75	5.8			7.5	7.6	7.55	5.8
Xa76	7.5			7.25	7.3	7.28	7.5
Xa77	11.4			8.3	8.45	8.38	11.4
Xa78	6.0			7.15	7.5	7.33	6.0
Xa79	13.1			8.4	8.55	8.48	13.1
Xa80	7.5			7.35	7.68	7.52	7.5
Xa81	9.8			7.3	7.6	7.45	9.8
Xa82	14.5			7.3	7.44	7.37	14.5
Xa83	15.7			8.7	8.9	8.80	15.7
Xa84	4.9			7.75	8.1	7.93	4.9
Xa85	3.3			7.4	7.6	7.50	3.3
Xa86	11.0			7.85		7.85	11.0
Xa87	1.3			7.75		7.75	4.5
Xa88	6.7			7.3	7.58	7.44	9.9
Xa89	0.8	4.0		7.41	7.64	7.53	4.0
Xa90		7.0		8.25	8.69	8.47	7.0
Xa91		7.2		8.20	8.30	8.25	7.2
Xa92		6.8		8.50	8.58	8.54	6.8
Xa93		6.3		8.25	8.40	8.33	6.3
Xa94		4.8		8.55	8.72	8.64	4.8
Xa95			17.8	8.91	8.81	8.86	17.8
Xa96			17.3	8.92	8.88	8.90	17.3
Xa97			7.9	8.92	8.91	8.92	7.9
Xa98			2.0	8.85	8.86	8.86	2.0
Xa99			1.6	8.74	8.77	8.76	1.6

pH measured using a Hanna Instruments "pH Checker" electrode calibrated daily to pH 7 and pH10, and also a Hanna HI 1280 Piccolo amplified electrode, calibrated previously between pH 4 and pH 7, but recalibrated daily to pH 7. These are designated pH(1) / pH(2)

In most cases the lower pH was measured using the Hanna "pH Checker" and the higher using the Hanna HI 1280 Piccolo pH amplified electrode. In samples Xa95, 96 and 97, the Piccolo gave the slightly lower reading.

Temperature measured initially (Xa70-Xa89) using a Hanna "CheckTemp" electrode. This malfunctioned around Xa87. Subsequently the temperature electrode on an ELWRO Konduktometr N5721M was used. Temperatures for the former electrode for Xa87 to Xa89 have been corrected by adding 3.2°C to attain agreement with the ELWRO meter.

Temperatures in Lake Shira (Xa95-Xa99) were measured by a permanently installed mercury thermometer in the depth sampler's Perspex barrel.

Temp.(used) and pH(used) are values used in database and data interpretation.

4.4 Analyses of Shira Lake Profile

4.4.1 Field Determinations

Depth (m)	pH1	pH2	pH (ave.)	Temp. (°C)	H_2S	t-Alkalinity (meq/l)	Sample no.
0.05	8.91	8.81	8.86	17.8	0	18.3	Xa95F
1	8.91	8.87	8.89	17.4	0		
3	8.92	8.88	8.90	17.3	0	17.7	Xa96F
5	8.93	8.89	8.91	17.2	0		
7	8.91	8.90	8.91	16.1	0		
9	8.92	8.91	8.92	7.9	0	19.9	Xa97F
11	8.87	8.91	8.89	3.1	0		
13	8.85	8.86	8.86	2.0	2	20.5	Xa98F
15	8.81	8.82	8.82	1.7	2		
17	8.81	8.77	8.79	1.7	2		
18.4	8.74	8.77	8.76	1.6	2	21.3	Xa99F

pH1 = Wayne's pH meter; Hanna "pH Checker"

pH2 = Olga's pH meter; Hanna HI 1280 Piccolo pH amplified electrode.

Temperature measured by mercury thermometer installed in Perspex sample cylinder

H_2S: 0 = no smell, 1 = some smell, 2 = strong smell

4.4.2 Chemical Determinations by Tomsk State University

Depth (m)	Sample no	Diss. O_2 mg/l	Diss. H_2S mg/l	NH_4^+ mg/l	NO_3^- mg/l	NO_2^- mg/l	NH_4^+-N mg/l	NO_3^--N mg/l	NO_2^--N mg/l	N-total mg/l
0.05	Xa95F	9.6	<	2.07	<0.18	<0.004	1.61	<0.041	<0.001	1.61
1		9.6	<	2.25	<0.18	<0.004	1.76	<0.041	<0.001	1.76
3	Xa96F	9.55	<	4.42	<0.18	<0.004	3.45	<0.041	<0.001	3.45
5		9.6	<	1.96	<0.18	0.004	1.53	<0.041	0.001	1.53
7		10.82	<	2.33	<0.18	0.004	1.82	<0.041	0.001	1.82
9	Xa97F	13.48	<	2.25	<0.18	0.015	1.76	<0.041	0.005	1.76
11		6.95	0.412	3.21	<0.18	0.026	2.50	<0.041	0.008	2.51
13	Xa98F	<	1.094	3.46	<0.18	0.015	2.70	<0.041	0.005	2.70
15		<	7.21	3.45	<0.18	0.017	2.69	<0.041	0.005	2.70
17		<	14.7	5.05	<0.18	0.014	3.94	<0.041	0.004	3.94
18.4	Xa99F	<	18.5	6.64	<0.18	0.006	5.18	<0.041	0.002	5.18

Depth (m)	N-total (mg/l)	PO_4^{3-} (mg/l)	PO_4^{3-}-P (mg/l)	Inorganic N/P ratio	$SO_4^{=}$ (g/l)	Cl^- (g/l)	$SO_4^{=}/Cl^-$ ratio	Fe total (mg/l)	Permanganate oxidation, (mgO/l)	Dry residue (mg/l)
0.05	1.61	0.48	0.16	10.2	8.23	1.42	5.81	1.09	6.72	19312
1	1.76	0.19	0.06	27.8	9.04	1.44	6.28	0.96	6.8	18705
3	3.45	0.17	0.05	63.3	9.15	1.44	6.36	0.93	6.8	18737
5	1.53	0.31	0.10	15.0	9.26	1.45	6.39	1.18	6.56	18646
7	1.82	0.41	0.13	13.5	9.72	1.42	6.83	1.29	6.56	18480
9	1.76	0.47	0.15	11.4	10.36	1.50	6.91	2.65	6.96	20278
11	2.51	0.43	0.14	17.7	9.62	1.58	6.08	1.82	6.45	20911
13	2.70	0.46	0.15	18.0	9.97	1.53	6.53	1.34	6.05	21363
15	2.70	0.48	0.16	17.1	9.48	1.58	5.99	1.05	3.69	21816
17	3.94	0.48	0.16	25.2	9.49	1.58	6.00	0.96	7.48	22210
18.4	5.18	0.52	0.17	30.1	9.30	1.58	5.89	2.00	11.5	22479

4.4.3 Bacteriological Determinations by Tomsk State University

Depth (m)	Aerobic saprophytes (cells/ml)	Sulphate reducing bacteria $\log_{10}$(cell/ml)	Anaerobic saprophytes (cell/ml)
0.05	30433	3	2.0E+05
1	nd	nd	nd
3	25067	7	3.0E+06
5	602	7	2.0E+05
7	248	7	3.0E+05
9	578	7	3.0E+06
11	528	7	3.0E+06
13	292000	10	2.0E+01
15	650	10	2.0E+07
17	50	10	2.0E+06
18.4	26	10	3.0E+07

4.4.4 Inter-laboratory Comparison of Water Quality, Lake Shira

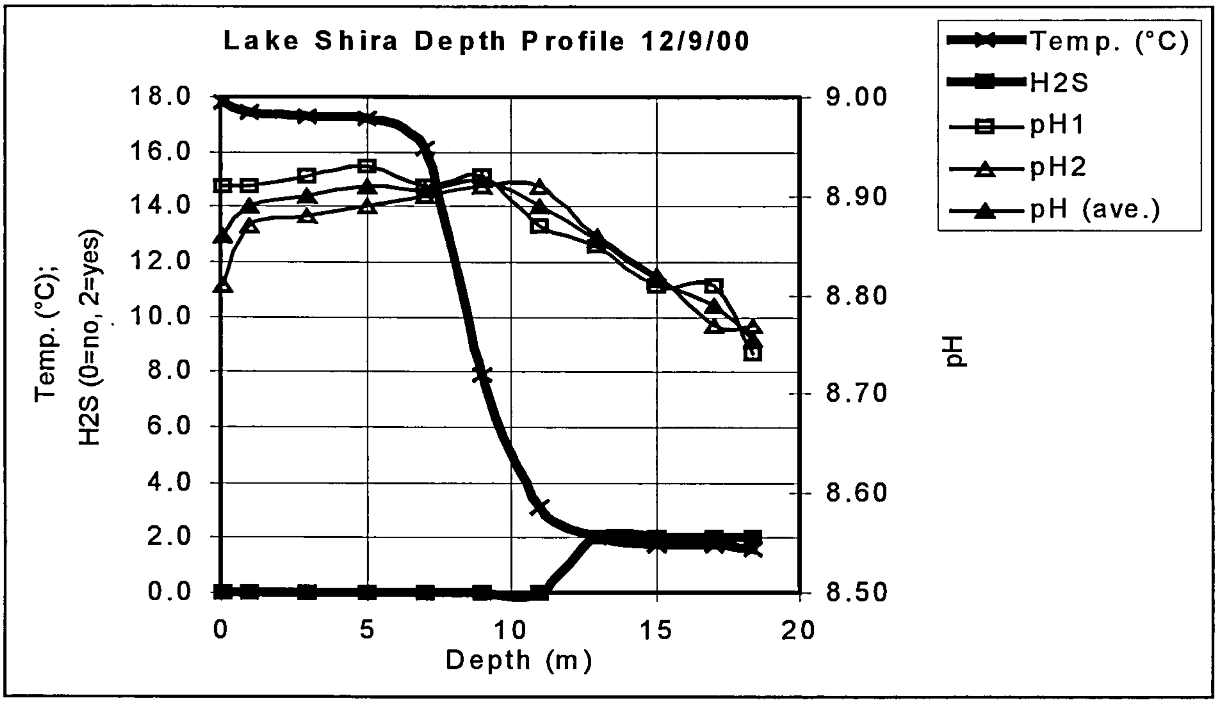
Sample no	NO_3^-		PO_4^{3-}		Cl^-		SO_4^{2-}		Fe	
	mg/l	mg/l	mg/l	mg/l	g/l	mg/l	g/l	mg/l	mg/l	mg/l
	TGU	NGU	TGU	NGU	TGU	NGU	TGU	NGU	TGU	NGU
Xa95F	<0.18	< 0.05	0.48	< 1.6	1.42	2000	8.23	9625	1.09	<0.01
Xa96F	<0.18	< 0.05	0.17	< 1.6	1.44	2047	9.15	9862	0.93	<0.01
Xa97F	<0.18	< 0.05	0.47	< 1.6	1.50	2299	10.36	10627	2.65	<0.01
Xa98F	<0.18	< 0.05	0.46	< 1.6	1.53	2331	9.97	10892	1.34	<0.01
Xa99F	<0.18	< 0.05	0.52	< 1.6	1.58	2401	9.30	10895	2.00	<0.01

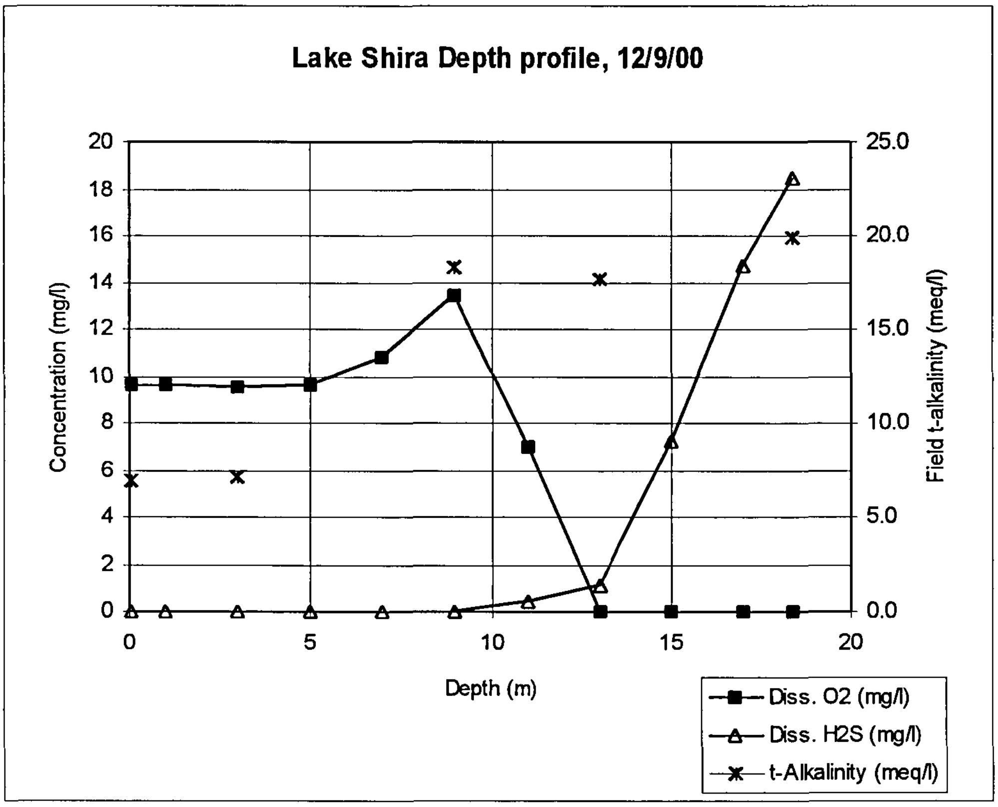
The above table compares results of analyses of nitrate, sulphate, phosphate, chloride and iron at the facilities of Tomsk State University (TGU) with the same parameters analysed by ion chromatography (nitrate, phosphate, chloride and sulphate) and ICP-AES (iron) at the Geological Survey of Norway (Tables 4.5 and 4.6). It will be seen from the table that reproducibility is rather poor, especially in the case of iron. The discrepancy in the case of iron may be related to a filtration effect (total iron by TGU) and dissolved iron (<0.45 μm) by NGU.

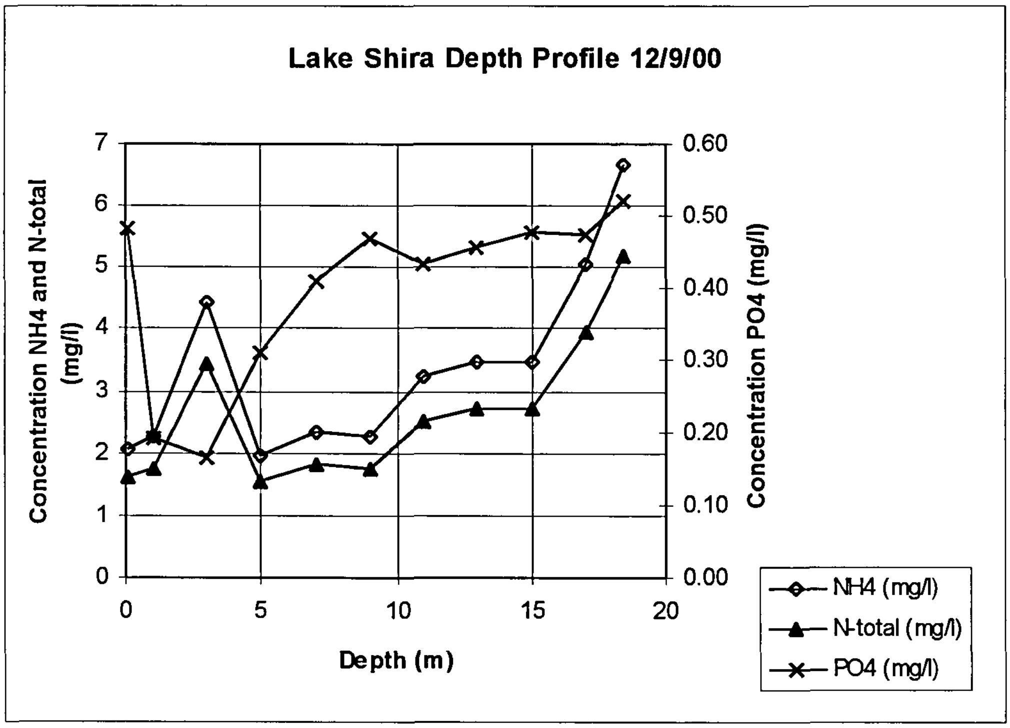
Lake Shira is characterised as a eutrophic water body (Degermendzhy et al. 1996). This fact suggests an elevated concentration of organic matter in the water column and the possibility that much of the iron may be complexed with organic matter. These complexes may have been excluded from 0.45 μm filtered samples, but included in the determinations of iron by Tomsk State University.

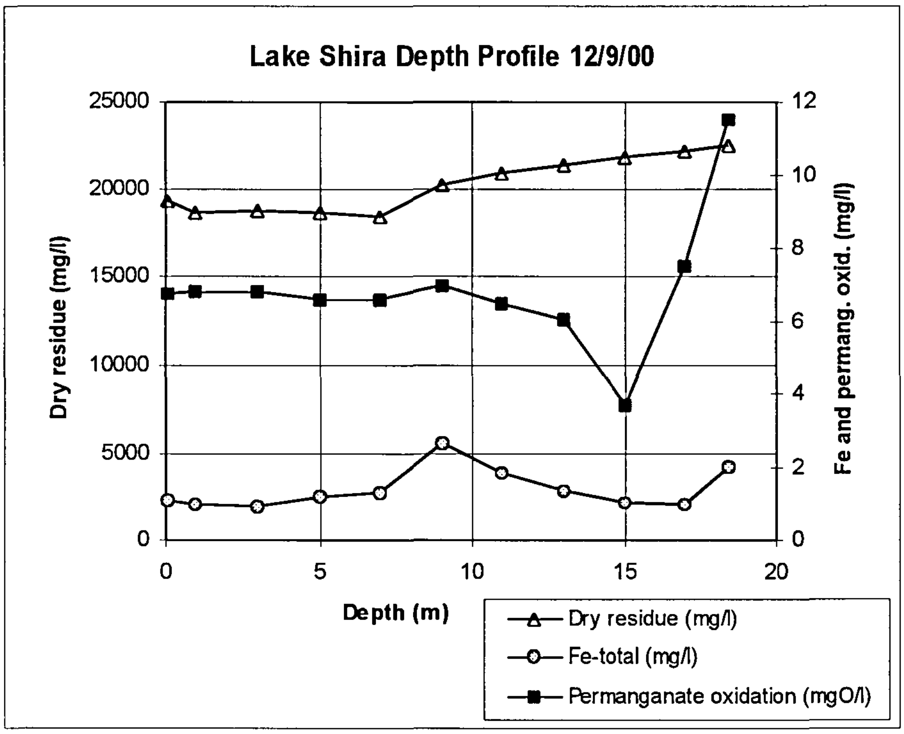
4.4.5 Graphical Presentation of Depth Profiles of Lake Shira

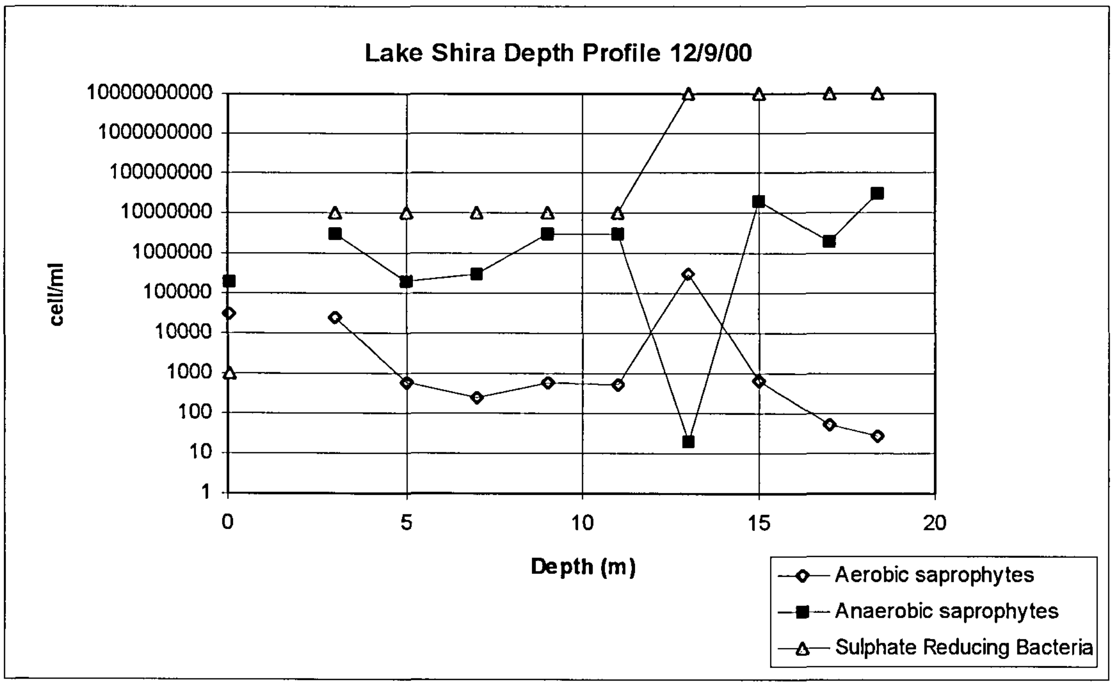
The following profiles are compiled on the basis of field determinations and TGU analyses culled from Tables in Sections 4.4.1, 4.4.2 and 4.4.3.




Lake Shira Depth profile, 12/9/00
Concentration (mg/l)
Field t-alkalinity (meq/l)
Depth (m)
Diss. O2 (mg/l)
Diss. H2S (mg/l)
t-Alkalinity (meq/l)
0
2
4
6
8
10
12
14
16
18
20
0.0
5.0
10.0
15.0
20.0
25.0
0
5
10
15
20


Lake Shira Depth Profile 12/9/00
Concentration NH4 and N-total (mg/l)
Concentration PO4 (mg/l)
Depth (m)
NH4 (mg/l)
N-total (mg/l)
PO4 (mg/l)
0
1
2
3
4
5
6
7
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0
5
10
15
20


Lake Shira Depth Profile 12/9/00
Dry residue (mg/l)
Fe and permang. oxid. (mg/l)
Depth (m)
Dry residue (mg/l)
Fe-total (mg/l)
Permanganate oxidation (mgO/l)


Lake Shira Depth Profile 12/9/00
cell/ml
Depth (m)
Aerobic saprophytes
Anaerobic saprophytes
Sulphate Reducing Bacteria

4.5 Analyses of Waters by ICP-AES at Norges Geologiske Undersøkelse

Sample	Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni	Co	V
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Xa70	5.16	<0.02	0.0187	<0.005	0.863	59.8	171	1.34	0.00261	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa71	6.67	<0.02	<0.01	<0.005	11.5	45.4	13.7	0.956	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa72	5.38	<0.02	<0.01	<0.005	13.1	77.0	4.13	1.51	0.00411	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa73	4.30	<0.02	<0.01	<0.005	8.06	60.8	2.82	0.841	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa74	2.01	<0.02	<0.01	<0.005	1.34	10.3	0.933	<0.5	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa75	5.55	<0.02	<0.01	<0.005	18.5	101	6.40	0.816	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa76	6.44	<0.02	<0.01	<0.005	30.8	232	40.1	1.93	0.224	<0.1	<0.005	0.00310	<0.05	<0.02	<0.01	<0.005
Xa77	5.78	<0.02	<0.01	<0.005	18.5	101	7.54	0.708	0.0119	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa78	5.52	<0.02	<0.01	<0.005	17.0	127	7.11	0.968	<0.001	<0.1	<0.005	0.0226	<0.05	<0.02	<0.01	<0.005
Xa79	4.22	<0.02	<0.01	<0.005	10.5	74.6	5.64	0.997	0.0136	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa80	6.54	<0.02	0.0170	<0.005	19.4	114	7.37	1.07	0.00439	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa81	6.43	<0.02	<0.01	<0.005	29.6	108	37.7	1.43	<0.001	<0.1	<0.005	0.0223	<0.05	<0.02	<0.01	<0.005
Xa82	5.73	<0.02	0.112	<0.005	42.3	150	67.2	2.03	0.0106	<0.1	<0.005	0.0344	<0.05	<0.02	<0.01	<0.005
Xa83	3.29	<0.02	<0.01	<0.005	9.16	48.3	5.82	1.00	0.00302	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa84	4.32	<0.02	<0.01	<0.005	10.5	48.8	1.90	0.617	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa85	3.66	<0.02	<0.01	<0.005	140	232	11.0	7.03	0.00480	<0.1	<0.005	0.00204	<0.05	<0.02	<0.01	0.00765
Xa86	3.81	<0.02	0.0136	<0.005	51.9	114	14.5	10.8	0.0314	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa87	6.94	<0.02	<0.01	<0.005	9.94	62.8	6.46	0.674	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa88	5.65	<0.02	0.0340	<0.005	77.1	201	69.5	4.54	0.00370	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa89	5.27	<0.02	<0.01	<0.005	43.3	116	102	3.99	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa90	3.87	<0.02	<0.01	<0.005	20.1	69.6	7.36	1.36	0.00233	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa91	5.69	<0.02	<0.01	<0.005	11.3	59.0	3.86	0.807	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa92	5.36	<0.02	<0.01	<0.005	22.1	81.7	7.26	1.66	0.00137	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa93	6.79	<0.02	0.0170	<0.005	33.2	82.1	31.6	1.79	0.0117	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa94	6.11	<0.02	0.0136	<0.005	39.8	85.4	42.2	1.73	0.0151	<0.1	<0.005	<0.002	<0.05	<0.02	<0.01	<0.005
Xa95	0.762	<0.02	<0.01	<0.005	1270	50.2	3701	39.3	0.00974	<0.1	<0.005	0.00576	<0.05	<0.02	<0.01	0.0358
Xa96	0.770	<0.02	<0.01	<0.005	1280	50.5	3707	39.3	0.0104	<0.1	<0.005	0.0237	<0.05	<0.02	<0.01	0.0341
Xa97	1.67	<0.02	<0.01	<0.005	1460	53.3	4190	44.1	0.0118	<0.1	<0.005	0.0199	<0.05	<0.02	<0.01	0.0359
Xa98	2.17	<0.02	<0.01	<0.005	1470	54.0	4161	44.9	0.0454	<0.1	<0.005	0.00842	<0.05	<0.02	<0.01	0.0359
Xa99	3.34	<0.02	<0.01	<0.005	1410	53.3	4214	43.3	0.0266	<0.1	<0.005	0.00727	<0.05	<0.02	<0.01	0.0385

Sample	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Xa70	0.0259	<0.005	<0.01	0.0118	0.861	<0.005	<0.01	2.20	<0.001	0.0217	<0.001	<0.05	<0.01	<0.001
Xa71	<0.01	<0.005	<0.01	0.00755	0.190	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa72	<0.01	<0.005	<0.01	0.0397	0.456	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa73	<0.01	<0.005	<0.01	0.0125	0.297	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa74	<0.01	<0.005	<0.01	0.00328	0.0381	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa75	<0.01	<0.005	<0.01	0.261	0.840	<0.005	<0.01	<0.02	<0.001	0.00612	<0.001	<0.05	<0.01	<0.001
Xa76	<0.01	<0.005	<0.01	0.171	1.88	<0.005	<0.01	<0.02	<0.001	0.0122	<0.001	0.105	<0.01	<0.001
Xa77	<0.01	<0.005	<0.01	0.188	0.954	<0.005	<0.01	<0.02	<0.001	0.00890	<0.001	<0.05	<0.01	<0.001
Xa78	<0.01	<0.005	<0.01	0.0952	0.437	<0.005	<0.01	0.0202	<0.001	0.0139	<0.001	0.0592	<0.01	<0.001
Xa79	<0.01	<0.005	<0.01	0.131	0.759	<0.005	<0.01	<0.02	<0.001	0.00556	<0.001	<0.05	<0.01	<0.001
Xa80	<0.01	<0.005	<0.01	0.133	1.06	<0.005	<0.01	<0.02	<0.001	0.00501	<0.001	<0.05	<0.01	<0.001
Xa81	<0.01	<0.005	<0.01	0.0722	4.25	<0.005	<0.01	0.0343	<0.001	0.0200	<0.001	0.0647	<0.01	<0.001
Xa82	<0.01	<0.005	<0.01	0.0131	1.49	<0.005	<0.01	0.0606	<0.001	0.0211	<0.001	0.0698	<0.01	<0.001
Xa83	<0.01	<0.005	<0.01	0.0703	0.473	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa84	<0.01	<0.005	<0.01	0.0552	0.107	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa85	1.02	<0.005	<0.01	0.0726	0.968	<0.005	<0.01	0.0485	<0.001	<0.005	<0.001	0.106	<0.01	<0.001
Xa86	0.495	<0.005	<0.01	0.0154	1.10	<0.005	<0.01	0.420	<0.001	<0.005	<0.001	0.0556	<0.01	<0.001
Xa87	<0.01	<0.005	<0.01	0.103	0.370	<0.005	<0.01	<0.02	<0.001	0.00779	<0.001	<0.05	<0.01	<0.001
Xa88	<0.01	<0.005	<0.01	0.00788	9.82	<0.005	<0.01	0.0727	<0.001	0.0378	<0.001	0.177	<0.01	<0.001
Xa89	<0.01	<0.005	<0.01	0.0194	3.95	<0.005	<0.01	0.141	<0.001	0.0401	<0.001	0.0607	<0.01	<0.001
Xa90	<0.01	<0.005	<0.01	0.0588	0.433	<0.005	<0.01	<0.02	<0.001	0.00501	<0.001	<0.05	<0.01	<0.001
Xa91	<0.01	<0.005	<0.01	0.0204	0.373	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa92	<0.01	<0.005	<0.01	0.0243	0.604	<0.005	<0.01	<0.02	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa93	<0.01	<0.005	<0.01	0.0430	1.01	<0.005	<0.01	0.0343	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Xa94	<0.01	<0.005	<0.01	0.0424	1.21	<0.005	<0.01	0.0565	<0.001	0.00668	<0.001	<0.05	<0.01	<0.001
Xa95	<0.01	<0.005	<0.01	0.00821	5.74	<0.005	<0.01	2.25	<0.001	0.196	<0.001	<0.05	<0.01	<0.001
Xa96	<0.01	<0.005	<0.01	0.00821	5.77	<0.005	<0.01	2.27	<0.001	0.199	<0.001	<0.05	<0.01	<0.001
Xa97	<0.01	<0.005	<0.01	0.00427	6.41	<0.005	<0.01	2.54	<0.001	0.224	<0.001	<0.05	<0.01	<0.001
Xa98	<0.01	<0.005	<0.01	0.00887	6.44	<0.005	<0.01	2.59	<0.001	0.226	<0.001	<0.05	<0.01	<0.001
Xa99	<0.01	<0.005	<0.01	0.00821	6.22	<0.005	<0.01	2.53	<0.001	0.221	<0.001	<0.05	<0.01	<0.001

4.6 Analyses of Waters by Ion Chromatography at Norges Geologiske Undersøkelse

Sample	Location	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Xa70	Abaza mine	3.23	148	< 0.05	1.26	0.13	< 0.2	219
Xa71	Silver Spring II	0.18	6.88	< 0.05	< 0.1	0.71	< 0.2	6.27
Xa72	km 212	0.09	1.12	< 0.05	< 0.1	1.41	< 0.2	11.2
Xa73	Radon spring, km 223	0.07	0.55	< 0.05	< 0.1	2.09	< 0.2	5.98
Xa74	River Bolshoi On	< 0.05	0.15	< 0.05	< 0.1	0.96	< 0.2	1.7
Xa75	Matur borehole	0.14	2.8	< 0.05	< 0.1	13.0	< 0.2	8.24
Xa76	Matur private well	0.1	75.1	< 0.05	0.11	39.6	< 0.2	150
Xa77	River Matur	0.12	0.84	< 0.05	< 0.1	0.8	< 0.2	37.8
Xa78	Baza DRSU Shepchul	0.25	0.32	< 0.05	< 0.1	1.66	< 0.2	7.97
Xa79	River Bolshaya Syeya	0.09	1.03	< 0.05	< 0.1	< 0.05	< 0.2	24.8
Xa80	Verkhnaya Syeya	0.14	5.64	< 0.05	< 0.1	7.86	< 0.2	25.0
Xa81	Tashtip North	0.36	3.77	< 0.05	< 0.1	9.93	< 0.2	36.9
Xa82	Imek North	0.3	28.0	< 0.05	0.26	23.6	< 0.2	256
Xa83	River Tyeya	0.11	4.43	< 0.05	< 0.1	1.19	< 0.2	36.4
Xa84	Vershina Tyei bore	< 0.05	0.47	< 0.05	< 0.1	2.22	< 0.2	6.97
Xa85	Mine stream, V. Tyei	0.33	12.7	< 0.05	0.15	93.0	< 0.2	988
Xa86	Mine water, V. Tyei	1.54	19.1	2.44	0.18	31.6	< 0.2	312
Xa87	Silver spring, Birikchul	0.3	1.1	< 0.05	< 0.1	3.55	< 0.2	20.6
Xa88	Kazanovka station	0.25	93.1	< 0.05	0.34	27.8	< 0.2	618
Xa89	Askiz station	0.33	75.8	< 0.05	0.27	26.0	< 0.2	199
Xa90	River Baza	0.26	2.48	< 0.05	< 0.1	2.11	< 0.2	18.0
Xa91	River Son, Sonskii	0.37	0.53	< 0.05	< 0.1	< 0.05	< 0.2	20.0
Xa92	River Son, Katyushkino	0.43	5.11	< 0.05	< 0.1	3.41	< 0.2	33.3
Xa93	River Son, S. of Borets	0.7	8.66	< 0.05	0.19	0.6	< 0.2	68.0
Xa94	River Son, d/s Borets	0.69	14.5	< 0.05	0.18	0.34	< 0.2	98.0
Xa95	Oz. Shira, 0.05 m	< 2.0	2000	< 1	12.5	< 0.05	< 1.6	9625
Xa96	Oz. Shira, 3 m	< 2.0	2047	< 1	14.0	< 0.05	< 1.6	9862
Xa97	Oz. Shira, 9 m	< 2.0	2299	< 1	16.1	< 0.05	< 1.6	10627
Xa98	Oz. Shira, 13 m	< 2.0	2331	< 1	16.4	< 0.05	< 1.6	10892
Xa99	Oz. Shira, 18.4 m	< 2.0	2401	< 1	16.3	< 0.05	< 1.6	10895

Analyses for nitrite (NO_2^-) are regarded as invalid due to period between sampling and analysis.

4.7 Analyses by ICP-MS at Norges Geologiske Undersøkelse (all results µg/l)

Sample	Li	Be	B	Rb	Zr	Mo	Cd	La	Ce	Pb	Al	Cr	Co	Ni
Xa70	13.84	<0.1	ICP-AES	0.92	0.28	31.92	0.083	0.049	0.058	0.086	10	<0.1	<0.03	<0.1
Xa71	0.45	<0.1	42.14	0.06	<0.1	1.01	<0.01	0.014	0.017	<0.02	<0.5	<0.1	<0.03	0.14
Xa72	0.46	<0.1	13.51	0.21	<0.1	1.24	0.017	0.013	0.017	<0.02	<0.5	0.34	<0.03	0.23
Xa73	<0.2	<0.1	6.79	0.25	<0.1	3.02	0.014	0.023	0.016	<0.02	<0.5	0.35	<0.03	<0.1
Xa74	<0.2	<0.1	2.93	0.38	<0.1	<0.5	<0.01	0.044	0.034	<0.02	9.11	<0.1	<0.03	<0.1
Xa75	2.63	<0.1	11.29	0.25	<0.1	3.39	0.015	0.033	0.018	<0.02	<0.5	0.15	<0.03	<0.1
Xa76	5.85	<0.1	26.03	0.11	<0.1	0.69	0.037	0.053	0.048	<0.02	<0.5	<0.1	0.116	1.75
Xa77	5.21	<0.1	15.91	0.23	<0.1	1.22	0.011	0.039	0.039	<0.02	0.62	<0.1	<0.03	0.14
Xa78	6.23	<0.1	23.27	0.56	<0.1	0.79	<0.01	0.016	0.018	<0.02	<0.5	<0.1	<0.03	<0.1
Xa79	2.72	<0.1	12.1	0.3	<0.1	1.82	<0.01	0.047	0.048	<0.02	1.9	<0.1	<0.03	0.17
Xa80	2.3	<0.1	17.93	1.12	<0.1	1.77	<0.01	0.019	0.02	<0.02	0.68	0.54	<0.03	0.17
Xa81	11.05	<0.1	37.47	0.55	<0.1	3.35	0.012	0.025	0.03	<0.02	<0.5	<0.1	<0.03	<0.1
Xa82	13.16	<0.1	57.43	0.79	<0.1	2.78	0.019	0.018	0.025	<0.02	<0.5	<0.1	0.062	0.19
Xa83	1.48	<0.1	14.29	0.4	<0.1	10.45	0.033	0.025	0.033	<0.02	0.68	<0.1	0.035	<0.1
Xa84	<0.2	<0.1	2.24	0.06	<0.1	0.93	<0.01	0.014	0.012	<0.02	1.78	0.5	<0.03	<0.1
Xa85	0.27	<0.1	63.62	8.7	<0.1	ICP-AES	2.562	0.047	0.029	<0.02	0.79	<0.1	0.951	0.92
Xa86	1.52	<0.1	ICP-AES	31.85	<0.1	ICP-AES	1.18	0.01	0.015	<0.02	1.089	<0.1	0.827	3.23
Xa87	4.46	<0.1	22.33	0.06	<0.1	8.63	0.025	0.018	0.01	<0.02	<0.5	<0.1	<0.03	<0.1
Xa88	28.45	<0.1	84.37	2.99	<0.1	7.52	0.023	0.02	0.031	<0.02	<0.5	<0.1	0.047	<0.1
Xa89	29.7	<0.1	153.71	1.31	0.16	6.67	0.018	0.019	0.025	<0.02	<0.5	<0.1	0.037	<0.1
Xa90	1.59	<0.1	21.35	0.22	<0.1	2.38	<0.01	0.018	0.031	<0.02	1.22	<0.1	<0.03	<0.1
Xa91	2.22	<0.1	11.74	0.24	<0.1	3.64	0.018	0.018	0.02	0.043	<0.5	<0.1	<0.03	<0.1
Xa92	1.04	<0.1	28.58	0.11	<0.1	2.07	<0.01	0.02	0.033	<0.02	0.55	<0.1	<0.03	0.11
Xa93	2.28	<0.1	47.91	0.25	<0.1	2.26	<0.01	0.02	0.026	<0.02	<0.5	<0.1	0.058	0.14
Xa94	5.24	<0.1	59.98	0.31	<0.1	2.43	<0.01	0.019	0.031	<0.02	<0.5	<0.1	0.089	0.23
Xa95	ICP-AES	<0.1	ICP-AES	3.48	1.44	7.25	<0.01	0.243	0.247	0.254	<0.5	<0.1	0.038	<0.1
Xa96	ICP-AES	<0.1	ICP-AES	3.48	1.43	6.95	0.039	0.277	0.309	0.424	<0.5	<0.1	0.062	19.71
Xa97	ICP-AES	<0.1	ICP-AES	4.04	1.58	8.02	0.039	0.442	0.451	0.505	<0.5	<0.1	0.039	3.59
Xa98	ICP-AES	<0.1	ICP-AES	3.87	1.62	7.28	0.019	0.49	0.532	0.582	<0.5	<0.1	<0.03	3.38
Xa99	ICP-AES	<0.1	ICP-AES	3.99	1.55	6.58	0.012	0.626	0.652	0.785	<0.5	<0.1	<0.03	12.94

NB: The cadmium results appear systematically too high. ICP-AES = refer to Table 4.5 for ICP-AES results

4.8 **Bacterial Analyses**, by Dr O.V. Karnachuk of Tomsk State University, Department of Plant Physiology and Biotechnology

Sample	Aerobic saprophytes	
	cell/ml	
Xa70F	72 x 10^3	7.2E+04
Xa71F	49 x10^2	4.9E+03
Xa72F	94 x 10^3	9.4E+04
Xa73F	71 x 10^3	7.1E+04
Xa74F	17 x 10^4	1.7E+05
Xa75F	24 x 10^4	2.4E+05
Xa76F	15 x 10^3	1.5E+04
Xa77F	56 x 10^4	5.6E+05
Xa78F	28 x 10^6	2.8E+07
Xa79F	49 x 10^4	4.9E+05
Xa80F	18 x 10^6	1.8E+07
Xa81F	42 x 10^4	4.2E+05
Xa82F	71 x 10^3	7.1E+04
Xa83F	12 x 10^3	1.2E+04
Xa84F	53 x 10^3	5.3E+04
Xa85F	95 x 10^4	9.5E+05
Xa86F	40 x 10^4	4.0E+05
Xa87F	12 x 10^4	1.2E+05
Xa88F	12 x 10^4	1.2E+05
Xa89F	89 x 10^5	8.9E+06
Xa90F	61 x 10^4	6.1E+05
Xa91F	92 x 10^3	9.2E+04
Xa92F	51 x 10^3	5.1E+04
Xa93F	92 x 10^3	9.2E+04
Xa94F	67 x 10^3	6.7E+04
Xa95F	30 x 10^3	3.0E+04
Xa96F	25 x 10^3	2.5E+04
XA97F	578	5.8E+02
XA98F	292 x 10^3	2.9E+05
XA99F	26	2.6E+01

4.9 Major Ion Chemistry

Sample	Location	Mg	Ca	Na	K	Alkalinity	Cl^-	NO_3^-	SO_4^{2-}
		ppm	ppm	ppm	ppm	meq/l	mg/l	mg/l	mg/l
Xa70	Abaza mine	0.863	59.8	171	1.34	0.4	148	0.13	219
Xa71	Silver Spring II	11.5	45.4	13.7	0.956	2.8	6.88	0.71	6.27
Xa72	km 212	13.1	77.0	4.13	1.51	3.4	1.12	1.41	11.2
Xa73	Radon spring, km 223	8.06	60.8	2.82	0.841	2.5	0.55	2.09	5.98
Xa74	River Bolshoi On	1.34	10.3	0.933	<0.5	0.6	0.15	0.96	1.7
Xa75	Matur borehole	18.5	101	6.40	0.816	4.3	2.8	13.0	8.24
Xa76	Matur private well	30.8	232	40.1	1.93	6.3	75.1	39.6	150
Xa77	River Matur	18.5	101	7.54	0.708	4.4	0.84	0.8	37.8
Xa78	Baza DRSU Shepchul	17.0	127	7.11	0.968	5.4	0.32	1.66	7.97
Xa79	River Bolshaya Syeya	10.5	74.6	5.64	0.997	3.8	1.03	< 0.05	24.8
Xa80	Verkhnaya Syeya	19.4	114	7.37	1.07	4.8	5.64	7.86	25.0
Xa81	Tashtip North	29.6	108	37.7	1.43	5.5	3.77	9.93	36.9
Xa82	Imek North	42.3	150	67.2	2.03	5.2	28.0	23.6	256
Xa83	River Tyeya	9.16	48.3	5.82	1.00	2.5	4.43	1.19	36.4
Xa84	Vershina Tyei bore	10.5	48.8	1.90	0.617	2.4	0.47	2.22	6.97
Xa85	Mine stream, V. Tyei	140	232	11.0	7.03	2.3	12.7	93.0	988
Xa86	Mine water, V. Tyei	51.9	114	14.5	10.8	2.3	19.1	31.6	312
Xa87	Silver spring, Birikchul	9.94	62.8	6.46	0.674	2.8	1.1	3.55	20.6
Xa88	Kazanovka station	77.1	201	69.5	4.54	3.3	93.1	27.8	618
Xa89	Askiz station	43.3	116	102	3.99	4.8	75.8	26.0	199
Xa90	River Baza	20.1	69.6	7.36	1.36	4.2	2.48	2.11	18.0
Xa91	River Son, Sonskii	11.3	59.0	3.86	0.807	3.7	0.53	< 0.05	20.0
Xa92	River Son, Katyushkino	22.1	81.7	7.26	1.66	5.1	5.11	3.41	33.3
Xa93	River Son, S. of Borets	33.2	82.1	31.6	1.79	6.9	8.66	0.6	68.0
Xa94	River Son, d/s Borets	39.8	85.4	42.2	1.73	7.2	14.5	0.34	98.0
Xa95	Oz. Shira, 0.05 m	1270	50.2	3701	39.3	18.3	2000	< 0.05	9625
Xa96	Oz. Shira, 3 m	1280	50.5	3707	39.3	17.7	2047	< 0.05	9862
Xa97	Oz. Shira, 9 m	1460	53.3	4190	44.1	19.9	2299	< 0.05	10627
Xa98	Oz. Shira, 13 m	1470	54.0	4161	44.9	20.5	2331	< 0.05	10892
Xa99	Oz. Shira, 18.4 m	1410	53.3	4214	43.3	21.3	2401	< 0.05	10895

4.10 Ion Balance / Quality Control

Sample	Location	Sum of anions	Sum of cations	Error
		meq/l	meq/l	%
Xa70	Abaza mine	9.16	10.53	6.97
Xa71	Silver Spring II	3.13	3.83	10.02
Xa72	km 212	3.66	5.14	16.74
Xa73	Radon spring, km 223	2.63	3.84	18.68
Xa74	River Bolshoi On	0.67	0.66	-0.24
Xa75	Matur borehole	4.78	6.86	17.91
Xa76	Matur private well	12.21	15.90	13.12
Xa77	River Matur	5.26	6.91	13.54
Xa78	Baza DRSU Shepchul	5.64	8.07	17.75
Xa79	River Bolshaya Syeya	4.30	4.86	6.06
Xa80	Verkhnaya Syeya	5.64	7.63	14.99
Xa81	Tashtip North	6.49	9.50	18.82
Xa82	Imek North	11.70	13.94	8.75
Xa83	River Tyeya	3.45	3.44	-0.11
Xa84	Vershina Tyei bore	2.61	3.40	13.06
Xa85	Mine stream, V. Tyei	24.77	23.75	-2.10
Xa86	Mine water, V. Tyei	9.88	10.86	4.73
Xa87	Silver spring, Birikchul	3.35	4.25	11.77
Xa88	Kazanovka station	19.20	19.51	0.80
Xa89	Askiz station	11.54	13.89	9.25
Xa90	River Baza	4.72	5.48	7.51
Xa91	River Son, Sonskii	4.15	4.06	-1.05
Xa92	River Son, Katyushkino	6.01	6.25	1.99
Xa93	River Son, S. of Borets	8.53	8.25	-1.71
Xa94	River Son, d/s Borets	9.63	9.41	-1.13
Xa95	Oz. Shira, 0.05 m	275.10	268.93	-1.13
Xa96	Oz. Shira, 3 m	280.78	270.03	-1.95
Xa97	Oz. Shira, 9 m	306.04	306.11	0.01
Xa98	Oz. Shira, 13 m	313.07	305.72	-1.19
Xa99	Oz. Shira, 18.4 m	315.85	303.02	-2.07

Anion sum calculated on basis of nitrate, sulphate, chloride, alkalinity
Cation sum calculated on basis of calcium, magnesium, sodium and potassium

5. INTERPRETATION AND CONCLUSIONS

This report documents the geochemical and microbiological data on water samples collected during field expeditions during the summers of 1999 and 2000 to the Republic of Khakassia (Russian Federation) in southern Siberia. Data have been obtained from groundwater (boreholes, springs, wells), rivers and lakes. It is not the purpose of this report to indulge in detailed interpretation of the data presented. However, statistical presentations of the data, according to land use, sample type and dominant geology can be found in Appendices D-I. The following main observations may be noted:

1. A preliminary interpretation of the data suggests an evolutionary pathway from groundwater to surface waters and lakes involving up-concentration of highly soluble solutes (sodium, sulphate, chloride, boron, magnesium), and removal of silicon and calcium by precipitation of mineral phases.
2. There is also a tendency to elevated pH and alkalinity in surface waters, which has yet to be satisfactorily understood. It is believed that this observation forms the key to understanding hydrochemical evolution in the study area and it will be the focus of subsequent interpretation.
3. There are clear indications of sulphate reduction processes occurring in saline lakes and lake sediments.
4. Mineral samples from lake / marsh areas have been analysed by XRD, which analyses confirm the formation of thin secondary evaporite crusts around lakes, comprising thenardite, calcite, dolomite and halite. In single cases, gypsum and mirabilite were detected.
5. Analyses also suggest that groundwaters in villages have a tendency towards elevated nitrate levels and bacterial counts, possibly resulting from contamination from latrines.
6. Analyses were also made of mine waters from coal mines in the Abakan-Chernogorsk syncline and from metalliferous mines at Abaza and Vershina Tyei. These mine waters had relatively high pH and low metals contents, due to the buffering nature of ambient groundwater and ore host rocks.

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FIGURES

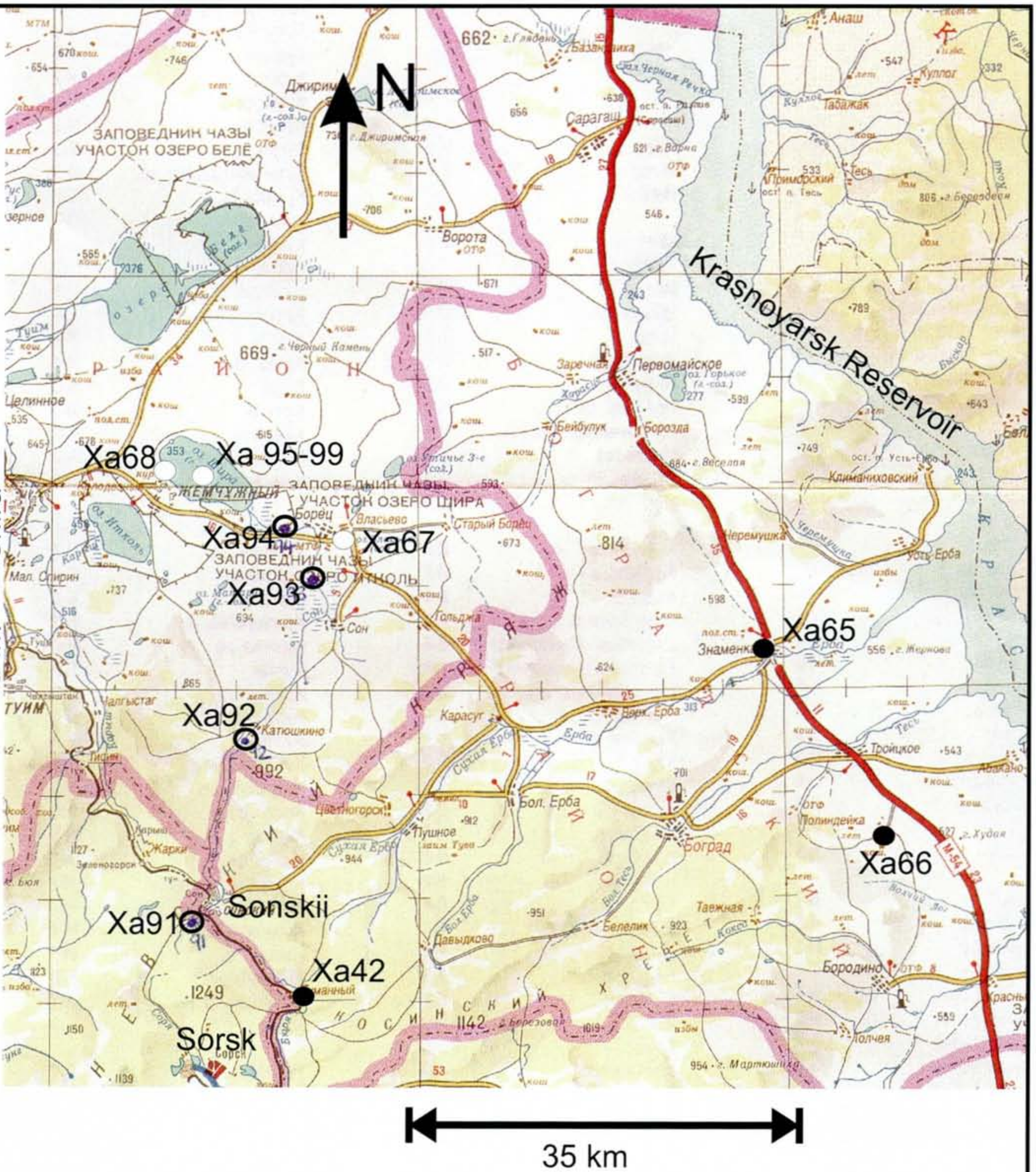


Figure 2.1. Sample locations, Shira region.

- Groundwater (spring, well, borehole)
- River / stream water
- Lake water
- Mine water

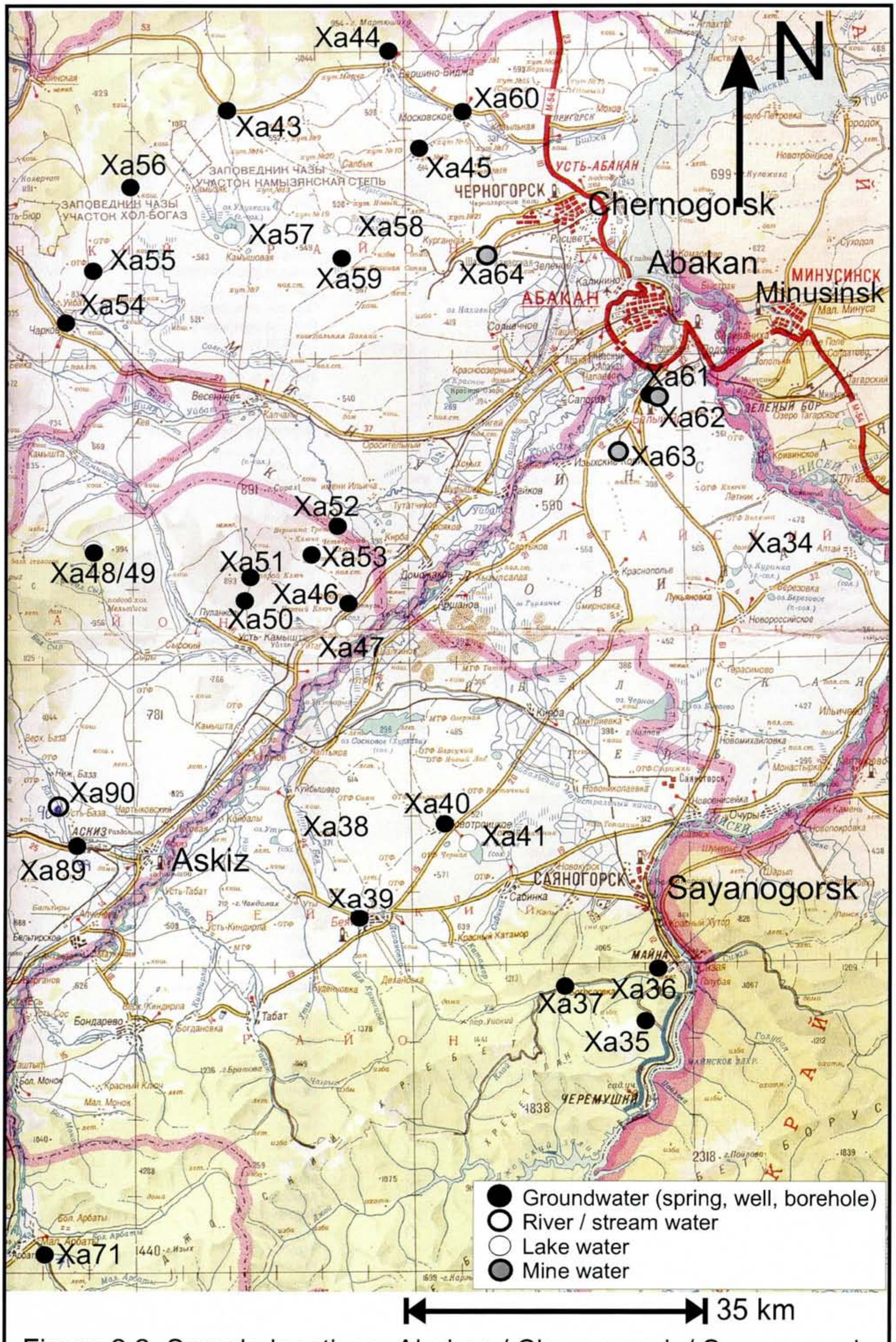


Figure 2.2. Sample locations. Abakan / Chernogorsk / Sayanogorsk

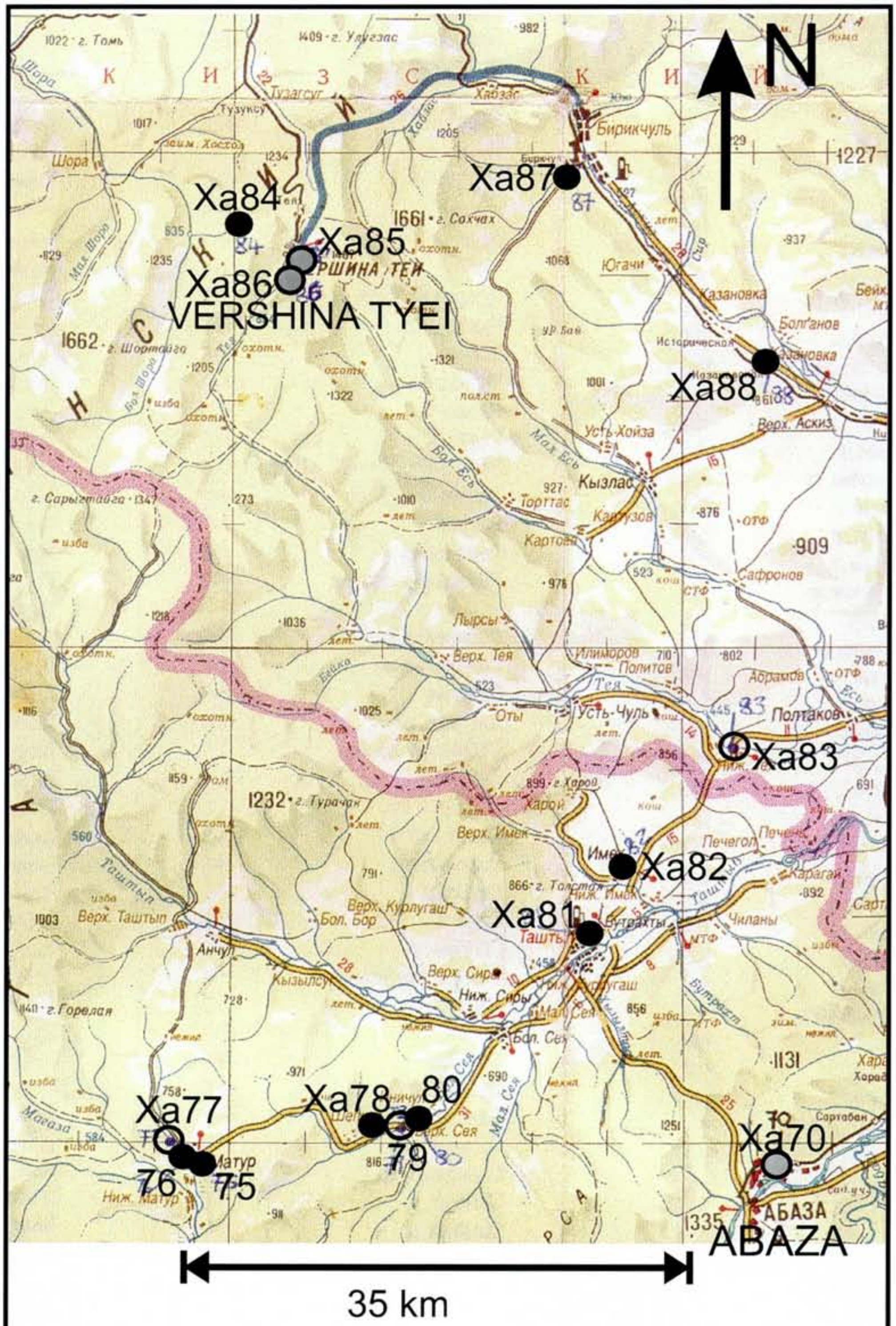


Figure 2.3. Sample locations. Vershina Tyei / Abaza

- ● Groundwater (spring, well, borehole)
- ○ River / stream water
- ● Mine water

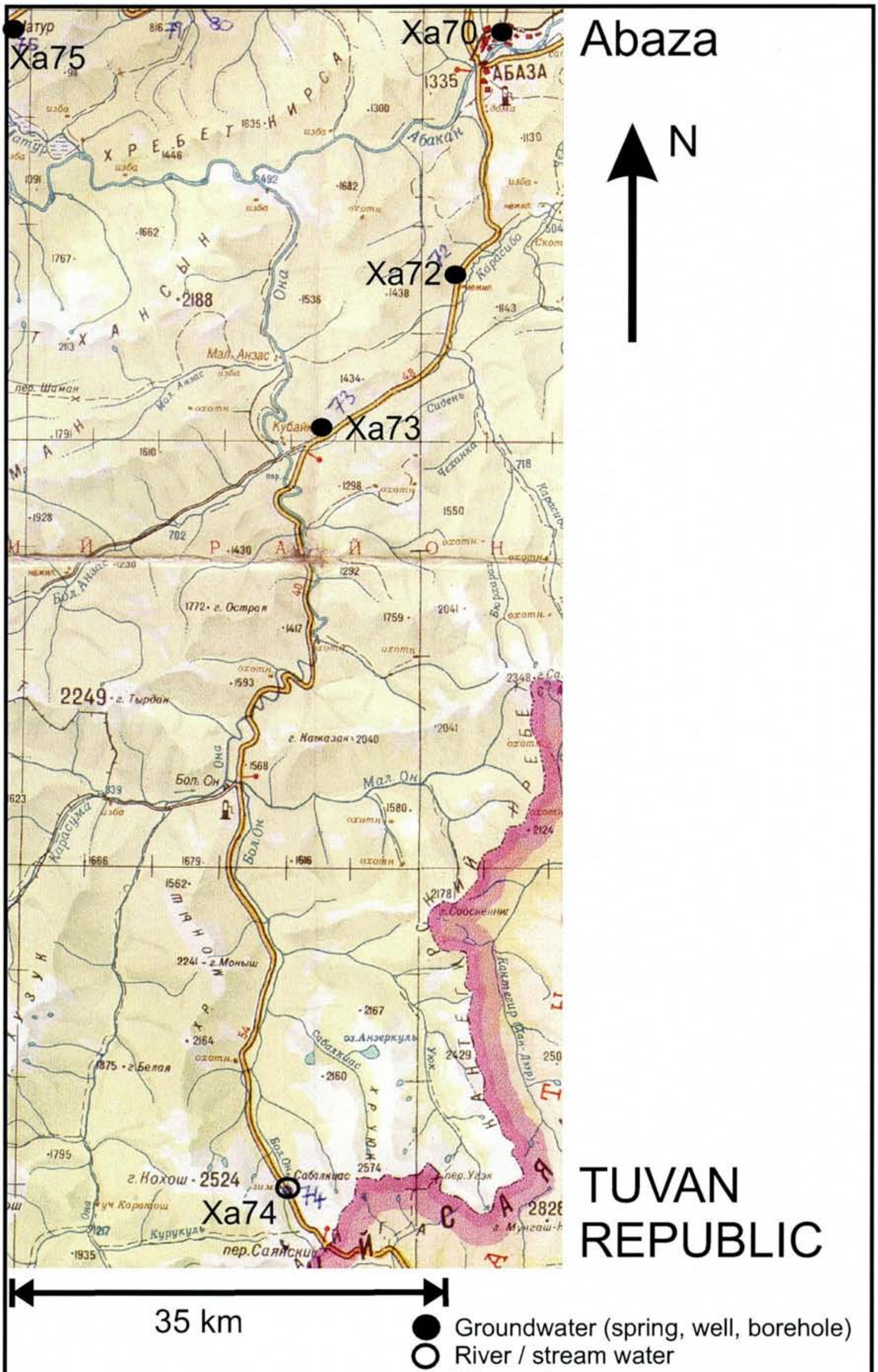


Figure 2.4. Sample locations south of Abaza

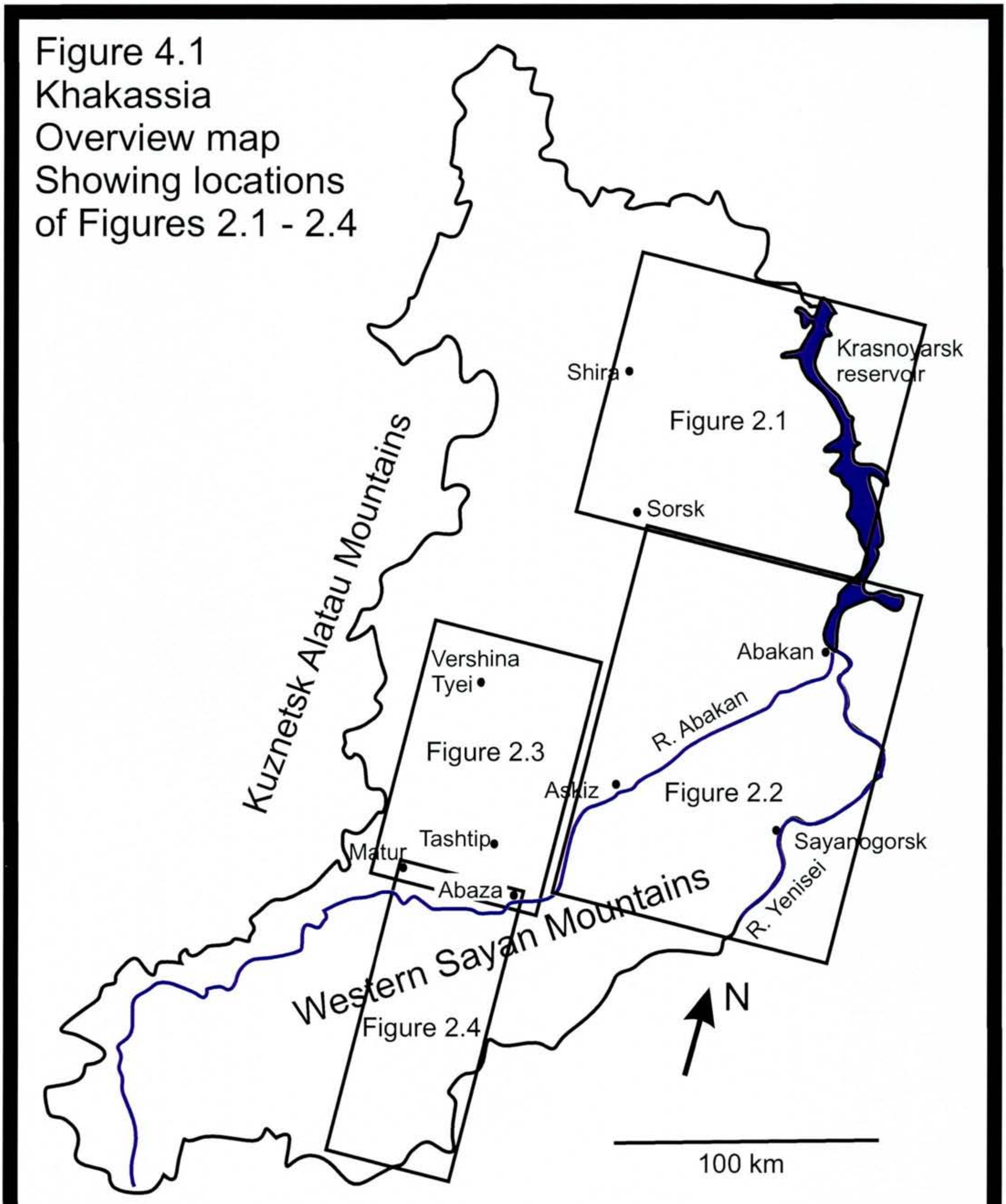


Figure 4.1
Khakassia
Overview map
Showing locations
of Figures 2.1 - 2.4
Krasnoyarsk
reservoir
Shira
Figure 2.1
Sorsk
Kuznetsk Alatau Mountains
Abakan
Vershina
Tyei
R. Abakan
Figure 2.3
Askiz
Figure 2.2
Tashtip
Sayanogorsk
Matur
Abaza
Western Sayan Mountains
R. Yenisei
N
Figure 2.4
100 km

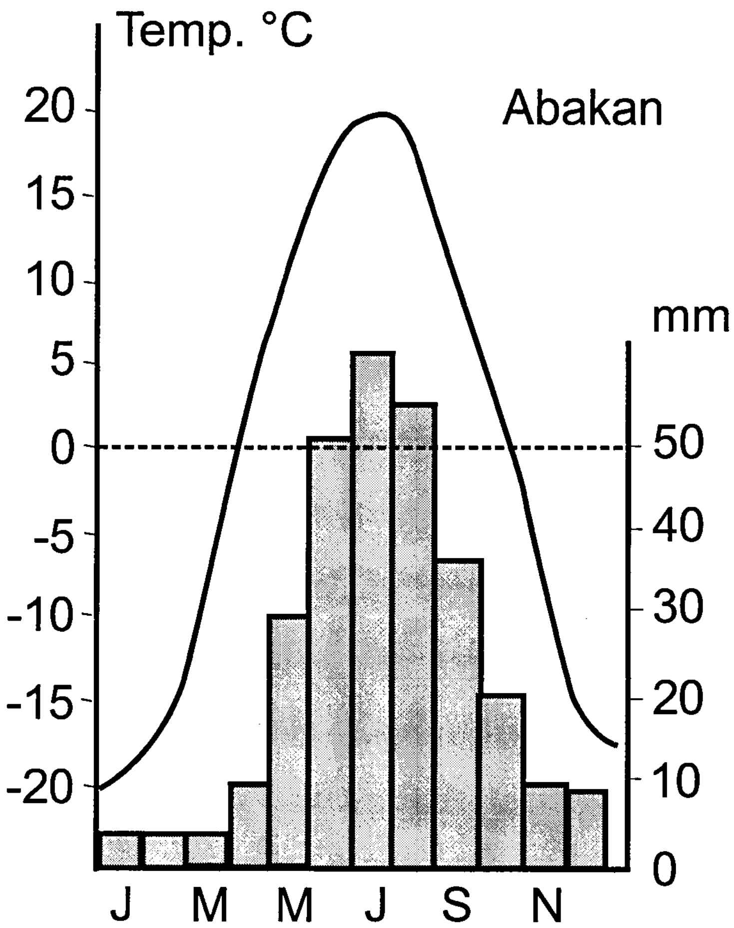


Figure 4.2. Average seasonal variation in temperature and precipitation at Abakan (after Balakhchina et al. 1999)

Figure 4.3
Khakassia
Average annual
precipitation (mm)
(after Balakhchina et al. 1999)

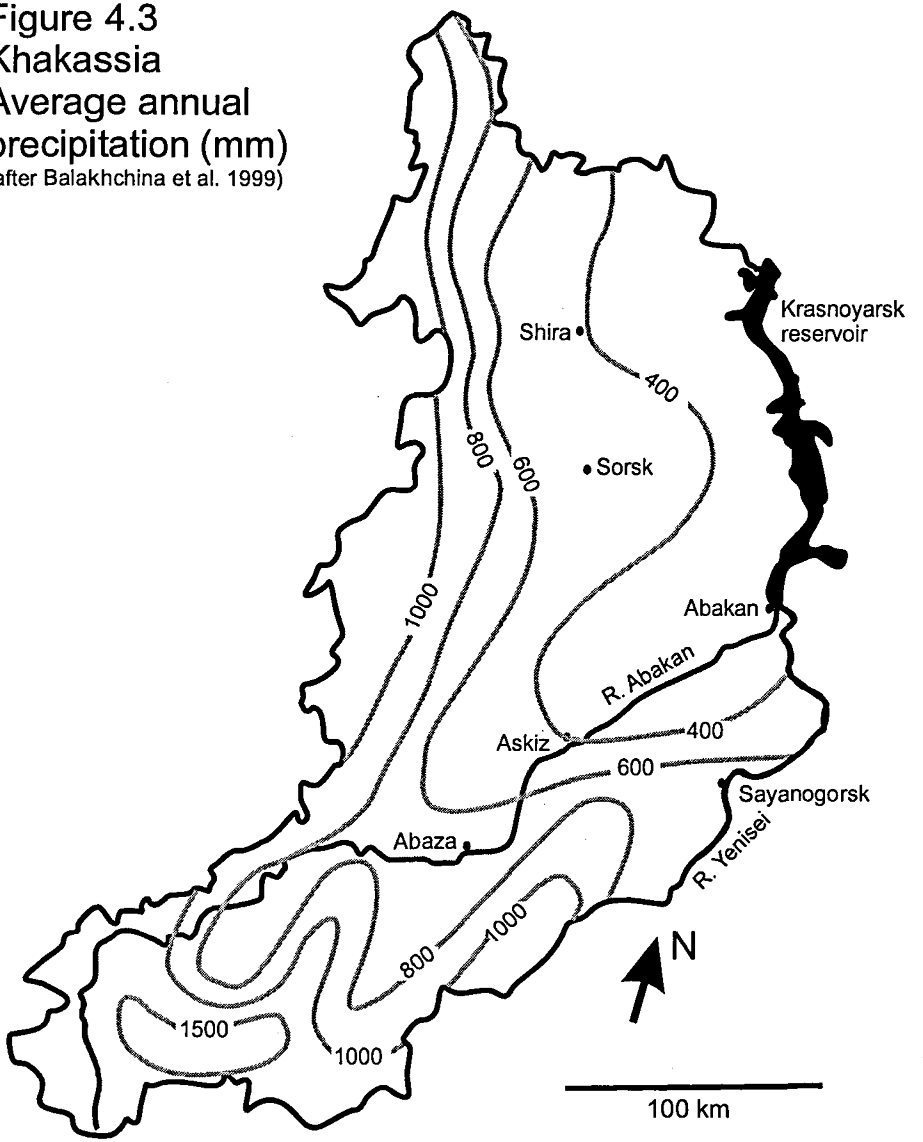


Figure 4.4.
Khakassia
Temperature
distribution
(after Balakhchina et al. 1999)

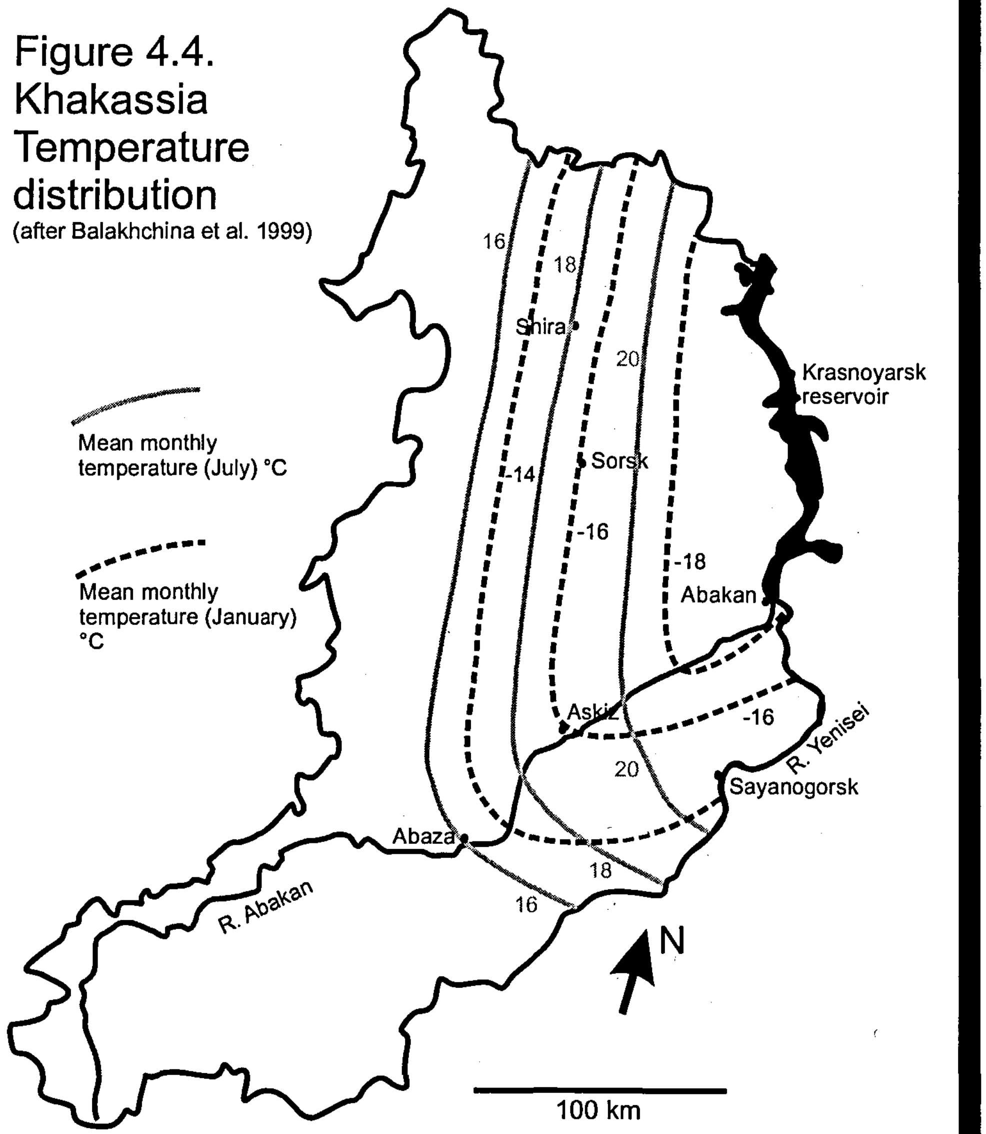
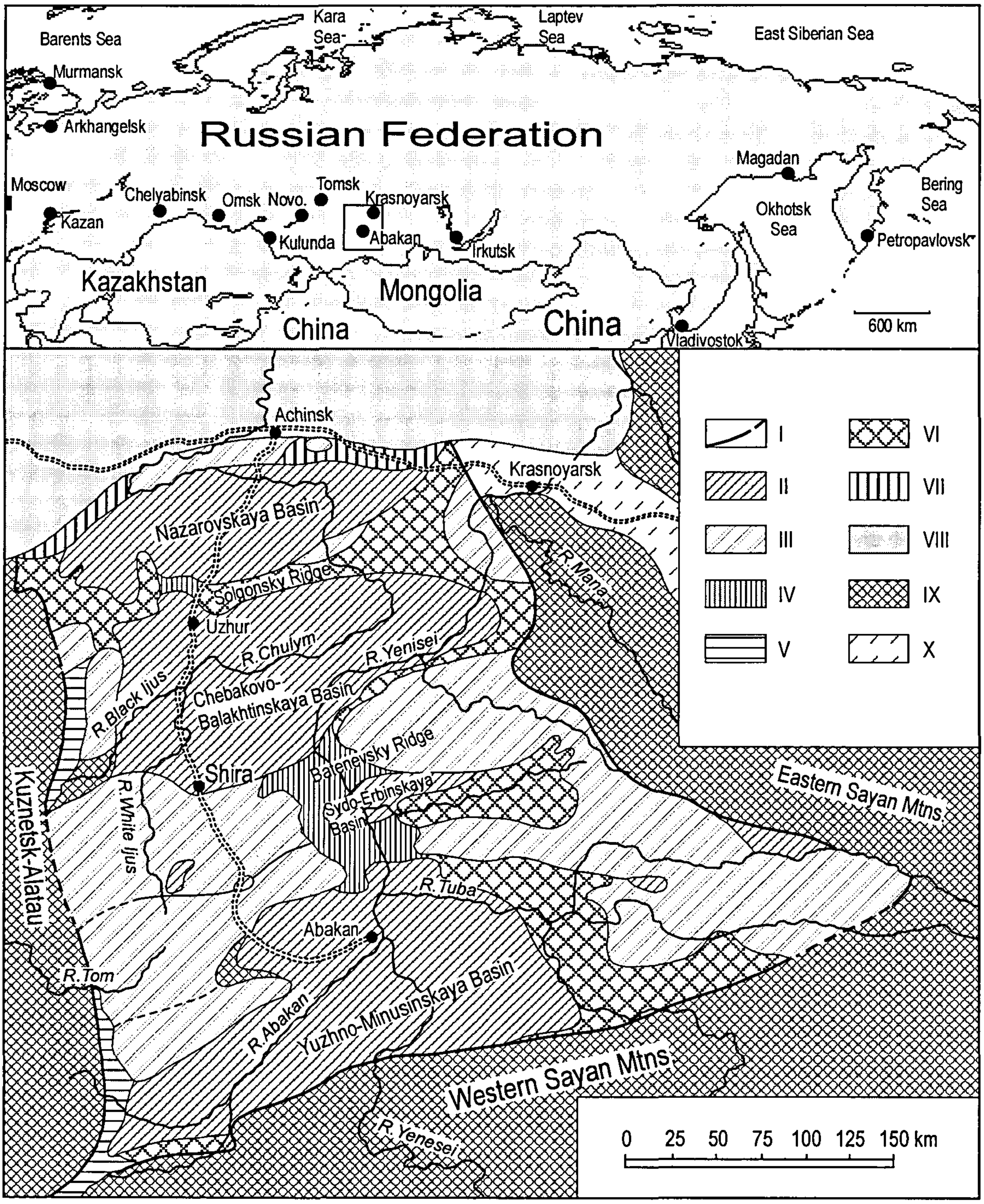


Figure 5.1



Kara Sea
Laptev Sea
East Siberian Sea
Barents Sea
Murmansk
Arkhangelsk
Russian Federation
Magadan
Moscow
Chelyabinsk
Omsk
Novo.
Tomsk
Krasnoyarsk
Bering Sea
Okhotsk Sea
Kazan
Kulunda
Abakan
Irkutsk
Petropavlovsk
Kazakhstan
Mongolia
China
China
Vladivostok
600 km
Achinsk
Krasnoyarsk
Nazarovskaya Basin
Solgonsky Ridge
Uzhur
R. Chulym
R. Yenisei
R. Mana
R. Black Ijus
Chebakovo-Balakhtinskaya Basin
Batenevsky Ridge
Shira
Syda-Erbinskaya Basin
Eastern Sayan Mtns.
Kuznetsk-Alatau
R. White Ijus
R. Tuba
Abakan
R. Tom
R. Abakan
Yuzhno-Minusinskaya Basin
Western Sayan Mtns.
R. Yenesei
0 25 50 75 100 125 150 km
I
II
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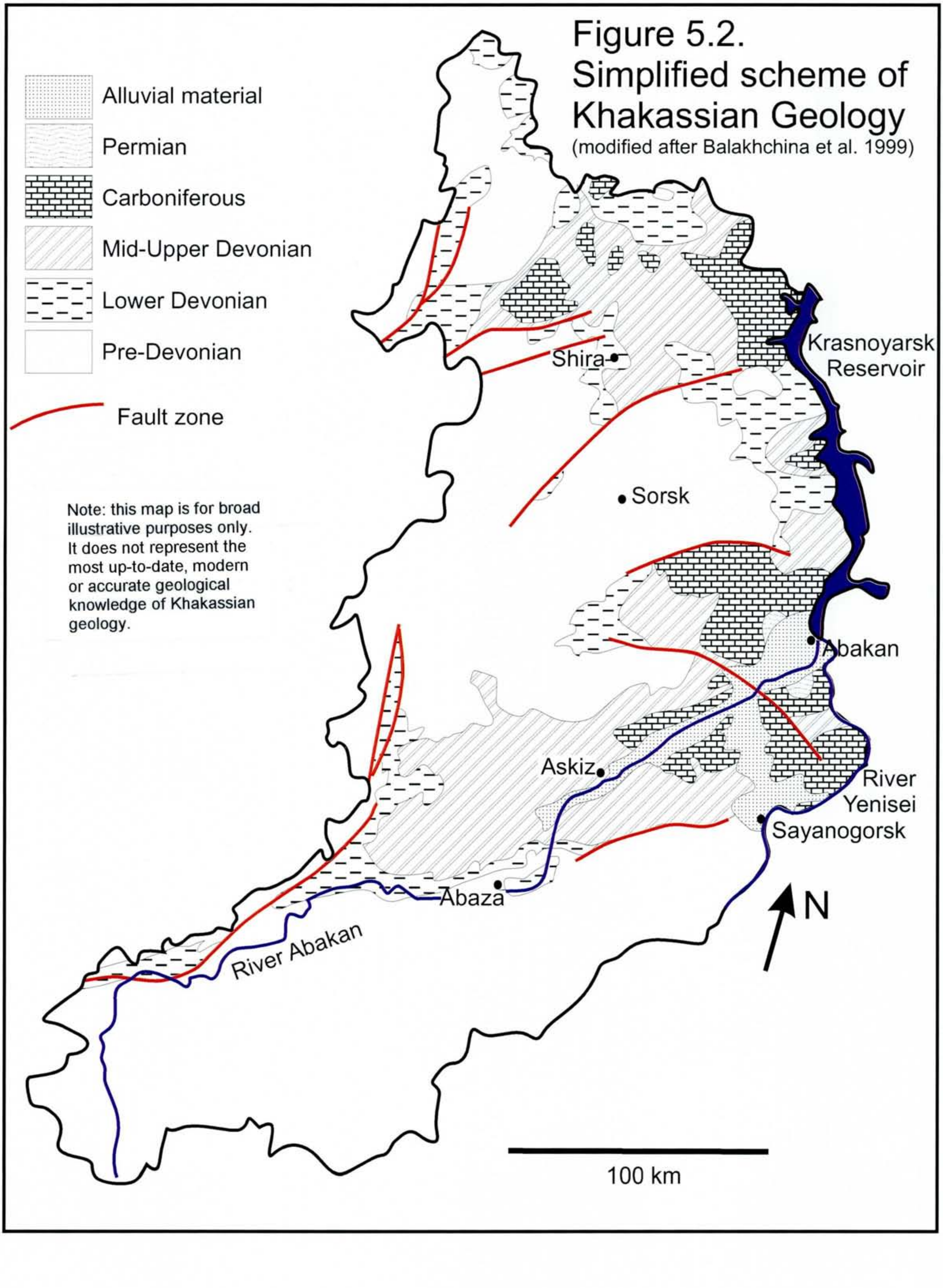


Figure 5.2. Simplified scheme of Khakassian Geology (modified after Balakhchina et al. 1999)

APPENDIX A. DESCRIPTION OF SAMPLE LOCALITIES, 1999 FIELDWORK

NB Ozero = Lake

9/6/99

Xa34	Ozero Kurinka. Lake water sample from eastern lobe of lake, northern shore. Shallow lake, with muddy bed. Immediately under the lake-bed, the mud is black, with a strong H_2S smell. In-situ measurements of water made c. 10 cm below lake surface. Geology = boundary between D3 Old Red Sandstone and C1. Land use = rural steppe (some free range cattle). No obvious evaporite minerals.
Xa35	Marble Quarry. 60 m deep borehole in Proterozoic schists, way below the quarry. Taken from tap at pumping station. No H_2S smell. Yield 25 m^3/hr. Owners believe they have an Fe problem, but no Fe observed on the filter. Land use = rural/forest. Designated $Riphean_{1-2}$
Xa36	Maina borehole. Communal water borehole of unknown depth in basaltic schists of probable $Cambrian_1$ age. Sampled from rising main pipe at a leak from a valve during pumping. Located way outside village, land use = rural/forest. No H_2S smell. Anatoly A Vedernikov ascertained later that borehole is 35 m deep.
Xa37	Bogoslovka village. From borehole 45 m deep, drilled into rock (according to later investigations by Anatoly A Vedernikov). Taken from a large water tank directly above the borehole. Aquifer rock believed to be $Cambrian_1$ ophiolite. Conceivably some input of water from Quaternary deposits. Pump rate = 10 m^3/hr. No H_2S smell. Surrounding land use = small village (urban).
Xa38	Ozero Utinoe. Lake sample. Samples and in-situ measurements from 10 cm below surface. Lake has quite a coarse grained, sandy bed, with only a little black H_2S-smelling mud in the subsurface. Some very sparse recent evaporite minerals around the lake (sampled). Geology = D3 sediments, land use = rural with some agriculture.
Xa39	Byeya - Maslo-Sir Zavod (Butter/cheese factory). Borehole to 40 m depth in D2 carbonate-bearing rocks (Byeyaskaya formation). Yield = 5 m^3/hr. Samples taken directly from tap on rising main. No H_2S smell. Surrounding land-use = urban.
Xa40	Novotroitskaya. Borehole for village supply in D3 sediments. Very strong flow from outlet of rising main (thus, Eh reading not meaningful). Slight colour and very slight smell. Depth unknown. Land use = urban.
Xa41	Chernoe Ozero (Black Lake). Lake water sample. On deposits consisting of C1 and Quaternary. Bed of lake is muddy, becoming black with some H_2S smell below the surface. Samples and in-situ measurements taken some 10 cm below the water surface. Surrounding land use = dominantly rural.

10/6/99

Xa42 Tumannii (near Sorsk). Artesian (overflowing) borehole drilled in Lower Palaeozoic igneous plutonic rocks, believed to be Nordmarkite / syenite (possibly $Cambrian_2$). Overflowing at a rate of 10 l per 16 s. Rural land use (outside main village area). Depth unknown. No H_2S smell. Some rumour of old mine shafts to uranium-bearing black shales in the vicinity.

Xa43 Spring near Mount Amoga. Well-defined spring from base of Vendian-Cambrian limestone outcrop (geological map indicates $Riphean_3$), feeding a small lake. Land use = rural.

Xa44 Spring area north of Vershino-Bidzha village. Flow = > 1 l/s derived directly from Vendian-Cambrian carbonates (map indicates $Riphean_3$). Land use = rural. No H_2S smell.

Xa45 Spring area south-west of Moskovskii Sovkhoz. Diffuse spring area, comprising a slow flowing channel, sampled in a rushy wetland area. Lots of recent evaporite salts in soils surrounding spring area (sampled). Sediment in base of channel black and smells of H_2S. Land use = rural but cattle obviously use the area as a watering hole.

11/6/99

Xa46 Khan Kul' mineral water borehole. Artesian overflowing borehole in D3 sedimentary rocks. Land use = urban (small village + railway). Depth believed to be some 350 m. Overflow = 1 litre per 14 s. No smell of H_2S.

Xa47 Ozero Khan Kul' (marked on maps as Ozero Solenoe). Lake water sample from southern side of lake. Geology appears to be D3/C1. Very clear water and many benthic flora. In the immediate subsurface of the lake bed is blackish sediment with a little H_2S smell. A recent evaporite crust exists on the shore (sampled). Land use = rural, with some agriculture on the northern shore.

Xa48 Ozero Bulankul' (northern lake). On outcrop of Cambro-Ordovician nepheline syenite / syenite. Bed of lake is coarse and gravelly with no clear H_2S smell from the sediments. All samples and measurements some 10 cm below lake surface. Land use = largely rural but some huts.

Xa49 Ozero Bulankul', children's sanatorium (south of Lake Bulankul'). Borehole to 45 m depth in Cambro-Ordovician nepheline-syenite/syenite. Sampled from water pumped directly from borehole into a bucket. Eh reading meaningless due to turbulence. Land use = urban (huts + sanatorium) and rural. No H_2S smell.

Xa50. 7 km east of Pulankol. Borehole in D1 basalts. Sampled from water pumped directly from borehole into a bucket (only short pumping time). Eh reading meaningless due to turbulence. Depth guestimated at 25 m. No H_2S smell in water. Land use = agriculture (cattle station)

Xa51 Vtoroi Kluch, spring 4 km north of cattle station. Believed to be in $Riphean_3$-Vendian-Cambrian igneous rock complex (basalts with some syenites???) according to one map. However, a more detailed map suggest Cambro-Ordovician igneous rocks. Discrete spring with flow 0.3 - 0.5 l/s. Land use = rural, no H_2S smell.

Xa52 Artesian overflowing borehole near Mount Timirtag, drilled in D2 carbonates. Surrounding land is rural, although borehole used for cattle watering. Rate of overflow 10 litres in 1 min 40 s.

Xa53 Kharasug spring. A fairly discrete spring, in D2 carbonates but with Cambro-Ordovician granites immediately up contact. A block was found by the spring, showing the D2 - granite contact. Probably also some component of flow through loose cover or head. Flow c. 1 l/s. Land use = rural. No H_2S smell.

12/6/99

Xa54 Charkov. Town borehole. Sampled from pipe direct from borehole pump. Appears to be drilled into D2 carbonates of Byeyaskaya Formation, but map indicates near boundary of D3. Possibly also some contribution from Quaternary deposits. No H_2S but slight metallic tang to water. Land use = urban (largish village)

Xa55 Spring north of Charkov from D1 volcanics and sedimentary rocks (possibly some Quaternary head also). Temp. varies between 7.5 and 6.8°C depending on whereabouts measured in the spring pool. Fairly discrete spring area but rather low flow. Probably quite a large, predominantly rural, catchment, No H_2S smell.

Xa56 Ust' Kamisyak. Spring from conglomeratic formation (maybe basal conglomerate of D3, but probably of C1). Water is fast and shallow at spring exit. Land use = rural. No H_2S smell.

Xa57 Ozero Ulugkol'. Lake water sample from southern side of lake. Samples and in-situ measurements taken some 5 cm under water surface. Geology = C1, land use = rural. Evaporite crusts present on shores of lake (sampled). Bottom sediments of lake are black with a strong smell of H_2S.

Xa58 Ozero Uskol'. Lake water sample from southern shore. Samples and in-situ measurements taken some 5 cm under water surface. Geology = C1, land use = rural. Evaporite crusts present on shores of lake. Bottom sediments of lake are black with a smell of H_2S. Round edge of lake is a reddish scum (halophile bacteria or algae ??)

Xa59 Abakanskii II Salt Well in bed of dry lake. Samples from and in-situ measurements in a 3 m x 3 m shaft (well) in lake bed. Geology = D3, land-use = rural. Under the surface of the lake bed (which is crusted with evaporites) is black, H_2S-smelling mud.

Xa60 Moskovskii Sovkhoz village borehole. Sample taken probably via a header tank. Land use = urban. Geology believed to be D2. No H_2S smell.

13/6/99

Xa61 Byelii Yar Coal Opencast. Sample of borehole-derived drinking water from tap in mine buildings (via water tower). Water has not been subject to any form of water treatment. Depth of borehole = 32 m, no H_2S smell. Land use = coal opencast area, but immediate land use unknown. Borehole drilled in alluvial sediments of the River Abakan.

Xa62 Accumulated water in base of eastern coal opencast (Izikskii I). Samples and in-situ measurements taken c. 5 cm below water surface in vicinity of dewatering pump. Level of base of quarry reported to be 185 m OD. Strata are of Permian age. In the walls of the quarry, the lower 2/3 of the sequence comprise dark, coal-bearing strata. The upper 1/3 comprises lighter, coal-free rocks. It is from near the base of the upper (light, coal-free) part of the section that the bulk of the water seeping into the opencast is derived. The water in the opencast is clear and free of ochre. The accumulated water in the pit is pumped continuously at a high rate, reported to be some 220 m^3/hr.

Xa63 Accumulated water in base of western coal opencast (Izikskii II). Level of base of quarry believed to be c. 200 m OD. The strata are of Permian age and are observed to include very carbonate-rich mudstones (tested with acid). In the walls of the quarry, the lower 1/3 of the sequence comprise dark, coal-bearing strata. The upper 2/3 comprises lighter, coal-free rocks. It is from near the base of the upper (light, coal-free) part of the succession that the bulk of the water seeping into the opencast is derived. The water in the opencast is not as clear as Xa62, but is free of ochre. The accumulated water in the pit is pumped at a lower rate than Izikskii I, reported to be some 18 m^3/hr.

Xa64 Khakasskaya Shaft. Minewater from underground coal-mine. All mine water from the working Yeniseiskaya Mine and from opencast mines to the west, collects in the Khakasskaya mine, from where it is pumped to the surface. The coal here is of Carboniferous (C3) age. The mined coal is a single seam of thickness 2.2 m. The water was sampled underground at the 140 m depth level, and brought to the surface in a bucket for analysis (the temperature of 10. 1°C was thus measured at surface). A maximum of 50 m^3/hr is pumped from the shaft. No iron/ochre coloration or deposits are noted, nor is any H_2S smell.

Xa65 Znamenka village borehole. Depth unknown, in D2 carbonate-bearing rocks. Water was sampled from a public standpipe some 80 m from the borehole. Land-use = urban, no H_2S smell.

Xa66 Polindeika village borehole. Borehole located above village near farm. Drilled in D1 basalts and sandstone. Sampled from the nearest village standpipe to the borehole (some 400 m away). No H_2S smell.

15/6/99

Xa67 Ozero Vlasyevo. Sampled on lake shore adjacent to main road. Lake has sandy bed, no smell of sulphide. Very slight evaporite crust around lake. Samples and in-situ measurements at 5 cm below lake water surface. Land use: village on N side of lake, otherwise rural (with main road running past). geology comprises Vendian-Cambrian carbonates on the north edge, D1 on the south. Land use designated as rural.

Xa68 Ozero Shira, water sample from near shore just north of the kurort. Samples and in-situ measurements at 5 cm below lake water surface. Lake bed stony/sandy, no sign of sulphate reduction / no H_2S smell. Land use rural + kurort resort. Geology = D3. Land use designated as urban.

APPENDIX B. DESCRIPTION OF SAMPLE LOCALITIES, 2000 FIELDWORK

NB. No rainfall during entire sample period

7/9/00

Xa70F Water inflow from a relatively newly-drilled horizontal exploration borehole in the service area (i.e. away from the main ore body) of the Abaza magnetite mine at the minus 95 m level (mine entrance at plus 537 m level). No salt taste or H_2S smell. Rock appears to be a dark carbonate rock with calcite fracture fillings. Geol. map indicates $Cambrian_{1-2}ar$.

Xa71F 2nd Silver Spring (Serebrianii Istochnik), Malii Arbati. Near Abaza. Flowing spring. Surrounding rocks believed to be Cambrian sediments / Devonian (?) dolerite. Spring probably emerges at boundary between alluvial fan from hillside and river flood plain. Surrounding area used for cattle pasture. Geol. map indicates $Cambrian_{1-2}ar$. (with D_1 nearby)

Xa72F Roadside seepage spring at km 212 on the Abakan-Ak-Dovurak Road. Rises from greenschists at foot of steep slope. Surrounding land use = rural forest (and roadside). Geol. map indicates $Cambrian_1vm$.

Xa73F Radon spring, near Kubaika at km 223 on the Abakan-Ak-Dovurak Road. Strongly flowing point spring from schists near roadside at foot of steep wooded hill. Surrounding land use = rural forest (and roadside). Geol. map indicates $Riphean_{1-2}dg$ (near boundary with $Cambrian_1nm$ and $P\gamma\pi Cambrian_1$).

Xa74F River Bol'shoi On, at top bridge where Abaza-Tuva road crosses river, near border with Tuva. River water sample. Surrounding land = completely rural mountain plateau area. Surrounding mountains composed of igneous intrusive and metasedimentary rocks. Run-off partly from snowmelt.

8/9/00

Xa75F Matur village borehole. Borehole 90 m deep, yield 15 m^3/d. Borehole accessed by a single tap, which operates c. 3 hrs/day. Sampled via this tap. Surroundings periurban, some cattle pasture. Geol. map indicates $D_{1-2}tl$ or D_2as or $D_{1-2}tl$.

Xa76F Domestic well at house on Sovjetskaya street no. 35, Matur. Well 6-7 m deep according to neighbour, 2-3 m deep according to owner. Located in centre of village (urban). The village has 6-7 times the average rate of hepatitis among children (according to Mr. Ivan I. Vishnivyetskii, Chairman of the Khakassian SCEP). Geol. map indicates $D_{1-2}tl$, but well is almost certainly in Quaternary deposits.

Xa77F River Matur, river sample from c. 1 km upstream of Matur village. Land use = agricultural. River channel c. 4 m across. Water rather particle-free (some resistance with filter). Geol. map indicates D_{1-2}tl.

Xa78F Highway Authority Base (Baza DRSU), Shepchul (on the Tashtip-Matur Road) Borehole 30-40 m in bedrock (probably D1 or D2) or (possibly) colluvial / alluvial material. Land use = agricultural / cattle pasture. Sampled directly adjacent to borehole, via pressure tank. Geol. map indicates D_2il.

Xa79F River Bol'shaya Sjeja at bridge at Verkhnaya Sjeja. River sample. River catchment upstream of bridge is largely rural. Water relatively particle free. D_2as.

Xa80F Communal borehole; Verkhnaya Sjeja village. Sampled via water tower and nearby standpipe. Borehole c. 40 m away from sampling point and c. 30 m deep. Surroundings urban (middle of village). Geol. map indicates D_{1-2}tl.

Xa81F Borehole at Tashtip (N of town). Drilled on higher ground at north fringe of town. Depth 40 m in Devonian D1 (Tashtipskaya Formation). Water sample from tap in house supplied by borehole. Borehole v. close to house but 150 m from water tower (i.e. water has 300 m journey to sample point). Land use = periurban, with some cattle pasture. Geol. map indicates D_{1-2}tl or D_1tš.

Xa82F Borehole at Imek town. 100 m deep borehole at northern end of town in D1 Imekskaya Formation. Sampled from domestic house tap (Yubileinaia Street No. 21), c. 100 m from water tower. Land use = urban / agriculture. Geol. map indicates D_1tč.

Xa83F River Tyeya. River water sample at main road bridge. Channel c. 10-12 m wide. Water relatively particle-free, with no sign of pollution. Geol. map indicates D_3tB and alluvial material.

9/9/00

Xa84F Vershina Tyëi, Borehole No. 2. Borehole supplying mine, c. 5 km from mine in river valley. Driller's log suggests 0-3.5 m Quaternary clay; 3.5-9 m Quaternary gravel; 9-35 m Cambrian_{1-2} limestone. Total depth 35 m, water level 5.9 m bgl. Aquifer = Cambrian limestone (+ Quaternary ?). Quite a lot of sandy particles in the water. Sampled from fracture in pipe. Land use = rural. Geol. map indicates $\text{Vendian}_1\text{Cambrian}_2$K.

Xa85F Stream flowing through mine waste areas of Vershina Tyëi mine and emerging from the toe of a coarse mine waste pile. Stream is thus not pure leachate - it commences above the mine waste area. Good flow (channel is c. 2 m across). No obvious iron/ochre staining in stream. Water is relatively particle-free and supports aquatic plants. The mine waste is largely coarse grained with little obvious sign of oxidation. Both large and small pyrite crystals were observed. No cover material. No obvious damage to vegetation at toe of wastes. Previous analyses indicate 858.4 mg/l sulphate (from pyrite oxidation ?) and 60 mg/l nitrate (from explosives). Geol. map indicates γ_1Cambrian$_3$Ordovician$_1$t.

Xa86F Piped mine water discharge from Vershina Tyëi opencast mine (normally flows through settlement ponds, but currently these are non-operational). Water appears fresh with no iron staining. Previous analyses suggest high sulphate and nitrate ($SO_4^=$ = 325.8mg/l; NO_3^- = 16.4 mg/l). Flow during sampling c. 2 l/s (pumped between 3 hrs/day and 24 hrs/day depending on hydrological conditions). Previous analyses also indicate c. 1.9 mg/l iron. The mine is an opencast magnetite mine with pyrite (often large crystals) in Cambro-Ordovician volcanics (trachybasalt, trachyrhyolite, granosyenite etc.) and also carbonates, dolomites, serpentinite, and explosion breccias. Geol. map indicates γ_1Cambrian$_3$Ordovician$_1$t.

Xa87F Silver Spring (Serebrianii Istochnik), Birikchul'. Fairly discrete spring at base of wooded hillside (rural land use). Geology observed in field = Cambro-Ordovician granite. Flow = 12 l in 20 s (0.6 l/s). Geol. map indicates γ_1Cambrian$_3$Ordovician$_1$t.

Xa88F Kazanovka Station (Stantsiia Kazanovka). Borehole drilled in D1 rocks beside railway line and line of houses. 75 m deep. Urban land-use. Sampled from standpipe ca. 40 m from water tower above borehole. Geol. map indicates $D_{1\text{-}2}$tl.

Xa89F Askiz Station (Stantsiia Askiz). Bore on fringe of town on entering the built-up area from the north. Borehole 40 m deep in D3 sediments. Sampled from standpipe 50 m from water tower. Periurban land use. Geol. map indicates D_3od.

Xa90F River Baza, river sampled upstream of Ust' Baza village. Smallish river, c.2-3 m wide. (Further upstream in the catchment are gold mines using heap leaching with cyanic acid). Geol. map indicates D_3kh.

10/9/00

Xa91F River Son. c. 1 km upstream of Sonskii railway embankment. Narrow wooded valley, some cattle pasture. Reasonable flow of water; channel some 2 m wide. Local geology is basalt, probably of Vendian-Cambrian age. Sampled at c. 19:00 hrs in evening.

Xa92F River Son. c. 1-2 km upstream of Katyushkino village. The surroundings are still hilly but the valley is wider than Xa91. More grass/pasture land. River still c. 2 m wide but a little deeper than Xa91. Some cattle grazing (but largely rural) and some particles in water. Sampled c. 20:00 hrs in evening.

11/9/00

Xa93F River Son, (3km upstream of Borets) south of Borets. (No rain overnight, sampled at 11:22 am). Clear deep, fast-flowing river channel, c. 1.5 - 2 m wide. Boggy area in a wide valley framed by D2 carbonate-rich rocks. Flow at least 5 times greater than Xa92, and probably 10 times greater.

Xa94F River Son, below Borets (2 km downstream of Borets). Sampled at 11:50 am. Wide (10-15 m), shallow channel in wide boggy plain with hills of D2 rocks to the south. Some cow-grazing but designated rural. Clear water.

12/9/00

Depth sampling in Shira Lake at location:

N54°30.420' E90°12.384' (boat GPS reading)

Sampled by boat at location of maximum lake depth (by depth sounder) of 20.8 m. Used a double barrel, weight-activated throughflow Rutner-type Perspex depth sampler.

Depth sounder indicates depth of thermocline at 7-12 m. Confirmed by temp. measurements

H_2S could be smelled in water from 13 m down. (analyses indicate that H_2S appears at 9m, with 0.412 mg H_2S/l)

All samples had significant particle content (probably due to microplankton).

Xa95F Shira Lake surface (5-10 cm depth)

Xa96F Shira Lake, 3 m depth.

Xa97F Shira Lake, 9m depth.

Xa98F Shira Lake, 13 m depth.

Xa99F Shira Lake, 18.4 m depth

APPENDIX C. GEOLOGY OF THE STUDY AREA

C1 Geological Setting (after NGU Report by Banks et al. 1998a)

Khakassia is situated in the central part of the Altai-Sayan Mountain region in southern Siberia, Russia (Fig. 5.1). The lowland areas comprise a number of graben-like basins within the Minusinsk intermontane trough, bounded by the mountain areas of Kuznetsk-Alatau in the west, and the Western and Eastern Sayans in the south and the east. The trough itself, containing Upper Palaeozoic sediments and volcanics, is divided, from north to south, into four sub-basins by ridges of Precambrian/Lower Palaeozoic rocks: the Nazarovskaya, Chebakovo-Balakhtinskaya, Sido-Eribinskaya and Yuzhno-Minusinskaya basins. The intervening ridges are offshoots of the Kuznetsk Alatau and Eastern Sayan ranges and include the Solgonskii and the Batenevskii ridges. From a tectonic perspective, the Minusinsk Trough is considered an early Devonian palaeo-rift structure (Parnachev et al., 1996a,b).

The region of Khakassia is particularly interesting inasmuch as it presents a very varied geology consisting of Precambrian and Palaeozoic metamorphic, sedimentary and igneous rocks (Fig. 5.2). The Kuznetsk-Alatau and Western Sayan ranges are comprised of Precambrian and Lower Palaeozoic formations (including volcanics, clastic and carbonate sedimentary rocks and granitoids), as are the ridges which define the borders of the sub-basins. The sub-basins are essentially synclinorial structures, infilled by Devonian and Carboniferous volcanics, evaporites and sediments, with a complex internal structure.

Very simply, the Sayan and Kuznetsk-Alatau mountains are described as being of Caledonian age (Silurian-Lower Devonian), resulting from the closure of a proto-Tethys-like ocean. The Upper Devonian sediments of Khakassia accumulated in extensional troughs behind the orogenic zones. Further extensional activity took place in Tertiary time, possibly related to the formation of the Baikal Rift.

C2 Shira (- Abakan) Region

The report of Banks et al. (1998a) considers the chemical quality of groundwater in the rocks of the Chebakovo-Balakhtinskaya Basin (and earlier rocks adjacent to the basin), in the vicinity of the town of Shira. The following description of the geology of this area, also holds true to a large extent for the Devonian lowland areas of the Abakan region, sampled in 1999-2000. (Formation names may, however, differ in the Abakan area).

Lower Devonian deposits are represented by the sedimentary-volcanogenic Biskarskaya series, which unconformably overlaps the Riphean-Vendian and Cambrian-Ordovician rocks bordering the Basin. The Biskarskaya series contains alternating horizons of volcanic and sedimentary rocks. The volcanics consist of interbedded acidic and basic (homodromous trachyrhyodacite-trachybasalt) rocks, while sedimentary horizons are generally discontinuous layers of red-bed sandstones, siltstones, tuffites and occasional conglomerates and gritstones. The deposits tend to reflect continental conditions, while the occurrence of evaporite minerals (halite and gypsum imprints) suggests deposition in enclosed lagoon or lake basins The thickness of the series is estimated to be 1800 - 2000 m.

The Middle Devonian is represented by the Saragashskaya and Beiskaya suites. The former transgressively overlies Lower Devonian deposits and contains thin interlayers of gritstone at the base of the sequence. These are replaced upwards by interbedded yellow- and greenish siltstones, sandstones, mudstones, marls and limestones. The thickness of the Saragashskaya Formation varies from 150 to 300 m and is conformably overlain by the Beiskaya Formation, comprising grey limestones, with interlayers of dolomites, marls, occasional calcareous sandstones, siltstones and mudstones. The thickness of the Beiskaya Formation varies from 60 to 250 m.

Upper Devonian deposits include the terrigenous red-bed sedimentary rocks of the Oidanovskaya, Kokhaiskaya and Tubinskaya Formations. The Oidanovskaya Formation is some 200 - 600 m thick, conformably overlies the Beiskaya limestones and consists of siltstones, mudstones and occasional cross-bedded gritstones. The Kokhaiskaya Formation is 30 - 600 m thick and is dominated by intercalated greyish siltstones and mudstones (containing thin beds of sandstones), marls and algal and brecciated limestones. The Tubinskaya Formation varies from 200 to 1200 m in thickness and is composed of red sandstones, with interlayers of siltstones, mudstones and conglomerates.

The Lower Carboniferous system (Turnaisian Stage) is represented by the Bystryanskaya and Altaiskaya Formation. The Bystryanskaya Formation conformably overlies the Tubinskaya red-beds, and comprises grey, yellowish and greenish sandstones, limestones, siltstones, mudstones and tuffites, with a total thickness of some 275 m. A gradual upwards transition introduces the Altaiskaya Formation, comprising red-brown and yellowish-violet tuffs, tuffites, siltstones and sandstones, which is 50 - 135 metres thick.

The sedimentary rocks of the Middle (Saragashskaya, Beiskaya) and Upper (Oidanovskaya, Kokhaiskaya, Tubinskaya) Devonian and Lower Carboniferous are believed to have been laid down in a post-rift sedimentary basin under shallow-water marine and lagunal (Middle Devonian and Carboniferous) or continental (Upper Devonian) conditions. Indicator-minerals of evaporite conditions (interbeds of gypsum, barite and fluorite, imprints of rock salt) are known from Devonian and Lower Carboniferous deposits.

The modern structure of the sub-basins of the Minusinskii Trough is traversed by sublatitudinal faults. The most recent displacements on these faults, accompanied by the formation of volcanic pipes, took place in the interval 28 - 78 Ma ago (Parnachev et al., 1996b).

Summary

Essentially, therefore, the geology simply comprises:

- Pre-Devonian metasedimentary and igneous rocks
- Lower Devonian sedimentary, clastic rocks, with a significant component of volcanic/volcanosedimentary strata. Contains some evaporite minerals (gypsum / imprints of halite)
- Middle Devonian sedimentary rocks, often with a significant content of carbonates.
- Upper Devonian tendency to red-bed facies ("Old Red Sandstone"), with evaporite minerals (gypsum / imprints of halite)
- Carboniferous sedimentary rocks of varied type, including tuffites, carbonates and, in the Chernogorsk/Abakan area, coals.
- In the core of the Abakan syncline, coal-bearing Permian sedimentary rocks also occur.
- Tertiary: fault reactivation. Volcanic plugs in the Shira area.
- Quaternary. Modest glaciation. Local, rather than regionally extensive, ice activity. Alluvial deposits along rivers.

C3 Kuznetsk-Alatau Region

The following is (selectively) translated from (Parnachev et al. 1998a), from the chapter entitled "Kuznetsk-Alatau Mega-Anticlinorium". It reflects the legend of Tables 6.1-6.3 in Appendix J.

Riphean Era (R): Includes four suites: the Sinnigskaya, Tyurimskaya, Charishtatskaya and Bidzhinskaya. The Sinnigskaya Suite comprises tuffaceous sandstones, tuffaceous conglomerates, effusives of intermediate and acidic composition, with rare layers of limestone and siliceous slates. I.e.: the composition of the rocks of this suite is fundamentally volcanogenic. The other three suites differ little lithologically - they are comprised of limestones, dolomites and rare sandstones, siltstones and slates. Thus, the Riphean deposits of the Kuznetsk Alatau have a fundamentally carbonate nature.

Vendian System (V): Comprises several suites: the Amarskaya (sandstones, conglomerates, siltstones), the Tarzhul'skaya (dolomites, limestones, silicilites), the Gidrinskaya (dolomites, limestones), and the Martyukhinskaya (dolomites, limestones) suites. Thus, in the deposits of the Vendian system is observed a dominance of carbonate lithologies.

Vendian - Lower Cambrian (V-$€_1$): Includes the Sorninskaya and Belkinskaya formations, comprised of limestones, siliceous slates, phosphorites and dolomites.

Lower Cambrian ($€_1$): To the Lower Cambrian belong the Ust' Kundatskaya, Brodovskaya, Bogradskaya, Usinskaya, Tunguzhul'skaya and Kolodzhul'skaya suites. All these have a rather mixed composition: limestones, dolomites, siliceous slates, siltstones, sandstones, argillites, with sparse basalts. Carbonate rocks dominate. Only in the Ust' Kundatskaya suite do clastic rocks predominate - slates, sandstones and siltstones. In these, vulcanites of primary composition are also rather frequently encountered.

Lower - Mid Cambrian ($€_1$ - $€_2$): Many suites coincide with this chronostratigraphical level and these are classified into different structural-facies zones under different names: Azirtal'skaya, Yefremkinskaya, Sonskaya, Bogoyul'skaya, Poltavskaya and Ulutagskaya. All of these suites occupy, in section, a close position, and are primarily composed of detrital rocks: sandstones, siltstones, conglomerates, amongst which occur layers of tuffs, limestones and flows of effusive rocks.

Middle Cambrian ($€_2$): In the middle Cambrian, the following suites are recognised: Tolcheinskaya, Sladkokorenyevskaya, Bezimyannaya, Kanimskaya, Batenevskaya and Berikul'skaya. These are composed predominantly of sandstones, siltstones, tuffs and clayey slates; but in the Bezimyannaya suite the rocks are dominated by carbonates (limestones) and in the Berikul'skaya by effusives of intermediate composition (andesites and andesobasalts).

Ordovician (O): The Koshkulakskaya suite, whose age is controversial, is tentatively allocated to the Devonian. Some researchers place the suite in the Middle Cambrian, others to the Devonian. Our point of view is that the Koshkulakskaya effusives have a riftogenic nature and were formed during the Ordovician / Silurian (Makarenko & Parnachev 1994).

Intrusive Magmatic Rocks of the Kuznetsk Alatau are fairly widely developed, and in our region of interest, belong to the Salanskii Complex of hyperbasites (R_1?), the Izikhskii Gabbro-Pyroxenite Complex (R_1?), the Tyurimskii Gabbro-Diorite Complex (R_3?), Kundustul'skii Gabbro-Plagiogranite Complex ($€_{1-2}$), the Kogtakhskii Gabbro-Monzodiorite Complex ($€_2$), the Tigertishskii / Martaiginskii Complex ($€_3$-O_1) and the Yulinskii Granitoid Complex (D_1?). All of these intrusive complexes form different-sized bodies.

Tectonically, the Kuznetsk-Alatau Mega-anticlinorium represents a folded (?) system of Salairo-Caledonian consolidation, which, in its turn, divides into still smaller structures. Within the bounds of the study area, two structural-formation zones are prominent: the Batenevskaya and the Mrasskaya. The first is developed between the Central and Northern parts of the Askiz region; the second follows a narrow belt along the western administrative border of the Republic of Khakassia. representing the extreme eastern limit of the Mrasskii platform. All the differently aged lithologies of these tectonic structures are intensively dislocated (?), developed with series of disjunctive discontinuities of north-west, submeridianal and north-east direction and perforated with granitoids and granite-granosyenite-syenite intrusives of the Tigertishskii, Martaiginskii and Uibatskii Complexes. In the northern part of the region is located the southern extremity of the Uibatskii graben-rift, representing a linear tectonic structure (400 x 30-70 km), formed as a result of Cambro-Ordovician continental riftogenesis, first demonstrated and substantiated by the researches of the authors (Makarenko & Parnachev 1994, 1996).

C4 The Western Sayan Mega-Anticlinorium

PreCambrian ($R_{1\text{-}2}$?): To the PreCambrian massif belong metamorphic slates, metasandstones with layers of marble, comprising the Dzhebashskii Platform, ascribed by many researchers to the Baikal Structure, although there also exist theories of a younger (Ordovician) age for the Dzhebashskii metamorphics (Kachalo 1996).

Lower Cambrian (€$_1$): Two suites are distinguished, in terms of composition, in the Lower Cambrian - the Lower Monokskaya, which is substantially volcanogenic, comprising basalts, andesites, plagiorhyodacites, tuffs and jaspers, and - the Upper Monokskaya, which is terrigenetic, comprising sandstones, siltstones, conglomerates, argillaceous and silicic slates, tuffs and limestones.

Middle Cambrian (€$_2$): In the Middle Cambrian, the Arbatskaya Suite is divided into two sub-formations: (i) the Lower comprises tuffaceous sandstones, tuffaceous conglomerates, tuffs, effusives of basic and intermediate composition, sandstones and siltstones; (ii) the Upper comprises sandstones, siltstones, conglomerates and rare tuffs.

Upper Cambrian - Lower Ordovician (€$_3$ - O_1): The Kurukulskaya Formation is mapped in this chronostratigraphic interval, comprising sandstones, siltstones, conglomerates, converted in zones of fracturing to crystalline slates and gneisses.

Ordovician System (O): This is present with all three parts: (i) the Lower, where the Yerinatskaya Formation is identified: diverse sandstones, siltstones, mudstones and conglomerates; (ii) the Middle, where the Kokhoshskaya Formation is recorded: diverse sandstones, siltstones, argillaceous-siliceous slates and conglomerates, and (iii) the Upper, where the Karatashskaya Formation is mapped: sandstones, siltstones and argillaceous-siliceous slates.

Silurian System (S): This comprises two parts. In the Lower Silurian, the following formations are distinguished (from the bottom upwards): the Oninskaya (limestones, marls, sandstones, siltstones and conglomerates), the Tostugskaya (sandstones, siltstones, siliceous-argillaceous slates and conglomerates), the Pozarimskaya (sandstones, siltstones, mudstones, tuffs and conglomerates). In the Upper Silurian is mapped the Kulogeshskaya Formation (limy sandstones, mudstones, limestones, tuffs).

Devonian System (D): Represented by the Lower Devonian (Kup-Khol'skaya Suite), composed of rhyolites, rhyodacites, trachyrhyolites, dacites, andesites, but also of tuffs and layers of tuffaceous sandstone and tuffaceous conglomerate.

Carboniferous System (C): The youngest (Pre-Quaternary) deposits occur in the Lower Carboniferous Uzyupskaya suite, comprised of sandstones, conglomerates, siltstones, tuffs, with layers of limestones.

Magmatic (Intrusive) Bodies of the Western Sayan zone are diverse. On the combined legend (Table 5.2, Appendix J) are shown all the intrusive complexes currently recognised. The oldest intrusions are found in the Aktovrakskii serpentinite complex of serpentinitised peridotites, dunites, pyroxenites, assumed to be of middle Riphean age. In the range middle Riphean - early Cambrian, is placed the Kurtushibinskii-Borusskii Melange - Olistostromic Complex, comprised of a combination of variolites, quartzites and siliceous slates with diabases, serpentinites and gabbroids. In the early Cambrian, the Subbotinskii Complex of gabbroids and gabbro-diorites was introduced. The intrusives of the early Palaeozoic Mainskii intrusive complex enjoy a wide distribution: the first phase comprises gabbroids, the second comprises diorites, tonalites and gabbro-diorites, the third phase, plagiogranites. Additionally, in the early Cambrian, we find the Lisogorskii intrusive complex of gabbroids, pyroxenites, dunites and diorites. In the Silurian is registered the Bol'sheporozhskii Complex of tonalites, granodiorites and diorites. The intrusives of the early Devonian sub-volcanic complex of granite-porphyries enjoy considerable development: as do the granite-diorites and granodiorites-leucogranites of the Dzhoiskii Complex. The "youngest" intrusives of the formation are the granodiorites / diorites of the Kozerskii Complex of Devonian age.

Tectonically, the Western Sayan behaves as a major mega-anticlinorium, in whose structure the smallest subdivisions (from north to south) are: (i) the Northern Sayan lineal zone, dividing the Western Sayan structures from the structure of the Minusinsk intermontane trough; (ii) the Dzebashskii anticlinorium (platform) and (iii) the Western Sayan synclinorium. The tectonic formation of the mega-anticlinorium was accomplished during several tectono-magmatic cycles - the Baikalskii, the Salairskii and the Caledonian. The ancient deposits are intensively metamorphosed; for the Caledonides a characteristic predominance of flyschoid and molassic facies-complexes is noted. All of the rocks are dislocated and perforated with intrusives of various ages. A widely distributed network of faults, which, in the north and north-east have the typical "Western Sayan" direction, but which, in the south-west, acquire a sub-meridianal, north-west and north-east trend - i.e. "Gorno-Shorskii" and "Altaian" trends.

5.5 Minusinsk Intermontane Trough

The deposits relating to this geological structure are widely distributed within the Askiz, and also in the northern part of the Tashtip, regions, where they form part of the South-Minusinsk depression. Here, they are characterised by effusive-sedimentary rocks, from all parts of the Devonian and Carboniferous systems.

Devonian system (D): The **Lower Devonian** suites are situated with a sharp angular unconformity on Pre-Devonian basement and comprise the Biskarskii sedimentary-volcanogenic complex. They were formed in the process of continental riftogenesis (Parnachev, Viltsan, Makarenko et al. 1996). By virtue of the sharp changeability of composition, they are allocated by different researchers to a large number of suites and strata, which form lateral sequences. Vertically, they are allocated to five chronostratigraphical levels of development of these and other stratons (from the bottom up): the Chilanskii, the Imyekskii, the Tolochkovskii, the Tashtipskii and the Timertasskii.

- In the Chilanskii chronostratigraphic level, is developed the following lateral sequence of contemporaneous formations: the Kharadzhul'skaya, the Kazanovskaya, the Matarakskaya, the Chernoiyusskaya and the Kop'yevskaya. These are developed in different structural-facies zones and have a general lithological-petrographical composition including basalts, andesites, dacites, sandstones, siltstones, conglomerates and tuffogenic rocks.
- The Imyekskii chronostratigraphic level includes the following contemporaneous formations: the Chergatinskaya and the Tastrezenskaya. The lithologies include the following: trachydacites, trachyrhyolites, tuffs, tuffaceous sandstones, siltstones, mudstones, limestones and dolomites.
- The Tolochkovskii age level, as well as the Tolochkovskaya Formation, includes the following: the Sidinskaya and Bereshskaya. This level comprises sandstones, tuffaceous sandstones, effusives and tuffs. The Sidinskaya and Bereshskaya formations are developed outside of the region under consideration.
- The Tashtipskii level is characterised by various contemporaneous formations of different facies: the Uibatskaya, the Koksinskaya, the Migninskaya and the Kachaevskaya. Of these, the Uibatskaya and Koksinskaya are fundamentally terrigenous and are composed of sandstones, siltstones, limestones and tuffs. The

Migninskaya and Koksinskaya are primarily volcanogenic: intermediate, acidic and basic effusives, often of elevated alkalinity.

- The Timirtasskii-age level, apart from the Timirtasskaya formation, includes the Sagarkhainskaya and Perevoznaya formations. These comprise volcanogenic-sedimentary rocks with a predominance of vulcanites of basic composition (trachybasalts) relative to terrigenous rocks.

Middle Devonian (D_2): In the middle Devonian is a sequence of suites, differing in position in section, and in composition of rocks. Typically, they are an alternation of terrigenous and carbonate sediments, the terrigenous sediments being distinguished for their colour (reddish, ????, and multicoloured) such that they are widely used during geological mapping. They are divided into the following formations (from the bottom upwards): the Toltakovskaya, the Askizskaya, the Ilyemorovskaya, the Beiskaya. In the Beiskaya suite, carbonate rocks (limestones, marls) predominate, while in the other formations, terrigenous-clastic rocks dominate (sandstones, siltstones, mudstones, with occasional conglomerates and layers of limestone).

Upper Devonian (D_3): The deposits of the Upper Devonian are divided into three formations (from the base upwards): the Oidanovskaya, the Kokhaiskaya and the Tubinskaya. The sequence of rocks in all formations is of one type: sandstones, siltstones, mudstones, with occasional conglomerates. They are primarily distinguished by the colour of the rocks.

The Carboniferous System (C): Within the **Lower Carboniferous (C_1)** are found nine formations (from the base upwards): the Bistryanskaya, the Altaiskaya, the Kamishtinskaya, the Samokhval'skaya, the Krivinskaya, the Solomenskaya, the Yamkinskaya, the Bainovskaya and the Podsin'skaya. The material composition of the formations is fairly uniform, namely tuffogenous-sedimentary rocks: tuffs, tuffites, sandstones, siltstones, mudstones, and occasionally limestones and conglomerates. In view of the similar lithological-petrological composition, it is often not possible to subdivide the stratigraphical succession into all the component members. In such a case one must combine these formations into three stratons: the Bistryanskaya, the Altaiskaya and the Kamishtinskaya are combined; the Samokhval'skaya, the Krivinskaya and the Solomenskaya likewise; and finally the Yamkinsko-Podsin'skaya (see Table 6.3 in Appendix J).

The Middle Carboniferous (C_2). The middle Carboniferous is divided into two formations (from the base, upwards): the Chernogorskaya (comprising siltstones, sandstones, conglomerates, coals) and the Poberezhnaya (siltstones, mudstones, sandstones).

The Permian System (P). The sediments of the undivided lower-middle parts of the Permian ($P_{1\text{-}2}$) comprise the rocks of the Narilkovskaya formation: siltstones, sandstones, mudstones, coals.

Magmatic (intrusive) rocks of the south Minusinsk depression are not very widely developed, and they have a sub-volcanic character. They are spatially and genetically related with the vulcanites of the Biskarskaya formation of the Lower Devonian. These smallish bodies are of rather diverse petrographic composition: trachyandesite-porphyries, trachyrhyolite-porphyries, trachite-porphyries, trachybasalts, andeso-basalts, gabbros, microgabbros, dolerite-basalts, microdiorites, diorites, syenite-porphyries, granosyenite-porphyries.

As regards **tectonic relationships**, the South-Minusinsk depression belongs to the system of Devonian riftogenic basins of the central part of the Altai-Sayan fold (orogenic ?) region (Parnachev, Viltsan & Makarenko 1996), for which a combination of vulcanites of elevated alkalinity with terrigenous rocks of continental molasse sub-formation (type ?) and distinctive "riftogenic" mineralisation is characteristic. Within the study region are recorded the southwestern margins of a depression, which, along the Kandatskii deep fracture, is accounted part of the tectonic structure of the Western Sayan mega-anticlinorium. In the north, northeast and northwest, it is regarded as belonging to the Salairskii-Caledonian megacomplexes of the Kuznetsk-Alatau fold system. In the last case, the character of the contact is complex - in places tectonic, in others stratigraphic, with distinct angular disconformities. The middle and upper Palaeozoic deposits of the basin are intensively folded by the "Western Sayan" extension and faulted by numerous disjunctive fractures of varying orientation. The system of plicate dislocations is united with the structure of the Abakanskii and Tashtipskii basins.

APPENDIX D - BOXPLOTS SHOWING DISTRIBUTION OF FIELD AND ANALYTICAL PARAMETERS BASED UPON SAMPLE TYPE, DOMINANT LAND USE (GROUNDWATERS ONLY) AND YEAR OF SAMPLING (ALL WATERS)

Boxplots are based on field determinations, and analytical determinations performed at NGU (i.e. analyses in Tables 3.3, 3.4, 3.5, 3.6, 4.3, 4.5, 4.6, 4.7). H_2S is based on 0 = no smell, 1 = some smell, 2 = strong smell. For the purposes of statistical presentation, concentrations below detection limit are set to half the detection limit.

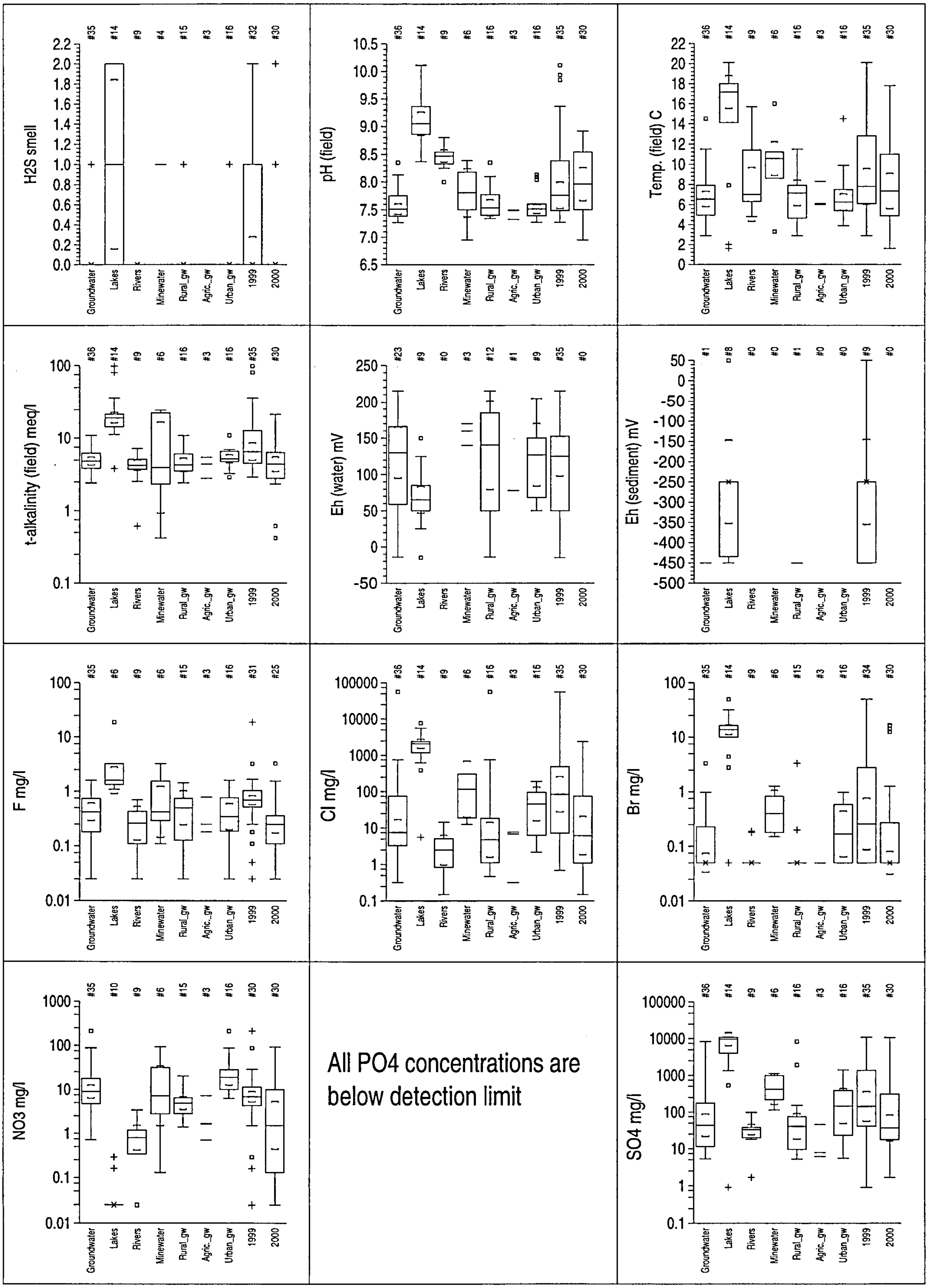
- 1st Figure: H_2S to $SO_4^=$
- 2nd Figure: Ag to Fe, by ICP-AES
- 3rd Figure: K to Si, by ICP-AES
- 4th Figure: Sr by ICP-AES to Co by ICP-MS
- 5th Figure: Cr to Zr, by ICP-MS

The following should be noted:

- H_2S smell is often observed at lake sites (sulphate reduction in lakes)
- pH values are highest in lakes, then in rivers and lowest in groundwaters
- Temperature and alkalinity are also highest in lakes
- Eh is lower in lake water than groundwater
- the following parameters are generally higher in lake waters than other water types, probably due to evaporation (or, in some cases complexation): F^-, Cl^-, Br^-, $SO_4^=$, B, K, Li, Mg, Mn, Na, P, Sr, V, Zn, La (ICP-MS), Ce (ICP-MS), Pb (ICP-MS), Zr (ICP-MS)
- the salinity of urban groundwaters tends to be greater than that of rural or agricultural groundwaters. This is probably related to the location of urban areas in lowlands, but may also have a contamination-related component.
- the following parameters tend to be higher in urban groundwaters than groundwaters with other land uses: Cl^-, Br^-, NO_3^-, $SO_4^=$, B, Ca, Ce, K, Li, Mg, Na, Si, Sr
- lake waters generally have less of the following parameters than other water types: Ba, Ca, Si
- urban groundwaters generally have less of the following elements than the other land use categories: Ba
- Mine waters tend to be relatively high in the following parameters compared with other water types: Fe, Mn, Mo, Al (ICP-MS), Co (ICP-MS)
- Cd (ICP-MS) is significantly higher in the year 2000 than in 1999, backing up the laboratory's suspicion that analysed Cd by ICP-MS was systematically too high for that year (see footnote to Table 4.7)

Note that the most saline samples were often not analysed by ICP-MS. This leads to distortion in boxplots for elements analysed by ICP-MS especially for lake waters, the majority of which are rather saline.

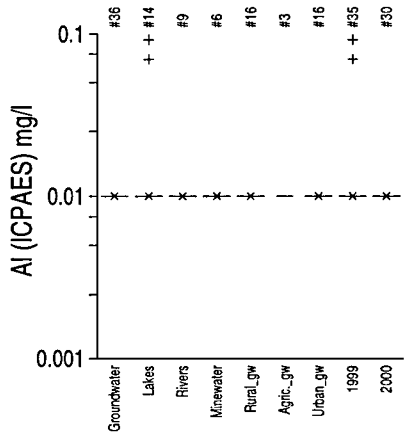
Di

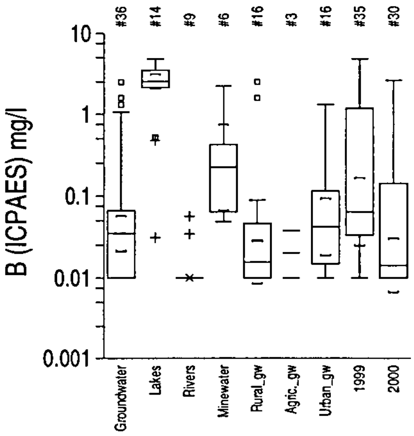


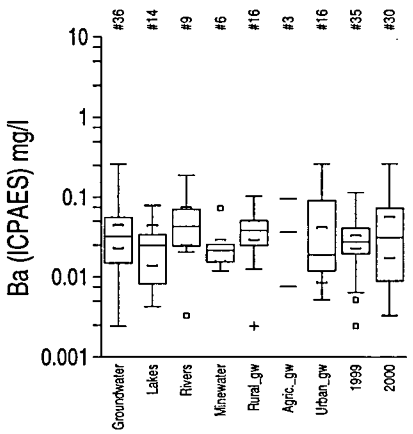
H2S smell
pH (field)
Temp. (field) C
t-alkalinity (field) meq/l
Eh (water) mV
Eh (sediment) mV
F mg/l
Cl mg/l
Br mg/l
NO3 mg/l
All PO4 concentrations are below detection limit
SO4 mg/l
Groundwater
Lakes
Rivers
Minewater
Rural_gw
Agric._gw
Urban_gw
1999
2000

Dii

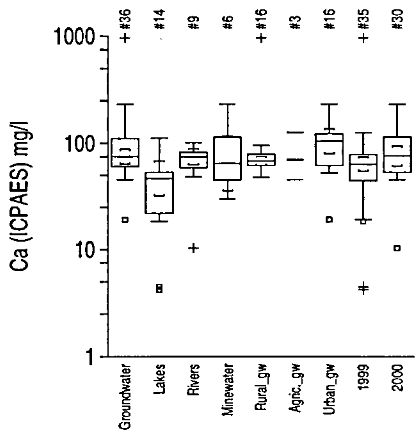
Ag by ICP-AES
all data below detection (0.01 mg/l)



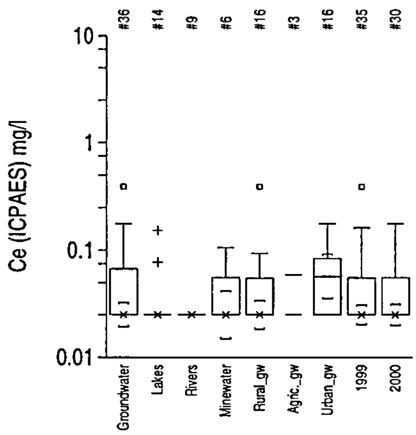




Be by ICP-AES
all data b.d.l. (0.001 mg/l)

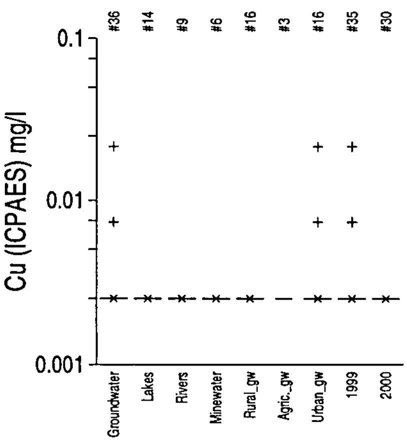


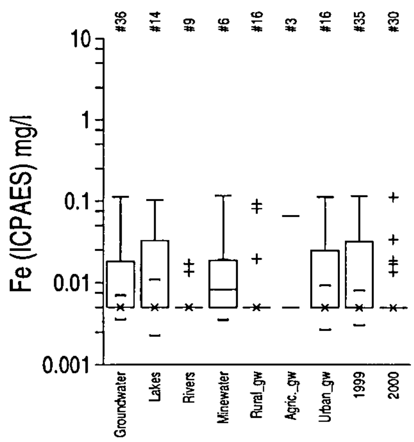
Cd by ICP-AES
all data b.d.l. (0.005 mg/l)



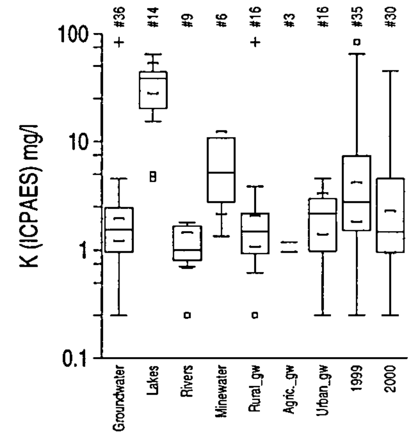
Co - by ICP-AES
all data below detection (0.01 mg/l)

Cr - by ICP-AES
all data below detection (0.01 mg/l)



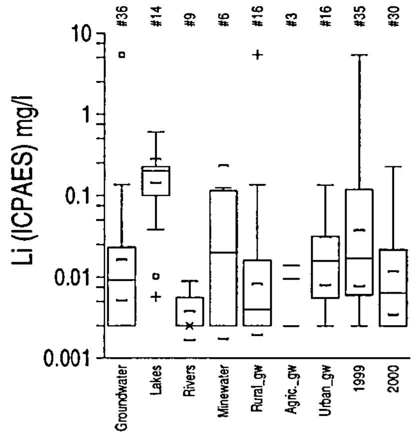


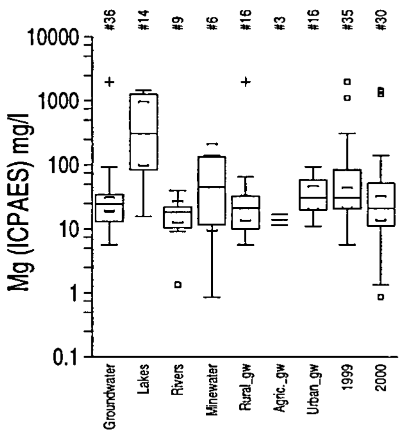
Diii

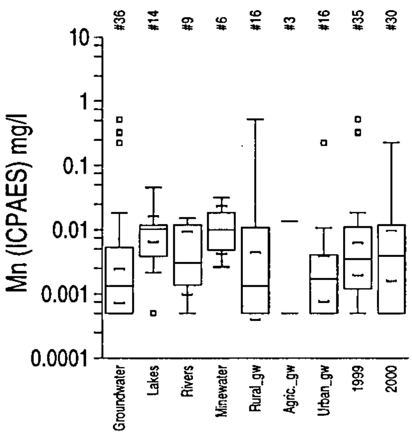


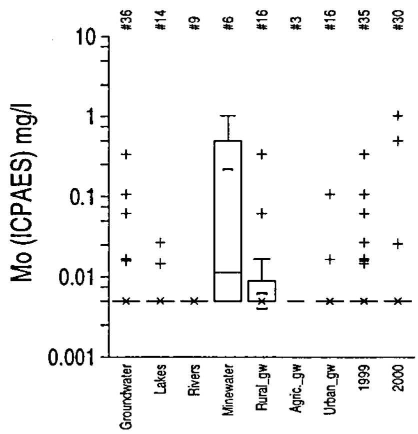
La by ICP-AES

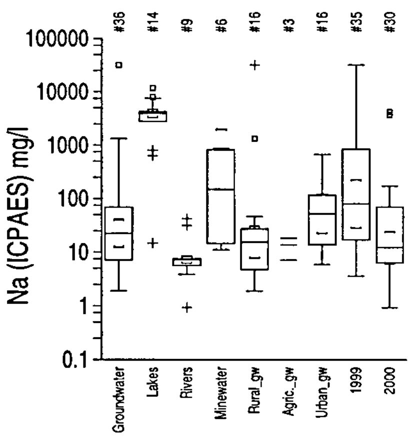
all data b.d.l. (0.01 mg/l)





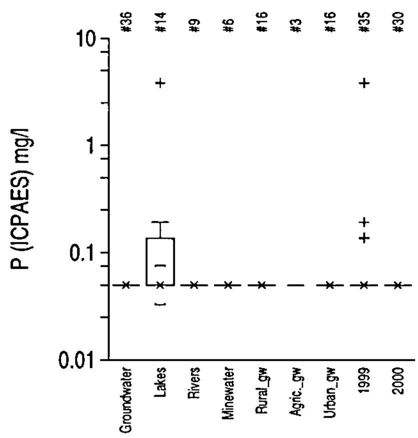






Ni by ICP-AES

all data b.d.l. (0.02 mg/l)

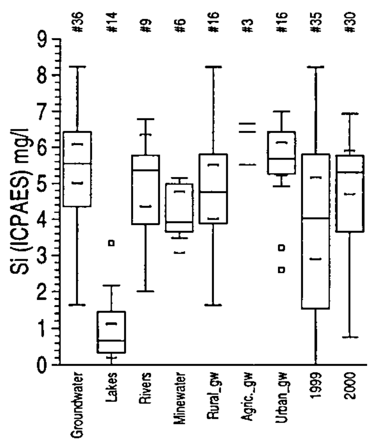


Pb by ICP-AES

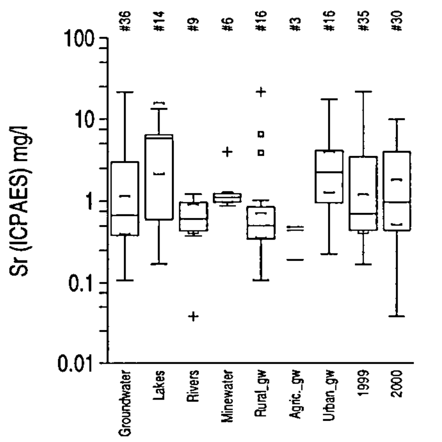
all data b.d.l. (0.05 mg/l)

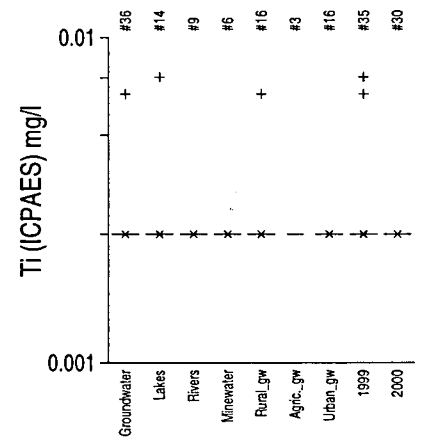
Sc by ICP-AES

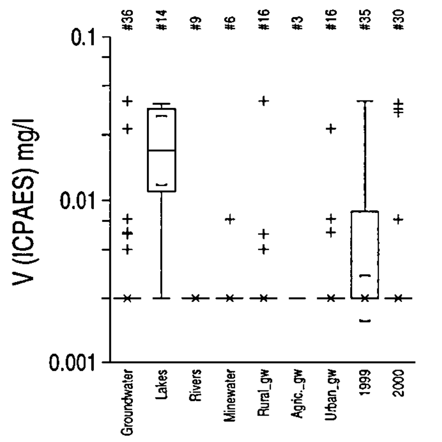
all data b.d.l. (0.001 mg/l)



Div

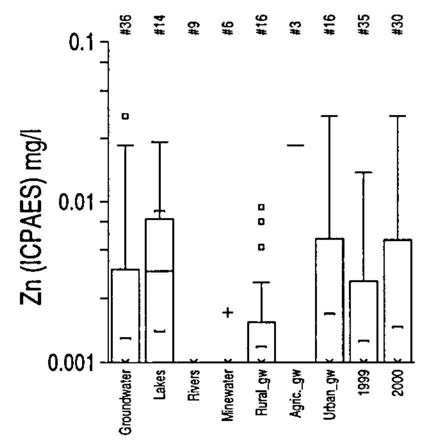


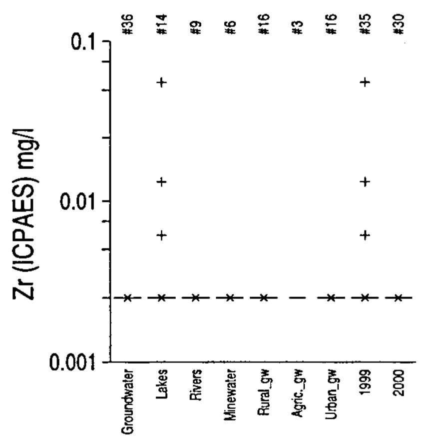


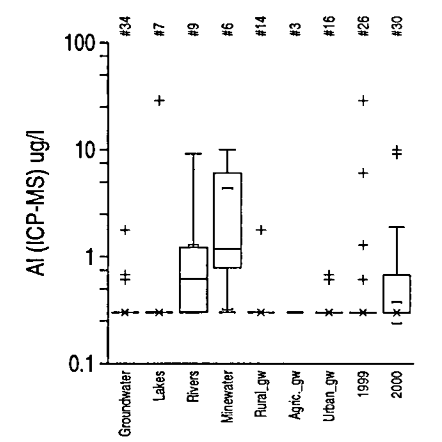


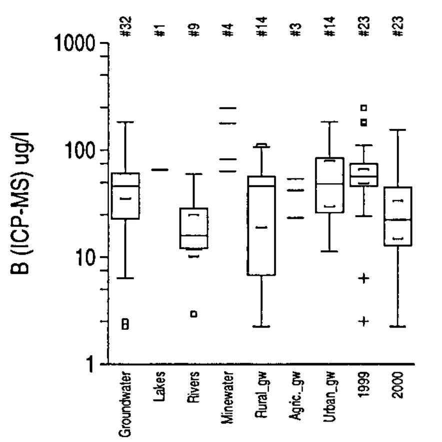
Y by ICP-AES

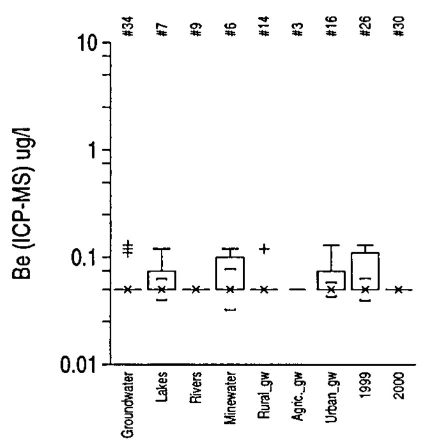
all data b.d.l. (0.001 mg/l)

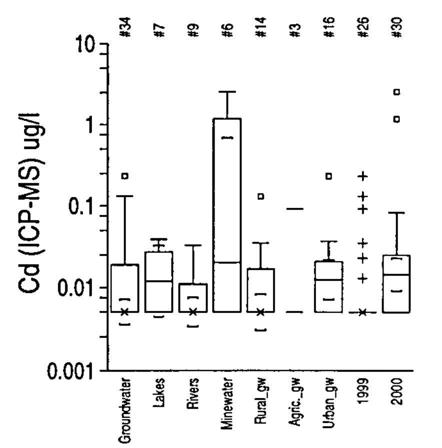


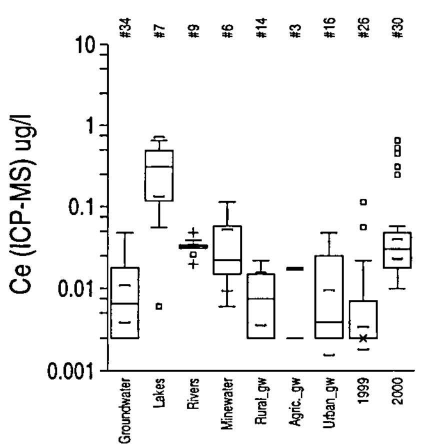


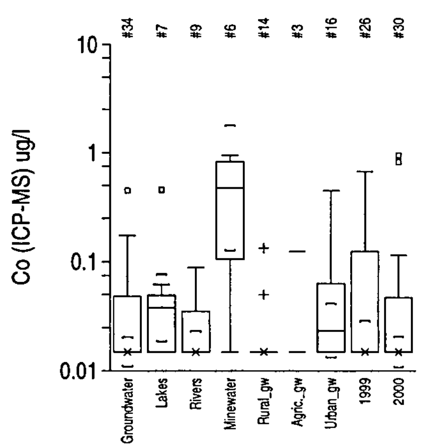




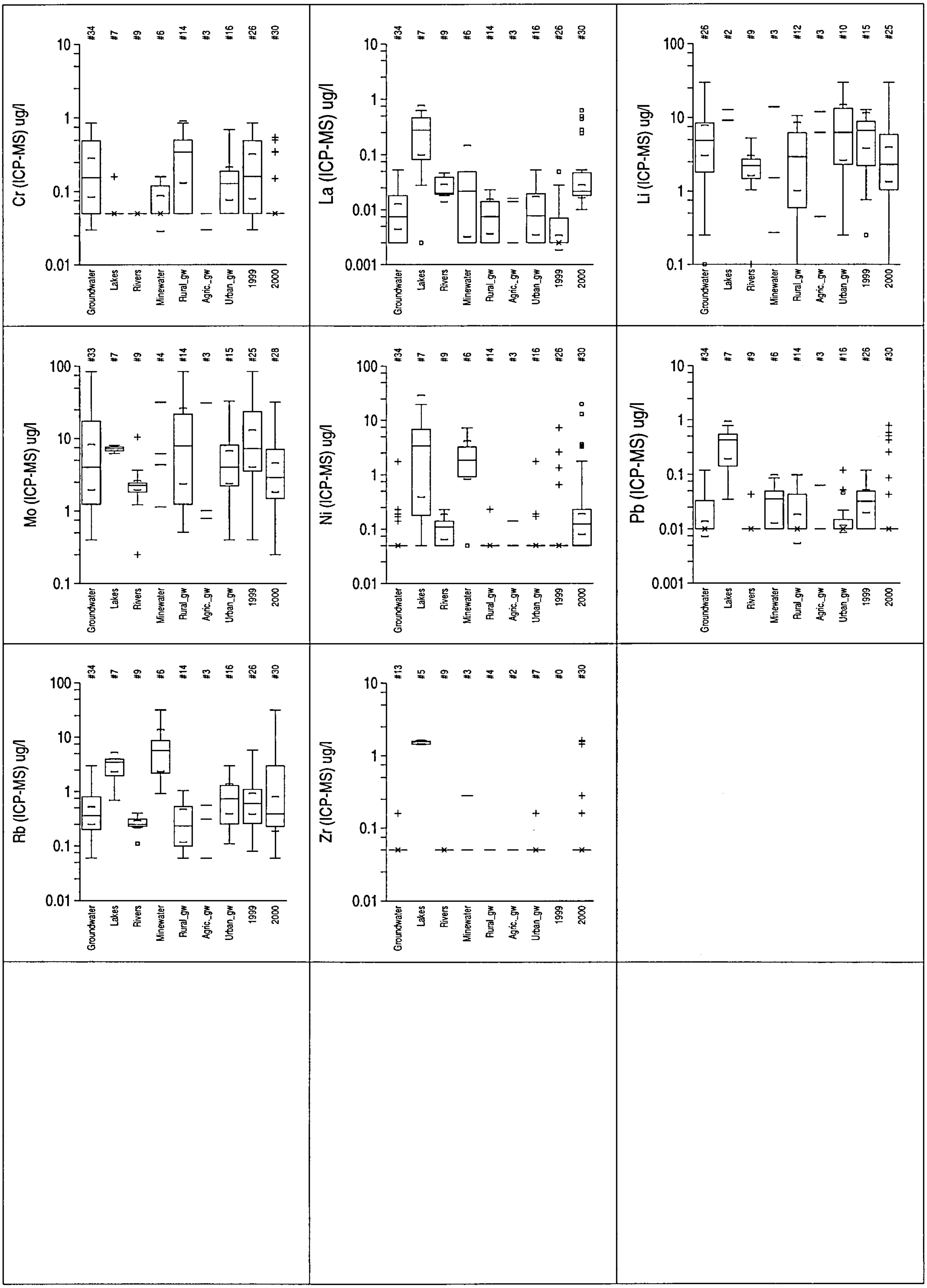








Dv



Cr (ICP-MS) ug/l
La (ICP-MS) ug/l
Li (ICP-MS) ug/l
Mo (ICP-MS) ug/l
Ni (ICP-MS) ug/l
Pb (ICP-MS) ug/l
Rb (ICP-MS) ug/l
Zr (ICP-MS) ug/l
Groundwater
Lakes
Rivers
Minewater
Rural_gw
Agric._gw
Urban_gw
1999
2000

APPENDIX E - BOXPLOTS SHOWING DISTRIBUTION OF FIELD AND ANALYTICAL PARAMETERS BASED UPON DOMINANT AQUIFER GEOLOGY

Boxplots are based on field determinations, and analytical determinations performed at NGU (i.e. analyses in Tables 3.3, 3.4, 3.5, 3.6, 4.3, 4.5, 4.6, 4.7). H_2S is based on 0 = no smell, 1 = some smell, 2 = strong smell. For the purposes of statistical presentation, concentrations below detection limit are set to half the detection limit.

1st Figure: H_2S to $SO_4^=$
2nd Figure: Ag to Fe, by ICP-AES
3rd Figure: K to Si, by ICP-AES
4th Figure: Sr by ICP-AES to Co by ICP-MS
5th Figure: Cr to Zr, by ICP-MS

Note: LPS = Precambrian and Lower Palaeozoic sedimentary rocks (groundwater only)
LPV = Precambrian and Lower Palaeozoic volcanic rocks (groundwater only)
C-O_Granite = Cambro-Ordovician intrusive igneous granitoids (groundwater only)
D12_tot = Lower and Middle Devonian strata (groundwater only)
D3 = Upper Devonian Strata (groundwater only)
Carb. = Carboniferous strata (groundwater only)
Q = superficial Quaternary sediments (groundwater only)

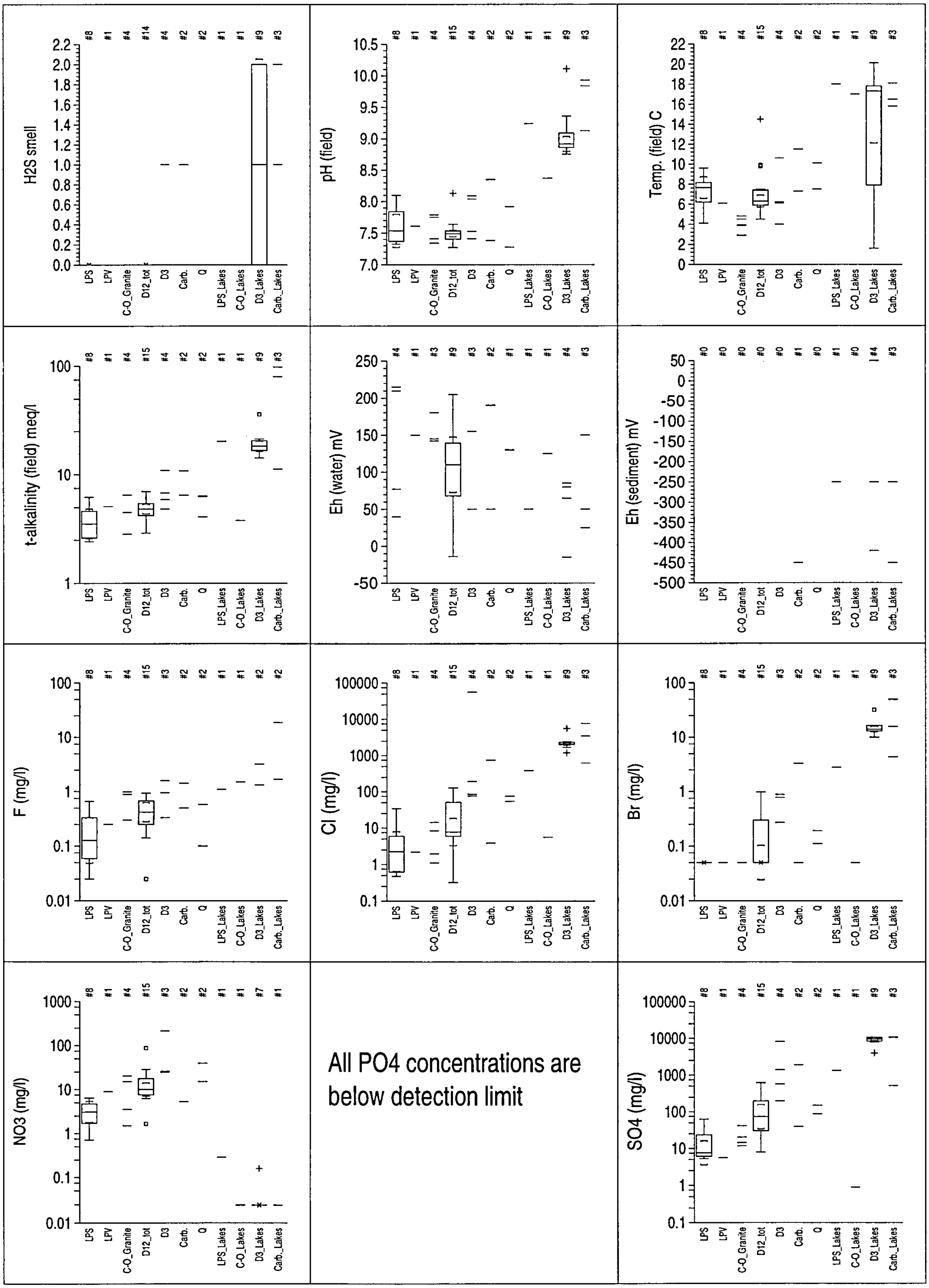
LPS_Lakes = Precambrian and Lower Palaeozoic sedimentary rocks (lake waters only)
etc.

The following should be noted:

- H_2S smell is typically observed at lake sites in D3 and Carboniferous geology (sulphate reduction in lakes)
- pH and alkalinity values are highest in lakes.
- Temperatures are also highest in lakes
- Many parameters in groundwater exhibit their highest values in D3 and Carb., followed by D12, with lowest values in the Lower Palaeozoic and Precambrian rocks. These include: F^-, Cl^-, Br^-, NO_3^- (although in this case not Carb.), $SO_4^=$, B, Ce, K, Li, Mg, Na, Sr, Rb (ICP-MS)
- Many parameters in lake water exhibit their highest values in lakes in D3 and Carb. These include: F^-, Cl^-, Br^-, $SO_4^=$, B, Fe, K, Li, Na

Note that the most saline samples were often not analysed by ICP-MS. This leads to distortion in boxplots for elements analysed by ICP-MS especially for lake waters, the majority of which are rather saline.

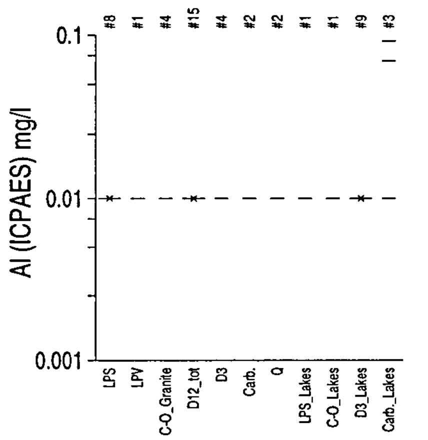
Ei

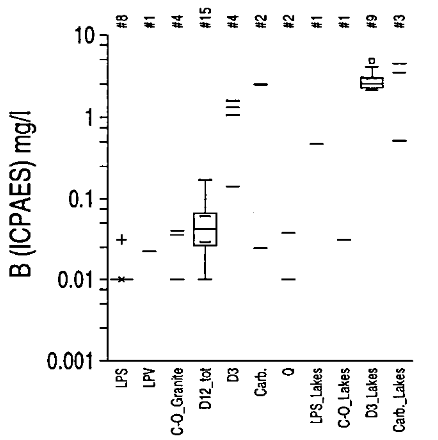

H2S smell
pH (field)
Temp. (field) C
t-alkalinity (field) meq/l
Eh (water) mV
Eh (sediment) mV
F (mg/l)
Cl (mg/l)
Br (mg/l)
NO3 (mg/l)
All PO4 concentrations are below detection limit
SO4 (mg/l)
LPS
LPV
C-O_Granite
D12_tot
D3
Carb.
Q
LPS_Lakes
C-O_Lakes
D3_Lakes
Carb._Lakes

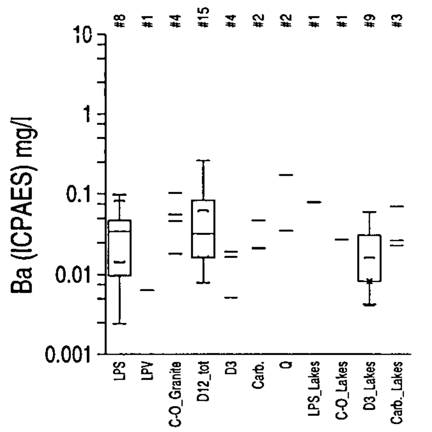
Eü

Ag by ICP-AES

all data below detection (0.01 mg/l)

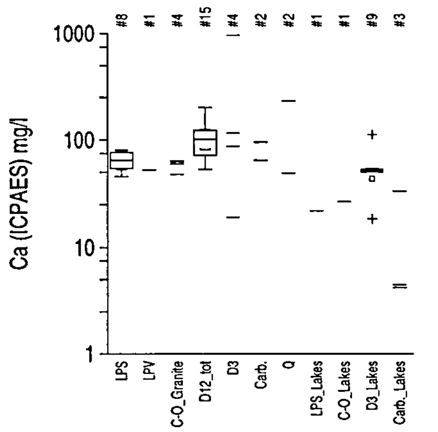






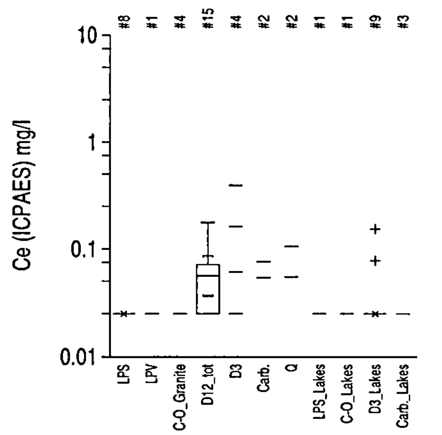
Be by ICP-AES

all data b.d.l. (0.001 mg/l)



Cd by ICP-AES

all data b.d.l. (0.005 mg/l)

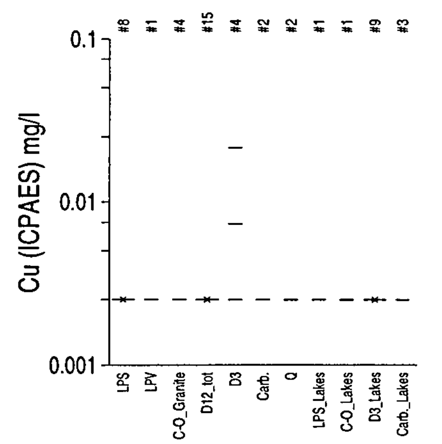


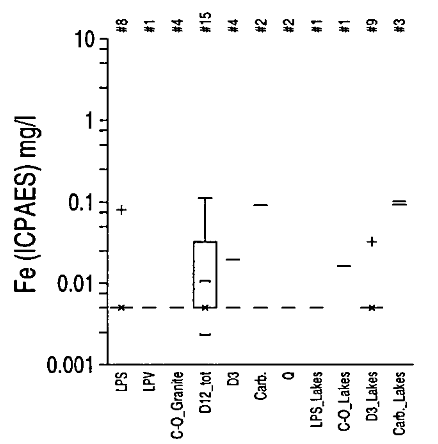
Co - by ICP-AES

all data below detection (0.01 mg/l)

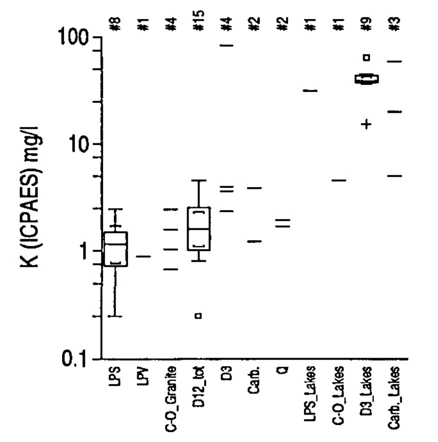
Cr - by ICP-AES

all data below detection (0.01 mg/l)



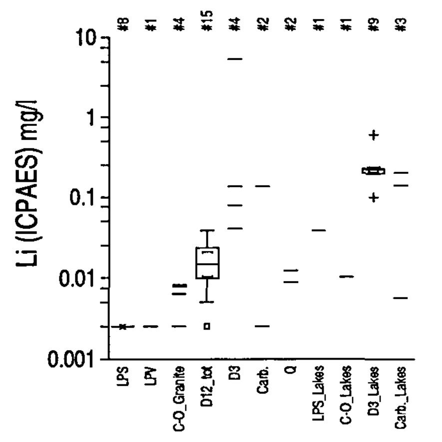


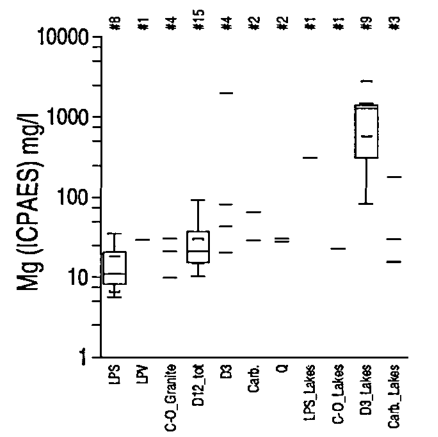
Eiii

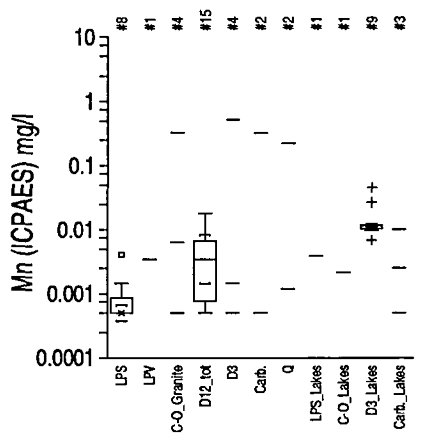


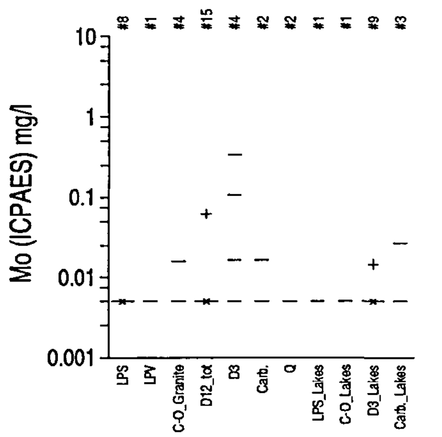
La by ICP-AES

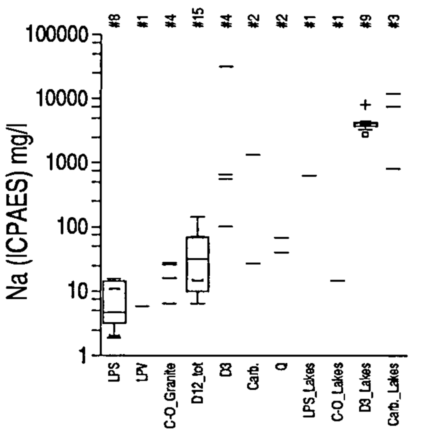
all data b.d.l. (0.01 mg/l)





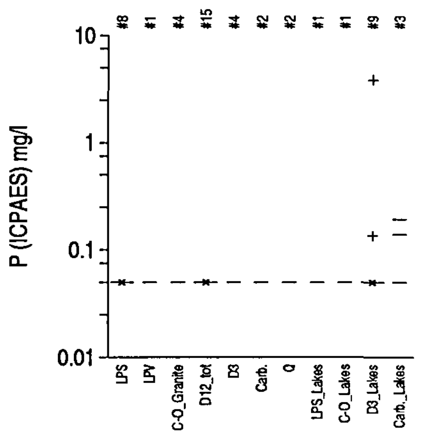






Ni by ICP-AES

all data b.d.l. (0.02 mg/l)

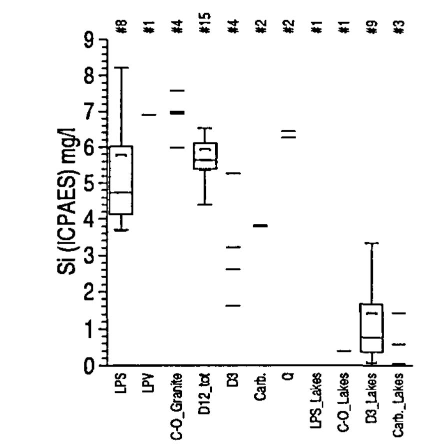


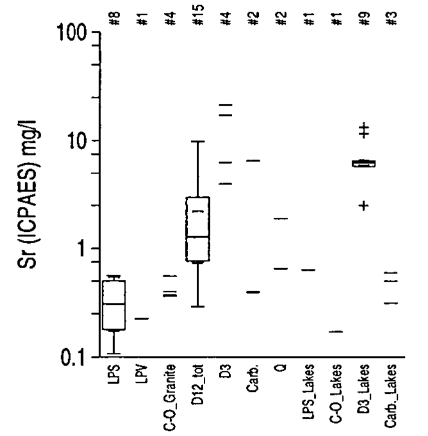
Pb by ICP-AES

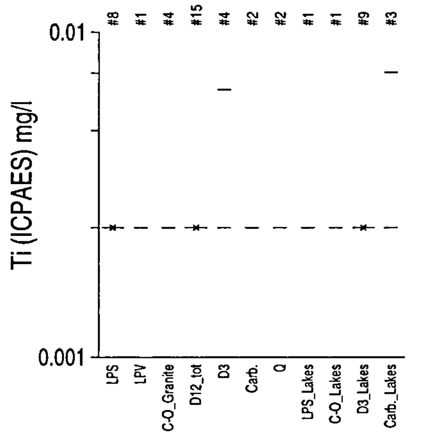
all data b.d.l. (0.05 mg/l)

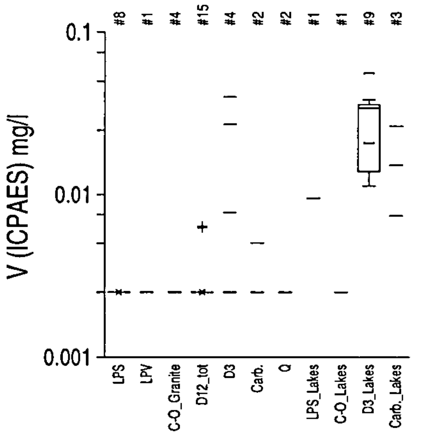
Sc by ICP-AES

all data b.d.l. (0.001 mg/l)



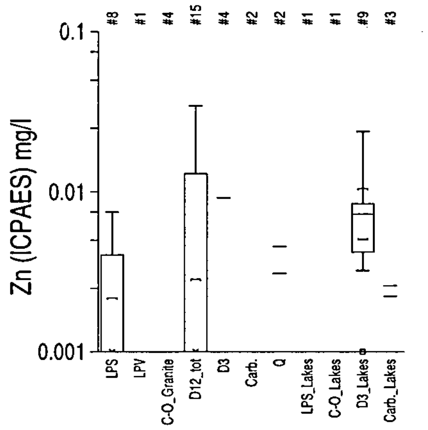


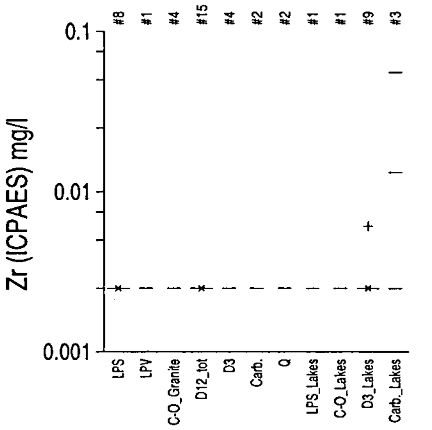


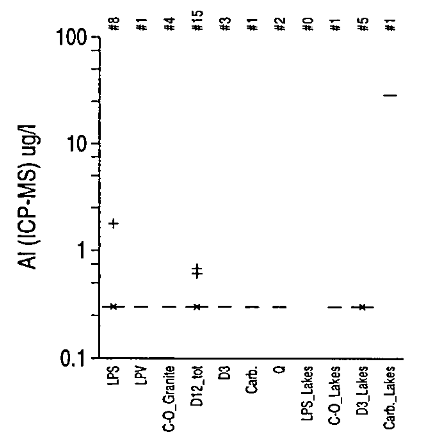


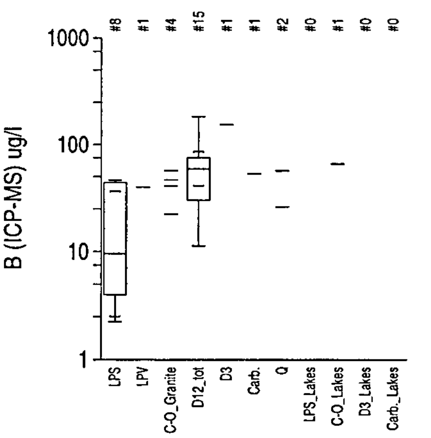
Y by ICP-AES

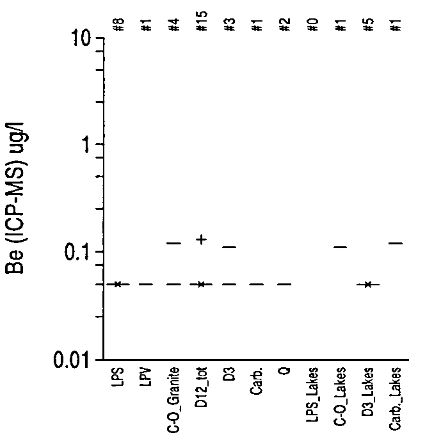
all data b.d.l. (0.001 mg/l)

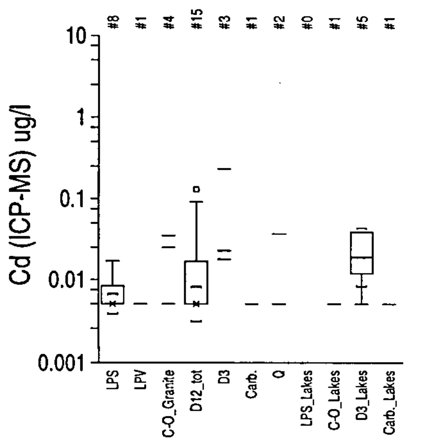


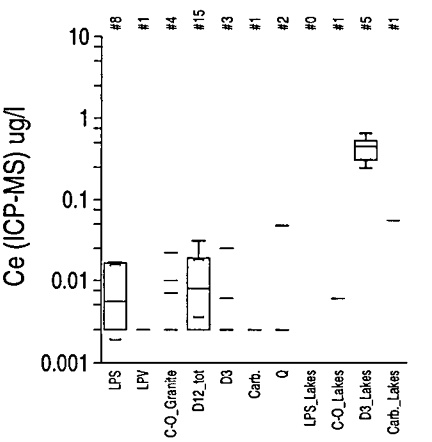


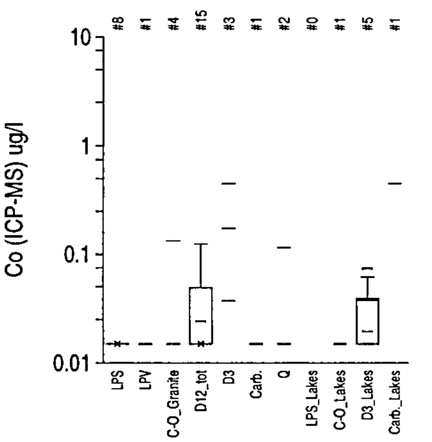




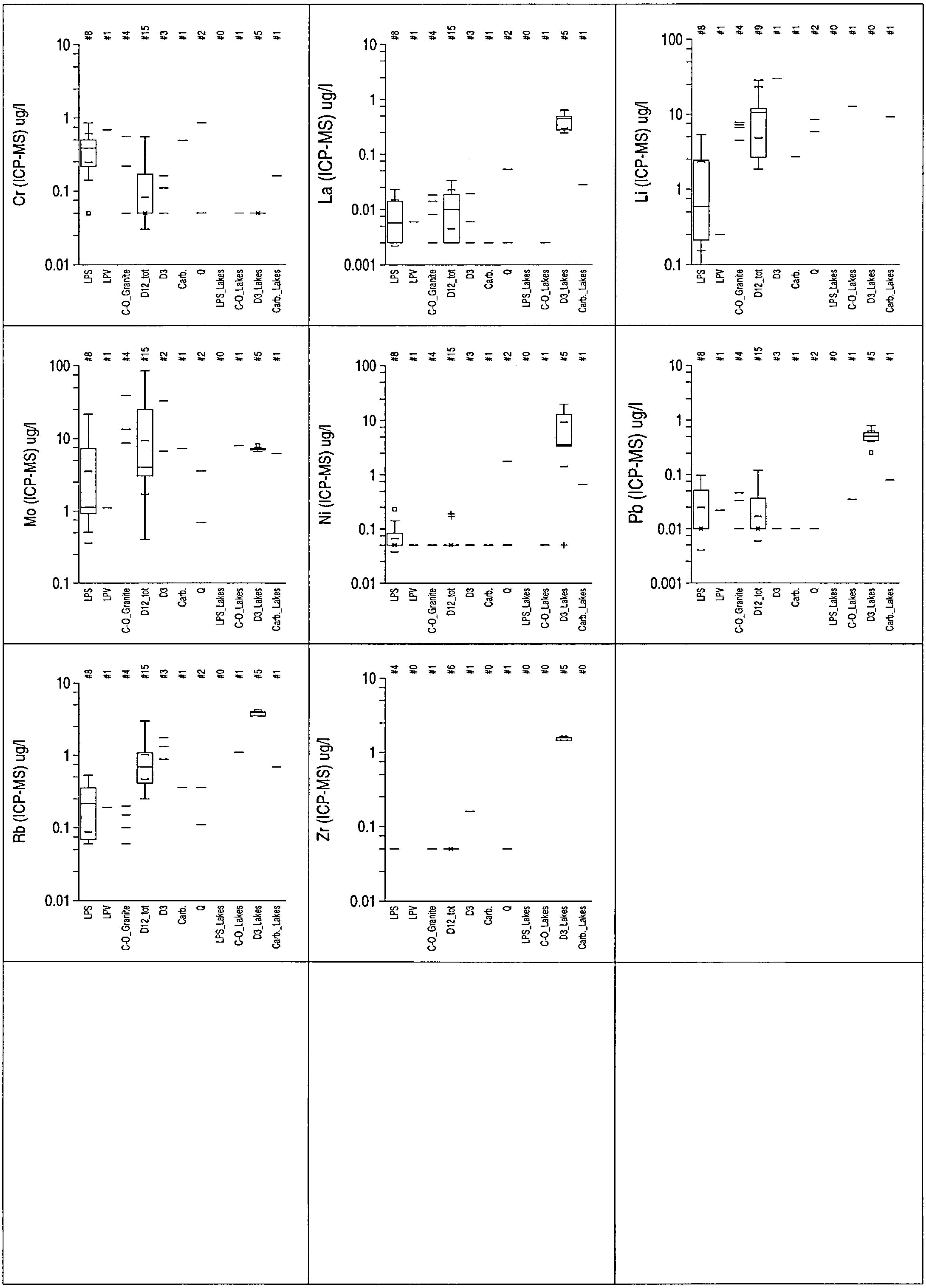








Ev



Cr (ICP-MS) ug/l
La (ICP-MS) ug/l
Li (ICP-MS) ug/l
Mo (ICP-MS) ug/l
Ni (ICP-MS) ug/l
Pb (ICP-MS) ug/l
Rb (ICP-MS) ug/l
Zr (ICP-MS) ug/l
LPS
LPV
C-O_Granite
D12_tot
D3
Carb.
Q
LPS_Lakes
C-O_Lakes
D3_Lakes
Carb._Lakes
#8 #1 #4 #15 #3 #1 #2 #0 #1 #5 #1
#8 #1 #4 #9 #1 #1 #2 #0 #1 #0 #1
#8 #1 #4 #15 #2 #1 #2 #0 #1 #5 #1
#4 #0 #1 #6 #1 #0 #1 #0 #0 #5 #0

APPENDIX F - BOXPLOTS SHOWING DISTRIBUTION OF BACTERIOLOGICAL PARAMETERS, BASED UPON WATER TYPE, DOMINANT LAND USE (GROUNDWATERS ONLY) AND YEAR OF SAMPLING (ALL WATERS)

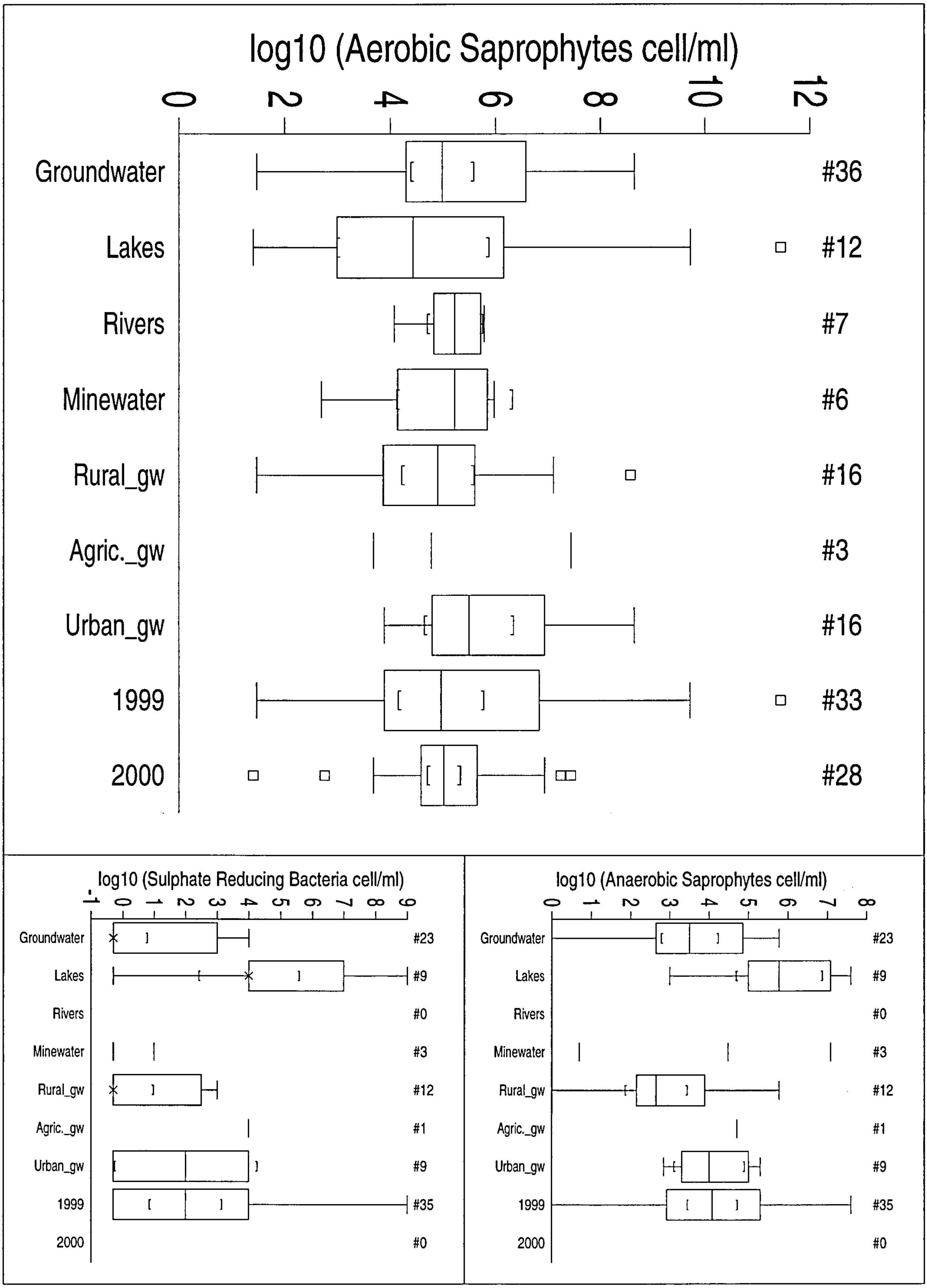
Boxplots are based analytical determinations performed at TGU (i.e. analyses in Tables in 3.7 and 4.8). Note that in the year 2000, only analyses for aerobic saprophytes were carried out).

1st Figure: Aerobic and anaerobic saprophytes, sulphate reducing bacteria

The following should be noted:

- of the water types, aerobic saprophytes are fewest in the lake waters, whereas anaerobic saprophytes and SRB are most abundant in the lake waters.
- as regards land use, all three classes of bacteria are most abundant in urban groundwaters.

Fi



log10 (Aerobic Saprophytes cell/ml)
0
2
4
6
8
10
12
Groundwater
Lakes
Rivers
Minewater
Rural_gw
Agric._gw
Urban_gw
1999
2000
#36
#12
#7
#6
#16
#3
#16
#33
#28
log10 (Sulphate Reducing Bacteria cell/ml)
-1
0
1
2
3
4
5
6
7
8
9
Groundwater
Lakes
Rivers
Minewater
Rural_gw
Agric._gw
Urban_gw
1999
2000
#23
#9
#0
#3
#12
#1
#9
#35
#0
log10 (Anaerobic Saprophytes cell/ml)
0
1
2
3
4
5
6
7
8
Groundwater
Lakes
Rivers
Minewater
Rural_gw
Agric._gw
Urban_gw
1999
2000
#23
#9
#0
#3
#12
#1
#9
#35
#0

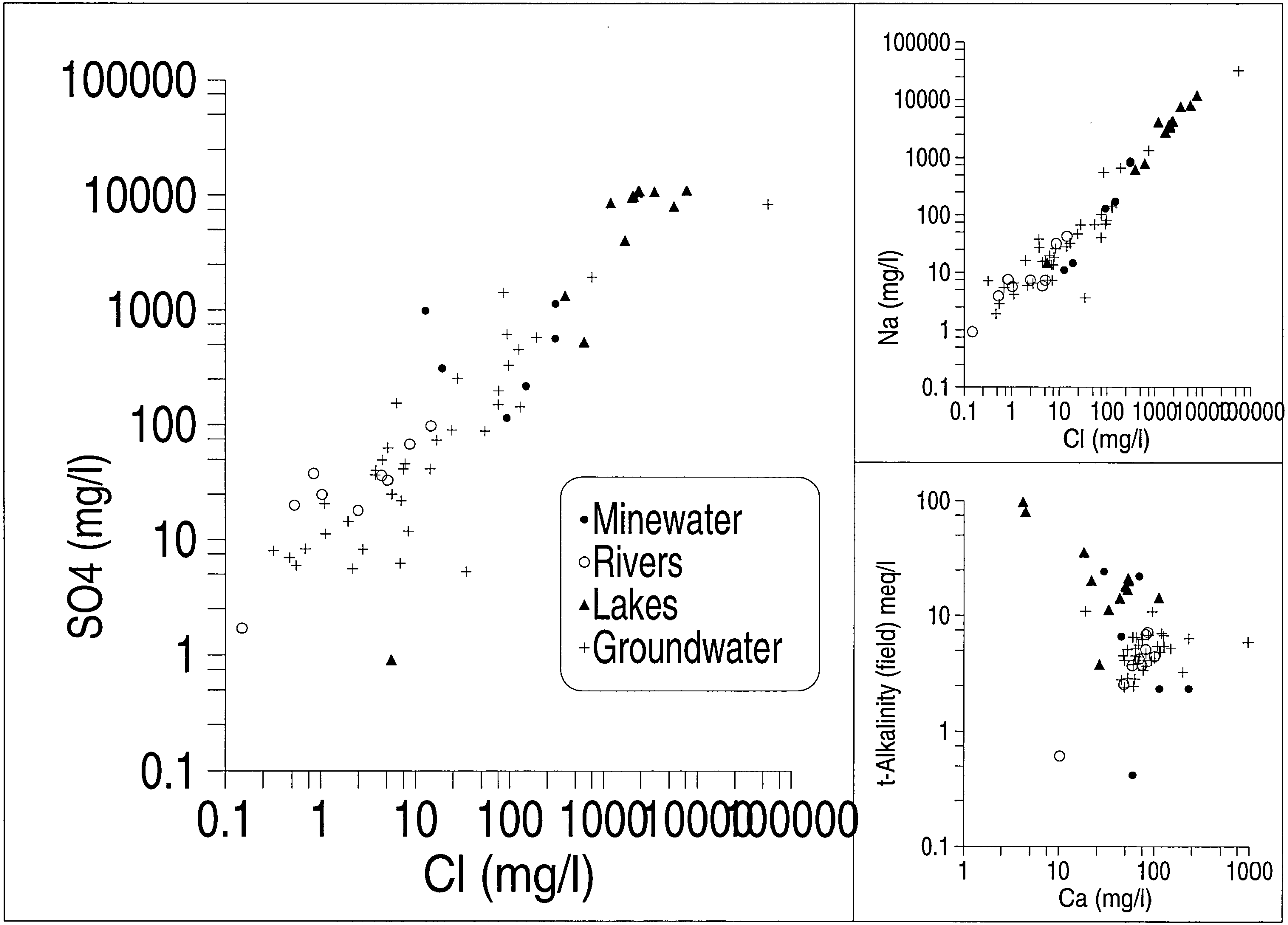
APPENDIX G - VARIATION OF ANALYTICAL PARAMETERS WITH CHLORIDE SALINITY

Boxplots are based on field determinations, and analytical determinations performed at NGU (i.e. analyses in Tables 3.3, 3.4, 3.5, 3.6, 4.3, 4.5, 4.6, 4.7). For the purposes of statistical presentation, concentrations below detection limit are set to half the detection limit.

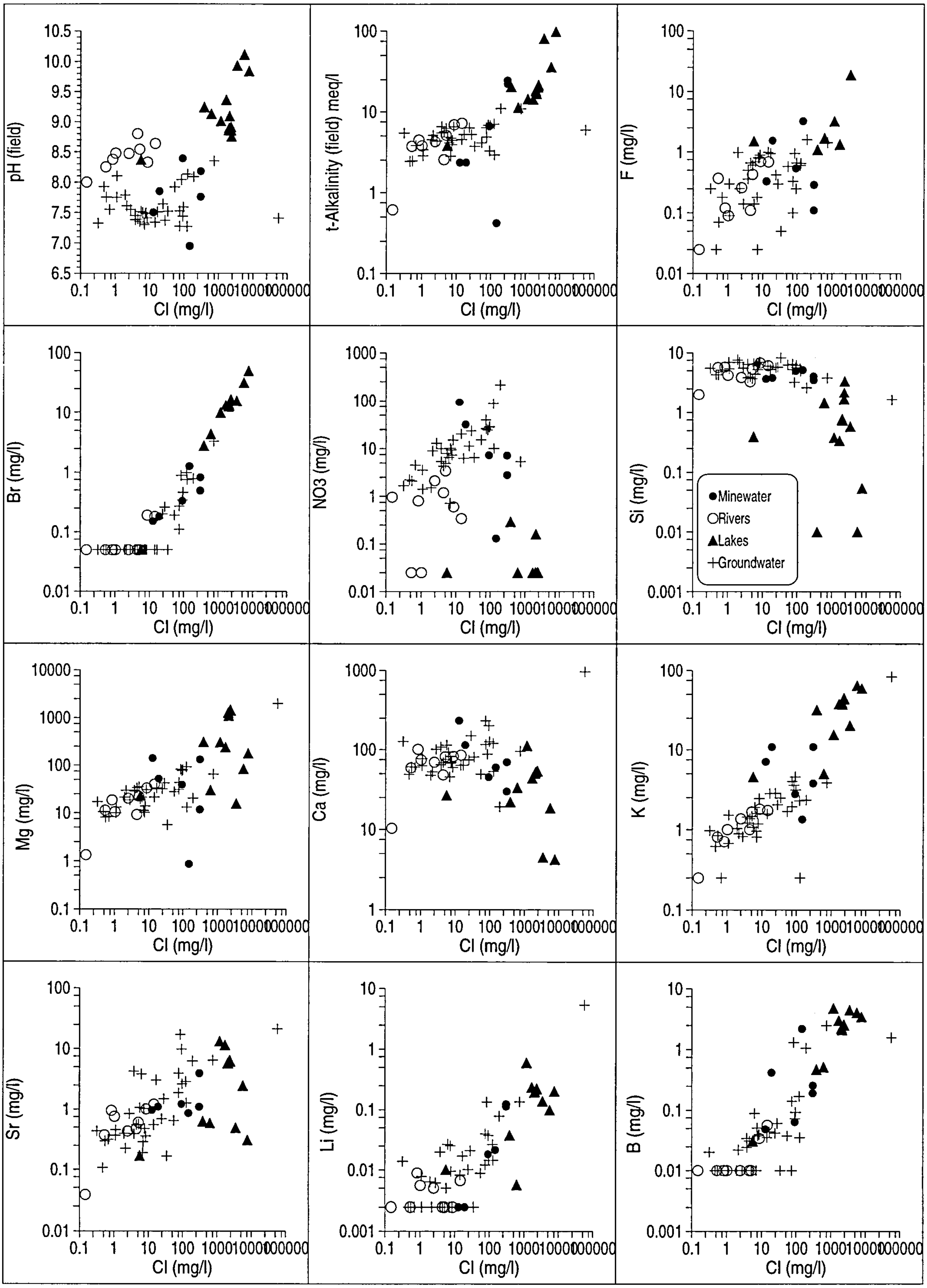
1st Figure: Correlations of chloride versus sulphate, chloride versus sodium and calcium versus t-alkalinity for all waters, according to water type.
2nd Figure: Correlation of various parameters (pH, t-alkalinity (field), F^-, Br^-, NO_3^- (by IC), Si, Mg, Ca, K, Sr, Li, B (by ICP-AES) with chloride (by IC) for all waters, according to water type.

The following should be noted:

- for Ca vs. t-alkalinity the upper envelope of the data shows a tendency towards a negative trend. This is indicative of the presence of calcium and alkalinity being limited by a saturation ceiling for calcium carbonate.
- There is a very good correlation between chloride and sulphate, but an even better one between sodium and chloride.
- There is a correlation between t-alkalinity and chloride, especially in higher salinity samples.
- Lake waters are characterised by high concentrations of salinity related parameters (Cl^-, $SO_4^=$, Na, Br^-, Mg, K, Sr, Li, B), all of which have a good correlation with chloride.
- Fluoride also shows some degree correlation with chloride, especially in the more saline water samples.
- Nitrate shows some degree of correlation with salinity in rivers and groundwaters, possibly indicating it to be concentrated by evaporation. In lakes, however, it exhibits low concentrations, probably related to nitrate reduction processes.
- Lake waters exhibit especially high pH values. River waters also exhibit higher pH values than groundwaters, for a given chloride concentration.
- Silicon and calcium concentrations are relatively constant in waters of low to moderate salinity, but decrease in ground- and lake-waters of high salinity.


SO4 (mg/l)
Cl (mg/l)
Minewater
Rivers
Lakes
Groundwater
Na (mg/l)
Cl (mg/l)
t-Alkalinity (field) meq/l
Ca (mg/l)

Gii



pH (field)
t-Alkalinity (field) meq/l
F (mg/l)
Br (mg/l)
NO3 (mg/l)
Si (mg/l)
Mg (mg/l)
Ca (mg/l)
K (mg/l)
Sr (mg/l)
Li (mg/l)
B (mg/l)
Cl (mg/l)
Minewater
Rivers
Lakes
Groundwater

APPENDIX H - COVARIATION OF BACTERIOLOGICAL WITH OTHER ANALYTICAL PARAMETERS

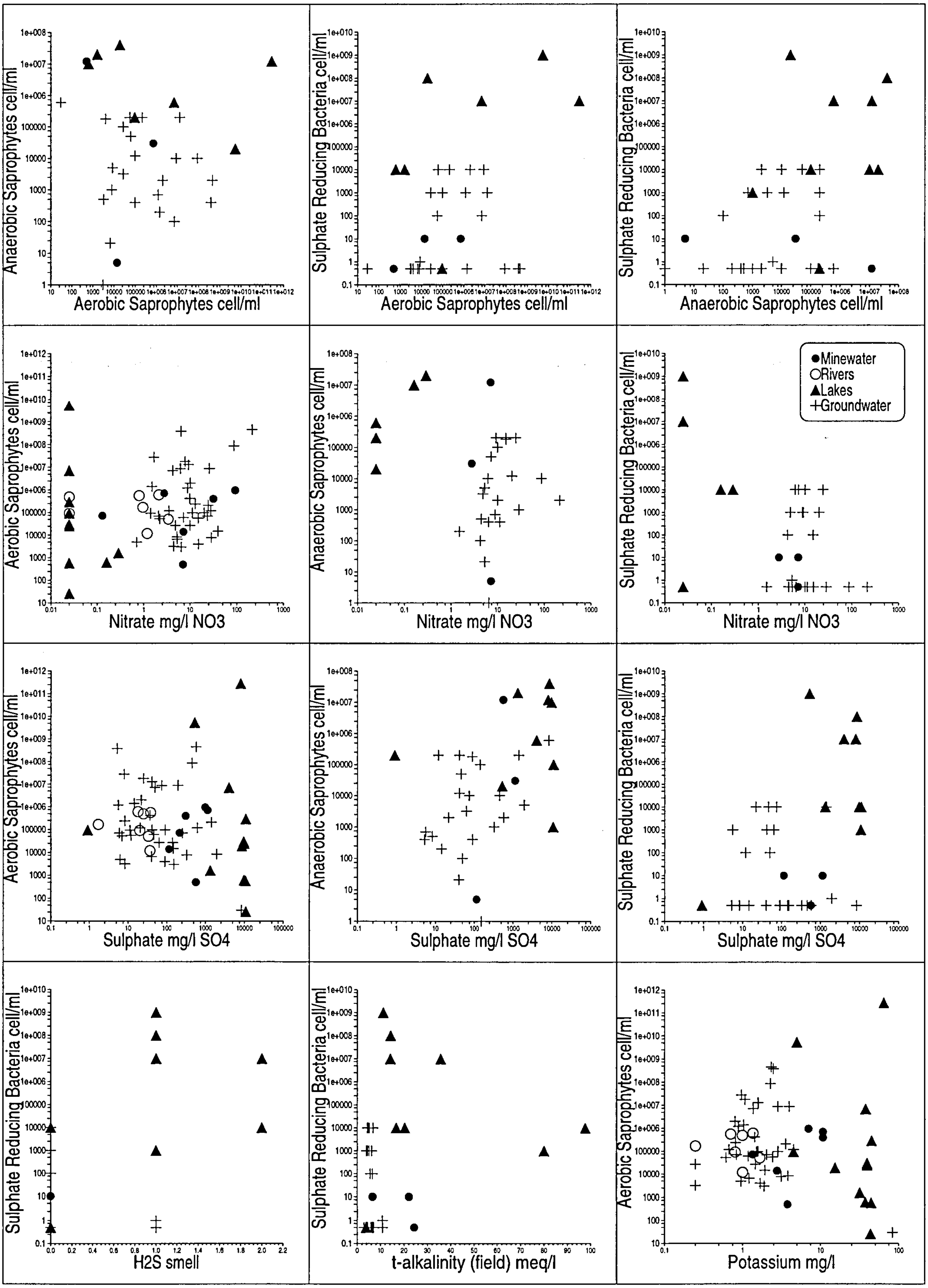
Boxplots are based on bacteriological analyses performed at TGU (Tables in Sections 3.7 and 4.8), field determinations, and analytical determinations performed at NGU (i.e. analyses in Sections 3.3, 3.4, 3.5, 3.6, 4.3, 4.5, 4.6, 4.7). For the purposes of statistical presentation, concentrations below detection limit are set to half the detection limit.

1st Figure: Inter-correlations of bacteriological parameters, correlation of bacteriological parameters with nitrate, sulphate, H_2S smell, t-alkalinity and potassium for all waters, according to water type.

The following should be noted:

- There is no clear correlation between aerobic saprophytes and anaerobic saprophytes / SRB
- There is a weak positive correlation between anaerobic saprophytes and SRB
- There is a weak positive correlation between aerobic saprophytes and nitrate
- There is a weak negative correlation between anaerobic saprophytes/SRB and nitrate
- There are weak positive correlations between anaerobic saprophytes / SRB and sulphate.
- There is a weak positive correlation between SRB and the presence of an H_2S smell
- There is no correlation between SRB and alkalinity, nor between aerobic saprophytes and potassium

Hi


Anaerobic Saprophytes cell/ml
Aerobic Saprophytes cell/ml
Sulphate Reducing Bacteria cell/ml
Aerobic Saprophytes cell/ml
Sulphate Reducing Bacteria cell/ml
Anaerobic Saprophytes cell/ml
Aerobic Saprophytes cell/ml
Nitrate mg/l NO3
Anaerobic Saprophytes cell/ml
Nitrate mg/l NO3
Sulphate Reducing Bacteria cell/ml
Nitrate mg/l NO3
Minewater
Rivers
Lakes
Groundwater
Aerobic Saprophytes cell/ml
Sulphate mg/l SO4
Anaerobic Saprophytes cell/ml
Sulphate mg/l SO4
Sulphate Reducing Bacteria cell/ml
Sulphate mg/l SO4
Sulphate Reducing Bacteria cell/ml
H2S smell
Sulphate Reducing Bacteria cell/ml
t-alkalinity (field) meq/l
Aerobic Saprophytes cell/ml
Potassium mg/l

APPENDIX I - COMPARISON OF ELEMENT ANALYSES BY VARIOUS TECHNIQUES AT NGU, AND COVARIATION OF SELECTED PARAMETERS ON X-Y DIAGRAMS (ALL WATERS)

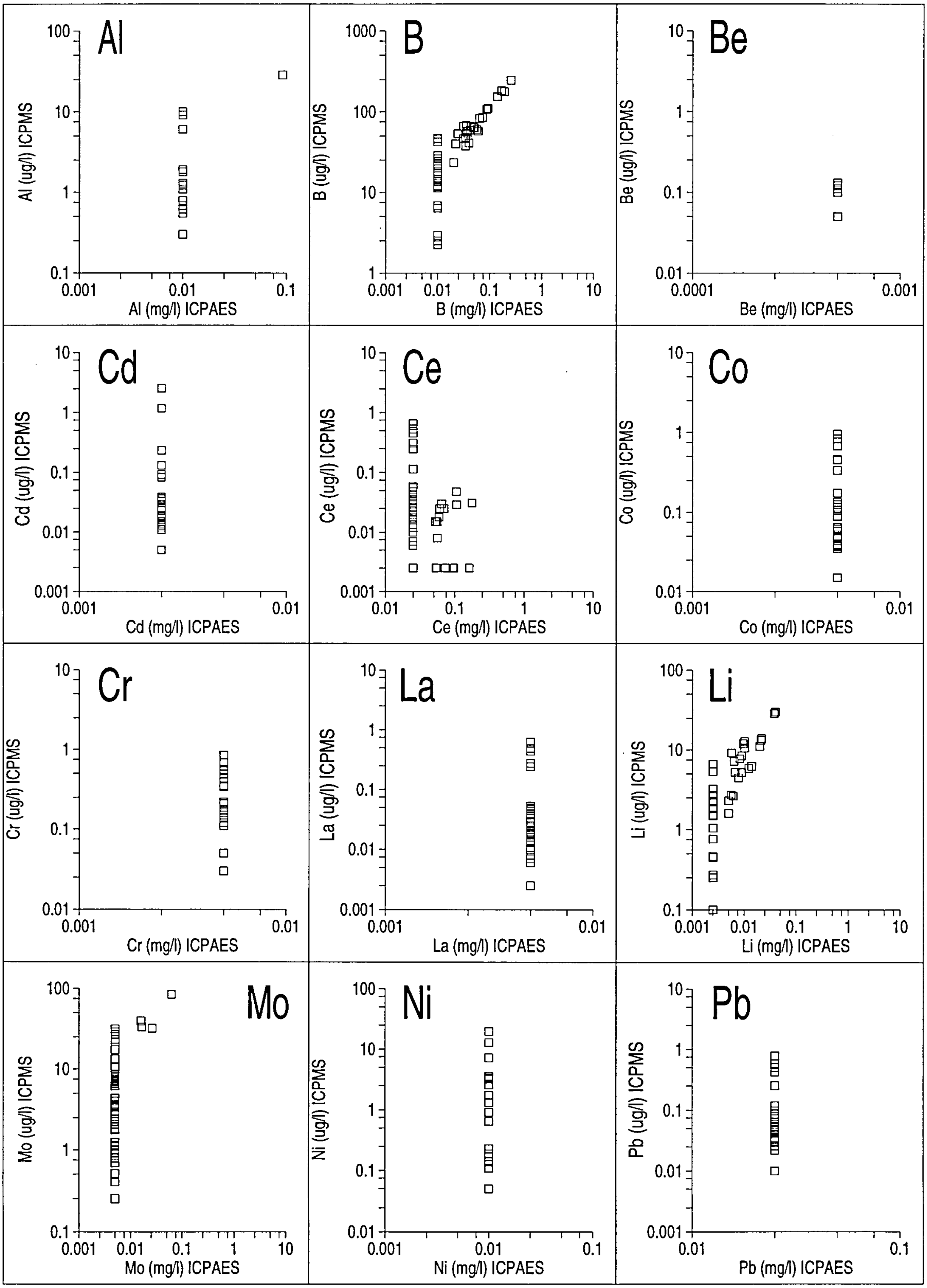
Boxplots are based on field determinations, and analytical determinations performed at NGU (i.e. analyses in Tables 3.3, 3.4, 3.5, 3.6, 4.3, 4.5, 4.6, 4.7). For the purposes of statistical presentation, concentrations below detection limit are set to half the detection limit.

1st Figure:	ICPMS vs. ICPAES for Al to Pb
2nd Figure:	ICP-MS vs. ICPAES for Zr
	IC vs. ICPAES for P
	t- and p-alkalinity in field and in lab. (year 2000 only - Table 4.3)
	Eh in sediment vs. Eh in water
	t-Alkalinity vs. calcium
	Fluoride vs. calcium
	Barium versus sulphate
	Sulphate versus chloride
	Sulphate versus sodium
	Sodium versus chloride
	t-alkalinity vs. chloride

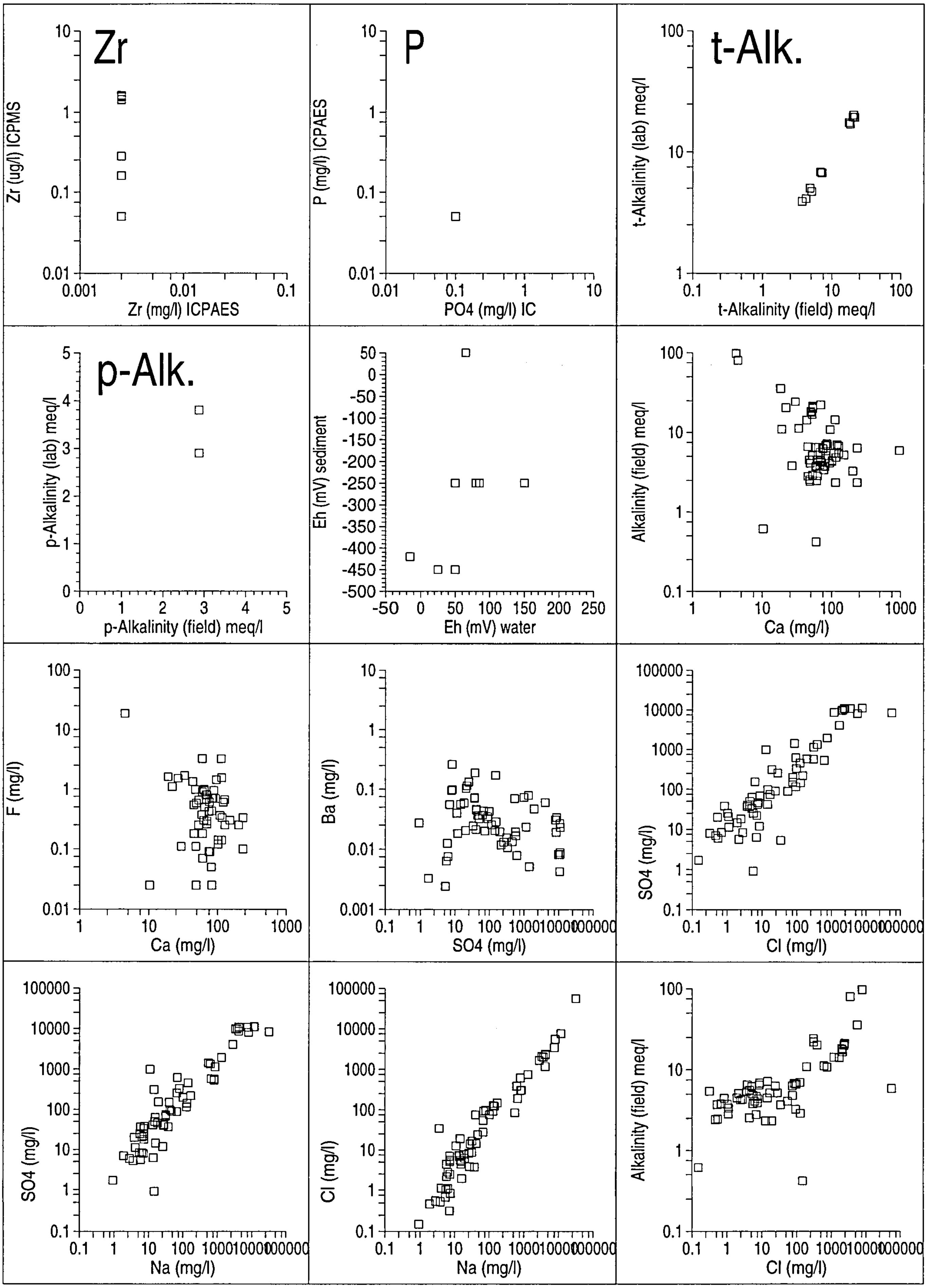
The following should be noted:

- ICP-MS and ICP-AES determinations are broadly compatible for the following elements: Al, B, Be, Cd, Co, Cr, La, Li, Mo, Ni, Pb, Zr. There is a rather poor degree of correlation between ICP-MS and ICP-AES for Ce.
- P by ICP-AES and PO_4^{3-} by IC are compatible
- field and laboratory determinations of alkalinity are compatible.
- there is some correlation between Eh in water and in sediment, with Eh in sediment generally significantly lower than that in water
- for Ca vs. t-alkalinity, fluoride vs. calcium and barium vs. sulphate, the upper envelope of the data shows a tendency towards a negative trend. This is indicative of the presence of calcium, alkalinity, barium and fluoride being limited by saturation ceilings for calcium carbonate, fluorite and barite.
- There is a very good correlation between sodium and sulphate, but an even better one between sodium and chloride.
- There is a correlation between t-alkalinity and chloride, especially in higher salinity samples.

Ii


Al
Al (ug/l) ICPMS
Al (mg/l) ICPAES
B
B (ug/l) ICPMS
B (mg/l) ICPAES
Be
Be (ug/l) ICPMS
Be (mg/l) ICPAES
Cd
Cd (ug/l) ICPMS
Cd (mg/l) ICPAES
Ce
Ce (ug/l) ICPMS
Ce (mg/l) ICPAES
Co
Co (ug/l) ICPMS
Co (mg/l) ICPAES
Cr
Cr (ug/l) ICPMS
Cr (mg/l) ICPAES
La
La (ug/l) ICPMS
La (mg/l) ICPAES
Li
Li (ug/l) ICPMS
Li (mg/l) ICPAES
Mo
Mo (ug/l) ICPMS
Mo (mg/l) ICPAES
Ni
Ni (ug/l) ICPMS
Ni (mg/l) ICPAES
Pb
Pb (ug/l) ICPMS
Pb (mg/l) ICPAES

Iii


Zr
Zr (ug/l) ICPMS
Zr (mg/l) ICPAES
P
P (mg/l) ICPAES
PO4 (mg/l) IC
t-Alk.
t-Alkalinity (lab) meq/l
t-Alkalinity (field) meq/l
p-Alk.
p-Alkalinity (lab) meq/l
p-Alkalinity (field) meq/l
Eh (mV) sediment
Eh (mV) water
Alkalinity (field) meq/l
Ca (mg/l)
F (mg/l)
Ca (mg/l)
Ba (mg/l)
SO4 (mg/l)
SO4 (mg/l)
Cl (mg/l)
SO4 (mg/l)
Na (mg/l)
Cl (mg/l)
Na (mg/l)
Alkalinity (field) meq/l
Cl (mg/l)

APPENDIX J - STRATIGRAPHIC TABLES (IN RUSSIAN) FOR THE STUDY AREA. AFTER PARNACHEV et al. (1998a)

Парначев et al 1998a
(work to 1997) Ji

Кузнецко-Алатаусский мегантиклинорий

Сводная схема стратиграфии района отражена в легенде (табл. 6.1, 6.2, 6.3)

Рифейская эратема (R) включает 4 свиты - сыннигскую, тюримскую, чарыштатскую и биджинскую. Сыннигская свита состоит из туфопесчаников, туфоконгломератов и эффузивов среднего и кислого составов с редкими прослоями известняков и кремнистых сланцев, т.е. состав пород этой свиты существенно вулканогенный. Остальные три свиты мало отличаются по литологии - они сложены известняками, доломитами с прослоями песчаников, алевролитов, сланцев. Таким образом, для рифейских отложений Кузнецкого Алатау характерен существенно карбонатный фациальный профиль.

Вендская система (V) объединяет несколько свит: амарская - песчаники, конгломераты, алевролиты; таржульская - доломиты, известняки, силицилиты; гидринская - доломиты, известняки; мартюхинская - доломиты, известняки. Таким образом, в отложениях венда наблюдается преобладание карбонатных литофаций.

Венд-нижний кембрий (V-C_1) включает сорнинскую и белкинскую свиты, состоящие из известняков, кремнистых сланцев, фосфоритов, доломитов.

Нижний кембрий (C_1). К нижнему кембрию относятся усть-кундатская, бродовская, боградская, усинская, тунгужульская, колоджульская свиты. Все они имеют довольно пестрый состав: известняки, доломиты, кремнистые сланцы, алевролиты, песчаники, аргиллиты, редко базальты. Преобладают карбонатные породы. Лишь в усть-кундатской свите превалируют обломочные породы - сланцы, песчаники, алевролиты. В ней довольно часто встречаются и вулканиты основного состава.

Нижний-средний кембрий нерасчлененные (C_{1-2}). К данному хроностратиграфическому уровню приурочено довольно много свит, которые выделены в разных структурно-фациальных зонах под разными названиями: азыртальская, ефремкинская, сонская, богоюльская, полтавская, улутагская. Все перечисленные свиты занимают в разрезе близкое положение и сложены преимущественно обломочными породами: песчаниками, алевролитами, конгломератами, среди которых выделяются прослои туфов, известняков, потоки эффузивов.

Средней кембрий (C_2). В среднем кембрии известны следующие свиты: толчеинская, сладкокореньевская, безымянная, канымская, батеневская, берикульская. Состоят они преимущественно из песчаников, алевролитов, туфов, глинистых сланцев, но в безымянной свите доминируют карбонатные (известняки), а в берикульской - эффузивы среднего состава (андезиты и андезибазальты).

Девон (D). К девонским отложениям условно отнесены вулканиты кошкулакской свиты, возраст которой дискуссионен. Одни исследователи относят их к среднему кембрию, другие - к девону, по нашим представлени-

Таблица 6.1.

Сводная легенда для Кузнецкоалатауского мегантиклинория (по материалам ГП "Красноярскгеология" и Хакасгеолкома)

$\gamma\xi D_1?ju$		Юлинский комплекс. Граносиениты (ξ), субщелочные граниты ($\varepsilon\gamma$)	
$D?ks$		Кошкулакская свита. Трахиандезиты, трахиты, трахибазальты, туфы. Тейская свита (*ts*) - трахириолиты, трахидациты, андезиты, туфы	
$l\gamma_2C_3\text{-}O_1t$	Тигерtышский комплекс	Вторая фаза. Лейкократовые граниты	
$\gamma_1C_3\text{-}O_1t$	Тигерtышский комплекс	Первая фаза. Граниты, гранодиориты	
ξ_3C_2k	Когтахский комплекс	Третья фаза. Сиениты, щелочные сиениты	
μ_2C_2k	Когтахский комплекс	Вторая фаза. Монцодиориты, монцониты, диориты	
ν_1C_2k	Когтахский комплекс	Первая фаза. Габбро, эссекситы	
$\beta\pi C_2?$		Берикульский субвулканический комплекс. Диоритовые порфириты	
$C_2?bt$		Батеневская свита. Песчаники, конгломераты. Берикульская свита (*br*)- андезиты, туфы, туфопесчаники	
C_2		Средний кембрий. Толчеинская, сладкокореньевскя, безымянная, каныиская свиты. Песчаники, алевролиты, гравелиты, конгломераты, известняки, эффузивы, туфы, глинисто-кремнистые сланцы	
$\rho\gamma_2C_{1\text{-}2}kn$	Кундустуюльский комплекс	Вторая фаза. Плагиограниты	
$\nu_1C_{1\text{-}2}kn$	Кундустуюльский комплекс	Первая фаза. Габбро, габбро-долериты	
$\nu\delta_1C_{1\text{-}2}$		Ранне-среднекембрийский субвулканический комплекс. Габбро-диориты, диоритовые порфириты ($\delta\pi$)	
$C_{1\text{-}2}az$		Нижний-средний кембрий. Азыртальская, ефремкинская (*ef*), сонская (*sn*), богоюльская (*bg*), полтавская (*pl*), улутагская (*ul*) свиты. Песчаники, алевролиты, конгломераты, туфопесчаники, эффузивы, туфы, известняки	
C_1us	C_1	Усинская свита. Известняки, алевролиты. Мазасская свита (*mz*) - кремнистые сланцы, известняки	Нижний кембрий. Бродовская, боградская, усинская, кутень-булукская, тунгужульская, колоджульская свиты. Известняки, доломиты, сланцы, кремнистые и глинисто-кремнистые алевролиты, песчаники, аргиллиты, базальты
C_1bg	C_1	Боградская свита. Известняки, кремнистые и глинисто-кремнистые сланцы. Мрасская свита (*mr*) - туфопесчаники, туфоалевриты, эффузивы	
C_1br	C_1	Бродовская свита. Известняки, доломиты, силицилиты. Карчитская свита (*kr*) - известняки, кремнистые сланцы. Тамалыкская свита (*tm*) - известняки, алевролиты, кремнистые сланцы, фосфориты. Кургусуюльская свита (*kg*) - известняки	
$C_1?uk?$		Устькундатская (?) свита. Сланцы глинисто-кремнистые, песчаники, алевролиты, эффузивы, туфы, известняки	
$V\text{-}C_1sr$		Сорнинская свита. Известняки, кремнистые сланцы, фосфориты. Белкинская свита (*bl*) - известняки, доломиты, сланцы, фосфориты	
Vtr	V	Таржульская свита. Доломиты, известняки, силицилиты. Гидринская свита (*gd*) - доломиты, известняки	Венд. Амарская и таржульская свиты объединенные, мартюхинская свита (*mr*) - доломиты, известняки. Западно-сибирская свита (*zs*) - доломиты, известняки, силицилиты
Vam	V	Амарская свита. Песчаники, конгломераты, алевролиты	
νR_3t		Тюримский комплекс. Габбро, габбро-диориты	
R_3bd	R_3	Биджинская свита. Доломиты, известняки	Верхний рифей. Кульбюрстюгская, лощенковская, арамонская свиты, литвинская толща. Основные и средние эффузивы, туфы, туфопесчаники, известняки, доломиты, кремнистые сланцы. Кабырзинская свита (*kb*) - известняки, доломиты, эффузивы, туфы
R_3cr	R_3	Чарыштагская свита. Известняки, доломиты, сланцы, эффузивы, туфы	
R_2tr		Тюримская свита. Известняки, прослои песчаников, алевролитов. Главстанская свита (*gl*) - известняки	

Таблица 6.1. Продолжение

R_2sn	Сыннигская свита. Туфопесчаники, туфоконгломераты, эффузивы и туфы среднего и кислого состава, известняки, кремнистые сланцы
$\nu R_1?i$	Изыхский комплекс. Габбро, габбро-пироксениты, анортозиты
$R_1?bi$	Белоиюсская свита. Метаморфизованные эффузивы и туфы основного состава, прослои кремнистых сланцев, мраморизованных известняков
$\sigma R_1?s$	Саланский комплекс. Серпентиниты

Таблица 6.2

Сводная легенда для Западносаянского мегантиклинория (по материалам ГП "Красноярскгеология" и Хакасгеолкома)

$C_{1-2}uz$		Узюнская свита. Песчаники, конгломераты, алевролиты, туфы, прослои известняков
$\gamma\delta D_1?k$		Козерский комплекс. Гранодиориты, диориты (δ)
$l\gamma_2 D_1 d$	Джойский комплекс	Вторая фаза. Лейкограниты
$\gamma_2 D_1 d$	Джойский комплекс	Первая фаза. Граниты, гранодиориты
δD_1		Раннедевонский субвулканический комплекс. Диориты, гранит-порфиры (γδ)
D_1kph		Купхольская свита. Риолиты, риодациты, трахириолиты, дациты, андезиты, туфы, туфопесчаники, туфоконгломераты
S_2kg		Кулогашская свита. Известковистые песчаники, аргиллиты, известняки, туфы
S_1pz		Позарымская свита. Песчаники, алевролиты, аргиллиты, конгломераты, известняки, туфы
$\gamma\delta S?bp$		Большепорожский комплекс. Тоналиты, гранодиориты, диориты
S_1ts		Тостугская свита. Известковистые песчаники и алевролиты, кремнисто-глинистые сланцы, мергели, известняки, конгломераты
S_1on		Онинская свита. Известняки, мергели, песчаники, алевролиты, конгломераты
O_3kr		Каратошская свита. Песчаники, алевролиты, глинисто-кремнистые сланцы
$O_{2-3}ks$		Кохошская свита. Пестроцветные песчаники, алевролиты, глинисто-кремнистые сланцы, конгломераты
O_1er		Еринатская свита. Пестроцветные песчаники, алевролиты, аргиллиты, конгломераты
$Є_3\text{-}O_2kl$		Курукульская свита. Песчаники, алевролиты, конгломераты, кристаллические сланцы, гнейсы
$Є_2ar_2$	Арбатская свита	Верхнеарбатская подсвита. Песчаники, алевролиты, конгломераты, туфы
$Є_2ar_1$	Арбатская свита	Нижнеарбатская подсвита. Туфопесчаники, туфоконгломераты, туфы и эффузивы основного и среднего состава, песчаники, алевролиты
$\nu\upsilon C_1l$		Лысогорский комплекс. Габбро, пироксениты, дуниты, диориты

Таблица 6.2. Продолжение

Є$_1vm$	Верхнемонокская свита. Песчаники, алевролиты, конгломераты, глинистые и кремнистые сланцы, туфы, известняки, базальты
$\rho\gamma_3$Є$_1m$	Майнский комплекс. Третья фаза. Плагиограниты
δ_2Є$_1m$	Майнский комплекс. Вторая фаза. Диориты, тоналиты, габбро-диориты
ν_1Є$_1m$	Майнский комплекс. Первая фаза. Габбро
$\nu\pi$Є$_1$	Раннекембрийский субвулканический комплекс. Габбро-профириты, плагиогранит-порфиры ($\rho\gamma\pi$)
Є$_1nm$	Нижнемонокская свита. Базальты, андезиты, плагиориодациты, туфы, кремнистые сланцы, яшмы
νЄ$_1?s$	Субботинский комплекс. Габбро, габбро-диориты ($\nu\delta$)
R_2-C_1kb	Куртушибинско-борусский меланж-олистостромовый комплекс. Вариолиты, кварциты, кремнистые сланцы, диабазы, туфы, яшмы, серпентиниты, габбро
$\sigma R_2?a$	Актовракский комплекс. Серпентиниты, серпентинизированные перидотиты, дуниты, пироксениты
$R_{1\text{-}2}?dg$	Джебашская серия. Метаморфические сланцы, прослои мраморов

Таблица 6.3

Сводная легенда для Минусинского межгорного прогиба (по материалам ГП "Красноярскгеология" и Хакасгеолкома)

Q_{IV}	Четвертичные отложения
νP-Tk	Копьевский комплекс. Габбро, долериты, пикродолериты, тешениты
$P_{1\text{-}2}nr$	Нарылковская свита. Алевролиты, песчаники, аргиллиты, каменные угли
C_3-P_1bl	Белоярская свита. Песчаники, алевролиты, каменные угли

C_2pb	$C_2\check{c}r+C_2pb$	Побережная свита. Алевролиты, аргиллиты, песчаники	Черногорская и побережная свита объединенные
$C_2\check{c}r$		Черногорская свита. Алеролиты, песчаники, конгломераты, каменные угли	
C_2sr	C_1sk+C_2sr	Сарская свита. Песчаники, алевролиты, аргиллиты, каменные угли	Сохкельская и сарская свиты объединенные
C_1sk		Сохкельская свита. Конгломераты, гравелиты, песчаники, алевролиты	

C_1ps	C_1jn+C_1ps	C_1bn+C_1ps	Подсиньская свита. Туфы, туффиты, песчаники	Ямкинская и подсиньская свиты нерасчлененные	Байновская и подсиньская свиты объединенные
C_1bn			Байновская свита. Песчаники, алевролиты, туфы, конгломераты		
C_1jn			Ямкинская свита. Туфы, туфопесчаники, туфоалевролиты, известняки		
C_1sl	C_1sm+C_1sl		Соломенская свита. Известняки, туфопесчаники, туфы	Самохвальская, кривинская и соломенская свиты объеднинные	
C_1kr			Кривинская свита. Туфы, туфопесчаники, туфоалеролиты		
C_1sm			Самохвальская свита. Песчаники, туффиты, туфы		

Таблица 6.3. Продолжение

C_1km	$C_1bs + C_1km$	Камыштинская свита. Туфы, песчаники, алевролиты, известняки	Быстрянская, алтайская и камыштинская свиты объединенные
C_1al		Алтайская свита. Песчаники, туфы, туффиты	
C_1bs		Быстрянская свита. Туффиты, песчаники, алевролиты, известняки, конгломераты	
D_3tb	D_3	Тубинская свита. Песчаники, алевролиты, конгломераты	Верхнедевонские отложения нерасчлененные
D_3kh		Кохайская свита. Алевролиты, аргиллиты, песчаники	
D_3od		Ойдановская свита. Песчаники, алевролиты, аргиллиты	
D_2bs	D_2	Бейская свита. Известняки, алевролиты, аргиллиты	Среднедевонские отложения нерасчлененные
D_2il		Илеморовская свита. Песчаники, алевролиты, аргиллиты, известняки, гравелиты, конгломераты	
D_2as		Аскизская свита. Алевролиты, мергели, аргиллиты	
D_2tl		Толтаковская свита. Песчаники, алевролиты, аргиллиты, гравелиты, конгломераты	
D_1 $\tau\alpha\pi$		Раннедевонский субвулканический комплекс. Трахиандезит-порфиры, трахириолит-порфиры ($\tau\lambda\pi$), трахит-порфиры ($\tau\pi$), базальтовые ($\beta\pi$) и андезит-базальтовые ($\alpha\beta\pi$) порфиры, габбро (ν), микрогаббро ($m\nu$), долерито-базальты ($\nu\beta$), микродиориты ($m\delta$), диориты (δ), сиенит-порфиры ($\xi\pi$), граносиенит -порфиры ($\gamma\xi\pi$)	
D_1tm	D_1	Тимиртасская свита. Трахиандезиты, трахибазальты, туфы. туфоконгломераты, песчаники, алевролиты, гравелиты. Сагархаинская свита (*sg*) - конгломераты, песчаники, алевролиты, базальты. Перевозная свита (*pr*) - песчаники, алевролиты, конгломераты, базальты. Марченгашская свита (*mr*) - базальты, песчаники	
$D_1t\check{s}$		Таштыпская свита. Известняки, алевролиты, мергели. Уйбатская свита (*ub*) - песчаники, алевролиты, известняки. Коксинская свита (*kk*) - алевролиты, песчаники, известняки, туфы, базальты. Мигнинская свита (*mg*) - средне-кислые эффузивы и туфы, песчаники, конгломераты. Арамчакская свита (*ar*) - терригенные и терригенно-пирокластические породы, туфы. Кагаевская свита (*kg*) - трахиандезиты, трахиты, туфы, песчаники. Ашпанская свита (*as*) - конгломераты, песчаники, эффузивы	Быскарский осадочно-вулканогенный комплекс нерасчлененный. Эффузивы и туфы различного состава, песчаники, конгломераты, гравелиты, алевролиты
D_1tl		Толочковская свита. Песчаники, туфопесчаники, эффузивы, туфы. Сыдинская свита (*sd*) - базальты, андезиты, туфы. Берешская свита (*br*) - щелочные и субщелочные базальтоиды, трахиты, туфы	
D_1imk		Имекская свита. Мергели, песчаники, аргиллиты, известняки. Идринская свита (*id*) - трахидациты, трахириолиты, туфы, туфопесчаники. Шунетская свита (*sn*) - алевролиты, аргиллиты, туфопесчаники, известняки, доломиты. Чергатинская свита (*črg*) - песчаники, алевролиты, конгломераты, базальты, туфы. Тастрезенская свита (*tst*) - эффузивы, туфы, туфопесчаники	
$D_1\check{c}l$		Чиланская свита. Песчаники, алевролиты, конгломераты, базальты, туфы. Харджульская свита (*hr*) - базальты, андезиты, дациты, туфы. Казановская свита (*kz*) - песчаники, алевролиты, конгломераты. Матаракская свита (*mt*) - базальты, трахиадезиты, туфы, туфопесчаники. Черноиюсская свита (*ci*) - базальты, андезиты, туфы. Копьевская свита (*kp*) - базальты, туфы	

ям кошкулакские эффузивы имеют рифтогенную природу и сформировались в ордовик-силурийское время (Макаренко, Парначев, 1994).

Магматические (интрузивные) породы в Кузнецком Алатау развиты довольно широко и в интересующем нас регионе отнесены к саланскому комплексу гипербазитов (R_1?), изыхскому габбро-пироксенитовому комплексу (R_1?), тюримскому комплексу габбро-диоритов (R_3?), кундусульскому габбро-плагиогранитному комплексу (C_{1-2}), когтахскому габбро-монцодиори-товому комплексу (C_2), тигертышскому, мартайгинскому комплексам (C_3 - O_1), юлинскому комплексу гранитоидов (D_1 ?).

Все перечисленные интрузивные комплексы формируют различные по размерам тела, пространственное распределение которых отражено на рис. 6.1.

В тектоническом отношении Кузнецко-Алатаусский мегантиклинорий представляет собой складчатую систему салаиро-кале-донской консолидации, которая, в свою очередь, разделяется на более мелкие структуры. В пределах изученной территории выделяются две структурно-формационные зоны - Батеневская и Мрасская. Первая развита в центральной и северной частях Аскизского района, вторая - трассируется узкой полосой вдоль западной административной границы Республики Хакасия, представляя собой крайнее восточное обрамление Мрасского выступа. Все разновозрастные отложения этих тектонических структур интенсивно дислоцированы, разбиты серией дизъюнктивных нарушений северо-западного, субмеридионального и северо-восточного простирания и прорваны гранитоидами и гранит-граносиенит-сиенитовыми интрузивами тигертышского, мартайгинского и уйбатского комплексов. В северной части региона находится южное окончание Уйбатского грабен-рифта, представляющего собой линейную (400×30-70 км) тектоническую структуру, сформированную в результате проявления кембро-ордовикского континентального рифтогенеза, впервые выделенного и обоснованного исследованиями авторов (Макаренко, Парначев, 1994, 1996).

Западно-Саянский мегантиклинорий

Докембрий (R_{1-2}?). К докембрийским толщам отнесены метаморфические сланцы, метапесчаники с прослоями мраморов, слагающие Джебашский выступ, относимый многими исследователями к байкальской структуре, хотя существуют представления и о более молодом (ордовикском) возрасте джебашских метаморфитов (Качало, 1996).

Нижний кембрий (C_1). В составе нижнего кембрия различают две свиты - нижнемонокскую существенно вулканогенную - базальты, андезиты, плагиориодациты, туфы, яшмы и верхнемонокскую - терригенную: песчаники, алевролиты, конгломераты, глинистые и кремнистые сланцы, туфы, известняки.

Средний кембрий (C_2). В среднем кембрии выделена арбатская свита с двумя подсвитами - нижней: туфопесчаники, туфоконгломераты, туфы и эффузивы основного и среднего состава, песчаники, алевролиты и верхней: песчаники, алевролиты, конгломераты, редко туфы.

Верхний кембрий-нижний ордовик (C_3 -O_1). На этом хроностратиграфическом уровне картируется курукульская свита: песчаники, алевролиты, конгломераты, местами в зонах разломов превращенные в кристаллические сланцы и гнейсы.

Ордовикская система (О) представлена всеми тремя отделами: нижним, где выделена еринатская свита - пестроцветные песчаники, алевролиты, аргиллиты, конгломераты; средним, где фиксируется кохошская свита - пестроцветные песчаники, алевролиты, глинисто-кремнистые сланцы, конгломераты; и верхним, где закартирована караташская свита - песчаники, алевролиты, глинисто-кремнистые сланцы.

Силурийская система (S) состоит из двух отделов. В нижнем силуре выделены следующие свиты (снизу вверх): онинская - известняки, мергели, песчаники, алевролиты, конгломераты; тостугская - песчаники, алевролиты, кремнисто-глинистые сланцы, конгломераты; позарымская - песчаники, алевролиты, аргиллиты, туфы, конгломераты. В верхнем силуре закартирована кулогешская свита - известковые песчаники, аргиллиты, известняки, туфы.

Девонская система (D) представлена нижним девоном (куп-хольская свита), состоящим из риолитов, риодацитов, трахириолитов, дацитов, андезитов, а также туфов с прослоями туфопесчаников и туфоконгломератов.

Каменноугольная система (С). Самые молодые (дочетвертичные) отложения объединены в нижне-среднекаменноугольную узюпскую свиту, сложенную песчаниками, конгломератами, алевролитами, туфами с прослоями известняков.

Магматические (интрузивные) образования Западно-Саянской зоны разнообразны, их размещение, размеры и принадлежность к тем или иным комплексам отражены на рис. 6.1. В сводной легенде (табл. 5.2) показаны все выделенные в настоящее время интрузивные комплексы. Самые древние интрузии объединены в актовракский комплекс серпентинитов, серпентинизированных перидотитов, дунитов, пироксенитов предположительно среднерифейского возраста. В диапазоне средний рифей-ранний кембрий выделен куртушибинско-борусский меланж - олистостромовый комплекс, сложенный сочетанием вариолитов, кварцитов, кремнистых сланцев с диабазами, серпентинитами, габброидами. В раннем кембрии внедрился субботинский комплекс габброидов и габбро-диоритов. Широким распространением пользуются интрузивы маинского раннепалеозойского интрузивного комплекса: первая фаза - габброиды; вторая - диориты, тоналиты, габбро-диориты; третья фаза - плагиограниты. Кроме перечисленных комплексов выделен нижнекембрийский лысогорский интрузивный комплекс габброидов, пироксенитов, дунитов, диоритов. В силуре отмечен большепорожский комплекс тоналитов, гранодиоритов, диоритов. Значительным развитием пользуются интрузивы раннедевонского субвулканического комплекса гранит-порфиров, а также гранит-диориты и гранодиорит-лейкограниты джойского комплекса. Самые "молодые" интрузивные образования представлены гранодиорит-диоритовой ассоциацией козерского комплекса девонского возраста.

В тектоническом отношении Западный Саян относится к крупному мегантиклинорию, в котором выделены более мелкие подразделения (с севера на юг): Северо-Саянская линейная зона, отделяющая Западно-Саянские структуры от структур Минусинского межгорного прогиба; Джебашский антиклинорий (выступ); Западно-Саянский синклинорий. Тектонические образования мегантиклинория сформированы в течение нескольких тектоно-магматических циклов - байкальского, салаирского и каледонского. Древние отложения интенсивно метаморфизованы; для каледонид характерно преобладание флишоидных и молассовых фациальных комплексов. Все породы дислоцированы, прорваны разновозрастными интрузиями. Широко развита сеть разломов, которые на севере и северо-востоке имеют типичное "западно-саянское" простирание, а на крайнем юго-западе разрывы приобретают субмеридиональное, северо-западное и северо-восточное простирание - "горно-шорского" и "алтайского" направления.

Минусинский межгорный прогиб

Отложения, относимые к данной геологической структуре, широко развиты в пределах Аскизского, а также в северной части Таштыпского районов, где они участвуют в строении Южно-Минусин-ской впадины (рис. 6.1). Здесь закартированы эффузивно-осадочные породы всех отделов девонской и каменноугольной систем.

Девонская система (D). Нижнедевонские свиты залегают с резким угловым несогласием на додевонском фундаменте и объединяются в быскарский осадочно-вулканогенный комплекс. Они сформировались в процессе континентального рифтогенеза (Парначев, Вылцан, Макаренко и др., 1996). В силу резкой изменчивости состава разными исследователями выделены многочисленные свиты и толщи, которые образуют латеральные ряды. По вертикали выделяются пять хроностратиграфических уровней развития тех или иных стратонов (снизу вверх): чиланский - имекский - толочковский - таштыпский и тимертасский.

На чиланском хроностратиграфическом уровне выделен следующий латеральный ряд одновозрастных свит: хараджульская - казановская - матаракская - черноиюсская - копьевская. Они развиты в различных структурно-фациальных зонах и имеют общий литолого-петрографический состав, включающий базальты, андезиты, дациты, песчаники, алевролиты, конгломераты, туфогенные породы.

Имекский хроностратиграфический уровень включает в себя следующие одновозрастные свиты: чергатинскую и тастрезенскую. Набор пород следующий: трахидациты, трахириолиты, туфы, туфопесчаники, алевролиты, аргиллиты, известняки, доломиты.

Толочковский возрастной уровень кроме толочковской свиты включает - сыдинскую и берешскую свиты. Это песчаники, туфопесчаники, эффузивы, туфы. Сыдинская и берешская свиты развиты за пределами района.

Таштыпский уровень характеризуется разнообразием одновозрастных разнофациальных свит: уйбатская, коксинская, мигнинская, качаевская. Из них уйбатская и коксинская существенно терригенные и состоят из песчаников, алевролитов, известняков, туфов. Мигнинская, коксинская преимущественно вулканогенные: средние, кислые и основные эффузивы, нередко повышенной щелочности.

Тимиртасский возрастной уровень, кроме тимиртасской включает сагархаинскую и перевозную свиты. Это вулканогенно-осадочные породы с преобладанием вулканитов основного состава (трахибазальты) над терригенными породами.

Более подробные сведения по составу каждой из отмеченных свит содержатся в сводной легенде (табл. 6.3).

Средний девон (D_2). В среднем девоне выделяется ряд свит, различающихся своим положением в разрезе и набором пород. Типично чередование терригенных и карбонатных отложений, причем терригенные отложения отличаются своей окраской (красноцветные, сероцветные, пестроцветные), что широко используется при геологическом картировании. Выделены следующие свиты (снизу вверх): толтаковская, аскизская, илеморовская, бейская, при этом в бейской свите преобладают карбонатные породы (известняки, мергели), а в остальных - терригенно-обломочные породы: песчаники, алевролиты, аргиллиты, редко конгломераты и прослои известняков.

Верхний девон (D_3). Отложения верхнего девона расчленены на три свиты (снизу вверх): ойдановскую, кохайскую, тубинскую. Набор пород во всех свитах однотипен: песчаники, алевролиты, аргиллиты, редко конгломераты. Отличаются они преимущественно цветом пород.

Каменноугольная система (С). Внутри нижнего карбона выделяются 9 свит (снизу вверх): быстрянская, алтайская, камыштинская, самохвальская, кривинская, соломенская, ямкинская, байновская, подсиньская. Вещественный состав свит довольно однообразен. Это туфогенно-осадочные породы: туфы, туффиты, песчаники, алевролиты, аргиллиты, редко известняки и конгломераты. Ввиду близкого литолого-петрографического состава часто не удается расчленить стратиграфический разрез на все стратоны. В этом случае приходится объединять эти свиты в три стратона: быстрянская, алтайская и камыштинская свиты объединенные; самохвальская, кривинская и соломенская свиты объединенные; и ямкинско-подсиньская свита объединенные (см. табл. 6.3).

Средний карбон (C_2). В среднем карбоне выделяются две свиты (снизу вверх): черногорская - алевролиты, песчаники, конгломераты, каменные угли; побережная - алевролиты, аргиллиты, песчаники.

Пермская система (Р). Отложения нерасчлененных нижнего - среднего отделов перми(P_{1-2}) сложены породами нарылковской свиты: алевролиты, песчаники, аргиллиты, каменные угли.

Магматические (интрузивные) породы Южно-Минусинской впадины развиты не очень широко и имеют субвулканический характер. Они пространственно и генетически связаны с вулканитами быскарской серии нижнего девона. Это мелкие тела довольно разнообразного петрографического состава: трахиандезит-порфиры, трахириолит-порфиры, трахит-порфиры, трахибазальты, андезибазальты, габбро, микрогаббро, долерито-базальты, микродиориты, диориты, сиенит-пофиры, граносиенит-порфиры.

В тектоническом отношении Южно-Минусинская впадина входит в систему девонских рифтогенных прогибов центральной части Алтае-Саянской складчатой области (Парначев, Вылцан, Макаренко, 1996), для которых характерно сочетание вулканитов повышенной щелочности с терригенными породами континентальной молассовой субформации и своеобразная "рифтогенная" минерагения. В изученном регионе фиксируется юго-западная окраина впадины, которая по Кандатскому глубинному разлому сочленяется с тектоническими структурами Западно-Саянского мегантиклинория; на севере, северо-востоке и северо-западе - с салаирско-каледонскими мегакомплексами Кузнецко-Алатауской складчатой системы. В последнем случае характер контакта сложный - местами тектонический, участками - стратиграфический с отчетливо выраженными угловыми несогласиями. Средне- и верхнепалеозойские отложения впадины смяты в интенсивные складки с "западно-саянским" простиранием осей складок и разбиты многочисленными разноориентированными дизъюнктивными нарушениями. Система пликативных дислокаций объединяется в составе Абаканского и Таштыпского прогибов.

6.3.Минеральные ресурсы

Аскизский и Таштыпский районы содержат в своих недрах значительное количество полезных ископаемых различных генетических и формационных типов. Профилирующими являются железорудные, золотороссыпные, полиметаллические месторождения, а также строительные материалы и химическое сырье. В изучении месторождений этих регионов в разные годы участвовали десятки геологов производственных и научных организаций. В последнее время была произведена переоценка прогнозных ресурсов ведущих твердых полезных ископаемых Республики Хакасия (Качало, 1996) и составлена сводная карта полезных ископаемых (авторы И.П.Качало, Д.М.Бондарев), по данным которых нами проведен краткий обзор минеральных ресурсов регона.

Аскизский район

Здесь отмечено относительно небольшое количество крупных месторождений. К ним можно отнести Аскизские каменные угли, месторождении скарновых железных руд Тейской группы (собственно Тейское, Абагасское, Ельгентагское), Казымчинское свинцово-цин-ковое метасоматическое месторождение, стратиформное месторождение самородной и сульфидной меди (Базинское, Тустужульское), строительные материалы и химическое сырье - известняки (Хабзас-ское), мраморы (Изасское) и некоторые другие. По р.Балыксу и ее притокам известны промышленные россыпи самородного золота. Пространственное распределение крупных месторождений отражено на рис. 6.1.

В настоящее время эксплуатируется лишь россыпи золота по р. Балыксу и ее притокам, а также железорудные месторождения Тейской группы; последние разрабатываются карьерным способом, с образованием значительных горнорудных отвалов и рудничных вод.

Остальные месторождения, отмеченные на рис. 6.1, относятся к категории резервных. Кроме вышеперечисленных месторождений на террито-