8.3 Terrestrial investigations in the Lower Yenisei during the 36 voyage of the RV «Akademik Boris Petrov». Preliminary results.

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Introduction

The main objective of the terrestrial study was to investigate distribution and migration of the ecologically significant elements in geochemically related landscapes of the Lower Yenisei. Landscape studies have been the first performed in the area simultaneously with the detailed Yenisei river and Kara Sea investigations carried out by the Vernadsky Institute since 1995. The work was an integral part of complex studies within the INCO project ESTABLISH "Estuarine Specific Transport And Biogeochemically Linked Interactions for Selected Heavy metals and radionuclides". The aquatic part of the project was carried out on board by other scientists from the Vernadsky Institute, the Norwegian Radiation Protection Agency , Agricultural University of Norway, and SPA TYPHOON.

Unlike Yamal Peninsula the Yenisei estuary remains outside the impact zone the aerial masses moving from the European industrial areas. (Shaw, 1988). However there are regional sources of the Yenisei basin contamination including chemical, mining, oil-chemical, pharmaceutical, metallurgical, pulp and paper industries (GOSKOMEKOLOGIA, Annual State Report, 1997). The Krasnoyarsk Mining and Chemical Combine (KMCC), concern "Noril'sky Nickel", the town of Tura noted for the gas-reprocessing industry are most significant for the Lower Yenisei area. Several investigations revealed considerable local contamination of the Yenisei flood plain soils and sediments by artifical radionuclides downstream KMCC as far as 2000 km (Kusnetsov et al. 2000, Kvasnikova et al. 2000).

Noril'sk industry releases annually 35,4 t of dust containing copper, nickel, sulfates, cobalt, lead, vanadium, nitrogen oxides, arsenic, antimony, phenols that are concentrating in the top layers of the peat soils on biogeochemical and sorption barriers. The established radius of the Noril'sk Combine impact zone extends up to 100 km km (Ford et al. 2000). According to wind rose the impact of the Noril'sk industry should be more significant for the estuary in winter period. The concentration of lead, copper and zinc in snow cover is 3-5 times higher in the lower reaches of the Yenisei river compared to the Yamal Peninsula and 10-15 times greater than that in Canadian Arctic (Solomatin et al. 1989).

Accounting of high interest to global ecology dynamics and vulnerable areas of the Artic basin in particular the a study of trace element and radionuclide distribution in the regions difficult to access and subjected to global and possibly regional contamination seems to be an interesting and reasonable idea.

Methods

Pre-selection of the study sites has been carried out on the basis of the landscape and soil maps (Soil Map of the USSR, 1988, Scale 1:2500 000; Landscape map, 1988, Scale 1:4000000) and space images helpfully provided by NUPI. Field selection of the plots was limited to the general executive plan of water and sediment sampling in the Yenisei estuary and the current weather conditions providing safe landing of the terrestrial group.

To characterize the contrasting conditions of trace element migration and deposition within the area the elaborated study sites were located in the main sections of the Yenisei estuary (the delta zone, the Yenisei Inlet and the Yenisei Bay). Every site was characterized by a landscape cross-section of the flood plain and the adjacent watershed area. On-site field work included leveling, a detailed description of geomorphological features, the soil and vegetation cover along the cross-section to evaluate the landscape structure and the flooding scenarios; determination of the permafrost table depth significant for water migration in the tundra landscapes. Altitude of the leveling points was referred to the current Yenisei water level that was 120-145 cm above the "zero" level of hydrological gauge station in set. Karaul and the standard sea level (Baltic system).

Soil depth profiles structure and texture were described in detail and sampled at elaborated plots with different conditions of the river deposition and atmospheric pollution. Flood plain profiles were sampled continuously with sampling increment ranging 2 to 10 cm to the depth of ground water or permafrost table or to 50-70 cm in case of their absence. Watershed profiles were sampled with due regard to the genetic soil horizons. Vegetation was characterized by description of the species composition and abundance and accompanied by herbarium collection. Sampling of the 1-3 m^2 plots located over the soil profiles was performed to calculate phytomass, to analyse dominating species for chemical elements. Every bulk vegetation sample has been separated into main agrobiological groups and species and weighted air dried to determine the phytomass structure. Soil samples were air dried and dried at 105 °C.

Surface and ground water samples were taken at selected points of the cross-section to characterize water migration parameters. Standard water parameters have been measured on-board. The radiation background has been determined along cross-sections with the help of a field scintillation detector. Several samples of fish, bird, berries and mushrooms were collected to determine chemical elements in local diet.

First results

The studied landscape cross-sections characterize the Yenisei flood plain and the adjacent watershed area typical for the southern and typical tundra of the Taimyr Peninsula. The length of cross-sections varied from 500 to 880 m, relative altitude of watershed plots over the Yenisei low stage ranged from 26,8 m at the northern cross-section (Cape Shaitansky) to 60 m at the southern profile (set. Karaul) (Fig.8.2).

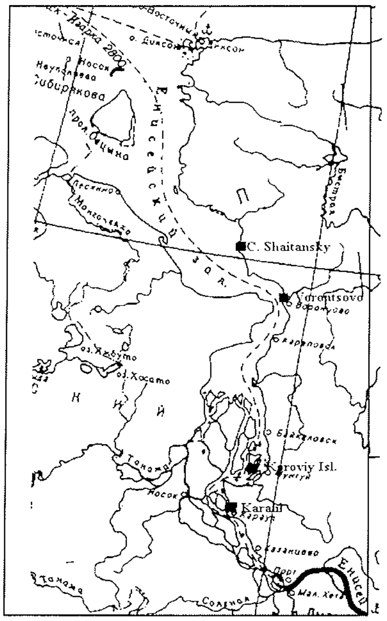

Fig 8.2. Location of terrestrial study sites

Exact location of the studied cross-sections and some sampling points is presented in Table 8.3.

Table 8.3. Location of the landscape cross-sections

Landscape cross-sections	Sampling plots indices	Geographical coordinates	
		Latitude, N	Longitude, E
Yenisei Bay Cape Shaitansky Typical tundra subzone	SK 1_0	$72^0$04' 547	$82^0$21' 408
	SK 1_6	$72^0$04' 559	$82^0$21' 444
	SK 1_10	$72^0$04' 573	$82^0$21' 490
	SK 1_15	$72^0$04' 608	$82^0$21' 595
	SK 1_25	$72^0$04' 824	$82^0$21' 650
	SAR 1	$72^0$03' 408	$82^0$25' 962
Yenisei Inlet Set. Vorontsovo	VR 1_16	$71^0$43' 076	$83^0$31' 301
	VR 1_14	$71^0$43' 031	$83^0$31' 039
	VR 1_8	$71^0$42' 981	$83^0$30' 504
	VR 1_6*	$71^0$42' 889	$83^0$30' 470
	VR 1_11a*	$71^0$43' 016	$83^0$30' 768
Yenisei delta zone Island Koroviy (Tysyara) Southern tundra subzone	TS 1_1a	$70^0$32' 359	$83^0$23' 336
	TS 1_4	nd*	nd
	TS 1_8	nd	nd
	TS 1_10	nd	nd
	TS 1_11	nd	nd
	TS 1_12*	nd	nd
	TS 1_12a*	nd	nd
	TS 2_7	nd	nd
Yenisei delta zone Right-coast flood plain Set. Karaul	KR 1_12	$70^0$04' 394	$83^0$10' 025
	KR 1_15	$70^0$04' 408	$83^0$10' 105
	KR 1_15a	$70^0$04' 409	$83^0$10' 116
	KR 1_25	$70^0$04' 465	$83^0$10' 432
	KR 2_0a	$70^0$04' 551	$83^0$10' 855
	KR 2_0	$70^0$04' 551	$83^0$10' 855
	KR 2_3	$70^0$04' 546	$83^0$10' 742
	KR 2_5	$70^0$04' 521	$83^0$10' 615

*not determined

Weather conditions and permafrost level

Fortunately, the weather conditions on the sampling dates were unusually favorable as registered on board the RV "Academic Boris Petrov" (Tab. 8.4). Air pressure was almost stable, air temperature varied from +5 to +19°C, wind velocity did not exceed 8-9 m/s during daylight hours. Wind direction changed from NE to SE not typical for the season and helped to study the right side of the river most suitable for landing.

Table 8.4: Weather conditions during sampling activity.

Date, m/d/y	Time, h/min	Cloudiness	Wind direction, compass degrees	Wind velocity m/s	Air pressure, mm of mercury	Air temperature, °C
08.17.01	04.00	clear		<3	761	10
08.17.01	08.00	clear		<3	761	13
08.17.01	12.00	clear		<3	762	16
08.17.01	16.00	clear		<3	763	15
08.17.01	20.00	clear		<3	763	11
08.17.01	24.00	clear	100	3	763	11
08.18.01	04.00	clear	25	10	764	8
08.18.01	08.00	clear	160	8	764	8
08.18.01	12.00	clear	90	9	764	8
08.18.01	16.00	overcast	50	8	764	11
08.18.01	20.00	overcast	20	9	764	10
08.18.01	24.00	clear	60	9	764	10
08.19.01	04.00	clear	55	6	765	4
08.19.01	08.00	clear	100	5	766	9
08.19.01	12.00	clear	90	5	767	9
08.19.01	16.00	clear	90	9	767	10
08.19.01	20.00	clear	90	8	767	5
08.19.01	24.00	clear	70	8	767	6
08.20.01	04.00	overcast	80	12	764	6
08.20.01	08.00	clear		<3	764	14
08.20.01	12.00	clear	80	10	764	19
08.20.01	16.00	overcast	60	6	763	16
08.20.01	20.00	clear	60	6	763	12
08.20.01	24.00	clear	90	18	762	12

The depth of permafrost in elaborated points is shown in Table 8.5. At some locations the ground thawed through to river bed alluvium while on watersheds the active layer thickness at some points did not exceed 40 cm despite a rather warm weather conditions.

Table 8.5: Depth of the permafrost table on the date of sampling at selected points of the landscape cross-section

Nature zone	Site Index	Landscape	Number of measure-ments	Thickness of active layer, cm
Southern tundra	KR	Hill tops and slopes, moss tundra	5	51,6±9,18
Southern tundra	KR	Hill tops and slopes, lichen and grasses communities	5	77±13,51
Southern tundra	TS	Flood plain, moss communities	5	62,6±11,45
Southern tundra	TS	Flood plain, grasses communities	8	No permafrost down to 180-200 cm, rarely 140 cm
Typical tundra	SK	Hill tops and slopes, moss tundra	11	43±12,2
Typical tundra	SK	Hill tops and slopes, lichen and grasses communities	12	86±18,2
Typical tundra	VR	Flood plain, moss communities	5	49,2±11,45
Typical tundra	VR	Flood plain, grasses communities	5	107 ±24,25 (5), or no permafrost down to 180-200 cm

As can be seen from the direct measurements at some plots the air temperature on top of the moss layer is 2-5 degrees higher than that at its bottom (Tab. 8.6). This supports the idea that moss layer plays a considerable buffering role in tundra landscapes isolating soil from heating in summer. Therefore on thick mossy areas seasoned thawing is shallower compared to thin ones or those without moss cover. This can be followed in both watershed and flood plain conditions. There is a clear tendency in decrease of the active layer from the southern tundra to the typical one.

Table 8.6: Air temperature above and below the moss layer

Index	Date	Time	Air, °C	Landscape	°C, moss top	°C, moss bottom	Moss height, c	Moss species
KR_2_5	17.08.01	9-00	14	Hill top, herb-undershrub-lichen-moss tundra	15,2 ·	11,3	4	Dicranum elongatum
KR_2_3	17.08.01	12-00	16	Eastern slope, grass-undershrub-moss tundra with shrubs	22,6	18,8	2,5	Dicranum elongatum
KR_2_0	17.08.01	15-00	15	Eastern slope, lake shore, high shrub(willow) tundra	15,4	13	4	Hylocomium splendens
SK_1_13	18.08.01	18-00	10	Western slope, grass-undershrub-moss tundra with shrubs	10,8	7	3,5	Hylocomium splendens
VR_1_8	19.08.01	16-45	10	Flood plain, ridge top, shrub(willow)-moss communities	12,5	7,8	5,5	Hylocomium splendens
VR_1_8	19.08.01	17-25	8	Flood plain, ridge top, shrub(willow)-moss communities	10,8	5,8	5,5	Hylocomium splendens

A brief landscape description of the main geomorphological elevation levels

Reconnaissance of the areas in the landscape cross-section vicinity allowed find out characteristic landscape features of different geomorphological elements in the Yenisei flood plain.

The basement of the flood plain within the study area is formed of the channel alluvium facies presented by coarse and medium-grain gray and yellowish-brown sands outcropping on wide beaches with flat or slightly rolling relief typical for the coastal zones and island periphery. The thickness of the loamy and peat deposits covering alluvial sands at the back of the flood plain varies from 20 to 80 cm. At the northern cross-section (Cape Shaitansky) the coastal beach consisted of boulder-gravel -shingle sediments filled with coarse sand.

The lowest level flood plain studied on the islands and the Yenisei coast is up to 500-600 m wide; its elevation above the low water level varies from 0 to 0.5-1.5 m. Low flood plain often consists of the former sandy islands now attached to the coast. it has flat relief and is almost bare, especially along the shoreline where sandy beach surface acquire peculiar rolling wavy-striped microrelief. River sediments are sandy to the depth of available boring (down to 2 m). Pioneer vegetation presented by thin *Arctophylla* meadows and sparse specimens of horsetail and grasses rise up to 1.3-1.5 m above the mean river water level in the river delta and to 1.8-2.m in the estuary. No permafrost has been observed there.

The coastal part of the flood plain is usually the highest (up to 6 m on the studied plots) and vary in width from 30-50 m to 1500 m on big islands. It is well drained that is typical for accumulative type of the rivers. The area has rolling relief with pronounced ridges and is formed of medium-grain and fine sand with weakly developed primitive and laminated soils where gley conditions are found only in the bottom horizons. Vegetation consists of mainly shrubbery (willow and alder stands) and of relatively "dry" meadows with predominance of grasses and herbs. Permafrost lies here at the depth of 80-150 cm.

Back sides of the coastal flood plain and the central parts of the islands present medium-level Yenisei flood plain that is flat and 0.5-1.5 m lower compared to the coastal part. The elevation marks range from 3,5 to 4-4.5 m above the low water level. Sandy deposits are overlain by silt and loamy cover 20-40 cm to 1-1,5 m thick. Peat interbeds in peat-gley loamy soils locally reach 0.5 m. Permafrost 40-60 cm deep promotes swamping processes. At the lowest back side usually abundant in hollows and depressions with elevation marks equal to 2.5 - 3.0 m above the low water level wet meadows are replaced by marshes and marshy shrubbery. The main area exhibit different landscape features in the southern and typical tundra subzones. In southern tunda medium level surfaces are covered by willow and alder shrub thickets 2-2.5 m high with herbaceous-leguminous-grassy and grass meadows (e.g. set. Karaul). Fig. 8.3 shows a flood plain part of the landscape cross-section investigated in the Yenisei delta zone close to settlement Karaul. Due to considerable range in altitude of the flood plain and watershed parts it was not possible to show in details the whole cross-section. Complex landscape description of the sampling points within this cross-section is given in Table 8.7.

Table 8.7: Field description of the sampling points along the Karaul landscape cross-section

KR 1_12	Flood plain, flat ridge herb-tussock meadow (VCP+70-80%) with willow shrubs (H=30 cm, VCP=5-10%) with spots of bare silt deposits m in diameter occupying 10% of the area. Alluvial soddy laminated (interbedding of sandy and loamy layers).
KR 1_15	Flood plain, flat inter-ridge depression, moist cotton-grass-sedges meadow (H=40 cm, VCP=80-90%) with willow undergrowth (H=50 cm, VCP=10-20%). Alluvial peat-gley silty loam soil.
KR 1_15a	Flood plain, a round lake with marshy coast. Lake silt.
KR 1_26	Flood plain, grass-horsetail high-shrub (willow) communities (H= m, VCP=80%) on the edge of the high-level flood plain. Soddy-gley loamy soil with buried humus horizon.
KR 2_0a	Watershed area. Gravel-shingle beach of the lake.
KR 2_0	Watershed area. Coastal part of the lake at the foot of eastern slope (5-8 grad) 5 m from the the water level, mounded surface, alder(20%)-willow(80%) thicket , high-shrub(willow) tundra m high, VCP=80-90%), grass-horsetail and green moss-horsetail-grass cover. Humus-peat soil on sandy and loamy eluvium.
KR 2_3	Watershed area. Gently convex slope (3-5 grad), hillock-mounding micro-relief on 50% of the area, elevation variation - 10 cm, grass-undershrub-dwarf birch lichen-moss tundra (H=5-10%, VCP=70%) with solitary willow bushes (),7-1,3 m). Peat-gley loamy soil.
KR 2_5	Watershed area. Flat area on the convex hill top, micro-polygonal (1x1.5 m) herb-undershrub-lichen-moss (H=15-40 cm, VCP=70%) tundra with solitary spots 0.5 m in diameter and thick dwarf birch in fissures. Peaty illuvial-humus loamy soil.

In typical tundra the same level is marshy and covered by wet meadows, moss-sedge swamps and grassy or grass-moss willow shrubs not higher than 0.6-1.0 m. Leguminous species are almost absent. Succulent species may reflect the influence of marine environment releasing salts and bringing them to land with air.

Adjacent watershed areas rise 20 to 70 m above the Yenisei flood plain. They are abundant in lake depressions and crossed by medium-wide (1-1.5 km) trough-like valleys of the Yenisei tributaries (rivers Gal'chikha, Yakovleva, etc.). Elevation amplitude (between the ridge tops and local lake and river bottoms) reaches 20-40 m. Watershed landscapes near set. Vorontsovo and Karaul are formed on clay and detritus eluvium of the terrestrial bed rocks while near Cape Shaitansky the studied site is located in the zone of marine loamy deposits.

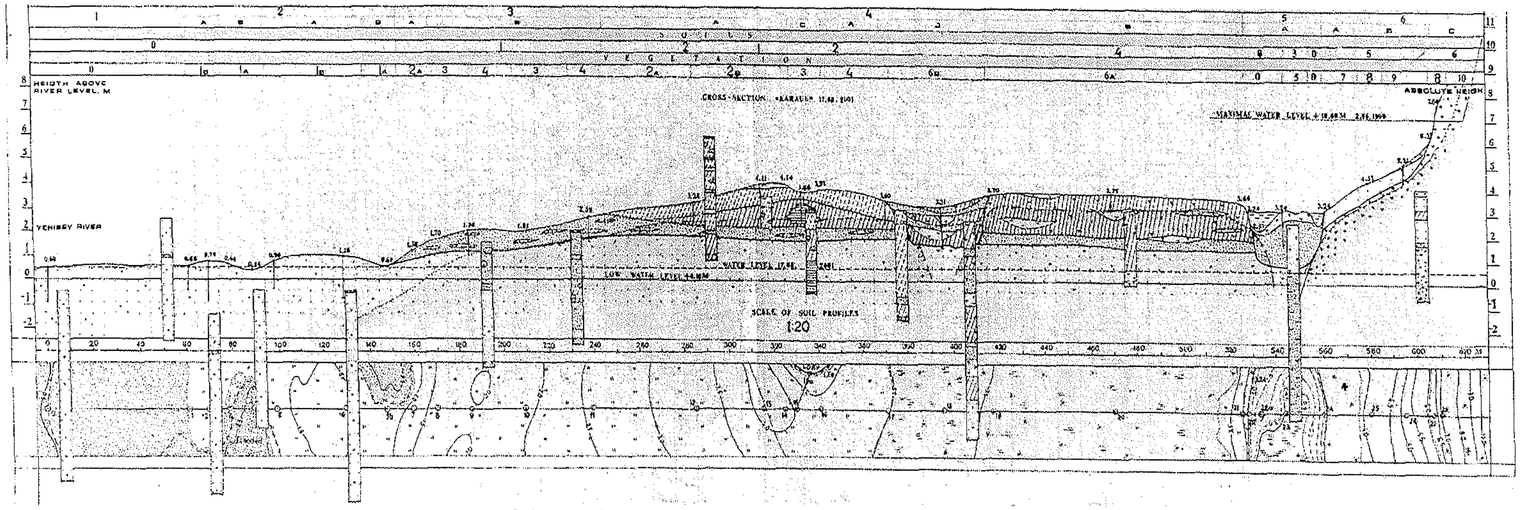

Fig.8.3: Vertical scheme and topographic plan of the landscape cross-section near set. Karaul (flood plain part). Made by V. V. Surkov.

Landscapes: 1 - Spits, middle-channel islands, coast-attached islands formed of medium- and small-sized sands locally covered by thin warp, rolling and flat barren soils; 2 - Low shoreline and island flood plain: A -ridges and elevations , primitive and laminated gley sandy soils overgrown by thin *Arctophylla* meadows; B - inter-ridge depressions overgrown by *Arctophylla* meadows; 3 - Middle and high-level shoreline and island flood plain composed of sands; A - ridges and levees with primitive soils covered by pioneer herbs; B - flat surfaces under horsetail-herbaceous-grassy and wet sedge-horsetail-grassy (cotton-grass-sedge-grassy) meadows with solitary willow shoots; 4 - Middle and high-level shoreline and island flood plain composed of loamy and peat deposits: A - ridges and elevations with primitive soils covered by pioneer grasses, horsetail and willow species; B - flat surfaces with bogged moss-cotton-grass-sedge willow shrubs; C - depressions and weakly pronounced inter-ridge depressions with meadow gley soils under wet sedge-cotton-grass-horsetail-grassy meadows; D - depressions under wet and marshy grass-horsetail-mossy willow scrubs; 5 - Ox-bow depressions and former river channels composed of sands; 6 - Deluvial slopes at the back of the flood plain: A - covered by tall shrubs of alder and willow with moss-herbaceous-sedge meadows on gley soils; B - with herbaceous-grassy meadows and shrubs on gley sandy soils; C- steep and gentle slopes, bumpy covered by alder thickets with willow and dwarf birch.

Lithology: litter; peat; fine sand; small-grain sand; medium-grain sand; loamy sand; sandy loam; loam; clay; detritus of parent rock; shingle; permafrost table

2.5 isohypse

Soil moisture

Due to low rate of organic decomposition the tundra soils are enriched in plant debris noted for high water-holding capacity. Therefore variation in moisture capacity of soil horizons should be carefully accounted of in water migration and volumetric calculations of chemical element inventories.

Table 8.8 shows the results of moisture determination in soil samples of the Karaul cross-section that distinctly confirms higher humidity of the organic-bearing layers. Different temperature of drying and uneven distribution of organic debris in soil samples can lead in some samples to considerable discrepancy in moisture determination by means of standard soil beaks at 105°C and in air-dried larger samples 0.5-1.5 kg by weight (Tab. 8.8). This proves the necessity to take more replicates while measuring this parameter.

Table 8.8: Moisture in soil samples of the Karaul cross-section.

Sampling plot	Soil horizon symbo texture	Depth interval cm	Water content, % (sample volume - 9 cm^3), dried at 105°C	Water content, % (sample volume 400-900 cm^3), a dried
KR 2-5	$A_{0\ Moss}$	0_2	-	106,6
	$A_{t\ Peat}$	2_6	149,1	177,5
	A1Bg Peat-loam	6_18	27,7	48,7
	Big loam	20_30	28,9	46,9
	Big loam	30_40	26,3	41,5
	G (Bg)loam	50_55	54,2	73,9
KR 2-0	At Peat, sand	0_6	16,3	147,0
	G (Bg) Peat, sand	6_10	71,0	101,7
	BCg loamy sand	10_27	18,6	46,2
	Dg Loam	27_37	21,4	18,6
	Dg Loam	37_47	23,1	-
KR 2-3	A0 Moss	0_6	60,6	191,1
	At Peat	6_14	149,0	153,1
	A1Bg Peat-loam	14_24	128,9	128,9
	BCg loam	24_34	27,3	64,1
	BCg loam	34_42	27,2	-
KR 1-12	Sandy loam	3_10	25,0	-
	Silty sand	16_21	10,2	-
	Sandy loam	24_29	29,6	-
KR 1-15a	Silt	0_5	81,2	-
KR 1-15	Peaty loam	1_5	48,0	43,4
	Sandy clay	25_30	27,0	27,9
	Sandy clay	47_53	32,4	29,3

Moisture loss in 100 peat and soil samples dried at 105°C ranged from 5 to 280% with median value equal to 32,8%. Humidity of peat layers varied from 74 to 280%, the sandy ones – from 5 to 26%, silty and clay horizons produced intermediate values.

Field determination of pH and red-ox parameters of the surface and ground waters sampled along cross-section are presented in Table 8.9. Water samples have been stored in flasks at the temperature of sampling. pH has been first roughly estimated by handheld pH-meter in situ. Other parameters were obtained next day of sampling in the on-board laboratory.

Table 8.9:

Study site	Plot	Sample	pH	Eh, mV	Alkalinity, meq l
Cape Shaitansky	SK1-7	Lake on landslide	9.00	+455	nd
	SK1-6	Lake on landslide	9.12	+410	12.0
	SK1-25	Ground water	7.60	+480	0.6
Set. Vorontsovo	VR-0	Yenisei	8.12	+370	1.2
	VR1-6	Ground water	6.40	+320	1.7
	VR1-11a	Ox-bow lake	6.07	+420	0.7
	VR1-14	Ground water	6.75	+470	1.0
	VR1-16	Ground water	7.20	+435	2.8
Tysyara Island	TS1-8	Ground water	7.08	+450	5.8
	TS1-11	Stagnant water	7.10	+435	-
	TS1-12	Ox-bow lake	8.12	+440	4.8
Set. Karaul	KR1-15	Ox-bow lake	7.75	+470	1.5
	KR2-5	Ground water	-	-	1.1
	KR2-3	Ground water	6.20	+440	3.1
	KR2-3	Thawed water (permafrost)	8.20	+440	1.8

pH values measured in water in situ were approximately 0.5 units higher as compared to the laboratory data despite the undertaken sample preservation measures. Compared to other water samples a small lake formed on the land slip had considerably higher pH value and detectable salinity (1.3 promille) due to outcropping marine sediments.

Phytomass of the studied watershed plots is composed mainly of lichens and mosses varied from 500 to 750 g/m^2 irrespective of subzone. Lichens, mosses and their debris make up approximately 55-60% of the growing stock (Fig. 8.4.). In slope landscapes having similar structure phytomass increases to $900g/m^2$.

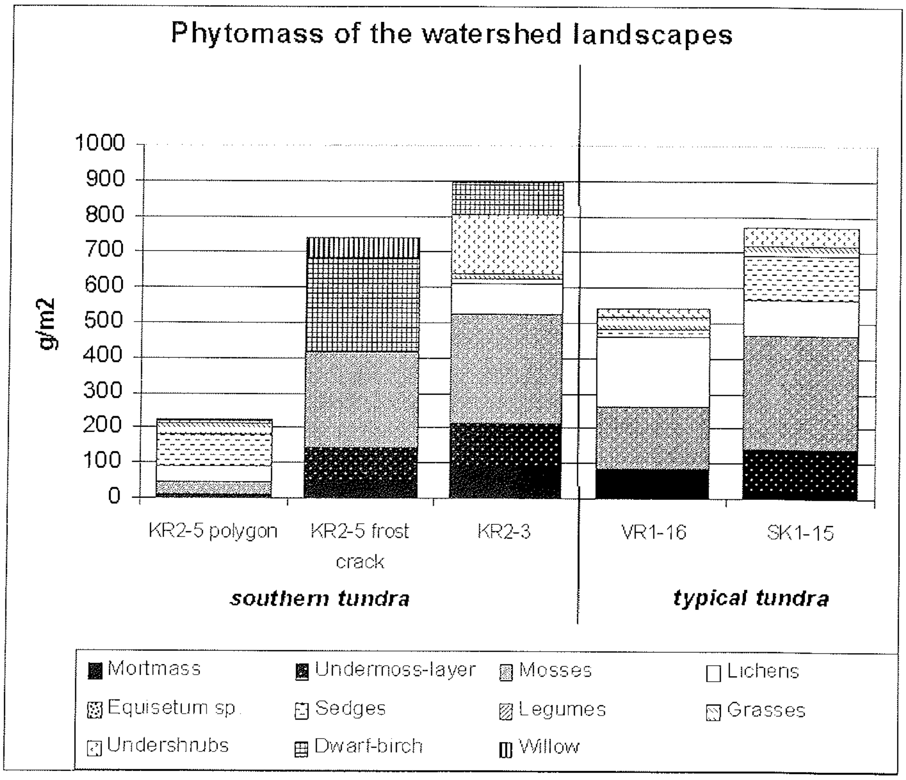

Fig. 8.4: Estimation of the overground phytomass parameters on the studied plots of watershed landscapes (DW)

Flood plain landscapes are characterized by predominance of herbaceous plants such as sedges, grasses and horsetails, locally legumes (Fig. 8.5). According to our earlier investigations on the Yamal Peninsular (1997-2000) in tall shrub thickets typical for swampy depressions the share of willow and alder in total phytomass can reach 70-80% (Ukraintseva et al., 2000).

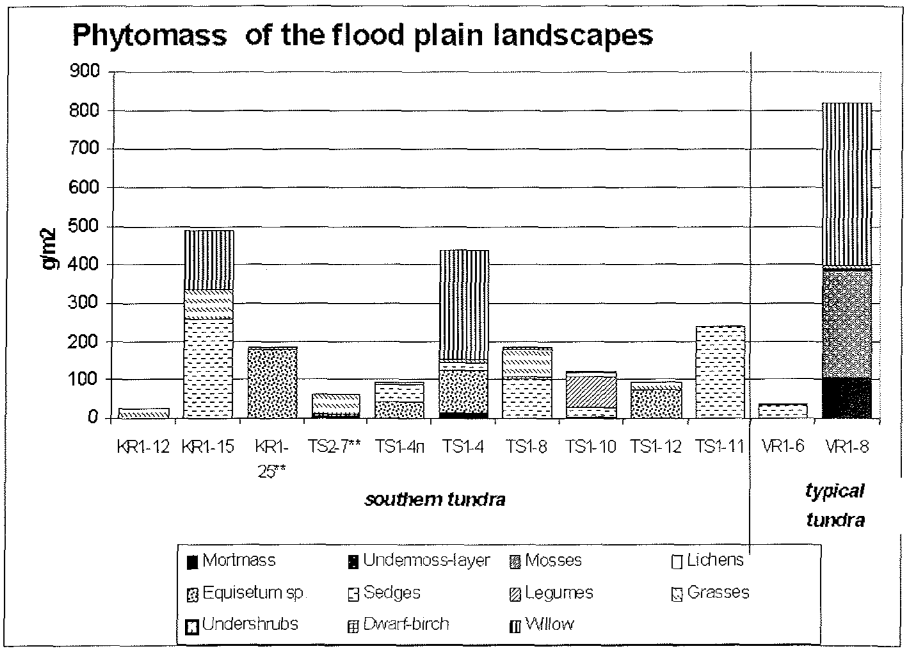

Fig. 8.5: Estimation of the overground phytomass parameters on the studied plots of flood plain landscapes (DW)

Density of the growing stock of the plots studied in the southern tundra subzone of the Yenisei delta ranged from 20 to 190 g/m^2 (100 on the average) for the grassy communities; approximated 400-500 g/m^2 in short willow thickets, and reached maximum values in tall scrub thickets that considerably exceeded phytomass of the watershed areas. In typical tundra subzone investigated in the Yenisy estuary the overground phytomass ranged from 36 to 820 g/m^2. Maximum values correspond to the areas overgrown by shrubs presented mainly by willow surviving in both tundra subzones.

Concentration of trace elements in selected soil samples is presented in Table 8.10. A brief overview gives evidence of slightly enhanced content of Cu and Pb in the watershed soils compared to those on the flood plain part presumably due to the industry activity since the studied slope is windward facing Noril'sk.

Table 8.10. Concentration of chemical elements in soil samples (XRF determination performed by E.M. Sizov)

Number	Soil profile	Depth, cm	Sample type	Mn	Cu	Zn	Pb	Cr	Ni	Co	V	Ba
1.	KR_1_15	1_5	Peaty loam	0,13	0,0044	0,0041	<0,0010	0,0109	0,0028	0,0019	0,0125	0,064
2.		25_30	Peaty sandy loam	0,09	0,0109	0,0066	<0,0010	0,0087	0,0032	0,0016	0,0116	0,080
3.		47_53	Loam	0,10	0,0090	0,0059	<0,0010	0,0091	0,0039	0,0021	0,0127	0,089
4.	KR_1_15a	0_5	Silt	0,05	0,0050	0,0055	<0,0010	0,0088	0,0022	0,0015	0,0112	0,102
5.	KR_2_5	2_6	Peat	0,08	0,0100	0,0101	0,0075	0,0131	0,0034	0,0017	0,0131	0,091
6.		6_18	Loam	0,08	0,0048	0,0042	<0,0010	0,0120	0,0031	0,0021	0,0133	0,103
7.		30_40	Loam	0,11	0,0042	0,0029	0,0013	0,0092	0,0028	0,0028	0,0128	0,126
8.		50_56	Loam	0,10	0,0031	0,0042	<0,0010	0,0117	0,0028	0,0025	0,0144	0,125
9.	KR_2_0	0_6	Sandy peat	0,03	0,0090	0,0033	0,0070	0,0060	0,0023	0,0013	0,0108	0,081
10.		10_25	Loam	0,08	0,0023	0,0031		0,0099	0,0021	0,0025	0,0127	0,084
11.	KR_2_0a	0_5	Silt	0,06	0,0069	0,0045	<0,0010	0,0146	0,0043	0,0018	0,0127	0,074

Conclusion

During the 36[th] voyage of the RV "Akademik Boris Petrov" within the INCO project ESTABLISH the first terrestrial studies have been performed in the three main sections of the Lower Yenisei. Landscape cross-sections established at four sites located in the Yenisei delta, estuary and its inlet characterize geomorphology, soil and vegetation cover of the flood plain and the adjacent watershed areas. Every cross-section included leveling, soil boring to determine the depth of permafrost table, a detailed description of soil and vegetation cover, as well as water, soil and plant sampling at the selected plots.

Subzonal differentiation has been revealed in landscape structure of the studied flood plain plots. Southern tundra is characterized by a predominance of tall shrub thickets and herbaceous-leguminous-graminea meadows on soddy sandy and loamy and humic-gley soils. In typical tundra the middle level flood plain is more waterlogged, the Yenisei middle flood plain is covered by wet meadows on humic-peat and peat soils and abundant in moss-sedge swamps and short (up to 1 m) grassy willow scrubs devoid of alder admixture. No structural difference has been found in watershed plots with tundra gley soils.

Overground phytomass of the watershed plots ranged on the average from 500 to 750 g/m^2 DM irrespective to the tundra subzone, with 55-60% share of mosses and lichens. On the slopes the total mass of the growing stock increased to 900 g/m^2 without significant changes in its structure.

Due to low temperature the tundra soils have peculiar water migration pattern depending upon dynamic active layer. Slow plant debris decomposition leads to inter-bedding of mineral and organic layers. Measurements of soil moisture confirmed considerable input of peat-bearing layers in soil water-holding capacity (up to 280%). Another peculiar feature confirmed during field studies is considerable alkalinity and mineralization of landslide soils due to outcrop of the frozen parent marine sediments. Moss layer play a buffering role in tundra landscape preventing soil from heating in summer both on watershed and flood plain areas. Thickness of active layer drops northward from southern to typical tundra.

Preliminary analysis of the heavy metal measurement in selected soil samples has not revealed ecologically significant contamination. Future chemical analysis of the whole set of samples for trace elements and radionuclides, soil properties is believed to allow to obtain patterns of distribution and migration of the ecologically significant elements in geochemically related landscapes of the Lower Yenisei.

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