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Thermokarst lake waters across the permafrost zones of western Siberia

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Electronic Supporting Information 1

Table S1. Physico-geographical characteristics of studied sites of the north of Western Siberia.

Site	MAAT, °C	precipitation	permafrost	vegetation	depth of peat
Gyda No 1	-12	Annual precipitation of 566 mm; ≤ 350 мм in summer; 150–190 мм in winter	Temperature from -5 to -10 C°, depth from 200 to 430 м except at the coast (≤ 200 m)	Tundra (moss, lichens, dwarf shrubs)	0.2 to 0.5 m
Pangody/ Novyi Urengoy No 2, 3	-6.9 to -7.6	Annual precipitation 410-460 мм, with 70 to 75 % occurring during snow-free period	Permafrsot from 50 to 200 м. Taliks under the thermokarst lakes of 12 to 85 m. Sporadic permafrost around large rivers	Forest-tundra (larch, pine, fir with tree height < 3-5 m. Forest occupies between 20 and 30%, tundra between 5 and 10%	Up to 5.5 m in the river valley and 0.5 to 4 m at the watershed divide
Nojabrsk/ Khanymey	-6.5	Annual precipitation of 498 mm (75 – 80% occurs from April to October and 20-25% during cold period)	Sporadic permafrost on flat-mounds peat and forest, with $T_{average}$ of -0.1 to -0.5°C*	Larch, fir and birch forests on sand podzol soils	2 to 4 m

*This site exhibit two-layer permafrost structure: the upper layer of 4 to 40 m and the 2nd layer represented by relict permafrost deeper than 100 m

Table ESM-1, continued.

Site	soil	% of lakes	lithology
Gyda No 1	Arctic tundra soil with thin peat horizon	8 to 10%	Marine accumulation plain: marine, lagune and lake alluvium deposits; broad alluvial river valleys .
Pangody/ Novyi Urengoy No 2, 3	Alluvium peat gley soil in river valleys; podzols on sands and gley soils Peat gelic soils	40% of lakes in forest-tundra zone; overall range from < 10% to 60-80%	Marine, glacial, and glacial till of Salekhard formation. Complex of lake deposits of Yalbinskaya suite and Zyryano-Kurganskaya stratas along the river valley
Nojabrsk/ Khanymey	Podzol of northern taiga and gley-podzol soils. Peat soils on bogs	40 to 45%	Middle- Pleistocene sands and clays and upper Pleistocene – Holocene lake deposits (clays, peats).

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Table S2. Physical and major chemical parameters of studied lakes.

Coordinates	Sample name	Stages of evolution	surface area, m²	pH	EC, μS cm^{-1}	DOC, ppm	Cl^-, ppm	SO_4^{2-}, ppm	UV 280_{nm}
65°59'32.9"/77°51'23.1"	RM1	2nd stage	800	4.29	13.3	14.8	0.15	0.63	0.29
65°59'34.6"/77°51'13.4"	RM2	2nd stage	6,390	4.73	6.1	3.67	0.059	0.63	0.03
65°59'34.5"/77°51'07.4"	RM3	1st stage	28	4.82	8	10.7	0.091	0.23	0.21
65°59'40.6"/77°51'10.3"	RM4	1st stage *	50	6.92	3.1	4.1	0.061	0.31	0.048
65°59'42.8"/77°51'09.0'	RM5	1st stage *	38	4.74	5.5	8.21	0.04	0.048	0.1
65°59'42.8"/77°51'04.3"	RM6	1st stage *	20	4.6	5.4	6.05	0.035	0.18	0.077
65°59'43.0"/77°51'00.6"	RM7	1st stage *	7	4.73	6.3	5.8	0.051	0.16	0.12
65°59'42.4"/77°50'49.7"	RM8	1st stage	30	4.38	14	21	0.079	0.058	0.41
65°59'39.6"/77°50'22.8"	RM9	3rd stage	12,000	4.83	6.8	4.3	0.12	0.62	0.08
65°59'49.3"/77°51'25.3"	RM10	1st stage	80	4.23	14	9.59	0.13	1.06	0.2
65°59'49.3"/77°52'09.2"	RM11	4th stage	200,000	5.35	4.6	4.05	0.074	0.46	0.047
66°00'33.9"/74°45'42.3"	RM13	1st stage	50	3.97	32.9	36.4	0.041	0.062	1.25
66°00'33.8"/74°45'39.2"	RM14	1st stage	64	3.91	29.2	31.5	0.016	0.066	0.89
66°00'34.0"/74°45'34.9"	RM15	1st stage	80	4.03	27.2	47.9	0.044	0.038	0.96
66°00'34.9"/74°45'28.0"	RM16	3rd stage	155,000	4.85	14.9	16.2	0.14	0.48	0.57

66°01'01.2"/74°45'21.4"	RM17	4th stage	212,000	4.5	14.8	15.6	0.16	0.51	0.51
65°55'31.8"/74°46'41.1"	RM18	5th stage	53,000	4.45	12.5	14.2	0.018	0.26	0.34
65°55'28.8"/74°46'45.8"	RM19	5th stage	1,300	4.93	12.2	13.9	0.02	0.16	0.36
65°55'16.1"/74°49'02.7"	RM20#	4th stage	915,000	4.98	17.6	8.62	0.2	3.51	0.12
65°52'10.5"/74°52'46.4"	RM21	2nd stage	7,000	4.43	10.9	9.34	0.1	0.42	0.29
65°54'09.9"/74°08'57.2"	RM22	5th stage	2,800	4.54	12.2	16.9	0.031	0.13	0.44
65°53'07.0"/75°10'37.7"	RM23	4th stage	515,000	5.01	11.6	9.75	0.3	0.89	0.19
65°53'29.8"/75°11'37.7"	RM24	4th stage	580,000	4.85	10	12.5	0.13	0.34	0.27
65°53'58.2"/75°12'38.2"	RM25	4th stage	950,000	4.93	12.4	13.1	0.24	0.96	0.26
65°54'15.0"/75°12'24.0"	RM26	5th stage	17,000	4.8	8.8	13.6	0.02	0.15	0.31
65°51'55.7"/75°20'22.7"	RM27	5th stage	9,500	4.8	11.4	17.2	0.027	0.24	0.4
65°51'51.5"/75°20'19.1"	RM28	5th stage	2,300	5.05	11.4	17.3	0.089	0.05	0.41
65°51'59.5"/75°16'49.9"	RM29	5th stage	180	4.34	21.6	21.4	0.021	0.26	0.61
65°51'57.8"/75°16'37.0"	RM30	5th stage	5,670	4.49	15.6	18.5	0.094	0.41	0.45
65°52'44.9"/74°57'42.7"	RM31	3rd stage	188,000	4.84	9.1	11.4	0.12	0.32	0.29
65°47'47.1"/75°27'08.1"	RM32	4th stage	1,130,000	4.87	8.9	10.2	0.14	0.33	0.22
65°47'22.8"/75°28'31.0"	RM33	2nd stage *	5,800	6.42	10.4	13.9	0.054	0.48	0.35

65°46'47.4"/75°28'11.7"	RM34	3rd stage	15,400	5.14	11.2	10.8	0.16	0.11	0.24
65°46'39.8"/75°27'34.9"	RM35	5th stage	1,960	4.86	10.9	15.5	0.038	0.045	0.47
65°45'31.8"/75°30'51.4"	RM36	5th stage	2,460	4.89	7.3	7.88	0.026	0.18	0.16
65°45'00.0"/75°31'07.4"	RM37	4th stage	229,000	5.22	12.6	12.4	0.34	1.09	0.23
65°44'11.0"/75°32'57.0"	RM38	2nd stage	2,380	4.43	15.4	14.8	0.016	0.24	0.41
65°44'18.5"/75°33'20.0"	RM39	2nd stage	1,390	3.9	35.8	27.8	0.027	0.61	0.85
65°44'23.5"/75°33'21.8"	RM40	4th stage	985,000	4.66	13.3	13.5	0.18	1.004	0.34
66°00'58.6"/74°47'42.5"	RM41	2nd stage	2,290	4.29	18.2	8.73	0.022	0.17	0.21
66°01'01.6"/74°47'45.5"	RM42	2nd stage	6,000	4.12	26.3	27.3	0.027	0.17	0.82
66°01'18.2"/74°47'32.1"	RM43	3rd stage	18,600	4.71	11.1	12.4	0.076	0.28	0.37
66°00'28.9"/74°48'30.7"	RM44	2nd stage	3,000	4.41	18.5	17.3	0.014	0.12	0.53
70°50'42.7"/78°33'33.8"	RM46	Gyda district	216,000	6.52	57.7	4.92	3.85	0.46	0.076
	RM47	Gyda district	125,000	6.35	63	5.36	3.04	0.64	0.101
70°53'43.8"/78°22'7.5"	RM48	Gyda district	17,600	6.18	40.7	5.15	1.01	0.042	0.011
70°51'4.3"/78°33'16.2"	RM49	Gyda district	152,000	6.58	60.6	8.18	6.94	0.22	0.096
70°51'31.3"/78°33'8.1"	RM50	Gyda district	113	6.46	64	18.2	4.14	0.2	0.35
70°51'49.3"/78°32'44.4"	RM51	Gyda district	1,960	6.22	253	21.3	4.13	1.62	0.54

70˚51'51.9"/78˚30'18.1"	RM52	Gyda district	68,300	6.42	59.5	4.2	1.51	0.22	0.045
70˚52'42.2"/78˚28'7.9"	RM53	Gyda district	384,000	6.42	66.5	3.81	1.96	0.082	0.078
70˚53'9.3"/78˚28'11.3"	RM54	Gyda district	105,000	6.3	76.5	3.82	6.65	0.42	0.037
70˚53'29.9"/78˚22'14"	RM55	Gyda district	32,300	6.19	43.5	3.21	1.64	0.16	0.043
70˚53'19.6"/78˚22'8.2"	RM56	Gyda district	73,000	6.21	42.1	4	1.87	0.016	0.049
70˚53'16.3"/78˚22'41.8"	RM57	Gyda district	198,000	6.5	115	4.35	1.9	0.073	0.055
70˚53'16.1"/78˚25'0.6"	RM58	Gyda district	13,300	6.48	43.5	7.54	0.6	0.17	0.12
70˚50'44"/78˚36'6.9"	RM59	Gyda district	41,500	6.51	62.2	5.79	3.8	0.6	0.104
70˚53'33"/78˚30'19.6"	RM60	Gyda district	70,600	6.45	46.5	5.79	2.22	0.34	0.12

Footnote: EC, specific conductivity; DOC, dissolved organic carbon; UV 280_{nm}, ultraviolet absorption at a wavelength of 280 nm; "*" - basins and subsidence filled with low-mineralized rain water which do not reflect the dynamics of the succession of lakes in chemical composition.

This lake exhibits an elevated sulfate concentration (3.5 mg/L), and this lake has a different, deep blue color on the remote satellite images of the territory. This lake is likely of non-thermokarst origin and subjected to the influence of subpermafrost groundwaters. Similar "blue" lakes were reported on the Tazovsky Peninsula (Kuzin et al., 2012).

Table S3. Average (± 2 σ) and the range of element concentration in thermokarst lakes of different surface areas and stages of evolution from the Novyi Urengoy region (1st-5th stage) and from the Gyda district (coastal lakes).

Element	units	1st, (3-80 m²) *n*=6	2nd, (100-8,000 m²), *n*=8	3rd, (8,000-200,000 m²), *n*=5	4th, (> 200,000 m²), *n*=9	5th, 200-50,000 m² (Khasyrey), *n*=10	Gyda lakes, 0.001-0.1 km² *n*=15	Average river water*
Na	mg/L	0.05–0.72 0.3±0.25	0.021–0.32 0.14±0.12	0.365–0.433 0.4±0.029	0.206–0.8 0.47±0.21	0.055–0.246 0.17±0.069	0.76–14.04 2.62±3.33	-
Mg	mg/L	0.14–0.386 0.24±0.1	0.072–0.266 0.19±0.06	0.143–0.391 0.24±0.097	0.072–0.472 0.3±0.12	0.194–0.535 0.35±0.11	0.819–2.71 1.48±0.51	-
Al	mg/L	0.075–0.262 0.16±0.075	0.04–0.198 0.11±0.06	0.032–0.13 0.086±0.049	0.043–0.149 0.081±0.031	0.047–0.187 0.11±0.047	0.002–0.061 0.015±0.018	0.032
Si	mg/L	0.2–1.99 0.85±0.7	0.175–0.943 0.3±0.26	0.184–0.349 0.26±0.061	0.167–0.355 0.23±0.067	0.172–0.825 0.37±0.21	0.007–1.16 0.23±0.33	-
K	mg/L	0.01–0.062 0.031±0.017	0.011–0.064 0.042±0.019	0.067–0.138 0.11±0.03	0.049–0.27 0.14±0.065	0.004–0.119 0.03±0.034	0.084–0.855 0.33±0.21	-
Ca	mg/L	0.238–0.93 0.49±0.25	0.125–0.67 0.4±0.16	0.205–0.668 0.44±0.17	0.125–0.879 0.54±0.22	0.362–0.756 0.53±0.14	0.442–1.5 0.85±0.3	-
Fe	mg/L	0.12–2.36 1.2±1	0.031–0.705 0.38±0.25	0.057–0.382 0.22±0.15	0.03–0.297 0.13±0.079	0.152–0.742 0.36±0.21	0.024–0.91 0.17±0.23	0.066
Li	µg/L	0.385–1.05 0.65±0.25	0.149–0.963 0.49±0.27	0.287–1.03 0.69±0.29	0.143–1.358 0.81±0.34	0.715–1.84 1.07±0.36	-	1.84
B	µg/L	1.76–2.62 2.1±0.33	1.74–2.64 2.1±0.33	1.35–4.18 2.2±1.1	1.28–4.92 2.8±1.03	0.837–2.94 2.04±0.73	0.711–6.97 3.1±2	10.2
Ti	µg/L	2.95–4.57 3.8±0.7	2.47–3.74 3.2±0.5	2.92–4.71 3.6±0.82	2.26–4.51 3.03±0.83	2.27–3.33 2.8±0.35	2.21–5.71 3.4±0.79	0.489
V	µg/L	0.181–0.771 0.35±0.2	0.118–0.644 0.33±0.19	0.1–0.799 0.45±0.29	0.227–1.1 0.41±0.27	0.113–0.286 0.19±0.061	0.043–0.667 0.2±0.19	0.71
Cr	µg/L	3.47–5.48 4.3±0.7	2.56–4.04 3.3±0.6	3.12–4.12 3.8±0.4	2.87–4.66 3.5±0.61	2.77–4.11 3.4±0.4	2.77–7.16 4.3±1.1	0.7
Mn	µg/L	5.44–48.1	3.53–44.5	3.1–34.6	4.77–34.01	6.23–52.1	0.375–20.4	34

		20±16	17±13	14.03±12.4	21.8±9.8	27.2±13.9	5.1±5.2	
Co	μg/L	0.319–1.17 0.7±0.3	0.19–0.68 0.43±0.17	0.093–0.715 0.3±0.25	0.169–0.847 0.48±0.24	0.155–0.963 0.6±0.22	0.002–0.439 0.08±0.11	0.148
Ni	μg/L	2.48–4.26 3.4±0.6	1.87–2.8 2.4±0.3	2.38–3.09 2.8±0.27	1.89–3.21 2.6±0.47	2.26–3.42 2.7±0.36	2.09–5.63 3.3±0.91	0.801
Cu	μg/L	0.161–0.487 0.3±0.13	0.085–0.245 0.17±0.06	0.161–0.49 0.34±0.12	0.086–0.664 0.48±0.18	0.104–0.427 0.25±0.1	0.298–11.6 1.6±2.8	1.48
Zn	μg/L	7.28–63.9 22.6±22.7	3.94–13.6 8.2±3	2.3–8.3 5.6±2.6	3.37–195.1 26.5±63.3	3.46–20.5 10.2±5	1.38–37.5 8.5±10.3	0.6
Ga	μg/L	0.021–0.044 0.029±0.009	0.017–0.048 0.03±0.01	0.0009–0.015 0.006±0.006	0.0002–0.01 0.003±0.002	0.0001–0.012 0.004±0.004	0.0002–0.009 0.004±0.003	0.03
As	μg/L	0.37–1.33 0.9±0.3	0.406–0.806 0.63±0.13	0.28–0.841 0.57±0.2	0.313–0.777 0.55±0.15	0.408–0.931 0.63±0.17	0.249–0.635 0.38±0.11	0.62
Se	μg/L	0.17–0.31 0.23±0.05	0.202–0.273 0.23±0.02	0.37–0.48 0.4±0.04	0.33–0.6 0.41±0.077	0.37–0.48 0.41±0.03	-	0.07
Rb	μg/L	0.041–0.242 0.12±0.07	0.053–0.275 0.16±0.08	0.217–0.577 0.32±0.16	0.15–0.684 0.28±0.16	0.037–0.275 0.1±0.07	0.097–0.549 0.29±0.15	1.63
Sr	μg/L	2.74–5.75 4.7±1.2	1.3–4.17 3.1±0.9	2.15–4.31 3.3±0.9	1.33–9.55 4.5±2.3	2.62–5.102 4.1±0.84	4.42–12.8 7.7±2.5	60
Y	μg/L	0.032–0.176 0.08±0.05	0.018–0.067 0.044±0.016	0.024–0.1 0.056±0.029	0.019–0.122 0.072±0.037	0.035–0.139 0.063±0.033	-	0.04
Zr	μg/L	0.142–0.702 0.32±0.2	0.094–0.244 0.16±0.05	0.112–0.27 0.19±0.062	0.09–0.33 0.24±0.073	0.114–0.3 0.2±0.061	0.002–0.214 0.033±0.056	0.039
Mo	μg/L	0.09–0.107 0.098±0.006	0.082–0.099 0.091±0.006	0.069–0.089 0.077±0.007	0.055–0.095 0.071±0.012	0.055–0.076 0.062±0.006	0.03–0.1 0.059±0.023	0.42
Cd	μg/L	0.079–0.136 0.1±0.02	0.074–0.099 0.087±0.009	0.028–0.035 0.032±0.003	0.021–0.04 0.03±0.006	0.027–0.044 0.037±0.005	0.015–0.035 0.023±0.006	0.08
Sb	μg/L	0.044–0.07 0.06±0.01	0.049–0.073 0.062±0.009	0.045–0.059 0.054±0.006	0.051–0.112 0.084±0.023	0.04–0.055 0.047±0.005	0.007–0.023 0.013±0.005	0.07
Cs	μg/L	0.017–0.023 0.019±0.002	0.018–0.022 0.019±0.001	0.012–0.018 0.014±0.003	0.011–0.017 0.012±0.002	0.011–0.014 0.012±0.0008	0.0003–0.003	0.011

							0.002±0.0009	
Ba	µg/L	1.43–9.32 4.8±2.9	0.316–4.34 1.8±1.5	1.9–4.8 3.2±1.1	1.6–14.1 4.3±3.8	1.55–5.79 3.1±1.5	0.246–2.65 0.93±0.7	23
La	µg/L	0.019–0.106 0.05±0.03	0.01–0.045 0.025±0.012	0.019–0.082 0.042±0.025	0.013–0.093 0.051±0.028	0.021–0.113 0.041±0.029	0.005–0.118 0.038±0.037	0.012
Ce	µg/L	0.048–0.33 0.15±0.1	0.031–0.118 0.074±0.03	0.043–0.213 0.11±0.066	0.031–0.258 0.14±0.078	0.058–0.298 0.11±0.075	0.01–0.267 0.075±0.079	0.262
Pr	µg/L	0.006–0.042 0.02±0.01	0.004–0.014 0.009±0.004	0.007–0.027 0.015±0.008	0.005–0.033 0.019±0.009	0.009–0.037 0.016±0.009	0.002–0.037 0.011±0.011	0.04
Nd	µg/L	0.036–0.186 0.09±0.05	0.026–0.07 0.05±0.014	0.026–0.112 0.058±0.034	0.019–0.134 0.076±0.039	0.036–0.148 0.064±0.035	0.006–0.2 0.055±0.061	0.152
Sm	µg/L	0.011–0.044 0.02±0.01	0.008–0.019 0.014±0.003	0.007–0.026 0.014±0.008	0.005–0.033 0.019±0.009	0.009–0.032 0.015±0.007	0.002–0.048 0.012±0.014	0.036
Eu	µg/L	0.01–0.018 0.013±0.003	0.007–0.011 0.01±0.001	0.006–0.013 0.009±0.002	0.006–0.015 0.011±0.003	0.007–0.013 0.009±0.002	0.0002–0.01 0.003±0.003	0.0098
Gd	µg/L	0.013–0.049 0.03±0.01	0.011–0.022 0.017±0.004	0.011–0.033 0.02±0.008	0.01–0.039 0.025±0.011	0.015–0.041 0.021±0.008	0.002–0.056 0.014±0.015	0.04
Tb	µg/L	0.003–0.008 0.005±0.002	0.003–0.005 0.004±0.0004	0.0003–0.003 0.002±0.001	0.0001–0.004 0.002±0.001	0.0009–0.004 0.002±0.001	-	0.0055
Dy	µg/L	0.008–0.034 0.02±0.009	0.005–0.015 0.01±0.003	0.006–0.021 0.012±0.006	0.005–0.025 0.016±0.008	0.007–0.025 0.012±0.006	0.002–0.042 0.01±0.011	0.03
Ho	µg/L	0.005–0.01 0.007±0.002	0.004–0.006 0.005±0.0007	0.003–0.006 0.004±0.001	0.002–0.006 0.005±0.002	0.003–0.007 0.004±0.001	0.0004–0.042 0.003±0.003	0.0071
Er	µg/L	0.013–0.03 0.02±0.006	0.012–0.017 0.015±0.002	0.004–0.014 0.008±0.004	0.004–0.016 0.01±0.005	0.006–0.017 0.009±0.003	0.001–0.03 0.007±0.007	0.02
Tm	µg/L	0.007–0.01 0.008±0.001	0.007–0.008 0.0074±0.0004	0.004–0.005 0.0042±0.0004	0.004–0.005 0.004±0.0006	0.004–0.005 0.004±0.0004	0.0003–0.005 0.002±0.001	0.0033
Yb	µg/L	0.008–0.025 0.01±0.006	0.006–0.012 0.009±0.002	0.005–0.014 0.009±0.003	0.005–0.015 0.011±0.004	0.006–0.016 0.009±0.003	0.0003–0.036	0.017

							0.007±0.009	
Lu	µg/L	0.003–0.005 0.004±0.0008	0.003–0.004 0.0034±0.0004	0.002–0.003 0.003±0.0005	0.002–0.004 0.003±0.0006	0.002–0.003 0.003±0.0004	0.001–0.006 0.002±0.001	0.0024
Hf	µg/L	0.027–0.044 0.03±0.006	0.025–0.03 0.028±0.002	0.025–0.031 0.028±0.002	0.025–0.031 0.029±0.002	0.025–0.031 0.028±0.002	0.0001–0.008 0.003±0.002	0.0059
W	µg/L	0.058–0.098 0.07±0.02	0.048–0.084 0.063±0.014	0.051–0.086 0.063±0.014	0.037–0.066 0.048±0.01	0.038–0.089 0.056±0.016	0.031–0.25 0.064±0.055	0.1
Pb	µg/L	0.095–0.512 0.28±0.2	0.028–0.316 0.15±0.097	0.041–0.11 0.079±0.034	0.047–0.23 0.088±0.059	0.044–0.17 0.084±0.04	0.024–0.158 0.055±0.035	0.079
Th	µg/L	0.01–0.08 0.03±0.02	0.003–0.019 0.01±0.005	0.005–0.025 0.017±0.008	0.004–0.024 0.015±0.006	0.007–0.025 0.015±0.006	0.0001–0.014 0.003±0.004	0.041
U	µg/L	0.003–0.011 0.005±0.003	0.002–0.007 0.003±0.001	0.003–0.01 0.007±0.003	0.002–0.012 0.008±0.003	0.003–0.005 0.004±0.001	0.001–0.014 0.005±0.004	0.372

The nominator represents the minimal and maximal value and denominator represents the average value with standard deviation; *n* is the number of studied water bodies; * stands for [Gaillardet et al., 2003]

Table S4. Pearson correlation coefficients between element concentration and surface area of the arctic coastal lakes. Significant correlations are given in bold.

Elements	DOC	pH	Mg	Ca	K	Na	Fe	Si	Al	Mn	Co	Zr	La	Ce	Yb	Th
Pearson correlation coefficients	**-0.61**	0.37	-0.23	-0.11	0.33	0.09	**-0.57**	**-0.58**	**-0.53**	**-0.62**	**-0.60**	**-0.57**	-0.38	-0.40	**-0.52**	**-0.55**

Comparison of TE concentration in small depressions and large lakes and comparison between western Siberian thermokarst lakes and the average world's rivers

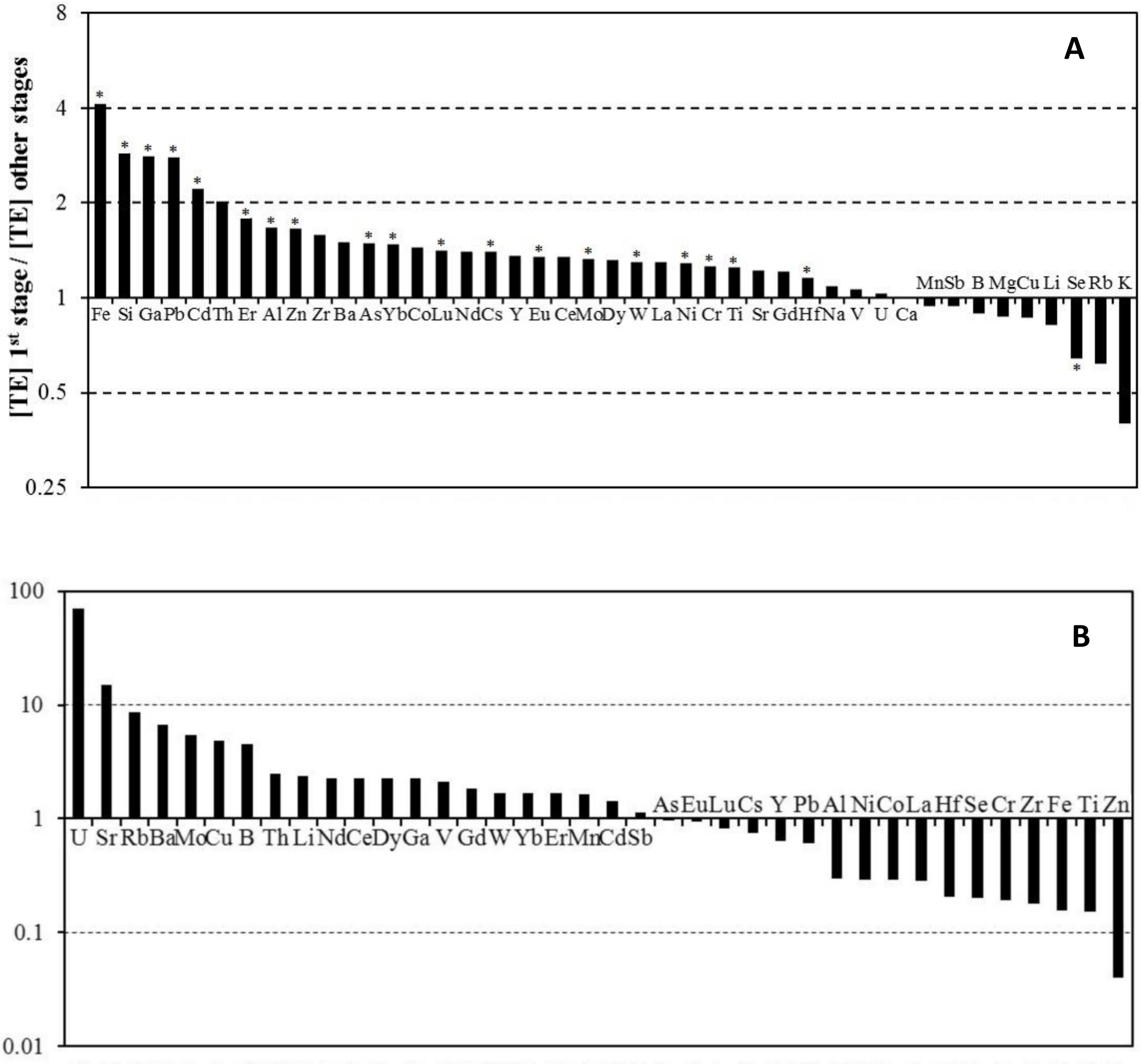

Figure S1. A: The ratio of element average concentration in the lakes of 1st stage of formation to the average value of all other stages. **B:** Concentrations of major and trace elements in two types of studied lake waters and the average river water value (Gaillardet et al., 2003) (log [world average]/[lakes average]). To assess statistically different element ratio, we used Mann-Whitney U Test which allows to estimate the difference between two independent set of data based on one given parameter. In our case of small number of data set, it allows to judge the difference of each element concentration between the 1st and the other stages at the significance criterion as of $p < 0.05$. Elements that met this criterion are labelled by asterisk.

Electronic Supporting Information 2

Correlation between Fe and DOC and trace elements in thermokarst water bodies of western Siberia

S2.1. Correlations between elements in the water bodies

In agreement with previous investigations in the northern (Novyi Urengoy region, Pokrovsky et al., 2011) and southern (Nojabrsk region, Shirokova et al., 2013) discontinuous permafrost zones, there was a significant correlation between Fe, Al and DOC concentrations in the lake water. There was a lack of correlation between any of these elements and alkali (Li, Na, K, Rb, Cs), alkaline–earth elements (Mg, Ca, Sr, Ba) and anions (Cl^-, SO_4^{2-}), as well as trace elements that are not linked to organic or organo-mineral , such as Mo, Sb, B, Y, Mn, Ni, and W. Additionally, Si and As, although present in the form of neutral molecules, exhibited significant correlation with Fe rather than DOC ($R^2 = 0.84$ and 0.71, respectively, as illustrated in the Electronic Supporting Information **Fig. S2 A, B**). For Si, which does not have any colloidal form, this link may suggest the input of Si from the soil at the beginning of water body development, concomitant with that of Fe and its removal from the water column by diatoms or aquatic macrophytes at the terminal stage of the lake development cycle. The control of Fe colloids over As speciation in boreal and thermokarst lake waters is fairly well-known (Pokrovsky et al., 2012, 2013).

Among the divalent heavy metals, only Co, Cd and Pb exhibit a significant correlation with Fe or DOC (**Fig. S2 C to E**) with Person coefficient equals to 0.59, 0.85, 0.67 and 0.61, 0.83, and 0.68, respectively. Whereas the concentration decrease for Co upon lake ecosystem maturation may reflect its uptake by growing phytoplankton cells and accumulation in the sediments, the decrease of Pb concentration is likely to be linked to the decrease of its input from coastal peat abrasion during lake broadening, thus leading to a decrease in the ratio of lake border (representing the source provenance) to lake volume or lake surface (representing metal sink in the sediment). The significant accumulation of Pb in peat deposits is fairly well-known (Shotyk et al., 2000). Notably, the direct atmospheric (aerosol) deposition on the thermokarst lake water surface within the continental discontinuous permafrost sites should be rather small. If such an input was significant, then the concentration of these elements should remain rather constant for all stages (surface areas) of sampled water bodies that all have similar depths (0.5 to 1.5 m), which is opposed to what is observed (cf. Fig. 6). In addition, Cd exhibits two clusters of data points in its correlation with DOC (**Fig. S2 E**). Almost a three-fold decrease in Cd concentration was observed both for arctic coastal and continental subarctic lakes during 3rd and 4th stages and in khasyreys. This likely reflects the change of metal source in the lake water depending on stage and the active biological uptake of this metal upon the lake maturation and lake size increase.

The rare earth elements (REEs) exhibited significant differences in concentrations in the thermokarst lake waters of the continental subarctic and arctic coastal zones. In the former, REEs correlate only with Al (R^2 = 0.51 and 0.59 for La and Yb, respectively), whereas in the latter, REEs correlate with DOC, Al and primarily with Fe (R^2 = 0.50, 0.88, 0.79 for La; R^2 = 0.68, 0.92, and 0.97 for Yb, respectively). Concentrations of REEs decrease with the increase in the lake size, similar to other trace metals that are controlled by organo-mineral colloids, as described above.

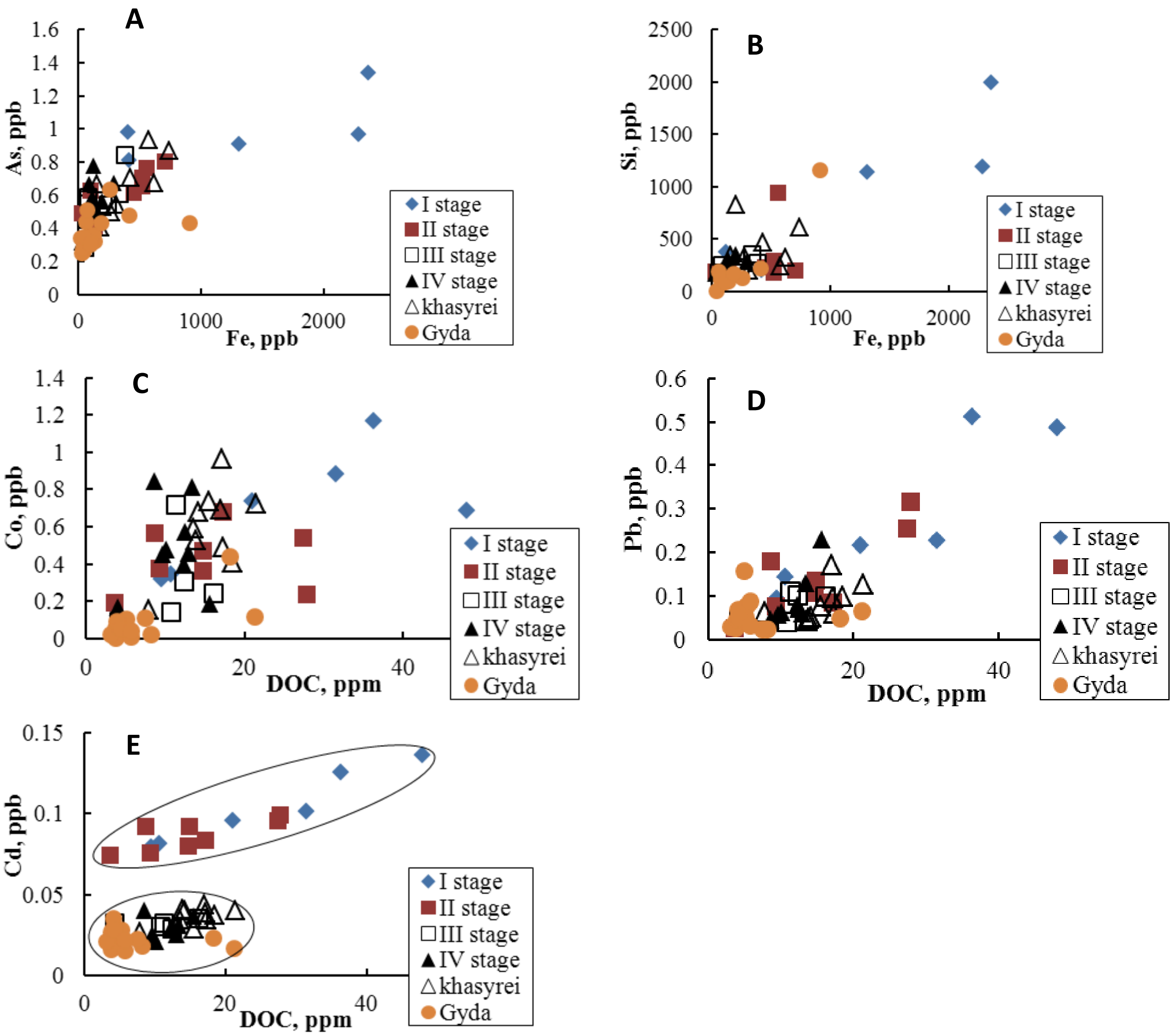

Figure S2. As (A) and Si (B) concentration as a function of Fe concentration in the water column of thaw lakes. Correlations between Co (C), Pb (D) and Cd (E) concentration and that of DOC in thermokarst lakes of two studied regions: in continnetal subarctic zone of the Pangody and Novuy Urengoy sites (from the 1st to the 4th stage of formation and khasyrei shown by diamonds, rectangulas and triangules) and the Gyda site (solid cicrles). Two clusters of data points for Cd concentration are encircled (E). See Table 2 for the correspondence between the lake stage of evolution and the lake surface area. The Pearson coefficient correlations of Fe and DOC with As, Si, Co, Pb, and Cd are equal to 0.71, 0.84, 0.59, 0.85, 0.67 and 0.70, 0.69, 0.61, 0.83, 0.68, respectively.