Supporting Information

The evolution of methane production rates from young to mature thermokarst lakes

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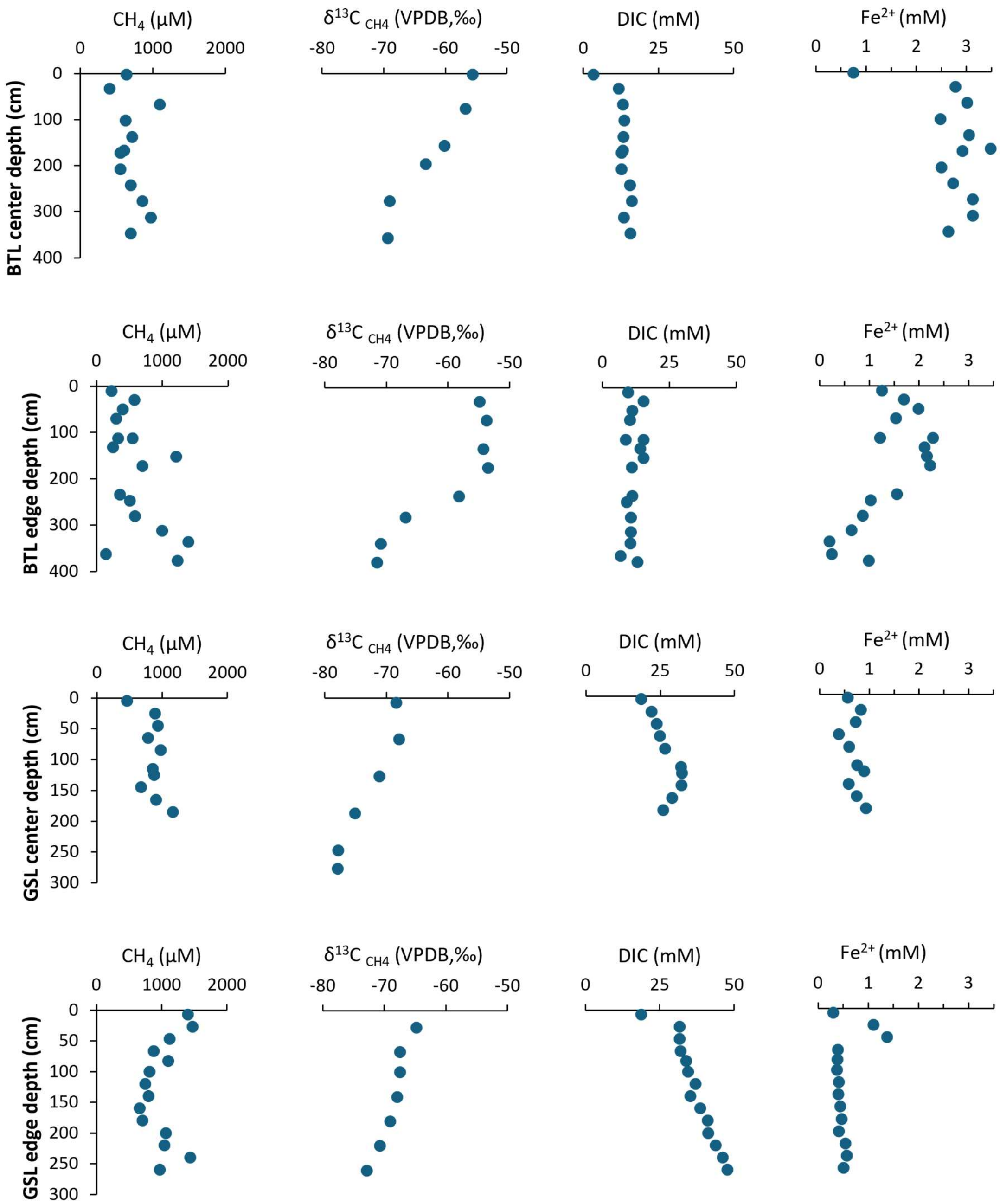

Figure S1: Pore water profiles of Goldstream Lake (GSL) center (A) and edge (B) cores and Big Trail Lake (BTL) center (C) and edge (D) cores. Error bars withing markers limit unless depicted otherwise.

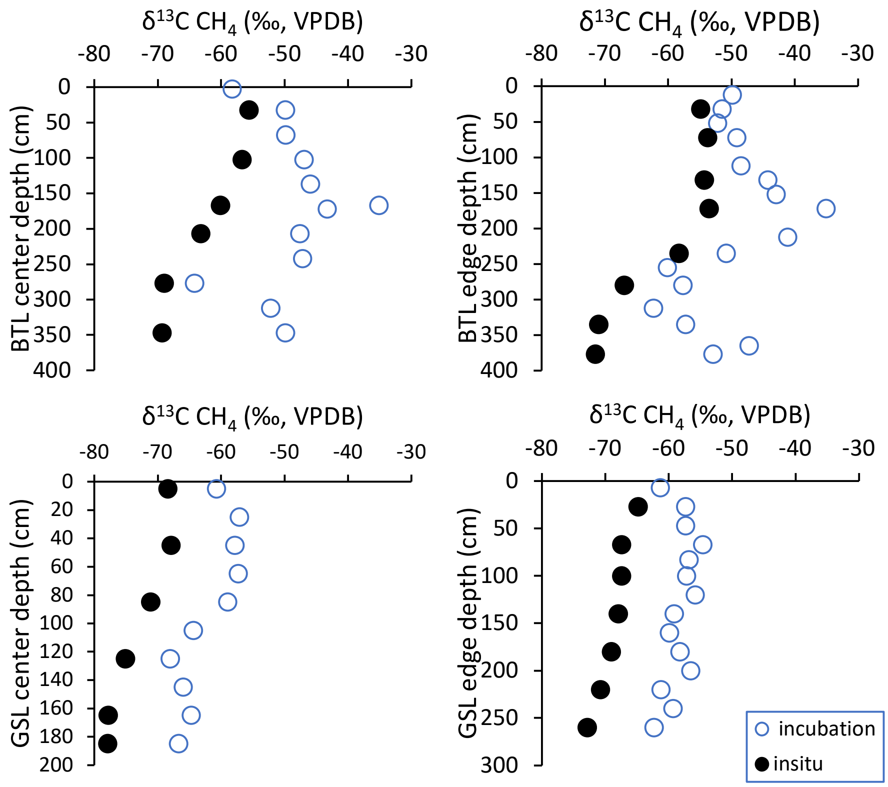

Figure S2: $\delta^{13}C_{CH4}$ profiles *insitu* and long term (90 days) incubations.

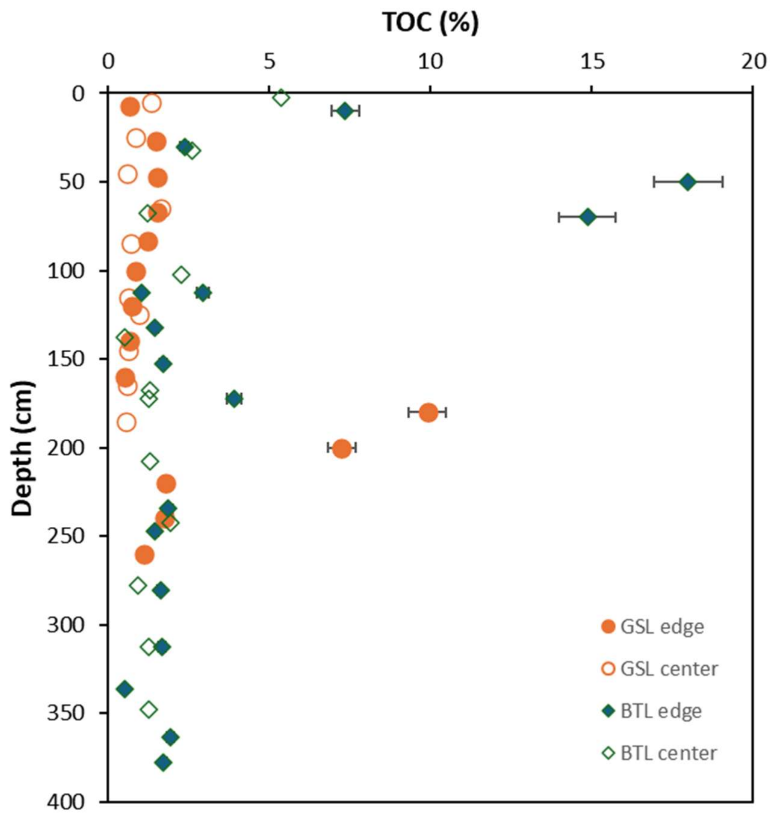

Figure S3: TOC percentage in cores.

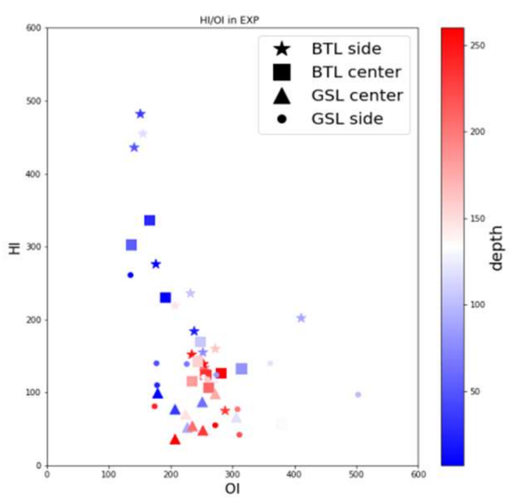

Figure S4: Hydrogen index (HI) versus oxygen index (OI) calculated from Rock Eval analyses at the study sites. The depths are marked as different colors. A decrease in HI and an increase in OI in greater depths and with lake aging is observed.

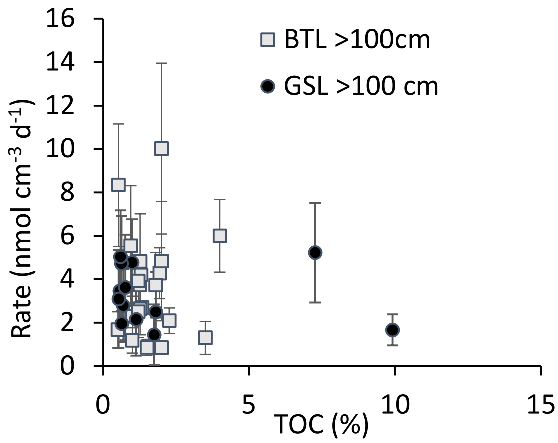

Figure S5: Methane production rates as a function of TOC in BTL and GSL depths greater than 100 cm. The methane production rates between GSL and BTL are not significantly different.

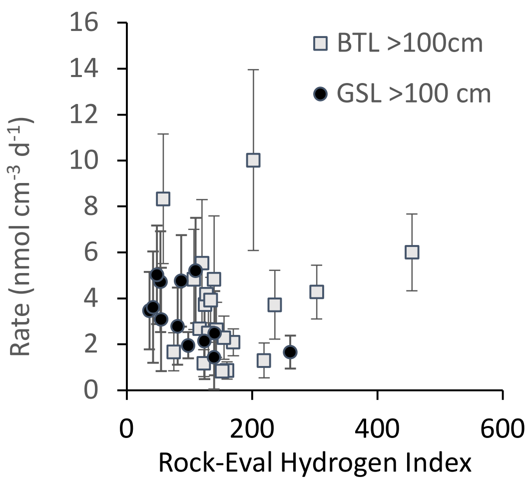

Figure S6: Methane production rates are not correlated to the lability of the organic matter for thermal reactions, as indicated by the hydrogen index obtained by Rock Eval pyrolysis at depths greater than 100cm in GSL and BTL talik.

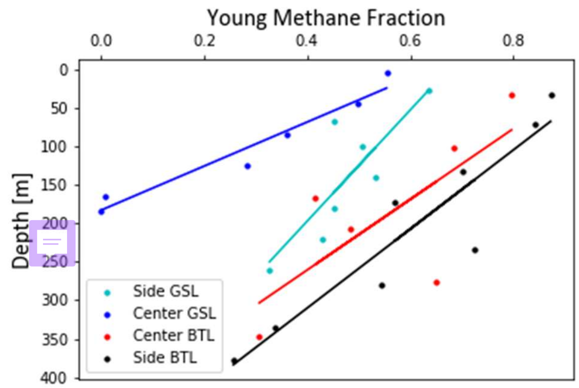

Figure S7: Newly Produced Methane Fraction in Each Core at Various Depths. Calculated from $\delta^{13}C_{CH4}$ measured *insitu* and from the incubation experiment. Blue dots denote GSL center core, light blue denotes GSL edge core, red dots denote BTL center core, and black dots denote BTL edge core. A similar color trend line has been fitted for each core. We can observe that the fraction becomes smaller with depth, and the fraction is smaller as the core area matures.

Table S1: Core sediments profiles data

Core	Dep.	Por.	S1	S2	Tmax	S3	PC	RC	TOC	HI	OI	MINC	$\delta^{13}C_{TOC}$		N	
	cm	Ww/Ws	mg/g	mg/g	°C	mg/g	%	%	%	-	-	%	‰ VPDB	±	%	±
GSL edge	7	0.4	0.00	0.67	429	3.47	0.18	0.51	0.7	97	503	1.02	-31.1	0.4	-	-
	27	0.3	0.01	2.10	427	5.42	0.38	1.12	1.5	140	361	1.55	-26.0	0.2	-	-
	47	0.3	0.01	1.87	425	3.92	0.30	1.25	1.6	121	253	0.37	-25.0	0.4	0.18	-
	67	0.3	0.00	1.81	429	3.98	0.29	1.24	1.5	118	260	0.30	-24.7	0.3	0.18	-
	83	0.4	0.01	1.43	430	2.89	0.22	1.02	1.2	115	233	0.27	-25.0	0.5	0.17	-
	100	0.27	0.01	0.68	425	2.71	0.14	0.74	0.9	77	308	0.31	-27.5	0.5	0.09	0.01
	120	0.28	0.00	0.32	434	2.36	0.10	0.66	0.8	42	311	0.32	-23.9	0.5	0.05	0.00
	140	0.28	0.01	0.56	423	1.20	0.09	0.60	0.7	81	174	0.39	-24.4	0.5	0.05	0.00
	160	0.24	0.00	0.29	432	1.44	0.07	0.46	0.5	55	272	0.32	-26.3	0.5	0.05	0.01
	180	0.24	0.09	25.8	339	13.3	2.75	7.16	9.9	261	135	0.69	-24.1	0.5	0.84	-
	200	0.24	0.02	7.97	291	12.9	1.22	6.04	7.3	110	178	0.68	-24.0	0.4	0.38	-
	220	0.23	0.00	2.52	413	3.19	0.34	1.46	1.8	140	177	0.30	-23.8	0.7	0.15	-
	240	0.21	0.01	2.43	415	3.96	0.35	1.40	1.8	139	226	0.42	-24.3	0.5	0.17	-
	260	0.20	0.00	1.40	425	3.10	0.23	0.90	1.1	124	274	0.68	-24.1	0.6	0.13	-
GSL center	5	0.37	0.00	1.34	429	2.44	0.21	1.15	1.4	99	179	0.25	-25.1	0.7	0.09	0.01
	25	0.31	0.00	0.66	431	1.78	0.12	0.74	0.9	77	207	0.33	-24.7	0.2	0.05	0.00
	45	0.34	0.01	0.31	430	1.36	0.07	0.53	0.6	52	227	0.19	-24.9	0.6	0.04	0.00
	65	0.33	0.01	1.08	434	5.02	0.27	1.37	1.6	66	306	1.00	-24.9	1.1	0.13	0.00
	85	0.36	0.01	0.49	436	1.57	0.10	0.60	0.7	70	224	0.20	-24.5	1.0	0.08	0.01
	115	0.27	0.07	0.63	342	1.74	0.12	0.52	0.6	98	272	0.27	-25.1	1.0	0.04	0.00
	125	0.33	0.00	0.86	432	2.48	0.16	0.83	1.0	87	251	0.34	-24.8	0.8	0.06	0.00
	145	0.30	0.01	0.34	434	1.48	0.08	0.55	0.6	54	235	0.23	-25.3	1.0	0.04	0.00
	165	0.27	0.01	0.29	433	1.51	0.07	0.53	0.6	48	252	0.17	-25.5	0.7	0.02	0.00
	185	0.28	0.00	0.21	432	1.20	0.06	0.52	0.6	36	207	0.17	-25.4	0.8	0.02	0.01
BTL edge	10	0.78	0.11	20.30	412	13.00	2.27	5.10	7.4	276	176	0.62	-28.8	0.0	0.78	-
	30	0.35	0.01	4.38	426	5.66	0.60	1.78	2.4	184	238	0.37	-26.3	0.3	0.24	-
	50	0.59	0.3	86.80	432	27.20	8.44	9.56	18.0	482	151	1.13	-28.1	1.0	0.97	-
	70	0.54	0.15	64.00	433	21.00	6.33	8.54	14.9	436	141	0.77	-28.8	0.5	0.98	-
	113	0.25	0.01	1.61	424	2.62	0.23	0.81	1.0	155	252	0.19	-26.9	0.3	0.11	-
	133	0.29	0.02	2.97	428	6.04	0.47	1.00	1.5	202	411	0.46	-29.0	0.5	0.13	-
	153	0.27	0.01	4.09	427	4.01	0.50	1.23	1.7	236	232	0.23	-27.3	0.5	0.17	-
	173	0.32	0.05	17.80	430	6.08	1.74	2.18	3.9	455	155	0.45	-27.8	0.1	0.28	-
	113	0.34	0.01	6.47	421	6.10	0.80	2.15	3.0	219	207	0.37	-28.3	1.5	0.27	-
	235	0.28	0.01	3.03	417	5.14	0.46	1.43	1.9	160	272	0.37	-26.3	0.4	0.22	-
	248	0.28	0.01	1.81	421	3.86	0.3	1.17	1.5	123	263	0.34	-25.3	0.5	0.17	-
	281	0.31	0.01	2.20	421	4.19	0.35	1.29	1.6	134	255	0.34	-24.6	0.5	0.17	-
	313	0.28	0.01	2.19	421	4.27	0.35	1.33	1.7	130	254	0.30	-25.4	0.4	0.18	-
	337	0.21	0.00	0.39	426	1.50	0.08	0.44	0.5	75	288	0.15	-25.6	0.5	0.08	-
	364	0.29	0.01	2.98	422	4.58	0.44	1.52	2.0	152	234	0.35	-25.6	0.6	0.21	-
	378	0.35	0.01	2.41	419	4.41	0.38	1.36	1.7	139	253	0.32	-26.1	0.6	0.18	-
BTL center	3	0.65	0.07	12.40	411	10.3	1.49	3.90	5.4	231	191	0.58	-27	1.6	0.18	-
	33	0.32	0.00	8.79	432	4.30	0.90	1.71	2.6	337	165	0.32	-27	1.0	0.13	-
	68	0.25	0.00	1.66	424	3.92	0.28	0.97	1.3	133	314	0.27	-27	1.0	0.17	-
	103	0.27	0.00	3.85	422	5.60	0.55	1.72	2.3	170	247	0.29	-28	1.0	0.13	-
	138	0.27	0.00	0.30	429	1.97	0.09	0.43	0.5	58	379	0.12	-27	1.0	0.09	-
	168	0.25	0.00	1.54	425	3.11	0.25	1.08	1.3	116	234	0.22	-27	1.0	0.13	-
	173	0.25	0.00	1.57	425	3.23	0.25	1.01	1.3	125	256	0.23	-25	0.9	0.15	-
	208	0.29	0.00	1.65	423	3.65	0.28	1.02	1.3	127	281	0.26	-25	0.7	0.18	-
	243	0.27	0.02	5.87	428	2.63	0.6	1.34	1.9	303	136	0.18	-26	1.2	0.17	-

	278	0.25	0.01	1.14	422	2.54	0.19	0.76	1.0	120	267	0.17	-28	1.3	0.08	-
	313	0.28	0.01	1.81	439	3.08	0.28	0.99	1.3	143	243	0.21	-26	1.3	0.13	-
	348	0.31	0.01	1.36	422	3.31	0.24	1.03	1.3	107	261	0.30	-25	0.9	0.15	-

Table S2: Cores porewater profiles data

sample	Sample ID	Dep.	Na	SO_4	Mn	Fe	PO_4	NH_4	NO_x	DIC	$\delta^{13}C$ DIC	CH_4	$\delta^{13}C$ CH_4	$\delta^{13}C$ CO_2
		cm	μM							mM	‰, VPDB	μM	‰, VPDB	‰, VPDB
GSL edge	vc1	7	3666	152	69	305	3.9	639	10.7	18.7	-2.0	1405	-	-
	vc2	27	5257	102	251	1107	3.6	1221	6.8	31.8	-2.1	1478	-64.8	-19.1
	vc3	47	3328	254	54	1377	5.3	1402	5.5	31.6	-3.6	1123	-	-
	vc4	67	3523	227	13	394	5.1	1580	3.5	32.1	-4.3	879	-67.4	-19.3
	vc5	83	3615	279	7	387	5.4	1549	6.7	34.0	-6.0	1103	-	-
	vc6	100	3150	291	6	378	9.4	1234	3.0	34.5	-6.3	817	-67.4	-21.3
	vc7	120	2772	293	6	415	7.2	1640	3.2	37.0	-6.9	750	-	-
	vc8	140	1308	311	6	406	6.2	1711	4.0	35.4	-5.4	802	-67.9	-21.3
	vc9	160	2396	327	5	443	7.7	1649	-	38.6	-5.6	664	-	-
	vc10	180	2540	339	5	469	8.1	1529	5.5	41.1	-5.3	710	-69	-20.5
	vc11	200	1545	363	5	410	7.6	1458	-	41.4	-4.6	1069	-	-
	vc12	220	2877	384	5	540	14.0	1443	5.6	43.8	-4.9	1042	-70.7	-21.2
	vc13	240	2233	400	5	569	11.8	1440	4.2	46.2	-4.3	1442	-	-
	vc14	260	5452	406	5	503	15.6	1448	4.8	47.7	-3.4	971	-72.8	-19.2
GSL center	mlg1	5	2462	81	54	568	3.8	750	2.3	18.5	-2.1	462	-68.4	-24.2
	mlg2	25	2502	108	53	830	4.8	583	3.0	22.1	-4.8	892	-	-
	mlg3	45	2044	104	32	726	3.3	400	2.3	23.8	-7.5	932	-67.9	-22.1
	mlg4	65	1604	574	20	387	2.9	264	3.3	24.8	-10.0	786	-	-
	mlg5	85	1648	221	21	596	4.0	278	3.8	26.6	-11.5	979	-71.1	-24.4
	mlg6	115	1401	75	39	757	4.3	230	1.5	31.9	-14.1	854	-	-
	mlg7	125	1334	70	48	893	6.9	207	1.8	32.2	-15.0	875	-75.1	-26.4
	mlg8	145	1285	46	57	585	5.9	189	3.6	32.2	-14.8	675	-	-
	mlg9	165	1142	57	52	745	4.5	188	3.3	29.0	-14.1	906	-77.8	-25.7
	mlg10	185	1072	32	49	929	4.0	196	1.3	26.1	-12.4	1164	-77.9	-25.6
BTL edge	slbt1	10	269	24	57	1249	10.5	505	8.1	9.7	5.2	229	-	-
	slbt2	30	404	29	97	1698	3.0	1361	5.6	15.5	10.7	583	-54.8	-6.0
	slbt3	50	482	122	106	1991	1.7	2861	0.5	11.1	17.1	404	-	-
	slbt4	70	821	85	59	1535	2.7	2603	4.6	10.3	17.1	299	-53.7	-8.5
	slbt5	113	666	125	28	2279	6.2	3293	4.5	15.3	15.3	331	-	-
	slbt6	133	1189	125	20	2111	7.9	2457	3.4	14.1	16.1	251	-54.2	-3.4
	slbt7	153	679	175	31	2156	6.0	3289	4.3	15.4	15.5	1210	-	-
	slbt8	173	-		-	2223	4.5	2901	4.3	11.0	17.1	699	-53.5	-6.2
	slbt9	113	566	61	14	1212	18.5	2037	11.2	8.8	16.1	550	-	-
	slbt10	235	616	90	13	1558	20.5	1805	3.5	11.1	15.3	361	-58.2	-13.4
	slbt11	248	722	70	10	1024	14.9	1406	5.6	9.1	15.9	507	-	-
	slbt12	281	1088	53	11	871	19.7	1432	5.3	10.7	16.0	589	-66.9	-13.4
	slbt13	313	767	11	9	643	15.3	1519	3.1	10.7	16.0	996	-	-
	slbt14	337	748	27	10	193	14.6	1723	3.4	10.5	16.7	1399	-70.9	-8.2
	slbt15	364	1506	20	7	244	14.2	1279	6.2	6.7	18.5	148	-	-
	slbt16	378	665	107	10	993	21.5	2092	3.0	13.0	15.2	1237	-71.5	-8.6
BTL center	mlbt1	2.5	301	5	42	742	4.1	378	1.7	8.0	3.4	637		
	mlbt2	33	720	49	47	2777	4.6	1882	3.8	14.2	11.7	405	-55.6	-10
	mlbt3	68	903	104	38	3017	9.6	2093	1.7	15.9	13.3	1100	-	-
	mlbt4	103	1310	94	49	2479	4.8	2029	3.6	19.3	13.7	628	-56.7	-7.7
	mlbt5	138	1224	130	48	3050	3.1	1763	2.5	22.0	13.4	715	-	-
	mlbt6	168	1374	112	49	3477	3.8	1488	1.9	27.0	13.2	607	-60.1	-6.4

	mlbt7b	173	1267	95	56	2924	7.0	1428	4.3	31.8	12.7	555	-	-
	mlbt8	208	1253	96	96	2504	3.2	1473	3.8	36.5	12.8	553	-63.2	-6.1
	mlbt9	243	1263	88	134	2733	4.1	1791	4.0	30.6	15.6	697	-	-
	mlbt10	278	1124	120	106	3125	6.7	2056	3.0	28.3	16.2	859	-69	-6.9
	mlbt11	313	1222	141	79	3131	7.7	2256	3.7	36.5	13.6	975	-	-
	mlbt12	348	2772	75	49	2639	4.0	2313	2.3	26.5	15.7	699	-69.3	-6.4

Table S3: Methane accumulated rates (mol CH_4 m^{-2} $year^{-1}$) based on linear fit extrapolation.

depth (m)	2	3	5	8	10	12	15	20	30	50
GSL edge	5.7	6.38	7.27	7.57	7.57	7.57	7.58	7.58	7.58	7.59
GSL center	2.02	2.95	4.85	7.78	9.79	11.84	15	20.49	32.28	59.16
BTL edge	5.65	6.06	6.57	6.72	6.72	6.72	6.72	6.73	6.74	6.76
BTL center	3.43	4.12	5.57	7.92	9.59	11.35	14.16	19.27	31.14	61.45

Table S4: Methane accumulated rates (mol CH_4 m^{-2} $year^{-1}$) based on the power law extrapolation down to the thawed talik (taberite) thickness.

Depth (m)	2	3	5	8	10	12	15
GSL edge	5.0	5.5	6.2	6.9	7.2	7.5	7.9
GSL center*	1.9	2.7	3.4	4.5	5.3	6.0	7.1
BTL edge	6.4	6.9	7.5	8.0	8.3	8.5	8.8
BTL center	2.7	3.4	4.6	5.9	6.7	7.4	8.4

*The accumulate rate in GSL center was calculated by different fits due to the short core of less than 2 meters. It ranges in 15 meters depth between 7.1 mol CH_4 m^{-2} $year^{-1}$ if constant 1 nmol cm^{-3} day^{-1} production rates are taken below 3 meters to 10.7 mol CH_4 m^{-2} $year^{-1}$ if the power law extrapolation is taken, and fits also to the error calculated below in table S5.

Table S5: Error percentage for accumulated rates in each depth from the power law extrapolation.

depth (m)	2	3	5	8	10	12	15	20	30	50
GSL edge	10.71	11.76	12.47	7.09	3.43	0.47	2.78	6.75	11.88	17.57
GSL center	2.16	4.87	10.17	16.75	20.50	23.89	28.70	35.98	48.92	72.11
BTL edge	8.09	8.25	8.44	11.54	13.46	14.94	16.65	18.64	21.32	24.21
BTL center	19.12	14.72	15.85	23.73	30.20	37.16	48.20	67.06	107.01	193.27