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The joint Russian-German Expedition BERINGIA/KOLYMA 2008
during the International Polar Year (IPY) 2007/2008

edited by
Sebastian Wetterich, Lutz Schirrmeister
and Aleksander L. Kholodov

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1 Introduction

Lutz Schirrmeister, Sebastian Wetterich and Aleksander L. Kholodov

1.1 Objectives

The expedition „BERINGIA/KOLYMA 2008“ focused on combined studies of permafrost sequences at Duvanny Yar (Lower Kolyma River) using boreholes and outcrops along the riverbank. Expected results of cryolithological and stratigraphical studies will be used as a reference for comparison and correlation with results of similar studies of permafrost sequences around the Laptev and the East Siberian Seas between 1998 and 2007 (Russian-German science cooperation SYSTEM LAPTEV SEA). Furthermore, in the course of the International Polar Year new sites were added to the IPY-monitoring program TSP (Thermal State of Permafrost). In preparation of the upcoming joint German-Russian Research project POLYGON dealing with the development and monitoring of polygonal landscapes local conditions and stakeholders in Cherskii were explored and preliminary studies in several thermokarst lakes and small ponds were undertaken. The topics of the fieldwork in August 2008 were the following:

- Permafrost temperature monitoring (TSP)
- Borehole studies
  - Gas measurements
  - Microbiological studies
  - Radiometry
- Modern cryosoils
- Cryolithology
- Stratigraphy
- Geochronology
- Limnology

1.2 Time Schedule and Participants

Scientists from the Institute of Soil Science Problems Pushchino, Russian Academy of Science (ISSP/RAS), the University of Alaska Fairbanks (UAF) and the Alfred Wegener Institute for Polar and Marine Research, Research Unit Potsdam (AWI Potsdam) took part in the fieldwork during the expedition BERINGIA/KOLYMA 2008 (Table 1-1). The fieldwork was greatly supported by Galina Ivanovna Savenko and her granddaughter Anastasiya from Cherskii, who ran the kitchen.

Table 1-1: Scientific staff of the expedition BERINGIA/KOLYMA 2008.

Participant	Organisation	E-mail
Dmitry G. Fyodorov-Davydov	ISSP/RAS	muss@orc.ru
Aleksander L. Kholodov	ISSP/RAS and UAF	akholodov@mail.ru
Gleb N. Kraev	ISSP/RAS	kraevg@gmail.ru
Vasiliy A. Mironov	ISSP/RAS	gambrinus.soil@gmail.com
Lutz Schirrmeister	AWI Potsdam	lutz.schirrmeister@awi.de
Sebastian Wetterich	AWI Potsdam	sebastian.wetterich@awi.de

The Russian colleagues arrived in Cherskii at the end of July and prepared the fieldwork. The timetable of the German participants is given below (Table 1-2).

Table 1-2: Time table of the German participants for the expedition BERINGIA/KOLYMA 2008.

Date	Route	Activities
28.07.-29.07.08	Flights Berlin-Moscow-Krasnoyarsk-Yakutsk	
29.07.-31.07.08	Stay in Yakutsk (Permafrost Institute)	Logistics, meetings
31.07.08	Flight Yakutsk-Cherskii	
31.07.-02.08.08	Stay in Cherskii (RAS Research station)	Logistics, meetings
02.08.08	Shipping Cherskii-Duvanny Yar by the vessel “Groznii”	
02.08.-23.08.08	Duvanny Yar, Camp on Dresvanny Island	Fieldwork
23.08.08	Shipping Duvanny Yar- Cherskii by the vessel “Groznii”	
23.08.-26.08.08	Stay in Cherskii (RAS Research station), Boat trip to the “Pleistocene Park” (24.08.08)	Fieldwork, logistics, meetings
26.08.08	Flight Cherskii-Yakutsk	
26.08.-03.09.09	Stay in Yakutsk (Permafrost Institute)	Logistics, meetings
03.09.08	Flight Yakutsk-Moscow	
03.09.-05.09.08	Stay in Moscow (Moscow State University)	Meetings
05.09.08	Flight Moscow-Berlin	

2 Description of the Duvanny Yar Permafrost Profiles

Lutz Schirrmeister and Sebastian Wetterich

2.1 Study Area and Scientific Background

The study area is situated at the right bank of the Lower Kolyma River, 40 km upstream the Omolon River mouth (Figure 2-1). The permafrost deposits of Duvanny Yar are exposed in a 12 km long section consisting of Yedoma hills and alas depressions (Figure 2-2).

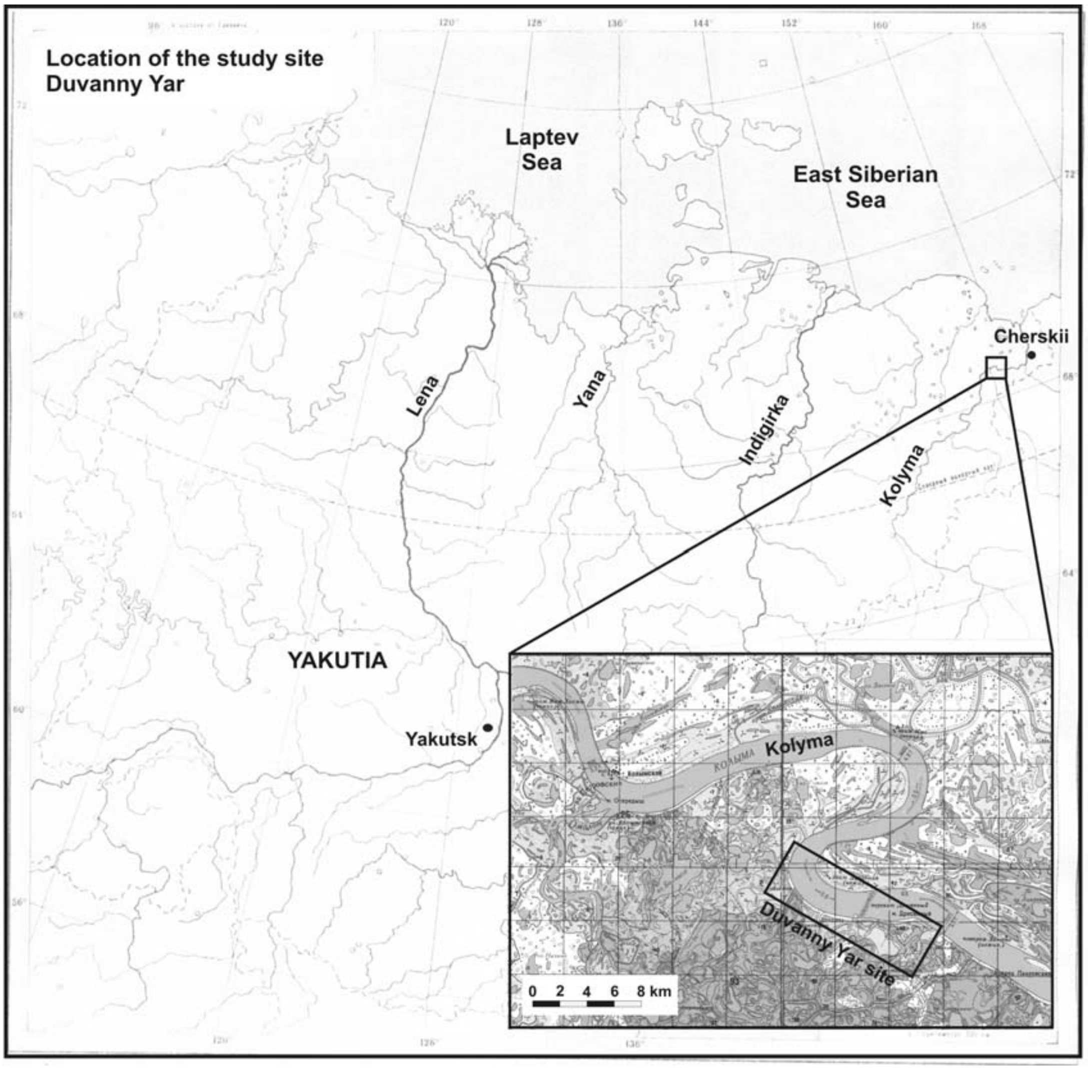

Figure 2-1: Position of the study area in Northeast Yakutia.

The Duvanny Yar section is considered the stratotype of the East Siberian Late Quaternary stratigraphy (Hopkins 1982; Sher et al. 1987) as well as an important key section for the palaeo-environmental history of the Late Pleistocene Beringia Land, the non-glaciated landmass between the Lena River and Alaska (Gitermann et al. 1982; Hopkins 1982; Tomirdiaro & Chernen'kiy 1987). The Duvanny Yar section was firstly described by Biske (1957) and Barandova (1957). Palaeo-zoological studies of horse bones differentiated the permafrost sequence in a lower Middle Pleistocene and an upper Late Pleistocene segment (Sher 1971). The first complex cryolithological, palaeo-ecological and geochronological study was carried out by Kaplina et al. (1978). The exposure was comprehensively described by Sher et al. (1979). Later the section was palaeo-pedological studied by Gubin (1999). Vasil'chuk et al. (2001) presented first stable isotope data from ice wedges of Duvanny Yar and a summary of radiocarbon data. In addition, pollen data from these ice wedges were published by Vasil'chuk (2001). Detailed cryolithological and sedimentological structures are described by Arkhangelov et al. (1979) and Konishchev (1983).

2.2 Field Methods

After first reconnaissance trips east and west of the Duvanny Yar section (Figure 2-2), selected sites were chosen for detailed studies. The whole section of Duvanny Yar (ca. 12 km long) at the right side of the Kolyma River was mapped using field observations in order to estimate sizes of alas and Yedoma sections (Figure 2-3).

Figure 2-2: The western part of the Duvanny Yar section at the right bank of the Kolyma River.

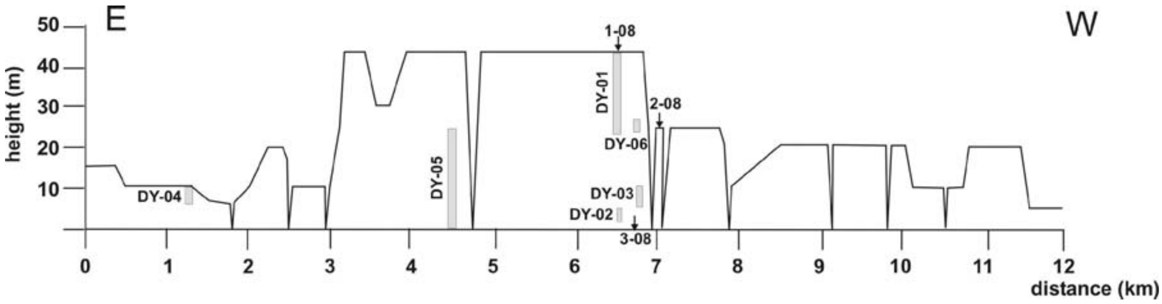

Figure 2-3: Scheme of the Duvanny Yar section with positions of the studied profiles and boreholes.

Two long composite profiles of Yedoma sections (DY-01, DY-05) and several smaller separate profiles of lake deposits underlying the Yedoma sequence (DY-02, DY-03, DY-06) as well as one exposure of an alas sequences (DY-04) were studied and sampled in detail. The profiles and subprofiles mostly exposed on thermokarst mounds (baydzherakhs) in thaw slumps (thermo-cirques) or at the lower riverbank were dug by spades and subsequently cleaned with hacks. Various subprofiles were stacked together to create composite profiles. The correlation of the sampling position in neighboring subprofiles was realized by height estimation using measuring tape. The exposed sequences were surveyed, described, photographed, and sketched according to sediment- and cryostructures. The frozen deposits were sampled for further multidisciplinary studies (sedimentology, palaeo-ecology, geochronology) using hammers and small axes. Sediment samples were packed in plastic bags. If the ice content in sediment samples was high enough, the remained meltwater was separated for hydrochemistry analyses. Some samples were collected unfrozen. In addition, frozen samples were taken in aluminum boxes in order to determine the gravimetric ice content already in the field. Selected ice wedges were sampled using ice screws or a small axe. Additional samples were taken for geochronological analyses. The sampling for luminescence dating was done in two ways. An electric hand-drilling machine (HILTI) was used to extract small sediment cores horizontally from frozen deposits. We used a special drill head and an opaque plastic cylinder, to properly protect the sample from daylight. Similar cylinders were hammered into unfrozen deposits. These samples were protected from daylight in black bags during sampling and after. Furthermore, larger ice wedge samples of about 2 liters were taken for $^{36}Cl/^{10}Be$ dating of ground ice (Gilichinsky et al. 2007).

2.3 Composite Profile DY-01 (Yedoma Horizon)

A first long exposure of the Yedoma horizon was studied directly below the site of the permafrost borehole 1-08 (see chapter 3). The studied 20 m long sequence reaches from the upper edge of the thaw slump down to the thermo-terrace where the older permafrost deposits were already buried by modern debris. The composite profile DY-01 consists of eight subprofiles (DY-01-A to DY-01-H) exposed in neighboring thermokarst mounds (Figures 2-4, 2-5).

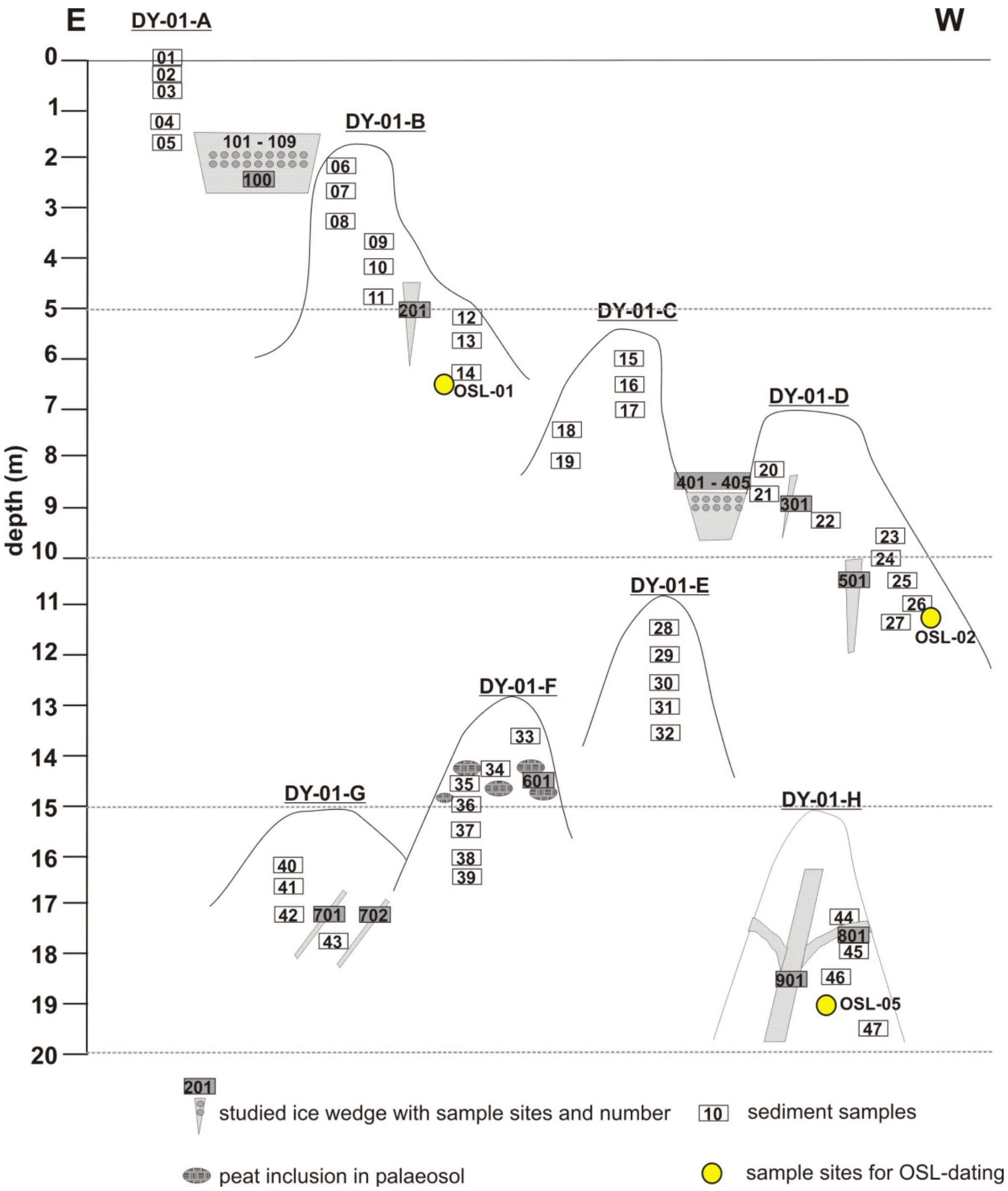

Figure 2-4: Scheme of the composite profile DY-01 with position of the subprofiles and sample sites.

Figure 2-5a: Overview of the thermocirque of exposure DY-01.

Figure 2-5b: The uppermost horizon of the Yedoma section, ice wedge covered by ice-banded deposits (subprofile DY-

Figure 2-5c: Thermokarst mounds at middle part of the composite profile (DY-01-D and E).

Figure 2-5d: Laminated cryostructures in subprofile DY-01-C.

Figure 2-5e: Ice wedge system in subprofile DY-01-H.

The uppermost horizon of about 2 m thickness exposed in a steep wall on top of the outcrop (Figure 2-5a) consists of a grey-brown silty palaeosol with a banded and lens-like cryostructure (subprofile DY-01-A). A four meter wide ice wedge was sampled for stable isotopes (DY-01-A-101 to 109) and $^{36}Cl/^{10}Be$ dating (DY-01-A-100). This ice wedge was composed of numerous separate ice veins (1-2 cm wide) and ground veins (< 1mm wide). The ice was clear and contains non-oriented gas bubbles.

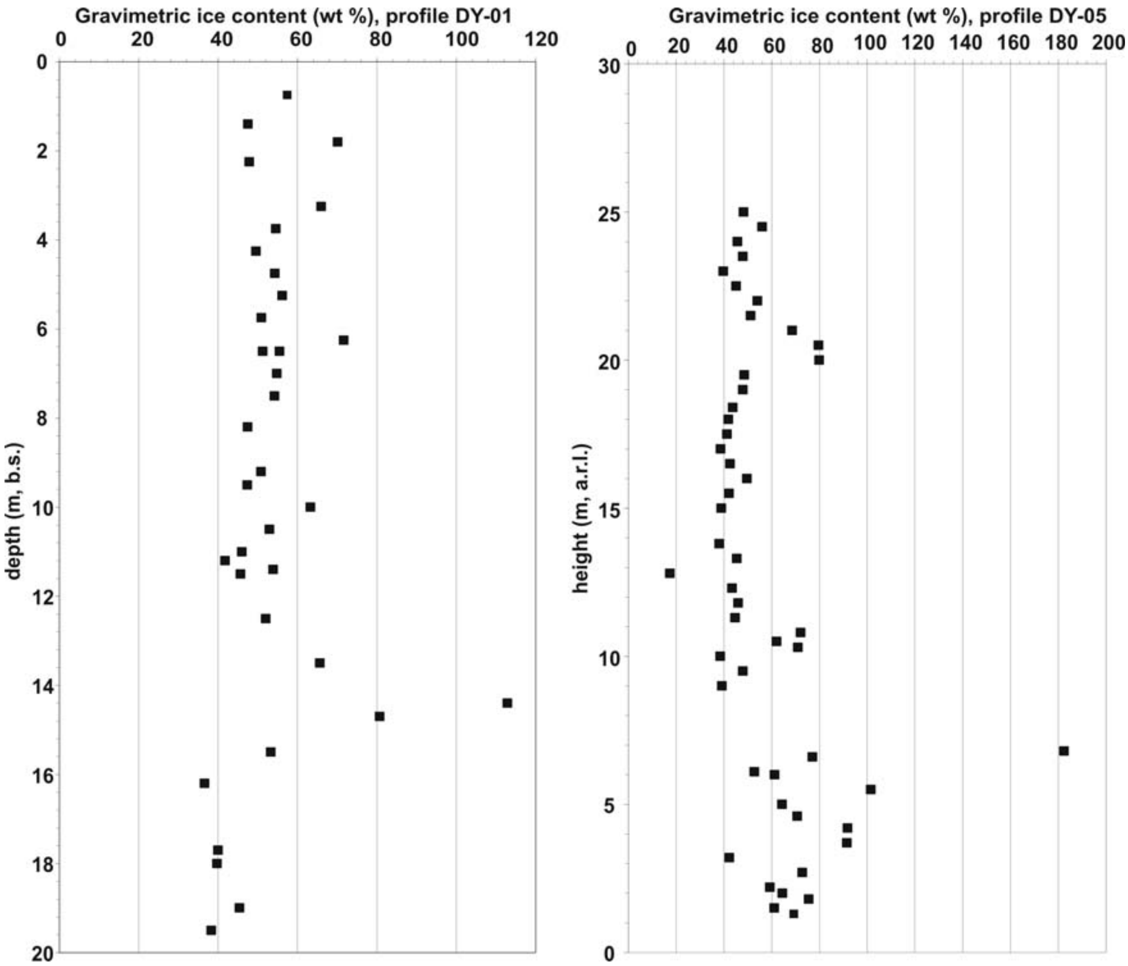

Figure 2-6: Gravimetric ice contents of both composite profiles of the Yedoma Suite (b.s. – below surface, a.r.l. - above the river level).

Large parts of the following sequence between 2 m and 14 m below surface (DY-01-B to DY-01-F) are quite homogenously composed of grey-brown and light brown fine sand with filamentous grass roots. Numerous small black patches were frequently observed. The gravimetric ice contents range between 40 to 65 wt %, but without any ice super saturation (Figure 2-6). The observed cryostructures were dominantly massive or micro lens-like. In place, micro lenses were ordered to laminated structures (Figure 2-5d).

A dark brown colored palaeosol horizon with wood fragments and peaty organic patches occurred in a depth of 14.0 to 15.5 m b.s. (DY-01-F34 to 37). The cryostructures were irregular lens-like. Diagonal ice veins occurred as well as ice segregation around wood fragments.

Table 2-1: Characterisation of the studied ice wedges.

Ice wedge	depth [m, b.s.]	height [m, a.r.l.]	width [m]	sample distance [m]	Description
DY-01-A-100-109	2.00		4.00	0.40	clear ice, non-oriented gas bubbles (1 mm), single ice veins 1-2 cm wide, small sediment veins (< 1 mm)
DY-01-B-201	5.25		0.03		clear ice, many non-oriented gas bubbles (1 mm)
DY-01-D-301	9.00		0.05		epigenetic, 1 m long exposed, connection to a large ice wedge below, roots of composite ice-sediment veins
DY-01-D-401-405	9.00		0.80	0.01	syngenetic, clear ice, non-oriented gas bubbles (1-2 mm), single ice veins 1-2 mm wide, in places in alternation with small sediment veins (< 1 mm)
DY-01-D-501	10.50		0.07		composite ground-ice wedge, ice veins 1-2 mm, ground veins 2-5 mm
DY-01-F-601	15.00				large ice lens with the peaty horizon of samples DY-01-F-34 to 36
DY-01-G-701	17.20		0.07		epigenetic, clear ice, composite ground-ice wedge, ice veins < 1 mm to 10 mm wide, ground veins, 1-2 mm wide, gas bubbles (< 1mm)
DY-01-G-702	17.70		0.50		clear ice, many non-oriented gas bubbles (1 mm)
DY-01-H-801	17.70		0.20		well-striated, single ice veins 5 mm thick, irregular gas bubbles (1-2 mm)
DY-01-H-901	18.40		0.20		well-striated, ice veins 2-5 mm thick ground veins 1-2 mm thick, numerous gas bubbles (2 mm)
DY-02-A-100-110		4.00	1.50	0.10	wide syngenetic ice wedge in the upper yedoma-like deposits (similar to the samples DY-02-A-01/02), smaller epigenetic ice wedge within the lower lake deposits, alternation of milky and clear ice veins (2-10 mm thick), irregular distributed gas bubbles (1-2 mm)
DY-05-A-100-104		1.40	0.35	0.08	syngenetic, ca. 0.5 to 0.8 m wide, diagonal cut, real witness 0.35 m, exposed height 1.8 m, numerous irregular gas bubbles (1 mm)
DY-05-B-201		5.70	0.70		epigenetic composite ground-ice wedge, ice veins 5-10 mm, ground veins 1-2 mm
DY-05-300-304		15.00	0.70	0.15	ice veins 0.5-3 cm wide, ground veins < 1mm, 2 to 3 veins in mm-distance bundled, clear ice, numerous gas bubbles (1-2 mm)

Further down to 20 m depth the sequence was similar composed as above the presumed palaeosol horizon and consisted dominantly of light brown fine sand with filamentous grass roots and micro lens-like and laminated cryostructure.

Several small ice wedges of 0.03 to 0.80 m width (Table 2-1) are composed of ice veins (1-10 mm wide) and thin sediment veins (1-2 mm wide). The clear ice contains numerous non-oriented gas bubbles (1-2 mm in diameter). Selected ice wedges were collected for hydrochemistry analyses.
In addition, two samples (DY-01-OSL-01, DY-01-OSL-02) were taken for luminescence dating in 11.2 and 19.0 m depth.

2.4 Profiles of Lake Deposits DY-02, DY-03, DY-06

Three short profiles exposing lake deposits were studied below and close to the Yedoma sequence of DY-01.
The *profile DY-02* was situated directly below the thermo-terrace in extension of the composite profile DY-01 (Figure 2-3). A temporal thermoerosional gully (ovrag) exposed a three meter high steep wall of frozen sediments and a large ice wedge (Figure 2-7). The lake sequence exposed between 2.0 and 4.3 m above the river level (a.r.l.) is alternate-bedded (grey fine-laminated silty fine sand, and brown plant detritus layers). In addition wood fragments (2 cm in diameter), separate plant remains, and shell fragments were observed. The cryostructure was dominantly lattice-like with diagonal and vertical ice veins (1-2 mm thick 2-10 cm long, 1-5 cm distance). The gravimetric ice content of this layer range between 30 und 68 wt%. In places, the assumed lacustrine sediment was brownish colored (iron oxide) also along ice veins.
The lake sequence was covered by a cryoturbated peat soil layer, which was composed of grey-brown silty fine sand, dark brown tongue-like peat inclusions (10-20 cm, roots, wood fragments). The cryostructure was banded, with 1-2 cm thick ice bands in a distance of 5-10 cm. Interlayers between ice bands showed lens-like structures (lenses 2-3 cm long, 1 mm thick). The gravimetric ice content amounts to 250 wt%. An about 1.5 m wide ice wedge penetrating the above mentioned sequence was exposed between 2.0 and 6.0 m a.r.l. at the opposite wall of the gully. The ice wedge was covered by thermo-terrace deposits and consisted of a wide syngenetic part in the upper peat soil layer smaller epigenetic part within the lower lake deposits. It is composed of alternation of milky and clear ice veins (2-10 mm thick) and contained irregular distributed gas bubbles (Ø 1-2 mm). The ice wedge was sampled for $^{36}Cl/^{10}Be$ dating (DY-02-101) and hydrochemical studies (DY-01-101 to 110).
Two more profiles of lake deposits (DY-03, DY-06) were studied about 150 m further west of DY-02 (Figure 2-3) in the wall of the river bank. The *profile DY-03* was exposed between 5.0 and 10.5 m a.r.l. (Figure 2-8). A large segment was unfrozen. The lower part of the sequence (5.0 to 6.0 m a.r.l.) consisted of disturbed bedded dark-grey, silty fine sand with light-grey streaks (assumed thawing or drying structures). The sediment is crumbly, contains shells and black spots (Ø 1-2 mm). The section between 6.0 and 9.5 m a.r.l. is composed of alternate partly disturbed bedding of brown plant detritus layers, grey silt layers, and light-grey fine sand. The individual layers have various thicknesses of only some mm up to several cm and are additional intern laminated. The sediment contained some larger trunks of 10 to 20 cm diameter, and several smaller wood fragments of twigs and roots. The wood samples DUV-01-1 (7.8 m a.r.l.) and DUV-01-2 (7.0 m a.r.l.) were taken by Gleb Kraev for dendrochronology. Two samples in the height of 6.5 m (DY-03-OSL-3) and 9.5

m (DY-03-OSL-4) were hammered into the unfrozen sediment for luminescence dating. Frozen deposits were only studied in the uppermost part of profile DY-03 between 9.3 m and 10.3 m a.r.l. The sediment is similar composed as below. The cryostructure was massive and the gravimetric ice content was rather low (24-29 wt%). Two diagonal ice veins (probably fissure ice) crossed this frozen segment.

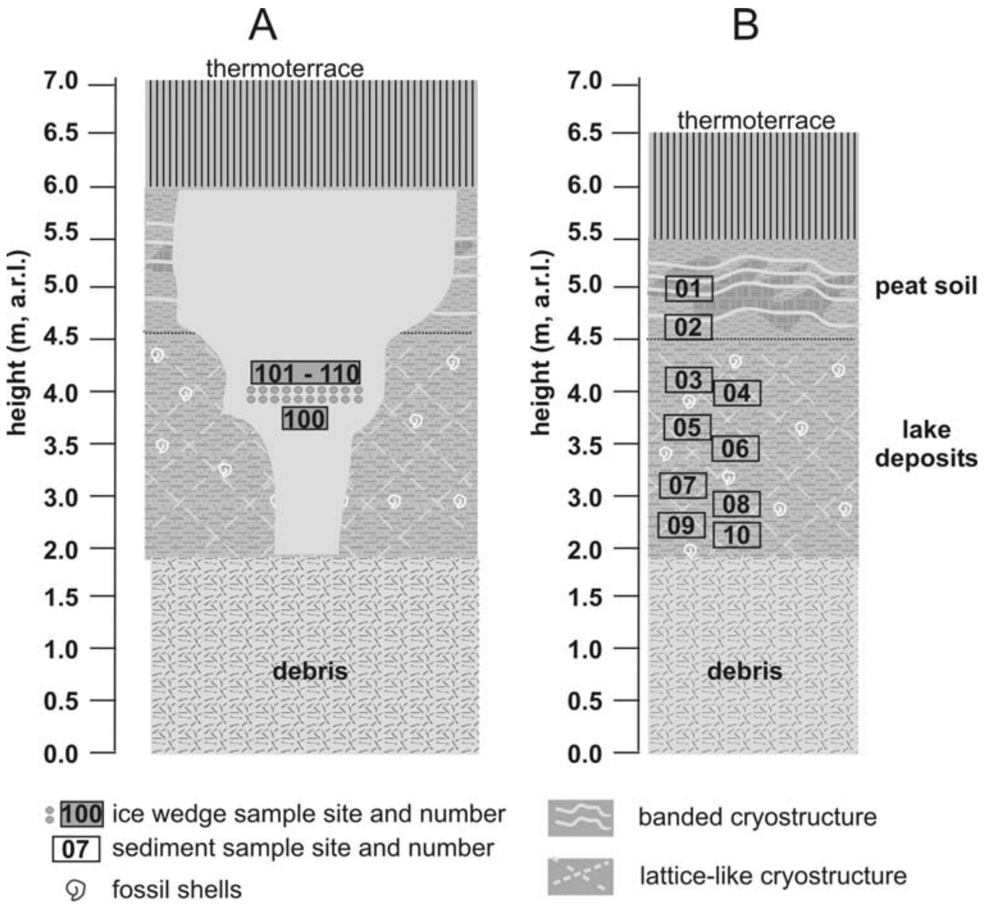

Figure 2-7: Scheme of the profile DY-02. A – Studied ice wedge, B- lake deposits covered by a peat soil horizon.

The *profile DY-06* was studied in the same position but about 15 m higher between 24.0 and 27.5 m a.r.l. (Figure 2-8, 2-9a). The unfrozen sequence consisted of alternate bedding (Figure 2-9b) of brown-grey laminated fine sand (1-4 cm), laminated grey silt (1-2 cm) and dark-brown plant detritus (2-10 mm). The detritus layers were irregular distributed (5-10 cm long segments). Cross and ripple bedding structures, rusty-brown coloration in sand layers, and small twigs (Ø 1-2 cm) and shell fragments were observed additionally.
A cryoturbated peaty horizon existed in 8.0 to 8.8 m a.r.l. (Figure 2-9c). Samples of larch trunks were taken in 25.4 m height for dendrochronology by Gleb Kraev (DUV-02 to 07). One sample for luminescence dating was hammered into the unfrozen sediment at 26.3 m a.r.l. (DY-06-OSL-7).

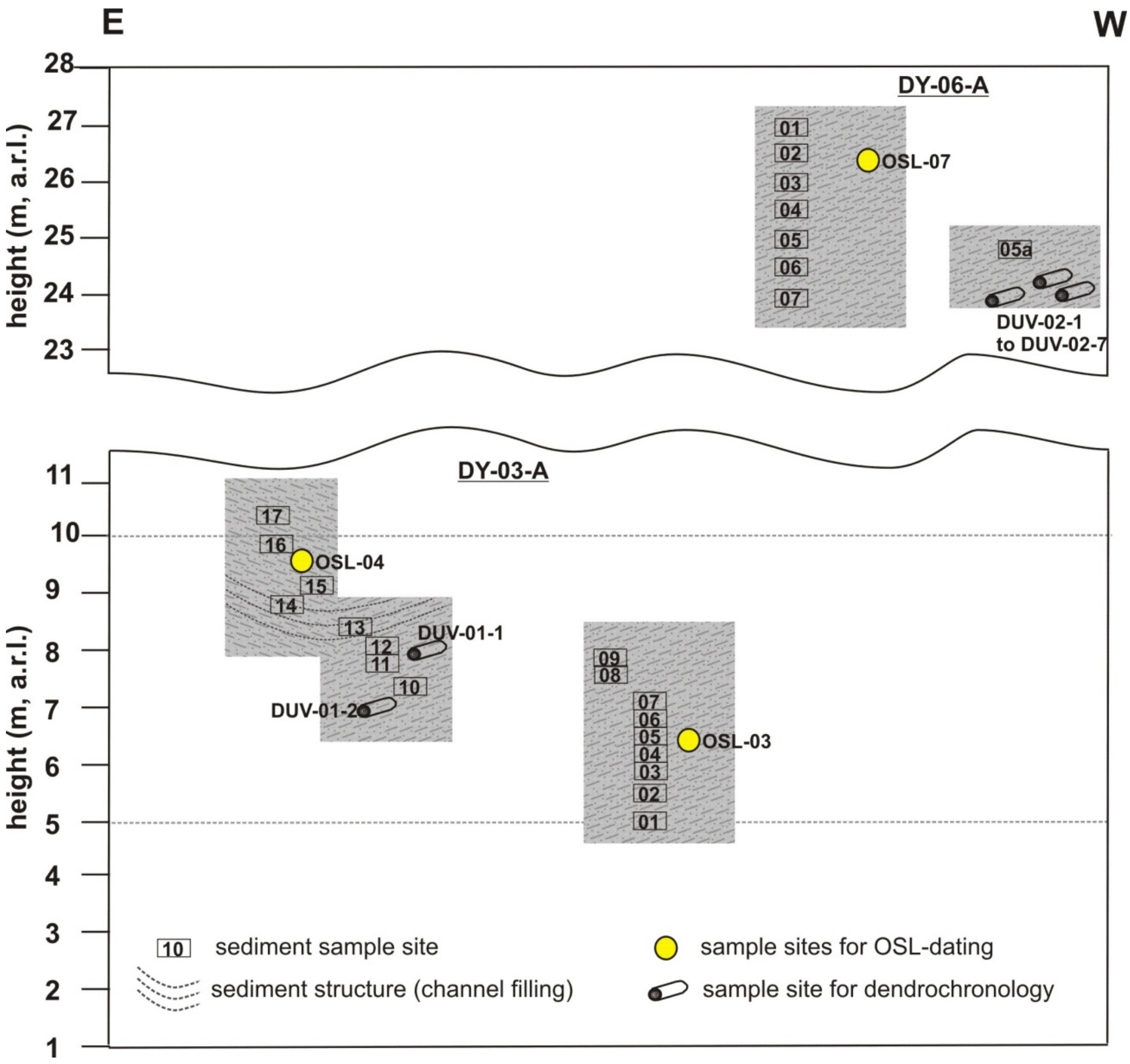

Figure 2-8: Scheme of the lake sediment profiles DY-03 (below) and DY-06 (above) with sample positions

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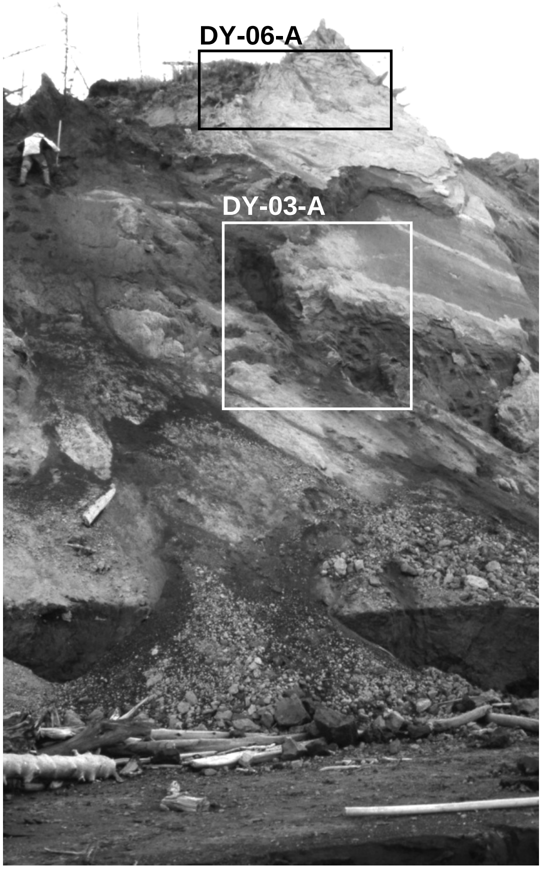

Figure 2-9a: Position of the studied lacustrine profiles DY-03-A and DY-06-A.

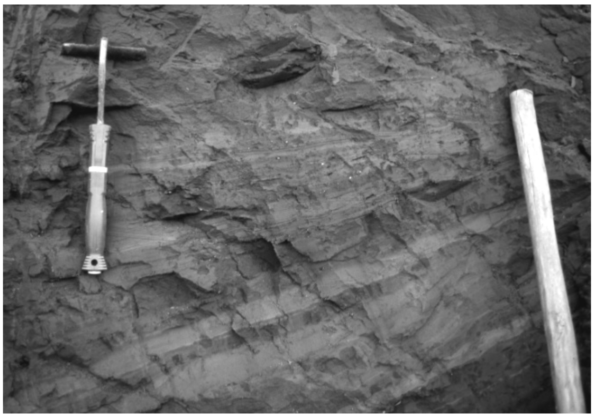

Figure 2-9b: Alternate bedding of fine sand, silty, and plant detritus layers.

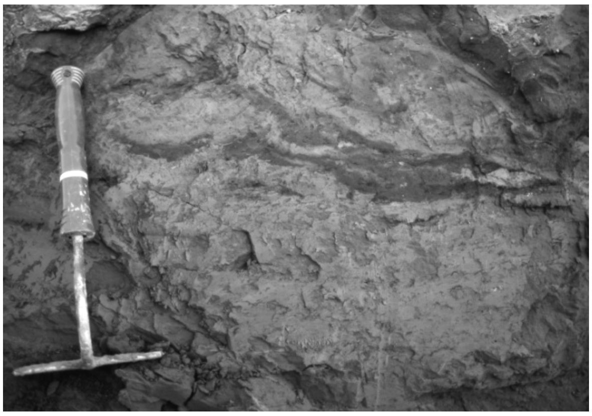

Figure 2-9c: Peat inclusions in silty matrix (sample DY-03A-13).

2.5 Composite Profile DY-05 (Yedoma Horizon)

A second composite profile covering the Yedoma horizon was studied in a thaw slump (thermocirque) about 2 km east of DY-01 (Figure 2-3). In this case the 25 m long sequence was surveyed upwards starting at the river level, crossing the thermo-terrace end ending at below the steep ice wall about 18 m below the surface level (Figure 2-10, Figure 2-11a-c). The entire sequence consists of eight subprofiles (DY-05-A to H) mostly exposed at thermokarst mounds (baydzherakhs).

The lowermost *subprofile DY-05-A* was exposed between 1.0 and 2.0 m a.r.l. at the wall of a temporary thermo-erosional gully (ovrag). An ice wedge and the surrounding frozen sediments of light-brown fine sand with filament roots were studied here (Figure 2-11b). The cryostructure was banded and micro to fine lens-like. Ice bands (distance 10-15 cm) composed of numerous micro lenses pass into the ice wedge shoulders. The gravimetric ice content amounts 70-75 wt%. The nearby studied syngenetic of 0.5 to 0.8 m wide ice wedge (Table 2-1) was diagonal cut (real wideness 0.35 m) and contained numerous irregular gas bubbles (Ø 1 mm). This subprofile was covered by deposits of the thermo-terrace.

The next *subprofile DY-05-B* between 2.0 and 6.0 m a.r.l. was characterized by dark-brown patches and the occurrence of wood fragments like twigs or roots (Ø 2-4 mm, max. 20 mm). The matrix of light-brown fine sand contained numerous filament grass roots and separate black spots (Ø 2-3 mm). This horizon is considered as palaeo-cryosol sequence. A sample was drilled for luminescence dating In 2.0 m a.r.l. The cryostructures were different and changed between laminated lens-like and micro lens-like. Clear segregation ice existed around larger wood fragments. In places ice bands of 2-3 cm thickness occurred and separate about 3 cm long ice veins. The gravimetric ice content varied between 40 and 100 wt% (Figure 2-6). An epigenetic composite ground-ice wedge with 5-10 mm wide ice veins and 1-2 mm wide ground veins were sampled at 5.7 m a.r.l. (DY-05-B-201).

The palaeosol sequence of seems to continue in *subprofile DY-05-C* (6.0-6.8 m a.r.l.). The cryostructure was banded. Ice bands were 0.5- 1.0 cm thick and had a distance of 2.0-4.0 cm. Interbeds were micro to fine lens-like structured. The gravimetric ice contents range between 50 and 180 wt%.

Further upwards between 10.0 and 25.0 m a.r.l. the sequence was rather homogenously (*subprofiles DY-05-D to H*). The sediments consisted of lightgrey-brown silty fine sand with filament roots, single black spots (Ø 1-2 mm). The cryostructure was massive to micro lens-like and the gravimetric ice content vary mostly around 40 wt%. Some separate layers contain larger amounts of plant fragments (stems). In addition a small layer of 5 cm thickness in 10.8 m a.r.l. containing dark-brown peat inclusions was considered as a cryoturbated palaeosol. In these cases the gravimetric was higher and amounted 60 to 80 wt% (Figure 2-6). Separate ice-filled fissures of 1-2 mm wideness cross the upper subprofiles. One ice wedge in 15.0 m a.r.l. was sampled for hydrochemistry studies and $^{36}Cl/^{10}Be$-dating (DY-05-F-300-304). Single ice veins were 0.5-3.0 cm wide. 2 to 3 ground veins of <1mm wideness were bundled in mm-distance. The clear ice contained numerous gas bubbles (Ø 1-2 mm).

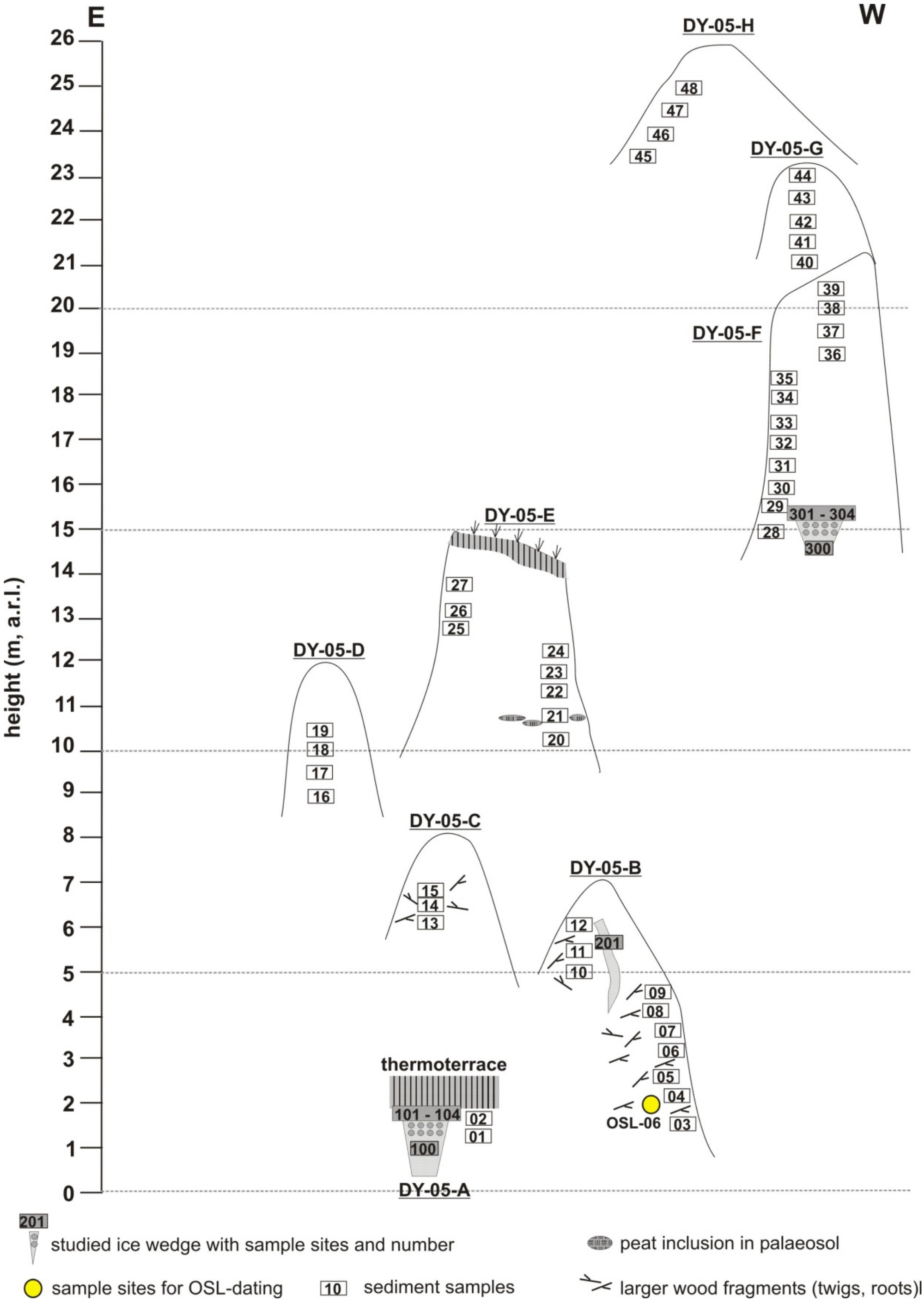

Figure 2-10: Scheme of the second composite profile DY-05.

Figure 2-11a: Overview picture of the thermocirque of the composite profile DY-05.

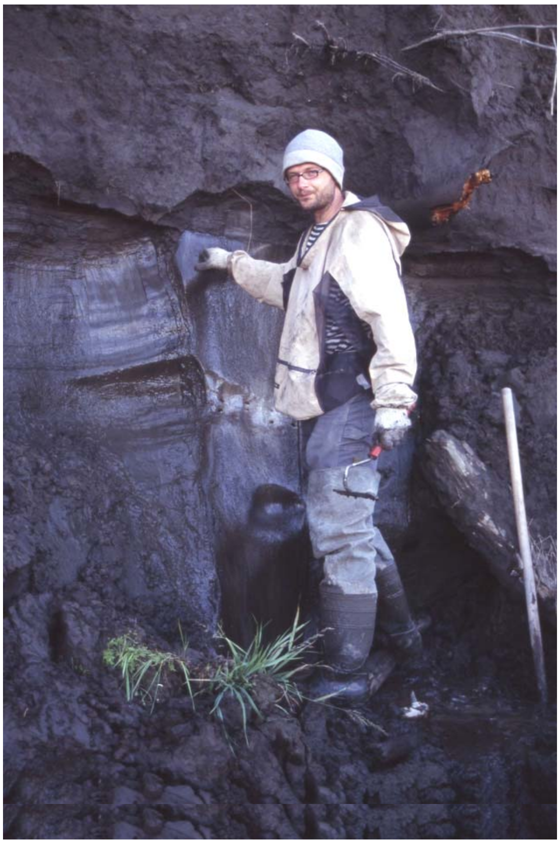

Figure 2-11b: Ice wedge of the lowermost subprofile DY-05-A exposed between 1.0 and 2.0 m a.r.l.

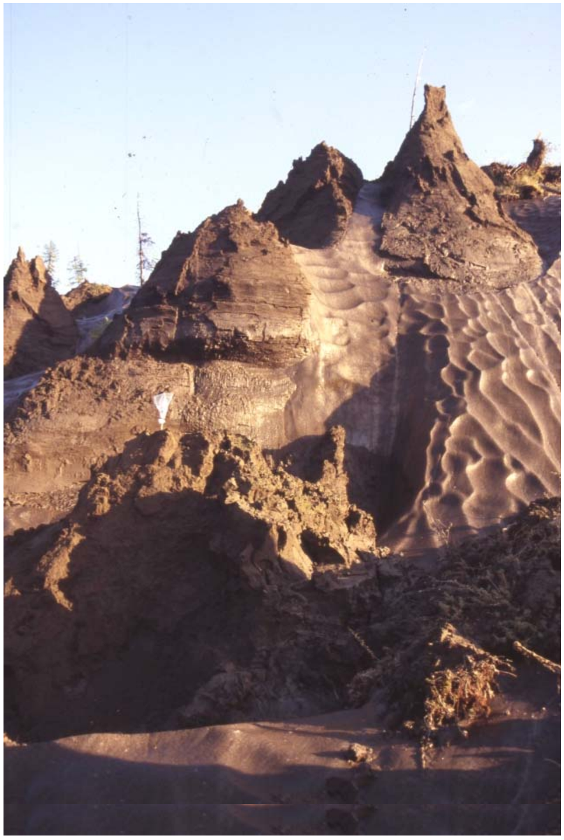

Figure 2-11c: Baydzherakhs and ice wedges of the upper part of the exposure DY-05

2.6 Alas Profile DY-04

The easternmost exposure was located at a depression (alas) about 3.2 km east of the Yedoma section DY-05 (Figure 2-3). The 8.0 m high steep wall of the riverbank cut the frozen sequence of alas deposits (Figure 2-12). The upper four meters were well-exposed. The profile ended at 3.5 m depth with a cavern (probably a wave cut niche) that was buried by talus material. The studied sequence started at the surface with an unfrozen moss cover, underlain by frozen silty fine sand with roots that belongs to the transition zone of the active layer. The cryostructure here was lens-like with 10-20 mm long and <1 mm thick ice lenses. At 0.35 m b.s. an horizon occurred with horizontal ice veins composed of small vertical ice needles. The gravimetric ice content amounts 136 wt %. The cryostructure at 0.5 m depth was already lattice-like and the ice content increased to 227 wt%. Further down the sediment consisted of grey and brown patched silty fine sand. The sediment was crumbly (1x1 to 2x2 cm crumbs) and contained white spots (Ø 2-3 mm) of unclear origin (shell fragments or mineral new formations). Twigs and plant detritus layer were also observed. The cryostructure was complex. Diagonal and horizontal 2-3 mm thick ice veins formed lattice-like structure of various sizes. In addition zones with horizontal ice bands and broken lens-like structures existed in place as well as vertical ice veins and massive structures. The gravimetric ice content varied between 40 and 150 wt% (Figure 2-12).

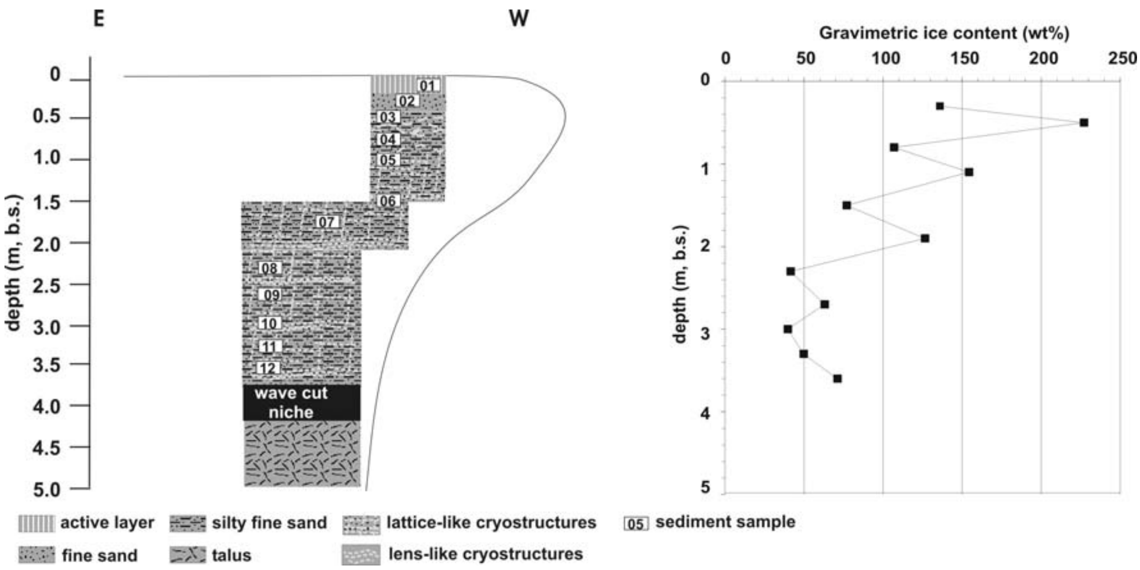

Figure 2-12: Scheme of the alas profile DY-04 with gravimetric ice contents.

3 Studies of Permafrost Cores and Boreholes at Duvanny Yar

Aleksander L. Kholodov, Dimitry G. Fyodorov-Davydov, Gleb N. Kraev and Vasiliy A. Mironov

Three boreholes were drilled on the Duvanny Yar site in the frame of the expedition BERINGIA/KOLYMA 2008 using the rotary drilling equipment UKB-12/25 (Figure 3-1b).

Figure 3-1: Impressions from the drilling work: (a) logger installation at borehole 2-08; (b) the rotary drilling equipment UKB-12/25 in use at borehole 3-08.

Borehole 1-08 is situated on the top of Yedoma (late Pleistocene accumulative plain) approximately 40 meters above river level (Figure 2-3), the later at the time of the fieldwork was approximately same with the sea level. The borehole is 8.5 m deep. It covers the cover layer and upper horizon of ice complex.
Borehole 2-08 was drilled in a depression 30 m above river level preliminary determined as alas (Figure 2-3). It is 25 m deep. The following deposits were covered: modern slope deposits; late Pleistocene lacustrine deposits and assumed taberal deposits and pre late Pleistocene lacustrine deposits.
Borehole 3-08 is situated on the river beach right near the foot of outcrops less then 1 m above the river level (Figures 2-3 and 3-1). It is 4.5 m deep and covers modern deposits of river bank from 0 to 3 m, ancient lacustrine deposits in interval 3 – 4 m and assumed ancient pebbles of Begunovskaya Suite in the interval 4 m and deeper.

All cores were described and sampled for lithological (each 1 m) and microbiological (each 0.5 m) analyses. Water (ice) content and soil density were determined in all investigated deposits. 25 samples were taken for the investigation of gas content and isotopic composition. After the drilling the gas flux from boreholes was measured.

Natural radiation (γ-logging) was measured in all boreholes.

HOBO U12, 4 channel data logger were installed in the borehole 2-08 for long-term continuous temperature measurements in course of the TSP program (Figure 3-1a). Sensors are situated at depths of 5 m, 10 m, 15 m and 25 m. First measurements were done in August, 22./23., 2008 and show the following temperatures versus depths (Table 3-1)

Table 3-1: Temperatures at different depth of borehole 2-08.

Depth below surface [m]	Borehole temperature [°C]
5	- 4.925
10	- 5.760
15	- 5.791
25	- 6.167

4 Limnological Studies in Modern Periglacial Waters on the Lower Kolyma Plain

Sebastian Wetterich and Lutz Schirrmeister

4.1 Scientific Background and Objectives

The studies and investigations presented in chapter 4 deal with the state and biological inventory of waters in modern forest-tundra landscapes in the lower Kolyma plain (Figure 4-1).

The topic of the fieldwork on present-day environments was to obtain modern analogue data and reference material of several bioindicators such as plants, pollen, diatoms, chironomids, rhizopods and ostracods, which were already and are planned to be used in palaeo-environmental applications based on the study of Quaternary permafrost deposits (see chapter 2).

Figure 4-1: Forest-tundra landscape near the settlement Cherskii with ponds and thermokarst lakes. Photograph by S. Zimov, Cherskii.

The intention of our limnological fieldwork in summer 2008 in the lower Kolyma plain was the record and monitoring of abiotic parameters such as climate conditions, temperature fluctuations, ionic and stable isotope composition in the waters in relation to bioindicators such as pollen, diatoms, chironomids, rhizopods and ostracods. The investigation of the modern conditions in the waters allows the quantification of influencing parameters, which control the modern occurrence of these indicator organisms. In future, results of the study can be useful for interpretations of fossil data from sediment cores and outcrops and also for quantitative palaeo-environmental reconstructions of the region using several palaeo-bioindicators.

4.2 Study Sites

Limnological studies were undertaken in two areas of different landscape characteristics in August 2008 (Figure 4-2).

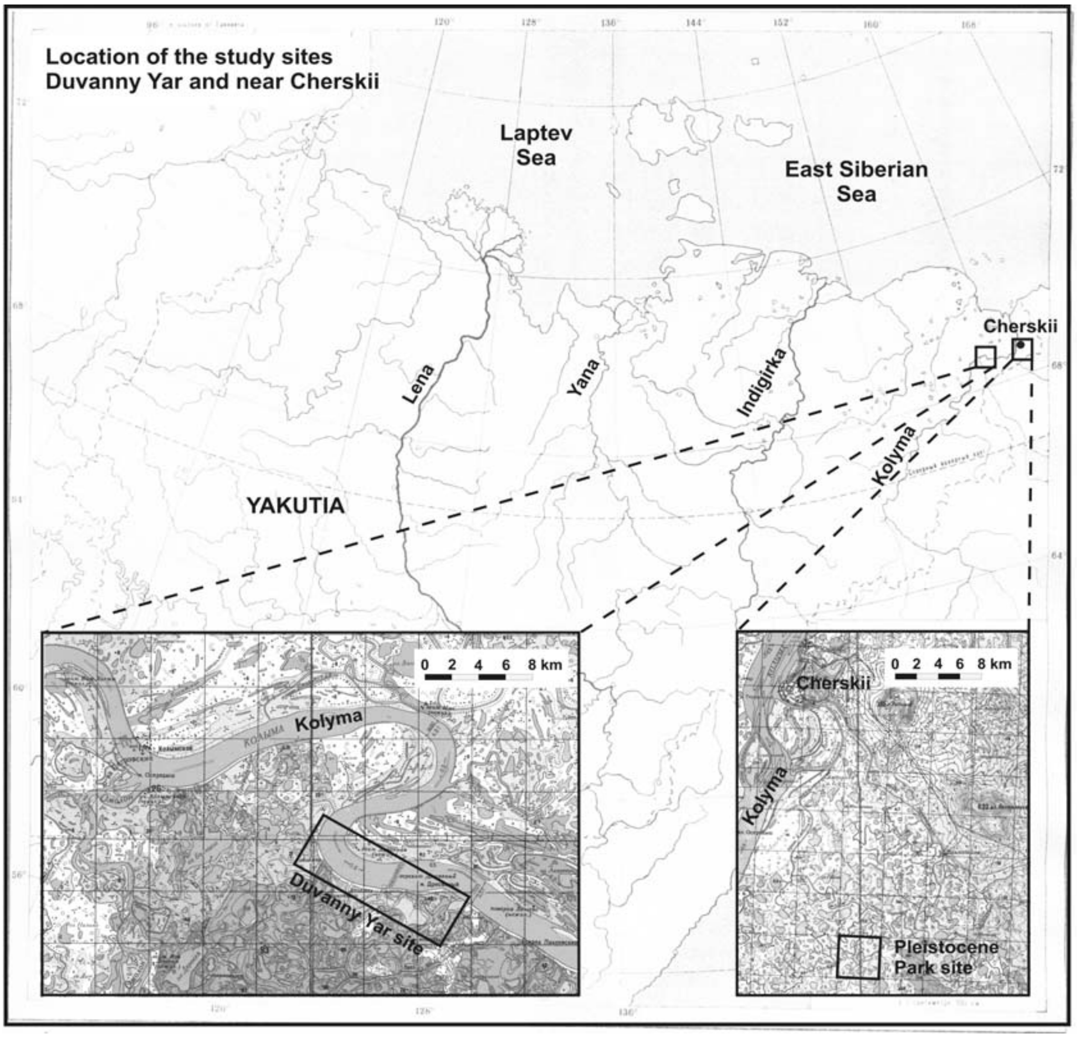

Figure 4-2: Location of the sampled waters (a) near the Duvanny Yar outcrop and (b) in the area of the “Pleistocene Park” near the settlement Cherskii.

The first site near the Duvanny Yar outcrop (68.63190 °N, 159.14200 °E) on the right-hand side of the lower Kolyma River is characterised by thermokarst depressions (alases) which are bordered by Yedoma hills (up to 50 m a.s.l.). These hills represent unthawed remains of Late Pleistocene Ice Complex deposits, whereas the thermokarst depression developed during the Holocene warming. Nowadays, the depressions next to the river appear well drained due to numerous small thermo-erosional valleys (logs) and thermokarst lakes and ponds were rare. However, four thermokarst lakes were studied in this area. The second study site was located on the floodplain of the Kolyma River about 40 km southeast of the settlement Cherskii (68.51285 °N, 161.49886 °E). This area is known as “Pleistocene Park” (Zimov, 2005). Here, we sampled three ponds at the end of August in preparation for an upcoming German-Russian research project POLYGON that will include study sites at this location.

4.3 Material and Methods

Investigations on properties of water chemistry and physics in the waters were undertaken in order to describe the recent life conditions for organisms. Our investigations included the estimation of water and size. We quantified pH, electrical conductivity (EC) and temperature using a WTW pocket meter. Still in the field, the determination of oxygen concentrations, total hardness, alkalinity and acidity was performed by means of titrimetric test kits (Viscolor).
For hydrochemical analyses in the lab the pond water was sampled above the sediment surface from each site. Samples for cation analyses (15 ml) were acidified with 200 µl HNO_3, whereas samples for anion analysis and residue samples were cool stored. Before conservation, samples for cation and anion analyses were filtered by a cellulose-acetate filtration set (pore size 0.45 µm). Additionally, precipitation and pond water samples for $\delta^{18}O$ and δD isotope analyses (30 ml) were preserved without any conservation.
Surface sediments of the ponds were sampled for sedimentological and botanical, zoological and paleontological analyses at the centre of the ponds. For these purposes studies on pollen, diatoms, chironomids, rhizopods and ostracods are planned. Living ostracods were caught in surface sediment samples from different pond zones using an exhaustor system (Viehberg, 2002) and preserved in 70 % alcohol. Further taxonomical work using soft body characteristics will provide the first description of modern ostracod assemblages from the study area.
One thermokarst lake (KOL-01) in an alas depression was selected as monitoring site. Here, we performed continuous temperature measurements at three levels using temperature loggering (MinidanTemp 0.1, ESYS). The loggers were placed in two different water depths (0.5 m and 0.05 m below the water surface) and in the air (2 m above the water surface). Additionally, every five days repeated hydrochemical measurements and sampling of water, sediments and ostracods were performed in order to obtain seasonal dynamics of the studied parameters and proxy as well as their relationships among each other.

4.4 Field Results

The studied waters belong to the thermokarst lake type in the first study site near Duvanny Yar and to the pond type (most probably of polygonal genesis) in the second study site near Cherskii (Figure 4-3). The size of the lakes reaches from 70 x 200 m up to 100 x 300 m whereas the ponds are generally smaller than 10 m in diameter (Table 4-1).

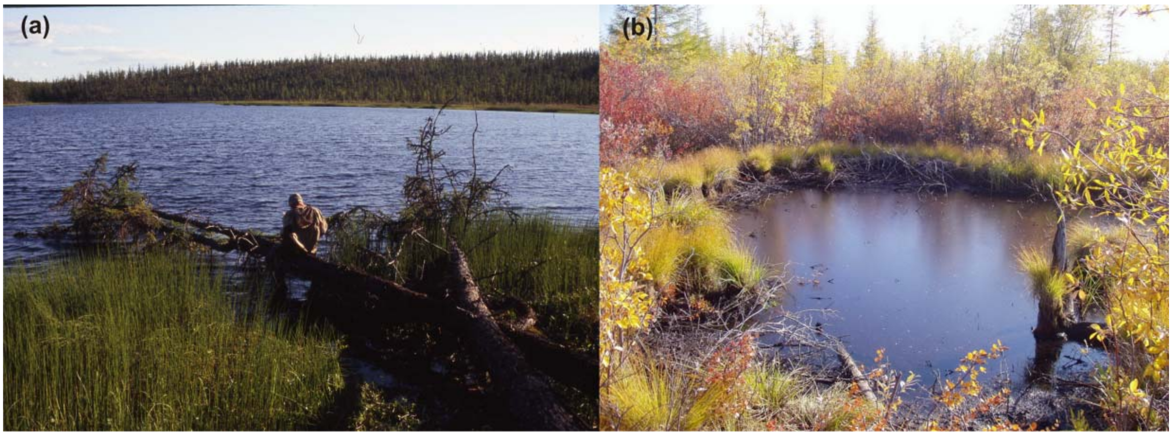

Figure 4-3: Exemplary photographs of the studied waters: (a) thermokarst lake near the Duvanny Yar outcrop (KOL-04) and (b) pond on the territory of the “Pleistocene Park” near Cherskii (KOL-05). Photograph by S. Zimov, Cherskii.

The ground substrate is mostly built up by organic mud and rich in more or less decomposed plant detritus. Results of the finger-print hydrochemistry during the fieldwork are presented in Table 4-1. In general, the lakes near Duvanny Yar are characterised by slightly acidic to neutral pH (pH 5.9 to 7.3) and very low EC (26 to 66 µS/cm). The ponds studied near Cherskii on the territory of the “Pleistocene Park” were slightly acidic to neutral (pH 6.4 to 7.3) and had higher EC (137 to 318 µS/cm). The acidity of the waters ranges between 0.4 and 0.6 mmol/l in both regions. The alkalinity in lakes near Duvanny Yar ranges from 0.4 to 0.8 mmol/l and shows general lower values as compared to ponds near Cherskii which ranges from 1.6 to 3.6 mmol/l. Trends in hydrochemical parameters are not obvious and do not show distinct gradients over the monitored periods in the monitored lake (KOL-01).

The temperature monitoring was performed during the fieldwork from August 5 to August 20 at the margin of the thermokarst lake KOL-01. Bottom (T_{bottom}) and surface ($T_{surface}$) water temperatures are co-varying in lower amplitude with air temperature variations and shows the same variations. Daily T_{air} amplitudes reach up to about 30 °C absolute T_{air} maxima of about 40 °C and T_{air} minima of about 3 °C. However, the very high daily maximum values of T_{air} during the early evening hours seem to be overestimated due to the west exposition of the logger and the consequently direct sun radiation during the mostly cloudless days. The absolute T_{bottom} maxima of about 18 °C occur in the middle of August and T_{bottom} minima of about 13 °C at the beginning (Figure 4-4).

Table 4-1: Characteristics of the studied waters.

Geographical features of the studied waters						
Sample KOL-	Date	Time	Region*	Locality	Coordinates °N	°E
01a	05.08.08	12:00	DY	Alas	68.62833	159.22316
02	05.08.08	15:00	DY	Alas	68.62733	159.21767
03	05.08.08	17:00	DY	Alas	68.62772	159.18996
01b	10.08.08	14:00	DY	Alas	68.62833	159.22316
01c	15.08.08	11:30	DY	Alas	68.62833	159.22316
01d	20.08.08	12:00	DY	Alas	68.62833	159.22316
04	21.08.08	16:00	DY	Alas	68.62936	159.14499
05	24.08.08	17:30	PP	Floodplain	68.51320	161.52887
06	24.08.08	18:30	PP	Floodplain	68.51150	161.52325
07	24.08.08	19:45	PP	Floodplain	68.51285	161.49886

* DY – near Duvanny Yar; PP – “Pleistocene Park” near Cherskii

Table 4-1: Continuation.

Morphological and sedimentological features of the studied waters						
Sample KOL-	Water type	Substrate	Size [m x m]	Depths [m] maximal	water samples	ostracod samples
01a	Thermokarst lake	Organic mud	200 x 200	no data	0.25	0.2-0.4
02	Thermokarst lake	Organic mud	100 x 300	no data	0.25	0.2-0.4
03	Thermokarst lake	Organic mud	70 x 200	no data	0.35	0.2-0.4
01b	Thermokarst lake	Organic mud	200 x 200	no data	0.3	0.3-0.7
01c	Thermokarst lake	Organic mud	200 x 200	no data	0.4	0.4-0.8
01d	Thermokarst lake	Organic mud	200 x 200	no data	0.3	0.4-0.9
04	Thermokarst lake	Organic mud	200 x 300	no data	0.4	0.4-0.8
05	Pond	Peat mud	7 x 9	0.5	0.3	0.2-0.5
06	Pond	Organic mud	1.5 x 7	0.2	0.2	0.2
07	Pond	Organic mud	1 x 2	0.3	0.3	0.3

Table 4-1: Continuation

Physico-chemical features of the studied waters										
Sample KOL-	T_{Air} [°C]	T_{water} [°C]	EC* [µS/cm]	pH Viscolor	pH WTW	O_2 [mg/l]	Alk* [mmol/l]	Aci* [mmol/l]	TH* [°dH]	TH* [mmol/l]
01a	22.0	13.2	26	6.5	5.9	7.0	0.6	0.4	7.0	1.2
02	23.6	15.5	66	6.5	6.3	6.2	0.8	0.4	4.0	0.7
03	23.0	14.0	49	6.5	6.5	9.0	0.6	0.4	5.5	0.9
01b	24.1	16.8	26	7.0	6.9	8.6	0.4	0.4	3.5	0.6
01c	17.3	16.5	26	6.5	6.0	7.8	0.4	0.4	4.5	0.8
01d	21.6	15.7	27	6.5	6.5	7.4	0.4	0.4	5.0	0.8
04	22.7	18.6	51	7.0	7.3	8.4	0.7	0.4	3.0	0.5
05	18.0	12.8	137	6.5	6.8	4.0	1.6	0.4	7.0	1.2
06	17.4	17.5	318	6.5	7.3	7.8	3.6	0.6	11.5	2.0
07	14.7	10.8	153	7.0	6.4	8.8	2.2	0.6	5.5	1.0

* EC – electrical conductivity; Alk – Alkalinity; Aci – Acidity; TH – Total hardness

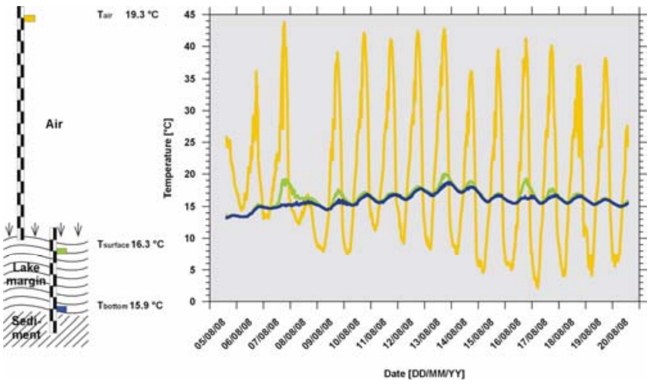

Figure 4-4: Daily temperature variations at the margin of one thermokarst lake near the Duvanny Yar outcrop (KOL-01). Three levels are figured out. T_{bottom}: above the sediments in 0.5 m water depth (blue graph); $T_{surface}$: directly below the water surface (green graph); T_{air}: 2 m above the water surface (yellow graph).

4.5 Outlook

Pollen, diatoms, chironomids, rhizopods from sediments and live caught ostracods will be investigated to illuminate their relationship to environmental factors such as temperature, pH, and conductivity. Later, this information will be applied to fossil assemblages obtained from sediment cores and permafrost deposits in order to infer quantitative environmental changes via organism-environment transfer-functions. In the laboratory, water samples will be analysed for element content by means of an ICP-OES and anion content by Ion Chromatography. Furthermore, analyses of $\delta^{18}O$ and δD isotopes on water and precipitation samples will be performed in order to compare these data with isotope values in calcareous ostracod valves. The understanding of the recent relationship between isotope ratios in waters and in ostracod valves will lead to an interpretation tool for palaeoenvironmental information preserved in fossil ostracods. For the same purpose trace element analyses (e.g. Ca. Mg. Sr) in waters and ostracod valves will be undertaken. Analyses of nitrogen organic and total carbon contents on surface sediment samples by CN-Analyzer as well as grain-size distribution by laser particle analyzer will be carried out in order to characterize the sedimentological setting of the investigated ponds. Furthermore, it is planned to continue such kind of monitoring and sampling of small waters in course of the joint German-Russian POLYGON project, where the “Pleistocene Park” will be one of three study sites in the Northeast Siberian lowlands.

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6 Appendix

6.1 List of Sediment Samples - Sedimentology and Cryolithology

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-01 (68.63284° N; 159.08755° E) 06.-09.08.2008								
DY-01-A-01	moss, surface	unfrozen	0.05					
DY-01-A-02	grey-brown, silt, moist, rooted, thin humus bands,	unfrozen	0.20				active layer	
DY-01-A-03	grey-brown silt, thin filament roots (10-15 cm long), brown organic patches (2-3 cm)	banded, ice band (5-7 cm thick, 10-20 cm distance), composed of ice needles, interlayers fine lens-like to lens-like reticulated, lenses 1-2 cm long, 1-2 mm thick, 5-10 mm distance	0.75		57.4	36.4		X
DY-01-A-04	grey-brown silt, many organic streaks, palaeosol (0,2 m)	not banded, fine lens-like above organic inclusions, coarse lens-like in other places (several cm long, up to 0,5 mm thick), vertical ice veins (5-10 cm long, < 0.5 cm wide))	1.40		47.4	32.2		
DY-01-A-05			1.80		70.0	41.2		X
DY-01-B-06	grey-brown silt, black patches (1-5 mm), filament roots (up to 3 cm long), in situ bone	massive	2.25		47.7	32.3	Connec-tion to Dy-01-A-05	
DY-01-B-07	grey-brown silt, black patches (1-5 mm), filament roots (up to 3 cm long)	massive	2.75					X
DY-01-B-08			3.25		65.9	39.7		
DY-01-B-09	grey-brown fine sand, filament roots	laminated, diagonal to horizontal ice veins (< 1mm, thick, mm distance), irregular, possibly orientation to the ice wedge	3.75		54.4	35.2		X
DY-01-B-10	light-brown fine sand, filament roots	laminated, dia-gonal to hori-zontal ice veins (mm distance)	4.25		49.5	33.1		X

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-01-B-11	light-brown fine sand, filament roots, small wood fragments	laminated, diagonal to horizontal ice veins (mm distance), irregular	4.75		54.2	35.1		
DY-01-B-12	light-brown fine sand, filament roots	laminated, diagonal to horizontal ice veins (mm distance), irregular	5.25		56.1	35.9		X
DY-01-B-13		laminated, diagonal to horizontal ice veins (mm distance), irregular	5.75		50.8	33.7		X
DY-01-B-14		coarse lens-like layer (6 m b.s.), laminated, diagonal to horizontal ice veins, irregular, < 1mm thick, several mm distance	6.25		71.6	41.7		X
DY-01-B-OSL-1	light-brown fine sand, filament roots	laminated	6.50		55.3	35.6	drilled	
DY-01-C-15	light-brown fine sand, filament roots, local brownish coloured	laminated, diagonal to horizontal ice veins (mm distance), irregular	6.00					
DY-01-C-16			6.50		51.1	33.8		X
DY-01-C-17	light-brown fine sand, filament roots, in places black spots (1-3 mm), several small wood fragments (twigs, roots ?)	massive	7.00		54.7	35.4		X
DY-01-C-18	light-brown fine sand, long filament roots	massive (ice cement)	7.50		54.1	35.1		X
DY-01-C-19	light-brown fine sand, long filament roots, numerous small (1-3 mm) black spots in a 2 cm thick layer	massive (ice cement)	8.00				upper part of a black spotted horizon	X
DY-01-D-20	grey-brown fine sand, filament roots, black spots (1-2 mm), single vertical oriented twig fragments (5-10 cm)	massive (ice cement)	8.20		47.3	32.1	lower part of a black spotted horizon	
DY-01-D-21	light-brown fine sand, long filament roots	massive (ice cement)	8.70					
DY-01-D-22			9.20		50.7	33.7		
DY-01-D-23	brown to light-brown fine sand, filament roots, black spoots (1-3 mm)	massive (ice cement)	9.50		47.2	32.1		

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-01-D-24	light-brown fine sand, filament roots	coarse lens-like, ice lenses 5-7 cm long, 1-5 mm thick, 2-3 cm distance, ice-rich horizon 10 cm thick	10.00		63.2	38.7		X
DY-01-D-25	light-brown fine sand, filament roots	massive	10.50		52.9	34.6		
DY-01-D-26	yellowish-brown fine sand, filament roots	laminated, ice lenses up to 5 cm long, 1-2 mm thick diagonal and parallel oriented	11.00		45.9	31.5		
DY-01-D-OSL-2			11.20		41.7	29.4	drilled	
DY-01-D-27			11.40		53.8	35.0		X
DY-01-E-28	grey-brown fine sand, filament roots, small twig fragments, black spots (1-3 mm)	massive, with some thin ice bands in 0,5 m distance, composed of micro lenses	11.50		45.6	31.3		
DY-01-E-29	light-brown fine sand, wood fragments (3 mm)	massive, with some thin ice bands in 0,5 m distance, composed of micro lenses	12.00					
DY-01-E-30	light-brown fine sand, filament roots, wood fragments, black spots	massive, with some thin ice bands in 0,5 m distance, composed of micro lenses	12.50		51.9	34.2		X
DY-01-E-31	light-brown fine sand, filament roots,	micro lens-like (< 1mm thick, 2-4 mm long), irregular distributed	13.00					X
DY-01-E-32	light-brown fine sand, filament roots, irregular brownish coloured	micro lens-like (< 1mm thick, 2-4 mm long), irregular distributed	13.50		65.5	39.6		
DY-01-F-33			13.70					
DY-01-F-34	light-brown fine sand, filament roots, dark-brown organic bands, larger wood fragments	irregular lens-like, diagonal ice veins, ice segregation around wood fragments	14.40		112.8	53.0		
DY-01-F-34-wood	large wood fragments		14.40					
DY-01-F-35	light-brown fine sand, filament roots, dark-brown organic bands, larger wood fragments	irregular lens-like, diagonal ice veins, ice segregation around wood fragments	14.70		80.7	44.6		
DY-01-F-36	light-brown fine sand, filament roots, small wood fragments (1-2 mm)	micro lens-like, in diagonal bands oriented	15.00					X

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-01-F-37	light-brown fine sand, filament roots, small wood fragments (1-2 mm)	micro lens-like, several horizontal ice bands between 15.0 and 15.5 m	15.50		53.2	34.7		X
DY-01-F-38	light-brown fine sand, filament roots	micro lens-like	16.00					X
DY-01-F-39			16.50					
DY-01-G-40	light-brown fine sand, filament roots, small wood fragments (1 mm)	micro lens-like	16.20		36.5	26.7		
DY-01-G-41	light-brown fine sand, filament roots, small wood fragments (1 mm), several black patches (1-3 mm), beetle remains	micro lens-like	16.70					
DY-01-G-42	light-brown fine sand, filament roots, dark-brown diagonal streaky coloured	diagonal ice veins 7 cm long, 1 mm thick	17.20					
DY-01-G-43	light-brown fine sand, filament roots	micro lens-like	17.70		39.9	28.5		X
DY-01-H-44	light-brown fine sand, filament roots, wood fragment (10 mm), black spots	laminated micro lens-like, several broken ice lenses (10 mm long, 1 mm thick)	17.40					X
DY-01-H-45			18.00		39.6	28.4		X
DY-01-H-46	light-brown fine sand, filament roots	micro lens-like	18.50					
DY-01-H-OSL-5		massive	19.00		45.3	31.2	drilled	
DY-01-H-47		massive	19.50		38.2	27.6		X
DY-02 (68.63425° N; 159.08757° E), 09.08.2008								
DY-02-A-01	peat soil, grey-brown silty fine sand, dark-brown, tongue-like peat inclu-sions (10-20 cm, cryoturbated, roots, wood fragments)	banded, ice bands (1-2 cm thick, 5-10 cm distance), with lens-like interlayers (lenses 2-3 cm long, 1 mm thick)		5.00	247.2	71.2	smells like Yedoma deposits	X
DY-02-A-02				4.60				X
DY-02-A-03	grey-brown silty fine sand	lattice like, ice veins 1mm thick, 2-3 cm distance		4.20	63.1	38.7	shells?	
DY-02-A-04	grey-brown silty fine sand	fine lens-like reticulated, lenses 3-5 cm long, 1-2 mm thick, 1 cm distance		4.00			shells?	X
DY-02-A-05	grey-brown silty fine sand, in places brownish coloured (iron oxide) also along ice veins	lattice-like, diagonal and vertical ice veins 7-10 cm long, 3-5 cm distance		3.70			shells?	

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-02-A-06	grey-brown silty fine sand, fine laminated (light grey to grey, < 1 mm), shells?, in places brownish coloured (iron oxide) also along the ice veins	lattice-like, diagonal and vertical ice veins 7-10 cm long, 3-5 cm distance		3.40				
DY-02-A-07	grey silty fine sand, laminated, shells?	diagonal ice veins, 2-4 cm long, < 1 mm thick, 1-3 cm distance		3.10	43.1	30.1		
DY-02-A-08	alternate bedding of grey silty fine sand and brown detritus layers, wood fragments (2 cm), separate plant remains, shells	horizontal ice veins, 2-4 cm long, < 1 mm thick, 1-3 cm distance, parallel to the bedding		2.80				
DY-02-A-09				2.50				
DY-02-A-10				2.10	30.1	23.2		
DY-03 (68.63475° N; 159.08444° E), 11.08.2008								
DY-03-A-01	dark-grey silty fine sand with light-grey streaks (thawing or drying structures?), crumbly, disturbed bedding, shells, black spots (1-2 mm)	unfrozen		5.00			channel filling or ice wedge cast (?)	
DY-03-A-02	dark-grey silty fine sand with light-grey streaks (thawing or drying structures?), crumbly, disturbed bedding, shells, black spots (up to 5 mm)	unfrozen		5.50				
DY-03-A-03	darkgrey silty fine sand with light-grey streaks, weakly bedded, crumbly, shells (?), black spots (2-5 mm)	unfrozen		6.00				
DY-03-A-04	alternate bedding of light-grey silty fine sand and brown organic layers, ripple bedding, twig fragments with bark (0,5-1 x 2-5 cm long)	unfrozen		6.30				
DY-03-A-05	light-grey fine sand layer (15 cm thick) with thin silt interlayers (0,5 cm))	unfrozen		6.50			below the discor-dance	
DY-03-A-OSL-3				6.50	27.9	21.8	ham-mered	

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-03-A-06	alternate bedding of plant detritus (brown, 2-3 cm), silt (grey, 1 cm), fine sand (light-grey, 5 cm), large wood inclusion (10 cm diameter) at 7,8 m	unfrozen		6.70			above the discor-dance	
DY-03-A-07	disturbed alternate bedding of plant detritus (1-2 mm) and fine sand (5-10 mm) layers	unfrozen		7.10				
DY-03-A-08	alternate bedding of silt layers(grey, 2-3 cm), plant detritus laminae within silt (brown, < 1 mm), and fine sand (light-grey, 5 cm), small twig fragments (2-4 mm)	unfrozen		7.60				
DY-03-A-09	grey silt, well-bedded, black elongated spots (3x5 mm), bluish vivianite inclusion (2-4 mm), 2 mm thick plant detritus layer, shells, single wood fragments (1-2 mm)	unfrozen		7.90			below the yellow-ish sand band № 1	
DY-03-A-10	light-grey fine sand (13 mm thick), bedded, 1x plant detritus layer (1-2 mm). 1x silt layer (5 mm), single wood fragments (1-3 mm)			7.40			overlap-ping upper window	
DY-03-A-11	alternate bedding of light-grey fine sand (2 mm) and brownish plant detritus layers (1-2 mm) covered by a dark-grey silt layer (15 cm) with several sand interbeds (5 mm), vivianite (3-5 mm), small twigs (2-3 mm), shells, the entire packet is diagonal layered	unfrozen		7.75			position of the wood sample DUV-01-1 (Gleb Kraev)	

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-03-A-12	yellowish sand band no. 2, framed by grey slit layer, bedded, above a 2 cm thick zone of bluish vivianite spots (1-3 mm), concentric black spots	unfrozen		8.10				
DY-03-A-13	brownish peat streaks (tongue-like) in greyish silty matrix, vivianite, shells, weakly bedded, disturbed	unfrozen		8.40				
DY-03-A-14	brownish peat streaks (tongue-like) in greyish silty matrix, vivianite, shells, weakly bedded, disturbed	massive, 2 subvertical ice veins (2 mm thick) fissure ice		8.80	29.1	22.5	channel filling with wood trunks in the centre	
DY-03-A-15	greyish silt, disturbed bedding, single plant detritus layers. 2 black layers (1 mm), wood fragments (2-4 mm), small white shiny grains (mica, quartz ?)	massive		9.30				
DY-03-A-OSL-4		unfrozen		9.50	24.0	19.4	ham-mered	
DY-03-A-16	grey fine sand, disturbed bedding, black interbeds (1 mm), single small twigs, unclear irregular yellowish sand interbeds	massive, 2 diagonal ice veins		9.80	27.2	21.4		
DY-03-A-17				10.30				
DY-04 (68.62912° N; 159.21606° E), 12.08.2008								
DY-04-A-01	light-brown moss layer (20 cm thick),	unfrozen	0.15	7.85			active layer	
DY-04-A-02	grey silty fine sand, rooted	lens-like (10-20 mm long, <1 mm thick), at 0,35 m b.s. horizon with horizontal ice veins composed of small vertical ice needles	0.30	7.70	135.8	57.6		
DY-04-A-03	brown silty fine sand, rooted	lattice-like, vertical, horizontal and diagonal ice veins, single horizontal ice bands (several cm long, 5 mm thick) composed of small vertical ice needles	0.50	7.50	227.0	69.4		

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-04-A-04	grey and brown patched silty fine sand, crumbly (1x1 cm), white spots (2-3 mm, shells or mineral new formations?)	lens-like broken (lenses 1 cm long, 1 mm thick, 1-3 cm distance),	0.80	7.20	106.9	51.7		
DY-04-A-05	grey silt, crumbly (1x1 cm), white spots (2-3 mm, shells or mineral new formations?)	lens-like, vertical ice veins, upwards-bended parallel lenses (2 cm long, 1-3 mm thick), ice band of clear ice at 1,2 m b.s.	1.10	6.90	154.4	60.7		X
DY-04-A-06	grey silt, crumbly (1x1 cm), white spots (2-3 mm, shells or mineral new formations?) cut by ice lenses, single plant remains	lattice-like (vertical dis-tances 3-5 cm, horizontal 1-2 cm), broken ice lenses, vertical and subvertical ice veins	1.50	6.50	76.9	43.5		X
DY-04-A-07	grey silt, crumbly (2x2 cm), white spots (2-3 mm, shells or mineral new formations?)	lattice-like (coarser), 2-3 mm thick ice veins	1.90	6.10	126.4	55.8		X
DY-04-A-08	grey fine sand, plant remains, twigs (mm to several mm long), withe spots (shells or mineral new formations?)	alternation of lattice-like layers (10 cm thick) and lens-like layers (10 cm thick), lenses 2-3 cm long, 1 mm thick	2.30	5.70	41.5	29.3		X
DY-04-A-09	grey fine sand, plant detritus layer (1 cm), twigs white spots (1-2 mm, shells or mineral new formations?)	three different cryostructures below 2,3 m b.s. : horizontal ice bands(5 mm thick), lens-like broken (2-4 cm thick zone), zones of small horizontal ice veins and sediment inter-layers both 1-2 cm thick	2.70	5.30	62.9	38.6		
DY-04-A-10	grey silty fine sand, white spots	alternation of lattice-like, coarse lens-like broken zones	3.00	5.00	39.6	28.4		
DY-04-A-11	grey fine sand, bedded, 20 cm thick packet, dark grey plant detritus layers, white spots	massive	3.30	4.70	49.8	33.2		X
DY-04-A-12	grey silty fine sand, bedded, layers 5 cm thick, separated by ice bands	banded (ice bands 1 cm thick), lattice-like, coarse lens-like)	3.60	4.40	71.1	41.5		

	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-05 (68.63067° N, 159.14078° E) 14.-18.08.2008								
DY-05-A-01	light-brown fine sand, filament roots	ice bands consis-ting of numerous micro lenses pass into the ice wedge shoulders (distance 10-15 cm), fine lens-like (3-5 mm long, < 1 mm thick)		1.30	69.2	40.9	ovrag wall	X
DY-05-A-02				1.80	75.3	43.0		X
DY-05-B-03	light-brown fine sand, filament roots, large wood fragments, in place dark-brown patchy coloured (palaeosol)	micro lens-like, horizontal enriched (2 mm thick), clear segregation ice around wood fragments		1.50	60.9	37.9	thermok arst mound	
DY-05-B-OSL-6	light-brown (partly yellowish-brown) fine sand, filament roots, twigs (2-4 mm)	laminated, lens-like (1-10 mm long, <1 mm thick)		2.00	64.3	39.1	drilled	
DY-05-B-04				2.20	59.1	37.2		
DY-05-B-05	light-brown silty fine sand, filament roots, large wood fragments (twigs, roots 5-20 mm), dark-brown coloured around wood fragments	micro lens-like, clear segregation ice around wood fragments		2.70	72.8	42.1		
DY-05-B-06	light-brown silty fine sand, filament roots, large woos fragments (twigs, roots 5-20 mm), dark-brown patchy coloured, black spots (2-3 mm)	micro lens-like, single diagonal thin ice lenses		3.20	42.1	29.6		
DY-05-B-07	light-brown fine sand, filament roots, single woos fragments (2-5 mm)	micro lens-like, partly horizontal ice lenses; covered a zone of horizontal clear ice 2-3 cm thick in 7, 10 and 23 cm distance)		3.70	91.4	47.8		X
DY-05-B-08	light-brown fine sand, filament roots, large wood fragments (5-10 cm long, 5-10 mm in diameter)	banded, micro lens-like interbeds		4.20	91.7	47.8		
DY-05-B-09	light-brown fine sand, filament roots, wood frag-ments, oval black patches (up to 5 mm long)	micro lens-like, separate diagonal ice veins (3 cm long)		4.60	70.6	41.4		
DY-05-B-10	light-brown fine sand, filament roots, single plant remains	micro lens-like		5.00	64.2	39.1		

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-05-B-11	light-brown fine sand, filament roots, black spots (1 mm), wood fragments (1 cm)	horizontal micro lens-like		5.50	101.4	50.3		
DY-05-B-12				6.00	61.1	37.9		
DY-05-C-13	light-grey-brown fine sand, filament roots, black spots (1 mm), wood fragments	micro lens-like		6.10	52.7	34.5		
DY-05-C-14	light-grey-brown fine sand, filament roots, large wood fragments (up to 1-2 cm) with barks	horizontal micro lens-like, banded (ice bands 1 cm thick, 2-7 cm distance), clear segregation ice around wood fragments		6.60	76.9	43.5		X
DY-05-C-15	light-grey-brown fine sand, dark-brown organic streaks, numerous wood fragments (twigs, roots, up to 2 cm)	banded (ice bands 0,5- 1 cm thick, 2-4 cm distance), interbeds micro to fine lens-like		6.80	182.3	64.6		X
DY-05-D-16	light-grey-brown silty fine sand, filament roots, single plant remains	micro lens-like		9.00	39.1	28.1		
DY-05-D-17				9.50	47.8	32.3		
DY-05-D-18	light-grey-brown silty fine sand, filament roots, single plant stems (several cm long)	horizontal micro lens-like		10.00	38.4	27.7		
DY-05-D-19				10.50	61.9	38.2		X
DY-05-E-20	light-grey-brown silty fine sand, filament roots	micro lens-like, diagonal ice veins (1-2 cm wide), vertical ice lenses (1mm thick, 1-2 cm long)		10.30	70.9	41.5		X
DY-05-E-21	peaty palaeosol (5 cm thick)l, dark-brown peat inclusions (2-3 cm), cryoturbated, filament roots, single plant remains,	horizontal micro to fine lens-like, single vertical ice veins (1 mm wide)		10.80	72.0	41.9		
DY-05-E-22	light-grey-brown silty fine sand, filament roots, single plant remains	massive		11.30	44.6	30.8		
DY-05-E-23	light-grey-brown silty fine sand, filament roots, single black spots (1-2 mm)	massive		11.80	45.8	31.4		
DY-05-E-24				12.30	43.2	30.2		

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-05-E-25	light-grey-brown silty fine sand, filament roots, single black spots (circular-oval, 1 mm), several plant remains (1mm, 1-2 cm long)	micro lens-like		12.80	17.3	14.7		
DY-05-F-26				13.30	45.2	31.1		X
DY-05-E-27				13.80	37.9	27.5		
DY-05-E-28	light-grey-brown fine sand, filament roots	massive		15.00	38.8	27.9		
DY-05-F-29	light-grey-brown fine sand, filament roots, black spots (2 mm)	massive		15.50	42.0	29.6		
DY-05-F-30	light-grey-brown fine sand, filament roots, small wood fragments (2-3 mm)	massive		16.00	49.5	33.1		X
DY-05-F-31	light-grey-brown fine sand, filament roots, black spots (1-4 mm)	massive, diagonal ice vein, 1mm wide (fissure ice ?)		16.50	42.4	29.8		
DY-05-F-32		massive		17.00	38.5	27.8		
DY-05-F-33	light-grey-brown fine sand, filament roots, small wood fragments (2-3 mm)	massive		17.50	41.1	29.1		
DY-05-F-34	light-grey-brown fine sand, filament roots (2-7 cm long), small wood fragments (1-2 mm)	massive, subvertical ice veins (fissure ice ?)		18.00	41.8	29.5		
DY-05-F-35	light-grey-brown fine sand, filament roots, black spots	massive, subvertical ice veins (fissure ice ?)		18.40	43.6	30.4		
DY-05-F-36	light-grey-brown fine sand, filament roots, small plant remains (1-3 mm), small black spots (2 mm)	massive		19.00	47.8	32.4		X
DY-05-F-37	light-grey-brown fine sand, filament roots, small plant remains (2-3 mm)	massive		19.50	48.3	32.6		
DY-05-F-38		micro lens-like		20.00	79.8	44.4		X
DY-05-F-39				20.50	79.5	44.3		X
DY-05-G-40	light-grey-brown silty fine sand, filament roots	massive to horizontal micro lens-like		21.00	68.4	40.6		X
DY-05-G-41	light-grey-brown silty fine sand, filament roots	massive to horizontal micro lens-like, diagonal ice lenses (1 cm thick, 3 cm long)		21.50	51.0	33.8		

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-05-G-42	light-grey-brown silty fine sand, filament roots	massive to horizontal micro lens-like		22.00	54.0	35.0		
DY-05-G-43	light-grey-brown silty fine sand, filament roots, single black spots, wood fragment (2 mm, 2 cm long)	massive to horizontal micro lens-like		22.50	44.9	31.0		
DY-05-G-44	light-grey-brown silty fine sand, filament roots, single small plant remains	massive to horizontal micro lens-like		23.00	39.6	28.4		
DY-05-H-45	light-grey-brown silty fine sand, filament roots	micro lens-like, single ice lenses (1-2 mm thick, 2-4 cm long)		23.50	47.8	32.4		X
DY-05-H-46	light-grey-brown silty fine sand, filament roots, peat inclusion (2x3 cm), single plant remains	micro lens-like		24.00	45.5	31.3		X
DY-05-H-47	light-grey-brown fine sand, filament roots	micro lens-like		24.50	55.9	35.8		X
DY-05-H-48	light-grey-brown fine sand, filament roots, black spots	micro lens-like		25.00	48.1	32.5		X
DY-06 (68.63465° N, 159.08417° E) 18.08.2008								
DY-06-A-01	alternate bedding of brown-grey laminated fine sand (1-4 cm), laminated grey silt (1-2 cm), dark-brown plant detritus (2-10 mm), detritus layer irregular distributed (5-10 cm long segments), cross and ripple bedding, rusty-brown coloration in sand layers, small twigs (1-2 cm)	unfrozen		27.00				
DY-06-A-02				26.50				
DY-06-A-OSL-7				26.30			ham-mered	
DY-06-A-03				26.00				
DY-06-A-04	grey bedded silty fine sand, grey-brown sandy interbeds (1-5 mm), black spots (irregular, streaky, 5-10 mm)	unfrozen		25.40			horizon was sampled by Gleb Kraev (DUV-02 to 07, Larix)	

Sample №	Sediment description	Cryostructure	Depth [m. b.s.]	Height [m. a.r.l.]	Ice grav. [wt %]	Ice abs. [wt %]	Re-marks	TI
DY-06-A-05	grey bedded silty fine sand, large wood fragments (up to 7 cm diameter) with vivianite, shells	unfrozen		25.00				
DY-06-A-5a	grey bedded silty fine sand, plant detritus layers (2-3 mm), shells	unfrozen		25.00			special sample for shell and plant macro fossil studies	
DY-06-A-06	grey, alternated bedding of fine sand and silt layers, peat lenses (10 cm), single black spots (1-2 mm), yellow-brown sand interbed (3 cm thick)	unfrozen		24.50				
DY-06-A-07	grey silty fine sand bedded, plant detritus layers, single plant remains, black spots, wood fragments with bark, yellow-brown sand interbed (5 cm thick), shells	unfrozen		24.00				
DY-07 (68.6319° N, 159.142° E) 22.08.2008								
DY-07-Kolyma sand	Dresvyanny Island bank	unfrozen		0.00				

Abbreviations

a.r.l. – above river level

b.s. – below surface

ice abs. – absolute ice content

ice grav. – gravimetric ice content

TI – texture ice samples

yellow: samples for OSL dating

6.2 List of Ice Wedge, River and Precipitation Samples

Ice wedge samples

Sample №	Depth [m. b.s.]	Height [m. a.r.l.]	Stable isotopes	Hydro-chemistry	^{36}Cl	pH	EC [µS/cm]
DY-01-A-100	**2.00**			**X**	**X**	**7.5**	**156**
DY-01-A-101	2.00		X				
DY-01-A-102	2.00		X				
DY-01-A-103	2.00		X				
DY-01-A-104	2.00		X				
DY-01-A-105	2.00		X				
DY-01-A-106	2.00		X				
DY-01-A-107	2.00		X				
DY-01-A-108	2.00		X				
DY-01-A-109	2.00		X				
DY-01-B-201	5.25		X	X		8.2	165
DY-01-D-301	9.00		X				
DY-01-D-401	9.00		X				
DY-01-D-402	9.00		X				
DY-01-D-403	9.00		X	X		8.0	97
DY-01-D-404	9.00		X				
DY-01-D-405	9.00		X				
DY-01-D-501	10.50		X	X		7.1	718
DY-01-H-601	15.00		X				
DY-01-G-701	17.20		X	X		7.2	653
DY-01-G-702	17.70		X	X		7.7	172
DY-01-H-801	17.70		X	X		7.5	113
DY-01-H-901	18.40		X	X		7.5	80
DY-02-A-100		**3.80**		**X**	**X**	**7.3**	**83**
DY-02-A-101		4.00	X				
DY-02-A-102		4.00	X				
DY-02-A-103		4.00	X				
DY-02-A-104		4.00	X				
DY-02-A-105		4.00	X				
DY-02-A-106		4.00	X				
DY-02-A-107		4.00	X				
DY-02-A-108		4.00	X				
DY-02-A-109		4.00	X				
DY-02-A-110		4.00	X				
DY-05-A-100		**1.40**		**X**	**X**	**6.5**	**61**
DY-05-A-101		1.50	X				
DY-05-A-102		1.50	X				
DY-05-A-103		1.50	X				
DY-05-A-104		1.50	X				
DY-05-B-201		5.70	X	X		7.4	178
DY-05-F-300		**15.00**		**X**	**X**	**7.4**	**103**
DY-05-F-301		15.00	X				
DY-05-F-302		15.00	X				
DY-05-F-303		15.00	X				
DY-05-F-304		15.00	X				

River water samples

Sample №	Date	Time	Location	Stable isotopes	Hydro-chemistry	pH	EC [µS/cm]
Kolyma River	06.08.08	20:00	DY	X	X	7.8	87
Kolyma River	20.08.08	20:00	DY	X	X	7.7	112

Precipitation samples

Sample №	Date	Time	Location	Stable isotopes	Hydro-chemistry	pH	EC [µS/cm]
Kolyma fog	08.08.08	8:00	DY	X			
Kolyma fog	09.08.08	8:00	DY	X			
Kolyma fog	16.08.08	8:00	DY	X			
Kolyma rain	25.08.08	8:00	Cherskii RAS station	X			

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