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THERMAL REGIME OF PEAT DEPOSITS OF PALSAS AND HOLLOWS OF PEAT PLATEAUS IN WESTERN SIBERIA

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The study has been focused on the thermal regime of peat soils (fibrist histosols) of palsas and peat plateaus in northern West Siberia. Autonomous loggers recorded temperature for 343 days every hour to a depth up to 60 cm in palsas and 120 cm in hollows (collapse scars) in four mire ecosystems: the forest-tundra collapse scar and palsa, and the northern taiga collapse scar and palsa. The data on the mean diurnal temperature, the mean annual temperature, the extremes, the annual range, the active layer dynamics, the sums of positive and negative temperatures at different depths have been adduced. The established differences in the thermal regimes of soils were due to the differences in the ecosystems of mires, rather than in bioclimatic zones they belong to. The high-latitude mires have the largest impact on the annual range and temperature parameters obtained for the cold period.

Thermal regime of peat deposit, peat plateau, palsa, hollows (collapse scars), permafrost, Western Siberia

INTRODUCTION

Soil temperature is an important abiotic factor controlling the rate and limiting the biological and physico-chemical processes in ecosystems, and thus defining the composition, structure and functions of biogeocenoses under specific climatic conditions. In the forest-tundra and northern taiga zones of Western Siberia, the wetland extent constitutes 25 and 40 %, respectively, reaching 70 % in some regions [*Romanova, 1985*]. Within the West Siberian permafrost zone, the dominant type of wetlands is peatland plateaus characterized by complex mesorelief and the combination of palsas (elevated microlandscapes), and collapse scars and pools (hollow microlandscapes) [*Pyavchenko, 1985; Romanova, 1985; Novikov, 2009*]. In literature, frozen palsas are sometimes called peatlands, while waterlogged wetlands are termed collapse scars (thaw pocket, hollows). Interconnected with each other, palsas and collapse scars differ in hypsometric level [*Pyavchenko, 1985; Novikov, 2009*; *Bobrik et al., 2015*], in species composition of phytocenoses [*Vasiliev et al., 2008; Bobrik et al., 2015; Pastukhov et al., 2016*], and in depth to the permafrost [*Moskalenko, 2009; Bobrik et al., 2015; Koronatova et al., 2015*].

Soil temperature regimes (STRs) are largely governed by the radiation balance of the surface and intensity of convective heat transfer between the atmosphere and the soil surface layer. The investigations conducted in different regions of Siberia have revealed that in winter, soil temperatures are more affected by snow cover depth, than by air temperatures [*Sherstyukov, 2008; Vasiliev, 2009; Dyukarev, 2015*]. In summer-time, the rapid heating of the upper moss-peat layer of mires occurs convectively, through the rain-producing runoff flow [*Dyukarev et al., 2009*]. Since the middle of the 20th century, soil temperatures in the North of Siberia have been showing an increasing trend [*Skryabin and Varlamov, 2013*], which, specifically, leads to the appearance of woody species on permafrost palsas (composed by frozen peat and mineral soil) [*Moskalenko, 2009; Koronatova and Milyaeva, 2014*]. The high-latitude areas of Western Siberia exhibit a long-term trend of increasing snow cover depth [*Kitaev and Kislov, 2008*] with affiliated warming of mean annual soil temperatures (MAST), which can lead to permafrost degradation [*Sherstyukov, 2008*]. At this, some researchers advocate for an increasing severity of the soil climate due to the looming increase in winter air temperatures capable of reducing the depth and duration of winter snow cover and likely causing colder soil temperatures [*Brown and DeGaetano, 2011*], which means that frost heave processes will continue to persist in Western Siberia [*Ponomareva et al., 2012*].

The type of mire ecosystems of the permafrost zone that affects STR in peat deposits is described as follows: in waterlogged habitats, both the vegetation and peat covers are stripped of their thermal insulation properties, with the thermal conductivity of the deposit approximating that of water or ice, while in more elevated and drier habitats where the heat-insulating effect of the moss cover is significant, the heat consumption for the phase transitions is reduced, and so is the depth of zero annual amplitudes [*Ospennikov, 2001*].

Results of the long-term research into thermal regime of permafrost mires of Western Siberia in the second half of the 20th century are summarized in the monograph published by the State Hydrological Institute, Saint Petersburg [*Novikov, 2009*]. Proceeding from the experimental and modeled data, the authors have adduced that STRs of peatland plateau deposits are largely governed by a shallow occurrence of permafrost, which is aggravated by the absence of heat flux ascending from the deeper layers.

This is manifested in sharply declining temperatures with depth, shallow penetration of diurnal fluctuations, large summer gradients in the surface layer, and in higher heat fluxes into soils compared to non-permafrost bogs in this region, whereas distinctions between the water regime of palsa and collapse scars cause different STR dynamics of their peat deposits.

Introduction of technologies using electronic equipment about 25 years ago enabled temperature measurements in different media in the autonomous mode, allowing thereby to obtain data in greater detail and to establish new STR patterns for peat deposits in the zone of permafrost distribution [*Vasiliev et al., 2008; Moskalenko, 2009; Bobrik et al., 2015; Goncharova et al., 2015*]. Given that the studies were conducted mainly in the Nadym weather station (WS) area, the observations in the rest of the region were sporadic [*Makhatkov and Ermolov, 2015*].

This paper set out to reveal specific features of the STRs of the active layer within the two types of mire micro-landscapes (palsas and collapse scars) of peat plateaus in the permafrost zone of Western Siberia.

STUDY AREA AND TEMPERATURE MEASURING TECHNIQUES

Thermometric observations in the mire complexes of northern West Siberia (Table 1) were carried out for: the forest-tundra (Pangody key site, 23 km east of the eponymous village); the northern taiga (Tetu-Mamontotyay key site, a mire located 15 km east of the city of Noyabrsk). Geographically, Pangody mire is situated 300 km north of Tegu-Mamontotyay mire. Both the objects belonging to the type of peat plateau palsa complex, widely spread in the northern taiga and forest-tundra of Western Siberia [*Romanova, 1985*], are characterized by their affinity in geomorphology and phytocenotic composition. Their landscapes are represented by a combination of frozen dry-peat dwarf-shrub-*Sphagnum*-lichen palsas with shallow occurring permafrost and waterlogged grass-*Sphagnum* collapse scars with the underlying permafrost either deeper-seated or missing within the peat mantle. The palsas were elevated from 50 to 100 cm above the hollow surface. The collapse scar surface was flattened, while the palsas surface interspersed with hummocks and lows was undulating. Given a lack of gravitational water and due to the peat of palsas being saturated with capillary moisture, free water table either did not form, or encountered as a thin water layer resting above the permafrost. Whereas the collapse scars were waterlogged, with water table standing 5–15 cm below the surface of *Sphagnum* moss carpet.

The thermal regime of peat deposits of palsas and collapse scars was studied using autonomous temperature loggers (IMCES SB RAS, Tomsk) [*Kurakov et al., 2008*]. In places of temperature measurements, the deposit was composed of *Sphagnum* peat with low (palsas) and medium (collapse scars) degree of decomposition. The loggers were installed on large hummocks covered by *Sphagnum* moss, to measure the temperature of palsas at depths of 2, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 cm.

In the center of collapse scars (area: 30–50 m^2) the loggers recorded temperatures at depths of 2, 5, 10, 15, 20, 30, 40, 60, 80 and 120 cm. The measurements were taken at a frequency of one hour. The data presented in the paper encompass the period from June 2, 2013 through May 9, 2014 (i.e. a full year short of 22 days), since the equipment was damaged in the northern taiga collapse scar and the temperature records therefore ceased to be running. The inferred annual characteristics, despite spanning an incomplete year, are adequate, inasmuch as the records made by the remaining operating loggers in the second and third decades of May indicate the mean diurnal temperature from 0 to –1 °C at all depths at minimal diurnal ranges or in their absence, which exerted little influence, if any, on the temperature characteristics in the focus of the paper.

We used data on air temperature and snow cover provided via the Internet resource by the Pravaya Kheta and Noyabrsk airport weather stations, the closest to the key sites [*Raspisaniye..., 2004*]. The established high correlation between the air temperature data obtained at the key site and at the weather station located within the radius of 30 km (k = 0.997) allowed to include the weather station data in the analysis [*Makhatkov and Ermolov, 2015*].

Table 1. **Characterization of the objects of study**

Key site	Space coordinates	Ecosystem	Phytocenosis composition	Inmost permafrost depth, m	Bog water availability
Pangody	65.87° N, 74.95° E	Palsa	*Ledum, Andromeda*, cranberry, lichens of the genus *Cladina*, species of *Sphagnum*	–0.6	no
		Collapse scar	Sedge, species of *Sphagnum*	–0.8	yes
Tetu-Mamontotyay	63.22° N, 75.71° E	Palsa	*Ledum*, cowberry, cranberry, lichens of the genus *Cladina*, species of *Sphagnum*	–0.6	no
		Collapse scar	Sedge, cottongrass, species of *Sphagnum*	>1.2	yes

RESULTS AND DISCUSSIONS

The annual course of temperature of peat deposits. The temperature dynamics of the surface moss cover, mat and peat proved to be generally consistent with the air temperature dynamics (Fig. 1). Despite the fact that the studied mires belong to different bioclimatic zones, the annual course of air temperature in the forest-tundra was largely congruent with the northern taiga (correlation coefficient $k = 0.96$).

The course of mean diurnal temperatures in the moss-peat layer during the warm period is found similar in all the ecosystems, with the three periods of temperature variation accentuated in the mire surface layer (2–20 cm) lasting:

a) between early June and mid July: the period of alternating warming and cooling waves against the backdrop of the generally growing temperature and deposit warming; the diurnal range at a depth of 2 cm constituted 9.1–15.5 °C (for palsas) and 7.4–15.7 °C (for collapse scars);

b) from mid to late July: the period of persisting high temperatures; the diurnal range at a depth of 2 cm was minimal: 2.6–2.7 °C (for palsas) and 1.1–4.3 °C (for collapse scars);

c) through August–September: the period of alternating warming and cooling waves against the backdrop of decreasing temperature in the surface layer of peat deposit; the diurnal range at a depth of 2 cm reached 13.8–14.8 °C (for palsas) and 15.6–16.4 °C (for collapse scars).

As such, the summer temperatures course, apparently, affected the growth of mire peat-forming plants, *Sphagnum* mosses, which actively vegetate in early summer, however their growth ceases in July given the consistently high temperatures and the concomitant increase in the evaporation from the surface of mosses and their desiccation [*Deane-Coe et al., 2015*].

At a depth of 30 cm during the first period, peat deposit in the palsas was just beginning to warm up, with the temperature approaching 0 °C, while the highest mean diurnal temperatures at this depth (about 10 °C) were observed in August. In the collapse scars within this layer, the temperature peaked in July, amounting to 13–14 °C.

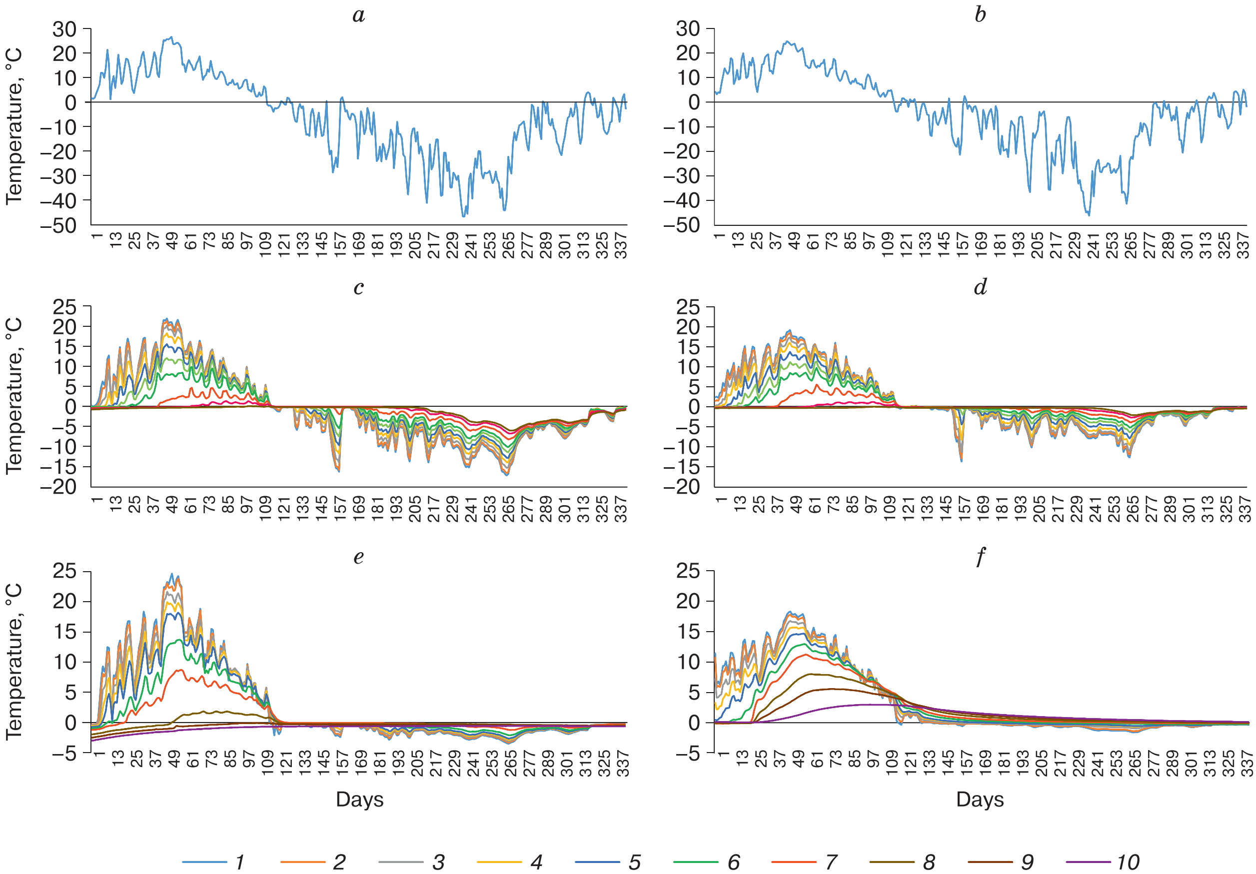

Fig. 1. Mean diurnal temperature values for:

a – air in forest-tundra; *b* – air in northern taiga; *c* – peat soil of palsa in forest-tundra; *d* – peat soil of palsa in northern taiga; *e* – peat soil of collapse scar in forest-tundra; *f* – peat soil of collapse scar in northern taiga. Depth: *1* – 2 cm; *2* – 5 cm; *3* – 10 cm; *4* – 15 cm; *5* – 20 cm; *6* – 30 cm; *7* – 40 cm; *8* – 60 cm; *9* – 80 cm; *10* – 120 cm.

In palsas (depth: 40 cm), the temperature turned above zero in mid-July (in the forest-tundra), a week earlier (in the northern taiga), which occurred as late as June, 22–23 in collapse scars. Rather weak warming-cooling waves (within 1–3 °C) were observed there in August–September, except for the northern taiga collapse scars, where the course of the mean diurnal temperature (DT) at this depth was smoothed, with the maximum DT reported at 5 °C for the palsas, about 9 °C for the forest-tundra collapse scars, and 11 °C for the northern taiga collapse scars.

During the cold period, the temperature dynamics in the moss-peat layer differed for palsas and collapse scars (Fig. 1). In the collapse scars, from October to May, the temperature at all depths remained about 0 °C, slightly falling in the upper 20-cm layer in some days of February down to –3.5 °C (Pangody mire) and to –1.6 °C in (Tetu-Mamontotyay mire). A decrease in the temperature of collapse scars was also observed in September during the ground frost events in the absence of snow cover. All in all, the “zero curtain” persisted in the collapse scars throughout the winter.

The temperature minima observed at the top layer of palsas were consistent with decreases in the air temperature. One of the most prominent decreases occurred in early November, when the temperature fell to –13…–16 °C at a depth of 2 cm at the air temperature of –21…–29 °C. According to the local weather stations data, at this time, the snow cover depth corresponded to the marks of 25 and 8 cm in the forest-tundra and northern taiga, respectively.

Redistribution of snow and its accumulation are inherent in the low-relief elements of peat plateaus [*Bobrik et al., 2015*]. The freezing-through of the top layer of palsas at this time is therefore associated with the low snow cover depth. The temperature decrease to –40 °C and lower in January and February did not produce any intensifying effect on the freeze-up of mires due to the subsequent growth of the snow cover depth (76 cm in the forest tundra and 40 cm in the northern taiga) according to the weather stations’ records (as of January, 1).

As temperatures gradually dropped below 0 °C in the palsas within the 0–30 cm layer during September–October, the period of negative temperatures lasted from October through May. While palsa temperatures in the layer below 30 cm began to fall from January in the forest tundra and from February in the northern taiga, reaching their minimum by March. The air temperature started warming early in March, and despite the continued snow accumulation, the deposits temperature of palsas showed an increasing trend throughout the entire 60-cm thickness with a minimum delay at depth, by comparison with a significant delay in its warming-up during the summer. The thermal properties of peat deposits are known to differ in the frozen and thawed state, which is corroborated by the frozen peat having several times higher thermal conductivity coefficient and lower specific heat capacity [*Ershov, 2001; Novikov, 2009*].

Absolute maximum and minimum temperatures in peat soils. The extreme air temperatures exhibited two peaks in the summer: July, 7 (32.1 °C) and July, 18 (23.3 °C), and two winter peaks: January, 25 (–49.8 °C) and January, 26 (–49.5 °C) for the forest-tundra and northern taiga, respectively. Within the studied mire systems, the temperature maxima were observed in the surface layer in July, specifically: 21.5 °C on July, 26 (palsa), and 22.8 °C on July, 28 (collapse scar) in the northern taiga mire; while in the forest-tundra mire, moss layer on the palsa warmed up to 27.3 °C, and up to 34.6 °C in the collapse scar on July, 27. The temperature minima (–5.0 °C in the forest-tundra and –2.2 °C in the northern taiga) were registered in the collapse scars in late September, largely accounted for by the frost action coupled with the lack of snow cover. On the palsa surfaces, the lowest values were reported a month and a half later (November, 7) (–15.7 °C in the northern taiga and –17.5 °C in the forest-tundra) due to the low snow cover depth, with most of the snow being blown into the topographic lows.

Thermal wave propagation in peat soils. The average monthly temperature in the palsas, while remaining negative, reached its maximum in July (surface layer), in August (depth: 30–40 cm), and in September (depth: 60 cm).

In the collapse scars, the maximum values were also registered in July (depth: 2–20 cm) and in August (depth: 40–60 cm). Peat layer of the northern taiga collapse scar warmed up to positive temperatures to a depth of 80–120 cm, reaching maximum in August–September. While in the forest-tundra the same layer that remained in the zone impacted by permafrost experienced thawing only to a depth of 80 cm, with the unfrozen state lasting two months. The mean monthly maximum (–0.6 °C) persisted from January through March at a depth of 120 cm, which manifested itself in September (3.0 °C) in the northern taiga.

The mean annual soil temperature (MAST) for peat soils was reported at –5.9 °C for the forest tundra and –3.7 °C for the northern taiga for the studied period. The mean annual temperature at the surface layer of mires was by 7–9 °C higher in the collapse scars and by 2–5 °C in the palsas as compared to the mean annual air temperature (MAAT) (Fig. 2). In the surface layer of collapse scars the values were 3.0...3.5 °C, while in the northern taiga they remained positive through-the-depth, and in the forest-tundra fell below 0 °C from a depth of 60 cm.

In the palsas, the MAST values for the surface layer were lower, averaging about 1 °C for the north-

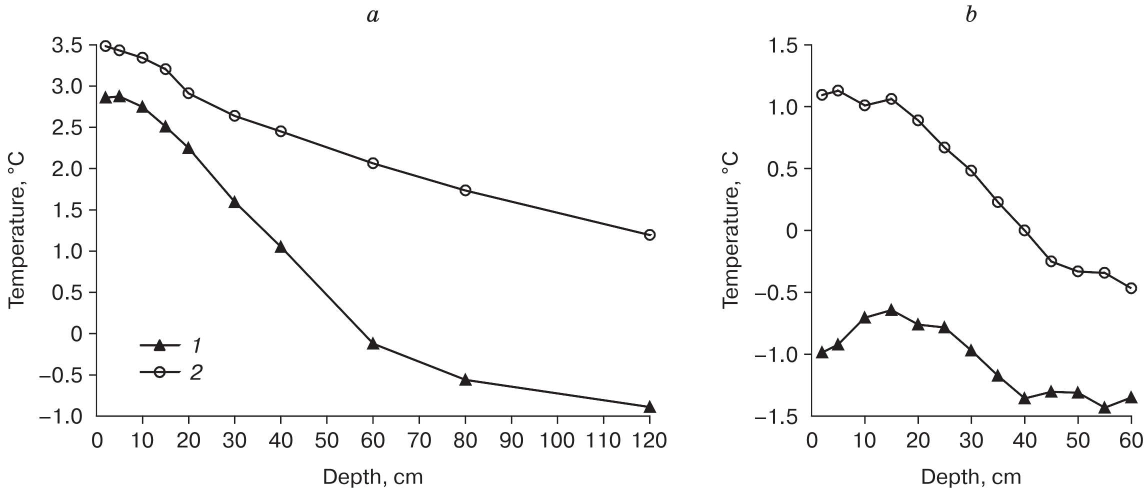

Fig. 2. Mean annual temperature values for peat soils at different depths in collapse scars (*a*) and on palsas (*b*).

1 – forest-tundra; *2* – northern taiga.

ern taiga and –1 °C for the forest-tundra. The MAST fell below 0 °C (from a depth of 40 cm) in the northern taiga, and remained in negative values at all measured depths in the forest tundra. A slight increase in the MAST values at a depth of 30 cm was reported from the palsas, which was most pronounced in the forest tundra (0.4 °C). This was probably caused by the fact that palsas are warmed from the top and on sides, which is not the case with the flattened hollows or inter-palsa lows.

Annual maxima and minima in the temperatures were determined from the mean monthly values of the warmest and coldest months of the year. The mean annual temperature maxima were similar in all ecosystems in the upper half-meter layer: thus, in July they were within 15...18 °C at a depth of 2 cm in all ecosystems (Fig. 3). By comparison with the northern taiga, higher air and soil surface temperatures, were reported from the forest-tundra, where the temperature values for the upper layer of collapse scars reached the highest values, however falling lower from a depth of 25 cm, than in the northern taiga collapse scar. At this, the curves for depth-dependent maximal temperature variations in the palsas were identical for the two climatic zones.

Unlike the temperature maxima, the MAST minima indicate more severe climatic conditions in the forest-tundra ecosystems (compared to the northern taiga) and in palsas (compared to collapse scars). The annual minima of not lower than –3 °C were recorded in February in the collapse scars (depth: 2 cm). Whereas at that same depth in the palsas, the values constituted –8 and –13 °C for the northern taiga and forest-tundra, respectively.

Annual temperature range in peat soils. The annual temperature range in the palsas and surface layer of collapse scars was higher in the forest-tundra, than in the northern taiga. In the topmost 30-centimeter

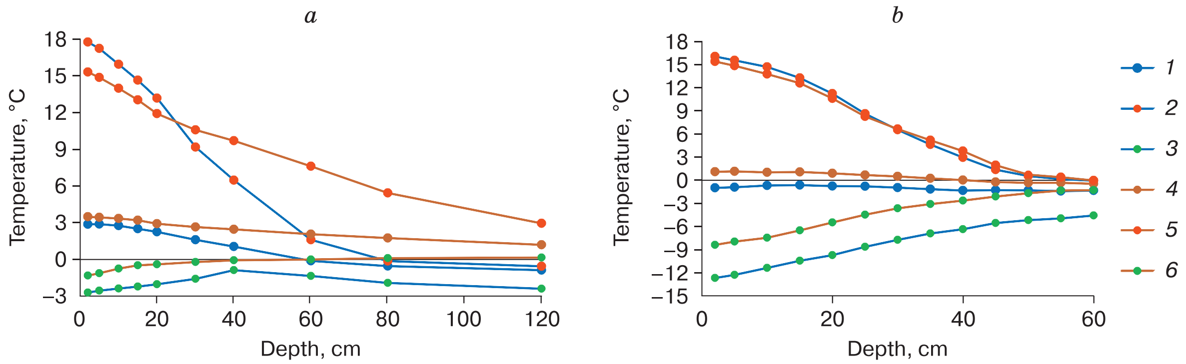

Fig. 3. Soil temperature from the peat profile of collapse scars (*a*) and palsas (*b*):

1 – mean annual for forest-tundra; *2* – mean monthly maximal for forest-tundra; *3* – mean monthly minimal for forest-tundra; *4* – mean annual for northern taiga; *5* – mean monthly maximal for northern taiga; *6* – mean monthly minimal for northern taiga.

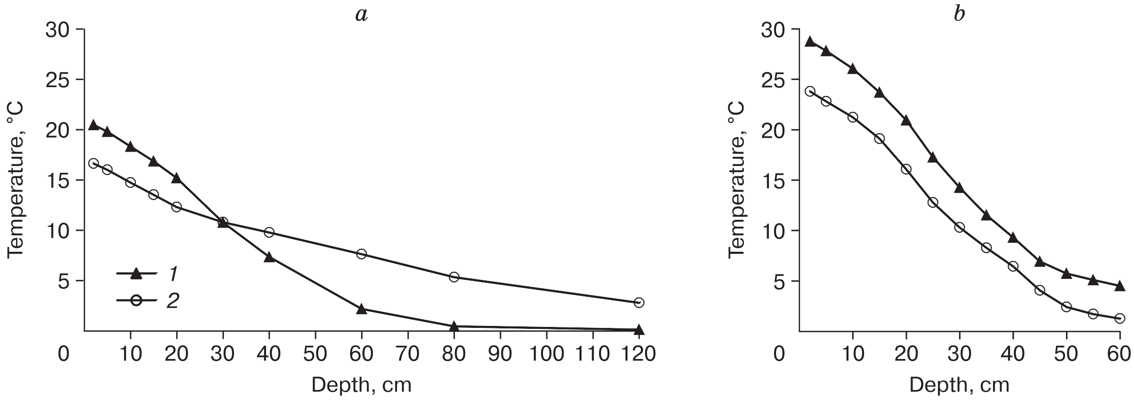

Fig. 4. Annual temperature range in peat soils at different depths in collapse scars (*a*) and on palsas (*b*).

1 – forest-tundra; *2* – northern taiga.

layer of palsas, it was 7–9 °C higher than in the collapse scars (Fig. 4). Inasmuch as the annual air temperature range constituted 48 °C in the forest-tundra and 46 °C in the northern taiga, the temperature range in the surface moss cover of mires (at a depth of 2 cm) showed 1.5–2.5-fold decrease due to the lowered absolute winter temperature values in the moss cover and peat deposits, compared to the near-surface air. According to *V.N. Dimo* [*1972*] the annual temperature range at a depth of 20 cm showed that the

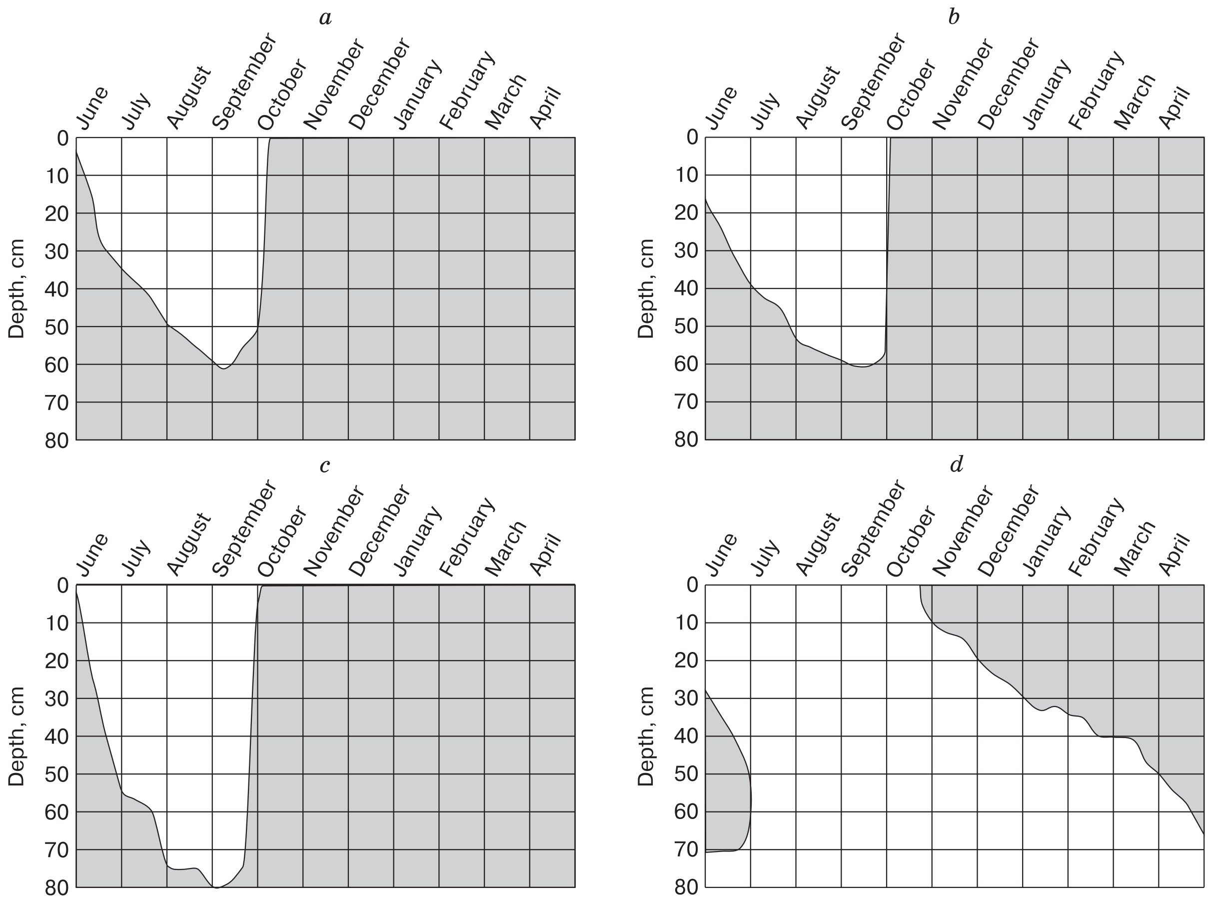

Fig. 5. 0 °C isotherms of soil temperature in different mire ecosystems:

a – forest-tundra, palsa; *b* – northern taiga, palsa; *c* – forest-tundra, collapse scar; *d* – northern taiga, collapse scar.

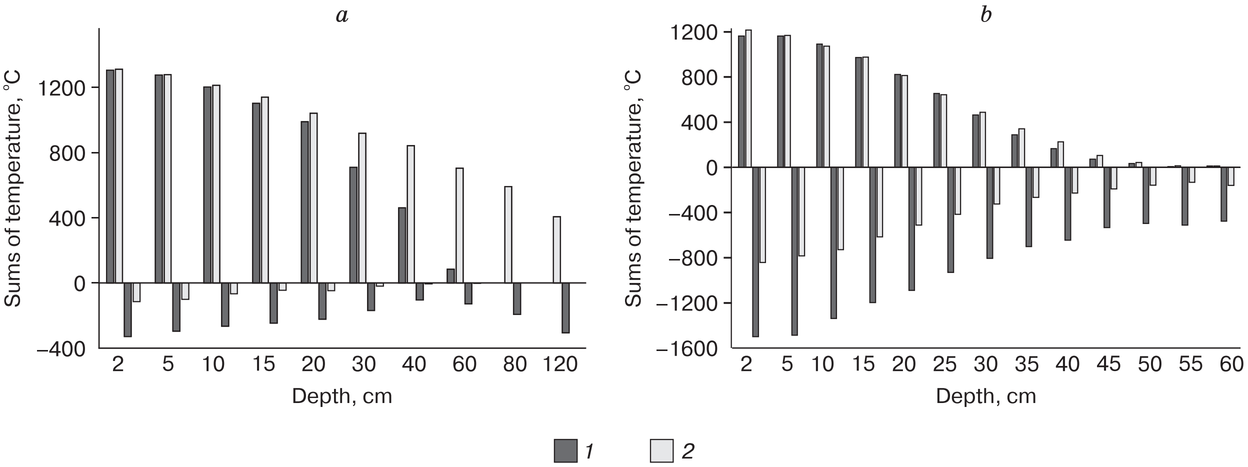

Fig. 6. Sums of positive and negative soil temperatures in collapse scars (*a*) and on palsas (*b*).

1 – forest-tundra; *2* – northern taiga.

degree of continentality of soil climate corresponded either to mild climate (collapse scars) moderate continental climate (palsas).

Active layer dynamics. After winter, the thawing of peat deposit started in May (northern taiga) and in June (forest-tundra). During the summer-time, positive temperatures reached a depth of 60 cm by early September in the palsas of both the studied mires, while thaw radius in the forest tundra collapse scars reached 80 cm by the end of July. The peat deposit of the northern taiga collapse scar was completely free from permafrost by the end of June (Fig. 5).

The autumn freezing of the palsas began in late September, and a week earlier in the forest tundra. It took three days to for the seasonal frost to completely penetrate the entire studied thickness in the forest-tundra palsa, and a week in the collapse scar. In the northern taiga palsa, the freeze-up lasting for a longer period was marked by episodes of thawing of frozen layers, with the seasonal frost set in ultimately in the second decade of October. The freezing of the northern taiga collapse scar commenced almost a month later, than in the palsas and reached a depth of 60 cm only by mid-April, while the peat layer below this depth remained unfrozen throughout the cold period.

Sums of mean diurnal temperatures in peat soils. The growth of mire flora begins at low temperatures, e.g. *Sphagnum* mosses whose photosynthesis process is activated during snowmelt and its growth starts at temperatures above 0 °C [*Asada et al., 2003; Moore et al., 2006*].

The sum of temperatures above 0 °C therefore enables estimation of heat budget of the vegetation cover of mires. In the forest-tundra, sums of positive mean daily air temperatures amounted to 1389 °C, and negative to –3418 °C, which constituted in the northern taiga 1502 and –2779 °C, respectively. The sum of the mean diurnal positive temperatures of peat deposits of palsas, as well in the upper layer (2–20 cm) of collapse scars were found to be close, even though they belong to different bioclimatic zones and their sums of positive air temperatures differ (Fig. 6). The main distinction between the mire types characteristics consisted in more remarkable heat budget of collapse scars, which was tending to increase with depth, unlike in the palsas. The absence/presence of permafrost in the mires made a difference for the sum of the mean diurnal positive temperatures below 30 cm in the northern taiga and forest-tundra. With respect to the sum of negative temperatures, both the types of mire ecosystems and bioclimatic zones differed strikingly.

The ratio of the sum of the mean diurnal soil surface temperatures to the sum of the mean daily air temperatures (*N*-factors) is one of the imperative characteristics of the temperature regime of various biogeocenoses [*Klene et al., 2001; Goncharova et al., 2015*]. The ratio of the sum of the mean diurnal positive to negative temperatures at a depth of 2 cm to the corresponding sums of air temperatures indicates a better heat budget of collapse scars (Table 2). The

Table 2. **A relationship between positive and negative soil temperature sums (at a depth of 2 cm) and the corresponding air temperature sums**

Temperature sums	Bioclimatic zone	Ecosystem	Ratio
Positive	Forest-tundra	Palsa	0.84
		Collapse scar	0.94
	Northern taiga	Palsa	0.81
		Collapse scar	0.87
Negative	Forest-tundra	Palsa	0.44
		Collapse scar	0.10
	Northern taiga	Palsa	0.30
		Collapse scar	0.04

efficiency of the summer heat accumulation by forest-tundra mires was higher than that of the northern taiga.

CONCLUSION

The three factors affecting the differences in STRs of peat deposits in the studied peat plateau mire (palsa) complexes are: their relatedness to different mire ecosystems, to bioclimatic zones, and the presence/absence of permafrost.

Given similar climatic conditions, the factor differentiating between ecosystems (collapse scars or palsas) consists in the nature of their waterlogging [*Ospennikov, 2001*]. In collapse scars, both the vegetation and peat are immersed in the water table and thermal conductivity of the active layer is close to the thermal conductivity of water or ice, which is evidenced by: the existence of a "zero curtain" (where soil temperature persists near 0 °C) during the winter period; higher mean annual temperatures throughout the profile; lower annual temperature ranges in the active layer; greater thaw depth of the seasonally frozen layer; to some extent larger sums of mean diurnal positive temperatures and much lower absolute values of the sums of negative temperatures.

Contrariwise, despite the peat of palsas is saturated with water, the amount of free gravitational water is minor; the thermal properties of the active layer are determined by thermal conductivity of the moss-peat layer, which prompts essential freezing of the upper layers of mires (acrotelm) during the winter, lower mean annual temperature values, a larger scale of annual ranges, lesser depth and speed of thawing of the active layer, and, lastly, significant absolute mean diurnal negative temperatures. The differences in temperature regimes of palsas and collapse scars might also result from the redistribution of snow between these ecosystems [*Bobrik et al., 2015*].

The mires falling into different bioclimatic zones did not affect such parameters as mean temperatures of the warmest month (in palsas) and the sums of positive temperatures in the 2–20 cm layer in collapse scars and palsas. Distinctions between the similar types of ecosystems by latitude were primarily manifested in differing temperature characteristics of the cold period.

These include: by comparison with the northern taiga, lower mean diurnal and minimal mean monthly temperatures and significantly higher absolute sums of negative mean diurnal temperatures, large annual temperature range in the active layer, a shorter period of seasonal thawing were observed in the forest-tundra mires. Distinctions in annual mean values between identical type ecosystems (forest-tundra and northern taiga) were caused by differences in temperatures of the cold period of the year.

The absence of permafrost in the northern taiga collapse scar affected the temperature parameters in the layer below 60 cm, which is evidenced by: the mean annual temperature remaining positive along the entire profile here; the sum of the mean diurnal positive temperatures decreasing with depth smoothly, whose values; never reached 0 °C or close values; the seasonally frozen layer thawing quickly in the spring and propagated downward extremely slowly throughout the cold period.

The obtained data on the mean annual temperature (depth: 20 cm) and the dynamics of seasonal frost and permafrost showed that peat soils of palsas are ranked as very cold permafrost (forest-tundra), cold permafrost (northern taiga palsa and forest-tundra collapse scar) and long-term seasonally freezing (northern taiga collapse scar) [*Dimo, 1972*].

Collapse scars are generally characterized by milder conditions which enable the activity of biota of peat deposits. Distinctions between STRs of palsas and collapse scars resulted primarily from their relatedness to different ecosystems, while the difference in bioclimatic zones was most manifest during the cold period of the year; the absence of permafrost in the northern taiga collapse scar was most manifest in higher (always positive) temperature values in the layer below 60 cm. The difference in STRs of palsas and collapse scars might be liable for the difference in the composition of phytocenoses [*Kosykh et al., 2008*], and also in the biotic cycle speed in the studied mires.

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