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Acting of shallow tundra lakes on thickness of active layer in Oscar II Land, Spitsbergen

ABSTRACT: During summer seasons of 1982 and 1985 the authors collected observations on rate of soil thawing under and around shallow tundra lakes. Two lakes were studied: A on the terrace 10 m a.s.l. in northern Kaffiöyra whereas B at about 40 m a.s.l. in southern margin of Sarsöyra. The lakes indicated considerable variation of water lavels (10—20 m) caused by limited water bodies (to 40—80%) at the end of the observation period. Soil thawing was studied in sections across lake basins and to 20 m around them. A thawing rate was found greater under the lakes than in their surroundings and it was noted to be in the same time the quicker the larger was the lake. Studies of the lake B proved also that increase in the reservoir depth made a greater rate and depth of summer thawing. This process varied also considerably in time. At the beginning of a polar summer the dry soil of elevated tundra thaws sooner while permafrost under water reservoirs gets conserved. Later on (in August) a quick aggradation of active layer in noted under the lake. A heat accumulated in water bodies prolongs the soil thawing as well.

Key words: Arctic, Spitsbergen, depth of soil thawing.

Introduction

During two successive Toruń polar expeditions to Oscar II Land (north-western Spitsbergen) in 1982 and 1985, the authors collected observations of depths and rates of soil thawing under and around tundra lakes located at different altitudes (Fig. 1). The lake A (1700 m^2) is located in northern Kaffiöyra at 10.2 m a.s.l. whereas the lake B (6700 m^2) — in southern Sarsöyra on a high terrace at about 40 m a.s.l. Both lake basins form small depressions amidst ancient storm ridges, permanently filled with meltwaters and permafrost waters. Considerable variations of water levels (10—20 cm and occasionally more) were noted in these lakes. At the end of summer seasons they resulted

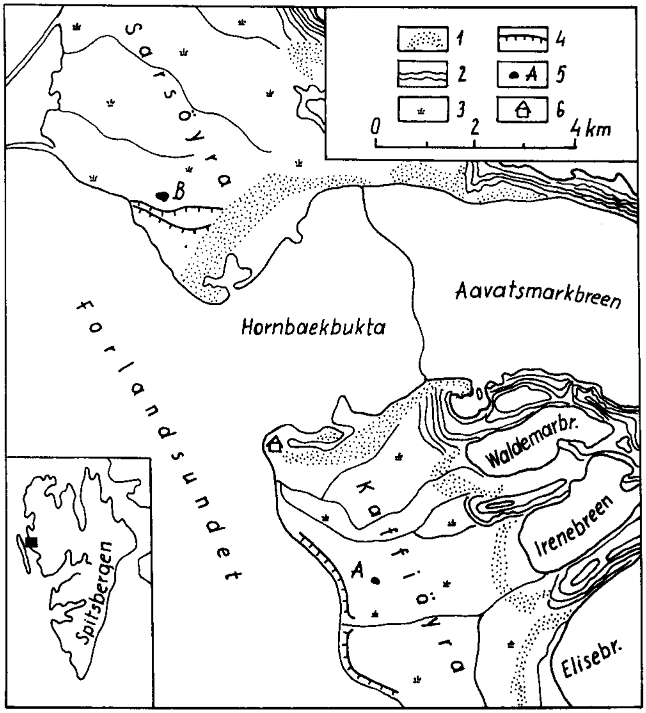

Fig. 1. Location of observation sites: 1 — end moraines, 2 — mountains, 3 — tundra, 4 — cliffs, 5 — sudied lakes, 6 — base of the Toruń polar expeditions

from considerably (40—80%) smaller water bodies. Different altitudes of these lakes are due to varying uplifting of western Spitsbergen (Klimaszewski 1960). Investigations, some results of which are presented below, have been carried through to find probable depenecies between rate and depth of soil thawing, and degre of water content in sediments expressed in exterme cases by occurence of surface waters.

The phenomenon od influence of soil water content on a thawing rate is not a new problem in literature. There is a well-know opinion that an increased water content in soil results in their higher thermic conductivity and therefore, in quicker thawing (Kossowski and Sikora 1978, Monteith 1977). Numerous information on depth of soil thawing and connections of this process with lithology, vegetation and thickness of snow cover are enclosed in papers of Stäblein (1970), McRoberts (1975), Washburn (1979), Jahn and Walker (1933). No detailed data are available however on soil thawing under water reservoirs.

Polish investigations of soil thawing were mainly carried through in the Hornsund region of Spitsbergen (Czeppe 1960, 1961, 1966; Baranowski 1968; Jahn 1961, 1982; Grześ and Babiński 1979). Since 1977 members of the Toruń polar expeditions have studied thawing of permafrost in Kaffiöyra and Sarsöyra (Oscar II Land). Such investigations dealt with varying depth of thawing as well as rate of aggradation of active layer and its spatial changeability due to lithology and thermics (Marciniak *et al.* 1981), Marciniak and Szczepanik 1983. Grześ (1985) presented a spatial variation of active layer thickness along the western seashore of Spitsbergen, thogether with a scheme of thawing and analysis of aggradation rate of the active layer, dependent on type of substrate („environment"). He accepted the beginning of June for the starting point of this process.

Observations during field works by the Toruń polar expeditions proved that active layer thickness reached its maximum at the end of August: 101.2 cm in a land covered by tundra, about 116 cm in vegetation-barren outwash and very wet areas (Marciniak and Szczepanik 1983). A particular attentation was paid to influence of climate, lithology composition, structure of soils and vegetation. Water content and occurence of surface water reservoirs have not been however taken into account.

The authors investigated this problem in areas with varying water contents: under and around water reservoirs (Pietrucień and Skowron 1987).

Analysis of results

Investigations were carried through in Kaffiöyra and Sarsöyra during two summer seasons (1982 and 1985) in the same measuring sections. Observations were done at very two weeks with application of the hammer method, using a steel rod and with the accuracy of 1 cm. Thickness of the active layer was measured three times and a mean was calculated. Working times of the expeditions (usually July and August) limited the observation period. The thawing starts already in June but on different days (Troitsky *et al.* 1975). Last measuments were done at the turn of August and September. Received results suggest that in time a thawing stopped and even a renewed aggradation of permafrost occured. Therefore, the greatest thickness of active layer seems to have been measured for every season. It creates also the basins for evaluation of varying rate of soil thawing, dependent on water content, lithology and vegetation.

The lake A is a typical, shallow and small tundra reservoir (Table 1). The lake B is considerably larger and deeper (Fig. 2).

Table 1

Main morphographic parameters of studied lakes

Lake	Area in m^2	Volume in m^3	Depth in m	
			maximum	mean
A	1737.5	239.3	0.26	0.14
B	6766.5	2816.0	0.92	0.42

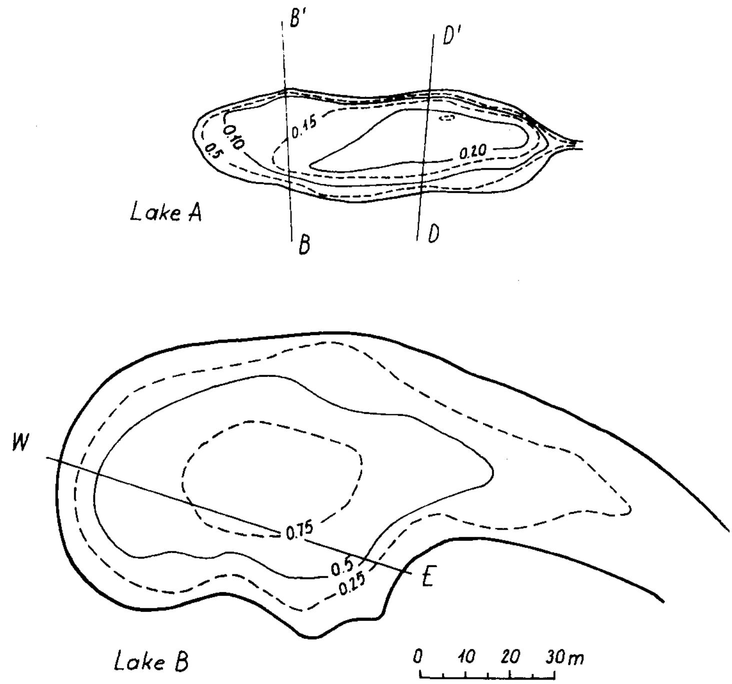

Fig. 2. Bathymetric plans of studied lakes with measurement sections: A — lake in Kaffiöyra, B — lake in Sarsöyra; lake depth in m

First observations of soil thawing under water reservoirs were done in 1982. They were carried through in and around lake A (Figs. 3 and 4). Although the data consider the end of the observation period, an influence of lake body on depth of thawing can be easily noted. On August 21, 1982, the active layer under the lake was distinctly thinner than in the nearest surroundings. A completely different situation occurred on September 6, 1982. Under the lake a further and distinct progress of thawing was noted, accompanied by aggradation of permafrost in the adjacent area. It is worth mentioning here that first snowfalls and air temperature drop below 0°C occurred already in the last decade of August 1982. Heat in lake water therefore considerably prolongs a thawing of permafrost. A spatial variation of active layer thickness around the studied lake looks quite interesting (Fig. 4) against the above remarks. On August 21, 1982, a thickness of active layer increased with a larger distance from the lake, reaching over 100 cm in a dry mossy tundra to the east (Fig. 4A). Largest thawing depths occurred in the central part of the lake (below 70 cm).

Measurements on September 6, 1982, proved quite a different situation (Fig. 4B). The active layer reached over 110 cm under the lake while decreased around it to 70—80 cm.

Results of 1982 encouraged the authors to undertake similar investigations in 1985 when they studied also another reservoir, the lake B, located on

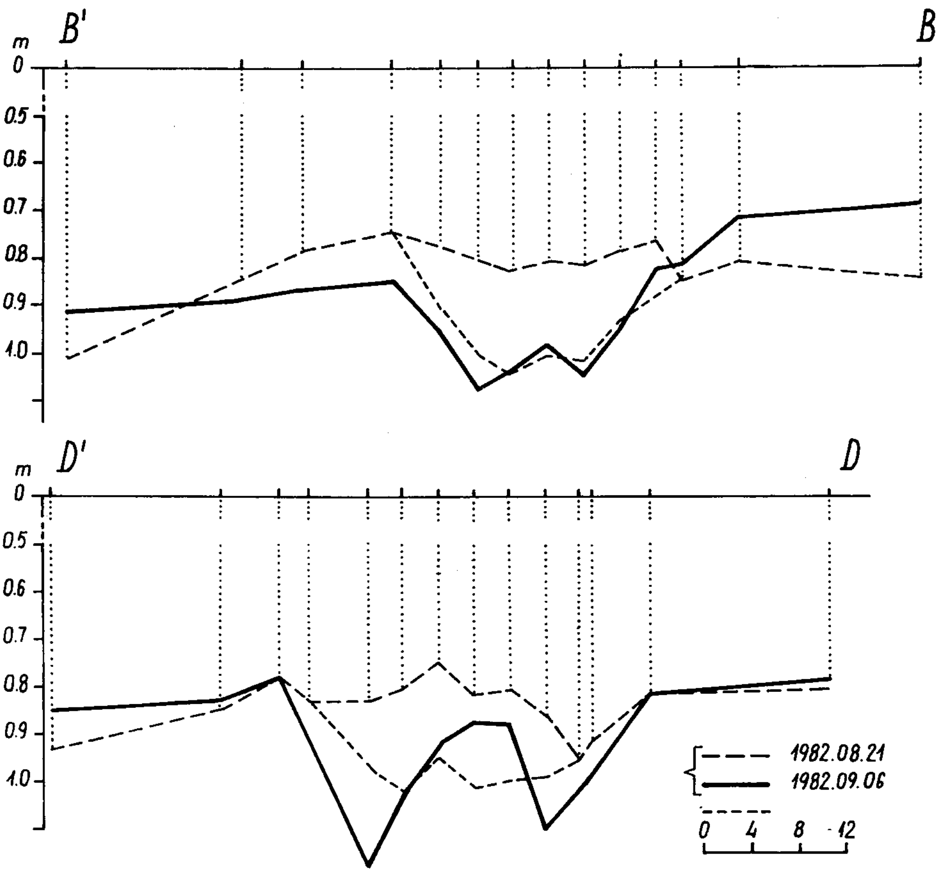

Fig. 3. Sections of soil thawing depths under and around the lake A in 1982 (*cf.* Fig. 2): 1 — thickness of active layer on presented days, 2 — depth of lake water

a raised marine beach in southern Sarsöyra. The water body of this lake is almost 12 times larger than the one of the lake A. This lake was chosen due to a possible comparison of water body action on depth and rate of soil thawing if referred to a size of the reservoir.

This idea supported a presentation of two sections running across the lakes A and B (Fig. 5). They indicate a soil thawing at the beginning of observations and at a maximum thickness of the active layer. There are similar relations in every case but of varying intensity of soil thawing was greater around than under the lakes on June 3, 1985. A spatial image of this phenomenon is presented (Fig. 6). The difference in soil thawing was equal to 32 cm only around and under the lake A but over 70 cm if the lake B is considered.

After a lapse of time when the lake water got warmer, a quick aggradation of the active layer occurred under the lakes. At the end of summer a total thickness of the active layer as well as differences of first and last measurement values were the largest. This problem is connected with varying rates of

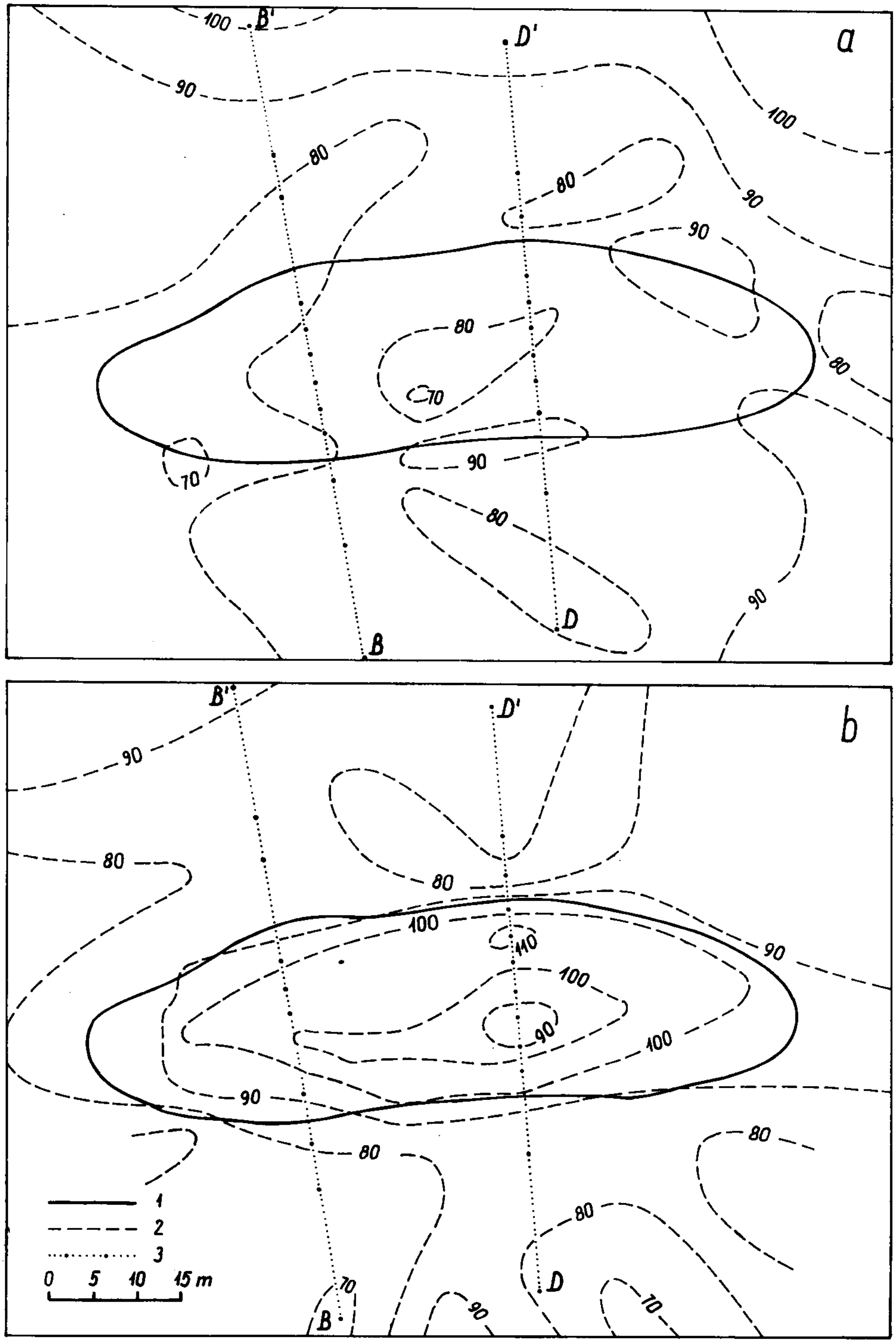

Fig. 4. Spatial variation of active layer under and around the lake A in 1982 on: a — August 21, b — September 6; 1 — shoreline, 2 — thickness of active layer in cm, 3 — measurement sections (*cf.* Fig. 2)

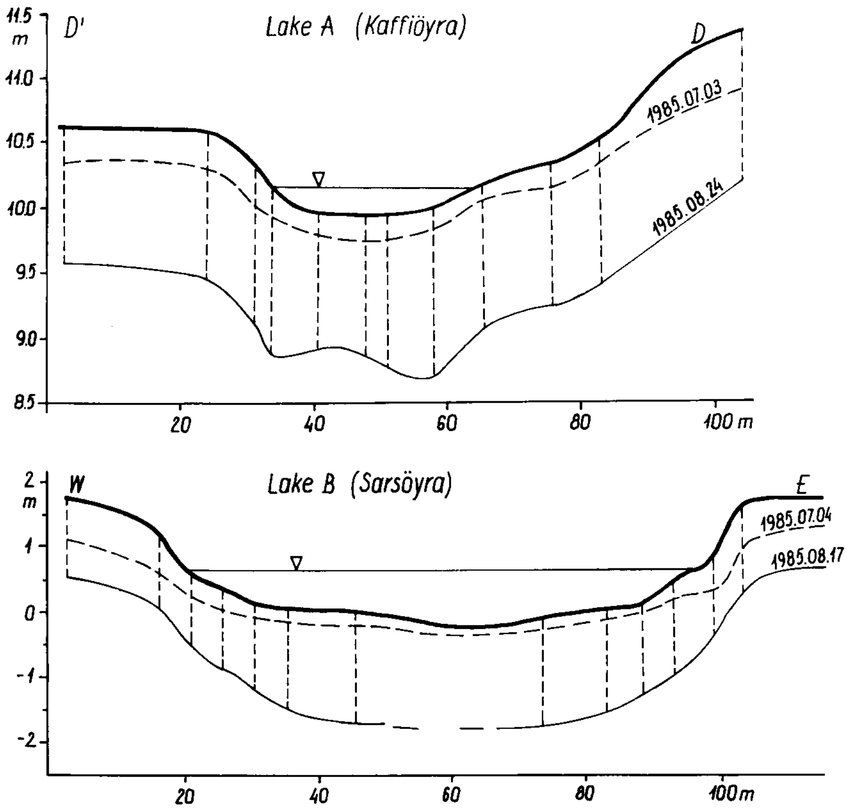

Fig. 5. Depth of soil thawing under and around the lakes A and B on presented days (*cf.* Fig. 2)

thawing of permafrost (Table 2). The aggradation of the active layer is varied in time and in space. It was the largest in July, particularly during its first half, and considerably smaller in August when the process gradually ceased. A spatial variation is best presented by mean values for the whole research period. It should be underlined that the largest rates occurred at a lake shoreline. Still a larger variation of soil thawing was noted around the lake B.

Table 2

Mean rate of soil thawing (in cm a day) under and around tundra lake *A* in Kaffiöyra in summer 1985 along the section west-east (*cf.* Fig. 2)

Period	W Distance from shore in m E								
	+20	+5	0,0	−5	−10	−5	0,0	+5	+20
07.03—07.16	2.4	2.5	2.4	2.7	2.9	3.3	3.3	2.7	2.5
07.16—07.29	2.2	2.6	2.7	2.6	2.7	3.1	3.0	2.8	2.5
07.30—08.34	0.7	0.8	0.9	0.8	0.8	0.9	0.8	0.7	0.6
07.03—08.24	1.5	1.7	1.8	1.6	1.6	2.0	1.9	1.7	1.6

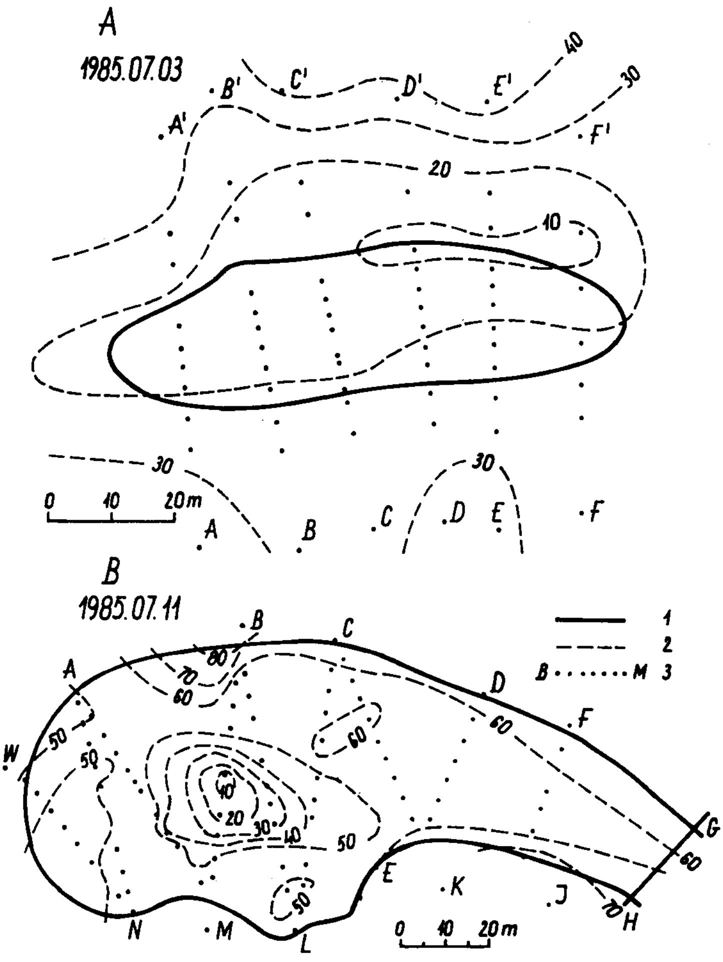

Fig. 6. Spatial variation of active layer thickness under and around the lakes A and B: 1 — shoreline, 2 — thickness of active layer in cm, 3 — measurement sections

A size of the reservoir is reflected either in development rate or in thickness of the active layer (Fig. 5). Differences in depths of soil thawing between July 4 and August 17, 1985, under this lake are particularly large and in extreme cases exceed three times the aggradation of the active layer in the surraoundings. Absolute values of the thawing depth are also very large, many a time over 150 cm. Such values were not noted for a substrate of the lake A.

A volume of the water body on thawing is illustrated by comparing the thawing rates of permafrost for both described lakes (Table 3). They are considerably larger for the lake B and also their distribution is more veried. The highest values were noted under this lake, to 3.6 cm a day, and only slightly over 1 cm a day in the surroundings. The rate of soil thawing near the

Table 3
Mean rate of soil thawing (in cm a day) under and around tundra lakes *A* and *B* in summer 1985 along the section W—E (*cf.* Fig. 2)

Lake (period)	W				Distance from shore in m							E
	+20	+5	0,0	−5	−10	−15	−15	−10	−5	0,0	+5	+20
A (07.03—08.24)	1.6	1.7	1.7	1.8	1.9	—	—	2.0	1.9	1.9	1.8	1.6
B (07.04—08.17)	1.27	1.25	2.0	2.09	2.64	3.59	3.11	2.77	2.43	1.54	1.95	1.16

lake A is distincly smaller, with mean values to 2 cm a day, and is also less varied, from 1.6 to 2.0 cm a day.

All these observations oncouraged to compare the rate of agradation of the active layer thickness under water reservoirs and in the adjacent tundra with mean air temperatures in the meantime of succesive measurements. Such comparison was possible for the lake A (Table 4). The rate of soil thawing correlates there (if the initial phase of thawing is excluded) with varying mean air temperatures noted between the measurements.

Table 4
Mean rate of aggradation of active layer for various types of substrate near the lake *A* in summer 1985

Observation period	Mean air temperature during the period	Dry mossy tundra	Lake substrate
07.03—07.16	5.4°C	2.4 cm	3.3 cm
07.16—07.29	8.2°C	2.1 cm	2.8 cm
07.29—08.10	5.6°C	1.2 cm	1.1 cm
08.10—08.24	4.4°C	0.4 cm	0.7 cm
07.03—08.24	5.9°C	1.6 cm	1.8 cm

Conclusions

Observations and results made the authors draw the following conclusions:

— studies of 1982 and 1985 of marine terraces of Kaffiöyra and Sarsöyra confirmed influence of soil water content on depth and rate of thawing what is especially distinct around tundra lakes,

— influence of surface water on thawing of permafrost depends on size of reservoirs and heat accumulated in a water body,

— at initial thawing (June, first days of July) cool surface water conserve permafrost and slow down its thawing,

— the greatest thawing ocours in July when water and air temperatures reach their maxima,

— mean aggradation of active layer corresponds with mean air temperatures,

— mean thawing of permafrost under water reservoir and in wetter areas is quicker than in adjacent areas,

— the active layer is also the thickness under water reservoirs.

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Streszczenie

W okresie 2 sezonów (lipiec—sierpień) badawczych w latach 1982 i 1985, autorzy przeprowadzili obserwacje tempa rozmarzania gruntu pod i w otoczeniu płytkich jezior tundrowych. Badaniami objęto 2 jeziora (fig. 1), z których jedno (A) położone jest na 10 m trasie morskiej w północnej części Kaffiöyry, natomiast drugie (B) ok. 40 m n.p.m. na południowym skraju Sarsöyry (tab. 1). W jeziorach obserwowano znaczne zmiany poziomu wody (10—20 cm), które powodowały pod koniec okresu badań zmniejszenie ich pojemności o 40—80%. Obserwacje głębokości rozmarzania gruntu prowadzono w profilach przebiegających przez niecki jeziorne i obejmujących teren przyległy do 20 m od linii brzegowej (fig. 2 i 6).

W trakcie badań stwierdzono m.in., że tempo rozmarzania gruntu pod zbiornikami wodnymi jest większe niż w ich otoczeniu (fig. 3, tab. 2) a szybkość rozmarzania jest tym większa im większy jest zbiornik wodny (tab. 3). Z obserwacji jeziorka B można sądzić, że wzrost głębokości zbiornika zwiększa tempo i głębokość letniego rozmarzania (fig. 5). Proces ten wykazuje jednak wyraźną zmienność czasową. Na początku lata polarnego rozmarza prędzej suchy grunt wyniesionych fragmentów tundry, „konserwuje" się zaś zmarzlina pod zbiornikami wodnymi (tab. 4). W drugiej części sezonu (sierpień) następuje szybki przyrost warstwy czynnej (odmarzniętej) pod jeziorkami (fig. 3 i 4). Zgromadzone w nich ciepło przedłuża także proces rozmarzania gruntu.