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SEASONAL THAWING OF A PALSA AT ENONTEKIÖ, FINNISH LAPLAND, IN 1974

Abstract

During the study measurements were taken to determine the thickness of the thawed layer of the palsa during the thaw period in 1974. The air temperature on the surface of the palsa was recorded continuously throughout the study. Melting was at its strongest in June—July and on the southern slope of the palsa. Those parts of the palsa where cracks had formed in the peat melted at the same rate as parts free of cracks. A rise in the surface of the frost layer occurs sporadically.

INTRODUCTION

Only seldom has it been possible to carry out longterm observations of the in, ternal temperature of palsas (*e.g.* FORSGREN, 1964: LINDQVIST & MATTSSON, 1965)- i.e. peat hummocks with a perennial ice core (*e.g.* SEPPÄLÄ, 1972). Each winter measurements are taken in conjuction with weather observations to trace the development of seasonal freeze and thaw but these are carried out principally in mineral soils. From what we know at present permafrost occurs in Finland only in palsas but no regular observations have been made of the frost in them.

The purpose of this study was to determine the speed of melting of the active layer in the course of a single thaw period in 1974, its depth and the effect of the weather on melting. A rather small palsa (max. height 3.2 m) almost completely covered with vegetation near the village of Nunnanen (68°24′N, 24°36′E, approx. 320 m above sea level) at Enontekiö was chosen for the study (Fig. 1, Pl. 1). Here the mean annual temperature is about —1° C, annual precipitation approx. 400 mm and the length of the termic winter (0°...0°) about 200 days (KOLKKI, 1959; Atlas of Finland, 1960; SEPPÄLÄ, 1966).

The palsa lies close to the northern limit of the boreal vegetation zone and in the southern part of the area which palsas are encountered (OHLSON, 1964: fig. 41).

METHODS OF STUDY AND MEASURING INSTRUMENTS

Measurements of the rate of melting of the ice core and air temperature were carried out from June 13 to November 2, 1974. Throughout the whole period a

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self-recording thermo-hydrograph (type Wilh. Lambrecht KG No 252c; Pl. 2) was sited on the surface of the palsa. On top of the instrument was placed a piece of aluminium sheeting 40×50 cm to protect it from rain and strong sunshine. From July 8 to August 2 the graph of the recorder was faulty and did not draw well. Con-

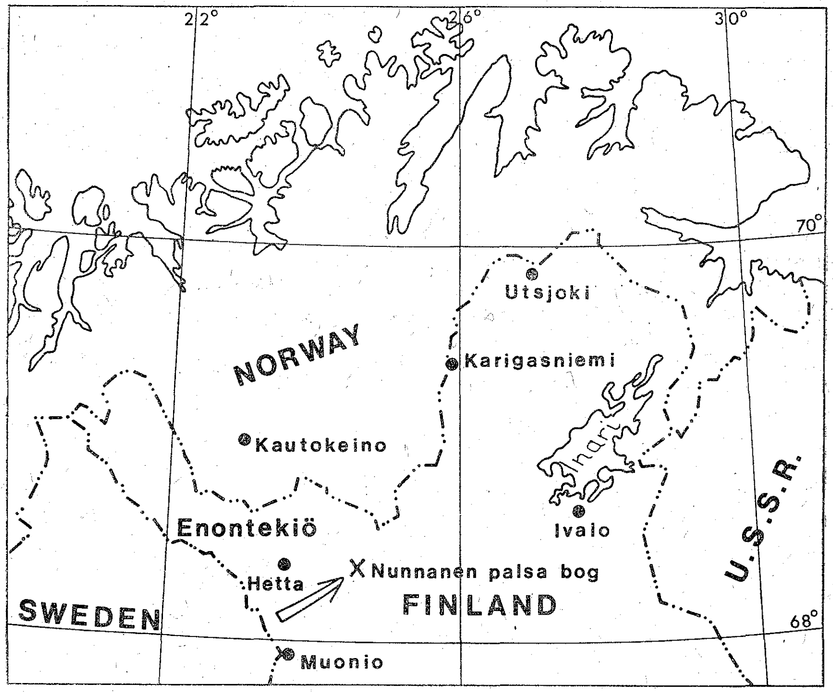

Fig. 1. General location of the region studied, Nunnanen

sequently, only daytime readings of that period could be used for the diagram in Fig. 3 (08, 14 and 20 hours): these were taken at a meteorological station (Kalmankaltio) some 8 km north of the Nunnanen palsa bog.

Cumulative temperatures for five-day periods were calculated from the temperature recordings (Fig. 4) by adding together the temperatures recorded every third hour (0, 03, 06 hours, etc.). Every pentad therefore comprises 40 temperature readings (Fig. 4).

The precipitation figures (Fig. 3) used were taken at the same meteorological station, Kalmankaltio, from June to August and at another station, Pulju, about 20 km SSE of the studied palsa.

A probe (length 147 cm) was inserted vertically into the melted peat layer to determine the position of the frost layer and a thermometer (Wallac-Thermex GS2) used to take the temperature of the surface of the frost layer (Pl. 3, Fig. 2). For technical reasons the type of probe used gave a reading +1°C for the surface of the frost layer at freezing point (Fig. 2). The surface of the palsa was levelled in N—S direction. Measurements of the thawing layer were taken at points lying along the levelling profile (Fig. 2).

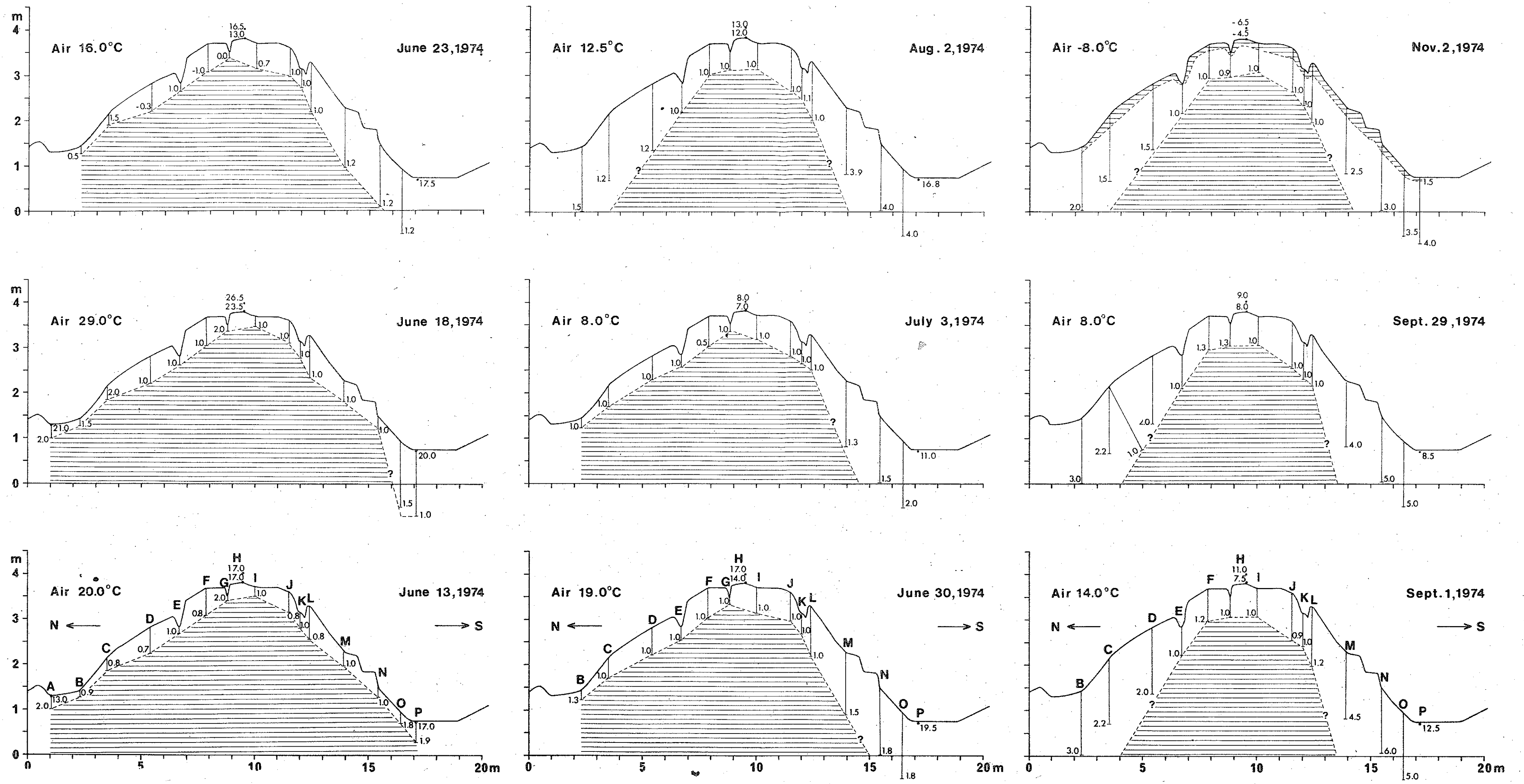

Fig. 2. Results of nine measurements taken of the frost layer of the Nunnanen palsa

Air temperatures are those taken with the aid of the recording thermometer on the surface of the palsa during the other observations. A, B, C...P are the measuring points. At point H measurements were taken both on the surface of the palsa an 20 cm above the surface in the air. The figures beside the measuring points are the temperatures, in °C, obtained with the probe. The vertical scale is twice the longitudinal scale. The hatched area indicates frozen parts of the palsa

OBSERVATIONS OF THAWING

The core of the palsa consisted of frozen peat, with ice occurring as small crystals in the peat. Thin layers of ice have also been recorded in many of the palsas in the Enontekiö region (*e. g.* SALMI, 1972).

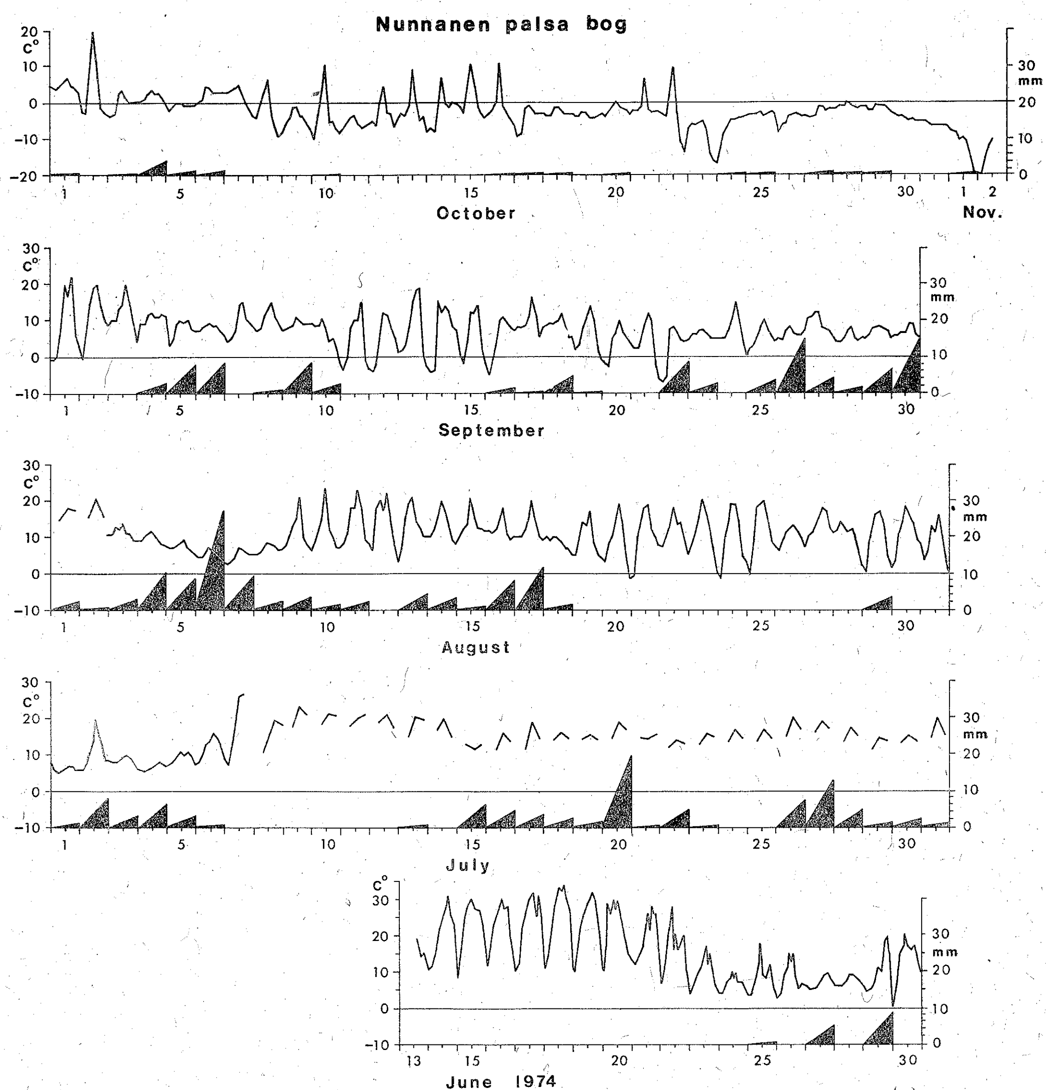

Fig. 3. Air temperature curve measured with thermo-hydrograph on the palsa (Pl. 2)
For records of July 8 to August 2 see text. Height of black triangles show the degree of precipitation in mm (scale on the right) and width of triangles duration of precipitation

The palsa had begun to melt some weeks before the study was begun. The summits of palsas are, of course, the first parts of palsa bogs to become free of snow; this often occurs as early as March (*cf.* LINDQVIST & MATTSSON, 1965). By the beginning of June 1974 the snow had melted entirely in the area.

On June 13, 1974, when measurements were first taken, the depth of the melted layer, measured vertically from the surface of the palsa, was less than 60 cm over the whole of the palsa. The melted layer was deepest on the upper slopes of the palsa, on the N and S sides (points D, F, J and L in Fig. 2). At the foot of the slopes of the palsa melting had just begun and the thickness of the melted peat layer was only some tens of cms (points A, B, C, N, and O in Fig. 2) and in cracks the situation was almost the same when measurements were taken from the bottoms of the cracks (points E, G and K in Fig. 2 and 4).

The following five days were marked by extremely warm weather (Figs. 3 and 4), and when measurements were again taken on June 18, it was noted that considerable melting of the frozen layer had occurred, especially on the lower parts of the southern slope. So strong was melting, in fact, that at the foot of the southern slope no ice at all was encountered. On the other hand, however, the high air temperature had not caused any great change in the summit of the palsa or on its northern slope (Fig. 2). There was still a layer of ice in pools of water around the base of the palsa on June 18. On the southern side of the palsa there was an open pool of water at the foot, the result of a thermokarst. Into this pool peat from the slope of the palsa had fallen. On the northern side open water was found on only the first two occasions when measurements were taken. Later this dried up entirely.

By June 23 melting had advanced considerably on the southern slope and on the summit of the palsa, too, (point I in Figs. 2 and 4) melting had progressed rapidly. It should be noticed that, subsequently, melting at this point on the summit of the palsa advanced only a further 8 cm in the course of the whole melting period.

From the beginning of the study up to this time there had been no rainfall whatsoever (Fig. 3). Melting was therefore purely the result of the air temperature and sunshine. The surface of the peat at this time was quite dry.

On June 25, 27 and 29, 13.9 mm of rain fell altogether (Fig. 3) and this seemed to have an effect on the northern slope in particular. Melting accelerated up to June 30 even though the temperature sum remained rather low (Figs. 2 and 4). One reason for this is perhaps that the heat conduction of wet peat is considerably better than that on dry peat. In cracks (points E, G and K in Figs. 2 and 4) melting progressed rapidly during this time. It became clear for the first time on June 30, the fourth occasion measurements were taken, that the surface of the frost layer may rise in the summer (*cf.* MACKAY, 1974). Above the frozen core of the palsa the peat had refrozen at point I (Fig. 4). During the period that followed (June 30—July 3) a rise in the surface level of the frost layer occurred at a number of points (D, E, G, I and L in Figs. 2 and 4). The reason is that the temperature of the core of the palsa remains below freezing throughout the year (*cf.* LINDQVIST & MATTSSON, 1965). On the other hand, an increase in melting was noted at point J where it progressed 15 cm in a vertical direction (Figs. 2 and 4).

The high day temperatures experienced in July (15—20° C) together with considerable rain (Fig. 3) caused an even melting of the palsa so that the asymmetrical shape of the core surface became substantially more regular (Fig. 2). On the southern slope, in fact, the temperature of the peat rose 2—2.5° C higher than at corresponding depths on the northern slope.

Between August 9 and 25 there was a rather warm period (Fig. 3) but this did not have any great effect on the core of the palsa. The reason may be that the insulating layer of peat was already so thick that higher temperatures would have been needed to raise the temperature inside the peat to a level where melting could continue. Melting was greatest at point J in August (Fig. 4), here the surface of the frost surface fell by 10.5 cm. An open crack nearby may have contributed to melting by affecting it from the side (Fig. 2).

During September melting was very slow except at point E (Fig. 2), which lies on the northern slope in a crack. Here the surface of the frost layer dropped a further 10 cm between September 1 and 29. The temperature sums for pentads in September were below 400° C (Fig. 4). On nine nights in September the temperature fell below freezing (on Sept. 22 to — 7° C).

October 5 was the first day on which the diurnal temperature did not rise above 0° C (Fig. 3). Daytime temperatures were with a few exceptions less than +10° C. Precipitation during this period was also small. The temperature sums of pentads from October 7 onwards were negative (Fig. 4). Nonetheless, melting continued in the palsa at points F, G, I and L (Figs. 2 and 4) because of conserved warmth in the peat layers. Elsewhere the surface of the frost layer began to rise.

On November 2 when the last measurements were taken there was about 5 cm of snow on the ground (Pls. 1 and 2) and the previous night the temperature had fallen to —20° C (Fig. 3). The surface of the peat bog had begun to freeze once more, and in places the frozen layer was as much as 10 cm thick (Fig. 2).

CONCLUSION

The seasonal melting of palsa is strongly asymmetrical, the southern slope melting more quickly than the northern slope.

The thawing of the frost layer in early summer is strongest on the top of the palsa and then continues in the slopes of the palsa but melting of the actual summit is in fact smallest. The reason for this is quite clearly that the summit of the palsa is the first part to become completely free of snow. However, the effect of the sun's radiation is not so strong later on the summit as on the slopes since the rays strike the summit at a rather low angle. Warmth penetrates into the palsas from the surrounding wet layers of peat on the sides of the palsa. The part played by ground water in melting the palsa is clearly not very great (*cf.* Forsgren, 1966).

In Salmi's (1970) cross-sections of palsas in Finnish Lapland the melted layers had obviously not been studied after the end of the melting season (the time is not mentioned). The fact that pure ice was found on the side of the palsa supports this assumption (SALMI, 1970: Figs. 2 and 8). In late September the ice would have already melted so that it would be a seasonal phenomenon. The shape of the surface of the frozen core differs considerably from that encountered in this study.

In cracks on the surface of the palsa melting of the frost layer advances in the same way as in parts where there are no cracks. In other words, the accumulation of air in the cracks, which is in shadow, acts as efficient an insulator as do the layers of peat at other parts of the palsa. The depth of the surface of the frost layer beneath cracks does not differ from that lying under layers of peat (Fig. 2).

Melting in cracks may be slowed down during sunny period since the cracks are narrow. On the other hand, rain accelerates melting in cracks and on the northern slope of the palsa.

After the end of July melting is slow. Cumulative temperature sums of over 400° C per pentad are normally required for melting to progress more deeply. These figures correspond to average diurnal temperatures of +10°C.

The polygonal crack patterns encountered in the surface of the palsa may result from the fact that between the perennially frozen core and the layer subject to seasonal refreezing there are tensional stresses which cause frost cracking (*cf.* SVENSSON, 1963; WRAMNER, 1973, p. 98-99). The cracks do not go any deeper than seasonal thawing layer. Widening of the cracks is obviously connected with the rise of the palsa, or its growth.

In mild winters with much snow the layer between the frozen core of the palsa and the seasonally frozen surface may well remain unfrozen on the slopes of the palsa throughout the whole of the cold season. SALMI (1970: Fig. 4) has found water inclusions inside palsas in the spring.

Wide tensional cracks on the slopes of the palsa seem to be sited in such a way that, at the end of the melting period, the edge of the frozen core of the palsa slopes steeply (points E and K in Fig. 2) and may act as a slide face for the peat, thus causing a widening of the cracks. On the southern slope of the palsa falling peat had caused the formation of shelf-like protrusions below a wide crack (points M and N in Fig. 2). The northern slope is more gentle than the southern slope as melting on the northern side is slower.

When measuring the thickness of the active layers of palsas the measuring point should be chosen on the summit of the palsa where there is vegetation cover. Then the results achieved in different regions will be very similar and can be compared. The melting values for the summit points reflect best the characteristic features of the melting season and changes in conditions from year to year.

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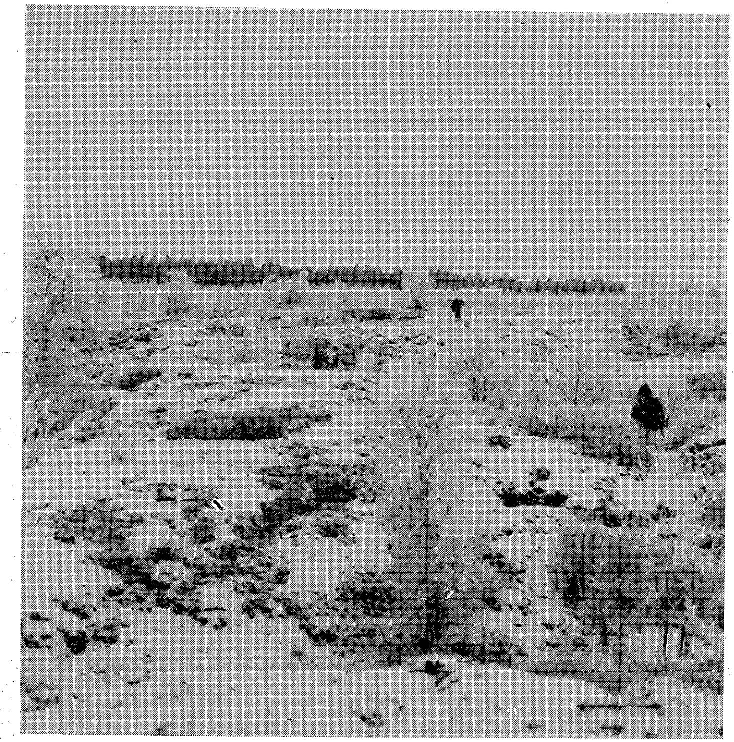

Photo. by the author

Pl. 1. The studied palsa bog on November 2, 1974

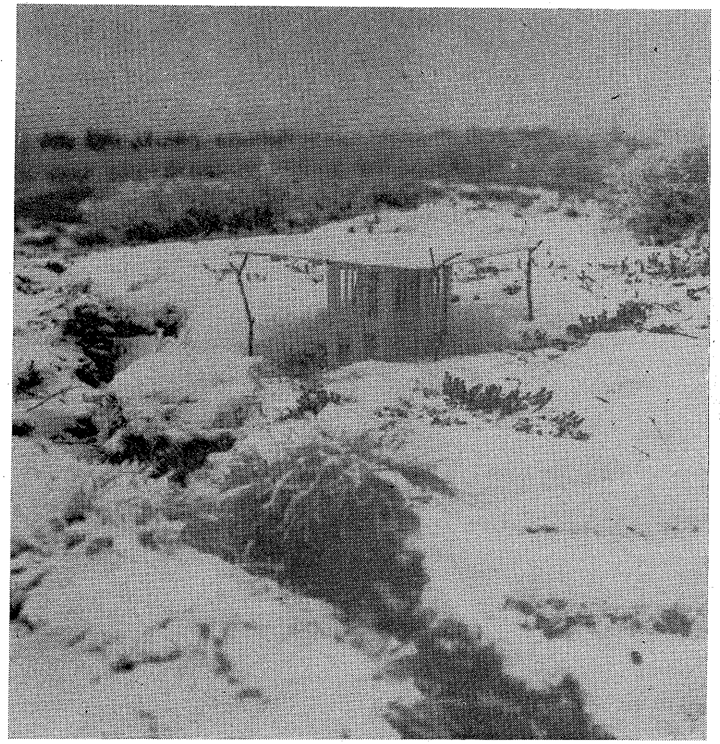

Photo. by the author

Pl. 2. Thermo-hydrograph sited on the palsa. Nov. 2, 1974

Photo. by the author

Pl. 3. Measurement of temperature inside palsa using Wallac-Thermex thermometer

The probe has been pushed into the palsa and temperature is read off from the scale in the person's hand