Study of the transient layer developed in permafrost-affected soils of southern tundra (European North-East of Russia)

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Introduction

Shur et al. (2005) developed the concept of the transient layer (zone), a layer of ground between soil active layer and permafrost that cycles through freezing and thawing at frequencies ranging from decadal to millennial. It is revealed in the upper permafrost according to specific structure and relatively higher ice content at depths of 0,5 – 2 m. This layer periodically becomes a part of a soil profile. Transient layer is considered to be the original buffer protecting permafrost from spasmodic thawing because of its high ice content. The transient layer was first revealed by V. Yanovsky (1933) in the basin of Pechora (the European North-East) in 1933. He noted that signs of pedogenic processes are marked not only in active layer but also in upper layers of permafrost.

Regional Background

The study area is attributed to northern forest-tundra, the southern border of discontinuous permafrost zone (Oberman, Mazhitova, 2003) of the European North-East of Russia (Figure 1). The terrain is thermokarst depression on a watershed area. Surface sediments: peat layers of different thickness (up to several meters) underlain with Pleistocene lacustrine clays. Vegetation: dwarf-shrub (lichen, moss) tundra (Figure 3). Mean annual air temperature is -5.30C, Mean annual DegreeDaysThaw is 11000C-days, Mean Annual Precipitation -597 mm.

Figure 1. Location map of study area

Objects and Methods

We studied the transient layer developed in tundra mineral (profiles 1, 4) and organic (profiles 2, 3) permafrost-affected soils (Figures 2, 3). Organic soils were developed in peaty deposits of different thickness. Profile №2 is characterized with peaty horizons of 0.9 m thick and №3 – 4.5 m. Field work was conducted at the end of August 2007 when the active layer is quite deep.

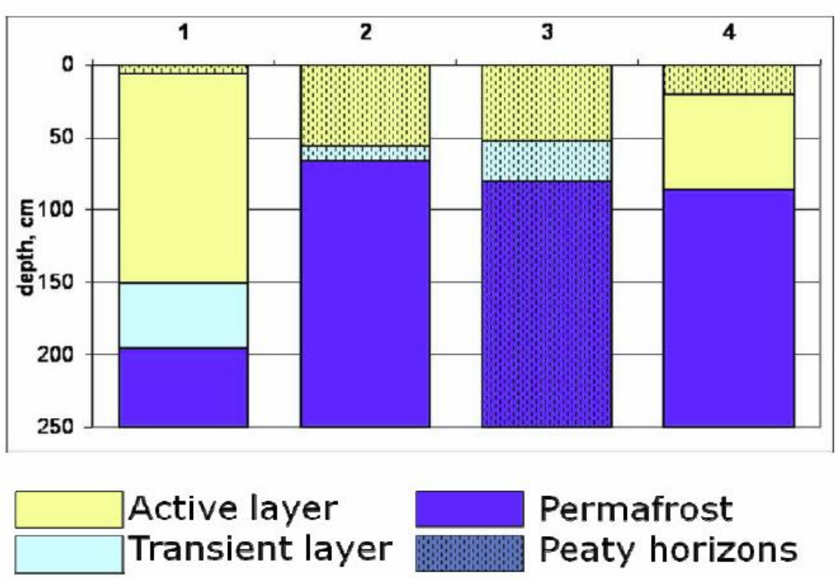


Figure 2. Profile structure according to schematic diagram of 3-layer conceptual model

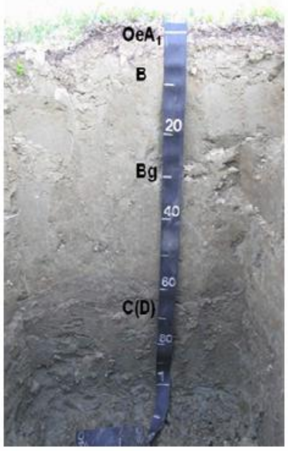
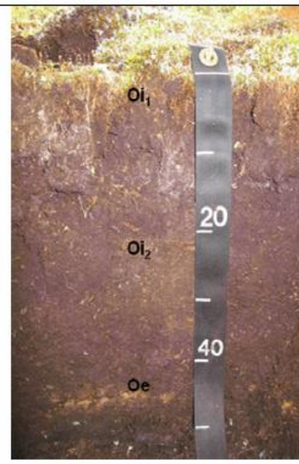
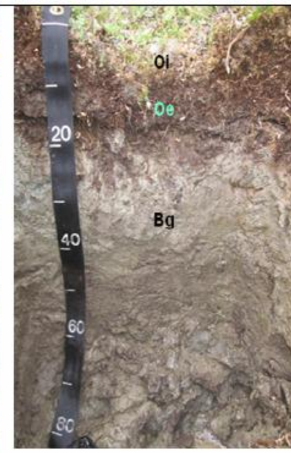
			
1. Dwarf shrub-moss tundra with frost boils	2. Dwarf shrub-lichen tundra on a peatland	3. Hummocky dwarf shrub tundra on peatland	4. Dwarf shrub - lichen tundra
			
1.Ednogleyic Cambisol(Gelic) Permafrost depth – 150 cm	2.Cryi-Folic Histosol Permafrost depth – 55 cm	3.Cryi-Folic Histosol Permafrost depth – 52 cm	4.Histi-Turbic Cryosol (Thixotropy-Reductaquic) Permafrost depth – 85 cm

Figure 3. Landscapes and soils

Permafrost cores were extracted by drilling (Fig. 4). We used both machine (up to a depth of 10 meters) and manual drilling (up to a depth of 1.5 meters).

a b

Figure 4. Permafrost drilling (a – machine, b- manual)

Results

Transient layer in permafrost is characterized by ataxic or layered cryostructure (Figure 5). In three profiles we determined expressed increase in ice content in the upper permafrost contacting active layer (Figure 6), gravimetric ice content - 40-70% (profile 1) in loamy soils, 300-800% in peaty ones. Absence of layers with high ice content in the upper permafrost of profile 4 could be explained by thawing of the transient layer in recent decades (Oberman, Mazhitova, 2003). Temperatures of upper permafrost are negative but close to zero and temperature gradients abruptly decrease at a depth of 4-5 m (Figure 7). Organic profiles are characterized with lower permafrost temperatures (-20C).

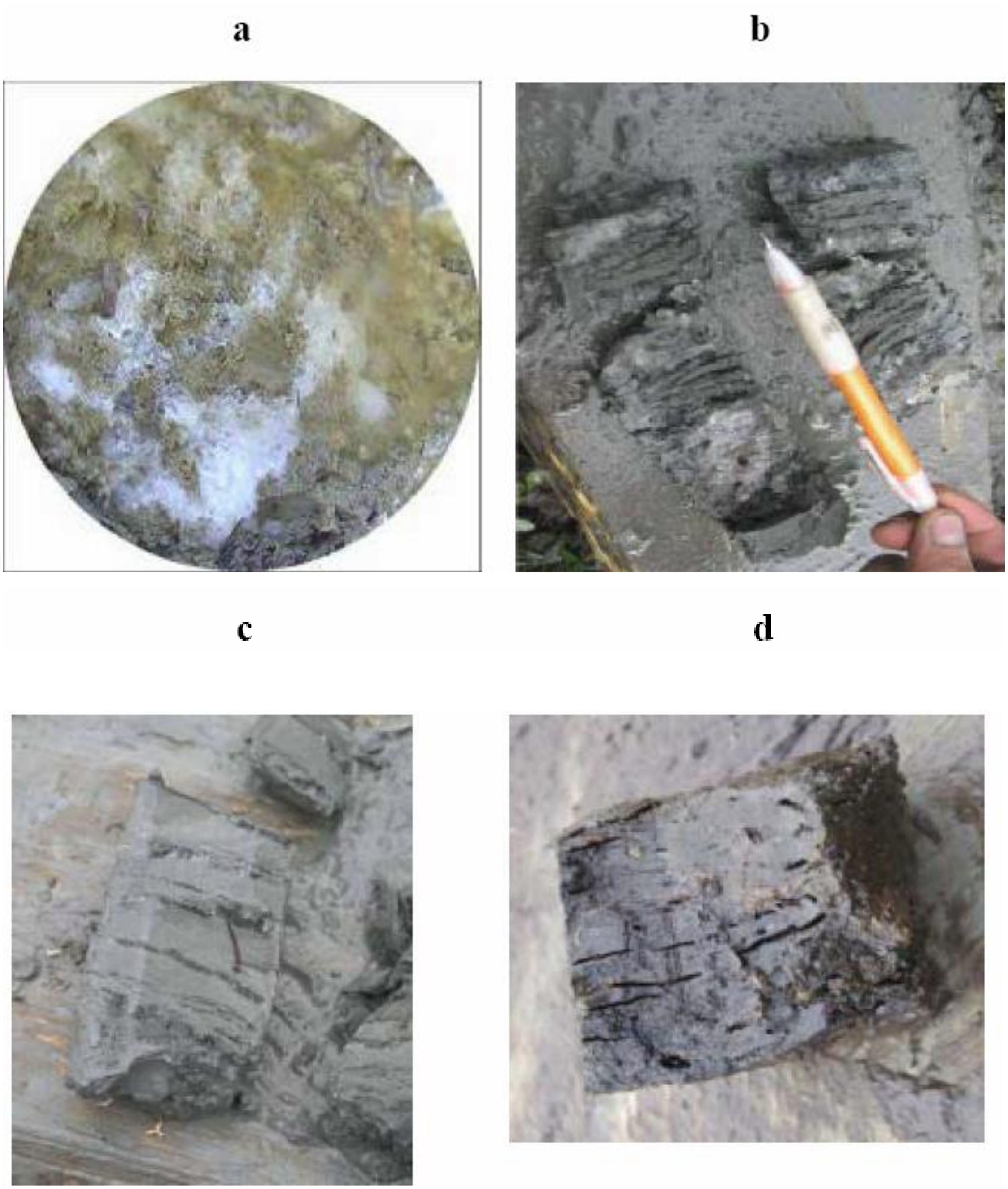


Figure 5. Cryogenic structure: a – ataxic, b, c – layered (mineral horizons), d – layered (peaty horizon)

Figure 6. Gravimetric water (ice) content, %

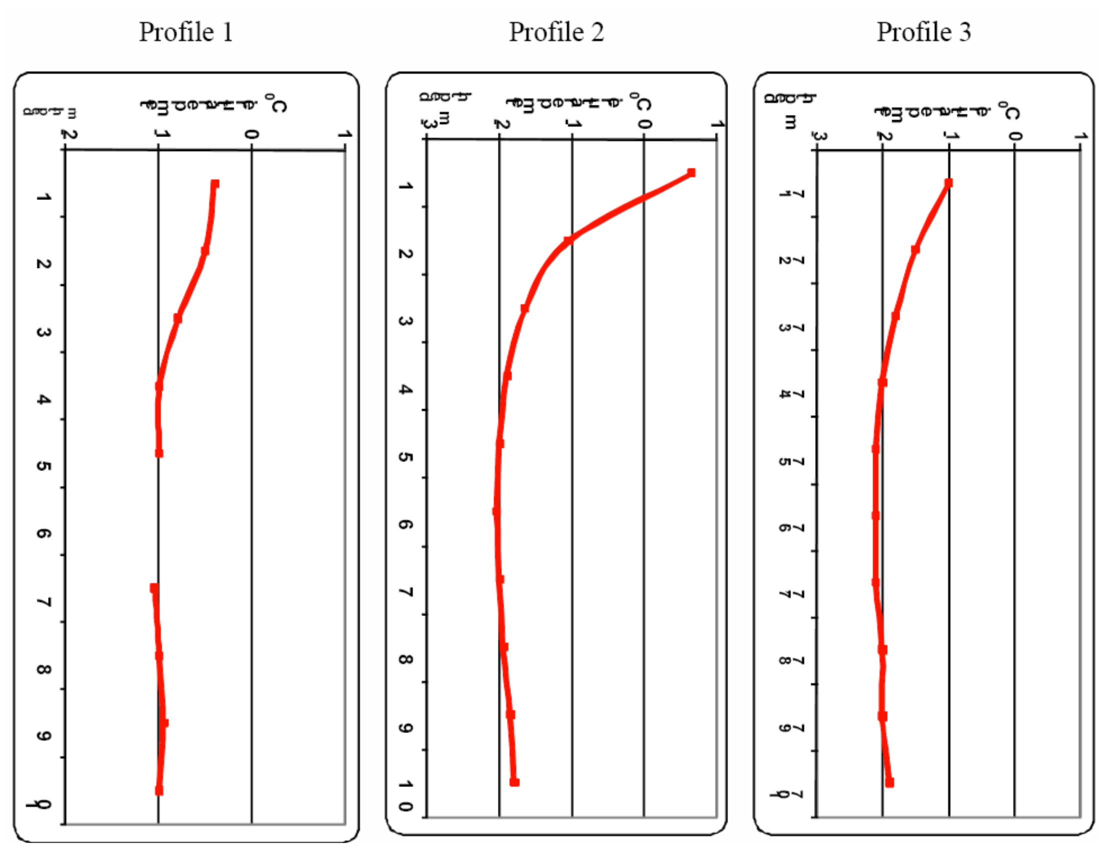


Figure 7. Permafrost temperature, 0C

Studies Under Calm Program

Data set within the Circumpolar Active Layer Monitoring (CALM) program will provide a significant source of information about the characteristics and dynamics of the transition zone. Significant increase in active layer thickness have been revealed for 3 CALM sites situated in the European North-East of Russia (Mazhitova et al., 2004; Mazhitova, Kaverin, 2007).

Besides active layer thickness subsidence has been measured at CALM R2 site since 1999. Site-averaged surface subsidence totaled 22cm and increase in active layer depth 15 cm. Permafrost retreat (as a summarized result of both subsidence and AL increase) comprised 37 cm during 1999-2007 (Figure 8).

In upper permafrost horizons volumetric ice content can be approximated by a "normalized subsidence" index (subsidence, cm to permafrost downward retreat, cm ratio). We calculated averaged index for CALM R2 site for 8 years and received a value of 0.46 (ice content of thawed upper permafrost was about 46%). Such quite high ice content is typical for mineral horizons of the transient layer. Surface subsidence is caused by thawing of ice-saturated layer in the upper permafrost

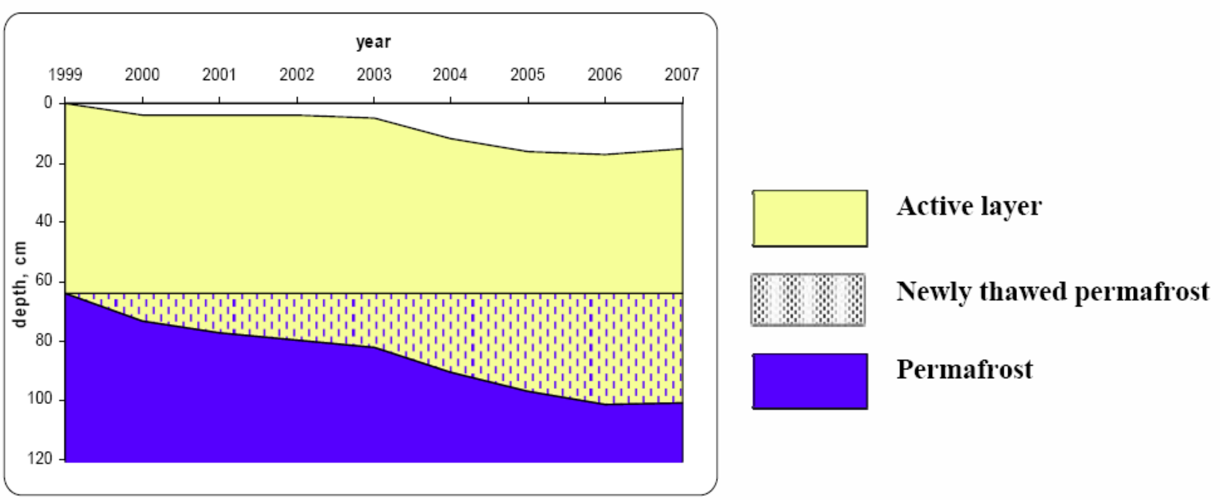


Figure 8. Active layer thickness, surface subsidence and permafrost retreat at R2 (Ayach-Yakha) CALM site.

Resume

1. Transient layer in tundra mineral and organic soils in the European North-East was determined according to higher ice content and it was found that the layer exists in both mineral and organic soils.
2. Ongoing increase of active layer thickness leads to degradation of ice-saturated horizons in the upper permafrost.
3. Surface subsidence processes are associated with thaw penetration into ice-rich (transient) layer of permafrost.
4. Absence of ice-enriched horizons in the upper permafrost of some profiles could be considered as a result of transient layer thawing in the conditions when the layer was less icy and ground temperatures were higher.
5. Future outlook: Study of physic-chemical properties (carbon content etc.) of the transient layer. There are some data about decrease in acidity in this layer (Figure 9 as a example).

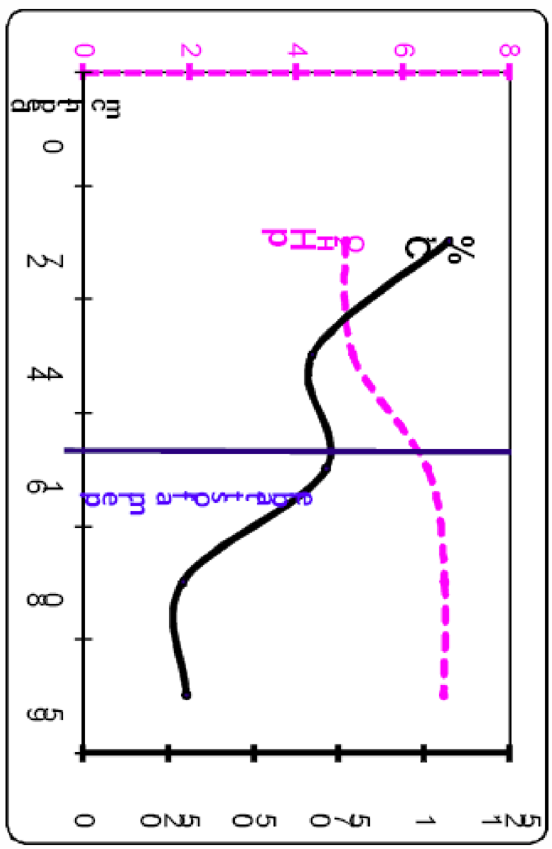


*Figure 9. pH and Carbon content of tundra Cryosol (*N 68.28.54,9; E66.07.22,9).

References

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