REGIONAL CHARACTERISTICS OF SUBFLUVIAL TALIK FORMATION AND STRUCTURE, YAMAL PENINSULA, RUSSIA

F. M. Rivkin

Industrial and Research Institute for Engineering of Construction
Okruzhnoi ps.18, Moscow, 105958, Russia
e-mail: rivkin@podolsk.ru

Abstract

Regional patterns in the formation and structure of taliks in Yamal valleys occupied by small rivers with seasonal run-off, are shown to exist from cross-section reconstructions using well logs. The dominant factor in talik formation is the warming effect of the snow cover, including its dynamics. The warming influence of snow in the river-bed, Dtsn = 5.8° C, reduces by nearly 60% the effect of the mean annual air temperature. The wide distribution of saline sediments leads to the formation of complex talik zones in river valleys. The outer boundary of a talik zone is the isotherm of soil transition to the plasticly frozen state, i.e. the isotherm at which ground freezing begins. The taliks have a horizontally stratified and vertically zoned structure. They include not only thawed sediments, but also unfrozen sub-zero sediments and plasticly frozen sediments.

Introduction

Studies were conducted in the western part of Central Yamal in the Bovanenko gas fields (Figure 1). Talik formation in this region is determined by the interaction of a number of natural factors (Baulin et al., 1996): the predominance of frozen strata at temperatures from -3 to -10°C, a short duration runoff season (< 3.5 months); low mean summer temperatures of the bottom water layer and underground water in subfluvial taliks (from 0.1 to 2.0°C); lowland and plain topography with low hydraulic slopes (0.0001-0.00001 m/m) which result in slow rates of ground water filtration in subfluvial taliks; non-uniform stratigraphy and the prevalence of riverbed sediments consisting of fine and silty sands and sandy loams characterized by low permeability.

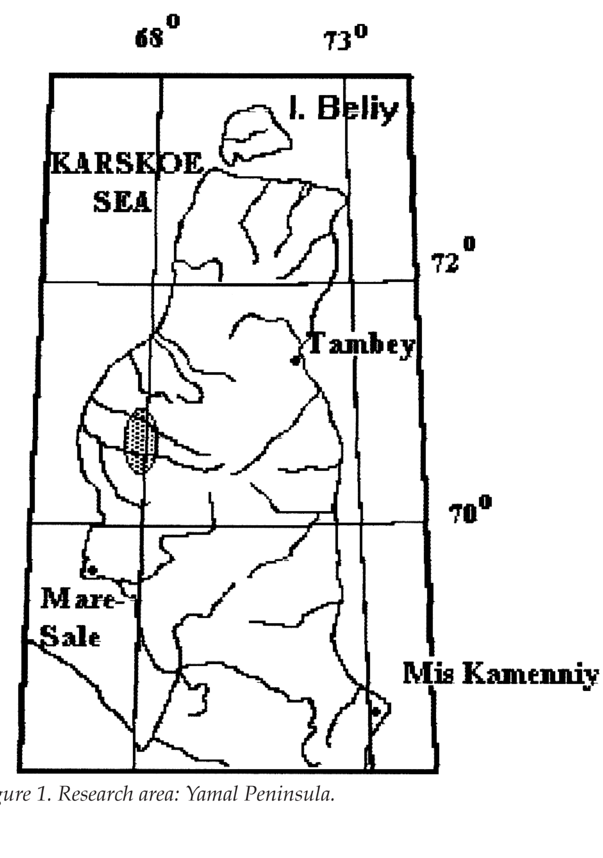

Figure 1. Research area: Yamal Peninsula.

Harsh climatic conditions, which prevailed in the Yamal in the Upper Pleistocene and Holocene, led to the development of continuous, thick permafrost. Despite generally unfavorable conditions, taliks are formed under virtually all waterways and lakes. They are also found in the valleys of small rivers with seasonal run-off and at the bottom of ravines having ephemeral run-off even in summer and, often, no morphologically expressed bed.

The Yamal Peninsula is known to be characterized by wind redistribution of snow. This effect is especially pronounced during the early winter months (October-December). This period accounts for 55-60% of winter precipitation. As a result of wind redistribution, the snow rapidly fills all depressions and especially the valleys of small waterways. The snow thickness in them is largely regulated by their depth of incision which varies from 1.5 to 5.0 m. The depth of snow usually is equal to 80-90% of the depth of the valleys.

Table 1 The warming effect of snow in river valleys with seasonal run-off

Valley Characteristics	Depth of snow, April 1992	Dtsn[1]		Depth of talik	
	m	^{0}C	%[2]	[3]m	[4]m
Seasonal river, upper reaches	2.0	3.5	35	3.6	4.0
Seasonal river, middle reaches	4.1	5.6	56	>8	-
Seasonal river lower reaches	5.0	6.1	62	>8	13.8
Tributary stream, upper part of the valley	1	2.0	20	0.75	-
Tributary stream, middle part of the valley	1.5	2.8	28	2.0	-
Tributary stream, lower part of the valley	2.5	4.1	42	2.2	-

[1] calculated warming influence of the snow;
[2] in relation to mean-annual air temperature, t = -9.9^{0}C;
[3] measurement, August 1992;
[4] computer simulation.

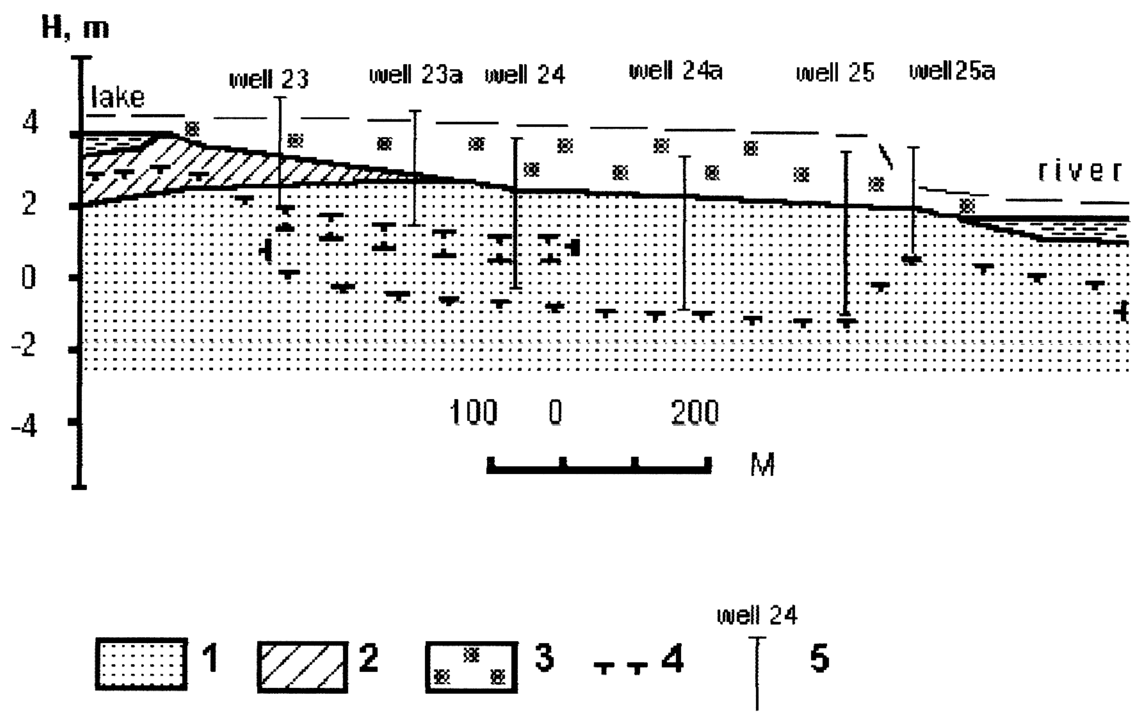

Figure 2. Longitudinal section of a river valley with seasonal run-off: 1 – sand; 2 – loam; 3 – snow; 4 – permafrost table; 5 – well.

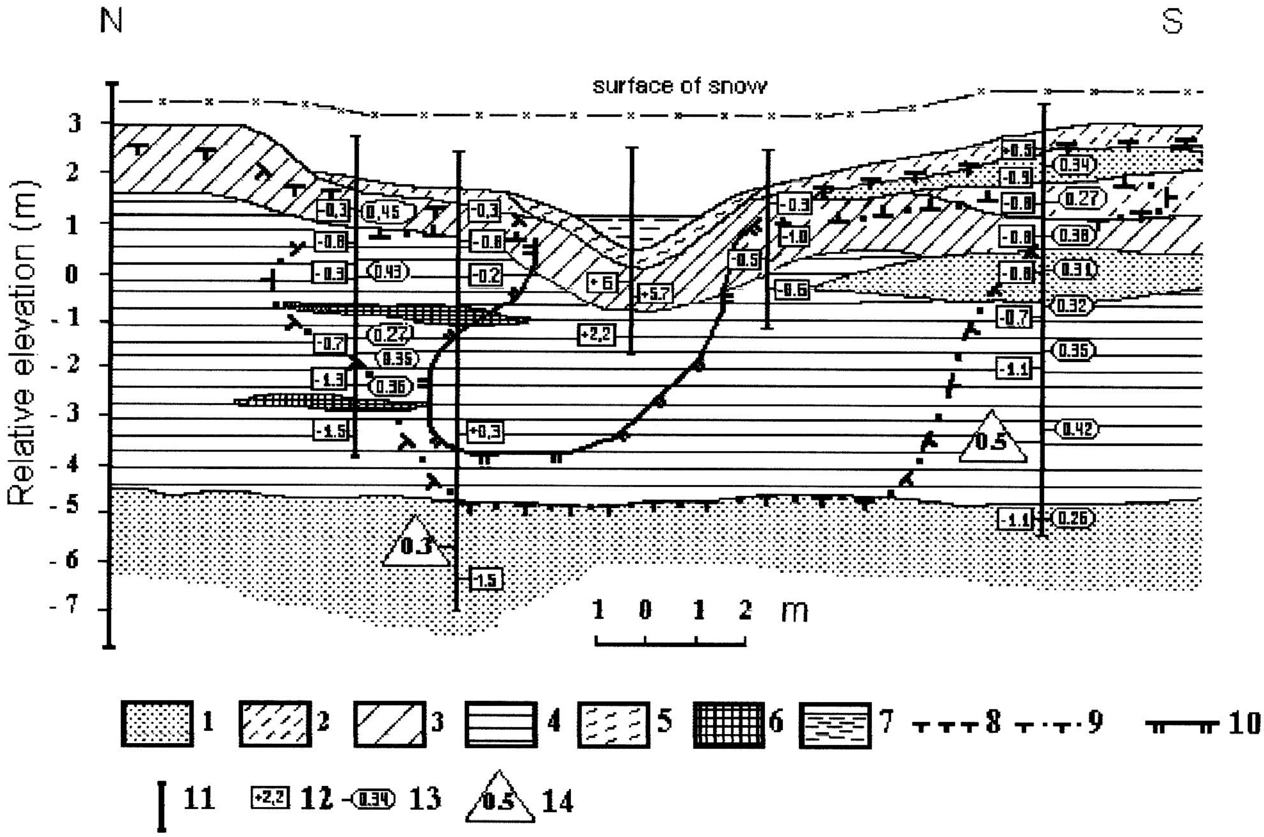

Figure 3. Cross-section of a valley with seasonal run-off:
1 – sand; 2 – sandy loam; 3 – loam; 4 – clay; 5 – silt; 6 – peat; 7 – river; 8 – permafrost table; 9 – border between plasticly and solidly frozen grounds; 10 – talik border; 11 – well; 12 – temperature of sediments; 13 – moisture; 14 – salt content of sediments.

Results

The depth of taliks under small rivers and streams varies from 2-3 m in the upper reaches to 13-14 m in the lower reaches. In the upper and middle parts of valleys with temporary runoff the taliks are generally covered by a layer of frozen ground 0.2-0.5 m thick. The warming effect of snow on the bed of small river valleys, Dtsn = 5.8° C, reduces by nearly 60% the sub-zero influence of the mean annual air temperature. Estimates of the warming effect of snow cover and talik depth are presented in Table 1.

Rapid filling of the valleys by snow at the very beginning of winter reduces markedly the effect of low winter temperatures. Typically, the snow cover reduces by 20-60% the effect of air temperature on sediments in the river bed. Consequently, with a 1-m depth of snow (hs), taliks are usually not present beneath the stream bed (thalweg) (Figure 2). At 1 < hs < 1.5 m, taliks exist, but they are covered by frozen ground, whereas at hs > 1.5 m, the thalweg includes a stable non-throughgoing talik. The ratio of dates of snow cover formation and the start of low negative air temperature strongly influences ground temperatures. Another crucial element of the heat balance is fast snow removal with flood water at the very beginning of summer. This creates conditions for a more extended and stronger heating of the ground during the summer.

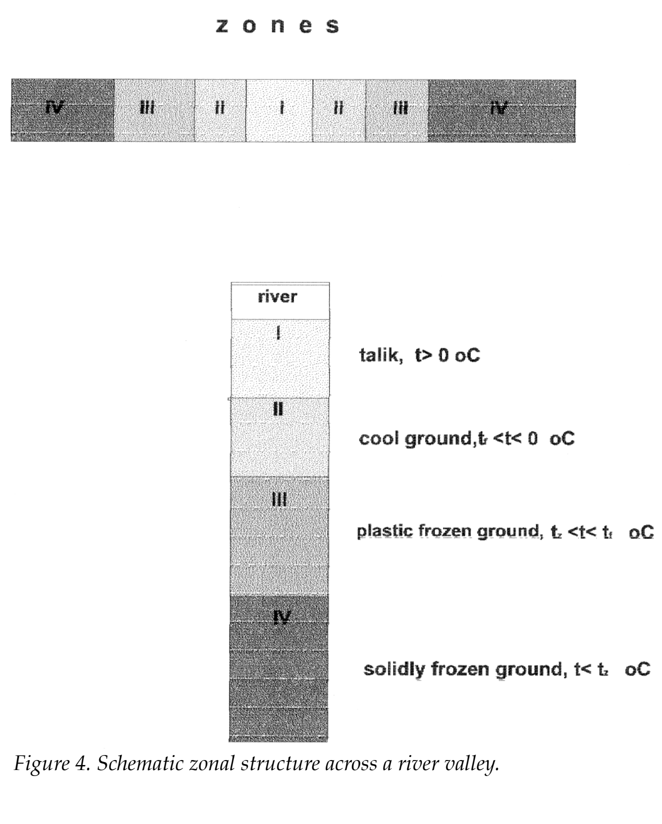

Figure 4. Schematic zonal structure across a river valley.

Complex taliks with zonal structures are formed in saline sediments within river valleys. The size and position of the inner and outer boundaries of the talik zones are determined by the lithology and temperature of their constituent soils and the extent of their salinity. A cross-section interpreted from wells is shown in Figure 3. In valleys with small rivers, the laterally zoned structure is best developed at sites composed of saline loamy sediments. In this cross-section, the zones of saline cooled sediments are poorly expressed and mainly represented by local lenses of cryopegs surrounded by plasticly frozen sediments. In sandy river valleys, the zone of plasticly frozen sediments is frequently poorly defined, whereas in the vertical section one can usually clearly detect the layer of cooled saline sediments situated directly under the thermal talik. In most cases this pattern is observed in the valleys of large rivers with year-round run-off, in which there are deep talik zones and hence their zonal structure is more pronounced.

Discussion

The salinity of sediments, a characteristic of the Yamal Peninsula in general, varied at our sites from 0.2 to 1.5%. The combination of high salinity and relatively high ground temperatures favours the formation of special talik zones in valleys. By talik zone we mean a zone within permafrost that includes a thermal talik (temperatures > 0°C) and/or a region of negative temperature containing saline unfrozen water. This special structure is due to the increase in the ground salinity, which induces a proportional decrease in the freezing temperature and enlarges the range of temperatures under which the ground is in the cooled and plastic state. The temperature of the transition to the solidly frozen state is also lowered.

Where saline sediments are present, several physically distinct zones are identifiable in transverse and vertical sections of a river valley (Figure 4):

1.- zone of thawed ground with positive temperatures;
2.- zone of ground saturated with unfrozen saline water at negative temperatures;
3.- zone of plasticly frozen ground;
4.- zone of solidly frozen ground.

The size of a talik zone varies within wide limits depending on the extent of the salinity, the lithology and the temperature field. The position of the inner boundaries between zones also varies within a wide range. Seasonal changes in the ground temperature also affect the talik zone size and its inner borders: within the limits of the layer of seasonal temperature oscillations, the talik size increases in summer and shrinks in winter. It is usual practice to accept the outer talik zone boundary as being at the transition to the plasticly frozen state (i.e. between the second and third zones in Figure 4), which corresponds to the isotherm where ground freezing begins.

In small river valleys, the valley shape can affect the warming influence of snow. Narrow V-shaped valleys contain a better defined vertical structure of talik zones, whereas the horizontal structure is more distinct in U-shaped valleys.

In terms of origin, the most frequent taliks are hydrologic, while radiation-thermal taliks are much less frequent. The former are formed under the beds of rivers and streams with permanent and seasonal run-off, while the latter occur at local sites in river valleys, ravine beds and run-off troughs. In most cases they form an integrated talik zone. The hydrologic talik is situated directly under the waterway bed, whereas the radiation-thermal talik is beneath the flood plain and as a rule, is covered by a layer of frozen ground. The overall structure reflects the history of talik formation and modern conditions of heat exchange.

Conclusion

On the Yamal Peninsula, the regional characteristics of talik formation are related to the widespread occurrence of saline sediments. The high degree of ground salinity, in combination with the warming effect of the snow cover in the valleys of small rivers, is conducive to the formation of complex talik zones. These talik zones have a vertically stratified and horizontally zoned structure. The size of a talik zone varies within wide limits and depends largely on the lithology and the temperature field.

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