

GEOHERMAL FEATURES OF ONE AREA OF THE YENISEI SECTOR OF THE ARCTIC

GEOPHYSICS

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Abstract

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GEOPHYSICS

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GEOHERMAL FEATURES OF ONE AREA OF THE YENISEI SECTOR OF THE ARCTIC

(Presented by Academician D. S. Korzhinskii, 9 VI 1967)

Having carried out extensive hydrogeological investigations for many years in the upper reaches of the Pyasina River basin, the author collected material characterizing the geothermal conditions over the area of one of the plateaus dissected by erosional valleys. The geothermal characteristics of the rocks were obtained from observations by means of temperature logging in abandoned boreholes at 96 points, down to a limiting depth of 500 m from the ground surface. The entire investigated area (about 15 km²) belongs to the zone of distribution of perennially (“permanent”) frozen ground on the areas of table mountains and their slopes, as well as taliks confined to stream valleys.

Table 1

Point no.	Depth from the surface, m	Depth from the surface, m	Depth from the surface, m	Depth from the surface, m	Depth from the surface, m
	100	200	300	400	500
In permafrost (on an elevation)					
1	-5.5	-3.4	-0.6	+1.9	+4.4
2	-3.5	-1.6	+0.3	+1.6	+3.4
In a talik (in a valley)					
3	+1.6	+3.1	+4.3	+5.7	+6.1
4	+0.9	+2.7	+4.8	+6.5	+8.1
5	+6.5	+7.4	+8.9	+10.2	+11.5

The maximum thickness of frozen rocks recorded by measurements was 347 m, and in this case the lower boundary of the frozen stratum was at an elevation

Fig. 1

Figure 1: Fig. 1

of 166 m above sea level. The lowest temperatures of frozen strata nowhere fell below -7°C . They are confined at different points to intervals from 25 to 120 m from the ground surface. Temperature values of the rocks at the same depths, and also at identical absolute elevations, proved to be sharply different not only at different points differing in their orographic position, but also at points situated under similar conditions in this respect. As an example, Table 1 gives temperatures measured at different points at the same depths from the ground surface. The geothermal steps, beginning from a depth of 50 m and down to 350 m, are presented in Table 2.

Table 2

	Point no.	Geothermal step, m/ $^{\circ}\text{C}$	Geothermal gradient, $^{\circ}\text{C}/\text{m}$
In permafrost (on an elevation)			
	1	44	0.0140
	2	58	0.0197
	Average	52	0.0173
In a talik (in a valley)			
	3	71	0.0237
	4	64	0.0213
	5	63	0.0227
	Average	68	0.0227
	Average for five points	61	0.0203

Frozen strata are characterized by a more significant increase in temperature with depth than thawed rocks. If one takes arbitrarily for

of all observation points vertical segments at 100 m intervals are taken and the geothermal gradients are calculated for them, it turns out that they undergo fluctuations from 30 to 250 m.

Fig. 1. Schematic geothermal profiles. **a** –strata of rocks with negative temperatures, **b** –strata of rocks with positive temperatures

When considering three geothermal profiles (Fig. 1), the relief scheme and iso-lines of the lower boundary of permafrost (Fig. 2), which characterize the spatial position of frozen strata, it is evident that the greatest permafrost thicknesses are confined not to the centers of the elevations of the table mountains, as might be expected, but to their slopes or watersheds (saddles). At the boundaries of through taliks and frozen areas, the contact angles between them are very different—from gentle to steeply dipping; and near through taliks the thickness of the frozen stratum is maximal.

Fig. 2

Figure 2: Fig. 2

The lower boundary of permafrost undergoes sharp fluctuations in its position above sea level. Over short distances, measured in the first units of kilometers, the amplitudes amount to more than 400 m. Thawed areas are confined

Fig. 2. Scheme of isolines of the lower boundary of permafrost. **a** –isolines of the lower boundary of permafrost at 50 m intervals, **b** –surface contours, **c** – talik area, **d** –lines of geothermal profiles

toward the thalwegs of stream valleys, coinciding with the main pathway of movement of subsurface fissure waters that warm the rocks. The formation of permafrost in this area proceeded asynchronously. The oldest permafrost is confined to the elevated parts of individual table mountains. In the erosional valleys, firn ice persisted longer during the glaciation epoch than on the uplands, where its thickness was considerably smaller or where there was even no ice at all, which promoted freezing of the rocks. Therefore, in the more severe postglacial period, the most elevated parts of the plateau were subjected to the strongest cooling.

Attention is drawn to the lower boundary of permafrost on the elevated part of the plateau, where it has a dome-shaped form, and to the fact that the edges of this inverted bowl have the greatest thickness, being in direct contact with a through valley talik.

It should be taken into account that the thawed rocks composing the plateau abound in natural gases–gas mixtures with the full range of transitions from nitrogen to methane and hydrogen. These gases are formed as a result of various chemical and biochemical processes. Filling pores and fractures in sedimentary and eruptive rocks, the gases accumulate in the arched part formed by the lower boundary of the permafrost.

In the peripheral parts of the uplands, near the valley through taliks, gas penetrates through fractures in the thawed rocks into the surface atmosphere, which leads to a drop in pressure and, as a result of the sharp expansion of the gas, to adiabatic cooling of the rocks, the so-called “cooling effect.” The degree of this cooling over a short period is negligible, but on the scale of geological time it could have led to an increase in the thickness of the frozen stratum. In places of gas caps, gas pressure increases, which leads to a diametrically opposite effect—to warming of the lower boundary of permafrost and, consequently, to a reduction in its thickness. This is what is observed in the given area.

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Note: Figure translations are in progress. See original paper for figures.

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