TEMPERATURE OF ICE IN THE LOWER PARTS OF THE TUYUKSU GLACIERS

E.N. VILESOV (U.S.S.R.)

The Glaciologic group of the Department of Geography of the Academy of Science of the Kazakh SSR.

SUMMARY

In this report the results of the preliminary analysis of the data on the temperature regime of the lower part of the Central Tuyuksu glacier in Zailisky Alatau (the North Tien Shan) are submitted. They are obtained by the action of a specially laid borehole, which was functioning from September 15, 1958 up to September 3, 1959. The period of the control made up a full year cycle. The temperature measuring was conducted three times a day by a platinum electrothermometre of resistance (3 T II-310a) set in the borehole at the depth of from 0,5 to 52,0 m., with the intervals of from 0,5 to 10 metres.

According to the temperature condition in the thick of the tongue-ice of the Central Tuyuksu glacier the following temperature zones are marked out (by G. A. Avsyuk) :

a) Ice tropozone— with the variable stratification of temperatures from the surface to the depth of 6 m. (with the crust of thawing - to 0,5 m.).

b) Stratozone of ice — with a constant stratification of the temperatures from 6 to 15 m.

c) Homothermic zone — with constant temperatures from 15 m and lower, up to the bed of the glacier.

The three temperature zones have clear run of the temperature during a year.

In this report we give middle temperature gradients, middle speeds of changing temperatures for the ice tropozone, the character of changing the sum of the inversional temperatures (in relation to their general stratification), which every 10 cm. of ice-thickness give.

The data of the distribution of temperatures in the bore-hole are co-operated with the motion speeds of the internal ice-strata.

The analysis of the temperature measuring in the bore-hole corroborates the supposition about a temperature regime of glaciers with a continental type of distribution of temperatures. (G. A. Avsyuk, Ye. N. Tsikin).

RÉSUMÉ

On trouve dans le rapport les résultats de l'analyse préliminaire des données sur le régime de température de la partie inférieure du glacier du Toujouksou dans l'Ala-Tau (Tien Chan septentrional) sur l'exemple des fouilles spéciales qui ont fonctionné du 15 septembre 1958 jusqu'au 3 septembre 1959. La période des observations comprit un cycle annuel complet. Les mesures de température furent faites 3 fois par 24 heures à l'aide d'électrothermomètres en platine (TII-310a) placés dans les fouilles à une profondeur de 0,5 à 52,0 m à des intervalles de 0,5 jusqu'à 10 mètres.

Dans l'épaisseur de la glace de la langue du glacier du Toujouksou central, on distingue d'après la température les zones de température suivantes (d'après G. Avsiouk) :

a) la tropozone de glace — avec une stratification alternative de la température de la surface jusqu'à 6 mètres de profondeur (avec une croûte de fusion d'une épaisseur pouvant atteindre 0,5 m);

b) la stratazone de glace — avec une stratification constante de la température de 6 à 15 m;

c) la zone homothermique — avec des températures constantes à partir de 15 m et plus bas, jusqu'au lit même du glacier.

Les trois zones de température ont une modification annuelle de température bien définie.

On trouve dans le rapport les gradients de température moyenne, la vitesse moyenne de changement de température pour les tropozones de glace, le caractère des modifications de la somme des températures d'inversion (par rapport à leur stratification générale pour chaque couche de 10 cm de glace).

Les données sur la distribution des températures dans les fouilles concordent avec les vitesses de progression des couches intérieures de la glace.

L'analyse des mesures de température dans les fouilles confirme l'hypothèse déjà émise concernant le régime de température des glaciers ayant une distribution de température du type continental (G. Avsiouk et E. Tzikine).

The study of the temperature regime of ice on the Tuyuksu glaciers, situated in the upper part of the river Malaya Almaatinka in the ridge of the Zailiysky Alatau had been carried out by the glacial expedition of the Department of Geography of the Academy of Science of the Kazakh SSR in 1957-1957 and is being continued until the present time. The largest valley glacier Zentralny Tuyuksu reaches 5,1 km and has in the cirque section a width of 1,3 km, on the tongue –0,5 –0,3 km. The highest point of the glacier basin is the peak Pogrebetsky (4218,9 m). The open end of the glacier's tongue lies at an altitude of 3370 m. The average inclination angle of the surface equals to 8-10°.

For the study of the temperature regime of intraglacial depths on different sections of the glacier of the Central Tuyuksu, in the summer of 1957, 4 pit-holes were bored 20 to 25 meters deep. In 1958, on the tongue of the glacier, another bore hole (No. 5) was bored that reached the bed moraine at the depth of 52,5 m. The characterization of the temperature regime of the glacier is given in this report according to the observations of temperatures in the bore hole No. 5. The latter was placed on the axis part of the glacier 600 m away from the extreme end of the tongue and 2300 cm from the foot of the back cirque wall at the altitude of 3480 m above sea level.

The highest average-monthly temperatures on the meteorological station Tuyuksu-2, that is situated directly near the bore hole are observed during four months of the year (from June to September) but they do not raise above +5,1°. The average monthly air temperatures for 1958 and 1959 on the station Tuyuksu –2 are given in table 1.

TABLE 1

Year	I	II	III	IV	V	VI	The year's average
1958	– 12.8	– 11.8	– 8.1	– 3.5	– 2.6	1.4	
1959	– 13.2	– 14.9	– 10.0	– 3.1	– 3.5	2.0	

Year	VII	VIII	IX	X	XI	XII	The year's average
1958	5.1	3.1	1.7	– 4.0	– 11.0	– 10.6	— 4.4
1959	4.1	4.7	4.6	– 2.5	– 10.6	– 13.3	— 4.6

The absolute maximum is noted here to be +19.1° (July 1959), minimum −28,2° (January 1959). The stable snow cover on the glacier is settled by the second half of September or the beginning of October. During the winter period the thickness of the snow cover varies from 100 to 160 cm with a density of 0.32-0.36. The tongue of the glacier is free from snow by the end of June, but the maximum melting takes place in July. During the ablation period in the region of bore hole No. 5, which is placed in the zone of maximum ablation, the glacier loses through melting as much as 150-200 cm of ice (converted into water).

The average duration of the melting period in the region of the bore hole lasts 70-80 days.

The observations of temperature on the tongue of the Zentralny Tuyuksu were carried out by means of platinum electrothermometers of resistance, frozen in the bore hole at depths of 0,5, 1,0, 2,0, 4,0, 10, 15,0, 20, 0,30, 0,40, 0, 46,0, 48,0, 50,0, 51,0, and 52,0 m. During the observation period these depths diminished for account of ablation—in 1959 almost by 1,5 m. Besides that, in the same bore hole, at depths of 11,0, 17,0, 26,0, 34,0, 46,0 and 52,0 m were placed metal block-electrodes to obtain data on the motion of the inner layers of the glacier.

The measurement of the temperature were carried out, with the aid of a portable Wheatstone bridge (MTW) that was connected to the thermometer circuit at the moment of measuring. Accuracy of temperature measurements with platinum thermometers equals to ±0,05°.

The readings off all thermometers were taken three times a day— at 7^{00}, 13^{00} and 19^{00} hours. The bore hole functioned from 15,09, 1958 to 3,09, 1959). during this period over 11 000 measurements of the ice temperature have been made.

As to the character of ice formed, the glacier Zentralny Tuyuksu, as well as all the Tien Shan glaciers, belongs to the infiltrate-congelation type, which is characteristic of continental districts. Therefore, the ice of the described glacier has a continental distribution of temperatures, that is, formed under the influence of rather considerable negative temperatures during the cold period of the year, and also a relatively low average temperature during the warmest month (+5,1°) and negative yearly average temperature of 4-6° below 0.

The analysis of the actual material of the temperature measurements on the tongue of the glacier Tuyuksu shows, that during the whole year, the entire 52 meter depth of ice has negative temperatures. Only in the upper layer of ice (at a depth of 0,7-1,0 m) which is intensively saturated by surface melt water during the warm season of the year, zero-temperatures are observed. In deeper horizons the following maximum temperatures have been noted: at a depth of 2 m −0,6°, at the depth of 4 m −2,0° and at the depth of 6 m −3,1°.

The results of temperature measurements throughout the entire depth of 52 meters are shown in the table 2.

From this table it follows that ice temperatures in the upper horizons down to a depth of 2 m and which are exposed to a direct influence of weather conditions, are very variable and follow the changes of the air temperature. The deeper horizons of the ice (below 2 m) have a rather smooth temperatures curve due to the air temperature having a lesser influence and with considerable delay. A strong cooling of the surface layer creates in deeper zones of the ice a dissimilar temperature field. This dissimilarity, connected with the penetration of the surface cooling of the body of the glacier, effects the value of the temperature gradient.

The calculations show that the absolute values of the temperature gradients diminish with depth, whereas in the upper part of the temperature field up to a depth of 2 m, sharper changes of the gradient correspond to a slight increase of depth, and inversely at greater depths (below 2 m), a slight decrease of the gradient corresponds to large changes of the depth. From table 2 it follows that on separate stages the strati-

TABLE 2

Average monthly ice temperatures by horizons

Period horizon m	15-IX 30-IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	Average
0.5	− 1.0	− 2.4	− 4.4	− 5.4	− 5.9	− 7.1	− 7.6	− 6.5	− 2.4	− 0.5	− 0.3	—	− 4.2
1.0	− 0.4	− 1.9	− 3.6	− 4.6	− 5.0	− 6.1	− 6.7	− 6.1	− 2.9	− 1.5	− 0.9	0.0	− 3.8
2.0	− 1.1	− 1.1	− 2.7	− 3.6	− 4.3	− 5.2	− 5.7	− 5.3	− 3.3	− 2.2	− 1.5	− 0.9	− 3.4
4.0	− 2.4	− 2.4	− 2.5	− 2.7	− 3.0	− 3.6	− 4.6	− 4.4	− 4.0	− 3.5	− 2.6	− 2.1	− 3.2
6.0	− 3.2	− 3.2	− 3.2	− 3.2	− 3.2	− 3.2	− 3.3	− 3.4	− 3.4	− 3.4	− 3.2	− 3.1	− 3.2
10.0	− 2.4	− 2.4	− 2.4	− 2.4	− 2.5	− 2.5	− 2.6	− 2.6	− 2.6	− 2.6	− 2.5	− 2.5	− 2.5
15.0	− 1.7	− 1.7	− 1.7	− 1.7	− 1.8	− 1.8	− 1.8	− 1.8	− 1.8	− 1.8	− 1.8	− 1.8	− 1.8
20.0	—	− 1.3	− 1.3	− 1.3	− 1.3	− 1.4	− 1.3	− 1.4	− 1.4	− 1.4	− 1.4	− 1.4	− 1.4
30.0	—	− 1.0	− 1.0	− 0.95	− 1.0	− 0.95	− 0.9	− 1.0	− 0.95	− 0.95	− 0.95	− 0.95	− 0.95
40.0	—	− 0.9	− 0.95	− 0.9	− 0.9	− 0.9	− 0.9	− 0.9	− 0.9	− 0.9	− 0.9	− 0.9	− 0.9
46.0	—	− 0.2	− 0.2	− 0.2	− 0.2	− 0.2	− 0.4	− 0.4	− 0.5	− 0.6	—	—	—
50.0	—	− 0.1	− 0.1	− 0.1	− 0.1	− 0.2	− 0.2	− 0.2	− 0.3	− 0.4	− 0.5	—	—
52.0	—	− 0.1	− 0.1	− 0.1	− 0.1	− 0.1	− 0.2	− 0.2	− 0.3	− 0.4	− 0.5	− 0.7	—

fication of the raise of temperatures by increase of depth (a direct or "winter" stratification) is replaced by an opposite one ("summer" stratification). A similar change of stratifications takes place in the upper part of the temperature field at a depth of 6 m by the approach of the winter cold and at the beginning of the warm period of the year. To have a clearer notion about the changes of the temperature stratification by the depth of all horizons, where a change of stratification takes place, we summed up the inversal temperatures that cover an ice layer by a thickness of 1 decimeter (table 3).

TABLE 3

Summaries of the average daily inversal temperatures by all upper ice horizons.

Horizon (m)	Sum of inversal temperatures, that cover an ice layer of 1-dm	
	From 20.IX.58 to 31.I.59	From 1.V.59 to 31.VIII.59
1.0	0°	12.4°
2.0	0.6°	6.5°
4.0	1.8°	6.4°
6.0	3.6°	2.4°

As this table shows, the upper ice layers are strongly warmed in the summer, and the maximum sums of inversal temperatures fall on the warm period (the temperature gradient changes at that time changes signs). Deeper than 6 meters and all the way down to the bottom moraine a direct stratification of temperature increase takes place, by increase of the depth, during the whole year.

As it has already been pointed out, the upper ice horizons (by a depth up to 2 m) are distinguished by an extremely unstable temperature regime, accompanied by rather frequent temperature changes (towards raise or fall). In the deeper layers of the glacier the amplitudes of the temperature variations are being noticeably decreased. The deepest ice horizons are being characterized by slight (at the depths of 6-10 m) and even zero (deeper than 10 m) temperature variations during the entire year's observation cycle (table 4.)

With the increase of the depth decreases also the rate of temperature changes, reaching at a depth of 10 m 0,02° within 24 hours, but at the depth of 15 m –0°.

Usually the study of the temperature condition of glaciers is accompanied by defining temperature zones, that are notable for specific peculiarities of the course of the temperatures.

The division of the depth of the glacier into zones is generally made according to character of the temperature stratification. Proceeding from above quoted material, the entire depth of the glacier tongue may be divided, according to its temperature regime, into three principal zones (G. Avsyuk, 1954, 1955, 1956; E. Tsykin, 1957): the surface, the middle, and deepest.

1. The superficial, or tropozone of ice spreads from the surface to a depth of 6 m; 2. The middle, or stratozone of a 9 meter-thickness is placed at the depth from 6 to 15 m; 3. The deepest zone is considered below 15 m all the way down to the bed-moraine.

TABLE 4

Regime of temperature variation in the upper horizons of the glacier

Horizon (m)	Number of changes of temperature variation symbol	Average duration of of changes of one symbol (days)	Average changing rate of temperature (in degrees within 24 hours)
0.5	88 to 313 days	3.5	0.23
1.0	45 in 320 days	7.1	0.15
2.0	17 in 227 days	13.3	0.09
4.0	7 in 332 days	47.7	0.06
6.	1 in 263 days	263	0.04
10.0	0 in 278 days	278	0.02

The superficial zone, or tropozone, is characterized by the regime of variable temperature stratification (Fig. 1). This regime is formed by the direct influence of air temperature fluctuation upon the glacier, and by warming or cooling of the upper ice layers, and also by the thermo-influence of the surface melt water that penetrates into these horizons. The influence of these processes, connected with the motion of the lower depths of ice, in comparison with the above said factors, effect very little the temperature regime of the tropozone.

The temperature stratification within the tropozone varies with the seasons of the year as follows. During the warm season of the year, owing to high air temperatures intensive solar radiation and melting, the upper ice layers are strongly warmed, and therefore with an increase in depth the air temperature sinks, i.e. a summer stratification is being created. According to the extent of warming of the upper ice horizons, the minimum temperature sinks down to the lower layers of the tropozone and in the middle of the warm period (July-August) settles down on the lower edge of zone, i.e. at the depth of 6 m. In the winter months, in view of the spreading of the cold, the high ice temperatures of the surface horizon sink rapidly, and the minimum temperatures are again transferred, but this time from the lower layers to the upper ones, according to the cooling extent of the latter. The ice temperatures, inherited from the warm period of the year, at depths of 4-6 m are preserved for a rather long time.

In February, March and April, throughout the entire depth of the ice tropozone, there takes place a regular winter temperature stratification, during which the minimum temperatures are on the ice surface. In the spring and autumn, in the surface zone there is observed a mixed temperature stratification. Within the limits of the tropozone, according to the character of temperature changes by depth and average temperature gradient, it is possible to single out two temperature subzones: 1. A subzone of variable stratification, conditioned by intraseason weather fluctuations, and 2. a subzone of variable stratification, conditioned by change of the seasons of the year.

The upper subzone is bedded at a depth of up to 2 m from the surface. Above 2 m the ice temperature is subject to rapid and sharp fluctuations. It is here that maximum amplitudes of the temperature fluctuation had been fixed. In particular,

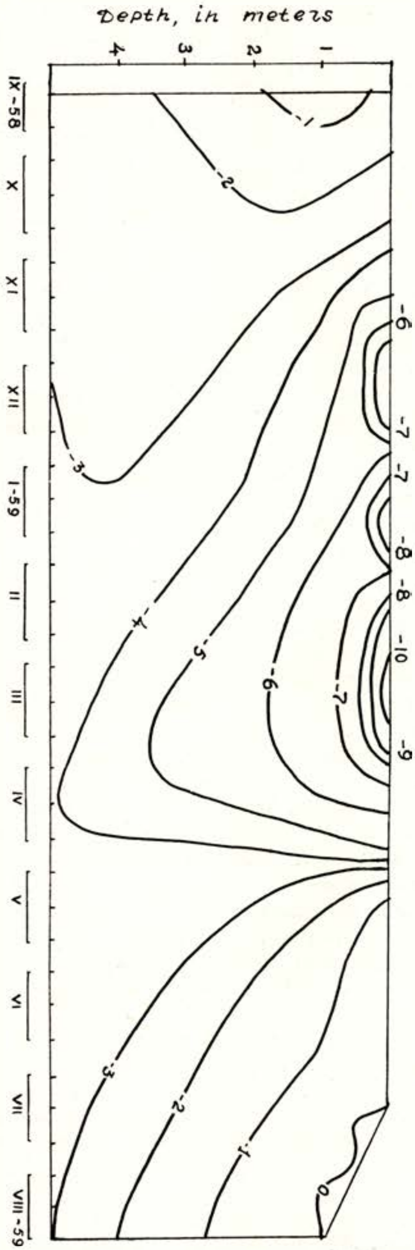

Fig. 1 — The course of the average ice temperature by decades, up to a depth of 5 m on the tongue of the glacier Zentralny Tuyuksu (from 20.IX.1958 to 31.VIII.1959).

the yearly amplitude reaches 8-10°. The ice temperature of the subzone is strongly dependent on the depth, and the temperature gradients have the most significance (averaging during the observation period 0.004-0.008 of a degree on each centimeter). The maximum gradient of the change of temperatures was noted in the winter (January-March), when it reached 0.02° on each centimeter and more. It is the winter when the largest diversity of temperature is noted within the limits of the subzone—up to 5-6°. The ice subzone considered here is characterized also by a maximum speed of the temperature change (0.09-0.023° during 24 hours. The influence of the daily temperature fluctuations of the air layer adjacent ot the glacier effects a depth 0,7-1.0 m, i.e. within the limits of the so called "thawing crust".

The subzone of variable temperature stratification, conditioned by the change of the seasons of the year, has a thickness of 4 m and is bedded on depths from 2 to 6 m. In the temperature regime of this subzone are distinctly shown the season changes of the temperature conditions of the surrounding air and solar radiation. Below 2 m are observed to be rather slow in comparison with the upper subzone changes of ice temperature. The speed of these changes is not quite dependent on the depth and varies within 0.04 to 0.09° within 24 hours. The significance of the temperature gradient noticeably decreases as the depth increases. The annual amplitude of air fluctuations within the limits of the subzone equals to 1.5-2.5°, but near the lower edge of the subzone it decreases to 0.4-0.5°. The maximum temperature diversities between separate horizons of the subzone do not exceed 2.0-2.5° even in the winter period.

The middle zone or ice stratozone is characterized by a regime with a constant temperature stratification. The temperature regime of the stratozone is formed u der the influence of both the outer factors, the influence of which predominates in the upper layers of the zone, as well as the intra-glacier processes (ice motion, etc.), the influence of which predominates in the lower part of the zone.

Within the limit of the stratozone the ice temperature is, during different seasons of the year, always negative and vises depth from —3.2° to −1.7−1.8°. The influence of the season temperature fluctuations of the air layer adjacent to the glacier upon the temperature condition of the stratozone ice, shows very faintly and with a considerable delay (3-4 months). By increases in depth the "waves" of cold and warmth show to a lesser extent and approaching the lower edge of the zone, die down almost completely. The temperature curve at depth in the zone is an extremely smooth one. The general character of the direction of the thermoisohypsos is to be drawing nearer to the parallel with the surface of the glacier, which proved by the distribution of temperatures within the limit of the stratozone in different seasons of the year (Fig. 2). The temperature diversities of different layers of the zone are not large—within 1.4-1.6°; the gradients of temperature changes are also not large and amount to 0.0014-0.0020° on each centimeter.

The zone of depth is characterized by the temperature regime that is formed under the influence of the energy from intraglacial processes and also under the influence of the temperatures, that were inherited by the ice at its formation out of the solid precipitations in the accumulation region of glacier. The ice temperatures within the zone are distinguished by the constancy of their significances. The isothermal character of the temperatures particularily distinctly traced in the upper and middle part of the zone, at the depths of 15-40 m, where during the yearly observation period the temperatures did not change more than by 0.1°.

However, on the whole, the distribution of the temperatures in zone of depth is distinguished by some other regularities, that could hardly have been expected. First of all, in the ice of the zone is marked a sufficiently expressed tendency to an increase of temperature by the depth (from −1.7° to −0.7°), although the average temperature gradients are decreasing to 0.001-0.0001°/cm. Particular consideration

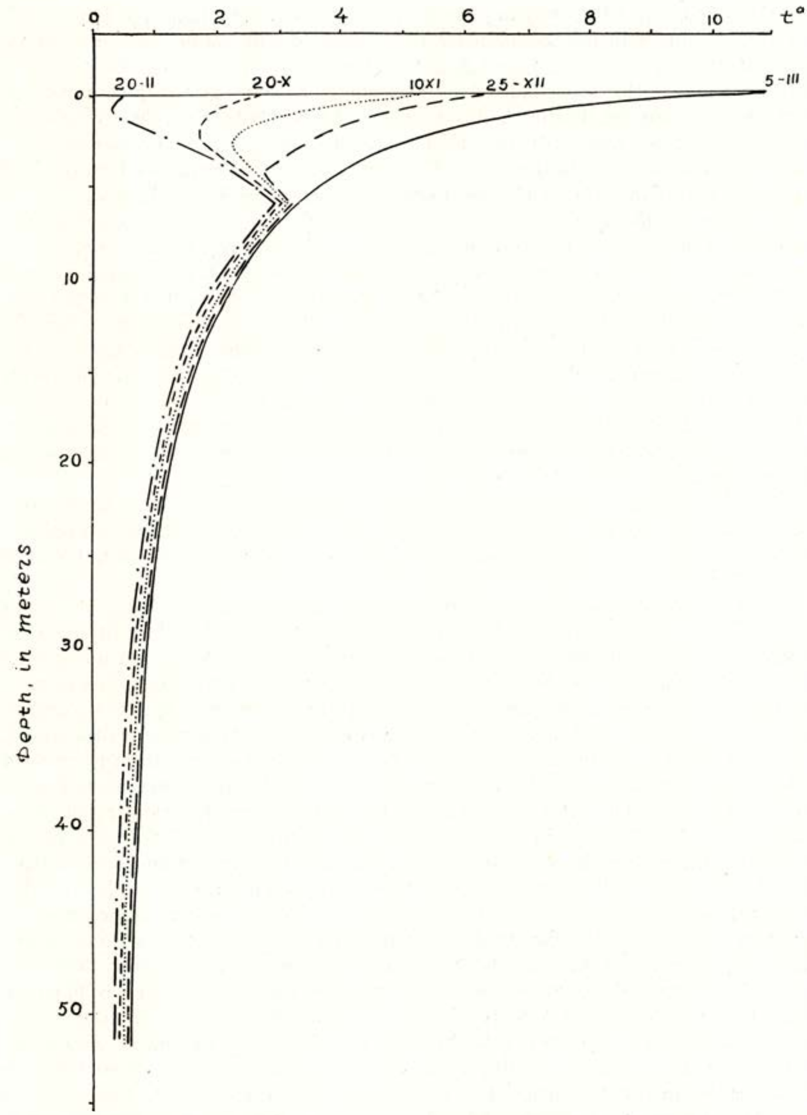

Fig. 2 — The distribution of the temperatures with depth in the ice on the tongue of the glacier Zentralny Tuyuksu (1958-1959).

is deserved of the distribution of temperatures in the lower part of the zone at the depths of 46-52 m. Here attention is attracted to the fact that the temperatures from October 1958 to February 1959 are equal, throughout the entire 6 m thick ice adjacent to the bed moraine, to about −0.1°. At the beginning of March there begins a gradual fall of the temperature that lasts until the end of the observation period (the end of August 1959), when it reached −0.6-—0.7°. Such sharp change of temperature for the depth — zone may be explained by the following factors.

On August 22 1958, on completion of boring of the pit hole, the latter (after lowering a cable with the thermometers), was flooded with water that for a certain space of time warmed up the ice adjacent to the pithole. It required about 30 days until the water in the upper half of the borehole froze and adapted the temperature of the surrounding ice. But in the lower part of the borehole (below 46 m) the water, apparently did not freeze till the end of October, when, at last, the thermometers showed a negative temperature $-0.1°$. This temperature was maintained on one and same level during the four winter months because during this period there was a maximum motion of the glacier tongue. Owing to the slowing-down of the speed after February (and also due to a certain extent by the time factor), the ice formed in the bore hole by freezing of the water begins to adapt, a great deal faster, the temperature of the surrounding ice layers. Apparently the temperature $-0.6°$—$0.7°$, that has been fixed at the depths of 46-52 m already at the end of the observation period, is the very temperature, which is natural to this zone at the given depths. Unfortunately, at the beginning of September 1959, all the thermometers went out of use (owing to a rupture of the feeding wires, caused by irregularity of the distribution of motion speeds at separate depth of ice layers in comparision with the surface speed of the glacier). Therefore, there was no possibility to trace the further source of the ice temperature in the bore hole.

It is known that in glaciers with infiltrate-congelation (continental) temperature regime, the ice motion, which has a plastic character, the dynamic intra-glacial processes cause a noticeable change of temperatures, especially in the deep layers of glaciers.

As G. Avsyuk (1956) shows the distribution of quantity of heat that is formed by the motion of ice on a vertical line, is proportional to the diversities of speeds of differential motion of separate ice layers, and therefore, the maximum quantity of heat ought to enter into the lower bed ice horizons, where it is possible to rise to near-bed melting temperatures. By the raising from near the bed of the glacier to its surface, the quantity of heat, and this means also the warming of the glacier, will diminish. At depths above 15 m the influence of the motion processes is not so large as more considerable influence is rendered here by the season and yearly temperature fluctuations of the external air. However, in connection with the small motion speeds of the glacier Zentralny Tuyuksu in the considered part of the tongue (5.8 m in a year at the surface the raise of the ice temperature, conditioned by the motion, is not strictly proportional to the diversities of the differential motion speeds, but has a more smoothed and regular character. The regularity of rise of the ice temperatures by increases of the depth is explained by the thermoexchange between separate layers, which, owing to the low flow speeds, has time to smooth out considerably the temperatures in the entire depth of the ice. On the tongue of the glacier Zentralny Tuyuksu, where the motion speed at a depth of 52 m is reduced by 34% in comparison with the surface speed (B. Borovinsky, K. Makarevich, 1959). This smoothing out of temperatures leads to such a condition that the ice temperatures rise almost equally in the depth-zone of the glacier. The above said is well illustrated by Fig. 3. On the curve of the relative transference of points (A), attention is attracted to the irregularity of the distribution of change of motion speeds of separate ice horizons in relation to the surface speed. The irregularity of change of speeds between separate ice horizons is particularity clearly shown by the speed gradients, that were calculated by five meter-distance sections (curve B). The position of the section "a^1" of the temperature gradient (curve C) shows that the change of the temperatures within the tropozone (from the surface down to a depth of 6 m), is dependent on seasonal and inter-seasonal weather fluctuations, occurs extremely sharply and is almost not dependent on the motion speed. The sections "b" (of the speed gradients curve B) and "b^1" (of the temperature gradients curve C), are, by their position, quite similar

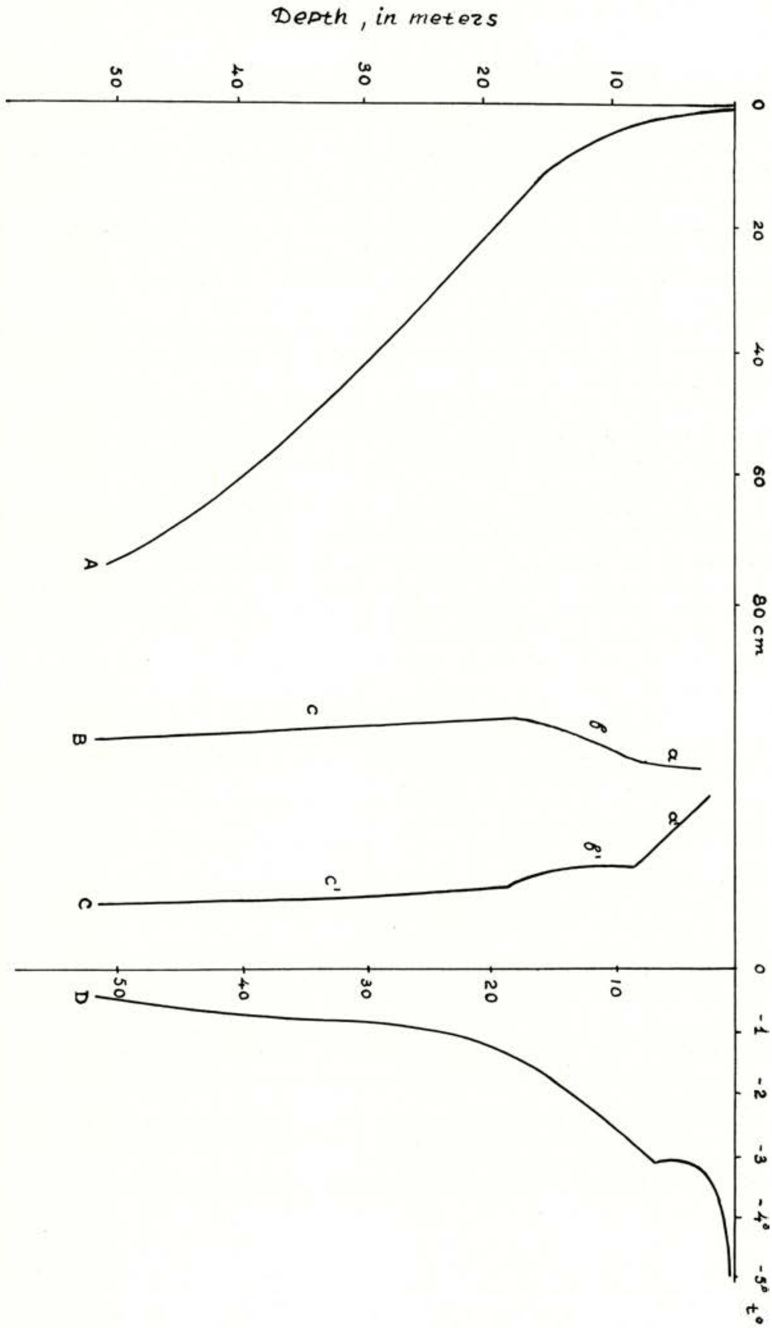

Fig. 3 — Change of motion speed and of temperatures with depth in the ice of the glacier Zentralny Tuyuksu according to data of a 52-meter deep borehole (from 22.VIII.1958 to 27.2.1959).
A — delay, in cm;
B — gradient values of motion speed;
C — the average ice temperature during the same time;
D — values of temperature gradients.

to aech other, i.e. on the change of the ice temperature at the depths from 6 to 15 m, to a certain degree also begins to tell on its motion. Lastly the position of the section "*c*" and "*c*¹" of both curves certify that the ice temperatures at a depth of 15 m and lower, change (increasingly) almost entirely according to the changes of the motion speed. The quantity of warmth that is formed by the motion on different ice horizons has not yet been calculated, but it may now already be established with confidence that the entire glacier, in relation to the distribution of motion speeds, can also be divided into three principal zones—the surface, middle and deep zone, the thickness depository limits, of which correspond to thickness and depository limits of the temperature zones.

The results of measurements of temperature and motion speed of the lower depths of the ice on the tongue of the glacier Zentralny Tuyuksy in 1958-59 lead to the following conclusions:

1. Owing to the fact that the surface of the lower part of the glacier is composed of ice so dense that is almost completely impervious to melt water, the ice temperature at every depth in all seasons of the year has a negative value, with the exception of the "melting crust".

2. The ice on the tongue is subdivided into 3 principal temperature zones: the surface, the middle, the deep zone and each differ from each other by the temperature regime and by the influence of the factors that form this regime.

3. A determinative influence upon the temperature regime of the depth-layers is rendered by the dynamic intraglacial processes; first of all is the motion of glacier which is also divided into 3 principal zones.

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