Title: DETERMINATION OF THE LOWER PERMAFROST BOUNDARY, By V. A. Kudryavtsev

Source: Russian per, *Merzlotovedeniye*, Vol II, No 1, Moscow, May 1947,

DETERMINATION OF THE LOWER PERMAFROST BOUNDARY

V. A. Kudryavtsev

There have been many searches for minerals in permafrost areas in the last decade. These explorations usually involve the drilling of shafts whose depths considerably exceed the permafrost's thickness. The shafts could have been used to study the permafrost layer, especially the depth of the lower boundary; unfortunately however, the organizations producing the drilling pursued a narrow production goal, namely exploration for minerals; ~~and~~ geological documentation of the wells is therefore limited, while data on permafrost is completely absent in these projects. This untoward situation is due in part to the unwillingness of these organizations to concern themselves with permafrost documentation, but mainly to the lack of trained personnel and proper equipment. But even when permafrost observations in the shafts are possible, serious obstacles are encountered which make documentation of permafrost difficult.

Deep shafts, mechanically drilled, are flushed with a warm salty ~~and heated~~ solution. The long flushing not only distorts natural temperature conditions in the shafts, but also melts the frozen ground and creates a thaw ring around the shaft. Therefore, the procedure for permafrost documentation requires that such shafts be left until natural temperature conditions of the permafrost are restored. Ordinarily, this takes 1 to 2 months or sometimes even longer.

The production organizations usually cannot meet such requirements and cannot permit the shafts to remain at the disposition of the permafrost scientists for long periods of time. We deem it necessary, therefore, to propose a method for determining the lower permafrost boundary which requires only several hours in all and which can be used during the drilling process without special interruption in the work. The main points of this method are set forth in this article.

In Yakutsk in 1943-1944, P. A. Solov'yev, a scientist at the permafrost station, measured the temperature in a hydraulically drilled shaft. These measurements gave a series of temperature curves (Figure 1) showing the gradual restoration of normal temperature conditions in the shaft during the year following the end of drilling.

The set of curves obtained is extremely interesting and leads to the following conclusions: 1) the temperature throughout the shaft was positive (i.e. above 0°C) when drilling ended; 2) heating of the shaft is a maximum in the upper part and gradually decreases with depth; and 3) the curves have a temperature minimum, a point of inflexion, at a depth coinciding with the actual lower permafrost boundary.

Similar curves were obtained from the hydraulically-drilled shaft at at Yakutsk, and also in a number of shafts at Vorkuta and other points. The coincidence of the point of inflexion with the lower permafrost boundary prompted Solov'yev to assume a general law governing this phenomenon. He advanced this hypothesis only on the basis of field observations, without any attempt at theoretical explanation. Later, however, his assumption was confirmed and as we shall see proved to be easily explained in theory.

Until drilling ends, the temperature throughout a shaft will be approximately equal to the temperature of the solution. The thawring around the shaft will be of the form of a truncated cone with the base turned upwards, i.e. the radius of the thawed area is a maximum at the top and gradually decreases downwards (Figure 2). The thaw ring will be of this form because the upper part of the shaft is flushed for a longer period of time than the lower part.

In accordance with the general theory of heat conductivity, all other conditions being equal, the amount of heat passing through a unit cross-section will be directly proportional to the temperature gradient.

In our case, the speed of restoration of natural temperature conditions in the shaft will be directly proportional to the temperature gradient existing right at the shaft wall, which will be the ratio of the temperature t_p in the shaft to the radius of the thaw ring.

Since t_p immediately after drilling ends is equal throughout the shaft while the radius of the thaw ring is a maximum at the top and gradually decreases with depth to the lower boundary of the permafrost stratum -- then the speed of restoration of natural temperature conditions will naturally be a maximum at the lower permafrost boundary and gradually decrease upwards. The speed of restoration of natural temperature conditions will be a minimum at the top of the shaft. Thus, within a certain time after drilling ends, the temperature distribution with respect to depth in the shaft is expressed by a sloping straight line with a smooth temperature decrease from the upper to the lower permafrost boundaries.

In the thawed stratum underlying the permafrost, the temperature gradient will be equal to the difference between the temperature of the solution and the natural temperature of the thawed ground divided by the radius of the heated area. Since the natural temperature increases downwards from the lower boundary of the permafrost because of the normal temperature gradient, the temperature gradient at the shaft wall in a direction normal to the shaft axis will be maximum at the lower permafrost boundary and gradually decrease downwards.

Thus, the speed of restoration of a natural temperature conditions will also be a maximum at the lower permafrost boundary and gradually decrease downwards. Because of this, within a certain time after drilling ends, the distribution of temperature in the shaft below the lower permafrost boundary with respect to depth will correspond to a sloping straight line with a smooth temperature increase from the lower permafrost boundary downwards. Consequently, within a certain time after drilling ends, an inflexion should be obtained in the temperature curve at the lower permafrost boundary, exactly as is actually obtained (Figure 1).

The preceding considerations show that exact coincidence of this inflexion in shafts with the lower permafrost boundary is a completely regular phenomenon, explainable, and should appear most prominently immediately after drilling ends, when natural temperature conditions have not yet been restored.

Thus, it is no longer necessary to wait until natural temperature conditions are completely restored in the shaft in order to determine the depth of the lower permafrost boundary. It is sufficient to conduct temperature measurements in the shaft several hours after drilling ends in order to obtain a temperature curve with an inflexion which will accurately show the depth of the lower permafrost boundary.

It is interesting to note that the lower permafrost boundary can be determined in a shaft around which the frozen area has thawed completely, and in which positive temperatures are observed throughout the entire depth.

The method cited for determination of the lower permafrost boundary is applicable mainly to icy rock. But since there are no absolutely dry rocks in nature, this method should be extended to all rocks, including

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the so-called dry frozen strata. The difference will consists only in the sharpness of the inflexion in the temperature curve; i.e., the inflexion will be sharp in icy rocks and slight in dry rocks.

from "Merzlotovedeniye" No 1, 1947
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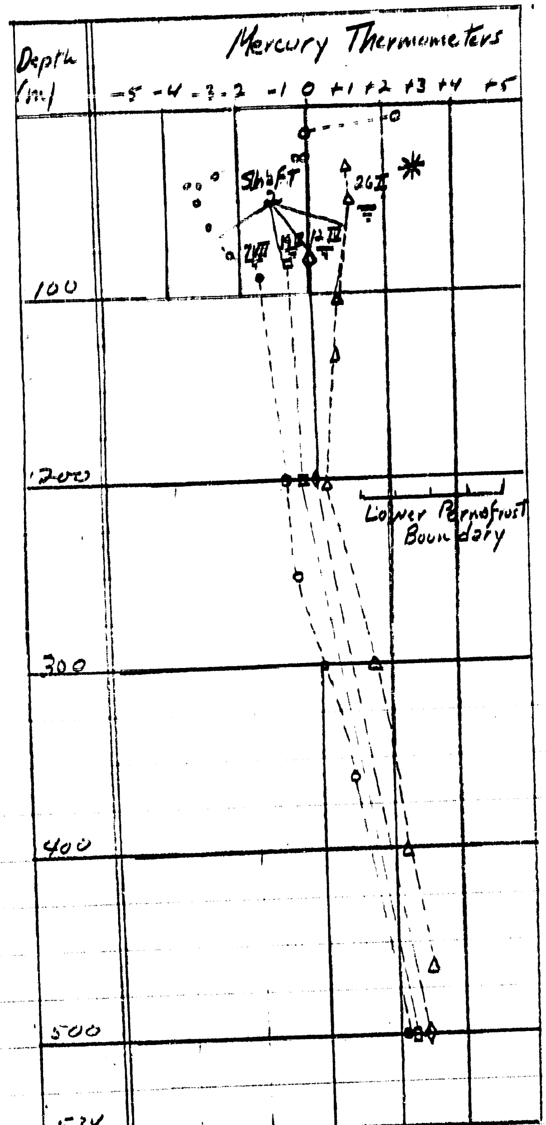

Figure 1 - Temperature Distribution Curves in Shaft 2 (Yakutsk)

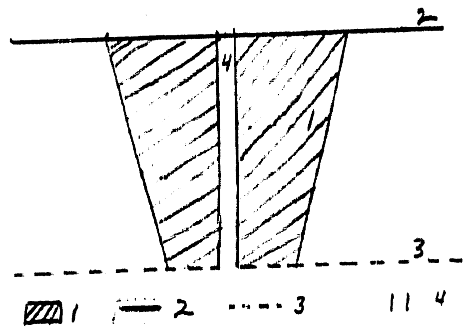

Fig. 2. Schematic Diagram of Thaw Ring Configuration, Obtained as a Result of Drilling Using a Flush in Krelios Shafts
1- Thaw Ring, 2- Upper Permafrost Boundary, 3- Lower Permafrost Boundary, 4- Shaft

(*Note: 26 I etc mean 26 January etc.)

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