MEASUREMENT OF HEAT FLOW THROUGH THE BOTTOM OF THE ARCTIC OCEAN IN THE REGION OF THE MID-OCEAN GAKKEL RIDGE

GEOPHYSICS

1969

SovietRxiv

Abstract

Full Text

UDC 550.361.2

GEOPHYSICS

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MEASUREMENT OF HEAT FLOW THROUGH THE BOTTOM OF THE ARCTIC OCEAN IN THE REGION OF THE MID-OCEAN GAKKEL RIDGE

(Presented by Academician M. A. Sadovskii, 2 XII 1968)

In communication ([1]) the results were given of the first experiment in determining the geothermal gradient and heat flow through the bottom of the Arctic Ocean, obtained on a drifting ice floe using the methodology and apparatus described in ([2]). The measurements were successfully carried out in the region of the Makarov Basin, the Lomonosov Ridge, and also at points close to the position of the North Pole. The results indicated normal values of heat flow in the basin region and an increase of it above the Lomonosov Ridge, on average up to $2.2 \cdot 10^{-6}$ cal/cm^2 • sec. Measurements of heat flow from the Earth' s interior from a drifting ice floe were also carried out by American and Canadian geophysicists ([3],[4]), who obtained a series of normal flow values for the Alpha Rise and the Canadian Plateau.

In the present communication new results are given of investigations in the region of the Gakkel Ridge, which from the geological point of view is of great interest. The Gakkel Ridge is an active median rise of the Arctic Ocean and occupies a medial position with respect to the Eurasian subbasin ([5]). There are suggestions that the ridge is a continuation of the Mid-Atlantic Ridge, i.e., the northernmost fragment of the active system of mid-ocean rises of the World Ocean ([6],[7]).

Associated with the axis of the ridge is a narrow linear belt of epicenters of shallow-focus earthquakes and an intense, though not continuous, positive anomaly ([5],[6],[8],[9]). According to aeromagnetic surveys, a linear structure of magnetic anomalies, symmetrical with respect to the ridge axis, has been discovered (Fig. 1); it encompasses not only the Gakkel Ridge but also the adjoining deep-water Nansen and Amundsen basins. This structure of the field is quite typical of other mid-ocean ridges as well.

Figure 2 presents a physiographic map of the Arctic Ocean and the position

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

of the heat-flow profile on the Gakkel Ridge. This ridge has an incomplete morphological expression in comparison with the Mid-Atlantic Ridge, which is apparently connected with its younger age. As can be seen from Fig. 2, the longitudinal troughs as a whole form an en echelon longitudinal depression or rift valley more than 1000 km long. The amplitude of relief elevations in some sections of the ridge reaches 4000 m. The sedimentary cover within the ridge is thin: from zero to 400 m, whereas in the basins it is up to 4 km.

The typical character of the submarine Gakkel Ridge and its special position on the planet make measurements of heat flow here especially interesting. It was of interest to establish whether, in comparison with the world average value, the heat flow increases in the rift zone of a mid-ocean ridge that has incomplete morphological (or more miniature) development.

The heat-flow measurements were carried out by separately determining the geothermal gradient and the thermal conductivity of the near-bottom layer of sedimentary deposits. Recording of the geothermal gradient was carried out—

···on the bottom by the autonomous installation of the PTT thermoprobe ([2]). Thermal conductivity was studied under laboratory conditions.

The PTT instrument, fastened to a bottom tube or rod carrying temperature sensors, was lowered on a cable through a hole in the drifting ice with the aid of the winch of the *North Pole*. At a height of 100–200 m above the bottom the descent was stopped and, for several minutes, the zero line needed for the subsequent determination of the temperature gradient was recorded. After this the winch brake was released; the recorder container with the probe, at free-fall velocity, reached the bottom, and the temperature sensors penetrated to a certain depth. Thermistors MMT-1, preliminarily calibrated in the laboratory over the working temperature interval from −2 to 1°, were used as sensors. The sensors were mounted on the probe at a distance of 1 m from one another. The characteristics of the sensors were selected to have a high degree of identity.

Fig. 1. Fragment of a sketch map of the anomalous magnetic field of the Arctic Ocean after ([8])

Fig. 2. Physiographic scheme of the Arctic Ocean, compiled from hydrographic measurements, and the position of the heat-flow profile on the Gakkel Ridge (the rectangle marks the position of the heat-flow profile)

Recording of the geothermal gradient during the stay of the installation on the

Fig. 3 and Fig. 4

Figure 3: Fig. 3 and Fig. 4

bottom was carried out for 5-10 min, in accordance with the time required for the establishment of thermal equilibrium disturbed by the process of friction of the probe body and sensors upon entering the bottom. A distinctive methodological feature of work on drifting ice was the possibility of repeated penetration and a double measurement of the temperature difference during a single lowering, while the ice was drifting slowly. The double record made it possible to increase the reliability of measurements of the small geothermal-gradient value. One example of such a record is presented in Fig. 3 for station No. 7 at a depth of 4250 m. In this case the second lowering was carried out after 8 min from a height of 30 m above the bottom. The first excursion on the record is due to the probe entering the

bottom sediments. The spikes after the recording of the gradient line are caused by considerable heating due to friction of the lower sensor during extraction.

The geothermal gradient dT/dz was determined from the amplitude of the working record ΔS_1, the amplitude of the calibrator record ΔS_2, the change in resistance in the calibrator ΔR, the distance between the sensors l, and the value of the temperature coefficient of the thermistors ([1]).

There were 8 accepted stations. The measurement results are given in Table 1 and in Fig. 4, where, for comparison, the profile of the bottom relief, constructed from discrete depth measurements, and the magnetic profile $(\Delta T)_a$ are also shown.

Fig. 3. Example of a record of the temperature difference by a thermogradientograph. *a*—first zero line; *b*—first amplitude of the geothermal gradient; *v*—repeat record (amplitude smaller owing to incomplete penetration of the probe); *g*—second zero line

Fig. 4. Comparison along the profile of the values of heat flow q (curve *a*) and gradient dT/dz (*b*)—upper graph; with the relief of the ocean floor—middle graph; and with the anomalous magnetic field (in gammas)—lower graph

Table 1 gives the values of the temperature gradient dT/dz, thermal conductivity λ, and heat flow q. The thermal conductivity of the sediments was determined from the moisture content of bottom samples by the Ratcliffe method ([2]). High heat-flow values, on the order of $3.0 \cdot 10^{-6}$ cal/cm$^2 \cdot$s, were observed mainly at points above the Gakkel Ridge. Lower values were observed at stations Nos. 1 and 4 (Fig. 4). They are confined mainly to the slope parts of the ridge, where, possibly, the disequilibrium of the near-bottom water layer due to the intensification of bottom currents is making itself felt. At present it is difficult to say definitively whether these reduced values, appearing against the general background of high heat flows, should be associated with manifestations of the indicated regional factors or with some other measurement error.

The maximum measured value of heat flow is $3.7 \cdot 10^{-6}$ cal/cm$^2 \cdot$ s. The average error in the determinations of heat flow is 8%. Comparing the data obtained with the results for the Lomonosov Ridge ([1]), one may note a tendency toward an increase by approximately $1.0 \cdot 10^{-6}$ cal/cm$^2 \cdot$ s in heat flow over the Gakkel Ridge, which as a whole corresponds to general ideas about the genetic difference of these structures. A considerable percentage of high heat-flow values above the Gakkel Ridge

agrees with the results on the crests of other mid-ocean ridges [(2)] on the floor of the World Ocean. It should be noted that, on the basis of the relatively small amount of data on heat flow obtained here (Fig. 4), no conclusion can be drawn about a direct correlation of heat-flow values with the sign or intensity of magnetic anomalies.

Table 1

Table of heat-flow stations in the region of the mid-Arctic ridge

Station No.	North latitude	East longitude	dT/dz, 10^{-3} deg/m	λ, 10^{-4} cal/cm · s · deg	q, 10^{-6} cal/cm^2 · s
1	83°10′	120°10′	13	23.7	0.3
2	83°10′	118°40′	120	24.5	2.9
3	83°10′	118°10′	115	25.0	2.9
4	83°10′	118°00′	35	25.5	0.9
5	83°10′	117°40′	70	23.5	1.6
6	83°10′	116°40′	145	21.5	3.0
7	83°10′	116°20′	150	21.0	3.2
8	83°20′	116°10′	170	22.0	3.7

The authors express their gratitude to A. A. Aleksandrov for improving the design of the recorder, and also to S. K. Nemilov for assistance in carrying out the work.

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Received
2 XII 1968

CITED LITERATURE

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