# 23. GEOTHERMAL STUDIES LEG 31, DEEP SEA DRILLING PROJECT

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## INTRODUCTION

Studies of marine heat flow, which consist of measurements of geothermal gradient and thermal conductivity, have been carried out energetically all over the world's deep oceans. In general, however, these measurements are limited to within several meters from the sea bottom surface. Therefore, there is some uncertainty as to whether the measured value represents true terrestrial heat flow. It has been proposed that the influence of heat generation due to chemical reactions within sedimentary portion very near to the sea bottom surface may be serious (Kobayashi and Nomura, 1972). The most direct means to examine the reliability of surface heat-flow data is to take measurements from as deep as possible in the sea bottom. If it can be shown that observed heat flow varies with depth from the sea bottom surface, even at the deep ocean floor where the present sea bottom temperature is stable enough, important information will be obtained about the thermal state of the ocean floor.

The method for measurement of subbottom temperature in deep-sea drill holes was developed at Woods Hole Oceanographic Institution (WHOI). The first results were published in the Initial Reports, Volume 8 by Von Herzen et al. (1971).

## OPERATIONS

Thermal conductivity was measured on the least-disturbed sedimentary sections of cores by means of both the laboratory needle probe method using shipboard apparatus developed by WHOI and Ratcliffe's water content method, following DSDP standard procedures.

The geothermal gradient was determined by measuring bottom-hole temperatures at several depths during drilling by using the down hole instrument (DHI). The DHI temperature probe was attached rigidly to the bottom end of the core barrel and sent down on the wire line. Drilling and coring is not attempted during this procedure. DHI temperature measurements were made at Sites 297, 298 and 301.

[1]Heat Flow Unit = $10^{-6}$ cal/cm$^2$ sec.

### Site 297

DHI measurements in Hole 297A were attempted at 77 meters (Figure 1) and 153 meters below mudline (Table 1), however, the record obtained from 153 meters was not usable. Since no cores were taken from Hole 297A, thermal conductivity was determined from the cores of Hole 297.

### Site 298

DHI temperature measurements were attempted at depths of 60 and 98 meters in Hole 298A. Unfortunately, at 98 meters due to time loss by winch trouble the temperature record after bottom penetration was interrupted. At 60 meters, in spite of considerable vertical movement of the ship by big swells due to approaching tropical depression Ellen, little disturbance is observed on the obtained temperature record (Figure 2).

No cores suitable for thermal conductivity determination were obtained in the upper 60 meters in either Hole 298 or Hole 298A. The thermal conductivity values were estimated from the nearest surface heat-flow stations, measured earlier (Yasui et al., 1965, 1970) and from the shallowest sediment section of Hole 298.

### Site 301

DHI temperature measurements were attempted at 126.5, 184.5 and 224.5 meters. At 126.5 meters, the quality of the record obtained is quite satisfactory (Figure 3). At 184.5 meters, the temperature record obtained was highly influenced by leakage of seawater into the thermistor probe, however, the bottom-hole temperature was managed to be estimated under several assumptions as discussed in the site report chapter (Chapter 12, this volume). At 224.5 meters, no temperature record was obtained because of serious water leakage into the thermistor probe.

Due to the large amount of gas released from the sediment, many cracks developed within the core samples. This may have influenced the measured thermal conductivity values, although the average of all thermal conductivity values at this site, $1.68 \times 10^{-3}$ cal/cm sec°C, is consistent with earlier measured surface data (Yasui et al., 1968, 1970). Possibly, the true thermal conductivity values should be slightly higher than the values listed in the Site Report (Chapter 12, this volume) and in Table 1.

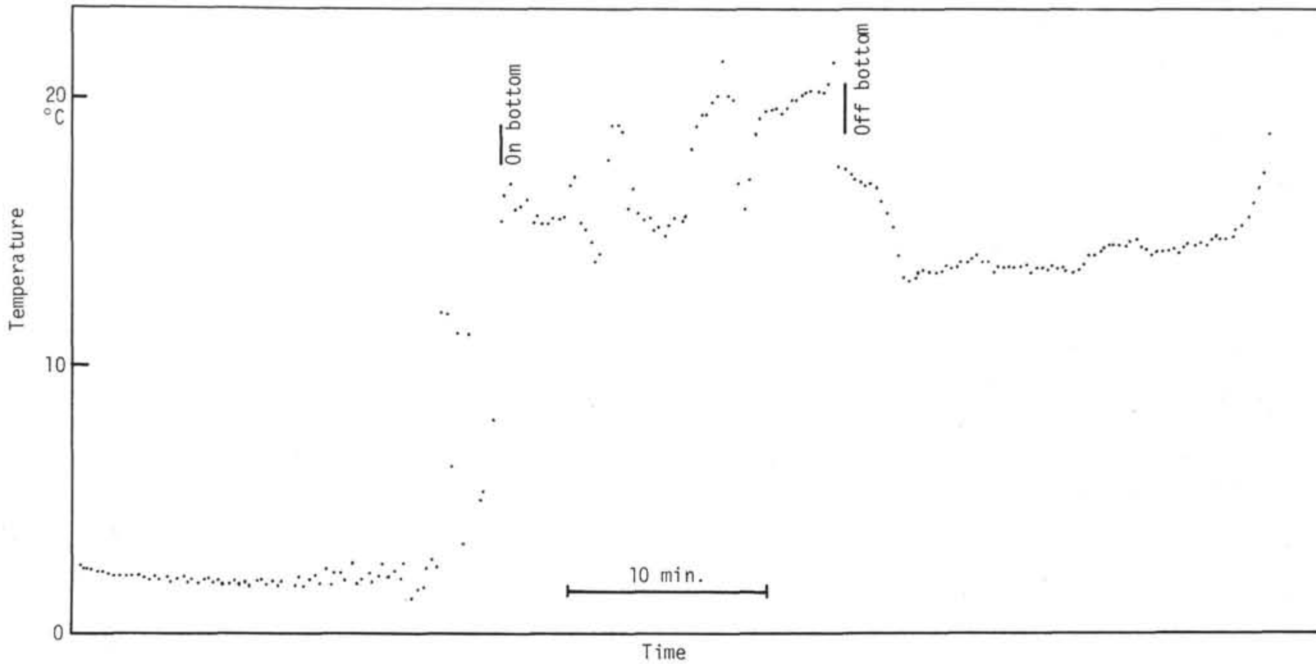


Figure 1. *Temperature record at Hole 297A, 77 meters below mudline.*

**TABLE 1**
**Summary of Leg 31, Heat-Flow Measurements**

| Hole | Location Latitude | Location Longitude | Echo Depths (m) | Hole Depth (m) | Temperature (°C) | Thermal Gradient ($10^{-3}$ °C/cm) | Thermal Conductivity ($10^{-3}$ cal/cm sec °C) | Heat Flow ($10^{-6}$ cal/cm$^2$ sec) |
|---|---|---|---|---|---|---|---|---|
| 297A | 30°52.36′N | 134°09.89′E | 4458 | 0 | 2.0[a] | | | |
| | | | | 77 | 14.0 | 1.56 | 2.03 | 3.17 |
| | | | | 77 | 22.0 | 2.33 | | 4.72 |
| | | | | 153 | Malfunctioning instrument | | | |
| 298A | 31°42.93′N | 133°36.22′E | 4622 | 0 | 1.4[a] | | | |
| | | | | 60 | 5.19 | 0.64 | 2.2[a] | 1.4 |
| | | | | 98 | Bottom-hole temperature was not recorded | | | |
| 301 | 41°03.75′N | 134°02.86′E | 3520 | 0 | 0.3[a] | | | |
| | | | | 126.5 | 15.5 | 1.20 | 1.68 | 2.02 |
| | | | | 184.5 | 22.4[a] | | | |
| | | | | 224.5 | Water leakage into the probe | | | |

[a]Estimated value.

## RESULTS AND DISCUSSION

The records of DHI temperature and needle probe thermal conductivity were processed at Meteorological College of Japan Meteorological Agency with an HITAC-10 computer by Prof. M. Yasui. The obtained temperature records and the heat-flow data are summarized in Figures 1, 2, and 3 and Table 1.

At Hole 297A (hole depth 77 m), two interpretations for the temperature value are listed because of the wide range of variance of the reduced temperature data. Considering that the temperature record indicates a tendency of increasing temperature fluctuation before penetration into the hole bottom and that the temperature records before penetration and after pull out are not consistent even considering the effect of water circulation within the drill pipe, the reliability of the result obtained cannot be very high. However, the reliability is high for Hole 298A (60 m), and Hole 301 (126.5 m). The temperature result at Hole 301 (184.5 m) is listed only for the sake of reference, and is not used in the computation of heat flow, although it is quite consistent with the value obtained.

Results of surface heat-flow measurements taken earlier (Yasui et al., 1968, 1970) in the areas concerned are summarized in Figures 4 and 5 along with the present Leg 31 data.

In the Philippine Sea, one of the most characteristic features of heat-flow distribution is that localized anomalies are distributed in a highly complex way, generally with sharp boundaries. Considering the low accuracy of position determinations, most of which were made with Loran A, a high reproducibility of the values

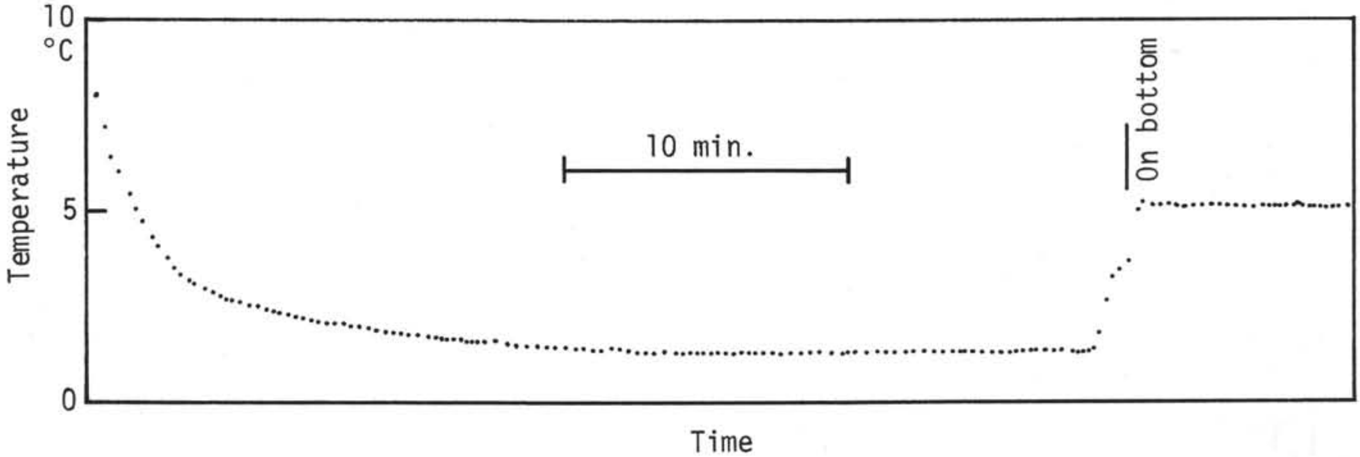


Figure 2. *Temperature record at Hole 298A, 60 meters below mudline.*

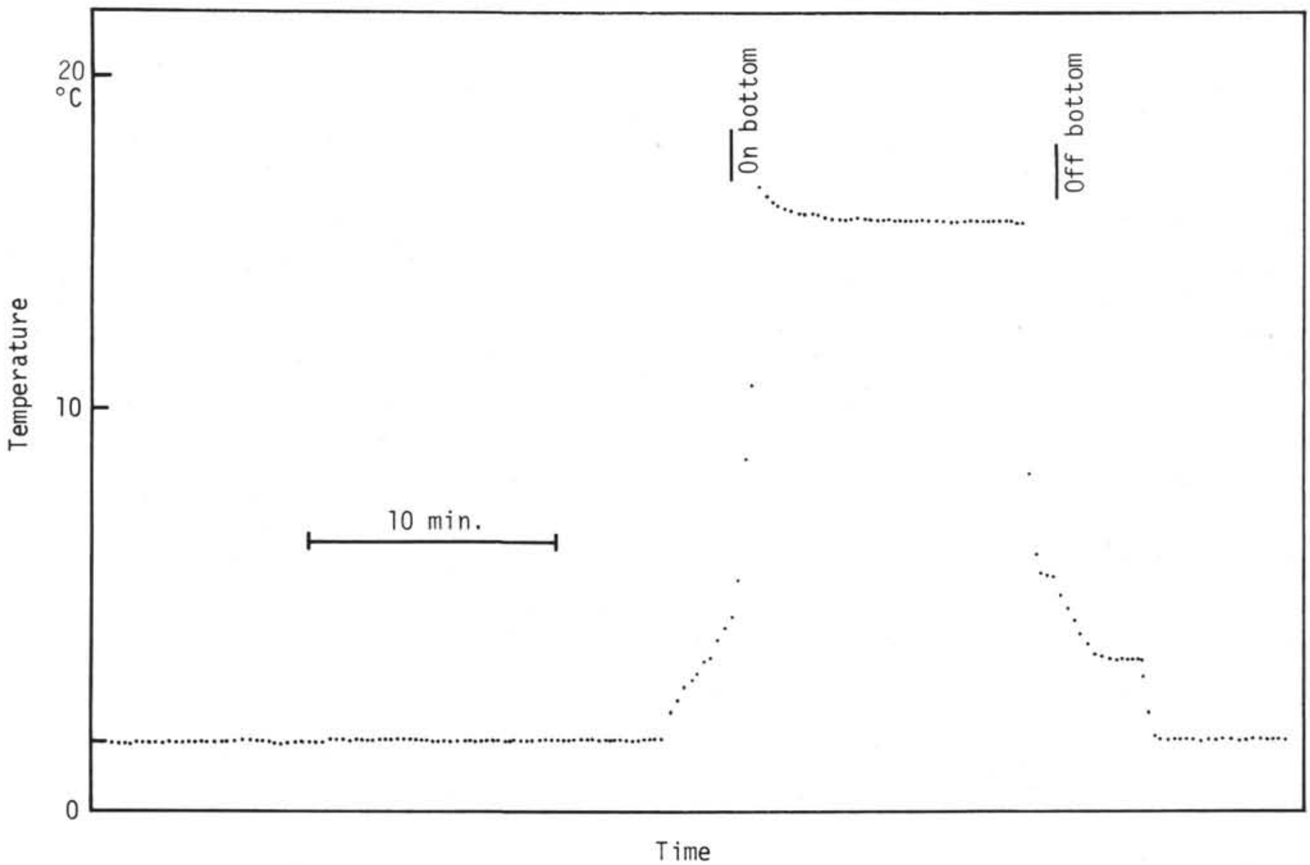


Figure 3. *Temperature record at Hole 301, 126.5 meters below mudline.*

obtained earlier (Yasui et al., 1968, 1970) cannot be expected. At present, it is hard to evaluate the inconsistency of the heat-flow values at Holes 297A and 298A with the earlier measured surface data. The quality of data from Hole 297A is not so high as to allow such comparison. However, the relatively low value at Hole 298A is comparable with another low value, 1.16 HFU,[1] also on the northern wall of the Nankai Trough, and can be explained by folding of the sedimentary layer or slumping of the wall sediment. Unpublished surface heat-flow data support this view.

In the Japan Sea, heat flow is very uniform and the reproducibility of the earlier measured values is high, for the most part within 10%. Unfortunately, however,

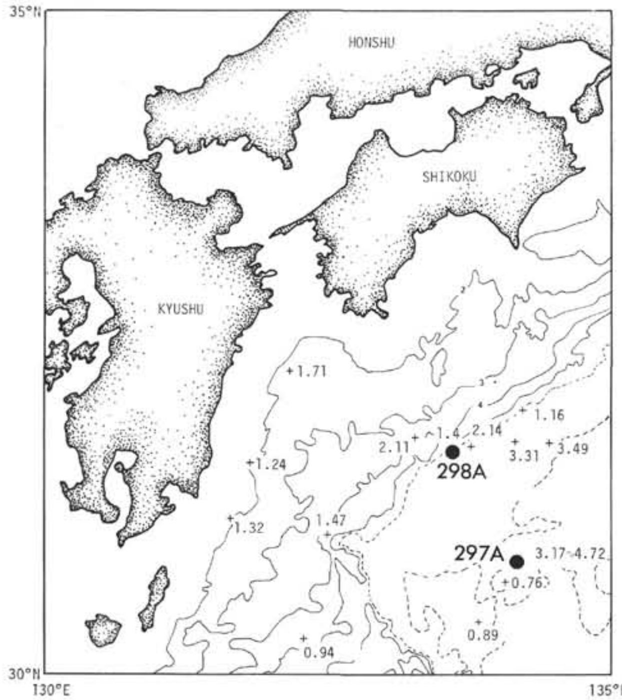


Figure 4. *Heat-flow distribution around Sites 297 and 298. Units of heat flow and depth are in $10^{-6}$ cal/cm$^2$ sec and km, respectively. Solid line indicates isobath of bottom depth after Chart 6302. Surface data are from Yasui et al. (1970) and Watanabe et al. (1970).*

there is no earlier measured surface data available for Site 301. The nearest reliable earlier measured stations show 2.03 HFU at 41°15′N, 133°35′E and 2.54 HFU at 40°56′N, 133°50′E. However, these stations are almost 25 miles apart. The value from Site 301, 2.02 HFU, is very consistent with the former value, but 20% or 0.52 HFU lower than the latter one. The amount of exothermic effect of oxidation of iron sulfides is estimated to be 1 HFU by Kobayashi and Nomura (1972). Although the heat flow at Site 301 is based on only one reliable downhole temperature measurement, it is comparable with the mean of the three nearest values obtained by oceanographic techniques (2.16 HFU), suggesting that the effect of iron sulfide oxidation on surface heat flow at this site is not as large as 1 HFU.

## ACKNOWLEDGMENTS

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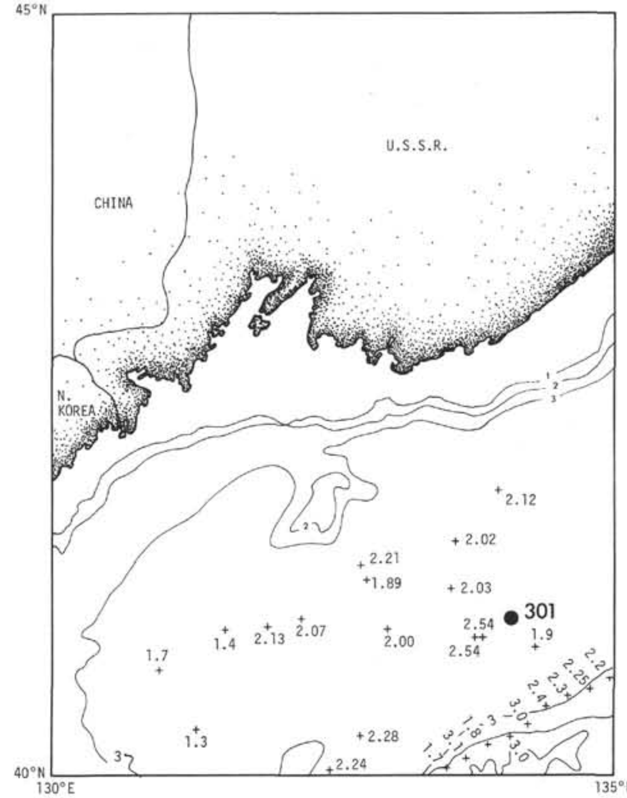


Figure 5. *Heat-flow distribution around Site 301. Units of heat flow and depth are in $10^{-6}$ cal/cm$^2$ sec and km, respectively. Solid line indicates isobath of bottom depth after Chart 6301. Surface data are from Yasui et al. (1968).*

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