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Report on DELP 1987 Cruises in the Ogasawara Area
Part VI: Heat Flow Measurements

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Abstract

Some heat flow measurements were conducted during the DELP 1987 cruise in the Ogasawara Trough. Good penetrations of the heat flow probe were infrequent during this cruise. The present data are combined with previous works. It is shown that the Ogasawara Trough presents, in general, relatively low heat flow values. This agrees with the view that rapid burial of the basement materials occurred after the cessation of rifting as suggested by seismic profiler study by the same cruise.

1. Introduction

Late in the fall of 1987, as a part of DELP (Japanese International Lithosphere Program), geophysical and geological surveys were carried out around the Ogasawara Trough. The trough region is known to be hostile to heat flow measurements because of its sandy bottom. We obtained several heat flow values along a N-S track line parallel to the trough axis. A list of data is presented in this article and they are plotted in the areal map in comparison with other previous data. The heat flow stations of the present survey are shown in Fig. 1.

Heat flow in western Pacific basins (including the Japan Sea Basin, Shikoku Basin, Philippine Basin and Parece Vela Basin) has been studied extensively to determine their tectonic features and ages based on the thermal state of the lithospheric plate in these basins. It is shown using the heat flow data (e.g., YAMANO and UYEDA, 1988) inplemented in the

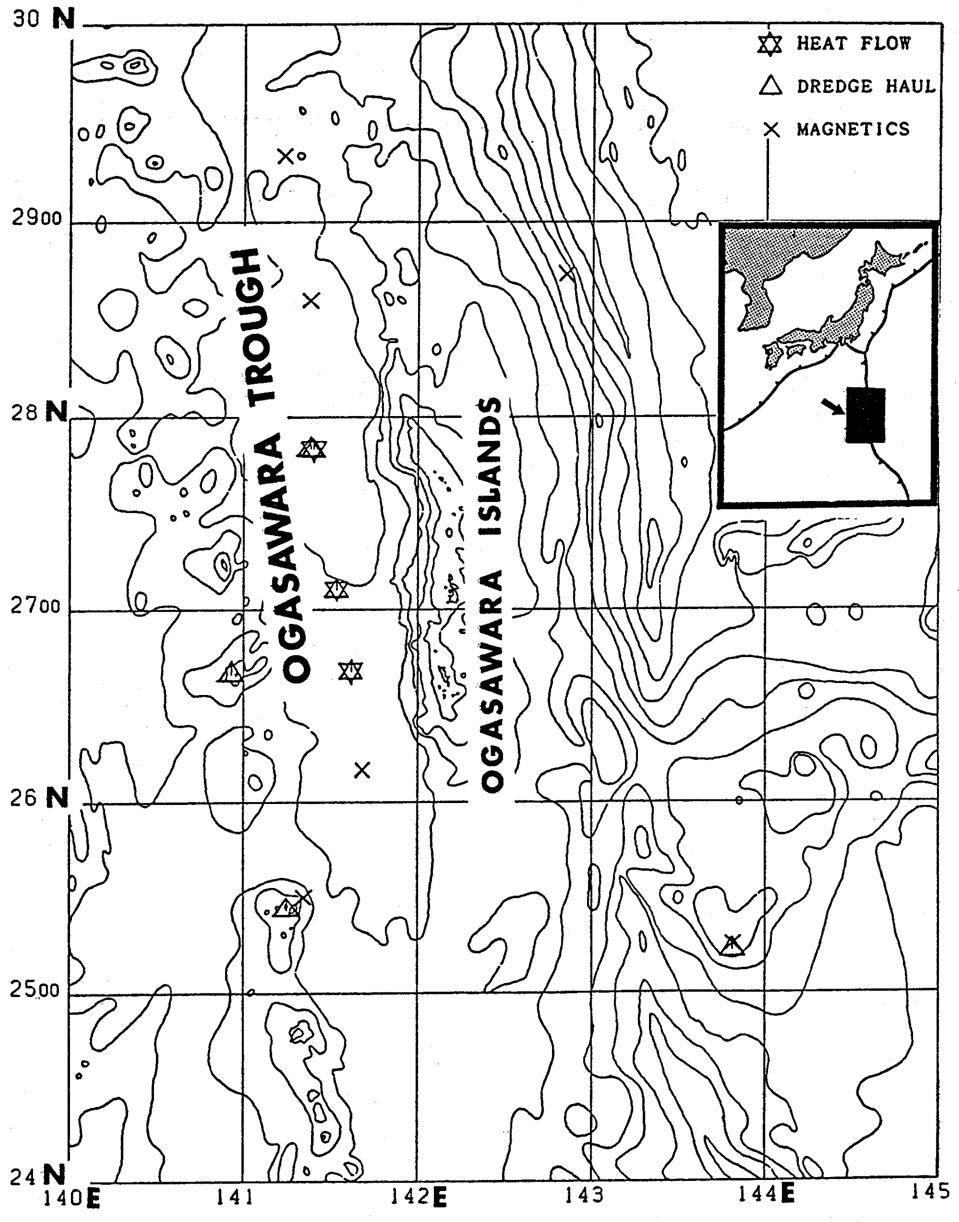


Fig. 1. Stations for heat flow measurements, dredge hauls and magnetic calibration for geomagnetic field surveys for the DELP 1987 cruise in the Ogasawara Trough area. Items are indicated by number of symbols in the legend.

MAGBAT system (Geophysical digital data tool, NAKANISHI *et al.*, 1987) that the Shikoku Basin and the western part of the Philippine Basin to the west of the Ogasawara Trough show highly variable heat flow values. This feature is caused not only by the small number of measurements but possibly by the existence of hydrothermal circulation systems functioning in these basins as discussed by NAGIHARA *et al.* (1989) for the northern part of the Shikoku Basin.

The Ogasawara Trough is characterized by southward deepening of negative free air gravity anomaly in spite of northward dipping of the bathymetric depths in the trough. This feature could have been formed by accumulation of the sediment which is thicker toward the south in the trough as discussed elsewhere (Part II, this issue). The origin of the turbid materials occupying the southern half of the trough was clarified by a series of Seabeam mapping surveys performed by the Hydrographic Department, Japan Maritime Safety Agency (KANEKO *et al.*, 1988 ; KASUGA *et al.*, 1988 ; Maps from JMSA ; unpublished) as well as a DELP cruise (Part II, this issue). The acoustically opaque sediment is believed to be a part of the volcaniclastic materials which erupted around Iwojima and were transported northward to fill deeper (southern) part of the trough basement.

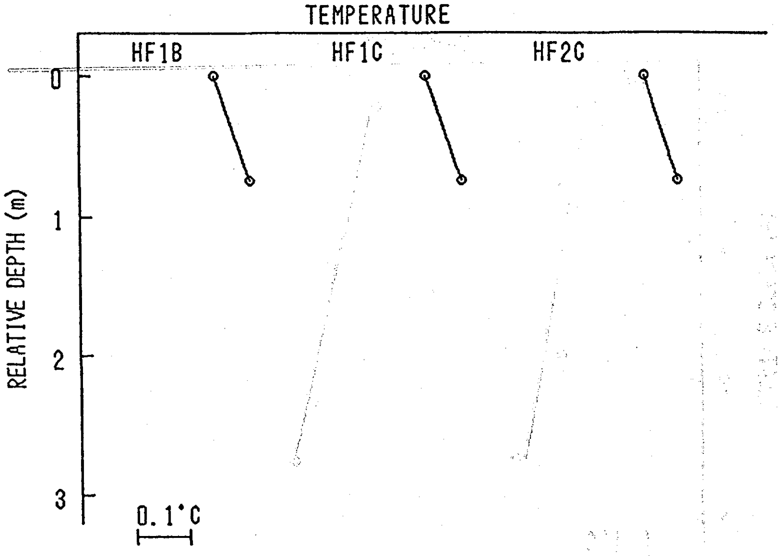
The heat flow values available to date from the trough area seem to be relatively low in the central part, probably due to a large sedimentation rate after rifting of the trough. This reasoning has to be tested by making more measurements of various geophysical parameters. The purpose of the present report is to add some heat flow data obtained in the southern part of the trough area by the DELP 1987 cruise.

2. Measurements and results

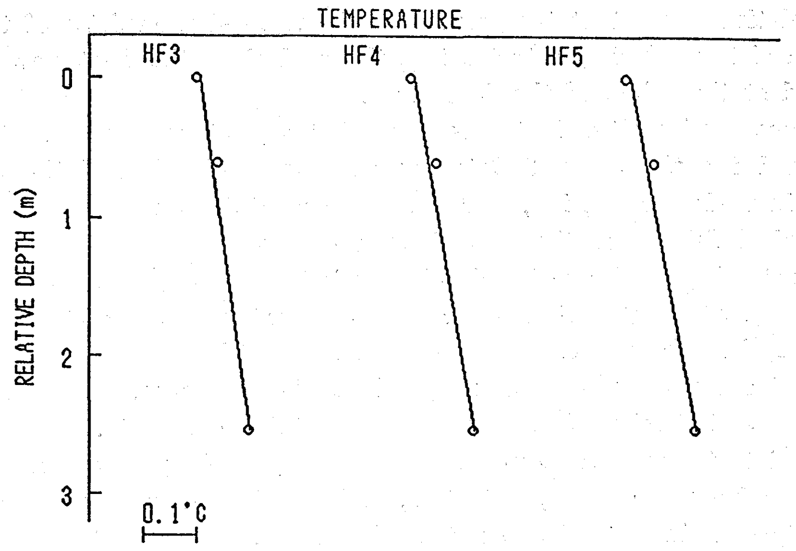
Measurements of subbottom temperature profiles were made using a multi-penetration type probe attached to a recording system in a pressure vessel which can stand water pressure as high as 120 MPa. Temperature sensors (thermistors) are mounted on a number of bladeshaped holders made of stainless steel attached along a strengthened steel shaft (Ewing type ; GERARD *et al.*, 1962). In addition to the temperature profiles versus depth profiles, we have to collect thermal conductivity (K_{sed}) data to deduce heat flow values. In situ thermal conductivity measurements were attempted in this cruise with poor success due to poor signal to noise ratio of the electronics hardware. No core sampling of bottom materials for thermal conductivity measurements was attempted and we do not have thermal conductivity data from our own experiment on the DELP 1987 cruise. Therefore, we assume that the thermal conductivity values of the bottom sediments at our stations can be represented by that from a 110 cm long sedimentary core recovered from the trough area ($K_{sed}=0.810$ W/m*K from station No. 5; MATSUBARA, 1981). Other examples can be obtained from MATSUBARA (station No. 6 and 10) and VACQUIER *et al.* (station No. 60; 1966) from the vicinity of the Ogasawara Trough. However, it is likely that the sedimentary materials from the bottom of the trough show K_{sed} values significantly lower than those from these other cases. For example, the average value and the dispersion of the K_{sed} from these four stations (including station 5 of MATSUBARA) is 0.852 ± 0.015 compared to 0.815 W/m*K of station 5 of MATSUBARA. Our station is geographically as well as geologically close to station No. 5 of MATSUBARA and, therefore, we take this piece of data as the only one available and suitable for the present calculation in converting the subbottom temperature gradient to a heat flow value. It is noted that the conductivity value used by MATSUBARA (1981) was obtained on board at normal pressure and temperature and no corrections were applied for water depth and bottom temperature.

Heat flow stations and heat flow values of the present cruise are obtained in the following way. Three groups of heat flow stations were taken. Multiple penetrations within a short distance due to drift of the research vessel during repeated penetration were grouped separately. Stations 1-A, 1-B and 1-C form one group, 2-A, 2-B and 2-C a second group, and stations 3 through 8 a third group.

The temperature gradient versus subbottom depth graphs obtained from eight heat flow penetrations are presented in Fig. 2a, b and c, respectively. Some of the graphs were prepared from only a couple of data points due to poor penetration of the temperature probe. The trend of relative temperature variation with subbottom depth (penetration depths) are plotted with open circles. Straight lines represent an eyeball fitting among plots of temperature versus depth from each penetration of the temperature probe. Station 1 (only two successful trials) and station 2 (one good trial) give unique temperature versus depth relations. Though the data set gives poor reliability from the first and second groups, the temperature gradients from these groups are obtained simply. Stations of group three (No. 3 through 7) gives five successful trials and, therefore, all these data are put together in one (relative) temperature versus penetration depth relation. In this case, the penetration depth is also used in

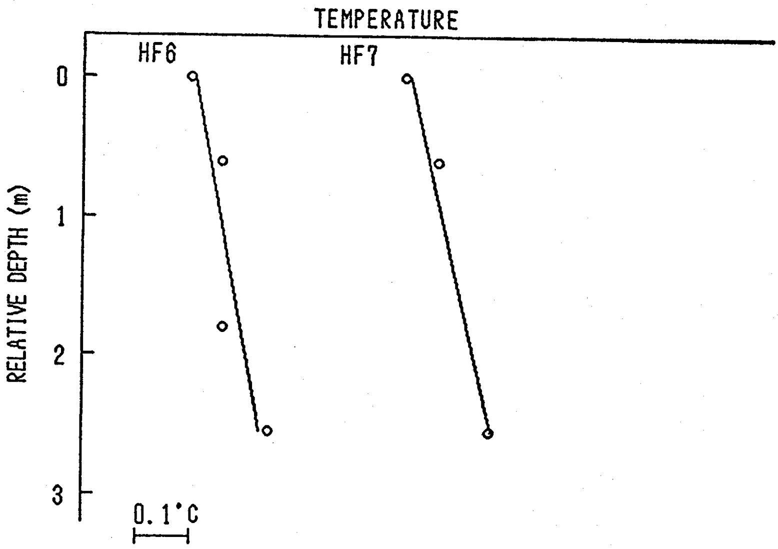


(a)



(b)

Fig. 2. Sub-bottom temperature gradients observed by the present study in the Ogasawara Trough. a: from stations HF1 and HF2, b: stations HF3, HF4 and HF5, and c: stations HF6 and HF7.



(c)

the relative sense that the position of the topmost thermistor of the set of thermistors which penetrated into the mud along the heat flow probe is fixed at the origin of the depth axis.

Some nonlinearities in the relation of temperature versus depth can be found for the group 3 data. The reasoning of this variation can be given in various ways, i.e., as due to some effect of pour water circulation, mechanical failure of the thermistor sheath when it hit the sea floor, mulfunctioning of electronics circuits by jostling shocks and so on. We have no way to relate this tendency to some particular cause at this stage of analysis. Therefore, we apply usual statistical methods to obtain apparent sub-bottom temperature profiles from these measurements.

Two statistical measures are applied to this set of data. One way is to calculate temperature gradients for every possible pair of thermistor sensors within a single penetration, and simple statistics are applied to the data set. The other way is to apply a laast square fit to the integrated plots of this third group of data to obtain a linear curve approximation. The dispersion of the gradient can be obtained in a similar manner as in the case of simple statistics (e.g., \$1-7; HAMMING, 1977; translation by MIYAKAWA and IMAI, 1980). Because all the data at zero relative sub-bottom depths are plotted at the origin of the vertical coordinate in the present calculation, a difference between these two statistical methods is that the former calculation treat all pairs of temperature gradients alike, while in the latter case data from deeper subbottom depths are weighed more heavily. We prefer to use the temperature gradient from the least square fit treatment.

The description of heat flow stations and the measurement trials are given in Table 1. Results of heat flow values obtained by the present calculations using an assumed thermal conductivity and the statistically deduced subbottom temperature gradients are given in Table 2. Heat flow values are plotted in Fig. 3 together with other data available through the MAGBAT system (NAKANISHI *et al.*, 1987). Circles in the figure represent the magnitudes of heat flow values, the radius of each circle is propotional

Table 1. Location, water depth of heat flow stations of DELP 1987 cruise are listed. Information on penetration of the heat flow probe is given.

HF station	Location*		Water depth	Penetration
Number	Lat. (deg. N)	Long. (deg. E)	(m)	(m)
HF1-A	26-41.11	141-36.92	3695	no good
HF1-B	26-40.96	141-37.02	3645	1.5
HF1-C	26-40.85	141-37.12	3633	1.5
HF2-A	27-06.15	141-31.68	3990	no good
HF2-B	27-06.04	141-31.60	3990	ditto
HF2-C	27-06.04	141-31.53	3985	1.5
HF3	27-49.87	141-23.97	4135	3.5
HF4	27-49.93	141-23.79	4135	3.5
HF5	27-49.90	141-23.61	4135	3.5
HF6	27-49.89	141-23.43	4135	3.5
HF7	27-49.85	141-23.24	4135	3.5
HF8	27-49.72	141-23.08	4130	no good

Table 2. Sub-bottom temperature gradients, thermal conductivity (assumed and taken from MATSUBARA, 1981) and heat flow values of three groups of heat flow stations calculated from good penetrations of the temperature probe.

Group	Stations (HF)	Average dT/dT (K/m)	Ksed (W/m*K)	Heat Flow (mW/m^2)
1	1-B, 1-C	85.5+/−0.5[a]	0.81[d]	69.2+/−0.4
2	2-C	79 +/− −[b]	0.81[d]	64.0+/− −
3	3 through 7	48.6+/−0.6[c]	0.81[d]	38.9+/−0.5

a: Simple upper and lower limits.
b: No qualification of error is given.
c: Deduced from dispersion factor of temperature gradient.
d: Assumed from MATSUBARA, 1981.

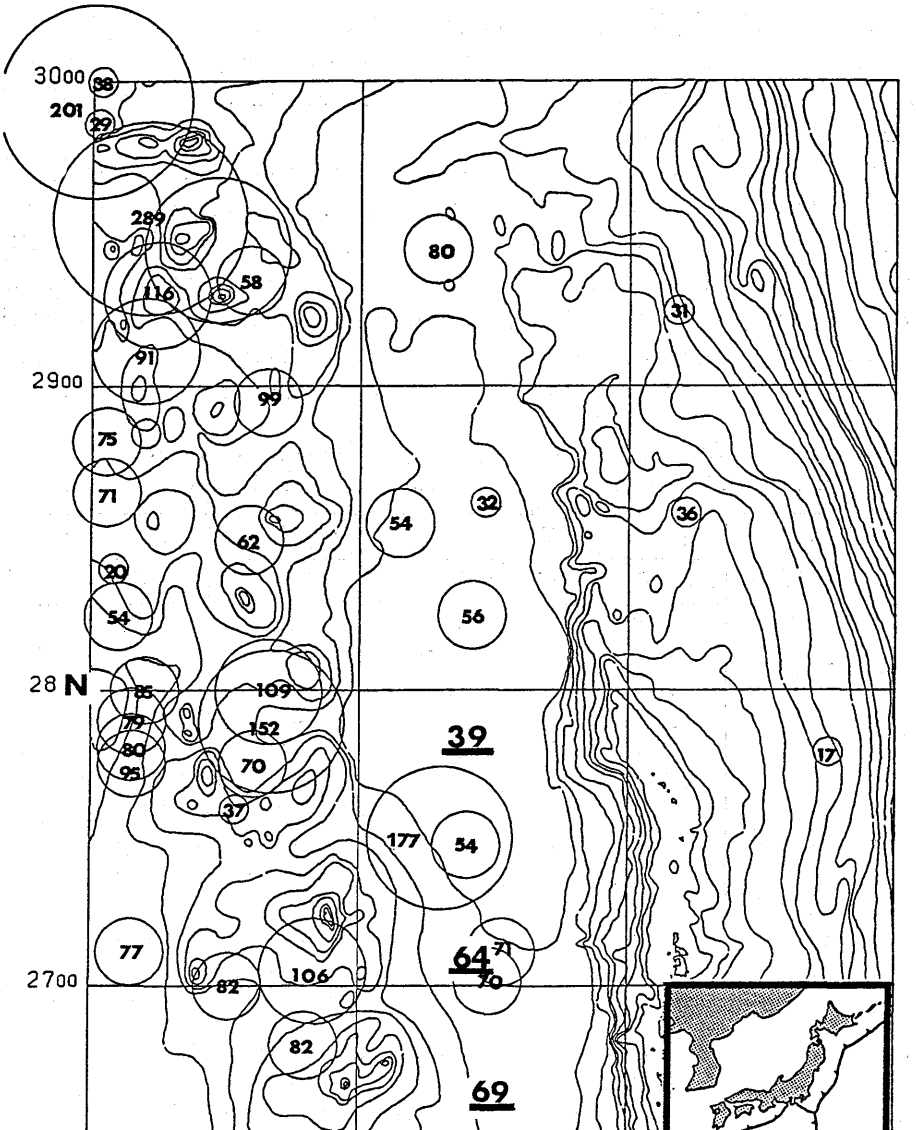


Fig. 3. Distribution of heat flow values available so far through the MAGBAT data system (see text). Heat flow values obtained by the present study are shown with boldface numbers underlined to distinguish them from previous data. Results from station HF1, station HF2 and stations HF3 through HF7 are presented separately. Details are referred to in the text.

(non-linearly but is monotonically increasing order) to heat flow values obtained from the point at the center of the circles. The heat flow values given in Table 2 from the present study are put in the figure also in underlined boldface numbers.

3. Summary

Characteristic features of the heat flow distribution of the Ogasawara area are summarized as follows in reference also to other previous data.

1. Heat flow values become minimum on the land-ward slope of the Ogasawara Trench.

2. Between the Ogasawara Ridge and the western rim of the Ogasawara Trough, heat flow values are relatively low, ranging from 30 to 70 mW/m^2. The value jumps up to 150–170 mW/m^2 near the Shichito-Iwojima Ridge reflecting volcanic activity in the present.

Low heat flow values along the axial part of the trough could be due to thick sedimentation in the trough area after the end of the rifting process. We have only poor information about detailed sediment sequences and structures, and the age of rifting associated with plutonic and volcanic activities of the area. Some hydrothermal system must be one of the biggest factors for controlling the heat flow distribution. These problems can only be discussed after accumulation of more heat flow data and related documents on deep seated structures of the area.

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DELP 1987年度　小笠原海域航海報告

VI.　地殻熱流量探査

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1987年の DELP 小笠原トラフ海域航海において海底地殻熱流量の測定が行われた．この航海での測定値で有効なものは余り多くないが，得られた結果に付いて報告する．今回の測定は過去に得られたデータに新たな測点を加えたに過ぎないが，小笠原トラフ内での海底地殻熱流量は一般的に低めの値を示すようである．このことと本報告第II部の海底音波探査記録についての記述にも有る様に，リフティング後の大量な堆積物によってトラフ基底層が急速に覆われた為ではないかと思われる．