Geological Survey of Japan Cruise Report No. 21, p. 49-55, 1986

V. HEAT FLOW MEASUREMENTS IN THE CENTRAL PACIFIC BASIN (GH81-4 AREA)

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Introduction

The program of heat flow measurements in the central Pacific by the Geological Survey of Japan has been carried out since 1980. In the central Pacific, previously reported data were scarce. The objective of our program is to clarify the detailed distribution of heat flow on the Mesozoic oceanic crust and the relation to other geological factors.

This paper presents twelve new heat flow data obtained from a 70 × 50 km study area centered at 3° N, 169° 40'W (GH81-4 area), and discusses about the difference between the observed and the theoretical heat flow. Possibility of pore water convection through sediments is examined. The age of the oceanic crust of the study area is not exactly clear, but it is estimated to be about 125 Ma from magnetic anomalies around the area (ISHIHARA and YAMAZAKI, in this report).

Measurement

For measuring the thermal gradient in the sediments below the sea-floor, a piston corer of 8 m in length along which three thermistor probes are mounted in outrigger fashion with about 1.5 m intervals was used. Data on temperatures are stored on a recorder settled in the hollow weight of the corer. A brief description of our apparatus is given in MATSUBAYASHI (1982). The accuracy in the temperature difference determination is within 0.01° C.

The temperature profiles in the sediments are presented in Fig. V-1. As the accurate depth to which a corer penetrated could not be known, a distance from the uppermost thermistor is given in the figure. The absolute depth of the uppermost thermistor is estimated to be about 4 m from the length of the cored sediments and a mud adhered to the core-barrel. Straight line was fitted by the least squares method for calculating the thermal gradient except for the stations where only two thermisters were active.

Thermal conductivity of half-split cores was measured by QTM (Quick Thermal Conductivity Meter, Showa Denko Co.) at every 30 to 50 cm. Samples were covered with thin plastic film (commercial transparent food-wrapping film) not to be dehydrated. The effect of this film to the conductivity is negligible (SASS *et al.*, 1984). Measurements were done on board as soon as the thermal steady state was attained at about 22° C several hours after the core was taken. As shown in Fig. V-2, there are little changes in the thermal conductivity along one core or among them. It reflects the uniform lithology of the sediments (siliceous clay or ooze).

Results of the heat flow measurements are summarized in Table V-1. The position of the measurements and the heat flow values are superimposed on a bathymetric chart in Fig. V-3.

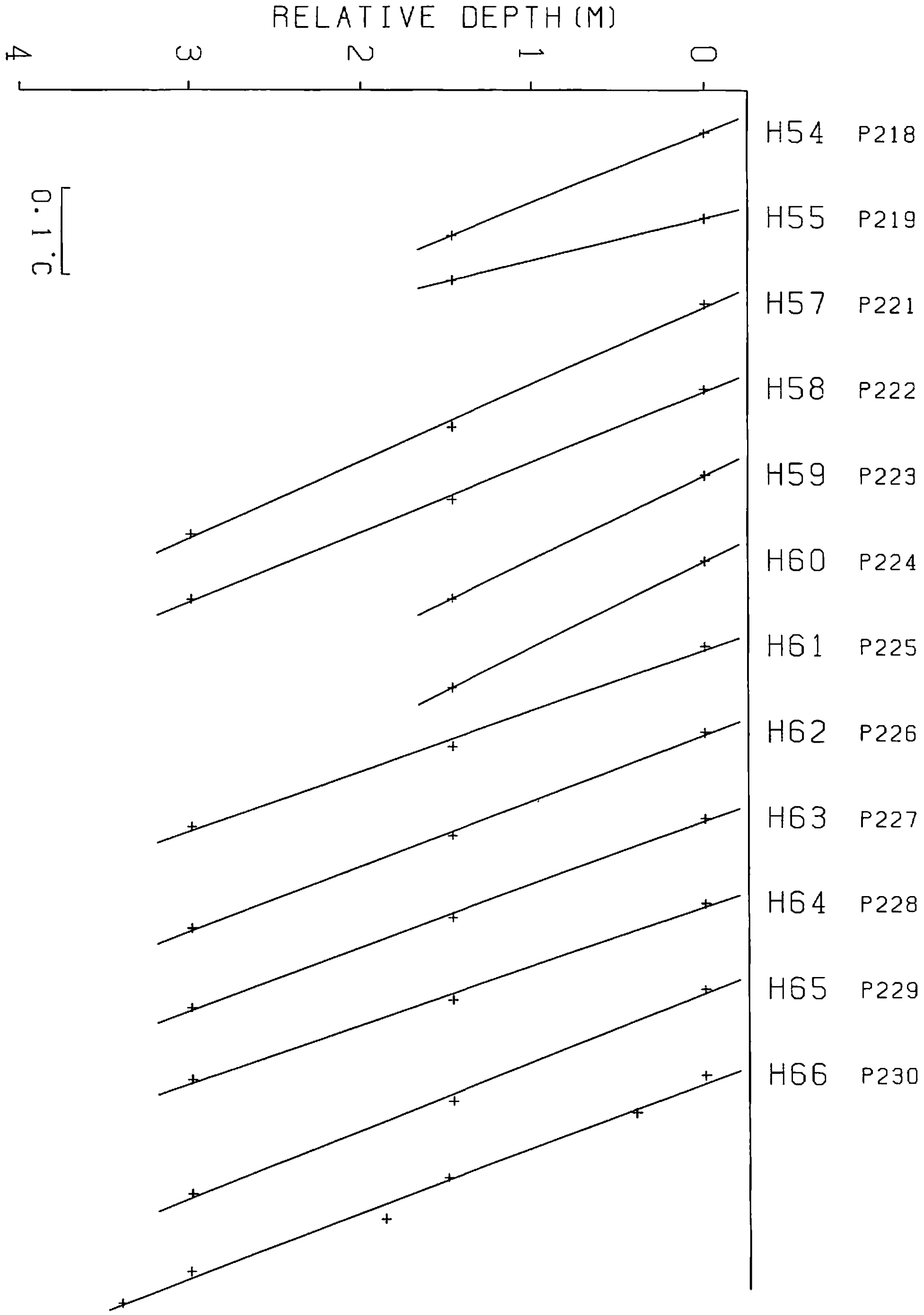

Fig. V-1 Temperature profiles in the sediments. Distance from the uppermost thermistor is given in the vertical axis. Lines are the best fitted linear relations, but it is possible to interprete them as slightly non-linear (upward convex).

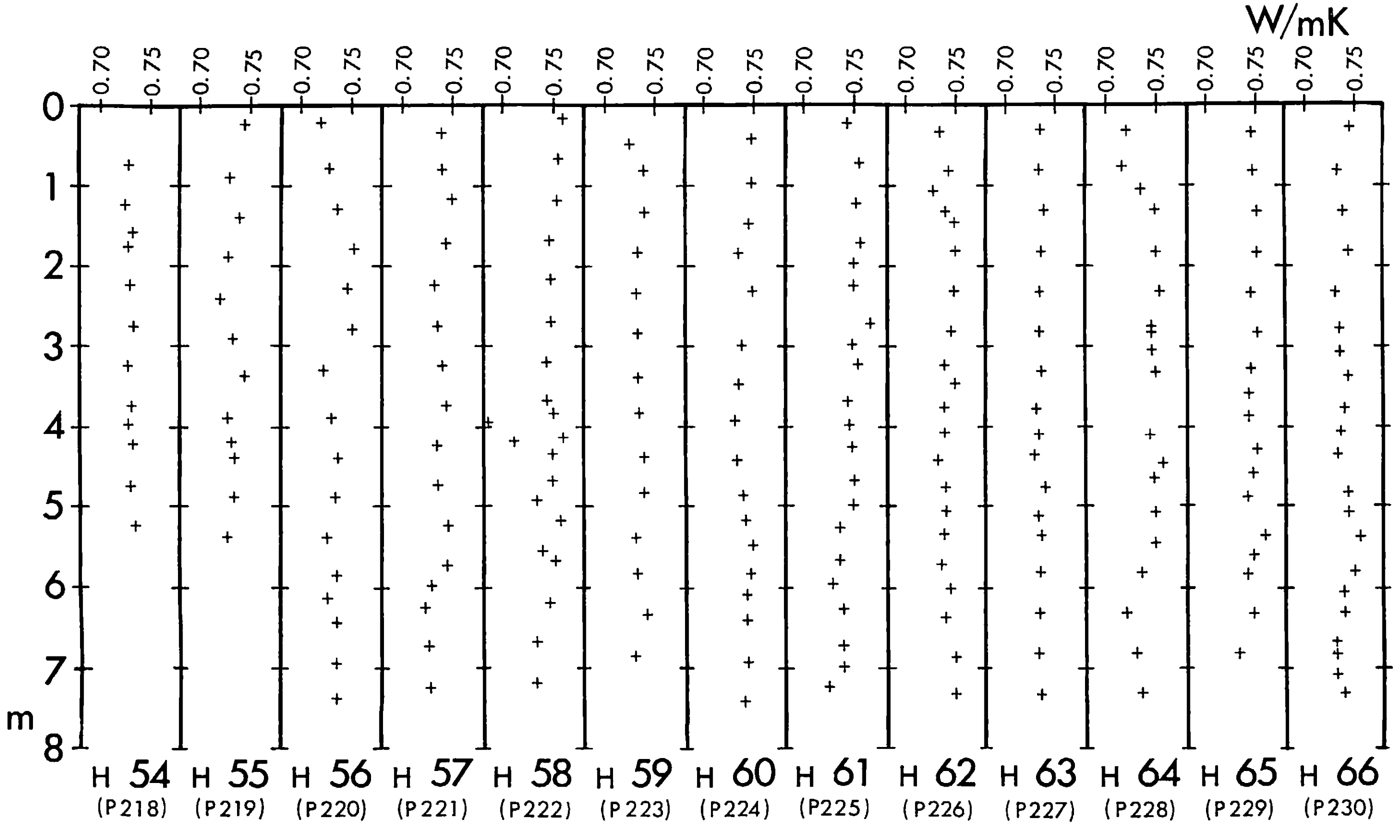

Fig. V-2 Thermal conductivity of the sediments after the correction for the differences of temperature and pressure between in situ and on-board laboratory condition (RATCLIFFE, 1960).

Table V-1 Summary of heat flow measurements.

Station	Position	Depth m	E.Q.F.	N	dT/dZ 10^{-2}°C/m	K W/mK	Heat flow mW/m^2
H54 (P218) ST.2579	3°19.86'N 169°35.06'W	5473	B	2	8.16	0.712	58
H55 (P219) ST.2586	3°10.57'N 169°44.69'W	5578	B	2	4.90	0.717	35
H56 (P220) ST.2583	3°15.30'N 169°40.79'W	5371	B	1		0.717	
H57 (P221) ST.2591	3°07.54'N 169°27.57'W	5538	A	3	8.96	0.722	65
H58 (P222) ST.2600	2°57.39'N 169°38.05'W	5584	B	3	8.16	0.725	59
H59 (P223) ST.2596	3°02.32'N 169°31.94'W	5309	B	2	9.80	0.719	70
H60 (P224) ST.2651	3°16.64'N 169°41.07'W	5500	B	2	10.07	0.725	73
H61 (P225) ST.2663	3°13.32'N 169°41.65'W	5427	B	3	6.99	0.728	51
H62 (P226) ST.2676	2°53.08'N 169°34.86'W	5547	A	3	7.62	0.726	55
H63 (P227) ST.2688	2°49.81'N 169°38.42'W	5355	B	3	7.35	0.718	53
H64 (P228) ST.2700	2°49.29'N 169°41.20'W	5568	B	3	6.82	0.726	50
H65 (P229) ST.2712	2°46.16'N 169°40.25'W	5646	B	3	7.96	0.734	58
H66 (P230) ST.2675	3°13.38'N 169°35.66'W	5600	A	6	7.55	0.724	55

E.Q.F.: Environment Quality Factor of Sclater *et al.* (1976). (A: flat or rolling hills with greater than 150 m of continuous sediment cover within 18 km of the station, B: flat or rolling hills with greater than 20 m of sediment but very thin or no sediment could be observed within 18 km of the station.)
N: Number of active thermistor probles in sediments.
dT/dZ: Thermal gradient.
K: Thermal Conductivity (corrected to in situ temperature and pressure).

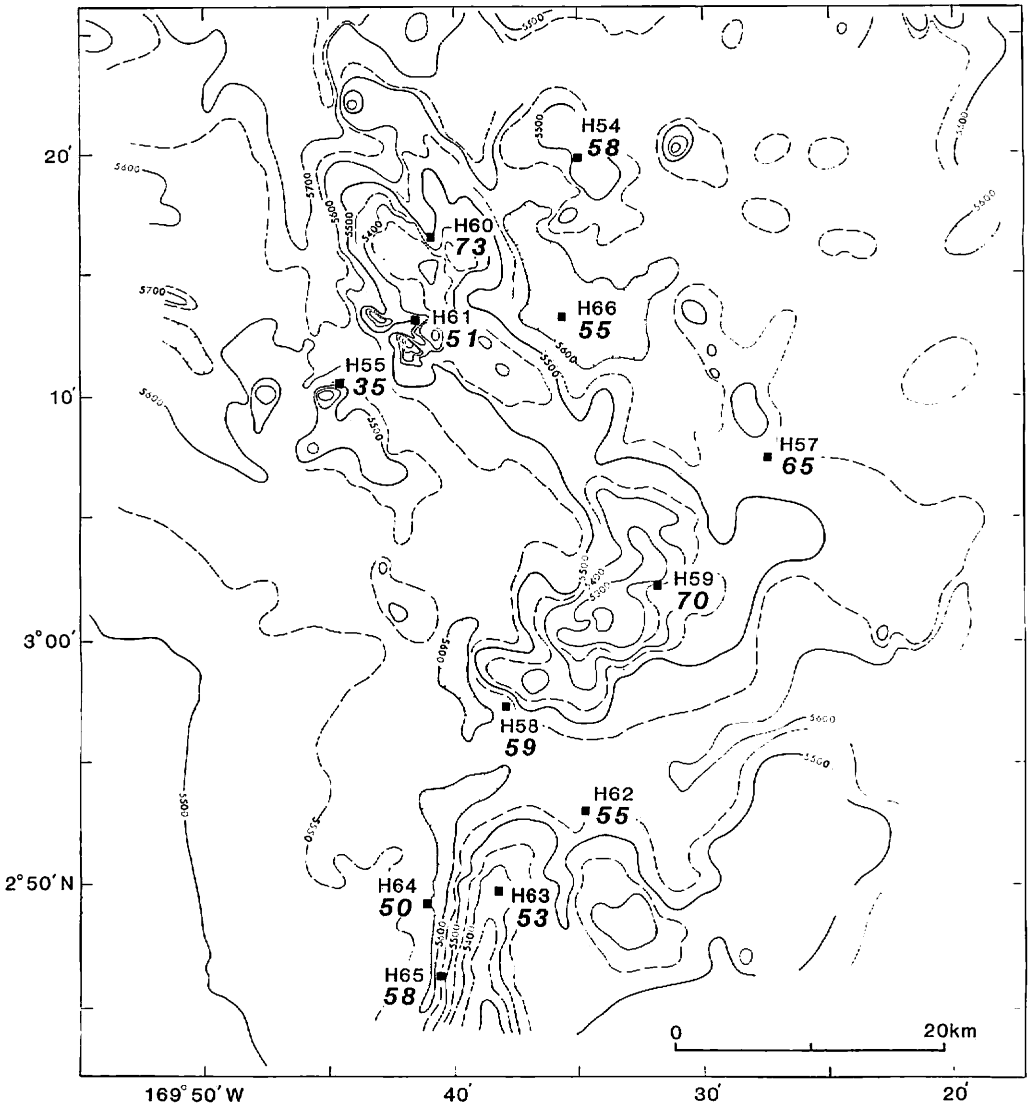

Fig. V-3 Distribution of heat flow (mW/m^2) superimposed on a bathymetric chart.

Discussion

The bathymetry of the study area consists of a few deep-sea hills that are 200-300 m higher than surrounding flat deep-sea basin 5600 m deep. Six among the twelve stations were located on the top or on the slope of these hills; the rests were in the flat deep-sea basin area. The seismic reflection records show that the sediments on the hills is 100 m or less in thickness, and probably there are a few basement exposures. Except on the hills, however, the basement is covered with thick (no less than 200 m) sediments. Therefore, according to the classification of SCLATER *et al.* (1976), the environment of each heat flow station is "A" or "B" (Table V-1). This means that the heat flow values have relatively high reliability. In the northern hill area, however, heat flow values range from 35 $\mathrm{mW/m^2}$ to 73 $\mathrm{mW/m^2}$. This will be not only due to the effect of the topography but also due to the effect of the sea-water convection in the basement outcrops probably existed on the hill.

A mean and a standard deviation of the twelve measurements are $57 \pm 10\ \mathrm{mW/m^2}$. The theoretical relation with the heat flow q ($\mathrm{mW/m^2}$) to the age t (Ma) of the oceanic crust based on the plate cooling model is

$q(t) = 473/t$ (Boundary layer model; LISTER, 1977)

$q(t) = 37.5 + 67 \exp(-t/62.8)$ (Plate model; SCLATER *et al.*, 1980)

These relationships predict the heat flow values of 42.3 $\mathrm{mW/m^2}$ and 46.7 $\mathrm{mW/m^2}$, respectively, for the oceanic crust of 125 Ma. The mean of the observed values is a little higher than these predictions. The depth of the basement of the study area after the correction for sediment loading (CROUGH, 1983) ranges from about 5,350 m (on the hills) to about 5,750 m (in the flat basin). This is shallower than that deduced from the plate cooling model, 5,960 m at 125 Ma (PARSONS and SCLATER, 1977). There is a possibility that the lithospher was reheated after its creation (VON HERZEN *et al.*, 1982; DETRICK *et al.*, 1986), but the number of the heat flow data is not enough for being concluded positively.

Next, a possibility of the existence of slow upward pore water movement through the sediments in the study area is discussed. In Fig. V-1, the straight line is fitted for the thermal gradient, but it is not impossible to be interpreted as slightly non-linear, upward convex, temperature profile. If it is non-linear, several naturally occurring phenomena can be responsible (NOEL, 1984). They are (1) pore water convection in sediments, (2) change in bottom water temperature, (3) sediment heat production, (4) rapid erosion of sediments, (5) effect of small-scale topography (say several meters) and (6) change in thermal conductivity with depth. As the study area is in deep-sea pelagic environment, the effect of (2), (3) and (4) will be negligible. If (5) was responsible, random changes in sign of curvature of the non-linearity would be observed. The item (6) can be ruled out as already shown in Fig. V-2. The most plausible explanation of the non-linear gradients is, therefore, the upward convection of pore water through the sedimentary layer.

It is known that where the thick "impermeable" sedimentary layer has not yet developed and relatively permeable oceanic crust has exposed sporadically, significant transport of the heat by the convection of sea-water through the oceanic crust has occurred. This is the case typically observed on the crests or on the flanks of the mid-oceanic ridges. It is also widely accepted that the transition of convective to conductive heat flow occurs when thick sedimentary cap isolates the convection system from the ocean. ANDERSON *et al.* (1979), however, have detected the non-linear temperature profiles in the Indian Ocean where the crust is not young (55 Ma) and has thick sedimentary layer (over 100 m) and few basement outcrop, and have pointed out that the slow pore water circulation can occur even in the thick "impermeable" sediment layer and can transport the heat convectively. Our results present the possibility that their idea will be extended to an older oceanic crust up to 125 Ma. The velocity of the upward moving water in the sediments in the study area can be estimated to be 10^{-8} to 10^{-9} m/s from an equation by WILLIAMS *et al.* (1979, eq. (5)) if the convection is actually occurring.

The thermal structure of the old non-active oceanic crust is not so simple as thought previously. Reports of reliable, detailed heat flow data of such areas have been much scarcer than those of younger oceanic crust. It is imperative that we have more opportunity to conduct detailed heat flow surveys on old oceanic crust.

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