XII. HEAT FLOW MEASUREMENTS IN THE BONIN ARC AREA

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Heat flow measurements were carried out and nine new heat flow values were obtained in the area of the Bonin (Ogasawara) Arc.

THERMAL CONDUCTIVITY

Measurements of thermal conductivity were made on 8 piston core samples and 2 rock core samples by the needle method of von HERZEN and MAXWELL (1959). The results are shown in Table XII-1 and plotted against the depth below the bottom of the sea in Fig. XII-1. The standard deviation for each sample is 2% to 4%. The thermal conductivity does not necessarily change linearly with depth due to compaction and dehydration, but depends on the bottom material. In general, the conductivity is high near the Shichito Ridge and the Bonin Ridge.

GEOTHERMAL GRADIENT

The geothermal gradient was measured with a two-metre-long BULLARD type probe (BULLARD, 1954). By means of the thermistors set in the probe, apparatus records two temperature differences at intervals of 80 cm and 160 cm in the sediment with an accuracy of 0.002°C. A detailed description of the equipment was given by UYEDA *et al.* (1961). The measurements were made simultaneously the piston or rock coring and the apparatus played the role of pilot corer. After the probe had penetrated the sediment, it took 15 minutes for thermal equilibrium be reached so that the undisturbed temperature differences could be recorded. The results are shown in Table XII-2. The thermal gradient was obtained at 9 of the 11 sites tried. The cause of the failures was insufficient penetration. Since the total weight of the apparatus was about 25 kg in sea water during the present cruise, it would be desirable to attach some additional weight for the full penetration.

HEAT FLOW

The heat flow value is obtained from the product of the geothermal gradient and the thermal conductivity. The average of the thermal conductivities measured to a depth of 250 cm is used to calculate the heat flow value. The results are listed in Table XII-2 and the spatial distribution is shown in Fig. XII-2 with previous data obtained by VACQUIER *et al.* (1966), WATANABE *et al.* (1970) and MATSUBARA (unpublished). In Fig. XII-2, the 3,000 m and 7,000 m contours were drawn to show the ridge and the trench respectively. 5,000 m contours were drawn with dashed lines to show the plateaus. In Fig. XII-3, heat flow values are

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Table XII-1 Thermal conductivities of the core samples

Sample No.	Depth (cm)	K(1)
P148	130	1.77
	266	1.89
	323	1.92
	474	1.85
	548	1.93
	592	1.87
	Av.	1.87
	(SD)	0.05
P149	45	1.89
	95	1.83
	166	1.84
	345	1.83
	409	1.87
	Av.	1.85
	(SD)	0.02
P150	30	1.84
	65	1.92
	100	1.86
	150	1.94
	220	1.92
	266	1.94
	357	1.98
	410	1.88
	490	1.91
	546	1.96
	643	1.89
	755	1.91
	882	1.93
	983	1.89
	1096	1.96
	Av.	1.92
	(SD)	0.04
P151	55	1.86
	158	1.82
	219	1.83
	311	1.82
	353	1.95
	530	1.85
	590	1.82
	674	1.95
	736	1.88
	Av.	1.86
	(SD)	0.05
P152	98	1.94
	137	1.90
	168	1.94
	201	2.00
	244	1.94
	285	1.86
	325	1.85
	363	1.76
	Av.	1.90
	(SD)	0.07
P153	121	1.99
	242	1.95
	Av.	1.97
	(SD)	0.02
P154	34	1.93
	56	2.03
	92	2.10
	183	1.99
	320	1.95
	506	1.93
	581	2.14
	638	1.91
	Av.	2.00
	(SD)	0.08
P155	29	1.93
	80	1.97
	123	2.04
	184	1.99
	250	2.00
	328	2.03
	377	2.08
	446	2.04
	529	2.00
	590	1.92
	676	1.95
	730	1.95
	Av.	1.99
	(SD)	0.05
RC50	12	2.07
	151	2.14
	Av.	2.11
	(SD)	0.04
RC51	40	2.15
	111	2.24
	162	2.27
	Av.	2.22
	(SD)	0.05

(1) Thermal conductivity in 10^{-3} cal/cm sec °C.
Av., Average.
(SD), Standard deviation.

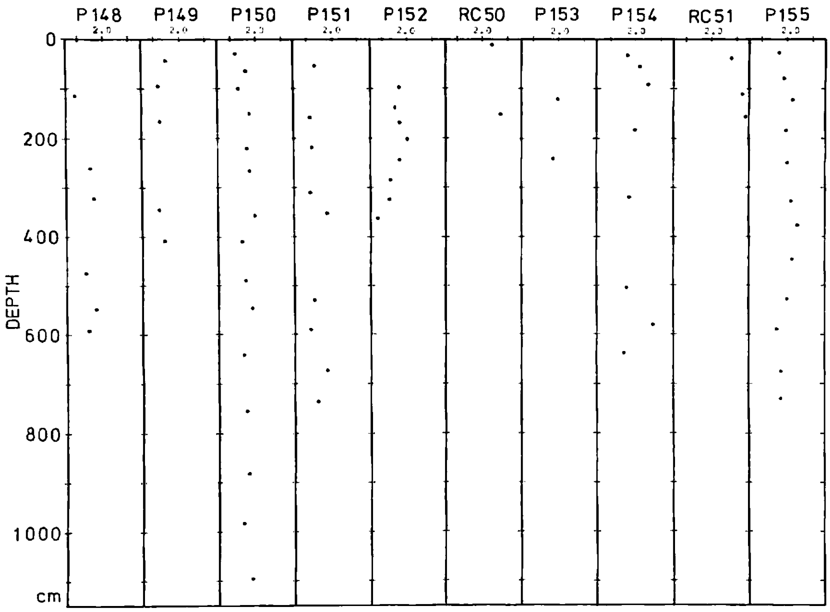

Fig. XII-1 Thermal conductivity data in 10^{-3} cal/cm sec °C from the coring stations. The horizontal scale is in units of 0.2×10^{-3} cal/cm sec °C.

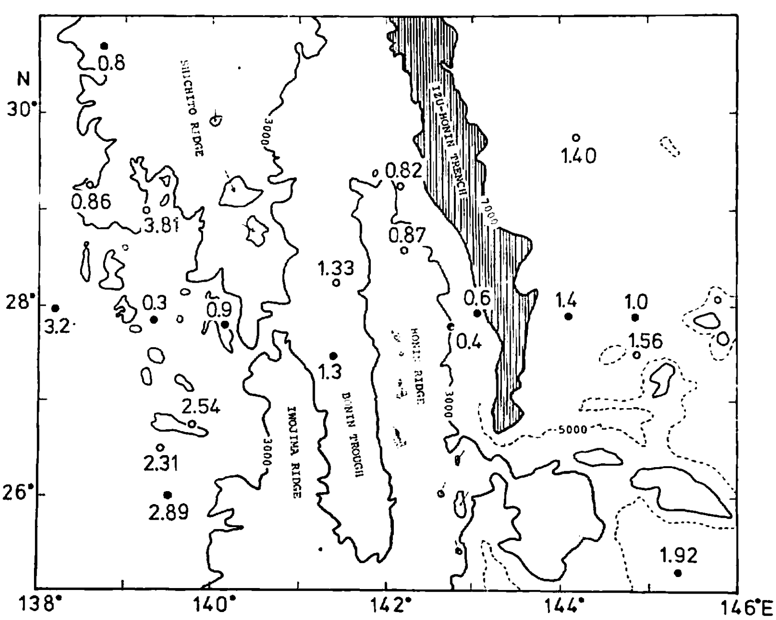

Fig. XII-2 Heat flow values in 10^{-6} cal/cm^2 sec in the Bonin area. Closed and open circles are previous and present stations, respectively. Contours in heavy and dashed lines are given in meters. Hatched area shows the trench.

Table XII-2 Heat flow data

Site	Station No.	Position		Depth (m)	Thermal Gradient(1)			K(2)	Q(3)	Pene-tration(4)
		Latitude	Longitude		80 cm	160 cm	mean			
HF 1	1528	26°00.2′ N	141°54.8′ E	3344	—	—	—	—	—	P 40 cm
HF 2	1532	26°30.2′ N	139°24.8′ E	4535	1.28	1.33	1.31	1.77	2.31	F
HF 3	1534	26°45.0′ N	139°47.1′ E	3835	1.33	1.42	1.37	1.85	2.54	F
HF 4	1538	27°30.2′ N	144°53.0′ E	5475	0.87	0.77	0.82	1.90	1.56	F
HF 5	1542	28°15.0′ N	141°25.1′ E	4150	0.69	—	0.69	1.94	1.33	P110 cm
HF 6	1546	28°35.3′ N	142°12.6′ E	2230	0.41	—	0.41	2.11*	0.87	P120 cm
HF 7	1547	28°45.1′ N	142°26.7′ E	4075	—	—	—	2.11	—	P 80 cm
HF 8	1549	28°59.6′ N	139°13.8′ E	3300	1.90	—	1.90	2.01	3.81	P160 cm
HF 9	1552	29°14.6′ N	138°35.3′ E	2420	0.39	—	0.39	2.22	0.86	P120 cm
HF10	1554	29°14.9′ N	142°10.5′ E	4550	0.39	—	0.39	2.11*	0.82	P120 cm
HF11	1559	29°44.9′ N	144°11.4′ E	5800	0.69	0.72	0.70	1.99	1.40	F

(1) Thermal gradient in 10^{-3}°C/cm.
(2) Thermal conductivity in 10^{-3} cal/cm sec °C. *, estimated value.
(3) Heat flow in 10^{-6} cal/cm^2 sec.
(4) F, full penetration. P, partial penetration.

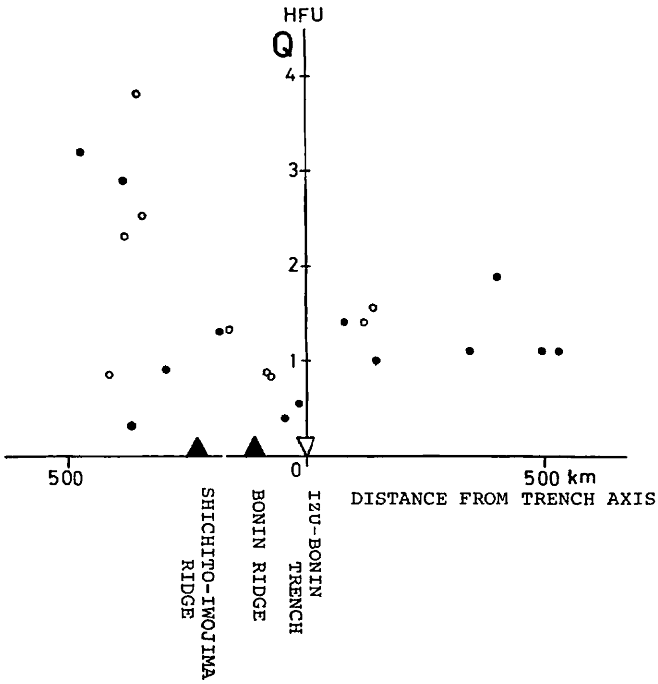

Fig. XII-3 Heat flow values plotted against the distance from the trench axis. Heat flow values Q are in 10^{-6} cal/cm^2 sec.

plotted against the distance from the axis of the trench for the Bonin Arc. During the present cruise, the environment around the heat flow stations were checked on the seismic reflection profiles. Of the stations, the heat flow at site HF9 (St. 1552), which is on a steep slope without thick sediment cover, is unusually low. It might be because the heat from the earth's interior is partly transferred by hydrothermal circulation (SCLATER *et al.*, 1976).

In a general view of Figs. XII-2 and XII-3 indicates some characteristic tendencies. (1) Heat flow values become a minimum just landward of the trench axis. (2) Between the trench and the volcanic front (Shichito Ridge) heat flow values are unusually low or less than 1.5 HFU (10^{-6} cal/cm^2 sec), gradually increasing toward the volcanic front independently of the Bonin Ridge and the Bonin Trough. (3) Behind the volcanic front heat flow values immediately become high with extremely low values in places. As mentioned above, these low values may be due to hydrothermal circulation caused by the rough topography behind the front and reliability of these low values is poor. (4) In the northwestern Pacific Ocean, the heat flow is uniform and relatively low, reflecting the age of the plate. Near the trench and the plateau the heat flow values may increase, although the reliability is low because of the small number of the stations. (5) In the Bonin Trough the heat flow values are unusually low with high reliability in good environments with flat topography and thick sediment cover. Even if the effect of sedimentation, indicated by von HERZEN and UYEDA (1963), are considered, the values are still less than 2.0 HFU and imply that the Bonin Trough is not a zone of recent extension.

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Plate XII-1 Late Mr. Yukio MATSUBARA, the author of this paper, died of the cancer on February, 1980.