Heat-Flow Values from the South-Eastern Pacific

PRIOR to these new measurements, twenty-five heat-flow values from the Pacific Ocean Basin and eight from the Atlantic have been published[1]. The surprising fact brought out by these measurements is the approximate equality of average heat flow of the oceanic and continental areas, about 1×10^{-6} cal./cm.^{2} sec. This result was unexpected on the basis of values of radioactivity indicated for typical continental and oceanic crustal rocks existing near the Earth's surface. It has usually been assumed that most of the surface heat flow in continental regions must originate in the relatively thick and radioactive continental crust. Under the oceans, nearly all the average heat flow must come from the mantle beneath the relatively thin oceanic crust.

The new heat-flow values from the Pacific were obtained during October 1957–February 1958 on the Scripps Institution of Oceanography *Downwind* International Geophysical Year Expedition. The measurements are listed in Table 1, and the geographical distribution of stations, with generalized 4,000- and 5,000-m. bottom-depth contours of the area, is shown in Fig. 1. The topography was kindly supplied by Dr. Henry Menard of the Scripps Institution of Oceanography. The field technique was to measure the temperature gradient in the upper few metres of ocean floor sediment with apparatus first described by Revelle and Maxwell[2], and also the thermal conductivity of a cored sample of this sediment by a transient method[1]. The resulting heat-flow values are most probably accurate within 10 per cent, unless otherwise noted. The 'less than' or 'greater than' signs indicate the uncertainty of imperfectly functioning apparatus, usually due to an uncertainty of depth of penetration of the temperature gradient probe into the ocean floor. The thirty-six new measurements comprise a relatively more detailed study in a somewhat limited area, compared to the previous measurements.

When the new heat-flow values are considered together with the previous measurements in the Pacific, some interesting features can be seen. (1) The East Pacific Rise, a broad elevated region of the eastern Pacific sea floor, appears to be associated with a relatively narrow band of high heat flow for at least 6,000 km. along its length. This was indicated by three stations of the previous Pacific measurements[1], and is represented by stations 7, 8, 9, 10, 27, 29, 31 and 32 of the present study. (2) The axes of the trenches bordering the eastern Pacific Ocean appear to be associated with low heat flow. The previous Pacific measurements indicated this for the trench off Central America. Stations 18, 19, 20 and 21 respectively, of the present measurements, represent a series of heat-flow values down the eastern flank of a part of the South American trench, with the last two measurements in the deepest part. Station 17 is just west of the western flank of the same trench. (3) There seems to be fair evidence for areas with low heat flow roughly paralleling, and to each side of, the high heat-flow band of the East Pacific Rise. To the west, the low heat-flow area is represented by stations 1, 2, 5, 6, 35, 36 and one of the previous Pacific measurements. To the east of the Rise, the evidence for a low is not as good, being

Table 1. HEAT-FLOW MEASUREMENTS

Station No.	Heat flow (10^{-6} cal./cm.^{2} sec.)	Depth (m.)	Latitude	Longitude	Station No.	Heat flow (10^{-6} cal./cm.^{2} sec.)	Depth (m.)	Latitude	Longitude
1	0·14	4,450	1° 23′ S.	131° 31′ W.	19	1·07	3,700	12° 54′ S.	78° 06′ W.
2	$0·52 < Q < 0·78$	4,510	14° 59′ S.	136° 01′ W.	20	0·17	5,950	12° 38′ S.	78° 38′ W.
3	0·97	4,760	21° 40′ S.	147° 41′ W.	21	0·17	5,900	12° 59′ S.	78° 21′ W.
4	1·1	5,120	40° 37′ S.	132° 52′ W.	22	0·26	4,220	18° 26′ S.	78° 16′ W.
5	0·14	4,620	42° 16′ S.	125° 50′ W.	23	0·98	3,090	18° 20′ S.	79° 21′ W.
6	0·73	4,140	46° 44′ S.	123° 18′ W.	24	1·02	4,230	19° 01′ S.	81° 29′ W.
7	2·06	3,180	44° 27′ S.	110° 44′ W.	25	2·12	3,880	27° 04′ S.	88° 53′ W.
8	3·06	3,180	43° 43′ S.	107° 33′ W.	26	0·23	3,200	28° 00′ S.	96° 20′ W.
9	2·09	3,850	43° 44′ S.	104° 25′ W.	27	4·54	2,910	27° 55′ S.	106° 57′ W.
10	2·30	4,580	42° 44′ S.	96° 03′ W.	28	$1·64 < Q < 1·89$	3,500	23° 15′ S.	117° 48′ W.
11	1·0	3,310	41° 06′ S.	86° 38′ W.	29	7·66	3,060	14° 44′ S.	112° 06′ W.
12	>0·89	4,110	23° 23′ S.	72° 10′ W.	30	1·01	3,580	13° 30′ S.	108° 31′ W.
13	0·80	3,750	23° 28′ S.	72° 58′ W.	31	8·09	3,280	11° 39′ S.	109° 48′ W.
14	1·62	4,550	21° 33′ S.	79° 09′ W.	32	7·95	2,840	9° 55′ S.	110° 39′ W.
15	0·79	2,340	20° 49′ S.	81° 08′ W.	33	0·87	4,040	5° 56′ S.	112° 29′ W.
16	1·54	2,400	20° 48′ S.	81° 09′ W.	34	1·71	4,330	3° 40′ S.	114° 13′ W.
17	1·46	4,440	13° 35′ S.	79° 09′ W.	35	0·56	3,810	1° 28′ N.	116° 04′ W.
18	2·72	2,260	12° 49′ S.	77° 53′ W.	36	0·43	4,200	4° 06′ N.	115° 41′ W.

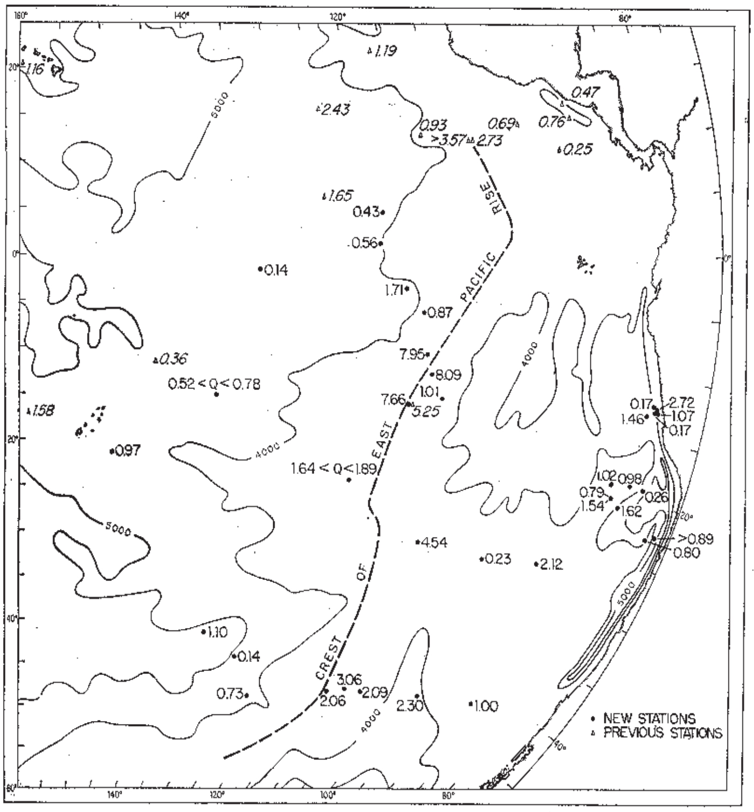

Fig. 1

represented only by station 26 and several of the previous Pacific measurements off the coast of Central America. The number of heat-flow measurements is not yet sufficient to establish how the trenches fit this general pattern; but the rough parallelism of the Rise and trenches may suggest a relationship.

An interesting result of these measurements is the extreme range of the heat-flow values, which extend from a low of $0 \cdot 14 \times 10^{-6}$ cal./cm.^{2} sec. to a high of $8 \cdot 09 \times 10^{-6}$ cal./cm.^{2} sec., a ratio of more than 1 : 50. Even though the area studied has large topographic features, where differences of heat flow might be expected, the large magnitude of the range of heat flow is somewhat surprising. It is believed that some of the variation in heat flow may be due to irregularities in bottom topography, or to an irregular surface of rocks of good thermal conductivity buried by a smooth sediment surface, as suggested previously[1]. Although it is difficult to evaluate the combined magnitude of these effects, it appears that they would not alter the observed heat flow at any station from the assumption of heat flow through uniform, horizontal layers by more than a factor of two, and would not be systematically distributed. The measurements have not been corrected for these disturbances, but irregular bottom topography may have had some effect on stations 6, 10, 11, 15, 16, and 30.

Undoubtedly, most of the variations observed in oceanic heat flow are due to differences in flow of heat from the mantle of the Earth. The pattern of heat flow in the eastern Pacific, if verified by further measurements, is suggestive of a large convective cell in the upper mantle of the Earth. The rising part of the convection cell, bringing hot material near the surface, may be represented by the East Pacific Rise, and the sinking parts by the possible low heat-flow areas on each side. Indeed, the lowest heat flows measured may be due entirely to the small amount of heat generated by radioactivity in the crust, with little or no heat coming from the mantle. The oceanic heat-flow values also show variations of relatively small horizontal extent not associated with topographic variations or with the large pattern, suggesting smaller-scale thermal anomalies in the mantle, perhaps also due to convection. A more closely spaced series of measurements in one of these areas is highly desirable.

Similar patterns may be expected for other areas of the Earth; high heat flow has been indicated also for the mid-Atlantic Ridge (Sir Edward Bullard, personal communication), a topographic feature of the Atlantic Basin similar to the East Pacific Rise. However, since convection could be driven by a deep distribution of radioactive heat sources under the ocean areas, it may be that similar patterns would not be observed in continental regions, where the radioactivity may be frozen uniformly in a relatively shallow crust. In fact, while the average heat flow seems to be about the same over continental and oceanic regions, the continental values show considerably less variation than the oceanic. However, this may result from a more limited distribution of continental heat-flow values; in fact, some areas of continents have been recently investigated which show unusually high heat flow[3,4]. Many problems have yet to be solved, and towards this end it is hoped that the results herein will be a stimulus for further measurements.

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