$d = 0.682$ at $-34°C$ (*19*) minus the atomic refraction of three hydrogen atoms.
15. Based on two ammonia nitrogen, eleven hydrogen, two carbon, two ester oxygen, one carbonyl oxygen, one hydroxyl oxygen, average of one primary amide nitrogen and one secondary amide nitrogen (assuming resonance), and average of one hydroxyl oxygen and one carbonyl oxygen (assuming resonance); ammonia nitrogen value calculated from the molar refraction of ammonia.
16. Based on one carbonyl oxygen, one ester oxygen, one hydroxyl oxygen, one carbon, five hydrogen, and one ammonia nitrogen as calculated from the molar refraction of ammonia (double salt calculation).
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Geothermal Heat Flow in the Gulfs of California and Aden

Abstract. *Eighteen measurements in and near the gulfs of California and Aden indicate the geothermal flux is several times the world-wide mean of 1.2×10^{-6} cal/cm^2 sec in both regions. Both gulfs closely coincide with the intersection of oceanic rises with continents and have likely been formed under tensional forces, which suggests an association with mantle convection currents.*

The gulfs of California and Aden (Figs. 1 and 2) are two elongated indentations of the sea into the continents, located nearly halfway around the earth from each other. They are of similar dimensions, and Girdler (*1*) has given a recent interpretation of the geology and geophysical measurements in both gulfs. Both regions are seismically active (*2*), probably in association with the San Andreas fault system for the Gulf of California, and with the great African Rift system for the Gulf of Aden.

Measurements of the geothermal flux in Table 1, shown in Figs. 1 and 2, range from 0.62×10^{-6} cal/cm^2 sec [μ (*3*)] to 6.15 μ in the Gulf of California, and from 2.47 μ to 5.98 μ in the Gulf of Aden. The mean of the measurements for the two regions, respectively, is 3.12 μ and 3.68 μ; this compares with the mean of the oceanic values of 1.2 μ to 1.4 μ (*4, 5*). The measurements were made in the usual method with a cylindrical probe to measure the temperature gradient in the ocean-floor sediments (*6*) and a transient needle-probe method to measure the thermal conductivity of a cored sample of the sediments (*7*). The distance between temperature-sensing elements in the probes used for temperature-gradient measurements ranged from 1.4 to 2.6 m. Thermal conductivities were corrected for ambient conditions of the sea floor, following Ratcliffe (*8*). The thermal conductivity values enclosed by parentheses in Table 1 were taken as the mean of the measurements on cores at adjacent stations.

Many of the measurements in Table 1 were made at locations where sea depths are about one-half the average for deep-sea regions. Such relatively shallow depths may introduce some uncertainty concerning the temperature stability of the bottom water, on which the accuracy of the measurements depends. Nevertheless, to account for the whole of the observed temperature gradient corresponding to a heat flow of 3 μ requires an improbable temperature drop of several tenths of a degree (C) of the bottom water immediately before a measurement is made. Except for the deep parts of the basins in the Gulf of California beneath sill depths, the deep waters of the gulfs of California and Aden are open to the oceans; the water temperatures at 2000 m for the respective gulfs are about 2.3°C and 3.2°C. Meager hydrographic data in the Gulf of California indicate the bottom water temperature there has remained constant to within 0.1°C over the past 70 years. Therefore, systematic errors due to changes of bottom water temperature are not likely to be significant in either region.

Recent carbon-14 data give present rates of sedimentation up to 300 cm/1000 years for topographic basins in the Gulf of California (*9*). These values are consonant with the high sedimentation rates for other basins near the coast off California (*10*), and about two orders of magnitude greater than normal rates for the deep-sea floor (*11*). There are two possible effects on the surface heat flow of a high-sedimentation rate: (i) after some time a reduced heat flow may result, as part of the heat from the interior is used to raise the temperature of the rapidly depositing sediments; (ii) an increased heat flow could result from chemical or other reactions producing heat after sedimentation, such as oxidation of organic carbon. As a result of (i), calculations indicate the equilibrium heat flow in the Gulf of California may be significantly greater than that measured in areas where the high rates of sedimentation occur (*5*); this increase would not change the conclusions presented here. At station V-6, the only low value measured in both gulfs also may result from a local high sedimentation rate or irregular topography; there is no clear evidence, however, to demonstrate that these effects are especially important at this locality. As many of the sediment cores obtained in the Gulf of California show chemically reducing conditions, the oxidation of carbon is probably not an important source of the heat flow measured there. Little is known about the Gulf of Aden, but both effects seem likely to be less important than for the Gulf of California.

The high heat-flow values in the Gulf of California are comparable to those obtained farther south on the East Pacific Rise (*4, 5*), where the results have been interpreted as an association with convection in the earth's mantle. Hamilton (*12*) has presented evidence that Baja California has split away from the mainland of Mexico as a result of tensional stresses, leaving behind the Gulf of California. A similar interpretation seems reasonable for the Gulf of Aden

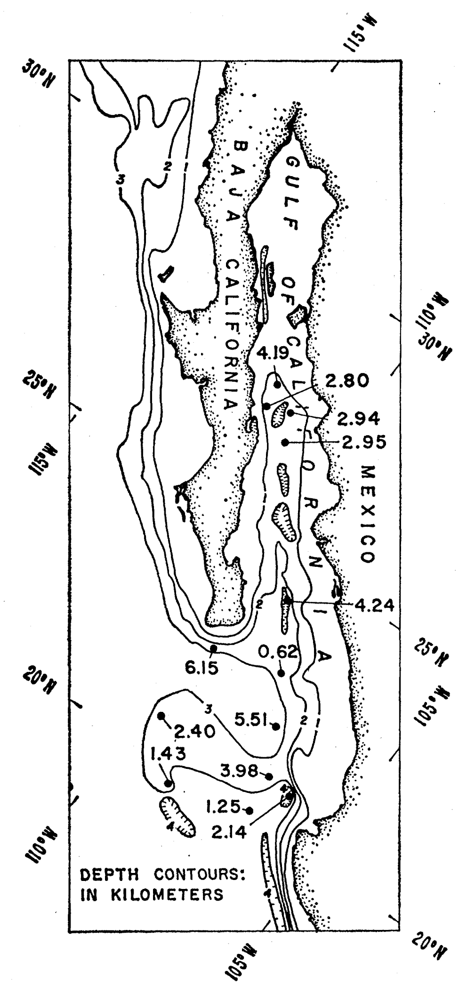

Fig. 1. Geothermal flux in the Gulf of California.

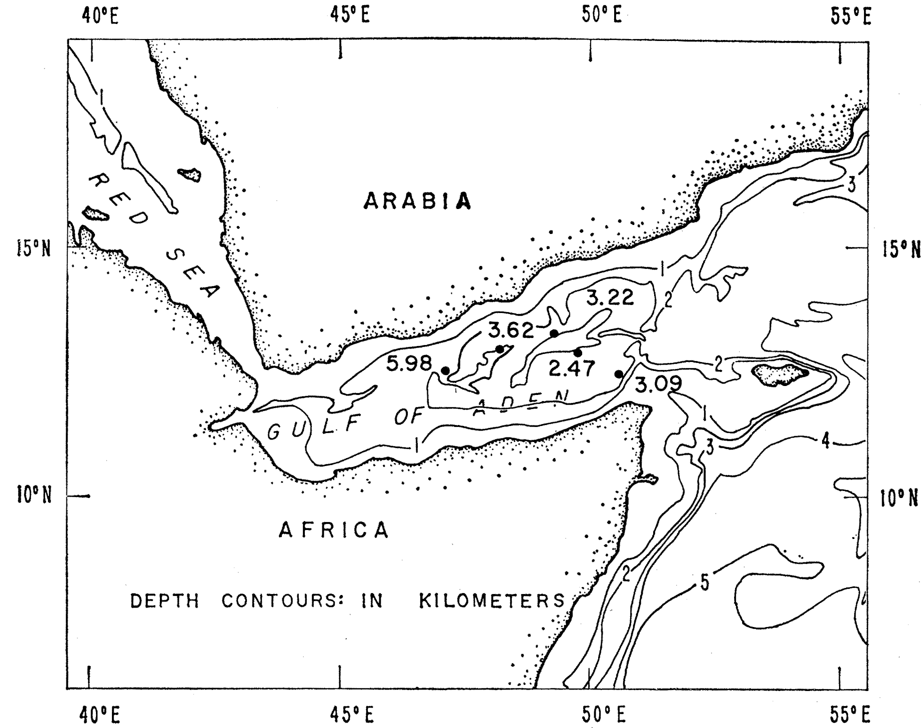

Fig. 2. Geothermal flux in the Gulf of Aden.

and the Red Sea, where gravity and seismic measurements indicate that a material of relatively high density now occupies the central part of these features along the respective longitudinal axes (*1*). However, the heat-flow measurements do not show any marked correlation with a relatively narrow central region of activity (for example, stations Z-3′, Z-4′, and Z-5′, extending most of the distance across the Gulf of Aden in transverse section). Measurements were not attempted in the Red Sea, but the similarity of the feature implies high heat flow will be found there also; the values may be subject to additional uncertainties owing to the high bottom water temperatures (*13*).

Table 1. Heat-flow measurements in the gulfs of California and Aden.

Station	Latitude	Longitude	Depth (m)	Thermal conductivity*	Heat flow†
		Gulf of California			
V-1	27°08′N	111°38′W	1840	1.77	2.80
V-2	27°17′N	111°22′W	1870	1.65	2.94
V-3	27°38′N	111°44′W	1775	1.64	4.19
V-4	26°46′N	111°04′W	1750	1.75	2.95
V-5	24°09′N	108°55′W	3020	1.99	4.24
V-6	22°58′N	108°04′W	2900	1.81	0.62
V-7	21°59′N	107°41′W	3055	1.86	5.51
V-8	21°00′N	107°04′W	3300	1.89	3.98
V-9	20°55′N	106°25′W	4450	2.00	2.14
V-10	20°10′N	107°43′W	3290	1.76	1.25
V-11	19°45′N	108°28′W	2600	1.82	1.43
V-12	20°48′N	109°34′W	2910	1.81	2.40
V-13	22°33′N	109°29′W	2860	2.08	6.15
		Gulf of Aden			
Z-1′	12°27′N	47°07′E	1820	2.03	5.98
Z-2′	12°57′N	48°16′E	2205	(1.92)	3.62
Z-3′	13°17′N	49°15′E	2425	1.81	3.22
Z-4′	12°54′N	49°38′E	2200	(1.92)	2.47
Z-5′	12°25′N	50°33′E	2420	2.02	3.09

* (10^{-3} cal/°C cm sec). † (10^{-6} cal/cm² sec).

The measurements of Table 1 are not detailed enough to reveal any definitely systematic variations of heat flow, although there is some indication that heat flow decreases toward the open sea in both gulfs. High heat flow probably may occur near or on the small continental bulge of Mexico southeast of the Gulf of California and extend south on the sea floor along the crest of the East Pacific Rise (*14*). The extension of a high-heat-flow region to the east of the Gulf of Aden seems less certain. Although the corresponding logical association would be with the crest of the Carlsberg Ridge extending southeast into the Indian Ocean, recent measurements (*15*) obtained across the ridge crest near 9.5°N latitude give normal, or only slightly higher, heat-flow values. Greater detail of geological and geophysical measurements in the vicinity of both gulfs will undoubtedly help to establish how these features relate to the oceanic rises, but the present heat-flow measurements appear to support the hypothesized association with convection in the mantle (*1*; *16*).

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Planets and Comets: Role of Crystal Growth in Their Formation

Abstract. *The application of crystal growth theory to the formation of smoke particles from the primordial solar nebula indicates that solid particles with filamentary structures would form. Such particles would facilitate successive aggregation into planets, comets, and asteroids. The difficulties associated with the aggregation of spherical smoke particles would thus be avoided.*

The earth and meteorites probably formed by accumulation of solid particles at temperatures below about 600°C (*1, 2*). This concept has been accepted in nearly all recent attempts (*3, 4*) to make models of the synthesis of the solar system which would fit the requirements of current theories of stellar evolution. These studies suggest that sometime during the process, conditions favorable for the formation of small solid particles occurred. The