

U, Th AND K CONTENT, HEAT PRODUCTION AND THERMAL CONDUCTIVITY OF SÃO PAULO, BRAZIL, CONTINENTAL SHELF SEDIMENTS: A RECONNAISSANCE WORK

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Abstract

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A reconnaissance of the natural potassium, uranium and thorium content, the radiogenic heat production, and the thermal conductivity of 80 bottom surface sediment samples collected in the Brazilian continental shelf off São Paulo, and in the Cananéia—Iguape lagoon was made. The average equivalent contents of these radioelements in the shelf samples were 1.20%, 1.21 ppm and 4.05 ppm, respectively, and 1.21%, 1.75 ppm and 4.29 ppm, respectively, in the lagoonal sediments. The largest radioelement contents were associated with the more fine-grained sediments. The $^{234}\text{U}/^{238}\text{U}$ isotopic ratios varied from 0.60 to 1.75 with an average of 1.11, indicating that the sources for the U in these sediments are both terrigenous and from the seawater. An average radiogenic heat production of $0.63 \pm 0.04 \mu\text{W m}^{-3}$ was calculated from the experimental concentration data. Data for the thermal conductivity measurements ranged from 0.83 to $2.51 \mu\text{W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$, with an average of $1.82 \text{ W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$.

1. Introduction

Studies of the concentrations of primordial natural radioelement and decay products in the marine sediments have drawn the attention of many geochemists mainly because of its application in marine chronology (Turekian and Cochran, 1978; Chanton et al., 1983). Near-shore and shelf sediments have been receiving an increasing interest also as im-

portant sites for studies concerning the exchange of natural and man-made radioelements from seawater (Joshi and Ganguly, 1975, 1976; Burton, 1978; Mackenzie et al., 1979; Hulings, 1982; Scott and Salter, 1983). Less effort has been given to studies on the thermal properties and radiogenic heat production of these coastal sediments. These depositional environments constitute important traps for hydrocarbon accumulation

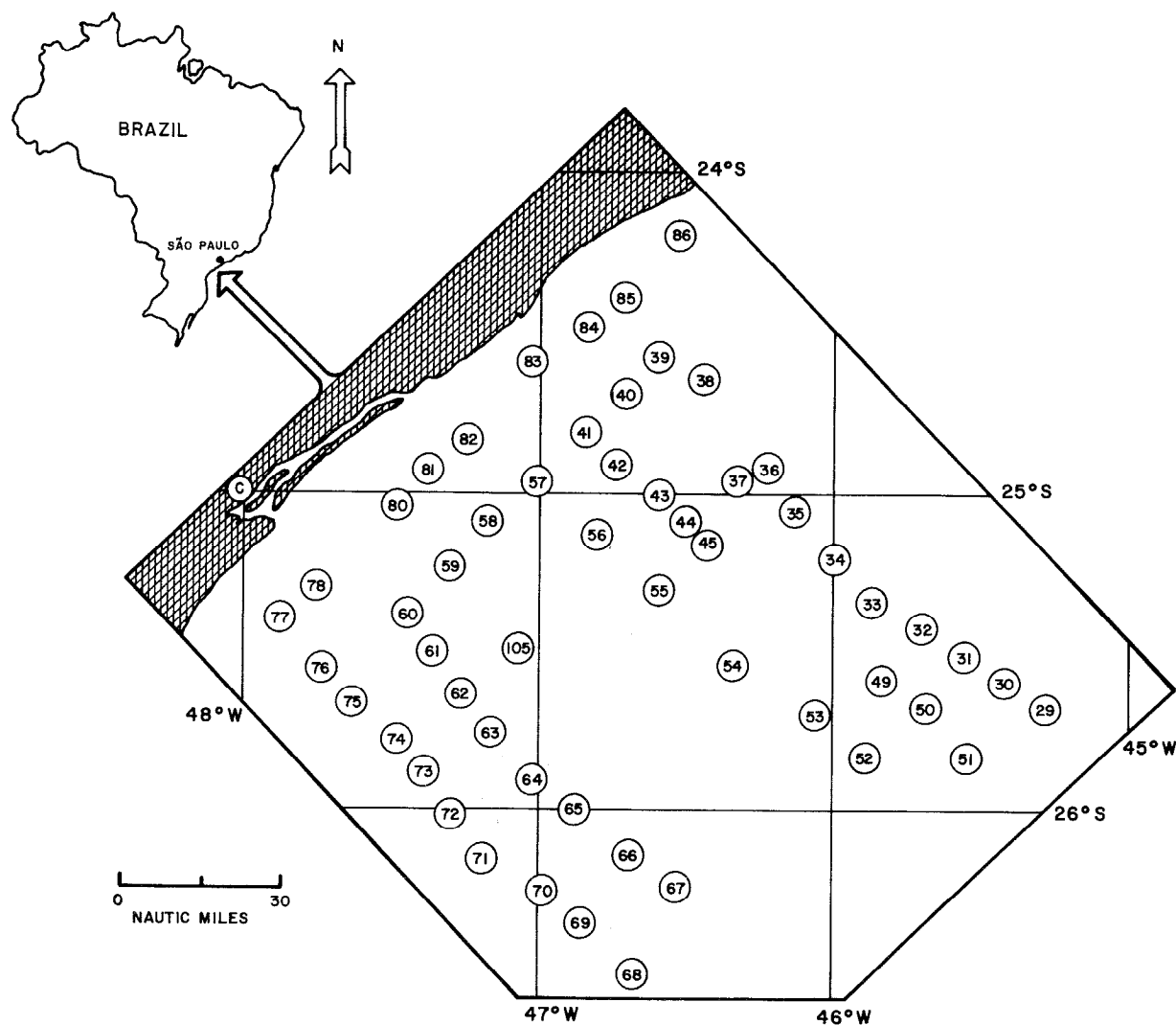


Fig. 1. Sampling sites of the sediment samples. Sampling site C is within the Cananéia-Iguape lagoon and represents the average of 26 samples. 1 nautical mile = 1,852 km.

and maturation. The natural radioelements represent here a supplementary source of heat, which in conjunction with compaction and dehydration will ultimately contribute to the slow chemical reactions involved in the petroleum genesis (Klemme, 1975; Gol'mshatok, 1981).

The Brazilian continental shelf sediments are still poorly known for their radioelements and thermal properties, except for a few isolated studies like those published by Thomson and Livingstone (1970), DeMaster

et al. (1980) and Maragoni and Hamza (1983), and perhaps by the studies performed by oil companies, which are not readily available through the scientific literature.

This work is a reconnaissance of the natural potassium content, the uranium and thorium equivalent content (eU and eTh, respec.*), the radiogenic heat production, and the thermal conductivity of sediments

*The concentration obtained by assuming secular radioactive equilibrium in the decay series.

in two distinct sedimentation environments: the continental shelf off São Paulo, and the lagoon formed at the estuary of the Ribeira de Iguape river. The study area is shown in Fig. 1 with the encircled numbers indicating the sampling sites. The bottom surface sediment samples were collected by use of a Phleger-type sediment sampler (gravity corer).

2. Experimental techniques

The samples were oven dried and homogenized in a small mortar, after which the samples were weighed (100–200 g) and stored in sealed plastic containers for more than 20 days in order to achieve equilibrium between Rn and its decay products. The γ -rays of the samples were then analysed by a low-noise mercury-shielded 5×5 in. (12.7×12.7 cm) NaI(Tl) detector and a 1024-channel pulse height analyzer. This system was regularly calibrated with a set of suitable standards, following a procedure described elsewhere (I.A.E.A., 1976). The activity of the 1.46-MeV photopeak of energy for ^{40}K , 1.76-MeV for U (^{214}Bi in the ^{238}U series), and 2.62-MeV for Th (^{208}Tl in the ^{232}Th series) was measured. Under the assumption of secular radioactive equilibrium in the U and Th series these activities are equal to the activities of the long-lived parents. Thus, the U and Th content can be determined by knowing the activity of any one of the short-lived daughter in each of the respective series.

The effects of background radiation and the crosstalk between photopeaks were minimized by use of a stripping technique described by the following equations (Stromswold and Kosanke, 1978):

$$C_i = \sum_{j=1}^i \kappa_{j,j} A_{i,j} + \kappa_{i,0} \quad (1)$$

where $i = 1, 2, 3$ stands for Th, U and K, respectively; C_i is the concentration of the i th radioelement in parts per million (ppm); $A_{i,j}$ is the counting rate per gram of sample

in the j th-photopeak of the spectra; and $\kappa_{i,j}$ are the calibration constants obtained from several combinations of the rock standards.

The isotopic ratio between ^{234}U and ^{238}U was measured by α -spectrometry after a chemical treatment described in detail by Anderson and Fleer (1982) with a few minor changes from the original paper in order to meet our simpler needs. Approximately 2 grams of sediment were employed for each analysis. Alpha spectrometry was carried out with a 1024-channel pulse-height analyser after electroplating the U from solutions onto 1-in. (2.54 cm) stainless-steel plates. A 300- m^2 silicon surface-barrier detector with minimum 100- μm depletion thickness was employed in the counting of the α particles. The resolution of the whole system measured at half maximum at 4.77 MeV was 30 keV at best. Counting time varied from sample to sample and was individually adjusted so that the fractional error was always less than 15% for each energy peak.

The heat production due to radioelement decay in the sediments was calculated from the equivalent concentration data obtained for K, U and Th. The contribution of Rb and other less abundant radioelements to the heat production is negligible and was not taken into account in our estimates. To convert the radioisotope concentration data into radiogenic heat production (ψ) the following equation was employed (Schmucker, 1969):

$$\psi \text{ (}\mu\text{W m}^{-3}\text{)} = \rho [3.35\text{K (\%)} + 9.79\text{U (ppm)} + 2.64\text{Th (ppm)}] \times 10^{-5} \quad (2)$$

where ρ is the sediment density in kg m^{-3} .

The thermal conductivity of the sediments was measured with the needle probe method (Von Herzen and Maxwell, 1959). This method presents some benefits as compared to the traditional steady-state methods; it is faster and less sensitive to changes in thermal conductivity due to evaporation and non-homogeneous distribution of inter pore water. We employed a 0.1-cm diameter by 6.3-cm

TABLE I

Experimental data obtained for the Cananéia- Iguape lagoon (C) and for the continental shelf (ST)

Sample	⁴⁰ K (%)	eU (ppm)	eTh (ppm)	²³⁴ U/ ²³⁸ U	ψ ($\mu\text{W m}^{-3}$)	K ($\mu\text{W m}^{-3}$)	Short description*
ST 29	0.7 (0.2)	1.5 (0.2)	4.9 (0.7)	1.0 (0.1)	0.7	—	fine sand, old BD, 65% carb.
ST 30	1.1 (0.2)	1.2 (0.3)	3.3 (0.8)	—	0.56	—	medium silt, old BD, 32% carb.
ST 31	1.5 (0.2)	1.7 (0.4)	7.4 (0.8)	—	0.98	—	medium fine silt, old BD
ST 32	1.8 (0.3)	2.2 (0.4)	13.0 (1.0)	1.2 (0.1)	1.5	—	fine silt, old BD
ST 33	2.0 (0.3)	2.3 (0.5)	13.0 (1.0)	—	1.5	—	very fine silt, old BD
ST 34	1.9 (0.3)	2.2 (0.5)	15.0 (1.0)	—	1.6	—	very fine silt, old BD, 27% carb.
ST 35	1.4 (0.2)	1.4 (0.4)	4.9 (0.8)	1.6 (0.1)	0.74	—	coarse silt, old BD, 17% carb.
ST 36	0.8 (0.2)	1.5 (0.3)	4.0 (0.7)	—	0.7	—	very fine sand, old BD, 23% carb.
ST 37	1.0 (0.2)	0.7 (0.3)	1.9 (0.7)	—	0.4	—	coarse silt, old BD, 17% carb.
ST 38	1.1 (0.2)	0.9 (0.3)	3.2 (0.7)	—	0.5	—	fine sand, shells, BD, 43% carb.
ST 39	1.3 (0.2)	0.2 (0.3)	tr.	—	0.2	—	very fine sand, 12% carb.
ST 40	1.2 (0.2)	1.4 (0.3)	2.3 (0.7)	—	0.57	1.96	very fine sand, 29% carb.
ST 41	1.1 (0.2)	1.1 (0.3)	2.0 (0.7)	—	0.46	1.93	very fine sand, 6% carb.
ST 42	1.3 (0.2)	1.7 (0.3)	3.4 (0.7)	—	0.69	2.19	very fine sand, some fragmental shells, 16% carb.
ST 43	1.3 (0.2)	1.2 (0.3)	3.0 (0.7)	—	0.57	1.69	very fine sand, less fragmental shells, 32% carb.
ST 44	0.8 (0.2)	0.8 (0.3)	2.4 (0.8)	—	0.4	1.78	same as before, 25% carb.
ST 45	0.9 (0.2)	1.2 (0.4)	3.8 (0.8)	—	0.6	1.39	coarse silt, 19% carb.
ST 49	1.9 (0.3)	1.9 (0.4)	7.9 (0.9)	—	1.1	0.86	very fine silt, 25% carb.
ST 50	2.2 (0.3)	2.2 (0.5)	9.0 (1.0)	—	1.0	0.91	fine silt, some BD, 21% carb.
ST 51	1.4 (0.2)	1.5 (0.4)	3.6 (0.8)	1.04 (0.06)	0.68	—	very fine sand, BD, 35% carb.
ST 52	0.9 (0.3)	2.0 (0.4)	4.0 (1.0)	1.7 (0.2)	0.8	—	same as before, 65% carb.
ST 53	1.0 (0.3)	2.2 (0.4)	5.0 (1.0)	—	0.9	1.62	coarse silt, some very fragmental shells, 45% carb.
ST 54	0.8 (0.2)	1.5 (0.4)	8.0 (0.8)	—	0.9	0.83	fine silt, 19% carb.
ST 55	0.9 (0.2)	2.3 (0.4)	6.1 (0.9)	1.15 (0.09)	1.0	1.35	medium silt
ST 56	1.0 (0.2)	1.1 (0.3)	2.0 (0.7)	—	0.46	1.94	coarse silt, 21% carb.
ST 57	1.0 (0.2)	1.2 (0.3)	2.1 (0.7)	—	0.49	1.88	fine sand, 14% carb.
ST 58	1.0 (0.2)	1.1 (0.3)	2.0 (0.6)	—	0.47	2.38	very fine sand, 12% carb.
ST 59	1.0 (0.2)	1.1 (0.3)	2.1 (0.6)	—	0.46	1.99	fine sand, 24% carb.
ST 60	1.1 (0.2)	1.4 (0.3)	2.9 (0.7)	—	0.61	2.01	very fine sand, 9% carb.
ST 61	0.8 (0.2)	1.1 (0.3)	5.5 (0.7)	—	0.66	—	very fine sand, 43% carb.
ST 62	1.0 (0.2)	0.4 (0.3)	tr.	—	0.2	—	coarse silt, 22% carb.
ST 63	1.2 (0.2)	0.4 (0.3)	0.3 (0.7)	—	0.2	—	very fine sand, 18% carb.
ST 64	1.4 (0.2)	0.2 (0.3)	4.0 (0.8)	—	0.4	—	fine silt, 25% carb.
ST 65	1.8 (0.2)	1.3 (0.4)	3.4 (0.9)	—	0.67	—	very fine silt.
ST 66	0.9 (0.2)	0.5 (0.3)	tr.	—	0.2	—	very fine sand, 68% carb.
ST 67	1.0 (0.2)	1.1 (0.3)	2.4 (0.8)	1.08 (0.08)	0.49	—	as above, 67% carb.
ST 68	0.7 (0.2)	0.5 (0.3)	tr.	0.8 (0.1)	0.2	—	as above, 67% carb.
ST 69	1.2 (0.2)	1.6 (0.4)	8.6 (0.9)	—	1.0	—	medium silt, BD
ST 70	1.9 (0.3)	2.5 (0.5)	15.0 (1.0)	1.3 (0.2)	1.7	—	very fine silt
ST 71	2.1 (0.2)	1.0 (0.3)	2.5 (0.8)	—	0.56	—	as above
ST 72	1.9 (0.3)	2.2 (0.4)	5.0 (1.0)	0.9 (0.2)	1.6	—	as above

ST 73	1.1 (0.2)	0.3 (0.3)	tr.	—	0.2	—	very fine sand
ST 74	0.9 (0.2)	0.9 (0.3)	2.3 (0.7)	—	0.4	—	coarse silt, 17% carb.
ST 76	1.1 (0.2)	0.7 (0.3)	tr.	—	0.3	—	very fine sand, some coarse BD, 10% carb.
ST 77	0.8 (0.1)	tr.	tr.	1.2 (0.1)	0.1	—	fine sand, some BD, 60% carb.
ST 78	0.7 (0.2)	0.8 (0.3)	0.7 (0.6)	—	0.3	0.27	some BD, 7% carb.
ST 80	0.8 (0.2)	0.8 (0.3)	1.1 (0.6)	—	0.3	—	medium sand, 1% carb.
ST 81	0.8 (0.2)	0.6 (0.3)	1.7 (0.6)	—	0.3	2.34	fine sand, some BD, 58% carb.
ST 82	1.4 (0.2)	0.5 (0.3)	tr.	—	0.2	2.23	32% carb.
ST 83	1.6 (0.2)	0.9 (0.3)	0.8 (0.7)	—	0.4	2.22	very fine sand, 20% carb.
ST 84	0.9 (0.1)	0.2 (0.2)	tr.	—	0.1	2.07	—
ST 85	0.9 (0.2)	1.1 (0.3)	6.0 (0.7)	0.60 (0.04)	0.7	—	fine sand, 10% carb.
ST 86	0.8 (0.2)	2.2 (0.3)	6.7 (0.7)	—	1.0	—	fine sand, 9% carb.
ST 105	1.1 (0.2)	0.6 (0.3)	tr.	—	0.2	—	—
C 17	1.1 (0.4)	2.0 (0.6)	12 (1)	—	1.3	1.28	coarse silt, 28% carb.
C 40	0.8 (0.2)	0.6 (0.3)	3.6 (0.8)	—	0.4	—	very fine sand, 18% carb.
C 41	1.2 (0.2)	1.7 (0.3)	3.3 (0.8)	—	0.69	—	fine silt, 35% carb.
C 42	1.3 (0.3)	2.4 (0.4)	6.1 (0.8)	—	1.0	—	very fine sand, 16% carb.
C 43	1.4 (0.3)	2.6 (0.5)	5.9 (0.9)	—	1.1	—	as above, 16% carb.
C 44	1.0 (0.2)	2.1 (0.4)	4.0 (0.8)	—	0.81	—	coarse silt, 19% carb.
C 45	1.4 (0.3)	1.8 (0.4)	7.7 (0.9)	—	1.0	—	fine sand, 5% carb.
C 46	1.8 (0.3)	1.9 (0.4)	10.0 (1.0)	1.2 (0.1)	1.2	—	very fine sand, 11% carb.
C 47	1.3 (0.3)	tr.	tr.	—	0.1	—	coarse silt, 23% carb.
C 48	1.9 (0.4)	2.9 (0.6)	12.0 (1.0)	—	1.5	—	very fine sand, 8% carb.
C 53	1.2 (0.4)	2.6 (0.6)	6.0 (1.0)	—	1.0	—	as above, 2% carb.
C 54	2.2 (0.3)	2.1 (0.5)	7.0 (1.0)	0.83 (0.09)	1.0	—	as above, no carb.
C 55	1.7 (0.3)	2.9 (0.5)	6.0 (1.0)	—	1.0	—	coarse silt, 31% carb.
C 56	1.1 (0.3)	2.0 (0.4)	4.3 (0.9)	—	0.81	—	fine sand, 1% carb.
C 57	1.0 (0.2)	1.7 (0.3)	5.0 (0.7)	—	0.79	—	very fine sand, 5% carb.
C 58	1.0 (0.2)	1.8 (0.3)	5.3 (0.7)	—	0.82	—	fine sand, no carb.
C 59	0.7 (0.2)	1.6 (0.4)	4.7 (0.9)	—	0.7	—	very fine sand, 5% carb.
C 60	1.1 (0.2)	1.5 (0.3)	3.7 (0.8)	—	0.67	—	medium sand, 2% carb.
C 61	0.6 (0.2)	1.0 (0.3)	3.0 (0.8)	—	0.5	—	very fine sand, 5% carb.
C 62	1.2 (0.3)	1.3 (0.4)	tr.	—	0.41	2.51	medium sand, 7% carb.
C 78	0.8 (0.2)	1.4 (0.3)	3.6 (0.7)	—	0.6	—	coarse silt, 19% carb.
C 79	0.9 (0.2)	1.3 (0.3)	1.9 (0.7)	—	0.5	—	fine sand, 5% carb.
C 81	1.0 (0.2)	1.2 (0.3)	0.8 (0.6)	—	0.4	—	fine silt, 55% carb.
C 82	1.6 (0.2)	1.4 (0.3)	2.7 (0.7)	—	0.62	—	very fine sand, 5% carb.
C 83	1.0 (0.2)	1.7 (0.3)	1.1 (0.7)	—	0.54	—	coarse silt, 23% carb.
C 84	1.1 (0.2)	1.9 (0.3)	1.8 (0.7)	—	0.64	—	coarse silt, 20% carb.

The symbols ψ and K stand for the radiogenic heat production and thermal conductivity, respectively. The figures within brackets are one standard deviation of each observation. BD = biogenic debris; carb. = total carbonate content of each sample; tr. = trace.

* Grain-size classification after Folk and Ward (1957). Description for estuary samples after Tessler (1982).

length stainless-steel probe with a 354- Ω linear heater and a thermistor in its interior. The sediment is deposited into a 4.0-cm diameter by 0.6-cm length Plexiglas[®] thermally insulated container. The measurements were made by fully inserting the needle probe into the sediment and the electric power furnished to the heater was adjusted to a present value. The change in temperature is obtained from the change in resistivity of the thermistor read by a digital multimeter. The change in temperature of the sediment due to the heat produced by the linear filament within the probe can be approximately given by (Carslaw and Jaeger, 1959):

$$T = \frac{Q}{4\pi K} [\ln(t/t_0) - b] \quad (3)$$

where Q is the heat produced by the probe; K is the thermal conductivity of the sediment; t_0 is a parameter with dimension of time and related to the thermal diffusivity and the diameter of the needle probe; t is the time elapsed from the beginning of heating; and b is a constant. A plot of the temperature vs. the natural logarithm of t will have a slope ($Q/4\pi K$) inversely proportional to the thermal conductivity of the sample.

3. Results and discussions

Table I presents the experimental data obtained in this work plus a short description

of the samples. From a statistical point of view, we observed that the concentration data for K and U both for the Cananéia-Iguape lagoon and for the continental shelf sediments follow normal distributions at a significance level (α) of 5% by the χ^2 test. The hypothesis of normality is rejected for the Th shelf environment data. Nevertheless, a log-normal distribution (Aitchison and Brown, 1957) fits the Th data by performing the same test to the logarithm of the concentrations. Further t and z statistical tests were applied and have shown that K is homogeneously distributed in the lagoonal and in the continental shelf environments, while U concentrations show statistically different average values and standard deviations in these two environments with larger values for the lagoon. This is probably due to a larger fraction of lithogenic material within the lagoon, as compared to more calcareous sediments in the continental shelf (see Table I). The Th is also more concentrated in the lagoon, although here we have to be careful since we are comparing averages performed with different averaging processes. Table II summarizes the statistical tests applied to the experimental data.

The $^{234}\text{U}/^{238}\text{U}$ isotopic ratio was measured for some of the samples in order to verify the prevailing origin of the U in the sediments. These ratios ranged from 0.60 to 1.75 with an average of 1.11 and standard deviation

TABLE II

Summary of the statistical tests applied to the radioelement content of the sediments

Environment	Radioelement	Average	Standard deviation	Test		
				χ^2 ($\nu=1$)	F ($\nu_1=25, \nu_2=52$)	t ($\nu=78$)
Lagoon	K	1.21%	0.38%	2.62	1.11	0.11
	U	1.75 ppm	0.66 ppm	1.38	1.03	1.66
	Th	4.29 ppm	2.88 ppm	1.0	—	—
Shelf	K	1.20%	0.40%	3.78	1.11	0.11
	U	1.21 ppm	0.65 ppm	2.59	1.03	1.66
	Th	4.05 (3.65) ppm	4.29 (2.33) ppm	8.5 (1.27)	—	—

The figures within brackets are the log-normal statistics.

of 0.43. This is slightly lower than the global average isotopic ratio for seawaters, 1.15. Nevertheless, it is larger than what would be expected for a purely terrigenous sediment, in which the isotopic ratio is typically lower than 1. At least two important sources for the U in the marine sediments are known besides the U brought by the crustal material entering the ocean: (1) the authigenic U precipitated directly from seawater (average of $3.3 \mu\text{g l}^{-1}$, after Burton, 1978) under reducing conditions; and (2) the continuous scavenging of the insoluble ^{234}Th (a ^{238}U daughter) from seawater, none of which can be efficiently measured by γ -spectrometric techniques. Whichever the depositional process might be, the net effect is an enrichment of additional non-equilibrium U in the shelf sediments.

A contour map of the radiogenic heat production was prepared from the γ -spec-

trometry data and is shown in Fig. 2. The granulometry of the sediments is also represented by the contour map of Fig. 3. It can be seen that the heat production is closely associated with the grain size. The finer the sediment the larger the heat produced. The same positive correlation has also been observed for each of the analyzed radioelements, but is not illustrated here.

The radiogenic heat data are presented also as a frequency distribution in Fig. 4, with an average of $0.63 \mu\text{W m}^{-3}$ and standard deviation of $0.04 \mu\text{W m}^{-3}$. In order to prevent any biasing of calculation due to a much larger number of samples per unit area in the lagoon as compared to a more spread sampling in the continental shelf, the former data were averaged and added to the other 54 shelf samples as a single data point representing the lagoonal environment. The average thus obtained is $\sim 25\%$ lower than the radio-

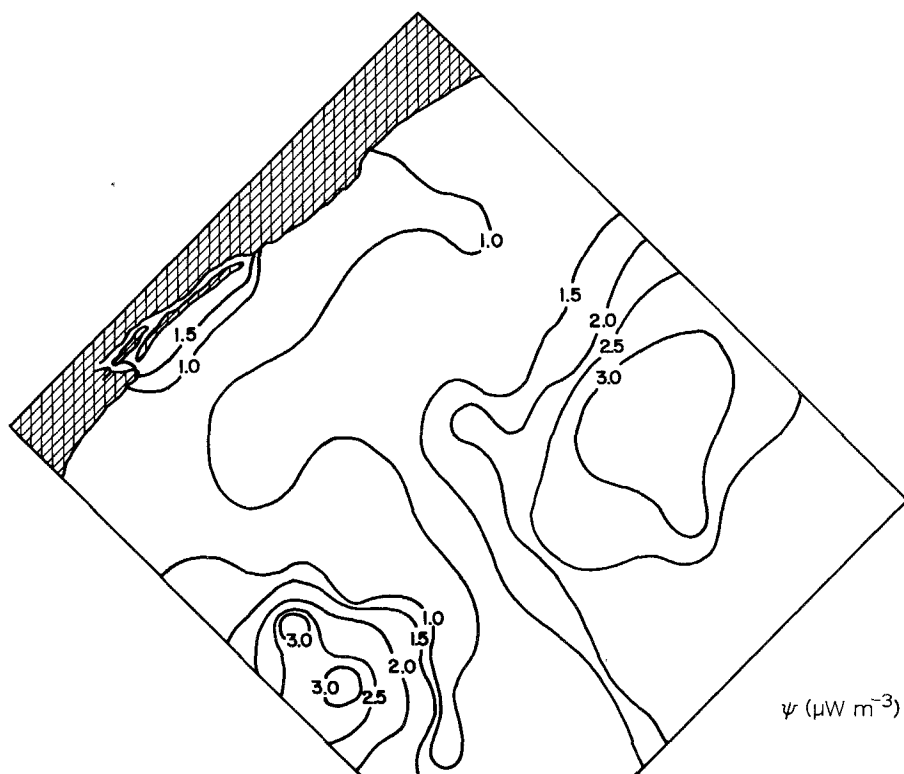


Fig. 2. Contour map for the radiogenic heat production data.

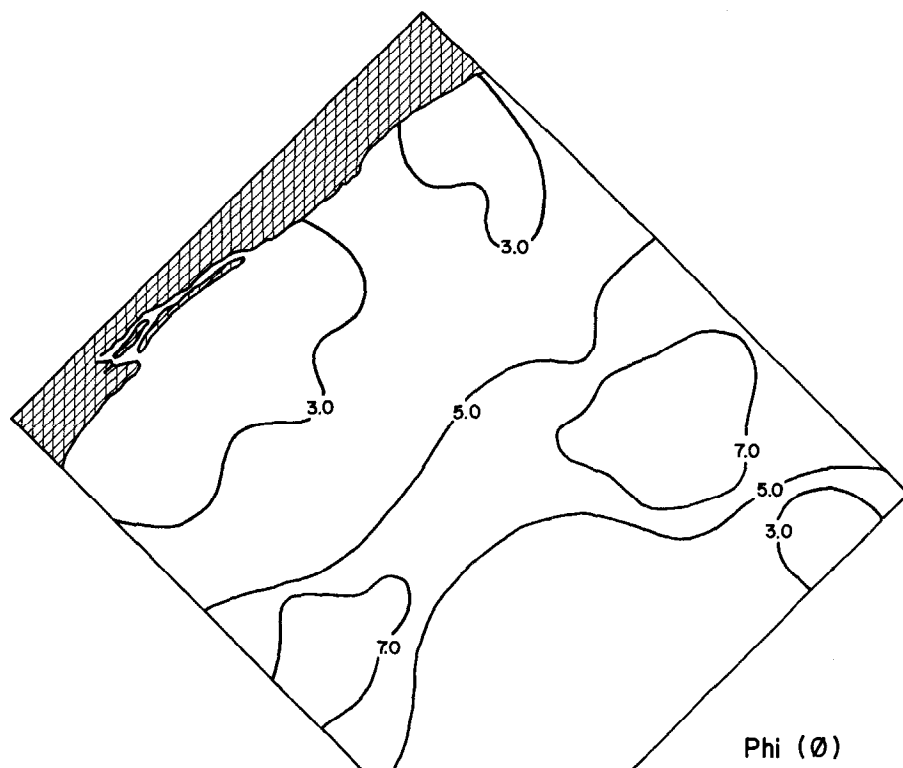


Fig. 3. Contour map for the grain-size data, following Folk and Ward's (1957) classification.

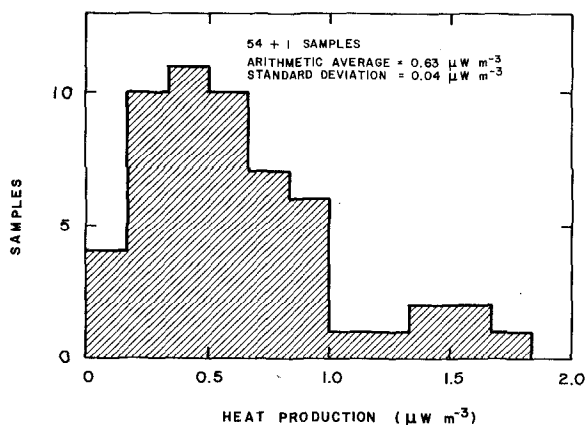


Fig. 4. Frequency distribution of the radiogenic heat production in the sediments.

genic heat produced by a rock having a representative crustal composition (see, e.g., Schmucker, 1969). The bimodal character of this histogram reveals once more the sediment grain-size dependency of the radioelement concentration process.

The γ -ray measurements were made on whole sediment samples without any chemical treatment or leaching. In this case, the secular radioactive equilibrium in the Th series assumed in the heat production calculation is probably valid. This is due to the rapid recovery from a disequilibrium between ^{232}Th and the daughter of longest half-life ^{228}Ra (50 a) as compared to the time scale typically involved in coastal sedimentation (see, e.g., Blanchard et al., 1967; Joshi and Ganguly, 1975; Joshi et al., 1983 for more thorough considerations). However, the same does not occur for the U series which can take up to 1 Ma to recover from a disequilibrium situation. The evidences discussed above suggest that as the sedimentation proceeds in time the nonequilibrium U begins to contribute more to the radiogenic heat. If we add this time dependence on the heat production to the fact that the compaction also contributes to further increase the heat

produced by the sediments (Klemme, 1975), we may arrive at the conclusion that the calculated data can be viewed only as a lower limit for the radiogenic heat actually produced by the whole sediment pile.

Data for thermal conductivity are also presented in Table I, measured for some of the samples (23 samples). The average value obtained is $1.82 \mu\text{W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$ with a standard deviation of $0.48 \mu\text{W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$. Maragoni and Hamza (1983) obtained an average of $1.79 \mu\text{W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$, with a standard deviation of $0.39 \mu\text{W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$ in a more spread analysis of 120 sediment samples from the Brazilian south continental shelf. Results from both studies present significantly higher thermal conductivities than data for deep-ocean sediments from Von Herzen and Maxwell (1959), Ratcliffe (1960), Gerard et al. (1962) and Kutas et al. (1979), which range from 0.7 to $1.1 \mu\text{W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$. Pelagic sediments are composed mostly of clay and calcareous oozes while shelf sediments are richer in coarser terrigenous constituents in which quartz dominates. The thermal conductivity of quartz is 2–3 times larger than that of all other major constituents of both the shelf and deep-ocean sediments. This should explain the larger thermal conductivity data for the shelf sediments.

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