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FIRST HEAT FLOW DENSITY ASSESSMENTS IN CUBA

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ABSTRACT

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The first determinations of heat flow density in Cuba are reported. Precise temperature loggings were carried out in 12 holes in the western and central parts of Cuba. Along the northwestern shore, the mean temperature gradient ranges from 14–16 mK/m in the Pinar del Rio province and 18–22 mK/m east of Habana to 30 mK/m in northern Matanzas. In the Central Basin it ranges from 23–24 mK/m west of Ciego de Avila to 28–39 mK/m east of Sancti Spiritus. Rock samples for laboratory determination of thermal conductivity could be collected only from two holes in Pinar del Rio; their mean conductivity amounts to 4.1 W m^{-1} K^{-1}. From other holes no core samples were available and characteristic rocks were collected from surface outcrops in the vicinity of each hole. The measured conductivity ranges from 0.8 to 3.0 W m^{-1} K^{-1}. Heat flow density assessments revealed very low heat flow near Habana and south of Varadero (30–40 mW m^{-2}) and relatively higher but still rather subnormal values in Pinar del Rio (60 mW m^{-2}) and in the Central Basin (50–65 mW m^{-2}). The generally low heat flow density found in western and central parts of the island thus seems to agree well with the results of marine observations in surrounding areas reported by other authors.

INTRODUCTION

Since temperature is one of the most important parameters in practically all theories concerned with the development and structure of the Earth, it is clear that direct temperature measurements in different localities are vital in geology and geophysics. Knowledge of the underground temperature and of the temperature gradient is further necessary for the determination of terrestrial heat flow density as well as for many practical purposes in exploration geophysics.

Within the agreement between the Academies of Sciences of Czechoslovakia and Cuba on joint studies in basic geophysical investigations, two of us (VČ and MK)

visited the Institute of Geophysics and Astronomy in Habana in 1981. The first scientific temperature measurements were performed with a precise thermometer in several boreholes in order to initiate geothermal research and to obtain necessary data for the evaluation of heat flow density. Temperature versus depth profiles were measured in twelve holes in five localities in the western and central parts of the island and rock samples were collected for the subsequent laboratory determinations of thermal conductivity.

So far no heat flow density values have been reported from Cuba or any other island in the Caribbean region (except for a single old value—25 mW m^{-2}—from Puerto Rico, Diment and Weaver, 1964). Heat flow density was, however, measured in the surrounding seas: Epp et al. (1970) published data from the Gulf of Mexico and from the Caribbean Sea and later Erickson et al. (1972) added information from the Cayman Trench and from the Yucatan Basin. Heat flow density is very low in the abbysal plain of the Gulf of Mexico ($\sim$ 33 mW m^{-2}), low to normal in the Florida-Bahama platform ($\sim$ 50 mW m^{-2}) and in the Yucatan Basin ($\sim$ 58 mW m^{-2}) and high to very high in the Cayman Trench ($\sim$ 88 mW m^{-2}).

TECTONIC SETTING AND LOCAL GEOLOGY

Cuba, the largest of the Caribbean islands, is of arcuate shape, concave to the south; it separates the Gulf of Mexico and the Florida–Bahama platform to the north from the proper Caribbean to the south. Cuba thus separates the very stable geological units from the extremely complex and much younger units of the Caribbean region (Pardo, 1975).

Most of the local geological information was taken from various unpublished reports of the Centro de Investigaciones de Petrol, Habana, as well as from Judoley et al. (1965); tectonic descriptions relate to data published by Marrero-Faz and Paz-Morales (1978) and by Pusharovski et al. (1967). For the reported heat flow sites, the following holes were available (for location see Fig. 1):

(1) Minas de Matahambre area (Pinar del Rio province): two near-by rather shallow holes (270 and 420 m) drilled for mineral prospects. The area belongs to the "Anticlinorium Pinar del Rio" on the northwestern shore of Cuba, the zone of general uplift tendency. The drilled layers are composed mostly of sandstones alternating with limy slates and claystones and clays. The equilibrium time from termination of drilling and mud circulation was several months.

(2) East of Habana: two holes about 6.5 km apart, both more than 1800 m deep. The Boca de Jaruco (BJ-55) hole was drilled in 1974, the Via Blanca (VB-1) hole in 1967. The drilled rocks are almost entirely pure and clayey limestones to limy sandstones, rather porous and unconsolidated near the surface and more compact in the deeper parts of Quaternary to Eocene Ageas. Below 900–1500 m the rocks are limestones to sandstones of Cretaceous Age. Together with the following group of

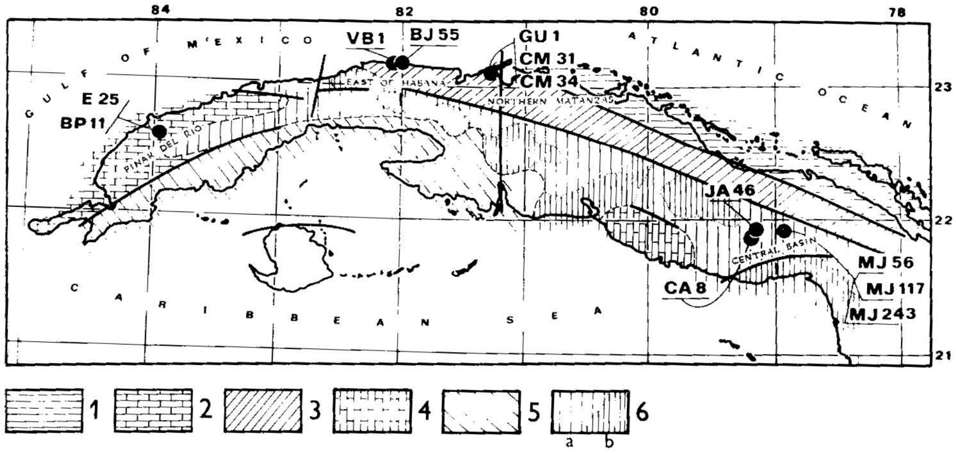

Fig. 1. Simplified tectonic setting of western Cuba with heat flow stations. *1* = miogeosynclinal zone (Bahama platform), *2* = anticlinorium Pinar del Rio, *3* = marginal suture zone, *4* = Trinidad anticlinorium, *5* = Batabanó structure, *6* = eugeosynclinal zone (*a*—depressions, *b*—elevations).

holes (3), the area belongs to the folded marginal suture zone, a narrow belt framing the northern coast of Cuba.

(3) South of Varadero (Matanzas province): a group of three holes (Guasimas and Camarioca) distributed in an area of approximately 20 km^2. The stratigraphy and lithology of the drilled rocks are very similar to the above group. Generally the uppermost 300 m are limestones, the interval 350–450 m are clays to limy claystones of the Eocene Age and below 450 m are serpentinites (Alb-Alt) and Maastrichtian sandstones. The depth of holes varies from 1200 to more than 2000 m. The equilibrium time after the drilling was ceased was more than 1 year (CM holes) and more than 5 years for the GU-1 hole.

(4) Jatibonico and Catalina (Sancti Spiritus province): two holes less than 6 km apart situated close to the western rim of the Central Basin (La Cuenca Central). Both holes were more than 10 years in equilibrium. The local geosyncline structure of Coniacian tuffs and conglomerates (oil bearing) rises up to a depth of only 350–450 m below Jatibonico and is covered by Quaternary to Eocene limestones, sandy limestones and clays with some coarse-grained limy sandstones at the base. The oil-bearing layers below Catalina are of a similar structure but much deeper (below 1000 m).

(5) Cristales–Majagua (Ciego de Avila province): a group of three holes distributed in an area smaller than 10 km^2, drilled between 1963 and 1977. The prevailing rocks are again limestones with limy clays and sandstones of Quaternary–Eocene ages; below 500 m are Palaeogene conglomerates. Oil deposits are below 1000–1400 m as in Catalina.

The first three of the above described localities are situated within the so called folded shore of the North Cuban Basin, which belongs to the North American

continent. The typical rocks of geosyncline origin (limestones, dolomites and other sedimentary rocks) are usually greatly disturbed by later processes and are underlain by rocks of eugeosyncline origin (serpentinites, mafic and ultramafic rocks and tuffs). Around and between Habana and Varadero, the basin was filled by younger (Campanian–Maastrichtian to Quaternary) transgressive deposits.

The Central Basin (localities 4 and 5) is represented by Campanian–Maastrichtian to Quaternary sediments deposited on a folded complex of eugeosyncline rocks (especially tuffs) probably obducted from south.

TECHNIQUES OF MEASUREMENT

Temperature

For the measurement of temperature a light portable thermometer (Krešl, 1981) was used with which the readings were taken point by point at an interval of 10 m. The basic configuration of the thermometer probe is a Wheatstone bridge circuit where the unknown resistance is the temperature sensitive thermistor. Calibration of the sensor was done against a set of precise mercury-in-glass thermometers in a laboratory and was checked in ten temperature points within the range of 5°–90°C. The accuracy of the probe can be estimated to be better than ± 0.05 K and the relative precision of the temperature readings is better than 0.01 K.

The thermistor is placed in a small metallic casing on the tip of the probe. To reach the proper steady-state during the loggings, it is sufficient to wait about 2–3 min if the probe is submerged in water. If the hole is dry, the temperature equalization of the probe is much longer; such readings were taken as the preliminary ones. Even though most of the holes were deeper, temperature was measured only in the uppermost sections till the depth of 500 m due to the limited length of cable.

Thermal conductivity

Both a steady-state comparative method using the divided-bar apparatus (Krešl and Veselý, 1973) and a transient line heat source method using the commercial "Shotherm" Quick Thermal Meter (QTM-2) (produced by Showa-Denko Co.) were applied to measure the thermal conductivity. The calibration of both devices was ensured relative to fused silica.

Rock samples from drill core were available from holes E-25 and BP-11. These samples were, however, too small and not suitable for the QTM-2 handling and therefore measured only with the divided-bar apparatus. Other holes were all rotary drilled and no core samples were available. As all the temperature records in the investigated depth interval of approximately 200–500 m are relatively straight and also the corresponding near surface layer is composed of fairly homogeneous rocks

(mostly limestones), the thermal conductivity was measured for the rock samples collected from the surface outcrops in the vicinity of each hole. Sufficiently large pieces of rocks were collected, which were cut into two parts to provide the required volume for the QTM-2 use (minimum dimensions $50 \times 100 \times 100$ mm). Several runs per sample with QTM-2 were done and thereafter the samples were drilled in order to prepare small size cylindrical discs required for the divided-bar apparatus (diameter of 21.5 mm). A set of 3–7 discs of various thickness ranging between 3

TABLE I

Thermal conductivity of rock samples—comparison of the results obtained on divided-bar and Showa-Denko instruments

No.	Locality		Thermal conductivity ± error	
			divided-bar ($W m^{-1} K^{-1}$)	Showa-Denko ($W m^{-1} K^{-1}$)
1	Cristales (CB)		3.00 ± 0.09	2.91 ± 0.06
2	Cristales (CB)		2.70 ± 0.08	2.78 ± 0.01
3	Cristales (CB)		2.59 ± 0.08	3.05 ± 0.02
4	Cristales (CB)		2.63 ± 0.11	2.68 ± 0.03
5	Cristales (CB)		2.43 ± 0.07	2.61 ± 0.04
6	Catalina (CB)		–	1.57 ± 0.09
7	Catalina (CB)		2.59 ± 0.13	2.67 ± 0.04
8	Camarioca (NM)		1.75 ± 0.25	0.81 ± 0.08
9	Camarioca (NM)		–	1.16 ± 0.17
10	east of Habana (EH)		1.16 ± 0.15	1.06 ± 0.05
11	east of Habana (EH)		1.75 ± 0.16	1.77 ± 0.11
12	east of Habana (EH)		2.23 ± 0.18	1.70 ± 0.05
13	Jatibonico (CB)		1.37 ± 0.14	1.50 ± 0.01
14	Jatibonico (CB)		1.25 ± 0.09	1.17 ± 0.06
15	basement rocks (EH)		1.84 ± 0.04	2.12 ± 0.04
16	basement rocks (EH)		2.12 ± 0.25	1.94 ± 0.02
17	basement rocks (EH)		1.95 ± 0.10	1.82 ± 0.03
	Borehole	Depth (m)		
–	BP-11	35	3.25 ± 0.16	–
–	BP-11	64	3.90 ± 0.19	–
–	BP-11	126	4.29 ± 0.39	–
–	BP-11	172	3.75 ± 0.49	–
–	BP-11	227	4.26 ± 0.21	–
–	BP-11	308	4.70 ± 0.19	–
–	BP-11	339	5.33 ± 0.43	–
–	E-25	97	4.04 ± 0.12	–
–	E-25	98	3.58 ± 0.14	–
–	E-25	188	4.99 ± 0.40	–
–	E-25	240	3.48 ± 0.45	–

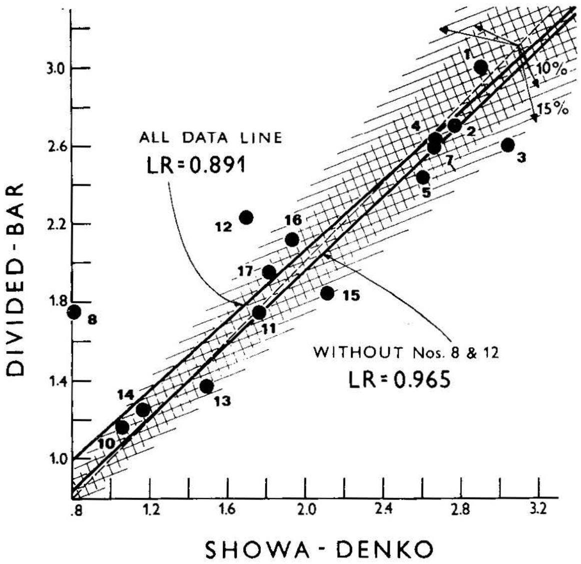

Fig. 2. Comparison of the thermal conductivity (in W m^{-1} K^{-1}) as measured by the divided-bar and by the Showa-Denko QTM device. The line of equality (dashed line), the areas of ± 10 and/or $\pm 15\%$ deviation, resp. (shaded areas) and the linear regression lines (full lines) are also shown. The individual values (solid dots) are numbered according to data given in Table I.

and 12 mm were measured and the conductivity calculated relative to the "standard" conductivity of the bars. In addition to the calibration by fused silica, the proper function of the divided-bar was also checked by a set of discs prepared from crystalline quartz cut perpendicular to the optical axis. All the measurements were performed on samples resaturated by water in a vacuum pump prior to the measurements.

Detailed comparison studies of both types of the above apparatus were recently reported by Sass et al. (1983) who demonstrated a generally very good agreement between the results obtained by both methods. In all their cases the QTM versus divided-bar points lie within $\pm 10\%$ of the line of equality. They found the coefficient of correlation of 0.98 and concluded that for isotropic material either apparatus gives the same conductivity over the range 1.4–5 W m^{-1} K^{-1}. Our combined conductivity data are summarized in Table I and their comparison is shown in Fig. 2. In our case Y is the divided-bar value and X is the QTM (Showa-Denko) value. The formal statistics gave the coefficient of correlation $LR = 0.89$ for all points and after two points of the poorest quality (Nos. 8 and 12) had been excluded, the correlation improved to $LR = 0.97$ and a value of A (slope) of 0.97 ± 0.08 (reciprocal $1/A = 1.03$ is close to the similar value of 1.04 reported by Sass et al., 1983). Our comparison was obtained incidentally as a side-product of the use of both methods and was not intended for special correlation studies. The quality of data is thus certainly poorer. Most of the observed deviations from the equality line are believed

to be caused by the sensitivity of the divided-bar results to the surface quality of the specimens. Some rock samples investigated were rather unconsolidated (in two cases it was impossible to prepare small discs, Nos. 6 and 9) and thus it was difficult to prepare specimens of good shape. However, no data of either technique were preferred and the characteristic thermal conductivity values for the heat flow density determination were taken as the means of all the information of both series available for each specific region.

TEMPERATURE DATA AND THEIR DISCUSSION

The temperature–depth profiles measured in individual holes are shown in Fig. 3. A characteristic feature of almost all records (except the E-25 and BP-11 holes) is the negative temperature gradient in the uppermost parts of the holes with the relative minimum temperatures found at a depth between 100 and 200 m. Below this depth the temperature gradient increases and it reached its "undisturbed" value at a depth of about 200–250 m. The temperature gradients in all the investigated holes are relatively constant in each locality below this depth. Numerical values are summarized in Table II together with the depth intervals of temperature readings and the coordinates of the holes.

Negative temperature gradient in the near surface layer and the specific "U" shape of the temperature–depth curve seems to be a general phenomenon in most of Cuba. As it does not depend on the depth to the water table, it is believed to reflect the effect of the recent climate changes (Čermak, 1971), possibly combined with the

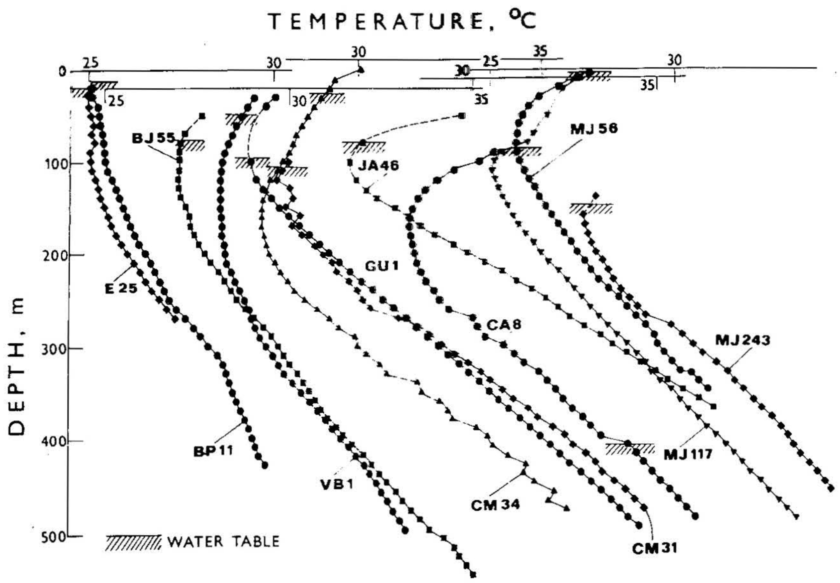

Fig. 3. Temperature–depth profiles. Sites are identified in Table II.

agricultural effect produced by clearing land 100–200 years ago, As this effect is limited to the uppermost part of the temperature record, which was excluded for the gradient determination, it does not pose any problem for the heat flow density calculation. However, if the recent climate produced some changes in the underground temperature field there might be a similar effect on the temperature gradient connected by the long term climatic variations and especially by the general global warming following the termination of the last Ice Age. Nowadays, it is generally believed that some perturbation of the underground temperature field due to the ice retreat need not be necessarily limited to the areas which were subjected to glaciation, but may be observed also in other regions (Beck, 1977). The warming in the world climate, which occurred some 11,000 years B.P., could have lowered the temperature gradient at a depth interval of 200–500 m by as much as 0.4–0.5 mK/m per 1°C change in the surface conditions (Čermák, 1977). For the geographical latitude of Cuba one can assume 8°–10°C temperature increase since the end of the Pleistocene; the corresponding climatic correction could amount up to 4–5 mK/m. The relatively more humid and warmer climate of the Atlantic age may have produced an opposite disturbance and partly compensated for the former. Thus it can be expected that the respective climatic corrections to the measured temperature gradients are lower than shown above and may range from 1 to 2 mK/m. However, such a value still amounts to 10% of the low temperature gradients found, e.g., in Pinar del Rio and therefore has a significant meaning in heat flow calculations. As there is no evidence which can either support or disprove this effect reliably and the climatic corrections cannot be evaluated properly, no corrections are proposed in this paper, but it may be necessary to include such a correction in the future when more information is available.

With the exception of the Pinar del Rio boreholes, all the measured temperature records were taken from holes located in a rather flat country and no topographic corrections were thus necessary. Even in the holes located in a hilly terrain, E-25 and BP-11, where topographic corrections were calculated, these are rather small and amount to only -0.05 and/or -0.12 mK/m, resp.

HEAT FLOW AND DEEP TEMPERATURES

The mean thermal gradients and thermal conductivities measured were used to calculate values of heat flow density (Table II). The obtained values range between 29 and 65 mW· m^{-2} and reveal the generally very low to subnormal geothermal activity in western and central parts of Cuba. Lowest heat flow is found in the region of La Habana–Western Matanzas (30–35 mW m^{-2}). Heat flow density increases to both sides and amounts to about 60 mW m^{-2} in Pinar del Rio and 55–65 mW m^{-2} in the Central Basin, still being lower than the world mean of 64.4 ± 28.4 mW m^{-2} reported by Jessop et al. (1976) for land measurements.

Such a low geothermal activity seems to agree well with the data reported from

TABLE II

Coordinates, temperature gradient, mean thermal conductivity and heat flow

Bore-hole	Lat. N.	Long. W.	Altitude (m)	Depth interval (m)	Temp. grad. (mK/m)	Thermal conductivity ($W m^{-1} K^{-1}$)	Heat flow (mW/m^2)
E-25	22°34.1′	83°56.6′	112	150–270	15.9 ± 3.7 *	4.02 ± 0.68	64
BP-11			109	150–430	13.9 ± 4.3 *	4.21 ± 0.67	59
BJ-55	23°11.3′	82°01.6′	3	200–530	22.2 ± 3.8	1.61 ± 0.43	36
VB-1	23°10.8′	82°05.3′	5	250–500	17.8 ± 3.1		29
GU-1	23°05.9′	81°15.4′	18	150–500	27.8 ± 1.4		34
CM-31	23°06.1′	81°18.8′	20	150–480	30.2 ± 7.2	1.22 ± 0.40	37
CM-34				220–480	30.3 ± 6.1		37
JA-46	21°57.4′	79°08.4′	105	150–380	39.3 ± 2.7	1.32 ± 0.14	52
CA-8	21°54.5′	79°09.5′	115	220–490	28.3 ± 5.4	2.10 ± 0.62	59
MJ-56				200–390	23.7 ± 4.6		65
MJ-117	21°57.5′	78°57.8′	140	200–490	23.5 ± 1.4	2.75 ± 0.20	64
MJ-243				280–490	23.1 ± 3.2		63

* Corrected for topography

the surrounding sea regions of the Gulf of Mexico (less than 40 mW m^{-2}) and the Florida–Bahama platform (~ 50 mW m^{-2}) (Epp et al., 1970).

Unfortunately, relatively little is known about the deep crustal structure of Cuba and therefore it is difficult to interpret the present heat flow density data. According to the regional setting given by Pardo (1975) all the reported heat flow data fall within a relatively narrow belt (50–150 km wide) of highly folded and faulted platform sediments underlain by ultrabasic igneous rocks. This belt separates the Florida–Bahama carbonate platform to the north from the southernmost rim of Cuba consisting of metamorphosed sediments and acidic volcanites. This belt thus includes the major part of Cuba, except for its southern part (the Isla de Pinos, the Trinidad Mts. and the Sierra Maestra). This area is of a relatively low elevation and of a generally positive Bouguer anomaly field (Bowin in Case, 1975), which is believed to confirm the existence of mafic to ultramafic basement rocks. The low heat-flow on the surface may be thus explained by low radioactive heat generation within the crust and low heat-flow contrubution of the crust to the terrestrial heat-flow.

Recent interpretation of seismological data reveals some information on the regional distribution of the crust–upper mantle boundary in western Cuba (Bovenko et al., 1975). According to it the dividing line (deep reaching crustal fault) between the northern platform and the southern faulted area is situated more to the south than placed by Pardo (1975) and runs approximately from Bahía Honda, then about

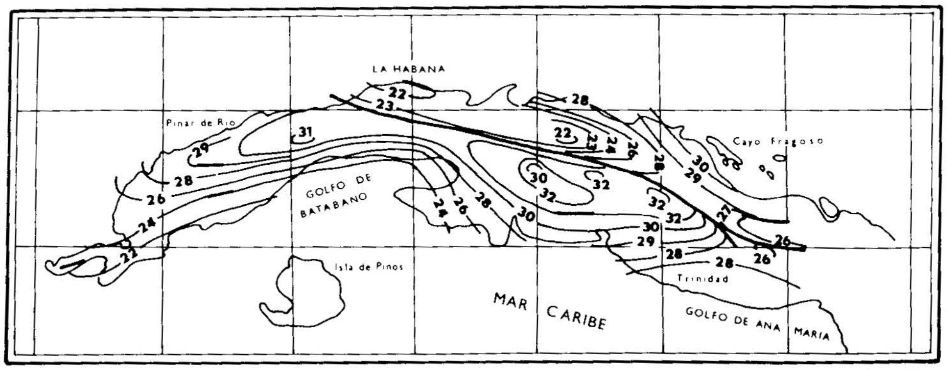

Fig. 4. The crustal thickness pattern (in km) of western and central Cuba (adapted after Bovenko et al. (1975)).

20 km south of La Habana to Santa Clara and just touches the Central Basin from the north. North of this boundary line the crustal thickness is 22–23 km in the region between La Habana and Varadero and it increases up to 30 km near Cayo Fragoso (Fig. 4). There is a step-like sudden change of the depth of the Mohorovičić discontinuity of about 2–6 km along this boundary diminishing to the east. Near Pinar del Rio the crustal thickness is about 28–29 km, in central Matanzas 30–31 km and in the Central Basin 26–28 km. Below the southern coast, the crustal thickness again decreases to 22–24 km. If the heat flow density data and crustal thickness are correlated (Fig. 5), the low heat-flow between La Habana and northern Matanzas (30–35 mW m^{-2}) corresponds to the Moho depth of 22–24 km and relatively higher heat flows found in Pinar del Rio and in the Central Basin (55–65

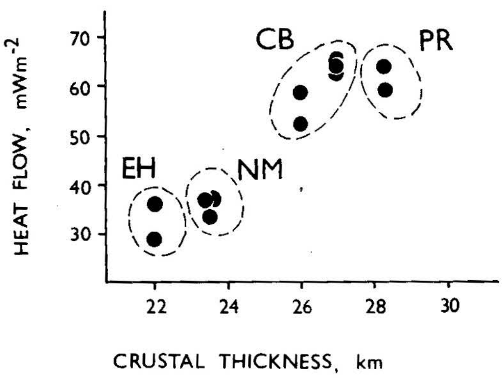

Fig. 5. Heat flow versus crustal thickness in Cuba. Explanations: *EH*—East of Habana, *NM*—Northern Matanzas, *CB*—Central Basin, *PR*—Pinar del Rio. For locations see Fig. 1.

TABLE III

Properties of the crustal rocks used for the model calculation of the deep temperatures

Layer	Thermal conductivity		Heat generation	
	k_0 (W m^{-1} K^{-1})	C (K^{-1})	A_0 (μW/m^3)	D (km)
Upper crust (sedimentary and volcanic)	2.5	0	1.0	∞
Granite layer	3.0	0.0008	3.0	10
Basalt layer	2.0	0	0.6	∞
Upper mantle	2.5	−0.00025	0.0084	∞

mW m^{-2}) correspond to the crustal thickness of 25–27 km. This relation is not to be overestimated, however, it is interesting to mention, that it is of an opposite tendency than the general relation between the heat flow and the Moho depth found, e.g. in Europe, where a negative tendency was reported (Čermák, 1979).

Since the Middle Eocene when the previous island-arc stage of evolution terminated, the platform type evolution has dominated in the modern geological history of Cuba (Iturralde-Vinent, 1975). That means that in the last 40–50 m.y. there were no significant tectonic movements and the steady state solution of the heat conductivity equation to find the deep temperature distribution in the 20–30 km thick crust may be justified.

Bovenko et al. (1975) proposed the schematic crustal sections for several selected locations in Cuba, which were used to calculate the characteristic temperature–depth profiles. For this purpose heat flow density must be complemented by a certain model of the vertical distribution of the heat sources and the thermal conductivity. As there are no specific data on both these parameters, mean values were taken from literature (see Čermák and Rybach, 1982; Rybach and Čermák, 1982). The steady-state one-dimensional temperatures were calculated for a model of layered lithosphere (Čermák, 1982) with temperature dependent thermal conductivity $k = k_0(1 + CT)^{-1}$ and the exponential heat production $A(z) = A_0 \exp(-z/D)$. The values of the individual parameters used in each layer are summarized in Table III.

The calculated temperatures at the depth of the Mohorovičić discontinuity for three regions: Pinar del Rio, Habana-Matanzas and the Central Basin, are given in Table IV. Below the northernmost coast of Cuba one must expect quite low temperatures of about 250°C at a depth of 20–25 km, which increases when passing the dividing line between the northern platform unit and the framing faulted zone. In Pinar del Rio and in the Central Basin the temperatures at the Moho may reach 500°C.

Of interest is also the calculated contrast in the outflow of heat from the upper mantle: 7 mW m^{-2} below the Habana–Matanzas province compared to 28–30 mW m^{-2} below Pinar del Rio and/or the Central Basin.

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TABLE IV

Data on the crustal structure (Bovenko et al., 1975), mean surface heat flow and calculated Moho heat flow and Moho temperature for several regions in Cuba

Region	Crustal structure-thickness (km)				Heat flow (mW/m^2)		Temp. (°C)
	upper crust	granite layer	basalt layer	total	surface	Moho	Moho
Pinar del Rio	5	9	15	29	60	28	555
Habana–Matanzas	8	7	8	23	35	7	220
Central Basin	8.5	6.5	10	25	60	31	515

Note: Surface temperature taken 25°C.

All the above calculations were done for a horizontally uniform model and may not be valid on the platform margin where some structural inconsistencies may be expected. If there is some horizontal contrast in the radioactivity between both zones and relatively more heat is generated in the crust below the major part of the island than below its northern rim (platform margin), then the actual temperatures as well as the Moho heat flows will be closer. However, to get the equal magnitudes of both the calculated parameters in both tectonic zones, an unusual heat production is to be supposed, which is very unlikely. Therefore some regional discrepancies in the heat flow at depth and in deep temperatures are to be expected in the studied part of Cuba, notably their increase from north to south on the contact of the Bahama platform with the faulted major part of the island.

The geological evolution of Cuba has been very complicated and sometimes quite contradictory explanations have been proposed (see, e.g., Pardo, 1975; Iturralde-Vinent, 1975). The present heat flow data are unfortunately not sufficient to support either of them. More data will be necessary to cover all the Cuban territory. As the present data are distributed relatively close to the dividing line between the eugeo- and miogeosyncline zones, they do not allow a more detailed interpretation in terms of the crustal structure. Next heat flow measurements should therefore include other tectonic provinces and a study of the relationship between the heat flow and the distance of the site from the axis zone. Of prime interest might also be the knowledge of the heat flow density in the eastern part of Cuba (Oriente province) with its anomalous crustal structure.

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