J Geophys (1984) 54:106–109

Journal of Geophysics

Heat flow density determination in the Strymon basin, NE Greece

I. Erki [1], N. Kolios [2], and L. Stegena [1]

[1] Eötvös University, Kun B. tér 2., 1083, Budapest, Hungary
[2] IGME, Mesoghion 70, 608 Athens, Greece

Abstract. Heat flow density determinations were carried out in the Strymon 1 and 2 boreholes, in the Neogene Strymon basin, NE Greece ($\varphi = 40°58'$ $\lambda = 23°40'$ and $\varphi = 41°0'$ $\lambda = 23°43'$ respectively). The most probable values of heat flow density are 98.2 mW/m^2 for Strymon 1 and 69.2 mW/m^2 for Strymon 2. It is suggested that $Q = 90 \pm 15$ mW/m^2 value is characteristic for the central part of Strymon basin under consideration.

Key words: Heat flow density – Strymon basin

Introduction

The Strymon basin lies NE from the Chalkidike peninsula, between the sea coast at Orfanos bay and the border of Greece. It has a length of 80 km in the NW–SE direction and a width of 25 km. It is a Neogene basin, with Plio-Miocene sediments of 3–4 km thickness in the centre (Fig. 1). The geological columns (Figs. 2 and 3) give some information on the lithology of the sediments.

Two boreholes, Strymon 1 (S1) and Strymon 2 (S2) were used for heat flow density determination. The geographic coordinates are: $\varphi = 40°57'53''$, $\lambda = 23°40'14''$ for S1 and $\varphi = 40°59'38''$, $\lambda = 23°43'2''$ for S2.

Temperature measurements

Continuous temperature log and bottom hole temperatures were measured in each borehole. A simple analysis and comparison with bottom hole temperatures showed that continuous logging temperature are unsuitable for estimating formation temperatures and only the bottom hole temperatures can be used for heat flow determination.

Temperature data are summarized in Table 1. All these data are uncorrected bottom hole temperatures, measured after 1–3 days standstill of the holes. An analysis taking into consideration the boring velocities showed that these temperatures are acceptable as formation temperatures within an error of $\pm 3°$ C.

Temperature measurements – as shown on Figs. 2 and 3 – satisfactorily fulfil the linear temperature increase between surface mean temperature (15°) and the deepest maximum temperature in both wells.

Offprint requests to: L. Stegena

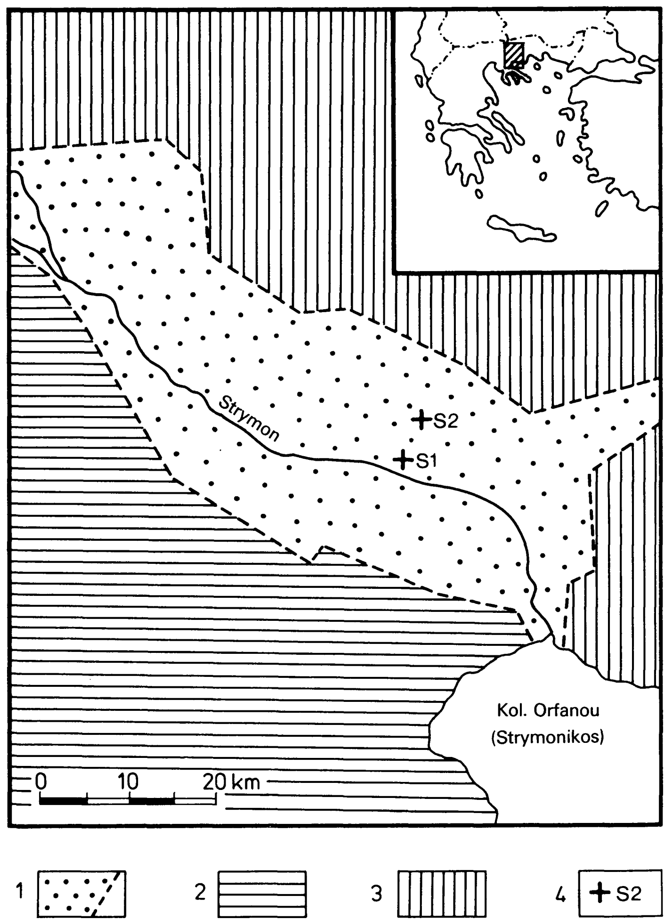

Fig. 1. Location map of Strymon 1 (S1) and Strymon 2 (S2) boreholes. Keys: 1 = Strimon basin and its boundary, 2 = Serbo-Macedonian zone, 3 = Rhodope zone, 4 = Location of investigated boreholes

Thermal conductivity measurements

Five cores were drilled from both S1 and S2 wells. All ten cores were measured for thermal conductivity, using a differentiated line source probe (Cull, 1974), which has an accuracy of $\pm 10\%$. Water saturated cores were measured; each measurement was repeated 3 times; the recur-

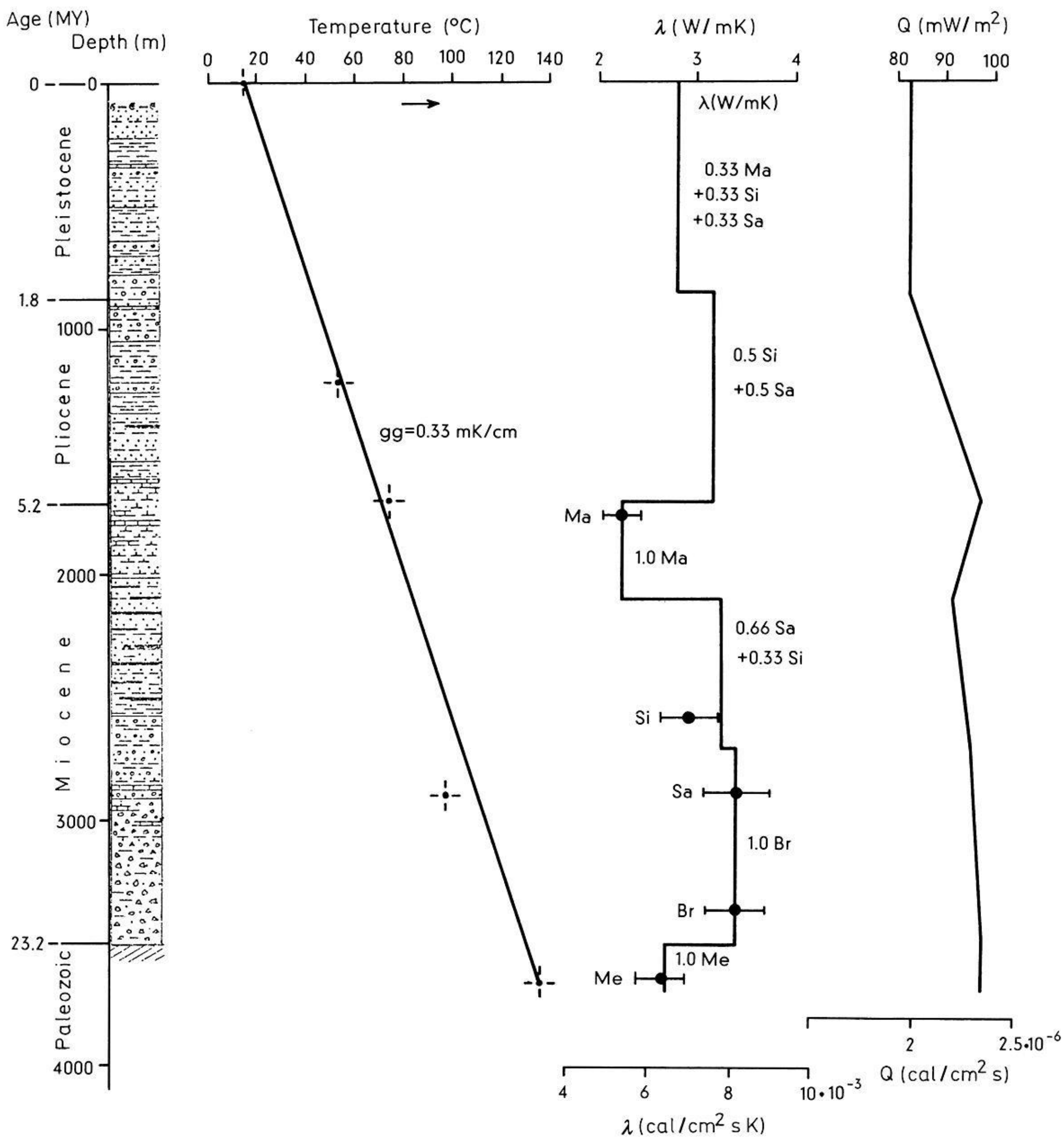

Fig. 2. Sedimentary column, geological ages, temperature and thermal conductivity measurements in Strymon 1 well. Radiometric ages after LaBrecque et al. (1977) and Nagymarosy (1981). Continuous thermal conductivity line was constructed using thermal conductivity measurements and lithology. Lithology after Stylianou (1981a). Abbreviations for rocks after Table 2. Heat flow density vs. depth function was calculated using continuous thermal cunductivity line

rency of repeated measurements lies between 3–4%. Table 2 and Figs. 2 and 3 show the results of thermal conductivity measurements.

Table 1. Bottom hole temperatures

Well	Depth (m)	Temperature (°C)	
Strymon 1	1212	53.3	Surface temp.: 15° C
	1752	73.3	Geothermal gradient
	2883	97.8	
	3650	135	gg = 0.330 mK/cm
Strymon 2	2030	70	Surface temp.: 15° C
	2680	88.7	Geothermal gradient gg = 0.275 mK/cm

Based on the measurements and on the lithology of wells shown on Figs. 2 and 3, a thermal conductivity vs. depth function was constructed as shown in Figs. 2 and 3 and on Table 3.

It is supposed that the weighted means of Table 3 reflect better the real thermal conductivity of the wells as the simple arithmetic means of measurements on Table 2. The right-hand curves of Figs. 2 and 3 show the heat flow density values calculated by the weighted means of Table 3, from the surface to various depths, with constant geothermal gradient (0.33 and 0.275 mK/cm, respectively). If the temperature and thermal conductivity vs. depth curves of Figs. 2 and 3 are really correct, the heat flow density vs. depth function has to be constant. In fact, Q varies between 82.5–98.2 mW/m² at Strymon 1, and between 54.7–69.2 mW/m² at Strymon 2.

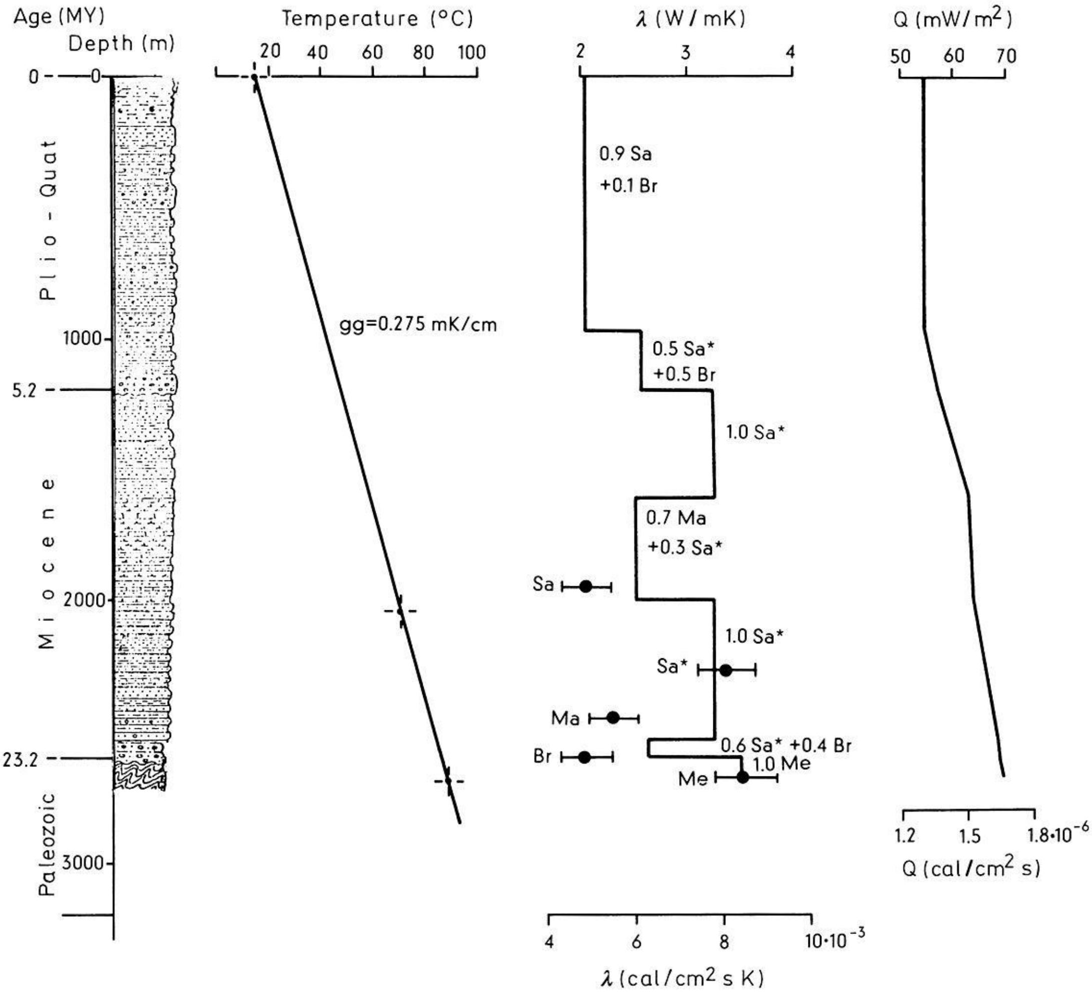

Fig. 3. Caption as Fig. 2, for Strymon 2 well. Lithology after Stylianou (1981 b)

Table 2. Thermal conductivity measurements

Well	Depth (m)	Lithology		Thermal conductivity (W/mK)	Arithmetic mean
Strymon 1	1760	Marlstone	Ma	2.25	
	2579	Siltstone	Si	2.95	
	2881	Sandstone	Sa	3.43	2.86
	3352	Breccia	Br	3.42	
	3631	Metam. schist	Me	2.67	
Strymon 2	1954	Sandstone	Sa	2.04	
	2273	Sandstone	Sa	3.36	
	2446	Marlstone	Ma	2.28	2.47
	2615	Breccia	Br	2.02	
	2677	Metam. schist	Me	3.53	

Table 3. Constructed thermal conductivity vs. depth functions

Well	Depth (m)	Lithology	Thermal conductivity (W/mK)	Weighted mean
Strymon 1	0– 950	0.33 Ma + 0.33 Si + 0.33 Sa	2.79	
	950–1700	0.5 Si + 0.5 Sa	3.17	
	1700–2100	1.0 Ma	2.24	2.96
	2100–2700	0.66 Sa + 0.33 Si	3.26	
	2700–3500	1.0 Br	3.42	
	3500–3650	1.0 Me	2.67	
Strymon 2	0– 970	0.9 Sa + 0.1 Br	2.04	
	970–1200	0.5 Sa + 0.5 Br	2.50	
	1200–1610	1.0 Sa	3.26	
	1610–2000	0.7 Ma + 0.3 Sa	2.50	2.53
	2000–2530	1.0 Sa	3.26	
	2530–2600	0.6 Sa + 0.4 Br	2.62	
	2600–2680	1.0 Me	3.53	

Heat flow density calculation

Table 4 shows the calculated heat flow density values, using the arithmetic and weighted mean of conductivity values.

The estimated error of these heat flow density values is about $\pm 15\%$, and the principal source of error seems to be in the temperature measurements, which were made a few days after stopping the drilling. Because of this error and of the nearness ($\sim$4 km) and geological similarity of the wells, it is suggested that the difference in the calculated values for Strymon 1 and Strymon 2 reflects subsurface water movements. The most probable mean value of heat

Table 4. Heat flow density in the wells S1 and S2

Well	Depth interval (m)	gg, (mK/cm)	Mean thermal conductivity (W/mK)		Heat flow density (mW/m^2)	
			arithm.	weighted	arithm.	weighted
Strymon 1	0–3650	0.33	2.86	2.96	94.2	98.2
Strymon 2	0–2680	0.275	2.47	2.53	68.0	69.2

flow density for the part of Strymon basin under consideration is:

$$Q = 90 \pm 15\ mW/m^2.$$

Acknowledgements. We thank the Public Petroleum Corporation of Greece and IGME, Athens placing at our disposal geological and temperature data and cores from the Strymon boreholes, and also Dr. P. Economou and Dr. N. Lalechos of PPC for valuable discussions.

This study was carried out partly during the stay in Greece of one of authors (Stegena), who enjoyed the kind hospitality of Professors S.S. Augustithis and C. Garagunis of the Geology Dept. of the National Technical University of Athens.

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Received July 21, 1983; Revised version October 3, 1983
Accepted October 4, 1983