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2. *Estimation of Heat Flow in Certain Exploration Wells in Offshore Areas of Malaysia.*

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Abstract

As a part of studies on the thermal state of the crust under shallow seas where heat flow data is rare, we estimated the heat flow in the offshore areas of Malaysia, based on the existing thermal gradient data and newly measured thermal conductivity of 152 core samples from exploration wells. The results show that the regional heat flow is anomalously high in the Malay Basin which is located on a now stable continental shelf. In contrast, the heat flow off the shore of Saban is subnormal to normal.

1. Introduction

Since the first work done in the oil fields of Iran (COSTER, 1947), there have been many attempts to determine the heat flow in sedimentary basins where deep wells are available. The role of the underground temperature distribution in the process of hydrocarbon maturation and accumulation has recently come to be recognized by petroleum geologists (e.g. PUSEY, 1973). In Southeast Asia, a compilation of geothermal gradient values released from oil companies was published jointly in 1977 by the Southeast Asia Petroleum Exploration Society (SEAPEX) and Indonesian Petroleum Association (IPA). It is hoped that all of these temperature gradient data can be converted into heat flow, so that the thermal state of the region can be discussed in terms of heat budget. For this purpose we made measurements of the thermal conductivity of rocks collected from some of the wells for which geothermal gradients are given in the SEAPEX-IPA compilation. In this paper, the data of the thermal conductivity of cores from the wells in the offshore areas of the West Malaysia and Sabah are reported and used to estimate the heat flow values. The core specimens were provided by the Exxon Production Malaysia Inc. with the permission of PETRONAS, Malaysia, to whom the authors are most grateful.

2. Method of thermal conductivity measurements

The apparatus used for the measurement of thermal conductivity is a transient type with a box-shaped hot wire probe, Type QTM-D1 of Showa-Denko Co. (ITO *et al.*, 1975). Core samples, which had been stored in dry state, were soaked in water for about two days, because it is unlikely that the air-filled pores existed in the *in situ* conditions. We made a comparison experiment to use a vacuum chamber to ensure saturation but it was found that the thermal conductivity values were different by less than ±2% from those of cores soaked in a water-bucket only. We believe that the simple soaking technique used reproduced the natural state of the sedimentary rock samples as far as this type of thermal conductivity measurement is concerned. A thin plastic film was laid between the surface of the soaked sample and the probe to prevent the heating wire and the temperature sensor from alteration due to contact with water. The effect of this film is found to be less than 1% of the thermal conductivity values when measured on a fused quartz standard sample. The room temperature of the laboratory was about 30°C. Hence, the data of the thermal conductivity we report below represents those at 30°C. After correction for instrumental drift, the thermal conductivity values of the rock samples were reproducible within ±2%.

3. Results and discussion

Results of the thermal conductivity measurements in the soaked state are listed in Table 1.

Table 1. Thermal conductivity of cores from offshore Exxon wells in Sabah and West Malaysia. Results are given in *m* cal/cm sec C°. Errors cited are one standard deviation.
*Number of samples measured for the interval.
**Very calcareous sandstones.

(a) **Sabah**

Well name	Core depth (m)	Sandstone N*	Sandstone K	Mudstone N*	Mudstone K	Others N*	Others K	Average of samples measured N*	Average of samples measured K
Dudar 1	1541-1542			1	3.42 (claystone)				
				1	9.23 (siltstone)			2	6.33
Kalutan 1	977- 980					6	5.65±0.95 (limestone)		
	1960-1966	1	7.65	4	3.22±0.05				
	average							11	4.94
Nosong 1	1629-1631			3	5.26±0.13			3	5.26
Tembungo 4	2349-2357	12	6.61±1.17	3	3.75±0.38			15	6.04

(to be continued)

Table 1 (Continued)

Well name	Core depth (m)	Sandstone N*	Sandstone K	Mudstone N*	Mudstone K	Others N*	Others K	Average of samples measured N*	Average of samples measured K
Timbalai 1	2388			1	4.81				
	2720-2728	7	7.54±2.36						
	average							8	7.20
Rizal	1493-1497	3	8.26±0.37	5	5.03±0.99			8	6.24
Average of each rock type		23	7.15	18	4.58	limestone 6	5.65	47	5.98
(b) West Malaysia									
Duyong 1	2701-2711	6	9.76±1.06						
	2713-2714			3	6.95±0.23				
	average							9	8.82
Angsi 1	1600-1603			3	6.76±0.07				
	2442-2453			5	8.92±1.09				
	2567			1	5.90				
	2773			2	6.92±0.55			11	7.69
Belumut 1	1185-1188	{1	6.65						
		{2	8.89±1.17**						
	1468-1471	3	6.68±0.30						
	average	6	7.41					6	7.41
Sepat 1	1384-1388	4	5.46±1.24						
	1746-1747	2	7.60±0.37			1	4.88 (coal)		
	1803-1811			6	7.63±0.66				
	average	6	6.17					13	6.75
Bujang 1	1151-1158	3	4.97±0.31						
	1391			1	5.99				
	average							4	5.23
Pilong 1	1763-1771	2	7.69±0.26	8	7.85±0.64	3	5.73±0.42 (coal)		
	2008-2016	1	8.54	9	6.80±0.87				
	2742-2750	9	8.60±0.65						
	average	12	8.44	17	7.29			32	7.58
Seligi 1	1224	1	8.08**						
	1608-1615	4	6.77±0.79						
	1883-1891	3	9.01±0.65						
	2574-2583	5	10.73±0.58						
	average	13	8.91					13	8.91
Tok Bidan 1	964- 965			2	5.74±0.81				
	1537			1	6.94				
	1860-1866	5	6.46±1.44	1	6.03				
	2011-2013	4	7.23±2.15						
	2194-2201	1	10.2	1	7.57				
	2377			1	6.44				
	2705					1	9.39 (metasediment)		
	average	10	7.14	6	6.41			17	7.01
Average of each rock type		56	7.92	44	7.27	4	5.52 (coal)	105	7.57

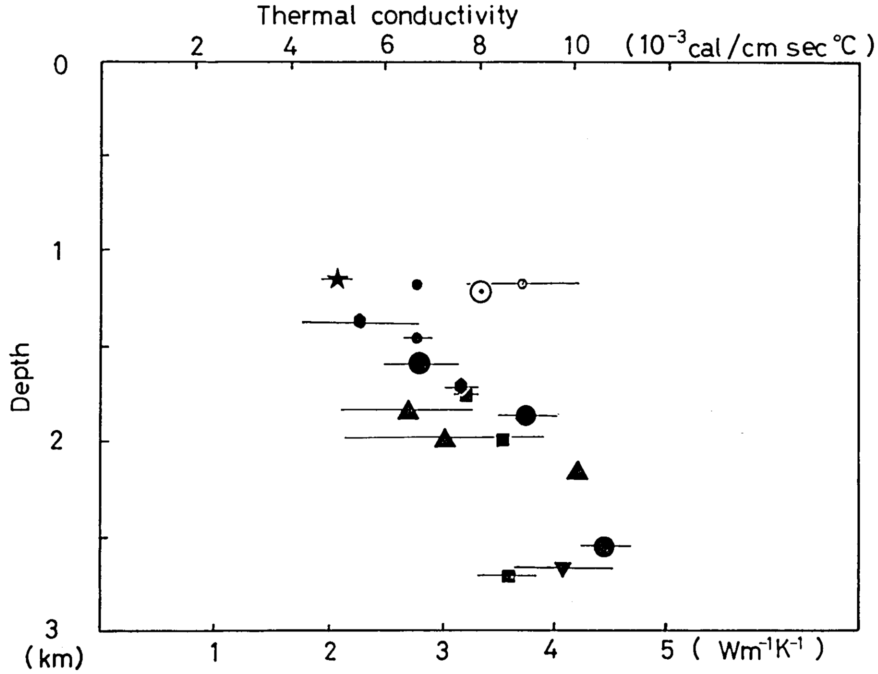

Fig. 1. Plot of thermal conductivity of sandstones vs. depth in the wells in the Malay Basin. Squares represent those of Pilong 1, triangles Tok Bidan 1, hexagons Sepat 1, star Bujang 1, large circles Seligi 1, small circles Belumut 1, inversed triangle Duyong 1. Open circles with dots indicate calcareous sandstones. Horizontal bars attached to the symbols represent one standard deviation at each core depth.

In Fig. 1, the thermal conductivity data of sandstones from the wells of the Malay Basin are plotted against core depths. There seems to be a roughly linear increase of conductivity values with increasing depth, which is represented by

$K=2.50+2.79\times z/1000$, where units of K and z are $m$cal/cm sec °C and meter,

for depths(z) from 1150 to 2850 m, if we exclude the singularly high values at about 1200 m in the wells Belumt 1 and Seligi 1 (these rocks are very calcareous sandstones). Except for the locally present calcareous sandstones, the lithology is nearly the same for all the wells, so that the relation between the thermal conductivity and the depth in Fig. 1 may be considered as caused by the porosity decrease with depth. The thermal conductivity data on mudstones from the same wells in the Malay Basin do not show such a marked increase with depth, as shown in Fig. 2. The reason for the different characteristics of the sandstones and mudstones is not clear. It may be that the com-

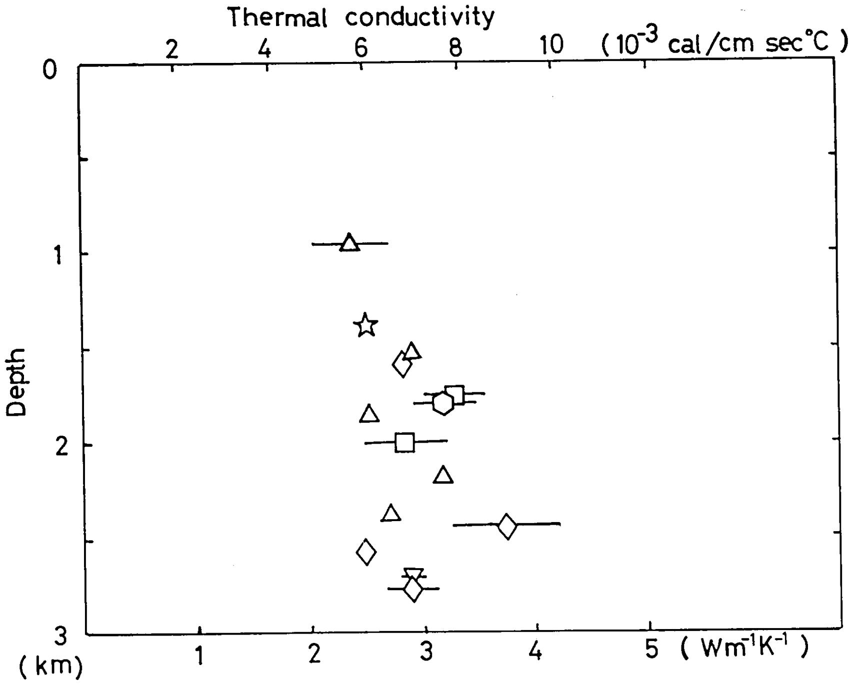

Fig. 2. Plot of thermal conductivity of mudstones vs. depth in the same wells as Fig. 1. Rectangles represent those of Angsi 1. Other symbols are the same as in Fig. 1, except that the open symbols show that these samples are mudstones.

positions of the grains and cementing materials in grain boundaries of mudstones are less uniform than those of the sandstone which we measured.

For the offshore wells in Sabah, only a small number of samples were available, so that the thermal conductivity data of sandstones and mudstones as well as limestones are shown together in Fig. 3. No systematic change of the thermal conductivity with depth is seen in this case.

With regard to the geothermal gradient values, we use the data by SEAPEX and IPA (1977), from which only the wells concerned in the present study are cited in Table 2. The values of static formation temperature given in this table are supposed to represent reliable one since they are derived from, by applying the extrapolation formula of DOWDLE and COBB (1975), the sets of data of bottom hole temperatures measured three times or more after the cessation of mud circulation.

There are certain difficulties in estimating the heat flow values from these data: the geothermal gradients given by SEAPEX and IPA (1977) are the average values through the total depth of the individual

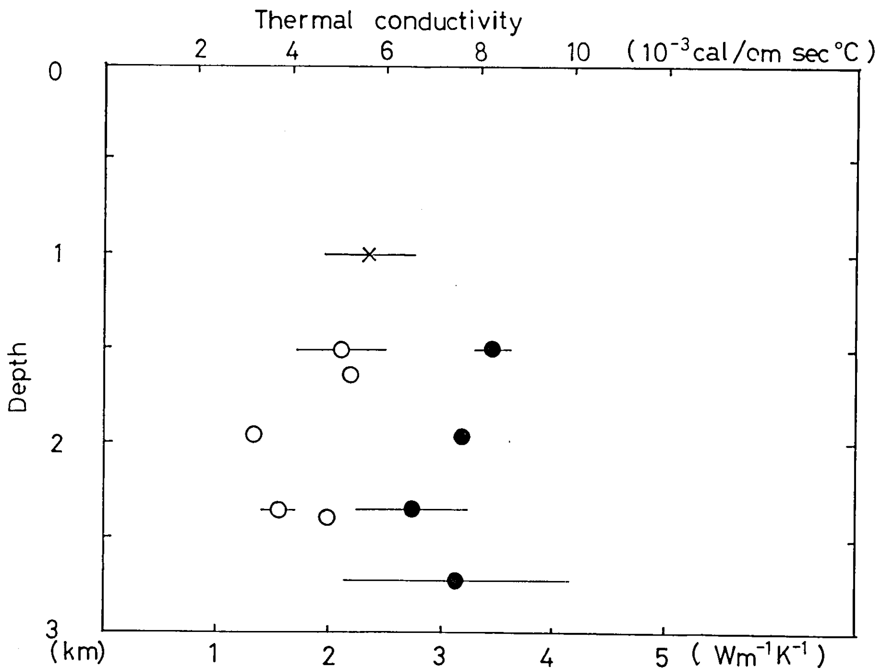

Fig. 3. Plot of thermal conductivity of limestone, mudstone, and sandstone in the wells off Sabah. Soild circles indicate sandstone, and open circles mudstones. The cross represents limestones.

wells. Therefore, the thermal conductivity data only on the consolidated cores taken by the oil company (the number of sandstone samples overwhelms that of other lithology in this case) may be biased information. Table 3 shows percentage breakdown of rock-types in each of the wells used in this work. If the average conductivity value of clays and mudstones at shallower part of the wells, for example depths less than 500 m, is as small as 1.0 $Wm^{-1}K^{-1}$(2.4 m cal/cm sec °C), the harmonic mean thermal conductivity from the top to the bottom is smaller by a factor from 0.52 to 0.91 than the simple average thermal conductivity of cores actually measured (the minimum core depth of all the wells used in this work is 964 m for Tok Bidan 1). In order to give a reasonable mean thermal conductivity estimate which should be combined with the $\Delta T/\Delta z$ data, it is desired that some way of lithologic correlation be introduced, such as in the method employed by CARVALHO *et al.* (1979) who used the electric logs for thermal conductivity estimation in the Central Sumatra Basin. However, all the information available to us is that listed in Table 3 and the descriptions of individual rocks on which the thermal conductivity has been measured. No attempt of estimating the thermal conductivity from other physical properties can be made.

Table 2. Geothermal gradient data of the wells off Sabah and West Malaysia published in SEAPEX and IPA (1977)

Map ref. No.	Well name	Location	Total depth (feet)	Rock type, age at total depth	Depth of temp. record (feet)	Measured temp.[1] (°F)	Height above datum[2] (feet)	Static formation temp.[3] (°F)	Calculated geothermal gradient[4] °F/100′(°C/100 m)
(a)	Sabah								
SH 1	Exxon Dudar-1	07°06′38″N 116°13′03″E	9,705	Sedimentary, Miocene	9,660 9,690	256(T) 200(L 4) 210(L 7)	366	256 255	1.39(3.45) 1.55
SH 2	Exxon Gaya-1	06°36′15″N 115°31′39″E	2,930	Sedimentary, Pliocene	2,909	129(L 3)	496	140	2.49(4.54)
SH 3	Exxon Kalutan-1	07°36′52″N 116°42′26″E	6,589	Sedimentary, Middle Miocene	6,558	167(L 4)	391	183	1.67(3.05)
SH 4	Exxon Nosong-1	05°52′21″N 114°53′28″E	8,680	Sedimentary, Late Miocene	8,654	174(L 3) 178(L 5)	360	185	1.27(2.32)
SH 5	Exxon Tembungo-4	06°36′08″N 115°46′56″E	8,784	Sedimentary, Miocene	8,747	180(L 4) 182(L 6) 200(L 24)	309	208	1.52(2.77)
SH 6	Exxon Timbalai-1	05°22′55″N 114°46′15″E	10,098	Sedimentary, Pliocene	9,563	172(L 7.5) 176(L 10.75) 182(L 19)	207	190	1.18(2.15)
SH 7	Forex Bangau-1	07°04′53″N 116°29′16″E	7,500	Sedimentary, Middle Miocene	7,498	170(L 5) 174(L 7)	217	185	1.44(2.63)

(to be continued)

Table 2 (continued)

Map ref. No.	Well name	Location	Total depth (feet)	Rock type, age at total depth	Depth of temp. record (feet)	Measured temp. (°F)	Height above datum (feet)	Static formation temp. (°F)	Calculated geothermal gradient °F/100/(°C/100m)
(b)	West Malaysia								
M 7	Exxon Angsi-1	05°13′43″N 104°43′58″E	10, 132	Sedimentary. Tertiary	10, 078	277 (L 6) 300 (L 9)	275	350	2.75 (5.02)
M 8	Exxon Belumut-1	05°31′39″N 105°38′18″E	4, 938	Sedimentary, Tertiary	4, 967	150 (L 6.5) 168 (L 9) 176 (L 15)	267	200	2.55 (4.65)
M 9	Exxon Sepat-1	06°21′58″N 103°50′39″N	5, 955	Sedimentary, Tertiary	5, 935	182 (L 3.25) 192 (L 7.5) 204 (L 12.25)	236	212	2.32 (4.23)
M 10	Exxon Bujang-1	05°59′59″N 104°01′46″E	5, 675	Sedimentary, Tertiary	5, 448	165 (L 3) 171 (L 5.5) 180 (L 8.5)	247	191	2.13 (3.89)
M 11	Exxon Peta-1	05°40′19″N 105°37′19″N	7, 333	Sedimentary. Tertiary	7, 329	171 (L 6)	255	188	1.53 (2.79)
M 12	Exxon Pilong-1	07°12′10″N 103°05′00″E	9, 200	Sedimentary, Tertiary	6, 587 9, 206	272 (T) 310 (L 5)	270	272 341	3.04 (5.54) 2.92
M 13	Exxon Seligi-1	05°23′50″N 105°23′10″E	9, 012	Sedimentary, Tertiary	5. 280 6, 750	209 (T) 206 (L 8)		209 227	2.58 (4.71) 2.27
M 14	Exxon Tok Bidan-1	06°25′34″N 102°39′27″E	8, 780	Metamorphic, Pre-Tertiary	8, 775	203 (L 6) 210 (L 8.5)	221	228	1.73 (3.16)

(1) Most temperatures are given at the bottom of the deepest logging interval (L). The number following L stands for the time duration (in hours) after stopping circulation of drilling mud. (T) indicate data from "Formation tests".
(2) Water depth plus Kelley Bushing elevation.
(3) Extrapolated temperature by the method mentioned in the text.
(4) Underlined data indicate those from formation tests which may be better static formation temperature.

Table 3. (a) Lithologic percentage breakdown of Exxon wells, western offshore, Sabah.

Well	Claystone	Shale	Sandstone	Siltstone	Mudstone	Coal	Limestone	others
Kalutan 1	2	5	9	—	11	—	73	—
Dudar 1	70	15	11	4	—	—	—	—
Gaya 1	84	—	13	1	—	—	2	—
Tembungo 4	43	—	47	4	—	—	6	—
Rizal 1	41	—	32	24	—	—	3	—
Nosong 1	46.8	—	44	9	—	—	0.2	—
Timbalai 1	2	—	78	1	19	traces	—	—

(b) Lithologic percentage breakdown of Exxon wells, eastern offshore, West Malaysia.

Well	Claystone	Shale	Sandstone	Siltstone	Mudstone	Coal	Limestone	others
Angsi 1	87.1	—	11.1	1.8	—	—	—	—
Belumut 1	36.4	—	46	—	16	—	—	1.6*
Bujang 1	63.4	3.6	33.0	—	—	—	—	—
Duyong 1	44.9	32.8	22.3	—	—	—	—	—
Peta 1	34.8	15.4	6.0	4.5	39.0	—	0.3	—
Pilong 1	46.6	31.2	15.1	5.3	—	1.8	—	—
Seligi 1	32.5	46.7	19.2	1.6	—	—	traces	—
Sepat 1	50.5	23.9	11.9	6.1	0.1	1.5	—	—
Tok Bidan 1	15.5	17.9	55.3	4.2	3.7	—	—	3.4+

* Granite. + Conglomerate & metasediments.

Table 4. Heat flow estimated from Exxon wells off Malaysia.

Map ref. no.	Well name	$\Delta T/\Delta z$ (°C/100 m)	Estimated heat flow[1] mW m^{-2}	(μcal/cm^{2}sec)	Estimated heat flow[2] temperature dependence of K corrected mW m^{-2}	(μcal/cm^{2}sec)
SH 1	Dudar 1	3.45	49.0	(1.17)	46.7	(1.12)
SH 3	Kalutan 1	3.05	52.3	(1.25)	51.0	(1.22)
SH 4	Nosong 1	2.32	37.3	(0.89)	36.3	(0.87)
SH 5	Tembungo 4	2.77	46.5	(1.09)	45.0	(1.08)
SH 6	Timbalai 1	2.15	44.0	(1.05)	42.8	(1.02)
M 2	Duyong 1	5.27	96.2	(2.30)	88.7	(2.12)
M 7	Angsi 1	5.02	106	(2.53)	98.4	(2.35)
M 8	Belumut 1	4.65	88.3	(2.11)	85.7	(2.05)
M 9	Sepat 1	4.23	81.2	(1.94)	78.5	(1.88)
M 10	Bujang 1	3.89	70.3	(1.68)	68.3	(1.63)
M 12	Pilong 1	5.54	107	(2.57)	103	(2.47)
M 13	Seligi 1	4.71	85.4	(2.04)	82.6	(1.97)
M 14	Tok Bidan 1	3.16	70.3	(1.68)	68.1	(1.63)

1) It is assumed that the lithologic percentage throughout the part lower than 500 m in each well is represented by those given in Table 3. The mean thermal conductivity of the upper 500 m is assumed in all cases to be 1.0 W m^{-1}K^{-1}. Heat flow is derived from the geothermal gradient by SEAPEX and IPA (1977) and the harmonic mean thermal conductivity by using this two-layer model.

2) Temperature dependence of thermal conductivity is assumed to be −1%/10°C. Heat flow is corrected by this factor employing the average temperature between the bottom hole and top (sea bottom) temperatures, because the measurement of thermal conductivity in laboratory was made at 30°C which is significantly lower than *in situ* temperatures.

Another difficulty in estimating heat flow values comes from our lack of knowledge on temperature dependence of the thermal conductivity ($\partial K/\partial T$) of the core samples. If the thermal conductivity (K) decreases 1% per 10°C (CLARK, 1966), observed K for 30°C should be corrected by a factor of 0.85 to get the *in situ* thermal conductivity at 180°C, for example. Pressure dependence of the thermal conductivity ($\partial K/\partial P$) may be negligible, since the total depths of the wells are at most about 3000 m (hydrostatic pressure of 300 atm).

Table 4 summarizes, in spite of the above mentioned difficulties, the estimated heat flow values with and without correction for the temperature dependence of thermal conductivity. Possible thermal effects of rapid sedimentation and fluid movement in the sedimentary rocks are not taken into account.

4. Implication of heat flow results and the work to be done in the future

If we can obtain sufficient information on the thermal conductivity values over the offshore areas of Southeast Asia, we can convert the

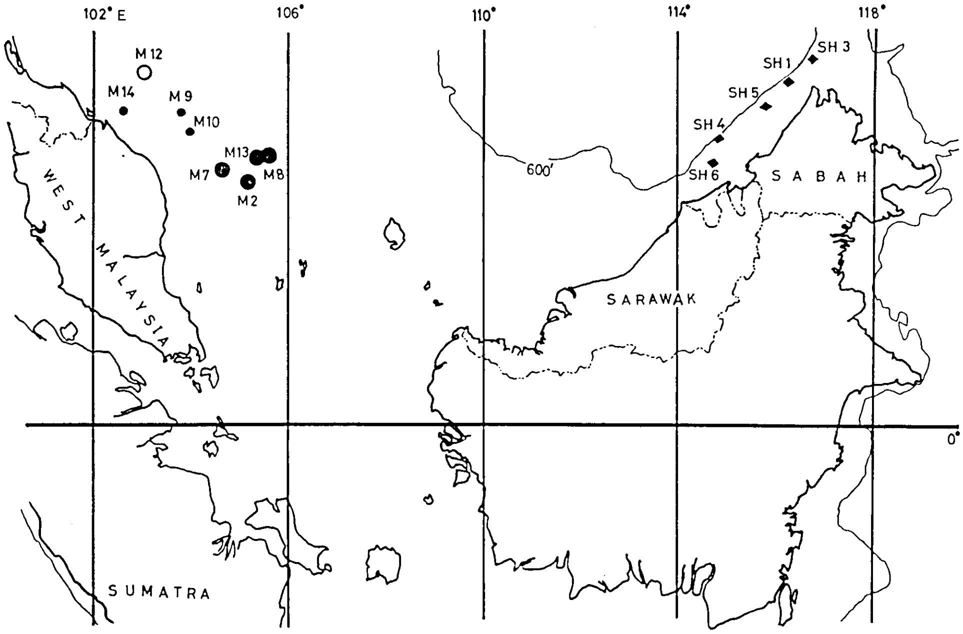

Fig. 4. Heat flow map of offshore areas of Malaysia. Heat flow values estimated in this study with correction for the temperature dependence of thermal conductivity are plotted; rhombi indicate heat flow lower than 60 mWm^{-2}, small solid circles 60-80 mWm^{-2}, large solid circles 80-100 mWm^{-2}, and large open circles higher than 100 mWm^{-2}.

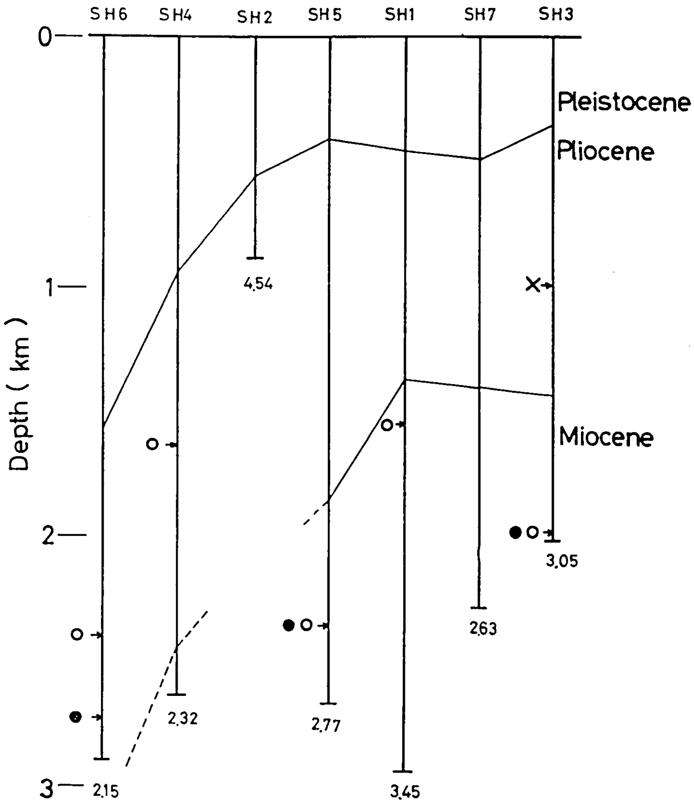

Fig. 5. Stratigraphy of the offshore area of Sabah based on Table 8 of CHUNG *et al.* (1977). The number attached to each of the wells (vertical lines) stands for the geothermal gradient value in °C/100 m given in SEAPEX-IPA's compilation. Arrows with solid circles show the core depths of sandstones of which thermal conductivity was measured. Those with open circles and cross show cores of mudstones and limestones measured in this work.

SEAPEX-IPA geothermal gradient map to a heat flow map. As the first step, we plotted our results in the areas off Malaysia (Fig. 4). It is evident that the heat flows in the Malay Basin and the offshore Sabah are quite different from each other. In Sabah, sub-normal to normal heat flows are observed in contrast to the anomalously high heat flow in all wells in the Malay Basin. If the simple subsidence-cooling model of sedimentary basins of TURCOTTE and AHERN (1977) is valid for the Malay Basin, the heat flow in the basin would be about 50 mWm^{-2} assuming the age of the basement to be Cretaceous (WOOLANDS and HAW, 1976). The "excess" heat flow observed there harmonizes with the possibility that some igneous events (post-subsidence magmatic intrusion) have occurred in the late Cenozoic time, which may be related to the reactivation of large scale older faults or fissures (SUENSILPONG *et al.*, 1978). If this is true, it is an interesting problem why and how this particular part of the Sunda Shelf underwent such revival of igneous activity. The geothermal information on the Malay Basin available to us is too limited to further discuss the nature of the high heat flow there. Yet the tectonic event which is represented by the major unconformity of the late Miocene throughout the Gulf of Thailand Basin and the subsequent block movement until the late Pliocene (WOOLANDS and HAW, 1976) is probably related to the anomalously high heat flow in the Malay Basin. Occurrence of high alkaline basalt flows on land at Kuantan and Segamat in the late Tertiary might also be related to this regional event (HUTCHISON, 1973).

Our heat flow data off the northwestern coast of Sabah may also be geologically interesting. Fig. 5 presents the generalized stratigraphy of the Tertiary and Quaternary formations in the offshore area of Sabah based on the well data in Table 8 of CHUNG *et al.* (1977). There seems to be a weak negative correlation of the heat flow values with the thickness and/or burial depths of the Neogene formations. The wells in the northeastern part (nos. SH 5, SH 1, SH 7 and SH3, in the SEAPEX-IPA map), having thinner and shallower Pliocene rocks and a higher heat flow, are in contrast to those in the southwestern part (SH6 and SH4), with very large burial depth and lower heat flow. This is important for understanding how the Tertiary Basins have been formed and what role the subsurface temperature played in hydrocarbon maturation and accumulation there. The recent report on the petroleum geology of the Tembungo Field (WHITTLE and SHORT, 1978) includes more details of the geology based on the data from SH5 and many other wells.

The two offshore Tertiary basins studied in this report are both located on the Sunda Shelf of which crustal structures were reviewed by BEN-AVRAHAM and EMERY (1973). It is important to note that almost all the Sunda Shelf (except for the southern Java Sea) is free from seismic activity while it has a great variety of heat flow. In previous works on heat flow in plate-consuming type continental margins, the relation of the Benioff-Wadati zone with the thermal structure has been discussed (SUGIMURA and UYEDA, 1974). However, in the Sunda Shelf the high heat flow pattern has no obvious correlation with the present Benioff-Wadati zones. According to the SEAPEX and IPA geothermal gradient map, offshore basins of Sarawak are represented by generally high values which may correspond to the heat flow in excess of 100 mWm^{-2} assuming the thermal conductivity of the same magnitude as in the Malay Basin. These high heat flows on the stable continental shelf is suggestive of the possibility that the region concerned may be under the extensional tectonics behind the Andaman-Sunda arcs. Further investigation, together with other geophysical, petrological and geochemical investigations, is needed to attain a thorough understanding of the tectonic evolution of this interesting region. For this purpose, it is hoped that more of the geophysical and geological information from exploration wells by oil companies be released to the scientific community.

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References

BEN-AVRAHAM, Z. and EMERY, K. O., 1973, Structural framework of Sunda Shelf, *Amer. Assoc. Petrol. Geologists Bull.*, **57**, 2323-2366.

CARVALHO, H. S., PURWOHO, SISWOYO and VACQUIER. V., 1979. Terrestrial heat flow in the Tertiary Basin of Central Sumatra, in press. Tectonophys.

CHUNG, S. K., GAN, A. S., LEONG, K. M. and KHO, C. H., 1977, Ten years of petroleum exploration in Malaysia, United Nations ESCAP, CCOP, *Tech. Bull.*, **11**, 111-142.

CLARK, S. P., 1966, Handbook of physical constants, *the Geological Society of America Memoir*, **97**, 459-482.

COSTER, H. P., 1947, Terrestrial heat flow in Persia, *Monthly Notices Roy. Astron. Soc., Geophys. Suppl.*, **5**, 131-145.

DOWDLE, W. L. and COBB, W. M., 1975, Static formation temperature from well logs: an empirical method, *Jour. Petrol. Technol.*, no. **11**, 1326-1330.

HUTCHISON, C. S., 1973, Volcanic activity, Chap. 7 in Geology of Malay Peninsula, eds. D.J GOBBETT and C. S. HUTCHISON, John Wiley-Interscience, New York, 177-214.

ITO, Y., SAITO, T., NAGUMO, M., and K. BABA, 1975, Box probe method for rapid determination of thermal conductivity of rocks (in Japanese with English abstract), *Journ. Japan Geotherm. Energy. Assoc.*, **12**, no. 3, 35-44.

PUSEY, W. C., 1973, How to evaluate potential gas and oil source rocks, *World Oil*, no. 4, 71-75.

SOUTHEAST ASIA PETROLEUM EXPLORATION SOCIETY and INDONESIAN PETROLEUM ASSOCIATION, 1977, Geothermal Gradient Map of Southeast Asia.

SUENSILPONG, S., BURTON, C. K., MANTAJIT, N., and WORKMAN, D. R., 1978, Geological evolution and igneous activity of Thailand and adjacent areas, *Episodes*, no. 3, 12-18.

SUGIMURA, A. and UYEDA, S., 1974, Island arcs, Japan and its environs, Elsevier.

TURCOTTE, D. L. and AHERN, J. L., 1977, On the thermal and subsidence, history of sedimentary basins, *Jour. Geophys. Res.*, **82**, 3762-3766.

WHITTLE, A. P. and SHORT, G. A., 1978, The petroleum geology of the Tembungo Field, East Malaysia, SEAPEX Program Offshore South East Asia Conference, 1978, paper 4.

WOOLAND, M. A., and HAW, D., 1976, Tertiary stratigraphy and sedimentation in the Gulf of Thailand, SEAPEX Program, Offshore South East Asia Conference, paper 7, 22p.

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2. マレーシア沖試掘孔による地殻熱流量の推定

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浅海底下の地殻熱流量測定計画の一環として，マレーシア沿海の石油会社による探査孔のコア試料の熱伝導率測定を行い既に公表済の地温勾配データを用いて熱流量を求めた．得られた熱流量値は，マレー堆積盆では現在安定な地域であるにもかかわらず異常に高く，サバの沖では普通又はやや低い値である．