CHAPTER 4

TERTIARY STRATA DISTRIBUTION AND ITS SOURCE ROCK POTENTIAL.

4.1 Introduction.

Although the stratigraphy of the Pattani Trough has been studied by Achalaphuti and Oudomugrorn [42] , Lian and Bradley [43] and Woolands and Haw [44] ,these studied generally have considered regional stratigraphy. This section describes interpretation of the stratigraphic successions in term of facies distribution, and constructing the structural base map for each stratigraphic unit (I-IV). The result from this study will be applied to the Thai-Vietnam overlapping area.

In Pattani trough, natural gas and condensate are produced from nonmarine and marginal marine Tertiary strata. Subsurface exploration and development provide geochemical and geological data to evaluate the factors controlling the distribution and deposition of source rocks in nonmarine and deltaic settings. In this chapter, possible source rocks are also indentified, degree of organic maturation and their regional extents are outlined.

4.2 Distribution of Tertiary Strata.

Based on stratigraphic depth (km) (resulting from interpretation by using gamma-ray and electric log) and location of the wells shown in Table 4.1and Figure 4.1 respectively, structural base maps of Tertiary strata are constructed and shown in Figure 4.2, 4.3, 4.4 and 4.5 for the stratigraphic unit I,II,III and IV respectively. The generalized W-E crosssection of the Pattani trough is showed in Figure 4.6 (modified after ASCOPE, 1993).

4.3 The distribution of total organic carbon (TOC) and quality of organic matter (QOM).

Results of geochemical analysis from wells as show in Table 4.1 are concluded in Table 4.2 and 4.3 , and used for construction the distribution map of total organic carbon (TOC) and quality of organic matter (QOM) in each unit as follows;

Unit I

The TOC content of unit I ranges from less than 0.10% to about 0.34% (Figure 4.7) with an average of 0.24%. In general, the TOC content of this unit decrease from the basin margin toward the basin center (Figure 4.7). The QOM of this unit varies from less than 0.5 mg HC/g rock to more than 4.0 mg HC/g rock (Figure 4.8) with an average value of 1.6 mg HC/g rock.

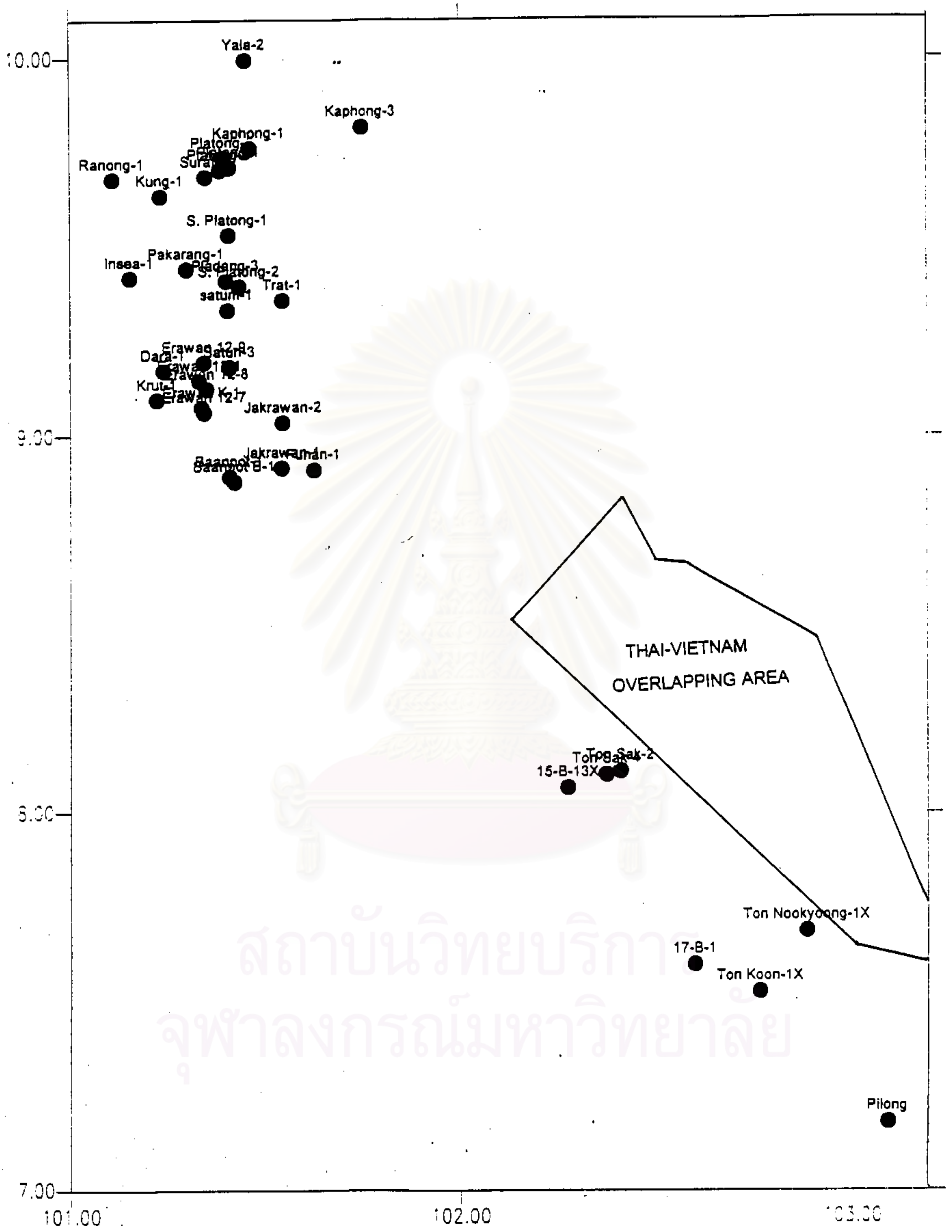

Figure 4.1 Location of wells used in the study.

Table 4.1 Stratigraphic unit depth (km) of the Tertiary strata in the Pattani Trough and the north Malay Basin.

Well name	Location of well		Stratigraphic Unit depth (km)			
	longtitude	latitude	unit IV	unit III	unit II	**unit I**
Yala-2	101-26-40	9-59-40	-1.75	-2.4	-2.7	-3.7
Kaphong-3	101-44-40	9-48-54	-2.2	-2.8	-3.4	-7
Kaphong-1	101-27-25	9-45-34	-2.5	-3	-3.6	-6.3
Platong-5	101-23-20	9-44-05	-1.9	-2.7	-3	-4
Platong-1	101-24-16	9-42-36	-2.25	-2.8	-3.3	-4.8
Platong-8	101-22-47	9-42-13	-1.8	-2.6	-2.9	-4.3
Surat-1	101-20-33	9-41-07	-1.75	-2.25	-2.65	-3
Ranong-1	101-26-40	9-40-43	-1.3	-2	-2.35	-2.5
Kung-1	101-13-43	9-38-08	-1.6	-2.15	-2.4	-2.75
S. Platong-1	101-24-05	9-31-51	-2.5	-3.4	-4	-5.6
Pakarang-1	101-17-41	9-26-30	-1.8	-2.5	-3.2	-4.8
Pladang-3	101-23-43	9-24-38	-2.3	-4.2	-5	-6.8
Insea-1	101-09-00	9-25-08	-1.2	-1.75	-2.2	-2.75
S. Platong-2	101-25-45	9-23-40	-3.2	-5	-6.4	-7.7
Trat-1	101-32-25	9-21-29	-2.6	-4.3	-5.5	-8
satun-2	101-23-56	9-20-00	-2.6	-4	-5	-6.5
satun-1	101-24-29	9-44-40	-2.3	-4.4	-5.2	-7.5
Erawan 12-9	101-20-22	9-11-40	-2.2	-3	-3.7	-6
Dara-1	101-14-09	9-10-22	-1.5	-2	-2.2	-2.3
Satun-3	101-24-16	9-10-56	-2.5	-3.9	-5.2	-8
Erawan 12-1	101-19-39	9-08-43	-2	-2.6	-4	-5.75
Erawan 12-8	101-20-44	9-07-25	-2.1	-2.7	-4.2	-6.5
Erawan 12-7	101-20-22	9-03-43	-2.5	-3.9	-5	-8
Krut-1	101-13-09	9-05-45	-1.4	-2.8	-3.3	-4.2
Erawan K-1	101-20-00	9-04-29	-2.2	-4.7	-5.9	-8.2

Table 4.1 Stratigraphic unit depth (km) of the Tertiary strata in the Pattani Trough and the north Malay Basin (continued)

Well name	Location of well		Stratigraphic Unit depth (km)			
	longtitude	latitude	unit IV	unit III	unit II	unit I
Jakrawan-2	101-32-25	9-02-02	-2.4	-4.5	-5.5	-7.2
Jakrawan-1	101-32-14	9-54-54	-2.8	-5	-6.2	-7.8
Jakrawan-13	101-30-03	9-56-36	-1.57	-3.09		
Jakrawan-15	101-29-56	9-01-26	-1.59	-2.95		
Jakrawan-B-1	101-31-40	9-02-38	-1.67	-3.279		
Jakrawan-B-3	101-31-41	9-02-37	-2.25	-3.57		
Jakrawan-B-7	101-33-01	9-03-10	-2.76	-3.15		
Jakrawan-D-4	101-34-08	9-04-11	-2.17	-4.02		
Jakrawan-D-9	101-33-39	9-04-46	-1.93	-3.18		
Funan-1	101-37-07	8-54-34	-2	-3.8	-5	-6
Funan-A2	101-36-49	8-56-06	-2.15	-3.39		
Funan-A11	101-36-51	8-54-23	-1.79	-3.71		
Funan-17	101-34-56	8-52-16	-1.76	-3.03		
Funan-18	101-36-01	8-53-50	-2.24	-3.55		
Funan-F8	101-36-43	8-54-02	-2.02	-3.12		
Baanpot-1	101-24-15	8-53-33	-2.2	-5.5	-7.3	-12
Baanpot B-1	101-25-00	8-52-45	-2.2	-5.55	-7.3	-14
15-B-13X	102-16-21	8-03-52	-0.976	-1.11	-1.65	-2.44
Ton Koon-1X	102-45-55	9-31-28	-0.9	-1.27	-3.03	-3.18
Ton Sak-2	102-24-21	8-06-32	-1	-1.3	-2.33	-2.79
Ton Sak-4	102-22-13	8-05-56	-0.8	-1.05	-2.24	-2.69
Ton Nokyoong-1X	102-53-10	7-41-10	-0.9	-1.31	-3.18	
Pilong	103-05-27	7-10-55				
17-B-1	102-35-49	7-35-49		-1.207	-1.801	-2.342

Table 4.2 Total organic carbon (TOC: percent) content summary.

Well name	Location of wells		Stratigraphic unit			
	longtitude	latitude	unit IV	unit III	unit II	unit I
Yala-2	101-26-40	9-59-40	0.46	0.11	0.09	0.19
Kaphong-3	101-44-40	9-48-54	0.15	0.13	0.2	0.27
Kaphong-1	101-27-25	9-45-34	0.26	0.13	0.26	0.2
Platong-5	101-23-20	9-44-05	0.44	0.17	0.22	0.26
Platong-1	101-24-16	9-42-36	0.45	0.23	0.38	0.18
Platong-8	101-22-47	9-42-13	0.71	0.35	0.41	0.33
Surat-1	101-20-33	9-41-07	0.37	0.27	0.18	0.1
Ranong-1	101-26-40	9-40-43	0.83	0.13	0.07	0.08
Kung-1	101-13-43	9-38-08	0.87	0.41	0.64	0.44
S. Platong-	101-24-05	9-31-51	0.42	0.26		
Pakarang-1	101-17-41	9-26-30	0.28	0.44	0.32	0.23
Pladang-3	101-23-43	9-24-38	1.37	0.53	0.29	
Insea-1	101-09-00	9-25-08	0.86	0.23	0.13	0.07
S. Platong-	101-25-45	9-23-40	0.62			
Trat-1	101-32-25	9-21-29	0.69	0.41		
satun-1	101-24-29	9-44-40	0.55	0.25	0.33	
Erawan 12-	101-20-22	9-11-40	0.32	0.44	0.45	
Dara-1	101-14-09	9-10-22		0.21	0.25	
Satun-3	101-24-16	9-10-56	0.54	0.2		
Erawan 12-	101-19-39	9-08-43	0.64	0.54	0.39	0.25
Erawan 12-	101-20-44	9-07-25	0.61	0.61	0.45	0.34
Erawan 12-	101-20-22	9-03-43	0.64	0.39	0.34	0.23
Krut-1	101-13-09	9-05-45	0.07	0.29	0.39	
Erawan K-1	101-20-00	9-04-29	0.64	0.8	0.51	
Jakrawan-2	101-32-25	9-02-02	0.6	0.22		
Jakrawan-1	101-32-14	9-54-54	0.72	0.66		
Funan-1	101-37-07	8-54-34	0.63	0.78		
Baanpot-1	101-24-15	8-53-33	0.46	0.8	0.61	
Baanpot B-	101-25-00	8-52-45	0.43	0.41	0.53	

Table 4.3 Quantity of Organic Matter (QOM: mg HC/ g rock) content summary.

Well name	Location of wells		Stratigraphic unit			
	longtitude	latitude	unit IV	unit III	unit II	unit I
Yala-2	101-26-40	9-59-40	1.02	1.09	0.74	0.97
Kaphong-3	101-44-40	9-48-54	1.14	2.11	0.51	0.66
Kaphong-1	101-27-25	9-45-34	2.21	2.11	0.3	1.36
Platong-5	101-23-20	9-44-05	1.43	1	1.76	2.49
Platong-1	101-24-16	9-42-36	1.32	1.8	1.14	1.49
Platong-8	101-22-47	9-42-13	1.32	1.46	2.59	2.21
Surat-1	101-20-33	9-41-07	0.72	0.31	0.79	0.75
Ranong-1	101-26-40	9-40-43	0.57	0.91	0.36	0.42
Kung-1	101-13-43	9-38-08	1.2	0.99	1.28	1.56
S. Platong-1	101-24-05	9-31-51	1.44	1		
Pakarang-1	101-17-41	9-26-30	1.68	1.18	1.35	1.63
Pladang-3	101-23-43	9-24-38	1.91	1.9	1.6	
Insea-1	101-09-00	9-25-08	0.74	0.55	0.51	0.48
S. Platong-2	101-25-45	9-23-40	1.17			
Trat-1	101-32-25	9-21-29	0.85	0.77		
satun-1	101-24-29	9-44-40	1.43	0.96	1.2	
Erawan 12-9	101-20-22	9-11-40	1.84	2.2	2.58	2.43
Dara-1	101-14-09	9-10-22		0.85	2.69	5.12
Satun-3	101-24-16	9-10-56	1.18	0.97		0.91
Erawan 12-1	101-19-39	9-08-43	1.44	1.13	2.22	1.9
Erawan 12-8	101-20-44	9-07-25	2.94	2.38	1.62	1.24
Erawan 12-7	101-20-22	9-03-43	1.4	2.38	1.33	0.89
Krut-1	101-13-09	9-05-45	2.65	1.62	1.63	
Erawan K-1	101-20-00	9-04-29	1.51	1.38	3.74	
Jakrawan-2	101-32-25	9-02-02	1.72	1.5		0.8
Jakrawan-1	101-32-14	9-54-54	1.06	0.42		
Funan-1	101-37-07	8-54-34	1.04	0.95		
Baanpot-1	101-24-15	8-53-33	2.28	2.02	1.01	
Baanpot B-1	101-25-00	8-52-45	1.48	0.9	0.57	

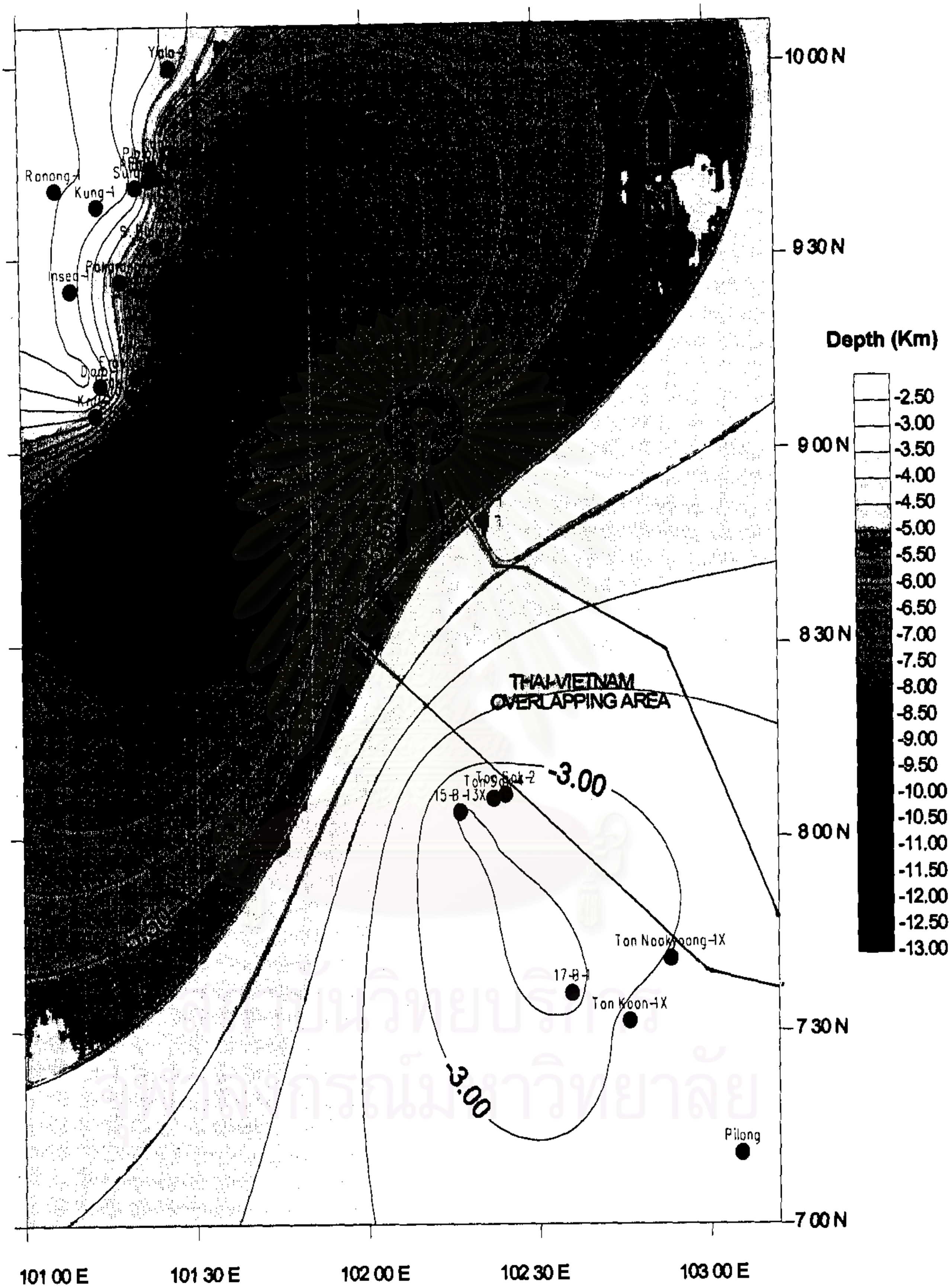

Figure 4.2 Structure base map of stratigraphic unit I of the Pattani Trough

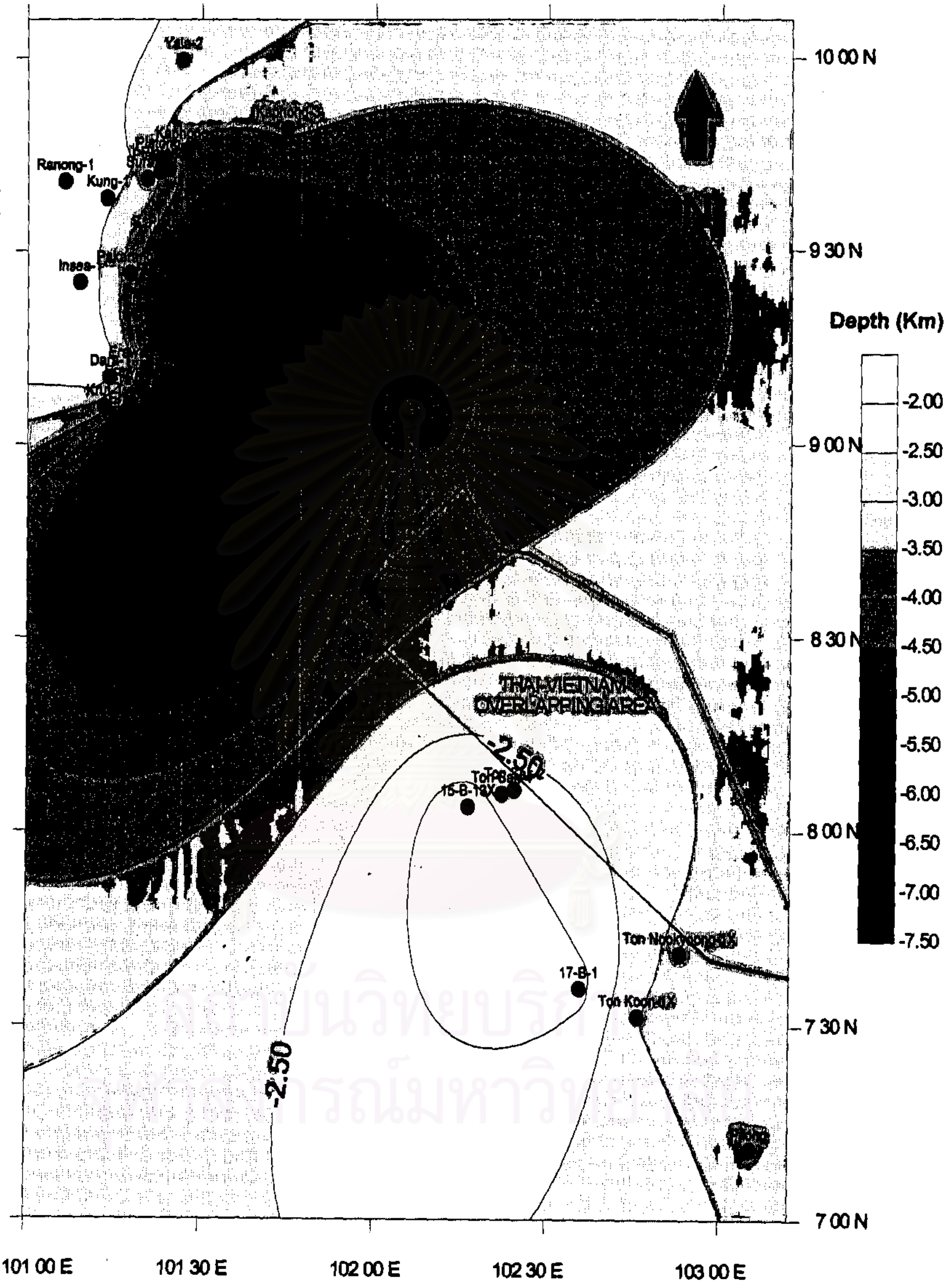

Figure 4.3 Structure base map of stratigraphic unit II of the Pattani Through.

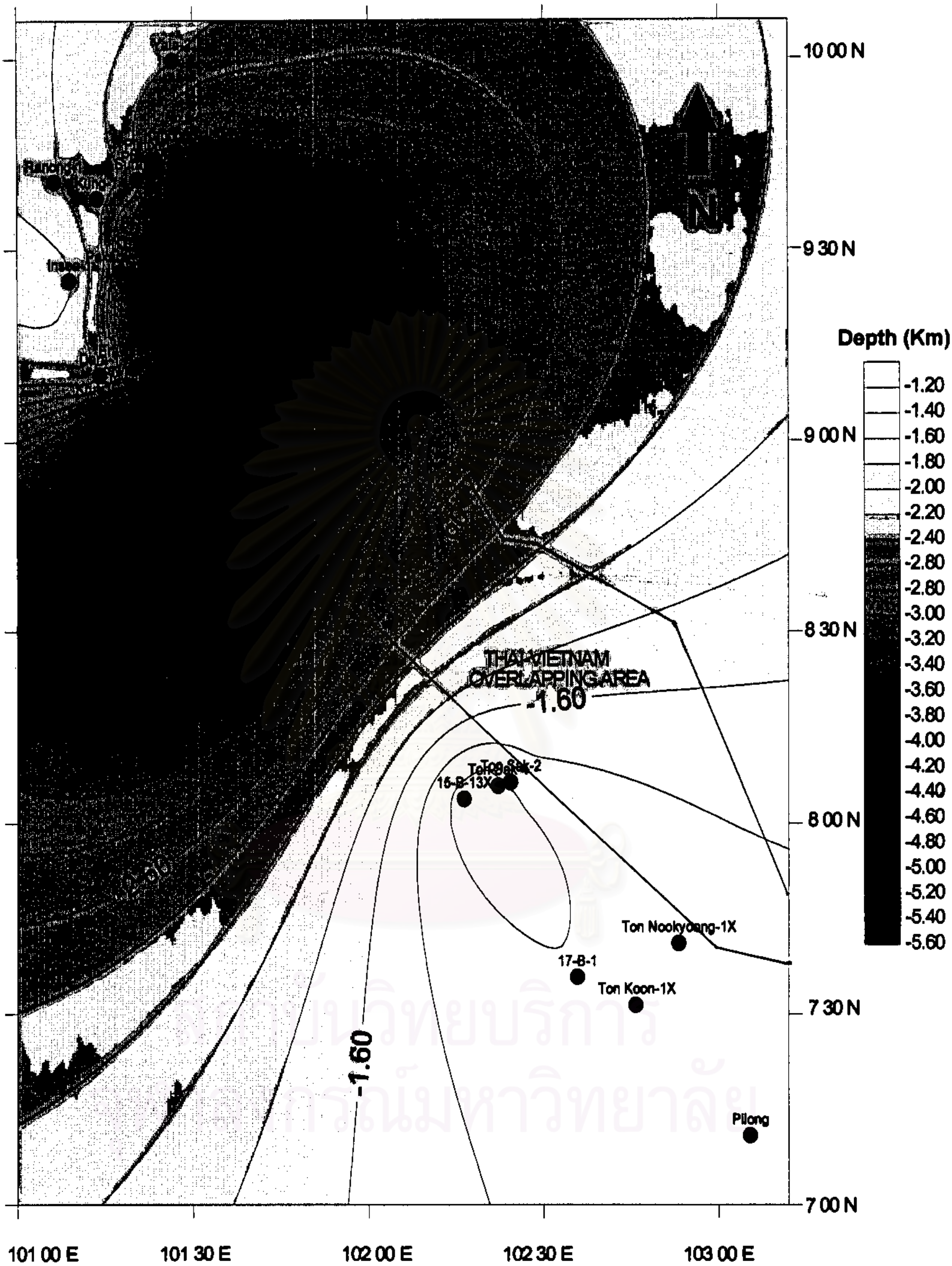

Figure 4.4 Structure base map of stratigraphic unit III of the Pattani Trough

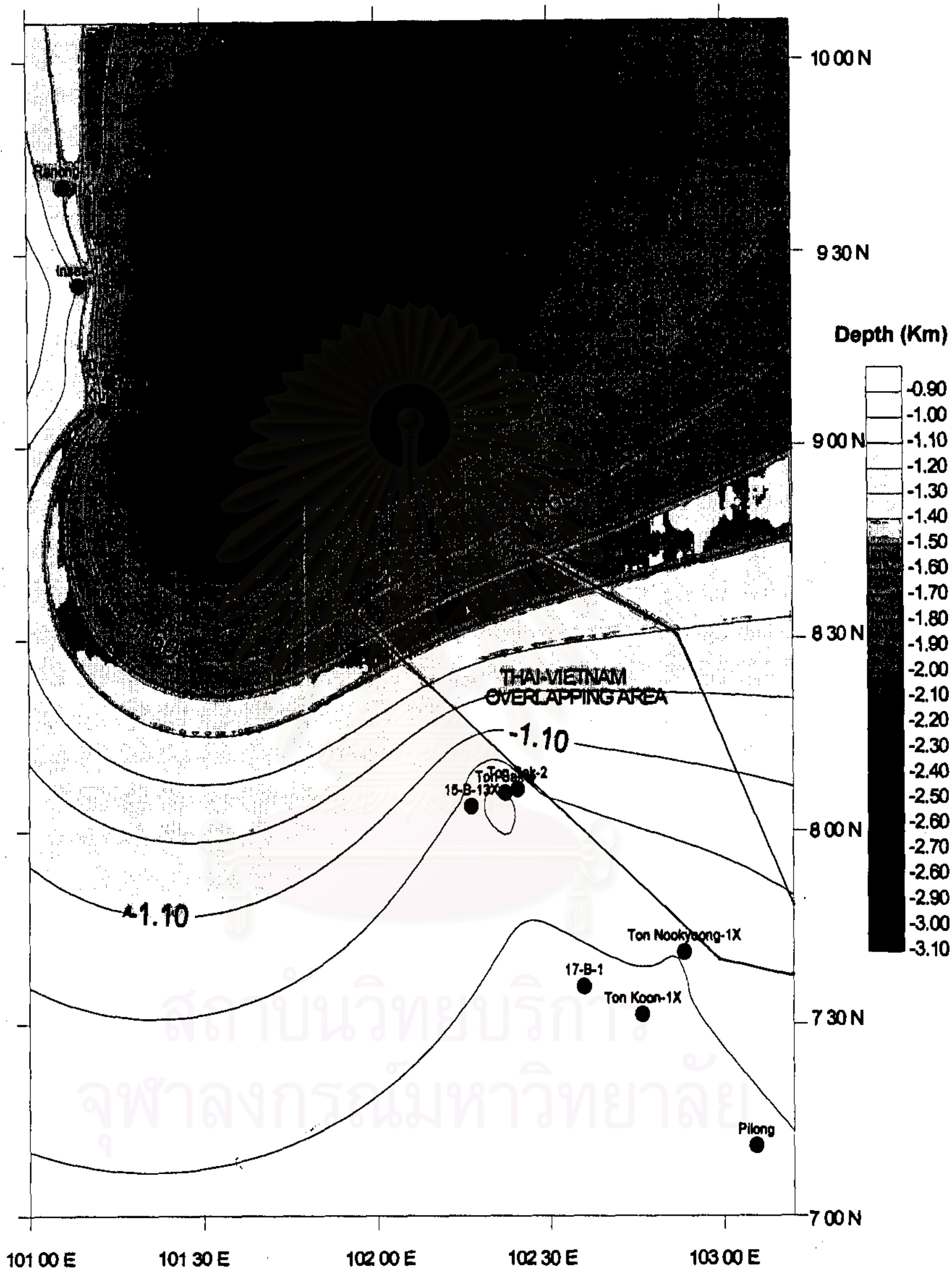

Figure 4.5 Structure base map of stratigraphic unit IVof the Pattani Through

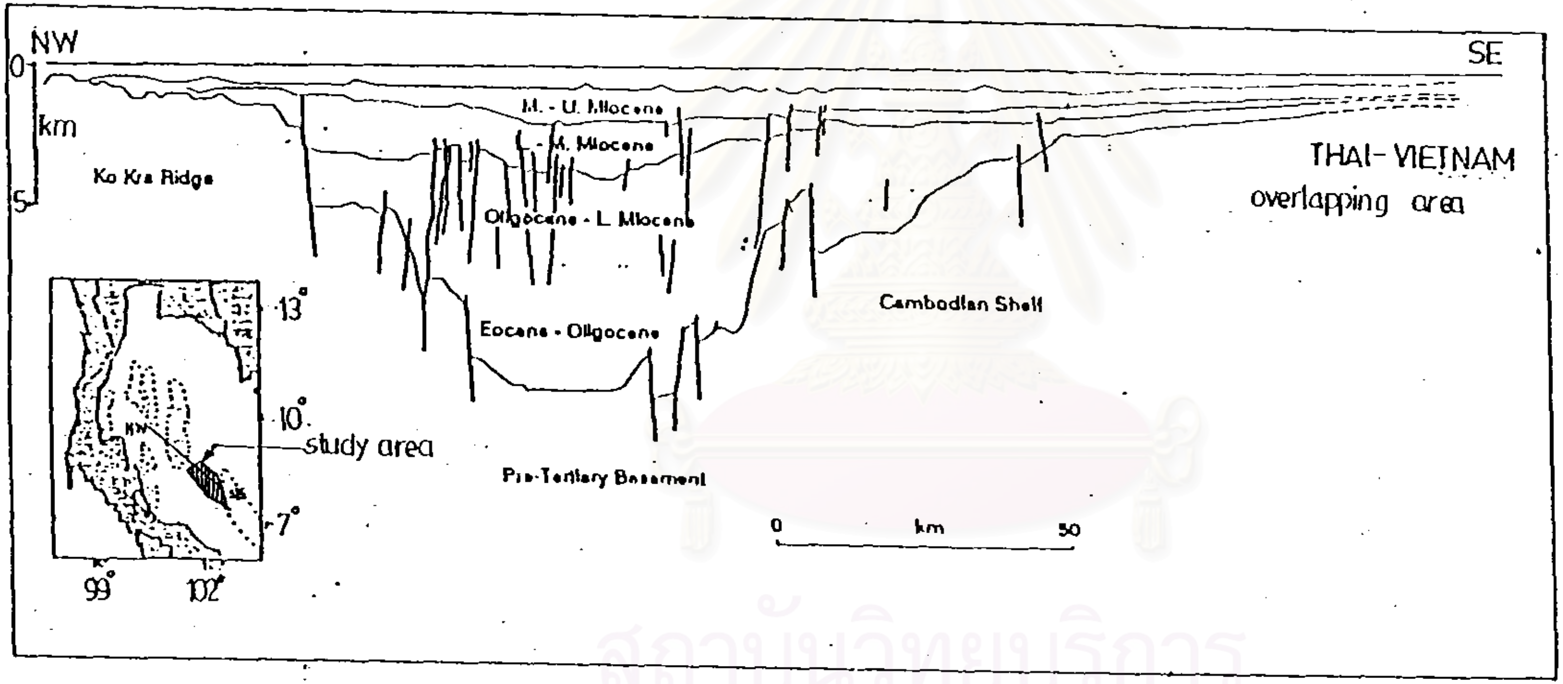

Figure 4.6 Generalized NW-SE cross section of the Pattani Basin(After ASCOPE, 1993)

For the Thai-Vietnam overlapping area, TOC content is slightly high (more than 0.26 %) compared with other parts in the region. QOM of this unit in the overlapping area is also slightly high (ranges from 0.6 to 1.0 mg HC/g rock).

Unit II

The TOC content of unit II ranges from less than 0.1% at the western margin of the basin to more than 0.5% at the basin center in the south-central part of the Pattani trough (Figure 4.9). The QOM varies from 0.36 mg HC/g rock to more than 3.0 mg HC/g rock (Figure 4.10) with an average value of 1.44 mg HC/g rock.

TOC content of unit II in the Thai-Vietnam overlapping area is slightly high (ranges form 0.45-0.5 %) as in unit I. While its QOM values is not high (less than 0.40 mg HC/g rock) as in unit I.

Unit III

The TOC content of unit III varies from about 0.5% to 0.8% in the south central part of the basin to less than 0.25% toward the west and the northeast (Figure 4.11) with an average value of 0.44%. Its QOM value shows a similar trend to TOC; it is highest (about 2.0 mg HC/g rock) in the south central part of the Pattani trough and decrease to less than 1.0 mg HC/g rock northwestward (Figure 4.12) with and average value of 1.34 mg HC/g rock.

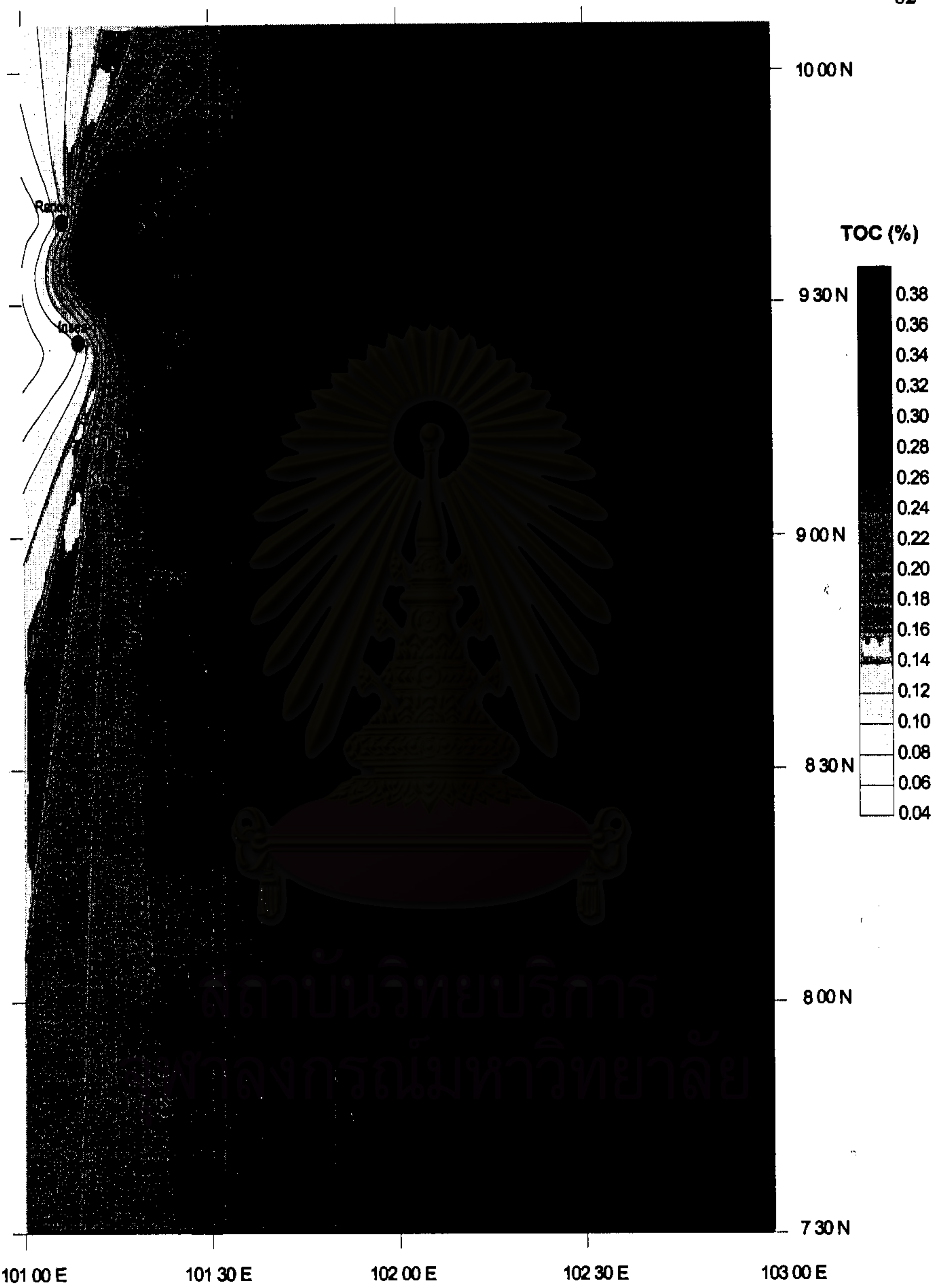

Figure 4.7 TOC (%) distribution map of stratigraphic unit I in the Pattani Trough and adjacent areas.

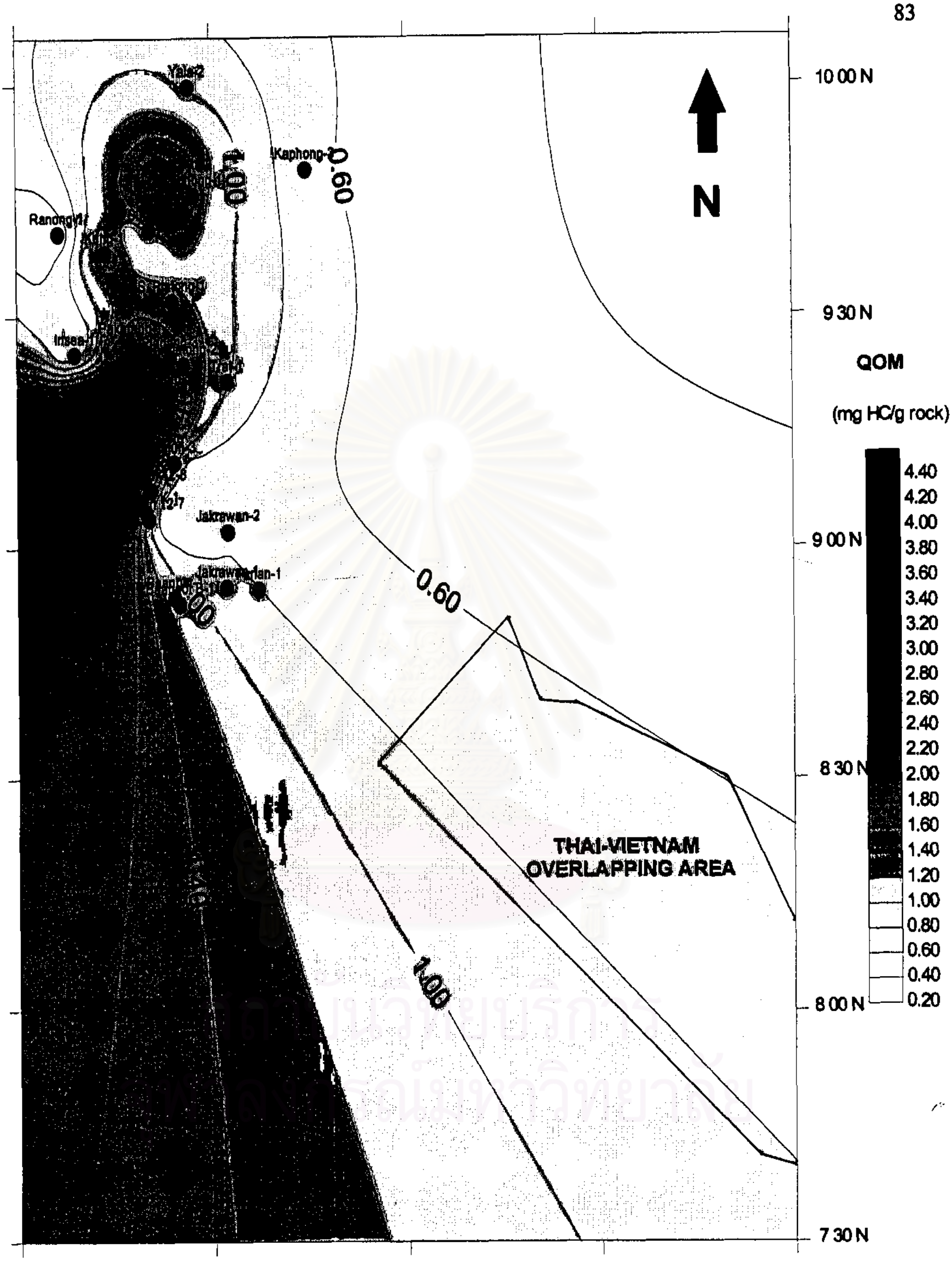

Figure 4.8 QOM (mg HC/g rock distribution map of stratigraphic unit I in the Pattani Trough and adjacent areas.

Figure 4.9 TOC (%) distribution map of stratigraphic unit II in the Pattani Trough and adjacent areas.

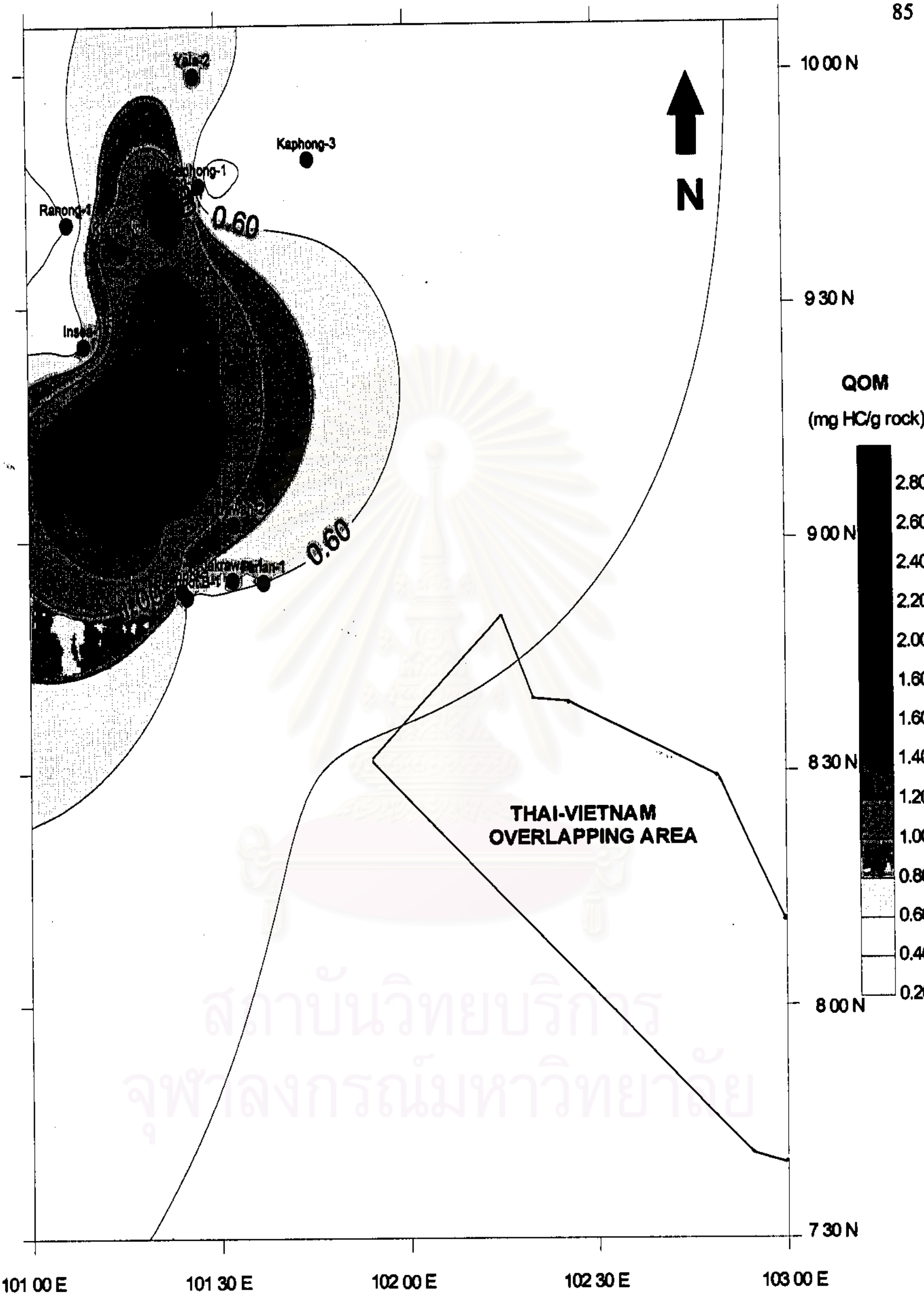

Figure 4.10 QOM (mg HC/g rock distribution map of stratigraphic unit II in the Pattani Trough and adjacent areas.

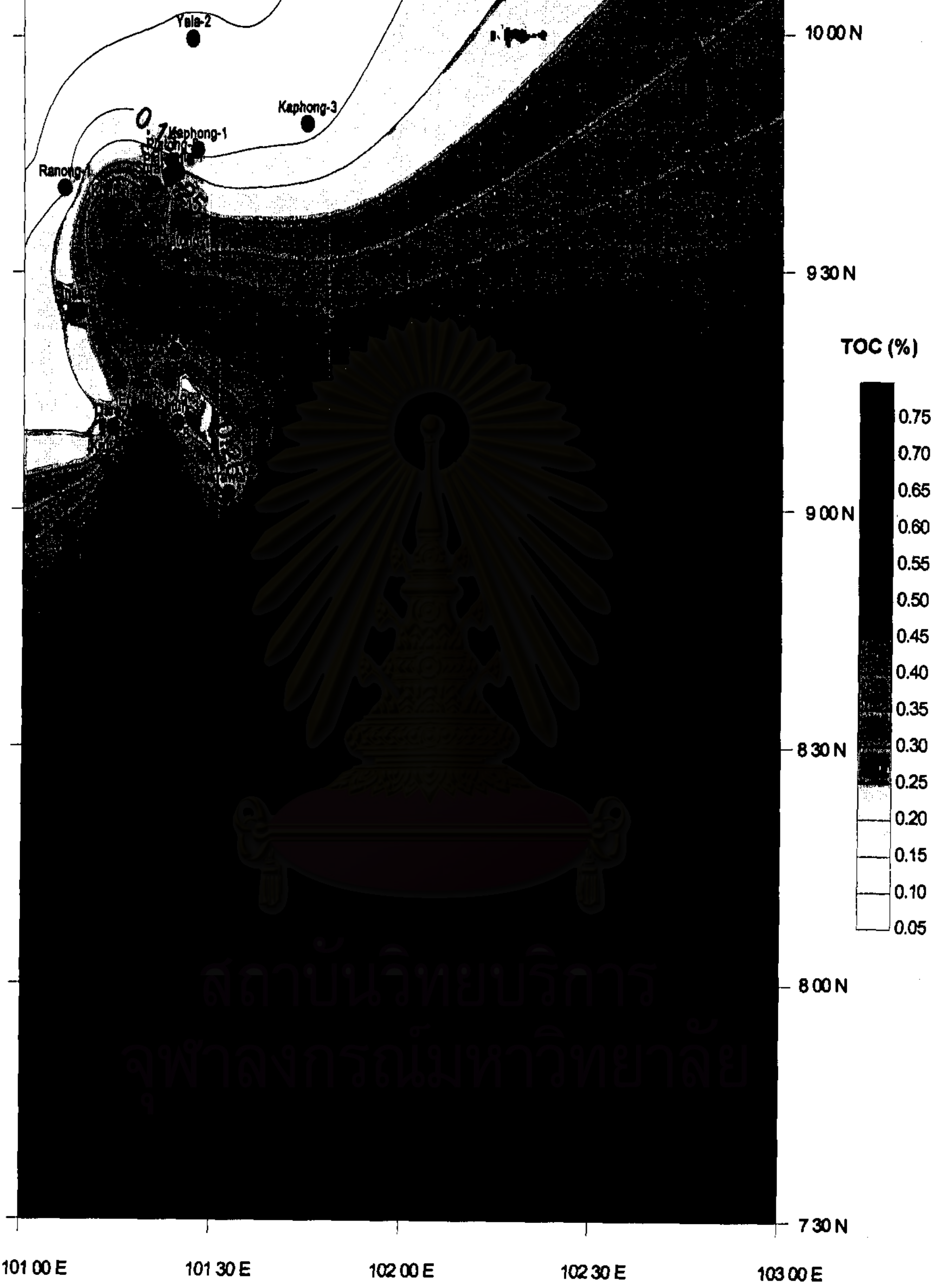

Figure 4.11 TOC (%) distribution map of stratigraphic unit III in the Pattani Trough and adjacent areas.

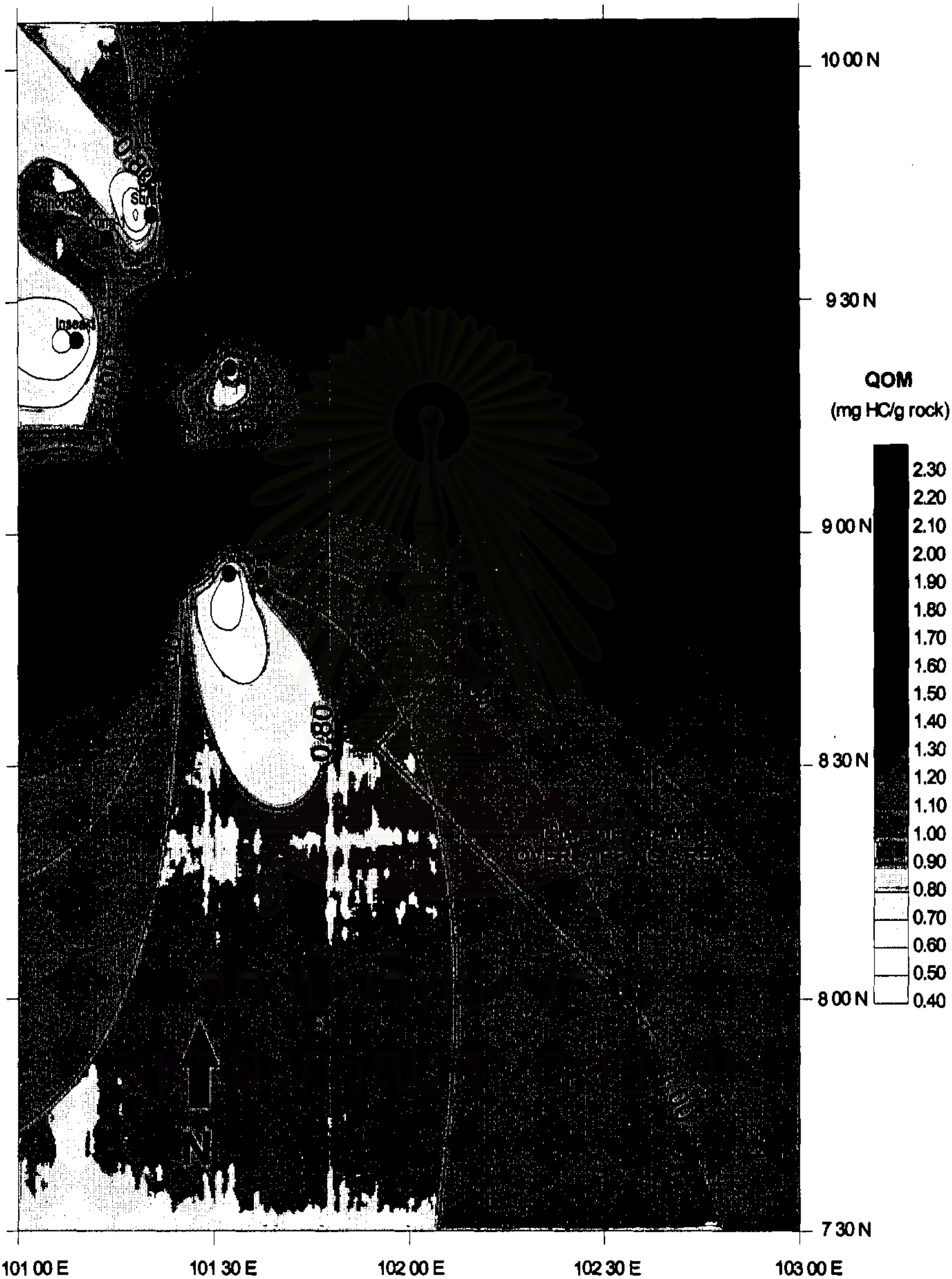

Figure 4.12 QOM (mg HC/g rock distribution map of stratigraphic unit III in the Pattani Trough and adjacent areas.

In the overlapping area, TOC content of this unit is slightly high (about 0.65%) as in the center of the trough. QOM values has the slightly increase toward the northeast and varies from about 0.95 to 1.10 mg HC/g rock.

Unit IV

Unit IV is characterized by two relatively high TOC area (more than 0.8% in the northwest and more than 0.6% on the southeast), separated by a NNE-SSW trending low TOC region (Figure 4.13), This unit has an average TOC of 0.54%. The QOM values range form less than 0.7 mg HC/g rock to more than 2.0 mg HC/g rock (Figure 4.14), with an average QOM of 1.44 mg HC/g rock.

TOC content of this unit in the overlapping area is slightly decrease toward the southeast and varies from about 0.45 to 0.40 %. While QOM values shows an increasing trend toward the southwest, varying from about 0.95 to 1.10 mg HC/g rock.

4.4 Discussion of The relationship between organic abundance ,age and TOC content.

Factors that control the abundance of organic matter in sediments include organic inputs, sedimentation rates, degree of preservation of organic matter after deposition, and degree of organic maturation [62,63,64]. Depending on the combination of these factors, the organic carbon content and characteristics in sediment vary significantly. It is very important that using any one of the factors may not

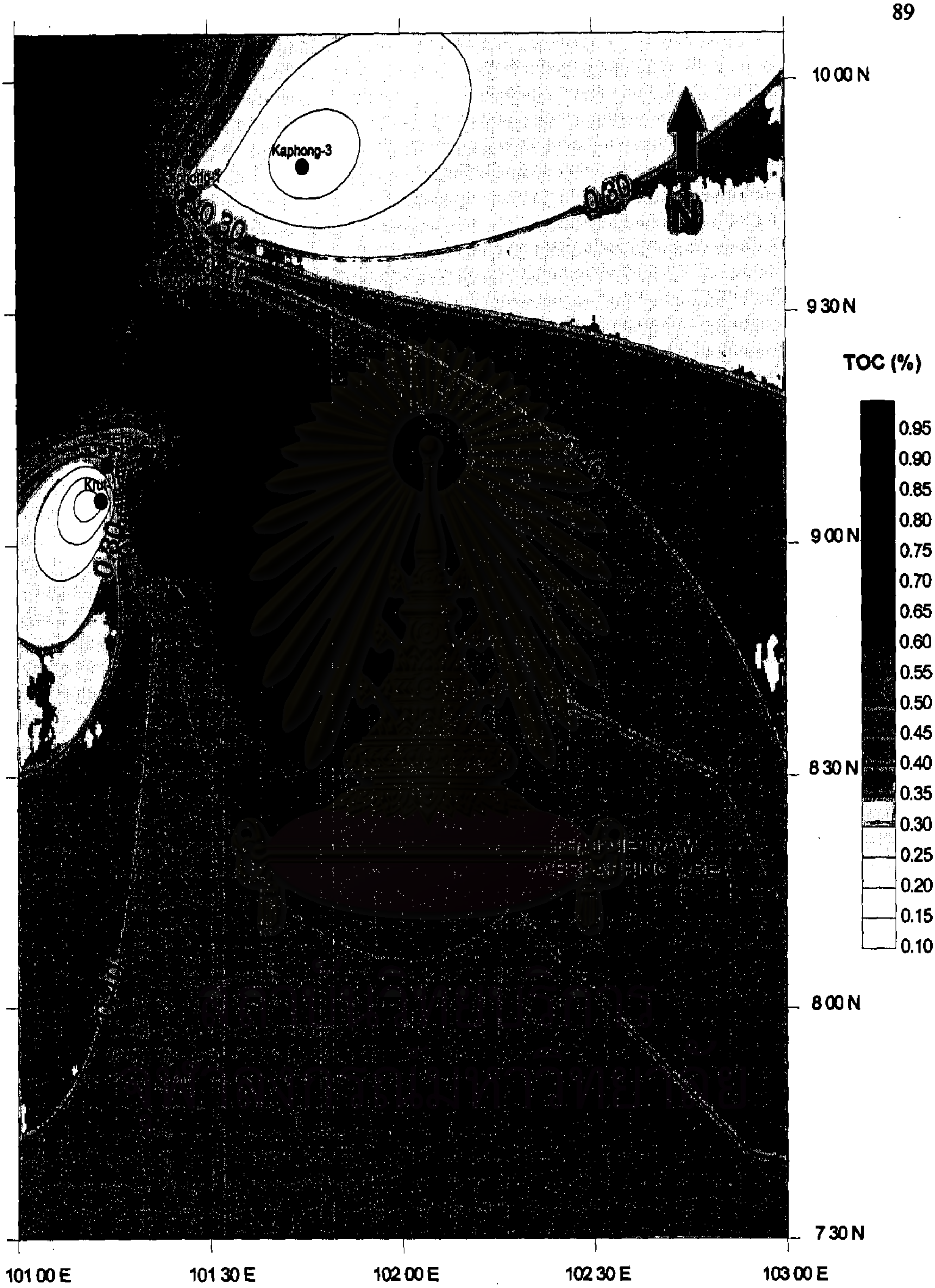

Figure 4.13 TOC (%) distribution map of stratigraphic unit IV in the Pattani Trough and adjacent areas.

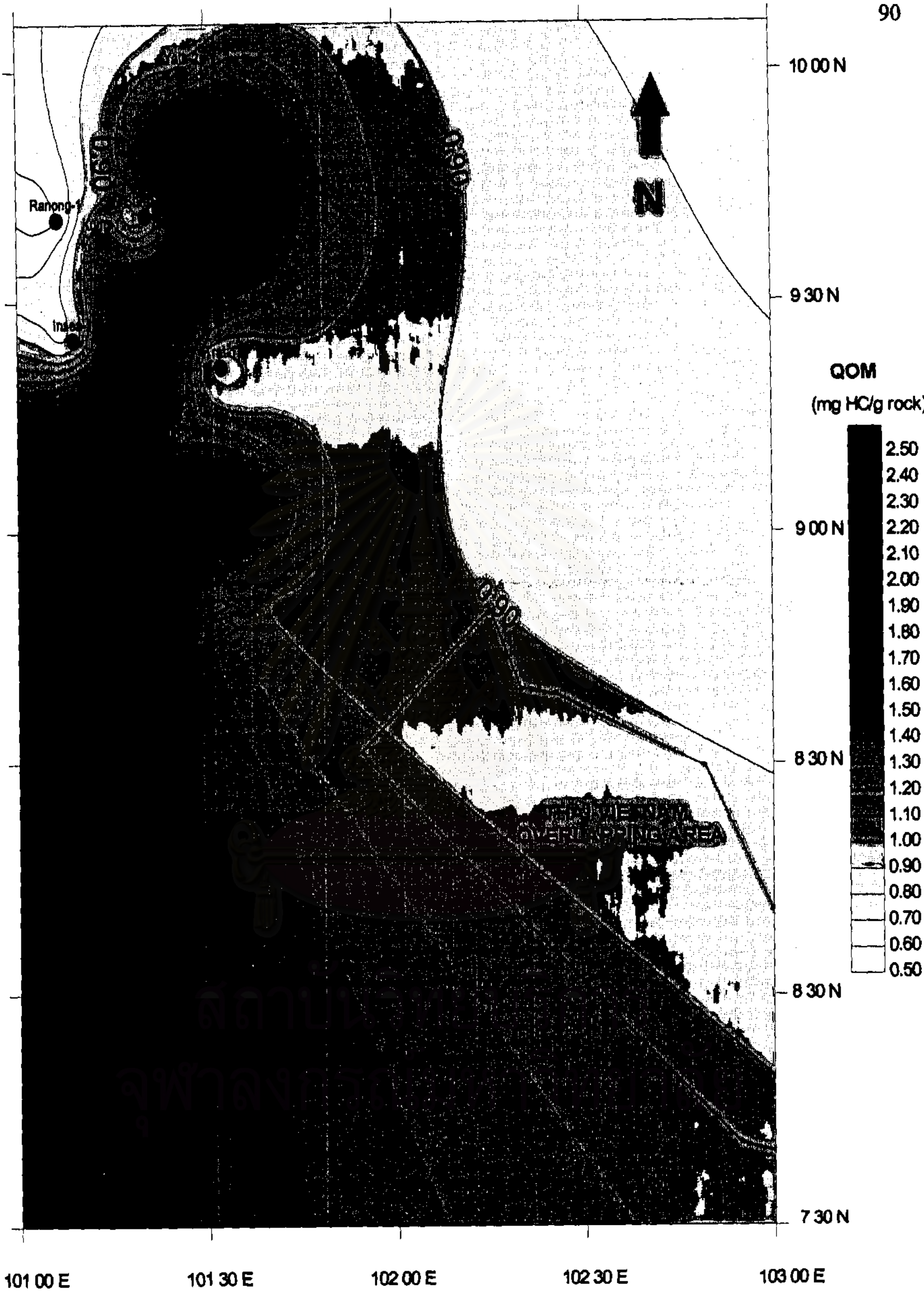

Figure 4.14 QOM (mg HC/g rock distribution map of stratigraphic unit IV in the Pattani Trough and adjacent areas.

exclusively explain the variation in organic characteristics in the sediment. This section discusses the source, character, and factors affecting the distribution of organic matter. In order to examine the influence of geology on the variation of organic characteristics of the Tertiary strata.

The relations of organic maturation with both the abundance and characteristics of organic matter in sediment can be assessed by comparing maps of organic maturation, in this case (Figure 4.7 through Figure 4.14).

The variation in quantity and in characteristics of organic matter is closely correlated with the age of strata. Younger strata have higher TOC and QOM, and the increases occur in almost all sedimentary facies. The variation of TOC and QOM with age is greater than the variation within strata of the same age but among different sedimentary facies. The strong correlation between the age of strata and TOC and QOM must be an induction of:

1) factors controlling either the relative availability of organic matter, such as organic supply, or the preservation of organic matter, such as sedimentation rate, organic maturation or both such as depositional environment;

2) changes in main plant types; and

3) changes in palaeoclimate.

The fact that there is no significant correlation between organic maturation and the quantity of organic matter in sediments indicate that an increase in TOC content in younger strata can not be accounted for the decreasing degree of organic maturation of younger strata.

Chonchawalit [40] studied the relationship between the variation in mean sedimentation rates and mean TOC (%) for strata of different ages. He also found that the sedimentation rate varies considerably with age although the mean TOC contents increase in younger strata. This relationship indicates that, for non-marine and deltaic deposits in general, sedimentation rate can not be used exclusively to predict organic abundance in sediments.

Of all the parameters influencing the abundance and types of the organic matter in the study area, the most prominent parameter is depositional environment. Hence, changes in organic characteristics both within and across the stratigraphic units are mainly the result of changes in depositional environments. Within the stratigraphic units, the abundance of organic matter generally increases from high energy nonmarine to low energy marine. Across the stratigraphic units, an increase in TOC and QOM values in younger strata also reflects the shift from high energy non-marine environment to low energy marine environments. Effects of sedimentation rate and the degree of organic maturation on organic characteristics in the the Pattani trough is not distinct. Such an ambiguous result, especially in the units with low TOC, may be the result of original variation of TOC within the sediments rather than the effect of sedimentation rate or the degree of organic maturation.

Therefore, The increasing in TOC and QOM in younger strata in the Pattani trough, the north Malay Basin and also in the Thai-Vietnam overlapping area may indicate that younger strata has more favorable depositional environments for organic input and preservation.

4.5 Conclusions.

It is evident that all stratigraphic units, except upper-unit IV, which is immature with respect to the oil generation window, have very low hydrocarbon source potentials as measured by pyrolysis [40]. Synrift sediments (unit I, and II) and early post-rift sediments (lower-unit III) contain very low TOC (less than 0.4%), and very low QOM (between 1.3 to 1.6 mg HC/ g rock). Based on a conventional definition of hydrocarbon source rocks [27,28], these sediments can not be considered as sources rocks. Although unit III has TOC of 0.5% , it also has very low QOM (1.4 mg HC/g rock). Upper-unit IV, on the other hand, has the highest hydrocarbon source potential with TOC content of 1.4%, and QOM of 1.4 mg HC/g rock. This unit is immature, relatively to the oil generation window.

The fact that the Pattani trough and the north Malay Basin are producing basin, it can be considered that:

1) either source rocks have been very effective even overall lower organic matter quality is closer than generally considered necessary;
2) higher quality source rocks, possibly at depths, and have not been reached by drilling, are present in the basin;

3) a combination of both factors.

The potential source rocks in the Pattani trough and the north Malay Basin, despite their very low oil generating potential, may represent an enormous volume of low quality source bed, which together with interbeded sandstones throughout the succession, would function as highly effective carrier beds during migration. In addition, the rapid subsidence rate and high heat flow, resulting in rapid in hydrocarbon generation, may also have facilitated creating commercial hydrocarbon accumulations.

Chinnabunchorn *et al.* [64] mentioned that the synrift and possibly post-rift lacustrine deposits, which widely occur in other Tertiary basins in Thailand, are believed to occur in the center of the Pattni trough as well. These lacustrine sediments may possibly be the source rocks contributing a major part of hydrocarbons to the commercial gas fields in the Thai-Vietnam overlapping area.

In addition, from the TOC and QOM distribution map in each unit, especially the unit that expected to be source rocks, unit II and III, it shows the high value of both TOC and QOM in the Thai-Vietnam overlapping area. These also indicate that there are potential source rocks in the Thai-Vietnam overlapping area.