CHAPTER 1

Introduction

1.1 General

For future world's economic development, non-renewable resources including petroleum, mineral commodity and construction aggregates (sands and gravels) are increasingly needed in the next century. Due to the depletion of non-renewable resources onland, therefore, exploration and exploitation for those mineral resources on the seabed and in the sub-seabed extensively take place in offshore areas. It can be seen that recent emphasis on resource exploration and development has largely shifted toward the world's offshore areas.

Geophysics can effectively assist exploration in several ways. To conduct an offshore exploration program, geophysical survey techniques, *e.g.* seismics, magnetometry, gravimetry, bathymetry, *etc.* are very useful, both in deep sea to search for petroleum reservoirs or poly-metallic minerals and in shallow sea to search for placer deposits of heavy minerals (tin, zircon, monazite, rutile, leucoxene, *etc.*), corundum (ruby and sapphire), diamond, gold and aggregates. Among the geophysical techniques, a seismic reflection method has played an important role in offshore exploration program since it can provide sub-seabed information such as sedimentary structures and sequences, depositional system, and depth to buried geological interests. Explorationist can use this information to determine favorable locations for hydrocarbon accumulation and mineral deposits.

A concept of seismic stratigraphy is one of the fastest growing geoscience disciplines used in seismic interpretation. For petroleum exploration, seismic interpretation technique uses this concept to recover stratigraphic information from qualitative analysis and numerical modeling (Brown and Fisher, 1979; Dobrin and Savit, 1988).

This study adopts the concept of seismic stratigraphy to interpret stratigraphic sequences and their related lithofacies as well as depositional systems from high resolution shallow marine seismic data of the Area 1 in the Gulf of Thailand. However, only qualitative analysis is applicable due to an absence of digital data. Results of the study should contribute to the search for economic placers on the seabed including heavy minerals, gemstone and aggregates in the study area. The results can also be used as a guide for interpretation of shallow marine seismic data elsewhere which has geological counterparts.

1.2 Objectives of the Study

The main objectives of the study are to :

1. study the techniques of an offshore exploration for economic seabed detritus using high resolution seismic reflection profiling,
2. interpret, by using concept of seismic stratigraphy with the confirmation of drilling results, the depositional environments

and development of the Quaternary stratigraphic sequences in the study area,

3. determine additional information for appraisal of the potentials of economic placers in the study area.

1.3 Scope of the Study and Thesis Framework

1.3.1 Scope of the Study

This study emphasizes a qualitative re-interpretation of high resolution shallow marine seismic reflection data and the main themes of the study are as follows :

1. sedimentary sequence analysis based on seismic sequence interpretation in correlation with drilling results,
2. reconstruction of geological model of the study area including depositional environments and processes, associated lithofacies and depositional and erosional histories, and
3. delineation of likely favorable targets for accumulation of offshore heavy minerals, gemstone and aggregates.

1.3.2 Thesis Framework

This thesis is divided into five chapters. The first describes general information of the study area, data used for the study and literature review. The second chapter briefs in theories of seismic reflection, techniques of seismic reflection profiling, and describes the concept of seismic stratigraphy, principle concerns, consideration of significant criteria and its limitation. The third chapter explains an interpretation of seismic data with the application of the seismic stratigraphic concept in the study area. The fourth chapter depicts the results of seismic interpretation and drilling to reconstruct the past geological models concerning depositional history and environments. The correlation between seismic facies and lithofacies and its application in exploration for offshore heavy minerals and aggregates are also discussed. Lastly, the fifth one summarizes the results of the study and discusses some significant remarks.

1.4 The Study Area

1.4.1 Location of the Study Area

The Department of Mineral Resources (DMR) with technical collaboration of the United Nations Development Programme (UNDP) conducted an eight-year project entitled "Offshore Mineral Exploration for Heavy Minerals and Gems in the Gulf of Thailand" during 1988-1996. The project's areas located around the Gulf of Thailand from the east coast to the south-east coast of Thailand comprise Area 1, Area 2 and Area 3 (Figure 1.1).

The study area is Area 1 which stretches from Rayong to Chanthaburi and Trat Provinces, covering the area of about 8,110 sq. km at the range of water depth from 5 to 45 m. It lies between latitudes 12° 05 ' N and 12° 43 ' N, and longitudes 100° 47 ' E and 102° 14 ' E, and is sub-divided into five small target areas, namely 1-A, 1-B, 1-C, 1-D and 1-E (Figure 1.2). Consequently, the sub-area 1-B is considered to be not worth for further

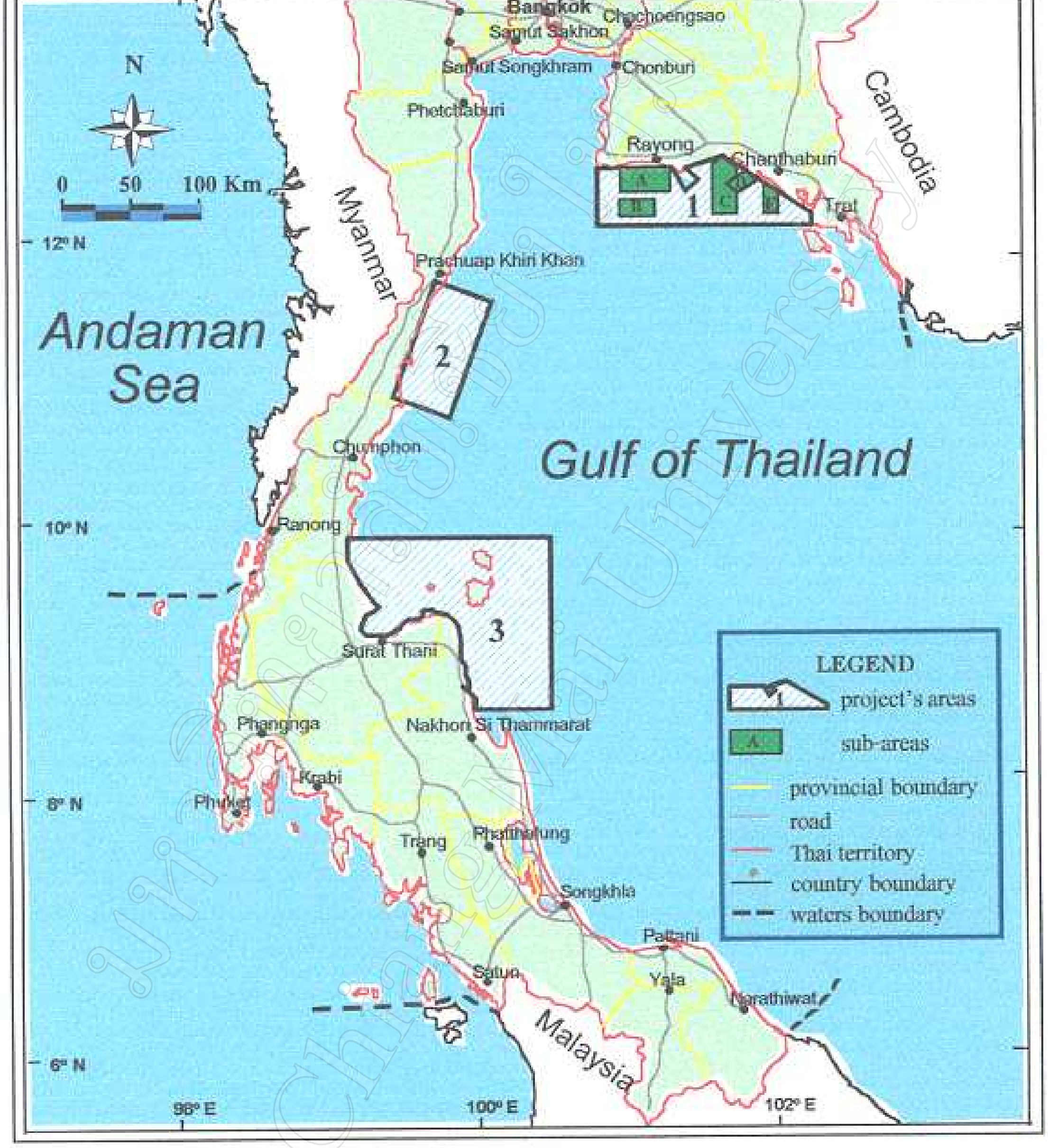

Figure 1.1 Map showing the Gulf of Thailand Project's areas. (after Chotikasathien, 1996)

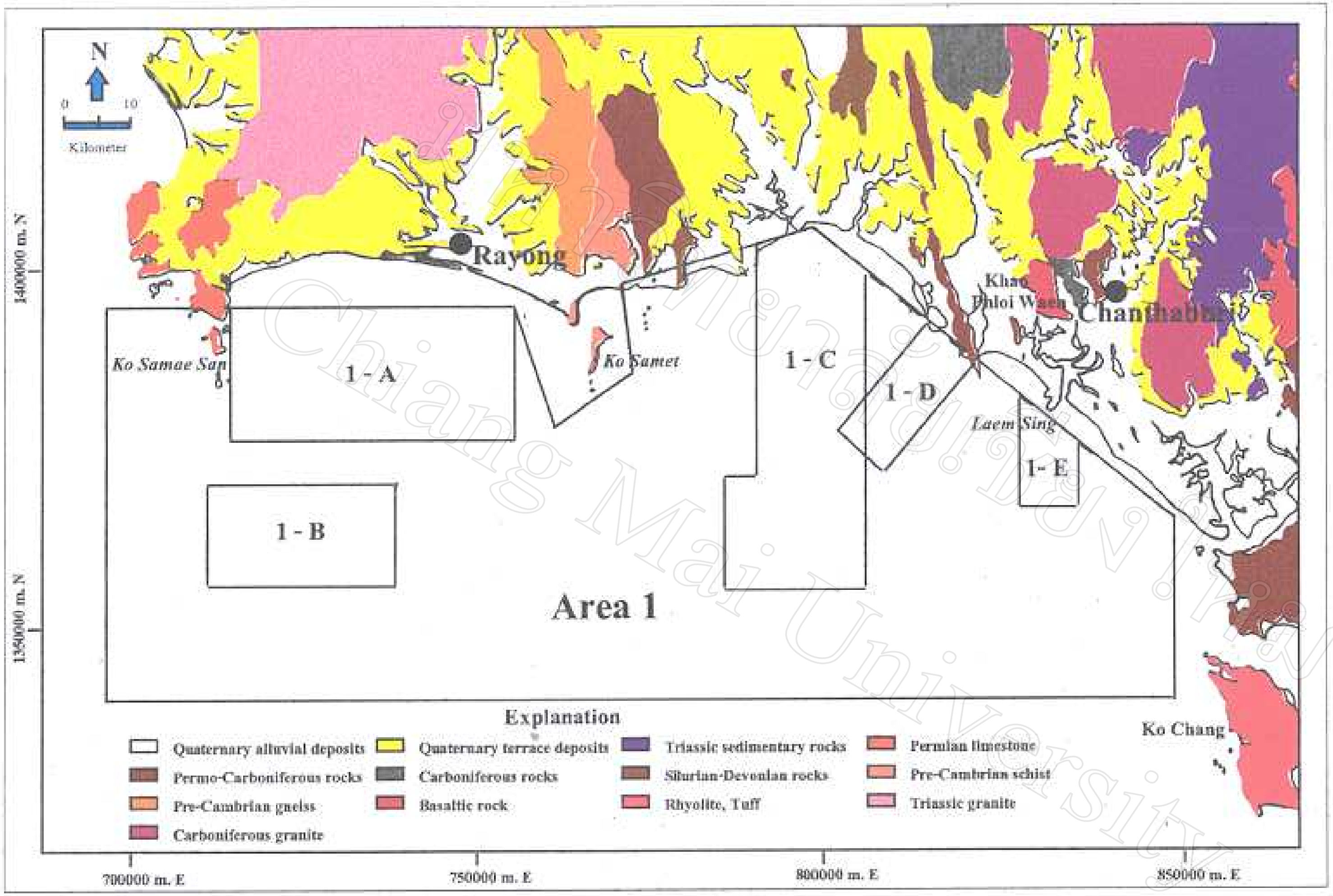

Figure 1.2 Map showing general geology of the eastern Thailand (after Chonglakmani et al., 1983) and sub-areas of the Project Area 1, including 1-A, 1-B, 1-C, 1-D and 1-E (after Gulf of Thailand Project, 1988a)

exploration due to the great water depth and thick cover of sub-seabed sediments.

1.4.2 Exploration History

In Thailand, exploration for mineral deposits in offshore areas has been carried out both in the Andaman Sea and in the Gulf of Thailand by the Marine Mineral Resources Section, Economic Geology Division, DMR. In order to accelerate mineral exploration programs in Thai's waters, since 1979 the DMR in collaboration with the UNDP launched two exploration projects as follows :

1) Offshore exploration for tin and heavy minerals in the Andaman Sea project, during 1979-1986 and

2) Offshore exploration for heavy minerals and gems in the Gulf of Thailand project, during 1988-1996 (Chotikasathien, 1996).

Since 1983 many geophysical surveys and drilling investigations were undertaken in the Gulf of Thailand. Before the commencement of the Gulf of Thailand Project, the first program of shallow marine geophysical investigation in the Gulf of Thailand was achieved with a total survey line of 2,480 km, off the east coast of Thailand during April 1983-December 1984 (Rasrikriengkri *et al.*, 1985). The survey program gathered preliminary seabed and sub-seabed information to support further project formulation.

After the project started in 1988, several exploration activities including marine geophysical survey, coastal drilling, seabed sampling, offshore drilling, and mineral analyses have been undertaken in the three large project's areas to obtain geological information of the areas and adjacent areas along the coasts. The exploration program aims at delineating the favorable targets for offshore economic placers, and evaluating the potential and reserve of the deposits. The number of geophysical survey lines and drillholes of the Area 1 are listed in Table 1.1 and Table 1.2 respectively.

The Area 1 was chosen for the study due to its showing high prospective targets for accumulation of economic seabed detritus including heavy minerals, gemstone and construction aggregates (Roy, 1989; Offshore Mineral Exploration in the Gulf of Thailand Project, 1988a, 1988b, 1989a, and 1989b; Kengkoom, 1990; Chotikasathien, 1996; Kohpina and Saisuthichai, 1996).

1.4.3 The Previous Works and Literature Review

The Gulf of Thailand is a part of Sundaland (Figure 1.3) which is tectonically stable throughout the Quaternary Period (Tjia, 1986). A regional stratigraphy of the Quaternary and Tertiary sequences of the Sunda shelf in Southeast Asia was firstly revealed by Aleva *et al.* (1973). They divided sedimentary sequences into three major units, in ascending order from bedrock surface : the older sedimentary cover (OSC); the alluvial complex (AC); and the upper sedimentary cover (USC). Later, Batchelor (1992) reviewed the work of Aleva *et al.* (1973) and considered that the OSC is early Pleistocene, the AC is late Pleistocene and the USC is Holocene in age. The sub-division

Table 1.1 List of number of geophysical survey lines of Area 1 of the Gulf of Thailand Project (after Chotikasathien, 1996)

SURVEY AREA	FISCAL YEAR	LINE DISTANCE (Km)	TOTAL LINE DISTANCE (Km)	COVERED AREA (Sq.Km)
1-A	1988	310		347
	1989	1,466		760
	1993	651		400
	1994	480		400
	1995	1,110	4,017	105
1-C (upper)	1988	763		875
1-C (lower)	1989	1,260		577
1-C (upper)	1993	353	2,376	130
1-D	1988	797	797	250
1-E	1988	706		190
	1989	436		73
	1994	797		1,630
	1995	263	2,202	30
GRAND TOTAL = 9,392 Km.				

Table 1.2 Drilling statistics of Area 1 of the Gulf of Thailand Project (data from the project during 1994-1997)

AREA	YEAR	NO. OF HOLES	W.D. (LSL.m)		DRILLING DEPTHS (m)	NO. OF HOLE(S) ENCOUNTERED BEDROCK	NO. OF SAMPLES
			MIN	MAX			
1A	1994	11	11.5	16	213.7	3	72
	1995	23	7.8	16.8	430.7	0	132
	1996	60			528.1	0	535
1C	1994	13	9	21.9	181.8	5	70
1D	1994	4	9	14.4	82.3	1	22
1E	1994	35	3.7	17.2	763.8	23	268
	1995	94	2.2	15	1786.3	43	567
	1997	30	4	15.1	513.6	9	CORE
	TOTAL	270			4500.3	84	1666
	MIN.		2.2				
	MAX.			21.9			

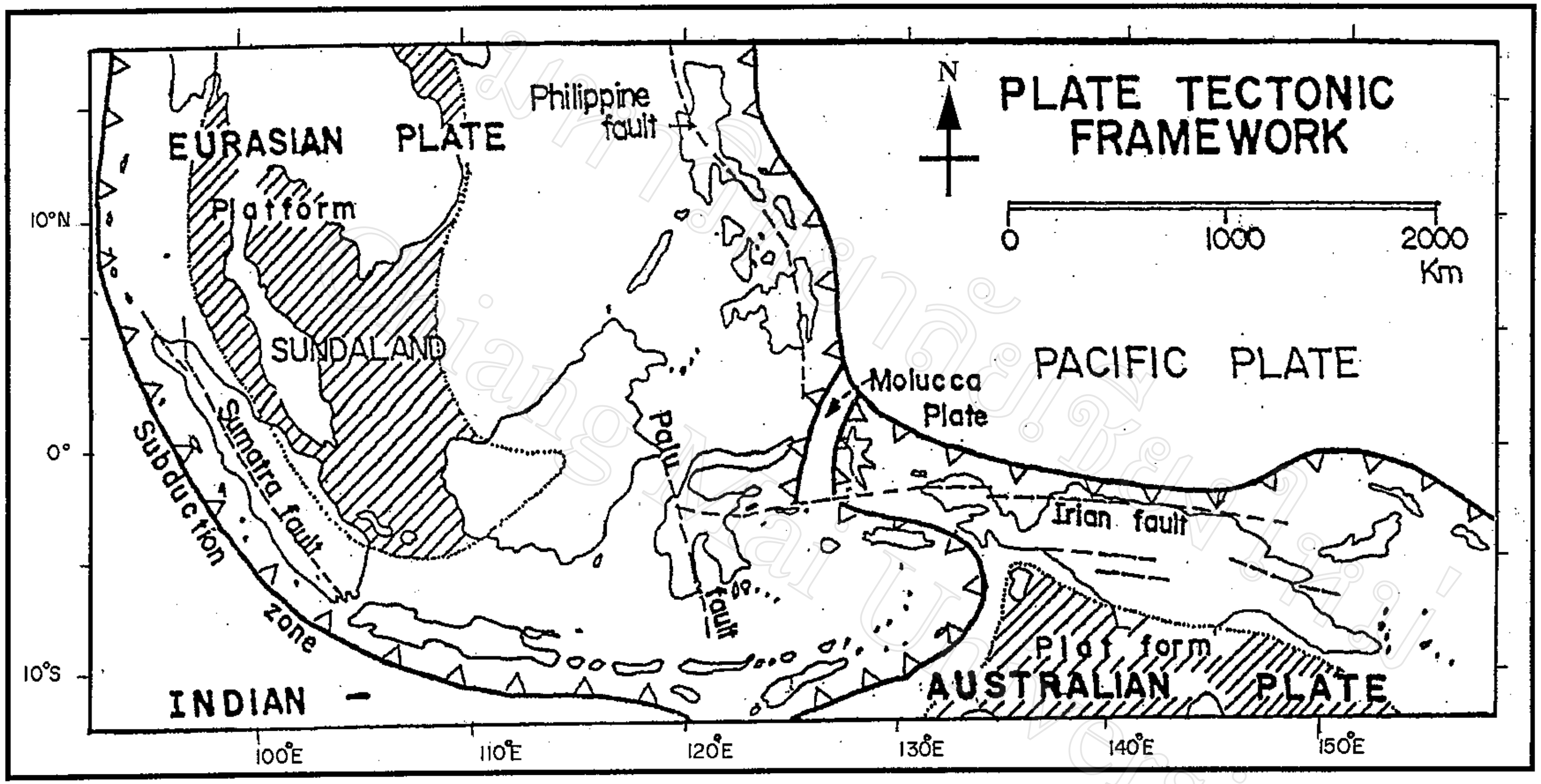

Figure 1.3 Plate-tectonic map of Southeast Asia. The Gulf of Thailand is a part of the tectonically stable Sundaland throughout the Quaternary (after Tjia, 1986).

of the sequence is still applicable to the tectonically stable tropical parts of the region (Evans *et al.,* 1995).

As the works of Rasrikriengkri *et al.* (1985), the results of preliminary interpretation of geophysical data, off the east coast in the Gulf of Thailand, revealed some geological interests as follows; 1) the presence of at least 7 magnetic anomalies in the east of the area, probably related to basalt flows, as the sources of ruby and sapphire; 2) the drowned shoreline likely preserved in the western part; and 3) granite bedrock mostly found in the western and middle part of the area, probably to be the source of heavy minerals deposited.

Offshore Mineral Exploration in the Gulf of Thailand Project (1988a, 1988b, 1989a, 1989b and 1994), Roy (1989), Kengkoom (1990), Chotikasathien (1996), and Kohpina and Saisuthichai (1996) indicated that the Area 1 is the most prospective area where the sub-area 1-A is for heavy minerals and seabed sands and gravels, and sub-area 1-E is for sapphire and ruby, but the sub-areas 1-D and 1-C do not show much economic geological interest.

1.5 General Coastal Geology

1.5.1 Pre-Quaternary Geology

Based on a geologic map of central and eastern Thailand at a scale of 1:500,000 prepared by Chonglakmani *et al.* (1983), pre-Quaternary rocks in the east coast, Rayong, Chanthaburi and Trat Provinces are geomorphologically formed as mountain range trending NNW-SSE to N-S (Figure 1.2). They include the Pre-Cambrian metamorphic suite in the west consisting of schist, amphibolite and calc-silicate rocks; the Palaeozoic sequence found from the east to the west consisting of quartz-mica schist, quartzite, limestone and chert. The igneous rocks are of lower Palaeozoic-Mesozoic era. They are mostly granite, but the minor rock types are granodiorite, andesite and rhyolitic tuff. The Mesozoic granites are thought to be the primary source of tin and heavy mineral placers in this locality.

1.5.2 Quaternary Geology

Basaltic rocks and coastal sediments are two rock types of Quaternary period in this area. Basalt in Chanthaburi-Trat is the most famous primary source of gemstone in Thailand. Based on gem-color variation, Vichit *et al.* (1987) classified the basalt in this area into three zones (Figure 1.4). The blue-green-yellow sapphire zone is in western Chanthaburi and its age determined by K-Ar dating is 0.44 ±0.11 my. BP. (before present). The blue-green sapphire and ruby zone is located between Chanthaburi and Trat Provinces. The ruby zone is in Trat next to the Cambodian border, with the dated age of 1.13 ±0.17 my. BP. Most basaltic outcrops are in NNW-SSE to N-S trends.

Roy (1989) suggested that the coastal sediments in eastern Thailand are deltaic in nature. The deposits in the western part commonly are sandy beaches and barriers, gradually grading to finer constituent of silt and clay and becoming mud flat and mangrove sediment in the east. Further inland, terrestrial and estuarine deposits are extensively present.

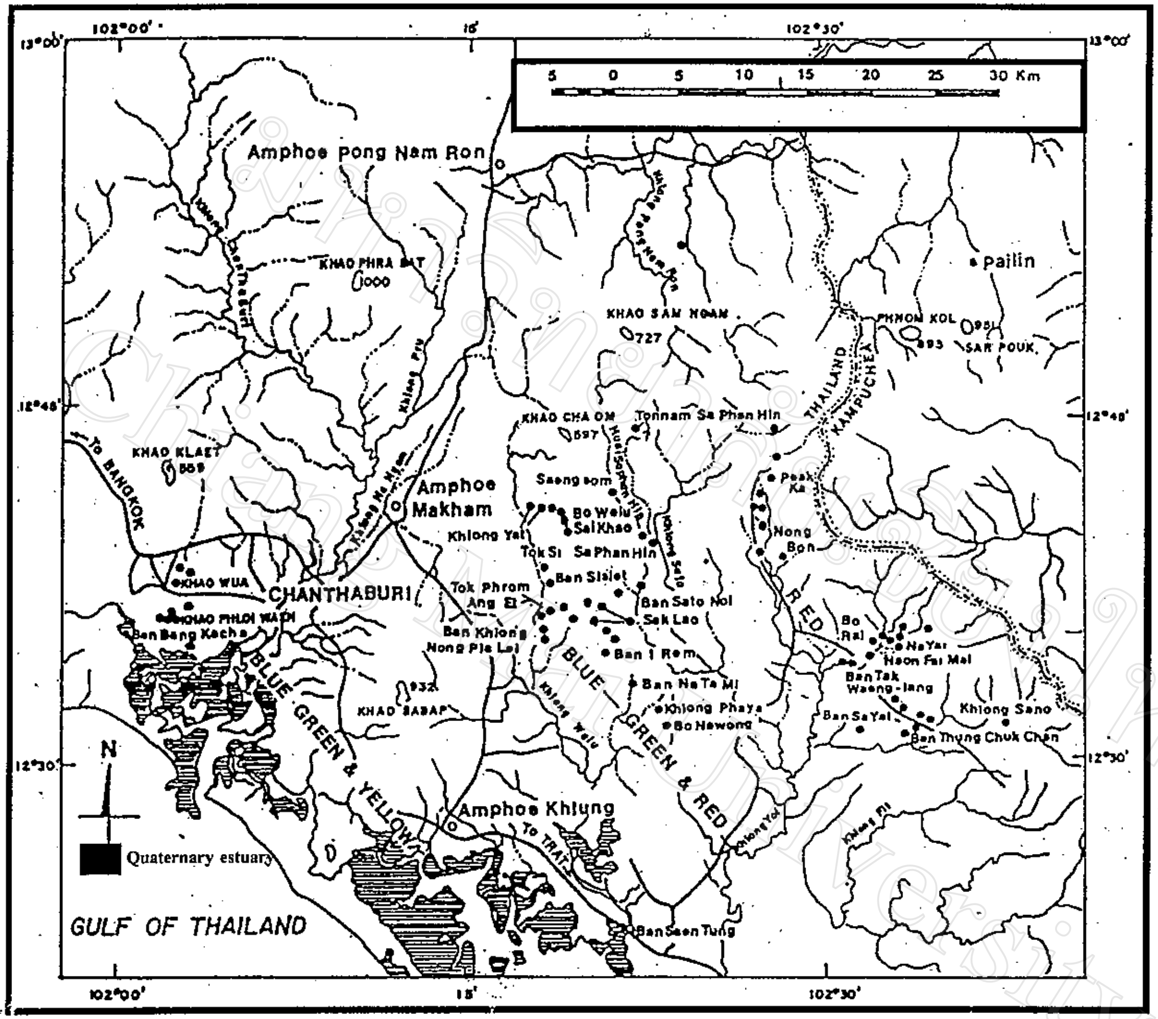

Figure 1.4 Map of gemstone localities and zones of blue-green-yellow sapphires, blue-green sapphires-ruby, and ruby of eastern Thailand (after Vichit et al., 1987).

Coastal deposits comprise three main depositional environments including terrestrial, estuarine and marine (Table 1.3). They grade from inland in-situ deposits of weathered bedrock, through the coast of estuarine environment, *i.e.* estuarine mud, tidal channel sand, tidal delta sand, and backbarrier sand and mud, and to marine environment adjacent to the beaches including barrier beach (dune), littoral mud flat, shoreface, marine transgressive lag sands and gravels, and shelf muds (Roy, 1989).

1.6 Significant Problems

The exploration programs of the Gulf of Thailand Project were mainly concentrated in gathering geophysical and geological data as much as possible in all areas for the prime aims of the search and evaluation of economic seabed detritus in due time of the programs (Roy, 1989). This results in enormous amount of data obtained from the exploration programs. In this regard, a significant problem has been noticed. There is less time to carefully interpret the data. This results in that the correlation of seismic facies to lithofacies to delineate targets of economic placers has not yet been effectively resolved.

1.7 Data Sets

The data sets of seismic reflection profiling from the Area 1 were used for the study of seismic sequence and seismic facies analyses. A total of 40 seismic sections were selected over the study area. In addition, a number of 18 drillholes from drilling investigation during 1994-1997 were selected to

Table 1.3 Lithofacies in eastern Thailand (after Roy, 1989)

Main Depositional Environment	***Lithofacies***
Terrestrial (T)	***T1 Regolith-deeply weathered, in situ rock*** ***(a) Basalt "soil"*** ***(b) Laterite lag gravels*** ***T2 Piedmont fan deposits*** ***(a) Active fan/ braided stream deposits*** ***(channel, levee, delta, overbank, back swamp)***
Estuarine (E)	***E1 Estuarine basin muds*** ***(a) Upper, organic-rich (intertidal/ mangrove) zone*** ***(b) Lower, shelly zone*** ***E2 Tidal channel sands*** ***E3 Tidal delta sands and muds*** ***E4 Backbarrier (washover) sands and muds***
Marine (M)	***M1 Barrier beach (and dune) sand*** ***M2 Littoral mud flats (including mangrove zone)*** ***M3 Shoreface (nearshore) sand and muds*** ***M4 Shelf muds*** ***M5 Erosional (transgressive) lag sands and gravels***

study lithology, environment of deposition, sedimentary processes, and lithofacies.

Other useful data *e.g.* mineralogical study, seabed sampling results, bathymetric chart, *etc.* were also used for interpretive analysis of possible depositional model of the study area, delineation of high potential areas of offshore economic placers, and determination of appropriate solution of encountered geological problems.