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Distribution of clay minerals in surface sediments of the western Gulf of Thailand: Sources and transport patterns

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A B S T R A C T

A high density sampling program during two joint China–Thailand scientific cruises in 2011–2012 included collection of 152 gravity box cores in the Gulf of Thailand (GoT). Samples from the top 5 cm of each core were analyzed by X-ray diffraction for clay mineral content. Several systemic analytical approaches were applied to examine the distribution pattern and the constraint factors of clay minerals in the surface sediments of the western GoT. The clay minerals mainly comprise illite, kaolinite, chlorite and smectite, having the average weight percent distributions of 50%, 34%, 14% and 2%, respectively. Based on the spatial distribution characteristics and statistical results, the study area can be classified into three provinces. Province I contains high concentrations of smectite, and covers the northern GoT, sediments in this province are mainly from rivers discharging into the upper GoT, especially the Chao Phraya and Mae Klong Rivers. Sediments in Province II are characterized by higher values of illite, located in the central GoT, where fine sediments are contributed by the Mekong River and from the South China Sea. Province III, in the coastal regions of southwestern GoT close to Malaysia, exhibits a clay mineral assemblage with complex distribution patterns, and may contain terrestrial materials from the Mae Klong River as well as re-suspended sediments. Results of integrative analysis also demonstrate that the hydrodynamic environment in the study area, especially the seasonal various circumfluence and eddies, play an important role in the spatial distribution and dispersal of clay fraction in sediments.

1. Introduction

Understanding of modern sedimentary processes is the prerequisite for paleoceanographic reconstructions of environmental change (Liu et al., 2007; Dou et al., 2014). Generally speaking, the diversity of transport patterns is a result of various grain size compositions, hydrodynamic conditions, transport agents and so on (Gelfenbaum, 1983; Qin et al., 1987; Lindsay et al., 1996; Tattersalla et al., 2003; Xu et al., 2009). The main constituents of fine-grained sediments, clay minerals, can be carried over long distances and land on places far away from their source area, especially when they are re-transported in the nepheloid layer (Biscaye and Eittreim, 1977; Jones, 1984; Gingele et al., 2001; Sionneau et al., 2008). The tendency of clay minerals remaining in suspension over long distances allows us to use their distribution pattern as the "fingerprint" to distinguish their origins and trace the suspended matter, by analyzing the clay mineralogy of surface sediments (Zöllmer and Irion, 1993; Liu et al., 2012).

The Gulf of Thailand (GoT) is a shallow arm of the South China Sea continental shelf largely enclosed by the landmasses of Thailand, Cambodia and Malaysia, with an area around 35,000 km^2 (Fig. 1). Most major rivers flowing into the GoT are located in the upper GoT, such as Chao Phraya, Bang Pakong, Tha Chin and Mae Klong Rivers (Table 1) (Srisuksawad et al., 1997), while many smaller rivers run into the GoT from both sides. Among these rivers extending to the GoT, Chao Phraya covers the largest drainage area, which accounts for one third of the entire area of Thailand (Adeeel et al., 2002). Large quantities of terrestrial materials have been transported into the GoT and become the potential and significant sources of terrestrial materials in the study area (Mekusmpun et al., 2005). The total flux of the suspended sediment from these rivers into the GoT could achieve

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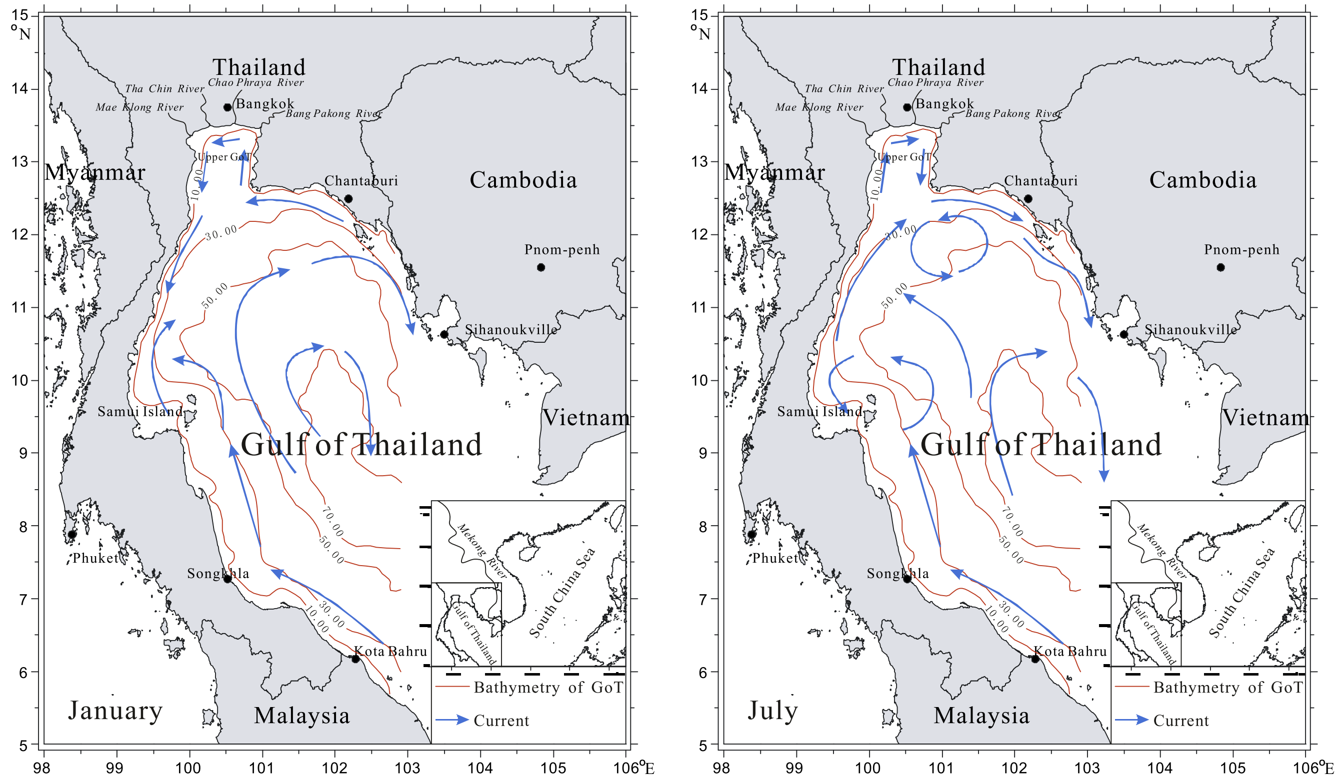

Fig. 1. Location of the Gulf of Thailand and mean circumfluence in winter and summer (modified from Anukul and Mahunnop (1998)).

Table 1
Main rivers drained into the Gulf of Thailand.

		River name			
		Mae Klong	Tha Chin	Chao Praya	Bang Pakong
Drainage area (km^2)		30,837	14,199	160,000	8706
Length (km)		520	439	1352	434
Annually runoff (m^3/s)		273	3.7	117	9.02
Annual rainfall (mm)		1146.5	1390.6	1487.3	1895
Land use type	Forest	73.35%	7.5%	2.1%	10.6%
	Bush	3.65%	–	–	–
	Agriculture & city	19.85%	90.8%	92.7%	89.2%
	Water resources	3.15%	1.7%	5.2%	0.2%

6.32 Mt/yr (Srisuksawad et al., 1994), and the average sedimentation rate may be as high as 0.8 cm/yr (Srisuksawad et al., 1997).

Seasonal variation in the gulf circulation pattern is an important characteristic of the GoT (Fig. 1). In winter, a large clockwise gyre in the central gulf and a small counterclockwise gyre in the upper gulf are developed. In the western part of the central gulf there is a northward flow and along the northern coastline of the upper gulf a westward flow dominates in winter; meanwhile, eddies appear in the north of Samui Island and Pattani province. In summer, complex flows are generated when a number of eddies and stronger currents develop. A large clockwise gyre is also common in summer. Nevertheless, the gulf current pattern is more complex, especially when a current flows from the southern to the central gulf, and then bifurcates westward and eastward. Counter-clockwise summer eddies appear in the north of Samui Island, Pattani province, and in the lower part of the upper gulf. A clockwise eddy often occurs in the northern part of upper GoT in summer when the circulation is very weak (less than 1 cm/s) (Anukul and Mahunnop, 1998).

Some studies on clay minerals in the South China Sea (SCS) have been conducted in recent years (Liu et al., 2010a,b, 2012), notably including the transport patterns of modern sediments and reconstruction of Asian monsoon weather patterns using the clay mineral assemblage of the seafloor sediments (Liu et al., 2007, 2010a,b; Wan et al., 2007, 2010). However, these studies focused on the deep-sea areas and northern coastal zones of the greater SCS (Liu et al., 2010a,b, 2012), and few have included samples from the whole GoT (Srisuksawad et al., 1997). High density sampling and systemic analytical work are needed in the GoT research to better understand the concentration, distribution and sedimentation of clay minerals, and to delineate the materials transport pattern from land to ocean in the southern margin region of SCS. The main objectives of this study include: (1) to determine the concentration and distribution of clay minerals in the surface sediments of the western GoT, (2) to identify the provenance of the modern fine sediments in the study area, and (3) to conclude the spatial transport patterns of clay minerals related to the gulf current circulation system.

2. Materials and methods

2.1. Sample collection

Sampling work was carried out in November 2011 and May 2012 by China–Thailand joint scientific cruises. The HYPACK navigational fixing system was adopted for sample location coordinates. The 152 sampling stations of this study in the western GoT are shown in Fig. 2. All of the seafloor surface samples were collected with a DDCT-3 gravity box corer (30 × 30 × 65 cm^3). Meanwhile, sediments selected are all from the depth range of 0–5 cm, and are removed carefully with a plastic spoon then stored in polyethylene bags at 4 °C immediately after collection, prior to