Morphology and origin of modern seabed features in the central basin of the Gulf of Thailand

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Abstract

For deciphering the morphology, bed forms development and the reconstruction of subsea shallow-stratigraphy of the central basin of the Gulf of Thailand a wide variety of geophysical techniques, such as side scan sonar imagery, sub-bottom profiling and swathe bathymetry, were used and ground-truthed with numerous gravity cores and supported by geotechnical drilling logs. Selected sediment samples were subject to laboratory tests, including X-radiography of sediment slabs, radiocarbon dating, sieve-pipette analyses, X-Ray diffraction and thermal (TGA, DTA and DTGA) techniques, analyses of microscopic images of thin sections of iron-oxide concretions, and identification of extracted fossils.

(1) Three main stratigraphic units were identified in the shallowest deposits of the central part of the Gulf of Thailand, based on seismic data, gravity cores, geotechnical logs and radiocarbon dating. Unit C is an Upper Pleistocene assemblage of transgressive-regressive sequences. Unit B represents marine sediments, which were subjected to lateritization during the last glacial maximum and were subsequently reworked during the Holocene transgression. Unit A omprises Holocene marine muds and clays. This tripartite stratigraphy is consistent across the whole basin and shares similarity to the Quaternary sequence known from the Lower Central Plain of Thailand, where marine sediments of Unit A correlate with the Bangkok Clay Formation and deposits of Unit B with the Stiff Clay Member of the Chao Phraya Formation, respectively.

(2) Unit C in the central gulf contains Upper Pleistocene prodeltaic and delta front sediments up 40 m thick, which were derived from an easterly source and are interpreted as the deposits of the palaeo-Mekong River. The other sediments of Unit C are either of marine origin or delivered from a northerly source, interpreted as deposits of the palaeo-Chao Phraya River.

(3) Units B and A are separated by erosional unconformity R1, which reflects a Holocene transgressive ravinement and forms one of the most important and easily recognizable stratigraphic horizons across the Gulf of Thailand. This surface is expressed as a strong seismic reflector at the soily top of Unit B, mantled locally by transgressive shell-gravel pavement below the seismically transparent marine muds of Unit A. The radiocarbon ages of shell detritus derived from the transgressive lag date the ravinement process at 10.4-10.6 cal kyr BP for the central-southern part of the basin and >6.5 cal kyr BP for the western area. These ages are

consistent with the rapid, though diachronous, northward spread of the Holocene transgression, which began in the central Sunda Shelf at 11–11.5 cal kyr BP and reached the head of the Thailand Bay at 8–7 cal kyr BP.

(4) The modern seabed morphology within the deepest part (below 50 m water depth) of the Gulf of Thailand basin can be divided into three main types: (i) a thick uniform layer of the Holocene soft marine mud, (ii) mounds and ridges of the Holocene soft marine mud, and (iii) flat pre-Holocene stiff silt surface veneered with thin semi-fluid mud. These morphological types are heavily pockmarked and linked by a variety of intermediate forms. This complex seabed topography is interpreted to reflect an interaction between sediment dewatering and the erosional activity of the present-day bottom currents. The sediment dewatering and fluid seepage result in the formation of numerous, randomly or distributed small pits and pockmarks. The sporadically occurring 138 larger pockmarks and fields of pockmarks reflect the emanation of gas or other fluids, which are sourced in deeper parts of the sediment column and are released in rapid bursts, or in a long-term, gradual way.

(5) The erosional activity of bottom currents results in an increased elongation of these features, which originated initially as circular forms within the unconsolidated muds. The long-term erosion imposed by currents of stable orientation modifies small, elongated pockmarks into long runnels and depressions, and ultimately, leads to formation of the most common present seabed morphology of the Gulf of Thailand that is represented by large fields of elongated mounds and ridges, as well as the residual outliers of un-eroded mud and clay sheets.

(6) The development the seabed morphology proceeded in five evolutionary steps.
These comprise (i) pre-erosive phase (early Holocene) when broad and thick sheets of soft clays covered the basal Holocene ravinement surface, (ii) formation of elongated pockmarks (mid-late Holocene); (iii) enlargement of depressions and channel development (mid-late Holocene), (iv) development of mud mounds and ridges (mid-late Holocene), and finally, (v) flattening of the seabed (mid-late Holocene) representing the ultimate output of prolonged erosion of mud mounds.

(7) The mud ridges and runnels located in-between show a stable NW-SE alignment.
This direction follows the basin axis trend and is generally persistent throughout the whole basin. Such elongation of pockmarks, mud mounds and ridges is believed to be generated by the combination of tidal currents, predominantly flood current, and density-driven currents, both related to water in- and outflow between the South China Sea and Gulf of Thailand. The erosion intensifies most likely during tidal maximums and during the March-October season when the strongest thermohalocline develops at ca 50 m water depth. The thermohalocline separates a

lower water mass, dominated by unidirectional bottom currents, from upper one, where wind-driven and ebb-flow tidal currents subjected to Coriolis force result in a multidirectional water circulation.

(8) The available current meter data from the Gulf Thailand are biased towards the surface water circulation and cannot simply be extrapolated to define the behaviour of a water mass extending below the 50 m isobath. The results of the present contribution emphasize the importance of bottom currents in creating the deeper-water bottom morphology of the gulf and highlight the significance of water stratification in this process. This also indicates a need for erecting a separate circulation model for waters located below the thermohalocline.

(9) The present dissertation brings the first detailed account on the morphology and evolution of the pockmarked mud mounds and ridges in Gulf of Thailand. Similar sea 139 floor topography has been reported from many shelf basins, though in none of these is the scale of mud ridges so large and their orientation as stable as in this area. The uniqueness of the Gulf of Thailand in this respect appears to reflect a combination of the presence of an unconsolidated mud veneer upon compacted mud at seabed with the activity of persistent unidirectional bottom currents, which were confined along the basin axis and decoupled by the thermohalocline from any major influence of the wind-driven surficial circulation.