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A muddy megaturbidite in the deep central South China Sea deposited ~350 yrs BP

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ABSTRACT

In the central South China Sea basin below 4200 m water depth in an area of about 90,000 km^2 a mud turbidite was observed that is a few centimeters to several tens of centimeters thick and hence, represents a fairly large volume of 15 to 20 km^3 classifying the deposit as megaturbidite. The host sediment accumulated below CCD and the mud turbidite itself does not contain any carbonate. Nonetheless, emplacement time could be dated by the AMS C-14 method at ~350 yrs BP while burrowing organisms that colonized the mud turbidite shortly after deposition stored shells of planktic foraminifera in their burrows. The origin of the mud mass is unknown, but it can be inferred from the grain size at the base of the turbidite that decreases from SE to W and NW. Furthermore, towards its SE tip, the turbidite occurs in a somewhat shallower water depth. These observations and topographical considerations imply the NW margin of Borneo as a possible source area wherein mass movements are known to occur frequently. The mud turbidite is throughout fine-grained and rich in organic matter (~0.8% C_{org}). The thickness of the cover sediment reflects local variations of sedimentation rate within the central South China Sea basin.

1. Introduction

Submarine mass movements are widespread geomorphological processes occurring in many different settings along continental margins (e.g., Locat and Lee, 2002; Canals et al., 2004). Submarine mass flows are initiated by earthquakes, (storm)wave action, sedimentation events, gas hydrate dissociation, erosion, diapirism, or sea-level change (e.g., Prior et al., 1984; Locat and Lee, 2002; Cauchon-Voyer et al., 2008).

Today submarine mass movements and slope stability are investigated in order to evaluate risk assessment related to natural hazards for a region, in particular for densely populated coastal plains and areas with offshore activities. Besides the direct effects of mass movements on offshore constructions, submarine mass failures may induce tsunamis (e.g., Bondevik et al., 1997; Harbitz et al., 2006; Lo Iacono et al., 2012). Large-scale events causing extreme disasters normally have long recurrence times that often exceed the historical record. To evaluate the hazard and risk potentials for an area, it is therefore necessary to supplement the historical data by evidences from the geological record in particular infrequent, but high-magnitude large-scale events.

The coasts of the South China Sea are densely populated and in some areas exploration of oil and gas is underway. On the other hand, various parts of continental margins surrounding the South China Sea have a high potential for submarine mass movements; in the NW part the Red River Fault System is still active (e.g., Morley, 2002; Li et al., 2008; Gong et al., 2011), the eastern and southeastern margin is formed by a steep convergent continental margin experiencing earthquakes and volcanic activity (Philippines; e.g., Hall et al., 2008) and reactivation of faults within an inactive accretionary wedge (Palawan Trough and Borneo Trough; Franke et al., 2008), and at the northern side gas hydrate has been encountered (e.g., Wang et al., 2006; Wu et al., 2008). Further details can be found in Wang and Li (2009). Nonetheless the number of studies dealing with mass movements is low (e.g., Gee et al., 2007).

The present paper describes a fairly large mass flow deposit observed in the central South China Sea. This deposit formed almost in historical time. The surface of the event bed represents a colonization surface and the sedimentary structures produced by burrowing organisms may provide valuable information about the environmental situation (just) after emplacement of the event bed. The sediment overlying the event bed reflects the spatial pattern of sediment accumulation since that time.

2. Regional setting

The South China Sea represents a western marginal sea of the Pacific Ocean, surrounded by the Southeast Asian mainland in the north and the west and islands to the south and the east (Fig. 1). It includes a prominent, ca. 4300 m deep basin between the Philippines and Vietnam having oceanic crust. The semi-enclosed South China Sea evolved from late Cretaceous to Paleogene rifting, late Eocene to middle

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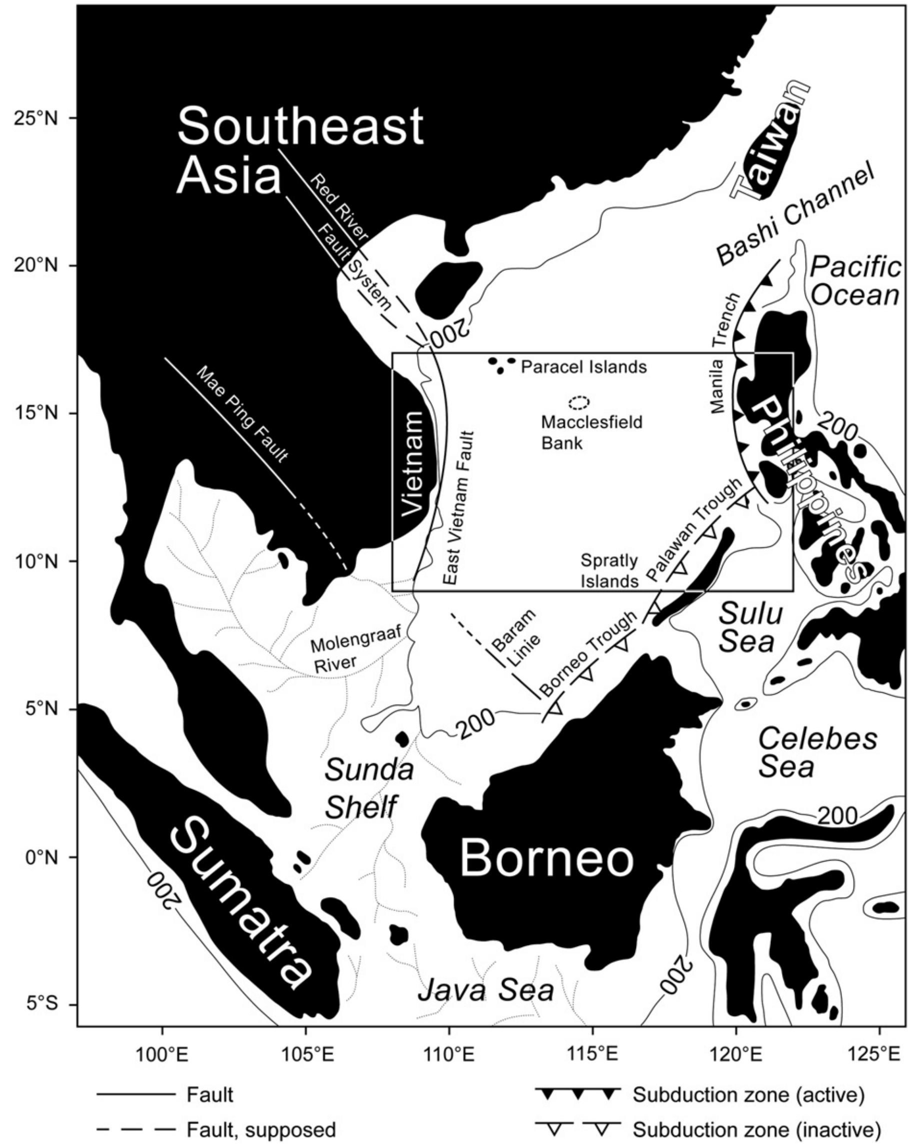

Fig. 1. Location of the study area. Inset represents area shown in Fig. 3; tectonic structures after Franke et al. (2008), Wang and Li (2009), and Hutchison (2010).

Miocene seafloor spreading, and post-spreading subduction and closing since the late Miocene (e.g., Hutchison, 2004; Hall et al., 2008; Wang and Li, 2009). With respect to modern geodynamic situation, there is a strong contrast between the NW part of the South China Sea that is bordered by a passive continental margin having continental crust and the SE "island" side that is characterized by subduction zones, in particular the Manila Trench off Luzon being active, whereas Palawan Trough and Borneo Trough became inactive, but show evidence of fault reactivation (e.g., Clift et al., 2008; Franke et al., 2008; Hutchison, 2010; Tingay et al., 2010). The NW side of the South China Sea is structured by the several fault systems, including the lateral Red River Fault System that continues along the continental slope off central Vietnam and possibly into the Baram Line (e.g., Morley, 2002; Tingay et al., 2010). The continental slopes of the western and northern South China Sea are fairly steep (e.g., Wang and Li, 2009).

The tectonic situation affects the sediment accumulation pattern of the South China Sea (see compilation by Wang and Li, 2009). These authors distinguished seven domains: the areas east of the Manila Trench and the Palawan Trough receive little sediment (3–4 $g/cm^2 \cdot kyr$), whereas the area off Borneo, Sunda Land and southern Vietnam shows the highest sediment accumulation (18–20 $g/cm^2 \cdot kyr$); off central Vietnam and Hainan sediment accumulation is in the range of 6–8 $g/cm^2 \cdot kyr$, and offshore Taiwan sediment accumulates at a rate of ~18 $g/cm^2 \cdot kyr$. Roughly 3/4 of the sediment is terrigenous, the rest is of biogenic origin (opal and carbonate; Wang and Li, 2009). The calcite compensation depth (CCD) is located today in about 3500 m water depth, but was several hundred meters shallower during the early Holocene (e.g., Wang et al., 1999).

3. Material and methods

Samples were collected during cruises 114, 132, and 140 of the German research vessel *Sonne* to the South China Sea in 1996, 1998, and 1999, respectively (Wiesner et al., 1997, 1998, 1999). In addition, a few cores taken during the *Sonne* cruise 95 were studied (Sarnthein et al., 1994). A 3D visualization of the South China Sea was accomplished by processing GEBCO bathymetric data of this region using the software Surfer 11 (Golden Software). Cores were taken by a 50 × 50 cm^2 box corer. Description of sediments is based on onboard visual observations, photographs, and radiographs. For the X-ray radiography, about 1 cm thick sediment slabs were taken onboard from the spilt core surface directly after opening and sealed to prevent desiccation (Werner, 1967). The slabs were irradiated at the Radiology section of the Medical Care Center (Prüner Gang) in Kiel (Germany) using Swissray ddR Multi