Continental Shelf Research 140 (2017) 27–36

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Research papers

Ecological and taphonomical influences on coccoliths in surface sediments in the shelf of the Yellow and East China Seas

Xiaobo Jin, Chuanlian Liu*

State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China

ARTICLE INFO

Keywords:
Coccolith
Surface sediment
Yellow Sea
East China Sea
Ecology
Taphonomy

ABSTRACT

Coccoliths, combined with sediment grain size, carbonate calcium and organic matters content, were analyzed to assess the ecological and taphonomical influences on coccolith distribution patterns in surface sediments in the continental shelf of the Yellow and East China Seas. Coccolith abundances ranged from 0 to 2.08×10^9 coccoliths g^{-1} sediment. The increasing abundance from the coastal inner shelf to the seaward middle shelf generally reflects the ecological fact that living coccolithophores are more abundant in the mesotrophic shelf waters than in the eutrophic coastal waters, although their deposits are still controlled by taphonomical effects, such as bottom (tidal) currents and calcite preservation conditions. Most abundant coccoliths are found in the fine-grained sediments of southwestern Cheju Island, where both ecology and taphonomy favor coccolith preservation. Still, large densities of coccoliths ($> 10^8$ coccoliths g^{-1} sediment) are also found in coarse-grained relict sediments in the middle shelf. Coccolith assemblages were predominated by *Gephyrocapsa oceanica* and *Emiliania huxleyi*. The relative abundance of *E. huxleyi*, in addition to ecological reasons, may relate to selective post-mortem dissolution, since small *E. huxleyi* coccoliths are more susceptible to dissolution. Coccolith calcite has minor contributions ($< 1\%$ to 12%) to total sediment $CaCO_3$, and the main parts are attributed to terrigenous $CaCO_3$ debris and relict shell fragments.

1. Introduction

The continental shelf is a region of active biological pumps, especially for the Yellow and East China Seas (YECS), and the uptake of CO_2 in this area is about twice the global average of marginal seas (Tsunogai et al., 1999; Guo et al., 2015). Coccolithophores are expected to be an important phytoplankton group for carbon cycles in oceans, which contribute 10–20% and 30–60% to marine primary production and calcite production, respectively (Poulton et al., 2007, 2010), since coccolithophores can produce both organic and inorganic carbon. The inorganic parts of a coccolithophore are called coccoliths, and a single coccolith has a tiny volume and weight; however, carbonate calcium based on these tiny, but abundant, particles can contribute more than 50% to $CaCO_3$ in oceanic sediments (Frenz et al., 2005; Broecker and Clark, 2009). Coccolith burial in sediments is important for carbon sequestration in shelf regions because organic carbon fixed by photosynthesis will be regenerated if it is not able to be added to open oceans (Tsunogai et al., 1999). Finally, it is important that the patterns of coccolith occurrence in sediments mirror the environmental gradients of upper waters based on whether coccolith assemblages in cores can be used to reconstruct water mass properties and ocean primary productivity in geological history for paleoceanographers (e.g., Saavedra-Pellitero et al., 2010, 2011, 2013; Guerreiro et al., 2015a, 2015b).

Previous studies in the YECS (Wang and Samtleben, 1983; Zhang and Siesser, 1986; Cheng and Wang, 1997; Tanaka, 2003) found that coccolith assemblages were dominated by two species, *Gephyrocapsa oceanica* and *Emiliania huxleyi*, and the relative abundance of *E. huxleyi* increased from the coastal inner shelf to the Okinawa Trough. More recently, field investigations of living coccolithophores in water columns have shown that coccolithophore distribution is mainly controlled by the chemical and physical properties of water mass (stratification, temperature and nitrate concentration) (e.g., Sun et al., 2014; Luan et al., 2016; Kang et al., 2016). Some studies about the comparison between living and fossil coccolithophores have reported that coccoliths in surface sediments generally reflect their ecology in overlying water columns (Baumann et al., 2000; Andruleit et al., 2004; Saavedra-Pellitero and Baumann, 2015). However, coccoliths in sediments are strongly affected by taphonomical processes, such as dilution by terrigenous materials in coastal regions (Guerreiro et al., 2015a). Therefore, these materials are still challenging whether coccolith distribution patterns in sediments could be the reflection of their ecology in overlying waters in the YECS, where the Yangtze River is the

---

* Corresponding author.
E-mail address: liucl@tongji.edu.cn (C. Liu).

http://dx.doi.org/10.1016/j.csr.2017.04.008
Received 17 May 2016; Received in revised form 31 March 2017; Accepted 17 April 2017

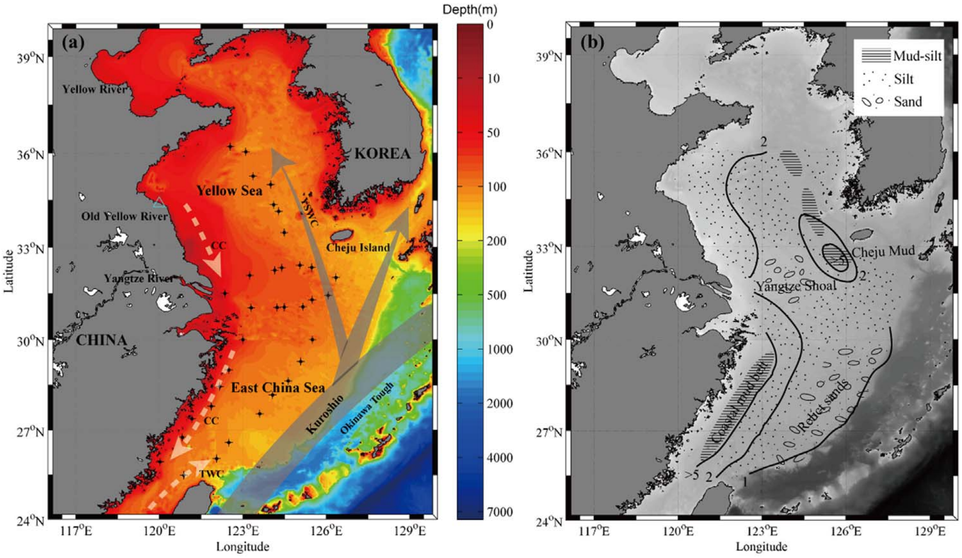

Fig. 1. (a) Sampling stations and surface circulations in the Yellow Sea and East China Sea. YSWC: Yellow Sea Warm Circulation. CC: coastal current. (b) Sketch map of sand-silt-clay distribution in the surface sediments modified from Wang et al. (2014), and sediments accumulation rates (mm yr^{-1}) according to Lim et al. (2007) in the study area.

third-longest river in the world, and it has exported ~480 million tons of sediment load historically and approximately 3% of the global fluvial input to the oceans (Liu et al., 2007). In the present study, absolute coccolith abundance combined with grain size and $CaCO_3$ as well as organic matter content of sediments, which were the direct reflection of sedimentary conditions, were carried out. By comparing the coccolith data with these abiotic parameters and with the published studies concerning living coccolithophores in the study area, this work was intended to assess the ecological and taphonomical effects on coccoliths in sediments, coccolith contributions to carbonate and the potential usage of coccoliths for paleoceanographic studies in the YECS.

2. Study area

There is a widespread continental shelf beneath the YECS that covers an area of ~0.9×10^6 km^2 (Chen, 1996). The water masses in the YECS were both influenced by the discharge from the large rivers and the Kuroshio Current (Fig. 1a). The turbid plume expanded intensively from the Yellow Sea coast of China to Cheju Island in winter and spring, and it was trapped coastally in summer. The Yangtze River plume can reach Cheju Island driven by the southwest monsoon in summer or flows southward along the coast in winter (Zhou et al., 2008; Wang et al., 2014). The fresh and nutrient-loading plume can trigger active biological pumps in this region as shown by satellite chlorophyll-*a* concentration (Fig. 2a), and furthermore, it can facilitate frequent harmful algal blooms due to enhanced anthropogenic discharge in the drainage basin (Zhou et al., 2008). The warm and oligotrophic Kuroshio surface water flows through the east edge of the YECS shelf, and its brunch, the Yellow Sea Warm Current (YSWC), brings warm and saline waters into the Yellow Sea. Nutrients are sufficient in the coastal and inner shelf surface waters and gradually decreased towards the Kuroshio regime (Zhang et al., 2007). Other authors also stated that the upwell of Kuroshio subsurface water onto the East China Sea shelf was an important nutrient source (Chen, 1996).

Approximately 1/3–1/4 of areas of the YECS shelf are covered by sand-dominated sediments (Wang et al., 2014). Two dominant sand regions in the study area were off the mouth of the Yangtze River (the Yangtze Shoal) and the middle and outer shelf of the East China Sea (ECS) (Fig. 1b). Active tidal currents formed the unique sand sheets and ridges in the Yangtze Shoal, while the sands in the middle and outer shelf were considered a relict paleo-Yangtze River submarine delta from the last glacial at low stand sea level (Liu, 1997; Liu et al., 1998). In the study area, there were also two mud areas, including one located in the southwest of Cheju Island (Cheju Mud, Fig. 1b). The sediments in this mud patch mainly originated from the large Chinese rivers (e.g., the Yangtze River and the Yellow River) (Lim et al., 2007). Another mud area is along the coast south of the Yangtze River mouth in the inner shelf of ECS (Fig. 1b). This mud belt was formed by the dispersal of the Yangtze River-derived sediments (Xu et al., 2009). The distribution patterns of sediment accumulation rates paralleled the distribution of sediment in the YECS shelf. For example, accumulation rates were the highest in the mud areas (> 5 mm yr^{-1}), while accumulation rates were low (< 2 mm yr^{-1}) in the sands of the Yangtze Shoal and middle-outer shelf (Huh and Su, 1999; Lim et al., 2007).

3. Materials and methods

A total of 35 samples (Fig. 1a) were obtained from the uppermost centimeter (~1 cm) of sediments that were collected with a multi-corer and box-corer during two cruises of *R/V Dongfanghong II* and *R/V Kexue I* in June and October 2011 on the shelf of YECS.

3.1. Coccolith analysis

Absolute coccolith abundances in the sediments were determined following the "drop technique", which has good accuracy and reproducibility (Koch and Young, 2007; Bordiga et al., 2015). Approximately 20 mg of dry sediments was weighed with electronic analytical balance (0.1 mg precision, Sartorius Quintix224) and mixed with a known volume (~20 ml) of distilled water in a test tube. Suspension is treated as ultrasonication for ~5 min to disintegrate and evenly mix the sediment particles. Immediately after ultrasonication, 300 µl of the suspension were extracted with a micropipette and evenly (important) dropped on a 24×24 mm sized coverslip on a hotplate at 50 °C. After drying, the coverslip was mounted on a slide with Norland Optical Adhesive (No. 74). The curing was done after exposure under 96 W (48 W×2) of UV light for 15 min and following cementing in the air for another 3 h.

Overall, 300–500 coccolith specimens were counted in usually 10–25 arbitrary field of views (FOV) using a polarized light microscope at ×1000 magnification (Leica DM6000B). For rare coccolith species and in coccolith barren samples, coccolith counting was performed in at least 100 FOVs. Absolute coccolith abundance was calculated with the