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Source, composition and reactivity of sedimentary organic carbon in the river-dominated marginal seas: A study of the eastern Yellow Sea (the northwestern Pacific)

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ABSTRACT

We investigated the source, composition and reactivity of sedimentary organic carbon (OC) in a river-dominated continental marginal sea, the eastern Yellow Sea. A multi-proxy approach was applied to 9 riverbank sediments and 69 marine surface sediments, combining bulk and molecular organic parameters. The riverbank sediments ($n=9$) have on average low C/N ratio (4.8 ± 0.5) and enriched $\delta^{13}C_{TOC}$ values (−21.5 ± 0.6‰) while the BIT index is on average 0.27. The sedimentary OC in the marine surface sediments appears to have a predominantly marine origin (on average C/N ratio = 7.0 ± 0.6 and $\delta^{13}C_{TOC}$ = −21.9 ± 0.5‰, $n=69$) with minor contribution of continental (i.e. soil- and lake/river-derived) OC (on average BIT index = 0.00 ± 0.01, $n=69$). However, the $\Delta^{14}C$ values were depleted (on average −227 ± 53‰, $n=8$). Accordingly, our results highlight that fossil OC, potentially derived from erosion of sedimentary bedrocks in the catchment areas and/or human activities is being contributed to the sedimentary OC pool in the eastern Yellow Sea. More work is needed to better constrain the source, composition, and age of the organic material supplied to the eastern Yellow Sea, given the lack of biogeochemical data from the Korean rivers.

1. Introduction

Since the anthropogenic era started at 1800 A.D., human activities (e.g. burning of fossil fuel, industrialization, and deforestation) have altered the chemical composition of the atmosphere through the buildup of greenhouse gases, primarily carbon dioxide (CO_2, IPCC (2013) and references therein). The question raised is how the atmospheric CO_2 increase above preindustrial levels affects the global climate and thus human society. Hence, many of the central issues in research concerning global climate changes involve understanding the exchange of organic carbon (OC) pools in the context of the global carbon budget. Globally, as much as 90% of riverine sediment burial (e.g. Deng et al., 2006) and of the oceanic OC burial (e.g. Berner, 1982; Hedges and Keil, 1995; Smith et al., 2015) occurs on the river-dominated continental margins. However, the role of the continental marginal seas in the global carbon budget is still debated: a net sink for atmospheric CO_2 or a net CO_2 source to the atmosphere (e.g. Cai and Dai, 2004; Thomas et al., 2004a, 2004b; Borges et al., 2005; Bauer et al., 2013). Therefore, if we are to balance and model successfully CO_2 flux budgets at regional (e.g. Frankignoulle and Borges, 2001) or global scales (e.g. Tsunogai et al., 1999; Le Quéré et al., 2014), we need to first understand the processes related to the origin, composition and quantities of sedimentary OC in these systems (e.g. Hedges, 1992; Hayes et al., 1999; Burdige, 2005). This will improve our knowledge about the global carbon cycle and thus the role of continental marginal seas to the oceanic uptake of anthropogenic CO_2.

The Yellow Sea (West Sea of Korea) is a semi-enclosed, northwestern Pacific marginal sea into which two of the largest rivers in the world, the Huanghe River (Yellow River) and the Changjiang River (Yangtze River) are flowing. The high terrigenous sediment

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inputs from the surrounding landmasses to the Yellow Sea result in high sediment accumulations in its subaqueous deltas (e.g. Alexander et al., 1991; Yang et al., 2003; Yang and Youn, 2007) and thus this marginal sea is considered to be an important sink for terrestrial OC (e.g. Chen and Borges, 2009). Previous bulk- and biomarker-based studies on the origin and distribution of sedimentary OC in the Yellow Sea showed that the contribution of terrestrial OC was predominant along the coast while that of marine OC was in the central basin (e.g. Xing et al., 2011, 2014; Hu et al., 2013, 2016; Lin et al., 2014). However, most of the studies have been focused on the western Yellow Sea, and comparable studies are rarely conducted in the eastern Yellow Sea. Hence, there is the necessity for investigating the source and composition of sedimentary OC in the eastern Yellow Sea in order to estimate better the overall carbon storage and carbon budget for this marginal sea.

In this study, we aimed to provide qualitative and quantitative assessments of sedimentary OC source and composition in the eastern Yellow Sea. For this purpose, we used a multi-proxy approach on 9 riverbank sediments and 69 marine surface sediments, combining bulk and lipid biomarker parameters. Our results revealed that refractory OC, possibly derived from fossil OC was preserved in surface sediments in the eastern Yellow Sea.

2. Study area

The Yellow Sea (West Sea of Korea), located between China and the Korean Peninsula, is a typical epicontinental sea in the mid-latitudes of the northwestern Pacific, occupying the broad continental shelf with a mean water depth of 44 m and a maximum depth of 140 m (Fig. 1A). The west coastline of the Korean Peninsula is characterized by a long stretch of a Ria-type coast, forming numerous inlets whose physiographic features significantly differ from each other (Hong et al., 1991). Because of high tide range (up to 10 m), the tidal flats are largely developed along the west coast of the Korean Peninsula. The surface circulation consists of the Yellow Sea Warm Current (YSWC, a branch of the Kuroshio Current) and the Yellow Sea Coastal current (YSCC) and the Korean Coastal Current (KCC) (Fig. 1A). The northward

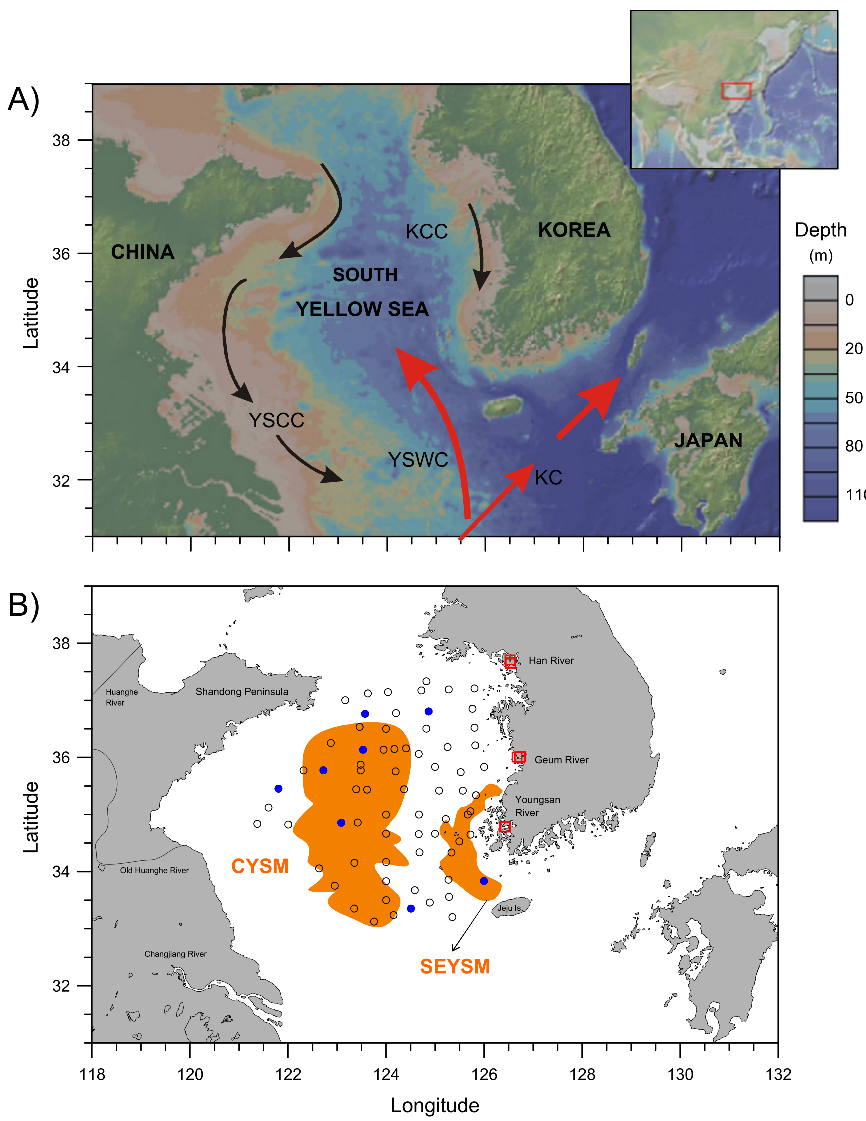

Fig. 1. (A) Regional circulation pattern of the south Yellow Sea (arrow) and (B) the locations of marine surface (○ black open circles) and riverbank (□ red open squares) sediments. Filled blue circles (●) indicate the sample locations where the radiocarbon measurements (^{14}C) were performed on TOC of surface sediments. KCC = Korea Coastal Current; YSCC = Yellow Sea Coastal Current; YSWC = Yellow Sea Warm Current; KC = Kuroshio Current (Su and Wong, 1994). The shaded areas represent the muddy deposition areas (> 6 ϕ in mean grain size): the CYSM (Central Yellow Sea Mud) and the SEYSM (Southeastern Yellow Sea Mud) redrawn from Lim et al. (2007). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)