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Environmental factors affecting regional differences and decadal variations in the buried flux of marine organic carbon in eastern shelf sea areas of China

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Abstract

To characterize environmental factors controlling decadal-scale variations in the buried flux of marine organic carbon (BF_{C_m}) in the eastern shelf sea areas of China (ECSS), four well preserved sediment cores collected from the central Yellow Sea mud (CYSM) area, the Yellow Sea Coastal Current (YSCC) area and the Changjiang River Estuary (CRE) were investigated in this study. In the CYSM, variations in BF_{C_m} were found to be dependent on variations in primary productivity and to exhibit a cyclical trend possibly related to fluctuations in the Pacific Decadal Oscillation (PDO) and the East Asian winter monsoon index (EAWM). In the YSCC, BF_{C_m} likewise depends on primary productivity. Prior to the 1950s, variations in BF_{C_m} were similar to that of the EAWM. After the 1950s, BF_{C_m} increased rapidly and exhibited maximum values in the surface layer, consistent with an increase in primary productivity caused by the input of terrestrial nutrients associated with China's economic development. In the CRE, variations in BF_{C_m} were affected by several competing factors making it difficult to identify clear relationships between variations in BF_{C_m} and primary productivity. In contrast, long-term variability in BF_{C_m} is more similar to changes in the Changjiang River sediment load. Thus, it is speculated that the construction of dams along the Changjiang River may be the main cause of variations in BF_{C_m} in this area. Given the disproportionate effects of human activities on marine environments and decadal variations in BF_{C_m} in the ECSS, careful attention should be paid to regional differences in organic carbon preservation and environmental changes lest estimates of these values be made imprecise or inaccurate.

Key words: marine organic carbon, buried flux, primary productivity, climate change, human activity

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1 Introduction

Biological carbon sequestration on continental shelves is mainly achieved through primary productivity and burial of marine organic carbon. Under the right circumstances, a large fraction of marine organic carbon can settle and be buried in sediment, leading to long-term removal of this carbon from the marine carbon cycle. Thus, burial of carbon in marine sediments is considered a long-term reservoir for atmospheric CO_2.

The South Yellow Sea (SYS) and the East China Sea (ECS) are important shelf seas off the coast of China. Recently, several studies have addressed various aspects of the sinks/sources of carbon burial in the continental shelf. For example, previous studies revealed that organic carbon buried in marine sediments primarily represent fluvial and marine sources. Notably, marine organic carbon derived from marine primary productivity is generally recognized as an important indicator of the potential for marine carbon sequestration. Several studies have demonstrated that the C/N ratio, $\delta^{13}C$ and phytoplankton biomarkers may be used as effective proxies for tracing marine organic carbon (Cai et al., 2014; Lin et al., 2014; Wu et al., 2016). To better evaluate the potential effects of natural processes and anthropogenic activities on coastal carbon sinks, chronological data were used to reconstruct the evolution of marine-derived organic carbon (C_m) storage in shelf sediments (Zhang et al., 2017). Li et al. (2015) analyzed the historical trend of total organic carbon burial in the CRE and determined that the proportion of organic carbon from terrigenous (C_t) buried in sediment is higher than C_m. These authors considered that the sedimentary record of the CRE can reflect the influence of human activities on the natural environment. Yang et al. (2011) analyzed the burial of organic carbon in the Holocene sediments of the Zhujiang River and the CRE, and found that the historical record of organic carbon in the Zhuji-

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ang River Estuary is closely related to the evolution of the East Asian winter monsoon index (EAWM), while the burial of organic carbon in the CRE is affected by many factors and exhibits no correlation with monsoon cycles. Cai et al. (2014) reconstructed sedimentary records of organic carbon in the ECS and the Yellow Sea and found that trends in C_m over the past 200 a were consistent with changes in sea surface temperature and primary productivity. Additionally, Hu et al. (2016) pointed out that the storage capacity of organic carbon in the Bohai Sea and the Yellow Sea is dominated by the fluvial input of land-based organic matter, high level of phytoplankton primary productivity, convergent hydrodynamic and stable depositional settings. The above studies indicate that there may be regional and temporal variations in the burial rate and eventual fate of organic carbon that have occurred over the last 100 a. However, these variations and the factors that influence them have not been systematically studied at the inter-regional scale. If the regional differences are common along the shelf as predicted, the conclusions of previous studies on relationships between marine organic carbon storage capacity and environment variations may be imprecise, as such regional differences are typically ignored or else poorly quantified.

In this study, four well preserved sediment cores collected in different regions of the eastern shelf sea areas of China (ECSS) are analyzed for ^{210}Pb isotopes and total organic carbon/total nitrogen (TOC/TN) ratios to reconstruct the historical records of the sources of modern organic matter (OM) and the related composition of C_m. Moreover, to assess regional differences in marine-derived carbon sequestration and the effects of natural processes and human activities on the buried marine organic carbon flux (BF_{C_m}) in different areas, BF_{C_m} in the SYS, ECS, and CRE was calculated.

2 Methods

2.1 *Sample collection*

The SYS and ECS are typical marginal seas of the Northwest Pacific Ocean. The coastal current in the SYS and the ECS mainly include the Yellow Sea Coastal Current (YSCC), the Yellow Sea Warm Current (YSWC) and the West Korean Coastal Current (WKCC). Sediments in these areas are primarily influenced by the supply of terrestrial sources from the Huanghe River and the Changjiang River. To the southeast, these sea areas mainly exhibit oceanic characteristics because of the effects of the YSWC, which is an offshoot of the Kuroshio Current. In contrast, the northeast and western regions are more greatly affected by the adjacent terrestrial environment and the YSCC. In this study, decadal variations in marine-derived carbon sequestration are determined based on four sediment cores collected from the ECSS in April 2006 and June 2009 (Fig. 1). Station B19, near the 50 m isobath off the southwestern coast of the Shandong Peninsula, is significantly affected by the YSCC. Stations A7 and B14 in the the central Yellow Sea mud (CYSM) area are significantly affected by the YSWC. Station H1-18 is located in the transitional zone between the Changjiang River Delta and the shelf sea, and is significantly affected by input of terrigenous source material from the nearby the Changjiang River Estuary (CRE).

Sediment cores were collected using a box sampler and then stored at –4°C prior to being cut in the laboratory. Subsamples were achieved at 1 cm intervals in the upper 15 cm of the core, and at 2 cm intervals for the rest of the core. After drying to a constant weight at 60°C, the sediments were analyzed. All samples in Core A7 and Core B14 are characterized by silty clay, while sediments in Core B19 and Core H1-18 were composed of clay and clayey sand, respectively.

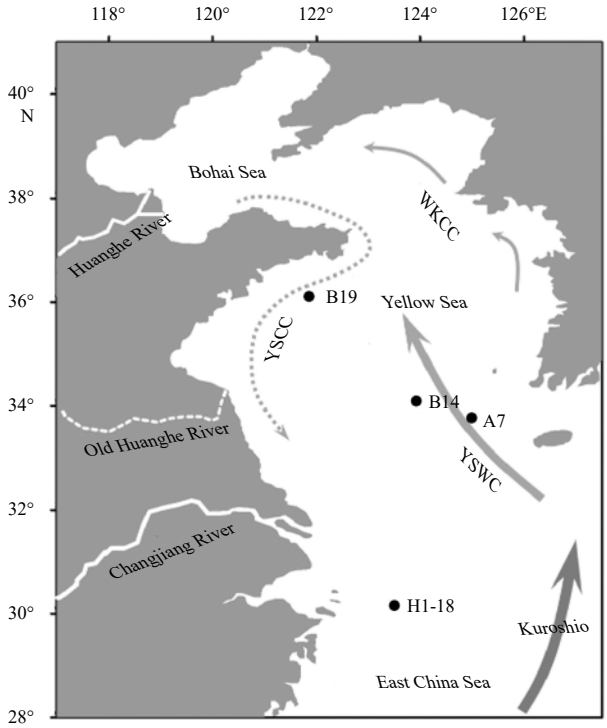

Fig. 1. Sampling stations of Cores B19, B14, A7, and H1-18. YSCC: the Yellow Sea Coastal Current; YSWC: the Yellow Sea Warm Current; WKCC: the West Korean Coastal Current.

2.2 *^{210}Pb analysis*

The activities of $^{210}Pb_{ex}$ and ^{226}Ra in cores were determined using a germanium detector manufactured by AMETEK Company at the Institute of Polar Environment, University of Science and Technology of China. ^{210}Pb-derived sediment accumulation rates (SARs) were calculated based on the constant initial concentration (CIC) model.

2.3 *Measurement of total carbon (TC), TOC and TN*

Original samples were dried to constant weight at 60°C. After being ground in an electric grinding mill and sieved through a 60-mesh sieve, TC was measured by element analyzer (Elementar vario ELⅢ, Langenselbold, Germany) with an analytical precision of 0.1%. Repeat measurement errors of TC are less than 1%. Approximately 1.5 g of freeze-dried samples was fumigated with hydrochloric acid for 24 h to remove inorganic carbon. TOC and TN values were then determined using the elemental analyzer.

2.4 *Estimation of C_m*

The C/N ratio has been previously identified as a valuable indicator of sedimentary organic matter sources. Terrestrial organic matter is generally characterized by ratios of C/N>12. Sedimentary organic matter is thought to be marine autogenic if the ratio of C/N is below 8 (Meyers, 1994; Dean, 1999). The C/N ratio has been widely used to evaluate the relative contributions of terrestrial and marine autogenic sources (Perdue and Koprivnjak, 2007; Chen et al., 2011). Previous studies have suggested that the terrestrial and marine end-member values of C/N are typically 5 and 20, respectively (Jia et al., 2002; Li et al., 2008). For this study, C_m was calculated based on the formula presented by Qian et al. (1997) as follows:

$$\mathrm{TOC} = \mathrm{C_m} + \mathrm{C_t}, \tag{1}$$

$$\mathrm{TN} = \mathrm{N_a} + \mathrm{N_t}, \tag{2}$$

$$\mathrm{N_m} = \mathrm{C_m}/5, \tag{3}$$

$$\mathrm{N_t} = \mathrm{C_t}/20, \tag{4}$$

where TOC and TN are the measured TOC and TN, respectively; C_m and N_m are the marine-derived organic carbon and nitrogen contents, respectively; C_t and N_t are the contents of organic carbon and nitrogen from terrigenous inputs, respectively. From the above equations, the following equation can be derived:

$$\mathrm{C_m} = (20\mathrm{TN} - \mathrm{TOC})/3. \tag{5}$$

2.5 *Organic matter provenance*

A binary mixing model was developed to quantitatively estimate the contribution of OM in the studied cores, based on the principle of a conservative mixture of different end-member values of C/N and the law of mass conversation.

$$\left(\frac{\mathrm{C}}{\mathrm{N}}\right)_{\mathrm{sample}} = \left(\frac{\mathrm{C}}{\mathrm{N}}\right)_{\mathrm{t}} \cdot f_{\mathrm{t}} + \left(\frac{\mathrm{C}}{\mathrm{N}}\right)_{\mathrm{m}} \cdot f_{\mathrm{m}}, \tag{6}$$

$$f_{\mathrm{t}} + f_{\mathrm{m}} = 1, \tag{7}$$

where f_t and f_m are the terrestrial and marine OM fractions, respectively; $(C/N)_t$ and $(C/N)_m$ are the terrestrial and marine end-member values of C/N, respectively; and $(C/N)_{sample}$ is the value of the proxy analyzed in the sediment sample. From the above equations, the following equation can be derived:

$$f_{\mathrm{m}} = \frac{20 - \left(\frac{\mathrm{C}}{\mathrm{N}}\right)_{\mathrm{sample}}}{15}. \tag{8}$$

2.6 *Carbon burial fluxes*

The carbon burial flux was calculated by measuring the carbon content, sedimentation rate, and dry density of sediment, based on the following equations (Ingall and Jahnke, 1994):

$$\mathrm{BF} = \mathrm{C_i} \times S \times \rho_{\mathrm{d}}, \tag{9}$$

$$\rho_{\mathrm{d}} = (1-\phi)/((1-\phi)/\rho_{\mathrm{s}} + \phi/\rho_{\mathrm{w}}), \tag{10}$$

where BF (g/(m²·a)) is the carbon burial flux; C_i (%) is the carbon content; S (cm/a) is the sedimentation rate; ρ_d (g/cm³) is the dry density of sediment; ϕ (%) is the water content in sediment; ρ_s (g/cm³) is the sediment grain density; ρ_w (g/cm³) is the density of water and ρ_s=2.56 g/cm³, ρ_w=1.027 g/cm³ (Dai et al., 2007).

3 Results

3.1 *Chronology of the sediment cores*

Based on the vertical distribution of ^{210}Pb (Fig. 2), surficial

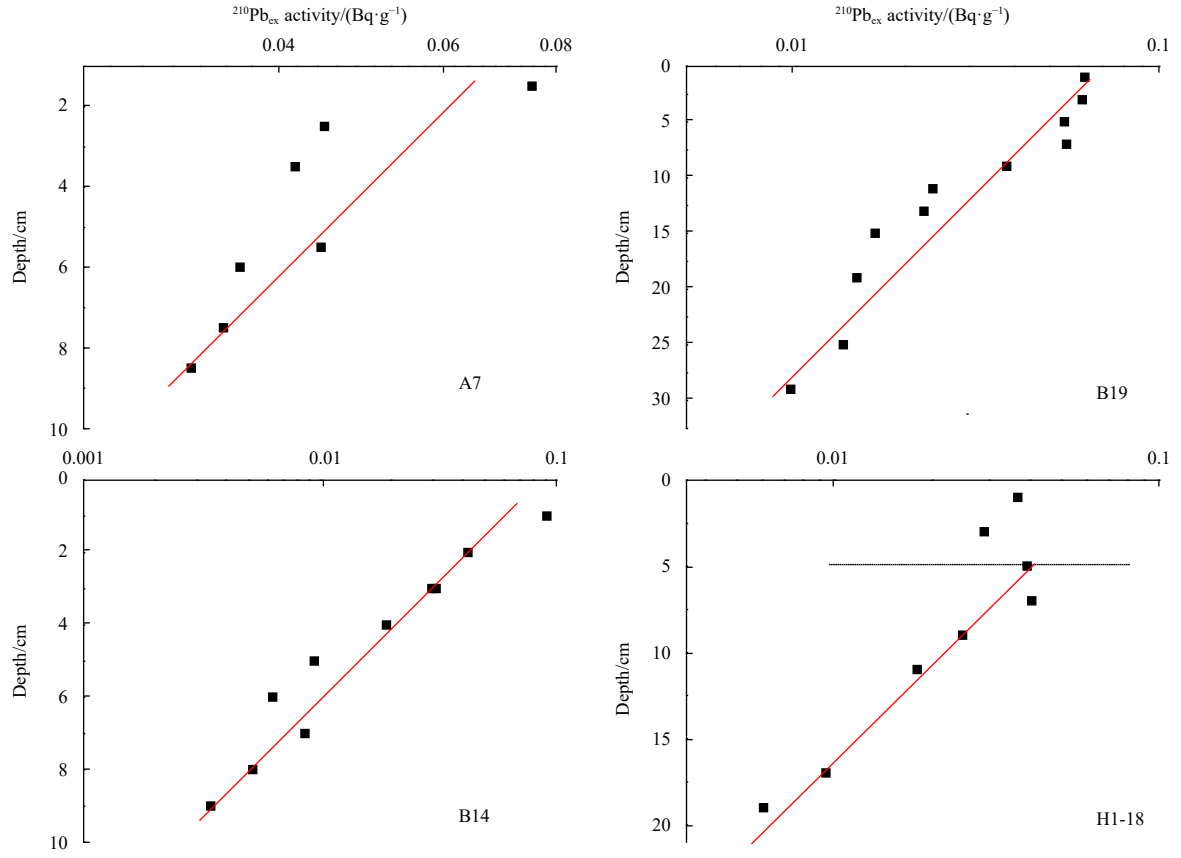

Fig. 2. Vertical distribution of ^{210}Pb activities in sediment cores (squares indicate excess ^{210}Pb ($^{210}Pb_{ex}$) activities).

Table 1. Sedimentation rate, total nitrogen content (TN), total organic carbon (TOC), the ratio of carbon content vs. nitrogen content (C/N), and marine-derived organic carbon content (C_m) in cores

Station	Water depth/m	Sedimentation rate/(cm·a^{-1})	TN		TOC		C/N		C_m	
			Range/%	Average/%	Range/%	Average/%	Range	Average	Range/%	Average/%
A7	87	0.14	0.050–0.075	0.064	0.37–0.55	0.46	6.66–7.68	7.23	0.21–0.33	0.28
B14	80	0.15	0.124–0.171	0.140	1.05–1.52	1.28	8.06–11.34	9.19	0.37–0.63	0.51
B19	43	0.44	0.039–0.091	0.057	0.36–0.66	0.43	6.27–9.42	7.52	0.14–0.39	0.26
H1-18	63	0.22	0.038–0.050	0.043	0.56–0.79	0.67	12.57–17.56	15.41	0.04–0.12	0.07

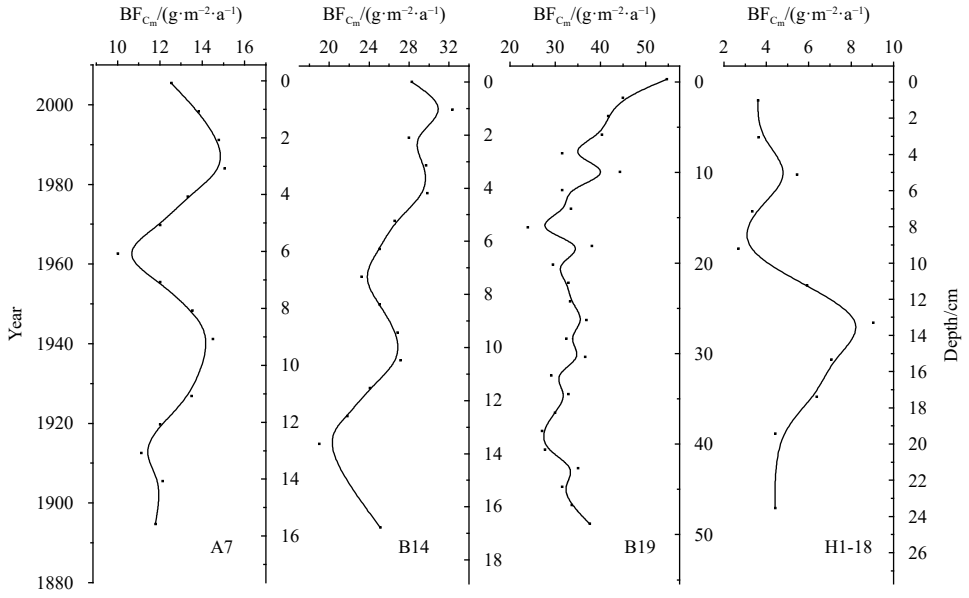

Fig. 3. The interdecadal distribution of the buried flux of marine organic carbon (BF_{C_m}) in cores.

mixing layers are observed in Core H1-18 but not in Cores A7, B19, and B14. Sedimentation rates are estimated based on a logarithmic decreasing trend of $^{210}Pb_{ex}$ with depth (Table 1). Notably, the calculated values were consistent with the sedimentation rates reported by Yang et al. (2012). The sedimentation rate of A7, B14, B19 and H1-18 were 0.14 cm/a, 0.15 cm/a, 0.44 cm/a and 0.22 cm/a, respectively (Fig. 3). Based on these sedimentation rates and the length of the core, the sedimentation in these cores can be dated back 100 a.

3.2 *TN, TOC, C/N and C_m in cores*

The values of TN, TOC, C/N, and C_m in these cores are listed in Table 1. As shown in Table 1, TN contents range from 0.038% to 0.171%, TOC contents range from 0.36% to 1.52%, C/N values range from 6.27 to 17.56, C_m range from 0.04% to 0.63% in these four cores, which are similar to previous results in the surrounding areas (Hu et al., 2016; Song et al., 2018).

3.3 BF_{C_m} *in sediment cores*

The vertical distribution of BF_{C_m} in cores is shown in Fig. 3. From these data, it may be seen that BF_{C_m} in Core A7 exhibited a slight upward trend from bottom to surface, with 2.5 cycles over the past 100 a. The peak value of BF_{C_m} in Core A7 was observed in 1941 and 1984, and the valley value appeared in 1912, 1963 and 2004.

The BF_{C_m} in Core B14 also showed a slight upward trend from the bottom layer to the surface layer. In the past 100 a, there were some obvious alternations of peaks and valleys, with peaks appearing in 1936, 1978, 1985, and 1999, and valleys appearing in 1915, 1951, 1991 and 2004.

The values of BF_{C_m} in Core B19 were relatively constant (27.08–37.59 g/(m^2·a)) from the bottom to 20 cm depth (about the 1960s). After the 1960s, the value of BF_{C_m} fluctuated significantly, especially after 1988, when it rose rapidly and reached its peak in 2006. However, other sedimentary columns did not experience such dramatic fluctuations.

The BF_{C_m} value in Core H1-18 was relatively high and stable before 1960, and the peak appeared in 1945 at 9.04 g/(m^2·a). Then, the BF_{C_m} at this station continued to decline, reaching the lowest value in 1964, and remained at a relatively low level in the last years.

By comparing the interdecadal distribution of the BF_{C_m} in Cores A7 and B14, it can be concluded that the similar trends of the decadal marine-derived carbon storage of the two stations is typical of the CYSM. Thus, the reconstructed sediment records in Cores A7 and B14 are effective materials to better understand the typical characteristics of C_m storage in the CYSM. Core B19 is located to the southwest of Shandong Peninsula. BF_{C_m} in Core B19 was relatively stable before the 1960s, while the value of BF_{C_m} increased rapidly after the 1960s and reached a maximum value in the surface layer. Core H1-18 is located in the ECS. The BF_{C_m} in Core H1-18 is relatively higher before the 1960s. In more recent years, there is a declining trend and BF_{C_m} remains at a relatively lower level. The above results indicate that although the four stations are located in the ECSS, interdecadal variations in BF_{C_m} exhibit significant regional differences.

4 Discussion

The cores used in this study are all located in the ECSS;

however, the factors leading to regional differences in the inter-decadal variation of the BF_{C_m} remain unclear. Therefore, to better understand the possible mechanisms controlling BF_{C_m} in our study area, four sediment cores were analyzed from which to derive a preliminary understanding of the causes of regional differences.

4.1 *Stability of C_m*

The stability of C_m is an important factor affecting C_m storage. The method of Tunnicliffe et al. (2001) was carried out to investigate the stability of C_m. From the data shown in Fig. 4, a significant positive correlation was observed between the ΣC_m and year in Cores A7, B19 and H1-18, indicating that the sedimentary C_m in these cores remained stable over the last 100 a. In contrast, the ΣC_m in Core B14 fluctuated significantly in the bottom layer (about the 1900s), suggesting that the state of the C_m was probably unstable. Recently the stability of C_m was also reported by Yang et al. (2012) and Yang et al. (2015). Their results showed that the depositional setting in the CYSM facilitates the preservation of sedimentary C_m over the 100 a time scale. Therefore, it is reasonable to infer that degradation is also not the main factor affecting the C_m storage in the study area (including Core B14).

4.2 *Sources of organic matter*

Organic carbon mainly exists in the form of OM. Consequently, studies on the origins of OM can reflect potential sources of organic carbon. Studies on the sources of sedimentary OM in the ECSS play an important role in exploring the problem of the regional differences of organic carbon buried flux in these sea areas.

As shown in Fig. 5, the f_m in Core B19 ranged from 77.41% to 91.53%, with a mean value of 83.36%±3.24%. In Core A7, the f_m ranged from 82.13% to 88.95%, with a mean value of 85.10% ±1.94%. In Core B14, the f_m ranged from 57.74% to 79.59%, with a mean value of 72.06%±5.78%. In Core H1-18, the f_m varied from 16.29% to 49.56%, with a mean value of 30.58%±9.75%. Compared with Core H1-18, Cores B19, A7, and B14 had higher f_m. Thus, it may be concluded that Core H1-18 is mainly affected by terrigenous source input, but that Cores B19, A7 and B14 are mainly controlled by marine source input. The results indicate that the regional differences in the sources of OM in ECSS play an important role in controlling regional differences in organic carbon burial flux.

4.3 *Primary productivity versus burial flux*

Decadal-scale variations in primary productivity cannot be directly studied because of the lack of long-term field investigation data in China. However, the historical records of primary productivity can be reconstructed from the contents of Biological silicon (BSi) in sediment cores (Jiang et al., 2011; Romero et al., 2015). In the ECSS, the stability of BSi and the positive correlation between the BSi and primary productivity indicate that trends in decadal primary productivities in our study areas could be largely related to decadal-scale alterations in BSi (Ye et al., 2004; Yang et al., 2012). In this study, we employed the long-term trends of BSi to qualitatively evaluate decadal-scale changes in primary productivities. The BSi data used in this study are quoted from Yang et al. (2012).

In Cores B14, A7 and B19, increased primary productivities are probably due to the increased inputs of terrestrial nutrients caused by the rapid development of agriculture and industry in China over the course of the 20th and beginning of the 21st centuries (Fig. 6). In China, chemical fertilizers were first used in 1952, and have since been widely used (Zhang, 1983). By wind, river runoff, and other means, a large number of terrigenous nutrients were transported to the offshore area, which promoted the rise of primary productivity. Increased primary productivity leads to increased burial of C_m. Thus, the increased BF_{C_m} in the Yellow Sea since the 1950s may be mainly affected by the changes in ecological environments caused by human activities. Additionally, it should be noted that the innovations of the western industrial revolution, which spread to China in roughly to 1860s, also had a promotional effect on China's economy in the late 19th century. However, the BF_{C_m}, BSi and phytoplankton biomarkers in cores did not change obviously between the late 19th century and the 1950s (Yang et al., 2012; Yang et al., 2017; Cao et al., 2017). Although China's economy developed at that time, this economic development was relatively slow and limited due to

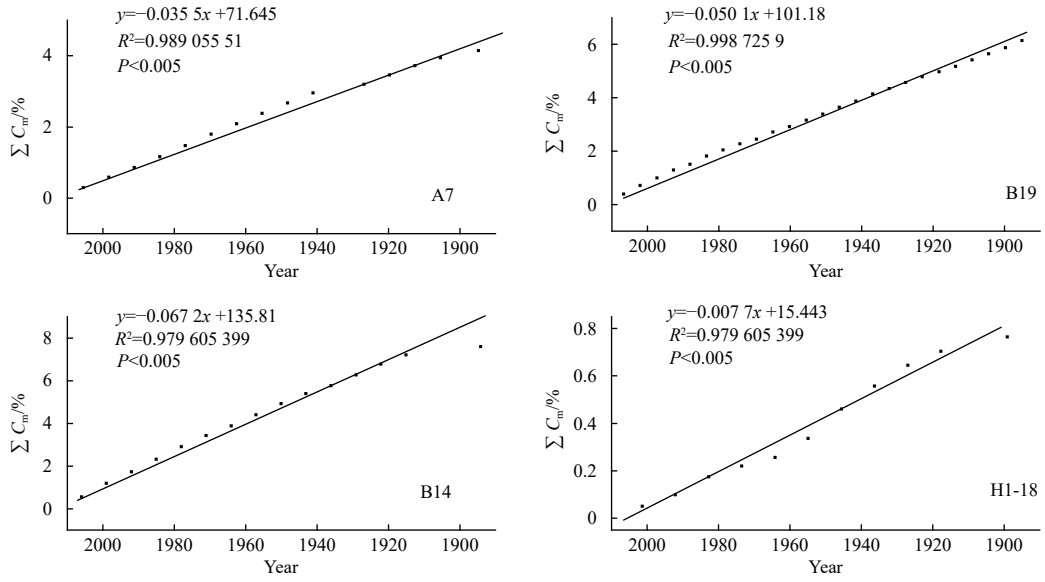

Fig. 4. Linear regression analysis of ΣC_m vs. year. C_m, marine-derived organic carbon content; ΣC_m, the sum C_m content of the increased C_m per year of all the previous years.

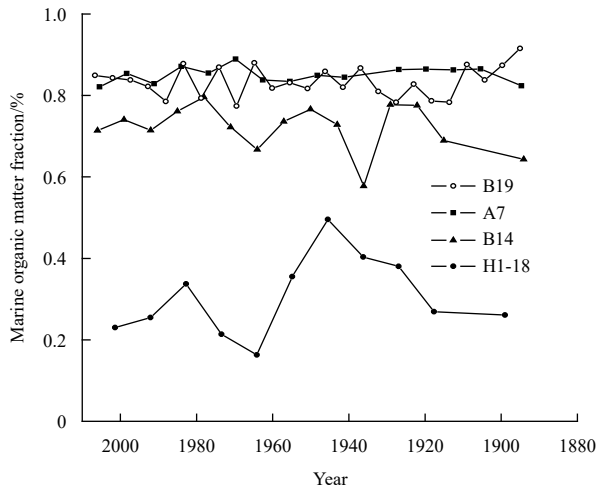

Fig. 5. Temporal variations in the marine organic matter fraction of cores.

national and international limitations. As a result, the ecologic environment in the Yellow Sea did not change obviously at that time, and the values of the BF_{C_m}, BSi and phytoplankton biomarkers in marine sediments remained relatively constant. The temporal variation of BF_{C_m} and BSi in Core H1-18 is different. This phenomenon is probably related to the disturbance of terrestrial organic matter inputs. Based on the data shown in Fig. 5, the terrestrial OM fractions (f_t) are 1.02–5.14 times the marine OM fractions (f_m). Given that the organic carbon contained in OM is mainly source from the land, the correspondence between BF_{C_m} and primary productivity may be different. This observation indicates that the relationship between the BF_{C_m} and primary productivities is an important factor leading to regional differences in organic carbon burial flux.

4.4 *Pacific decadal oscillation (PDO) and EAWM versus the BF_{C_m}*

Variations attributable to the PDO were determined based on the first mode of the empirical orthogonal function decomposition of abnormal monthly SST data in the North Pacific north of 20°N. We smoothed the PDO to explain the influence of PDO on changes in BF_{C_m}. Considering the extensive influence of the EAWM on the ECSS, EAWM variations are also drawn in the figure and smoothed to discuss the influence of EAWM on BF_{C_m} changes (Fig. 7).

Cores A7 and B14 are located in the CYSM. BF_{C_m} in these two cores exhibited obvious correlations between the PDO and EAWM over the past 100 a (Fig. 7). This similar phenomenon also appeared in the early studies of the CRE, the ECS and the Japan Sea (Kuwae et al., 2006; Wang, 2014), which could be predicted through nutrient supplement analysis in these areas. Nutrients are necessary for phytoplankton growth. Nutrients in the euphotic layer of the open sea are mostly supplied from deeper water by vertical mixing (Tian et al., 2003). Figure 7 shows that the PDO index is positive, and that the EAWM index is also higher. A stronger EAWM leads to stronger winter winds derived from the north, enhancing the YSCC. As a compensation for the YSCC, upwelling associated with the YSWC increases, which can also enhance bottom intrusions (Wang and Yu, 2014). Hence, more nutrients from deeper water are transported to the euphotic layer and consumed by phytoplankton for their growth (Tan and Shi, 2012). In contrast, when the PDO is negative, the EAWM index is also lower. Limited bottom intrusions can reduce the transportation of nutrients from deeper water to upper water and limit the growth of phytoplankton and the BF_{C_m}.

Core B19 is located near the 50 m isobath southwest of Shandong Peninsula. Before the 1950s, the trends of EAWM and BF_{C_m} in this core are similar (Fig. 6). When the EAWM increases, strong

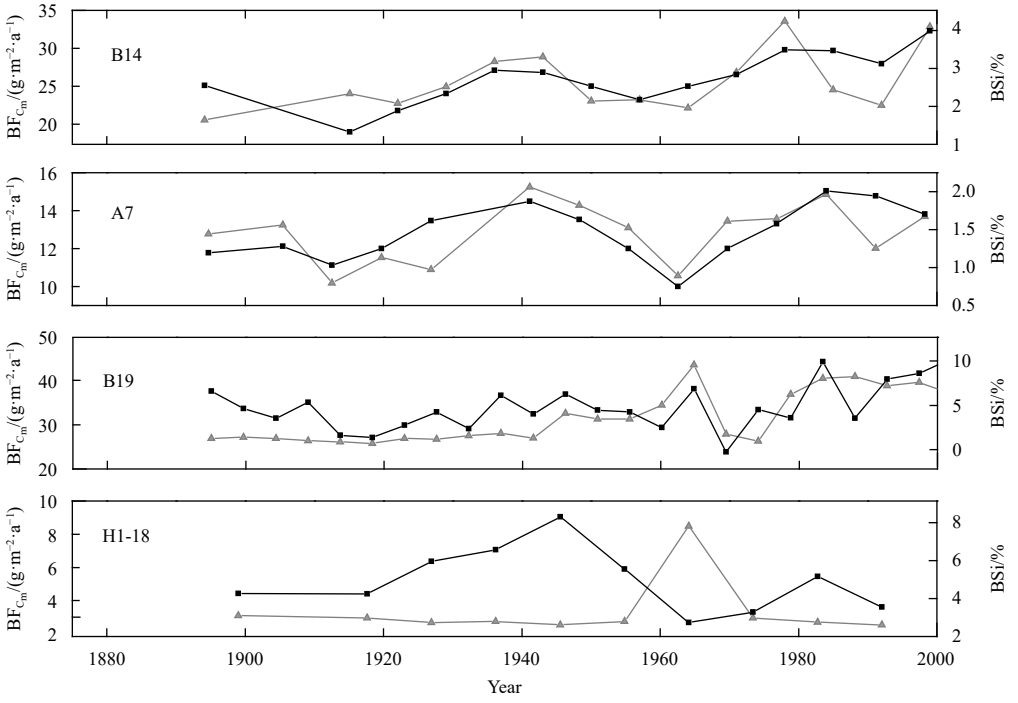

Fig. 6. Temporal variations in the buried flux of marine organic carbon (BF_{C_m}) and biological silicon (BSi). The triangle represents BSi, and the square represents BF_{C_m}. BSi data are quoted from Yang et al. (2012).

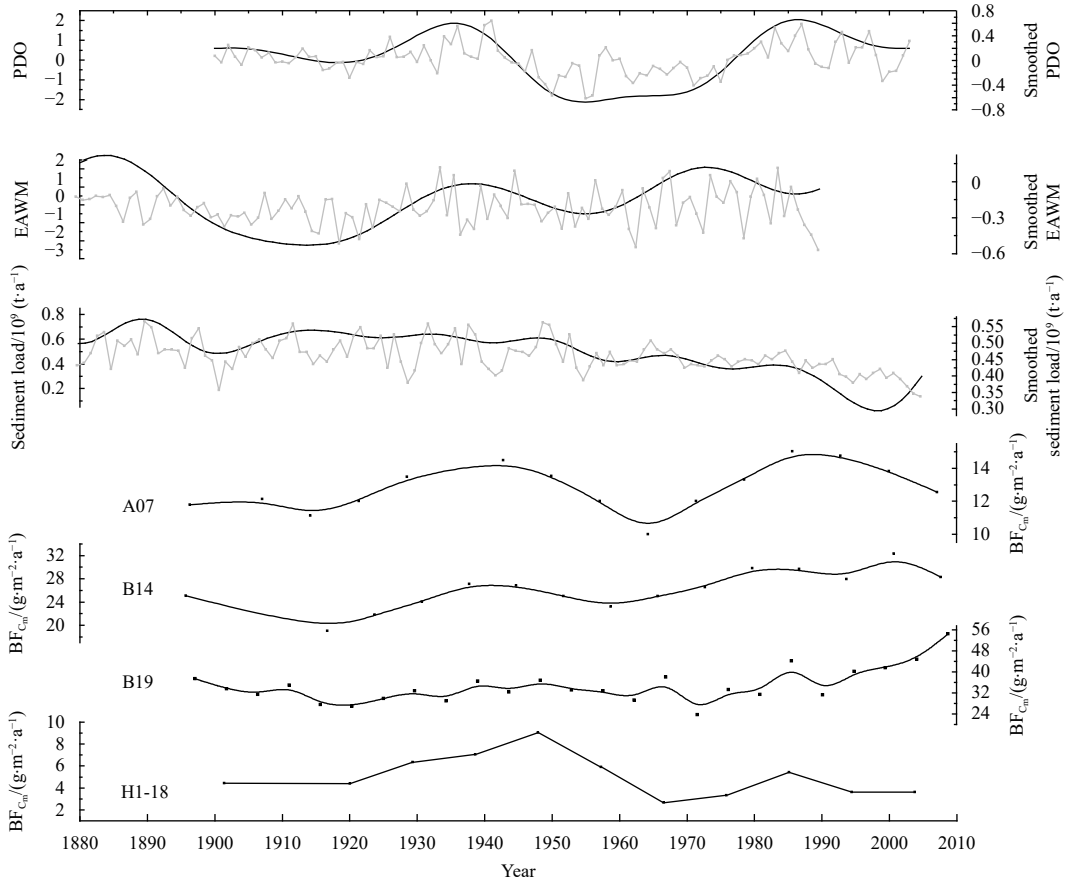

Fig. 7. Decadal changes of the buried flux of marine organic carbon (BF_{C_m}), Pacific decadal oscillation (PDO), East Asian winter monsoon index (EAWM) and Changjiang River Estuary sediment load. Raw data of PDO, EAWM and sediment load are cited from Yang et al. (2017), Huang (2015), and Wang et al. (2008), respectively.

winter winds blow from the north, enhancing the YSCC and transport of nutrients from the Huanghe River Estuary to the location of Station B19. Thus, an enhanced EAWM can promote primary productivity in the surrounding sea area, leading to increases in BF_{C_m}. In contrast, the BF_{C_m} exhibits a decreasing trend with EAWM. After the 1950s, the BF_{C_m} at Station B19 continued to rise and remained at a higher level. Increased BF_{C_m} in Core B19 could be attributed to the enhanced inputs of terrestrial nutrients caused by China's economic development. GDP in China increased from 105.8 billion dollars in the 1970s to 2 552.9 billion dollars in the 2000s (Yang et al., 2017). In support of this conclusion, the correspondence between EAWM and BF_{C_m} also decreased during this time.

4.5 *Sediment load versus BF_{C_m}*

Sediments in the SYS and ECS are primarily influenced by the supply of terrestrial sources from the Huanghe River and the Changjiang River. Cores B19 and H1-18 are close to the shore and are likely to be most affected by river input. Previous studies revealed that the nutrients in Shandong Peninsula are mainly attributable to transport of nutrients from the Huanghe River by the YSCC (Hu et al., 2016). Since the 1980s, the sediment load from the Huanghe River decreased rapidly. However, it still contributes a huge flux of sediments (up to 1.1×10^9 t/a) to the adjacent sea. Therefore, the deposition rates of sediment in Core B19 are relatively higher (mean value of 0.44 cm/a). High sediment accumulation rates could facilitate a rapid burial of particulate organic carbon, which in turn may reduce the exposure time of sediments to bioturbation and/or oxic decomposition, enhancing its preservation (Kuehl et al., 1993; Carroll et al., 2008). Therefore, Core B19 has the largest BF_{C_m} among the four cores. Core H1-18 (30.5°N, 123.5°E) is located near the CRE (the east of the high deposition area). Because the belt at longitude 122.5°–123°E is the front where the diluted water of the Changjiang River meets the sea water on the continental shelf, flocculation is strong and the deposition rate can reach up to 6.3 cm/a (Duan et al., 2005). Flocculation of dissolved/particles in the high deposition area inhibits the eastward transportation of suspended particles in the CRE, which can decrease the transport of nutrients and total primary productivity to the sea (Shi, 2016). Thus, the conservation efficiency of f_m in sediments and the average of the BF_{C_m} in Core H1-18 is the lowest among the four stations we studied.

Because Core H1-18 is mainly affected by inputs from terrigenous sources (Fig. 5), this study suspects that the core may also be influenced by the input of organic matter and nutrients from the Changjiang River, which is consistent with the sediment load of the Changjiang River. Sediment loads are drawn in Fig. 7 to discuss the influence of sediment load on regional differences in BF_{C_m}.

From the data shown in Fig. 7, it can be seen that the BF_{C_m} in H1-18 has no significant correlation with the PDO or the EAWM. However, the variation of the BF_{C_m} is similar to the input of sediment load from the Changjiang River during the past 100 a. This

similar phenomenon also appears in the investigation and analysis of biomarkers in the CRE (Cao et al., 2017). Human activities dominated the transport of large sediment loads (0.5×10^9 t/a) from the Changjiang River Basin to the sea between 1900 and 1950. Sediment load decreased from 0.5×10^9 t/a (1950–1960) to 0.33×10^9 t/a (1970–1990) due mainly to the construction of dams along the river. This reduction in sediment load means the organic matter and nutrients from the Changjiang River was reduced and primary production was also reduced, leading to a reduction in BF_{C_m}.

5 Conclusions

This study concludes that decadal-scale variations in BF_{C_m} in the studied cores are affected by numerous factors including the organic matter sources, primary productivity, sediment accumulation rates, sediment load, PDO and EAWM. However, human activities and differences in marine environments are key factors controlling regional differences and decadal changes of the BF_{C_m}. Before the 1950s, the burial of BF_{C_m} in the ECSS was mainly controlled by the marine environment under natural conditions. After 1950, BF_{C_m} in the CYSM remained under the influence of natural conditions and exhibits periodic changes. In contrast, BF_{C_m} in the YSCC and the CRE exhibit trends that suggest BF_{C_m} in these regions is now primarily controlled by human activities. Taken together, these results suggest that decadal changes in BF_{C_m} are characterized by regional variations in a complex ocean environment. To gain a better understanding of the long term changes of BF_{C_m} on the continental shelf and the related mechanisms of C_m sequestration, future research should focus on the relationship between the BF_{C_m} and long term environmental changes in the complex shelf environment.

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