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Clay mineral evolution in the central Okinawa Trough since 28 ka: Implications for sediment provenance and paleoenvironmental change

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ABSTRACT

The Okinawa Trough is a natural laboratory for the study of later Quaternary land–ocean interaction and paleoenvironmental changes. In this study we reconstruct the evolution of clay mineral assemblages in Core DGKS9604 retrieved from the central Okinawa Trough. Illite dominates the clay mineral compositions, with average contents above 60%. Clay mineral evolution since 28 ka is closely related to changes in sediment provenance and paleoenvironment. Sea level rise and the strength of the Kuroshio Current control the dispersal and deposition of clays on the East China Sea shelf and in the Okinawa Trough, and thus, determine the clay mineral compositions in the core sediments. During the late last glacial period (28.0–14.0 ka), the paleo-Changjiang River mouth was situated at the shelf edge close to the central Okinawa Trough and thus, together with the outer shelf, supplied large volumes of terrigenous sediments directly into the trough. From 14.0 to 8.4 ka influence from the Changjiang decreased while the mid-outer shelf of the East China Sea became the dominant sediment source to the central Okinawa Trough as sea level rose and the Changjiang river mouth migrated west. Strong sediment reworking and erosion at the shelf edge at 15–13 ka significantly increased the lateral transport of fine-grained shelf sediments to the central Okinawa Trough. Since ca. 8.4 ka clays from Taiwan have dominated the sediment flux to the site, coinciding with the re-entry of the Kuroshio Current into the trough. The increasing influence of the Changjiang-sourced sediments since 1.5 ka was probably related to the weakening of the Kuroshio Current and/or a higher river flux.

1. Introduction

The impact that climate change has on continental environments is a topic of interest to those trying to understand the Earth's climate system, and possibly predicting responses to future climate change. In theory marine sediments may store a record of the environmental conditions and allow us to compare these with changes in oceanographic circulation and with global temperatures. However, in order to read this record we need to understand what controls the delivery of clastic sediment to continental margins. Here we present an example from East Asia where sediments from the Okinawa Trough are influenced by strong changes in the Asian monsoon since the Last Glacial Maximum (LGM), as well as by rising sea level and fluctuations of the powerful Kuroshio Current that flows northward along the eastern edge of Asia.

The Okinawa Trough, extending from southwest Kyushu, Japan, to the Lanyang Plain of northeast Taiwan, is a back-arc basin separating the continental shelf of the East China Sea (ECS) from the Ryukyu arc (Sibuet et al., 1998). It is an ideal research area for paleoceanography and continent–ocean interactions because of its continuous sedimentation and because the region is affected by a series of rapid paleoenvironmental changes since the late Quaternary (Liu et al., 1999, 2001; Li et al., 2001; 2005; Lin et al., 2006; Xiang et al., 2007). The supply, transport and deposition of terrigenous materials in the Okinawa Trough are controlled by many factors, including sea level fluctuation (Lambeck et al., 2002; Liu et al., 2004), variability in the strength and location of the Kuroshio Current (Ujiié et al., 1991; 2003; Ujiié and Ujiié, 1999; Jian et al., 2000), changes in fluvial run-off, many of which are controlled or linked to variability of the summer monsoon, which dominates the regional climate (Wang et al., 1999; Wang, 1999; Clift et al., 2002; 2008; Boulay et al., 2005).

The strong relation between environmental changes and variations in terrigenous sediment supply can be addressed through clay mineral signals in the marine sediments that bear information on terrigenous sediment provenance. Clay minerals are common

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components in most marine sediments, especially those deposited on continental margins, where there is a significant terrigenous input (Biscaye, 1965; Griffin et al., 1968). Clay minerals can provide valuable information on sediment provenance, such as relative contributions of river and eolian inputs, but can also constrain sediment transport and depositional processes, as well as providing information on weathering regimes within the continental interior (Biscaye, 1965; Petschick et al., 1996; Thiry, 2000). Recent studies suggest that clay mineral assemblages in west Pacific marginal seas can be closely related to climate fluctuation on orbital timescales, such as those known to affect the evolution of the Asian monsoon (Wehausen and Brumsack, 2002; Liu et al., 2003; 2005; Tamburini et al., 2003; Boulay et al., 2005). During the Quaternary and Tertiary the flux of clay minerals into the Pacific marginal seas is mostly controlled by changes in sea level, oceanic circulation, and the relative intensities of physical erosion and chemical weathering in the source areas. However, over shorter time scales, such as in the last glacial–interglacial interval, clay mineral assemblages can predominantly reflect changing influence of different sediment sources, together with partitioning processes during transport (Steinke et al., 2008). These latter are in turn tightly linked to sea level and paleoenvironmental changes (Diekmann et al., 2008). Reconstruction of the evolving clay mineral assemblage in the terrestrial sediment fraction within a continental margin sequence may help to better understand the interactions between detrital sediment supply, paleoceanographic changes and paleoclimatic variability in the source areas.

The clay mineral assemblages in the East China Sea primarily consist of illite, which constitutes average contents of about 60–70%, while smectite, kaolinite and chlorite are subordinate (Aoki and Oinuma, 1974; Xu, 1983; Yang, 1988; Fan et al., 2001; Yang et al., 2003). Most previous studies on clay mineral assemblages in the ECS focused on the estuarine area and continental shelf, while the Okinawa Trough was less studied. Yu et al. (2008) used clay mineral compositions in Core DGKS9603 from the central trough to define a cooling event at 8.2 ka (Fig. 1). In the southern Okinawa Trough, clay mineral data pointed to increased sediment supply from northwestern Taiwan between 28 and 19.5 ka and from sources of eastern mainland China between 19.5 and 11.2 ka (Diekmann et al., 2008). During the Holocene the southern Okinawa Trough was dominated by the sediments delivered by northeast Taiwanese rivers (Diekmann et al., 2008). The change in provenance at 19.5 ka is interpreted to reflect increased fluvial run-off from the Changjiang (Yangtze River) and strong sediment reworking from the ECS shelf caused by increased humidity (Diekmann et al., 2008).

In this paper, we present a high-resolution reconstruction of clay mineral evolution in Core DGKS9604 taken from the central Okinawa Trough. The main objectives of this study are to quantitatively estimate the relative contributions of fine-grained terrigenous sediments from different provenances, and thus to explore the link between clay mineral assemblages and paleoenvironmental changes in the sea and surrounding continental areas since the Last Glacial Maximum.

2. Geological and oceanographic settings

The Okinawa Trough is 230 km wide at its northern end, and 60–100 km wide in the south, and extends for about 1200 km between Taiwan and the Kyushu Islands (Fig. 1). The maximum water depth is about 200 m in the north and ~2300 m in the south. The thickness of the sedimentary cover decreases from ~8 km in the north to about 2 km in the south (Sibuet et al., 1987). Sediment accumulation rates in the middle and southern Okinawa Trough were very low during the

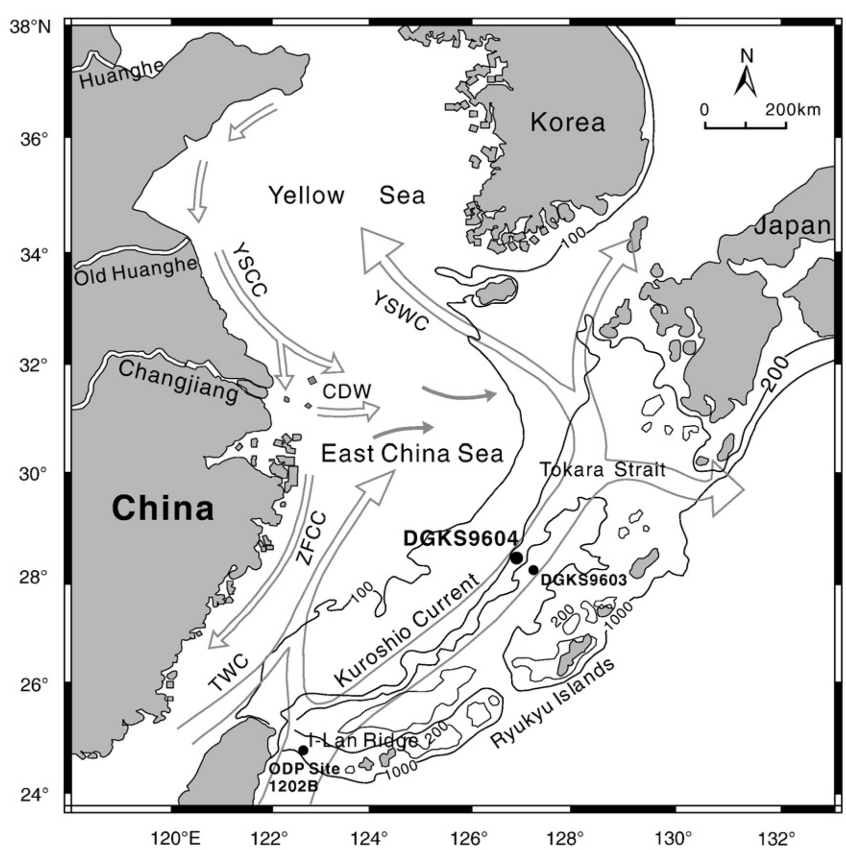

Fig. 1. Location map of the East China Sea with the location of Core DGKS9604 and other reference cores. The regional circulation pattern in the East China Sea and adjacent areas are from Huh and Su (1999) and Yu (2006). YSCC: Yellow Sea Coastal Current, YSWC: Yellow Sea Warm Current, CDW: Changjiang Diluting Water, ZFCC: Zhenjiang and Fujian Coastal Current, TWC: Taiwan Warm Current.