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Paleoceanographic implications and cyclostratigraphy of variations in well-log data from the western slope of the Ulleung Basin, East Sea

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ABSTRACT

Cyclic variations of density and gamma-ray logs achieved from the two drill sites of UBGH2-1_1 and UBGH2-1_2 in the western slope of the Ulleung Basin were investigated to reveal their paleoceanographic implications and establish cyclostratigraphy of the well logs. Integration of the core, log, and seismic data from the two sites indicates that the sediments of the drilled intervals mostly consist of hemipelagic muds, with a few sporadic mass transport deposits intercalated only in the downslope site of UBGH2-1_1. Comparison with variations in sediment composition suggests that ratios of terrigeneous to biogenic materials which were modulated by orbital-scale climate changes should be responsible to the well-log variations. The established cyclostratigraphy of the well logs based on correlation with marine oxygen isotope records indicates such climatic modulation of the sedimentation in the western slope of the Ulleung Basin has persisted at least since 2.6 Ma, consistent with the variation reported from the Oki Ridge.

1. Introduction

In addition to oil and gas reservoir characterization, well logs of marine sediment sequences have been widely applied to paleoceanographic and cyclostratigraphic studies (e.g., deMenocal et al., 1992; Barthès et al., 1999; Gorgas and Wilkens, 2002; Paulissen and Luthi, 2011) because most of the well logs are primary affected by sediment porosity that are closely related to mineralogical and grain-size compositions which in turn can vary significantly with cyclic changes of climate and sea-level (Goldberg, 1997). Well-logs are particularly useful for time-series analysis to reveal orbital and sub-orbital cyclicity by providing continuous data with uniform sampling rates, which are often impossible or hard to achieve with discrete core sections. However, before applying the well logs to paleoceanographic and cyclostratigraphic studies, site-specific relations between log variables and sediment properties should be clarified by correlation of core and log data. Moreover, presence of event beds and significant hiatus or changes in sedimentation rates has to be examined to ensure consistency in environmental conditions and relatively uniform thickness–time relationship (Weedon, 2003).

Density and gamma-ray logs achieved by logging-while-drilling (LWD) from the two drill sites in the western lower slope of the Ulleung Basin during the Second Ulleung Basin Gas Hydrate Drilling Expedition (UBGH2) show fairly consistent cyclic variations with each other in most of the log intervals (Ryu et al., 2012). To reveal paleoceanographic implications of the cyclic variations of the logs and establish cyclostratigraphic framework, we first examined which sediment properties are responsible for the cyclic variations of the logs using available core data. Comparisons of the logs and the core data with the seismic section across the drill sites provided further control of the intervals suspected as event beds such as mass transport deposits. The gamma-ray logs devoid of the event beds were converted to time series mainly based on correlations with the well logs from Site ODP 798 from the Oki Ridge which have established age–depth relations before 1 Ma and LR04 stack of global benthic $\delta^{18}O$ records (deMenocal et al., 1992; Lisiecki and Raymo, 2005). The time-series gamma-ray logs evidence that, for the first time, orbital-scale cyclic modulation of ratios of terrigeneous to biogenic materials had been persistent during the entire Pleistocene and rates and changes of hemipelagic sedimentation in the western and the southern margins the East Sea had been nearly identical.

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2. Geological and oceanographic settings

The East Sea (Japan Sea) is a semi-enclosed marginal sea that is connected to the North Pacific and adjacent seas through four shallow and narrow straits (water depths of 12–140 m; Fig. 1). The Tsushima Warm Current, a branch of the warm saline Kuroshio Current, enters the East Sea through the Korea Strait and flows out through the Tsugaru and Soya straits. A cold (<1 °C), highly oxygenated (5–6 ml/l) water mass that originates from winter cooling of surface water in the northern part occurs below the water depths of 200–300 m (Kawamura and Wu, 1998; Kim et al., 2002). Significant changes in oceanographic conditions have been expected in response to the glacio-eustatic sea-level fluctuations which resulted in a sea-level drop of as much as about 120 m during the last glacial maximum. Tada et al. (1999) suggested that the modulation of the volume and character of the surface water inflow through the Korea Strait associated with glacio-eustatic sea level changes played a key role in the changes in deep-water ventilation and surface productivity. According to their hypothesis, the East Sea was nearly isolated by a sea-level drop of more than 90 m during the glacial maximum periods. During such periods, low-salinity surface water developed because of excess precipitation and caused strong density stratification of the water column, resulting in euxinic deep water and low surface productivity (Tada et al., 1999). Together with the changes in oceanic circulations and surface productivity, variations in influx of Asian aeolian dust to the East Sea also have been suggested in both orbital and sub-orbital timescales (Irino and Tada, 2002; Nagashima et al., 2007).

The Ulleung Basin in the southwestern part of the East Sea was opened in the Late Oligocene to Early Miocene by crustal extension accompanied with southward movement of SW Japanese Islands (Tamaki et al., 1992; Yoon and Chough, 1995). At the end of the Middle Miocene (11–12 Ma), basin closure was caused by the northward collision of the Bonnic Arc with central Japan (Chough and Barg, 1987). The basin closure led to uplift of the southern margin and basin-wide deposition of mass transport deposits (MTDs) which were evolved from frequent slope failures along the southern slope during the latest Neogene (Lee and Suk, 1988; Lee

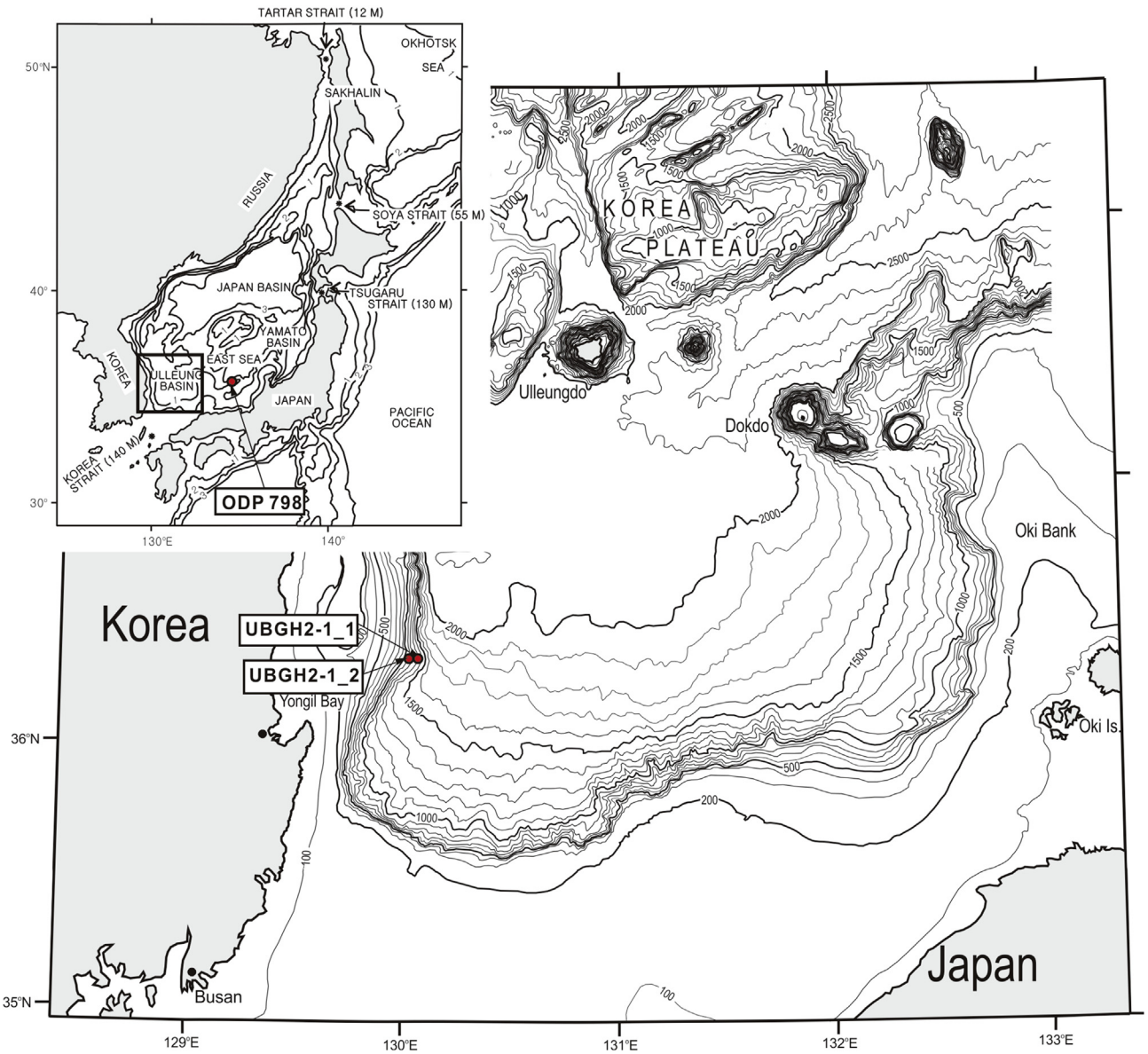

Fig. 1. Bathymetric map of the Ulleung Basin (contours in meter), showing the locations of drill sites UBGH2-1_1 and UBGH2-1_2. Also shown is the location of ODP Site 798 and shallow sills and straits of the East Sea in the inset. Box in the inset indicates the location of the enlarged area. Modified from Lee et al. (2004).

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