Revealing causes, timing and magnitudes of sea-level changes during Terminations

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Abstract Terminations (glacial-interglacial transitions) are regarded as possible analogues for modern rapid climate changes and associated environmental changes. The precise reconstruction of sea levels is critical for understanding ice-sheet dynamics and suborbital climate variability during Terminations. Previous studies showed that sea-level changes during the last deglaciation (Termination I) was characterized by smooth and continuous rises of sea levels associated with several brief intervals of accelerated sea-level rises. On the other hand, sea-level changes during older Terminations are not yet clear. Recent drilling researches from offshore Tahiti by IODP Expedition 310 found new shallow-water sequences during Termination II (TII), which provide continuous and direct evidences for sea levels during this transition. These new works revealed the two steps of rising sea levels with an intervening sea-level drop, confirming the presence of a sea-level reversal event during TII. However, there remains to be answered if this phenomenon was unique only for TII or common for Terminations. Furthermore, causes of sea-level reversal events during TII and older Terminations if exist are not yet to be determined. Thus, goals of this proposal are 1) to reconstruct sea levels and associated environmental changes during older Terminations, 2) to compare similarity and differences in sea-level changes among several Terminations, and 3) to reveal the existence and causes of sea-level reversal events during Terminations. Resulting sea-level data will help 1) modeling ice-sheet dynamics, 2) understanding the role of high-latitude summer insolation in Northern or Southern Hemisphere as a trigger for deglaciation, and 3) clarifying the response of coral reefs to rapid sea-level rises. Proposed drilling sites are French Polynesia (Tahiti), which has tectonically slow and constant subsidence rates and is located at considerable distance from the former major ice sheets (far-field). Many sediment cores on transects from shallow shelf to shelf slope are recovered and analyzed.

During glacial-interglacial transitions known as Terminations, ice volume decreased, instead sea level, temperatures, and greenhouse gas concentrations increased abruptly (e.g., Petit et al., 1999; Lambeck et al., 2002). Thus, Terminations are regarded as possible analogues for modern rapid climate changes and associated environmental changes. Since key parameters such as ice volume, sea level and temperature are closely related to each other, the precise reconstruction of sea levels is critical for understanding ice-sheet dynamics and suborbital climate variability during Terminations. Previous studies showed that sea-level changes during the last deglaciation (Termination I: TI) was characterized by smooth and continuous rises of sea levels associated with several brief intervals of accelerated rates of sea-level rises due to meltwater pulses (Fairbanks, 1989); however, they have yet to be completely established (Camoin et al., 2007). This is partly due to the limited availability of shallow-water sequences encompassing terminations, most of which are eroded or were deposited below the present sea level. Detailed sea-level and climate changes during TI will be revealed soon by IODP Expedition 310 (Tahiti Sea-Level; Camoin et al., 2007) and the forthcoming IODP Expedition 325 (Great Barrier Reef Environmental Changes; Webster et al., 2009).

On the other hand, structures of older Terminations are not yet clear. In particular, course, timing, and magnitude of sea-level changes during older Terminations have yet to be reconstructed in detail. Studies on the termination of the penultimate glacial period (Termination II: TII) are progressing and revealing the timing, events and suborbital variability of climate changes during this transition. Coral U-Th dates corrected for open-system effects (Thompson and Goldstein, 2005) and high-resolution paleoceanographic works (e.g., Cannariato and Kennett, 2005) suggest that the start of TII occurred in accordance with the increase in the Northern Hemisphere summer insolation, although the incompatibility of the timing of TII with Milankovitch orbital theory has long been debated (e.g., Henderson and Slowey, 2000; Thomas et al., 2009). Several climatic events have been known during TII. In particular, a Younger Dryas-like climate oscillation, called as “TII pause” or “TII oscillation”, occurred midway through the deglaciation (Lototskaya and Ganssen, 1999; Cannariato and Kennett, 2005; Risebrobakken et al., 2006). During this cooling event, sea-surface temperature (SST) was $\leq 1\ ^{o}C$ cooler than at present (Allison et al., 2005), and sea-level decreased several ten meters in amplitude, lasting for several millennia before the final sea-level rise to the last interglacial (Esat et al., 1999; Gallup et al., 2002; Antonioli et al., 2004; Thompson and Goldstein, 2005; Siddall et al., 2006). Furthermore, millennial to centurial (suborbital) variability of SST (Cannariato and Kennett, 2005) and sea level

(Thompson and Goldstein, 2005; Siddall et al., 2006) has been recognized throughout TII.

Integrated Ocean Drilling Program (IODP) Expedition 310 to the reef terraces around Tahiti, French Polynesia, was conducted in 2005 and 2006. Relatively long Pleistocene cores were recovered at some holes, which were expected to contain information on sea level and reef growth for time windows comprising several marine isotopic stages (Camoin et al., 2007). Recently, Thomas et al. (2009) reported U/Th ages of *in situ* fossil corals, suggesting the presence of the penultimate deglacial period in the Pleistocene sequence of Tahitian cores. The author and his collaborators also found another new sequence recording the course of sea-level rise during Termination II (TII) from the older Pleistocene sequence off Tahiti (Fig. 1; Fujita et al., submitted). This sequence contains more continuous and direct evidences for sea levels and associated environmental changes during TII. The sea-level changes during TII reconstructed by these works were characterized by the two steps of rising sea-levels with an intervening sea-level drop, confirming the presence of a sea-level reversal event during TII (Esat et al., 1999; Siddall et al., 2006). Such sea-level reversal event is similar to the Younger Dryas (YD) climate reversal event, though the YD event was not associated with sea-level drop. However, there remains to be answered if this phenomenon was unique only for TII or common for older Terminations. Furthermore, causes of the sea-level reversal events during TII and older Terminations if exist are yet to be determined.

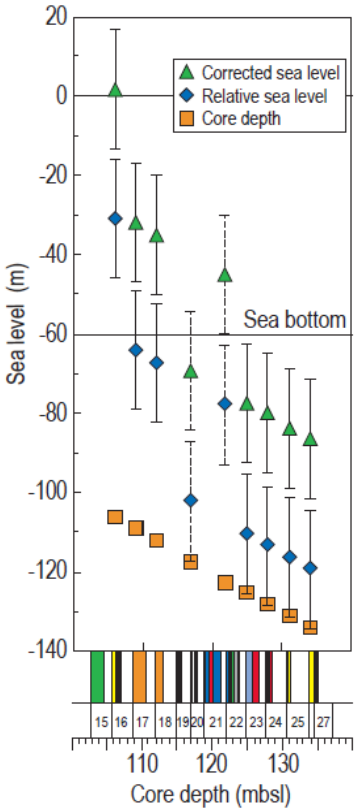

Fig. 1. Sea-level changes during Termination II, reconstructed using a new shallow-water sequence found from offshore Tahiti by IODP Exp. 310 (Fujita et al., submitted). Dotted lines indicate a sea-level reversal event midway through TII.

Thus, goals of this proposal are 1) to reconstruct sea levels and associated environmental changes during older Terminations, 2) to compare similarity and differences in sea-level changes among several Terminations, and 3) to reveal the existence and causes of sea-level reversal events during Terminations. Resulting sea-level data and associated environmental records will help 1) modeling ice-sheet dynamics, 2) understanding the role of high-latitude summer insolation in Northern or

Southern Hemisphere as a trigger for deglaciation, and 3) clarifying the response of coral reefs to rapid sea-level rises.

Proposed drilling sites are French Polynesia (Tahiti), which has tectonically slow and constant subsidence rates (Bard et al., 1996) and is located at considerable distance from the former major ice sheets (far-field). Many cores on transects from shallow shelf to shelf slope are recovered and analyzed. Collaboration with carbonate sedimentologists (sequence stratigraphy), paleontologists (paleodepth estimates by reef fossils), and geochemists (U-series dating by corals, SST/SSS reconstructions by coral archives) are required.

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