

PREFACE

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Preface for the article collection “Stratigraphy and paleoclimatic/ paleoenvironmental evolution across the Early– Middle Pleistocene transition in the Chiba composite section, Japan, and other reference sections in East Asia”

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Keywords: Early–Middle Pleistocene transition, Marine Isotope Stage (MIS) 19, Matuyama–Brunhes reversal, Global Boundary Stratotype Section and Point (GSSP), Chiba composite section

The Earth experienced dramatic and progressive changes in oceanic and atmospheric circulation, ice sheet distributions, and biotic evolution from the Early to Middle Pleistocene. This interval is now known as the “Early–Middle Pleistocene transition (EMPT)” (Head and Gibbard 2015; Head 2019). Because East Asia is an important region for land–ocean–atmosphere heat and moisture exchange owing to its location at the boundary between Eurasia and the Pacific Ocean (e.g., Tada and Murray, 2016) (Fig. 1), understanding paleoenvironmental change in this region will provide valuable insights into Earth’s climate system. Continuous deep-ocean records across this climatic transition are not rare, but constructing detailed links between atmospheric circulation, terrestrial environmental change, and evolution of the biota have been hampered by an inevitable scarcity of continuous and expanded sedimentary records from coastal, shallow-marine environments.

The Chiba composite section, including the Chiba section itself which was recently ratified as the Global

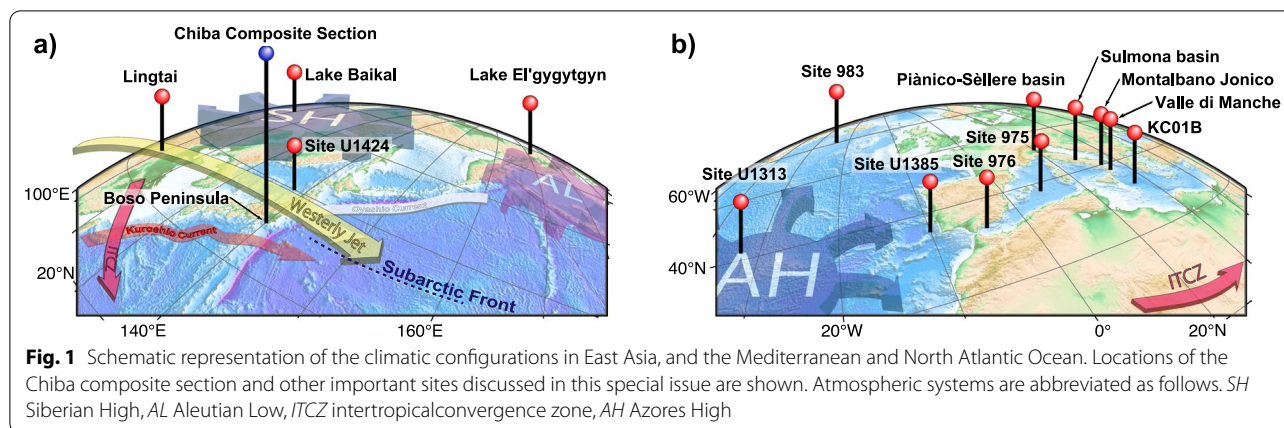
Boundary Stratotype Section and Point (GSSP) defining the base of the Middle Pleistocene Subseries/Subepoch and Chibanian Stage/Age (Head 2021; Head et al. 2021; Suganuma et al. 2021), is a continuous marine silty sedimentary record from upper Marine Isotope Stage (MIS) 20 to lower MIS 18, representing one of the most expanded and chronostratigraphically constrained sections yet documented across the Lower–Middle Pleistocene boundary (e.g., Kazaoka et al. 2015; Suganuma et al. 2018). This composite section comprises five individual exposures cropping out along a 7.4 km transect, all securely linked by a detailed framework of tephra beds. Deposited on the continental slope and receiving substantial organic input from both marine and terrestrial sources (Balota et al. 2021; Izumi et al. 2021; Suganuma et al. 2018), it therefore provides a rare opportunity to capture both terrestrial and marine environmental variability continuously across MIS 19 and hence the Lower–Middle Pleistocene boundary.

This special issue focuses on sedimentary records from the Chiba composite section and its stratigraphic correlation with other reference sections in East Asia and across the globe. It addresses terrestrial and marine paleoclimatic and paleoenvironmental co-evolution with an emphasis on the midlatitude westerly jet stream, East

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Asian monsoon, North Pacific Gyre, and the interplay of subtropical and subpolar settings across MIS 19 and through the Early–Middle Pleistocene transition. We hope the articles collected in this issue within the Special Call for Excellent Papers on Hot Topics (SPEPS) series will stimulate and promote future research on stratigraphy and paleoenvironmental changes in this region. Detailed comparisons between reference sections in East Asia and the global record will help further our understanding of Earth’s climate system.

The Chiba composite section, located near the Pacific margin of the central Japanese archipelago (Fig. 1), belongs to the Kokumoto Formation of the Kazusa Group, which is one of the thickest (~3000 m) and best exposed Lower and Middle Pleistocene marine sedimentary successions in the world (e.g., Kazaoka et al. 2015; Takao et al. 2020). It represents the infill of the Kazusa fore-arc basin, developed in response to the west–north–westward subduction of the Pacific plate beneath the Philippine Sea plate along the Japan and Izu–Bonin trenches (e.g., Seno and Takano 1989).

The stratigraphy of the Kazusa Group has been evaluated since the 1940s (e.g., Kanehara et al. 1949; Shinada et al. 1951; Mitsunashi et al. 1961), with more recent focus shifting to the depositional systems and glacioeustatic sea level changes (e.g., Ito and Katsura 1992; Pickering et al. 1999; Takao et al. 2020). In this issue, Takao et al. (2020) report a detailed investigation into the depositional processes responsible for deepwater massive sandstones (DWMSs) occurring in the middle to upper parts of the Kazusa Group. The authors suggest that these DWMSs represent density flows developed in response to prograding shelf-margin deltas or fan deltas during the falling and lowstand stages of relative sea level. These sandstones contrast with the muddy deposits of the Chiba composite section which are interpreted to have formed in the uppermost part of a transgressive

systems tract (Takao et al. 2020), explaining their suitability for high-resolution paleoceanographic and paleoclimatic studies.

The Matuyama–Brunhes (M–B) paleomagnetic boundary represents a clear and global isochronous marker and hence serves as the primary guide to the Lower–Middle Pleistocene boundary (Head et al. 2008; Suganuma et al. 2021). A tightly defined M–B paleomagnetic polarity boundary has been observed throughout the Chiba composite section and adjacent areas (Suganuma et al. 2015, 2018; Hyodo et al. 2016; Okada et al. 2017; Haneda et al. 2020a), providing a precise tie point for global stratigraphic correlation. Haneda et al. (2020a) report in this issue a detailed record of the geomagnetic field reversal behavior over time. A clear drop observed in paleointensity is supported by the authigenic $^{10}\text{Be}/^9\text{Be}$ record (Simon et al. 2019). An astronomically estimated M–B boundary age of 772.9 ± 5.4 ka at the Chiba composite section (Haneda et al. 2020a) is consistent with that of paleomagnetic records (e.g., Channell et al. 2010, 2020; Channell 2017; Valet et al. 2019) and cosmogenic nuclide records (Raisbeck et al. 2006; Suganuma et al. 2010; Simon et al. 2018; Valet et al. 2019), around the world. This age is also consistent with a weighted mean $^{40}\text{Ar}/^{39}\text{Ar}$ age of 773 ± 2 ka from new measurements and the recalibration of all M–B transitionally magnetized lava flow sequences (Singer et al. 2019), which facilitates a robust chronostratigraphic framework for the Chiba composite section.

In this special issue, Hyodo et al. (2020) report a detailed paleomagnetic record across the M–B boundary from a loess succession in Lingtai, central Chinese Loess Plateau (CLP). Loess-paleosol sequences can be excellent archives of past changes in the geomagnetic field not only for polarity but also direction and intensity, although the process leading to magnetization lock-in remains unclear. Hyodo et al. (2020) have investigated more than

100 high-resolution paleomagnetic samples from the succession and found millennial-to-sub-centennial-scale polarity flips around the M–B paleomagnetic boundary. Although further investigations from adjacent sections in the CLP, along with other expanded sedimentary sections and lava sequences, are needed to confirm the nature of these high-speed polarity flips, their documentation should yield new insights into the physical processes leading to this geomagnetic reversal and improve global correlation and age constraints for terrestrial sections.

Other polarity boundaries recorded in and around the Japanese archipelago are similarly useful for understanding the dynamics of geomagnetic field reversals and in refining their chronological framework. Konishi and Okada (2020), in this issue, reconstruct a high-resolution paleomagnetic record of the lower part of the Matuyama Chronozone from the Chikura Group in the southern part of the Boso Peninsula (Naruse et al. 1951; Kotake 1988) which contains the Réunion Subchronozone and the lower Olduvai polarity reversal. Although these sections have not been chronologically well constrained, they are thought to be the most expanded records so far obtained. Thus, the timings and durations of geomagnetic field variations obtained from the Chikura Group will help understand the general phenomenon of geomagnetic field reversals. Meanwhile, Xuan et al. (2020) present a Pliocene–Pleistocene magnetostratigraphy of deep-sea sediments at Integrated Ocean Drilling Program (IODP) Expedition 346 Site U1424 in the Yamato Basin, Japan Sea, based on the transitions of polarity chrons and subchrons coupled with a detailed tephrstratigraphy. The integrated stratigraphy proposed for Site U1424 offers an excellent chronological framework for both marine and terrestrial Pliocene–Pleistocene sections in the region.

The Chiba composite section has yielded a diverse array of well-preserved marine and terrestrial microfossils and provides an ultra-high-resolution benthic and planktonic foraminiferal isotope record that captures centennial- to millennial-scale paleoceanographic and paleoclimatic changes from late MIS 20 to early MIS 18 (Suganuma et al. 2021). In this issue, Kameo et al. (2020), Balota et al. (2021), and Itaki et al. (2022) document the assemblage changes of calcareous nannofossils, dinoflagellate cysts, and radiolarians, respectively, to explore variations in the position of the Subarctic Front between the subtropical Kuroshio and subarctic Oyashio currents. Because the Subarctic Front is presently situated just east of the Boso Peninsula (Qiu 2001), the Chiba composite section is located at an ideal position to record the past displacement of the front. Changes in marine microfossil assemblages and indicator taxa along with foraminiferal isotope data reveal millennial-scale fluctuations

superimposed on glacial–interglacial orbital-scale variability, in which the phenomenon is generally coherent with detailed records from the North Atlantic and Mediterranean region (Haneda et al. 2020b; Head 2021). Based on the abundant occurrences of a warm-water calcareous nannofossil and radiolarian species, Kameo et al. (2020) and Itaki et al. (2022) respectively show periodic intensifications of the Kuroshio Current following the end of MIS 19c and continuing into MIS 18, indicating repeated northward shifts of the Subarctic Front. In addition, the dinoflagellate cyst record reveals instability in the Kuroshio Extension system throughout MIS 19c and the abrupt influence of the Kuroshio–Oyashio Interfrontal Zone in MIS 19b, signaling the first stadial of the latter part of MIS 19 (Balota et al. 2021). This instability and similar rapid shifts are also seen in the cyclic appearance of cold-water calcareous nannofossil and radiolarian taxa from MIS 19b to MIS 18 (Kameo et al. 2020; Itaki et al. 2022).

The total organic carbon (TOC) values of the Chiba composite section also show millennial-scale oscillations in the latter part of MIS 19a (Izumi et al. 2021). Although the $\delta^{13}\text{C}_{\text{org}}$ and C/N records are generally modulated by glacial–interglacial orbital-scale variability, Izumi et al. (2021) show that peaks of TOC at warmer intervals in MIS 19a represent enhanced organic matter preservation owing to water column stratification caused by the northward displacement of the Subarctic Front rather than increased surface water productivity. However, the radiolarian records infer that the warmer intervals are characterized by higher productivity, which may reasonably be explained by a stratified Kuroshio–Oyashio structure (Itaki et al. 2022). The dinoflagellate cyst record, which might represent warm-season conditions rather than the cold-season signal reflected by most of the other proxies, includes increased cyst concentrations during the initial stadial following MIS 19c. This implies increased surface water productivity resulting from a southward shift of the Subarctic Front and increased influence of the nutrient-rich waters of the Oyashio Current (Balota et al. 2021).

Also in this issue, Kubota et al. (2021) examine calcareous nannofossil and radiolarian assemblage records and geochemical data from planktonic foraminifera ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$, and Mg/Ca) of the Chiba composite section and offer new paleoceanographic insights based on their quantitative analysis. Through the use of principal component analysis (PCA) to capture dominant patterns of temporal variation in these records, the authors confirm that the microfossil assemblages are consistent with the water mass types inferred from the geochemical proxies. They also show that oceanic conditions, including latitudinal shifts of the Subarctic Front, were closely linked both to the East Asian Winter Monsoon and the orbitally

modulated global climatic signal, as previously suggested by Suganuma et al. (2018). This approach identifies independent signals in geological records, such as those generated by surface and subsurface ocean processes, and therefore has great potential to advance our understanding of the ocean circulation and East Asian climate.

MIS 19c is of special relevance to our present interglacial (Holocene) owing to similar orbital configurations. Both interglacials are characterized by low orbital eccentricity, and their precession and obliquity parameters are nearly in phase allowing their inception to be unambiguously aligned. For this reason, MIS 19c has been used as a baseline to understand the trajectory of our future interglacial under natural conditions (e.g., Tzedakis et al. 2012; Suganuma et al. 2018; Head 2021). Detailed paleoclimatic records of MIS 19 are therefore particularly significant. With this in mind, Head (2021) in this issue reviews the climatic characteristics of MIS 19 on a global scale, incorporating records from East Asia with other key sites from the Mediterranean and North Atlantic Ocean. A critical feature of MIS 19 is its pronounced millennial-scale climate variability following the inception of glaciation that terminates MIS 19c. Head (2021) covers key topics including the interrupted deglaciation of Termination IX, the length and amplitude of full interglacial condition within MIS 19c, the stadial–interstadial oscillations during MIS 19b–c, and the teleconnections responsible for the remarkable coherence observed in MIS 19 records globally. The bipolar seesaw mechanism via Atlantic meridional overturning circulation (AMOC) across the Atlantic certainly played a major role in climatic oscillations, causing shifts in the intertropical convergence zone (ITCZ). These oscillations were especially pronounced during MIS 19b–a, with low-latitude monsoon dynamics likely having amplified responses regionally (Nomade et al. 2019; Haneda et al. 2020b). Similarities between high-latitude Asian and northern North Atlantic records suggest the concurrent influence of high-latitude teleconnections (Head 2021). Therefore, the importance of additional high-resolution studies from East Asia and northern Asia as well as from the southern hemisphere is needed to fully understand the nature of these phenomena during MIS 19. In addition, a detailed history of the Middle Pleistocene, from its first use as a term to its final ratification along with the Chibanian Stage, is reviewed by Head (2021).

This special issue encompasses a broad range of methodologies and demonstrates the importance of paleoclimatic interpretation in Quaternary stratigraphy to understand global linkages in the climate system. It also highlights the value of paleomagnetic reversals for defining formal chronostratigraphic units. In focusing on MIS 19, with a duration of only around 30 kyr, the special issue exemplifies

the value of ultra-high-resolution stratigraphic analysis for understanding climatic evolution on a global scale during an orbital configuration similar to the present and at a timescale relevant to the future of our planet.

Abbreviations

M–B boundary: Matuyama–Brunhes boundary; MIS: Marine isotope stage; GSSP: Global Boundary Stratotype Section and Point; CLP: Chinese Loess Plateau; AMOC: Atlantic meridional overturning circulation; ITCZ: Intertropical convergence zone.

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Acknowledgements

We thank all members of the Chiba composite section research community. We are also grateful to the PEPS staff for their support and patience during the submission and revision of manuscripts and the PEPS editorial board for its helpful and swift editorial handling of these contributions. This article has been improved by helpful comments from Ryuji Tada. We are grateful to Jun'ichi Okuno for drafting Fig. 1.

Authors' contributions

YS wrote the draft of the manuscript, and MJH and TS rewrote and confirmed the contents. All authors read and approved the final manuscript.

Availability of data and materials

Please contact the authors contributing to this special issue for data requests.

Declarations

Competing interests

The authors declare that they have no competing interests.

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Received: 13 January 2022 Accepted: 13 January 2022

Published online: 25 January 2022

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