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History of Asian eolian input to the Sea of Japan since 15 Ma: Links to Tibetan uplift or global cooling?

Xingyan Shen [a,c], Shiming Wan [a,b,d,*], Christian France-Lanord [d], Peter D. Clift [e], Ryuji Tada [f], Sidonie Révillon [g], Xuefa Shi [b,h], Debo Zhao [a,c], Yanguang Liu [b,h], Xuebo Yin [a], Zehua Song [a], Anchun Li [a]

[a] *Key Laboratory of Marine Geology and Environment, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China*
[b] *Laboratory for Marine Geology, Qingdao National Laboratory for Marine Science and Technology, Qingdao 266061, China*
[c] *University of Chinese Academy of Sciences, Beijing 100049, China*
[d] *Centre de Recherches Pétrographiques et Géochimiques (CRPG), UPR 2300, CNRS-Université de Lorraine, 15 Rue de Notre Dame des Pauvres, 54501 Vandoeuvre les Nancy, Cedex, France*
[e] *Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803, USA*
[f] *Department of Earth and Planetary Science, University of Tokyo, Tokyo 113-0033, Japan*
[g] *SEDISOR/UMR6538 "Domaines Oceaniques", IUEM, Place Nicolas Copernic, 29280, Plouzane, France*
[h] *Key Laboratory of Marine Sedimentology and Environmental Geology, First Institute of Oceanography, SOA, Qingdao 266061, China*

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ABSTRACT

We present high-resolution analyses of clay mineral assemblages combined with analysis of Sr–Nd–Pb isotopic compositions of the <2 μm silicate fraction of sediments from Integrated Ocean Drilling Program (IODP) Site U1430 in the southern Sea of Japan, in order to trace the sources of clay minerals and reconstruct proxy records of past changes in Asian eolian input to the basin since 15 Ma. The clay mineral assemblages at IODP Site U1430 mainly consist of smectite (∼51%) and illite (∼36%), with minor kaolinite (∼7%) and chlorite (∼6%). Provenance analysis suggests that the fine-grained sediment at the study site is a two end-member mixture of eolian dust from Central Asia and fluvial input from the Japanese islands. The Central Asian end member supplied illite-rich and high $^{87}Sr/^{86}Sr$ and low $\varepsilon Nd(0)$ eolian dust to the study site by wind, while the Japanese end member, characterized by young volcanic rocks, contributed smectite-rich, low $^{87}Sr/^{86}Sr$ and high $\varepsilon Nd(0)$ weathering products via rivers. The ratio of illite/smectite and $\varepsilon Nd(0)$ values of clay-sized silicate sediments at Site U1430 were used as proxies for tracing the changing strength of central Asian eolian input to the Sea of Japan, and thus reconstruct the aridification history of its source region. Our study presents for the first time a continuous, high-resolution record that highlights the four-step drying of Central Asia that occurred at ∼11.8 Ma, 8 Ma, 3.5 Ma and 1.2 Ma. Considered the nature and timing of major climatic and tectonic events in Asia, we conclude that the strengthened aridification of Central Asia starting at ∼11.8 Ma was possibly driven by the combined effect of Tibetan surface uplift and global cooling, whereas the rapid drying at ∼8 Ma was caused primarily by the uplift of the northern Tibetan Plateau. In contrast, global cooling, overwhelming the influence of Tibetan Plateau uplift, has become the primary control on Central Asia aridification since ∼3.5 Ma.

1. Introduction

The topography and palaeogeography of Asia have dramatically changed during the Cenozoic, with the progressive uplift of the Himalaya and Tibetan Plateau and the westward retreat of Paratethys following India–Asia collision, probably at ∼50–60 Ma (Wang, 2004). At the same time that Asia was deforming global climate gradually cooled after the Eocene (Zachos et al., 2001). Meanwhile, paleoenvironmental patterns in Asia shifted from a planetary-wind-dominant type to a monsoon-dominant type around the late Oligocene–early Miocene (Sun and Wang, 2005). Since that time precipitation over inland Asia significantly decreased, eventually resulting in development of deserts and extensive deposition of loess in Central Asia (Guo et al., 2002; Zheng et al., 2015). However, it remains controversial as to what mechanisms have been

* Corresponding author at: Key Laboratory of Marine Geology and Environment, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China.
E-mail address: wanshiming@ms.qdio.ac.cn (S. Wan).

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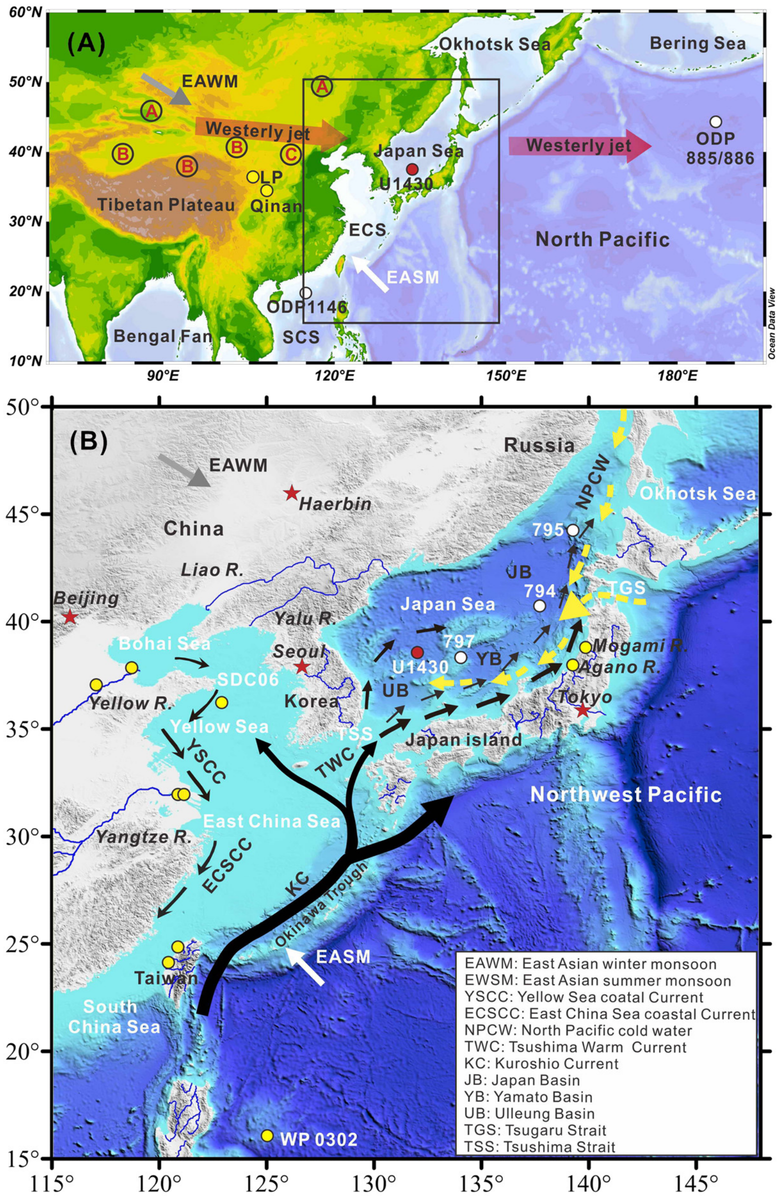

Fig. 1. Locations of geographic features and terrestrial and marine records. The upper map (A) showing IODP Site U1430 in the Sea of Japan, ODP Site 1146 in the South China Sea, ODP Site 885/886 in the North Pacific, and loess sequence at Qinan in the Chinese Loess Plateau (LP) mentioned in this paper. The distribution of three major deserts regions (A, the deserts on the northern boundary of China, including the Gurbantunggut Desert, Hunlun Buir sandy land, Onqin Daga sandy land, and Horqin sandy land; B, the deserts on the northern margin of Tibetan Plateau, including the Taklimakan Desert, Qaidam Desert, Badain Jaran Desert, and Tengger Desert; C, the deserts on the Ordos Plateau, including Hobq Desert and Mu Us Desert) constrained by Sr–Nd isotopes (Chen et al., 2007) is also shown. The investigated Site U1430 (red solid circle) in the southern Sea of Japan and adjacent landmass are highlighted in the lower map (B). The location of the rivers surface sediment samples and dust samples used in this study is marked by yellow solid circles. The other related cores cited in this study are shown by white solid circles. Also shown are the major rivers (blue line), modern surface current (black arrows), intruded North Pacific cold waters at the Middle Miocene–Late Pliocene (Itaki, 2016; Kaizuka, 1980) (yellow dashed arrows), the westerlies (Westerly jet) (red shaded arrow), the East Asian summer (white arrow) and winter monsoon (gray arrow) directions and major cities (red star). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

responsible for the long-term drying since the middle Miocene (Lu and Guo, 2014). The potential driving factors primarily include uplift of the Tibetan Plateau (An et al., 2001), Cenozoic global cooling (Lu and Guo, 2014) and retreat of the Paratethys Sea (Ramstein et al., 1997). One way of testing the proposed climate–tectonic interactions is to precisely define the history and timing of major climatic changes in Asia, especially the development of Asian aridity.

Until now, most studies that have tried to reconstruct Asian aridity since the Miocene were based on terrestrial studies, including pollens (Miao et al., 2012), oxygen isotopes (Zhuang et al., 2011), magnetic susceptibility (Zhang et al., 2014), accumulation rate (Guo et al., 2002), and bulk mineralogy (Sun et al., 2015) of loess or lacustrine deposits in the northern Tibetan Plateau. Most of these studies suggested a long-term drying trend of Central Asia since the Miocene, although the details remain poorly dated.

In contrast, marine eolian deposits are generally more continuous and easier to date at high-resolution by biostratigraphy and paleomagnetism. The western Pacific is the major area of Asian dust deposition and receives annually about 70 million tons of dust from Central Asia through the westerlies and East Asian winter monsoon (Fig. 1) (Shao et al., 2011). A long-term eolian record since the late Miocene has been reconstructed from the North Pacific (Rea et al., 1998), but remains poorly known in the Sea of Japan where studies have concentrated on variations in eolian dust input and transport pathways during the late Quaternary