Atmospheric and oceanic circulation systems during the Cretaceous: Evidences from the continental desert deposits and marine biota

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Understanding of the process and interaction of various components of the Earth System during the Cretaceous greenhouse world is one of the major targets of paleoclimatology. During the Cretaceous period, the equator-to-pole temperature gradient was much lower than the present, implying larger meridional heat transport either by atmospheric or by oceanic circulations. Thus, these circulation systems during the Cretaceous greenhouse world might have been quite different from the modern ice-house world. However, reconstruction of the atmospheric circulation pattern during the Cretaceous has been retarded due to the lack of appropriate indicators.

Deserts are mostly developed under the subtropical high-pressure zone, and westerlies and northeast trade winds are prevailed in northern and southern part of the desert area in case of the Northern Hemisphere. Thus, deserts are direct product of general atmospheric circulation, and their distributions and prevailing surface wind patterns preserved in their deposits are direct indicators of the past atmospheric circulation system. Hence, we examined the Cretaceous desert deposits from low- to middle-latitude non-marine sedimentary basins in Asian interior (Gobi basin of Mongolia; Ordos, Subei, Jianguan, Sichuan, Simao basins of China; Khorat basin of Thailand), in order to reconstruct the spatio-temporal changes of desert distributions and prevailing surface wind patterns in Asia during the Cretaceous.

As a result, the spatio-temporal change of desert distributions reveals that northward expansion of the subtropical arid zone in Asia during the early and late Cretaceous, whereas southward shrinkage of such zone during the mid-Cretaceous. Reconstructed prevailing surface-wind pattern also suggests the drastic latitudinal shift of the subtropical high pressure zone. Namely, subtropical high was shifted poleward (much higher latitude compared to today) during the early and late Cretaceous. On the other hand, it was shifted equatorward during the mid-Cretaceous time. Therefore, it is suggested that Hadley Cell was expanded poleward than the present during the early and late Cretaceous greenhouse period, in response to the globally warmer climatic condition, whereas it was shrunk equatorward during the mid-Cretaceous supergreenhouse period. Hence, it is indicated that there are at least three states of the atmospheric circulation system (esp., width of the Hadley Cell) in response to the CO2 inducing global warming.

We also examined the spatio-temporal changes of the marine biota in both the Pacific and the Tethys oceans in order to reconstruct the latitudinal distributions of the tropical and subtropical zone in these oceans during the Cretaceous period. We further conducted the climate modeling study for investigating the variability of the atmospheric circulation system in response to the increase of atmospheric CO2. Finally, we will discuss the role of the atmospheric and oceanic systems for enhanced meridional heat transport in the greenhouse world.