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Long-period astronomical forcing of Miocene westerly moisture transport to Central Asia

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A 450-m-thick succession of lacustrine deposits, exposed in the Aktau section in the Ili Basin, SE Kazakhstan, is representative for a phase of widespread lake formation in Central Asia. The succession is of mid-Miocene age and covers the interval between 15.5 Ma and 10.0 Ma based on an integrated approach of magnetostratigraphy, U/Pb dating of carbonates and cyclostratigraphy. Results of cyclostratigraphy developed from changes in facies and lake level show a strong sensitivity of sedimentary facies to moisture availability under arid to semi-arid climate conditions.

Our results suggest a control of low-frequency modulation of obliquity and eccentricity on sedimentary facies, salinity, and lake level of Lake Aktau. In particular, the development of precipitation-sensitive marker beds and lithofacies changes likely correspond to the 1.1 Myr obliquity cycle. These modulations affected the development of atmospheric pressure gradients and westerly wind intensity which in turn was crucial for the magnitude of moisture transport evaporated from the Eastern Paratethys and Mediterranean seas. Here we present a stable oxygen isotope record from the Aktau succession which documents a stepwise increase of aridity across the Middle Miocene climate transition paced by maxima of three successive 405 kyr eccentricity cycles.

The minimum in the low-frequency modulation of obliquity at 14.3 Ma is equivalent to strongest cryosphere growth after the Middle Miocene climatic optimum. At these times cooler temperatures and stronger atmospheric pressure gradients promoted intensified westerly wind activity and elevated atmospheric moisture transport capacity to the interior of Central Asia. The sedimentary response in the Aktau succession is the first-time establishment of an alkaline lake with subsequent drying and gypsum formation. Later on, aridity increased documented by two large and sudden increases in oxygen isotopes at 14.1 Ma and 13.75 Ma, respectively. Between 13.75 Ma and 13.55 Ma, the formation of gypsum and anhydrite represents a period of maximum evaporation and aridity in Central Asia. This period likely corresponds to seasonally enhanced changes in net evaporation in the Central Mediterranean Sea and the establishment of a dry-wet climate oscillation system evident from high-amplitude planktic oxygen isotope variability. On longer tectonic time scales, the occurrence of Miocene lakes in Central Asia coincides with the closure of the Eastern Gateway between the Indian Ocean and the Mediterranean Sea when enhanced salinity and evaporation in the Mediterranean and Eastern Paratethys seas likely served as main moisture source for Central Asia.