Five million years of climate change preserved in one place

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Charlotte Prud'homme is rapelling to collect soil samples. The 80-meter-thick sedimentary sequence in Charyn Canyon, Kazakhstan, documents climate change over the past 5 million years. Credit: Charlotte Prud'homme, MPI for Chemistry

An international team of researchers, led by the Max Planck Institute for Chemistry in Mainz, Germany, has now succeeded in reconstructing

changes in rainfall in Central Asia over the past five million years. The information preserved within the sedimentary succession provides the missing link for understanding land-water feedbacks for global climate.

Paleo researcher Charlotte Prud'homme, who until recently worked at the Max Planck Institute for Chemistry and is now a researcher at the Université Lausanne, explains: "The 80-meter-thick sedimentary sequence we found at Charyn Canyon in southeast Kazakhstan provides us with a virtually continuous record of five million years of climate change. This is a very rare occurrence on land!" The alternating dust and soil layers provide the first reliable evidence, in one place, of long-term interactions between major climate systems on the Eurasian continent.

"Over the past five million years, the land surfaces of Eurasia appear to have more actively contributed to the land-atmosphere-ocean water-cycle than previously acknowledged. The sediments preserved at Charyn Canyon acted as a litmus test for the influx of freshwater into the Arctic Ocean, stimulating the transport of moist air masses from the North Atlantic back onto land via westerly air flows," corresponding author Prud'homme says. The results of the research have now been published in the scientific journal *Communications Earth and Environment*.

The researchers focused their investigation on the Pliocene and Pleistocene periods. The Pliocene, five to 2.6 million years ago, represents the best analogue for the climatic conditions of the Anthropocene: this geologic time period was the last time concentration of carbon dioxide in the atmosphere was comparable to today, around 400 parts per million (ppm). "That's why our insights from the Charyn Canyon sediments are so essential for understanding future climate," Prud'homme says.

Until now, little has been known about the role Central Asia plays in global climate evolution past and present. Earth's climate evolution over

the past five million years has been understood mainly from the perspective of marine mechanisms. In contrast, the significance of climate feedbacks that originated on land—rather than in the oceans, lakes or ice cores—has remained largely unexplored. The international research team has filled this gap with their field research in Charyn Canyon.

Interactions between mid- and high-latitude climatic systems

The geographical location of the study site in the middle of Central Asia was of key importance to the team: "We needed to find a place that was inland and as far away from the ocean as possible," Kathryn Fitzsimmons, Group Leader of the Terrestrial Paleoclimate Reconstruction Research Group at the Max Planck Institute for Chemistry, explains. "We could hardly find a more continental situation than at Charyn Canyon in southeastern Kazakhstan." The semi-arid climate of the canyon, and its landscape, was shaped by the interaction between the mid-latitude westerlies and the high-latitude polar fronts, and by sediment transported from the nearby Tien Shan mountains. Charyn Canyon is ideal, according to Fitzsimmons, for studying long-term land-climate feedback mechanisms.

The researchers examined the 80-meter-thick sedimentary succession and sampled by abseil to ensure continuous coverage of the record. By measuring the relative concentrations of isotopes within soil carbonates, they reconstructed the changing availability of moisture in the soil through time. A combination of paleomagnetic analyses and absolute uranium-lead dating of soil carbonates established the age and accumulation rates of the sediment record. The soil samples revealed a region characterized by ever-increasing aridity over the last five million years. In the early Pliocene, the soil was significantly wetter than in

subsequent epochs or than today's climate. This process of aridification was not linear, however; it was interrupted by short-term climate fluctuations which provide insights into the interaction between the mid-latitude westerly winds and the Siberian high-pressure system.

Interaction between the Siberian high and rain-bringing westerlies

The research at Charyn Canyon enabled the scientists to investigate the long-term interaction of the Siberian high with the rain-bringing westerlies. Fitzsimmons says: "We're confident that the changes in soil moisture we found at our site can also be used as a proxy for Siberian river activity further north." The hydroclimate at Charyn Canyon reflects that of the steppe to the north, from where a number of large Siberian rivers, such as the Irtysh and Ob, flow, she says. These are similarly influenced by the dynamics of the Siberian high and westerly air masses. One particular phase where this link is important stands out: a sustained period of wet conditions at Charyn Canyon just prior to the first major global glaciation around 3.3 million years ago. It is likely that these wet conditions extended to the Siberian rivers to the north, whose outflow of fresh water to the Arctic ocean may have breached a tipping point for widespread increased sea ice formation.

The information from this most complete terrestrial climate archive for the past five million years provides a very valuable basis for future climate models. "We have opened a door," Prud'homme concludes.

More information: Charlotte Prud'homme et al, Central Asian modulation of Northern Hemisphere moisture transfer over the Late Cenozoic, *Communications Earth & Environment* (2021). DOI: 10.1038/s43247-021-00173-z