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Identifying tectonic versus climatic controls on Late Cenozoic landscape development of the central Great Plains, Nebraska

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The Cenozoic sedimentary succession of the central Great Plains, Nebraska, records the erosional history of Rocky Mountains. However, the main driver of landscape evolution in this area over the past ca. 8 Myrs is poorly understood. Tectonically induced surface uplift and incision have been suggested, with some evidence that late Miocene fluvial sediments have been tilted by several degrees beyond their original depositional slopes. The timing, magnitude and cause of these events are currently unknown. The majority of studies have focused on the elevated regions of the Rocky Mountains to the west. This region represents a degraded or remnant landscape since ca. 8 Ma, but does not necessarily provide detailed information of landscape development since that time.

We focus on the Miocene to Pliocene fluvial succession of the central Great Plains, which offers a high resolution archive of landscape development over this period. We present grain size data, surface gradient data, thickness distributions, and gross rates of incision from these successions to quantitatively assess the potential contribution of tectonic and climatic forcing since 8 Ma. We find that mean grain size of sediment exported from the central Rockies increases more than two-fold from Miocene to Pliocene times, from ca. 20 mm to >45 mm, and we document an increase in the total effective water discharges from ca. 100-500 m3 s-1 to 1000-1500 m3 s-1. We also demonstrate, using a Shields stress inversion, that palaeo-depositional slopes of the Pliocene succession, which is incised into the Miocene stratigraphy by up to 90 m, are indistinguishable from the present day gradients. This result suggests that the gentle tilting of the Miocene stratigraphy must have happened between 4 and 6 Ma. The greater mean grain sizes and lower transport gradients associated with the Pliocene succession also translates into specific stream power values of ca. 100 to 200 kg s-3 compared to values of ca. 20 to 25 kg s-3 calculated for the Miocene succession, suggesting that Pliocene rivers draining the Rockies could have been up to an order of magnitude more erosive than their Miocene predecessors.

These changes to river discharge and sediment load are best explained by a shift in climate that led to greater seasonality/magnitude of rainfall, or enhanced snow melt run-off. Existing global and regional climate records demonstrate that the early Pliocene was a time of marked climate degradation, and we therefore argue that this Pliocene climate shift provided a highly significant but under-recognised role in the landscape development of the Great Plains from the Miocene onwards. More widely, our data provides a crucial and underexploited down-system perspective of landscape evolution, and offers key insights into the stratigraphic response of sediment routing systems to complex tectono-climatic forcing.