Human-induced soil erosion and landscape changes in the Mongolian Altai – a biogeochemical multi-proxy approach from Lake Khar Nuur

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During the “Paleoanthropocene”, humans have become one of the major factors affecting Earth surface processes, with intensified soil erosion being one of the most notable human-induced process. Especially semi-arid regions are vulnerable to human-induced soil erosion and landscape changes, which is particularly true for the Mongolian Altai, where extensive pastoralism and the rise of nomadic empires strongly influenced landscape changes. So far, only little is known about the impact of humans in the Mongolian Altai and whether landscape changes are naturally or human-driven. Therefore, our study investigates a 5 ka sediment core from Lake Khar Nuur, which is located at ~2500 m a.s.l. in the Mongolian Altai. More specifically, we carried out a biogeochemical multi-proxy approach to disentangle between natural and anthropogenic signals in the Khar Nuur sediments, which includes extensive $^{14}$C-dating, XRF analyses, CNS analyses and their stable isotopes, and fecal sterols.

For the 5 ka sediments from Khar Nuur, XRF, $C_{org}$ and bulk $\delta^{13}$C results show alternating phases of in-situ produced aquatic sediments/organic material versus increased terrestrial input from the catchment. Since no hardwater effect is observed for Khar Nuur sediments, phases of dominated in-situ aquatic production (i.e. high Ca/Ti ratios, higher $C_{org}$ and positive bulk $\delta^{13}$C values) gave $^{14}$C-ages close to the timing of sediment deposition/biomass formation. In contrast, during phases of increased terrestrial input (i.e. low Ca/Ti ratios, low $C_{org}$ and negative bulk $\delta^{13}$C values), $^{14}$C-ages become successively older and show larger age offsets compared to their timing of deposition in the lake. Thus, clear evidence is given that old organic carbon became mobilized from the catchment soils by increased soil erosion during three terrestrial phases from ~4.3 to 3.7 cal. ka BP, ~3.2 to 2.8 cal. ka BP and ~2.0 to 0.7 cal. ka BP. Abundances of fecal sterols start to increase at ~2 cal. ka BP, and human and herbivore feces strongly increase until ~1 cal. ka BP. This increase in fecal sterols falls directly into the last erosive phase between ~2.0 to 0.7 cal. ka BP and indicate that soil erosion during that time was mainly human-induced by increased pastoralism. Moreover,
beginning human presence at ~2 cal. ka BP corresponds to the Xiongnu (the Huns), whereas the strongly increased anthropogenic activity in the region at ~1 cal. ka BP falls into a period where Turks, Uighurs and Mongols are present in western Mongolia and the Altai. Thus, soil erosion and landscape changes in the Mongolian Altai are strongly driven by the rise of pastoralism and nomadic empires during the late Holocene.