Surface processes and associated timescales: Cosmogenic nuclide and sediment yield data from the Central Andes of northern Chile

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The desert parts of the Andes of northern Chile are regarded as being one of the oldest landscapes on Earth. Therefore, landscape forming processes must act at very slow rates. These slow rates have promoted controversial ideas on the evolution of the central Andean mountain chain and discussions whether climatic or tectonic forces predominate the geodynamic evolution of the Andes (see: Lamb and Davis, 2003; Hartley, 2005).
In order to quantify the rates of various landscape forming processes we analyzed erosion rates of hillslope interfluves across the slope of the western Central Andes (Arica area, northern Chile) in a transect from the Coastal Cordillera to the Western Escarpment into the Western Cordillera. The data consist of the analysis of several long-lived terrestrial cosmogenic nuclides (^{10}Be, ^{21}Ne, ^{26}Al - mostly in quartz of the Oxaya-ignimbrites) forming bedrock and preliminary data from catchment wide denudation rates derived from cosmogenic ^{21}Ne in river sediments. These long-lived cosmogenic nuclides are associated with timescales of millions of years, depending on the erosion rate. Furthermore, we analysed sediment yield data from river gauging stations representative for the last decade. Erosion rates determined by the cosmogenic nuclide analysis are estimated back into the middle to late Miocene and rates are on the order of 10-100cm/My at the hyperarid Western Escarpment (Atacama Desert) and the Costal Cordillera. In contrast, bedrock erosion rates for the semiarid Western Cordillera are up to >3000cm/My, at least back into the Holocene/late Pleistocene. Likewise, catchment wide erosion rates of the Lluta-drainage system yield similar orders of magnitudes. Sediment yield data obtained on a decadal scale indicate denudation rates of - again - a similar order of magnitude. These landscapes forming processes rates are one to two orders of magnitude higher compared to the desert parts (Western Escarpment) but suggest a coupling between hillslope and channel processes.
Erosion and denudation rates positively correlate with elevation and the historical precipitation record, suggesting a coupling between climate and erosion. In addition, it is suggested that the very old landscapes could be preserved in the western Central Andes thanks to low tectonic activity and the prevailing dry climate during the late Cenozoic.

The analyses of multiple terrestrial cosmogenic nuclides and the use of various “erosion-island” diagrams allowed the identification of system states (disequilibrium, transient, steady state) of the nuclide system as well as possible complex exposure histories. Complex exposure histories for samples analysed by cosmogenic nuclides were identified for non-bedrock samples, such as boulders or amalgamated clast samples (disequilibrium state). Cosmogenic nuclide concentrations from bedrock samples of the lower Western Escarpment, however, imply near steady-state or transient states over

million year timescales likely caused by processes such as episodic bedrock spalling in the cm-scale.

Landscape processes studied by morphometric analysis suggest near-steady state conditions for most of the western slope of the Andes (Kober et al., 2005, in press; Kober et al., subm. 2005). Although the surfaces have demonstrably exposed since the Miocene, timescales to achieve cosmogenic nuclide saturation (dynamic equilibrium) and landscape steady states may not be necessarily the same. Nevertheless, landscape forming processes during the late Cenozoic act with very low rates and relief modification is therefore almost negligible.

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