Scale of relief growth in the Andes of northern Chile.

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Theoretical models for the development of mountainous topographies have animated discussions about the magnitudes and rates of growth and/or decay of relief in response to changes in climate, rock uplift and exposure of bedrock lithologies. The western margin of southern Peru and northern Chile represent such a mountain belt for which one would anticipate substantial relief growth. This is the case because this part of the Andes has been an active plate-boundary zone as documented by crustal shallow seismic activities along the forearc and volcanic eruptions since the Oligocene. In addition, the occurrence of >1000 m deep valleys (e.g., Lluta and Azapa valleys) that dissect pediplains several thousands of km^2 wide suggest that this part of the Andes has also been the location of substantial topographic modifications.

This paper, however, suggests that in the Andes of northern Chile, the location of substantial relief growth has been limited to ca. 20 km-long segments along the major rivers since the Late Pliocene at the latest. These segments are knickzones in the longitudinal stream profiles, separating the stream profiles in two graded sections. In each of these sections, the valley and channel morphologies reveal distinct trends in the upstream direction that correlate with the channel gradient and the distance from the knickzones. In the flat segments beneath the knickzones, the valleys are occupied by a 250 and 500 m-wide river belt, and a >400 m-wide floodplain. Towards the knickzones, the valleys narrow to several tens of meters, and the valley floor becomes occupied by single mixed bedrock-alluvial channels. In the area of the knickzones, gravel bars are to large extent absent, and the bedrock is exposed on the channel floor. Above the knickzones, the valleys are several tens to hundreds of meters wide, and the river belt occupies the entire valley floor and is made up braided channels and gravel bars.

In the lower reaches where the gradient is flat, the presence of braided alluvial channels indicates sediment bypass. The narrowing of the valleys towards the knickzones, the increase in the channel gradients and the mixed bedrock-alluvial nature of channels imply that these valley segments are in a phase of valley lowering. In the area of the knickzones, exposure of bedrock implies ongoing dissection into bedrock. Above the knickzones, however, the presence of braided channels with longitudinal gravel bars implies sediment bypass. Hence, the narrowing of the valleys towards the knickzones, the increase in the channel gradients and the associated change in the channel morphologies from alluvial to bedrock channels imply that these valleys are in a phase of headward erosion. Von Rotz et al. (2005) suggested that headward erosion was initiated in response to baselevel lowering in the coastal area that occurred somewhen after 7.5 Ma. The knickzones then represent the erosional fronts that have shifted headward since that time. They separate the lower reaches that have adjusted to the lowered baselevel from the headwaters that still record the Late Miocene situation.

The pattern of fluvial incision rates is based on elevation differences between the valley floor and the 2.7 Ma-old Lauca ignimbrite that was deposited at the bottom of the Lluta valley at various locations (Wörner et al., 2002; García & Hérail., 2005). In the flat segment, the Lauca ignimbrite rests at the bottom of the Lluta valley at ca. 15 km distance from the Pacific coast, and at 50 m above the valley floor 40 km farther inland. This implies no significant downcutting since the Pliocene. Similarly, concentrations of multiple terrestrial cosmogenic nuclides (TCNs, ^{10}Be, ^{26}Al, ^{21}Ne; Kober et al., 2005) imply extremely low erosion rates of <1 m/My for the pediplains adjacent to these valleys due to the hyperarid climate. In the area of the knickzoned, the occurrence of the Lauca ignimbrite between 400 and 700 m above the recent valley floor implies incision rates >250 m/My between the Pliocene and the presence. On the adjacent pediplains, erosion rates have occurred at the order of ca. 1 m/My according to concentrations of TCNs (Kober et al., 2005). In the headwaters above the knickzones, the post 2.7 Ma depth of incision is <150 m, resulting in incision rates between 50-60 m/My since that time. Similar magnitudes of erosion rates are measured with TCN analyses for the hillslope interfluves (Kober et al., 2005).

The geomorphic data imply that the 20 km-wide knickzones in the longitudinal stream profiles of northern Chilenean rivers represent headward shifting erosional fronts. There, rates of valley downcutting exceed erosion rates on adjacent pediplains by two orders of magnitudes. Hence, these segments are locations of substantial relief growth. Headward incision was initiated in response to baselevel lowering in the Late Miocene. Since that time, no substantial changes in baselevels are recorded in the topography. Indeed, beneath the knickzones, the valley elevations have been stable since 2.7 Ma at the latest as indicated by sediment bypass in these segments and the occurrence of the 2.7 Ma-old Lauca ignimbrite at the coast and in the Lluta valley. Also, there is no evidence of substantial erosion on the adjacent pediplains. Similarly, the channel morphologies suggest no substantial fluvial dissection and relief growth above the knickzones. Additionally, identical erosion rates in valleys and on pediplains and hillslope interfluves imply a nearly steady local relief since the Late Pliocene at the latest. Hence, the only geomorphic recorders of relief growth are the knickzones, and therefore, the scale of relief growth has been limited to 20 km-long segments since the Late Pliocene. This also indicates that in the Andes of Northern Chile, crustal uplift of the Western Escarpment, and possibly of the Altiplano, has ceased or has probably been negligible for the observed timescale.

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