Drainage development in an intra-continental mountain belt : A case study from the south-Central Tian Shan

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Abstract

EGU 23-5117

GM 9.1 X 3.65

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QUESTIONS

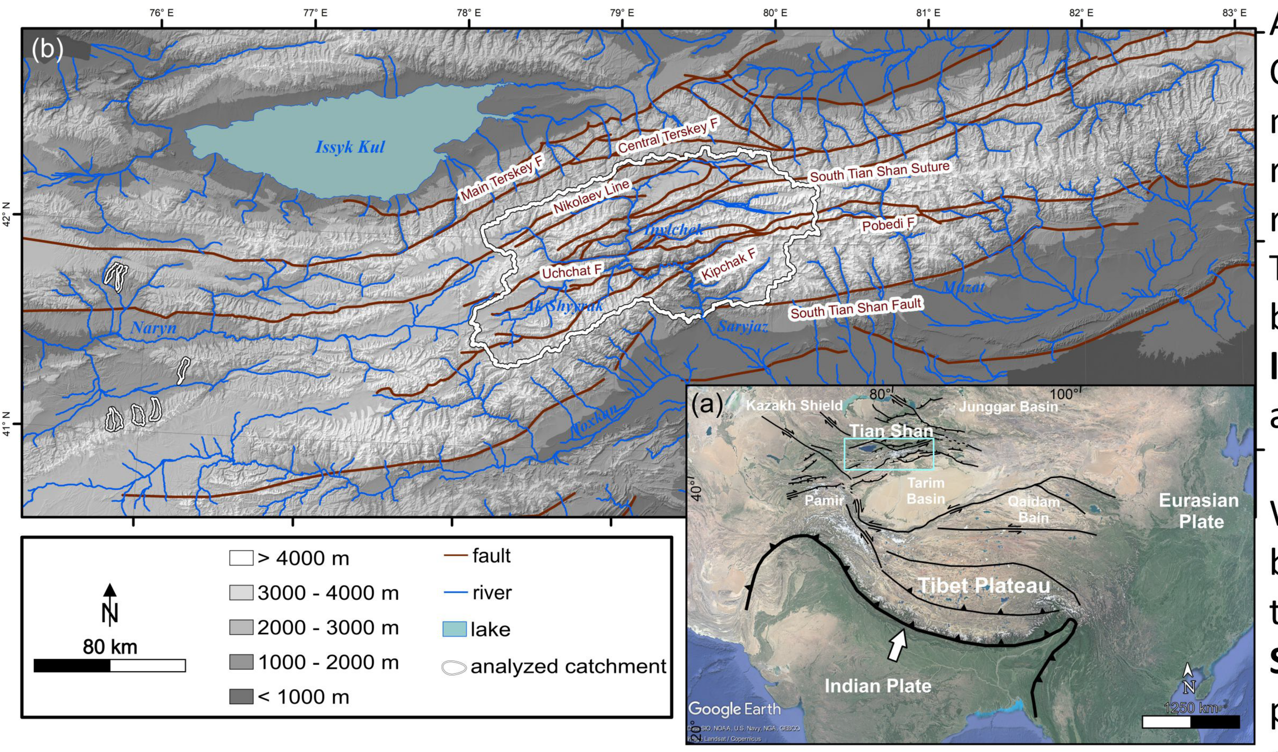
- What pattern is indicated by the current drainage observed in the south-Central Tian Shan?

- How did the drainage patterns respond to Cenozoic structural reactivation and uplift of individual ranges? And when?

ANSWERS

- The Saryjaz catchment in the south-Central Tian Shan shows a transient pattern characterized by steepened fluvial channels with retreating knickpoints downstream of a sharp "U-shape" bend;
- The transverse reaches appear to capture the longitudinal ones, increasing incision downstream and causing knickpoint retreat starting from the Pliocene time.

1. OVERVIEW

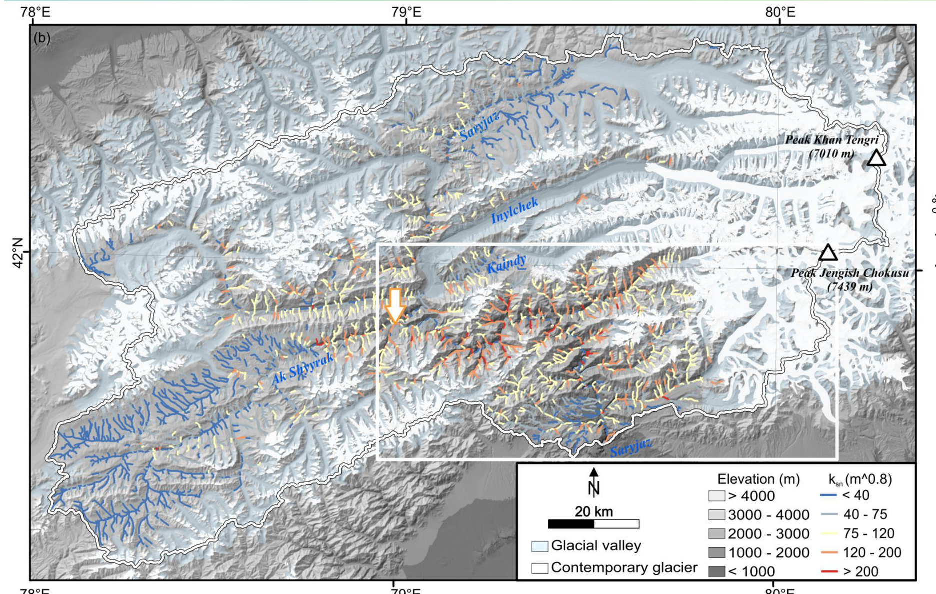


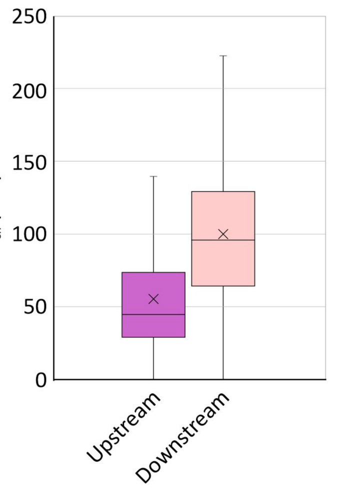
As the highest intra-continental orogen in Central Asia, the Tian Shan has experienced multiple phases of orogeny, and has been reactivated since the early Cenozoic in response to the India-Asia collision.

The south-Central Tian Shan is characterized by a significant contrast between a **longitudinal** drainage pattern in the west and a **transverse** drainage in the east.

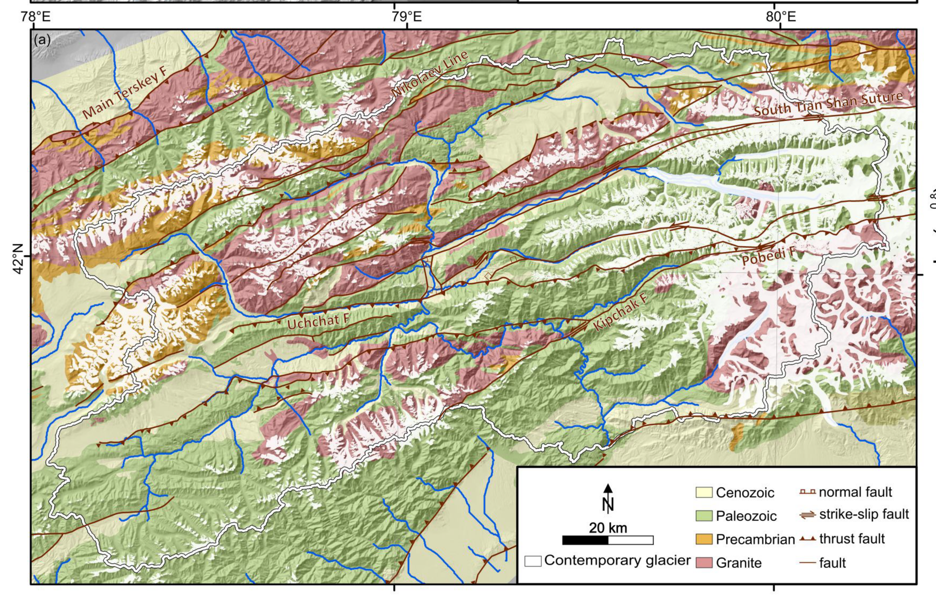
We focus here on the transition area between the regions of longitudinal and transverse drainage: the anomalously large **Saryjaz catchment**, which drains the highest part of the south-Central Tian Shan and shows a complex and peculiar drainage pattern.

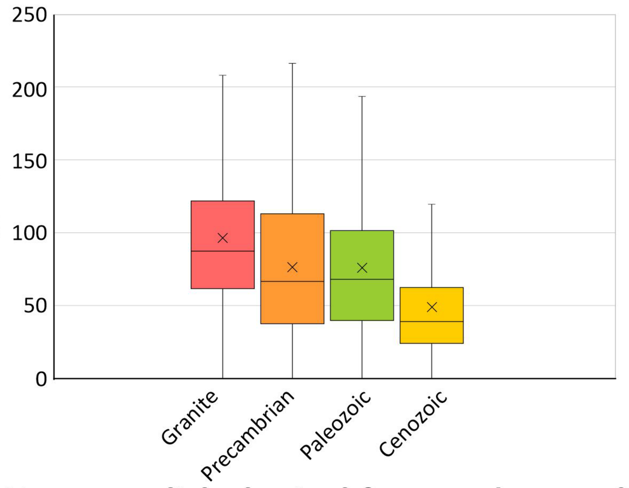
2. CHANNEL STEEPNESS PATTERNS





The pattern of k_{sn} is consistent with topography: steeper reaches are mostly found downstream of a "U-shape" turn in the main Saryjaz river, while more moderate reaches are located upstream, particularly in the Ak Shyrak and Saryjaz basins.

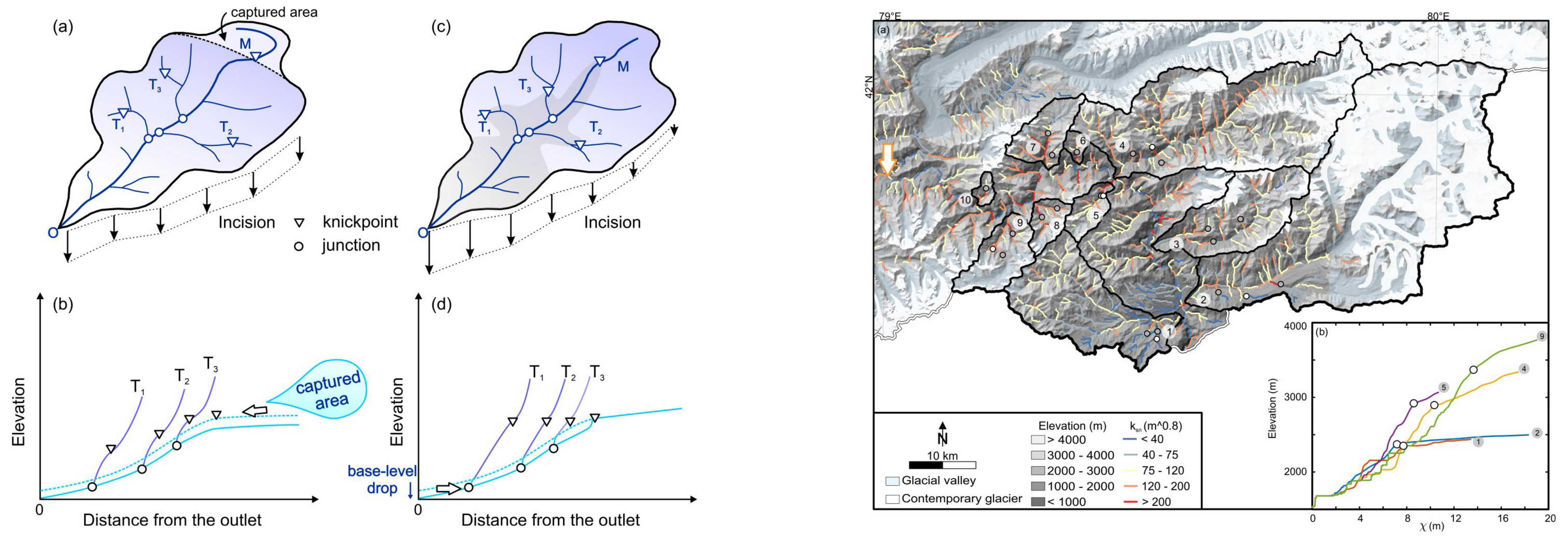




k_{sn} values are higher in Granite, Precambrian metamorphic basement and Paleozoic sedimen -tary rocks, than in Cenozoic sediments.

However, **lithological factors do not show a dominant control on the transient landscape**.

3. DRIVERS OF KNICKPOINT RETREAT

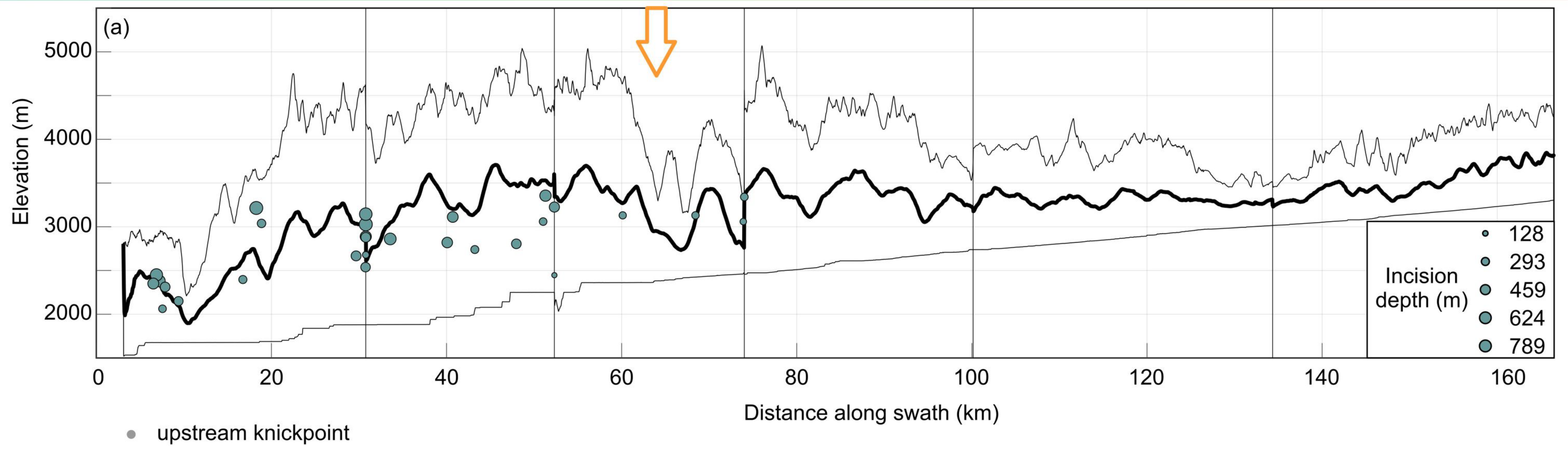


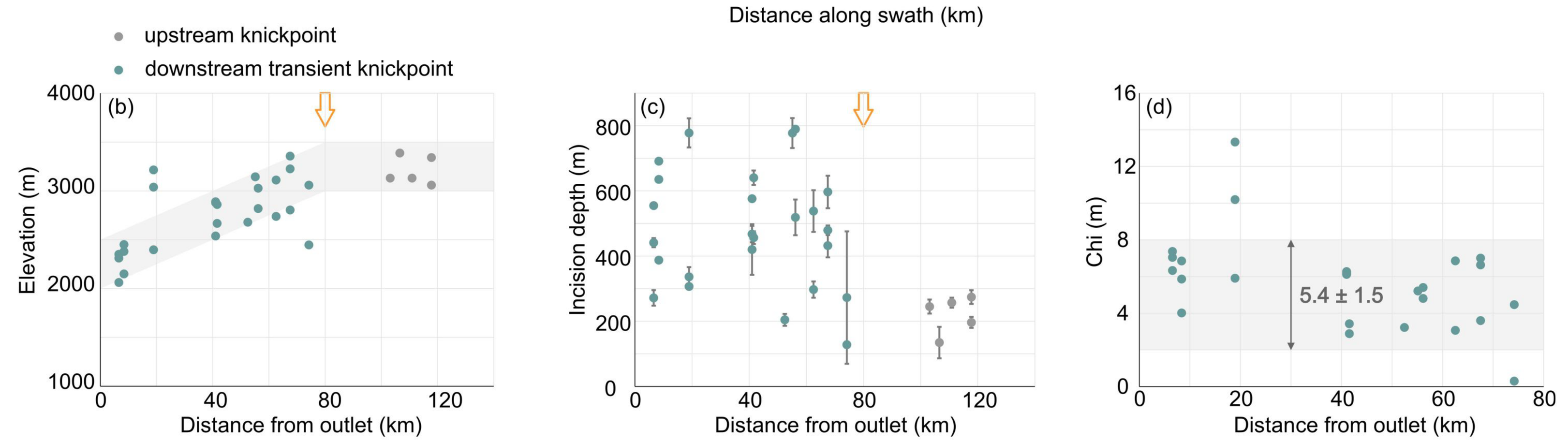
Two models for transient knickpoint retreat based on the Detachment-limited Stream Power Law (Whipple and Tucker 1999):

Model 1 (figure up left c&d): discrete capture events or diversion can also trigger knickpoints. These knickpoints react almost at the same time with constant vertical velocity.

Model 2 (figure up left a&b): base-level fall at the outlet of the catchment triggers knickpoints with constant vertical velocity but different response time: usually the tributaries closest to the outlet react first;

4. TRANSIENT KNICKPOINT PATTERNS





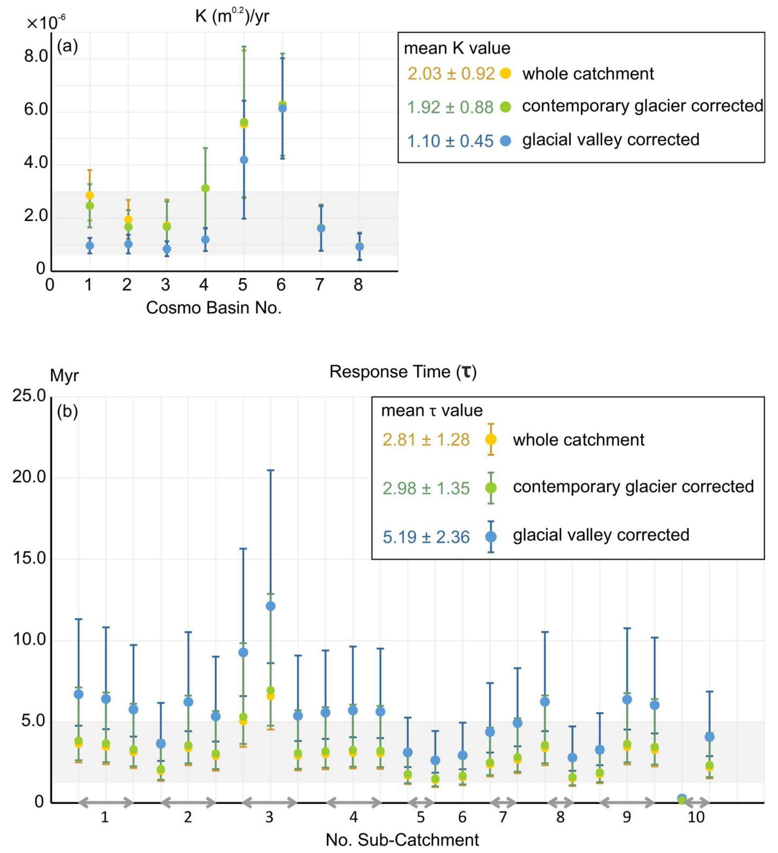
(a) X plots along tributaries indicate 25 major slope-break transient knickpoints distributed in tributaries downstream of the "U-shape" turn. Plotting of knickpoint metrics indicate the following patterns:

(b) the **elevations** of most knickpoints **increase** from ~ 2000 m to ~ 3500 m, with increasing upstream distance;

(c) **incision depths** vary between 200 and 800 m, but **do not show an apparent trend** with upstream distance;

(d) **X distances** of knickpoints from tributary junctions in most sub-catchments **fall between 2 and 8 m**, with 3 exceptions. Note that these are the same knickpoints that do not follow the increasing elevation pattern either.

5. RESPONSE TIME



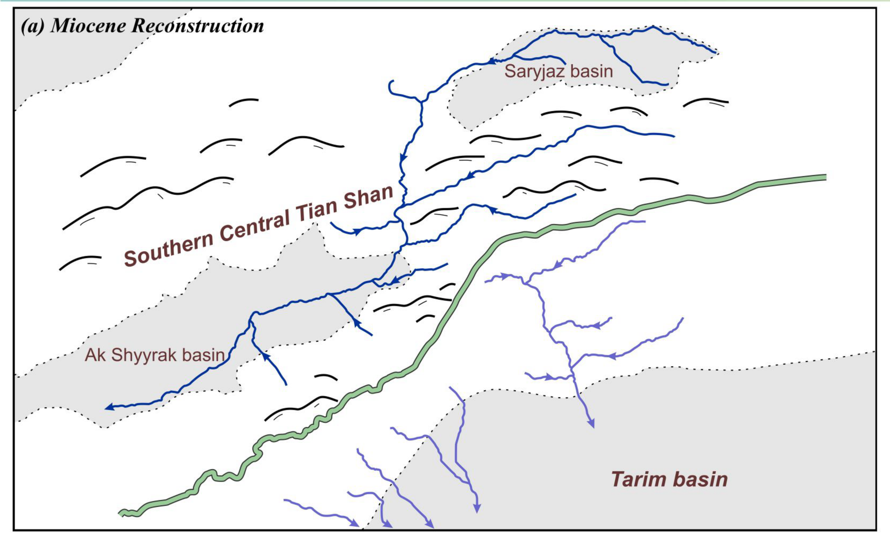
Based on the knickpoint propagation model (e.g. Whipple and Tucker 1999; Berlin and Anderson, 2007; Goren et al., 2014), the **response time** of the river from a reference base-level position to a knickpoint represents the **knickpoint travel time**.

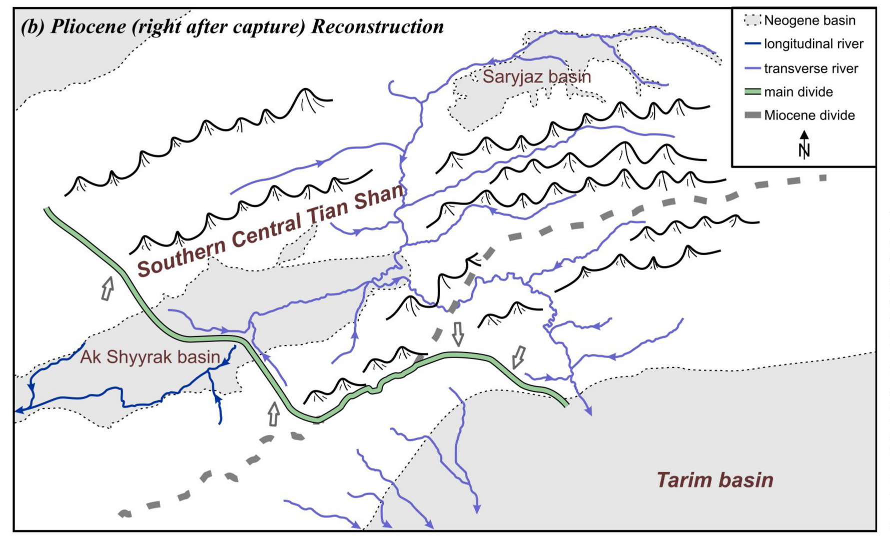
We use 8 catchment-average denudation rates calculated from cosmogenic data from adjacent catchments to estimate a response time from the tributary junctions to the current location of knickpoints.

In the calculations, catchment-average denudation rates are corrected for contemporary glacier cover or for maximum glacier extent (glacial valley); uncorrected rates (whole catchment) are also used.

All three calculations show consistent response times since the Pliocene, which indicates **a common origin for transient knickpoints** in the Saryjaz catchment.

6. DRAINAGE EVOLUTION RECONSTRUCTION





Both channel steepness and knickpoint metrics indicate recent incision along the lower reaches of the Saryjaz river and suggest that **incision is driven "top-down" by a large-magnitude capture event**.

We link this capture to ongoing replacement of the longitudinal drainage system to the west by the transverse one to the east, consistent with inferred patterns of drainage development in other intra-continental mountain belts (e.g. Babault et al., 2012).

We suggest that the capture was triggered by **overfilling** of the **Neogene intramontane Ak Shyrak basin.**

Reference

Babault, J., Van Den Driessche, J., & Teixell, A. (2012). Longitudinal to transverse drainage network evolution in the High Atlas (Morocco): The role of tectonics. Tectonics, 31(4).

Berlin, M. M., & Anderson, R. S. (2007). Modeling of knickpoint retreat on the Roan Plateau, western Colorado. Journal of Geophysical Research: Earth Surface, 112(F3).

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