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Supplement of

Rapid Holocene bedrock canyon incision of Beida River, North Qilian Shan, China

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Contents of this file

Figures S1 to S6
Table S3, S4

Additional Supporting Information (Data restored at https://osf.io/bpvw9/)

Captions for Tables S1, S2

Introduction

1. Geologic background of neighboring major rivers

Neighboring major rivers exhibit similar deep incised canyons (**Figure S2**) and knickzones. In order to exclude the influence of the lithology in the hinterland, we include a geologic map of the three rivers with the knickzones highlighted (**Figure S1**).

2. Field Survey

The Beida River terraces and riverbed were surveyed during the year 2016 and 2017. The elevation and coordinates of all the points were determined using laser range finder (~0.3m distance accuracy, 0.25^{o} inclination accuracy) and differential GPS. For terrace survey points (Figure 2a), we specifically surveyed the terrace tread where gravel in contact with loess or alluvial deposits, and the terrace strath where gravel in contact with bedrock. The longitudinal profiles (**Figure 3a, Table S1**) are generated later by projecting survey points to the river channel.

The terrace treads and the paleo channel are relatively well preserved inside the mountains due to meandering of the river. **Figure S5** shows field photos of the reaches with well-preserved paleochannels and their location relative to present river channel. The locations of each photo are also annotated on Figure 4.

We identified inactive structures in the hinterland. One of the inactive faults is underlying the knickzone. We include a photo of the undisturbed T2 terrace fill on top of the fault, indicating the fault has been inactive at least since the penultimate glacial period (**Figure S6**).

3. Geochronology

10 ^{14}C samples were collected from 3 sample sites (Figure 2), on terrace treads of T1 inset terraces. All of the samples are composite of charco fragments that buried within sand and silty sand layers on top of the gravels (**Figure S3**).

OSL sample was collected in the field by hammering stainless steel tubes into cleaned excavation walls. Sample data and age results were provided by State Key Laboratory of Earthquake Dynamics, China Earthquake Administration. The equivalent doses (De) for the pure fine-grained quartz were determined by following the simplified multiple aliquot regenerative-dose (SMAR) protocol. **Figure S4** and **Table S3** show the growth curve of the OSL sample we present in Table 2 of the main manuscript.

4. Channel width measurements

We measure present channel widths from Google Earth imagery. We define the channel width here as the width of the water surface during the summer wet season. The Google Earth images we analyzed were generally acquired during July through September between 2010 to 2016, only a few measurements were based imagery acquired in May. Measurements were taken along the river at 100 m intervals, except for the ~1.5 km reach that around the dam (Figure 3c). The survey points are listed in **Table S2**

5. χ plots of Beida, Hongshuiba, and Maying River

To examine the relative location of the main river knickzones, we present elevation plots of Beida, Hongshuiba, and Maying River as a function of χ, following Perron and Royden (2013) by normalizing upstream drainage areas **(Figure S7 b(1) b(2) b(3))**. Here we use a reference drainage area of 1 km^2, and a concavity of 0.45.

Because of the strong west-east and north-south precipitation gradients along the North Qilian Shan, major river basins located east of the Beida River have higher specific discharge (discharge per unit area). Specific discharge for the Hongshuiba (18.2 x 10^{-5} m) and Maying (18.7 x 10^{-5} m) are about double that for the Beida (9.5 x 10^{-5} m), Therefore, we also present river profiles as a function of χ adjusted for the ratio of specific discharge relative to the Bieda River **(Figure S7 c(2) c(3))**. **Figure S7 c(1)**, presented for comparison of these adjusted profiles to the Beida River, is identical to b(1).

Noted that the river profiles and drainage areas are extracted and calculated from 30 m SRTM, therefore may slightly defer from the Beida River profile we surveyed along the river.

Figure S1 Geologic map of the Beida, Hongshuiba and Maying River drainage.

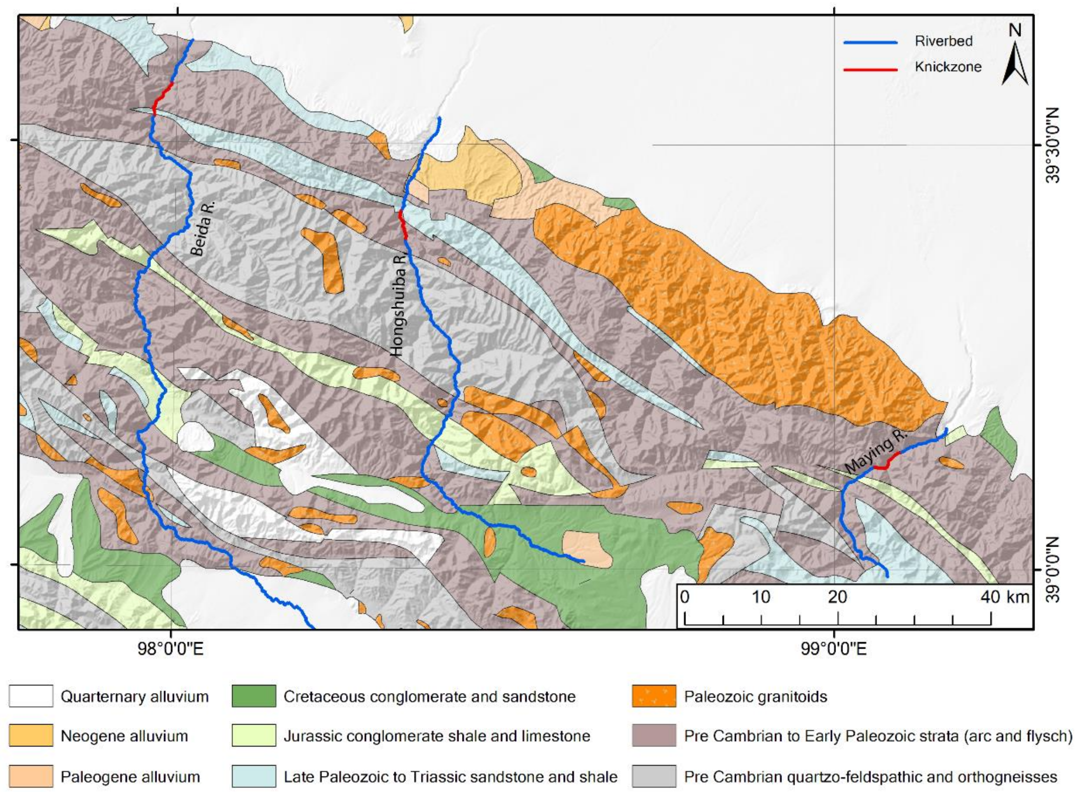


Figure S2 Photos of the major river canyons close to the mountain front. a. Beida River. b. Maying River. c. Hongshuiba River.

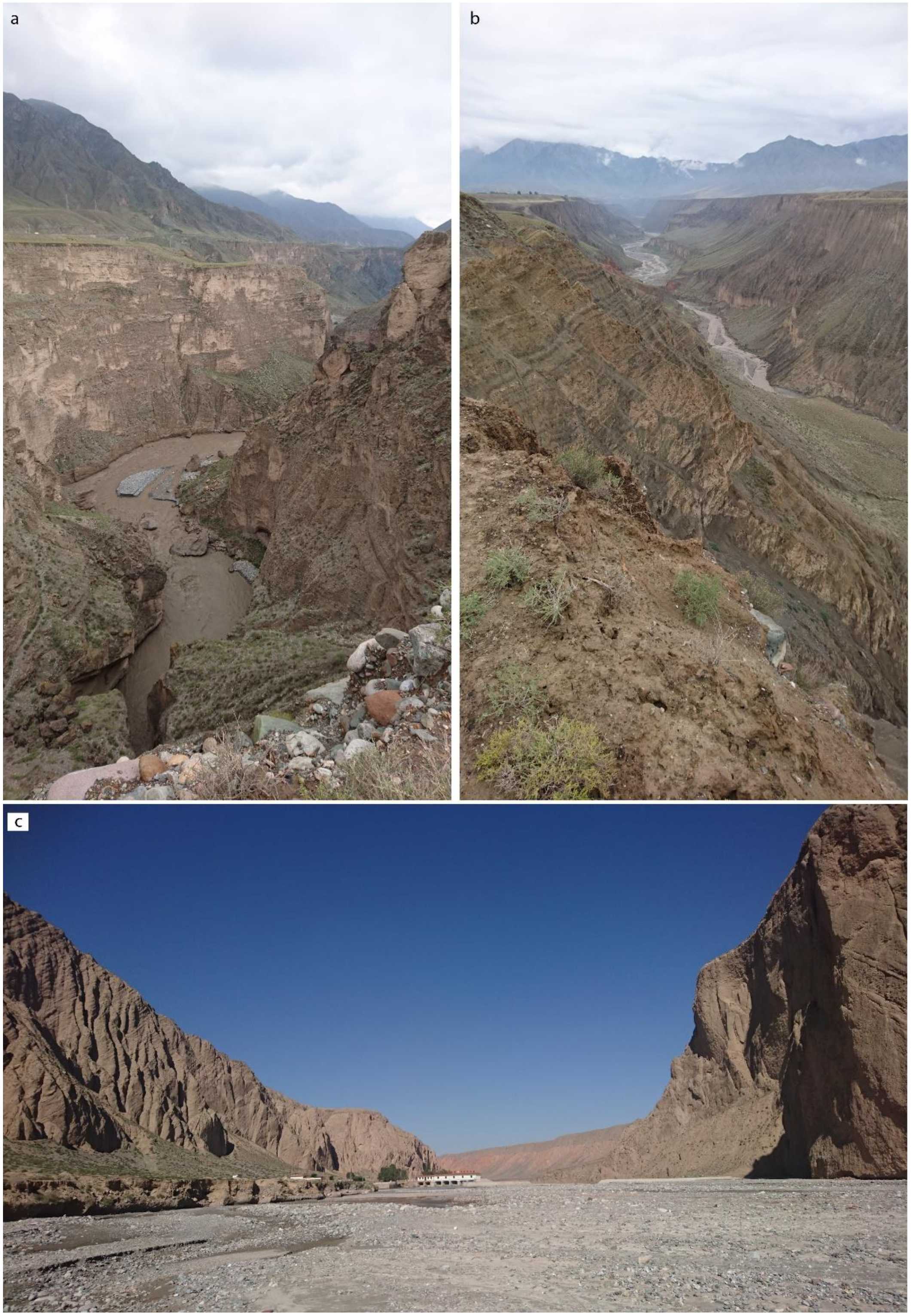


Figure S3a Photos of sample site B-03

Figure S3b Photos of sample site B-04

Figure S3c Photos of sample site B-05

Figure S4. Multiple aliquot regenerative-dose growth curve (SMAR) of sample BD-O-12. Detailed data in **Table S3**

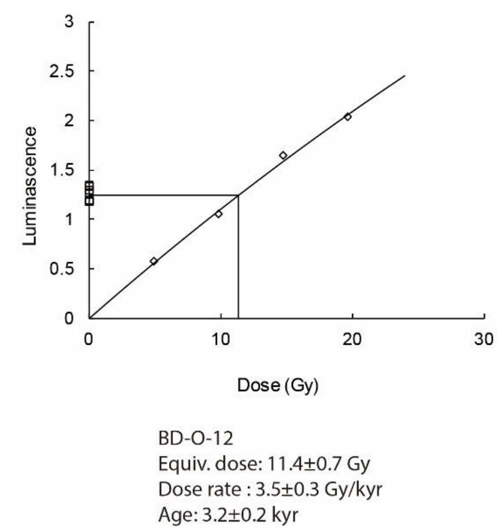
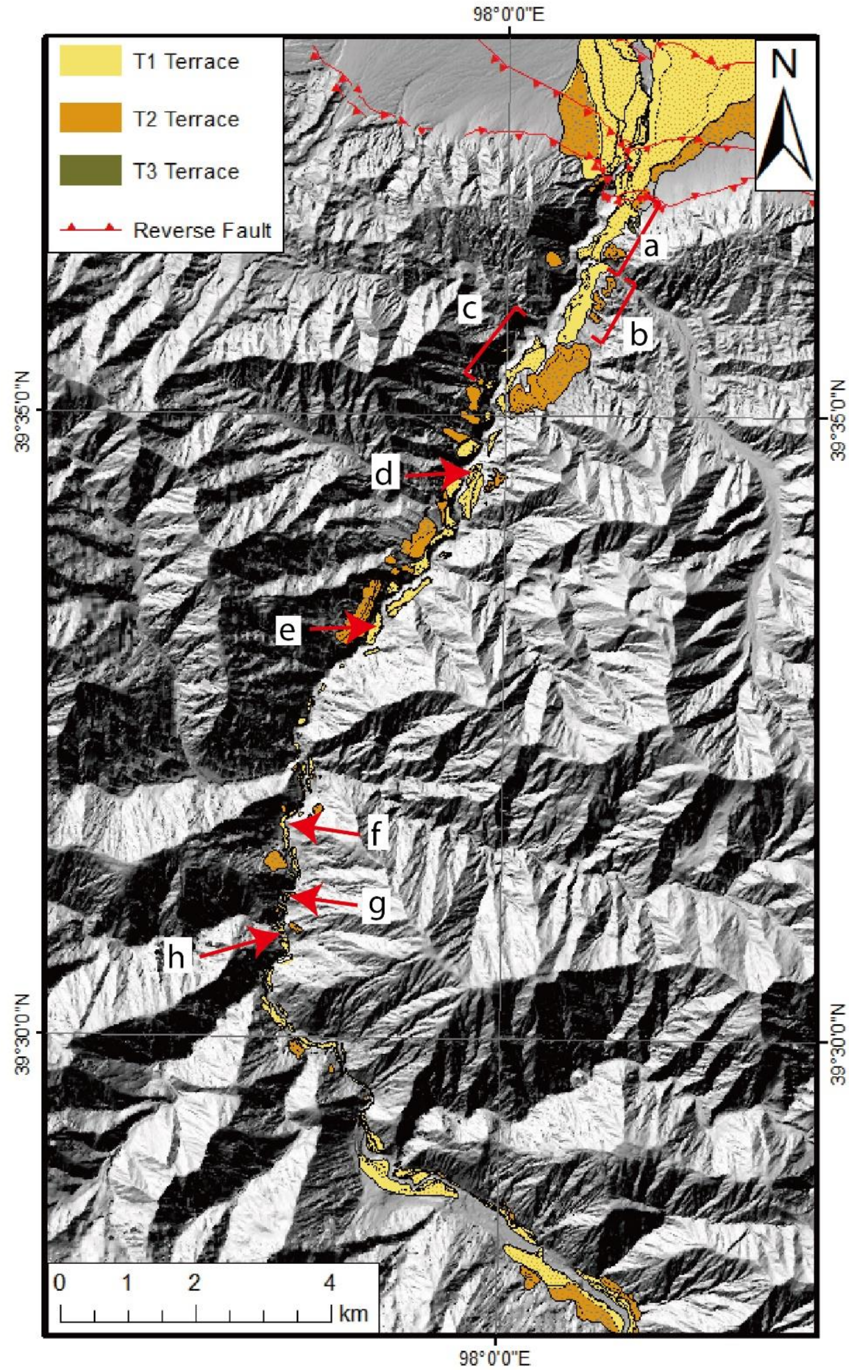
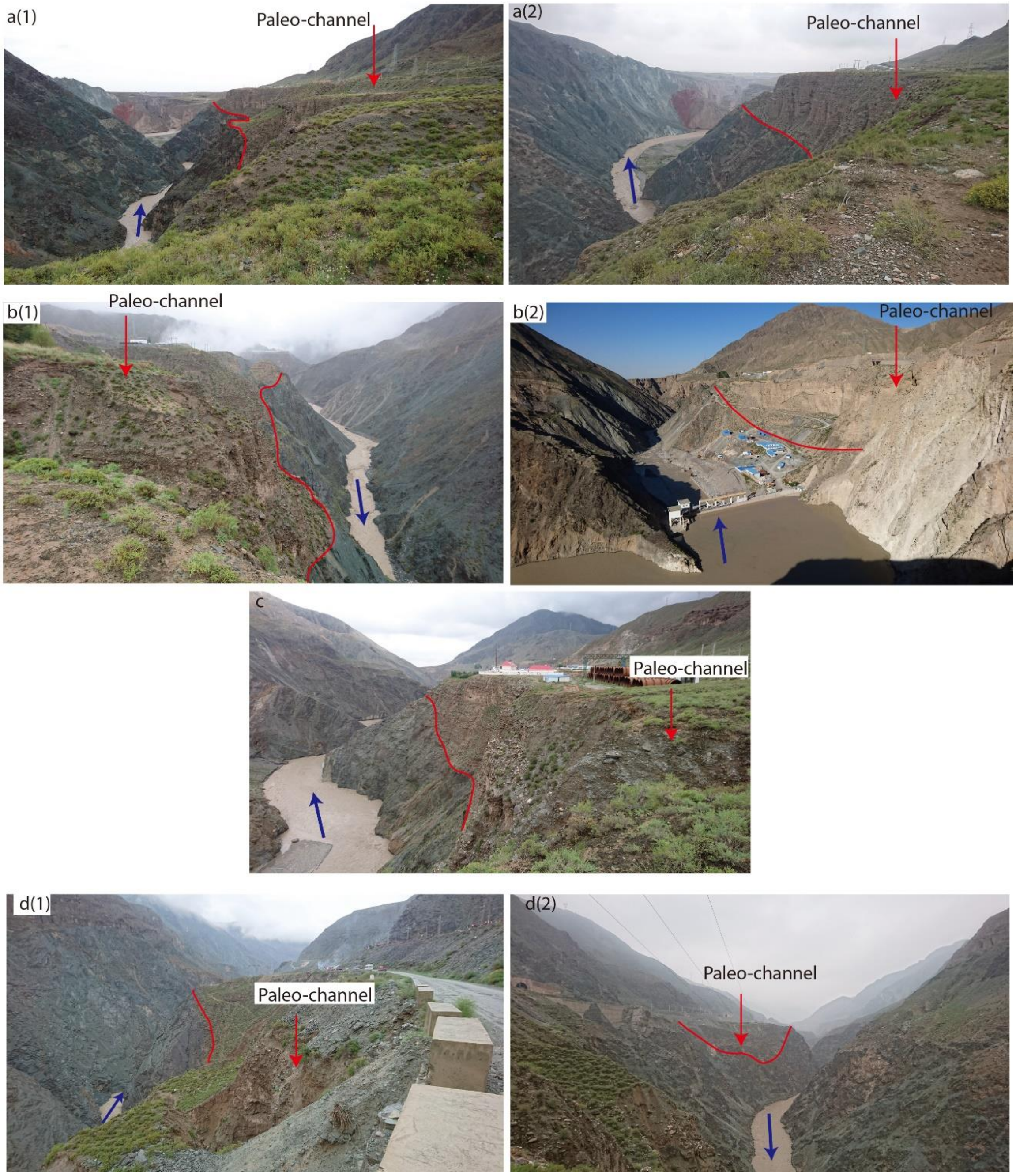


Figure S5 Field photos of well-preserved terrace treads and buried paleocanyons.




a(1)
Paleo-channel
a(2)
Paleo-channel
b(1)
Paleo-channel
b(2)
Paleo-channel
c
Paleo-channel
d(1)
Paleo-channel
d(2)
Paleo-channel

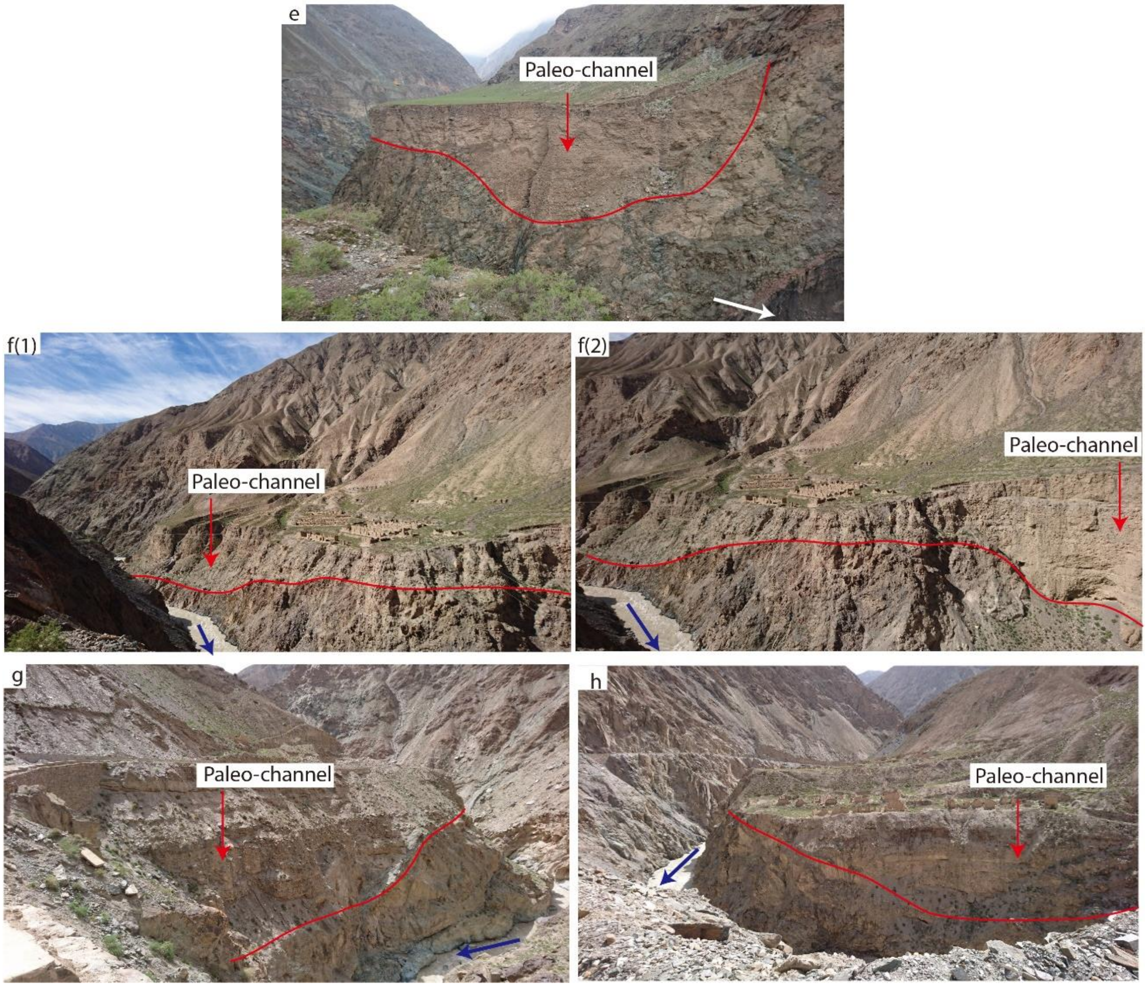

e
Paleo-channel
f(1)
Paleo-channel
f(2)
Paleo-channel
g
Paleo-channel
h
Paleo-channel

Figure S6 Inactive hinterland fault capped by T2 fill. Photo was taken at patch 2 (knickzone).

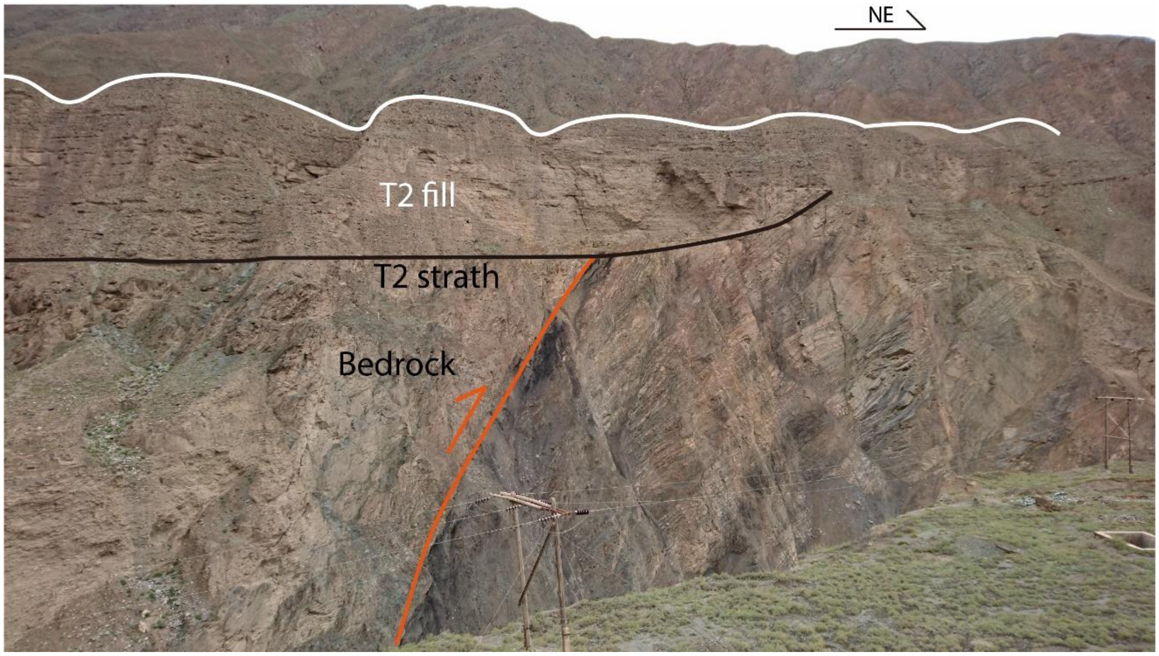


Figure S7 a. River profile (elevation vs. distance upstream of the mountain front) of the Beida, Hongshuiba and Maying River. b. χ plot (Perron and Royden, 2013) of the Beida, Hongshuiba and Maying River, normalizing with a reference drainage area of 1 km^2, and a concavity of 0.45. c. Adjusted χ plot of the Beida, Hongshuiba and Maying River; the discharge ratios for adjustment are 1, 1.9, and 2, for Beida, Hongshuiba, and Maying River respectively.

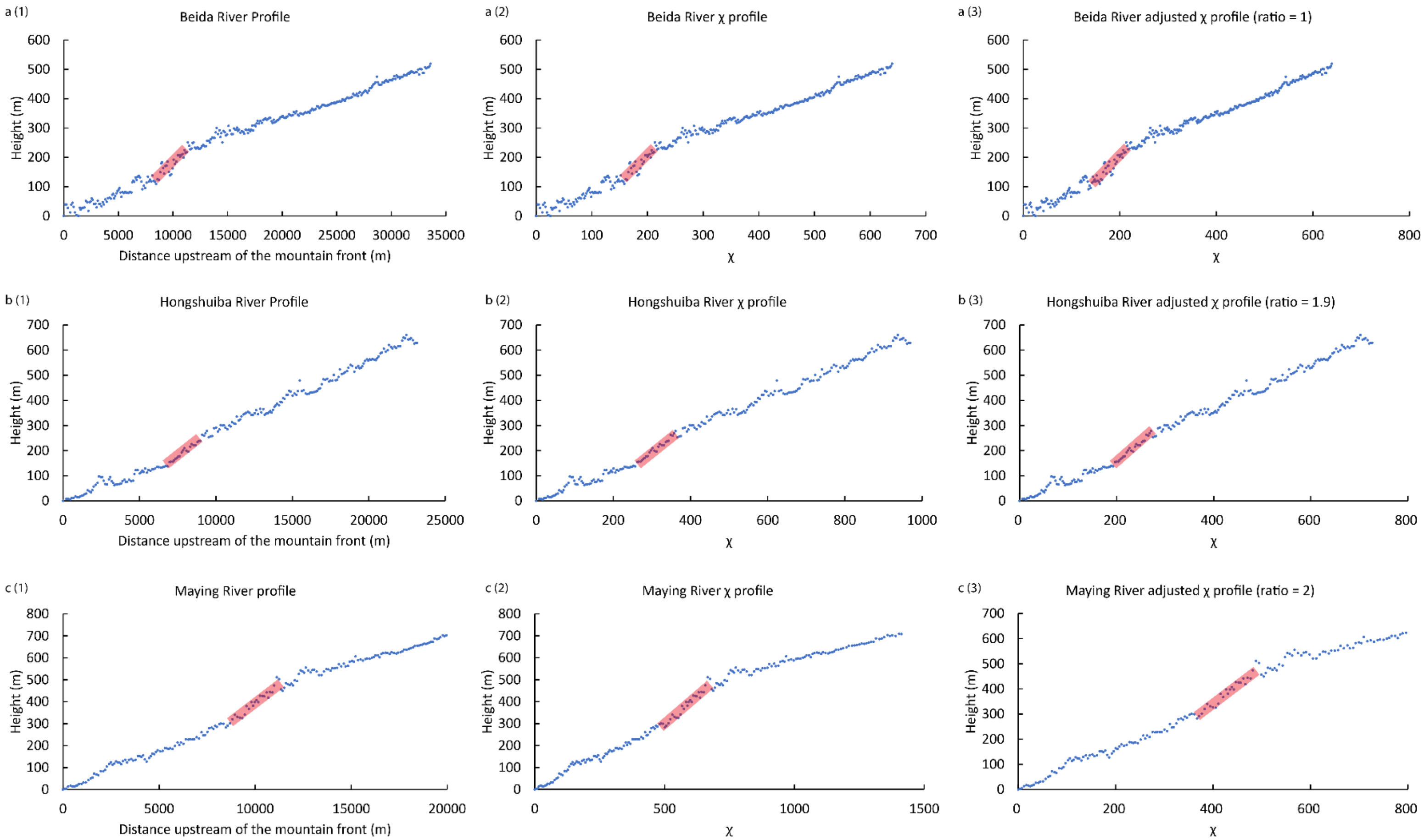


Table S1. Coordinates and elevation data for riverbed and terrace survey points (Files uploaded separately).

Table S2. Channel width measurements along the Beida River (Files uploaded separately).

Table S3. Data for sensitivity-corrected multiple aliquot regenerative-dose growth curve (SMAR) of sample BD-O-12

Sample ID	Dose (Gy)	Regenerative Luminescence Signal (Lx/Tx)	Natural Luminescence Signal (Lx/Tx)
BD-O-12	4.92	0.57	1.27
	9.83	1.05	1.33
	14.75	1.64	1.19
	19.67	2.04	1.18
	0.00	0.00	1.35
			1.19
			1.29
			1.18

Table S4. Variables used to calculate stage 2 duration and incision rate

Variable	*Value/ equations*	*Explanation*
z_{b1}	50-53 m	Apparent base level of patch 1 with respect to present river outlet.
z_{b2}	-172- -117 m	Apparent base level of patch 2 with respect to present river outlet.
I_1	3.47~7.79 m/kyr	Incision rate at outlet during formation of patch 1.
I_3	10.15-12.97 m/kyr	Incision rate at outlet during formation of patch 3.
t_3	> 2800 yr, < 4815 yr	Duration of patch 3 formation.
$T_{9.5}$	9332-9657 yr	Age of the T1’ terrace near the mountain front
$T_{6.9}$	6797-6934 yr	Age of the inset T1 terrace above patch 1
$H_{9.5}$	97-107 m	The amount of incision at mountain front during $T_{9.5}$
$H_{6.9}$	32-42 m	The amount of incision along patch 1 during $T_{6.9}$