Exploring the causes of widespread late Pleistocene river aggradation in the Himalaya

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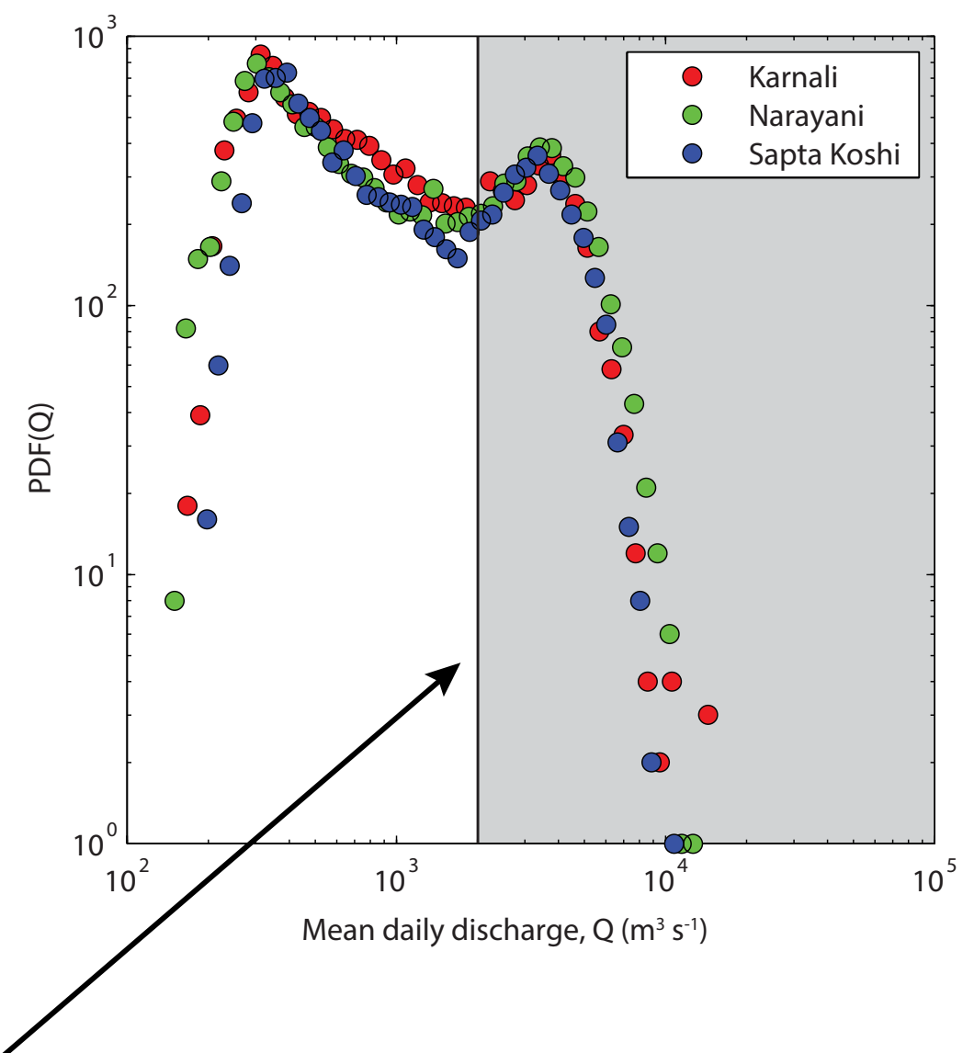
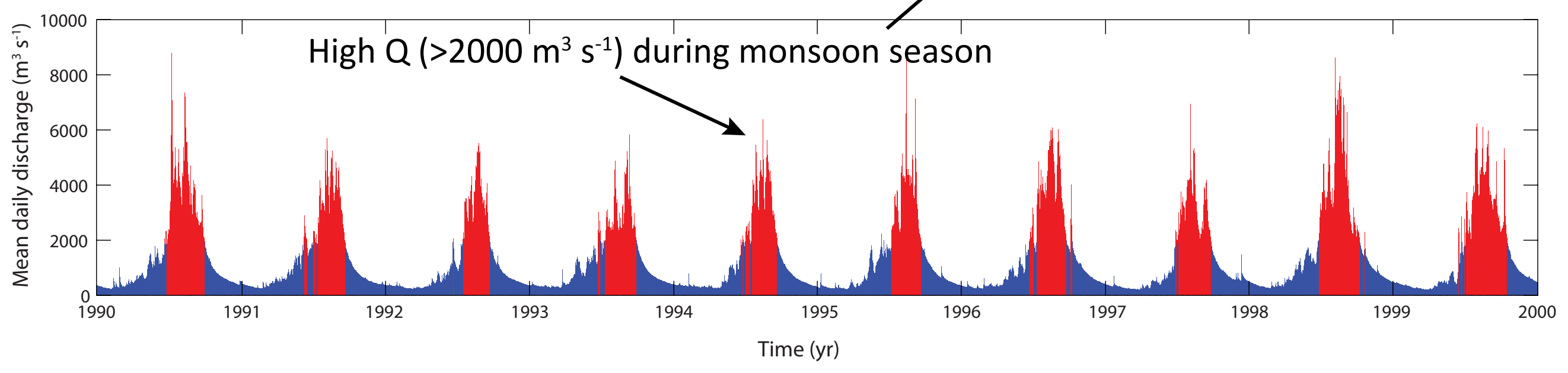
Summary

Fluvial fill terraces are found in most Himalayan valleys and testify periods of fluvial aggradation resulting from an imbalance between sediment supply and discharge. Various causes have been invoked to explain this imbalance, mostly involving climatic oscillations. We collected river and terrace sediment samples in the Yamuna catchment (Fig. 1, Fig. 2) to compare recent (late Holocene) and palaeo-(late Pleistocene) erosion rates derived from cosmogenic ^{10}Be. Recent basin-wide erosion rates (1) increase towards higher elevations and steeper catchments (Fig. 3), (2) are on average lower than thermochronologically derived exhumation rates (Fig. 3a), (3) and appear lower than palaeo-erosion rates (Fig. 4). We also obtained OSL, ^{14}C, and ^{10}Be ages from the terraces (Fig. 1), which - together with published terrace ages from nearby valleys (Fig. 5) - indicate a late Pleistocene aggradation episode that ended with the onset of the Holocene, probably due to a strengthening monsoon (Fig. 6).

Future work

The current data may suggest increased sediment supply (higher palaeo-erosion rates) as well as reduced river discharge (decreased monsoon strength) to be the cause of the aggradation episode. However, it is not clear if reduction in total discharge or changes in discharge variability are more important for changing sediment transport in Himalayan rivers, where annually recurring monsoon floods (Fig. F1) appear to achieve most geomorphic work.





As a next step, I (Dirk Scherler) want to use a numerical model to explore the relationship between monsoon strength, discharge variability, and river aggradation in a rapidly uplifting and eroding orogen like the Himalaya in more detail.
Further field work and sample data, both from rivers and hillslopes, would help to test the initial findings about elevated palaeo-erosion rates (Fig. 4), and hopefully provide better chronological control that may allow assessing spatial synchroneity of the aggradation period.

References

Fig. 3a: *Thiede, R. C., Ehlers, T. A., Bookhagen, B., Strecker, M. R.*, 2009. J. Geophys. Res. 114, F01015.
Fig. 5 & 6: *Barnard, P. L., Owen, L. A., Finkel, R. C.*, 2004. Sed. Geol. 165, 199-221; *Bookhagen, B., Fleitmann, D., Nishiizumi, K., Strecker, M. R., Thiede, R. C.*, 2006, Geology 34, 601-604; *Dutta, S., Suresh, N., Kumar, R.*, 2012. Palaeogeogr. Palaeocl. 356-357, 16-26; *Herzschuh, U.*, 2006. Quatern. Sci. Rev. 25, 163-178. *Ray, Y., Srivastava, P.*, 2010. Quatern. Sci. Rev. 29, 2238-2260; *Scherler, D., Bookhagen, B., Strecker, M. R., von Blanckenburg, F., Rood, D.*, 2010. Quater. Sci. Rev. 29, 815-831; *Singh, A. K., Parkash, B., Mohindra, R., Thomas, J. V., Singhvi, A. K.*, 2001. Basin Res. 13, 449-471; *Sinha, S., Suresh, N., Kumar, R., Dutta, S., Arora, B. R.*, 2010. Quatern. Int. 227, 87-103; *Srivastava, P., Tripathi, J. K., Islam, R., Jaiswal, M. K.*, 2008. Quatern. Res. 70, 68-80; *Suresh, N., Bagati, T. N., Kumar, R., Thakur, V. C.*, 2007. Sedimentology 54, 809-833.

The Yamuna River basin - ^{10}Be-derived erosion and palaeo-erosion rates

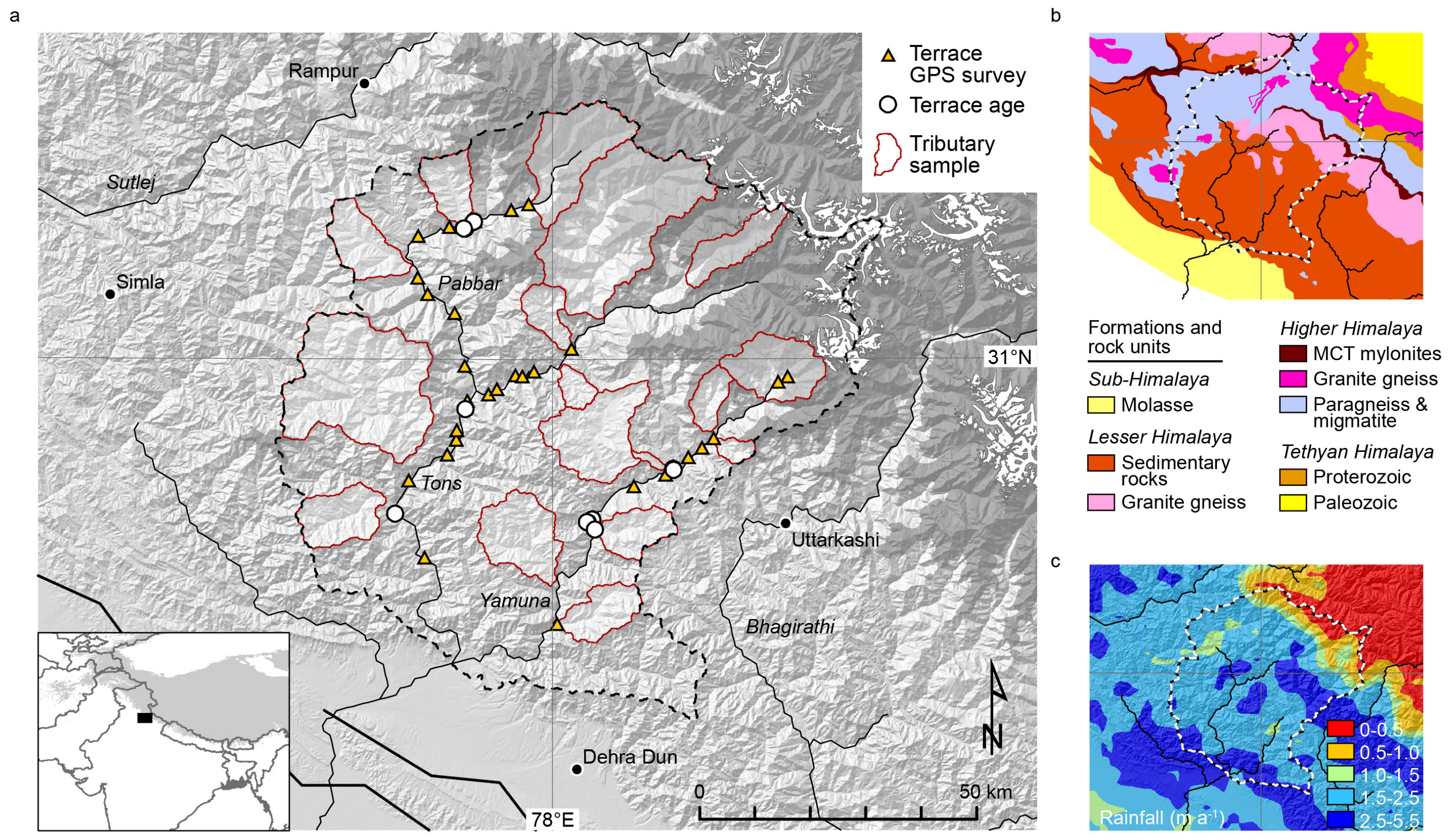


Fig. 1: Yamuna River basin in the NW Indian Himalaya. (a) Catchment outline, GPS terrace surveys and sample locations, (b) geology, (c) annual rainfall.

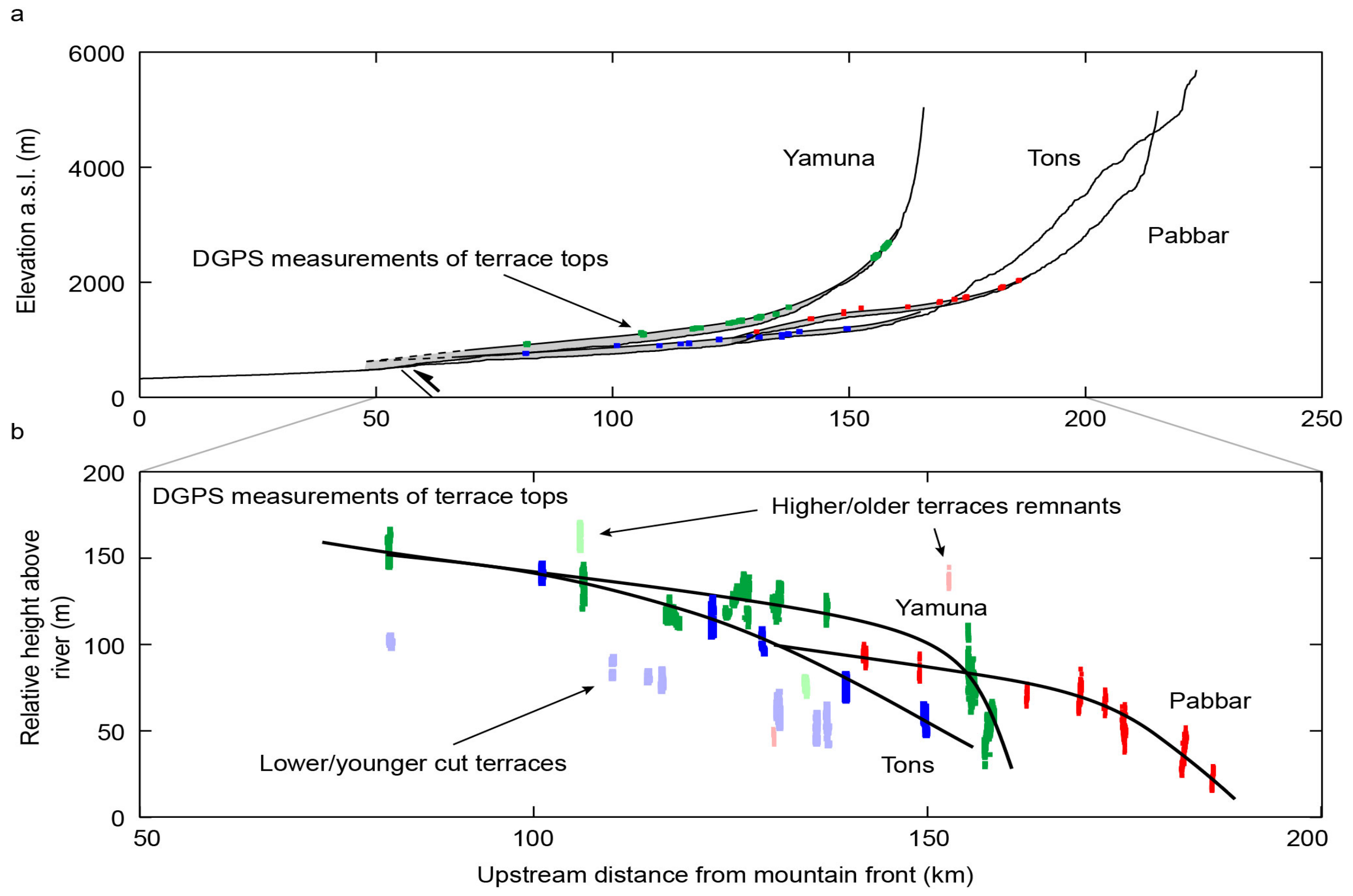


Fig. 2: Longitudinal profiles of rivers and fluvial fill terraces. (a) Absolute elevations and (b) relative height above river as a function of distance from mountain front. Colored data points denote DGPS surveyed points, colored by river.

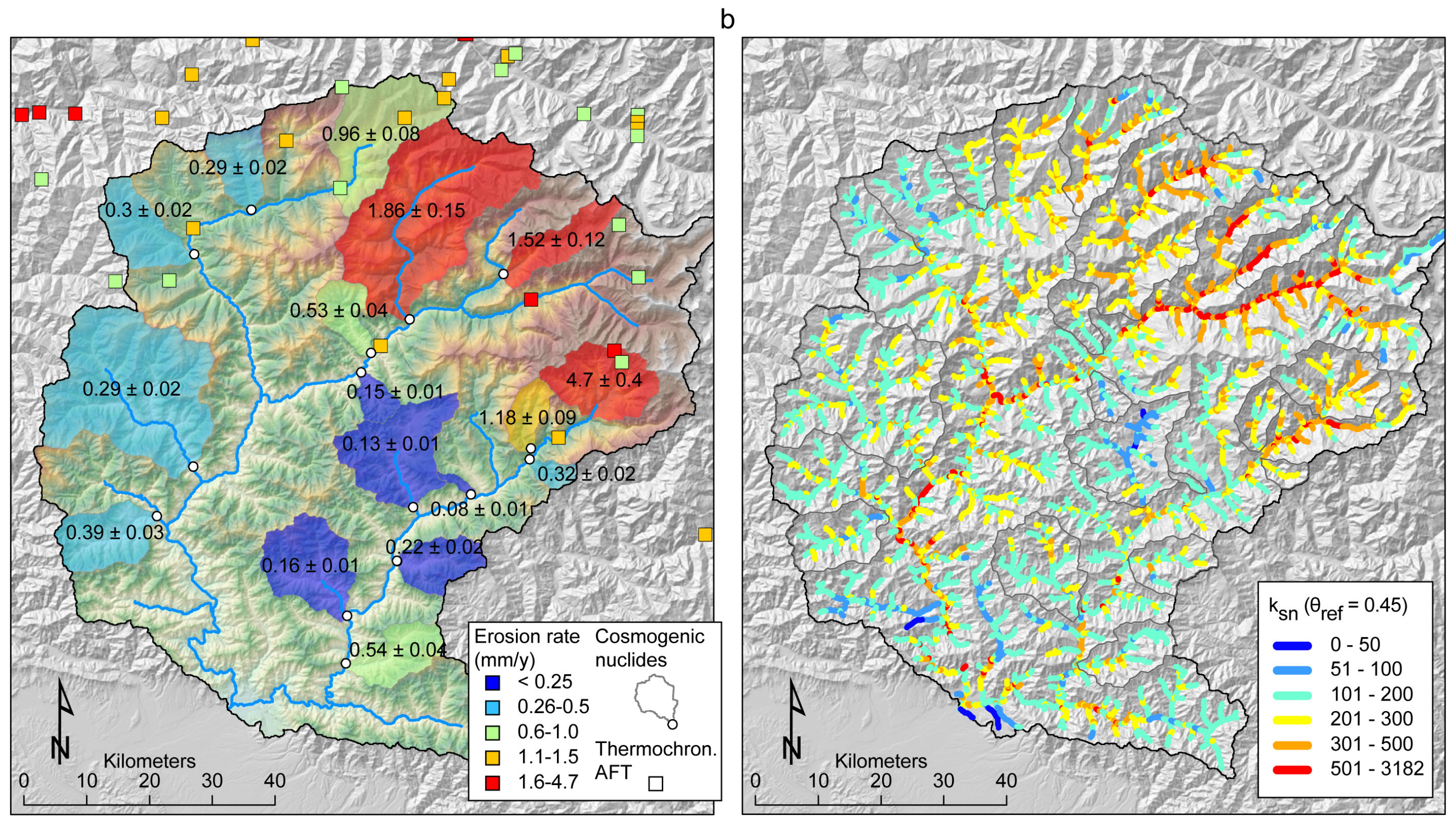
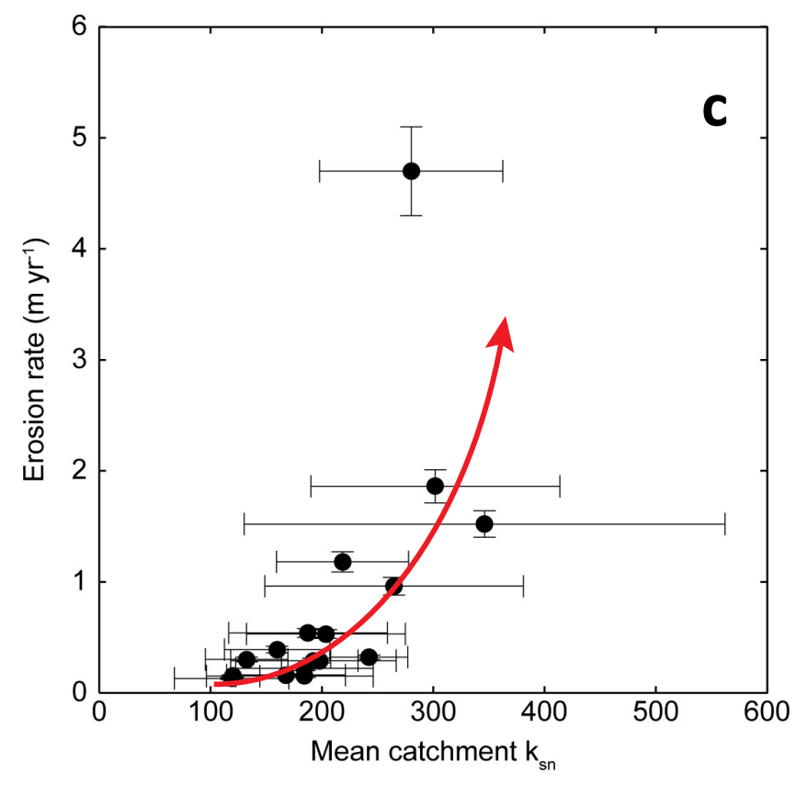


Fig. 3: Erosion rates and channel steepness. (a) ^{10}Be-derived erosion rates (this study), erosion rates derived from fission tracks in Apatite (Thiede et al., 2009). (b) Normalized channel steepness index (k_{sn}, θ_{ref}=0.45). (c) ^{10}Be-derived erosion rate versus mean ksn for the catchments shown in (a) and (b).



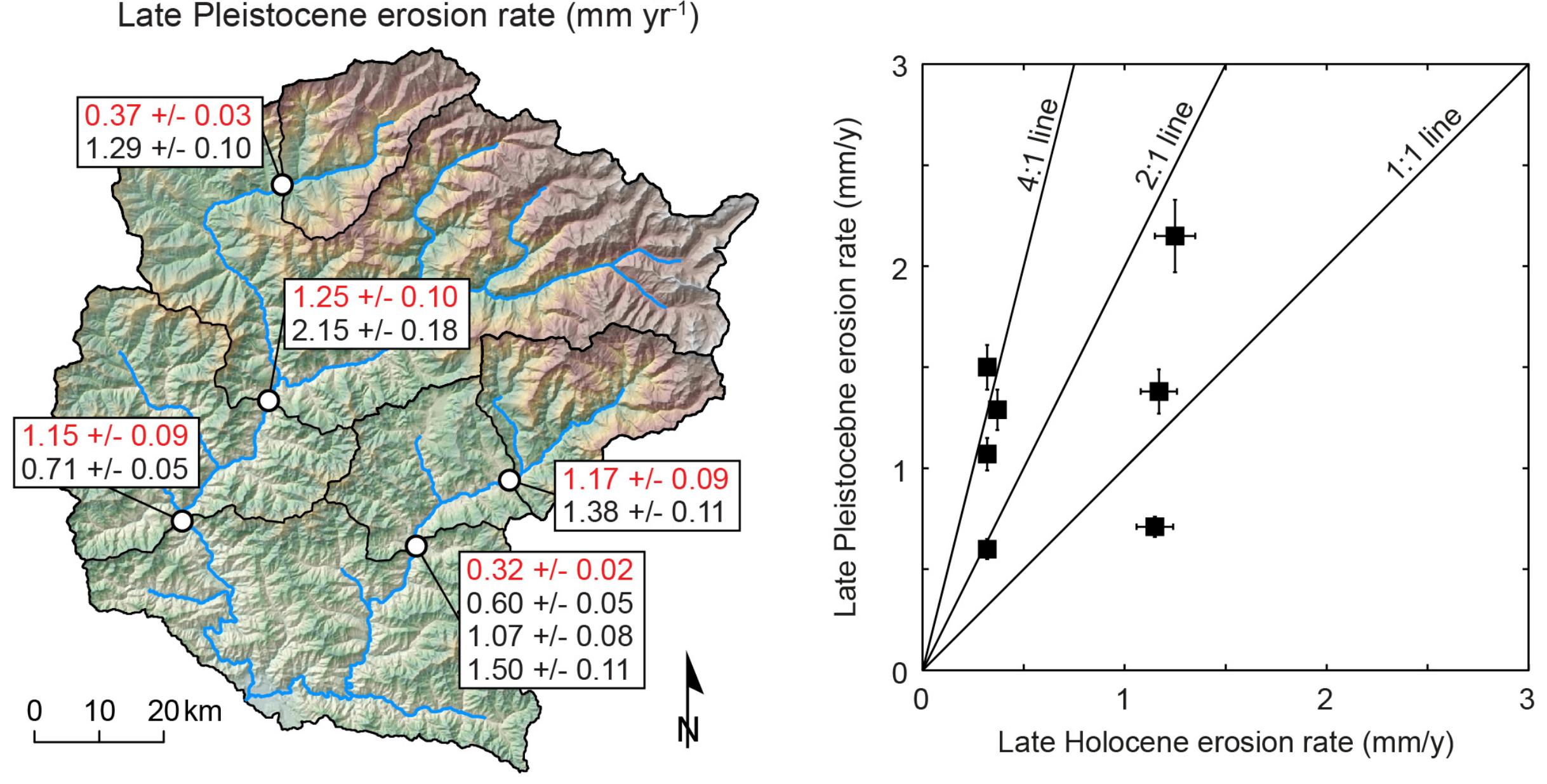


Fig. 4: Late Holocene vs late Pleistocene ^{10}Be-derived erosion rates from main stem rivers. (a) Spatial context of samples. At each location the modern river sediment as well as terrace sediment was sampled. Terrace samples stem from fresh road cuts inferred to have been shielded for most of the burial time. (b) Comparison of erosion rates. Most terrace samples yield higher erosion rates compared to their corresponding river sediment samples.

Regional considerations and links to climatic changes

Fig. 5: Regional distribution of fill terraces and chronological constraints. Fluvial fill terraces (red) are found in all major rivers in the Garhwal Himalaya. Existing chronological constraints stem from moraines, terraces, and alluvial fans and shed light on the timing and causes of aggradation events.

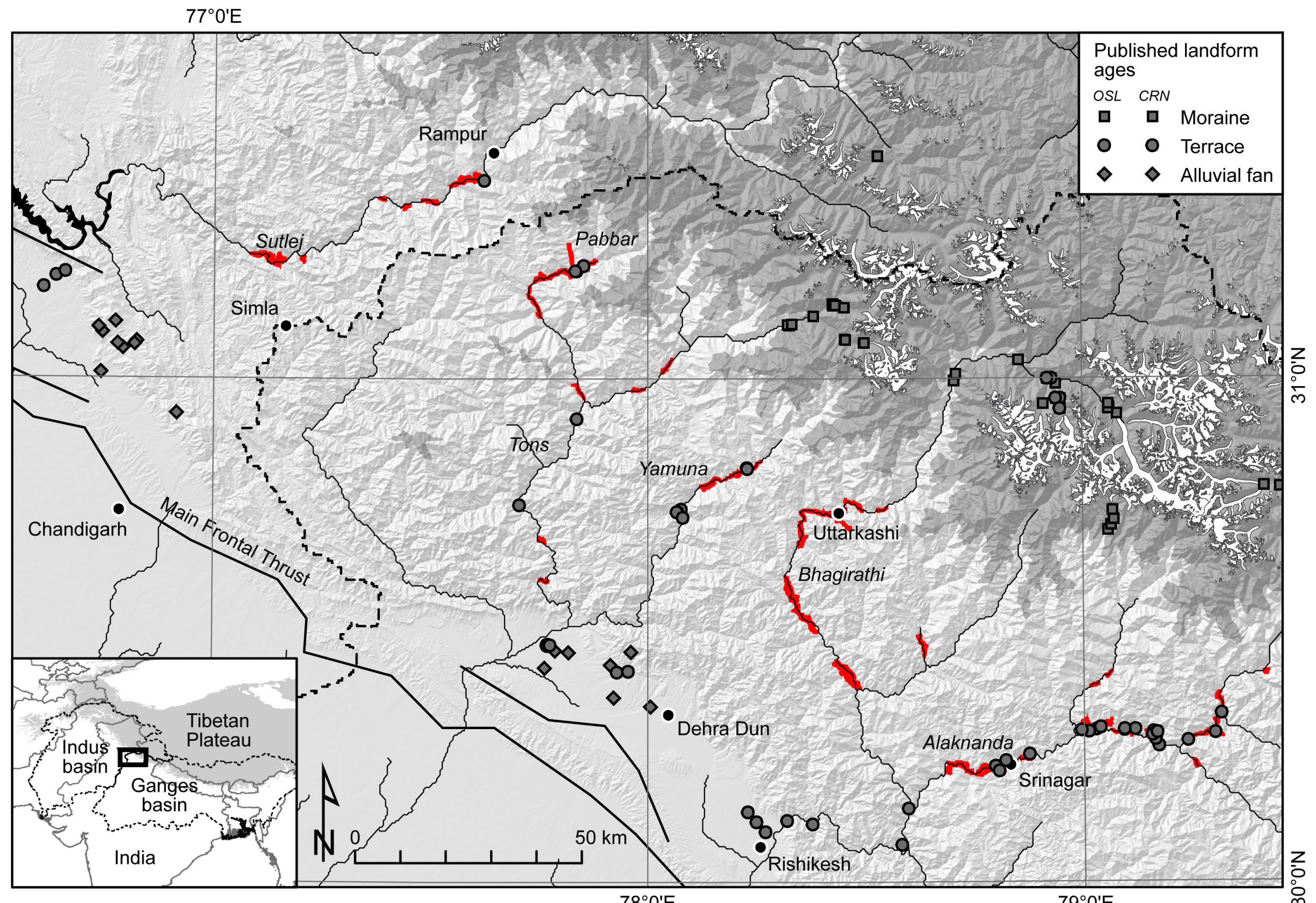


Fig. 6: Late Quaternary aggradation and incision history in the Garhwal Himalaya. New and published chronological constraints from OSL, ^{14}C, and ^{10}Be surface exposure dating suggest regional fluvial aggradation during the latest Pleistocene and a switch to incision at the onset of the early Holocene, when the South Asian monsoon intensified. Data from references X-Y.