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Earth Surface Dynamics Discussions

# *Interactive comment on* "Timing of exotic, far-travelled boulder emplacement and paleo-outburst flooding in the central Himalaya" *by* Marius L. Huber et al.

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This paper investigates the origin and timing of boulders found along two major rivers in Nepal. It uses cosmogenic exposure dating to date several boulders from each valley making up the largest grain sizes of river deposits in these valleys. It analyses their geology to identify potential source areas and thus travel distances of the boulders. Finally, it estimates the river discharges that would have been needed to transport the boulders using three different approaches. The authors find a clustering of ages around 5 Ky in both valleys. They also find that boulders have travelled over 10s of kms based on their geology. It calculates that discharges of 10ˆ3 – 10ˆ5 cubic meters



per second were needed to transport the boulders, exceeding the flows on record at discharge gages along these rivers but inline with estimates of several paleo lake outburst flood discharges. The authors discuss potential triggers of lake outburst floods, namely earthquakes (via generation of landslide dams) and climate (through generation of glacial lakes and outburst floods). The authors reason that boulders were likely transported by GLOFS that coincided with widespread glacial retreat around 5Ky in the region at a period of increased aridity. This suggests the significance of climate events in the evolution of these valleys.

I enjoyed reading this paper, which investigates the interesting and important question of the origin and transport history of large boulders, a prominent feature of mountainous valleys in the Himalaya. The clustering in boulder ages in the two valleys is interesting and hints at a large event that transported or exposed these boulders. If the trigger was indeed a series of glacial lake outburst floods related to widespread glacial retreat, this raises concerns about what may await such valleys under current warming conditions and glacial retreat. The paper is well written and presented and I think needs just a few minor/moderate revisions.

I made some comments on the manuscript (attached) and some of these may be duplicated here, but my main comments are as follows:

I wonder if you could validate your methods for backcalculating paleodischarges from mobilizing boulders of varying sizes with the event documented by Cook et al., 2018 in the Sunkosi? Cook et al. 2018 found that the event mobilized boulders as large as 5.7m. Additionally, discharge is known for this event. You could also investigate the distances moved of boulders in the 2016 event, if this information is available (I'm not sure if Cook et al, 2018 were able to track individual boulders in fact), and compare these with the distances you suggest your boulders moved in a single event.

I am wondering whether these boulders could have been moved by successive events and that potentially a particularly large event around 5000 years exposed these? For

example, could these have been transported in an older event or a series of older GLOFs, buried, e.g. in a terrace and then exposed around 5000 years ago for example by erosion of the surrounding terrace? Perhaps more potential storylines should be discussed in light of uncertainties.

Whilst you emphasize the clustering in time of your boulder dates, there seems to be a lot of spread in ages of other dated boulders in the region, particularly in the Everest region (Figure 6). More discussion of this spread would be good as it perhaps goes against the idea of a synchronous GLOF response to glacier retreat.

I also discussed this paper in our regular group reading session and the following additional comments came up:

Could you include potential source zones in Figure 1 based on the geology of the region? Could there be local, undocumented intrusions that these boulders could originate from? (this came from a group member who had actually visited the boulder in Figure 2D with Nepalese scientists)

Would it be possible to reconstruct the size of lake needed to generate a flood of the range of magnitudes you predict with your paleo flood estimates? Is there evidence in the topography that such a lake could have existed i.e. in terms of available accommodation space? Similarly, is there evidence that glacial lakes today are not completely filling this available space and hence may generate smaller magnitude GLOFS than in the past, as you suggest in the discussion?

Finally, I have just read the Paul Carling's comments and the authors' response before uploading my review (I'm not sure if this is common practice or not, being a relatively new ESurf reviewer!) I will just make the comment I agree with the authors that a creep mechanism of boulders is highly unlikely for boulders >2m, based on observations of boulders in the Upper Bhote Koshi by Cook et al (2018) who observed no movement of boulders during monsoon floods; only in the 2016 GLOF did boulders >2m actually move.



Please also note the supplement to this comment:
https://www.earth-surf-dynam-discuss.net/esurf-2020-17/esurf-2020-17-RC1-supplement.pdf

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