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Interactive comment on "Sediment size on talus slopes correlates with fracture spacing on bedrock cliffs: Implications for predicting initial sediment size distributions on hillslopes" *by* Joseph P. Verdian et al.

Anonymous Referee #1

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The problem of predicting sediment size distributions on hillslopes has seen recent interest in the geomorphology community. Sediment size, especially when larger than typical "soil" grain sizes, influences dynamics both on hillslopes and adjoining river channels that must carry hillslope-derived sediment. However, data regarding hillslope sediment size and dynamics is scarce. Important parameters such as initial sediment size distributions, as well as their subsequent evolution through transport and weathering through the hillslope system, are not well known. A common assumption is that fracture spacings can be used to estimate initial size distributions in hillslope sediment

derived from bedrock outcrops. However, weathering of blocks in situ or immediately after detachment may alter the initial size distribution.

In order to test this, Verdian et. al present field measurements of fracture spacing in exposed rock walls and sediment size in immediately adjoining talus slopes at 5 different sites in California. They find that size distributions are not smaller than their respective rock wall fracture spacings (in fact, they are coarser) and conclude that weathering does not substantially alter the initial size distribution. However, they find that initial sizes and to some extent particle shape do depend on lithology. Finally, they propose a simple ratio of timescales that determines the importance of weathering in setting size distributions before detachment from parent material (bedrock or saprolite).

Given the scarcity of hillslope sediment size data, the data presented in this paper are useful for their own sake. The basic confirmation that fracture spacing sets initial size distributions is also useful for models of hillslope sediment transport. However, I find the scope of the paper and presentation and interpretation of the data to be misleading and confusing. Below I outline the main points that need to be addressed, along with suggestions for improvement.

Main suggestions

The primary claim of the paper is that pre-existing fractures in exposed bedrock cliffs set the initial size distributions of hillslope sediment. This is in contrast to the idea that weathering- either in situ or soon after sediment detachment- substantially alters sediment sizes. It is currently unclear in the paper 1) why we care about latent fracture spacing 2) how "initial" sediment size is defined 3) why initial sediment size in important.

On one hand, I appreciate that the authors have taken the time to try to test this hypothesis with field data. The sediment size and fracture spacing data are vitally important for our understanding of hillslopes. On the other hand, it seems fairly obvious that boulders in a talus pile immediately next to a rock wall would have sediment sizes that correspond to the fracture spacing in that rock wall. Fracture spacings are measured at the free boundary of the wall, where weathering processes can occur. Isn't it possible that the measured fracture spacings reflect a combination of latent and weathering-derived fractures? Either way, what is the functional importance of grain size set by latent fractures vs. a combination of latent and weathering? It is perhaps more interesting to find that talus material has not weathered since release from the wall. However, because there is no constraint on age of the talus pile, it is difficult to draw conclusions about the relevant weathering timescale. Further, the data presented in this paper do not have any relevance for subsequent weathering of sediment as it moves through the hillslope system and ultimately into channels. Other studies have found sediment size fining indicating a combination of selective transport and weathering. The authors contrast their findings with Neely and Dibiase 2020 and Sklar et al 2020, but these studies measured sediment sizes far away from their exposed bedrock sources. The authors should clarify that their findings have no bearing on sediment size evolution and transport long after detachment.

Looking at Figures 3 and 4, I am not convinced that sediment sizes in the talus pile are indistinguishable from fracture spacing in the rock wall. In fact, they seem to be substantially larger at many of the sites. The authors explain that this may because block detachments occur along wider fracture spacings, and subsequent blocks thus contain some of the smaller fractures within them. This is interesting and a fine interpretation, but conflicts with the conclusion that fracture spacing can be used to predict initial sediment size on hillslopes. The authors point out that p values for their data are large enough to be "insignificant." However, it is unclear how p values are calculated and whether they are meaningful for the data presented: "In each case, the increase in median particle diameter with increasing fracture spacing follows a trend with a slope that is statistically indistinguishable ($p>0.45$) from a 1:1 relationship in log-log space." From figure 4 it looks like perhaps the slopes are equivalent, but particle sizes are substantially shifted from fracture spacing. The smallest offset between particle size and fracture spacing is 42%. Let me be clear: this is not a flaw in the data, but in the interpretation and presentation.

Finally, it would be very helpful for the authors to more clearly outline the importance of this data. Even if fracture spacings perfectly matched sediment size in the talus piles, how is this helpful for future studies? Fracture spacing is very difficult to measure accurately, even in landscapes where clear, exposed bedrock exists. It is even more difficult in soil-mantled landscapes. The framework proposed in the paper is useful, if only because it points toward the difficulty and necessity for us to better understand rock and saprolite weathering and its role in producing initial sediment sizes. Perhaps one of the most interesting findings in this paper is the difference in grain size between lithologies. I think the paper would be much more interesting and useful if the authors amplified these findings. Overall, I think the findings in this paper are useful for advancing our fundamental understanding of hillslopes: but this does not come across clearly in the paper. I hope the authors can clarify the importance of their work.

Minor points

Sediment shape: Figure 6 shows differences in sediment shape between lithologies. While this is useful information, the discussion around shape could be toned down. The authors contrast their findings with Domokos et al., 2015, stating that "there is no evidence in our data that initial particle shape varies with size, contrary to the predictions from previous work that smaller particles should be more block-like on average." However, the particle shape-size trends in Domokos et al., 2015 saturate for grains around 50mm in length. Most of the data in this paper are at or above this range, so I wouldn't expect them to see the shape-size trends. Perhaps a more interesting comparison is to look at differences between the average shape data presented here and the saturation values in Domokos ($\sim$0.425 for c:a and 0.675 for b:a). Further, I'm not sure that finding difference in mean shape values between lithologies can be directly compared with the probability distributions of shape parameters in Domokos et al.

Ratio of timescales: The authors propose a framework in which the ratio between regolith residence time and particle detachment time determine initial sediment sizes. I think this framework is fine; however, the way it is presented assumes that regolith is necessary for weathering. I am still unconvinced that fracture spacing does not include effects from mechanical weathering (frost cracking, tree roots, thermal fluctuations, etc.). Perhaps the authors just need to clarify when the particle size clock starts (see next suggestion below). If it starts after particles are released from bedrock, then their framework makes sense. However if it starts when pure bedrock first begins to weather/crack, it may not be appropriate.

Definition of “latent” and “initial”: It’s currently a bit difficult to understand what the authors mean by “latent” and “initial.” A clear definition in the introduction would help a lot.

Talus sampling: In line 139 the authors explain that spatially uniform sediment sampling along the talus slope should yield an accurate grain size distribution even with size-selective entrainment. However, this assumes that size distributions change linearly downslope. The authors might want to simply point out this assumption.

Figure 3: The authors refer to parts of the figure by letter, but they’re not included in the figure.

Figure 4: A legend that identifies data points is needed. It is unnecessarily difficult to refer to figure 1 and remember the colors and shapes to understand figure 4.

Missing references: The authors should also cite some missing recent relevant studies: Shobe et al., 2016, who explore hillslope sediment size controls on river incision; Glade et al., 2017, who show data for boulder size distributions in an exposed bedrock system; and Glade and Anderson, 2018, who discuss the implications of weathering vs. erosion rate timescales on hillslopes; Ward 2019, who discusses ratios between incision rate and cliff retreat timescales; Duszynski et al., 2019 who review scarp retreat mechanisms and the role of weathering.

Suggested references:

Duszyński, Filip, Piotr Migoń, and Mateusz C. Strzelecki. "Escarpment retreat in sed-

imentary tablelands and cuesta landscapes–Landforms, mechanisms and patterns." Earth-Science Reviews 196 (2019): 102890.

Glade, R. C., and R. S. Anderson. "Quasi-steady evolution of hillslopes in layered landscapes: An analytic approach." Journal of Geophysical Research: Earth Surface 123.1 (2018): 26-45.

Glade, Rachel C., Robert S. Anderson, and Gregory E. Tucker. "Block-controlled hillslope form and persistence of topography in rocky landscapes." Geology 45.4 (2017): 311-314.

Shobe, Charles M., Gregory E. Tucker, and Robert S. Anderson. "Hillslope-derived blocks retard river incision." Geophysical Research Letters 43.10 (2016): 5070-5078.

Ward, Dylan J. "Dip, layer spacing, and incision rate controls on the formation of strike valleys, cuestas, and cliffbands in heterogeneous stratigraphy." Lithosphere 11.5 (2019): 697-707.

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