Review of the manuscript “Downstream rounding rate of pebbles in the Himalaya” by Pokhrel, et al., submitted to Earth Surface Dynamics

General Comments:
The authors present the paper “Downstream rounding rate of pebbles in the Himalaya”, which outlines a method for measuring roundness of pebbles, as well as proposes a model for relating pebble roundness to transport distance. They specifically address challenges with previous methods of measuring pebble shape parameters, and identify a method for automatic and repeatable extraction of these shape parameters (namely isoperimetric ratio) from 2D photographs of pebbles using publicly available software. This shape characterization method was applied to pebbles collected from two rivers in Nepal, as well as clasts found within conglomerate deposits in a similar region, which were then used to calculate rounding curves for two rock types within these watersheds. By determining transport distance of historical clasts, the authors drew conclusions about the length of paleo rivers in the Himalayas.

This work contributes a useful approach for relating clast shape to transport distance, especially for river systems where data collection is limited to shorter distances or a smaller number of field sites, or for applications in paleoenvironment reconstruction. Additionally, from my exposure to the pebble rounding literature, it seems that others emphasize rounding as a function of mass loss in order to draw general conclusions, while this study seems more practical for direct use in specific watersheds. However, I do think that this work could be even more impactful if the authors connected their results to the larger context of universal pebble rounding behavior, such that their work could readily be applied to other geomorphic settings. Given discussion of the results within this context, as well as editing for clarity and conciseness, I think that this paper suitable for publication in ESURF and believe that it contributes to the pebble rounding literature. I hope the authors find my comments to be helpful and constructive, and I wish them the best in their research endeavors.

Specific Comments:
Broadly, I think that the organization of the introduction (Section 1) can be improved and streamlined. Section 1.1 includes discussion on both previous pebble abrasion research, as well as shape parameters that have traditionally been used to quantify pebble roundness. Subsequently, Section 1.2 discusses shape parameters in depth, then Section 1.3 discusses controls on pebble shape and summarizes previous research in more depth. I would recommend combining the first two paragraphs of Section 1.1 with Section 1.3 and presenting this information first as background on pebble abrasion processes. I would then combine the last paragraph of Section 1.1 with Section 1.2 and present this information as background on shape indices.

Section 1.1, paragraphs 1 and 2 address previous research on pebble chipping/abrasion/attrition. It seems worthwhile to include a sentence or two at the outset on the definitions used in this paper, since previous studies use different terms to refer to specific breakdown mechanisms. For example, in paragraph 2, the authors write that “processes like sandblasting, chipping, and granular removal by crushing or grinding” fall under abrasion and

increase pebble roundness, but then in the same sentence, use the phrase “chipping of large fragments” as a process that reduce pebble roundness. As a reader, I am slightly confused as to how chipping is defined such that is can both increase and reduce roundness, especially since chipping appears to primarily be used in the literature to describe the process of pebble rounding due to bedload transport (e.g., Novak-Szabo, et al., 2018). Additionally, I am aware that crushing or grinding tends to fall under the purview of “comminution”, which primarily breaks rocks down into smaller pieces and may increase sphericity, but would not necessarily increase roundness. From my experience with the pebble abrasion literature, the terms “abrasion” and “chipping” tend to be used to describe the small-scale breaking off of edges and corners that progressively round rocks (e.g., Miller, et al., 2014; Szabo, et al., 2015; Novak-Szabo, et al., 2018), while “attrition” is a more general term that could describe small or large scale breakdown (e.g., Miller and Jerolmack, 2021), and “fragmentation” is used for significant breakdown into large pieces (e.g., Novak-Szabo, et al., 2018).

In general, I found Section 1.1 (last paragraph) and Section 1.2 to be rather lengthy in the description of shape parameters used in the literature and methods for calculating those shape parameters. For example, I think that the discussion of automated image processing methods for grain shape detection can be reduced to only methods utilized or built upon by this study. It may also help readers if you state that circularity and isoperimetric ratio are equivalent shape indices earlier in the paper, since some readers may be more familiar with the term circularity.

Section 1.3 addresses the effect of lithology on pebble rounding. I think this section could be strengthened with the addition of background on the relationship between material strength and attrition. Since rock strength is known to control rate of attrition (Sklar & Dietrich, 2001; Wang, et al., 2011 – Abrasion of Yardangs) and has implications for attrition mechanism (specifically for abrasion/chipping in Miller & Jerolmack, 2021), I feel that this may be useful in interpreting rounding of your granite vs quartzite pebbles.

I think that the inclusion of a figure (or addition to a pre-existing figure) could improve the discussion in Section 2.1 regarding selection of the normalized isoperimetric ratio as the roundness parameter. The reader might be able to better conceptualize the isoperimetric ratio and normalized isoperimetric ratio for different pebble shapes if there was a figure showing shapes and their *IR* values. Figure 12 already does this for normalized isoperimetric ratio.

In Figure 2 panel b, it may help to draw the reader’s eye to the location of the study catchments by outlining them in red or bolding the catchment names. Currently, the brown outline is a similar color to mid-elevations on the map.

The last three paragraphs of Section 2.4 include specific instructions for pebble shape extraction and measurement in ImageJ and ArcGIS. I feel that the explicit step-by-step instructions are unnecessary and could largely be eliminated, or included as an appendix, to shorten the paper.

Sternberg's law is first brought up in Section 3.1 (other than the abstract). Given that this is the basis of the proposed abrasion model, it may be appropriate to introduce Sternberg's law in the introduction section of the paper.

In Figure 4, you may want to increase font or bold the panel labels (a., b., c., d.) since they are a similar font size to the letters used for site locations.

The Figure 8 identifies a sample site along the Karnali River. When the figure is first referenced in Section 4.1, it is not immediately apparent to me whether additional field data was collected during this study, or of the same site is from Quick, et al. (2019). Later in Section 4.1, you state that the recycled pebble field data is from Quick, et al. (2019), but it may help to clarify this in the figure caption. Further, in Section 4.2, you mention more field data from the Bagmati River collected during this study. It may be relevant to briefly introduce this field site in the methods section, as well as place this site and the Quick, et al. (2019) site on the map in Figure 2.

In the discussion section, the authors address the coefficient of roundness, λ, and prefactor, k, which corresponds to initial shape of the pebbles. Since λ varies for the two rock types in this study, it would be interesting to address the relationship between material strength and the coefficient of roundness. There is also discussion of how the prefactor, k, varies depending on a variety of factors. Domokos, et al. (2015 – Universality of fragment shapes) show that fragmented rocks have a general mass and shape distribution. Assuming that rock fragments entering upland river systems in the Himalayas were generated by energetic processes, it might be interesting to address how the prefactor could be generalized across different watersheds. Further, assuming a general size distribution for initial fragments and that bedload dominates subsequent transport, a universal mass loss curve for particle rounding by bedload can be reached (Novak-Szabo, 2018). While this universal rounding curve relies on knowing the mass of an initial particle, perhaps you can discuss how universal behaviors, along with material-specific properties, can allow you to generalize your model and determine transport distance across a variety of watersheds/conditions.

Additionally, there is discussion of rapid rounding of granite pebbles within 8km of the source. I am interested whether the authors considered utilizing shorter distances, rather than 50km for the distance over which to fit a linear regression. In Figure 5a., the median roundness values appear to show the expected relationship where roundness increases toward 1 over the surveyed distance. Additionally, other studies (Miller, et al., 2014; Novak-Szabo, et al., 2018) observe the expected rounding curve over distances of ~10km in the field. Since some granite pebbles are already fairly rounded at 8km in your study area, I expect that even this short distance is sufficient for noticeable shape changes to occur. Would the results change if the same analysis was applied over shorter distances? Would the results agree if the authors compared them to a more traditional rounding curve applied to the 50km over which the granite clasts were collected?

Technical Comments:

L14: In the abstract, you state that the roundness coefficient is 8x greater for granite pebbles, but later state that it is 7x greater.

L23: Recommend use of semicolon or em dash rather than colon as punctuation after “This also applies to modern rivers”.

L26: Same as above regarding the colon after “not limited to Earth”.

L115: Appears to be a typo; should read “how *the* pebbles round”.

L175: Might consider referencing Figure 2c at the end of the sentence.

L181-182: Sentence is slightly confusing; I would recommend indicating that there is both quartzite and granite in *upstream reaches*, but quartzite bands are exposed downstream.

L188: No need for comma in this sentence.

L191: Citation for Mudd et al., 2022 should be in parentheses.

Figure 2 caption: The word “lithology” is misspelled in Line 3.

L217: Need a comma before the word “but”.

L240: Recommend use of semicolon rather than colon as punctuation after “object in a raster environment”.

L271-272: Consider rewording sentence for clarity.

L278: Recommend use of semicolon or period instead of colon.

L330: End quote of ‘scipy.optimise.minimise’ is facing outward.

L331: Start quote of ‘Nelder-Mead’ is facing outward.

L333: Start quote of ‘Nelder-Mead’ is facing outward.

L336: End quote of ‘minimise’ is facing outward.

L342: Recommend use of semicolon rather than colon for punctuation.

L342-343: Granite rounding coefficient is 7x that of quartzite differs from abstract.

Figure 7 caption: Rounding coefficient differs from abstract.

L358: Should be “boulders” rather than “boulder”.

L360-362: Sentence is confusing to follow.

L364-365: I also find this sentence somewhat confusing.

L371, 372: The letter “s” in sample should be lower case.

L377: Should be “behave”.

L379, 380: Missing word – *the* sampling site.

L391: Missing be comma before the word “which”.

L398: The word clast should be plural after granite and quartzite.

L401: Missing word – *the* modern channel.

Figure 9 caption: Missing *the* before “modern river”; could also say “modern Bagmati river” for succinctness.

Figure 10 caption: Needs space after period in Line 2.

L403-404: The Kathmandu Basin is repeated twice in the same sentence.

L408: End quotes at the end of the sentence are unnecessary.

L411: Word pebble should be plural.

L417: Missing end parenthesis after Figure 12.

L435: Citation for Lajeunesse, et al. 2010 should not be in parentheses.

Figure 12 caption: start quote before ‘a’ is facing out.

L456: Missing word – *a/this* new roundness model.

L456: Extra *the* before “ancient and modern sediments”.

L467: “fluvial environment” should be plural.

Section 6: Recommend paragraph form rather than bullet points.

L471-472: Extra *the* before word “pebble” and “2D”.

L478: Should remove “and” and replace with a comma.

L480-482: Run-on sentence; recommend rephrasing.

L480: Start quote for ‘Sternberg’s Law’ is facing out.