This paper demonstrates how ongoing impacts result in rock disaggregation from low to high impact energy/material strength.

This paper is a revision of a past version.

Overall, the revised version appears to adequately address past reviewer comments. For example, the variability in rock strength is a key component of the study that both reviews noted. I am in agreement with how the authors address this point. Natural rock heterogeneity will also be large due to differences in past exposure history of individual clasts. And sufficient language of the limitations of this study (concrete) vs. real rock are now discussed.

There were significant reluctance from Reviewer 2 as to the applicability of these experiments on cement to real rocks. Nevertheless, the authors note in their comments to reviewer that "*it is better to put out this new finding, and have other researchers build on and refine it, then to not put it out at all".* I agree. The authors now address limitations – and appropriate applications – for the study in the discussion.

Overall, based on experimental results, the authors conclude that there are three regimes of rock attrition that occurs due to impact. This is an important finding for understanding how and why – and predicting – particle size in stream environments.

I have two primary suggestions for revision 1) place the findings and work in the context of a subcritical to critical cracking conceptual framework from the beginning 2) considerably reorganize/simplify the writing of the text so that the hypotheses, results and conclusions more linearly fit together. Below are my comments regarding these two primary points and also some other minor issues.

1) **Placing the results in the context of subcritical vs. critical cracking**

- It is not clear what the difference between "chipping and fatigue failure" are from the introduction (or really even in the discussion). The introduction focuses on the former, but appears to say (pg 4ish) that fatigue is somehow a separate mechanism. There does appear to be a clearer explanation in the discussion. Move this to the intro. But do these compressional 'chipping' cracks not continue to grow then by fatigue (subcritically)?

- Overall, are you not in fact observing a transition from 'subcritical' to 'critical' regimes in your data? i.e. QuasiStable/progressive – vs. unstable crack growth for a given impact? The initial 'chipping cracks' at the contact zone are the first to grow once a subcritical threshold is met? Then, more growth sets in at intermediate energy? Then failure?

- From fracture mechanics experiments and theory (some of which is mentioned in the discussion), we know this relationship (subcritical to critical) is similarly non-linear, would produce the reduction in strength that you observe, and is known to be a "continuous phase" transition (see reviews like (Brantut et al., 2013).

- For this subcritical to critical regime, as the impact strength approaches the tensile strength (fracture toughness) of the rock, the probability of fragmentation due to crack propagation

would exponentially increase (after empirical relationships like Paris' Law). It seems this theory could also be called on to explain your observations.

- Ok – I see that you get to this in the discussion, but it seems a bit buried – and focused on 'life time' rather than 'cracking velocity'. Why not acknowledge this conceptual framework up front? It seems a simpler conceptual model for what you observe than what is presented. You even acknowledge that is likely what is happening. Also it would represent some of the first acknowledgement of the role of subcritical cracking generally in bedload attrition – which would eventually bring in the roll of climate, water temperature and chemistry etc.

- At a minimum it should be acknowledged that fatigue growth of cracking is a subcritical mechanism of time-dependent failure (see Atkinson, 1987) that is marked by progressive lengthening of individual cracks; and that such subcritical growth of fractures causes material strength to decrease. And that fragmentation is 'critical failure' by rapid unstable growth of an entire fracture network. **This is an unambiguous unequivocal rock mechanics concept to point out that nicely explains your data.**

- The resulting comparisons between 'strong' vs. 'weak' appear to support a subcritical progressive linear phase of cracking well below the material strength Fig 6), that is insensitive to material strength (consistent with fractures growing subcritically at impact energies well below the strength; controlled instead by subcritical material parameters).

- In any context, what, then, is chipping? Critical Fragmentation at a much smaller length scale? That is the real question here that your data can't really address, as you say, because of your high variance in strength. Very interesting.

2) Organization & clarity.

Similar to the other reviews, I still find the introduction to still be a bit overly long and wordy. I don't finish reading it fully understanding – from what is written there – why we should care to know that there is a continuous phase transition. It feels buried.

In pg 14 line 2. "proposed that in the low energy limit of impact attrition, the number of impacts required to cause dynamic fragmentation, Ni, diverges" Diverges from what to what? Meaning not clear.

Section 3.1– is this really how you want to lead off your results?! With a long discussion of why your cement did not behave? This entire section can be moved to the end of the results, and the 'whys' to the discussion as a caveat to your interpretation.

Indeed, the results section does not seem to clearly make the link between the stated goal of the proposed study and the results from the methods used. This could be addressed by some clear statements at the beginning of the methods – we measure xxx in order to determine xxxx. If we see xxx

in our results, then we can interpret that as pxxx. The sentence along these lines"By measuring attrition rate, particle shape, and material strength under a known collision energy, we are able to characterize the relevant quantities needed to examine the transition from chipping to fragmentation." at the end of the introduction is sufficiently vague as to provide no clarity or direct link for the reader.

Another example of this is the first line of the conclusion – where you talk about particle shape. The reader should have a clear sense from the beginning how and why this maters, but does not.

Overall, the manuscript seems quite rambly and poorly focused. There are real gems of conclusion and results in there, but the reader has to work to find them.

1) **Other minor points/questions**

Folks cite 10-20% of strength for a subcritical threshold. Do you see that in your data?

What controversy is there over fracture toughness? In fact it is very relevant because how it changes as cracks grow for a given impact energy directly speaks to the existing flaws in the material being fractured, and again provides a nice conceptual framework that is consistent with your observations.

Why does material strength change – because cracks are growing. I don't see this link drawn clearly as an explanation of the overall gradation between chipping to fragmentation.

The newly incorporated discussion of results by Pal et al., (2021) strenghthens the overall conclusions/results of the study.

BRANTUT, N., HEAP, M., MEREDITH, P. & BAUD, P. 2013. Time-dependent cracking and brittle creep in crustal rocks: A review. *Journal of Structural Geology,* 52**,** 17-43.