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Interactive comment

Interactive comment on "Short communication: Runout of rock avalanches limited by basal friction but controlled by fragmentation" *by* Øystein T. Haug et al.

Anonymous Referee #2

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General Comments **

In summary, the present "short communication" (from now on: SC) displays the text-part (introduction, methods, results and discussion, conclusion) of a previous open access publication of experimental data (Haug et al. 2020). Additionally, the present SC constitutes a follow up article to the authors previous publication Haug et al. 2016.

The scientific results and conclusions are presented in a clear, concise, and well-structured way.

The present SC addresses fragmentation, a generally observed feature of rock avalanches, and its role within the still not thoroughly understood emplacement (run-

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Discussion paper

out) of highly mobile rock avalanches, despite more than a century of research. Fragmentation itself became a field of interest in rock avalanche research, about two decades ago and remained a promising attempt since then. Rock avalanches, because of their size, violent dynamics and nevertheless overall scarce occurrence (luckily), pose a huge challenge in their investigation at laboratory scale or to be addressed within the limits of available computational power, as the authors correctly state in the SC.

The present SC presents and discusses the results of so called 1g laboratory experiments. The drawback of these experiments is, that governing velocities and stress states are reduced by 2 to 3 orders of magnitude compared to the natural prototype model. Furthermore, the model boundaries have to be set so close, that the models resemble not even a millionth of the natural volumetric scale. Other fields of science experience similar problems: Especially physics faces since decades a growing gap between theories proposed by theoretical physics and the (even theoretical) ability of experimental physics to put these theories to observable and repeatable tests which threatens their epistemological validity. Inventing to a certain degree simple but useful experiments for big theoretical questions displays a main quest in physics today. Hence, 1 g experiments (and corresponding, relatively small-scale numerical models) are, what is currently available to many research groups, after reviewing further publications on the current topic. In this sense the present SC matches the, let's call it "relative state of the art", as defined by the cited articles. In that way the SC can be considered a good contribution to scientific progress.

But on the other hand, it shall be stated, that more rigorous publications on the present topic already exist which are more or less ignored by the SC. Especially the publication of Imre et al, 2010 *) not only presents data derived from a physical modelling environment of much higher velocities and stress states, such as much closer to natural situation, but also suggests quantities of energy dissipated by fragmentation. They also suggest what fragmentation due to inter-particle collisions actually may cause –

the dispersive stress model and show, applying a numerical model, how the spreading of a rock avalanche – hence the rapid propagation of the front at minor propagation of the center of mass, emerges from the dispersive stress model. Since velocities and stress states within their physical model applied still not fully resembled the natural model, they present in Imre et al, 2011 **) an brittle analogue material together with a rigorous scaling of all properties of the analogue material according to the physical modelling applied within. Based in these, dependencies are derived how physical properties of natural rock materials, like strength, pre-fracturing etc., governs the run-out of rock avalanches which may became a truly useful tool in practical hazard mitigation in future.

These topics are alle covered or sometimes at least scratched within the SC also, but within Haug et al. 2016, Imre et al., 2010 just serves as yet another reference on fragmentation in rock avalanches without referring to any details. Within the present follow up SC this publication is completely ignored by the authors. To be clear, there is no intention to advocate the work by Imre et al. They applied a complicated and expensive physical modelling environment and it may become useful to refer to 1g experiments instead to speed up research on rock avalanches as I stated above on physics in general. But scientific progress can be achieved only if something which is proposed as a valid attempt, is thoroughly discussed, in its strengths and weaknesses, to its predecessor, or in the case of Imre et al., 2010, to a model which is by physics much closer to the natural situation than the 1g experiment presented within the SC. Since the present SC lacks such a proper discussion, the SC is considered just a fair overall contribution to scientific progress, although the scaling law presented is innovative. The fact that currently a number of research groups apply 1g experiments of the kind presented within the SC, proofs by its own their popularity but not necessarily their suitability for lasting progress in rock avalanche research.

*) Imre, B., J. Laue, and S. M. Springman (2010), Fractal fragmentation of rocks within sturzstroms: Insight derived from physical experiments within the ETH geotechnical

drum centrifuge, Granular Matter, 12(3), 267–285, doi:10.1007/s10035-009-0163-1 **)
Imre, B., Wildhaber, B., and S. M. Springman (2011), A physical analogue material to simulate sturzstroms. Int. J. of Physical Modelling in Geotechnics 2011 11:2, 69-86.

Specific Comments **
In section 3.3 the authors apply their experimentally derived data to “a natural data set”. This data set resembles nine rock avalanches reported by Locat et al. (2006). Due to comprehensible reasons the authors derive a data fit to four natural cases. According to the text theses four cases “cover a range of two orders of magnitude (from 2 Âů 10*6 to 90 Âů 10*6 m3)”.

Based on these fit authors claim:

“The similarity seen between experimental and natural data suggests universality with respect to the empirical constants and that the rock avalanches considered here all have a close to constant effective friction of about 0.15.”

“This shows that fragmentation plays a governing role in the runout of rock avalanches and should be included in hazard assessments.”

In section 4 the author finally come the conclusion that: “The law is validated against a natural data set proving its universality and predictive power.”

First: A data set of four fits out of nine cases is extremely limited. There are data of much more cases of rock avalanches available. Furthermore, known cases of rock avalanches range from 1 10*6 to 1 10*10 m3, these are 4 orders of magnitude. Adding Martian rock avalanches this range extends to 7 orders of magnitude. Therefore, the data presented within the SC are in fact limited to a very narrow fit giving no justification for the claimed “universality” and “predictive power” of their derived fit. These terms shall be omitted therefore as unproven.

Second: The fact that the experiments yielded an effective friction of about 0.15 displays an interesting observation, but for this class of rock avalanches this was known since Albert Heim. It remains unclear how fragmentation contributes to such a low friction within the experiment, hence how it "plays a governing role in the runout of rock avalanches", especially since fragmentation has been identified as a major energy sink at the same time. Therefore, while fragmentation truly displays an important role in further research on rock avalanches, and this SC contributes to it, this SC provides no hint at all, how a fragmentation shall be "included in hazard assessments" in practise. This claim shall be omitted.

Technical Corrections **
None.

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