<u>Response to the Referee 2's comments</u>

Manuscript ID: EGUSPHERE-2022-268
Title: An experimental perspective on the effects of initial structures on rock avalanches' propagation and sedimentary characteristics
Authors: Zhao Duan, Yan-Bin Wu, Qing Zhang, Zhen-Yan Li, Lin Yuan, Kai Wang, and Yang Liu

Dear Luigi Guerriero:

On behalf of my co-authors, we would like to express our sincere gratitude for your comments. We have considered your comments very carefully and made corresponding revisions. The revisions are highlighted in red in the manuscript. The responses to your comments are detailed as follows, in which the paragraphs in **<u>normal fonts</u>** are the comments and the authors' responses are in ***<u>italic</u>***.

Yours sincerely,
Yan-Bin Wu
Corresponding author: Yan-Bin Wu
E-mail: 19209071021@stu.xust.edu.cn

<u>Response to the comments:</u>

Comment 1: This manuscript entitled "An experimental perspective on the effects of initial structures on rock avalanches' propagation and sedimentary characteristics" presents results from a rock avalanche runout experiment, in terms of propagation characteristics and deposit morphology, to identify potential controlling action of geologic setting of the source volume (i.e. rock fragmentation due to discontinuities) and slope angle. The topic fits the scope of the journal and might be of interest for the scientific community, however, in my opinion, the manuscript, in its actual form, is not ready for publication in an international journal as Solid Earth. My major concern is related to the novelty that the paper brings to the scientific community, since the authors refers their interpretations to similar experiments already conducted. In addition, the significance of the experiment is limited by i) the lack of a specific geologic contextualization (i.e. it is not clear to me if the results of the experiment are of general interest or refer to a specific geologic predisposing condition), ii) an oversimplification of the analysis that use blocks of a single dimension and shape (i.e. in natural rock avalanches block shape and dimension can be extremely variable in relation to the local geologic setting and their interaction during motion is consistently related to their variable form and shape), iii) the lack of a robust interpretation of the results based on results from real rock avalanches field analyses (i.e. the authors substantially interpreted the results on the basis of the results of further experiments). Finally, the significance of the paper and the novelty bring to the knowledge of the topic do not emerge from the text. To facilitate the process of addressing the indicated limitations, I attached an annotated manuscript with specific comments.

Answer: Thank you very much for your comments. The novelty of this paper is the different arrangement of blocks to simulate the differences in rock structures in the source volume of rock avalanches. We know that rock avalanches often evolved from disaggregated rock masses by discontinuous sets. The disaggregated rock masses are blocky and with different orientation of long axis for different rock avalanches (Figure 1, 2, 3, and 4) (Mavrouli et al., 2015; Jaboyedoff et al., 2009; Brideau et al., 2009; Pedrazzini et al., 2013). In previous studies, Manzella and Labiouse (2009, 2013) performed experimental rock avalanches considering conditions the long axis of the blocks was adjusted parallelly to the strike of the inclined plate (LV configuration in this study) and the blocks were filled randomly. In these two conditions, the experimental material is only the blocks but without fine matrixes. However, the rock structures in the source volume of rock avalanches are various, including the long axis of the blocks perpendicular to the strike of the inclined plate EP, parallel to the strike of the inclined plate LV, perpendicular to the inclined plate LP. In addition, the materials of rock avalanches also include fine matrixes. Yang et al. (2011) conducted experiments on the materials comprising simultaneously large blocks and granular matrixes. However, the blocks were cubes; therefore, the researchers could not examine the orientation characteristics of large blocks in deposits. We supplemented the section "4.5 Comparison with previous studies" to compare with previous studies in multiple aspects and to point out the novelty of this study. Please see line 405-425.

The results of the experiment are of general interest because the rock masses of rock avalanches are often disaggregated by discontinuous sets (Figure 1, 2, 3, and 4), and therefore having different rock structures in their source volume, such as the distributions of the long axis of the blocks aforementioned.

We simplified the shape of irregular blocks in real rock avalanches. In the study of Manzella and Labiouse (2013), they demonstrated a similarity in transfer of momentum in spite of a simplification of block shape. The deposit architecture showed similarity with natural avalanche events with the simplified blocks. Moreover, this kind of simplification in shape of blocks has been applied to many previous experimental researches (Okura et al. 2000a, b; Phillips et al. 2006; Yang et al. 2011; Manzella and Labiouse. 2013) and numerical simulating studies (Jaboyedoff et al. 2009; Welkner et al. 2010), and showed good results in simulating the influences of initial structured block arrangement to the fragmented rock mass.

We have supplemented more descriptions and discussions on to relate the experiments and natural avalanche events in section "3.2.2 Surface structures and sedimentary

characteristics", "4.1 Runout of rock avalanches", and "4.2 Morphological differences and corresponding reasons". Please see line 247-253, 303-315, and 325-329.

We provide the significance and the novelty of this paper in section "1 Introduction" and "5 Conclusions". Please see line 100-104 and 437-441.

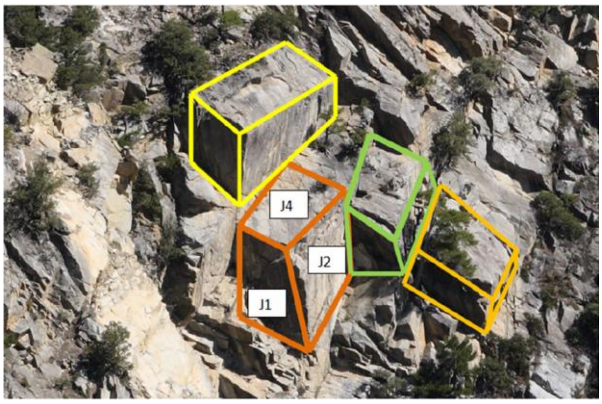

Figure 1: examples of blocky rock masses in source volume (Mavrouli et al. 2015)

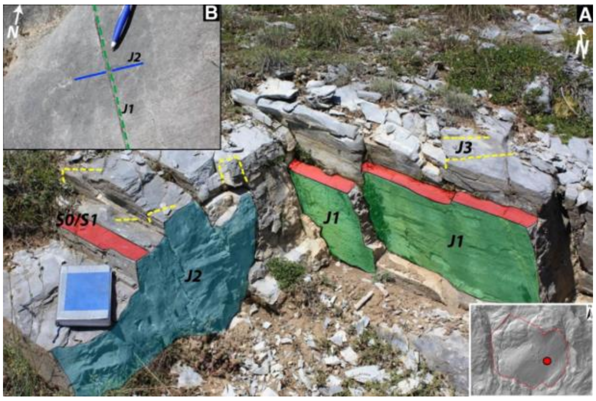

Figure 2: examples of blocky rock masses in source volume of the Sierre rock avalanche (Pedrazzini et al. 2013)

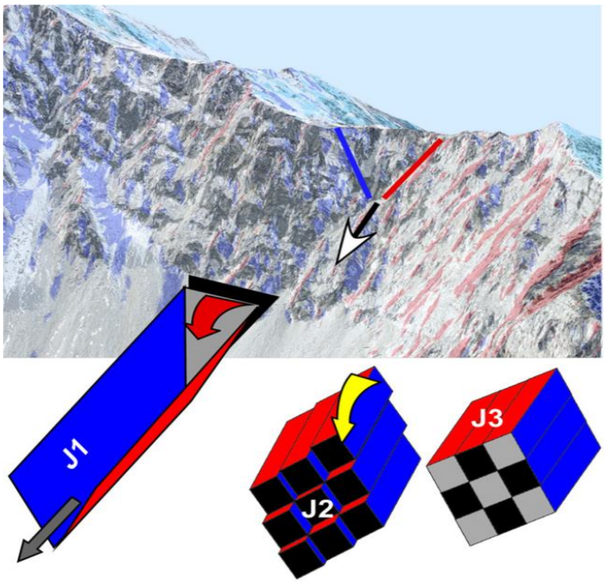

Figure 3: examples of blocky rock masses in source volume of the Frank rock avalanche (Jaboyedoff et al. 2009)

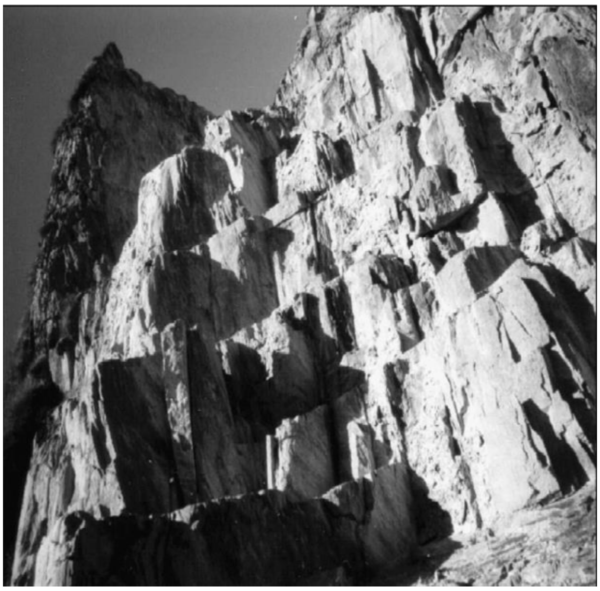

Figure 4: examples of blocky rock masses in source volume of the Randa rockslide (Brideau et al. 2009)

Ref:

Mavrouli O, Corominas J, Jaboyedoff M (2015) Size Distribution for Potentially Unstable Rock Masses and In Situ Rock Blocks Using LIDAR-Generated Digital Elevation Models. Rock Mechanics and Rock Engineering, 48(4):1589-1604. https://doi.org/10.1007/s00603-014-0647-0

Pedrazzini A, Jaboyedoff M, Loye A, Derron M-H (2013) From deep seated slope *deformation to rock avalanche: Destabilization and transportation models of the Sierre landslide (Switzerland). Tectonophysics, 605:149-168. https://doi.org/10.1016/j.tecto.2013.04.016*

Jaboyedoff M, Couture R, Locat P (2009) Structural analysis of Turtle Mountain (Alberta) using digital elevation model: Toward a progressive failure. Geomorphology, 103(1):5-16. https://doi.org/10.1016/j.geomorph.2008.04.012

Brideau M-A, Yan M, Stead D (2009) The role of tectonic damage and brittle rock fracture in the development of large rock slope failures. Geomorphology, 103(1):30-49. https://doi.org/10.1016/j.geomorph.2008.04.010

Okura Y, Kitahara H, Sammori T, Kawanami A (2000) The effects of rockfall volume on runout distance. Engineering Geology, 58(2):109-124. https://doi.org/10.1016/S0013-7952(00)00049-1

Okura Y, Kitahara H, Sammori T (2000) Fluidization in dry landslides. Engineering Geology, 56(3):347-360. https://doi.org/10.1016/S0013-7952(99)00118-0

Phillips JC, Hogg AJ, Kerswell RR, Thomas NH (2006) Enhanced mobility of granular mixtures of fine and coarse particles. Earth and Planetary Science Letters, 246(3):466-480. https://doi.org/10.1016/j.epsl.2006.04.007

Yang Q, Cai F, Ugai K, Yamada M, Su Z, Ahmed A, Huang R, Xu Q (2011) Some factors affecting mass-front velocity of rapid dry granular flows in a large flume. Engineering Geology, 122(3):249-260. https://doi.org/10.1016/j.enggeo.2011.06.006

Manzella I, Labiouse V (2013) Empirical and analytical analyses of laboratory granular flows to investigate rock avalanche propagation. Landslides, 10(1):23-26. https://doi.org/10.1007/s10346-011-0313-5

Jaboyedoff M, Couture R, Locat P (2009) Structural analysis of Turtle Mountain (Alberta) using digital elevation model: Toward a progressive failure. Geomorphology, 103(1):5-16. https://doi.org/10.1016/j.geomorph.2008.04.012

Welkner D, Eberhardt E, Hermanns RL (2010) Hazard investigation of the Portillo Rock Avalanche site, central Andes, Chile, using an integrated field mapping and numerical modelling approach. Engineering Geology, 114(3):278-297. https://doi.org/10.1016/j.enggeo.2010.05.007

Comment 2: Consider to change the title in: Effect of structural setting of source volume on rock avalanche mobility and deposit architecture.

Answer: Thank you very much for your suggestions. We have changed the title of the manuscript into "Effect of structural setting of source volume on rock avalanche mobility and deposit architecture".

Comment 3: Not clear! The implication of relating morphology of rock avalanches deposit and their mobility with characteristics of involved rocks should be better clarified also in the context of landslide hazard.

Answer: Thank you very much for your comments. We have reorganized the sentence and pointed out the morphology of rock avalanches deposit and their mobility with characteristics of involved rocks. Please see line 10-12.

Comment 4: Please avoid parenthesis.

Answer: Thank you very much for your comments. We have deleted parenthesis and set the content in the parenthesis as a complete sentence. Please see line 12-15.

Comment 5: In my opinion this research might provide a significant contribution relating geologic setting of source volume to landslide mobility and deposit architecture. In this perspective a better description of this aspect and related interpretation in the context of potential settings promoting rock avalanche initiation should be provided.

Answer: Thank you very much for your comments. Just as you stated that this research might provide a significant contribution relating geologic setting of source volume to landslide mobility and deposit architecture. We have supplemented more descriptions of this aspect and related the experiments to natural avalanche events. Please see line 247-253, 303-315, and 325-329.

Comment 6: Not clear. Do you meant discontinuity fill by soils? In this case, the presence of a granular fill is often related to the proximity to the ground surface so that it is not fully generalizable in terms of controlling action on rock avalanche development.

Answer: Thank you very much for your comments. Just as you guessed, here we mean discontinuity filled by soils. However, it is not proper to the case of this study. Therefore, we deleted the sentence.

Comment 7: It would be useful here to add a couple of sentences about the phenomenon of rock avalanche hypermobility and associated conditions.

Answer: Thank you very much for your suggestions. We have supplemented sentences on rock avalanche hypermobility and associated geologic settings including the Sierre rock avalanche in Switzerland (Pedrazzini et al., 2013), the Randa rockslide in Switzerland (Brideau et al., 2009), and the Frank rock avalanche in Turtle Mountain, Canada ((Jaboyedoff et al., 2009). Please see line 44-51.

Ref:

Pedrazzini A, Jaboyedoff M, Loye A, Derron M-H (2013) From deep seated slope deformation to rock avalanche: Destabilization and transportation models of the Sierre landslide (Switzerland). Tectonophysics, 605:149-168. https://doi.org/10.1016/j.tecto.2013.04.016

Brideau M-A, Yan M, Stead D (2009) The role of tectonic damage and brittle rock fracture in the development of large rock slope failures. Geomorphology, 103(1):30-49. https://doi.org/10.1016/j.geomorph.2008.04.010

Jaboyedoff M, Couture R, Locat P (2009) Structural analysis of Turtle Mountain (Alberta) using digital elevation model: Toward a progressive failure. Geomorphology, 103(1):5-16. https://doi.org/10.1016/j.geomorph.2008.04.012

Comment 8: Are you sure you are considering rock avalanche dynamics? Or simply the kinematics (i.e. only characteristics of motion such as velocity distribution, movement direction etc...).

Answer: Thank you very much for your comments. We mean the kinematics of rock avalanches and do a corresponding revision. Please see line 52.

Comment 9: Not clear. Are you still referring to the geologic setting of the source volume?

Answer: Thank you very much for your comments. We mean the geologic setting of the source volume of rock avalanches and do a corresponding revision. Please see line 69.

Comment 10: Here you need to clearly state the effective contribution of the paper. In addition, consider to briefly describe intrinsic limitation of the analysis. For instance, the limitation relates to the consideration of blocks of a regular form, which is not often true in natural conditions.

Answer: Thank you very much for your comments. We have added descriptions on the contribution of the paper in this part. Just as you pointed "this research can provide a contribution relating geologic setting of source volume to landslide mobility and deposit

architecture." Moreover, we have supplemented the limitations of this work. Please see line 100-104.

Comment 11: Are you sure that this simplification does not prevent to obtain reliable results? My question is related to the observation that rock avalanches commonly involve irregularly shaped blocks (i.e. variable shape and dimension) that might have a consistently different kinematics.

Answer: Thank you very much for your comments. We simplified the shape of irregular blocks in real rock avalanches. In the study of Manzella and Labiouse (2013), they demonstrated a similarity in transfer of momentum in spite of a simplification of block shape. The deposit architecture showed similarity with natural avalanche events with the simplified blocks. Moreover, this kind of simplification in shape of blocks has been applied to many previous experimental researches (Okura et al. 2000a, b; Phillips et al. 2006; Yang et al. 2011; Manzella and Labiouse. 2013) and numerical simulating studies (Jaboyedoff et al. 2009; Welkner et al. 2010), and showed good results in simulating the influences of initial structured block arrangement to the fragmented rock mass.

Ref:

Okura Y, Kitahara H, Sammori T, Kawanami A (2000) The effects of rockfall volume on runout distance. Engineering Geology, 58(2):109-124. https://doi.org/10.1016/S0013-7952(00)00049-1

Okura Y, Kitahara H, Sammori T (2000) Fluidization in dry landslides. Engineering Geology, 56(3):347-360. https://doi.org/10.1016/S0013-7952(99)00118-0

Phillips JC, Hogg AJ, Kerswell RR, Thomas NH (2006) Enhanced mobility of granular mixtures of fine and coarse particles. Earth and Planetary Science Letters, 246(3):466-480. https://doi.org/10.1016/j.epsl.2006.04.007

Yang Q, Cai F, Ugai K, Yamada M, Su Z, Ahmed A, Huang R, Xu Q (2011) Some factors affecting mass-front velocity of rapid dry granular flows in a large flume. Engineering Geology, 122(3):249-260. https://doi.org/10.1016/j.enggeo.2011.06.006

Manzella I, Labiouse V (2013) Empirical and analytical analyses of laboratory granular flows to investigate rock avalanche propagation. Landslides, 10(1):23-26. https://doi.org/10.1007/s10346-011-0313-5

Jaboyedoff M, Couture R, Locat P (2009) Structural analysis of Turtle Mountain (Alberta) using digital elevation model: Toward a progressive failure. Geomorphology, 103(1):5-16. https://doi.org/10.1016/j.geomorph.2008.04.012

Welkner D, Eberhardt E, Hermanns RL (2010) Hazard investigation of the Portillo Rock Avalanche site, central Andes, Chile, using an integrated field mapping and numerical modelling approach. Engineering Geology, 114(3):278-297. https://doi.org/10.1016/j.enggeo.2010.05.007

Comment 12: Please clarify why it is needed.

Answer: Thank you very much for your comments. We should test the frictional features for comparing the friction coefficient of the interface between sand and the plexiglass. The frictional features will influence the motion characteristics of experimental rock avalanches.

Comment 13: This is a description of the method. Please move this sentence to the appropriate section.

Answer: Thank you very much for your suggestions. We have moved this sentence to the section of experimental method. Please see line 162-164.

Comment 14: Please clarify in the method section how duration was derived.

Answer: Thank you very much for your comments. The duration of experimental rock avalanches was from the moment the material was released to the moment the front of the sliding mass ended moving forward. We added the description in line 164-165. Please check.

Comment 15: Please use a consistent unit (i.e. cm).

Answer: Thank you very much for your comments. We have revised the unit and use consistent unit of meter in runout section and morphological parameters of the experimental rock avalanches.

Comment 16: Although an effect is observed a much significant control seems to be related to slope angle.

Answer: Thank you very much for your comments. Just as you said that slope angle has a larger influence to the runout of the mass flows, however the influence from the initial configuration is still great. In addition, the decrease of runout at different slope angles is also related to the decrease of horizontal projected length of the inclined plate when keeping a constant height of the centre of gravity. Comparing the morphological

parameters of the resulting deposits, we found that the initial configuration had a greater influence than slope angle. There are previous studies on rock avalanches affected by slope angle, but few studies on rock avalanches affected by the initial configuration.

Comment 17: Please support you interpretation through appropriate references. In absence of references they can be considered only speculations.

Answer: Thank you very much for your comments. We have added references to support the statement. Please see line 277-278.

Comment 18: Please support you interpretation through appropriate references. In absence of references they can be considered only speculations.

Answer: Thank you very much for your suggestions. the configuration of EP is absence in the study of Manzella and Labiouse (2013) and previous others' studies. Therefore, this part is a speculation according to the experimental phenomena.

Ref:

Manzella I, Labiouse V (2013) Empirical and analytical analyses of laboratory granular flows to investigate rock avalanche propagation. Landslides, 10(1):23-26. https://doi.org/10.1007/s10346-011-0313-5

Comment 19: Please support you interpretation through appropriate references. In absence of references they can be considered only speculations.

Answer: Thank you very much for your suggestions. the configuration of LP is absence in the study of Manzella and Labiouse (2013) and previous others' studies. Therefore, this part is a speculation according to the experimental phenomena.

Ref:

Manzella I, Labiouse V (2013) Empirical and analytical analyses of laboratory granular flows to investigate rock avalanche propagation. Landslides, 10(1):23-26. https://doi.org/10.1007/s10346-011-0313-5

Comment 20: Please support you interpretation through appropriate references. In absence of references they can be considered only speculations.

Answer: Thank you very much for your comments. We have supplemented references to

support the statement. Please see line 386.

Comment 21: Please provide a better description of the significance of the paper in the context of the international literature and comprehensively describe the contribution it brings to the topic.

Answer: Thank you very much for your comments. We have rewritten this part and pointed out the possible significant contribution of this work. Please see line 437-441.