Responses to Reviewer #2

General Comments:

This manuscript provides a systematic investigation of the dynamics of the strong earthquake-induced Mogangling paleo-landslide by integrating topographic reconstruction, discrete element simulation, energy analysis, and Alpha Shape-based morphological quantification. The research demonstrates methodological innovation and in-depth analysis. Its outstanding contribution lies in proposing a quantitative method for identifying "effective collisions" and successfully revealing the intrinsic relationship between energy evolution and the structural fragmentation of the landslide mass (i.e., volume expansion and surface area growth). This offers a novel perspective for understanding the energy and structural evolution processes of high-altitude, long-runout landslides. Although certain limitations exist, the robustness of the conclusions has been ensured through sensitivity analysis and other means. The study holds significant theoretical value and practical implications for risk assessment of such landslides, representing a comprehensive and solid piece of outstanding work.

In summary, I see potential in the manuscript and it may eventually meet standards of Natural Hazards and Earth System Sciences after a moderate revision after addressing my concerns listed below.

Response: We would like to express our sincere gratitude for your encouraging evaluation and the time you took to review our manuscript. We are particularly heartened by your recognition of the methodological innovations in this study, especially regarding the quantitative identification of "effective collisions" and the analysis of the intrinsic relationship between energy evolution and structural fragmentation. Your positive feedback has given us great confidence in the value of this work.

We have carefully studied the specific concerns listed below and have made corresponding revisions to further improve the quality and rigor of the manuscript.

Please find our point-by-point responses to your comments below.

Specific comments:

1. Some figure titles could be shortened to enhance clarity.

Response: We agree with the reviewer that concise figure titles significantly enhance clarity and readability. We have carefully reviewed all figure captions and simplified those that were overly wordy or repetitive without losing necessary information.

Figure	Original Caption	Revised Caption
Fig. 5	Effective collisions identification: (a) definition of effective collisions; (b) threshold=10%; (c) threshold=20%; (d) threshold=30%; (e) threshold=40% and (f) threshold=50%.	Effective collisions identification: (a) definition of effective collisions; (b-f) threshold=10%, 20%, 30%, 40% , 50%.
Fig. 9	Energy analysis for 10 individual blocks in Mogangling landslide: (a) energy evolution of point 1 ; (b) energy evolution of point 2 ; (c) energy evolution of point 3 ; (d) energy evolution of point 4 ; (e) energy evolution of point 5 ; (f) energy evolution of point 6 ; (g) energy evolution of point 7 ; (h) energy evolution of point 8 ; (i) energy evolution of point 9 and (j) energy evolution of point 10.	Energy analysis for 10 individual blocks in Mogangling landslide: (a-j) energy evolution of point 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

2. The physical and mechanical parameters assigned to the Discrete Element Method (DEM) model should be clearly documented with their sources.

Response: We thank the reviewer for emphasizing the importance of parameter

documentation. In the revised manuscript, we have clarified the sources for the physical and mechanical parameters in Section 2.1 and the caption of Table 1.
Specifically, we have detailed that:

1. Basic physical parameters were obtained from laboratory tests on rock samples collected from the site.

2. Rock mass strength parameters were estimated using the Hoek-Brown criterion based on field geological survey data and empirical values for similar granite lithologies in the Dadu River region.

Citations for the empirical values and comparative studies have been added to the revised text and table caption to ensure reproducibility.

References:

Wu, H., Shi, A., Ni, W., Zhao, L., Cheng, Z., and Zhong, Q.: Numerical simulation on potential landslide–induced wave hazards by a novel hybrid method, Eng. Geol., 331, 107429, https://doi.org/10.1016/j.enggeo.2024.107429, 2024.

Wu, J., Wang, Y., Dong, S., Chen, Y., and Wang, L.: Genetic Mechanism and Failure Process of the Mogangling Seismic Landslide, J. Geol. Soc. India, 82, 277-282, https://doi.org/10.1007/s12594-013-0150-3, 2013.

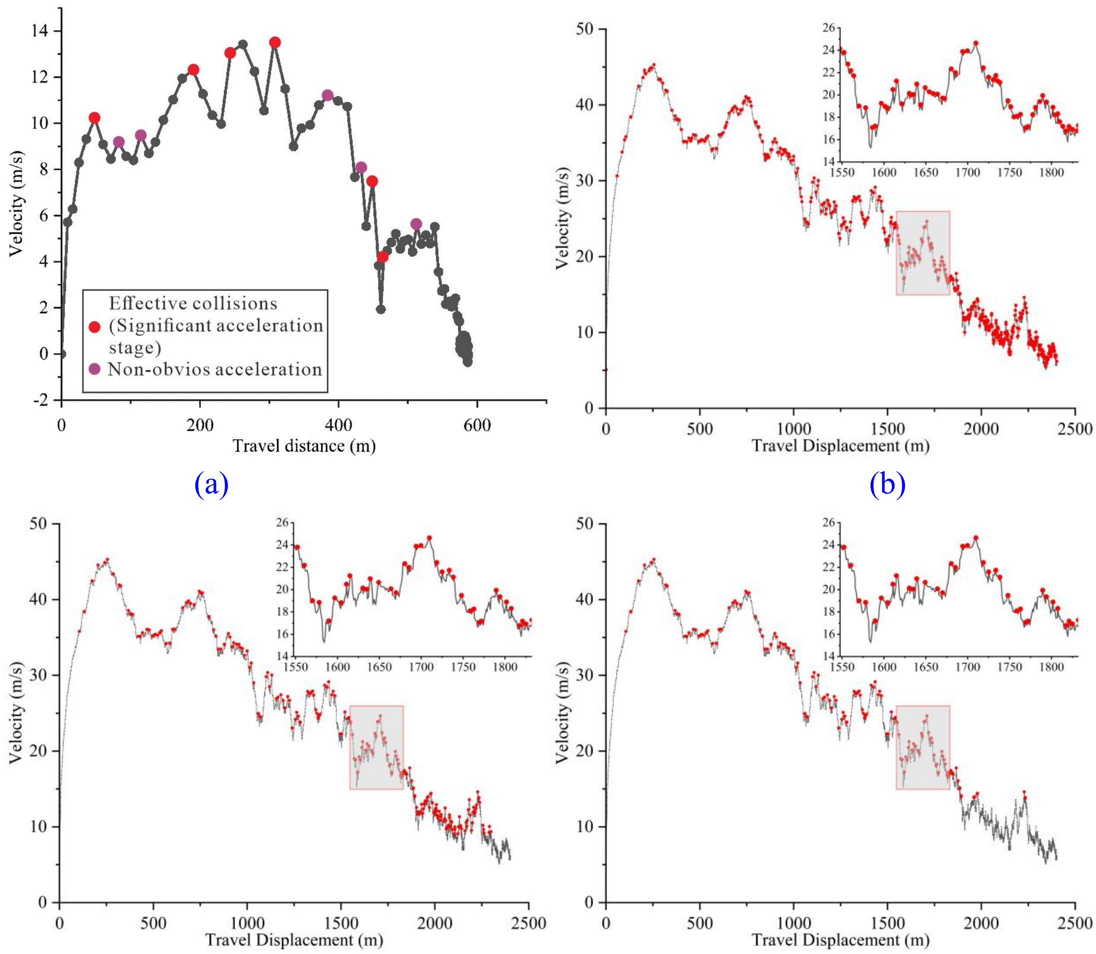
Zhao, B., Wang, Y., Wu, J., Su, L., Liu, J., and Jin, G.: The Mogangling giant landslide triggered by the 1786 Moxi M 7.75 earthquake, China, Nat. Hazards, 106, 459-485, https://doi.org/10.1007/s11069-020-04471-1, 2021.

3. The rationale behind the 30% threshold for defining effective collisions requires further elaboration.

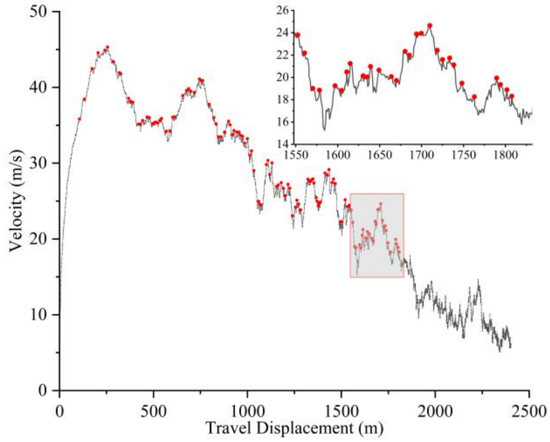
Response: We appreciate the reviewer's request for further clarification on this critical parameter. The selection of the 30% threshold was not arbitrary but was determined through a systematic sensitivity analysis aimed at optimizing the Signal-to-Noise

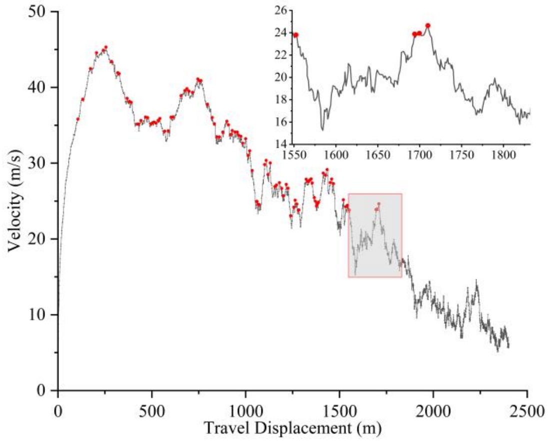
Ratio (SNR) in the velocity data. In Discrete Element Method (DEM) simulations, block velocities often exhibit minor high-frequency fluctuations due to numerical contact adjustments and friction, which do not represent physical collisions. As shown in Fig. 5, the lower thresholds (10%–20%) were too sensitive, capturing these minor numerical fluctuations (noise) as false positives, leading to an overestimation of collision frequency. These higher thresholds were overly stringent, filtering out legitimate impact events that involved significant energy transfer but lower instantaneous acceleration peaks (false negatives).

Therefore, the 30% threshold was identified as the optimal balance point where numerical noise is effectively filtered out while significant kinematic changes induced by physical impacts are accurately retained. We have expanded the explanation in Section 2.2 of the revised manuscript to articulate this rationale more clearly.



(c) (d)





(e) (f)

Fig5. Effective collisions identification: (a) definition of effective collisions; (b-f) threshold=10%, 20%, 30%, 40%, 50%.

4. The conclusion should be started with a short paragraph briefly explaining the study's topic, contribution, and methodology. Then, present the main findings as clear and concise bullet points.

Response: We appreciate the reviewer's constructive suggestion regarding the structure of the conclusion. We have rewritten the Conclusion section to strictly follow the recommended format. In the revised manuscript, we have added an introductory paragraph that summarizes the study's topic (the Mogangling landslide), its main contributions (energy-structure coupling analysis), and the methodology used (topographic reconstruction and DEM simulation). Following this summary, the specific findings are presented as clear and concise bullet points:

4. Conclusions

This study investigated the dynamic evolution and energy transfer mechanisms of the Mogangling high-altitude long-runout landslide triggered by the 1786 Kangding earthquake. By integrating pre-landslide topographic reconstruction based on contour continuity, 3D discrete element numerical simulation and Alpha Shape structural quantification, we successfully reproduced the landslide process. This work establishes a quantitative framework linking microscopic block collisions to macroscopic morphological changes, providing a theoretical basis for analyzing energy conversion in complex rock avalanches.

5. The typesetting of equations in the manuscript could be further standardized. For instance, variables should be italicized, while mathematical operators should remain upright. As shown in Equation (2), the mass m and velocity v should be italicized.

Response: We thank the reviewer for their meticulous attention to typesetting details. We have thoroughly reviewed and standardized all mathematical equations and inline math symbols throughout the manuscript.

6. The manuscript contains a considerable number of physical variables in its equations. To facilitate reader reference and ensure clarity and consistency in terminology, it is recommended to add a Nomenclature section before the main text or in an appendix. This table should list all variable symbols, their corresponding physical meanings, and units, which will significantly enhance the readability and standardization of the paper.

Response: We fully agree with the reviewer's recommendation. Given the number of physical variables involved in the energy and structural evolution analysis, a dedicated nomenclature section is essential for clarity and consistency. We have added a Nomenclature section (placed as Appendix A in the revised manuscript) that lists all variable symbols, their physical meanings, and corresponding units. This addition ensures standard terminology and enhances the overall readability of the paper.

Appendix A: Nomenclature

Symbol	**Physical Meaning**	**Unit**
	Energy Parameters	
ME	Mechanical Energy	J
KE	Kinetic Energy	J
PE	Potential Energy	J

DE	Dissipated Energy	J
t_i	Time instance i	s
t_0	Initial time (t=0)	s
Block Kinematics		
m	Mass of the monitored block	kg
v	Velocity of the block	m/s
h	Elevation (height) of the block	m
g	Gravitational acceleration	m/s^2
Structural Evolution		
VS	Volume Swelling rate	%
AG	Area Growth rate	%
V_t	Volume of the landslide envelope at time t	m^3
V_0	Initial volume of the landslide mass	m^3
S_t	Surface area of the landslide envelope at time t	m^2
S_0	Initial surface area of the landslide mass	m^2
α	Alpha parameter for Alpha Shape algorithm	-

7. The selection of the Luding station record from the Wenchuan earthquake as input for the 1786 Kangding earthquake represents a reasonable alternative. However, could you provide a more detailed explanation regarding the similarities in source mechanism, epicentral distance, and propagation path between the two events to further strengthen the justification for this substitution?

Response: We thank the reviewer for this insightful suggestion. In the revised Section

3.1, we have added a detailed explanation covering the source mechanism, propagation path, and site effects. The justification is based on three key similarities:

1. Tectonic Affinity: Both earthquakes occurred within the Y-shaped fault zone system at the eastern margin of the Tibetan Plateau, sharing similar thrust-strike-slip stress regimes and crustal rupture characteristics.

2. Site Response Consistency: The Mogangling landslide and the Luding recording station are both located in the Dadu River valley . Using the record from Luding station captures the specific valley-site effects and topographic amplification characteristics unique to this high-relief canyon terrain, which are critical for slope stability analysis.

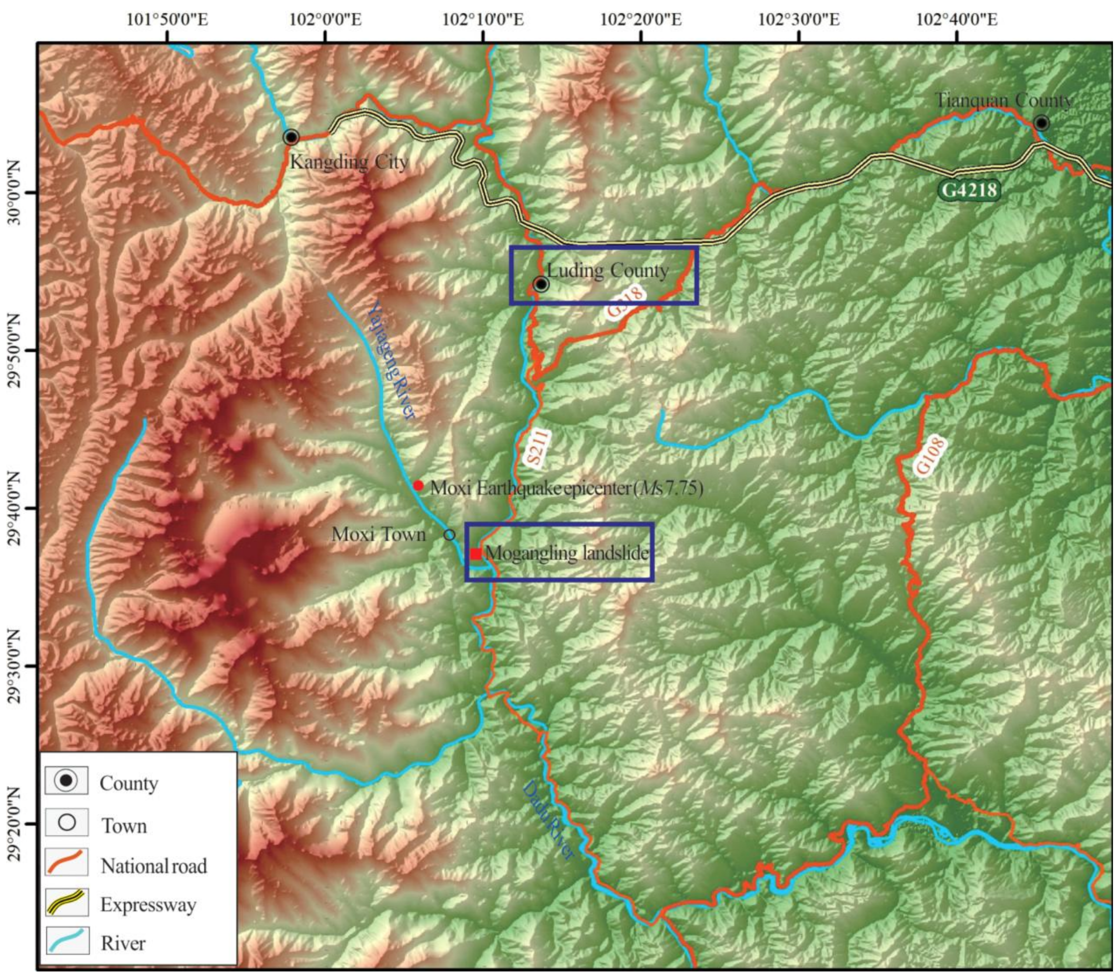


Fig. 11 The location of Luding County and Mogangling landslide (Zhou et al., 2024)

Reference:

Zhou, H., Ye, F., Fu, W., Liu, B., Fang, T., & Li, R. (2024). Dynamic effect of landslides triggered by earthquake: A case study in Moxi Town of Luding County, China. Journal of Earth Science.

8. The description of the regional geotechnical conditions in Section 2.1 "Geo-mechanical model building" could be condensed without compromising academic rigor. It is recommended to streamline the content by focusing on the key geological features directly relevant to the model construction, while retaining all critical data and parameters necessary for reproducibility.

Response: We appreciate the reviewer's suggestion to improve the conciseness of the manuscript. To accommodate a structural suggestion from another reviewer, we have extracted the general background description and placed it into a newly dedicated section: "**2 Study Area and Geological Background**" Consequently, the revised Section 2.1 has been significantly condensed. It now strictly focuses on the geological features and parameters explicitly implemented in the 3DEC model (e.g., specific lithology and fault geometry), fulfilling your recommendation to focus on key features while retaining critical data for reproducibility.