Responses to Review Comments

In the following, review comments are in ***blue italic*** font, while responses are in **black normal** font.

Reviewer #1 (Adam Daniel McArthur)

(1) I enjoyed reading this manuscript, which is a rare example of trying to model submarine sedimentation across an active fault scarp. The methodology of combining a sand-box model with flume tank experiments is novel and for this alone is worth publication, especially the supplementary videos, which would be great to include in the main publication if the journal has this capacity. It's mostly clearly written (with some noted exceptions in the Results and Discussion sections), with a logical flow and supported by good quality figures and explanation of the data and results. However, there are limitations in applying the modelling fine grained, diffuse sedimentation to the typically coarse-grained deposits associated with canyons and hangingwall fans, which are typically dominated by mass-wasting. Particularly, if this work is to be used to "predict the morphological evolution and sedimentary processes of submarine canyon-fan systems in active fault settings", which unfortunately, as written it does not. I outline my main concerns below; with some careful re-framing this could be published after major revisions.

Reply: We are grateful and thank the reviewer for thorough assessment of our manuscript and for providing us constructive comments and suggestions. In the revised version, all the comments and suggestions have been considered and changes have been made to improve the presentation. We now add point-by-point reply (in black normal font) to the comments and suggestions of the reviewer (blue italic font) and make clear where and what changes have been made in the revised version of the manuscript.

(2) I have annotated a PDF with a number of comments and minor corrections that will improve the final paper. The main points to remedy, which will improve the readers confidence in the work are: The study needs to be better framed, in terms of 1) modern work on source to sink systems (e.g., Sømme et al., 2009; Nyberg et al., 2018), 2) recent work on canyon systems (e.g., Bernhardt and Schwanghart, 2021; Soutter et al., 2021) and 3) the wealthof work on active margin systems (e.g., Bührig et al., 2022; McArthur et al., 2022). As it stands many of the motivations for doing this work seem dated and ignorant of the wealth of work on active margins over the past twenty or more years.

Reply: We appreciate receiving the reviewer's annotated PDF, which is very helpful. We have followed the recommendations of the reviewer and reframed the entire article, making significant revisions to the Introduction and Discussion sections. Please refer to our revised manuscript.

(3) This leads to some confusion on the actual features being modelled, which are really hangingwall fans (sensu Leeder and Gawthorpe, 1987), rather than classical submarine fans. This is an important distinction and the study needs reframing in this light. This has the added complication that most hangingwall fans are constructed by a mixing of turbidity currents and mass-wasting (e.g., McArthur et al., 2013; Barrett et al., 2021). This at least needs to be considered and discussed, otherwise the whole premise of the study seems flawed.

Reply: We agree with the reviewer's suggestion and will change all instances of "submarine fans" to “submarine hangingwall fans”. In discussion 4.1, we discussed the formation of submarine canyons and hangingwall fans, which involves a combination of turbidity currents and mass-wasting processes, as described by McArthur et al. (2013) and Barrett et al. (2021).

(4) Furthermore, the basic assumption that flows through canyons and that form said hangingwall fans are fine grained, here modelled as saturated brine to represent mud-rich turbidity currents, using a diffusion model really limits the application of this to understanding how natural systems evolve. We know that most active margin canyons are conduits for- and hangingwall fans build stratigraphy that is a mix of high concentration turbidity currents, debris flows and mass transport deposits. Furthermore, recent work has shown how varying grain size and sorting of flows strongly influences their ability to erode, bypass or deposit (Crisóstomo-Figueroa et al. 2021; Amy and Dorrell 2022). Therefore, the limitation of modelling fine grained particles with diffusion vs. the complicated nature of reality should at least be stated up front and discussed if the authors truly believe this work will help us “understand the initiation and evolution of fault-controlled submarine canyon-fan systems driven by downslope gravity flows”.

Reply: Thank you for the reviewer’s suggestions. We have made modifications to the wording of “mud-rich turbidity currents”. We acknowledge that the current one-dimensional geometric relationship (Eq. 1 and Eq. 2) and morphodynamic model (Eq.3 and Eq. 4) are simplified models that cannot accurately describe the details of grain size and sorting.

However, our main goal is to construct a simple mathematical model to describe the long-term geomorphic evolution of the continental slope and submarine canyon-hangingwall fans, and we hope to explore the existence of self-similarity in the system (which indeed exists, as shown in Fig. 10 in the revised manuscript). In our model, we have decoupled complex phenomena into two primary mechanisms: (1) breaching processes driven by gravity; (2) submarine canyons and hangingwall fans formed by saline underflow. The comparison between experiments and models is presented in Fig. 8, Fig. 9, and Fig. 10 in the revised manuscript.

At the laboratory scale, the breaching process itself includes debris flows and mass wasting processes. The morphological response is that the slope will maintain the angle of repose, which can be described by a simple geometric relationship and the comparison is acceptable (Fig. 8). This angle of repose slope is consistent with the experiments in Lai et al. (2016), i.e., the final steady state of laboratory-scale breaching processes is a featureless slope, and the angle will be maintained at the material's angle of repose.

In addition, we describe the long-term geomorphic evolution of the submarine canyon-hangingwall fan subjected to saline underflow using the diffusion equation. This idea was inspired by the theoretical foundation of our previous studies on hyperpycnal deltas (Lai and Capart, 2007; 2009; Lai et al., 2017; 2019; Lai and Wu, 2021). Although not perfect, the comparison between experiments and models has yielded acceptable results (Fig. 9 in the revised manuscript). Although a 1D model cannot capture the details of grain size or sediment sorting (e.g., Crisóstomo-Figueroa et al., 2021;

Amy and Dorrell, 2022), the diffusion equation provides a transparent mathematical relationship that can serve as a scientific basis for validating complex phenomena. There are also many successful cases of using the diffusion equation to describe long-term geomorphic evolution (Paola et al., 2009). For instance, Spinewine et al. (2011) applied a nonlinear 1D diffusion model to the Amazon channel of the Amazon Submarine Fan. Likewise, Lai and Wu (2021) applied a 1D diffusion model to describe the foreset evolution of the field-scale Po River delta, which can depict over 200 years of long-term geomorphic evolution. We appreciate the reviewer's comment, which enabled us to enhance the comparison between our model and reality, highlighting both the strengths and limitations of the approach we are proposing. This content has been incorporated into the new section titled "4.1 Why do geomorphic experiments work?" within the discussion.

(5) Much is made of varying the effects of varying inflow discharge. However, upon seeing the supplementary videos, it appears that most of the sedimentation through your canyons to build the fans is actually via footwall erosion and reworking – this is actually closer to reality that your described methods and results. Much more description of this process, perhaps accompanied by greater investigation of this erosion would help address some of the concerns of how appropriate it is to use these experiments to understand natural systems. Further information on the composition of the footwall is required in the methods and this process needs to be incorporated into your Morphodynamic model.

Reply: Please refer to our previous response. We discussed the relevant mechanism in Discussion 4.1.

(6) However, the flows shown in the supplementary videos do not appear to resemble the "long-lived hyperpycnal flows or mud-rich turbidity currents" that are claimed to be modelled. Particularly, the flows moving sediment and building your hangingwall fans appear as simple sediment gravity flows, i.e., grain flows/avalanches, which have very different flow properties to turbidity currents. This fundamentally questions the applicability of this study to natural systems dominated by turbidity currents.

Reply: Indeed, saline underflow and turbidity current are fundamentally different, but these two types of density currents may exhibit similar changes in morphology in response to bed load transport (e.g., Sequeiros et al., 2010). At the reduced scale of our experiments, unfortunately, gravity currents cannot be sustained by turbulent sediment suspension, hence the need for salinity to provide a sustained density contrast. We have decoupled the complex phenomenon into the breaching process and saline underflow transport process. These two mechanisms show significant differences in laboratory experiments. Please refer to our previous response. The field conditions are, of course, much more complex, and the results of various processes need to be thoughtfully interpreted when comparing to our research findings.

(7) The Discussion needs to be just that. I.e., you should compare your results to those of other studies to discuss what works and what doesn't. At the moment it's just a rather long winded attempt to further explain the results of your models. Breaking up the discussion into distinct sub-sections to address specific points will also help build a narrative.

Reply: We have rewritten the Discussion section, dividing it into sections 4.1, 4.2, and 4.3, to better address and organize the issues raised during the reviewing process.

(8) As it stands, this main conclusion and other broad statements about how this modelling can help us understand the geological evolution of submarine canyons and "submarine" (hangingwall) fans is not supported by your data or results. That is before even considering the multitude of natural complications that may arise e.g. other processes (i.e., canyon tides and internal waves, contourites etc.), variability of natural systems (e.g., seasonal, Milankovitch cycles etc.), variation in catchment area (size and composition), structural complexities (e.g., faults are rarely just one fault, but normally a fault zone of many structures active at different times with different effects; effects of earthquakes on landslides and sediment remobilisation, etc.) and many more besides. I appreciate these natural variabilities cannot be addressed by simple modelling, but they should at least be acknowledged if you want to suggest these results can be applicable to natural systems. One of the key things to consider in an attempt to reframe the impact of this work, is that your models are free from many of those complexities, e.g. climate change, variation in sediment supply. So with all things being equal it appears tectonics is the overriding control; this would be a very useful main conclusion and agree with work on natural systems (e.g., Soutter et al., 2021). References above are all listed in the annotated PDF at the appropriate points.

Reply: Thank you for the suggestions. We have revised the Conclusions. Our research findings align with the conclusions of Soutter et al. (2021), highlighting tectonic as the overriding control. We have also addressed the limitations of our research findings and reminded readers to consider the various complex conditions in interpreting field phenomena.

In the revised manuscript, we have added Fig. 12 where we compare the experimental data with the field data (over 10,000 data points spanning from underwater to above water). We have also included the modern data from Bührig et al. (2022). Finally, we propose a scaling relationship from laboratory-scale to field-scale.

In addition, we have also made modifications to Fig. 13 in the revised manuscript. We have individually labeled all 26 field cases (covering passive margin, active margin, and mixed margin) and added estimated data from Bührig et al. (2022) to demonstrate how our proposed empirical formula can assist in estimating hard-to-obtain fan volume information.

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