Point-by-Point Response to Reviewer #2 Amos Salamon

RC: Laor et al. demonstrate that high-resolution seafloor stratigraphy can have a substantial influence on hazard assessment for marine infrastructures that crosse active fault zones in thin-skinned tectonic settings. The authors show that fault slip rates derived from high-resolution seismic reflection data for the post-14 ka horizon are approximately an order of magnitude higher than those inferred from earlier lower-resolution studies based on the post-350 ka horizon. This finding suggests that conventional hazard assessments relying on older stratigraphic horizons may significantly underestimate present-day fault activity and, consequently, the level of risk posed to associated infrastructure facilities.

The manuscript further proposes that this increase in fault activity may be linked to rapid post-glacial sea-level rise, potentially through increased pore pressure along thin-skinned faults and detachment surfaces. In this respect, the study highlights the importance of resolving post-glacial stratigraphic horizons when evaluating submarine fault hazards. This topic is particularly relevant to geo-marine hazard assessment along the "…circum-Mediterranean margins, where the unstable Messinian salt giant drives salt tectonics."

Overall, the manuscript presents a unique and important contribution and addresses a topic of broad significance. I therefore recommend publication in *Natural Hazards and Earth System Sciences* after revision. The comments below are intended to help strengthen the manuscript further.

AC: We thank the reviewer for a positive and comprehensive assessment of our manuscript. We are pleased that the reviewer recognized the significance of our findings, specifically the order-of-magnitude difference in slip rates revealed by high-resolution data and its implications for submarine hazard assessments. We also appreciate the acknowledgment of the study's relevance to salt-tectonic settings like the Messinian margin. We agree that the reviewer's constructive comments will further strengthen the manuscript and improve the clarity of our interpretations.

General considerations

RC: The discussion focuses primarily on increased pore pressure as a mechanism for enhanced fault activity during sea-level rise. However, sea-level rise may also increase the pre-existing load of the water column and overlying sediments above the Messinian evaporites, potentially accelerating their downslope flow into the deeper Levantine Basin.

AC: We thank the reviewer for suggesting this alternative mechanism. The reviewer suggests that the increased pressure of the added water may enhance the squeezing of the salt basinwards. Note, however, that the added water mass covers the entire salt layer and does not increase the horizontal pressure gradient, which is often suggested as a cause of increased salt squeezing. However, we agree with Reviewer #2 that elaborating on this issue will increase the quality of our study.

Consequently, we intend to maintain our focus on the pore-pressure hypothesis as the primary driver for the observed fault acceleration. To address the reviewer's point, we will add a brief discussion to the revised manuscript that acknowledges the possibility of loading-induced flow and clarifies why we consider it a less likely mechanism in this specific geological setting.

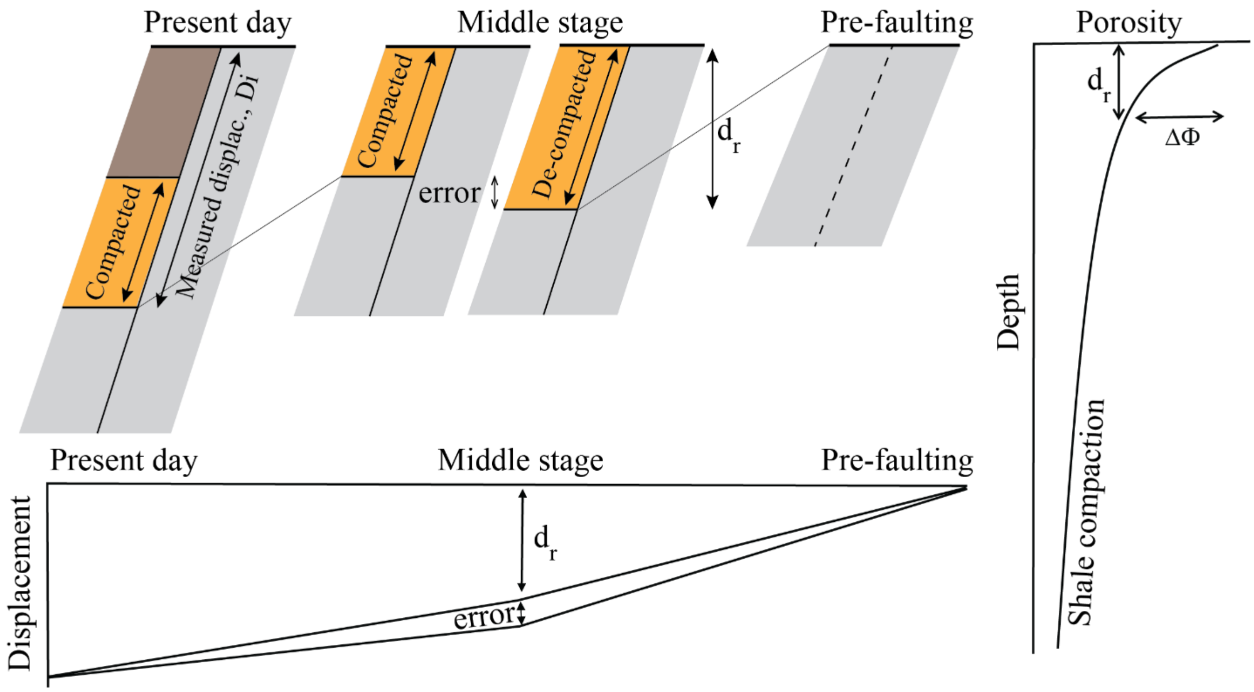
RC: Such downslope movement could promote extension around the pinch-out margins of the Messinian units and thereby enhance normal fault activity. In turn, evaporite accumulation in the deeper basin may increase contraction, folding, and reverse faulting. It would therefore be helpful if the authors could comment on whether there is any evidence for accelerated deformation within corresponding post-glacial strata in the deeper Levantine Basin

AC: We thank the reviewer for this insightful point regarding the potential for accelerated contraction in the deeper basin. While we acknowledge the theoretical link between margin extension and basin contraction in salt-tectonic systems, identifying such evidence in the post-glacial strata of the deep Levantine Basin is challenging. The structural signal in that region is strongly dominated by the long-term overprint of the Circum-Nile folding system, which generates folds in a different direction and masks the Israeli offshore deformation system. Additionally, the available industrial seismic data coverage and vertical resolution in the deep basin are insufficient to isolate post-glacial acceleration from broader regional tectonic processes. To provide further geological context and address resolution limitations, we intend to add relevant geological information regarding the relationship and interaction between the two salt-tectonic systems existing in the Levantine Basin within the 'Thin-skinned tectonics offshore Israel' section.

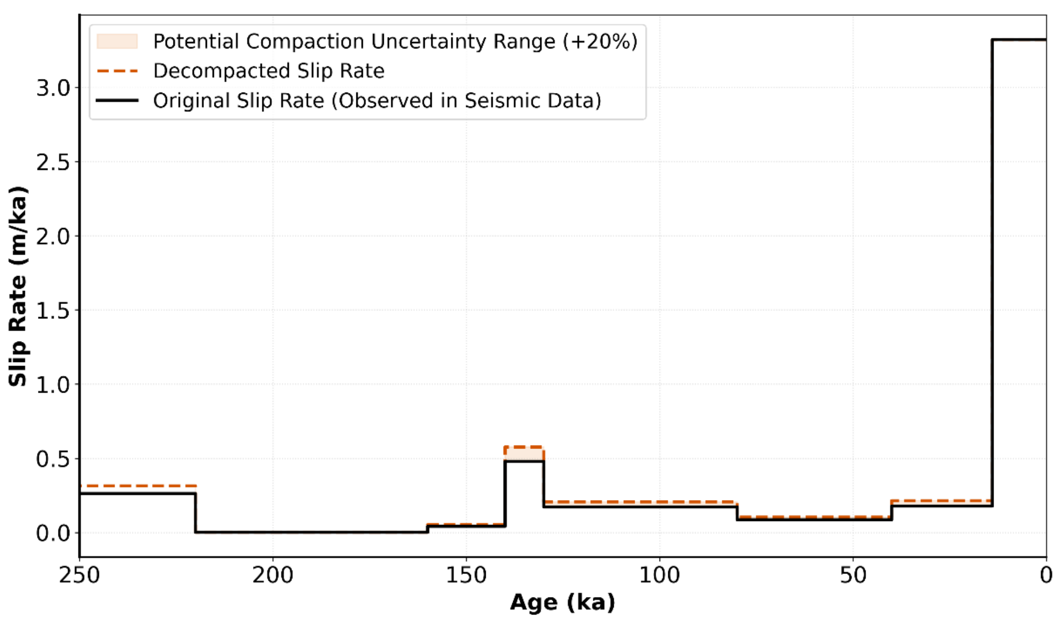
RC: The possible influence of sediment compaction on the reconstruction of fault displacement rates deserves further discussion. The post-14 ka activity rates are derived from relatively young and largely uncompacted sediments, whereas the average post-350 ka rates are based on older strata that are likely to be at least partly compacted. The authors may wish to clarify whether compaction could systematically influence the comparison of displacement rates and whether any correction should be considered.

AC: We thank the reviewer for pointing out the potential influence of sediment compaction on the reconstruction of displacement rates. We acknowledge that while the post-14 ka rates are derived from shallow, less-compacted sediments, the post-350 ka rates are based on strata that have undergone deeper burial. First, we wish to clarify the problem. The average displacement rate of a specific horizon buried at a depth **d** is, by definition, the total displacement **Di** divided by its age **t**. This is correct for any horizon and particularly the 350 kyr and 14 kyr horizons. No compaction-related uncertainty for these calculated rates.

So, what is the error associated with neglecting compaction? This relates only to the reconstruction of the displacement at a middle stage, when the horizon was partially buried to a depth **Dr** (see figure below). The error associated with neglecting decompaction is proportional to the reduction in porosity with depth. Considering the 100-300 m depth range in which we measured displacements, thickness reduction is inferred from a shale porosity-depth curve to about 10%. This provides an approximation for the error associated with our middle-stage reconstructions. To consider a more extreme scenario, we applied a 20% increase to the measured displacement of the buried unit. Even under this extreme condition, the resulting error in fault slip rates remains highly negligible, as demonstrated in the uncertainty plot below.



Compaction uncertainty plot:



In response to this point and to related concerns raised by Reviewer #1, we plan to add a dedicated subsection to the Discussion chapter that focuses on uncertainties. The attached figures will be added to the text or as a supplement.

RC: It would also be valuable to discuss whether the inferred acceleration in fault activity is thought to occur through aseismic creep, coseismic rupture, or a combination of both. Or that the style of fault activity cannot be resolved yet.

AC: We thank the reviewer for this insightful comment regarding the mechanical style of fault activity. We recognize that determining whether the observed acceleration occurs via aseismic creep or coseismic rupture is essential for a comprehensive hazard evaluation. Our observations suggest that fault activity is likely episodic, characterized by alternating periods of activity and quiescence, which indicates that the deformation is not a continuous process. However, we agree that the specific style of movement, whether through slow creep or sudden rupture during these active phases, remains unresolved at this stage. We intend to address this by adding a discussion on the episodic nature of these faults to the revised manuscript, evaluating how this non-continuous behavior relates to external forcing such as sea-level rise, while acknowledging the current limitations in resolving the exact rupture mechanism.

RC: Some of the youngest scarps may potentially be influenced by slope instability. The authors may therefore wish to comment on whether any of the fresh fault scarps could partly reflect landslide-related scarps, which might affect the apparent offset and the inferred post-14 ka displacement rates

AC: We thank the reviewer for this point. Our seismic data clearly demonstrate that the seafloor scarps are structurally continuous and connect directly to the underlying faults, distinguishing them from landslide-related features.

1. Introduction

RC: The Introduction, particularly the opening paragraph, gives the impression that the study addresses surface-fault displacement hazard in a broad sense. However, the manuscript title and the reference to Laor and Gvirtzman (2023) clearly place the work in a marine context, whereas the PFDHA framework was originally developed for onshore environments. It would therefore improve clarity if the authors explicitly stated whether the manuscript intends to address both marine and terrestrial applications, or whether it focuses exclusively on the marine environment.

It would also be useful to indicate and support with suitable references whether any existing PFDHA methodology or engineering code has been adapted for the seafloor environment.

AC: We thank the reviewer for this observation. We intend to clarify in the Introduction that our study focuses exclusively on the marine environment. We will emphasize that while the PFDHA framework can theoretically be adapted for offshore applications given relevant data, such data are often scarce, missing, or difficult to obtain in marine settings, particularly for faults where the seismic mechanism remains poorly understood. Consequently, our objective is to propose an alternative approach and establish methodologies specifically tailored to the unique requirements and constraints of the marine domain.

RC: Additional points:

- Lines 52–57: Results are introduced before the study objectives are fully defined.
- Lines 58–59: Please explain why the Levant continental margin is considered an especially suitable natural laboratory for this investigation.
- Lines 60–61: Recommendation is presented before the principal findings have been fully introduced.

The Introduction might be strengthened by reorganizing it to:

- define the broader research context (marine or terrestrial),
- summarize previous work (or refer the reader to the Background Section),
- identify the knowledge gap,
- state the study objectives, and
- describe the significance of the study and the importance of the expected results.

AC: We intend to revise and restructure the Introduction in accordance with the reviewer's valuable recommendations.

RC: 2.1 Thin-skinned tectonics offshore Israel

The background section could benefit from a broader tectonic framework before focusing on post-glacial faulting. In particular, the following aspects may help place the study into a wider regional context:

- the evolution of the thin-skinned tectonic system in the Levantine Basin, its deformation history and the relationship between extension at the margins of the Messinian evaporites and contraction in the deeper basin (e.g. Moneron and Gvirtzman, 2025),
- regional seismicity (e.g. Katz and Hamiel, 2019),
- the main offshore geomorphic and tectonic domains beyond the Dor Complex.
- Lines 80–81: Please specify the absolute age range of the Messinian evaporite unit.

AC: We thank the reviewer for these suggestions to broaden the tectonic framework. We intend to expand the Background section; however, we wish to maintain a clear focus on thin-skinned tectonics, which is the primary scope of this manuscript. In particular, we will clarify the different salt-tectonic systems in the Levantine Basin and the interactions between them. We will also incorporate references regarding regional seismic sources and seismicity. Finally, we will provide the absolute age range for the Messinian evaporite unit as requested.

3. Methods

RC: Before describing the individual assessment methods, the manuscript would benefit from a concise overview of the methodological workflow, either as a short bullet-point list or a schematic figure. This would allow readers to understand the study design more easily before engaging with the methodological details.

AC: We thank the reviewer for this helpful suggestion. We agree that a concise overview will enhance the accessibility of our study design. We will clarify this issue.

RC: The rationale for selecting faults F1–F4 should also be clarified. It would be useful to explain whether these structures are representative of the broader fault population and whether comparable post-glacial faults exhibit similar behavior elsewhere in the study area.

AC: We thank the reviewer for this comment. Faults F1–F4 were selected because they are representative of "Group 2" faults (as defined in Laor and Gvirtzman, 2023), which exhibit the highest average displacement rates over the last 350 ka. Furthermore, these specific structures are situated within Israel's national infrastructure corridor, making them a primary focus for hazard assessment. We will ensure that this selection rationale is explicitly stated and clarified in the revised manuscript to better justify the focus on these specific faults.

6. Conclusions

RC: The study convincingly shows that slip rates of normal faults along the eastern Mediterranean Messinian margin may be associated with rapid post-glacial sea-level rise. However, the mechanism responsible for this relationship remains uncertain. At present, the proposed pore-pressure explanation should therefore be presented as a working hypothesis only.

AC: We will revise the Discussion section to more clearly frame the pore-pressure explanation as a working hypothesis. We will ensure the language reflects the appropriate level of scientific caution, presenting it as a plausible primary driver while acknowledging the inherent uncertainties in pinpointing the exact mechanical trigger.

RC: Similarly, the terms *climatic forcing*, *environmental forcing*, and *sea-level rise* should be used carefully, as they are related but not interchangeable. The Conclusions may be strengthened by remaining closely aligned with the direct empirical findings while presenting mechanistic interpretations more cautiously.

AC: We thank the reviewer for these insightful remarks on terminology and the framing of our conclusions. We recognize that "climatic forcing," "environmental forcing," and "sea-level rise" represent distinct, non-interchangeable concepts, and we will carefully revise the manuscript to ensure they are used with precision. Furthermore, in accordance with the reviewer's suggestion, we will restructure the Conclusions to stay more closely aligned with our direct empirical findings. We will ensure that mechanistic interpretations are presented with appropriate scientific caution, clearly distinguishing between observed slip-rate trends and the proposed driving hypotheses.

RC: Figures

- Font sizes in several figures are too small for comfortable reading. Please ensure that all labels, axes, scales, and legends remain legible at publication size.
- Yellow lines, including the 14 ka reflector, are difficult to distinguish in several figures. Improved contrast would enhance readability.

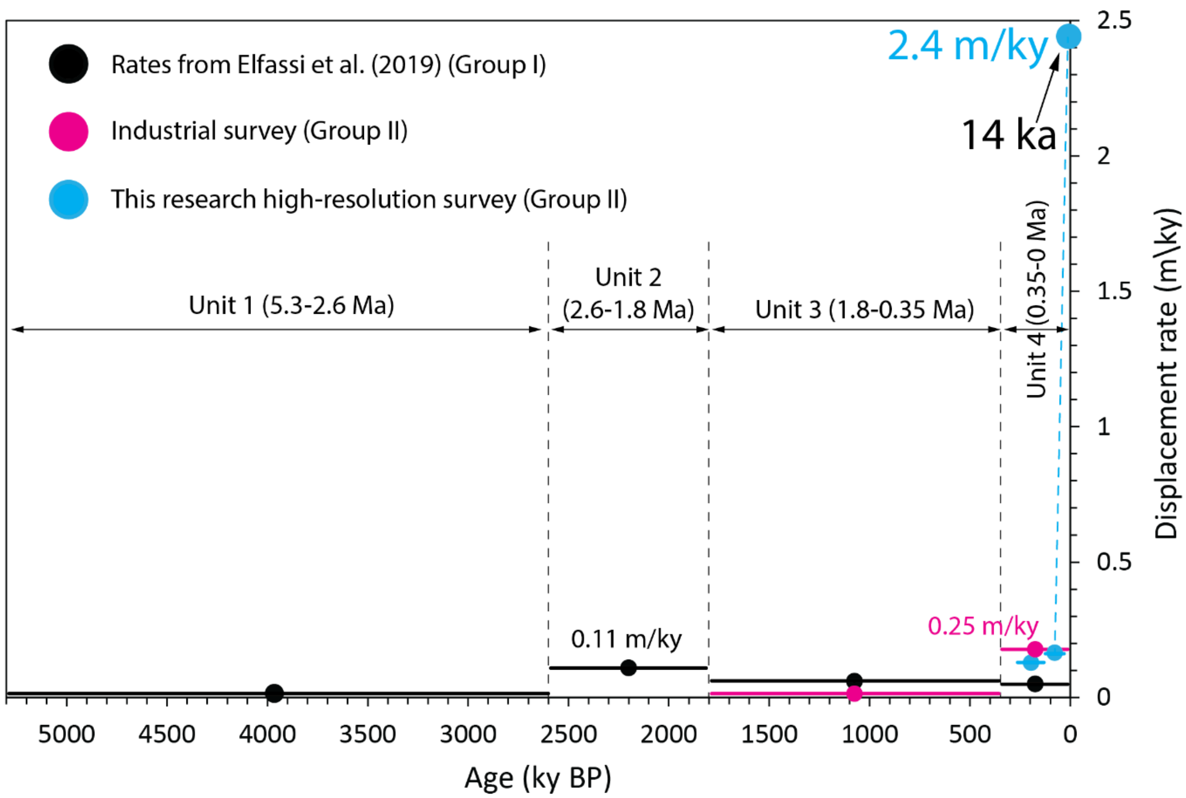
Specific figure comments

- Figure 1A: Please add the coastline.
- Figure 1B: Please explain the background colors outside the study area.
- Figure 4B: Please define TWTT, TST, and HST in the caption.
- Figure 4C: Please provide a reference for the sea-level cycles shown.
- Figure 5: Please verify whether "4C" should appear in bold.
- Figure 7: Consider labeling the principal geological units (Messinian, Plio-Quaternary, etc.) directly in the figure.

AC: We thank the reviewer for the specific feedback regarding the graphical elements of the figures. We intend to revise and update the illustrations in accordance with these recommendations to enhance their clarity, readability, and overall presentation in the revised manuscript.

RC: The interpolation line between black data points may unintentionally suggest continuous changes in slip rate through time. For example, Unit 2 appears to show rate fluctuations between 2.6 and 1.8 Ma, whereas the intention appears to show a fixed average over the entire interval. A similar issue applies to the 14 ka interval.

AC: The reviewer makes an excellent point regarding the potential for misinterpretation when using interpolation lines. To address this, we have modified the slip-rate plots. Instead of simple line-connected points, we now use step-like plots to represent each interval (see the new figure below). This clearly illustrates that the calculated rates are time-averaged values for the entire duration of each unit (e.g., the 2.6–1.8 Ma or the 0–14 ka intervals) rather than continuous fluctuations.



RC:

- Figure 8: Consider directing readers back to Figure 2 for methodology explanation.
- Figure 9B: Please explain the undulating (sea-level curve?) line shown at the base of the figure.

AC: We intend to revise and update the illustrations in accordance with these recommendations to enhance their clarity, readability, and overall presentation in the revised manuscript.

RC: Technical comments

- Introduction and line 154: Statements regarding building codes should be supported by references.
- Lines 97–107: Laor and Gvirtzman (2023) are cited repeatedly within a short paragraph; some consolidation may improve readability.
- Please provide a reference for the AspenTech SSE software package (formerly Emerson-Paradigm).

- Please use *ka* and *ky* consistently throughout the manuscript.
- Lines 251 / 262: Please clarify whether the intended color is *light blue* or *turquoise*.

AC: We intend to revise and update these points in accordance with these recommendations.

RC: References not mentioned in the manuscript

Katz, O. and Hamiel, Y. 2019. The nature of small to medium earthquakes along the Eastern Mediterranean passive continental margins, and their possible relationships to landslides and submarine salt tectonic- related shallow faults, Geol. Soc. London, Spec. Publ., 477, 15–22, https://doi.org/10.1144/sp477.5.

Moneron and Gvirtzman, 2025. Multiphase deformation of a multilayered salt giant: Salt tectonics in the Levant Basin. GSA Bulletin; November/December 2025; v. 137; no. 11/12; p. 4919–4937; https://doi.org/10.1130/B38116.1.

AC: We will incorporate these references in the relevant sections, specifically within the Background and Discussion.