Response-to-Review Document:

Summary of revisions: We have completed revisions of our study submitted to Seismica: "No evidence for an active margin-spanning megasplay fault at the Cascadia Subduction Zone" based on comments from three Seismica reviewers and one USGS internal reviewer. This manuscript has been greatly improved from these reviews. Improvements include streamlining of text throughout the manuscript to improve flow, edits to figures to improve clarity of evidence for fault activity and/or inactivity, and, overall, a more direct communication of key results unique to this study. See below for direct responses to each reviewer comment.

Reviewer's comments in black, Author's responses in blue.

Reviewer D:

This paper reports that that there is not an active, through-going megasplay fault in Cascadia, but instead that the structure and activity of faulting at the inner-outer wedge transition zone is variable and segmented along strike. The paper suggests that both wedge sedimentation and subducting plate topography play a major role in controlling megasplay fault development and evolution.

This paper provides an overview of shallow portion of the Cascadia subduction zone, and more detailed research is needed to verify the proposed hypotheses. However, it is significant in that it will form the basis of long-term prediction research for earthquake and tsunami hazards that occur not only in this region but also affect in circum Pacific coastal areas. Therefore I believe it is worth publishing with the technical minor corrections described below.

Figures:

In all drawings, the figure numbers are written in uppercase, but the text descriptions and citations in the text are written in lowercase. Please unify these.

We have unified caption labels with in-figure labels.

Figure 8. Caption explains no vertical exaggeration but input scale for reading convenience.

We have added a vertical scale to this figure.

Recommendation: Accept Submission

Reviewer F:

Review of "No evidence for an active margin-spanning megasplay fault at the Cascadia Subduction Zone” by M. C. Lucas et al.

Thanks for inviting me to review this interesting study by Lucas et al. This manuscript presents multiple along-dip MCS reflection images from the regional Cascadia margin, based on recently collected CASIE 21 data. Using these seismic data, along with high-resolution seafloor bathymetry, the authors refute the possibility of megasplay faults continuously extending from off Vancouver Island to off Oregon. Instead, they propose that the accretionary wedge is highly variable, and the fault system is segmented along strike. This is an important finding, particularly for assessing seismic and tsunami hazards in this region.

The primary challenge for this manuscript lies in clearly distinguishing the new results contributed by this study from those already presented in previous works using the same dataset, including Carbotte et al. (2024), Ledeczi et al. (2024), and Watt and Brothers (2020). While I see some clear new contributions, these need to be even more strongly emphasized so that readers can fully appreciate the advancements this study makes. For example, the absence of a margin-spanning splay fault system — one of the main conclusions of this manuscript — seems closely linked to previous studies suggesting a highly heterogeneous upper-plate structure that is segmented along strike.

Overall, I find this study to be a valuable contribution in the field, as it documents detailed geological structures across an extensive subduction margin. However, as note above, the authors should highlight their findings more clearly and further develop some of their interpretations. I have included specific comments and questions below for consideration. I recommend a minor-to-moderate revision to address these points.

General comments:

The authors describe “faults that either deform or offset inferred late Quaternary sedimentary horizons” as the definition of active splay faults (In Line 286-288). To better support this definition, could you provide additional examples of enlarged raw reflection images (without interpretations) highlighting active (positive), inactive (negative) and inconclusive fault systems? Currently, only a negative case is shown (Figure 6 B-inset), making it challenging for readers to distinguish fault activity in the figures due to the limited resolution and the presence of interpretative overlays. In particular, I find it difficult to determine whether the faults exhibit any offset, which leaves me unconvinced by the “positive” and “negative” interpretations in most cases (e.g. Figures 7 and 9). Since this forms a key foundation of this paper, enhancing the resolution and clarity of the figures would significantly improve the readers’ understanding and the overall impact of the paper.

We added enlarged zoom-ins of seismic images in Fig. 5, 6, 7, 8, 9, and 12 to show positive, negative, and inconclusive evidence of faulting. We lightly interpreted these seismic images upon recommendation from other reviewers and USGS internal review. Uninterpreted processed seismic images can be downloaded from MGDS database linked in Data & Resources section.

Similarly, the authors' interpretations on decollement and underthrust sediments are not fully convincing. In Figures 6, 7 and 9, the reflections at the interpreted decollement (thin black line) appear either absent or faint. The same issue seems to persist in Figures 11 and 12 as well. Have you observed polarity reversals at the decollement that could serve as evidence of low-velocity underthrust sediments? Including such observations would help substantiate the interpretations.

The topic of the decollement and basement locations is thoroughly evaluated and discussed in Carbotte et al. (2024). We do not make a new interpretations of the decollement or plate basement boundaries in this study. All interpretations of the decollement/basement are consistent with Carbotte et al. (2024). Where relevant, we added more references to Carbotte et al. (2024) to indicate this.

Additionally, I have some concerns about Figure 4 and its related explanations in the text. First, the criteria for classifying the accretionary wedge into these five category remain unclear to me. Specifically, I was not sure how you define the boundary of each unit. For example, do you observe the deformation front? And is it consistent with the boundary between "Incoming/underthrust sediment" and "Outer wedge"? A transition zone between the outer wedge and inner wedge (IOWTZ) is not a universal feature of global subduction zones. If any, why is such a wide transition zone developed in Cascadia? Lastly, your interpretation of thick underthrust sediments in Figure 4d is puzzling. This thick layer seems to abruptly disappear at ~36 km distance and landward. Could you clarify how the decollement terminates or where it transits? Addressing these points would strengthen the clarity and robustness of your interpretations.

We have added a "Summary of Results" subsection to the end of the Results section to clarify how segment and subsegments are classified based on our structural observations. As indicated in the caption of Fig. 4 and in the text, the seismic images are only *representative* of the different wedge segments. The criteria for defining structural boundaries in accretionary wedge can also be found in Table 1. We proposed a mechanism for the development of the IOWTZ in Section 4.2 of the Discussion and corresponding Figure 14. We have modified Fig. 4d to be consistent with more detailed interpretations in Fig. 11. Color overlays in Fig. 4 were simplified to show broad wedge structural domains. We add reference to Carbotte et al. (2024) for subducting sediment/plate boundary.

Comments for Figures:

Figure 1 or 3

I recommend adding "boxes" to indicate the map locations of Figure 5 and other related figures. Without these indicators, it may be difficult for readers unfamiliar with the region to follow the discussion.

We added boxes to Figure 1 that show the extent in Figures 5-12.

Figure 2 and Line 270-277

The seismic characters appear to vary not only laterally but also with depth. Specifically, the inner wedge may include “coherent” or “mostly coherent” layers at the shallowest depths. Therefore, I am uncertain if the description “overall demonstrating a gradational transition in seismic character across the IOWTZ” is entirely accurate or the best expression. Additionally, I was confused that while the deep part of the inner wedge is characterized as “incoherent”, you label “imbricated thrust sheets” by the white arrow at the same location. It is unclear which phases or reflectors you are referring to as “imbricated thrust sheets”. Please clarify these points.

To address this comment, in Fig. 2B we added an arrow and label that indicates seismic coherency generally decreases with depth due to seismic attenuation and other factors including changes in material properties (compaction, lithification, etc.). We also added a corresponding sentence in Section 2.3.2. This clarifies how we are able to make shallow observations of structure while still observing a loss of coherency laterally across the IOWTZ. We adjusted the labeling on Figure 2 and added two separate panels for “structural style” and “seismic character” to make the demonstration of our methods clearer that we are mapping broad, regional-scale structural domains.

Figure 4

I suggest moving the legend for “Incoming/underthrust sediment” to the far left for consistency with the reflection images. Could you clarify the origin of these profiles? Aligning the profiles relative to the deformation front rather than the profile ends may make it helpful to visualize the along-strike variations in upper-plate structure.

We moved incoming/underthrust sediment label to be consistent with images. In the caption it is indicated that these are CASIE21 profiles. We added a sentence clarifying the origin of the profiles are from the CASIE21 survey and that the extent of the profiles is shown by the thick black lines in Figure 3. To help visualize along-strike variations, we aligned the profiles relative to the deformation front and drew a dotted line along the deformation front that crosses each image.

Figure 5

Are the reflection images shown as depth sections? Please add units to the vertical axis. In panel A, you imply a “slab tear”, but it appears more like a seamount, and it is unclear where exactly the tear occurs. This point is also not discussed in the text. The white arrows labeled as “megasplay faults system” are not clearly pointing to specific features. Please clarify.

We added depth labels/units to the figure.

The “slab tear” is discussed in section 3.1. To clear up confusion, we labeled the feature as “basement topography” in Fig. 5 and referred to it as such in the text. We reference previous studies (Shuck, Carbotte) that observed this structure and mention their interpretation of this feature as a slab tear since this information is relevant to our analysis of upper plate faults.

We adjusted labels to more clearly point to megasplay fault systems in PD02, PD03 and PD04. We also added enlarged seismic panels to show evidence for these faults in the near surface.

Figures 6, 7 and 9

The vertical axis in panel A-C is missing units. Please include these.

Depth labels have been added to figures.

Figure 8

Please add a vertical scale for clarity. Vertical scale added.

Figure 11

Please add units to the vertical axis. Units added.

Figure 12

Panel A requires latitude labels. Please also add units to the vertical axis.

Latitude labels added to panel A. Vertical axis units added.

Figure 13

The label “128°W” is misplaced. Please correct this.

It is not misplaced. This map was exported with labels directly from GIS. The map is projected in UTM zone 10. This is the correct label.

Line-by-Line Comments:

Line 107

The phrase “a long-term asperity” is unclear. Could you rephrase this with a more specific term or provide additional context to clarify its meaning?

It was suggested in USGS internal review that the Introduction section be shorted. This detail about megasplay faults was removed. We include a shorted description of what a megasplay fault is as opposed to typical splay faults with references to previous studies who propose the idea of a megasplay fault.

Line 190

The abbreviation “OAH” is not used elsewhere in the manuscript. It would be better to remove it.

It has been removed.

Line 271

Consider deleting “seismic character” to avoid redundancy in the sentence.

We think the sentence loses some of its meaning without including “seismic character” since we are describing how we evaluate seismic character based on coherency of reflectors. We chose to keep this word.

Line 1105

More detailed information on “oblique convergence” (e.g. rate and direction) would be helpful in earlier sections of the manuscript. It might also be beneficial to illustrate it in map figures (Figure 1 and/or 3).

We added a subduction direction vector and obliquity angle with reference to McCaffrey et al. (2007) to Fig. 1.

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Recommendation: Revisions Required

Reviewer H:

I have reviewed the paper: *"No evidence for an active margin-spanning megasplay fault at the Cascadia Subduction Zone"* by Lucas and co-authors.

The paper aims to evaluate the presence and activity of the hypothesized continuous megasplay fault in the Cascadia accretionary wedge. The presence of this fault has significant implications for tsunami risk assessment.

The manuscript is well-written, with several well-described datasets, and the discussion is both well-supported and articulated. However, I have a few minor comments to improve readability and enhance the figures:

Title: I suggest changing the title to something like: *"Evidence for a Highly Variable (Segmented?) and (only) Locally Active Megasplay Fault at the Cascadia Subduction Zone."* In my opinion, this version is more informative about the content of the paper. Please note that I am not a native English speaker.

We choose to maintain the original title because it describes our primary finding that there is *no evidence* for a margin-spanning megasplay fault at Cascadia.

Lines 186- 188: Is there any independent information (e.g., dating) about the age of the deformed sediment across the IOWTZ, or is it based on inference?

The ages of the accretionary wedge complexes are inferred from onshore bedrock outcrops and industry boreholes on the continental shelf. We added sentence to the Introduction: "The age of offshore accretionary wedge complexes was previously inferred from bedrock outcrops on the western Olympic Peninsula and industry boreholes on the continental shelf (Palmer and Lingley, 1989; McNeill *et al.*, 1997)."

Line 237: In my opinion the reference to "Fig. 3" here is out of place.

Figure 3 shows the landward extent of the inner wedge domain which is mentioned in this line. Based on this comment, we moved this sentence into the results section where we discuss this boundary so that the reference to Fig. 3 is more relevant to the paper text and the text flows with the progression of the figures.

Par. 2.2.1: I found it difficult to follow the paragraph using Figure 2 as a reference. The paragraph becomes easier to understand when also referring to Figure 5. Therefore, I suggest including the interpreted section in Figure 2 to improve clarity and alignment with the discussion.

We edited Figure 2 to include a panel for structural style that includes structural interpretation of the PD04 seismic image.

Additionally, I noticed a couple of issues in Figure 2:

- The arrow pointing to "imbricated thrust sheet" seems to indicate the wrong area.
- The description "closely spaced, imbricated thrust sheet dominated by seaward vergence" appears to correspond more accurately to PD04 than PD03.

Removed the arrow and adjusted labels on Figs 2A and 2B to reflect either structural style or seismic character in each wedge domains.

Lines 286-287: If possible, it would be helpful to provide an estimate of the minimum displacement detectable based on the resolution of the seismic image.

Total displacement along the fault varies depending on along-strike location and depth. This would be a difficult value to determine and is not directly relevant to this study since we do not measure displacement on individual faults, but instead focus on broad patterns in wedge structure.

Line 297: Please define the difference between 'megasplay fault' and 'other splay fault at the IOWTZ'

This sentence has been removed. We added a sentence to the Introduction describing why a megasplay fault is different from a splay fault and included references to previous studies.

Lines 300-345: I suggest moving this summary, along with Table 1 and Figures 3 and 4, to the end of the 'Results' section, where it would be easier for the reader to understand. Additionally, the discussion at the end of each segment could potentially be integrated into the main paragraph for better flow and coherence.

Moved the Table 1 and summary paragraph to the end of the results section and labeled it "Summary of Results". Flow has been improved throughout results section through line-by-line edits. Figures 3 and 4 remain at the beginning of results because this information is needed for context in more detailed interpretation of each section.

Fig. 3. Please include the name of each segment in the figure and define "NFZ" in the caption.
New added segment names and NFZ has been defined in figure caption.

Table 1: Please define in the caption what the "-" symbol means (e.g., "absent"?)

We have changed this "-" to N/A and define what this means in the table caption.

Figures 5-12. Please add the uninterpreted seismic images (either in the main article or in the supplementary text).

Processed uninterpreted seismic images are available for download on MGDS database. This is linked in “Data & Resources” section. Many other papers, including recent Ledeczi et al. (2024) in Seismica, do not include uninterpreted images as the data are openly available for download online.

Line 389: The term "plate hinge" is defined in line 487. It would probably be better to move the definition to this point.

Definition of plate hinge is now introduced early in the results in section 3.1**.**

Line 620: The red triangles represent the active strike-slip faults, right? I clarified what the triangles represent in the text and figure caption.

Lines 816-820: In my opinion, it would be informative to add a quantification (e.g., percentage of the length) of the positive or inconclusive evidence relative to the total length.

This would not be a clear or straightforward analysis because one of the main points of this paper is show that the structure is highly variable where a simplified megasplay fault was previously predicted. Comparison between the hypothesized megasplay and our analysis is clearly illustrated in Fig. 13. This reference is added to this sentence.

Fig. 13: Please include the name of each segment in the figure This has been added.

Lines 950-951: This phrase is confusing in this context and is not referenced in the following paragraph. It might be helpful to include a brief introduction before section 4.2, mentioning the two different proposed mechanisms for the different segments.

This sentence was completely deleted to reduce confusion and focus on main point of paragraph.

Line 952: Please insert a reference to a figure here.

Reference to Fig. 11 added.

Lines 1081- 1083: I’m not sure this is the only possible explanation; an alternative could be the development of a fault inside the upper plate.

We add mention to this alternative hypothesis in the text. However, we argue that since there is no significant topography associated with these faults, it is unlikely that developed recently.

Recommendation: Revisions Required

USGS Internal Review: We have gone through the USGS internal review process and made additional changes to the manuscript based on this review. We have received final USGS Bureau approval for resubmission to Seismica.