Referee #1

My main concerns centre around Figures 4 and 6.

Ice base reflection

In figure 4 the ice-base reflection is shown in panels c and f. These plots are still too zoomed out to adequately interpret. It would be better to zoom in on a 50-100 ms window that encompasses the ice-water interface and its ghost. This would allow the reader to assess the polarity, and any possibility of a mixed phase return resulting from either thin water or saturated sediments, with the later reflection indicating the base of the sediments. I don’t expect the reflections to resemble ricker wavelets but significant mixed phase may suggest thin layer effects. I don't suggest this is the case but as the results presented here may guide a drilling program it pays to proceed with an abundance of caution.

More importantly, the theoretical ice-water amplitude versus offset curve has peak (-ve) amplitude at zero offset, decreasing to zero at ~60 degrees then increasing again. That's not what these reflections appear to do. This may be a result of a processing step, or may indicate the presence of something other than water at the bed. Again, I don’t suggest this is the case, but it would be good to present the data in a way that allows this to be assessed. This difference is again highlighted in the synthetic—field comparison in Figure 9a where the field data show low amplitudes at near offsets.

➔ Before proceeding with our response, we have redefined the symbols to avoid confusion. We have added Table 2 to the manuscript.

Table 2: Symbols for each reflection event

Interface symbols	Model 1	Model 2
①	Ice-water	Ice-water
②	Ice-water ghost	Ice-water ghost
③	-	Water-sediment
④	-	Water-sediment ghost
⑤	Water-bed	Sediment-bed
⑥	Water-bed ghost	Sediment-bed ghost
⑦	Ice-bed	Ice-sediment
⑧	Ice-bed ghost	Ice-sediment ghost

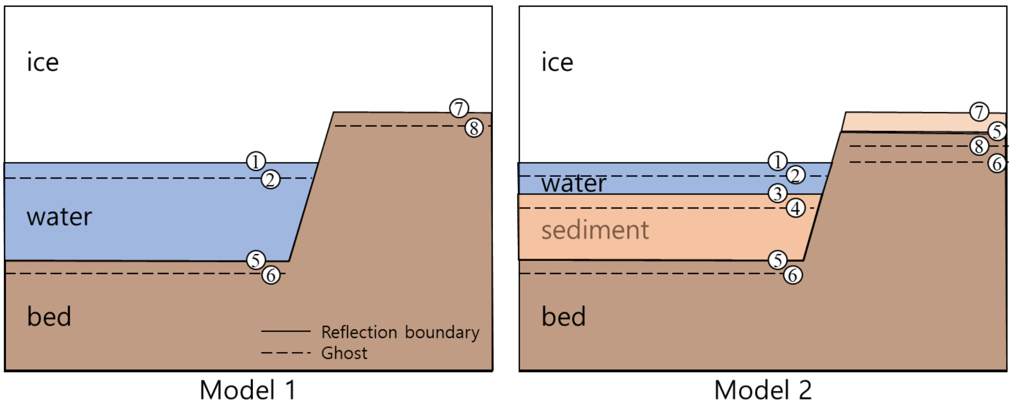

Figure R 1. Velocity model for the subglacial lake structure interpretation. Boundary numbers correspond to those indicated in the manuscript, and the theoretical reflection coefficients at each interface are shown.

➔ We identified an error in the display of near-offset signal weakening in the field data during the Python-based rendering process. We appreciate the reviewer's observation, which helped us identify this issue. Accordingly, Figures 4c, 4f, and 9a have been updated. In response to the reviewer's insightful suggestion, we agree that the presence of subglacial sediments beneath the lake provides a valuable interpretative framework. To explore this possibility, we propose an additional model (Model 2) that includes a sedimentary layer beneath the subglacial lake, in addition to the original ice–water–bedrock model (Figure R1). We extended our interpretation to include a weak reflection approximately 11 ms below the ice–water interface, which may represent the water–sediment boundary. However, in some areas, signals attributable to the sediment interface are not clearly observed. Considering this interpretational ambiguity regarding the sediments, we compared two structural models with the field data. Accordingly, we have revised Section 5 of the revised manuscript and Figure 8 as follows.

(Page 14, Lines 277-289) "In all seismic profiles, the glacier–water interface (①) is characterized by strong, reverse polarity reflections. Following this, a relatively weaker reflection (③) with limited lateral continuity, which may indicate an unconsolidated sediment layer, or an unknown interface beyond the scope of current interpretation. […] To address these challenges, this study developed a subsurface structural model and conducted a comparative analysis of synthetic seismograms generated from the model with observed field data. Focusing on the interpretation of basal reflections beneath the subglacial lake—excluding the glacier–lake interface (①)—two plausible structural models were proposed. Model 1 assumes the absence of a sedimentary layer, in which reflection (③) is not present, and reflection (⑤) represents the base of the subglacial lake. In contrast, Model 2 includes a sedimentary layer, where reflection (③) corresponds to the lake–sediment interface and reflection (⑤) indicates the sediment–bedrock interface (Figure 8)."

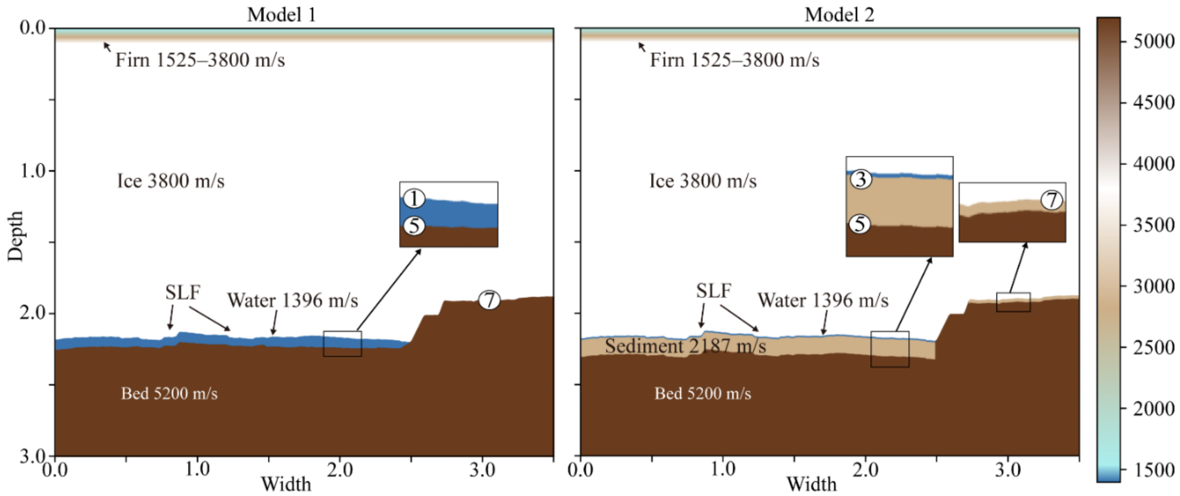

Figure 8: P-wave velocity model used in forward modeling for line 21YY. The upper ~100 m represents firn with velocities ranging from 1525–3800 m s⁻¹ (Kirchner and Bentley, 1979; Picotti et al., 2015; Qin et al., 2024). The ice below this depth has a velocity of 3800 ± 5 m s⁻¹ (Kohnen, 1974), and the subglacial water layer has a velocity of 1396 ± 2 m s⁻¹ (Thoma et al., 2010; Tulaczyk et al., 2014). In Model 2, the velocity of 2817 m s⁻¹ for the sediment layer was taken from the lower sediment layer model of Lake Vostock (Carcione & Gei, 2003).

➔ In addition, regarding AVO analysis—a method for quantitative interpretation—we note that the maximum usable angle in this dataset is limited to approximately 36° due to acquisition geometry (Figure R2), which prevents a clear observation of amplitude variation with offset (-ve -> 0 -> +ve). We computed theoretical AVO curves using estimated material properties for each layer, and overlaid amplitude values extracted by picking the ice–water interface in Shot Gather #2 of the 21YY line. The observed AVO trend for the ice–water interface is consistent with theoretical predictions. However, since this comparison is based on a single-shot gather, a comprehensive analysis would require significant additional processing. We are currently conducting further research—such as velocity optimization in the firn layer, deghosting, and extended AVO analysis—with the intention of presenting these findings in a future publication.

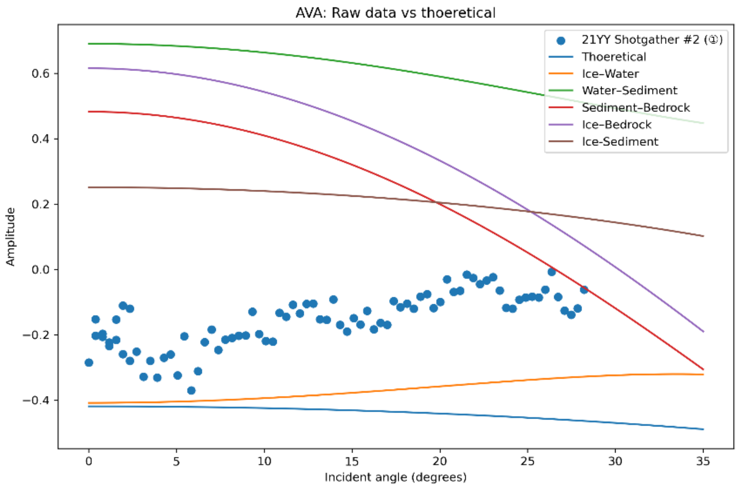

Figure R 2. Reflection amplitude versus incidence angle curves for the ice–water boundary (①) from Shot gather #2 of the 21YY line and for each media interface.

Sub ice-base reflection

Figure 6 raises the possibility that the currently interpreted water-bottom (floor of the subglacial lake) reflector may be deeper than the actual lake bottom. The grounds for this come from the presence of reflectivity between the ice-base reflector and its ghost.

For example, in Figure 6a) the reflectivity between the ice-base (1) and the ghost (2) needs explaining. If (1) is an ice-water interface is this reflectivity the base of the water column? Why is (3) the preferred water column base? The reflectivity at distance 2.5-3 km that impinges on the basal return looks to me like an ice-bed reflection. Again in Figure 6b, the reflectivity between the bed return and the ghost needs to be explained. Is it possible that this is the lake bottom instead of (3)? In Figure 6c between ~2.7 km and ~4 km there is a prominent reflector arriving before the ghost. How can this reflector be explained? Why is the deeper reflector the preferred lake bottom? As the survey will likely guide site selection for a subglacial access program it would pay to clearly outline the reasoning behind the preferred interpretation, and provide alternative interpretations.

➔ We present both the original and additional interpretations in Figure R1. The weak reflection observed between the ice–water interface and its corresponding ghost may represent the water–sediment boundary. Given that the uppermost part of the sediment layer is likely unconsolidated, resulting in low reflection amplitudes, this interpretation is considered more plausible. Accordingly, we have introduced Model 2 in the manuscript and conducted a comparative analysis using synthetic data. We have revised Section 4 of the revised manuscript as follows.

(Page 11, Lines 231-233) "Between reflections ① and ②, a weak normal polarity reflection (③), presume d to represent an interface, is observed. However, in some shot gathers, signal ③ appears with reverse po larity (Figure 4c), leading to partial cancellation and ambiguity in layer interpretation. Approximately 25 ms later, an opposite polarity ghost reflection (④) follows."

Minor/technical points.

Title. I suggest a change to "A seismic analysis of subglacial lake D2 (Subglacial Lake Cheongsuk) beneath David Glacier, Antarctica."

➔ Thank you. We have changed the title.

L34-35 ‘largely isolated’ Not an important point, but I still don't think this can be concluded. A stable lake just implies steady-state where inputs and outputs are balanced.

➔ (Page 2, Lines 36-38) We have revised the sentence from

"These closed systems do not exhibit significant surface elevation changes and where subglacial water remains largely isolated, with minimal exchange due to slow and stable recharge and discharge cycles" to

"These closed systems do not exhibit significant surface elevation changes and are characterized by long-term balance between recharge and discharge, although the extent of subglacial water exchange remains uncertain in the absence of direct observations".

L106 ‘...presence of subglacial sediments’ I think a reference is needed here. Perhaps https://doi.org/10.1130/G50995.1

➔ (Page 5, Line 113) We have added the reference “(Siegfried et al., 2023)”

L113-115. Please break up this sentence. The meaning in currently unclear.

➔ (Page 5, Lines 120-122) We have revised the sentence from

"To better constrain the lake's extent and basal conditions of SLD2, airborne IPR survey data from 2016/17 (Lindzey et al., 2020) and 2018/19 (Ju et al., 2025) field campaigns indicate that glacier surface elevations in the SLD2 region range from approximately 1820 to 1940 m, with ice thicknesses varying between 1685 and 2293 m" to

"To better constrain the extent and basal conditions of SLD2, we used airborne IPR data collected during the 2016/17 (Lindzey et al., 2020) and 2018/19 (Ju et al., 2025) field campaigns. These surveys show that the glacier surface elevation in the SLD2 region ranges from approximately 1820 to 1940 m. The corresponding ice thicknesses vary between 1685 and 2293 m".

L117 ‘Bain-like topography’ is not a well-known term in glaciology. Please define.

➔ (Page 5, Line 124) Sorry, it's a typo. We have revised the from “Bain-like” to “basin-like”.

L127 ‘were aligned’ sounds deliberate, I suggest ‘happened to be aligned’.

➔ (Page 5, Line 134) Thank you. We are not deliberate. We have revised from “were aligned” to “happened to be aligned”.

L132 ‘reduces’ -> ‘reduced’

➔ (Page 6, Line 138) We have revised from “reduces” to “reduced”.

Figure 3. The seismic lines in this figure need distance annotations so that the seismic stacks can be referenced to the basemap.

➔ We have added the length at the end of each seismic line.

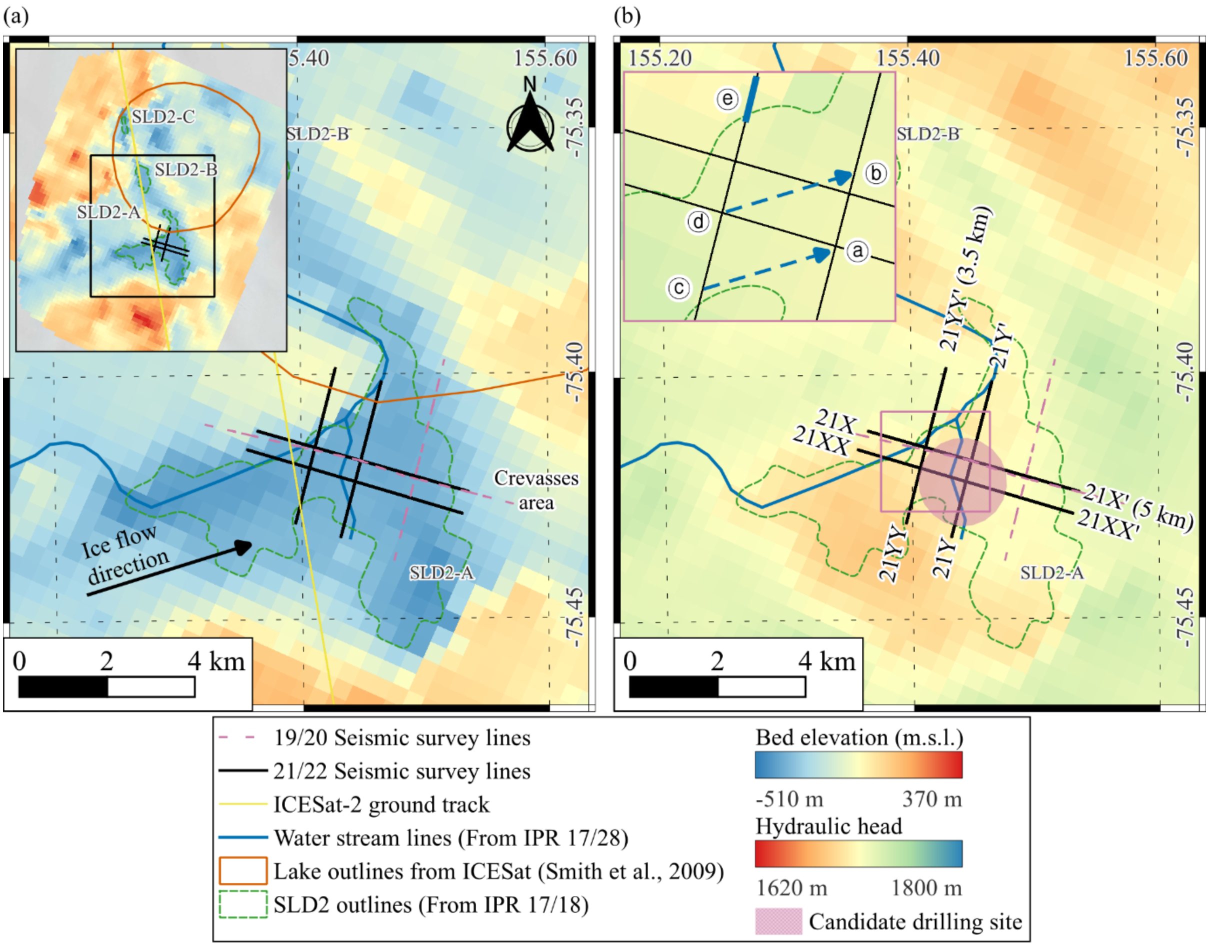

Figure 3

Table 1 (or the text) requires additional details of shot positioning (off-end, centre shots?) and near offset distance.

➔ (Table 1) We have added the details of shot positioning.

(Page 8, Line 163) We have added the sentence "Detailed shot positioning information is provided in supplementary information S1".

Table 1: Parameters of the active-source seismic survey.

Survey Parameters	Survey lines			
	21X line	21Y line	21XX line	21YY line
Line length (km)	5	3.5	5	3.5
Fold	8	8	4	4
Shot interval (m)	90	90	180	180
Number of shots	56	40	28	20
Shot positioning	**Use both off-end and center shots**			
Receiver channels	96			
Receiver interval (m)	15			
Near offset (m)	**0**			
Far offset (m)	**1425**			
Recording time (s)	4			
Record peak frequency (kHz)	1			
Record sampling rate (ms)	0.25			

Survey time (days)	34
Survey crew size	Hot water drilling (3), Seismic (6)

➔ Supplementary information S1. Seimsic data acquistion

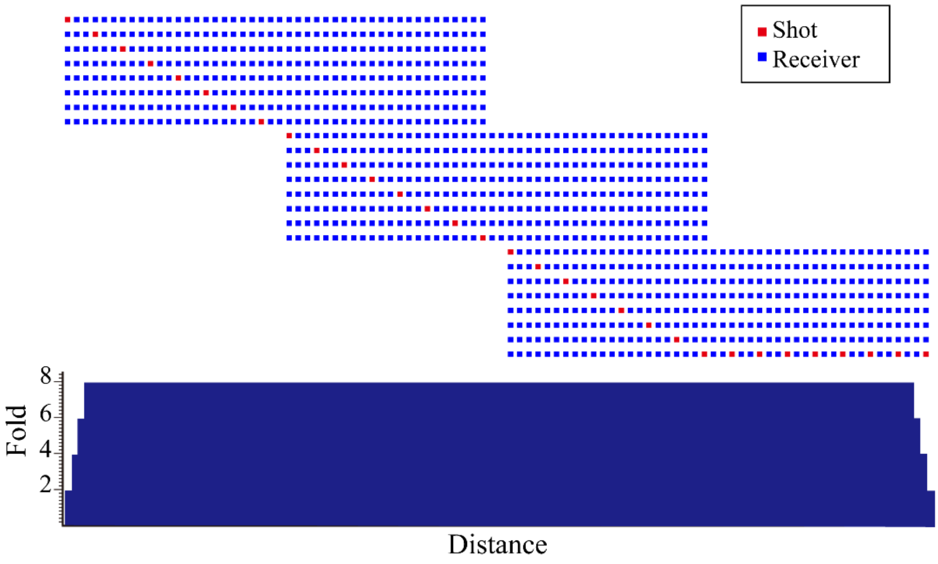

Figure S1: In the seismic survey layout, only the odd-numbered receivers are displayed, that is, one receiver marked every two channels.

L160 Citing the Voigt publication on georods seems more appropriate here.

➔ (Page 8, Line 167) We have revised from "(Ju et al., 2024)" to "(Voigt et al., 2013)".

Figure 4. b) I appreciate the lines are indicative only and not supposed to represent picks, but the shallow gradient on the direct arrival implies a very high velocity. I suggest changing the gradient to one more representative of the velocity estimated.

➔ The slope lines have been adjusted to reflect the correct velocities.

L211-212 'This resolution is adequate...' I don't think this statement is needed. The data are what they are and are capable of imaging the top and bottom of an approximately 2 m thick water column.

➔ (Page 11, Line 224) We have revised the sentence from "This resolution is adequate for imaging SLD2" to "The data can image both the top and bottom of a water column approximately 2 m thick or thicker.".

Figure 6 caption: Include comment in caption that the annotations are discussed in the main text.

➔ (Figure 6 caption) We have added the sentence "See Table 2 for symbols definitions".

L352—354 I think a more nuanced description is required here.

➔ (Page 20, Lines 397-400) We have revised the sentence from

"The seismic data revealed strong, laterally continuous reflections with reverse polarity at the glacier–lake interface, whereas normal-polarity reflections were observed at the glacier–bed and lake–bed interfaces.” to

“The field seismic data revealed strong, reverse polarity reflection at the glacier–lake interface. In contrast, the basal reflections beneath the lake are less well-defined, suggesting the presence of subglacial sediments. This ambiguity gives rise to two alternative interpretive scenarios based on the presence or absence of a sedimentary layer.”.

L358 Again, I worry that the drilled water depths could be much thinner than this if the reflection events that are evident between the primary bed return and the ghost or the bed returns are in fact the base of the water column.

➔ (Pages 20-21, Lines 401-417) We have revised the sentence from

“A comparison between synthetic and field PSTM sections demonstrated strong agreement in the timing and polarity of major reflection events at the glacier-lake and lake-bed interfaces, confirming the validity of the velocity model. This model estimated the ice thickness and lake water column height to be 2250–2300 m and 53–82 m, respectively.” to

“Given this interpretational ambiguity regarding the sediment layer, two velocity models were constructed: Model 1, which assumes the absence of sediment, and Model 2, which includes a sediment layer beneath the lake. Synthetic seismology was generated using wave propagation modeling based on these models. Sediment thickness in Model 2 was uniformly assigned using the average time difference (①–③) calculated from selected areas of the dataset. Comparisons between the synthetic and field PSTM sections show consistent TWT times and polarities for key reflection events at the glacier–lake interface (①), the lake–bedrock interface (⑤) in Model 1, and the sediment–bedrock (⑤) interface in Model 2. […] Furthermore, the integrated analysis of seismic and synthetic data provides a quantitative structural model of the SLD2-A geometry beneath David Glacier. These results provide critical guidance for future clean hot-water drilling. In particular, we identify an area within a 1 km radius of S 75.422°, W 155.441° as a suitable candidate site, based on its broad spatial extent, minimum estimated water depth exceeding approximately 10 m, and absence of contamination from surface field camps.”.

L367. Regarding the suggested drill site, this should be included on a previous basemap and the corresponding seismic profile and distance marker referenced here.

➔ (Figure 3) We have revised the map in Figure 3, and the candidate drilling site is marked.

Referee #2

1. Figure 6d: I see how the reflections 3/4 on the left side of the image 6d show normal then reverse polarity respectively, but on the right side, the polarity is flipped for 3 and 4. The reflection claimed to be from the ice-bed interface at 3 km on line 21 YY is negative polarity then positive polarity, which is opposite to what is described in the text and what would be expected for ice-rock. I mentioned this in the first submission but it may not have been seen by the authors. Clearly, given the geometry of the reflection, arrivals 3 and 4 have to represent the edge of the subglacial lake. However, following the logic of the authors, from the polarity I would assume this region too has subglacial water, or at least material with lover velocity than the ice above. If the authors are certain this region should have bedrock or lithified sediment, then it brings question to the use of polarity on its own to describe the subsurface velocities and materials.

➔ Before proceeding with our response, we have redefined the symbols to avoid confusion. We have added Table 2 to the manuscript.

Table 2: Symbols for each reflection event

Interface symbols	Model 1	Model 2
①	Ice-water	Ice-water
②	Ice-water ghost	Ice-water ghost
③	-	Water-sediment
④	-	Water-sediment ghost
⑤	Water-bed	Sediment-bed
⑥	Water-bed ghost	Sediment-bed ghost
⑦	Ice-bed	Ice-sediment
⑧	Ice-bed ghost	Ice-sediment ghost

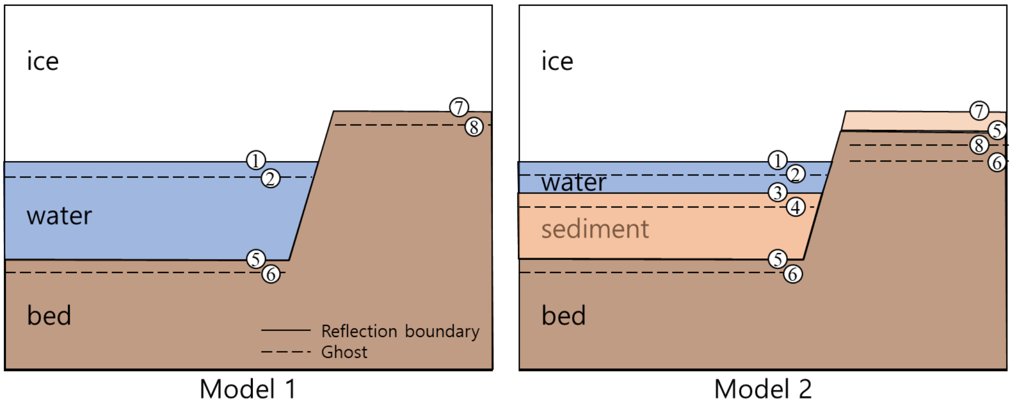

Figure R1. Velocity model for the subglacial lake structure interpretation. Boundary numbers correspond to those indicated in the manuscript, and the theoretical reflection coefficients at each interface are shown.

At the 3 km of the 21YY line, reflections ③ (redefined as ⑦) and ④ (redefined as ⑧) exhibit reverse and normal polarity, respectively. In line with the reviewer's suggestion, we acknowledge that this interface may represent an ice–sediment boundary rather than an ice–bedrock boundary. Booth et al. (2012) showed that when a dilatant till exists as a thin layer, it can give rise to reverse polarity reflections. The observed phase reversal, therefore, strongly suggests the presence of a dilatant till at the ice–sediment interface. By contrast, our synthetic model, which does not include a till layer, produces normal polarity reflections. We simplified the synthetic modeling and incorporated sediment properties predicted for Lake Vostok. However, because the physical parameters of materials such as dilatant till span a wide range and site-specific values are difficult to constrain, it is challenging to include them directly in the modeling. Accordingly, to clarify that the observed reverse polarity can be plausibly explained by the presence of subglacial till, we have added the following sentence in section 5 of our revised manuscript.

(Pages 18-19, Lines 361-366) "However, the field data show that reflection ⑦ exhibits reversed polarity, suggesting the presence of subglacial sediments with lower acoustic impedance than assumed in the models. This discrepancy may be explained by the presence of a dilatant till beneath the glacier, which can produce reverse polarity reflections depending on its physical properties. Booth et al. (2012) demonstrated that the seismic response of such tills is highly sensitive to variations in P-wave velocity, density, and thickness. In particular, their study showed that when the till forms a thin layer, reverse polarity reflections may occur."

(Pages 20-21, Lines 406-411) "Nevertheless, synthetic data generated by modeling a velocity model that simplifies a complex geological structure has limitations in thoroughly explaining the entire waveform of the complex field data. For example, subglacial sediments are generally expected to produce normal polarity reflections due to acoustic impedance contrasts with overlying water. However, in field data, the polarity and clarity of the water-sediment interface vary with the degree of sediment consolidation. In particular, the reverse polarity reflection observed at the ice–sediment interface in the 21YY profile suggests the potential presence of dilatant till."

2. Figure 9: This issue is even more prominent here, and hasn't changed since the first submission. In figures 9c and 9d, arrivals 3 and 4 in the synthetic data appear to be the opposite polarity than what is observed in the field data. The strongest first reflection in 9d corresponding to the field data appears to be blue with red side lobes (negative polarity) while the synthetic shows red with blue side lobes (positive polarity). This is true for 9c as well, where the lake-bed interface is supposed to show normal polarity corresponding arrival 3 based on the synthetics, but in the field data this arrival is negative polarity. Further, it appears that there is a transition where at 0.4 km, the arrival 3 is normal polarity, but by 1.2 km, the polarity has flipped. Whether this is a geometrical eTect (unlikely since oTsets are small) or a difference in material (hard rock vs wet sediment), this needs to be addressed. Alternatively, the argument can be strengthened with evidence besides polarity of the first arrival. If you are able to perhaps compute reflectivity curves or compare it to later phases' polarity (PS, SS etc.), these discrepancies between the data and synthetics may be reconciled. As it stands, the simple velocity model and generated synthetic wavefield cannot describe the full wavefield of the field data.

➔ The explanation regarding the reverse polarity of reflections ⑦ (pre-revision ③) and ⑧ (pre-revision ④) has been addressed in Response 1.

For reflection ⑤ (pre-revision ③) observed in the 21YY section, we maintain that it is a normal polarity event consistent. In the final migrated image—particularly after residual static correction—we acknowledge that the red amplitude (the black arrow) above the side lobe (blue) appears prominent and that the peak (red) can appear less prominent than the side lobe (blue) (Figure R2). This visual ambiguity may, at first glance, make the reflection look like a reverse-polarity event. To aid interpretation and resolve this ambiguity, we have added a guideline (black dashed line) in Figure 6d that explicitly indicates our interpretation of the normal polarity peak of reflection ⑤.

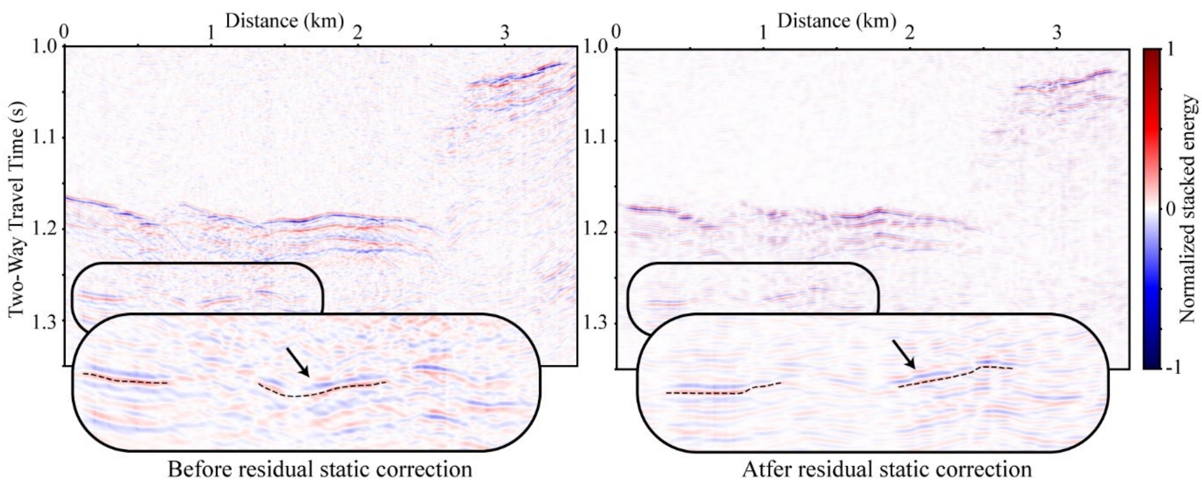

Figure R2. Comparison of the lower reflection signal before and after residual static correction.

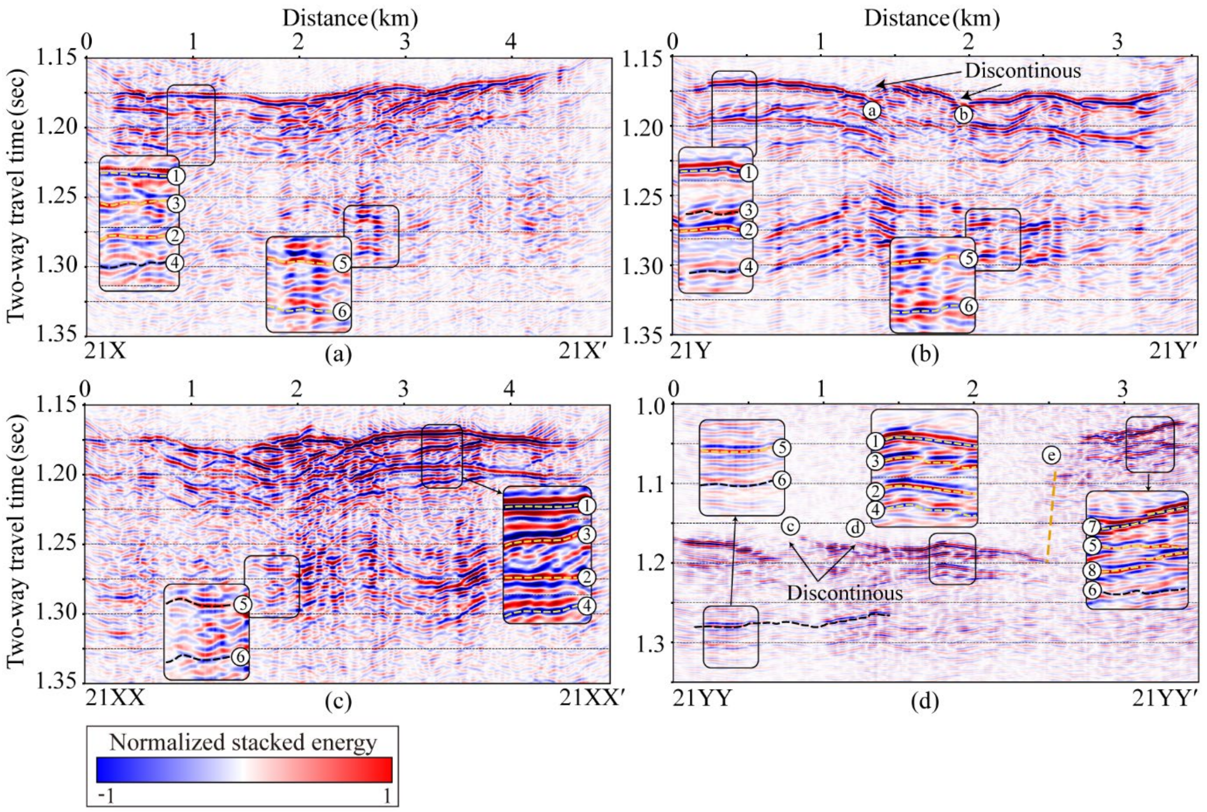

Figure 6: PSTM seismic sections for lines (a) 21X, (b) 21Y, (c) 21XX, and (d) 21YY prior to ghost removal. Ghost reflections appear 25–30 ms beneath the glacier–lake and lake–bed interfaces due to the 25 m source depth. See Table 2 for symbols definitions.

3. As an overall note, the field data is clearly more complicated than the synthetic data. For the broad identification of arrivals and discontinuous features, the synthetic data seems to do a good job in guiding one based on qualitative similarity to the field data. However, the actual arrivals, both in terms of polarity but also in terms of coherence, can be quite diTerent. Use 9d as an example. In addition to being diTerent polarity than the synthetic, why does the reflection become discontinuous laterally? Is it data quality, subsurface topography, variable materials properties? While the “scour” related discontinuities are explained by c and d on labeled on figure 9, there is significant incoherence and amplitude variation laterally in addition to these discontinuities.

➔ Lateral reflection discontinuities observed beneath the glacier may result from subsurface topographic variations—such as subglacial features like the SLF—as well as from data quality issues or spatial heterogeneity in material properties. In this context, topographic variations beneath the surface are functionally equivalent to lateral variations in physical properties. In this study, we carefully assessed the quality of all raw data and completed the preprocessing and validation procedures. Elevation corrections were also performed to minimize errors associated with surface topography. Events ⓐ, ⓒ, and ⓓ appear to be caused by the loss of coherent reflections due to structural scattering along inclined surfaces. Accordingly, the lateral discontinuities are interpreted as expressions of subglacial terrain changes, such as the SLF, which reflect material contrasts. In the case of ⓑ, the feature resembles a bow-tie pattern and may indicate a protruding ice structure beneath the glacier, as in Figure 7.

4. In terms of resolution, the authors discuss the vertical resolution of the water layer. However, in terms of lateral resolution, the discussion is a bit lacking. If, for example, there are small pockets of water on the ice-bed region at higher elevations, how would this affect the polarity and coherence of the arrivals here? Would they be resolved at all? Similarly, at the ice-lake-bed interface, can discrepancies in synthetics and observations be explained by varying properties laterally, i.e. some kind of water-wet sediment distribution at the glacier base rather than purely

water?

➔ The ice–bed interface is interpreted as a gently dipping structure. If small water pockets are present, they would fall below the vertical resolution limit and thus be difficult to distinguish on the seismic section. Moreover, Ju et al. (2025) reported a low probability of subglacial water in this area, and Booth et al. (2012) showed that thin layers of till can produce reversed polarity. Accordingly, the presence of a dilatant till is the more plausible interpretation. The lateral resolution, defined by the CDP spacing, is approximately 7.5 m. Although this is finer than the vertical resolution, it is sufficient for interpreting basal topography, as demonstrated by previous seismic studies at Subglacial Lake Whillans and Lake Ellsworth. We also compared the field data with synthetic seismograms to reduce interpretational uncertainty. Admittedly, synthetic data generated from a velocity model that simplifies complex geology cannot perfectly reproduce the full waveforms of field records. Nevertheless, the principal reflection events are consistent, and the data possess adequate resolution for our interpretation.
Clean hot-water drilling is planned at the SLD2 site during the 2028/29 austral summer season. If the drilling is successful, we will install a distributed acoustic sensing (DAS) cable in the borehole to conduct a seismic tomography survey. This approach is expected to yield a more accurate structural characterization of SLD2.

Overall, I find the paper to be a great read which presents interesting and novel results from an important (and understudied) region. I think there are still some considerations missing from the interpretation and discussion sections, particularly in terms of polarity and synthetic modeling, but I believe these can be addressed with relatively minor corrections. Line specific comments and more in depth description of points above are attached in the pdf.

Minor comments

Add a note about how you deal with the crevasse noise? This couldn't go away with increased fold coverage.

➔ (Page 3, Line 78) We have added the sentence "Furthermore, the sound source was positioned further from the crevasse (end-shot), delaying the arrival of crevasse-generated noise and preventing it from obscuring key reflections".

I think this should be rephrased. Without reason to think this stability should be threatened, this seems unnecessary. Also, clarify the difference between a stable glacier but an active subglacial system, which is what you claim to have here

➔ (Page 4, Lines 97-99) We have revised the sentence from
"Although the overall mass balance of David Glacier currently appears stable, it remains uncertain how long this stability can be maintained." to
"Although the overall mass balance of David Glacier currently appears stable, several active subglacial lakes observed by satellites have the potential to influence glacier dynamics (Ju et al., 2025; Kim et al., 2025).".

I think this section can be compressed

➔ (Page 6, Lines 135-141) We have revised the sentence from
"Consequently, the acquired seismic data were significantly contaminated by strong linear coherent noise associated with crevasses, which severely degraded the signal quality of key reflectors, particularly reflections from the subglacial lake–bedrock interface. In addition, explosives are deployed within shallow boreholes (< 20 m depth), and owing to the absence of proper backfilling and the rapid timing of detonation, poor coupling between the explosives and the borehole walls further reduced energy transmission efficiency, resulting in overall low-quality reflection signals (Ju et al., 2024). As a result, due to the limitations of single-fold acquisition, stacking was not feasible, resulting in a low signal-to-noise ratio (SNR) and the presence of dominant coherent noise, rendering the seismic dataset unsuitable for quantitative structural interpretation." to
"Consequently, the acquired seismic data were significantly degraded by strong linear coherent noise generated by crevasses, severely compromising the quality of key reflectors, particularly those at the subglacial lake–

bedrock interface. Furthermore, explosives were deployed in shallow boreholes (< 20 m depth), and due to the absence of proper backfilling, poor coupling between the explosives and the borehole walls further reduced energy transmission efficiency, resulting in overall low-quality reflection signals (Ju et al., 2024). Combined with the limitations of single-fold acquisition, stacking was not feasible, the dataset exhibited a low signal-to-noise ratio (SNR) and was unsuitable for quantitative structural interpretation."

Many seismic surveys claim to need 10 + fold coverage to appropriately image/resolve subglacial features. Based on the data, it's clear 8 folds is sufficient for your analysis. Do you have a thought on this discrepancy? Are 10+ folds more than necessary?

➔ While 10+ fold coverage is generally preferred for optimal seismic imaging, such acquisition geometries are often challenging to achieve in polar environments due to logistical, meteorological, and budgetary constraints. In this study, we acquired seismic data with 4- and 8-fold coverage. Despite the relatively low fold, the data quality was sufficient to resolve key subsurface features, including those indicative of subglacial lake structures. Our interpretation is supported by analogous cases, such as Horgan et al. (2012), where subglacial lake features were successfully identified using low-fold seismic data.

Here, specifiy the refraction you believe to be observing. Refraction from the firn-ice transition?

➔ (Page 8, Line 169) We have revised the sentence "In these shot gathers, the velocity of the direct wave is estimated to be approximately 1800 m/s, and the refracted wave velocity in **firn-ice transition** is approximately 3800 m/s".

Is there a reason the linear coherent noise couldn't be removed from the previous survey? if the crevasse noise is all linear as you claim, shouldn't this be possible too?

➔ During the initial seismic survey, linear noise from surface crevasses overlapped with key lake reflections. Although attempts were made to attenuate this noise, much of the amplitude information was also removed in the process, rendering the lake reflections nearly indiscernible. Moreover, approximately half of the acquired data were severely affected by crevasse-induced noise. To mitigate this issue in the subsequent survey, the survey line orientation was reversed, ensuring that crevasse-generated noise would not coincide temporally with primary reflection events. As a result, the crevasse noise arrived at later times in most of the data, thereby preserving the quality of the primary reflections except in a limited portion of the dataset.

(Page 8, Lines 176-179) We have added the sentence
"The survey was designed to place the seismic source at a distance from crevasses, ensuring that crevasse-related noise would be recorded after the main reflections (1.1–1.3 s), thereby minimizing its impact (Figure 4a). While most data exhibit crevasse noise occurring after the main reflections, a reduction in the source–crevasse distance causes this noise to increasingly overlap with the primary arrivals, thereby complicating interpretation.".

what frequency band is the final migrated image in?

➔ The migrated data have a center frequency of approximately 180 Hz. Below is the frequency analysis result of PSTM for the 21YY line.

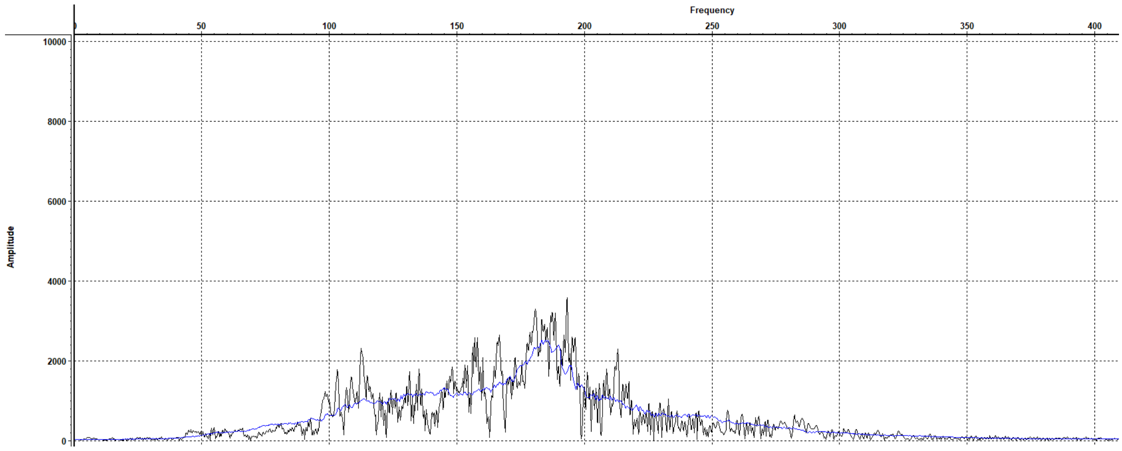

Figure R 3. Average frequency of the entire trace (blue line).

I see how the reflections 3/4 on the left side of the image 6d show normal then reverse polarity respectively, but on the right side, the polarity is flipped for 3 and 4. The reflection claimed to be from the ice-bed interface at 3 km on line 21 YY is negative polarity then positive polarity, which is opposite to what is described in the text and what would be expected for ice-rock.

➔ This issue has been addressed in Response 1.

Booth, A. D., Clark, R. A., Kulessa, B., Murray, T., Carter, J., Doyle, S., and Hubbard, A.: Thin-layer effects in glaciological seismic amplitude-versus-angle (AVA) analysis: implications for characterising a subglacial till unit, Russell Glacier, West Greenland, Cryosphere, 6, 909–922, https://doi.org/10.5194/tc-6-909-2012, 2012.

Ju, H., Kang, S., Han, H., Beem, L. H., Ng, G., Chan, K., Kim, T., Lee, J., Lee, J., Kim, Y., and Pyun, S.: Airborne and Spaceborne Mapping and Analysis of the Subglacial Lake D2 in David Glacier, Terra Nova Bay, Antarctica, J. Geophys. Res.: Earth Surf., 130, https://doi.org/10.1029/2024jf008142, 2025.

Supplement of

A Seismic analysis of subglacial lake D2 (Subglacial Lake Cheongsuk) beneath David Glacier, Antarctica

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S1. Seismic data acquisition

Table S1: Seismic survey work schedules

Date (dd/mm/yy)	Job	Work day (day)
01/12/21	GPR survey	1
04/12/21 – 05/12/21	Marked shot position	2
06/12/21 – 28/12/21	Hot water drilling (25 m) and explosive installation (4 lines, total 144 points)	14
12/12/21 – 02/01/22	Seismic survey (4 lines)	11

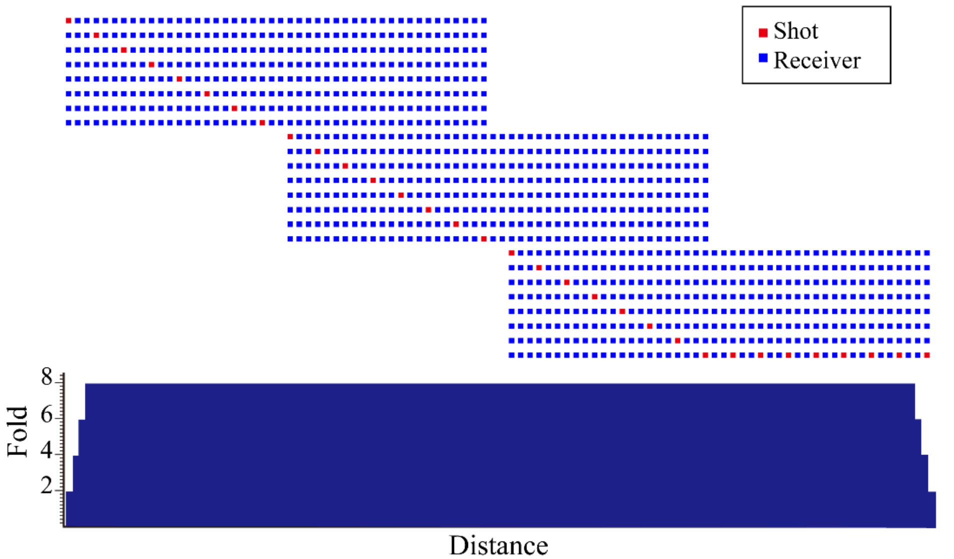


Figure S1: In the seismic survey layout, only the odd-numbered receivers are displayed, that is, one receiver marked every two channels.

S2. Seismic data processed parameters and results

This study utilized the Omega geophysical data processing platform (SLB) for seismic data processing. Among the various processing steps, we provide below the key parameters applied during procedures that directly influence the ice–bedrock interface signal, such as noise attenuation.

1. Anomalous amplitude attenuation (AAA) for the 1st round

AAA is a frequency-domain filtering technique designed to suppress spatially coherent anomalous amplitudes such as swell noise and rig noise, by comparing amplitude spectra across traces and attenuating outliers based on spatial median statistics. The method identifies frequency bands with anomalous energy by comparing each trace's amplitude spectrum within a spatial window to the median of its neighboring traces. Detected anomalies are either scaled or replaced using interpolated values from adjacent traces, preserving relative amplitude relationships. Key parameters include TIME, which defines the temporal window of threshold application; THRESHOLD FACTOR, which sets the amplitude level considered anomalous; and SPATIAL MEDIAN WIDTH, which specifies the number of adjacent traces used for median computation. Proper tuning of these parameters is essential to avoid signal distortion while effectively attenuating coherent noise. AAA is particularly useful in prestack data conditioning as it enhances seismic data quality without compromising true subsurface reflections (SLB, 2025a).

- SPATIAL MEDIAN WIDTH: 21 traces
- Threshold factor tables:

TIME	THRESHOLD FACTOR
0	15
1000	10
3000	7
4000	6

2. Curvelet transform-based filter for 1st round

Curvelet Transform is a multi-scale, multi-directional decomposition technique that provides a sparse representation of seismic data by capturing curved wavefronts more efficiently than conventional fourier or wavelet transforms. An important aspect of the Curvelet Transform implementation involves user-defined control over the scale and angle bounds that determine which components of the data will be transformed. The LOWER BOUND OF SCALE and HIGHER BOUND OF SCALE specify the range of spatial frequencies (scales) to be included in the transform. Lower scales correspond to coarse, low-frequency components, while higher scales capture fine, high-frequency structural details. The LOWER BOUND OF ANGLE and

HIGHER BOUND OF ANGLE define the directional sectors (angles) within each scale to be analyzed. This allows selective enhancement or suppression of events based on their dip or propagation direction (SLB, 2025b). Figure S2 illustrates how the f–k domain is partitioned into curvelet panels by scale and angle. Adjusting these bounds allows for targeted signal processing, such as isolating curved events or attenuating directionally coherent noise. These parameters provide valuable flexibility in customizing the transform for specific seismic applications.

- Panel manager

LOWER BOUND OF THE SCALE	HIGHER BOUND OF THE SCALE	LOWER BOUND OF THE ANGLE	HIGHER BOUND OF THE ANGLE
2	2	1	3
2	2	8	10
3	3	1	6
3	3	13	18
4	4	1	6
4	4	13	18

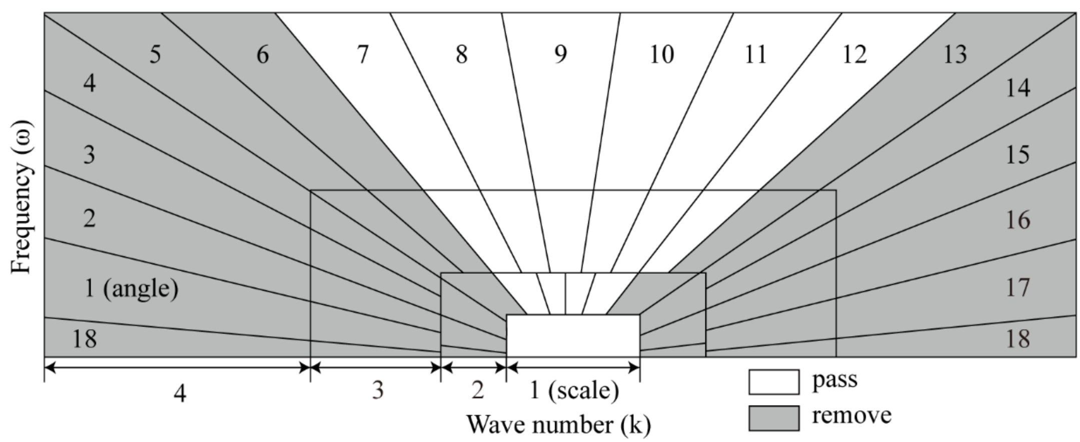


Figure S2: Illustration of the panel manager. In the f-k domain, the hatched area is identified as noise and removed accordingly.

3. Surface-consistent deconvolution

Surface-Consistent Deconvolution is a technique for generating and applying deconvolution operators that are consistent across seismic sources, receivers, offset ranges, and CMP locations (SLB, 2025c; Yilmaz, 2001).

Key processing parameters used in this workflow include:

- CONSTANT_ACOR_LENGTH = 100: Defines the half-length of the autocorrelation window used in operator design, balancing spectral resolution and filter stability.

- WHITE NOISE PERCENT = 0.01: Adds 1% white noise to stabilize the autocorrelation estimation and prevent over-whitening of the signal.
- PREDICTION DISTANCE = 2.5: Specifies the prediction lag in the predictive filter design; this parameter controls the temporal range of the filter's effect, influencing multiple suppression and resolution.

4. Anomalous amplitude attenuation (AAA) for the 2nd round
- Spatial median width: 11 traces
- Threshold factor tables:

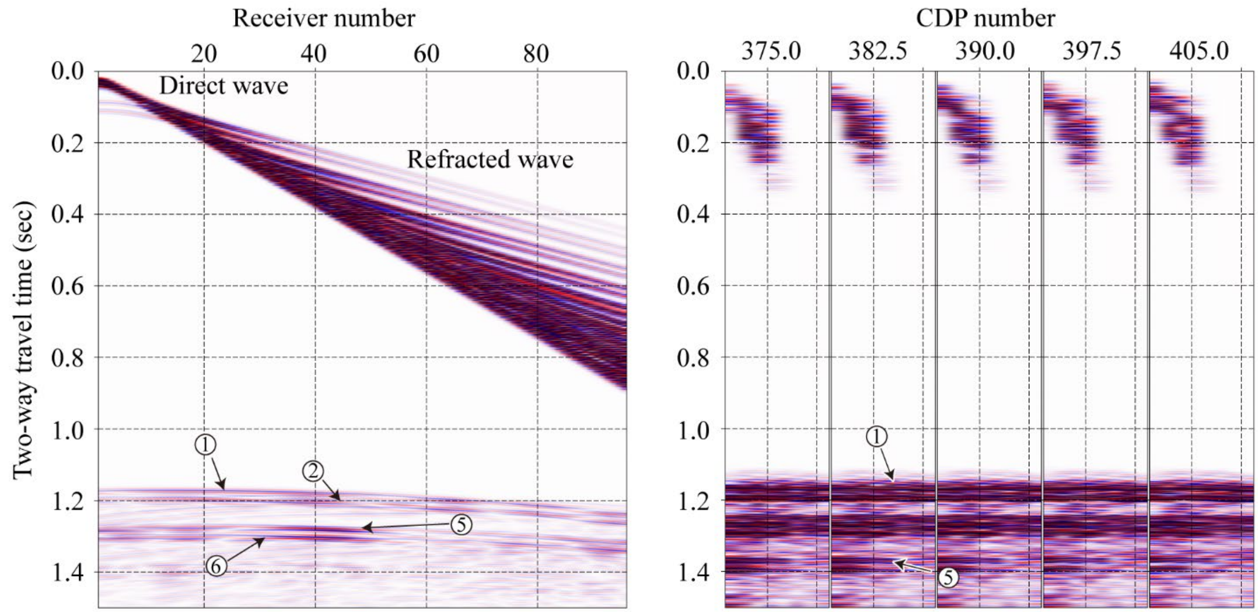
Time	Threshold factor
0	8
1000	6
3000	4
4000	3

5. Curvelet transform-based filter for the 1st round: same as 1st round parameter

6. Frequency-offset coherent noise suppression (Figure S4.c)

The frequency–offset (F-X) Coherent Noise Suppression (FXCNS) module is designed to attenuate near-surface shot-generated coherent noise, such as dispersive surface waves and trapped modes, which interfere with primary seismic reflections, particularly in 3D shot or receiver gathers with irregular spatial sampling (Hildebrand, 1982). FXCNS operates in the frequency domain by modeling coherent noise using fan filters and estimating it in a least-squares sense for each trace based on local neighbors within a specified azimuthal sector. The estimated coherent noise is then subtracted from the original signal, preserving true reflection events (SLB, 2025d).

- LOW PASS VELOCITY: 100
- LOW STOP VELOCITY: 300
- HIGH PASS VELOCITY: 8000
- HIGH STOP VELOCITY: 10000



(a) Raw data shot gather of synthetic (b) After pre-stack time migration

Figure S3: Results before and after data processing. (a) Synthetic data of shot gather #1. (b) Result after pre-stack time migration. Symbols (see Table 2).

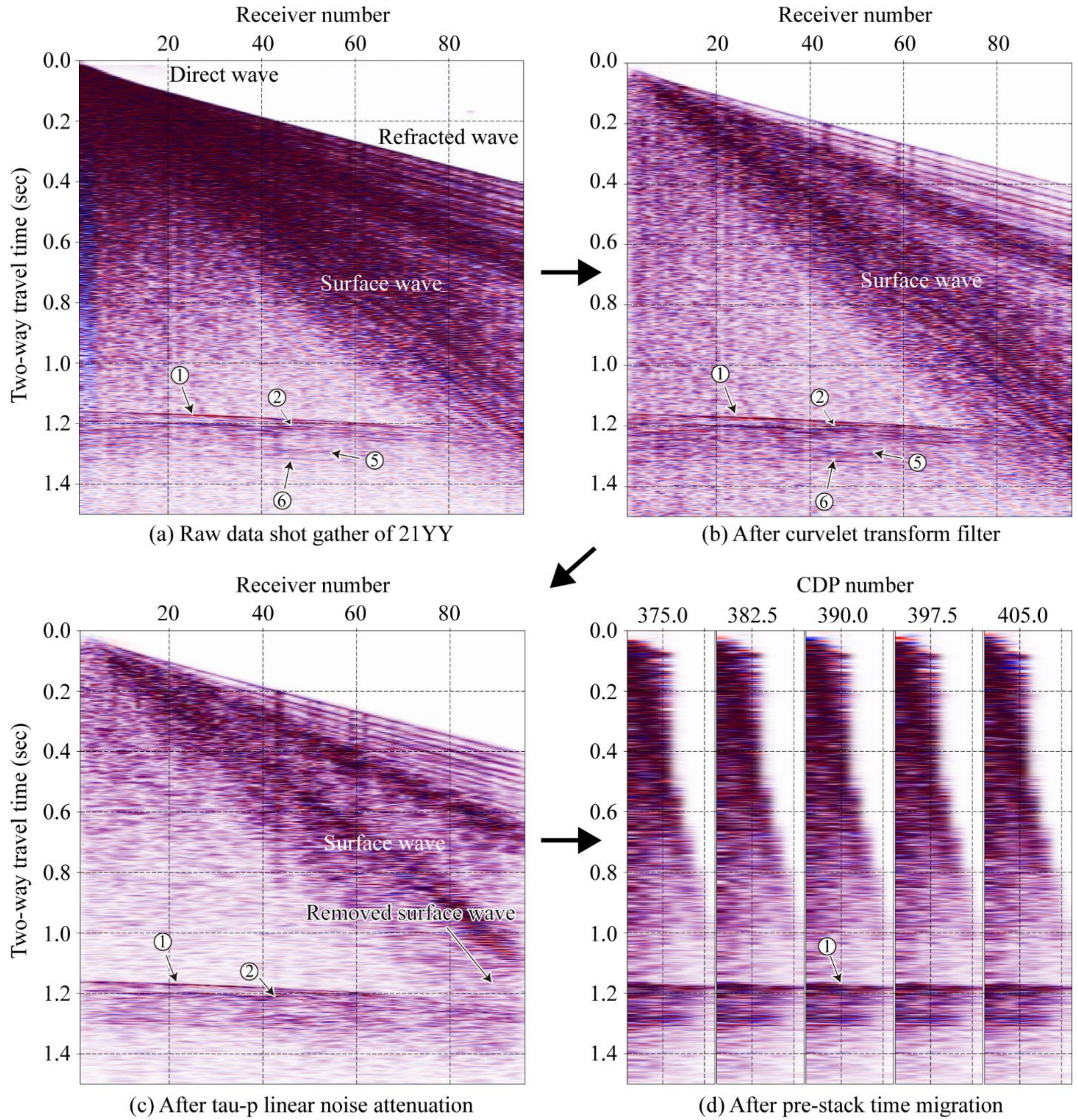


Figure S4: Results at each stage of data processing. (a) Shot gather #1 from 21YY. (b) Removal of high-frequency random noise and coherent linear noise. (c) Application of a frequency-offset coherent noise filter and tau-p linear noise attenuation for surface wave removal. (d) Result after applying pre-stack time migration.

References

Hildebrand, S. T.: Two representations of the fan filter, Geophysics, 47, 957–959, https://doi.org/10.1190/1.1441363, 1982.

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SLB: Omega Geophysical Processing System – Curvelet Transform (CURVELET_TRANSFORM) Module Documentation, Version 22.1, SLB manual, Houston, TX, 2025b.

SLB: Omega Geophysical Processing System – Surface-Consistent Deconvolution Analysis (SC_DCN_SPCTRL_ANL) Module Documentation, Version 13.18, SLB manual, Houston, TX, 2025c.

SLB: Omega Geophysical Processing System – F-X Coherent Noise Suppression (FXCNS) Module Documentation, Version 3.16, SLB manual, Houston, TX, 2025d.

Yilmaz, Ö.: Seismic data analysis: Processing, Inversion, and Interpretation of Seismic Data, Appendix B.8 (Surface-Consistent Deconvolution), Society of Exploration Geophysicists, 262–266 pp., 2001.