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INTRODUCTION

Natural Resources Canada (NRCan) has been tasked, under the Marine Conservation Targets (MCT) initiative announced in Budget 2016, with evaluating the petroleum resource potential for areas identified for protection. Such resource assessments are in the mandate of the Geological Survey of Canada (GSC), within NRCan. In order to carry out this mandate, the GSC has drawn on legacy reflection seismic data from the National Energy Board (NEB) catalog as well as seismic data that has been accessed from private industry through seismic data agreements. Most of the legacy data exists as paper sections and on micro-fiche if not available in digital format from the data owner. Significant efforts have been made to preserve this seismic data through digital scanning followed by either vectorization or registration to convert into SEGY format. In some cases, the GSC was able to locate original unstacked field data and supporting information, which allowed for the reprocessing of key 2D lines using Landmark's SeisSpace® seismic processing software.

The objective of this report is to illustrate the benefit of reprocessing legacy seismic data and to acknowledge the application of current petroleum industry imaging techniques to improve the seismic data quality.

Since October 2017, the GSC has fully reprocessed over 1500 km of 2D data and performed post-stack processing on over 8600 km of scanned sections. At market rates, this represents roughly $500,000 in added value. In some areas this seismic data is the only detailed geophysical information available which can be used to better understand regional sub-surface geology for petroleum resource assessments, which is essential to the MCT mandate. Seismic data is expensive to record and the legacy data in this report is located in areas that are difficult or even impossible to access presently, making the seismic data extremely valuable.

Much of the seismic data presented in this report was recorded and originally processed between the 1960's and early 1980's, during a time period when computing power and digital storage space was very expensive. Figure 1 indicates the areas of seismic data coverage in this report.

In many cases the original processing did not include seismic processing steps such as source de-signature, de-multiple, deconvolution, modern noise attenuation, relative amplitude preservation, residual statics, and other work flows that are now considered standard. By utilizing modern techniques, software, and computer performance, the original recorded data is transformed to help scientists gain new geological and geophysical insights.

FIGURE 1. Seismic data reprocessing location map.

SEISMIC REPROCESSING EXAMPLES

Banks Island Example – Line BK-31

Acquisition Type: Land			
Area: Banks Island	Date Shot: April 1971	Instrument: DFS III	Format: SEG-B
Sample Interval: 2ms	Recording Time: 6146ms	Field Filter: 12/36/62	Notch: Out
Channels Per Shot: 48		CDP Fold: 3	
Source Type: Dynamite			
Source Size: 50 lb	Source Depth: 27 M	Source Interval: 200m	
Receivers per group: N/A	Spacing N/A	Frequency: 14 Hz	Type: EV-22
Group interval: 50m			
Pattern:	1175 -----------------25 X 25 ----------------- 1175		Distance in meters
	1 ---------------------24 25 ------------------ 48		Channel number

Table 1. Line BK-31 acquisition parameters

Comparison Before and After Reprocessing

The acquisition parameters for line BK-31 can be found in Table 1. The large 50 pound charge size and long far offsets (for the time period) indicate that this survey was designed to image deep and steeply dipping reflectors. The recording time of 6 seconds is longer than the 4 second legacy sections, meaning that the reprocessed section recovers an additional 2 seconds of recording time. The legacy BK-31 section was processed in the early 1970's and was cut off at 4 seconds to save storage space and computer time during a period when both were very expensive. Using the originally recorded field data to reprocess the line allowed us to incorporate the full 6 seconds of length. This additional length allowed for imaging of deeper events, which in turn a more allows scientists solid foundation of the geology in the Banks Basin and how it relates to adjacent regions. Figures 1, 2, 3 and 4 are screen captures that illustrate just how much information can be gained by using original field data.

In addition to the deeper imaging, the reprocessing better preserved relative amplitude information, improved the character of seismic events, imaged events that are not visible on the legacy data, and improved signal-to-noise (Figures 1, 2, 3 and 4). The reprocessing flow also accounted for the structural nature of the area, the low fold (3 fold data), and the shallow velocity inversion caused by the permafrost layer. These improvements should allow interpreters to map seismic stratigraphy with increased confidence.

Figures 5 and 6 are close-up screen captures of a heavily faulted zone that was difficult to interpret before reprocessing. Figure 5 is the legacy data while Figure 6 is the reprocessed. Note that reprocessed section has been pre-stack migrated while the legacy data is a CMP stack, meaning that diffractions and dipping events have been moved to the best apparent positions in in time and space that can be determined with the information available. The signal-to-noise ratio and event continuity have improved with reprocessing and clearly defined fault edges are now more evident.

There are hints of what appears to be a paleo shoreface sequence in the legacy data (zoomed in on Figures 7 and 8). After reprocessing, the shore face sequence is clearer complete with what could be a barrier island and lagoonal system. Note that the legacy data has been cut off at 4000ms while the reprocessed data has not.

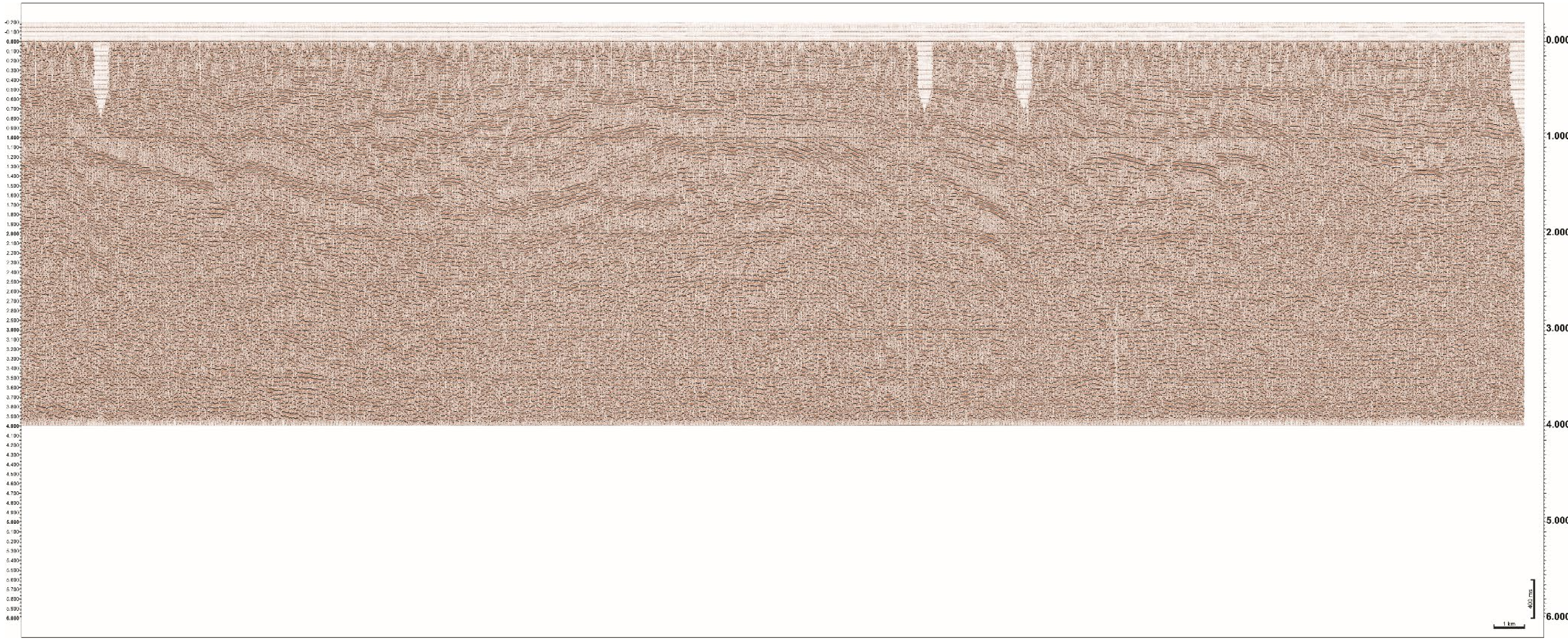

FIGURE 2. Line BK-31 (part 1) - Legacy processing. Note that the time length was limited to 4000 ms during legacy processing.

FIGURE 3. Line BK-31 (part 1) - GSC reprocessing. Note that reprocessing has recovered an addition 2000 ms from field tapes, revealing deeper events.

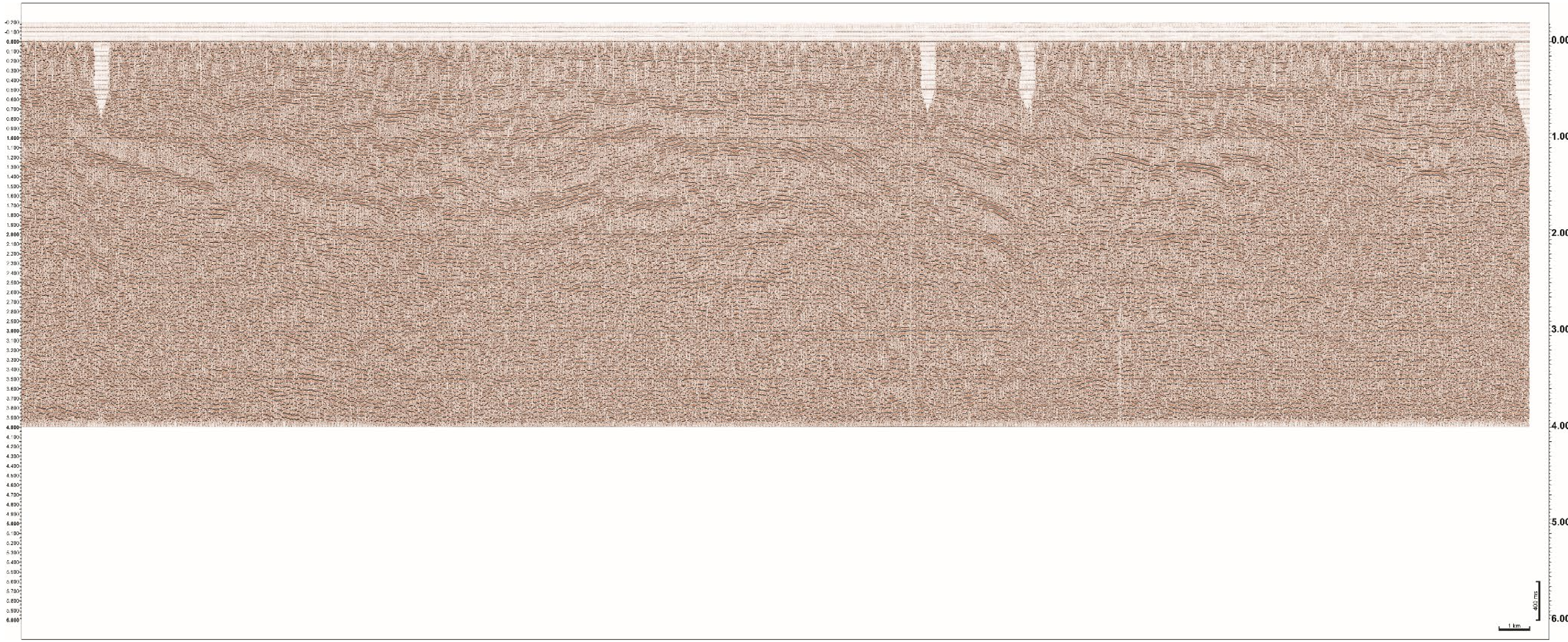

FIGURE 4. Line BK-31 (part 2) - Legacy processing. Note that the time length was limited to 4000 ms during legacy processing.

FIGURE 5. Line BK-31 (part 2) - GSC reprocessing. Note that reprocessing has recovered an addition 2000 ms from field tapes, revealing deeper events.

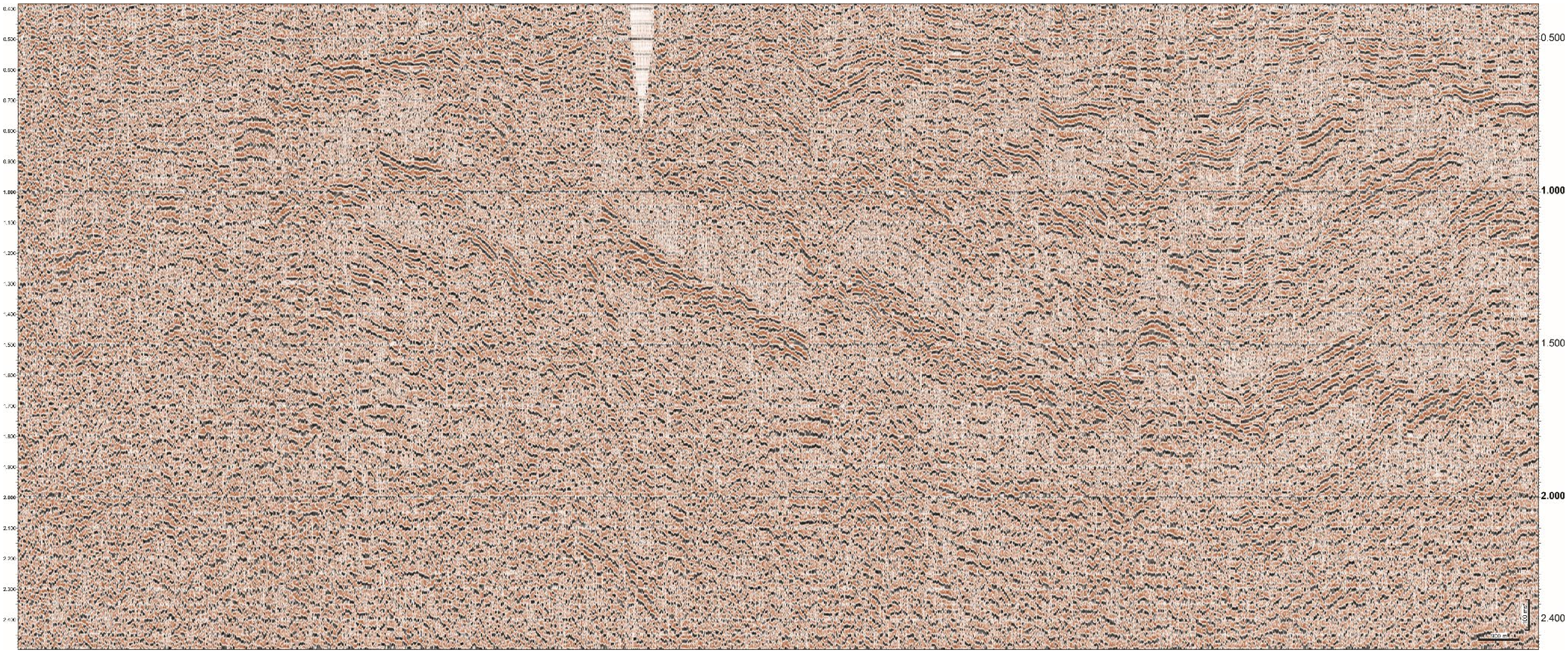

FIGURE 6. Line BK-31 (zoomed in, part 1, heavily faulted zone) - Legacy processing. Amplitudes in the legacy processing are fairly uniform, seismic character is lacking. Note that the legacy processing is unmigrated.

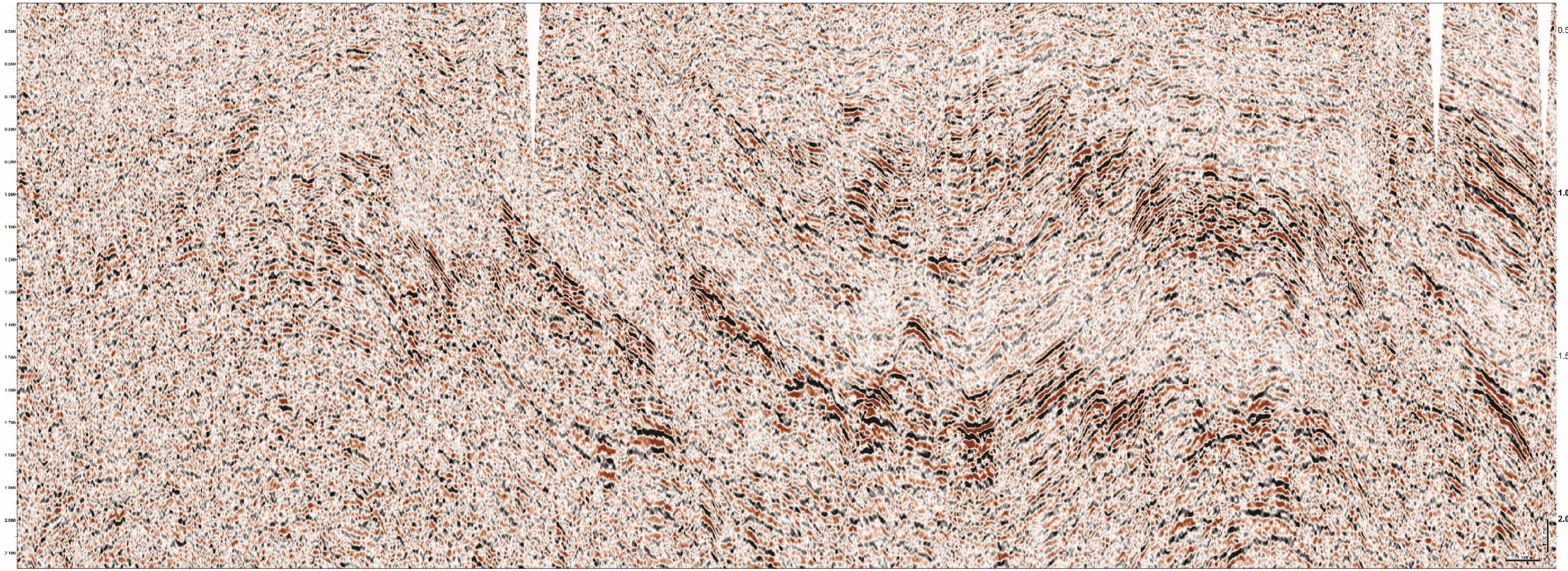

FIGURE 7. Line BK-31 (zoomed in, part 1, heavily faulted zone) - GSC reprocessing. Relative amplitudes have been preserved with modern processing, signal contains a broader band of frequencies leading to improved seismic character. Note this section is unmigrated.

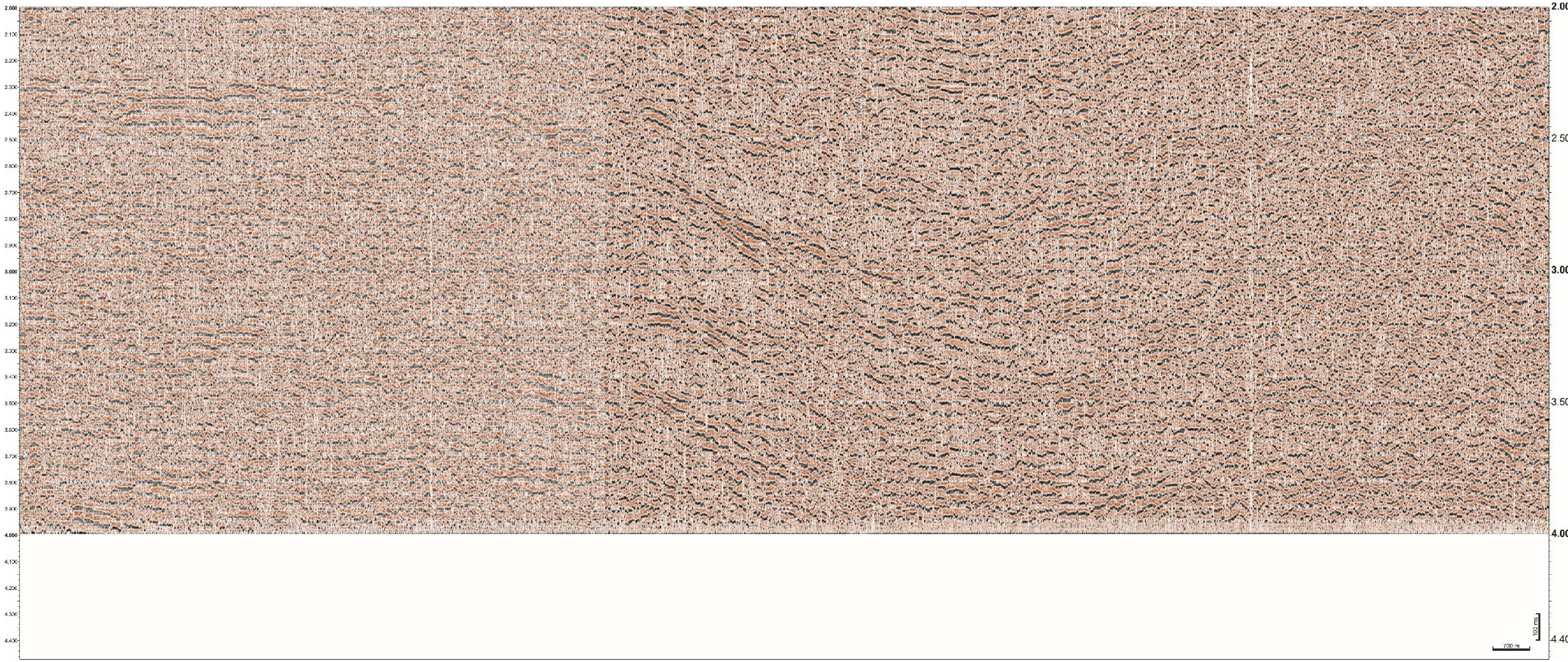

FIGURE 8. Line BK-31 (zoomed in, part 2, paleo shoreface) - Legacy processing. Amplitudes in the legacy processing are fairly uniform, seismic character is lacking. Note that the legacy processing is unmigrated.

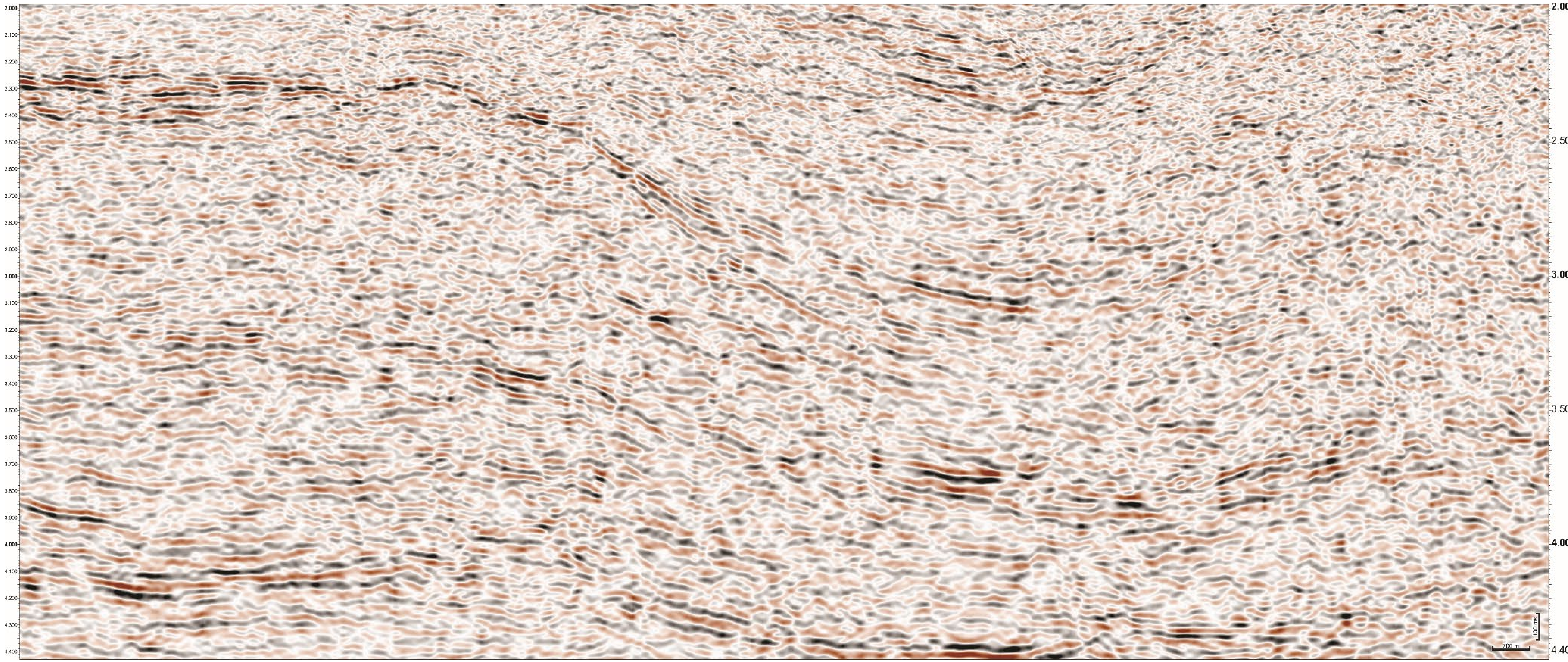

FIGURE 9. Line BK-31 (zoomed in, part 2, paleo shoreface) - GSC reprocessing. Relative amplitudes have been preserved with modern processing, signal contains a broader band of frequencies leading to improved seismic character. Pre-stack time migration has moved events to their apparent positions.

M'Clure Strait Example – Line 1858

Acquisition: Sea Ice			
Area: M'Clure Strait	Date Shot: March 1975	Instrument: DFS III	Format: SEG-A
Sample Interval: 2 ms	Recording Time: 8000ms	Field Filter: Out-124 Hz	Notch: Out
Channels Per Shot: 48	CDP Fold: 16		
Source Type: Dynamite - Sub Sea Ice			
Source Size: 60 lb	Source Depth: 23 m	Source Interval: 536 m	
Receivers per group: 6	Spacing: 9m	Frequency: 14 Hz	Type: Mark L10
Group interval: 50 m			
Pattern:	1250 -----------------100 X 100 ----------------- 1250		Distance in meters
	1 ----------------------24 25 ------------------- 48		Channel number

Table 2. Line 1858 acquisition parameters

Comparison Before and After Reprocessing

Table 2 outlines the acquisition parameters of line 1858 from M'Clure Strait. The biggest issues with the legacy seismic sections in M'Clure Strait are the strong water bottom and peg-leg multiples that obscure primary energy at key intervals. Additional issues include a low-signal-to-noise ratio, reverberations related to the sub-ice source, and the poor fidelity of the digitized paper copy. Mitigating these challenges with modern processing and forgoing the fidelity issue by starting from original field tapes resulted in a reprocessed section with good continuity from one end to the other, good seismic character, and preserved relative amplitudes.

Water bottom multiples occur when down going energy reflects off of the sea bed and the ocean-air interface (or in this case the ocean-*ice* interface). This energy can be recorded by receivers at the same time as primary signal that geophysical interpreters are interested in, superimposing itself on top of the signal and obscuring it. Using Halliburton Landmark's SeisSpace surface related multiple estimation tools we modeled this surface related multiple energy and used adaptive subtraction to remove it from the data. This processing step was not available in the 1970's, but by applying it to the data today reveals structures that were completely obscured by surface related multiples in the legacy data (red ellipse in Figures 9 and 10).

Peg-leg multiples are similar to surface related multiples in that they are unwanted echoes that can obscure primary signal, however they are caused by energy reflecting between two high impedance boundaries instead of between the water bottom and water/ice surface. Key parts of the legacy data have events with conflicting dips and peg-leg multiples are the suspected cause. By applying a pass of radon de-multiple to the prestack time migrated gathers, the conflicting peg-leg energy (blue ellipse in Figures 11 and 12) has been suppressed.

A migration velocity model was constructed through iterative analysis of both pre-stack time migrated velocity semblances and migrated panels. When the model was deemed satisfactory, it was smoothed and used for a final pre-stack time migration before a residual velocity was picked and applied to the gathers. As with previous processing steps these imaging techniques are considered standard practice today, but were not available in the 1970's when the data was originally processed.

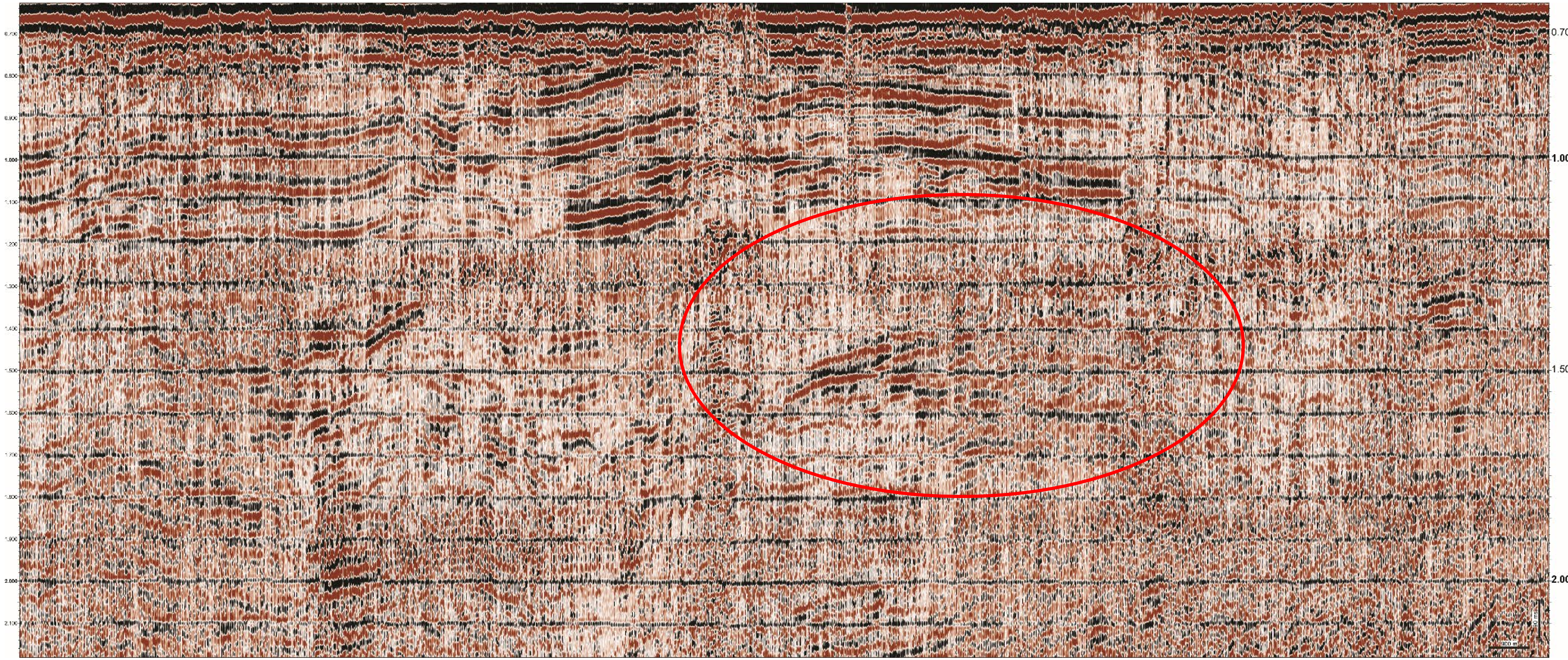

FIGURE 10. Line 1858 (Part 1) - Stack - Legacy processing digitized by GSC. Data is noisy, low frequency, lacking amplitude information and contaminated with waterbottom, peg-leg multiple and source signature contamination caused by sub-ice source. Conflicting dips beneath unconformity are highlighted in blue circle.

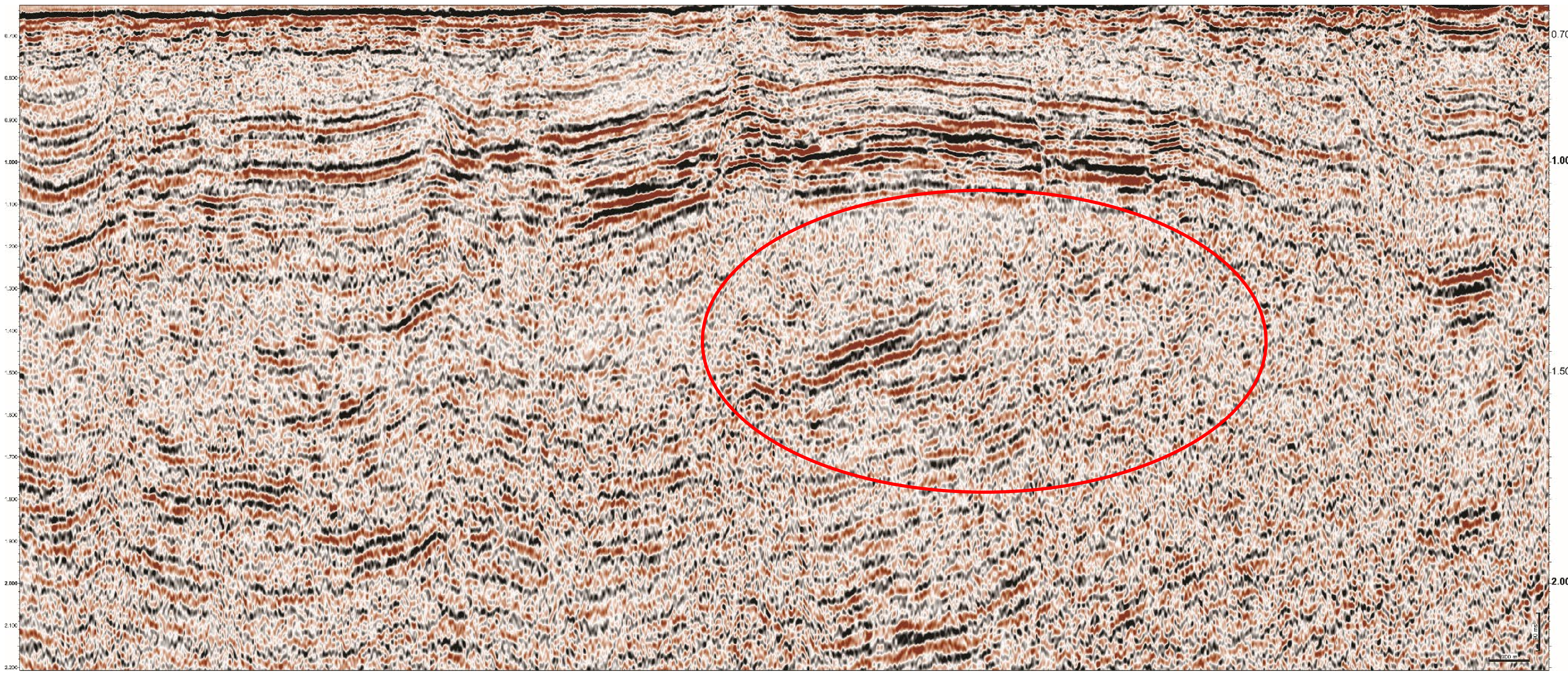

FIGURE 11. Line 1858 (Part 1) – Pre-stack time migration – GSC reprocessing. Noise has been better attenuated, there is more balanced frequency content, and amplitudes are better preserved. Surface related and inter-bed multiples have been attenuated largely resolving the problem of conflicting dips seen in the blue circle.

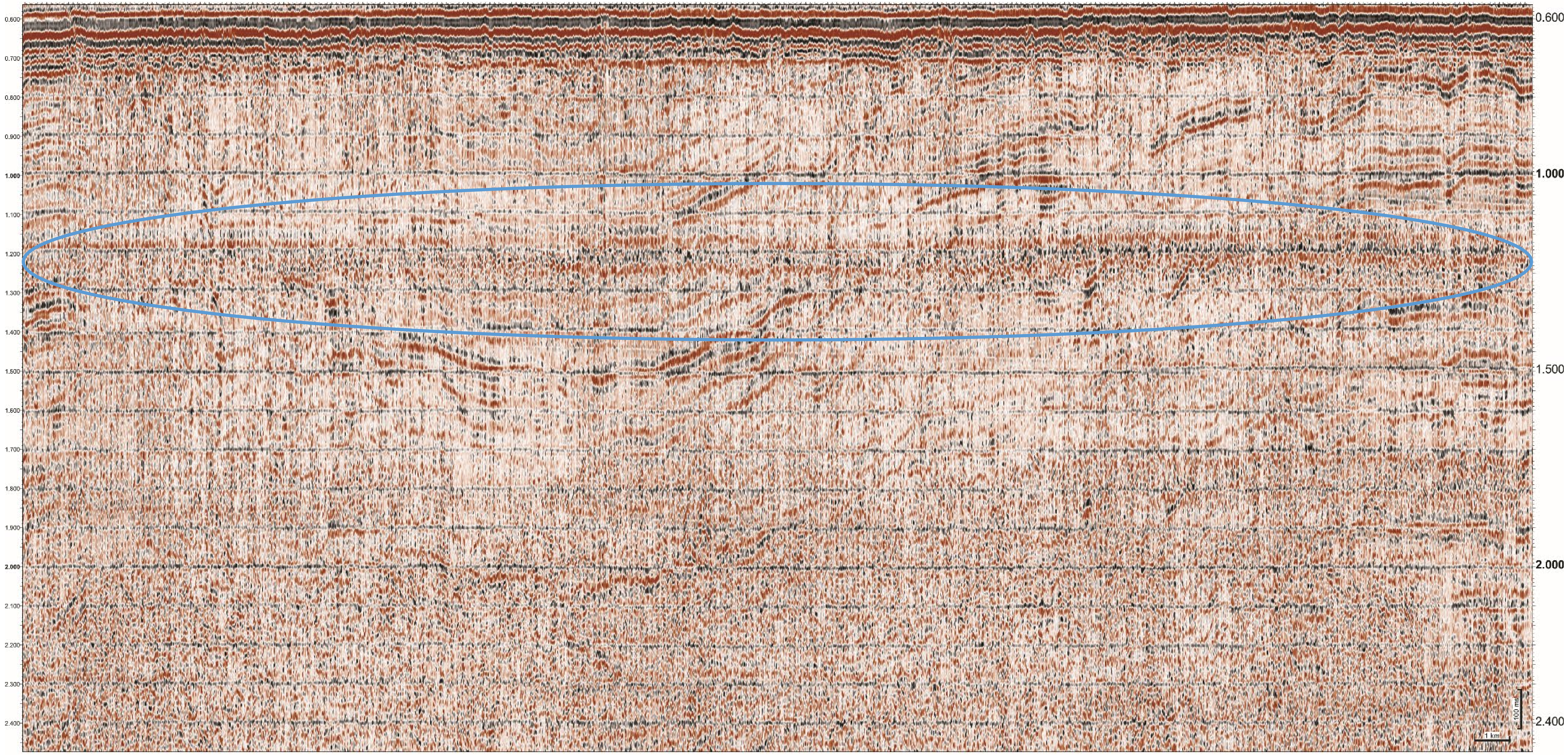

FIGURE 12. Line 1858 (Part 2) - Stack - Legacy processing digitized by GSC. Data is noisy, low frequency, lacking amplitude information and contaminated with water bottom and peg-leg multiples, as well as source signature contamination caused by sub-ice source. The zone highlighted by the blue circle is obscured by a strong surface related multiple.

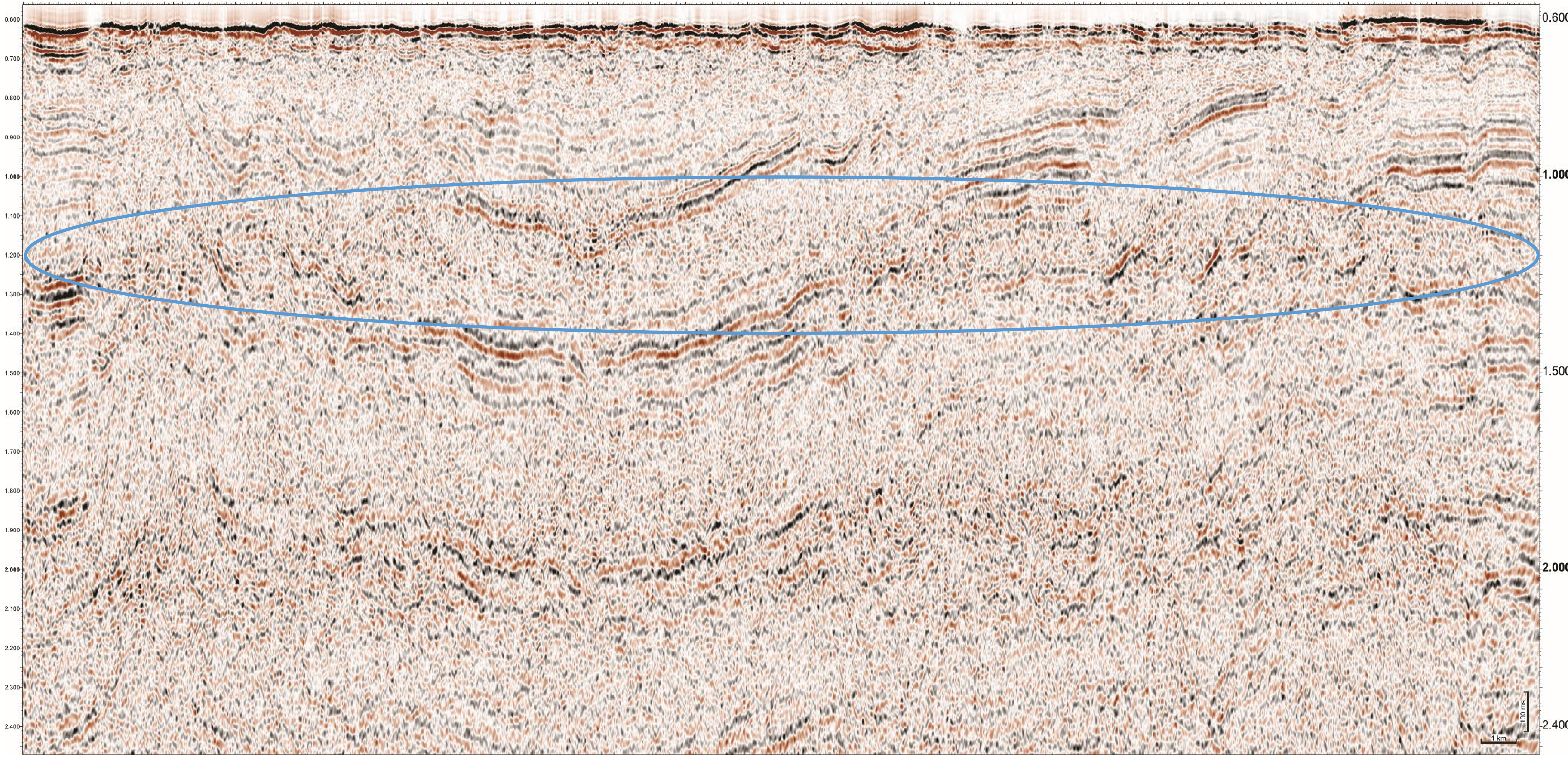

FIGURE 13. Line 1858 (Part 2) – Pre-stack time migration – GSC reprocessing. Noise has been better attenuated, there is more balanced frequency content, seismic character is better preserved. Inside the blue circle surface related multiples have been attenuated revealing primary events that were previously completely obscured in the legacy data.

CONCLUSIONS

This report illustrates the economic and geoscientific value of re-processing older seismic data. In areas where legacy seismic exists and field tapes can be accessed, reprocessing can lead to valuable new geophysical and geological insights. In general, the older the data the more re-processing can improve the final product. Through post-stack processing of digitized paper copies, deteriorated information can be improved, digitally preserved, and imported into modern interpretation software. Therefore, legacy seismic data can be used in a variety of geoscience applications and as reconnaissance for additional seismic data acquisition. The Government of Canada has built an immensely valuable library of seismic data in areas where seismic can no longer be acquired at this time without great expense and time. This seismic data should not be lost to deteriorating mediums and could be digitally captured and reprocessed through considerable effort but would present great value to science applications in the future related to mapping the Canadian sub-surface.

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