Geologic model building for optimized depth imaging in the presence of Sinú mud volcanoes onshore

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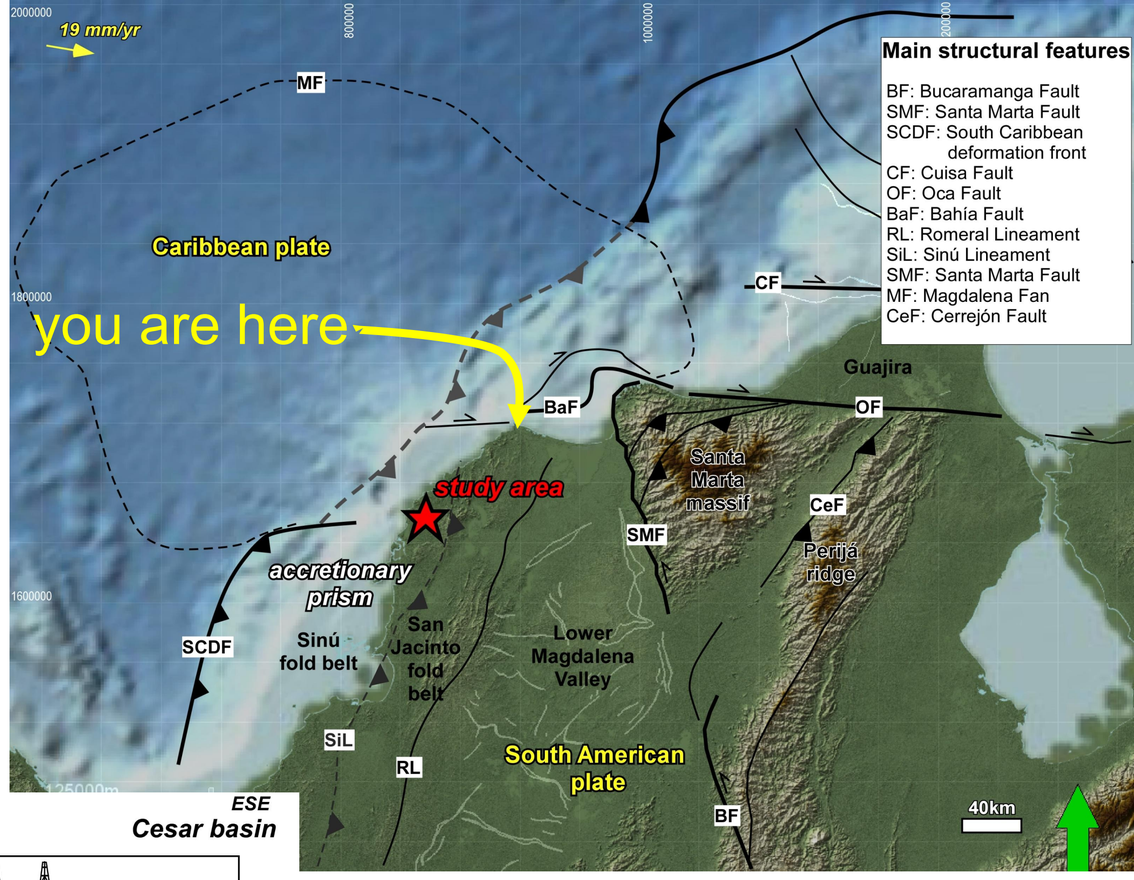
[1]TBI Colombia SAS

[2]Hocol S.A.

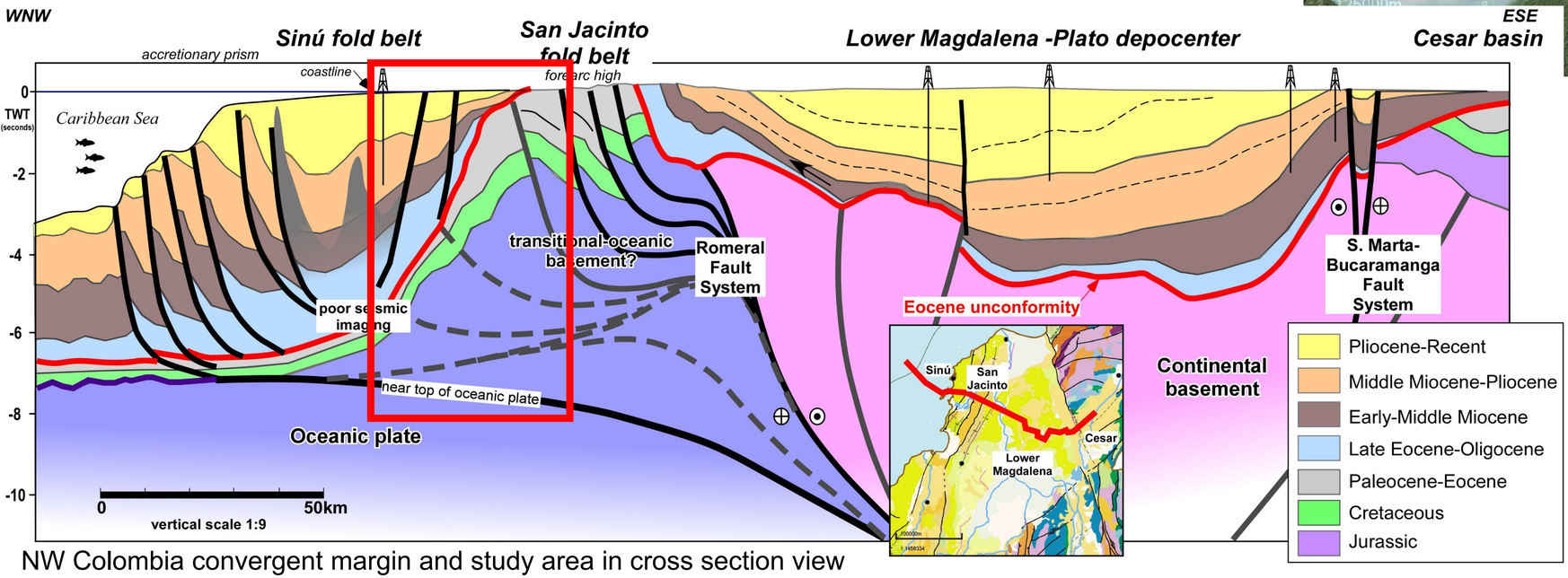
Study area & geological framework



Overview of main clusters of mud volcanoes distributed around the globe (Mazzini & Etiope, 2017), showing the cluster in the NW Colombia convergent margin



NW Colombia convergent margin and study area in map view

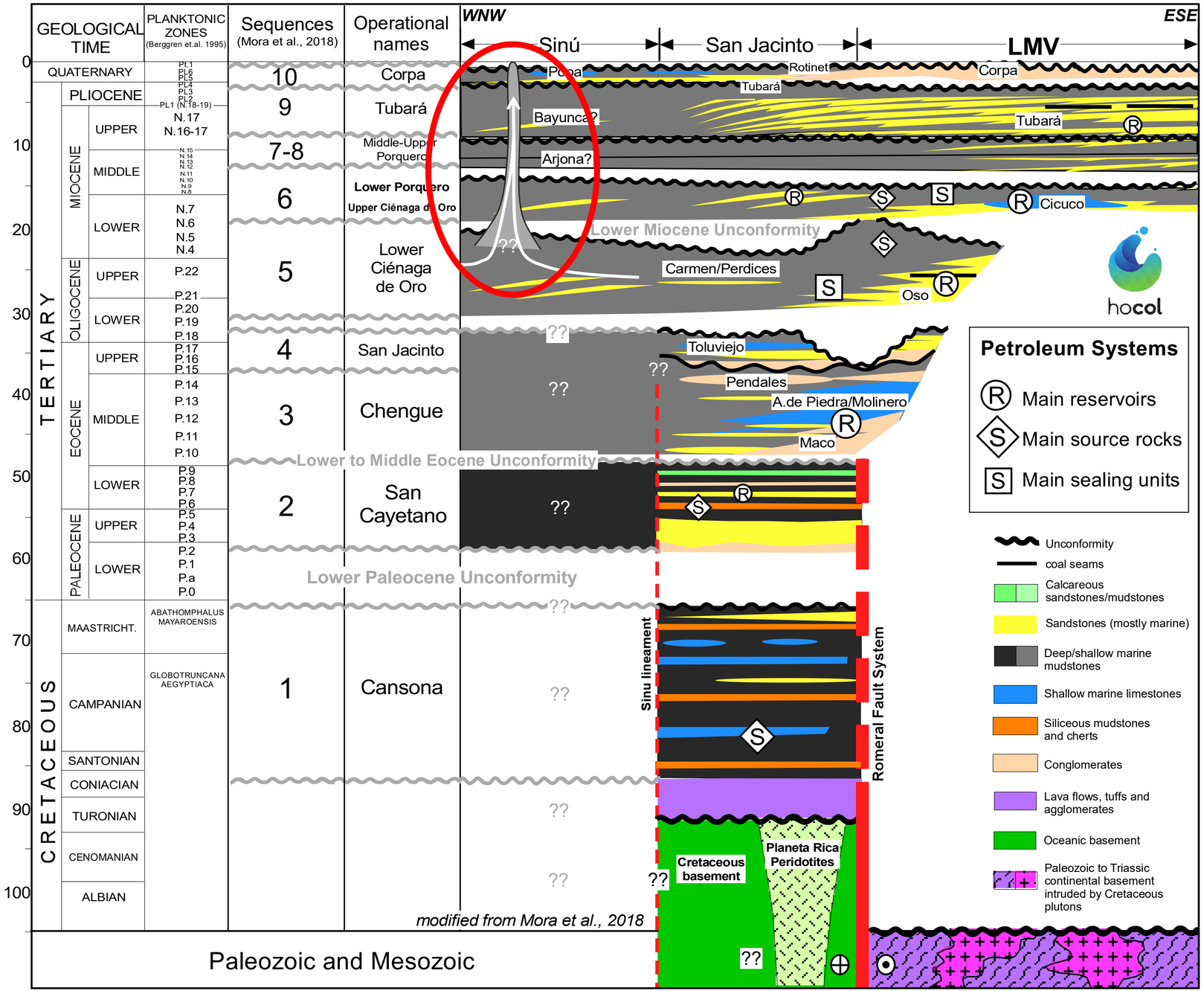


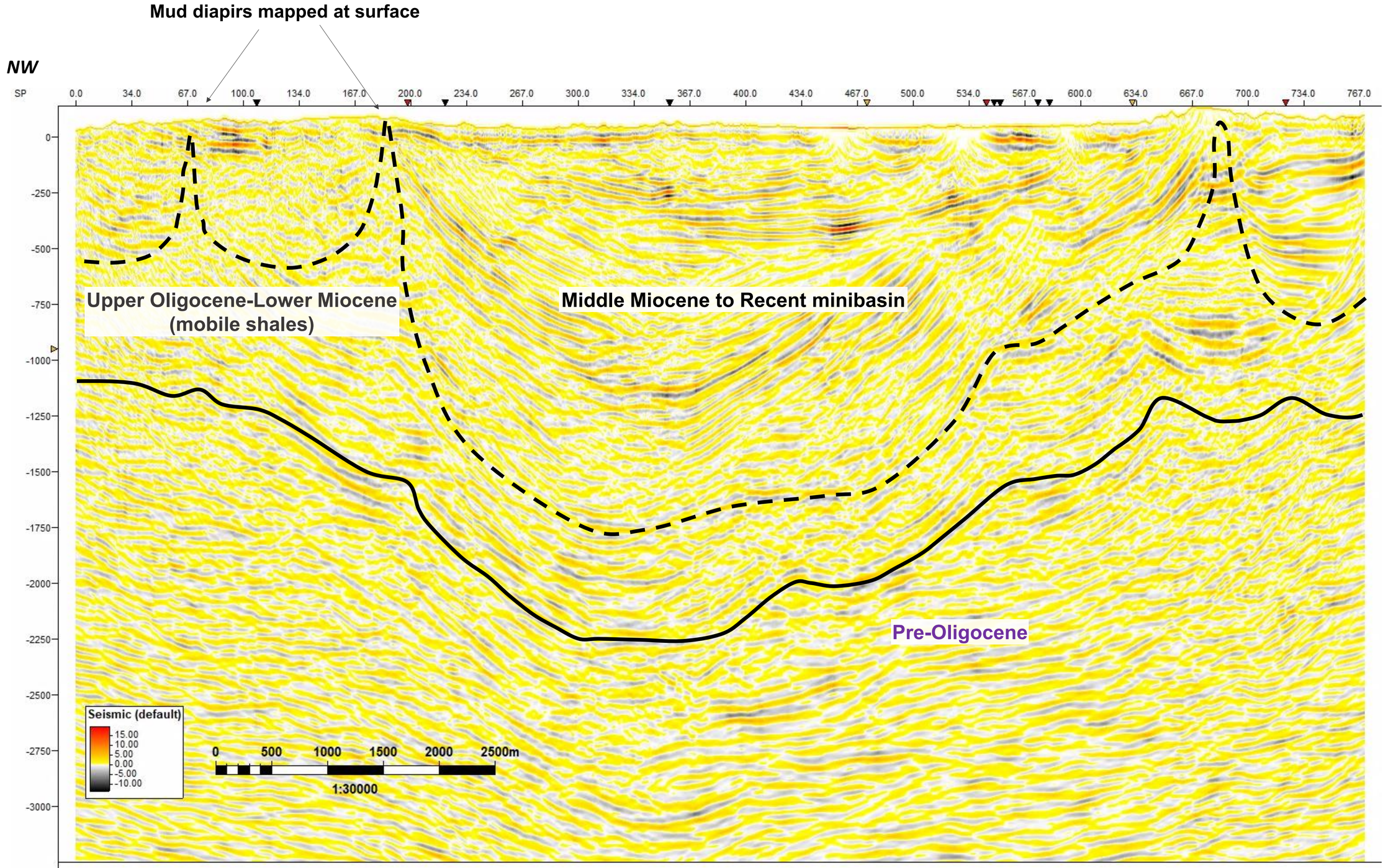
NW Colombia convergent margin and study area in cross section view

Stratigraphic chart of NW Colombia (onshore)

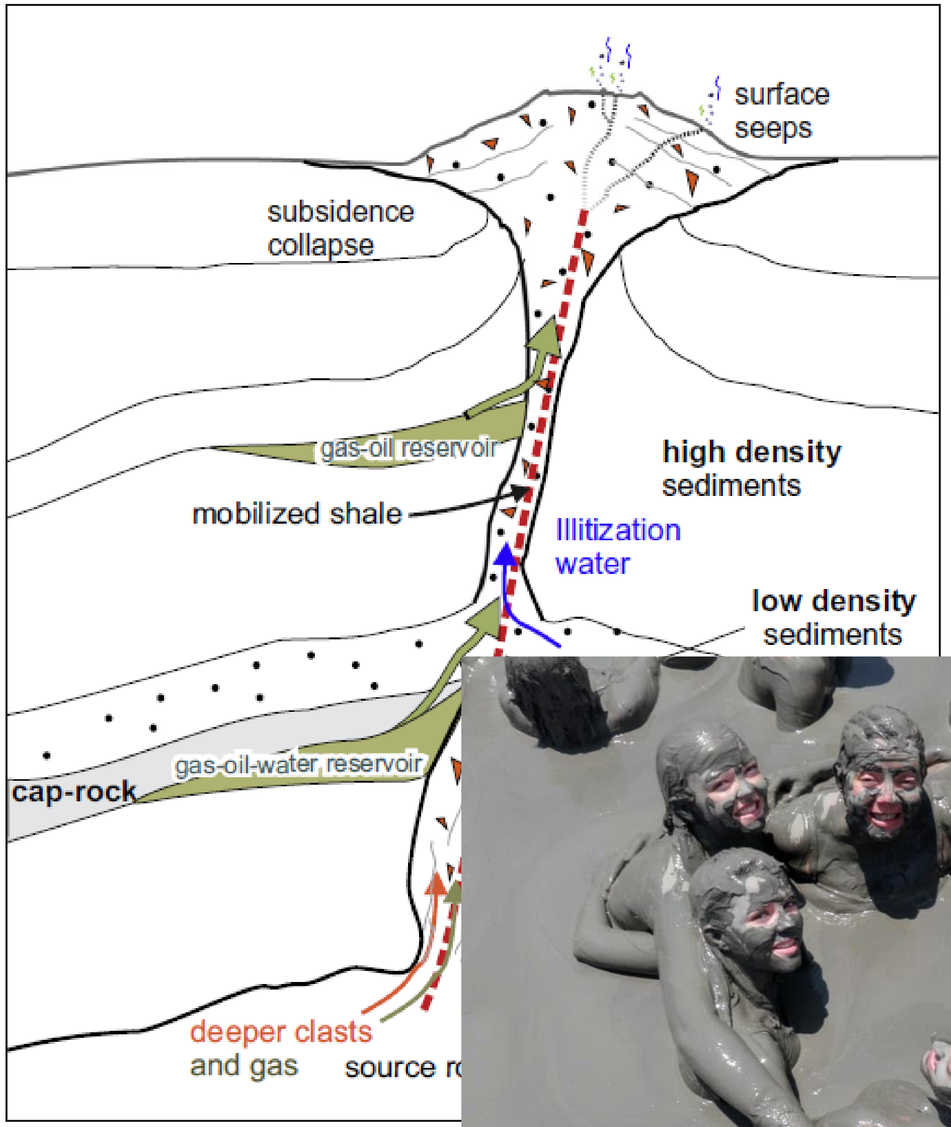
The study area is located in the Sinú fold belt, which is part of the accretionary prism of the NW Colombia convergent margin, where there is active mud diapirism and volcanism.

The Sinú fold belt is ideal for exploring for Neogene, hydrocarbon plays (mainly gas), related to mud diapirism and volcanism.




Mud diapirs mapped at surface
NW
SP
0.0
34.0
67.0
100.0
134.0
167.0
200.0
234.0
267.0
300.0
334.0
367.0
400.0
434.0
467.0
500.0
534.0
567.0
600.0
634.0
667.0
700.0
734.0
767.0
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
-3000
Upper Oligocene-Lower Miocene
(mobile shales)
Middle Miocene to Recent minibasin
Pre-Oligocene
Seismic (default)
15.00
10.00
5.00
0.00
-5.00
-10.00
0
500
1000
1500
2000
2500m
1:30000

Mud diapirism and volcanism in northern Colombia



Conceptual drawing summarising
most mud volcanoes (Mazzini & Et

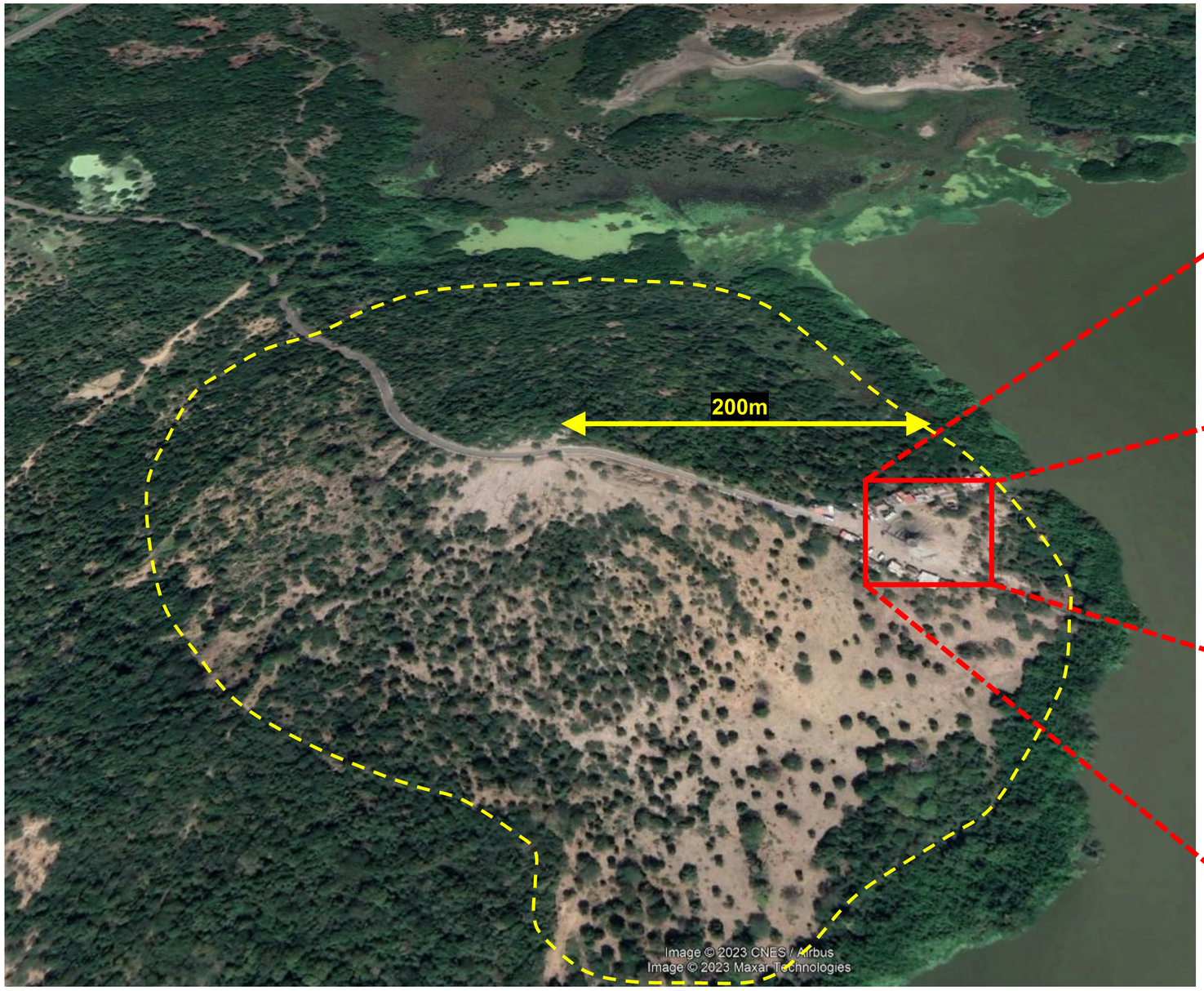




N of Cartagena, Colombia; (photo by J.A. Mora, 2022).

Mud diapirism and volcanism in northern Colombia

El Totumo mud volcano, N of Cartagena
(photos from Google Earth)

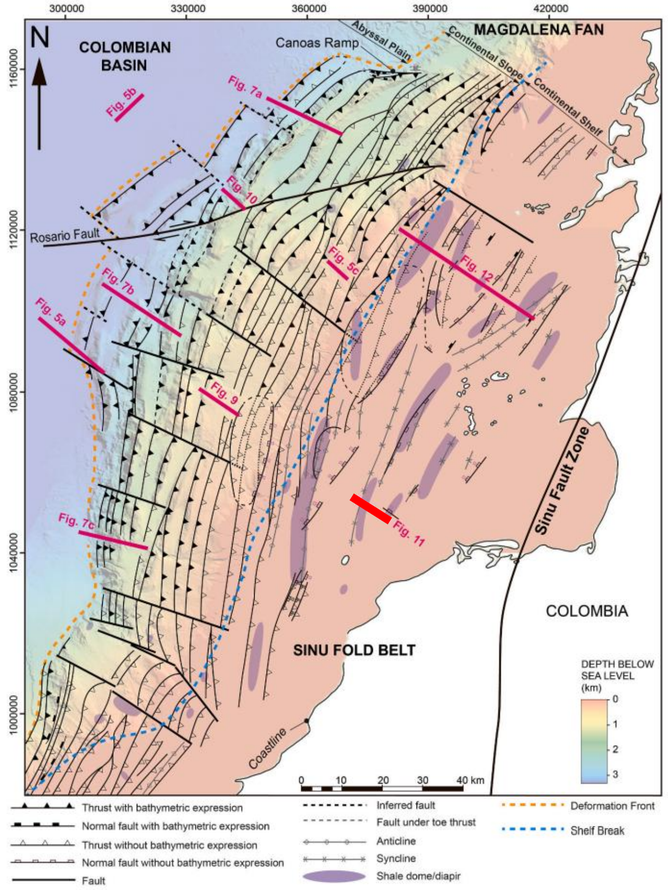


In the highest part of the hill to the W, there are small (cm-scale) conduits where mud is bubbling.

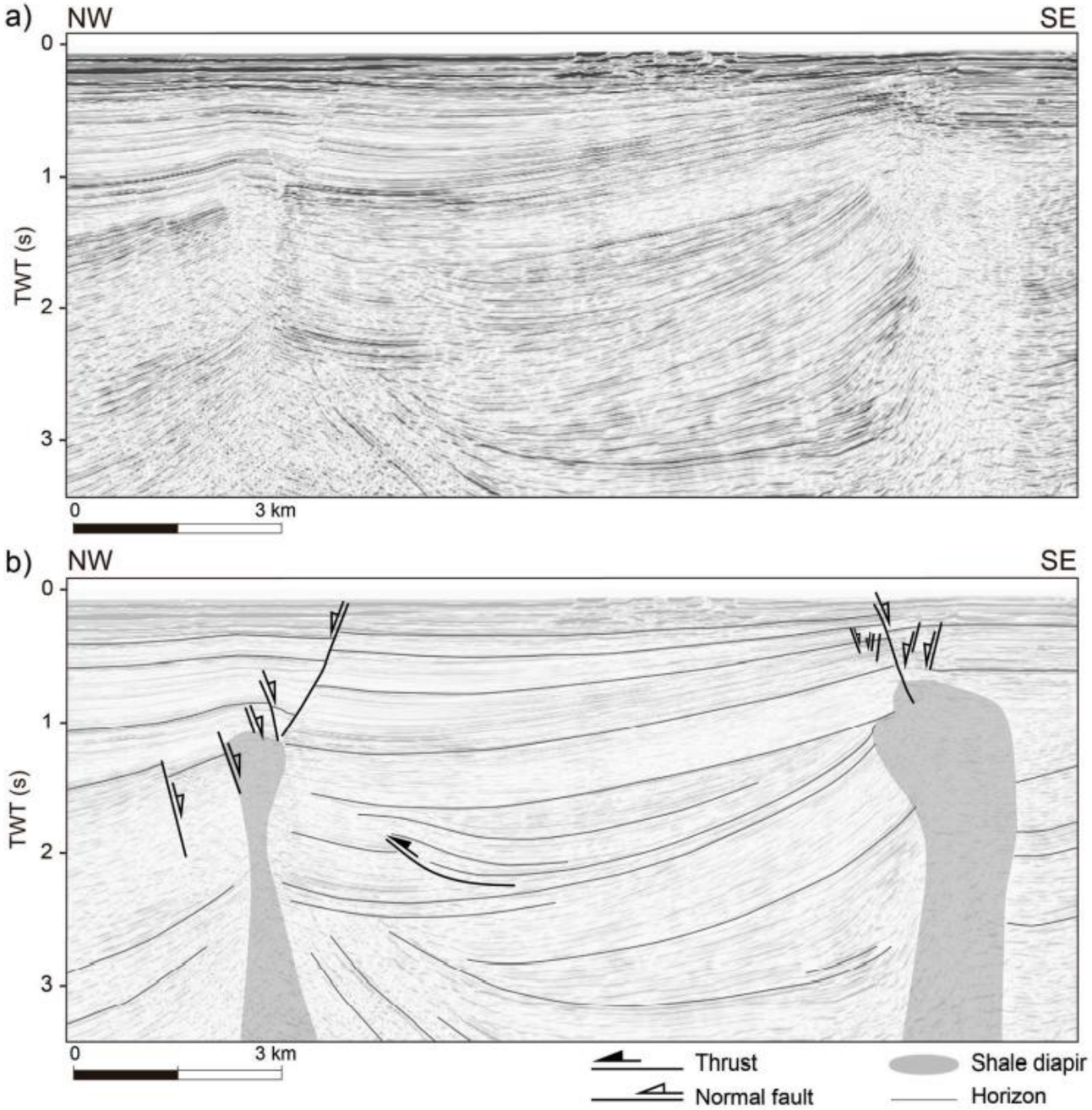


El Totumo touristic crater (13m high approx.)

Mud diapirs in offshore areas

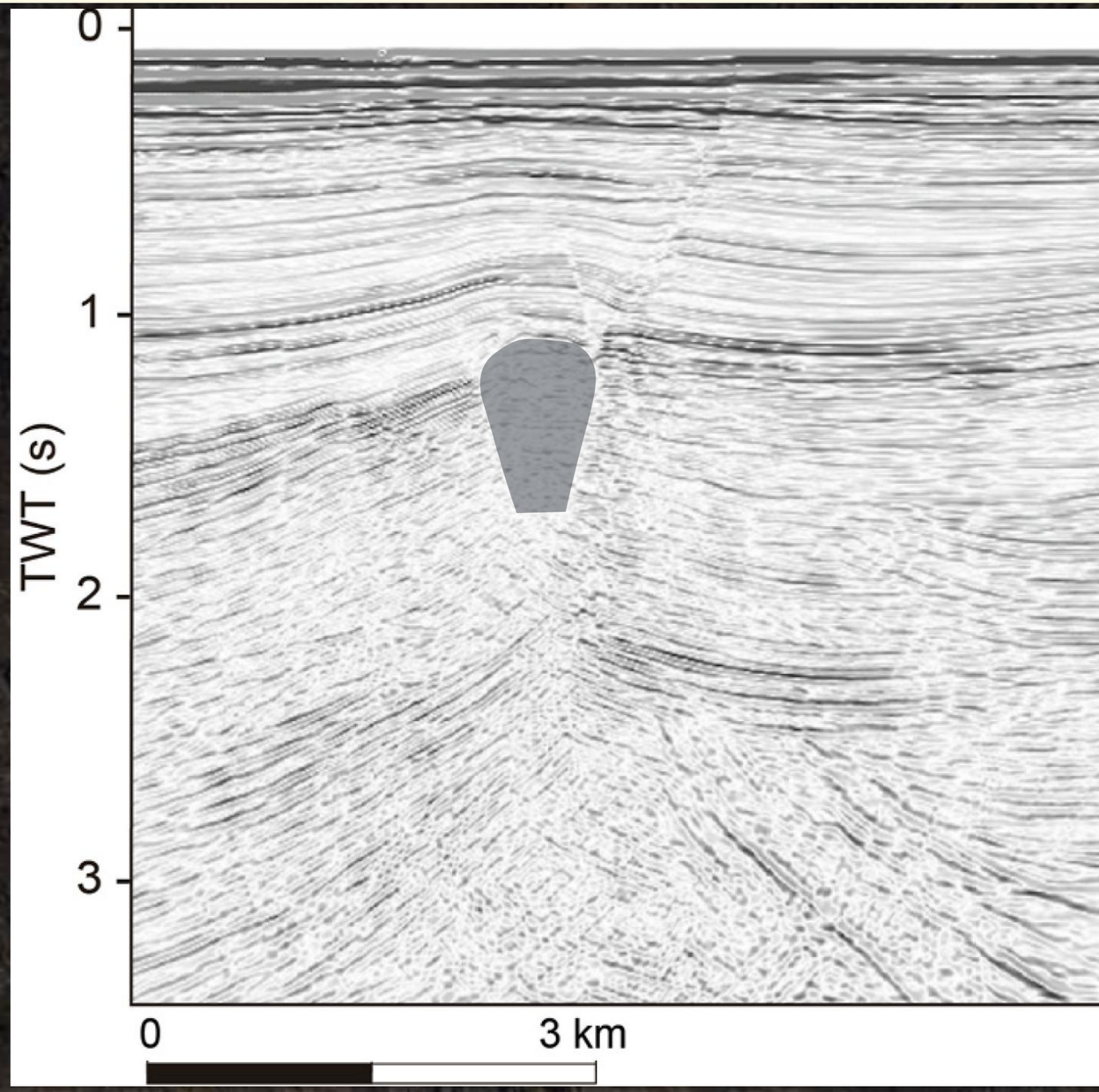


From Rodríguez et al., 2021.



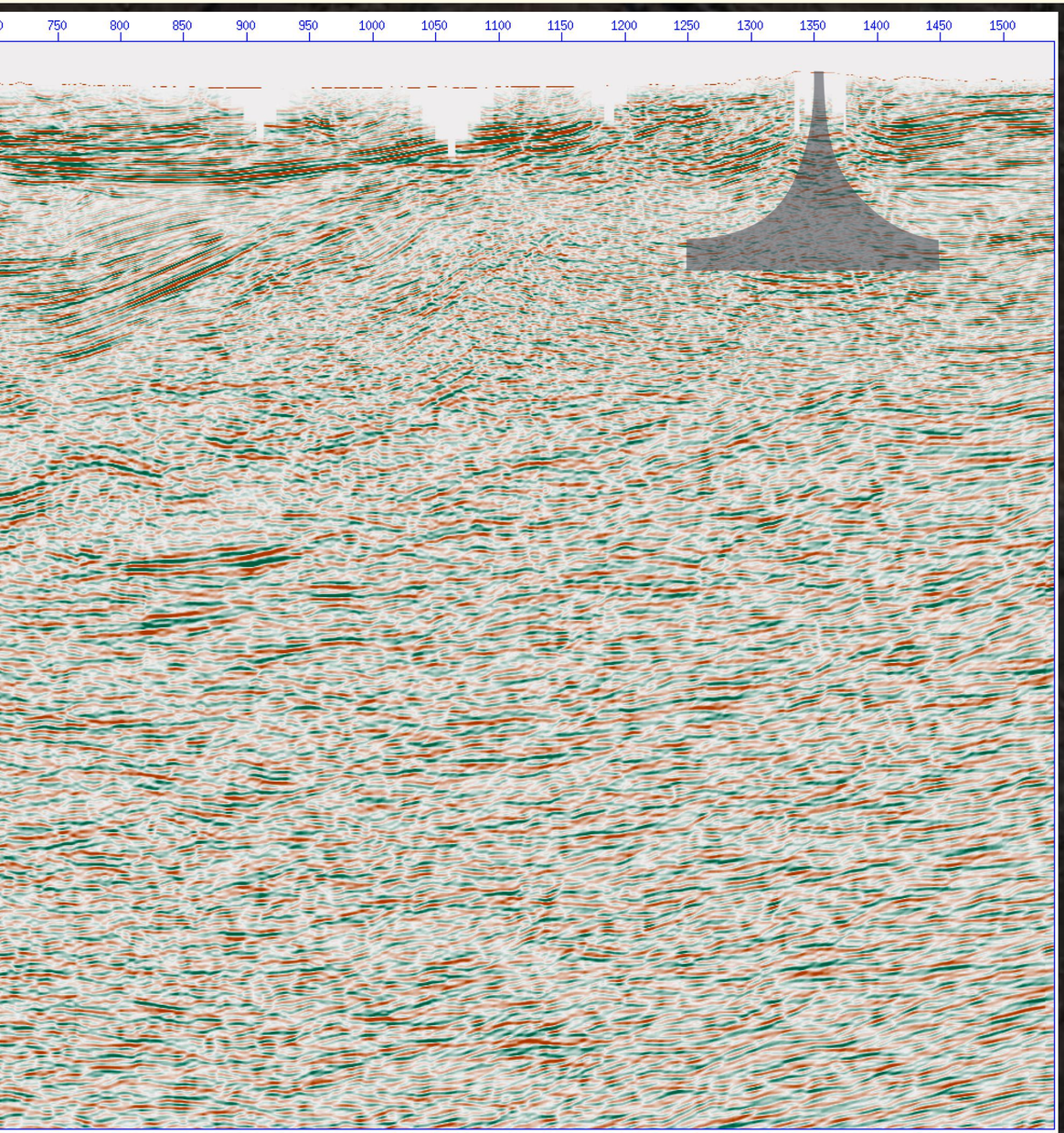
Marine seismic images the mud structures very well

- **Rodríguez et al (2021) show several examples of how clearly one can image the mud structures on offshore seismic data**



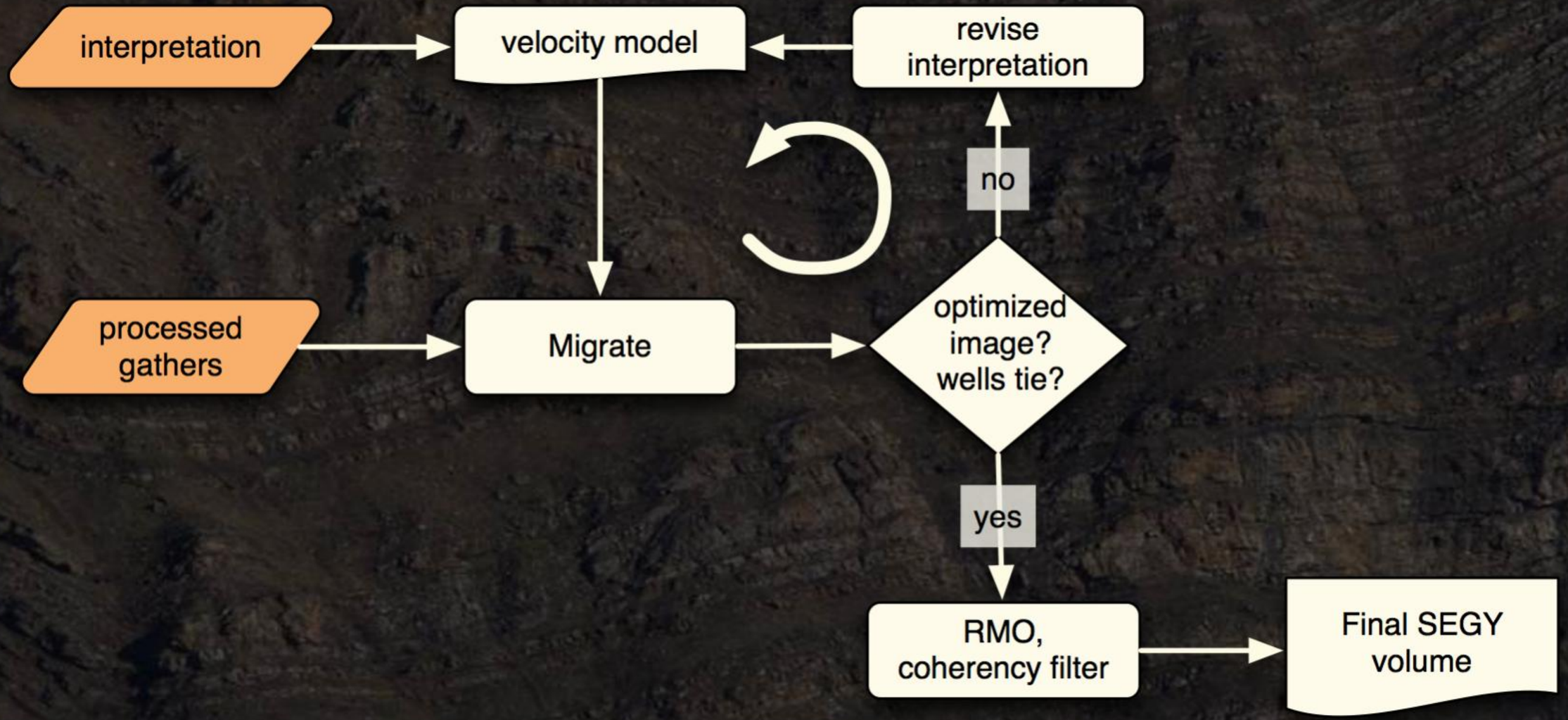
Rodríquez, I., Bulnes, M, Poblet, J., Masini, M. and Flinch, J, 2021, Structural style and evolution of the offshore portion of the Sinu Fold Belt (South Caribbean Deformed Belt) and adjacent part of the Colombian Basin, Marine and Petroleum Geology **125**

Legacy seismic image from onshore Sinú Fold Belt

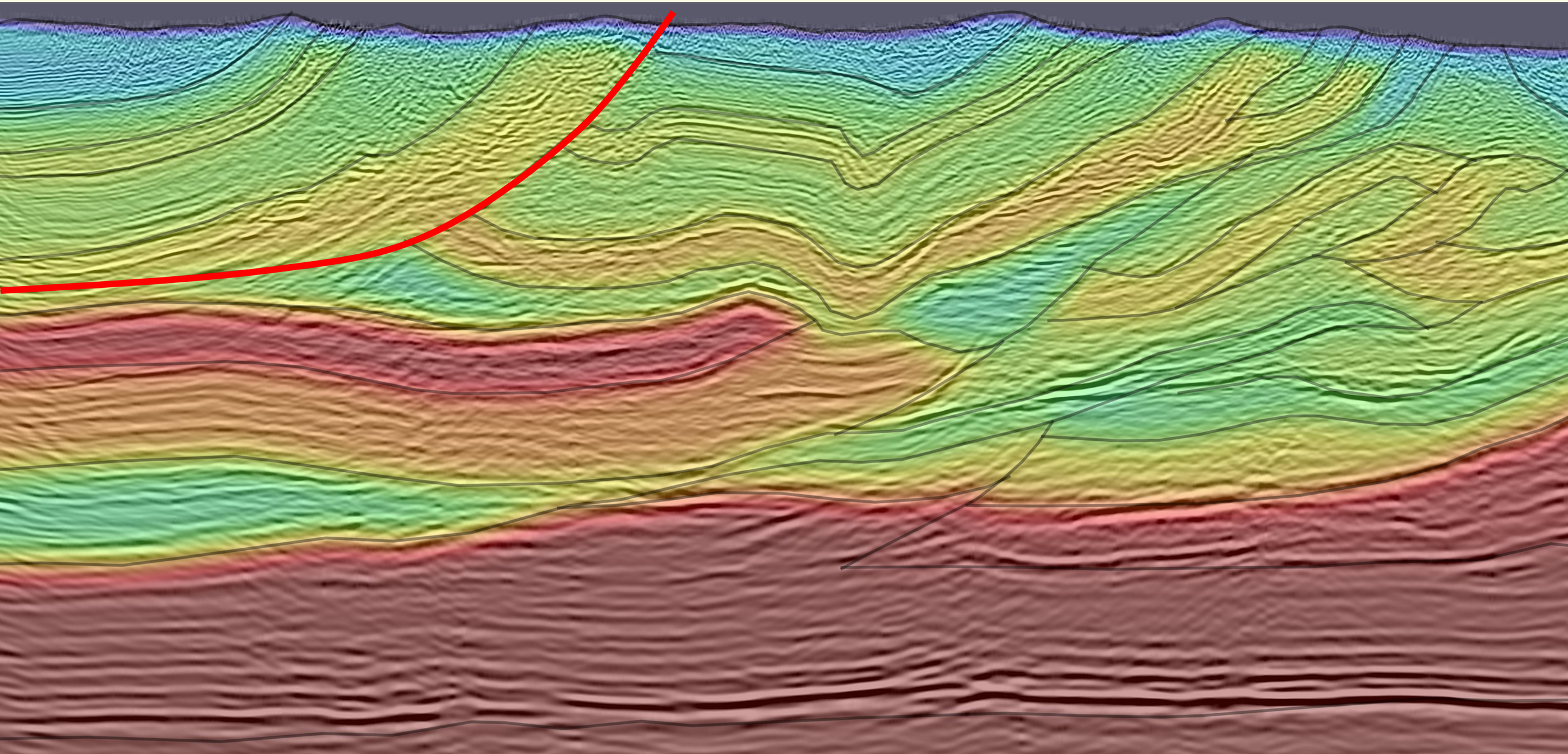


- Onshore basin has more difficult surface conditions for seismic data
- Mud features come to surface, creating an abundance of mud volcanoes
- Near-surface seismic coverage is low, so we have low data density, low signal-to-noise ratios, and high geologic complexity

Interpretive workflow for PSDM model building



Fault scenario test: aligned with truncation of reflectors



Fault scenario test: match surface geology and follow potential fault-plane reflector

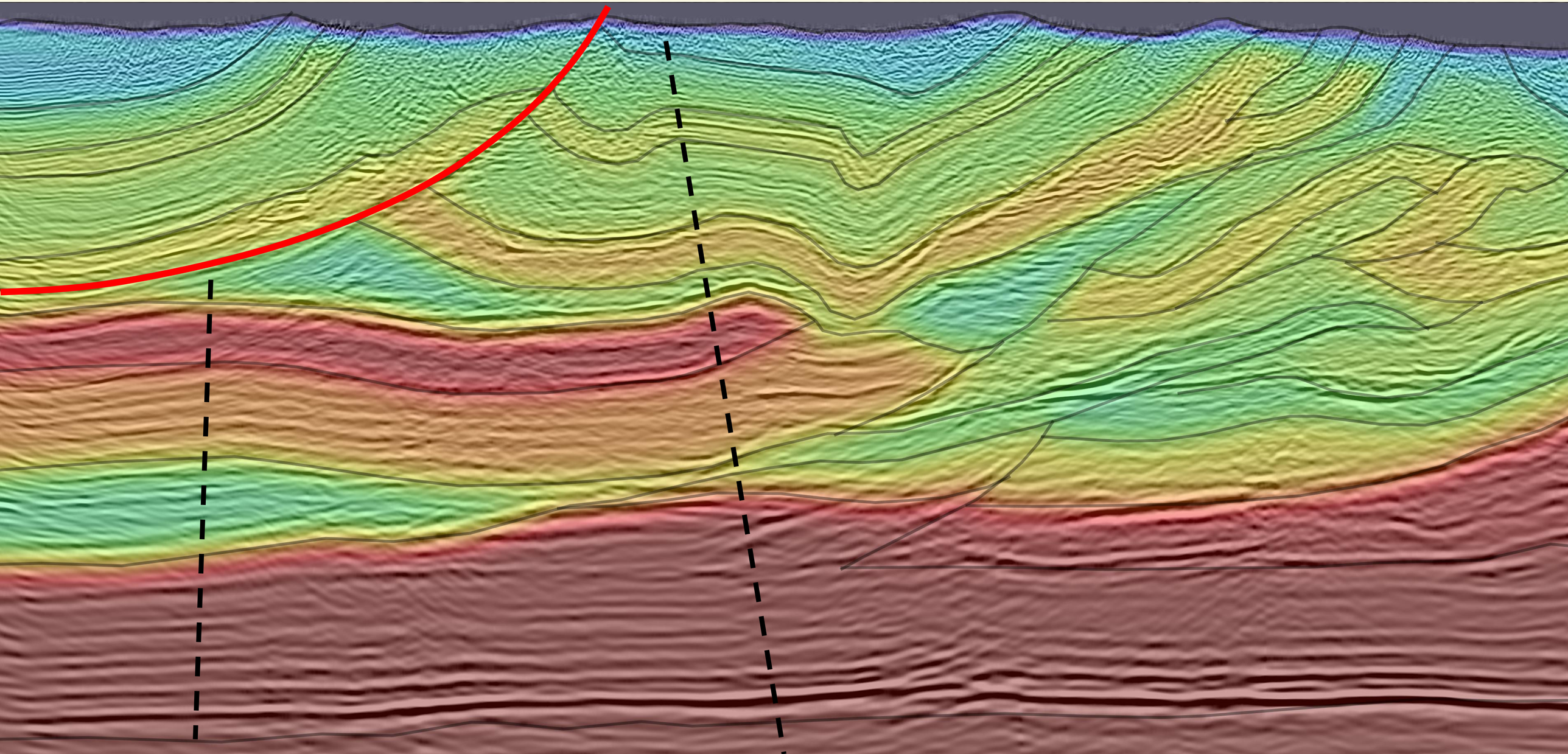


Image with first fault scenario

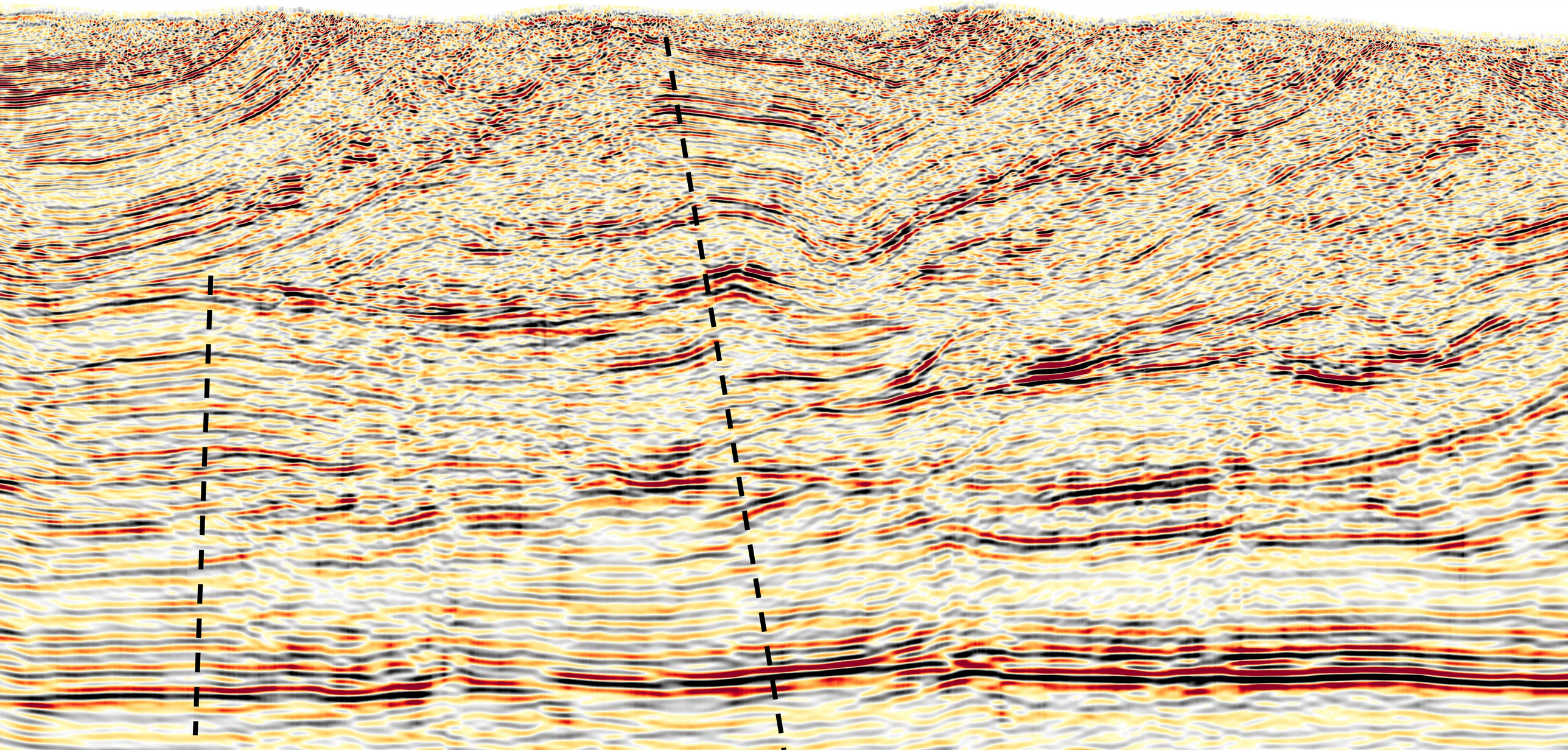
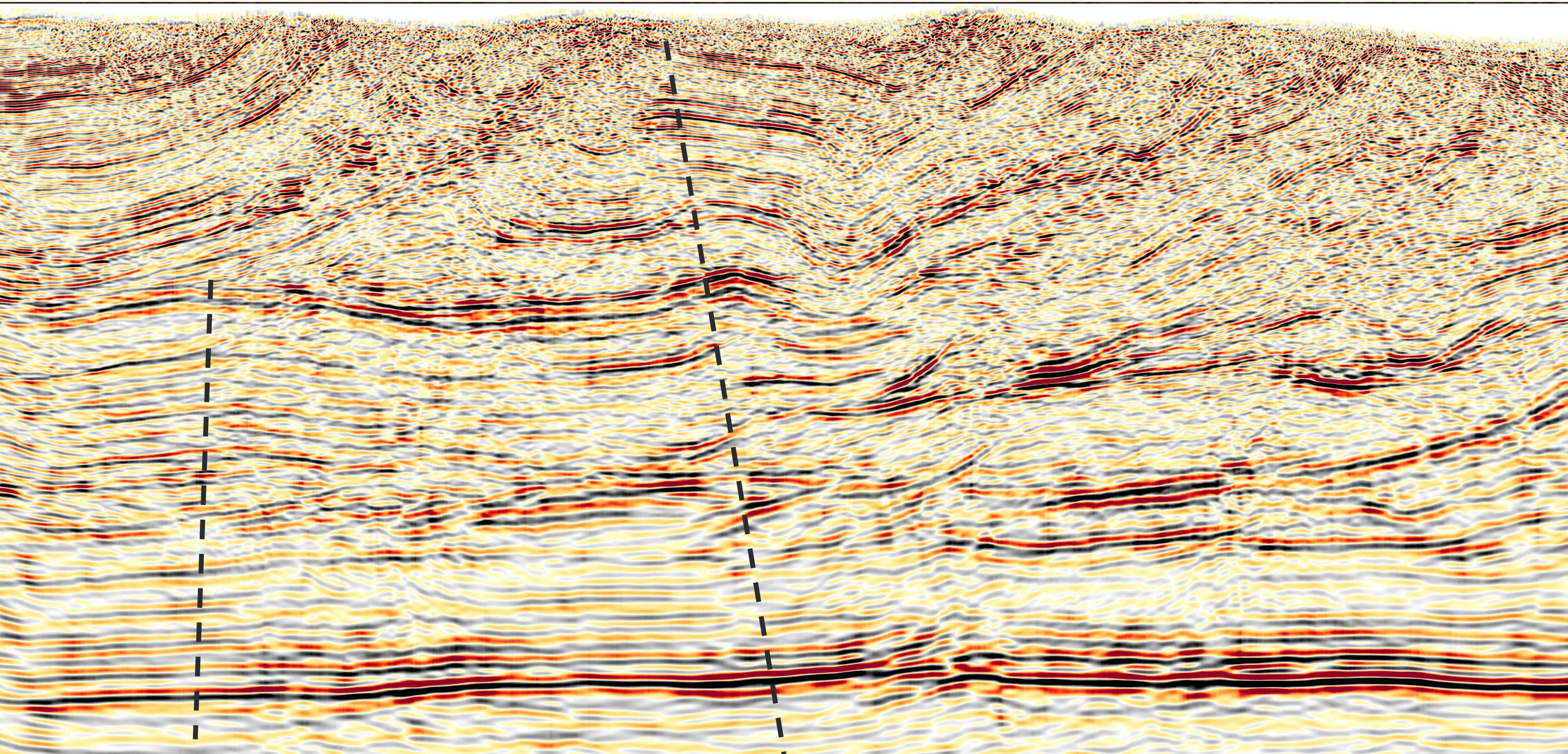


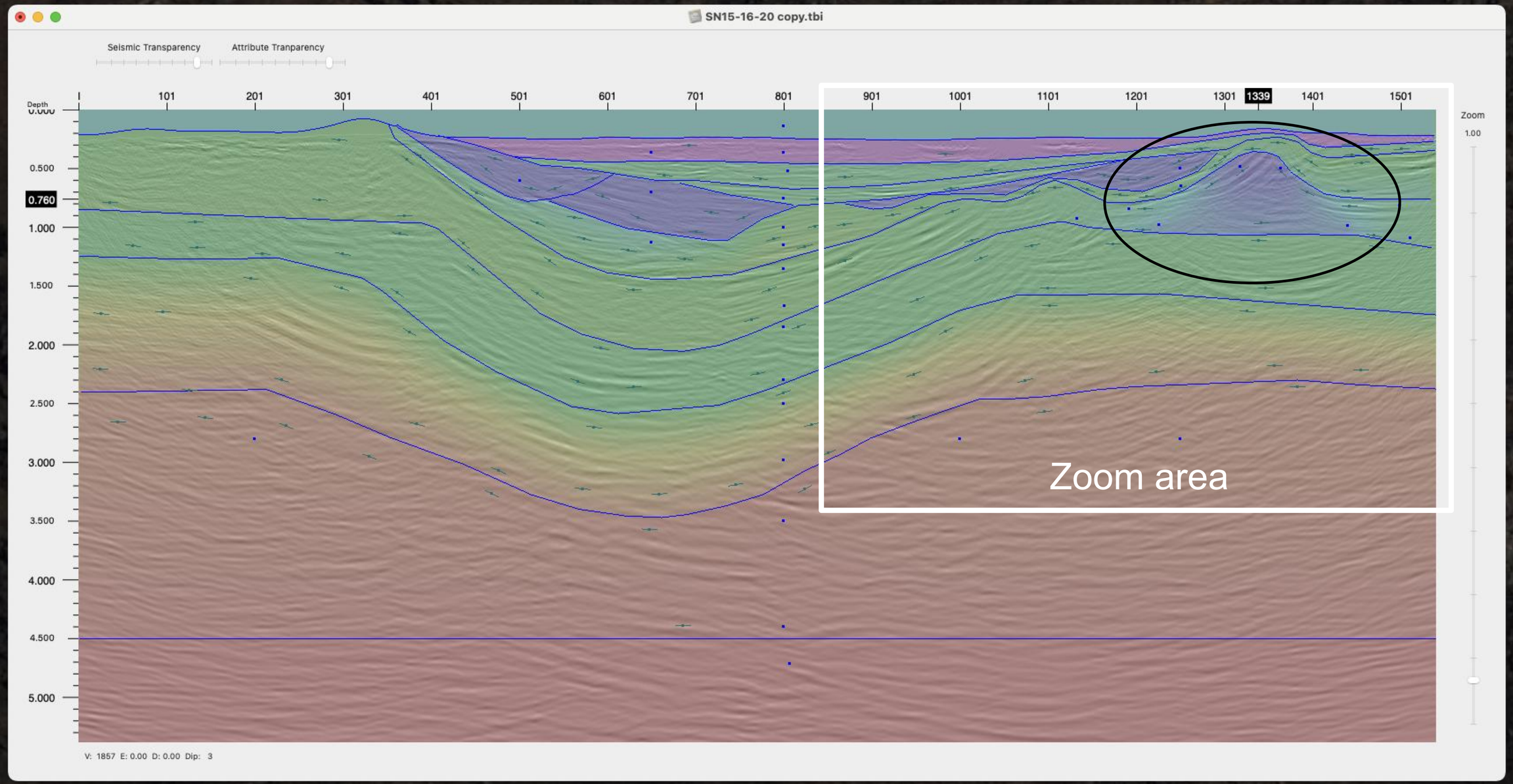
Image with second fault scenario



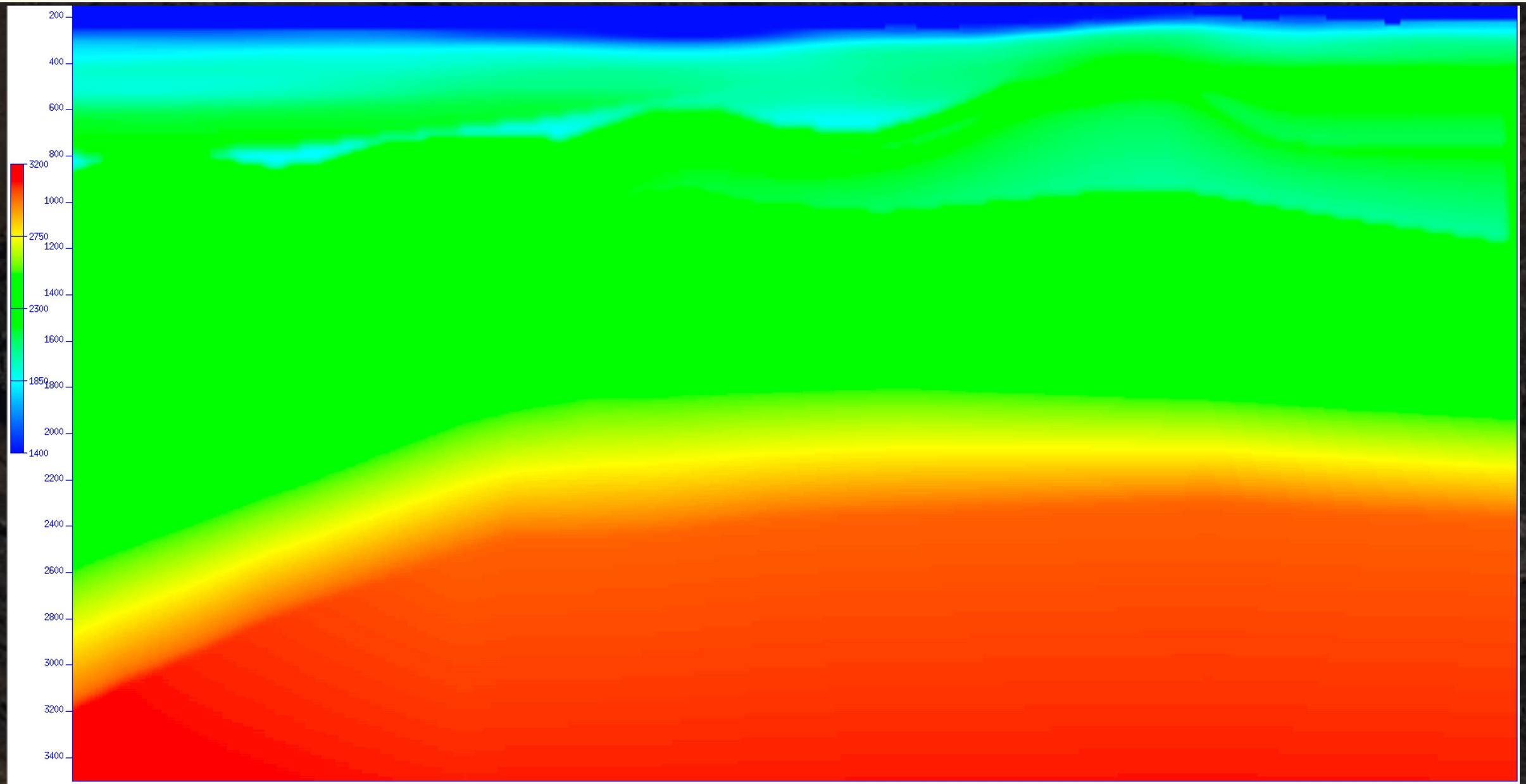
Testing for mud velocities in the Sinú volcano

- After several iterations of PSDM model building, there were imaging improvements everywhere, with the exception of the east end, below the known mud volcano
- We observed reflectors that curve upwards below the mud volcano, which could indicate the model velocity is too high
- Image gathers are extremely noisy, so we chose to vary the modelled mud velocity and assess the response of the seismic stack
- We tested the velocities in the mud volcano, scanning through a range of velocities from 2100 m/s as the base case down to water velocity at 1400 m/s

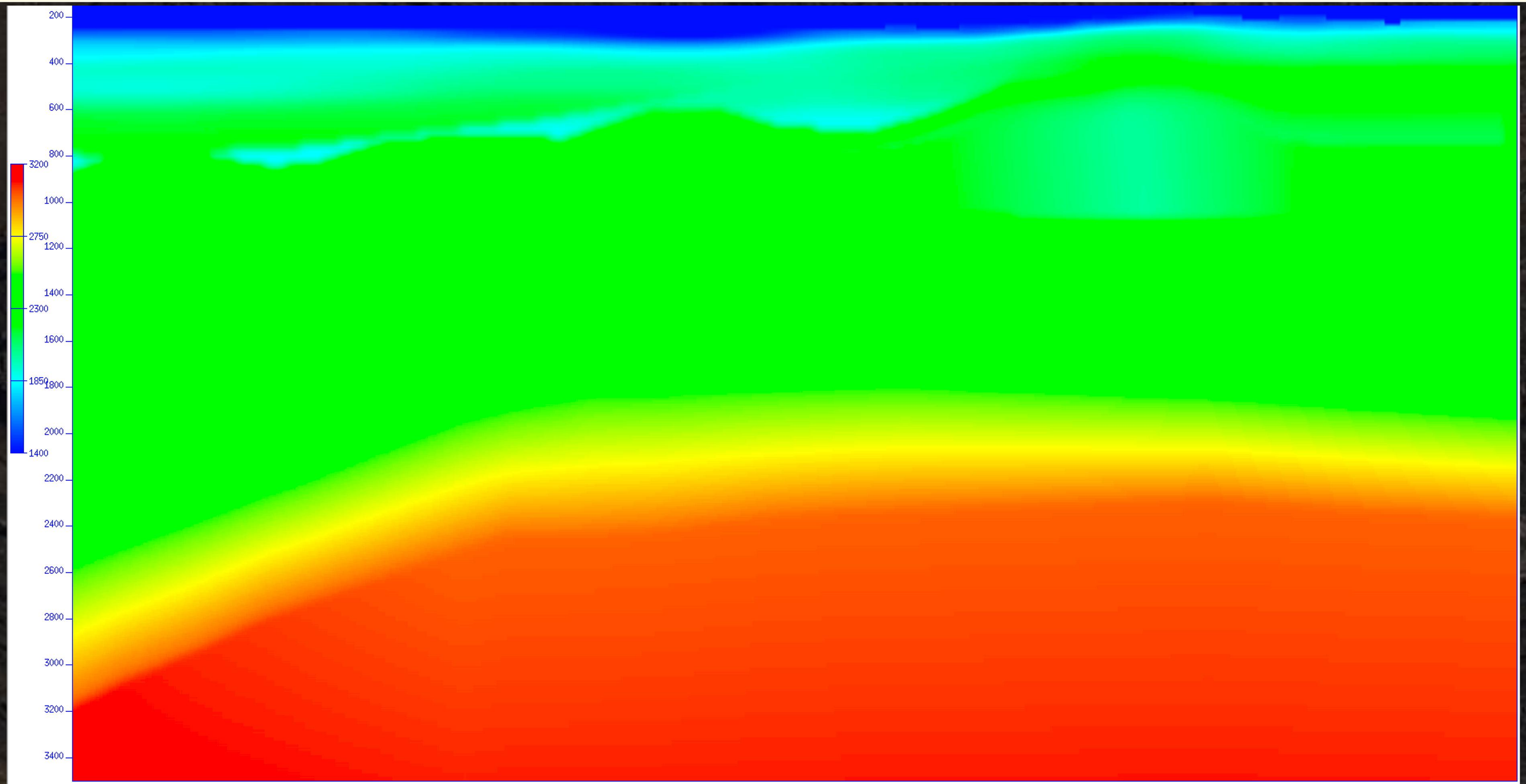
Model tests for mud velocities



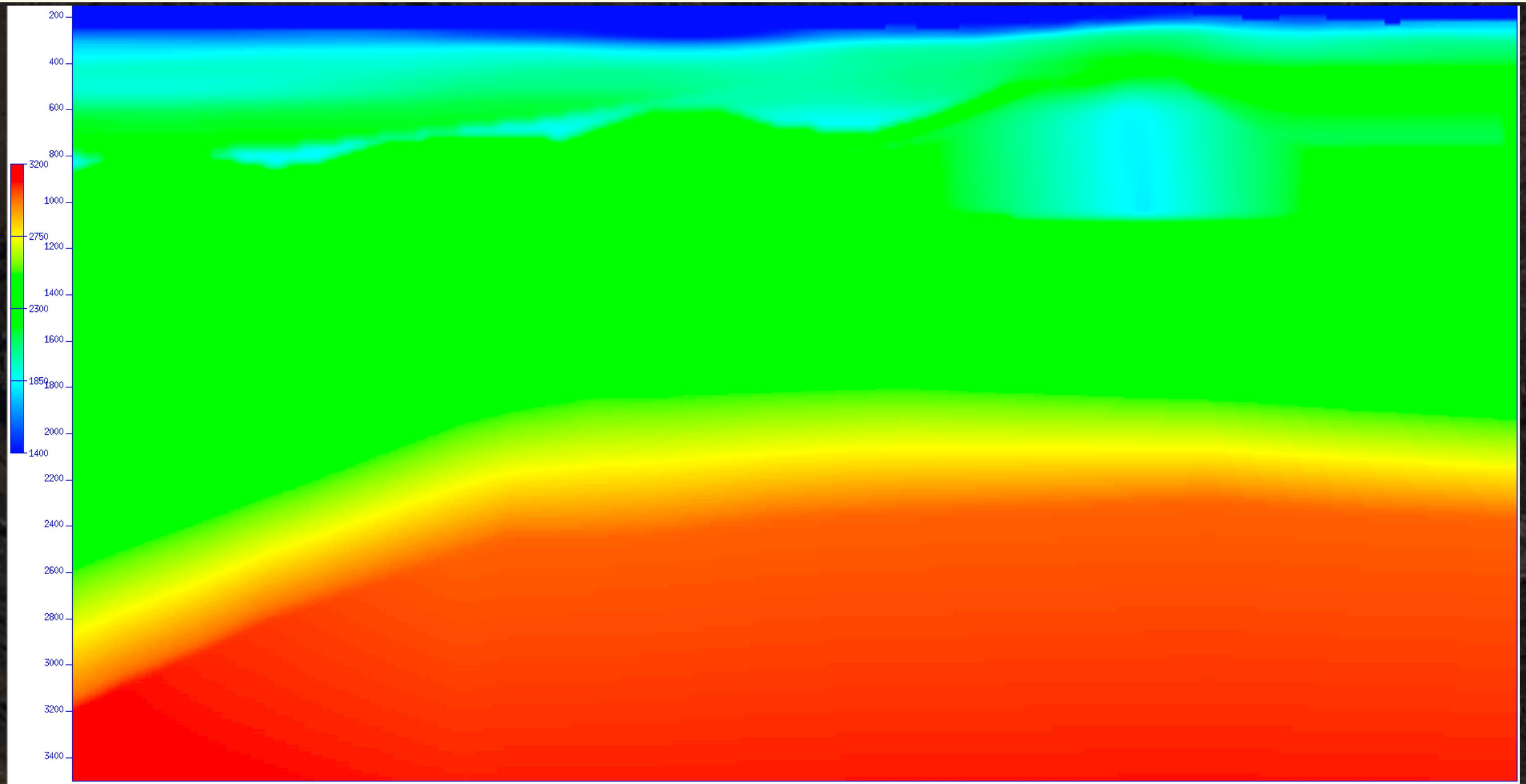
Base case for the test: 2200 m/s



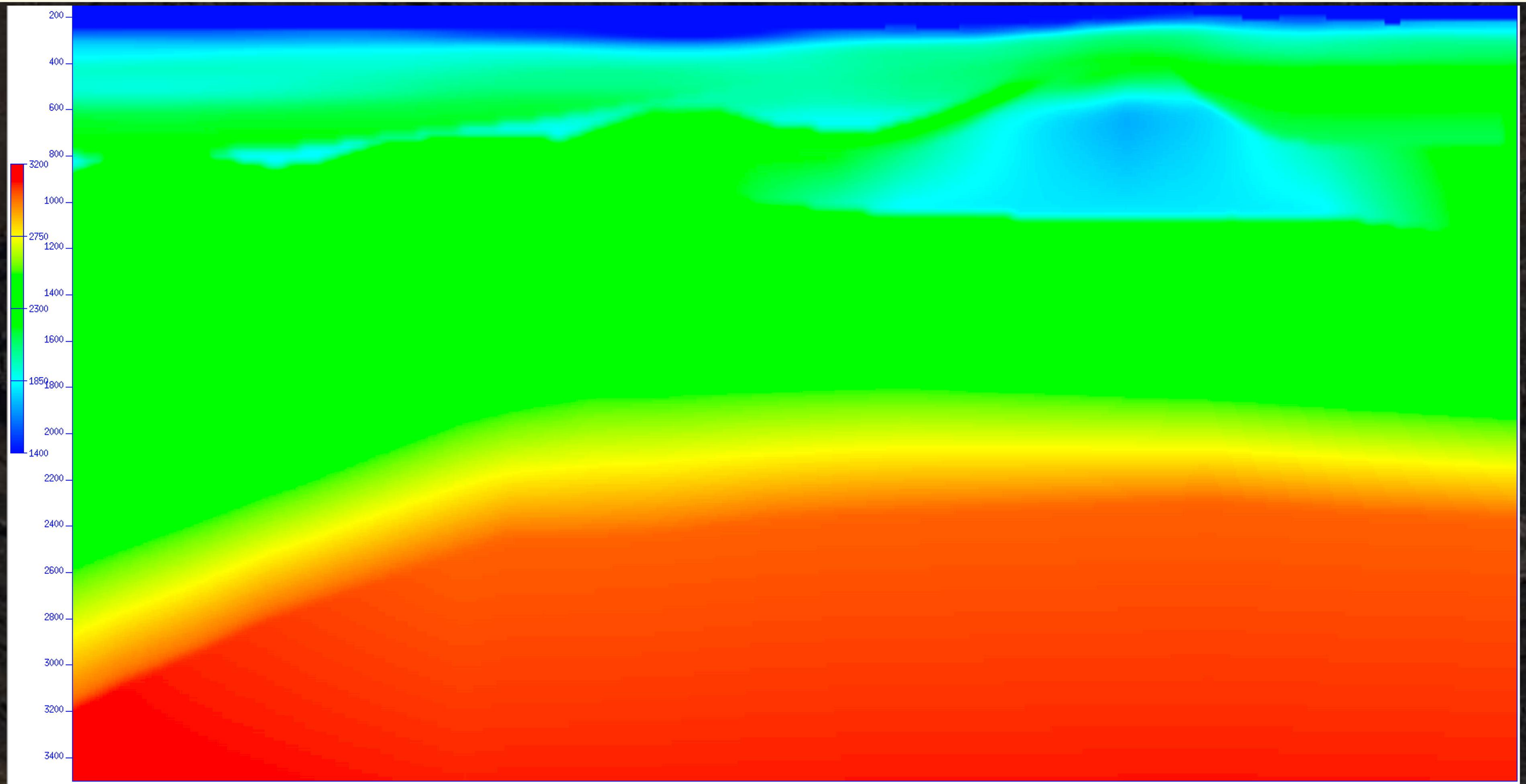
Mud velocity: 2000 m/s



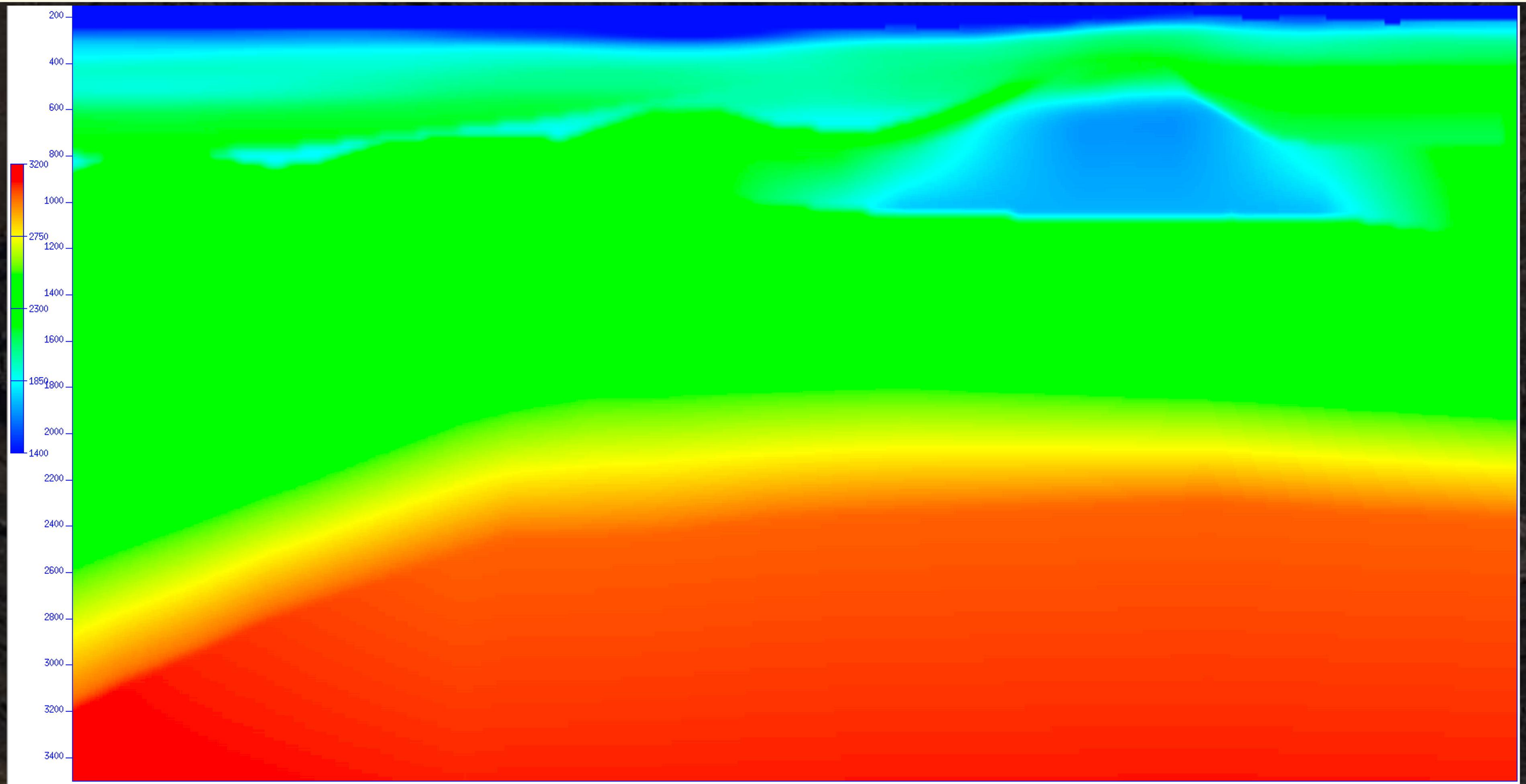
Mud velocity: 1800 m/s



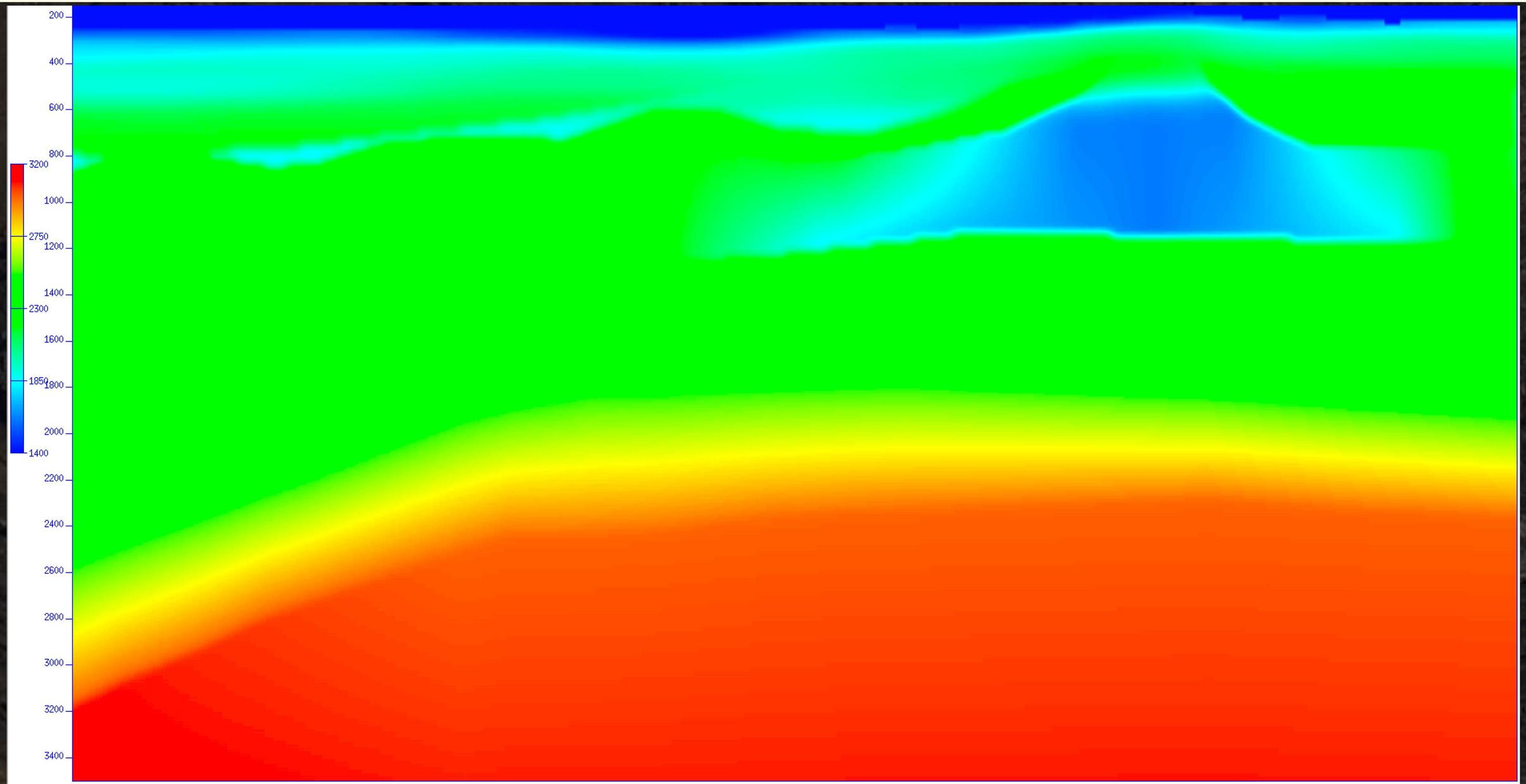
Mud velocity: 1800 m/s with wider extent



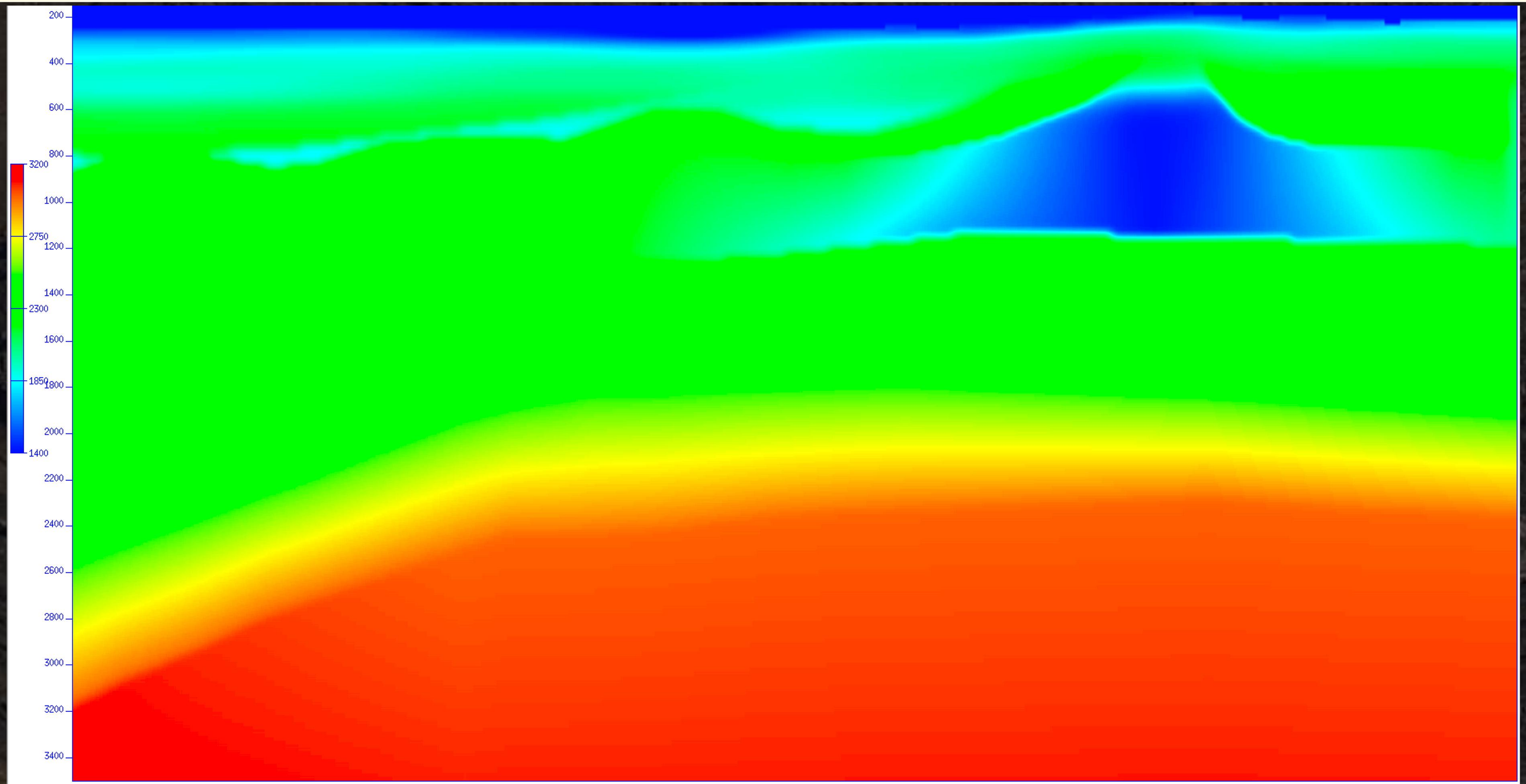
Mud velocity: 1600 m/s with wider extent



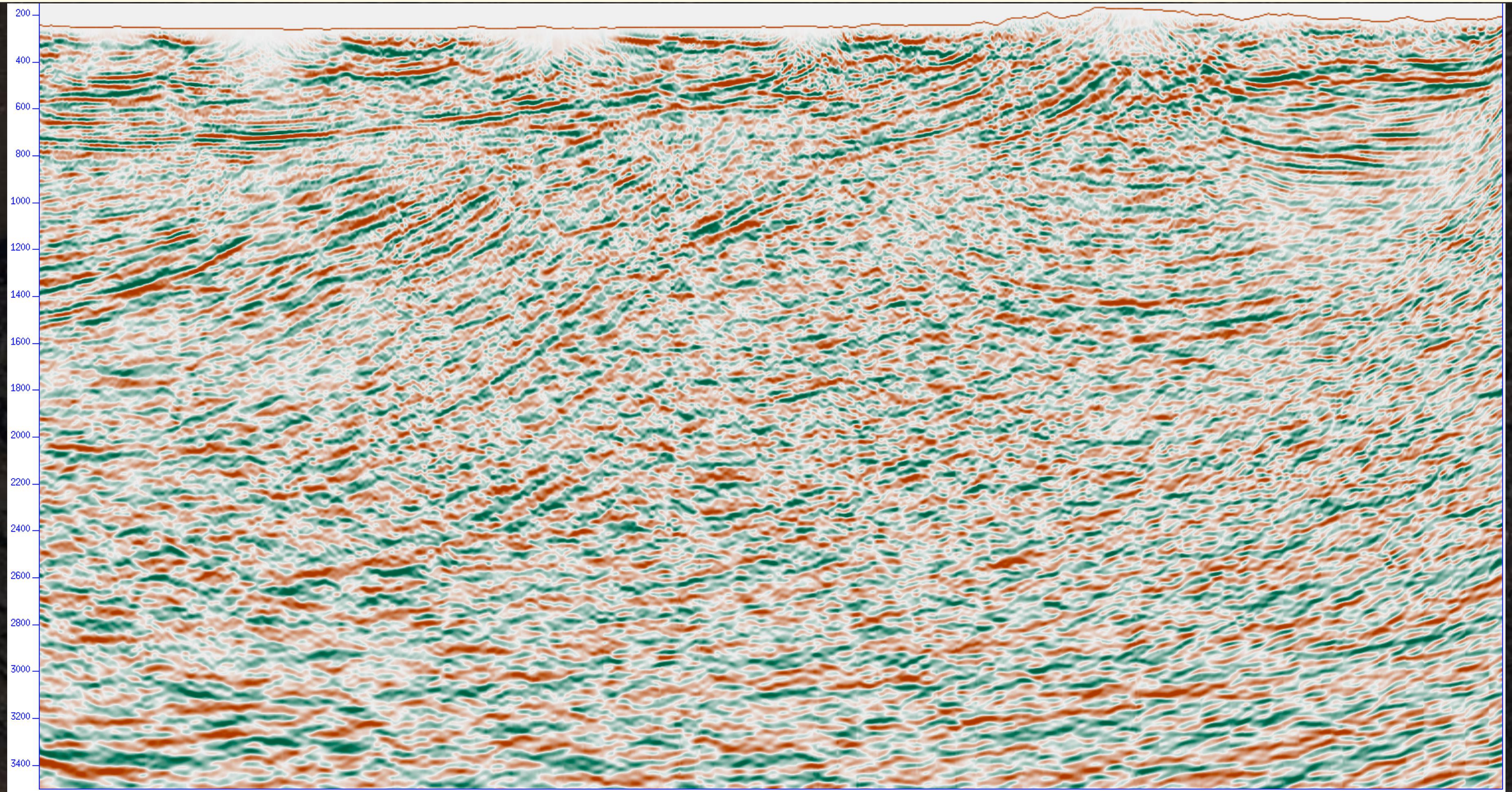
Mud velocity: 1600 m/s wider again



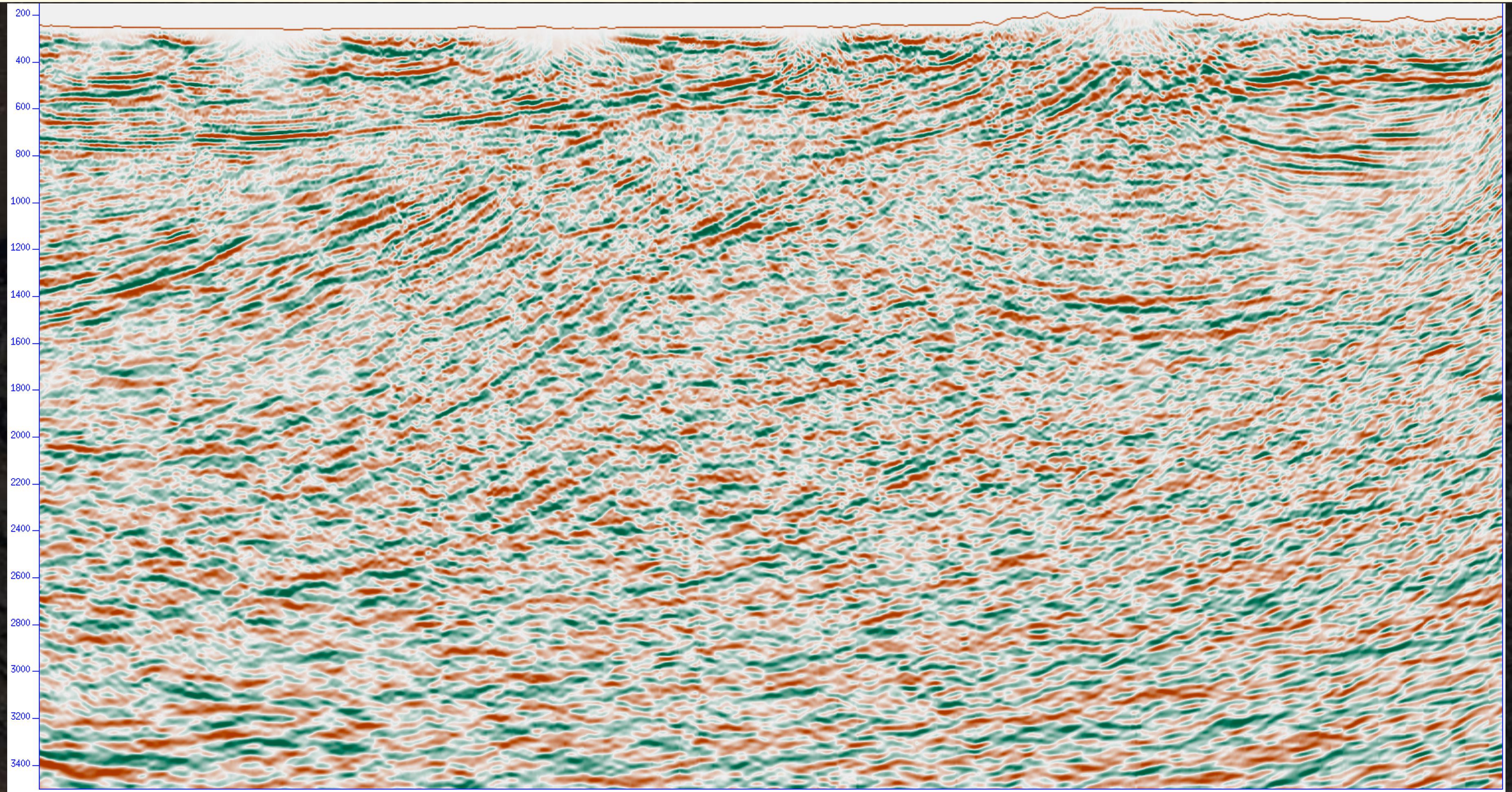
Mud velocity: 1400 m/s



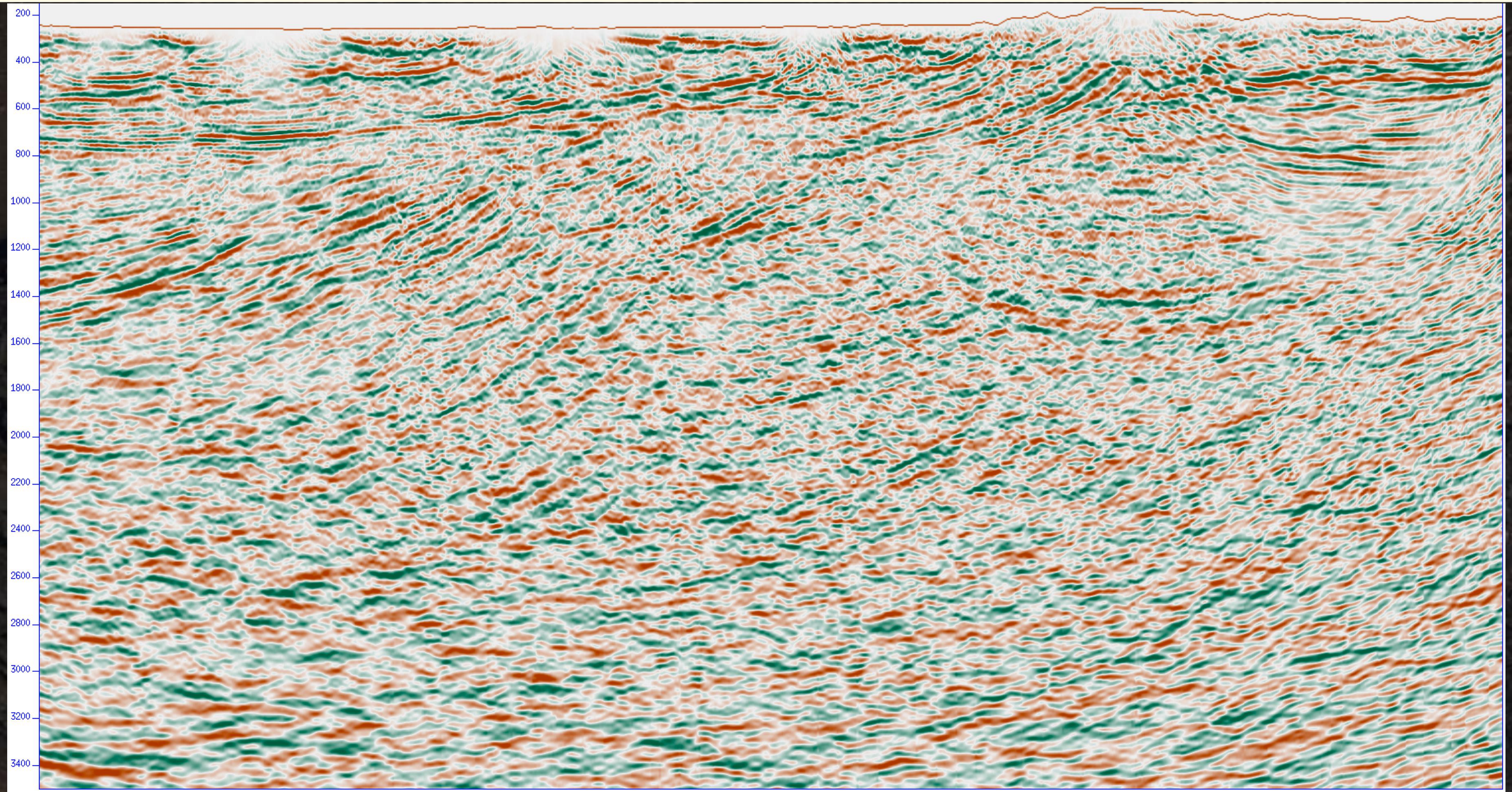
Base case for the test: 2200 m/s



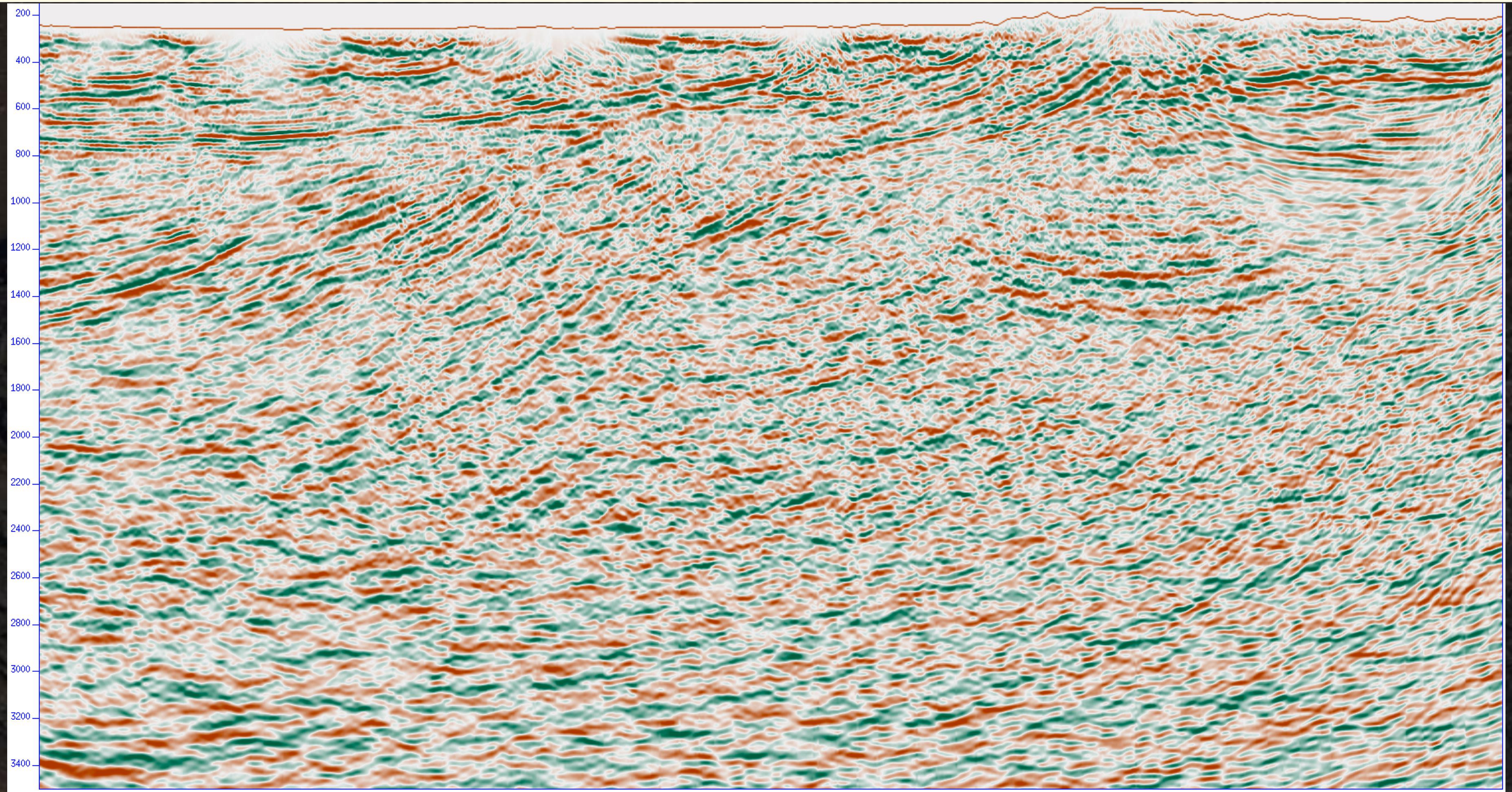
Mud velocity: 2000 m/s



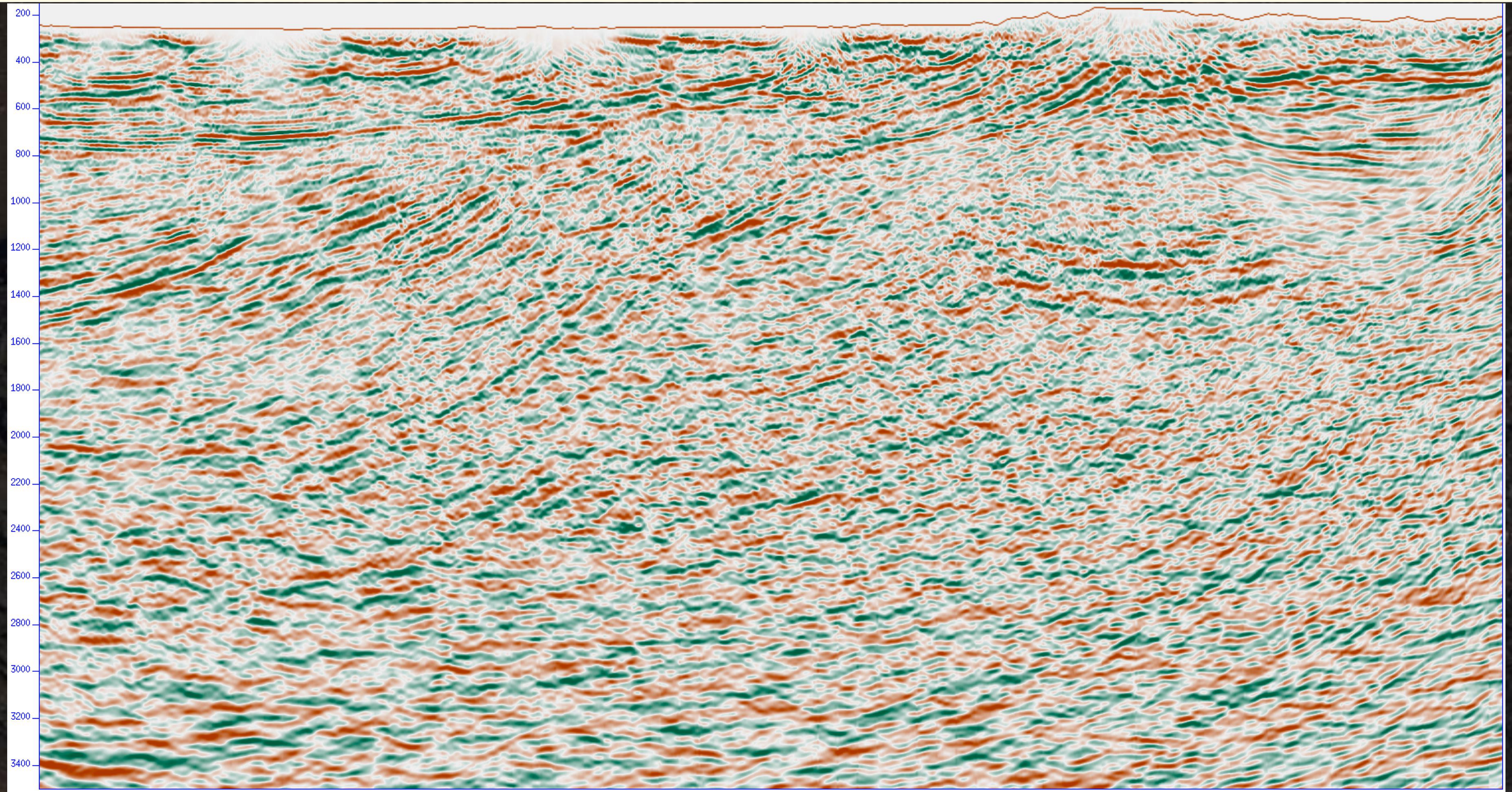
Mud velocity: 1800 m/s



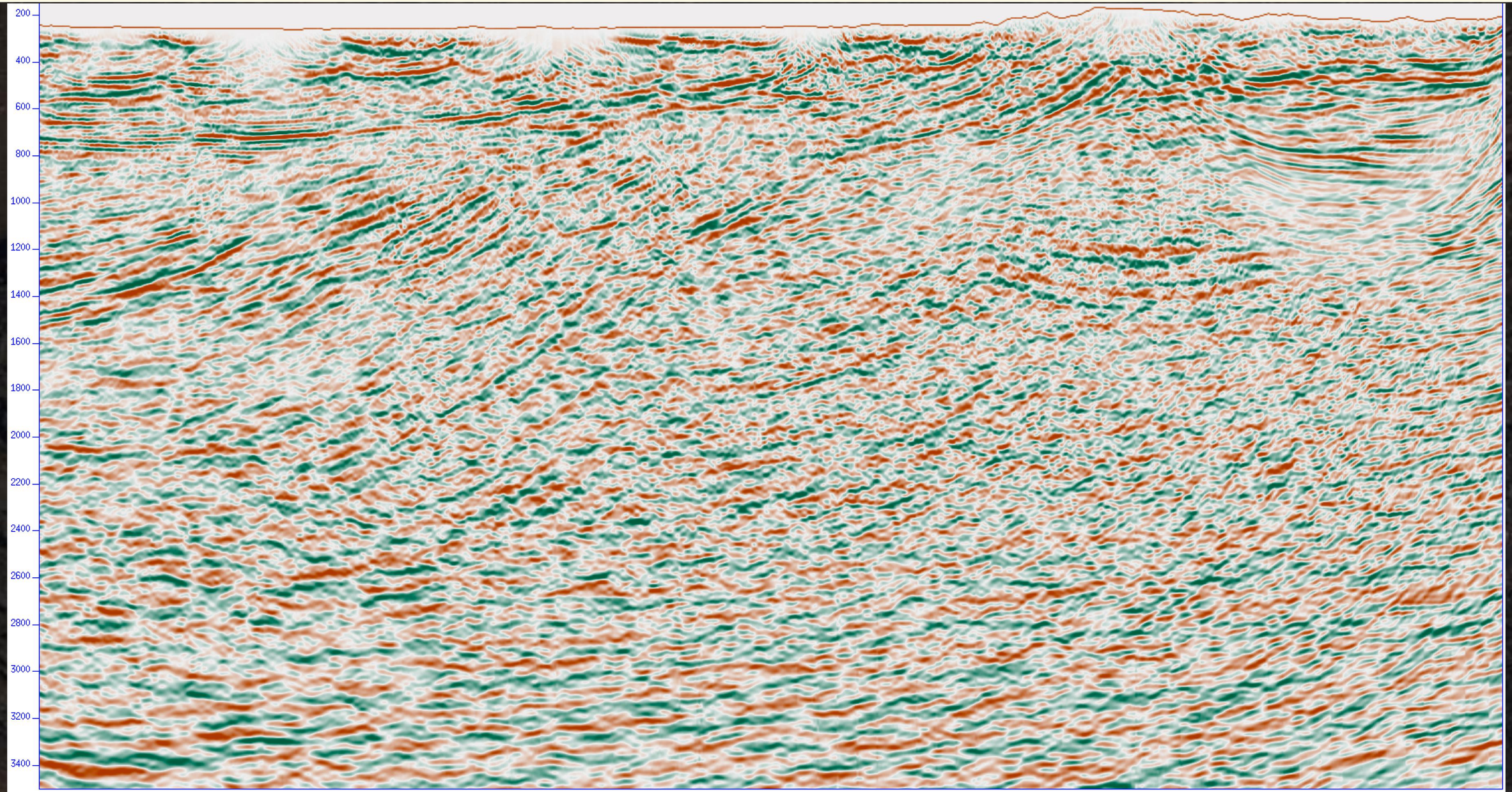
Mud velocity: 1800 m/s with wider extent



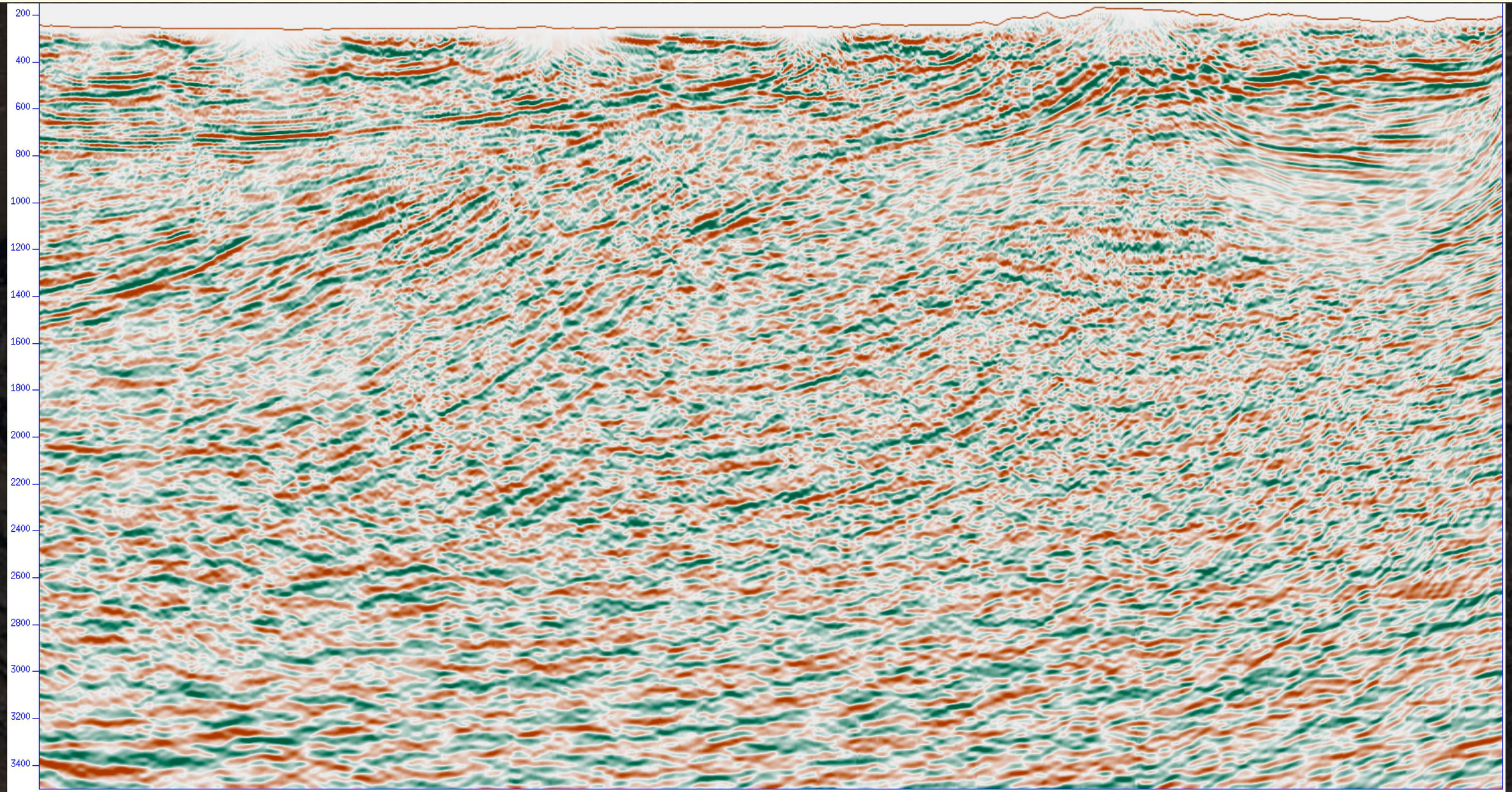
Mud velocity: 1600 m/s with wider extent



Mud velocity: 1600 m/s wider again



Mud velocity: 1400 m/s



hocol

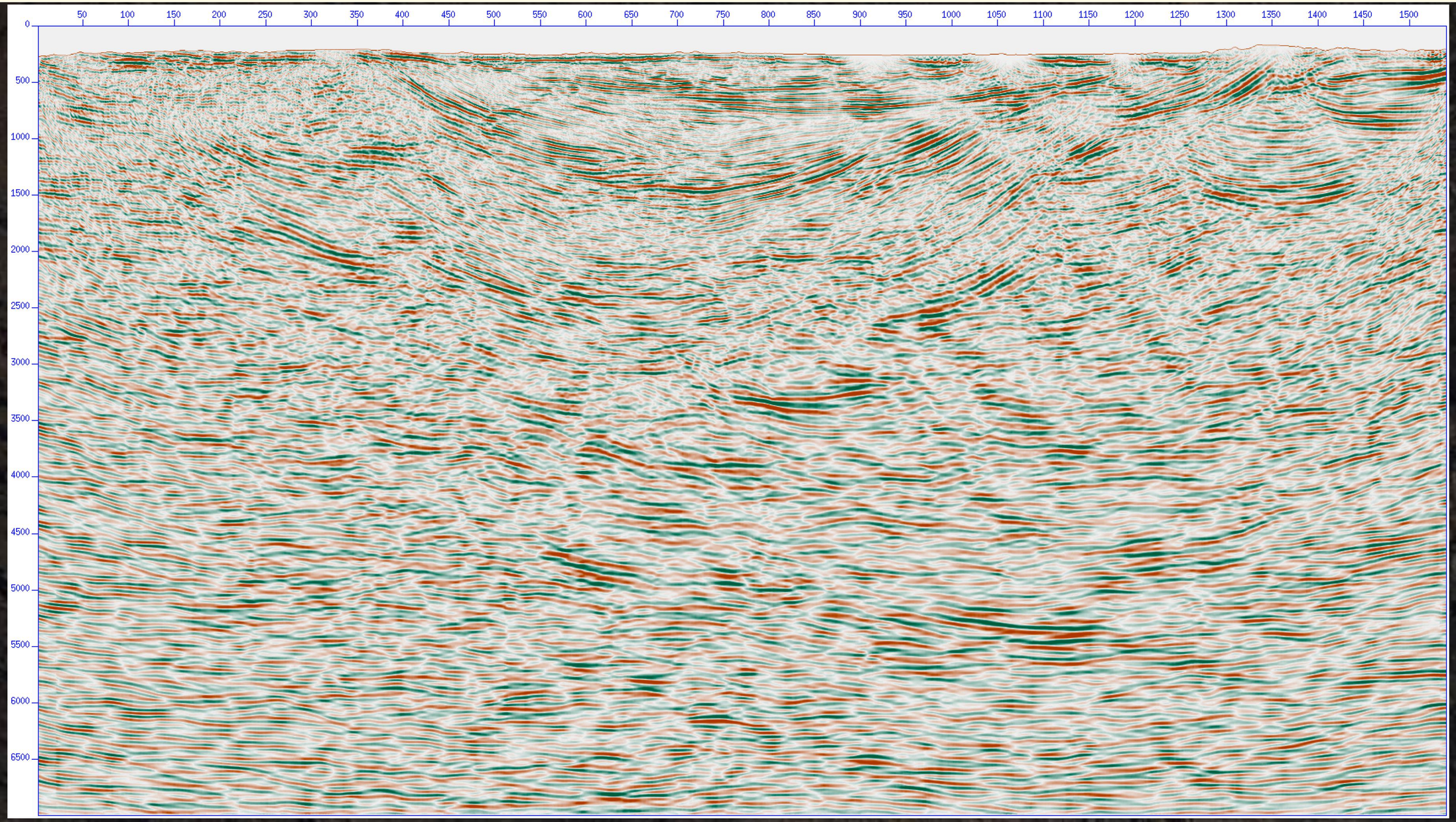
TBI

TBI Colombia SAS

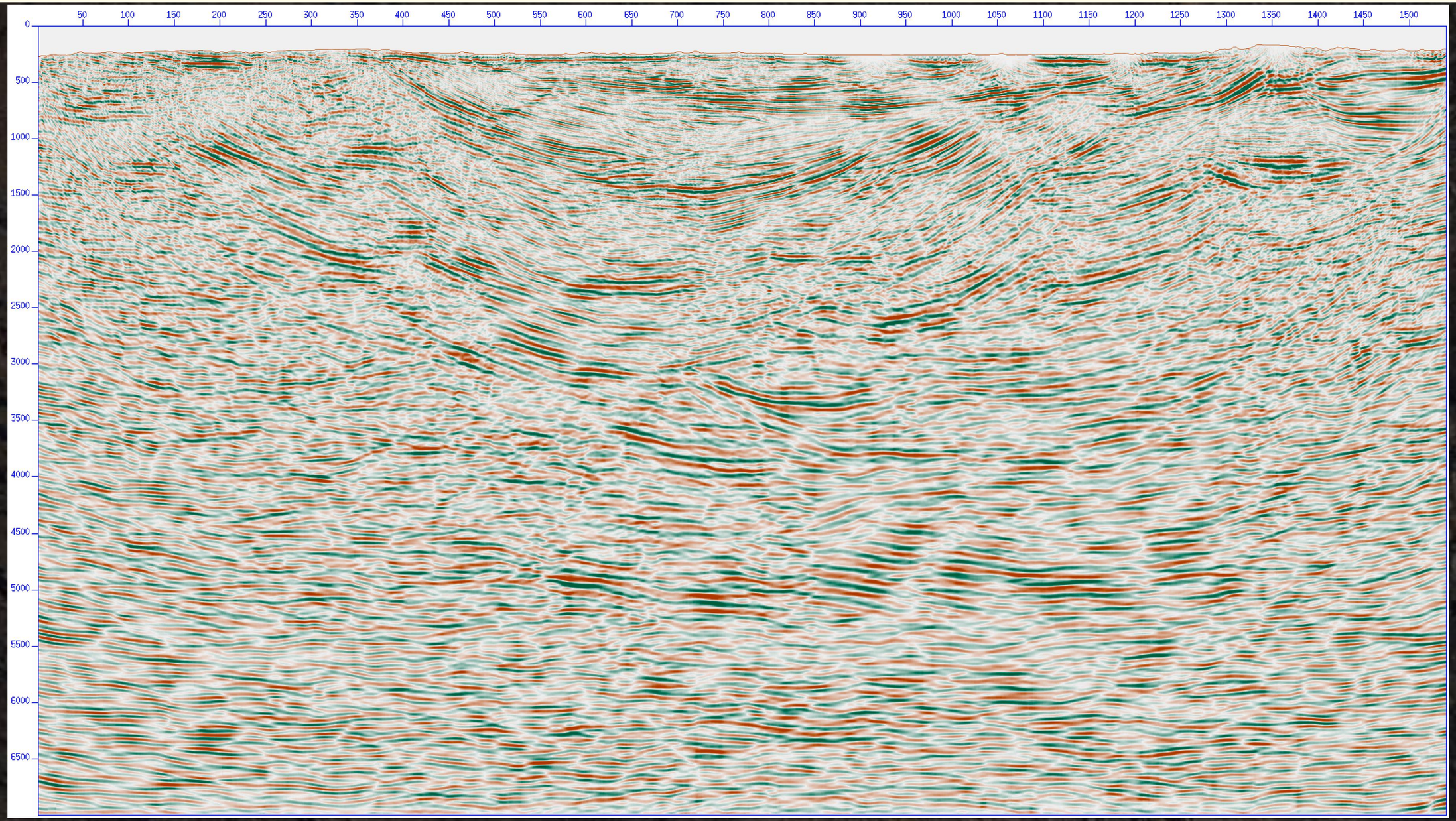
Comparison of PSDM images with signal processing applied

Seismic images with and without our favourite mud volcano

Previous migration with background velocity model



Updated model



hocol

TBI

TBI Colombia SAS

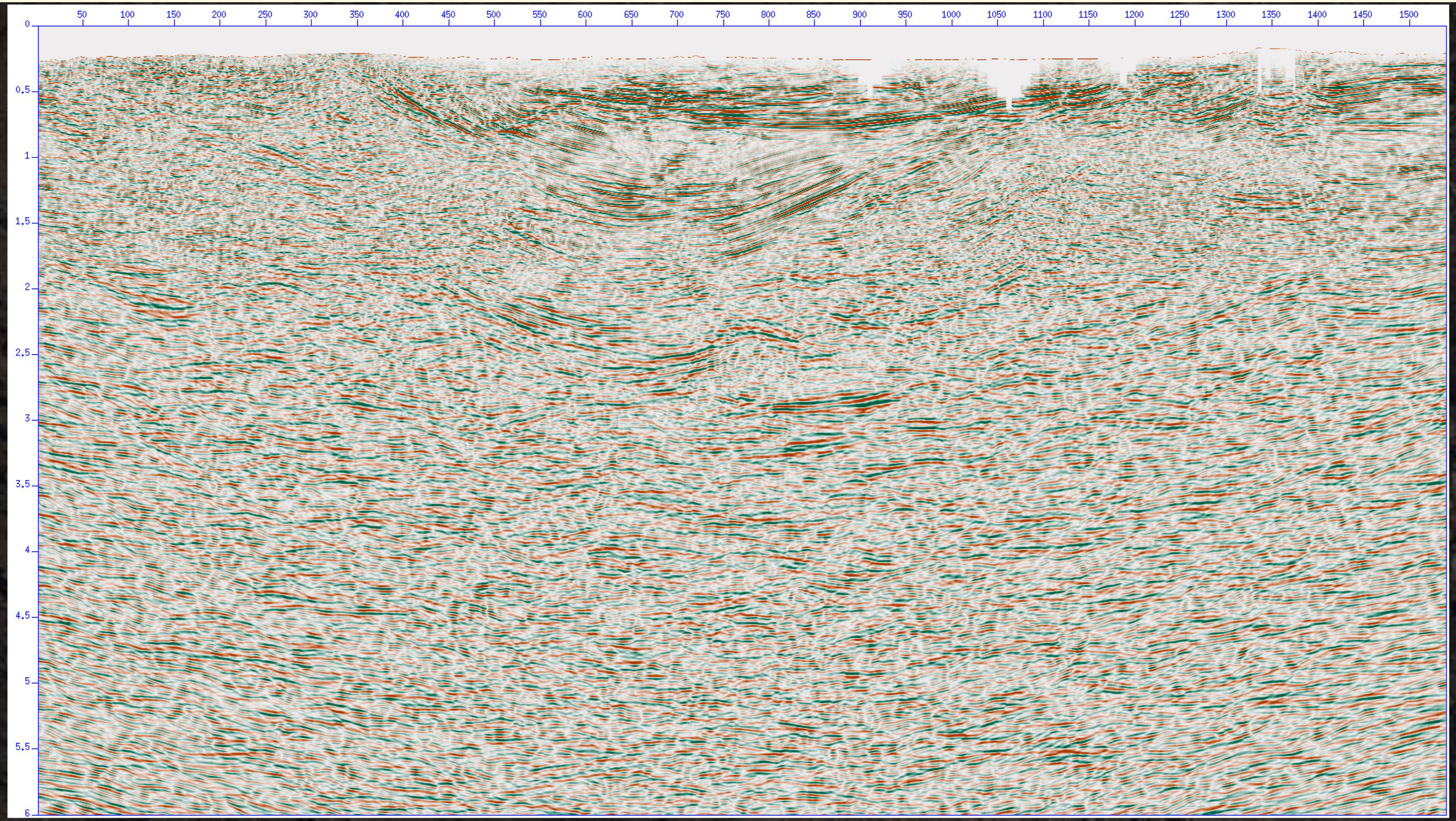
Comparison to previous PSTM images

Legacy image from TBI 2018

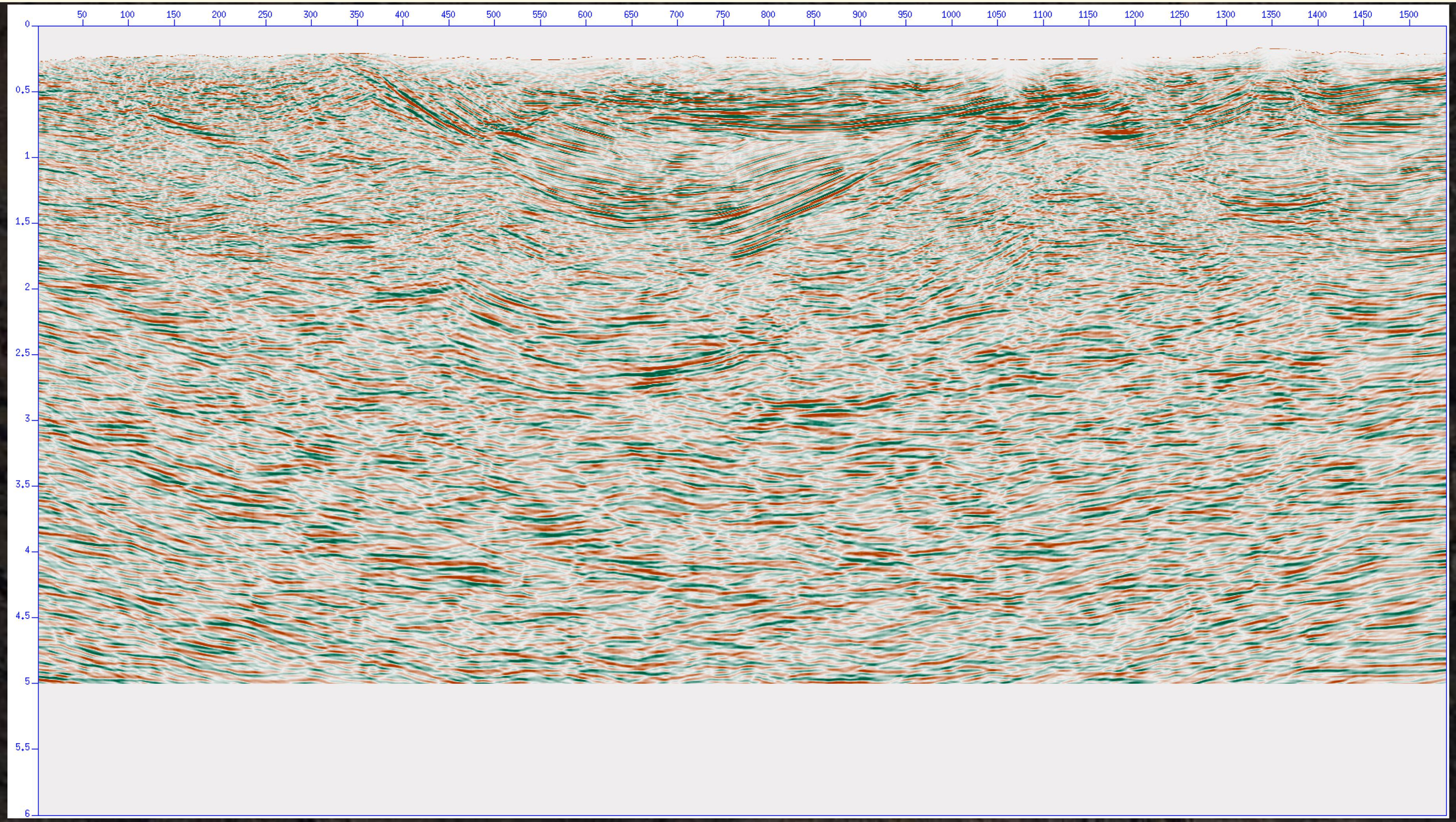
Improved correction for near-surface weathering using ToModel

Revised workflow from TBI Colombia office to increase signal-to-noise ratios

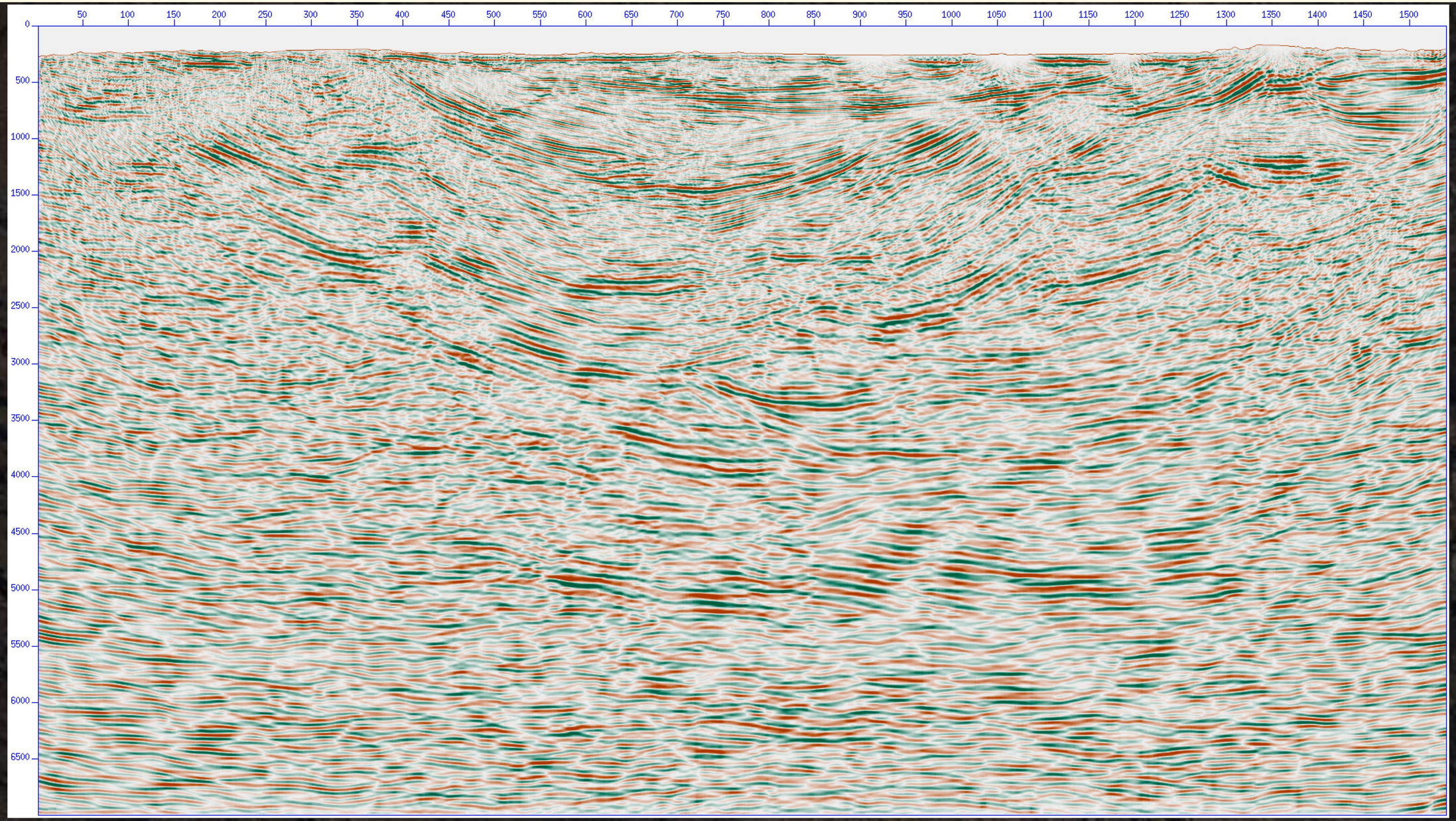
Legacy PSTM image from TBI in 2018



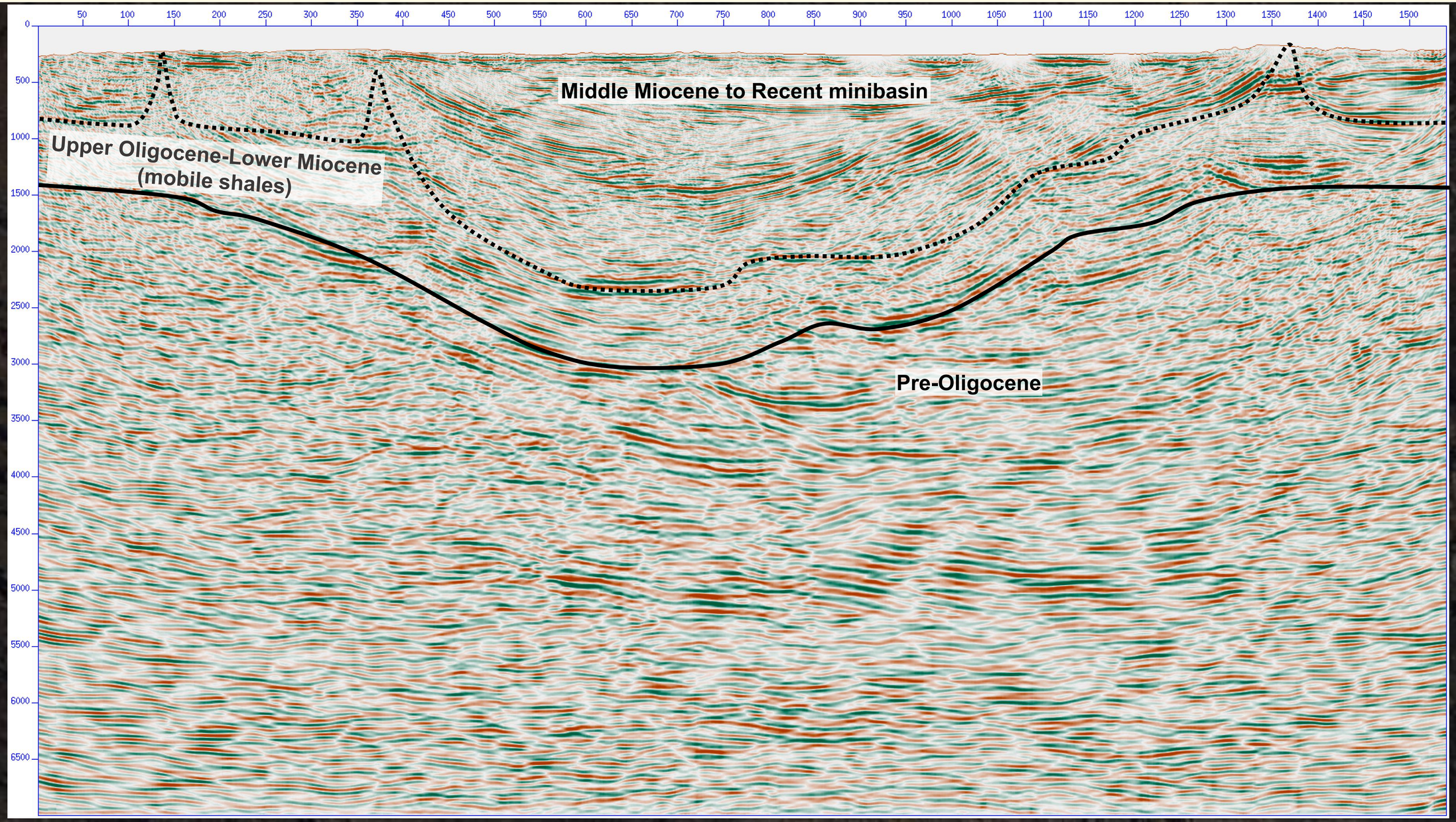
Reprocessed PSTM from TBI Colombia 2022



PSDM from 2022



PSDM from 2022



Observations and discussion

- Imaging improvements over the legacy imaging came from new weathering corrections and improved signal enhancement
- PSDM took revised input then improved the imaging over the PSTM
- Velocity scans of a possible subsurface geobody related to the surface mud volcano resulted in further imaging improvement of the PSDM
- Geologic integration improved seismic imaging, which then, in turn, offered more information for the geologic interpretation