APPENDIX G: SEISMIC INVESTIGATION REPORT

Pickles Butte Sanitary Landfill 3D Seismic Survey Report

Nampa, Idaho

Project No. 114-571040-2022
February 21, 2022

PRESENTED TO

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DISCLAIMER

The subsurface conditions and recommendations presented in this document are based on conditions encountered at the specific geophysical survey locations at the time they were conducted. Due to the complexity and variability of natural earth and rock formations and materials, significant variations may occur between and around these locations or with time. Because these data represent a very small statistical sampling of subsurface conditions, it is possible that conditions may be encountered that are substantially different from those indicated. In these instances, modification and adjustment to the recommendations presented may be warranted.

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1. INTRODUCTION

Acronyms	
Ft	Feet
ka	Kiloannum (thousand years)
mm	millimeters
PBSL	Pickles Butte Sanitary Landfill
QC	Quality Control
USGS	United States Geologic Survey
WSRP	Western Snake River Plain

1.1 Background

The Pickles Butte Sanitary Landfill (PBSL) is an operational landfill site in southwestern Canyon County Idaho (**Figure 1**). The county is in the process of expanding the footprint of the landfill, primarily to the northwest of the current landfill site. The site is located within the Western Snake River Plain (WSRP) fault system and a portion of an undifferentiated Quaternary aged northeast-dipping WSRP normal fault is mapped within the project boundaries, extending northwest through the proposed expansion area (**Figure 1**). The mapped fault is labeled as a normal fault with an approximate slip rate of less than 0.2 mm/year. Proposed excavations within the fault areas are expected to extend up to 150 ft below ground surface, potentially intercepting this fault.

1.2 Purpose

This report presents results from an active-source 3D seismic survey conducted at the PBSL site in Nampa Idaho. Tetra Tech was contacted to support and provide technical insight for the ongoing expansion program at the PBSL site. Tetra Tech developed a technical approach and an expedited timeline for a seismic survey to help delineate a mapped fault at the site. The seismic survey was designed to image and delineate a suspected fault in support of the proposed expansion program at the PBSL (**Figure 1**). Seismic imaging over the suspected fault area was attained by using 3D seismic velocity tomography and reflection processing. Seismic reflection is a reliable method for imaging the faults when present and can help to orient the faults and subsurface structure as well. The 3D seismic tomography provides the information needed to accurately convert seismic reflection data in time to depth and elevation. The information gained from this survey was used to direct the final proposed boring of the larger geotechnical investigation at the site.

1.3 Geologic Background of the Western Snake River Plane Fault System

The fault segments from the Western Snake River Plain (WSRP) fault system were extracted from Personius (2003). The WRSP faults closest to the project are shown as red lines in **Figure 1**, herein referred to as USGS WSRP faults. From Personius (2003), "The Western Snake River Plain fault system consists of numerous northwest-striking, northeast- and southwest-dipping normal faults that offset older (Plio-Pleistocene) fluvial deposits (Glenns Ferry Formation, Tuana Gravels, Tenmile Gravel) associated with the Snake River, and isolated volcanic and sedimentary rocks of the Snake River Group, in southwestern Idaho. Some faults form asymmetric linear ridges as much as 30-m-high of Plio-Pleistocene deposits and some early Quaternary deposits and surfaces are tilted or downwarped, but most have subdued expressions on the floor of the Snake River Plain. No detailed studies on the age of faulted deposits have been published, but most fault traces are confined to older Quaternary deposits on the western Snake River Plain, so the faults are herein assigned a Quaternary age until further detailed studies are conducted." Measured fault dips are 55-88° NE from the subset of exposed USGS WSRP fault segments mapped by Wood and Anderson (1981).

The USGS WSRP faults are subdued and do not show evidence of activity within the past ~100 ka (Wood and Anderson, 1981). From Personius (2003), "Most faults in this zone have subdued expressions on the floor of the

Snake River Plain, and some are mapped in the subsurface and have little surface expression. Faults form asymmetric linear ridges as much as 30 m high of Plio-Pleistocene deposits, and some early Quaternary deposits and surfaces are tilted or down-warped (Wood and Anderson, 1981; Othberg and Stanford, 1992 ; Ostenaa, October 2, 1985). Faults in the Western Snake River Plain fault system offset older (Plio-Pleistocene) fluvial deposits (Glenns Ferry Formation, Tuana Gravels, Tenmile Gravel) associated with the Snake River, and isolated volcanic and sedimentary rocks of the Snake River Group (Wood and Anderson, 1981; Gilbert and others, 1983; Othberg and Stanford, 1992; Othberg, 1994). Othberg (1994) noted that fault movements are older than the sediments underlying the Whitney Terrace; Wood and Anderson (1981) used soil development to infer an age of more than 100 ka for these deposits." A caution is that inferred ages based on soil development are very uncertain. Inferred soil ages can be in error by a factor of five (meaning an inferred age based on soil development of 100ka could really be as little as 20ka or as long as 500 ka). Consequently, it is prudent to map WSRP fault system structure that is mapped to extend within the project site (Personius, 2003).

In the project area the USGS WSRP fault segments approach the site from the northwest as a northeast dipping normal fault, making a right step to the south to another USGS NE-dipping WSRP fault segment, and then stepping southwest to a second SW dipping USGS WSRP fault segment (**Figure 2**). Consequently, within or close to the project site USGS WSRP fault deformation is expected to splay to accommodate the right step in the USGS WSRP fault system across the project site (**Figure 1**). Further there is another USGS WSRP fault segment mapped northeast of the project site (**Figure 2**) so the USGS NW-striking NE-dipping WSRP fault segment that approaches the project site from the northwest would be expected to also possibly split or step left (northeast) at some position close to or within the project site. If the USGS NW-striking NE-dipping WSRP fault segment (red line in **Figure 2)** is splaying out then in addition to fault structure complexity like splays, steps, and horsetails, this fault segment might become locally steep or even change dip direction along strike, structures typical near the ends of normal faults, and may partition slip between normal slip and strike slip deformation (Mandl, 1988; pgs. 24-44).

2. SEISMIC IMAGING

2.1 Seismic Data Acquisition

In December 2021 Vantage Geo LLC. with support from and under the direction of Tetra Tech deployed a 3D array of single component, wireless seismic nodes over an approximate 9-acre area at the PBSL site. The primary objective was to intercept the suspected fault trace with the geophone array and provide meaningful imagery of the fault (**Figure 3**). Seismic stations were positioned within the seismic array using a proprietary in-house method developed to produce surveys with high fold data while also minimizing source points and total number of receiver stations. A total of 285 GTI© single channel wireless nodes were deployed over the surveys area and installed into the ground surface. The installation of the GTI nodes below grade provides excellent geophone-ground coupling while also reducing acoustic noise thereby increasing seismic signal relative to noise. To further reduce noise at the site Tetra Tech timed the survey to coincide with a non-operational day at the landfill along with posting signage to temporarily restrict access to the site. Both measures helped to improve the signal against noise in the data, which was critical for imaging a weak fault trace in low-contrast unconsolidated geologic conditions (**Figure 4**).

Once installed, the GTI nodes run self-diagnostic routines to ensure high data quality and proper installation. The nodes also record GPS positions, instrument tolerances, and assigned station numbers for efficient data processing. Tetra Tech chose to utilize an IVI© Envirovibe2 (EV2) as the active source vehicle for the survey. The EV2 provides excellent signal and can provide custom sweep lengths and frequencies which help to overcome site and geologic conditions that may interfere with data quality. Based on the geologic conditions at the PBSL site, Tetra Tech chose a linear sweep table with a limited frequency range of 5-75Hz. The relatively low sweep frequencies allow energy to better penetrate the slow materials at the site, mainly the loose unconsolidated overburden and weathered bedrock profile. Pre-plot source positions were provided to the EV2 operator via a heads-up display in the cab of the EV2. The EV2 operator recorded 440 individual shot locations within and around the survey area (**Figure 5**). A portion of the proposed shot locations were inaccessible for the EV2 primarily due to steep terrain along the western half of the of the site. To ensure safe operation of the EV2 most of the western source points were confined to road tracks and relatively flat areas (**Figure 5**). The 440 EV2 shot points and 285 receiver stations provided 124,224 receiver traces for data processing.

Data were acquired over the course of two days following the installation and QC of the GTI nodes. The nodes were then picked up from the survey area and data were harvested from using the EV2 shot records as the data harvest template. The nodes record data continuously for up to 21 days and EV2 source files are used to re-create individual shot records from each node for processing. No data QC or health and safety issues were noted during the field work at PBSL.

2.2 Seismic Data Processing

To provide rapid data turnaround, Tetra Tech utilized the services of Agile Seismic LLC to provide 3D seismic velocity tomography and reflection processing. Seismic data were assigned geometry based on the measured survey parameters and imported into a GeoTomo® database to QC the raw shot gathers and the project geometry. A processing grid was established with a 3-meter nominal spacing between stations to calculate fold from the survey and assign inline numbering and crossline numbering. First arrival times were straightforward to pick and with the GeoTomo® 3D traveltime P-wave velocity tomography software to estimate 3D P-wave velocities. The 3D P-wave velocity model provided refraction statics and the information required to convert seismic reflection two-way time images to depth and elevation. 3D P-wave are critical for seismic reflection migration processing since it is not possible to derive shallow (near-surface) velocities from reflection analyses and provide an initial 3D velocity model for seismic reflection processing. Seismic reflection velocity analyses updated the 3D velocity model to calculate residual statics and create the initial stack to produce 3D reflection-two-way-time volume. Several iterations of velocity analyses and denoising were used to improve imaging of stratigraphic horizons before final time migration were completed. Post Stack Time Migration (PoSTM) was selected to produce the final reflection results based on testing by Agile. The PoSTM data were produced using true amplitude processing to improve imaging of structural truncations produced by faulting. All seismic processing is performed using NAD83 UTM Zone 11 positions in meters and elevations in meters to ensure a processing is accurate; state plane coordinates use a foot (U.S. survey foot) which has a different length than the standard international foot used for vertical coordinates. Details of seismic processing steps are provided in **Appendix A**.

Overall, the data acquired at PBSL was relatively clean data with little environmental noise but strong surface waves (**Figure 4**). Denoising was used to attenuate the surface waves and provide clean data with good first breaks picks for the 3D P-wave travel time velocity tomography. Initial interpretations using early processing of the seismic data and final PoSTM interpretations was used to select a boring location to intercept faulting at similar depths.

2.3 Seismic Data and Interpretations

The seismic reflection data are relatively low frequency in spite of the 5-75 Hz vibroseis sweep (**Appendix B**). The combination of a deep water table, thick surficial dry sediments, and weathered rock strongly attenuate high frequency reflections. However, the broadband low-frequency data provide good signal-to-noise and good resolution of first order fault structure as discussed below.

Two tip splay fault structures are identified and mapped in 3D using seismic inlines (SSW-NNE cross sections) spanning the range of inline 1033 (northwest extent of good continuous 3D imaging) to inline 1053 (southeast extent of good continuous 3D imaging). Uninterpreted seismic reflection two-way-time cross sections are presented first in **Figures 6A-8A** paired with the same data with fault picks in **Figures 6B-8B**. The positions of inlines 1033, 1040, and 1053 in **Figures 6-8** are provided in **Figure 5**. The signed energy reflection attribute is used in **Figures 6-8** because it provides the sharpest delineation of fault structure (**Figures 6B-8B**). The central horst between the two faults (**Figure 9**) is likely less deformed, resulting in high amplitudes within the horst relative to the hanging wall (downthrown) sides of the two faults to the south and north (**Figures 6B-8B**). Conventional true amplitude color wiggle travel reflection cross sections with fault picks are provided from inline 1033 to inline 1053 in **Appendix B** for reference.

Both mapped 3D fault segments correspond to tip splay faults since they have substantially different strikes than the N34°W strike of northwest NE-dipping WSRP fault segment postulated to run through the project site (**Figure 5**). This is best illustrated in 3D perspective (**Figure 9**) with comparison to observed normal-faulting termination structures in **Figure 10**. Perrin et al (2016) provide field scale examples near the termini of normal faulting tip splay faults that develop and extend beyond main normal fault traces (**Figure 10**). We interpreted the southwest dipping fault (medium green fault in **Figure 9**) that strikes N47°W is a tip splay fault since it changes strike 15° and changes dip direction to the southwest whereas the USGS NW-striking WSRP fault is mapped as dipping northeast. The second, north-northeast dipping tip splay fault (blue fault in **Figure 9**) strikes N69°W which cuts off the main USGS NW-striking WSRP fault further west than the SW-dipping tip splay fault (**Figure 11**).

Preliminary borehole data are used from Boring B2021-5, abbreviated as borehole B5 in this report. Borehole B5 provided preliminary geotechnical and geologic data at depth within the extent of the 3D seismic volume (**Figure 9**). The 3D mapping of the two tip splay faults in **Figures 6-9 and 11** demonstrates that main USGS NW-striking WSRP fault deformation terminates northwest of borehole B5 and splinters into a series of tip splay faults within the project site. These tip splay faults are typical of normal-fault termination structures observed for normal faults (**Figure 10**). Thus, the mostly likely scenario is that primary USGS NW-striking WSRP normal-faulting deformation is unlikely to occur within the project site. Since the USGS WSRP normal faults are not observed to display ~100 ka deposits, the likelihood of primary WSRP normal fault deformation occurring within the project site likely has a very small probability. It is possible that main USGS NW-striking WSRP normal fault deformation transfers to a southwest-dipping right-stepping splay fault segment west of the project site (cyan fault in **Figure 11**). This would produce uplift between the main USGS NW-striking WSRP normal fault and the right-step to the SW-dipping fault segment producing a topographic fault-parallel horst ridge (outlined in yellow in **Figure 11**). It is clear from the 3D fault mapping that primary USGS NW-striking WSRP faulting is decreasing west of the project site as faulting splinters to splay faults (**Figure 11**), typical of the terminus regions of normal faults (**Figure 10**). Where main USGS NW-striking WSRP faulting ends is constrained to be no further southeast than the west extent of the NE-dipping tip splay fault (blue fault in **Figure 11**).

The shallow limit of faulting of the tip splay faults within the project site is not directly constrained by the 3D fault mapping in **Figure 9** because fault structure does not produce consistently discernable seismic signatures above the water table. However, combining the seismic 3D tip splay fault mapping with observations from borehole B5 provides a constraint on the potential shallower manifestations of tip splay fault deformation along the SW-dipping tip splay fault. Three possible cases to considers for the upward progression of the tip splay faults from the mapped position in the 3D seismic volume are:

1. Fault deformation continues upward at a SW dip of 71° through borehole B5 as a narrow fault plane
2. Fault deformation becomes complex in the 66-86-foot depth interval of clay (shale) between sands (sandstones) in borehole B5 due to flexure and complex faulting within the clay (shale) interval like deformation in this case from Mandl (1988) (see **Figure 12**).
3. Fault deformation does not extend above the elevation of the water table and does not intercept borehole B5, but instead produces flexure in strata located above the water table.

Case 2 seems most likely since it explains the observed broken pieces of consolidated clay observed in borehole B5 and general lack of deformation in the overlying and deeper sands, e.g. the WSRP southwest-dipping tip splay fault intersects borehole B5 near the base of the silty clay at a depth of 81 feet in **Figure 9** producing complex deformation and low blow counts within the 66-86-foot deep clay interval in a pattern similar to the shale interval in **Figure 12**. Based on age constraints on WSRP faulting, deformation observed within the 66-86-foot depth interval in borehole B5 may be older than ~100 ka (Personius, 2003).

It may seem unrealistic to consider that a right-stepping splay normal fault could develop with a southwest dip on the southwest side of the main USGS NW-striking NE-dipping WSRP normal fault, but this has been observed at other sites. For instance, Marchal et al. (2003) provide marine seismic reflection data with exactly this style of normal faulting with a southwest-dipping spay fault developing on the southwest side of a northeast-dipping primary normal fault (**Figure 13**). The important point is that primary normal-faulting deformation from the main NW WSRP fault is clearly decreasing toward its terminus no further southeast than the west side of the northeast-dipping (blue) tip splay fault in **Figure 11**, although primary faulting may already be decreasing prior to entering the far western side of the project site with fault slip partitioning to the southwest dipping right stepping splay fault further west (cyan fault in **Figure 11**).

The 3D seismic fault mapping clearly shows there is no single continuous NW-SE northeast-dipping normal fault extending through the entire 3D seismic volume extent (**Figure 11**). There may be additional unmapped limited extent (lengths < 200 feet) fault splays or relay faults within or outside of the 3D seismic volume extent shown in **Figure 11**. Distributed small stepover and relay faults commonly occur between large fault stepovers, like the less than one-mile right step from the northwest USGS NE-dipping WSRP fault (red fault in **Figure 1**) to the southwest USGS NE-dipping WSRP fault (purple fault in **Figure 1**) (Marchal et al., 2003; Perrin et al., 2016). The primary conclusion of these investigations is that any primary normal faulting deformation on the USGS northwest-striking NE-dipping WSRP normal fault (red line in **Figure 2**) will be confined to the northwest 800 feet of the fault's extension within the project site boundary. Any slip on the USGS northwest-striking NE-dipping WSRP normal fault will be decreasing toward the project site since this investigation shows that the primary fault terminates before reaching the area near borehole B5 in the project site (**Figure 11**).

3. CONCLUSIONS AND RECOMMENDATIONS

Seismic reflection results from the Pickle Butte 3D survey revise the location and structure of the USGS mapped NW-striking NE-dipping WSRP normal fault across the project site (**Figure 11**). The new 3D imaging of fault structure (**Figure 9**) demonstrates that faulting along the USGS NW-striking NE-dipping WSRP normal fault is tapering to zero west of borehole B5 and that residual fault deformation is distributed amongst a network of tip splay faults across the project site (**Figure 11**). Thus, primary normal fault slip is unlikely east of the west edges of the tip splay faults mapped in **Figures 9 and 11**. Instead, any fault slip associated with earthquakes along the USGS mapped NW-striking NE-dipping WSRP normal fault will likely partition into attenuated fault slip among the splay faults within the project site. There may be additional limited extent (strike lengths < 200 feet) fault splays and relay fault within or outside of the 3D seismic volume extent shown in **Figure 11**. Distributed small stepover and relay faults commonly occur between large fault stepovers, like the less than one-mile right step from the northwest NE-dipping WSRP fault (red fault in **Figure 1**) to the southwest NE-dipping WSRP fault (purple fault in **Figure 1**) (Marchal et al., 2003; Perrin et al., 2016).

Typically, in highly weathered rock or in poorly consolidated sediments, fault slip transitions to distributed deformation or bedding flexure prior to reaching the ground surface. Tip splay faulting may decrease with decreasing depth above the water table (**Figure 9**) and transition to flexure or distributed deformation (**Figure 12**). This is the most likely scenario for the PBSL project site. The projected intersection of the SW-dipping tip splay fault at a depth of 81 feet in borehole B5 (**Figure 9**) near the base of a zone of distributed broken clay deformation, suggests the fault has produced distributed deformation in the 66-86-foot depth interval of borehole B5. Since the age of this depth interval in borehole B5 is probably much greater than the ~100 ka overlying unfaulted geologic strata used by Personius (2003) to constrain the most recent age of active faulting along the WSRP normal faults, this possible fault deformation observed in borehole B5 in the 66-86-foot depth interval is likely older than 100 ka.

The USGS NW-striking NE-dipping WSRP normal fault that is mapped as extending into the project site from the northwest does not appear to displace ~100ka age sedimentary units (Personius, 2003). From a probabilistic perspective there seems to be little possibility of significant shallow (< 200 feet) faulting within the project site southeast of the west edges of the mapped tip splay faults in **Figure 11** (negligible nonzero fault slip for annual exceedance probabilities greater than 0.01%). To best characterize the potential movement and absolute location of faulting would require geologic mapping during excavation of the future landfill cell. This area of the proposed landfill expansion would be constructed in >50 years in the future. When the area is excavated for cover material in the future before waste is placed in this area it is recommended that geologic mapping of the fault is conducted, with particular attention to identifying narrow fault zones with evidence of recent activity and areas of potential distributed deformation. Careful sampling can yield materials suitable to date the most recent age of fault activity to determine if any detected fault activity is recent (unlikely) or > 100 ka in age (most likely).

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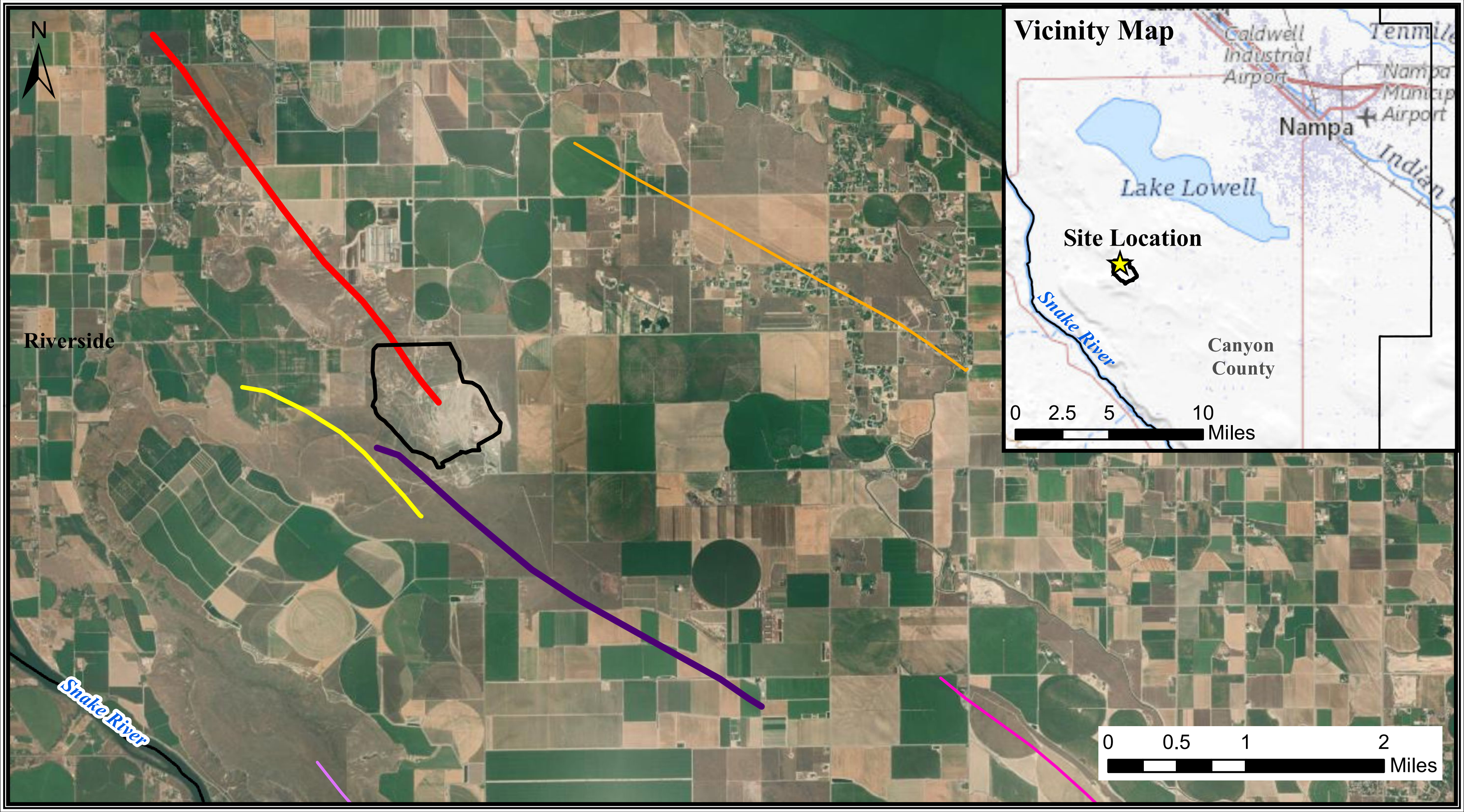
FIGURES



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Legend

Approx. Project Area Boundary

Western Snake River Plain Fault System

- Primary Site NW Segment
- SW Site NE Dipping Segment
- SW Site SW Dipping Segment
- Upper NE Segment
- Lower SW Segment
- Lower SE Segment

Note: US Geological Survey and Idaho Geological Survey, Quanternary fault and fold database for the United States, accessed Feb. 14, 2022, at: https://www.usgs.gov/programs/earthquake-hazards/faults

TITLE:	Faults Mapped Near the Project Area
LOCATION:	Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO	FIGURE
DRAFTED	CEC	1
PROJECT#	114-571040-2022	
DATE	2/14/2022	

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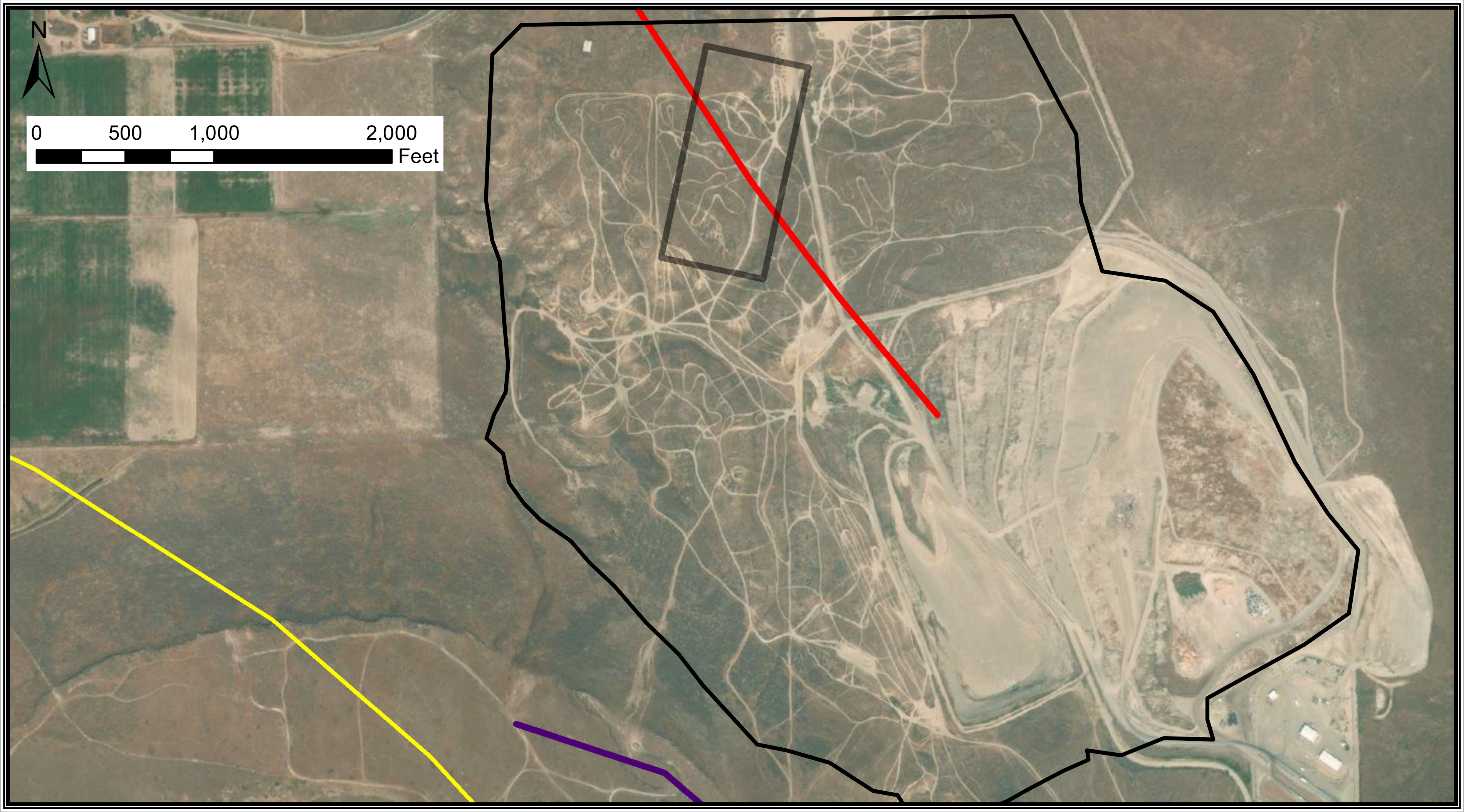

Legend

Approx. Project Area Boundary

3D Seismic Volume Geographic Extent

Western Snake River Plain Fault System

- Primary Site NW Segment
- SW Site NE Dipping Segment
- SW Site SW Dipping Segment

Note: US Geological Survey and Idaho Geological Survey, Quanternary fault and fold database for the United States, accessed Feb. 14, 2022, at: https://www.usgs.gov/programs/earthquake-hazards/faults

TITLE: **PBSL 3D Seismic Survey**

LOCATION: Nampa, Idaho

TETRA TECH

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PROJECT#	114-571040-2022	
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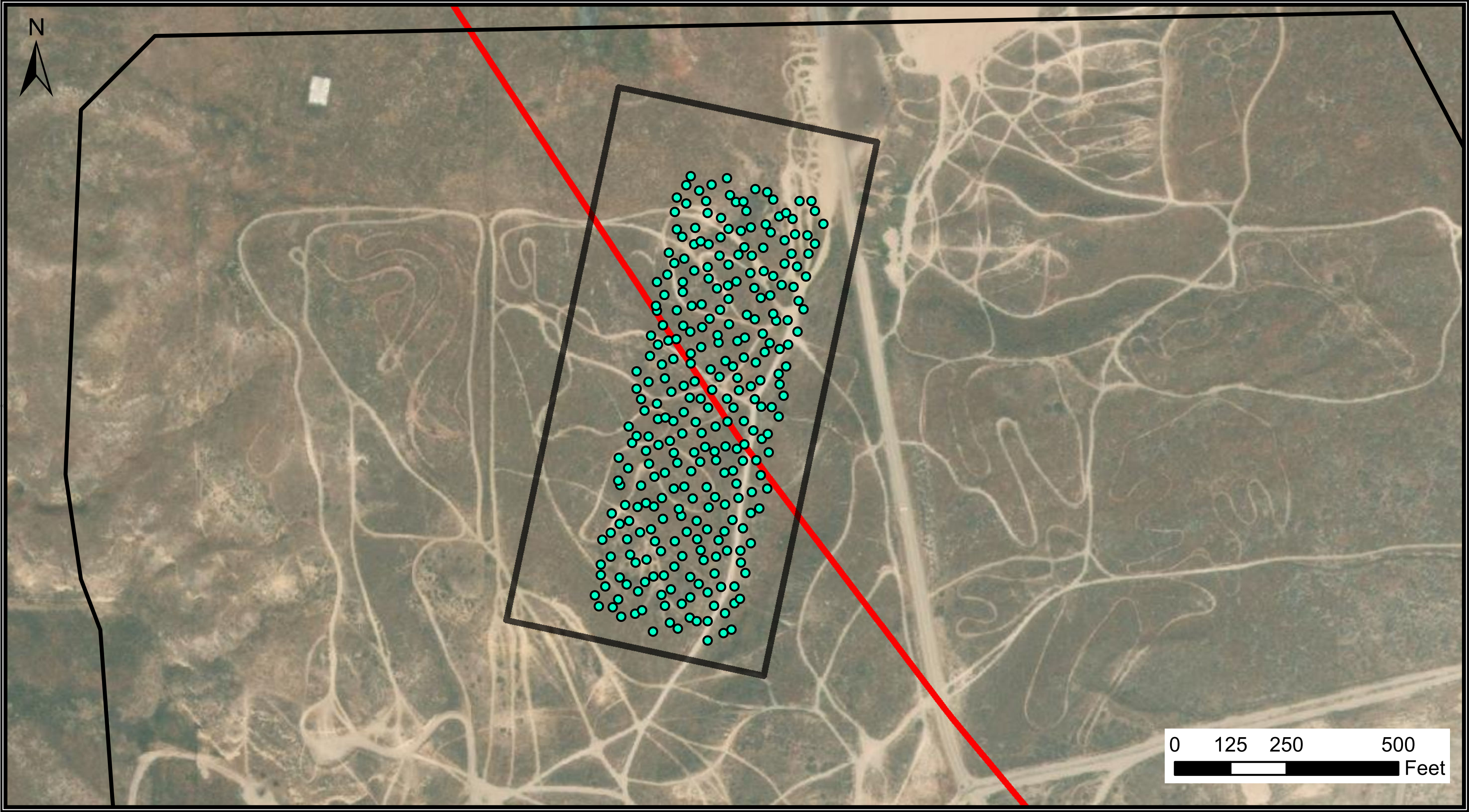

Legend

Approx. Project Area Boundary

3D Seismic Volume Geographic Extent

Seismic Node

Western Snake River Plain Fault System

Primary Site NW Segment

Note: US Geological Survey and Idaho Geological Survey, Quanternary fault and fold database for the United States, accessed Feb. 14, 2022, at: https://www.usgs.gov/programs/earthquake-hazards/faults

TITLE: **PBSL 3D Survey Area and Seismic Node Positions**

LOCATION: Nampa, Idaho

TETRA TECH

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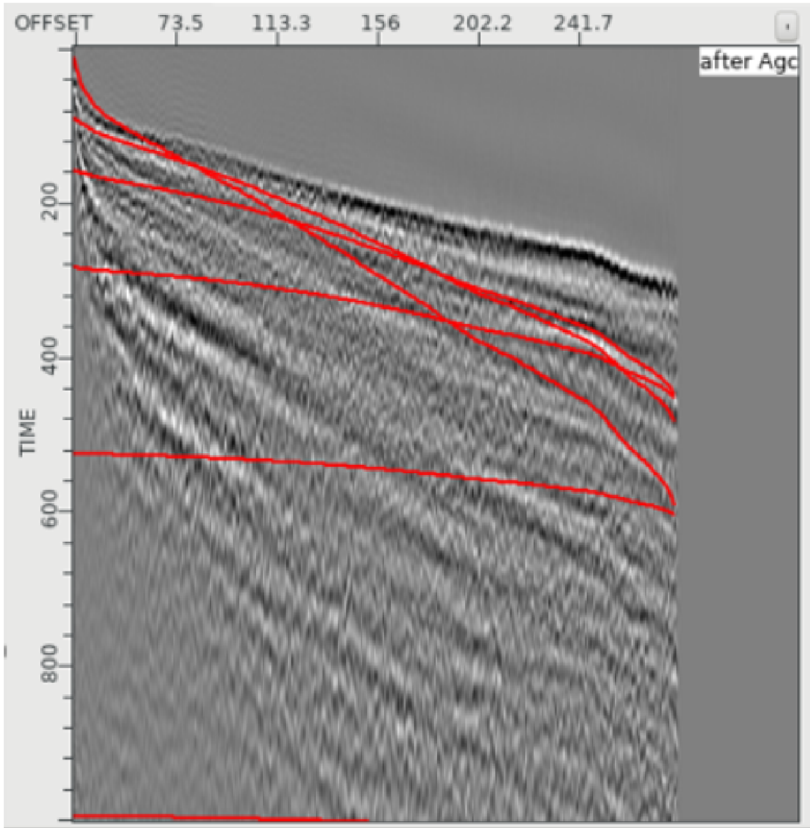
DRAFTED	CEC	3
PROJECT#	114-571040-2022	
DATE	2/14/2022	

a)



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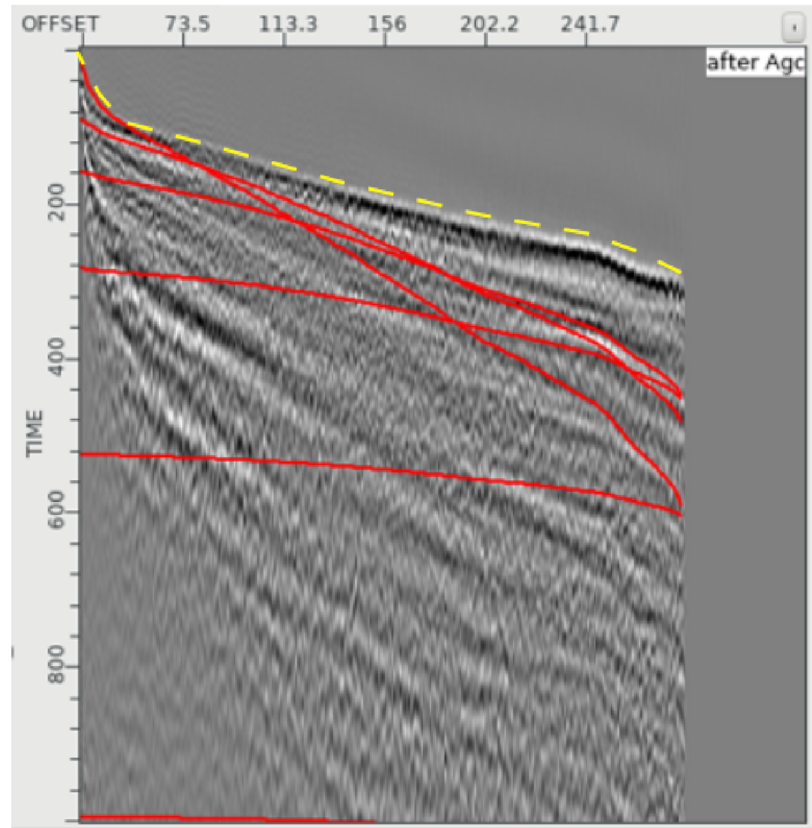

TITLE:

PBSL 3D Seismic Field Data Example

LOCATION:

Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO	FIGURE
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PROJECT#	114-571040-2022	
DATE	2/15/2022	

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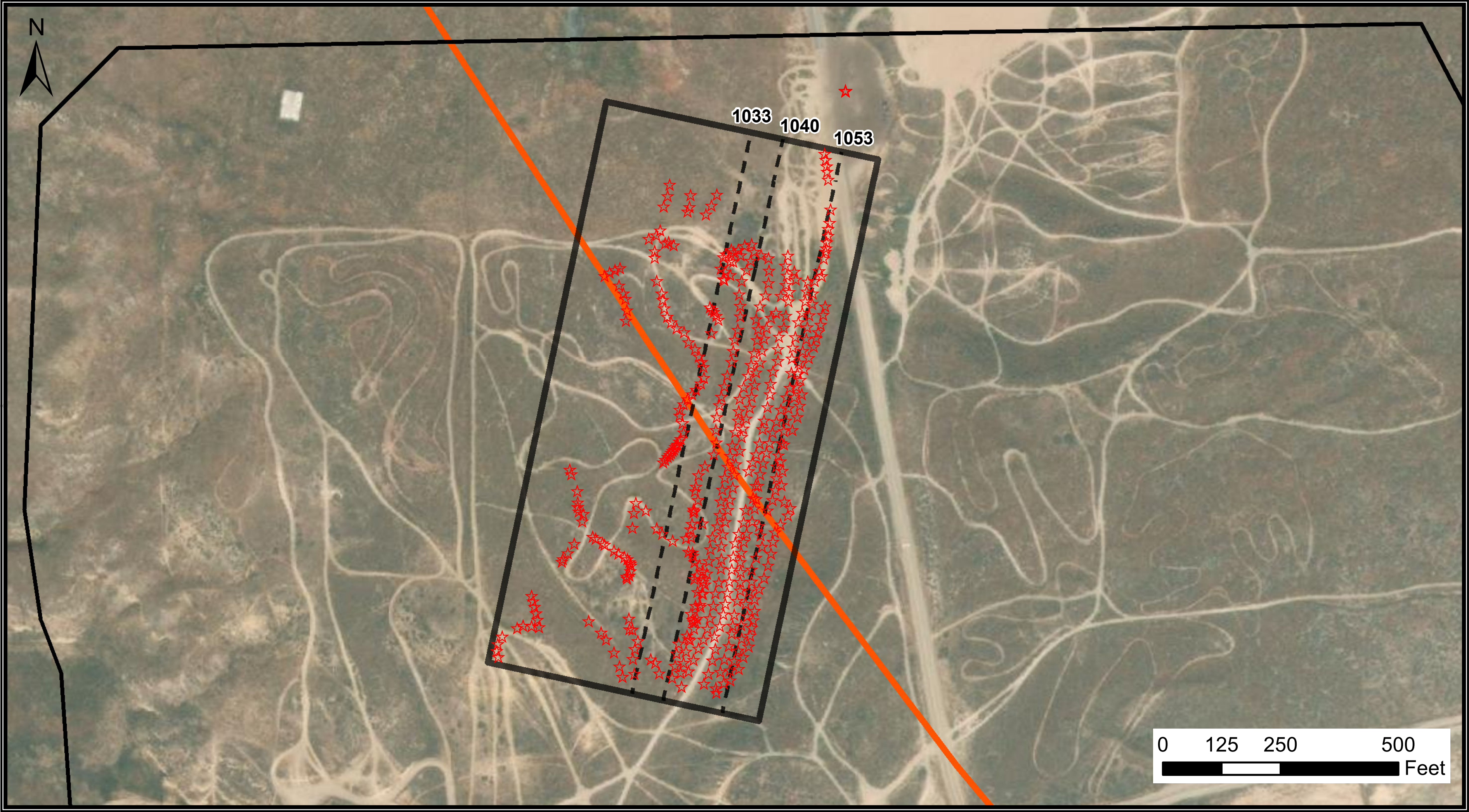

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Legend

Approx. Project Area Boundary

3D Seismic Volume Geographic Extent

Seismic Source Points

Inline Positions

Western Snake River Plain Fault System

Primary Site NW Segment

Note: US Geological Survey and Idaho Geological Survey, Quanternary fault and fold database for the United States, accessed Feb. 14, 2022, at: https://www.usgs.gov/programs/earthquake-hazards/faults

TITLE:

PBSL 3D Seismic Source and Inline Profile Positions

LOCATION:

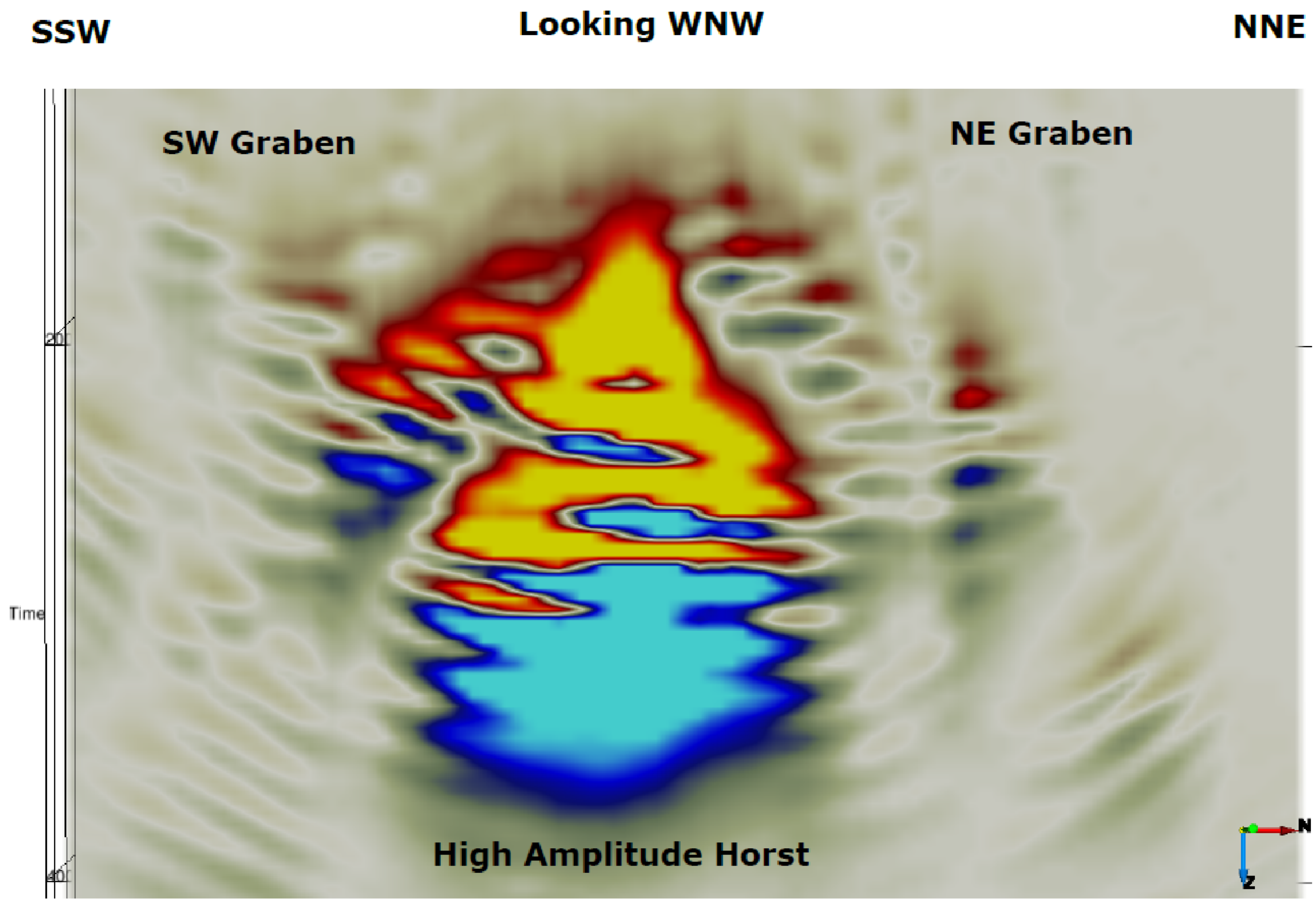
Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO
DRAFTED	CEC
PROJECT#	114-571040-2022
DATE	2/15/2022

FIGURE

5

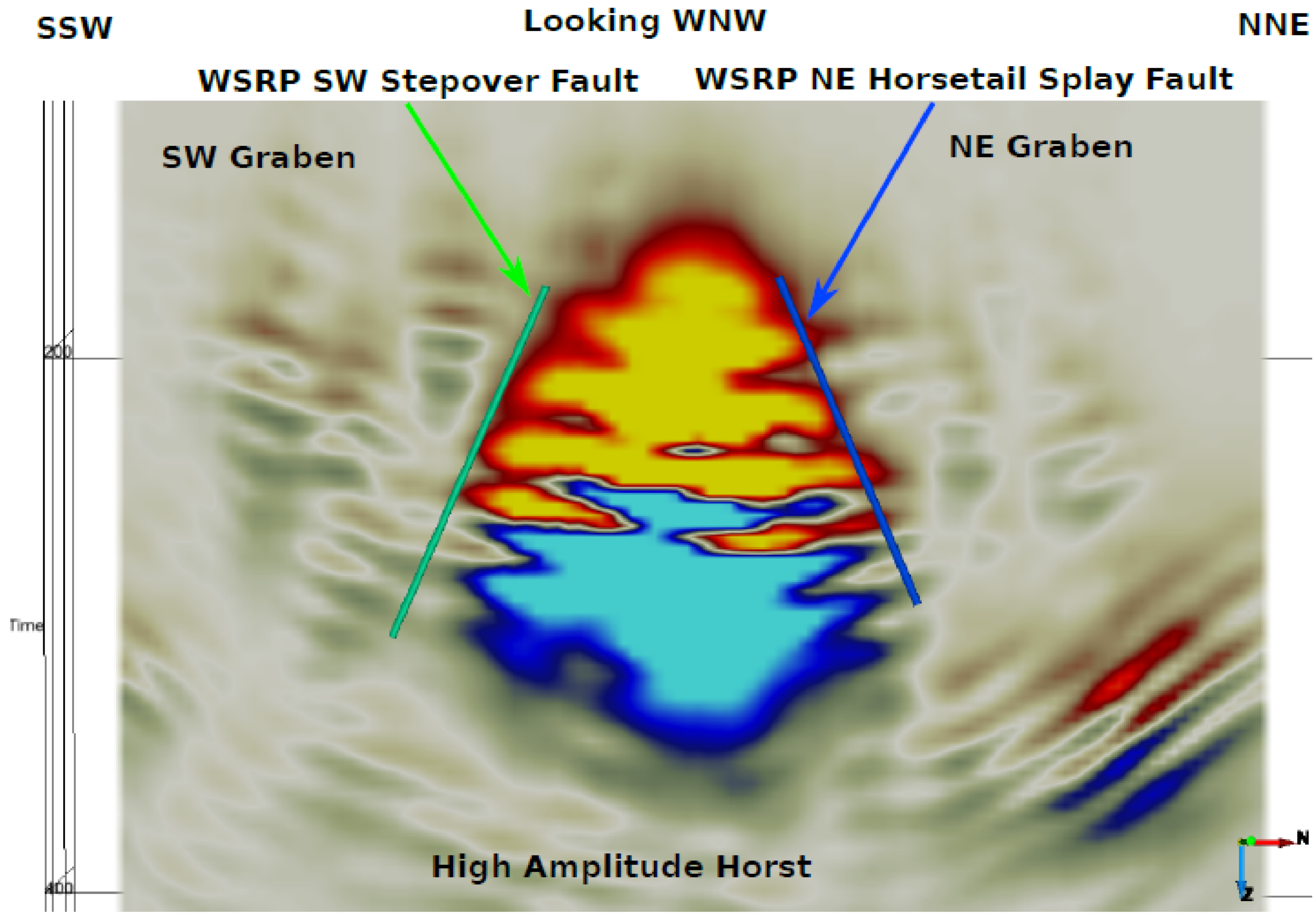


West Mapping (Inline 1033)

TITLE:	Seismic Reflection Two-Way-Time Cross-Section Along Western Inline 1033
LOCATION:	Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO	FIGURE
DRAFTED	CEC	6a
PROJECT#	114-571040-2022	
DATE	2/16/2022	



East Mapping (Inline 1053)

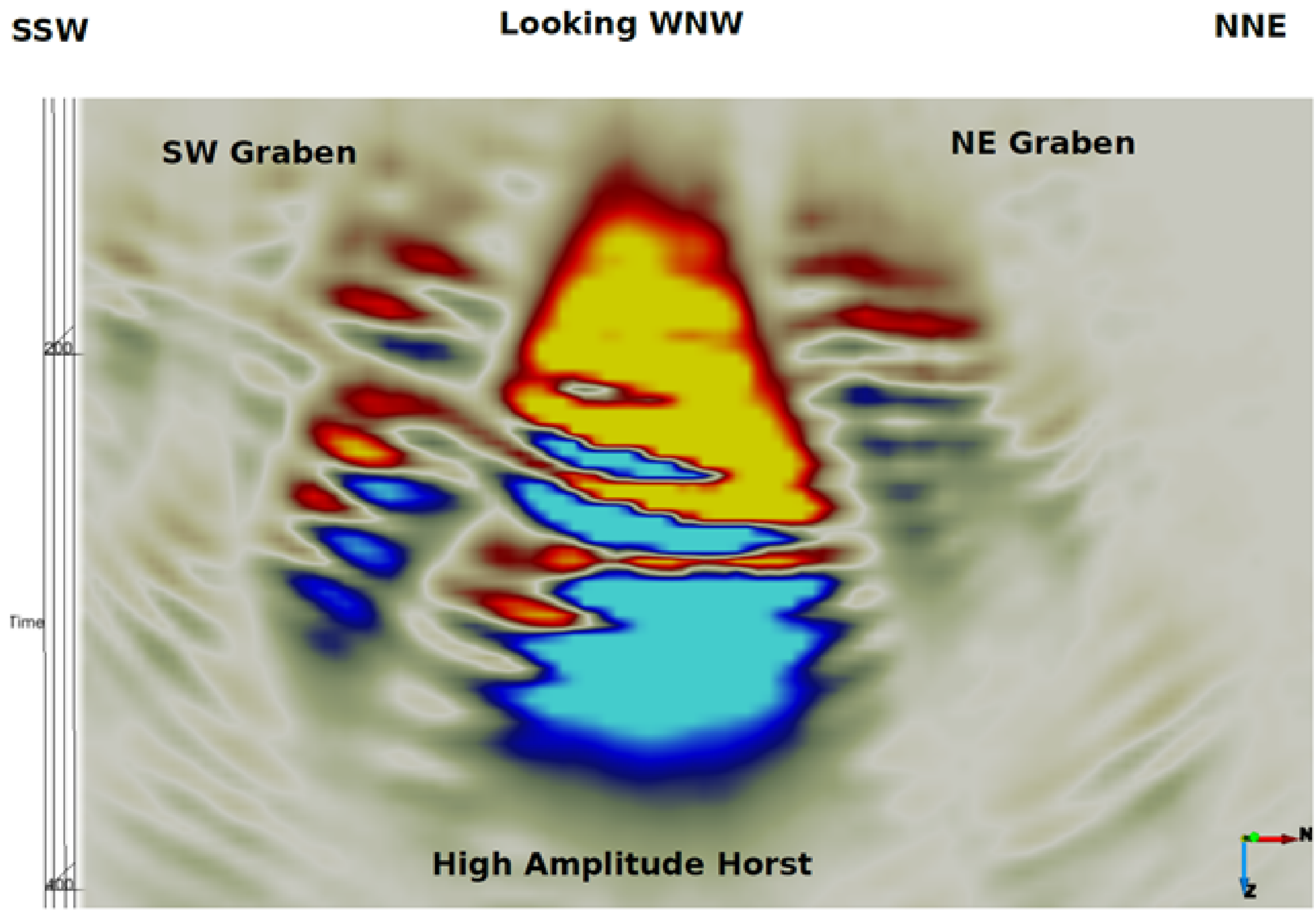
TITLE: **Interpreted Seismic Reflection Two-Way-Time Cross-Section Along Western Inline 1033**

LOCATION: Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO	FIGURE
DRAFTED	CEC	6b
PROJECT#	114-571040-2022	
DATE	2/16/2022	

C:\Users\christina.coulter\OneDrive - Tetra Tech, Inc\Documents\Pickles Butte Boise Seismic\Pickles_Butte_Figure6b.mxd February 2022



Middle Mapping (Inline 1040)

TITLE:	Seismic Reflection Two-Way-Time Cross-Section Along Middle Inline 1040
LOCATION:	Nampa, Idaho

TETRA TECH	APPROVED	LS, DRHO	FIGURE
	DRAFTED	CEC	7a
	PROJECT#	114-571040-2022	
	DATE	2/16/2022	

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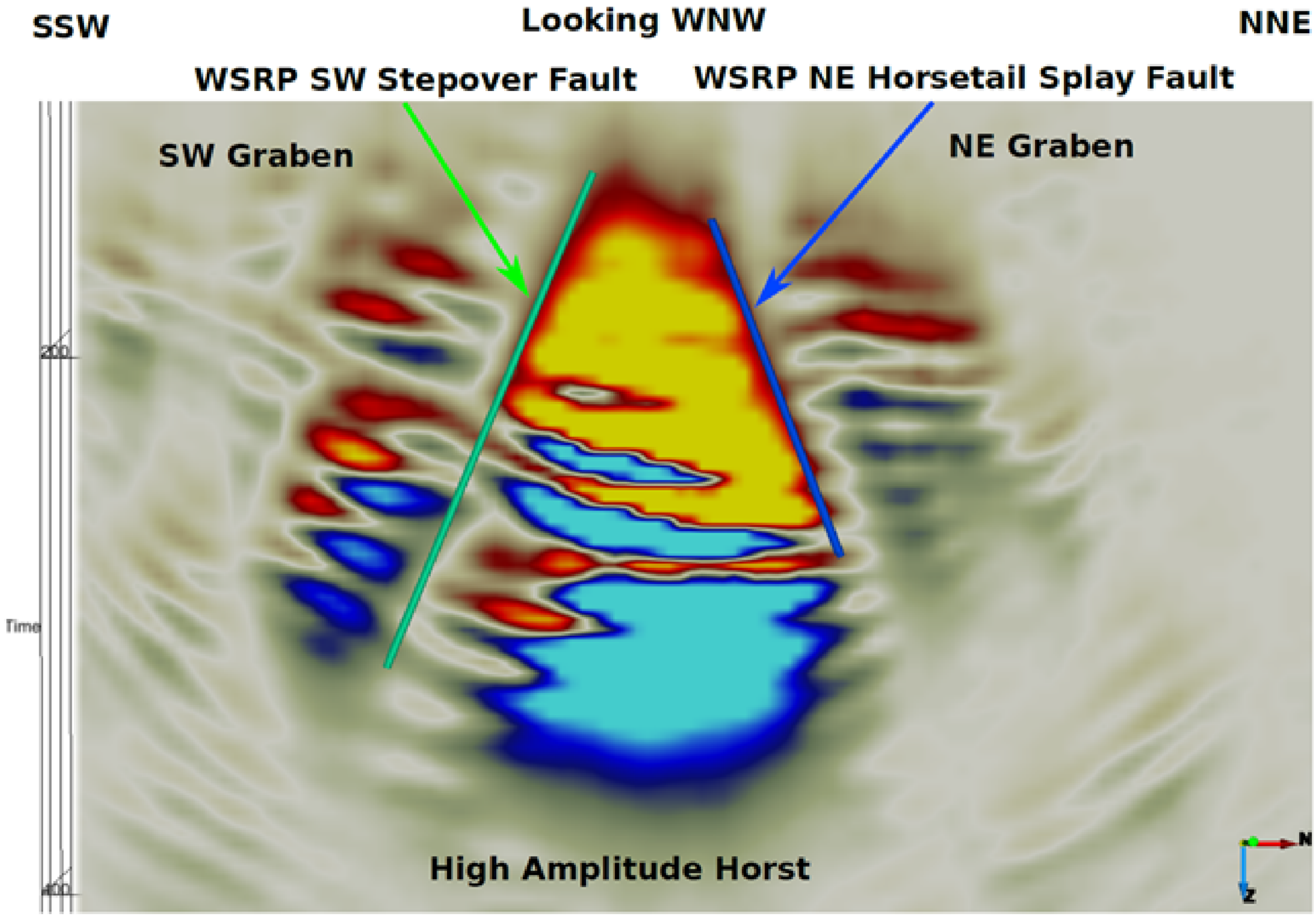

Middle Mapping (Inline 1040)

TITLE: **Interpreted Seismic Reflection Two-Way-Time Cross-Section Along Middle Inline 1040**

LOCATION: Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO
DRAFTED	CEC
PROJECT#	114-571040-2022
DATE	2/16/2022

FIGURE 7b

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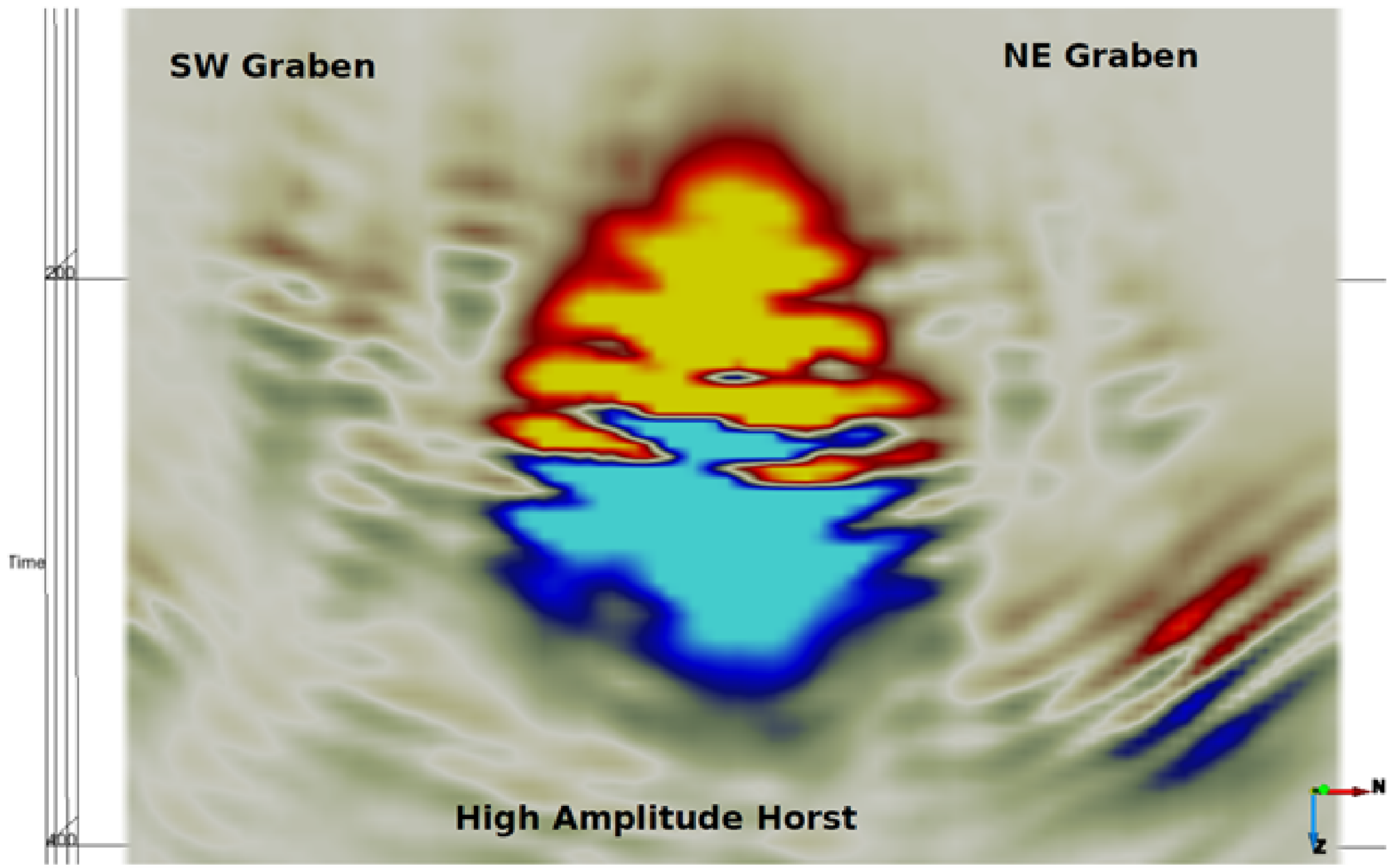

East Mapping (Inline 1053)

TITLE:	Seismic Reflection Two-Way-Time Cross-Section Along Eastern Inline 1053
LOCATION:	Nampa, Idaho

TETRA TECH			FIGURE
	APPROVED	LS, DRHO	8a
	DRAFTED	CEC	
	PROJECT#	114-571040-2022	
	DATE	2/16/2022	

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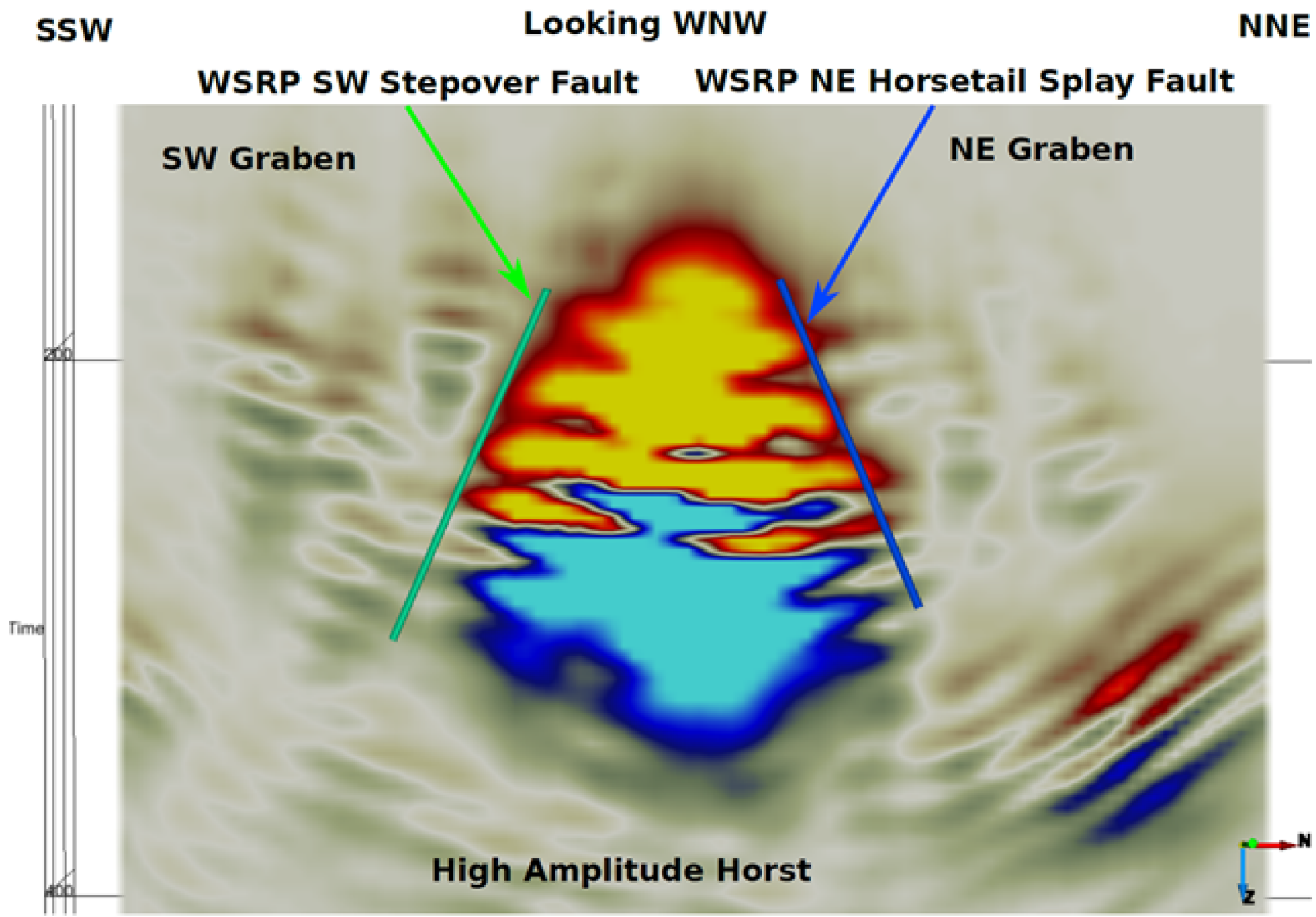
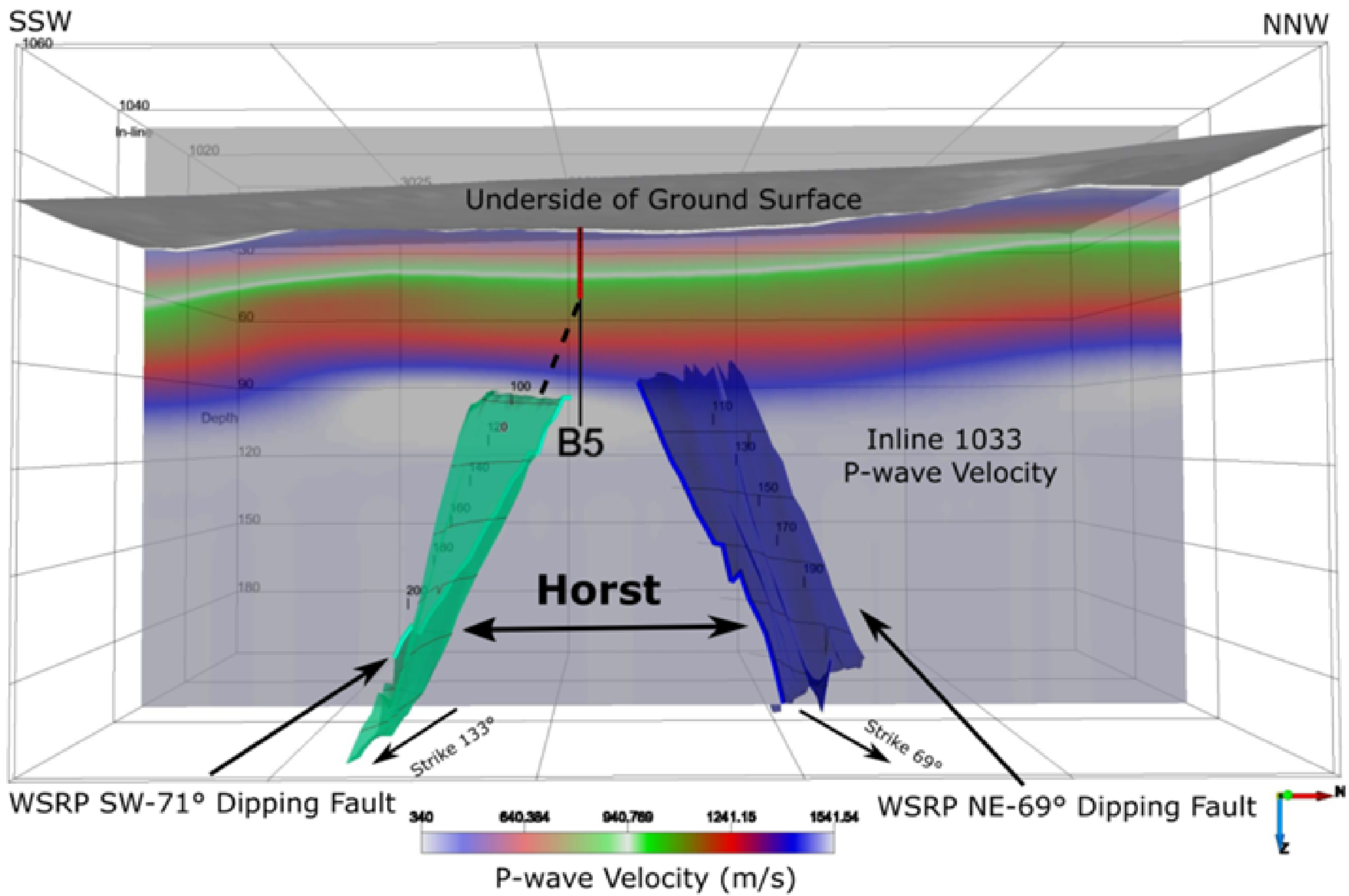


East Mapping (Inline 1053)

TITLE: Interpreted Seismic Reflection Two-Way-Time Cross-Section Along Eastern Inline 1053			
LOCATION: Nampa, Idaho			
TETRA TECH	APPROVED	LS, DRHO	FIGURE
	DRAFTED	CEC	8b
	PROJECT#	114-571040-2022	
	DATE	2/16/2022	



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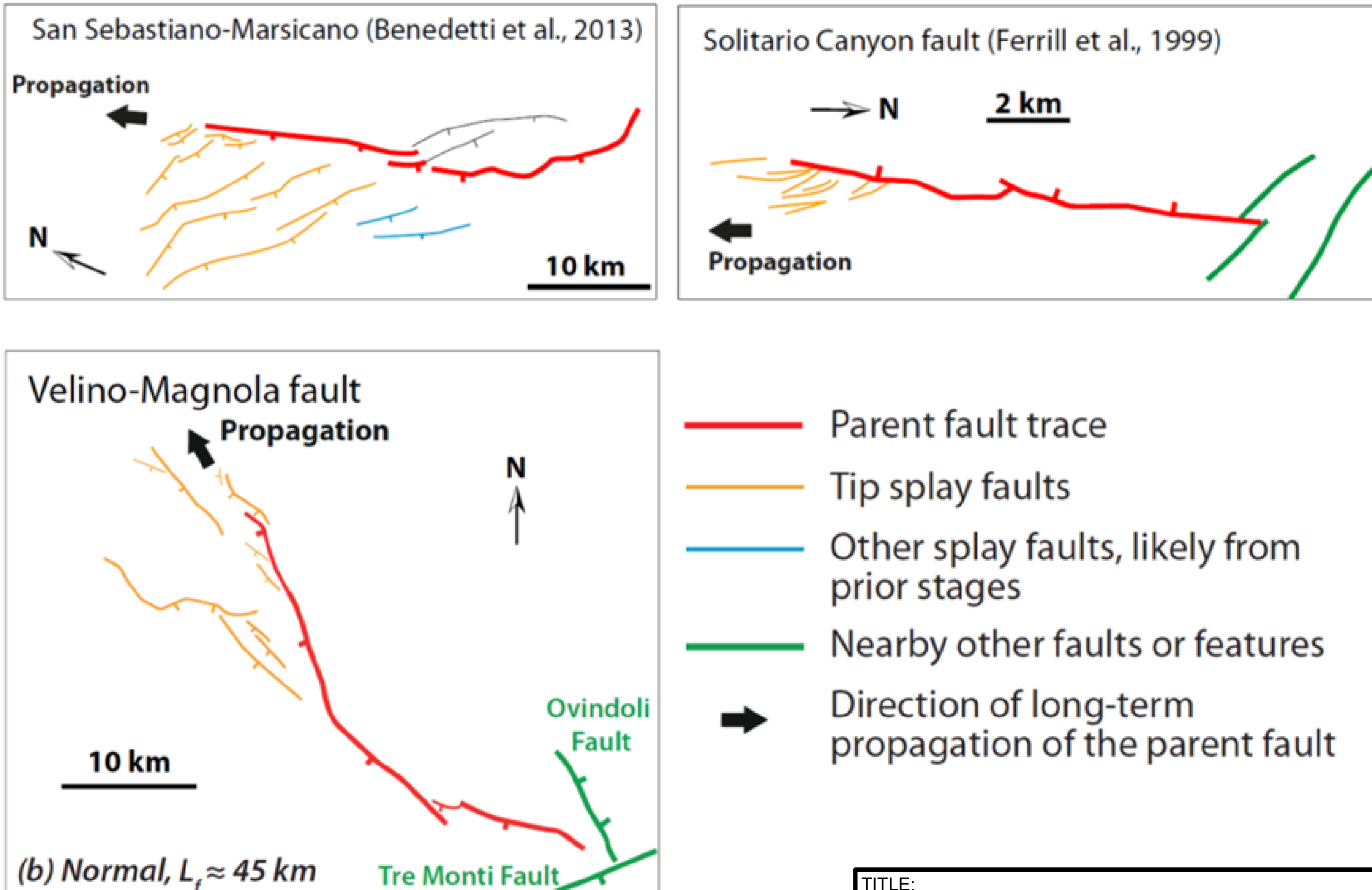
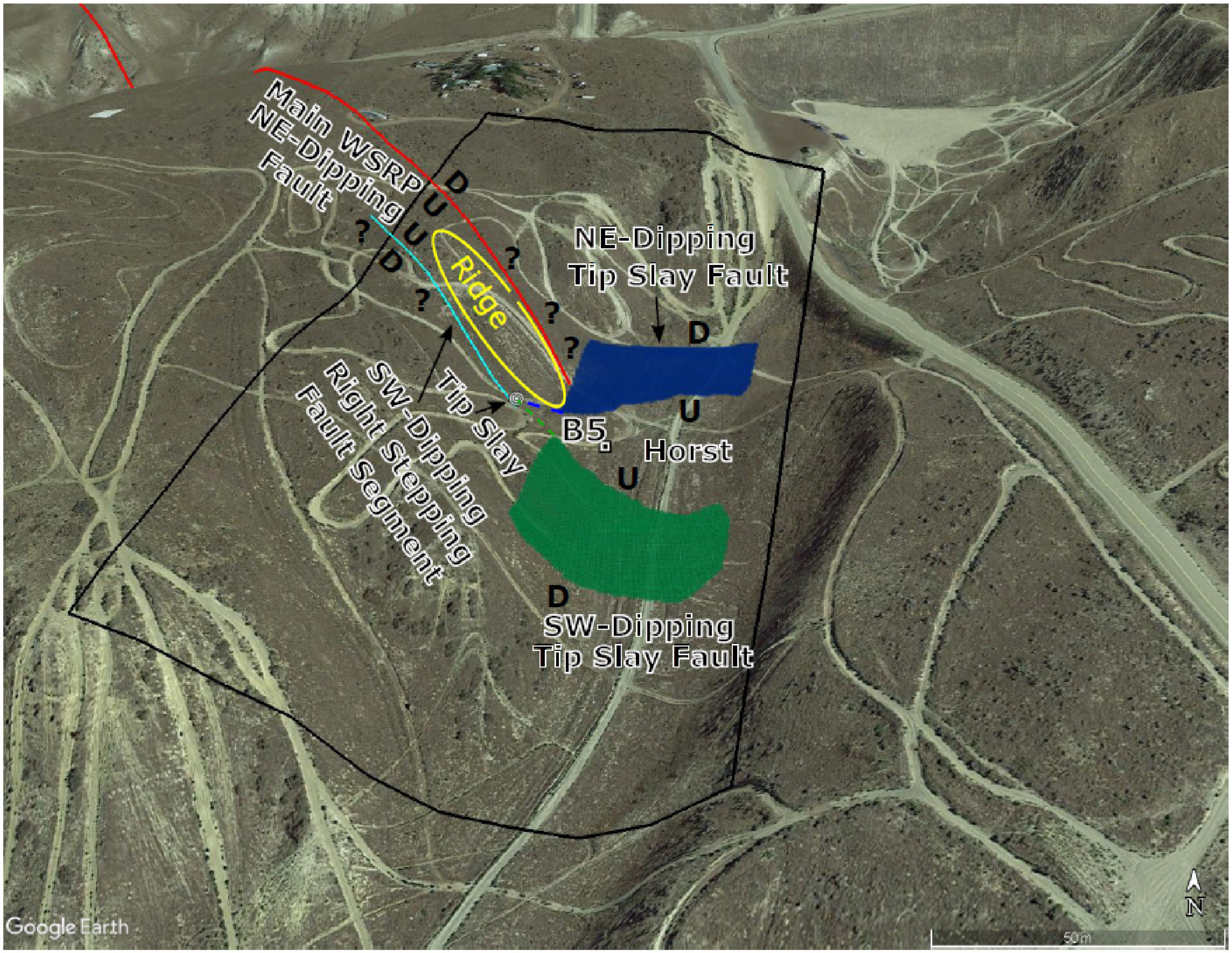
TITLE: **3D Perspective of Mapped Western Snake River Plain Fault Surfaces**	TETRA TECH	APPROVED	LS, DRHO	FIGURE **9**
		DRAFTED	CEC	
LOCATION: Nampa, Idaho		PROJECT#	114-571040-2022	
		DATE	2/21/2022	



Note: Illustration from Perrin et al., 2016

TITLE:	**Examples of Normal Faulting and Splay Faulting Distributions**		
LOCATION:	Nampa, Idaho		
TETRA TECH	APPROVED	LS, DRHO	FIGURE
	DRAFTED	CEC	**10**
	PROJECT#	114-571040-2022	
	DATE	2/16/2022	



TETRA TECH

3D Map Perspective (3x Vertical Exaggeration)

Nampa, Idaho

APPROVED	LS, DRHO	FIGURE
DRAFTED	CEC	**11**
PROJECT#	114-571040-2022	
DATE	2/18/2022	

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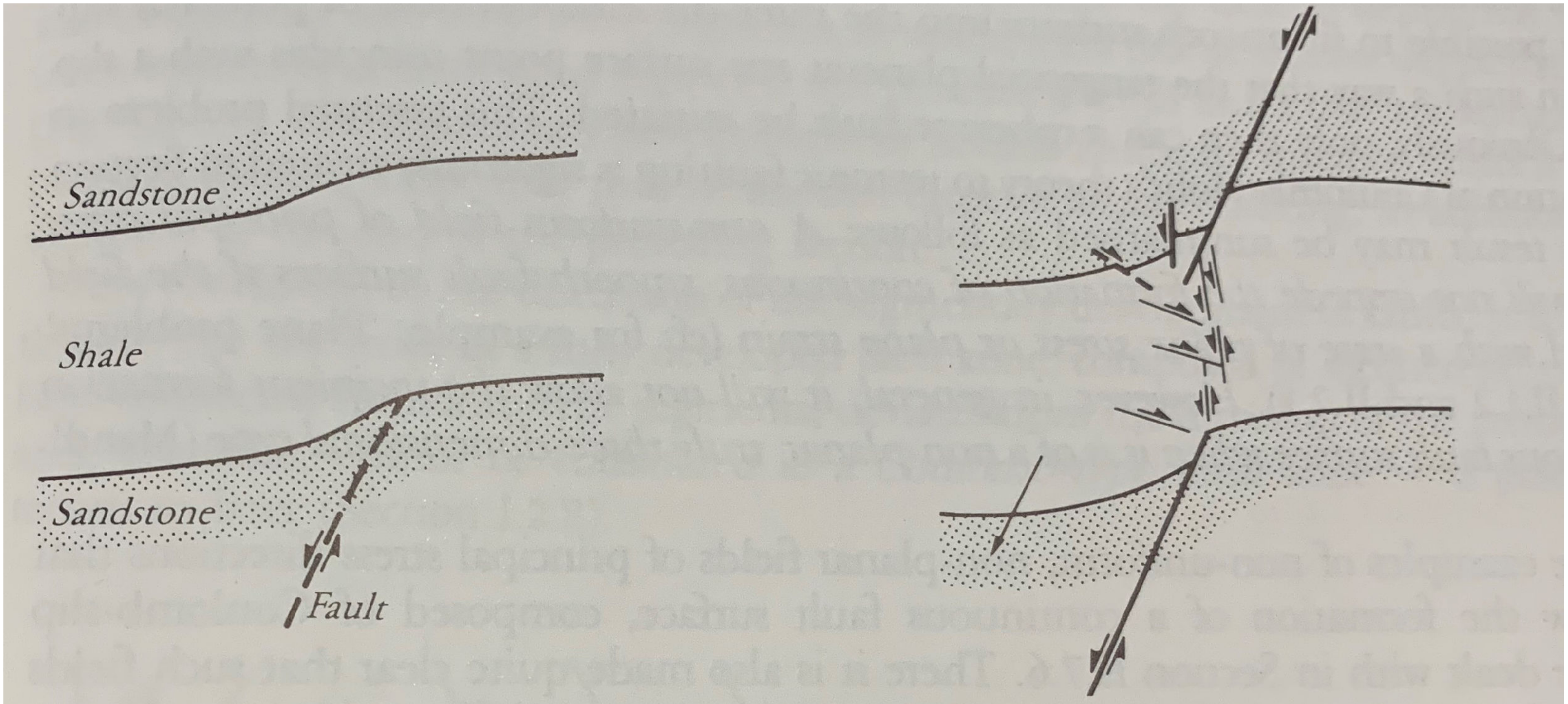

A Continuous flexuring of shale bed in response to faulting of substratum.

B Upward progressing fault experiences lateral offset in dip direction.

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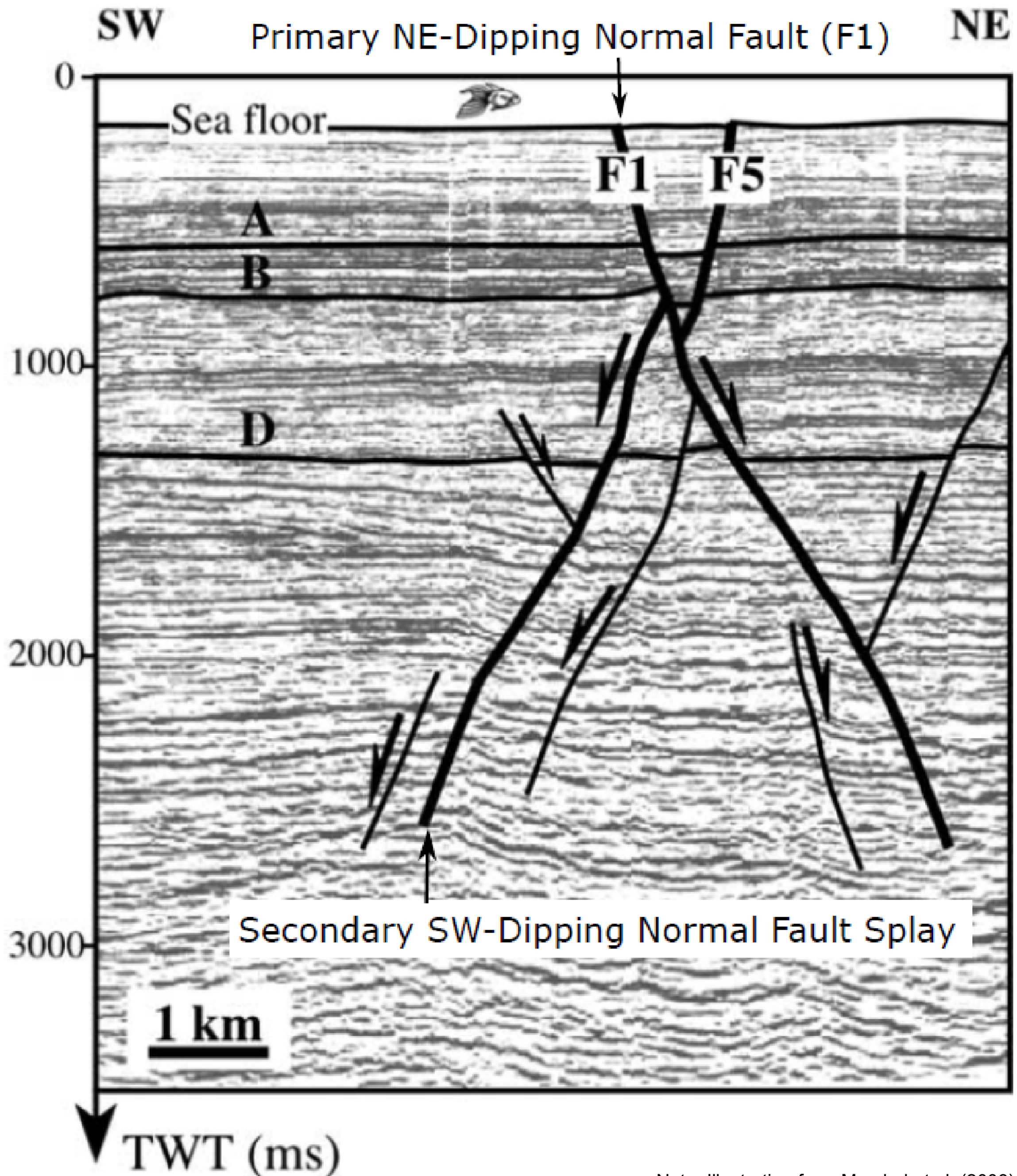
Note: Illustration from Mandl, 1988 (pg. 45)

TITLE: **Example of Flexure Leading to Fault Offsetting**

LOCATION: Nampa, Idaho

TETRA TECH

APPROVED	LS, DRHO	FIGURE
DRAFTED	CEC	**12**
PROJECT#	114-571040-2022	
DATE	2/16/2022	



Note: Illustration from Marchal et al. (2003)

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Field Example		
APPROVED	LS, DRHO	FIGURE 13
DRAFTED	CEC	
PROJECT#	114-571040-2022	
DATE	2/21/2022	

Appendix A

Seismic Processing
Agile Seismic LLC

Pickles Butte 3D Seismic Survey Report
Pickles Butte, Idaho
Project No. 114-571040-2022

Tetra Tech
350 Indiana Street, Suite 500
Golden, CO 80401

(303) 217-5700
tetratech.com

Pickles Butte

Seismic Processing

Final Report

January 16th 2022

Agile Seismic LLC

Processing Steps

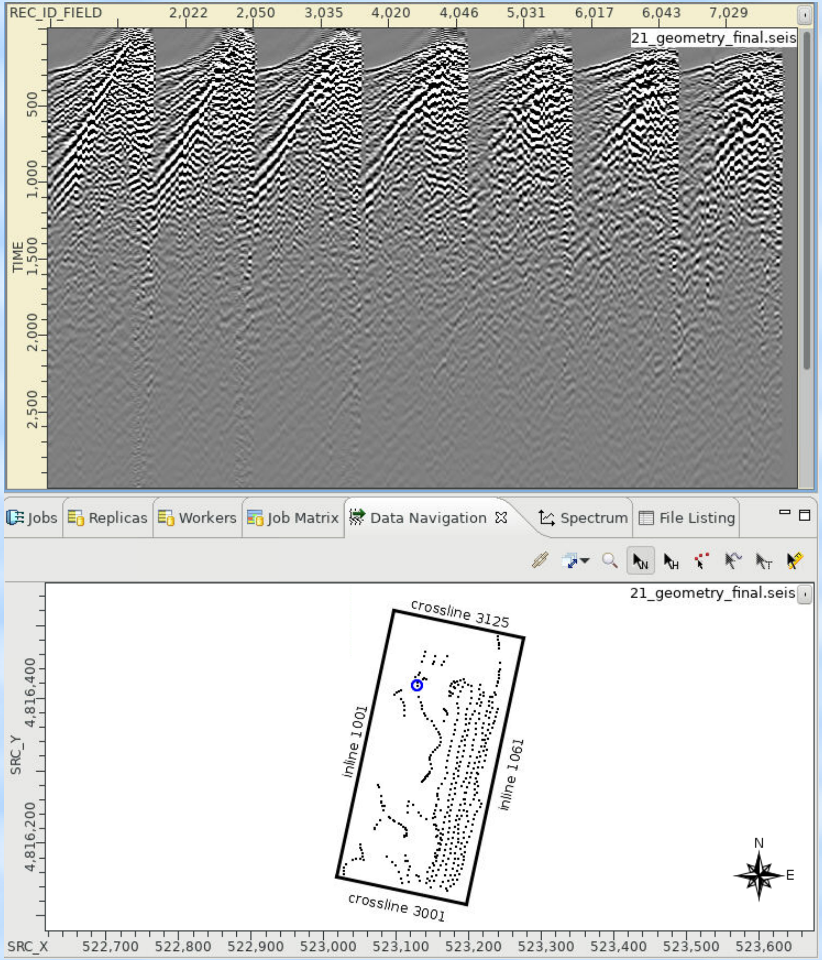
- Pickles Butte seismic processing are shown below:

01_IMPORT
02_GEOMETRY
04_NO_REFRACTION_STATICS
05_DENOISE
06_SCAC_1
07_DECON
08_SCAC_2
09_RESIDUAL_STATICS_1
10_Q-COMPENSATION
11_FINAL_PROCESSING
12_PoSTM
13_PSTM

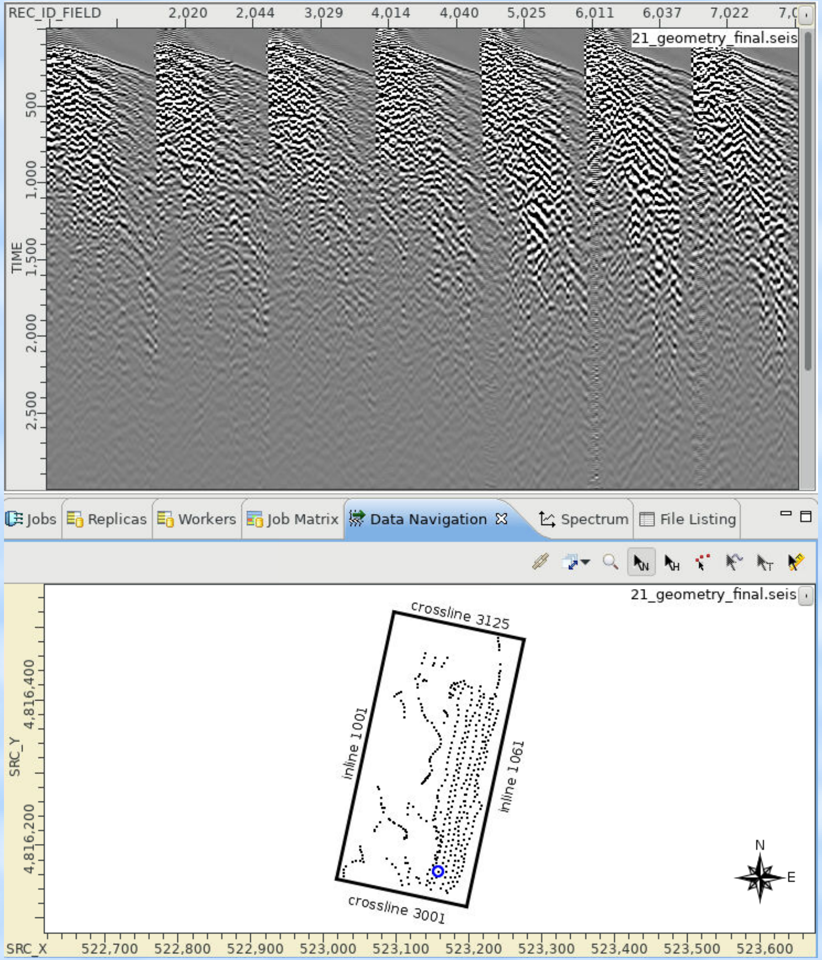
Data Import

- Seismic source was vibroseis
- Receivers were GTI nodes
- Pilot sweep frequency range is 5-75 hz.
- Seismic data was acquired at 2 ms and resampled to 4 ms.
- Total number of shots is 440
- Total number of receivers is 285
- Total number of traces is 125224
- All data had coordinates and elevations for sources and receivers in the headers.
- Vibroseis data was mostly clean with strong ground-roll and occasional noise from water pumps.

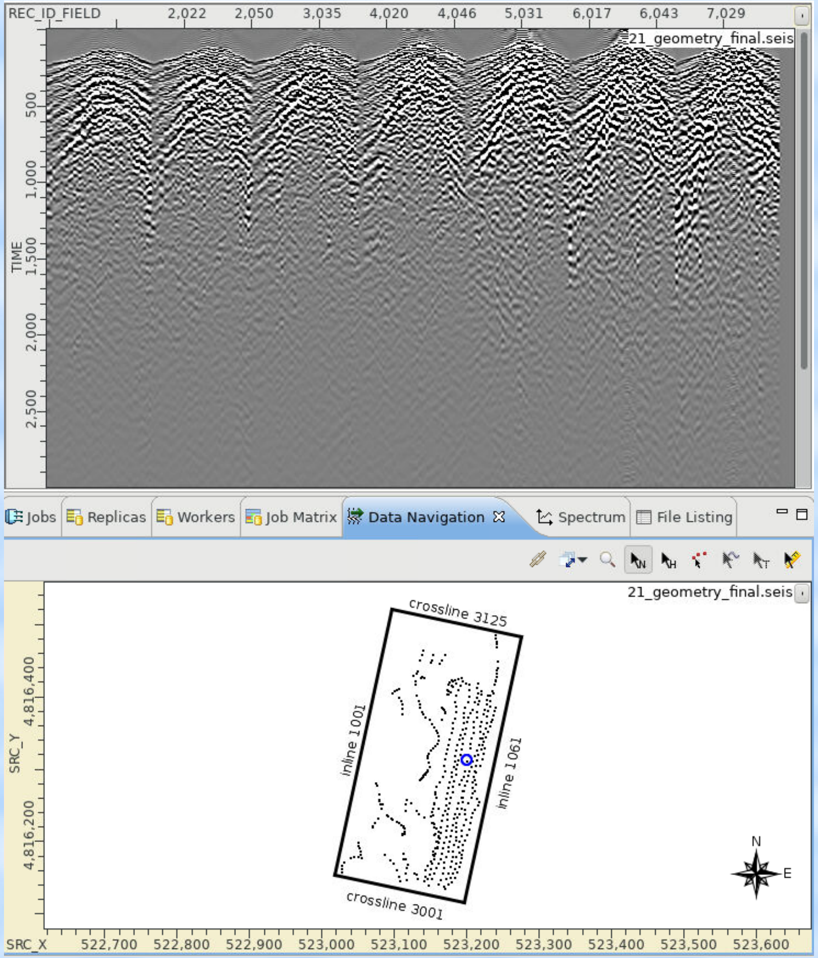
Raw Data: Shot Gathers – Example #1



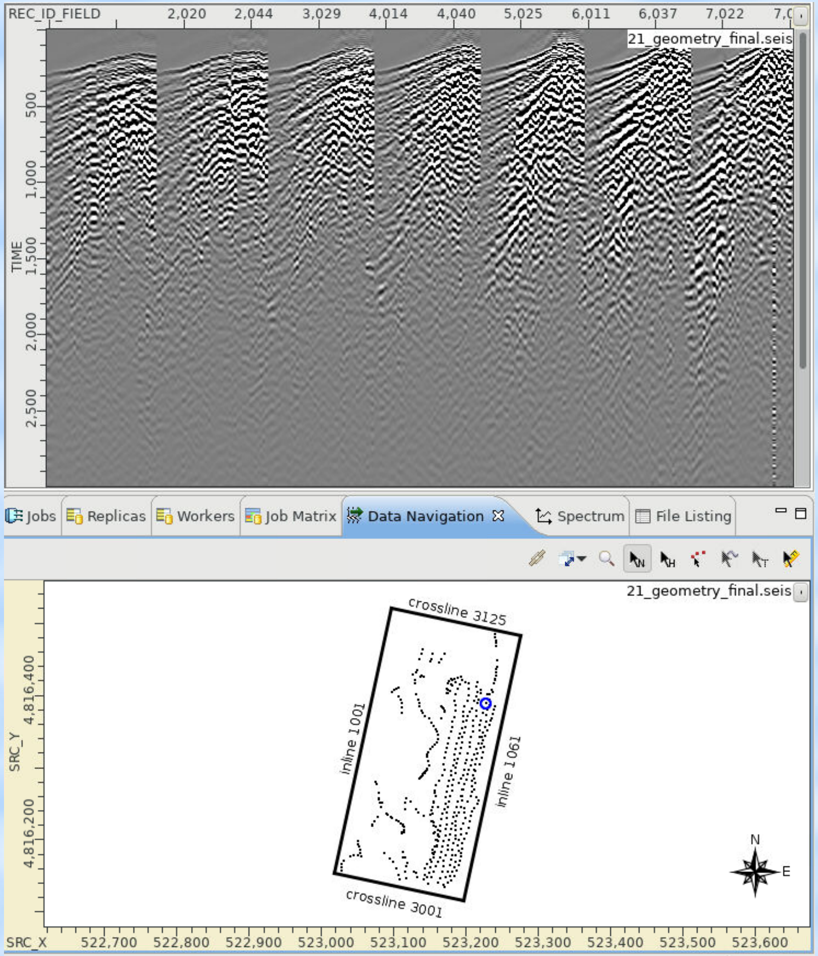
Raw Data: Shot Gathers – Example #2



Raw Data: Shot Gathers – Example #3



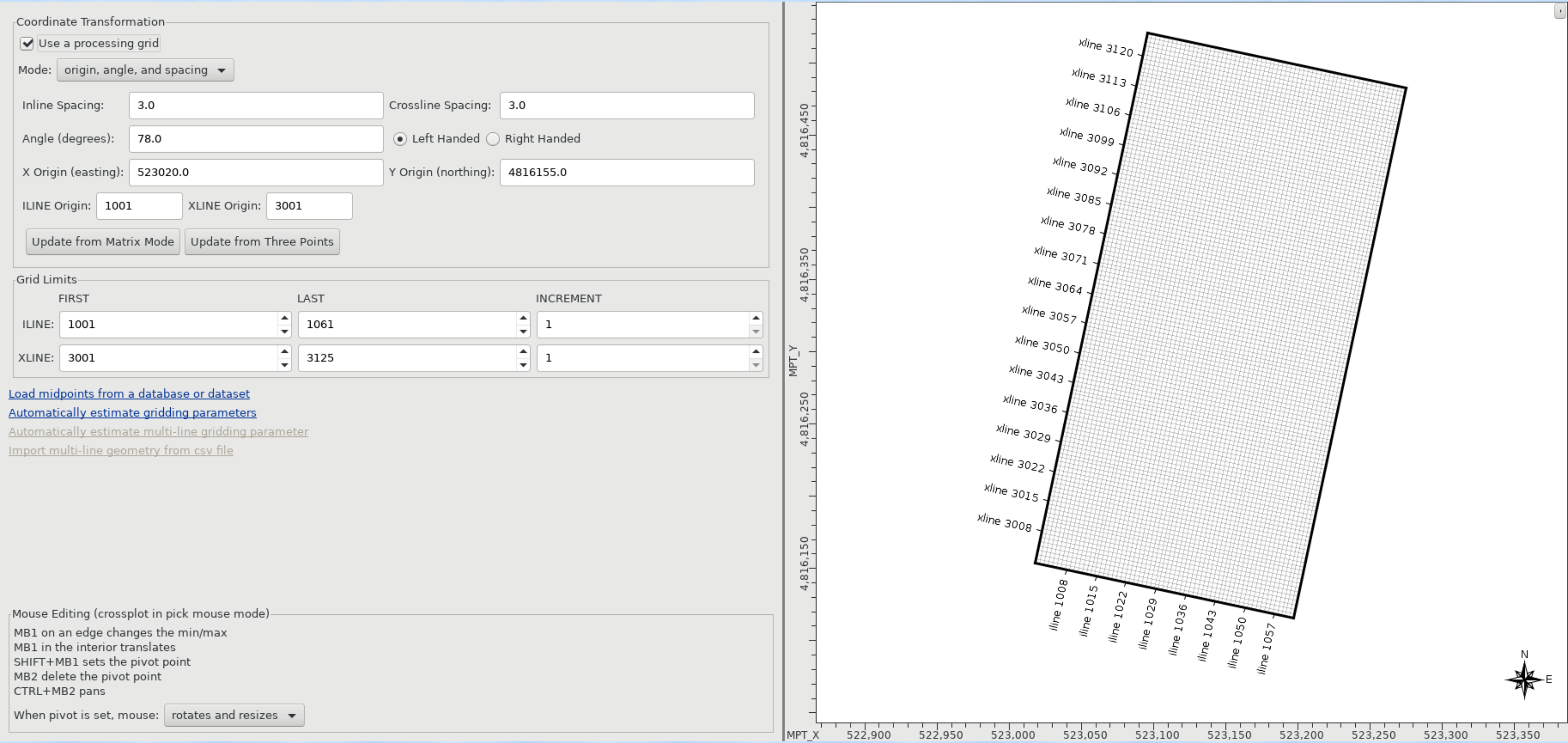
Raw Data: Shot Gathers – Example #4



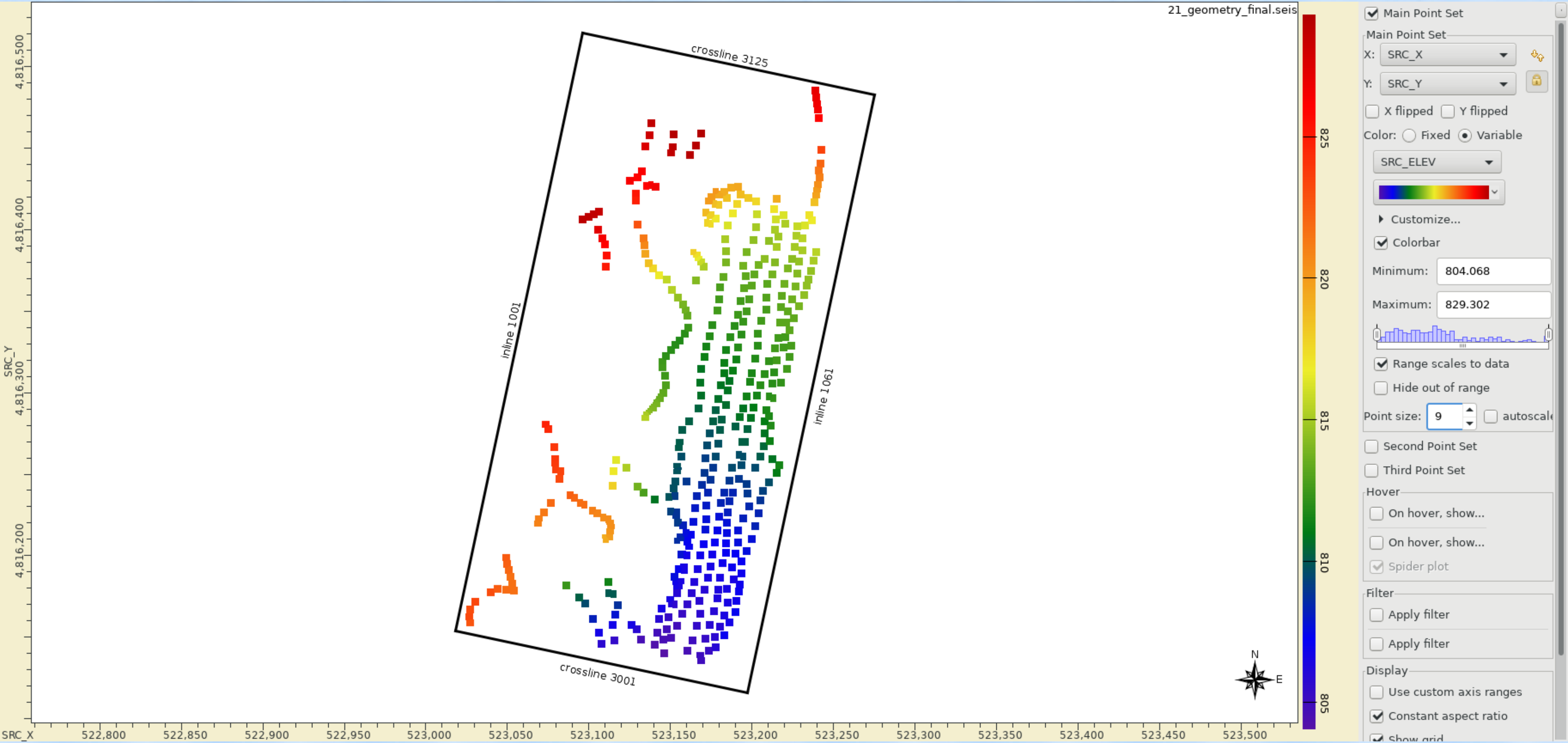
Geometry

- Seismic data already had source and receiver coordinates and elevations in the headers.
- Processing grid was created with the following parameters:
    - Inline range 1001-1061
    - Crossline range 3001-3125
    - Inline and crossline spacing was set to 3 m
    - Fixed datum 850 m and replacement velocity 1500 m/sec
- Geometry was built using coordinates and elevations in the headers.
- Geometry brute stack was shown for select inlines only since good fold was very narrow in xline direction.
- Following processing was done for Geometry brute stack:
    - Sparse velocity analysis
    - AGC
    - Spiking Decon
    - Stack
    - FXYDecon 5-75 Hz
    - Low Cut Filter 12-20-- Hz

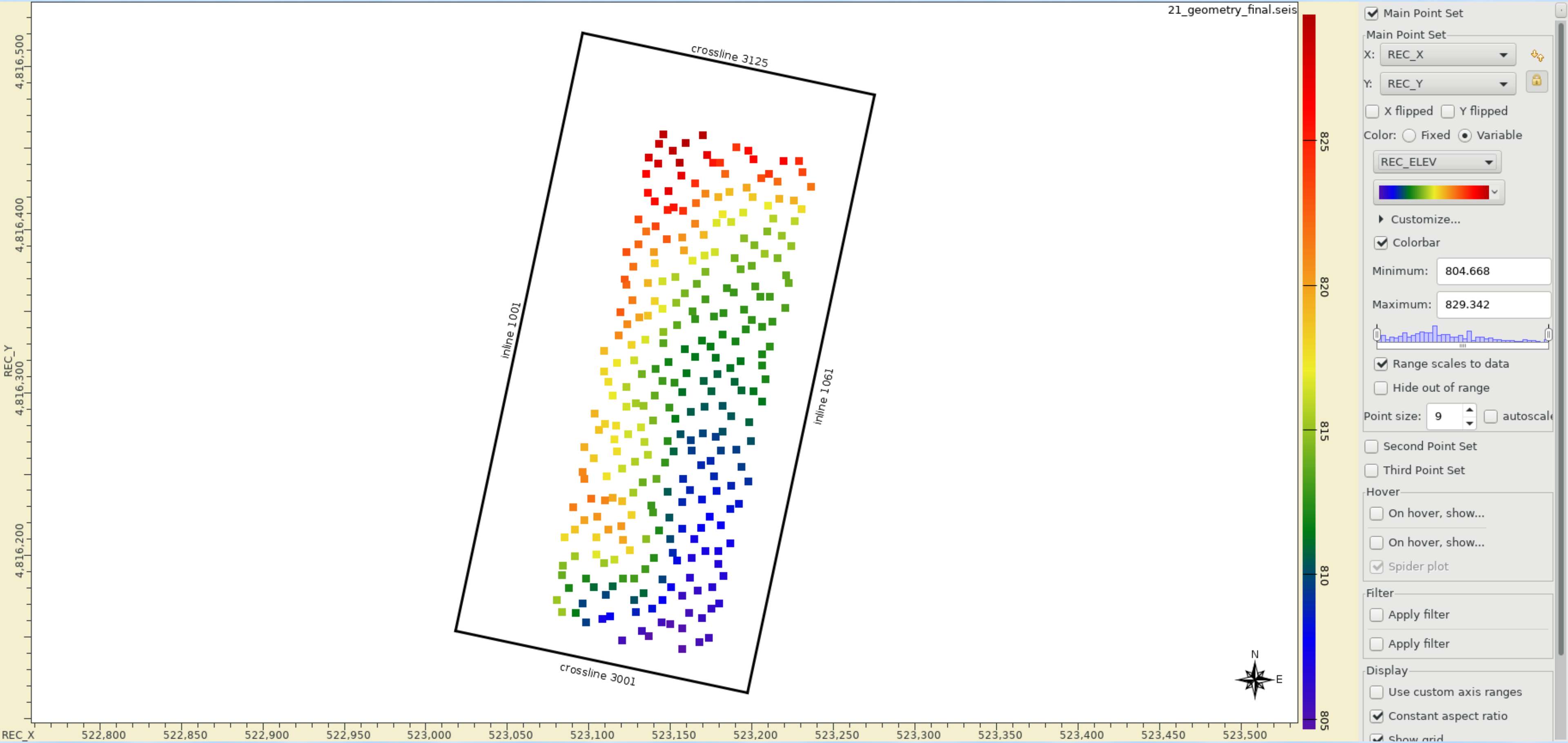
Processing Grid



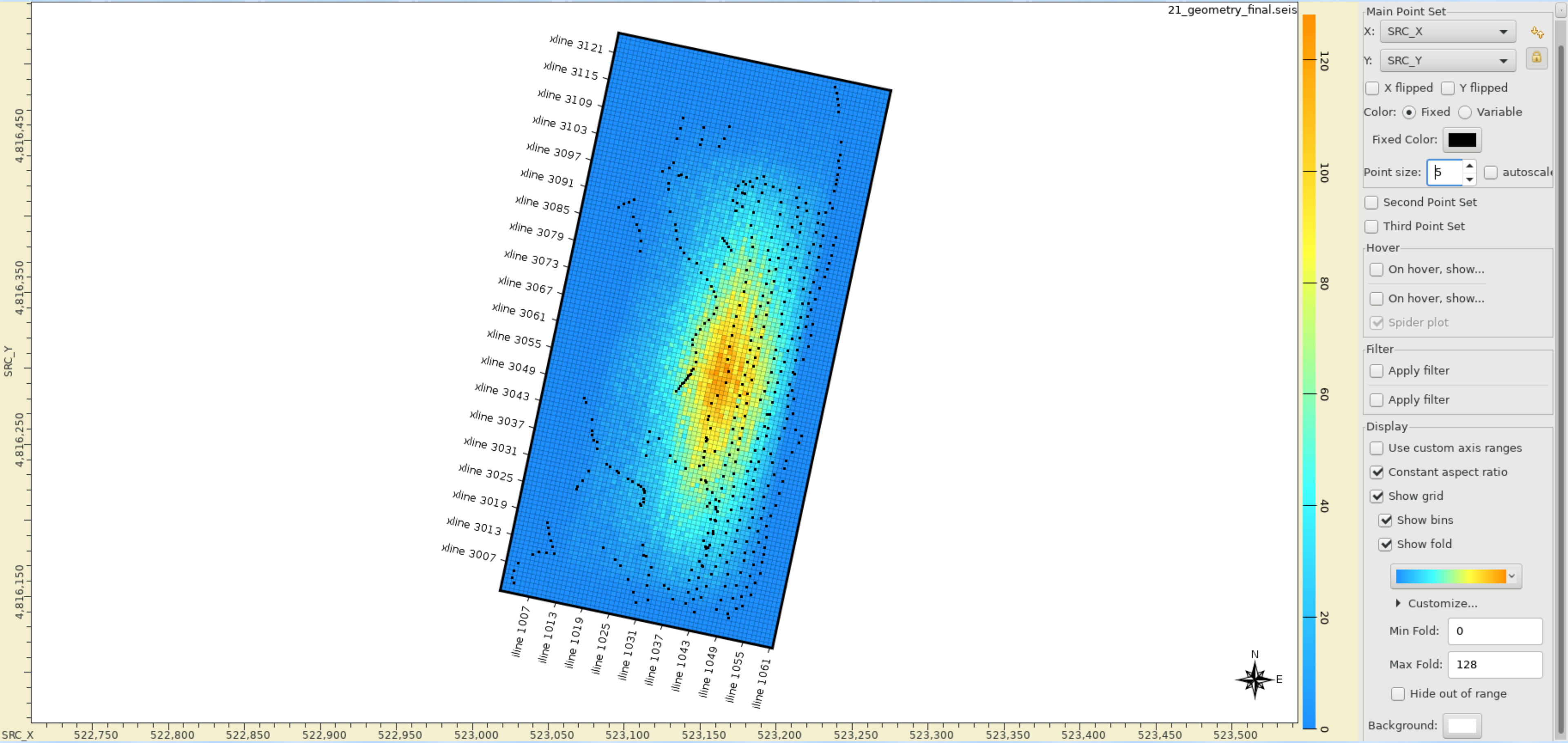
Geometry: Sources



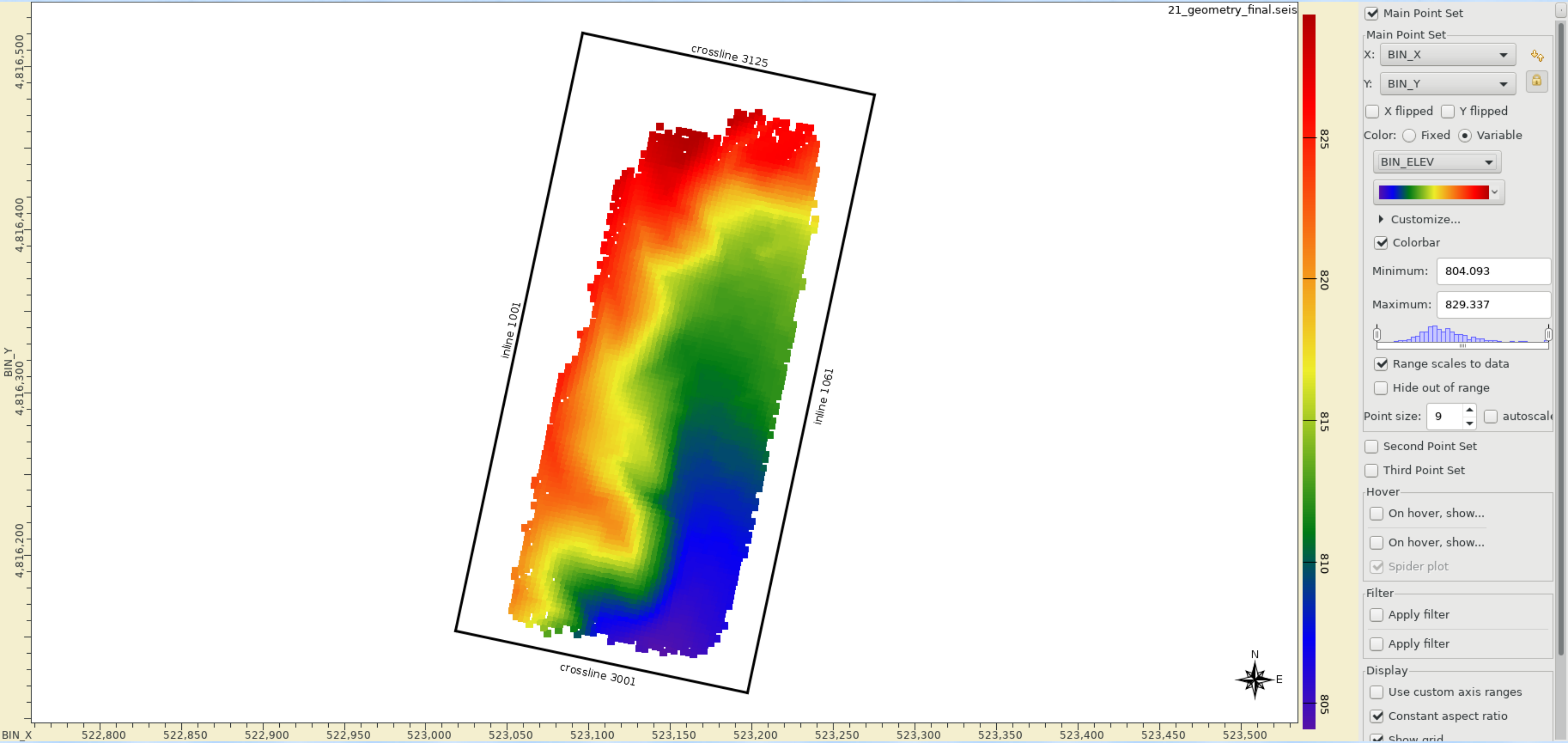
Geometry: Receivers



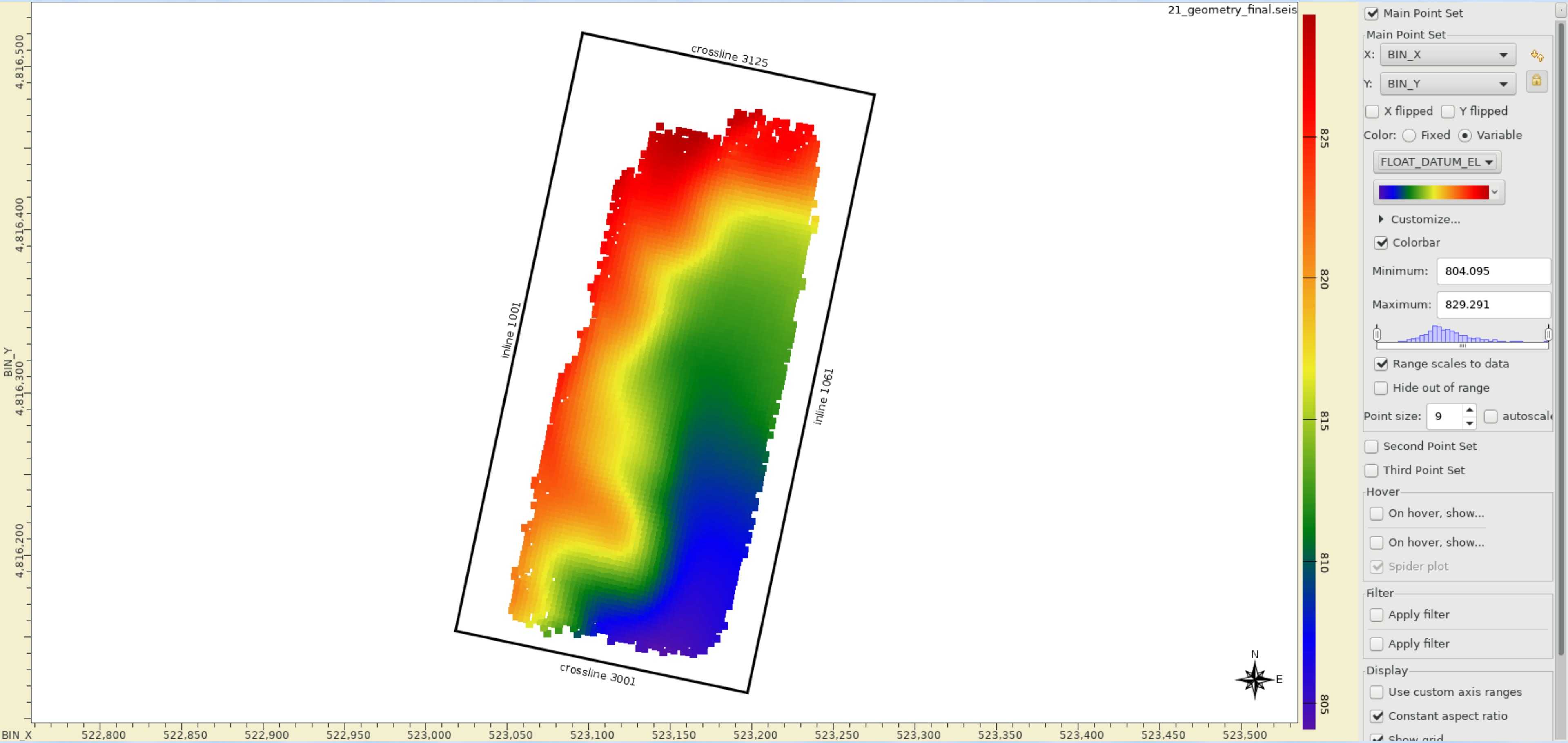
Geometry: Fold



Geometry: Surface Elevation



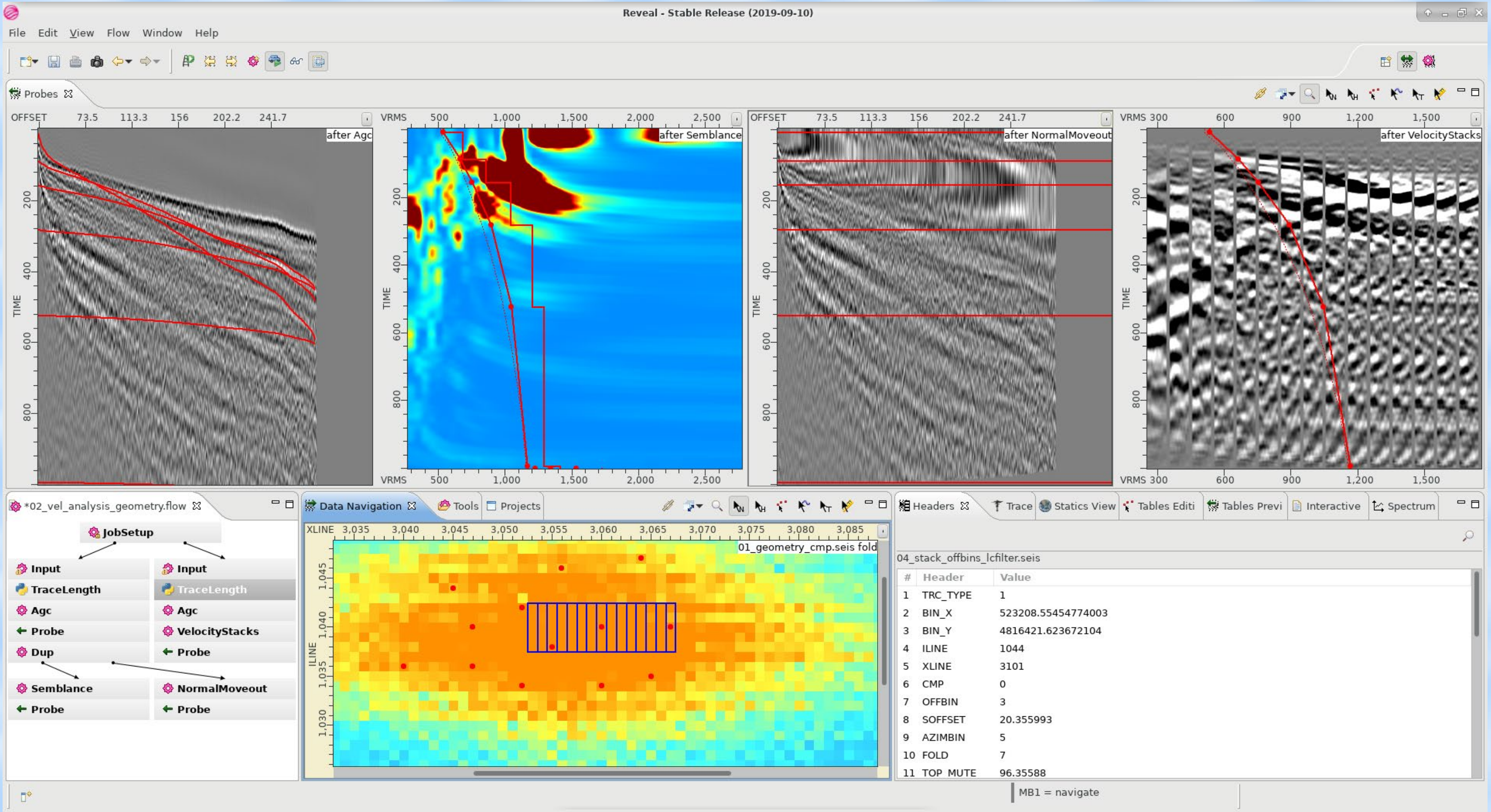
Geometry: Floating Datum Elevation



Geometry: Brute Stack

Velocity Analysis

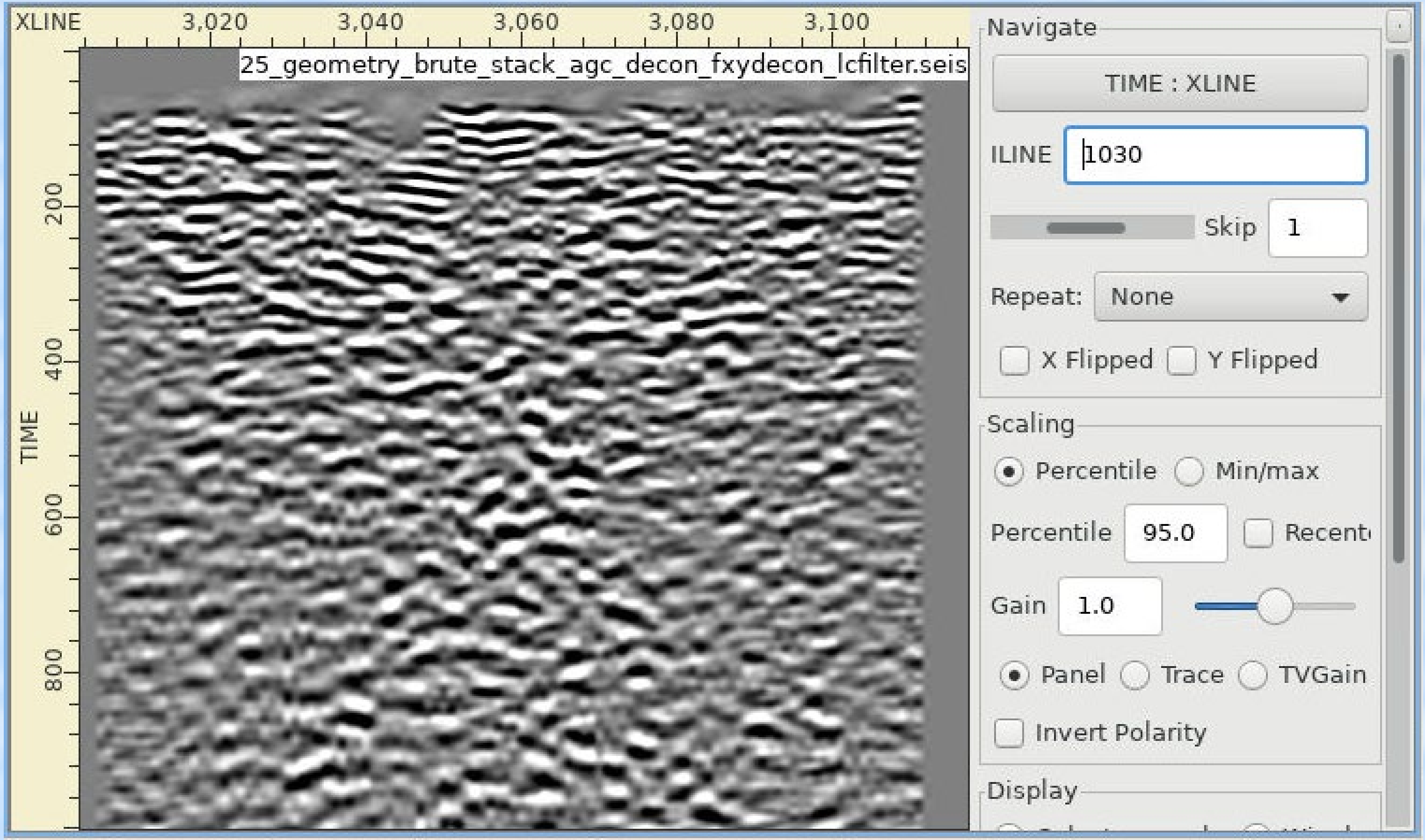
Geometry: Velocity Analysis



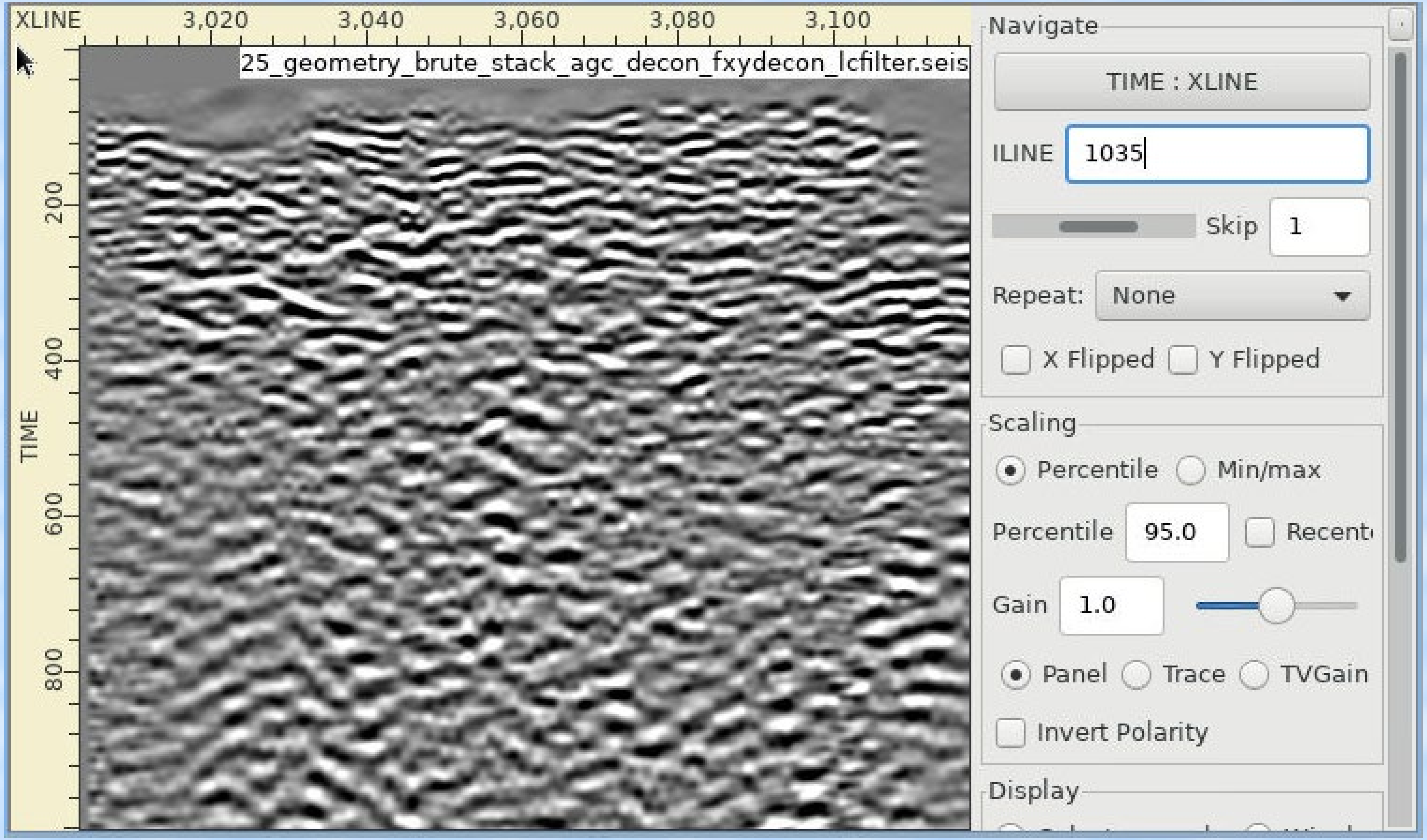
Geometry: Brute Stack

Inlines

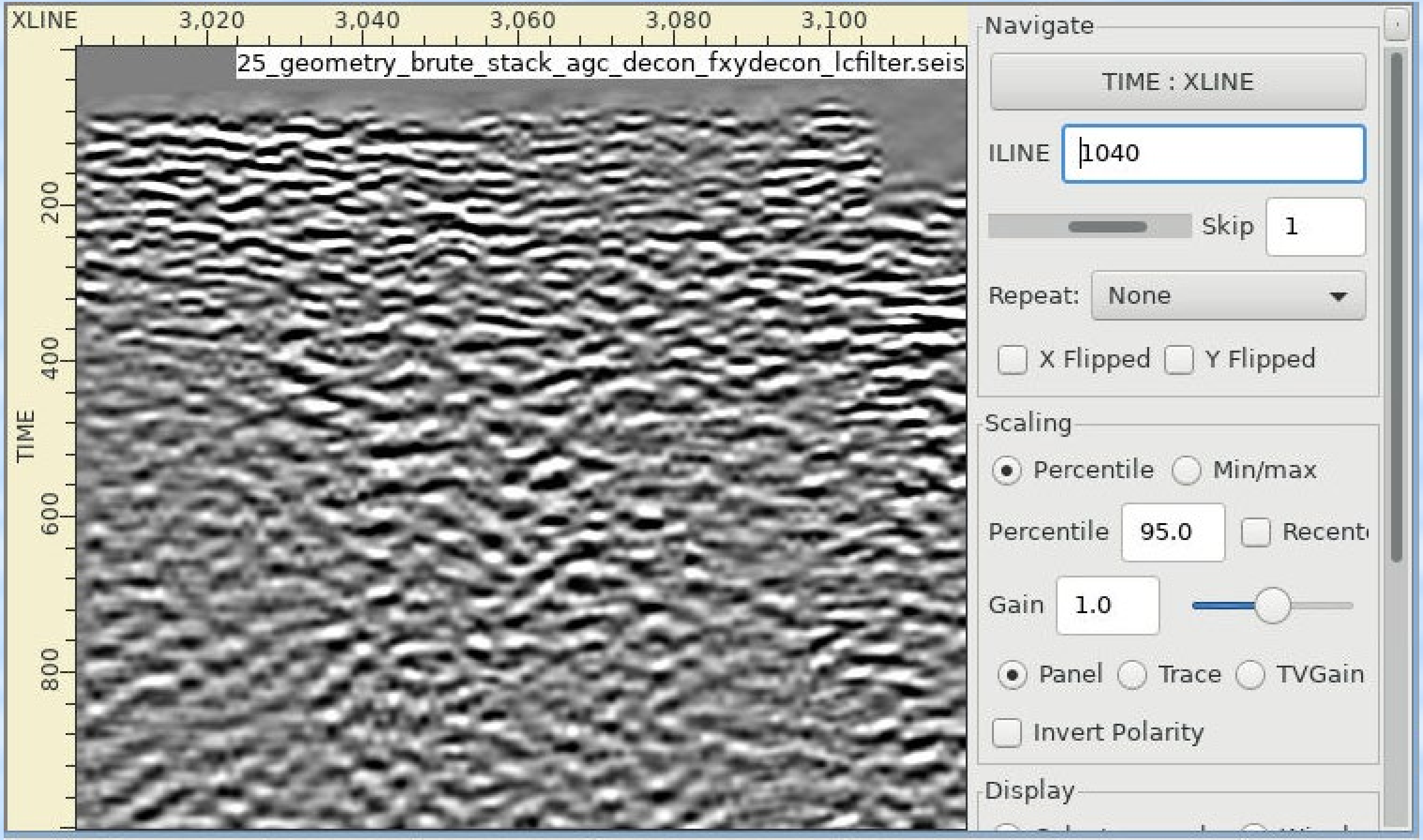
Geometry: Brute Stack - IL 1030



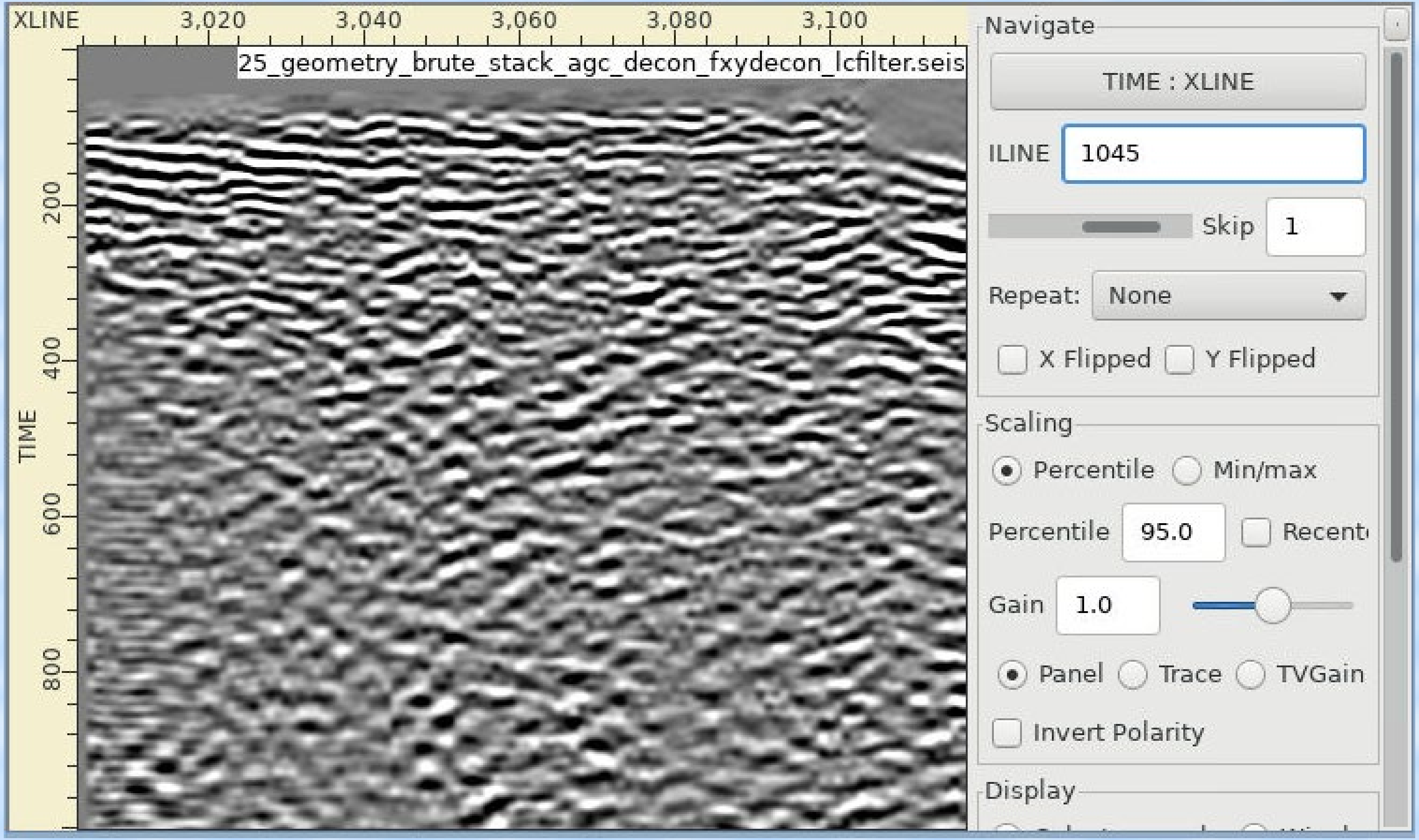
Geometry: Brute Stack - IL 1035



Geometry: Brute Stack - IL 1040



Geometry: Brute Stack - IL 1040



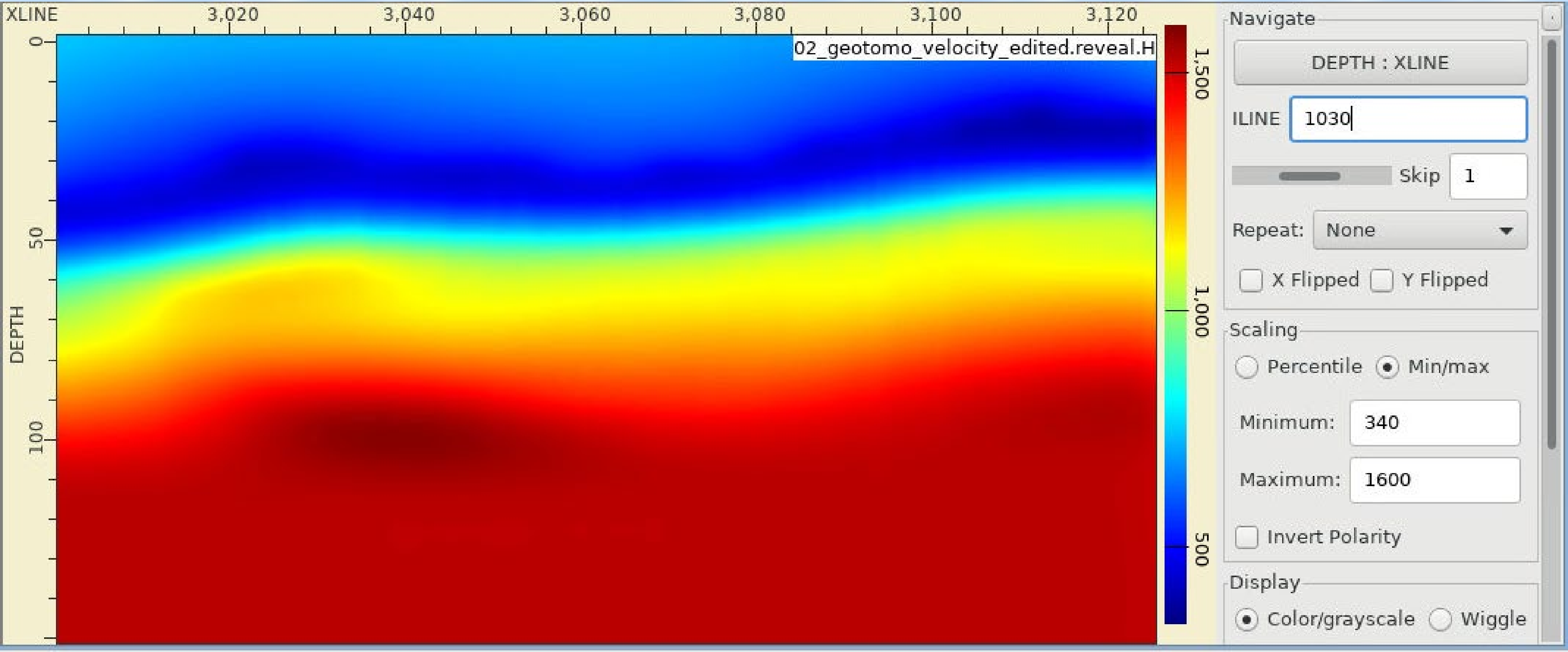
Refraction Tomography

- Refraction Tomography was used to produce near surface velocity as well as refraction statics.
- Refraction statics were not used and instead statics were handled in residual Statics processing.
- Refraction tomography velocity was used in all stacks and for migration since it is not possible to derive very shallow velocity from reflection data.

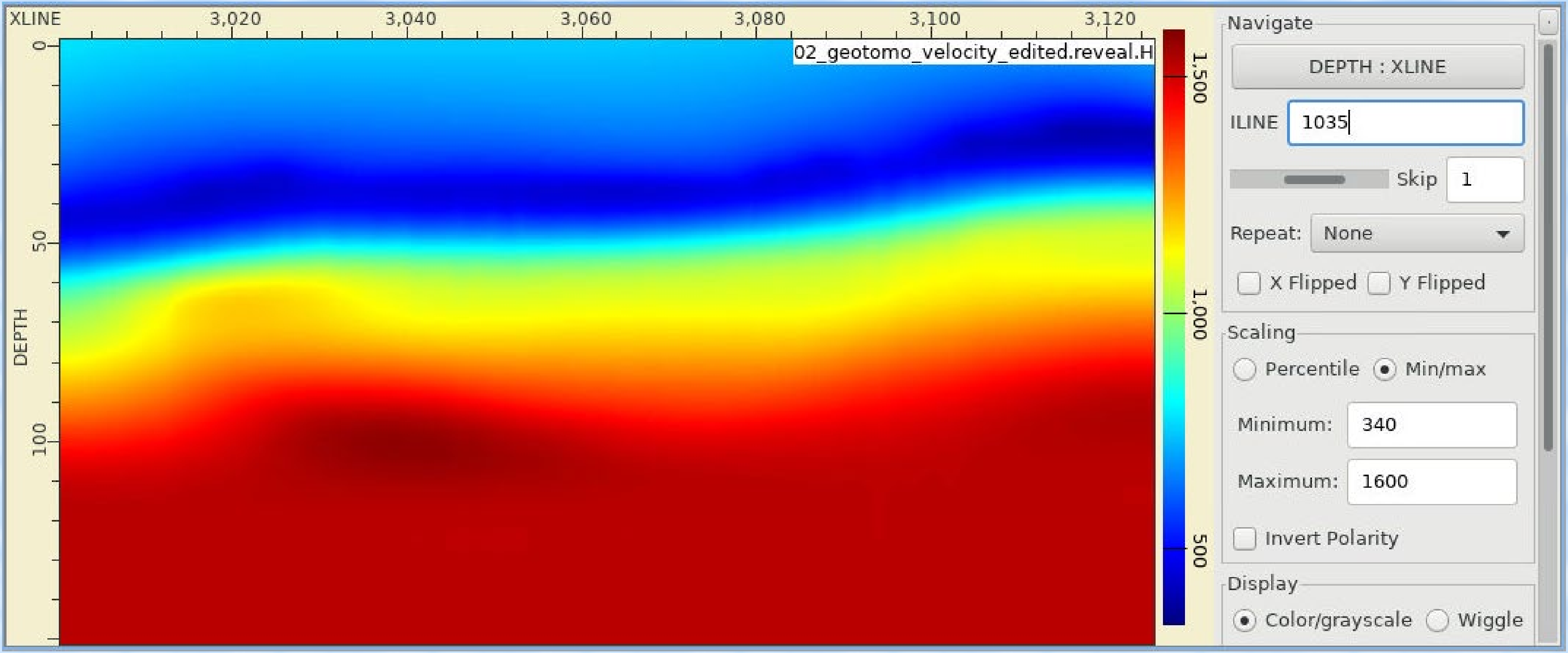
Refraction Tomography: Velocity

Inlines

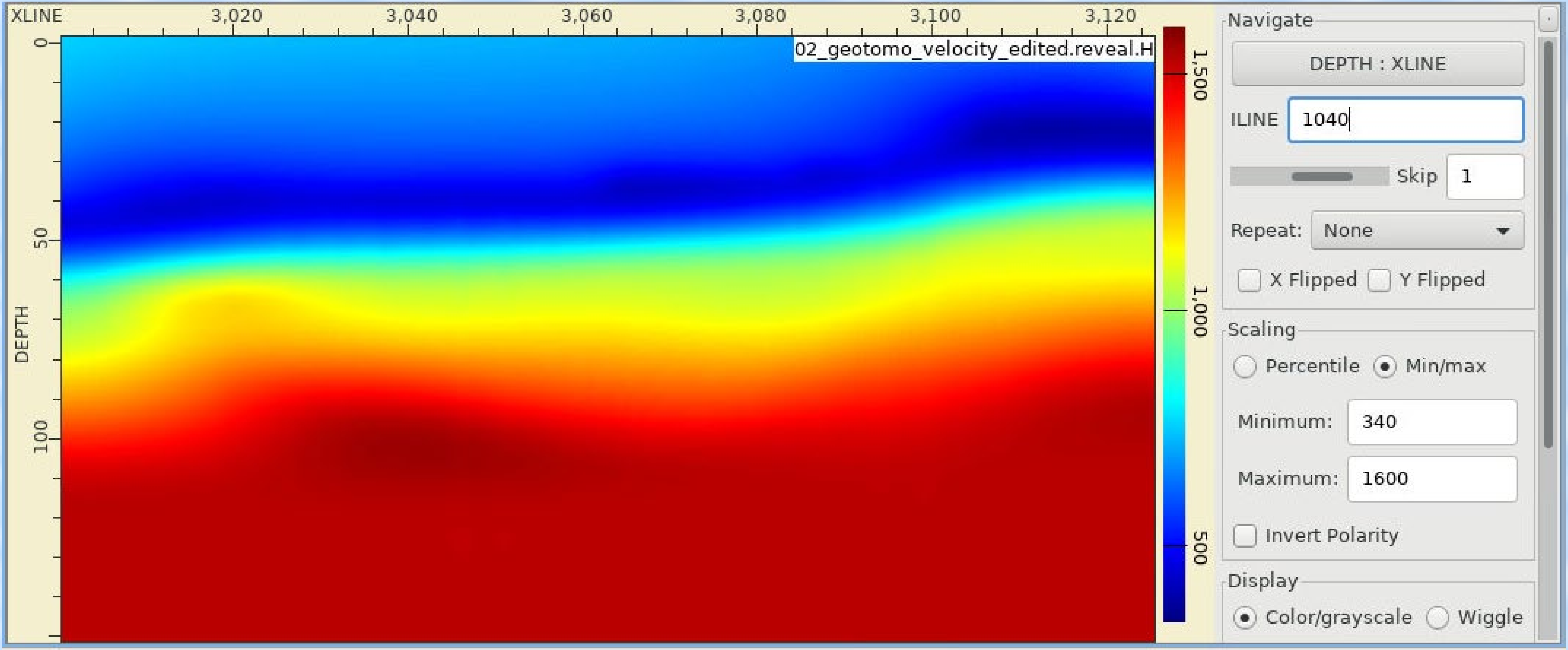
Refraction Tomography: Velocity - IL 1030



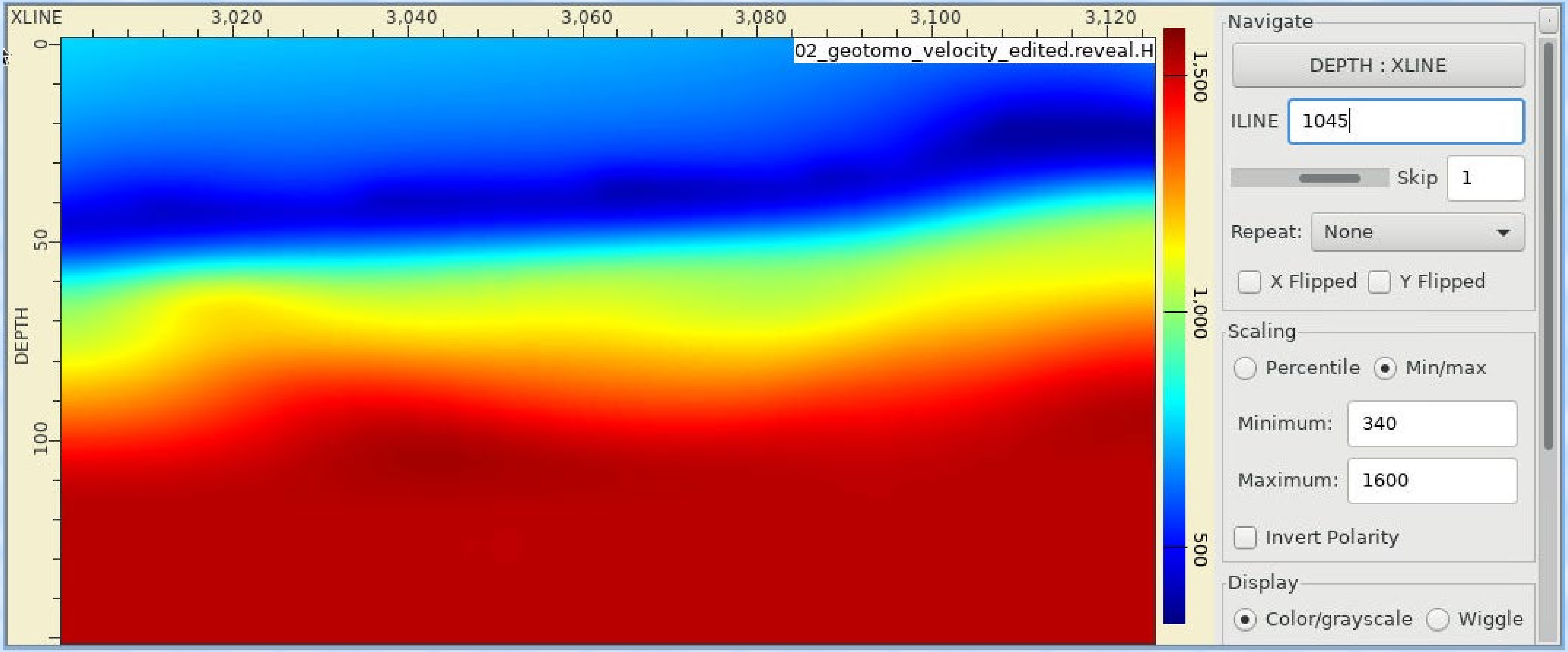
Refraction Tomography: Velocity - IL 1035



Refraction Tomography: Velocity - IL 1040



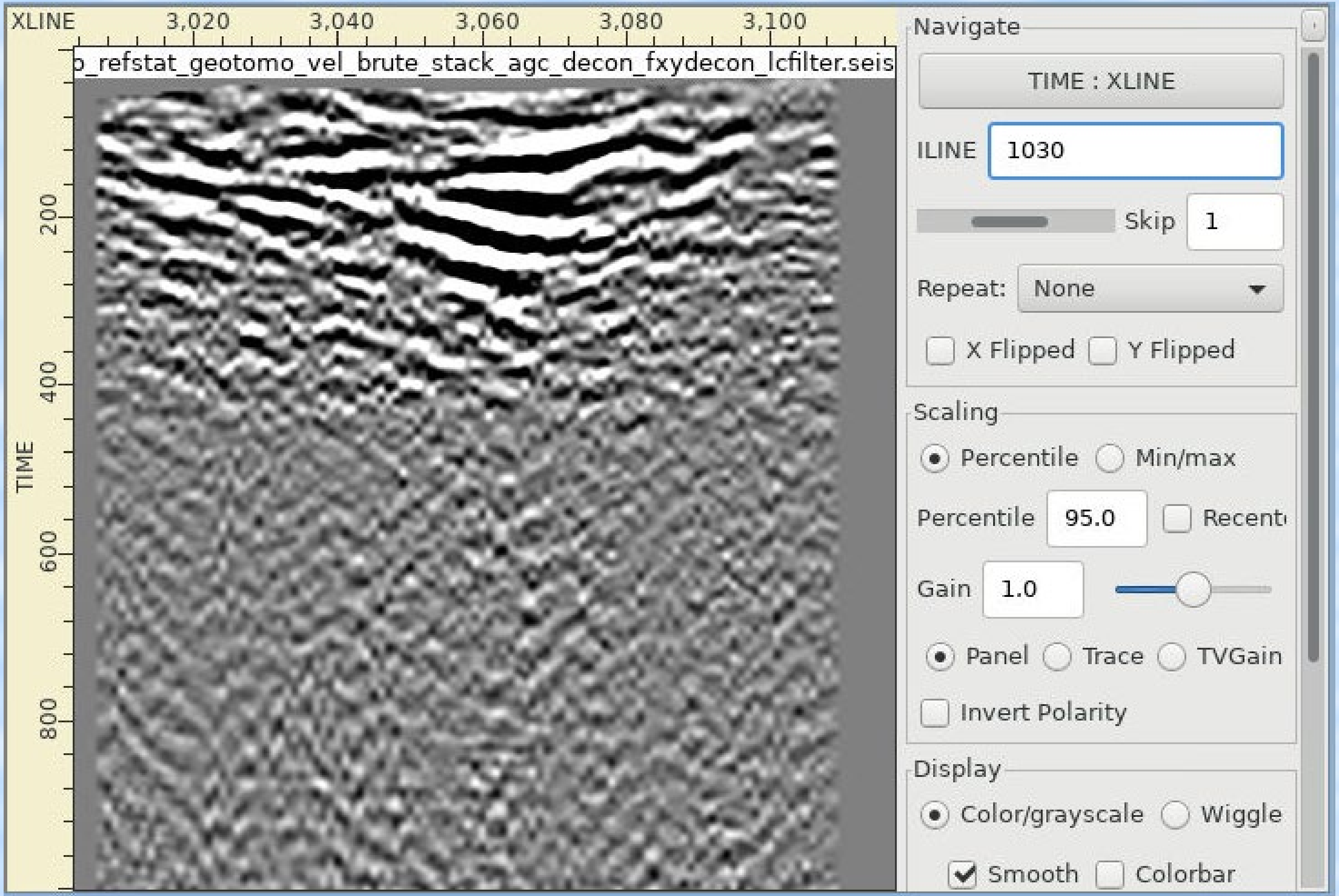
Refraction Tomography: Velocity - IL 1045



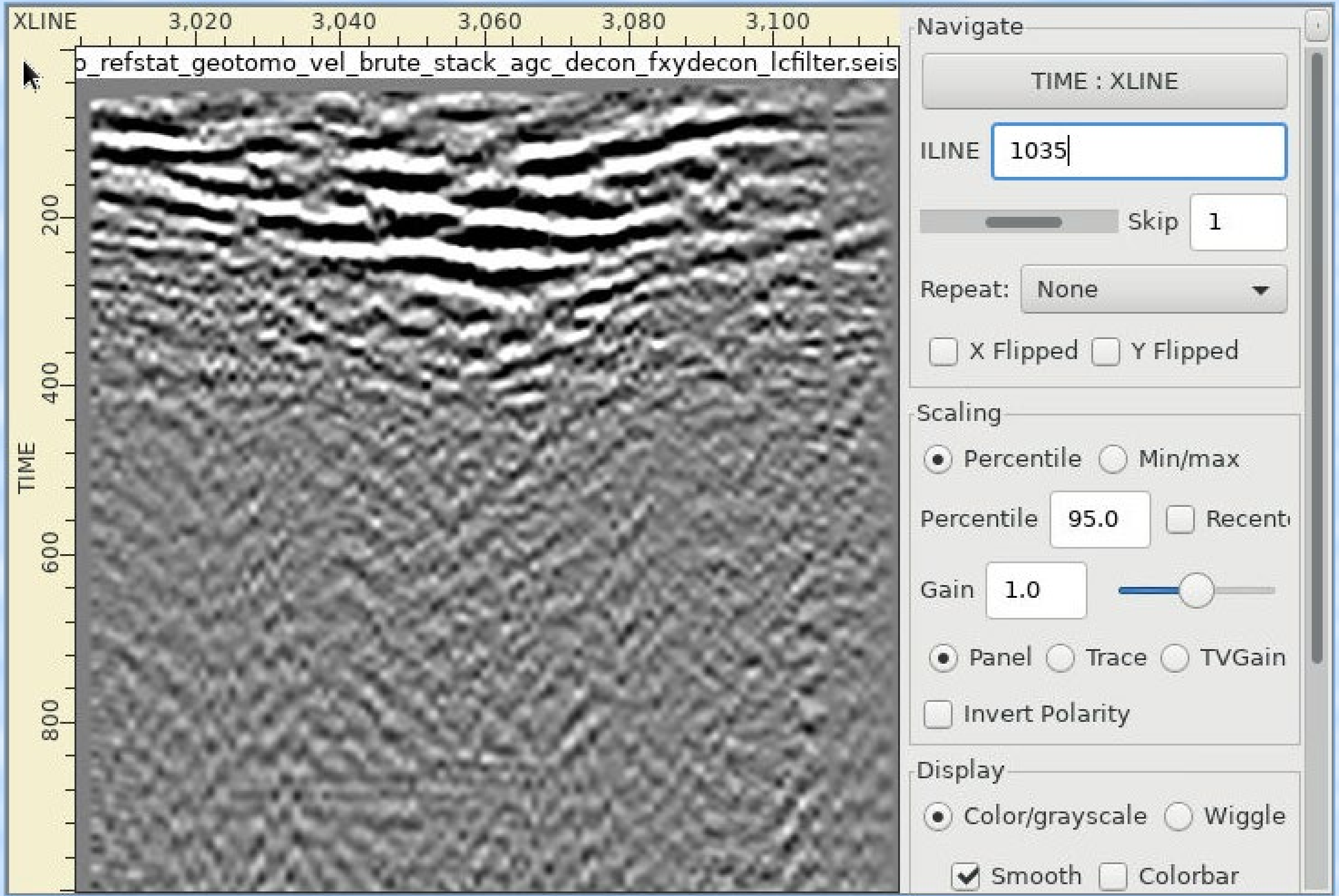
Refraction Tomography: Stack

Inlines

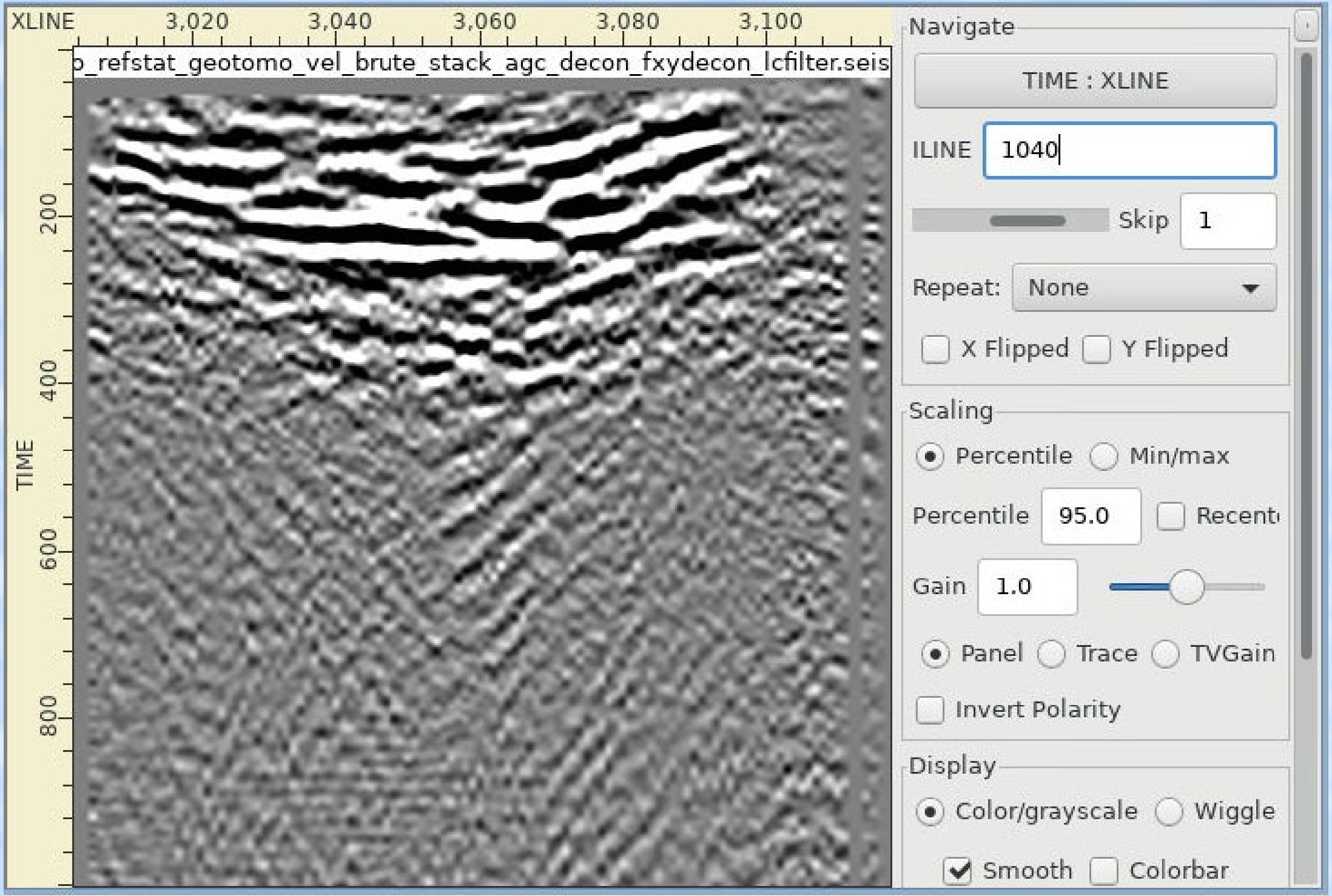
Refraction Tomography: Stack - IL 1030



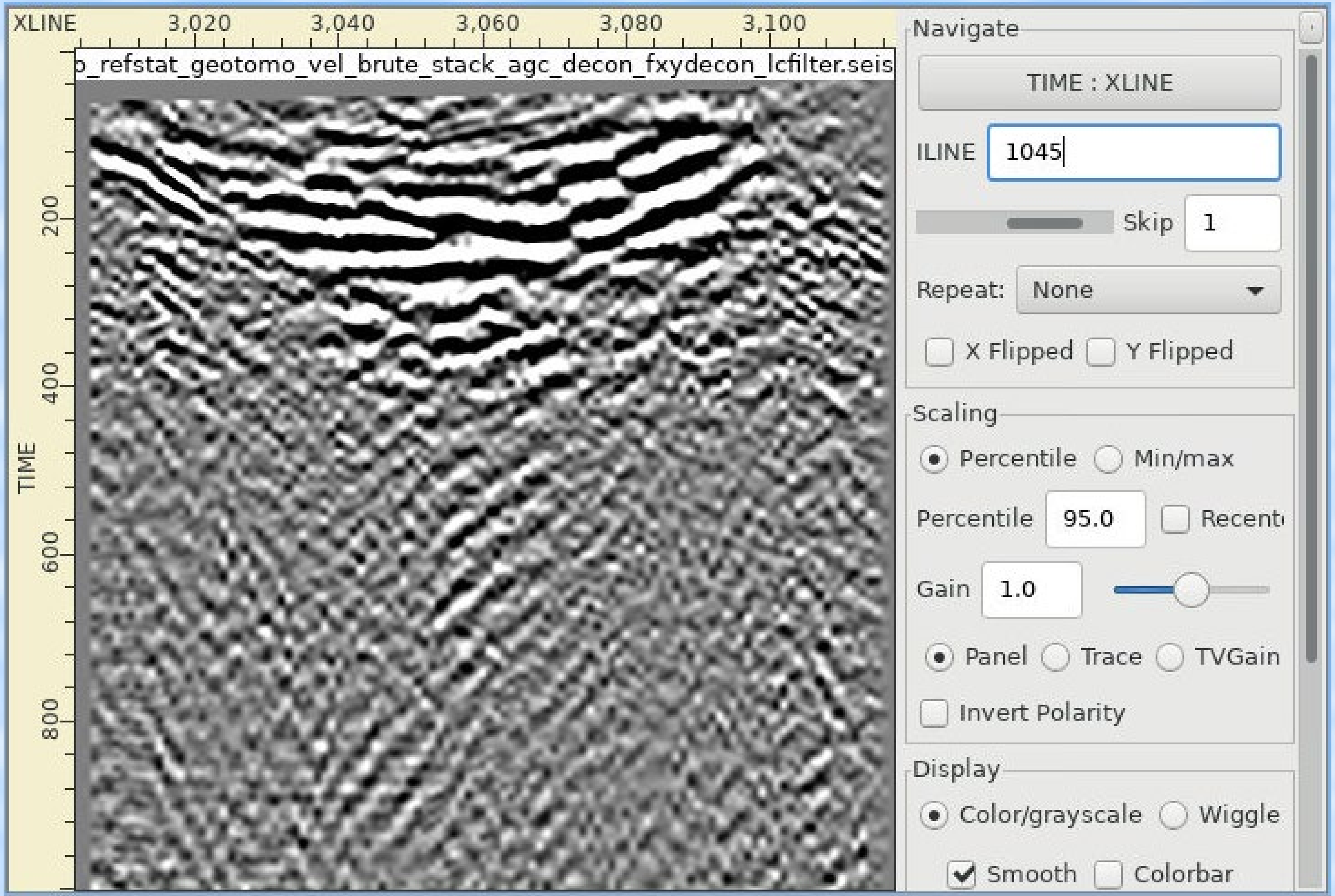
Refraction Tomography: Stack - IL 1035



Refraction Tomography: Stack - IL 1040



Refraction Tomography: Stack - IL 1040



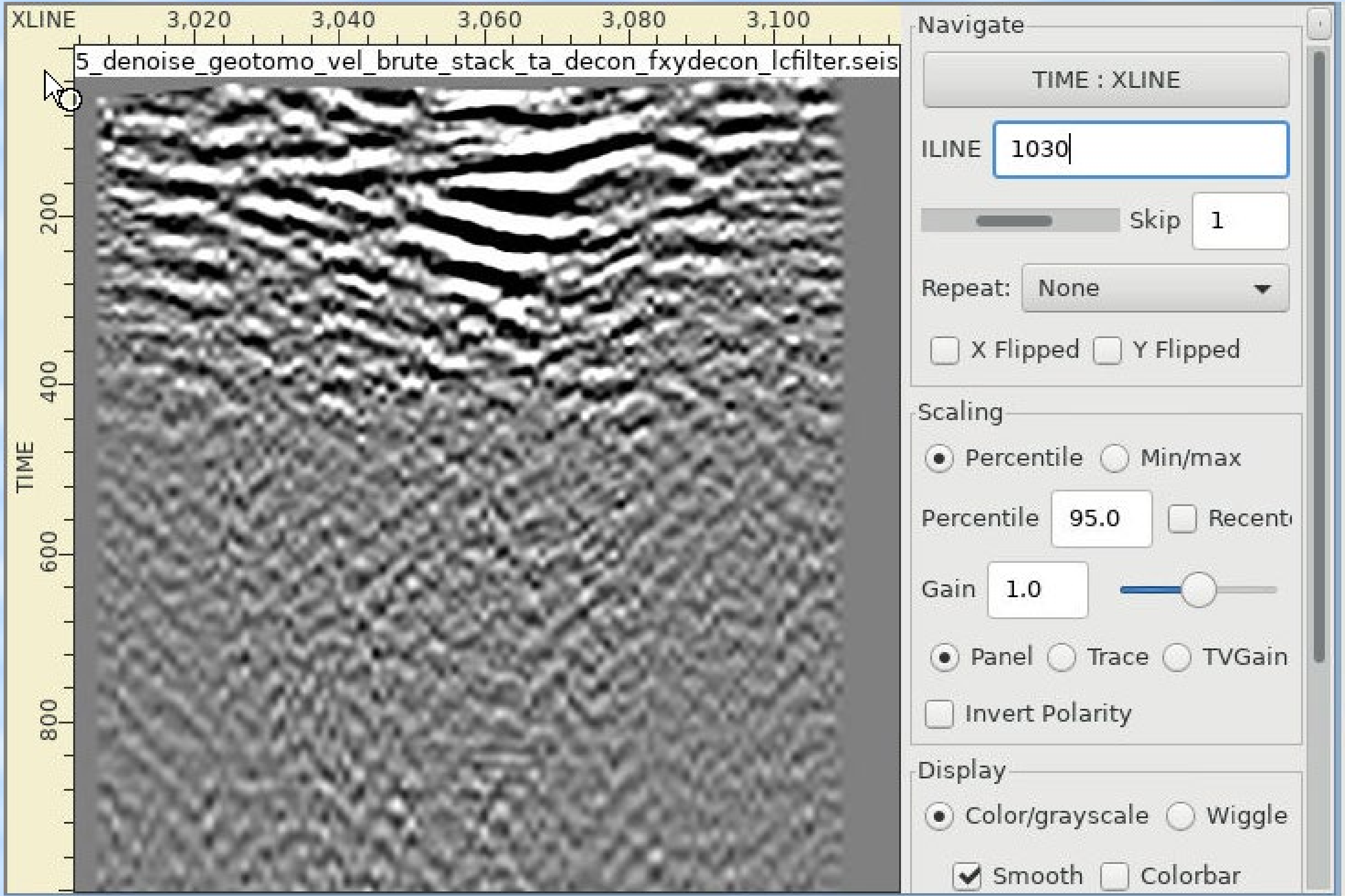
Denoise

- This data is clean as far as burst/environmental noise is concerned.
- Surface waves are strong.
- Main goal of denoising was to attenuate surface noise.

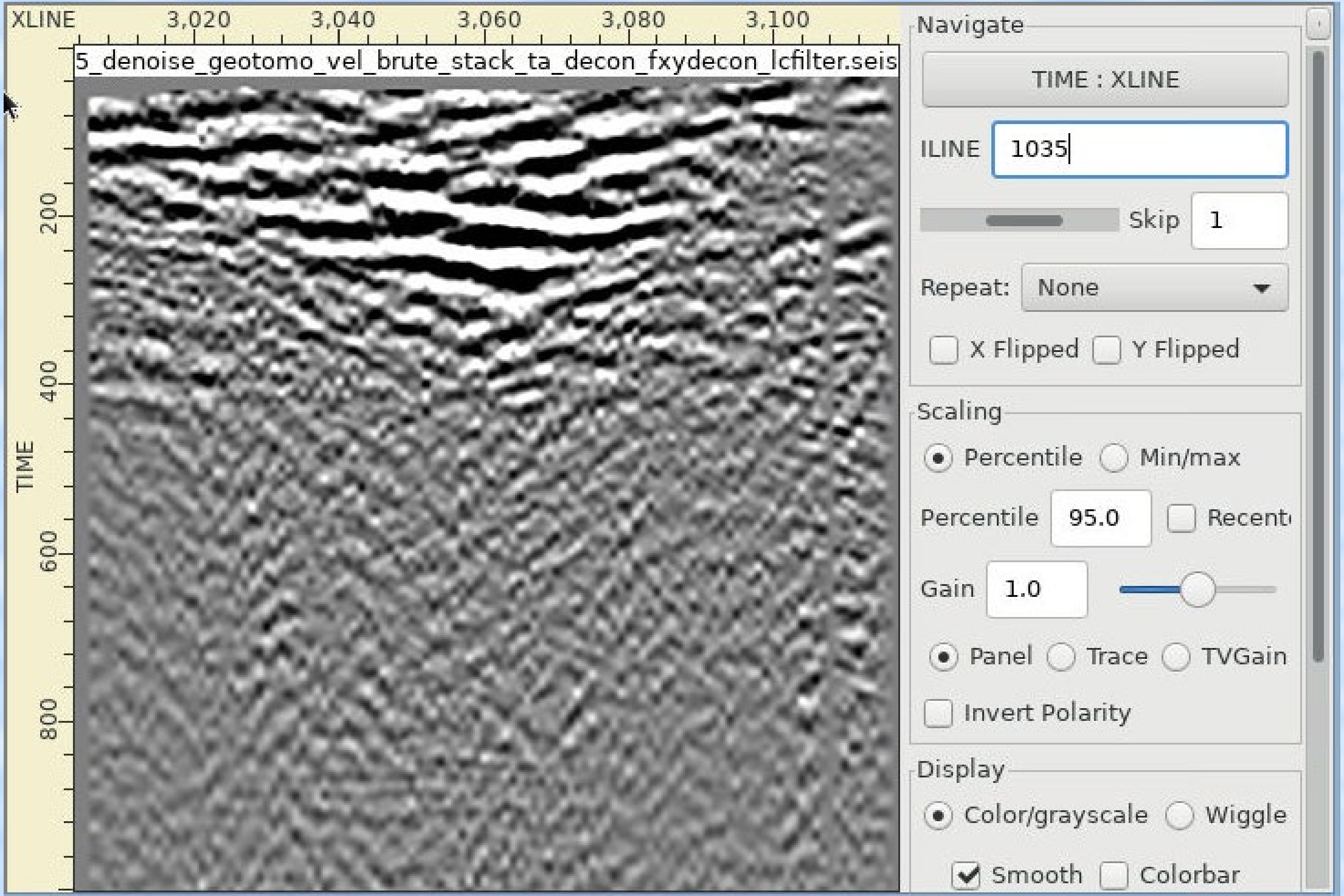
Denoise: Stack

Inlines

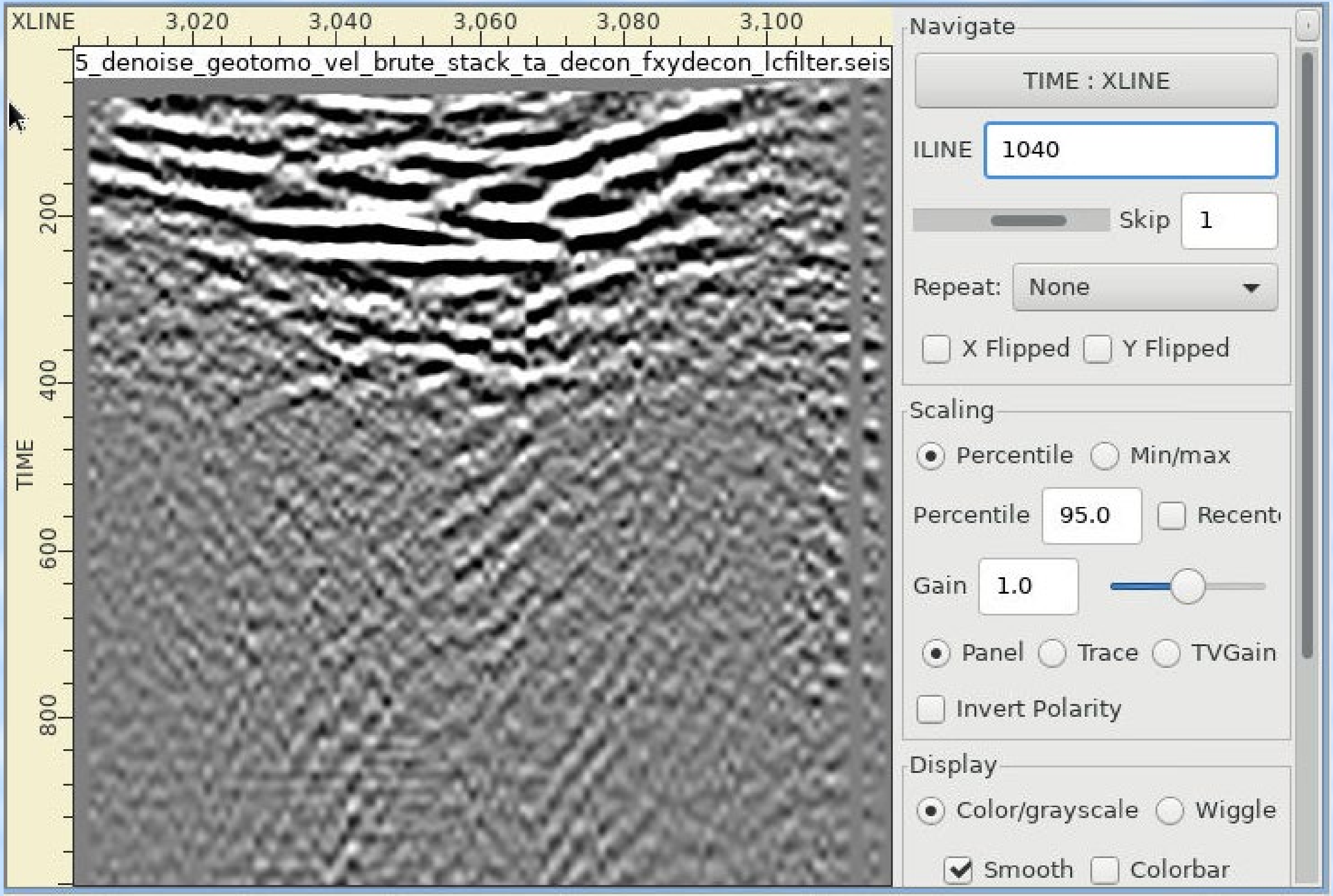
Denoise: Stack - IL 1030



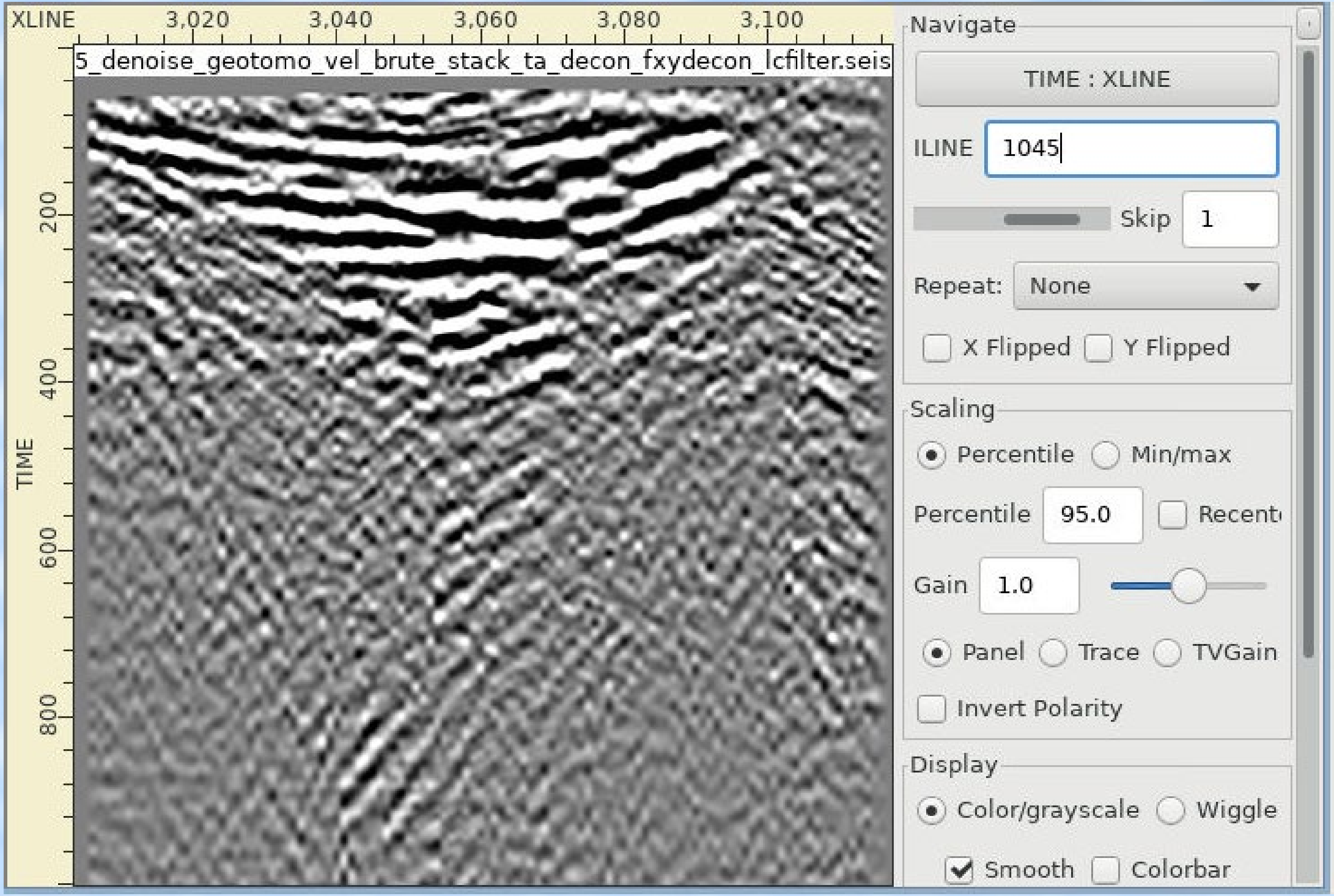
Denoise: Stack - IL 1035



Denoise: Stack - IL 1040



Denoise: Stack - IL 1045



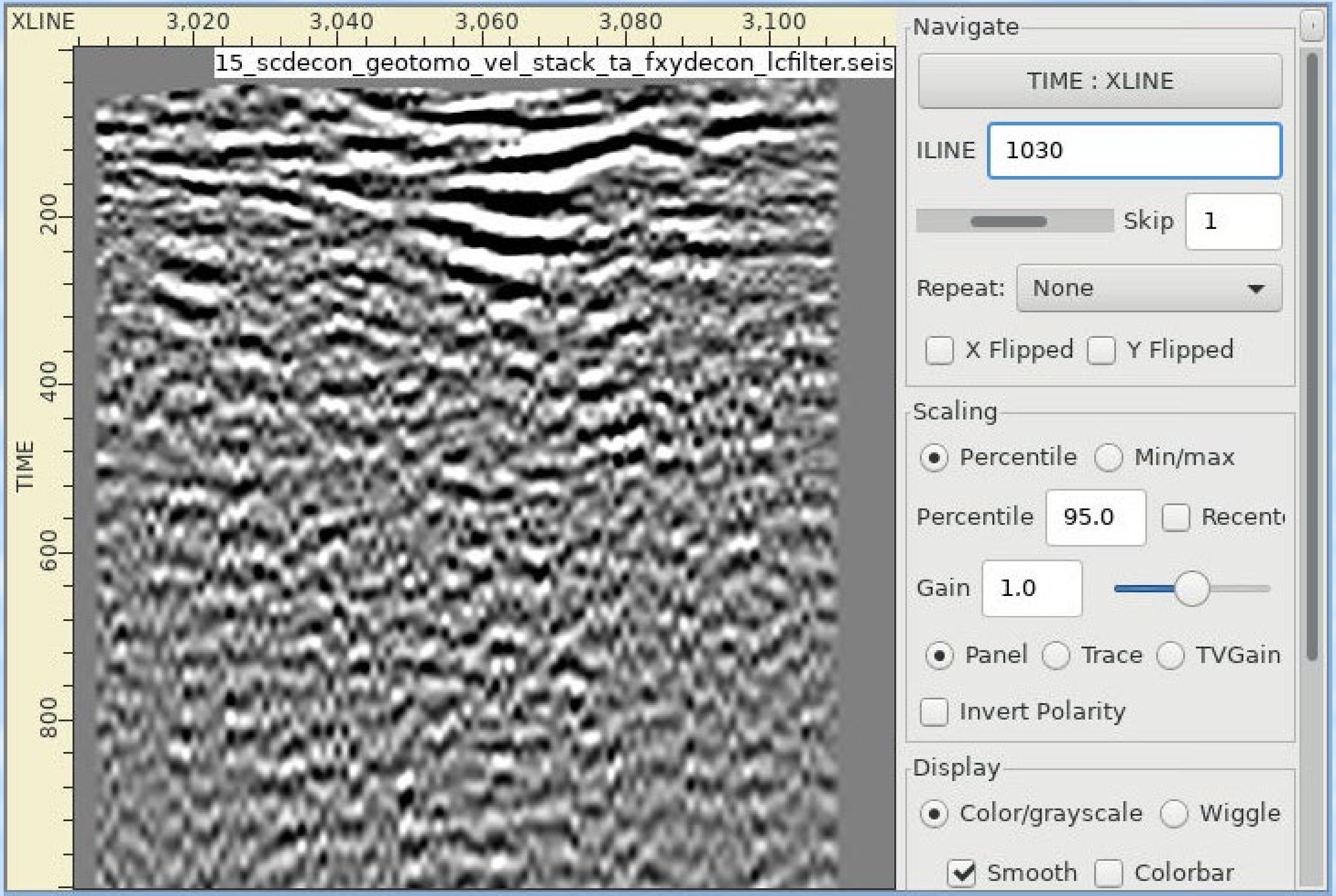
Surface Consistent (SC) Deconvolution

- Surface Consistent (SC) Deconvolution was used to compress the seismic wavelet and broaden frequency band of the data.
- SC Decon parameters used were:
- Gap: 0 ms (Spiking Decon)
- Operator Length: 180 ms

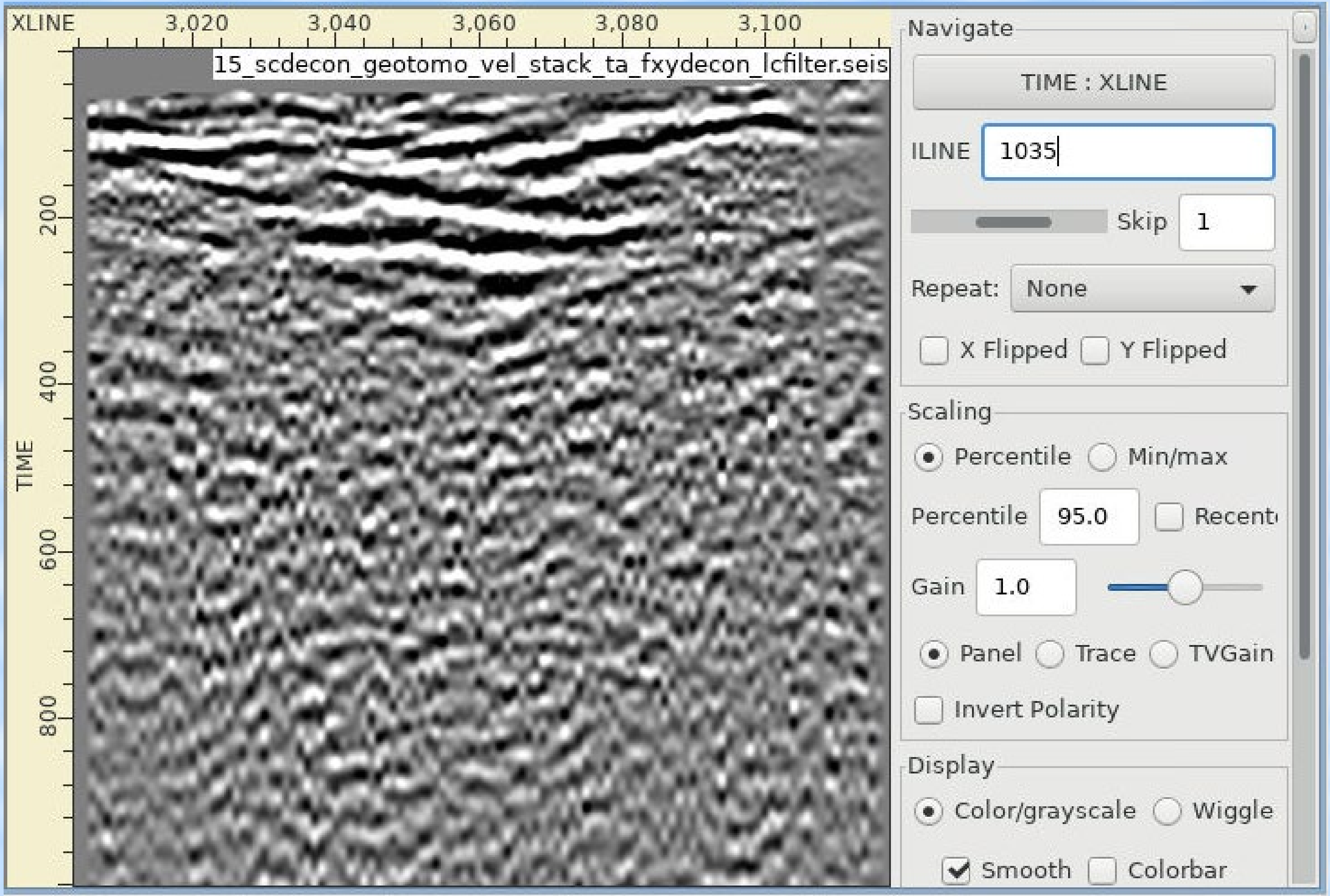
Surface Consistent (SC) Deconvolution: Stack

Inlines

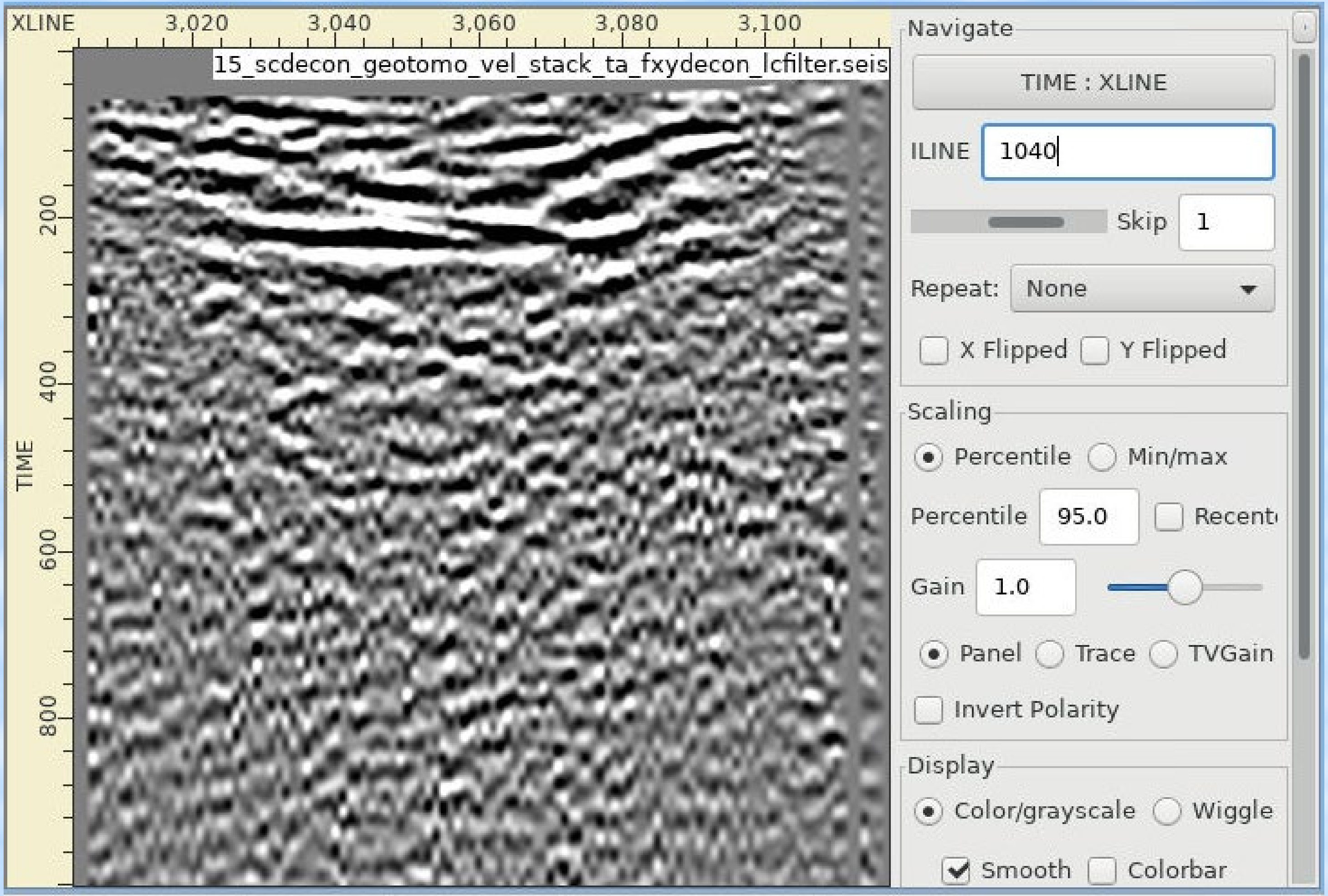
SC Decon: Stack - IL 1030



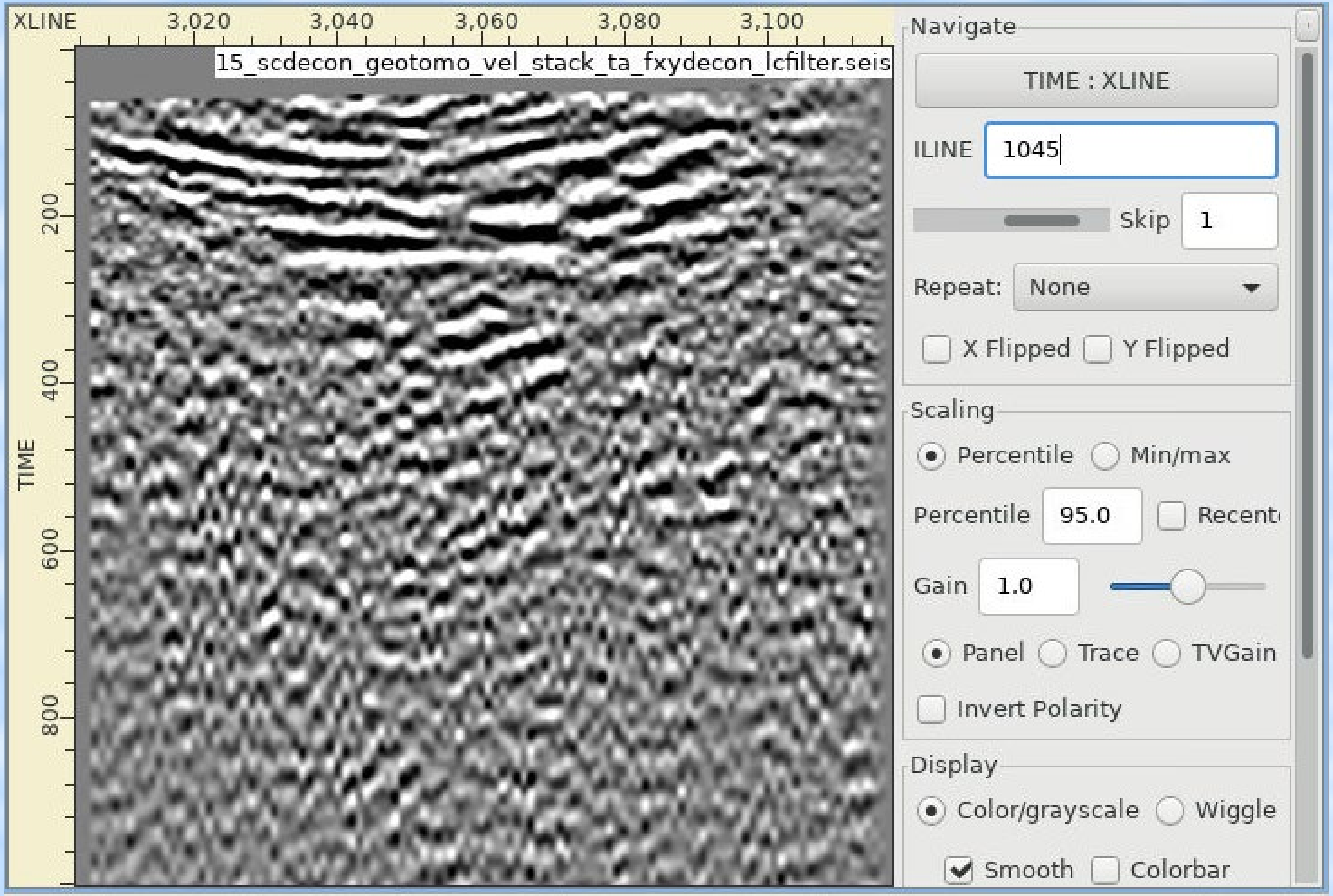
SC Decon: Stack - IL 1035



SC Decon: Stack - IL 1040



SC Decon: Stack - IL 1045



Residual Statics and Q-Compensation

- Residual Statics was done to enhance continuity of horizons.
- Q-Compensation was done to compensate for loss of frequency due to low Q (Quality Factor).

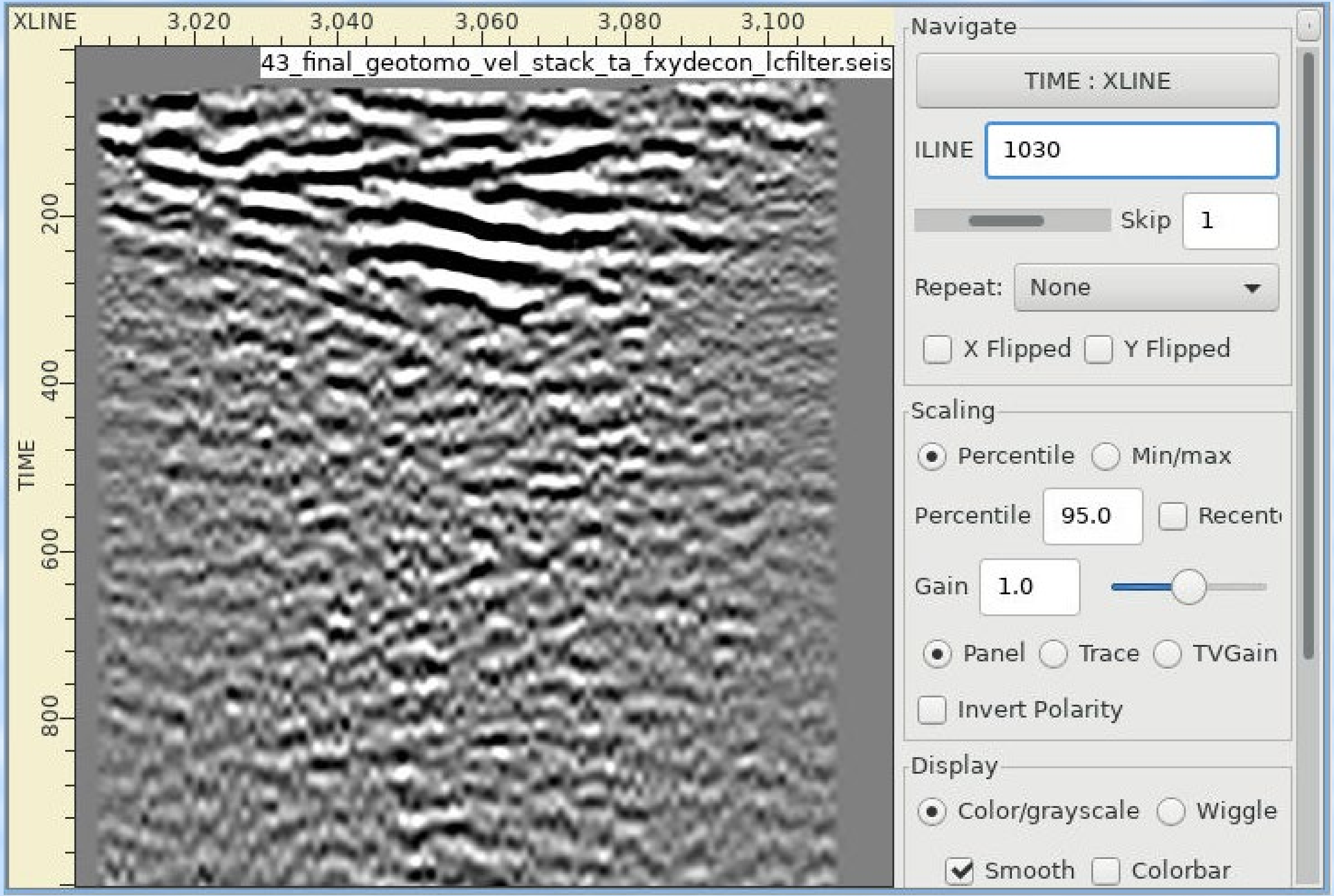
Final Processing

- Final processing steps included Residual Statics and Q-Compensation.
- Residual Statics was done to enhance continuity of horizons.
- Q-Compensation was done to compensate for loss of frequency due to low Q (Quality Factor).
- Often, additional denoising is done in the final stage of processing. However, in this case because the data was clean no additional denoising was done.

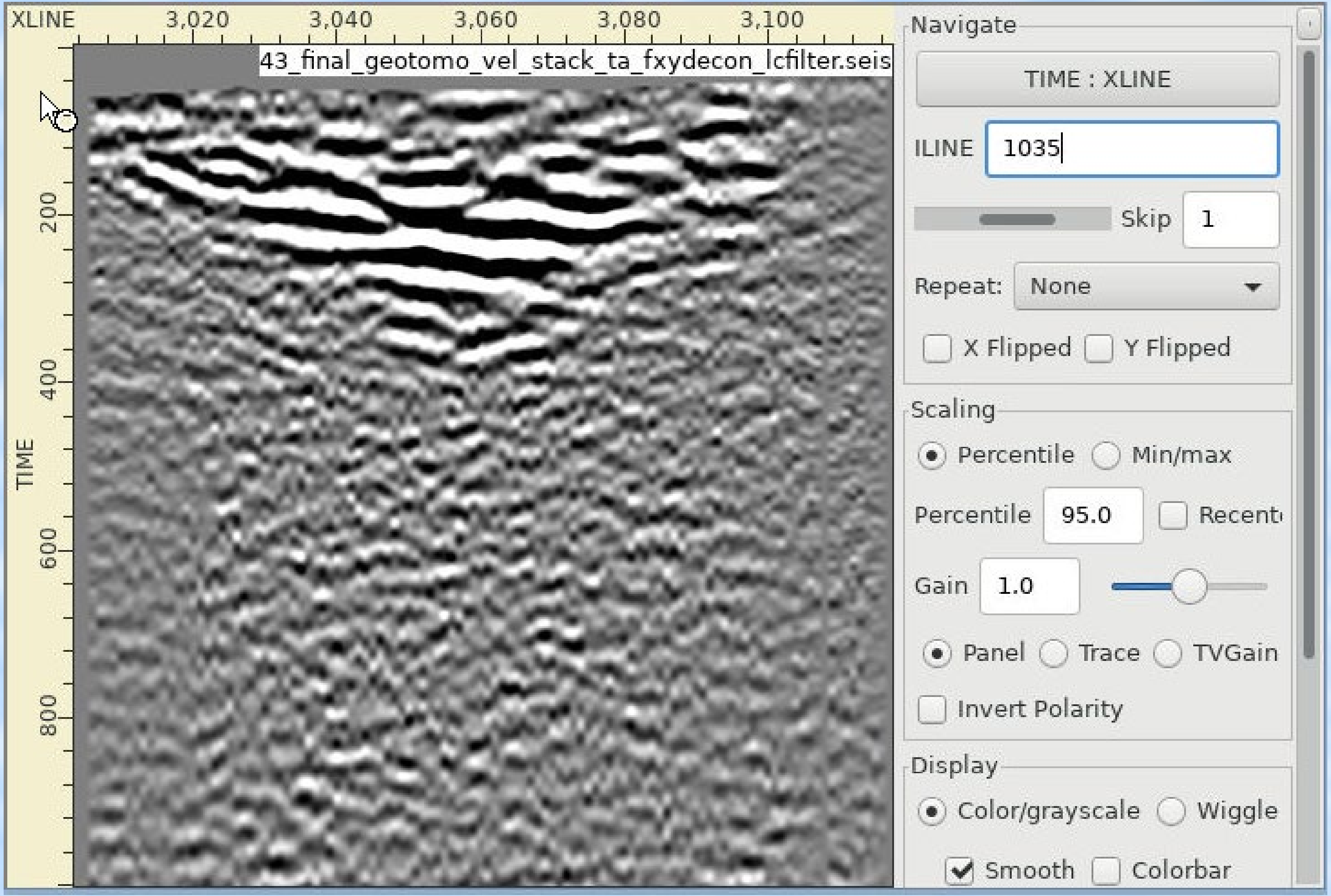
Final Processing: Stack

Inlines

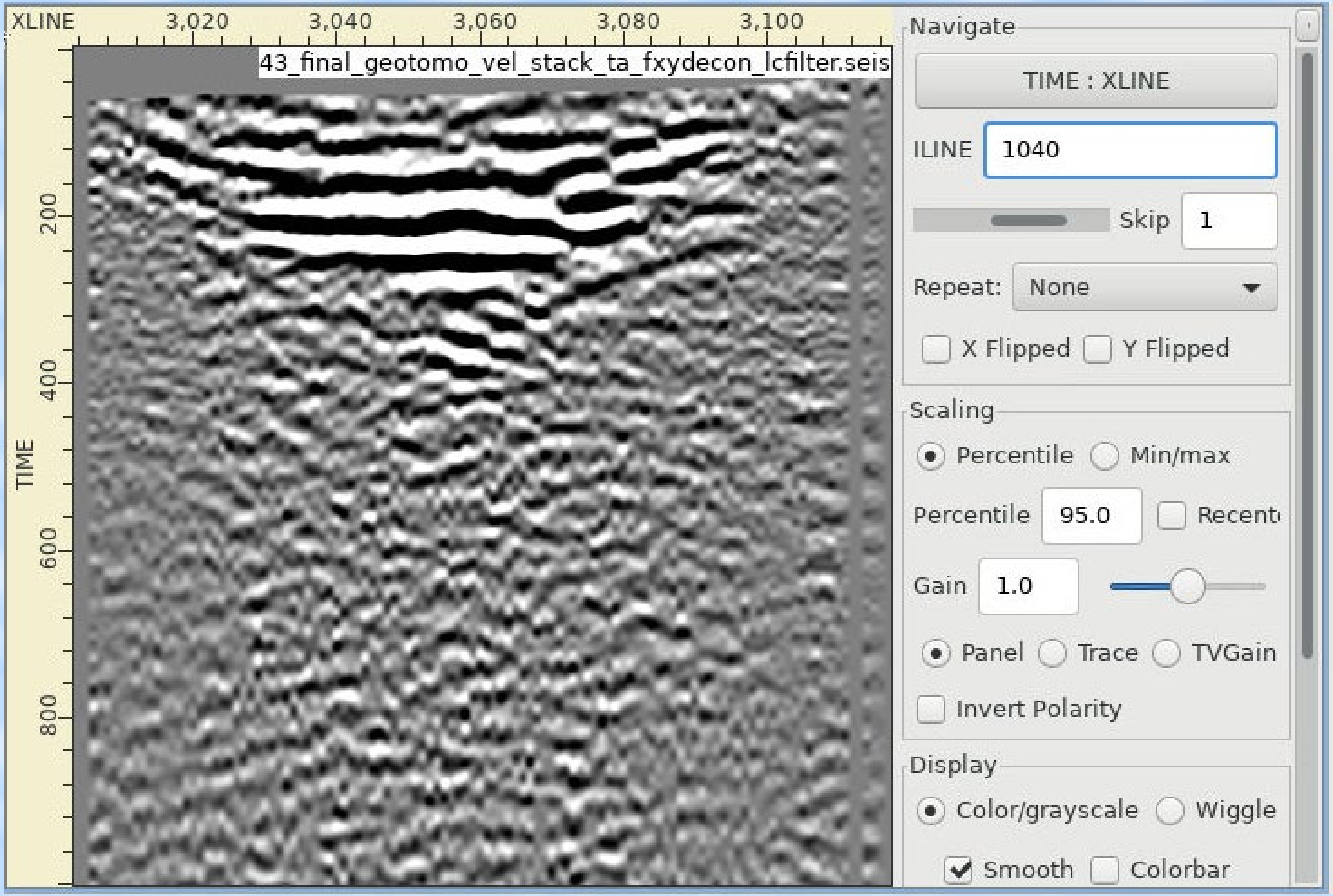
Final Processing: Stack - IL 1030



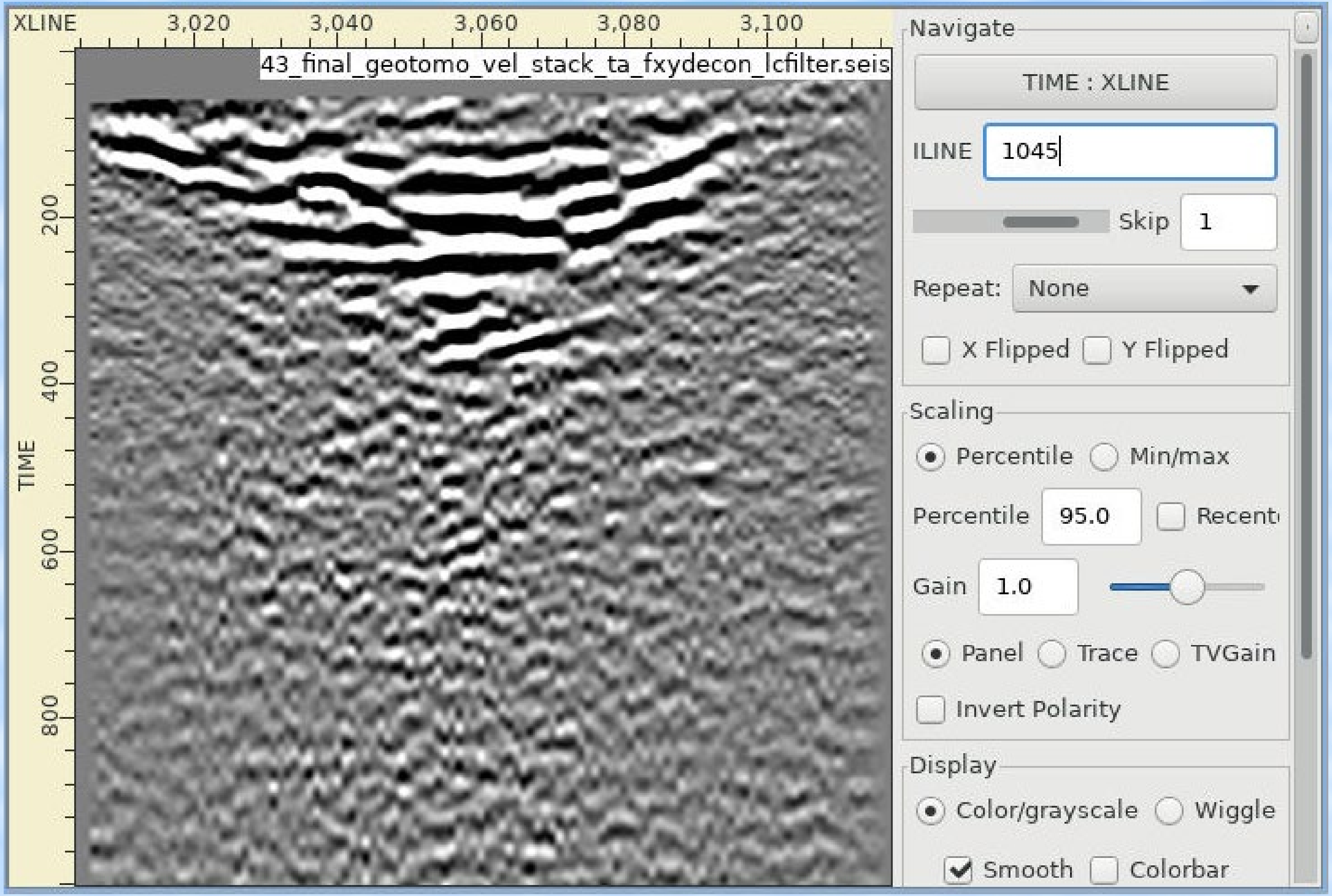
Final Processing: Stack - IL 1035



Final Processing: Stack - IL 1040



Final Processing: Stack - IL 1045



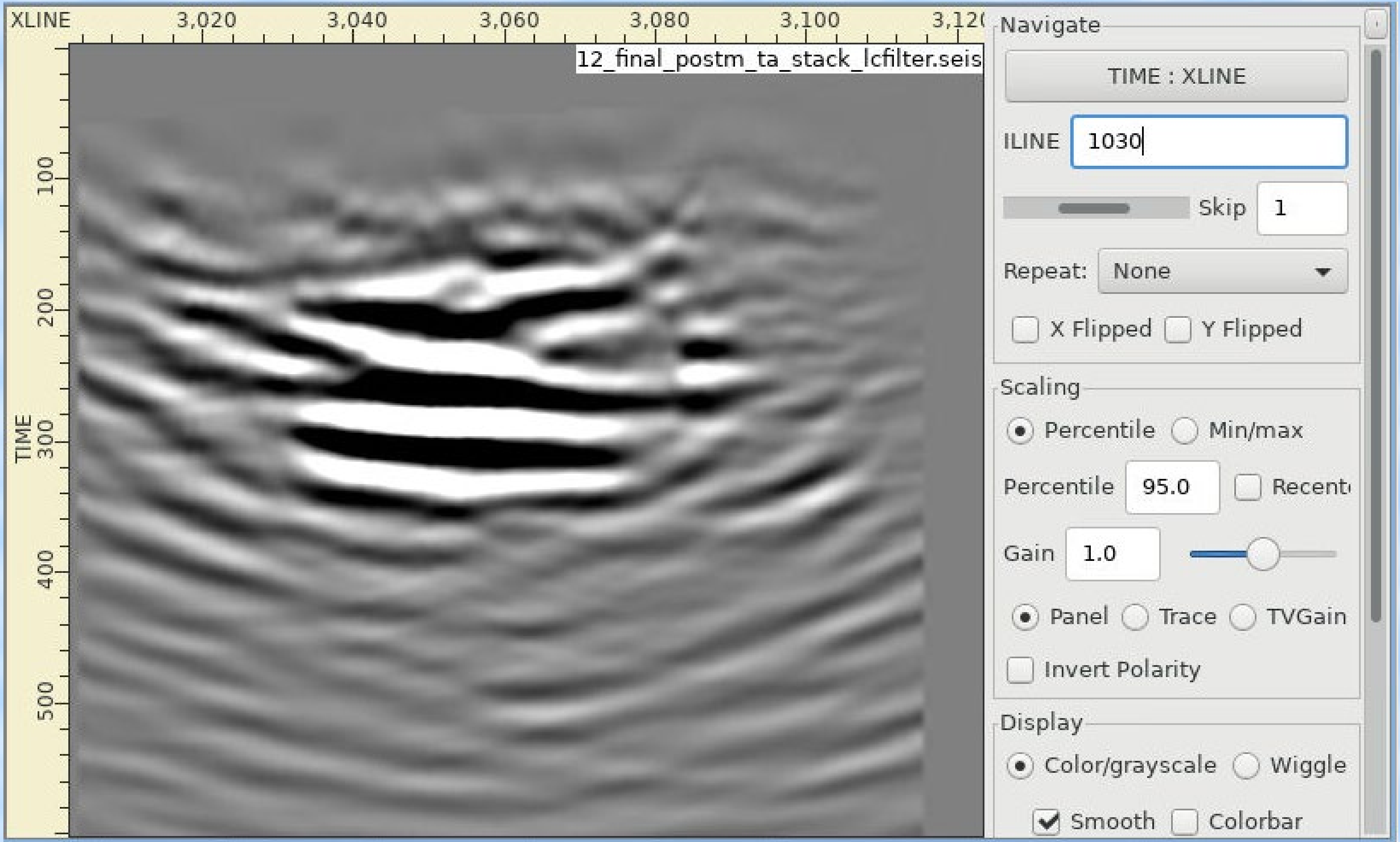
Time Migration

- Migration is done in order collapse diffraction hyperbolas at reflectors and faults as well as to correctly position steeply dipping seismic events.
- Two types of seismic time migration were tested:
    - Kirchhoff Post-stack Time Migration (PoSTM)
    - Kirchhoff Pre-stack Time Migration (PSTM)
- Better results were produced by Kirchhoff PoSTM.

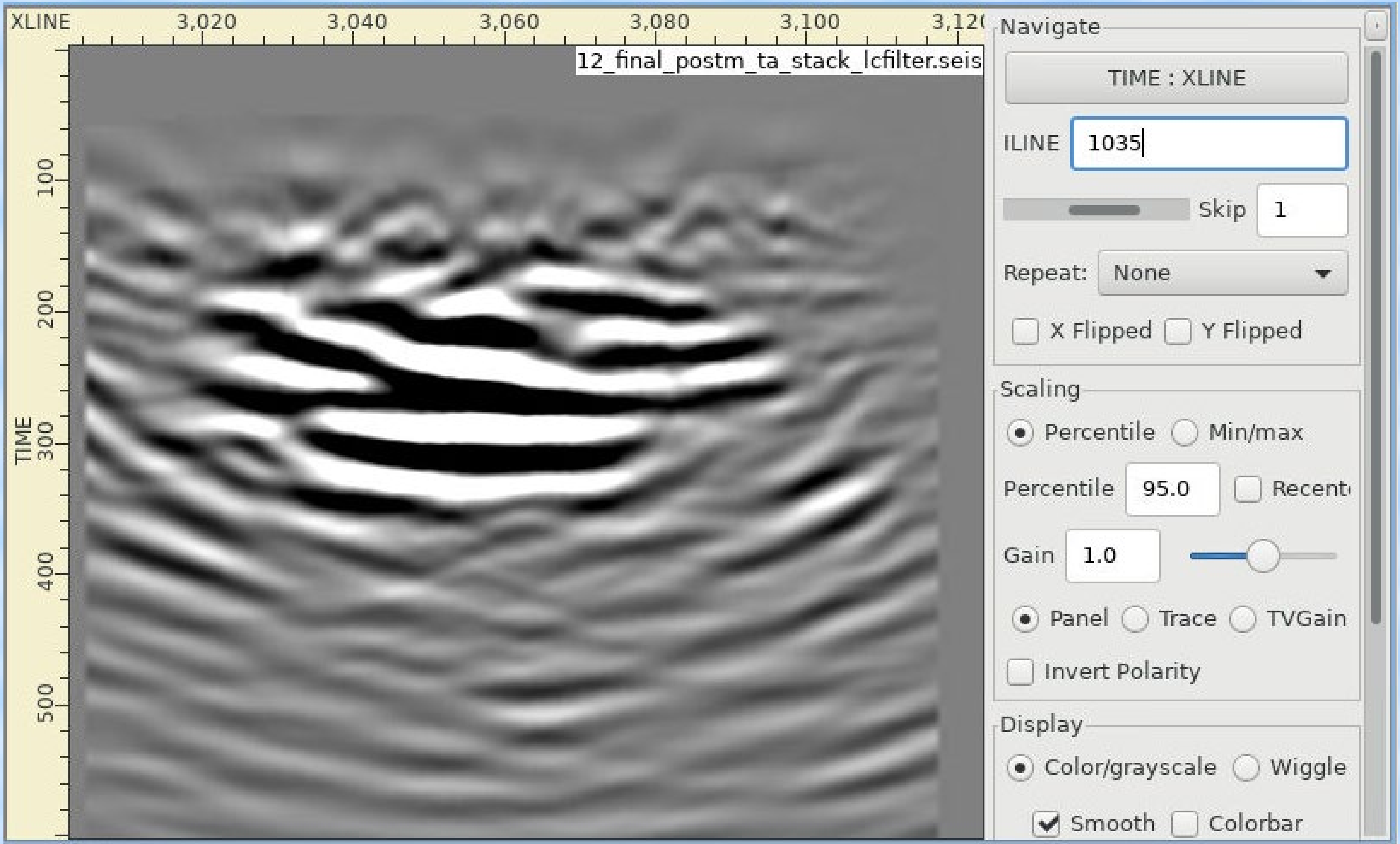
Final Processing: PoSTM Stack

Inlines

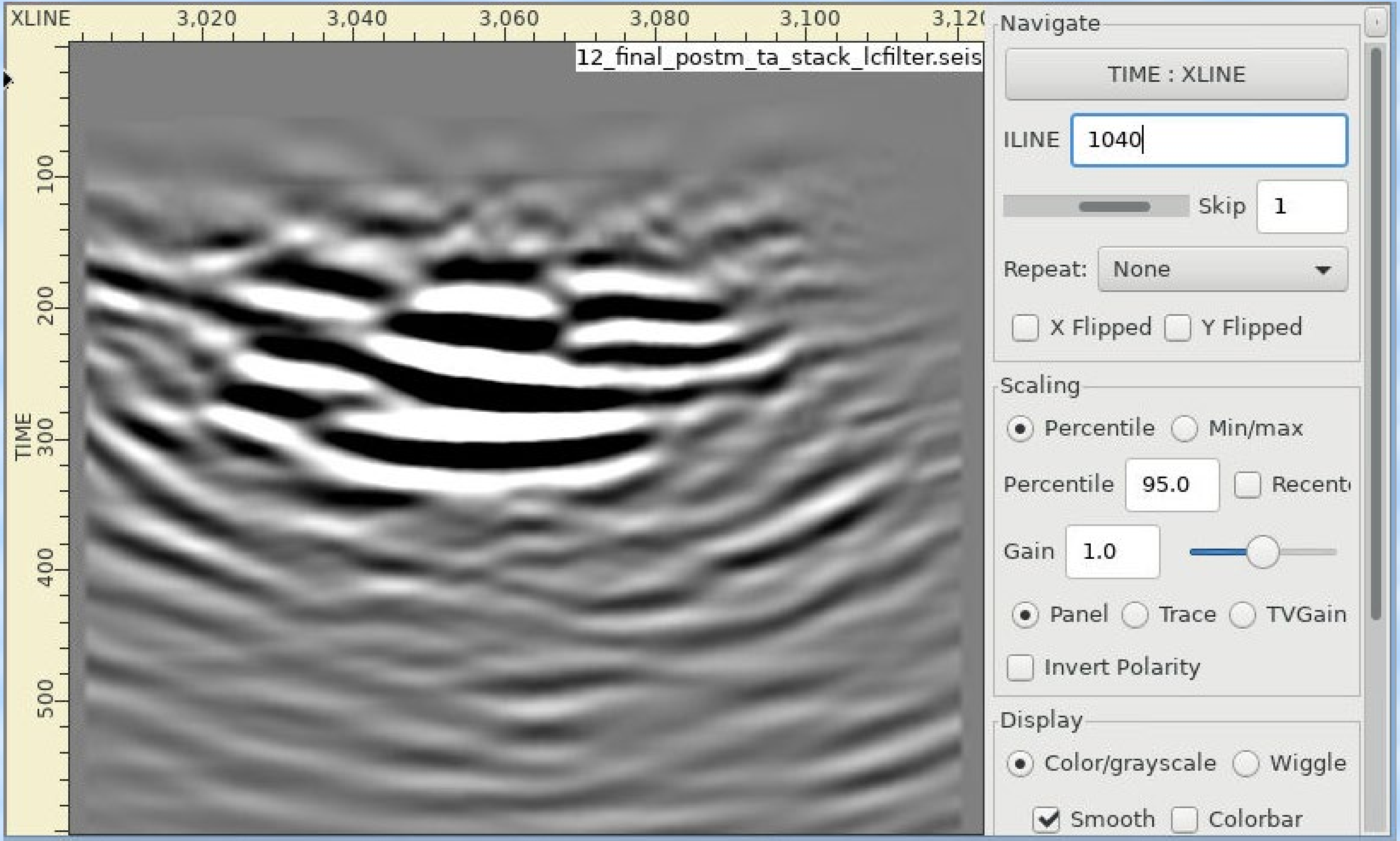
Final Processing: PoSTM Stack - IL 1030



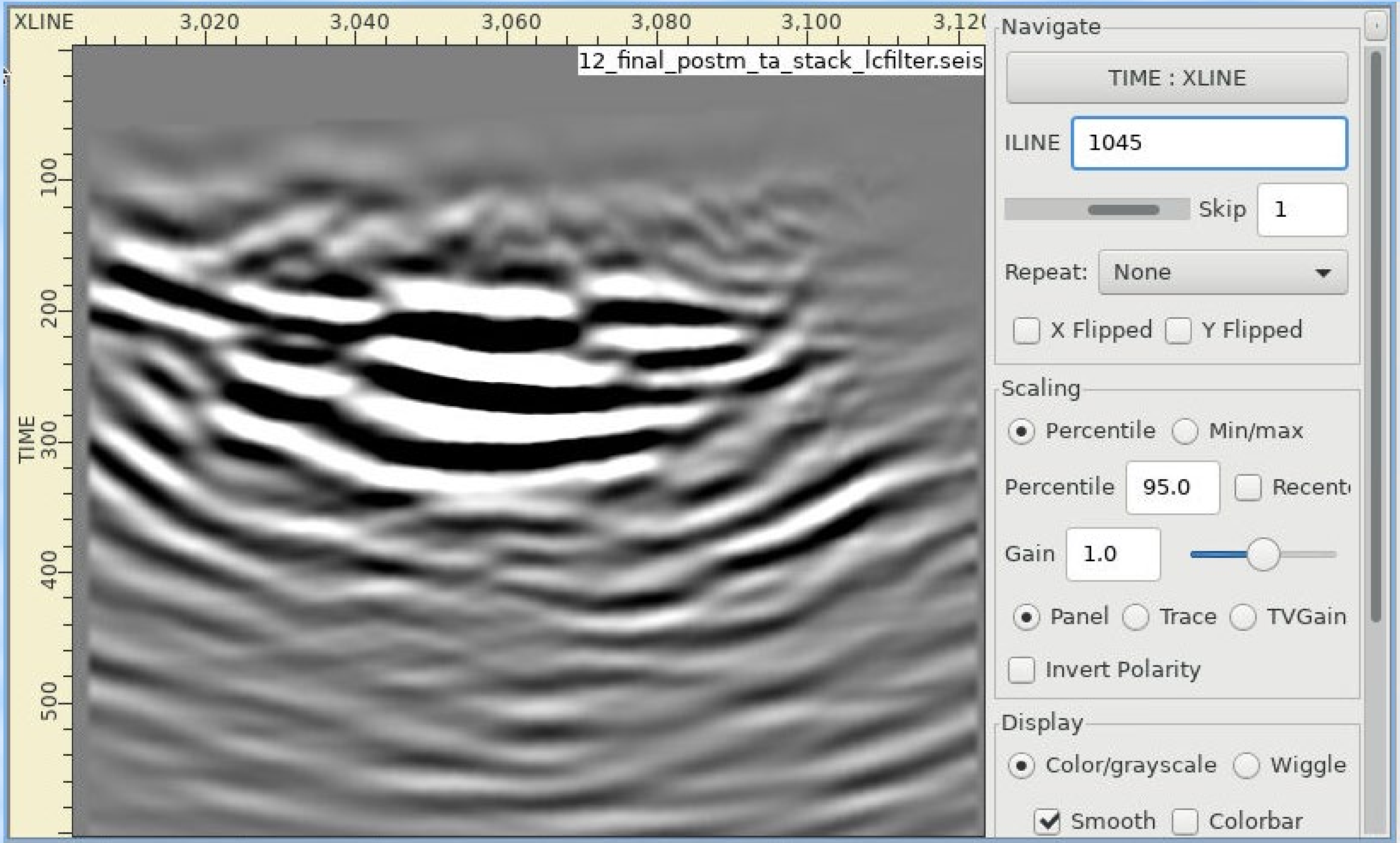
Final Processing: PoSTM Stack - IL 1035



Final Processing: PoSTM Stack - IL 1040



Final Processing: PoSTM Stack - IL 1045



Final Deliverables

- Pickles Butte seismic processing Final Deliverables are shown below:

- CMP_GATHERS
  - TRUE_AMPLITUDE
    - Pickles_Butte_Final_True_Amplitude_CMP_Gathers.segy 506M
- GEOTOMO_VELOCITY
  - Pickles_Butte_GeoTomo_Velocity.segy 3312K
- PoSTM_STACK
  - AGC
    - Pickles_Butte_Final_PoSTM_AGC_Stack.segy 4M
    - Pickles_Butte_Final_PoSTM_AGC_Stack_90_perc_velocity.segy 4M
  - TRUE_AMPLITUDE
    - Pickles_Butte_Final_PoSTM_True_Amplitude_Stack.segy 4M
    - Pickles_Butte_Final_PoSTM_True_Amplitude_Stack_90_perc_velocity.segy 4M
- STACK
  - AGC
    - Pickles_Butte_Final_AGC_Stack.segy 5M
  - TRUE_AMPLITUDE
    - Pickles_Butte_Final_True_Amplitude_Stack.segy 5M

Conclusions

- Pickles Butte seismic surveys was processed through time migration.
- Data was clean as far as environmental noise is concerned but it had strong surface waves.
- Clean data enabled good First Break (FB) picks and that is important for refraction Tomography.
- Denoising goal was to attenuate surface waves.
- SC Decon improved resolution of the data.
- Residual statics improved continuity of the data.
- Both Kirchhoff PoSTM and PSTM were tested. PoSTM results were better.

Appendix B

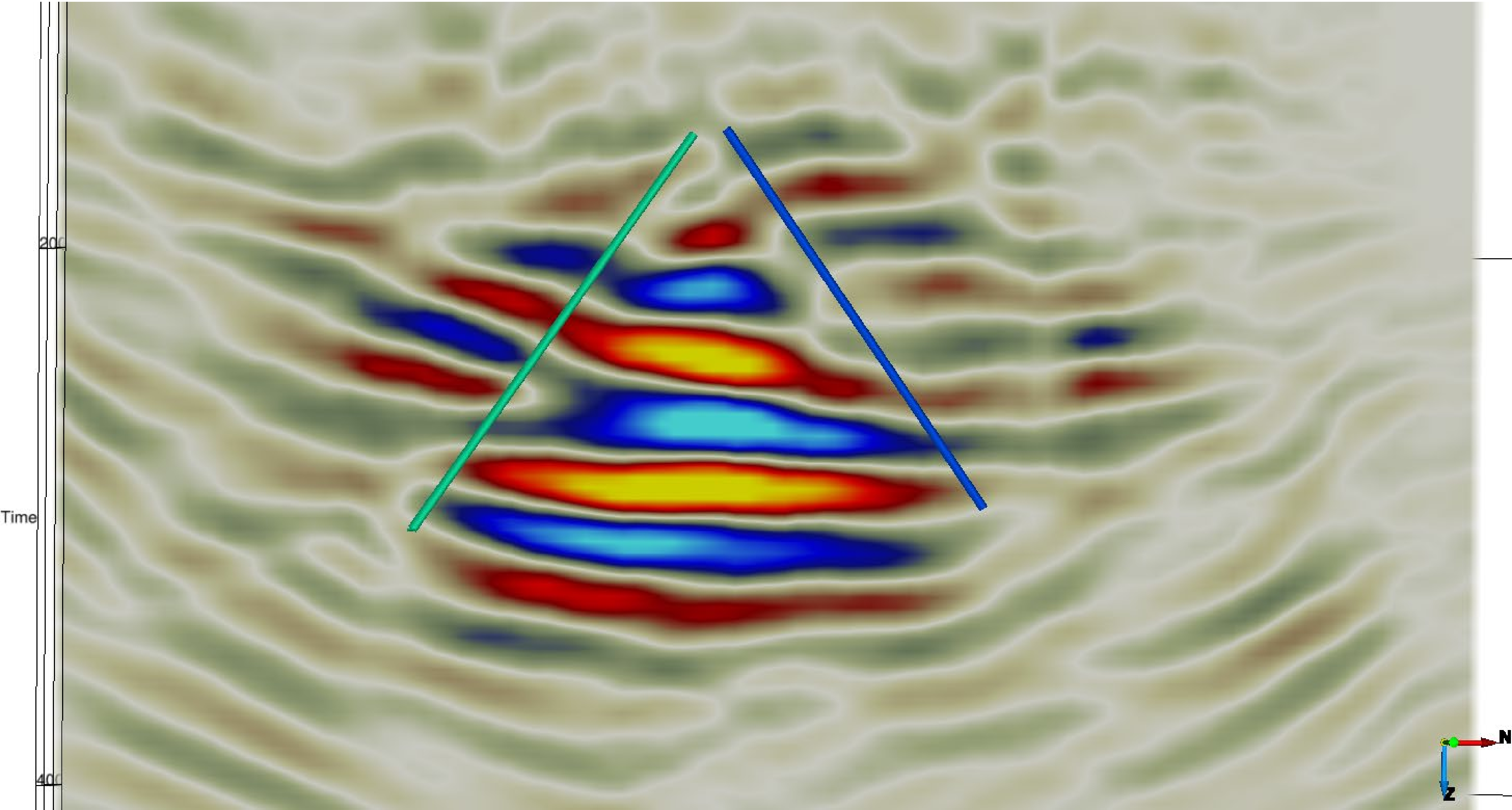
True Amplitude Inline Snapshots With Fault Picks

Pickles Butte 3D Seismic Survey Report
Pickles Butte, Idaho
Project No. 114-571040-2022

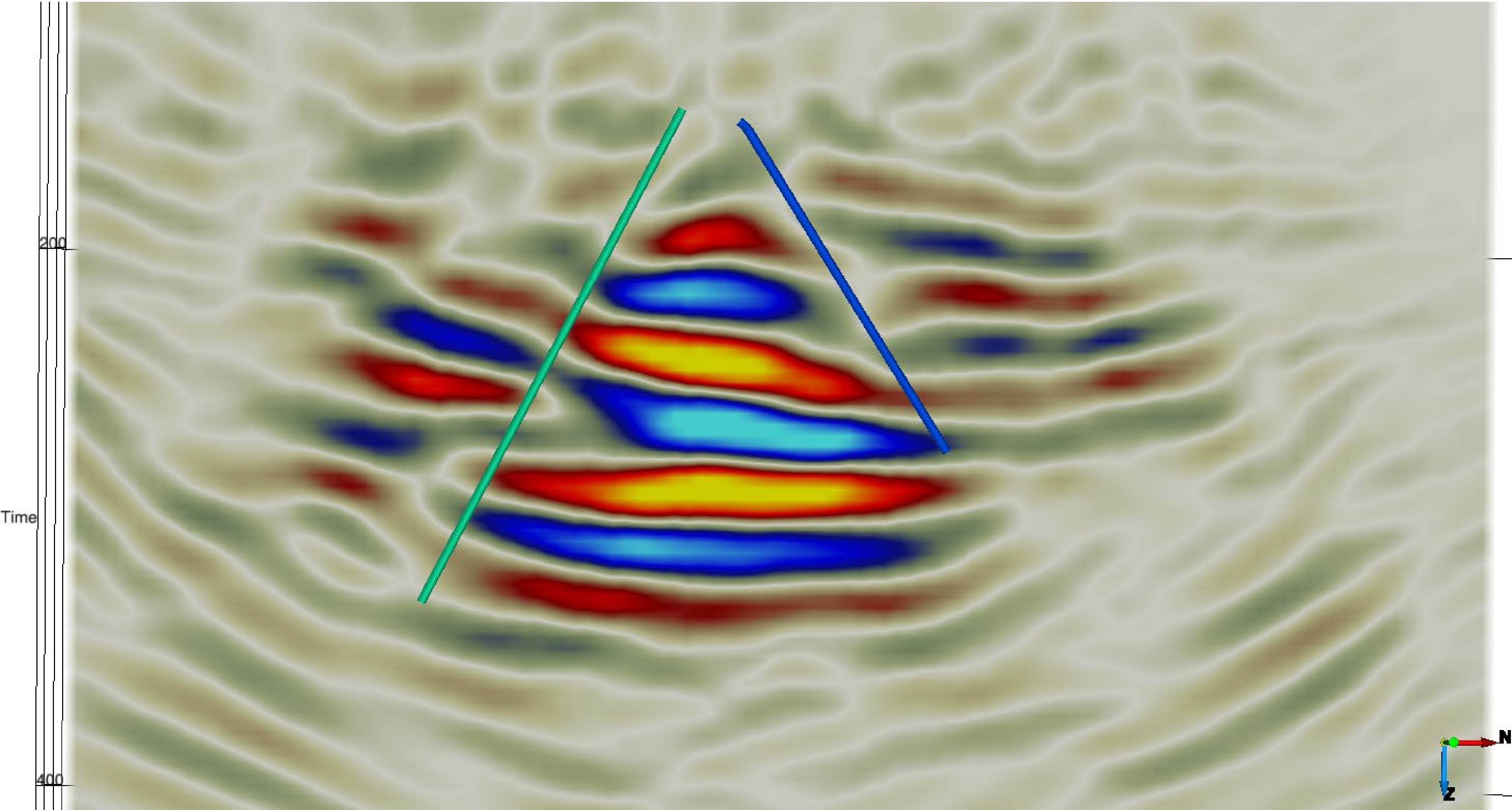
Tetra Tech
350 Indiana Street, Suite 500
Golden, CO 80401

(303) 217-5700
tetratech.com

Inline 1033



Inline 1036



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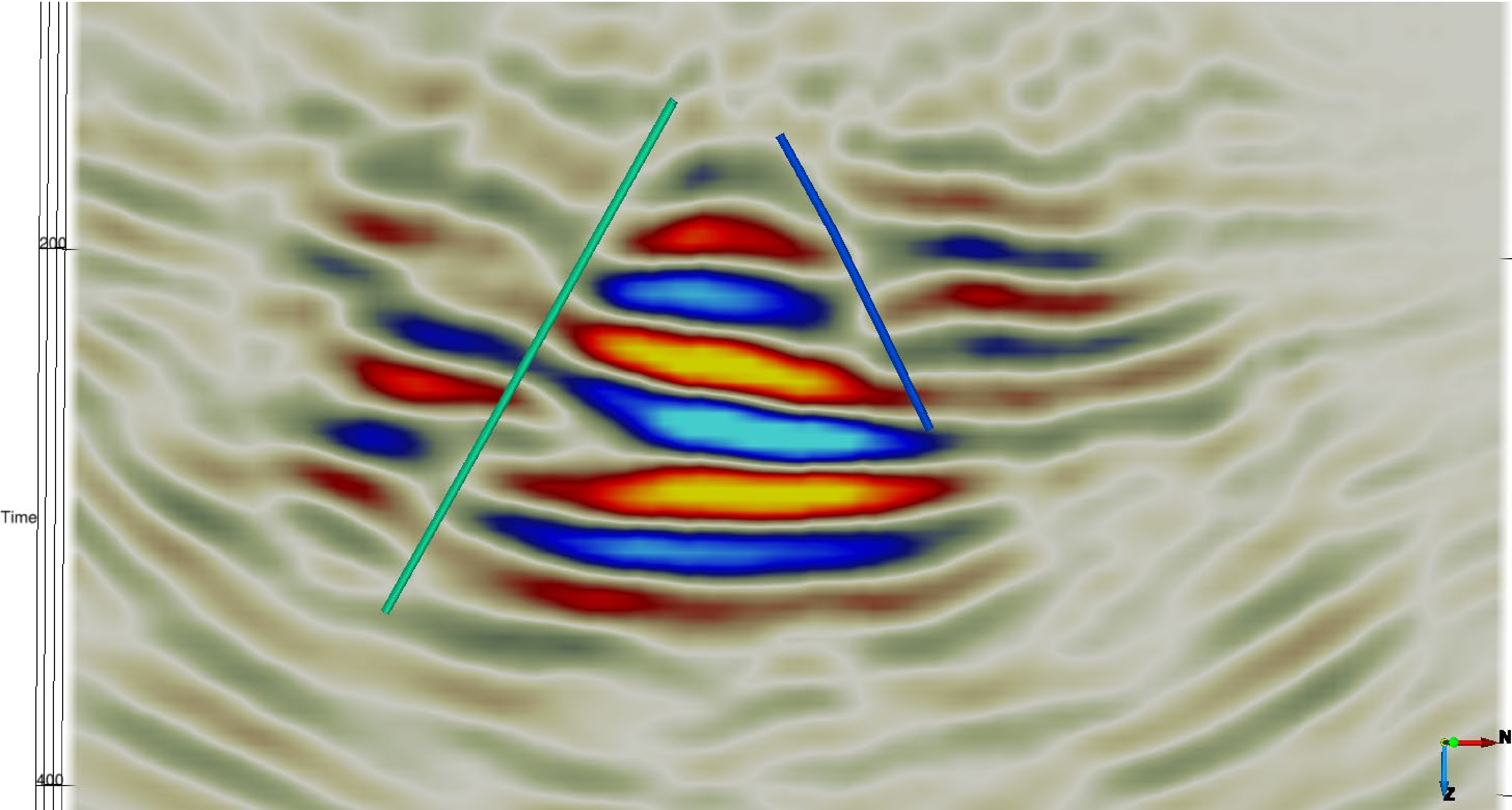

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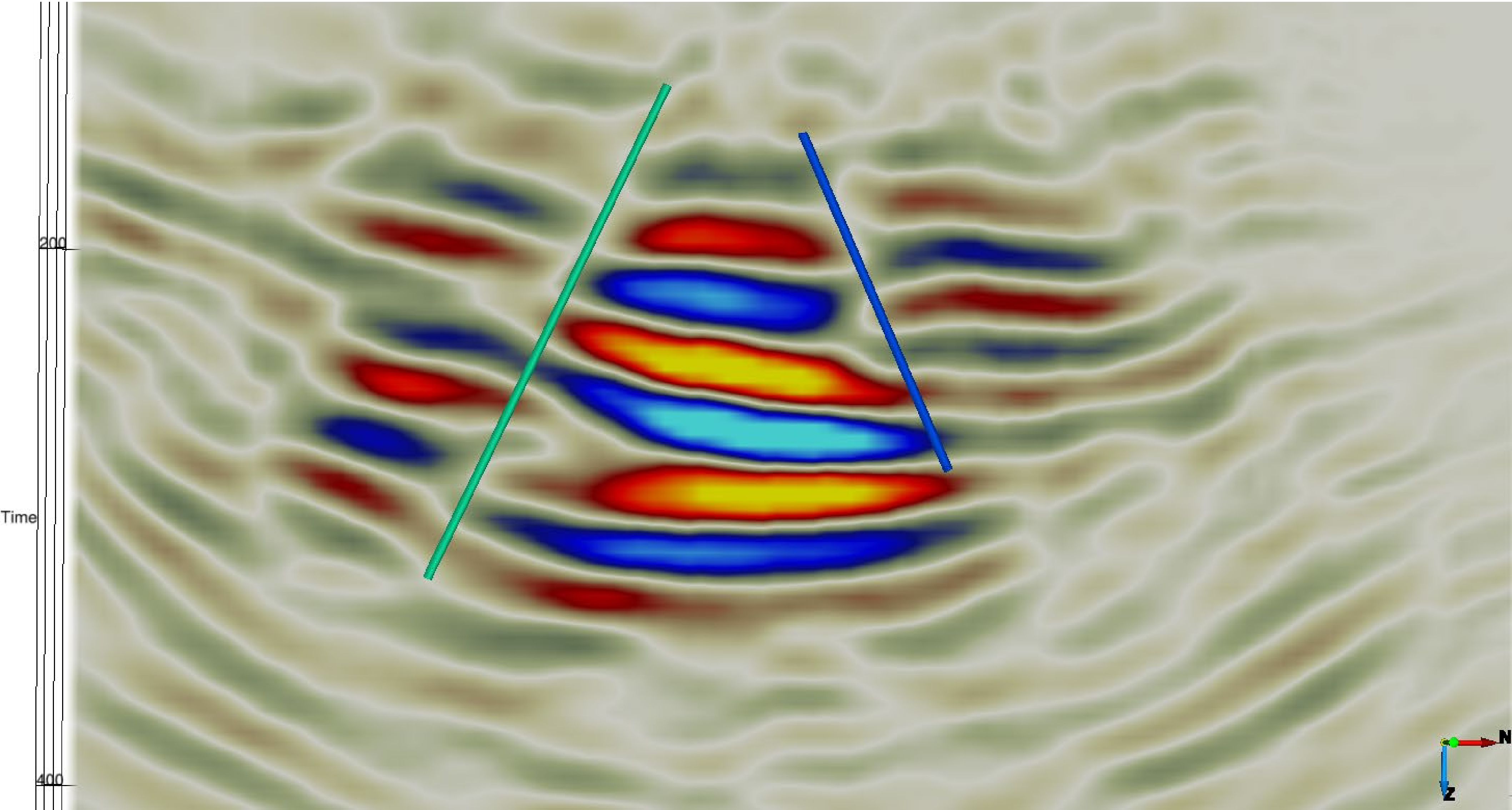

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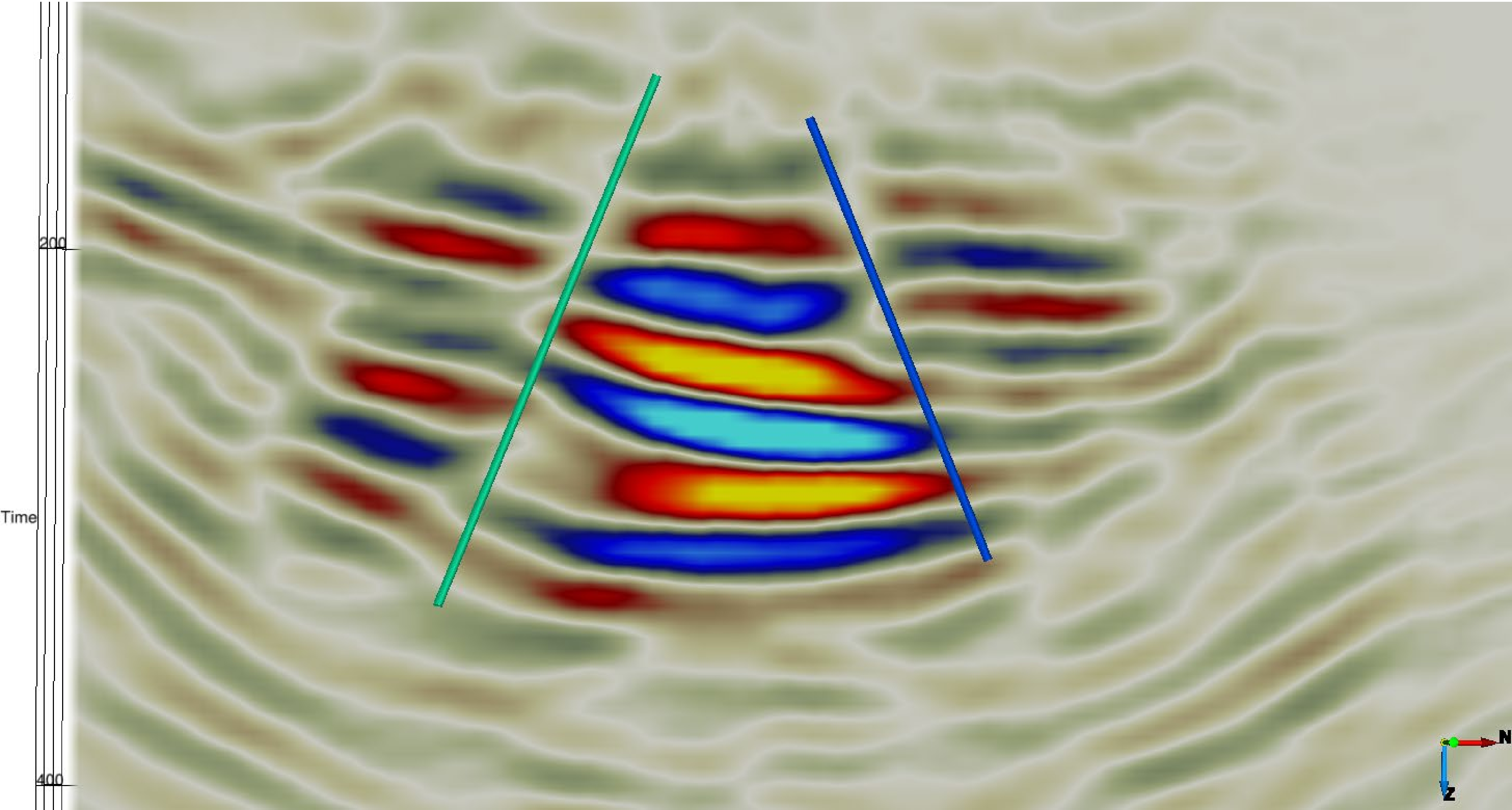
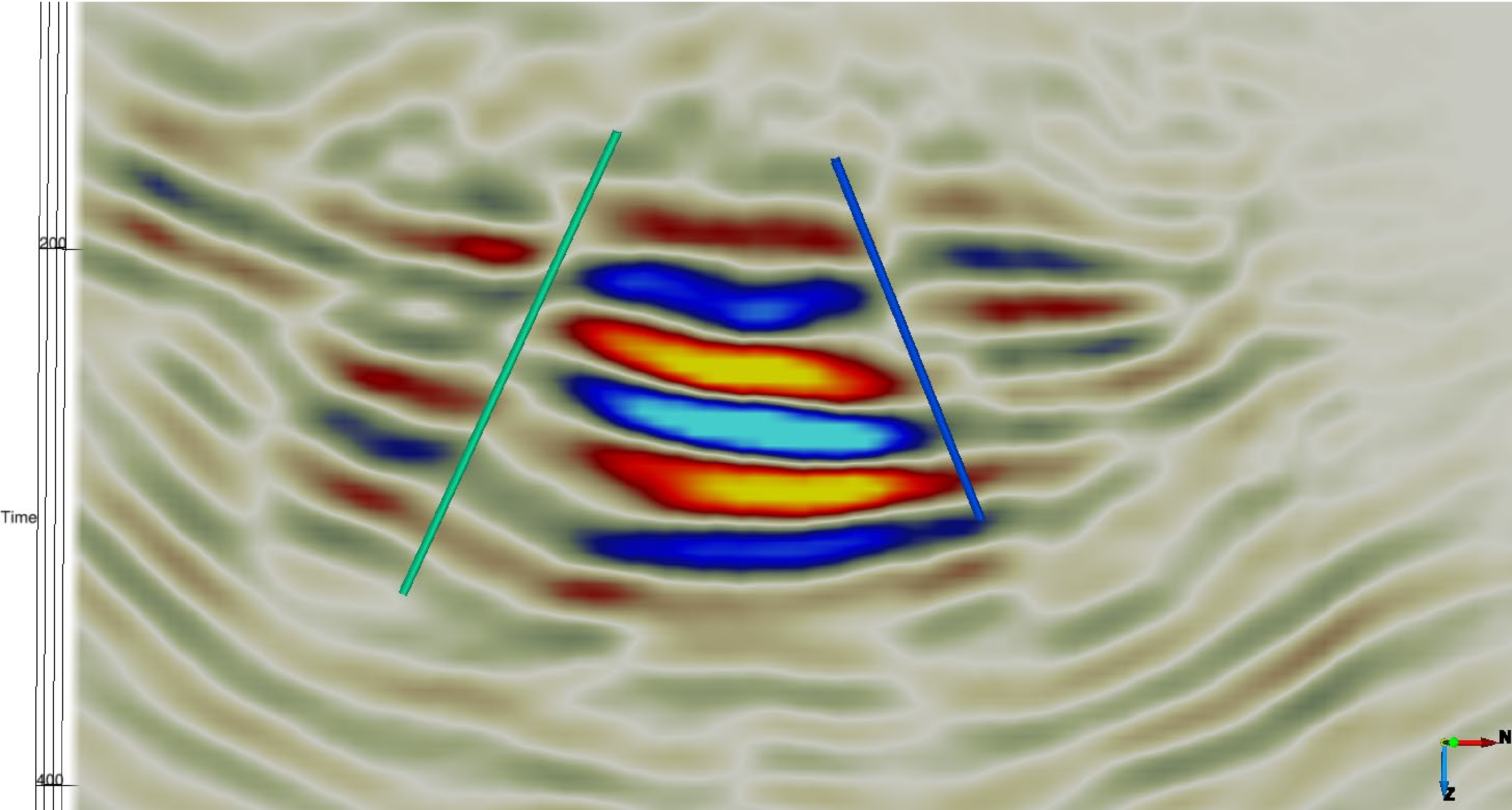
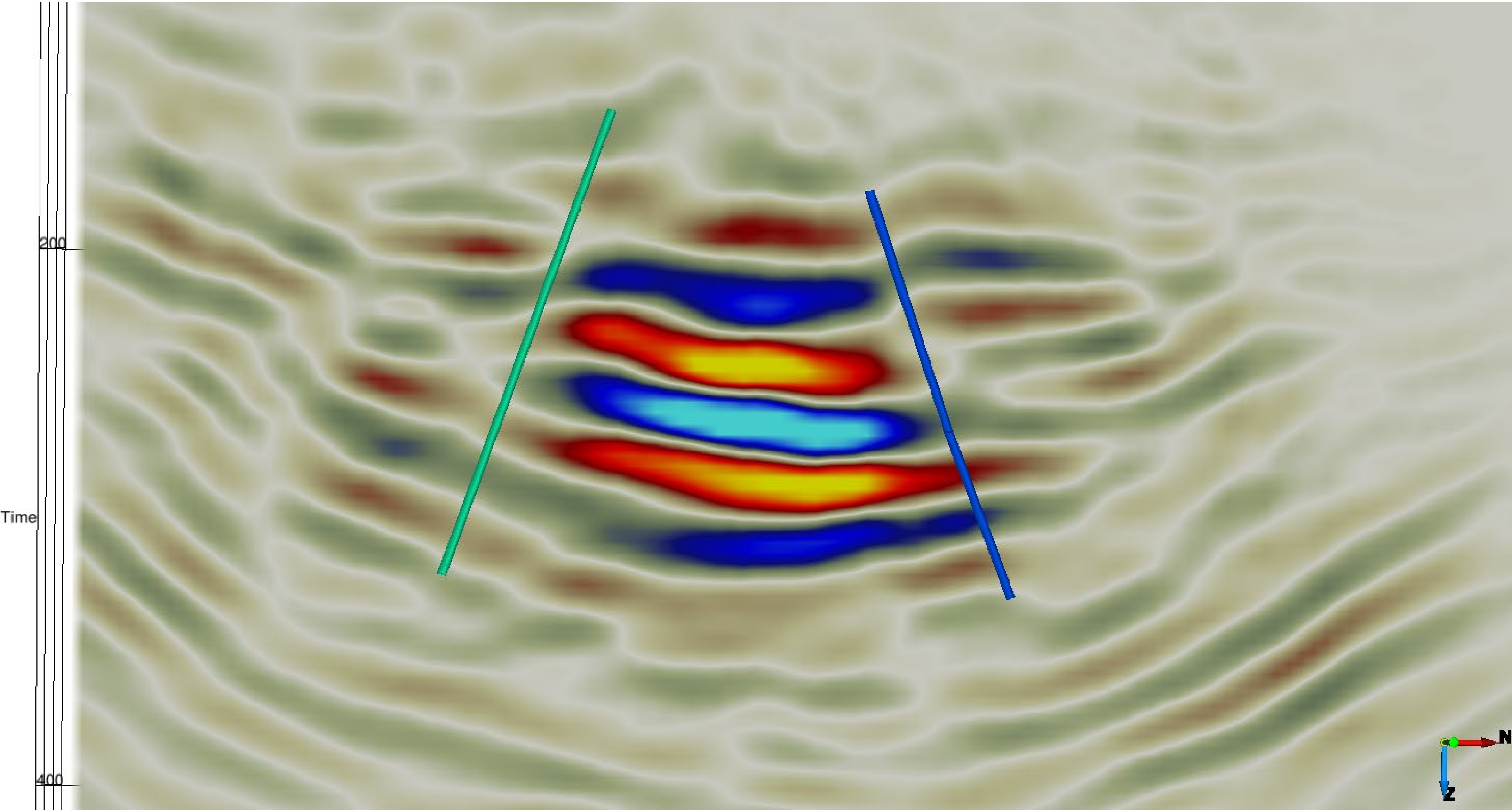


Inline 1045



Inline 1048



Inline 1053