Underground Injection Control – Class VI Permit Application for Hackberry Carbon Sequestration Well No. 001

Cameron Parish, Louisiana

3D Seismic Survey Interpretation Report

January 2024

I, Charles Joel Luckow, certify that the 3D seismic evaluation discussed in the following report was prepared by me or under my direct supervision and that the information and analyses presented herein are true and accurate to the best of my knowledge.

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Date Signed: January 19, 2024

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Overview of 3D Seismic Survey

Two 3D seismic volumes were licensed by the Hackberry Carbon Sequestration (HCS) in the Hackberry Sequestration Project area. First, to the east, the "Hackberry" volume of the SEI Alligator Cove was used, as shown in Figure 1. To the west, the "Seitel Black Bayou seismic volume was used as shown in Figure 2. The two surveys slightly overlap. These two primary volumes were used for 3D seismic interpretation in this study.

The years of Seitel Black Bayou seismic acquisition and processing are not clear. The SEI Hackberry 3D survey was acquired by GRANT Geophysical Corp. between August and October 1995. The parameters and layout are described in Figure 3. Given the very shallow water environment, the seismic source was dynamite with holes drilled down to 120 feet to position the seismic energy below the mud and weather layers.

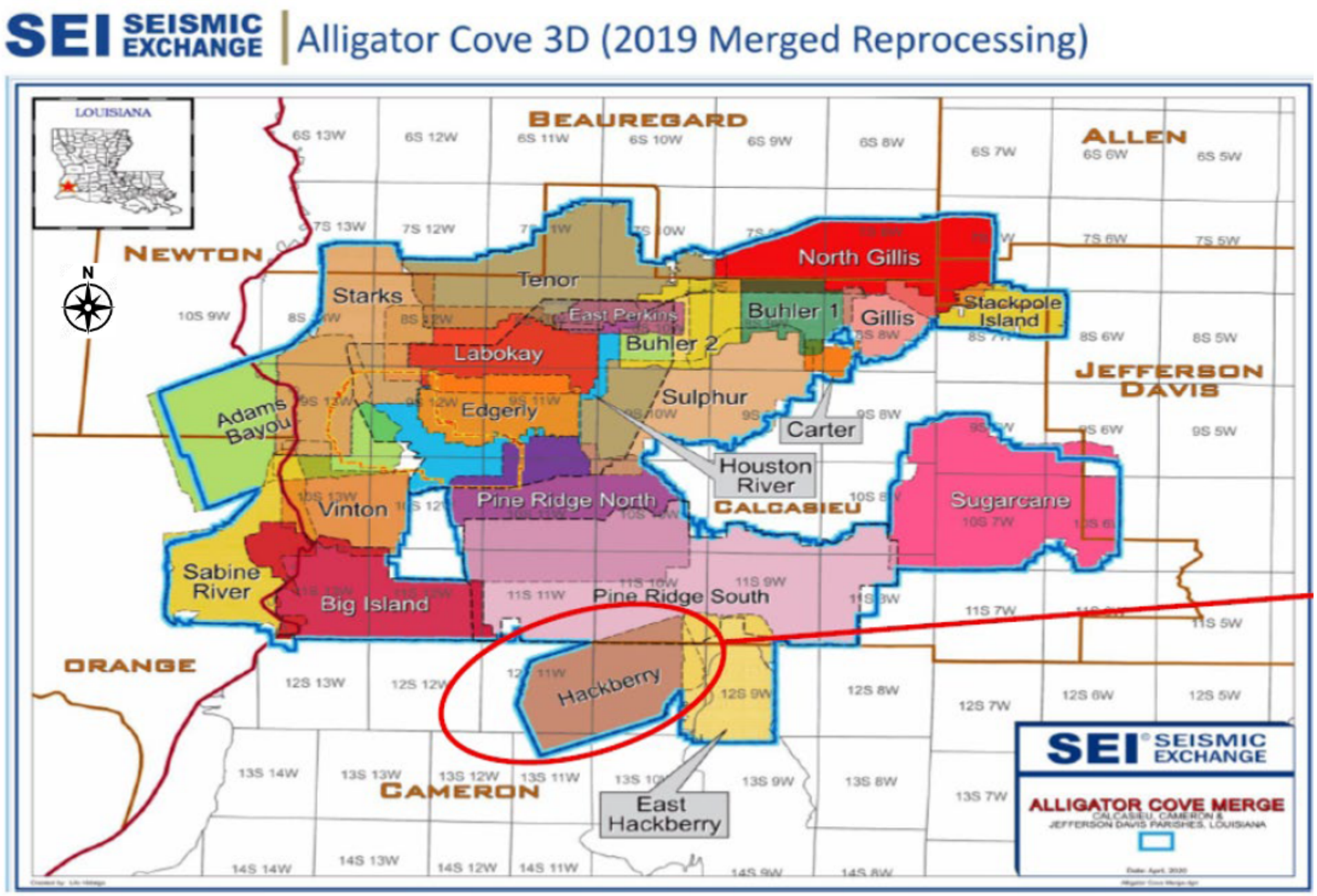


Figure 1 – The location of the Hackberry portion of the greater SEI Alligator Cove merge 3D seismic surveys.

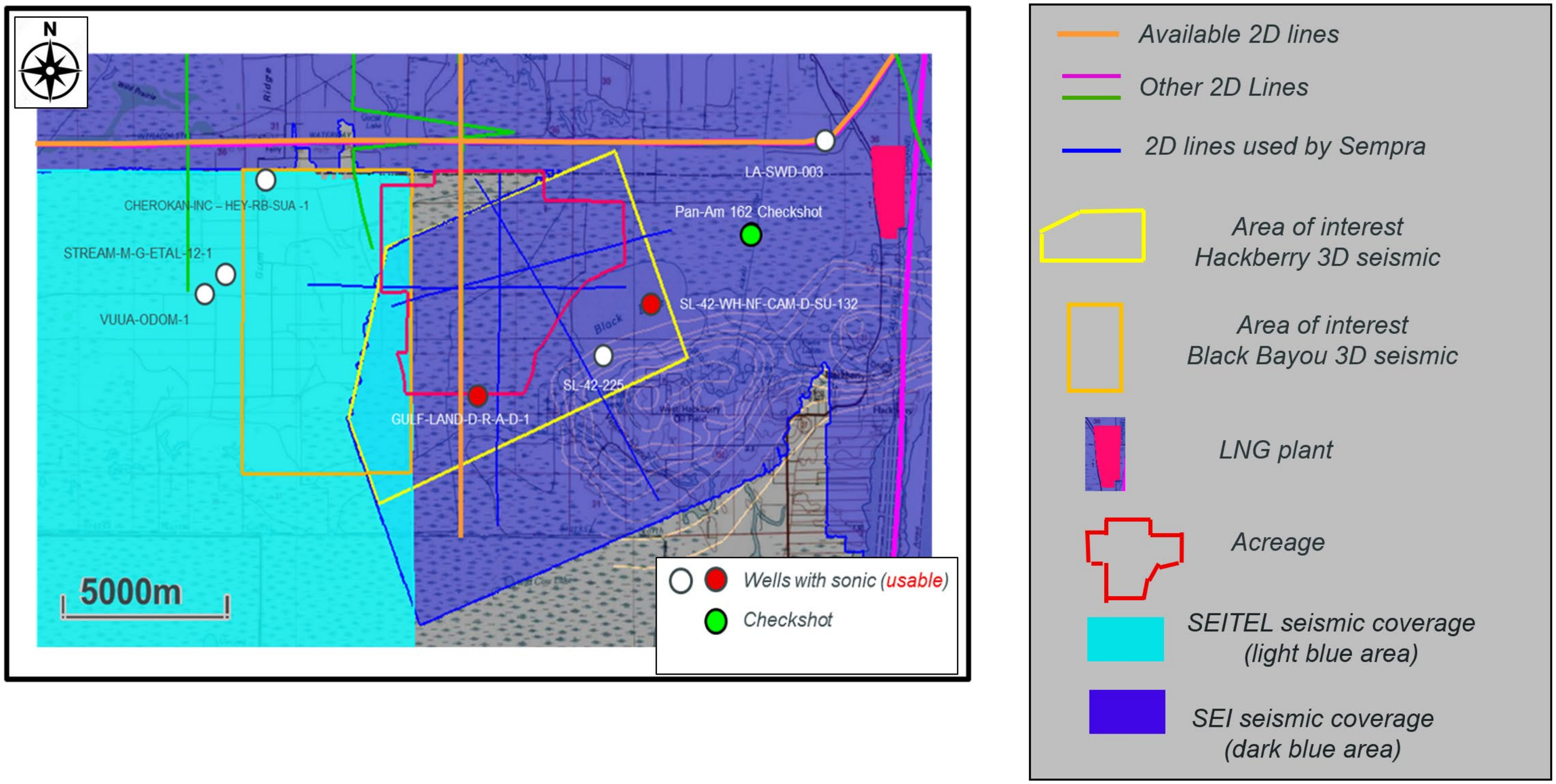
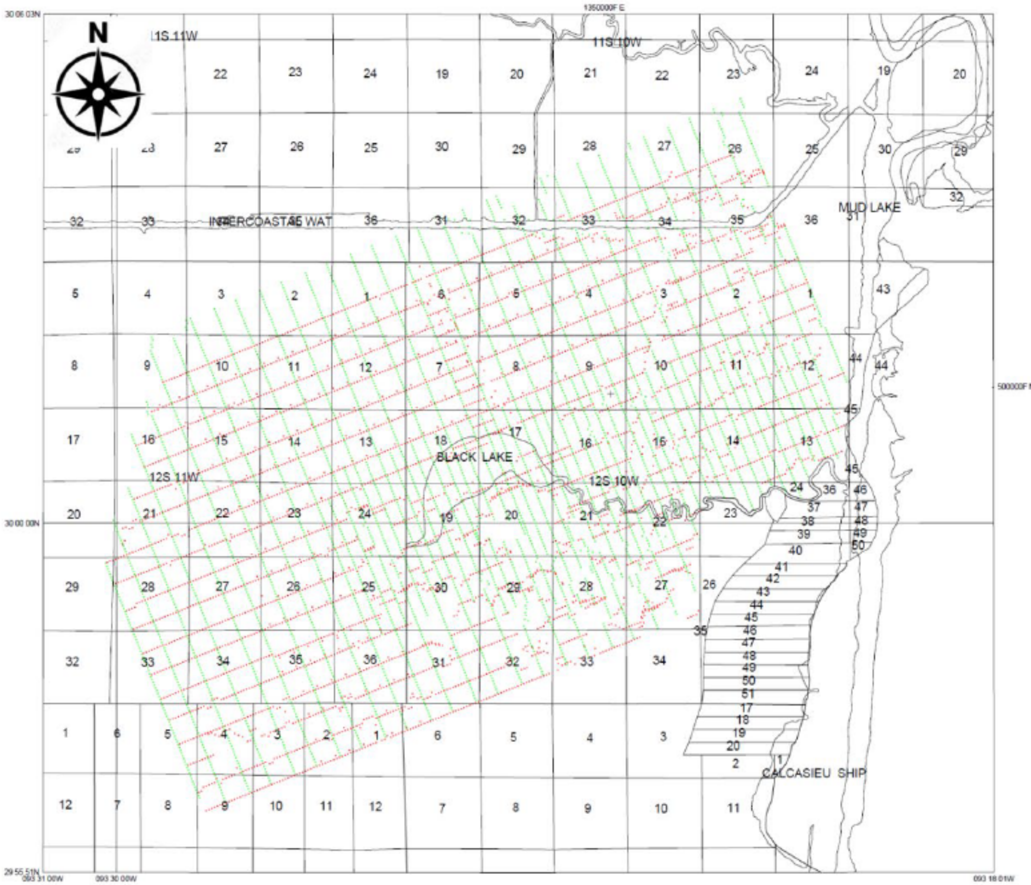


Figure 2 – The relative locations of the SEI Alligator Cove survey (yellow box), the Seitel Black Bayou survey (orange box), and the Sempra acreage (red outline). The licensed portions of data are smaller than their associated master surveys (cyan and dark blue shaded areas).

Hackberry



HACKBERRY 3D

HIGH LAND ACQUISITION SUMMARY

CONTRACTOR:	Grant Geophysical Corp.	**PROGRAM DATES:**	06AUG95 - 31OCT95
FOLD:	30	**PROGRAM SQ. MI.:**	59.2579
MAX FAR OFFSET:	30976 (ft.)	**SOURCE LINE ORIENT:**	SW - NE
BIN DIMENSIONS:	110 x 110 (ft.)	**RECEIVER LINE ORIENT:**	SE - NW

ENERGY SOURCE DESCRIPTION

TYPE :	Pentolite
SOURCE INTERVAL (ft.) :	220
LINE SPACING (ft.) :	1760
CHARGE SIZE (lbs.) :	11
DEPTH (ft.) :	120
SOURCE PATTERN :	Cross-Line
ARRAY DESCRIPTION :	1 charge per shot point. 8 SPs per rack.

RECEIVER DESCRIPTION

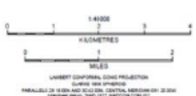
TYPE :	Geophone
STATION INTERVAL (ft.) :	220
LINE SPACING (ft.) :	1760
LINE LENGTH (ft.) :	29700
NUMBER OF LINES :	10
NUMBER OF STATIONS PER LINE :	192
ARRAY DESCRIPTION :	6 geophones bunched

RECORDER DESCRIPTION

TYPE :	SGR
SAMPLE RATE (ms.) :	2
RECORD LENGTH (sec.) :	12
TOTAL SEISMIC CHANNELS RECORDED :	1920
LO-CUT FILTER (Hz.) :	8
HI-CUT FILTER (Hz.) :	200 Hz
TAPE FORMAT :	SEG-Y

POSITIONING DESCRIPTION

METHOD :	DGPS
PROJECTION :	StatePlane Louisiana South FIPS 1702
DATUM :	NAD 1927



SEI

Hackberry 3D

Source (red) - Receiver (green)

Coverage Map

Date : September 30, 2008

Figure 3 – SEITEL Black Bayou seismic acquisition layout and parameters.

The received seismic volumes were reprocessed in 2019 using a PreStack Time Migration (PSTM) workflow. For PSTM, the data are considered good quality with the ability to clearly see most faults and the reflections are generally continuous and coherent. The amplitude spectrum is in the 10 to 20 hertz (Hz) part of the frequency band for both surveys.

Well to Seismic Calibration and Depth Prediction

No publicly available checkshots or VSP surveys are known to exist in the seismic survey area. The Pan Am 162 well (Serial No. 124348) checkshot was purchased and is the only checkshot in the vicinity of the SEI Alligator Cove seismic survey (Figure 1-16). The Pan Am 162 well is approximately 1.8 miles to the east of the eastern edge of the SEI seismic survey. The checkshot was used for two purposes: 1) the checkshot was compared with PSTM stacking velocities and deemed similar and 2) the checkshot was used as a time-depth relationship, from which a velocity cube was created to depth convert the SEI and Seitel seismic cubes. Because there is only one well that can be used for depth conversion, a simple, pragmatic approach was used. This approach used the velocity values at each depth of the checkshot and projected the values out in 3D, thus creating an entire cube of checkshot-derived values (3D velocity cube that covers the areas of both SEI and Seitel surveys) as shown in Figure 1-4.

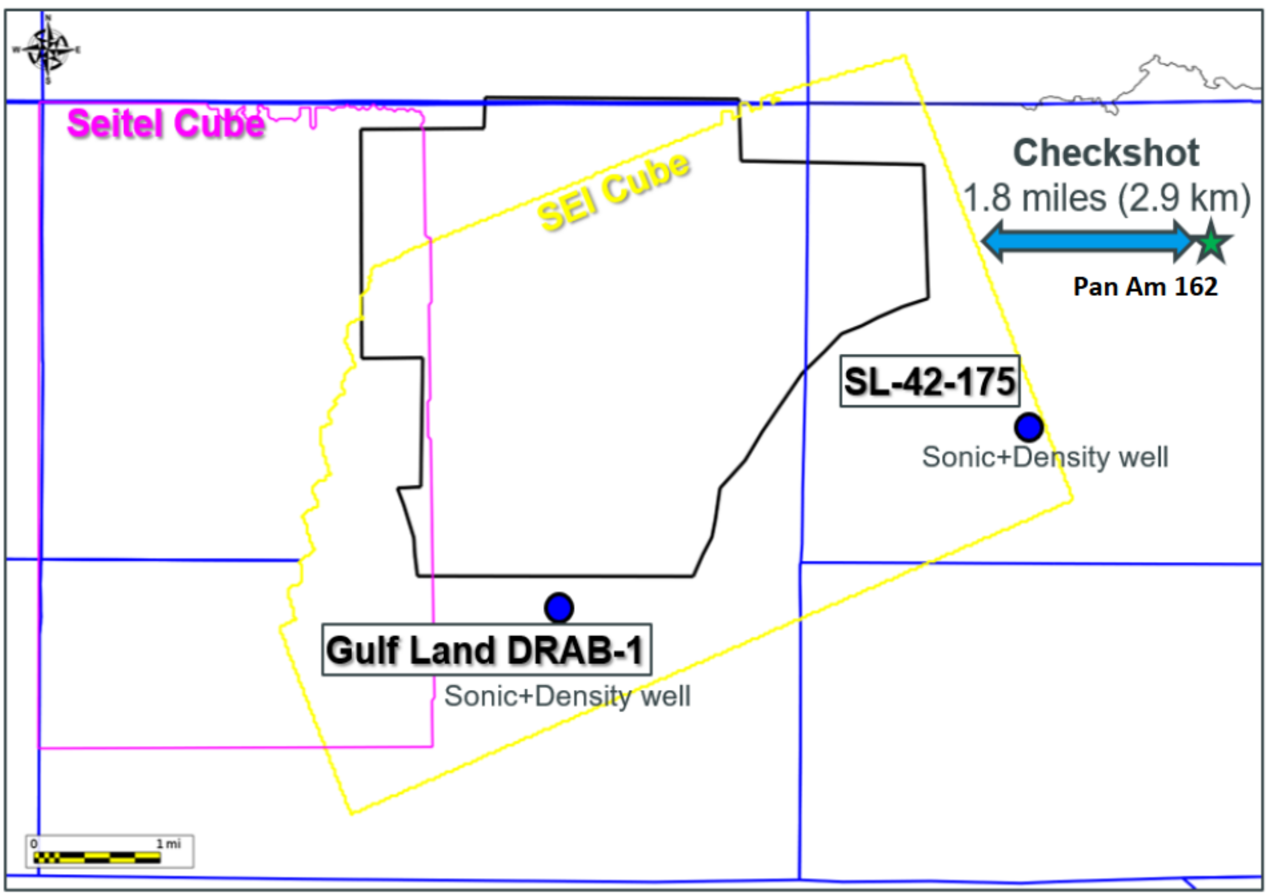


Figure 4 – The Pan Am 162 checkshot well (shown as green star) with respect to the two seismic surveys

Continuous, total-well-length sonic and density logs were not available in the well log data set purchased from TGS to make acoustic impedance logs for synthetic generation. Spontaneous Potential (SP) and Gamma Ray (GR) logs were used as proxies or pseudo-acoustic impedance logs. These pseudo-impedance logs were convolved with a ricker wavelet, producing a synthetic seismogram. The wells used for tying the synthetics are Gulf Land DRAB-1, Gulf Land DRAA-28, and SL-42-175. Synthetic seismograms proved moderately helpful in tying the wells to seismic, but displaying the SP and GR curves over the seismic improved the tie. The matching of the visual seismic packages with the SP and GR curves was ultimately used to tie, as close as possible, the seismic reflections and the well markers picked on lithology events (Figure 5).

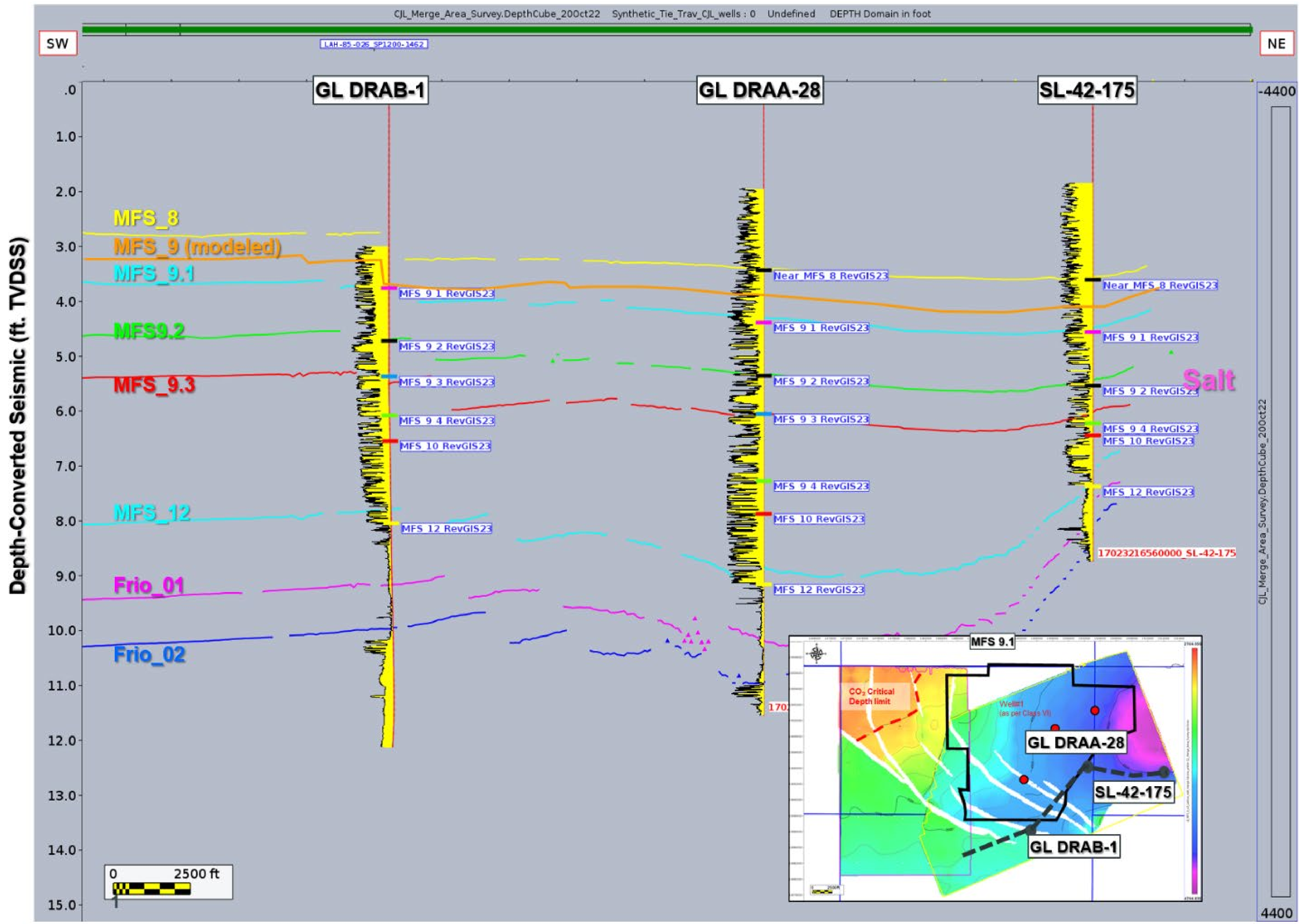


Figure 5 – Depth-converted seismic traverse between key wells. GR and SP curves match major seismic reflection events, supporting the robustness of the time-depth conversion method used.

Seismic Interpretation

Interpretation Software

Total Energy's proprietary (in-house) seismic interpretation software called Sismage was used to interpret both faults and horizons on the previously described 3D seismic volumes.

Fault Interpretation

The most well-imaged aspect of both seismic cubes are the faults. A dominant signal of faulting was interpreted with a combination of inline-crossline, time slice, and horizon-local extraction-based interpretations (Figure 1-6). Additionally, fault edge detection seismic attributes were used to detect faults in the map-view.

Once the faults were interpreted, maps were created at key intervals that showed the fault gap for those intervals (Figures 1-7 and 1-8). Fault throws varied from roughly 50 to 650 ft, depending on the fault. Most faults strike northwest to southeast, and their development is interpreted to be directly induced by the local Hackberry salt diapir movements. The faults form a graben structure, rooted in the deep salt, and dip both northeast and southwest. The fault throws decrease from the MFS12 up to the MFS9 and above, which shows that fault activity is decreasing with time (syntectonic fault system). To the northeast of the SEI survey, faults are non-existent (Figure 1-9; C-C').

The 3D evaluation better defined the faults originally identified in the 2D survey to the south-southwest of the HCS property. A potential east-west striking normal fault was proven not to exist. The 3D interpretation provides clear affirmation that faults do not exist across the project area.

[redacted]

Figure 6 – Fault edge detection maps at varying intervals in the Hackberry Project area.

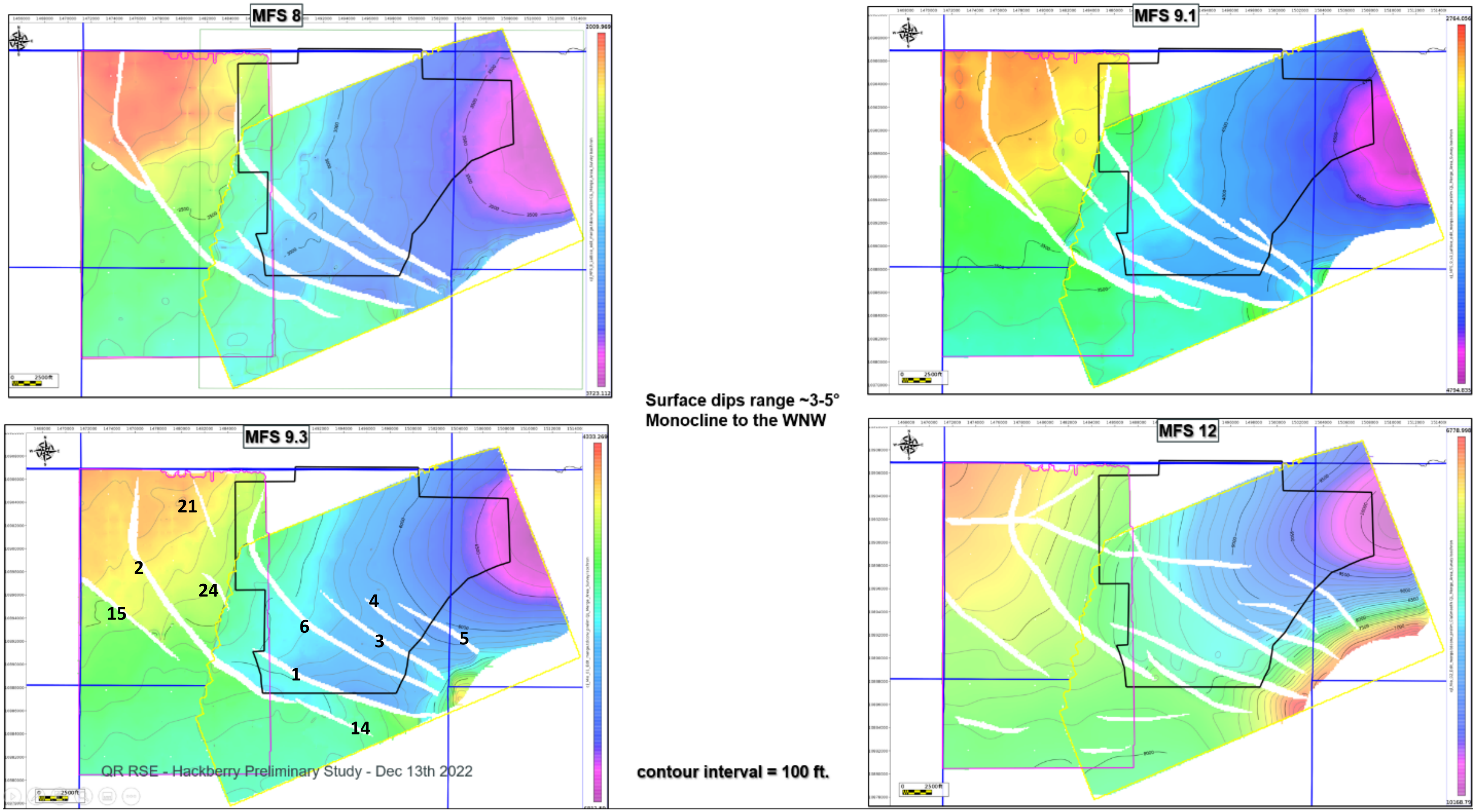


Figure 7 – Maps of faulting at key stratigraphic intervals. The fault numbers are also shown as an example on the MFS 9.3 map.

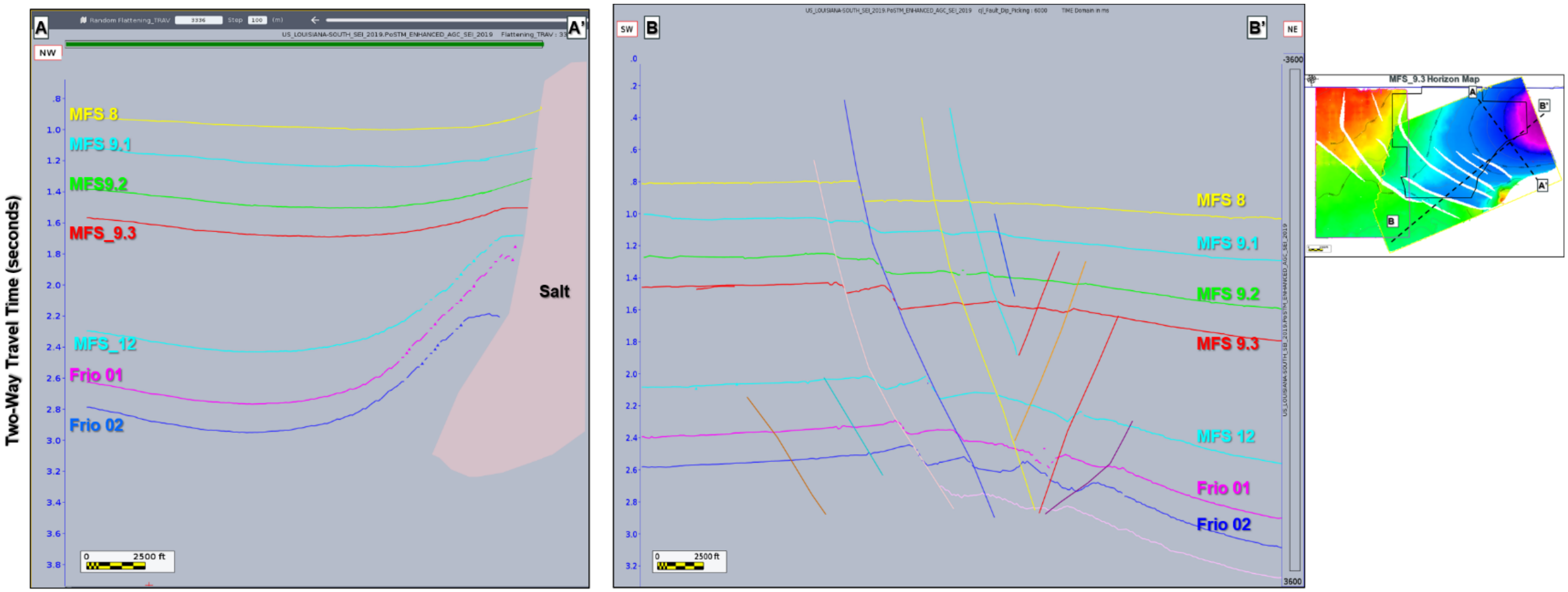


Figure 8 – Two cross sections of the subsurface structure. A-A' shows a southeast-trending traverse with little faulting, but the salt body can be seen. B-B' is a NE-trending traverse across all the major faults in the area, showing the extensional, salt-derived graben feature

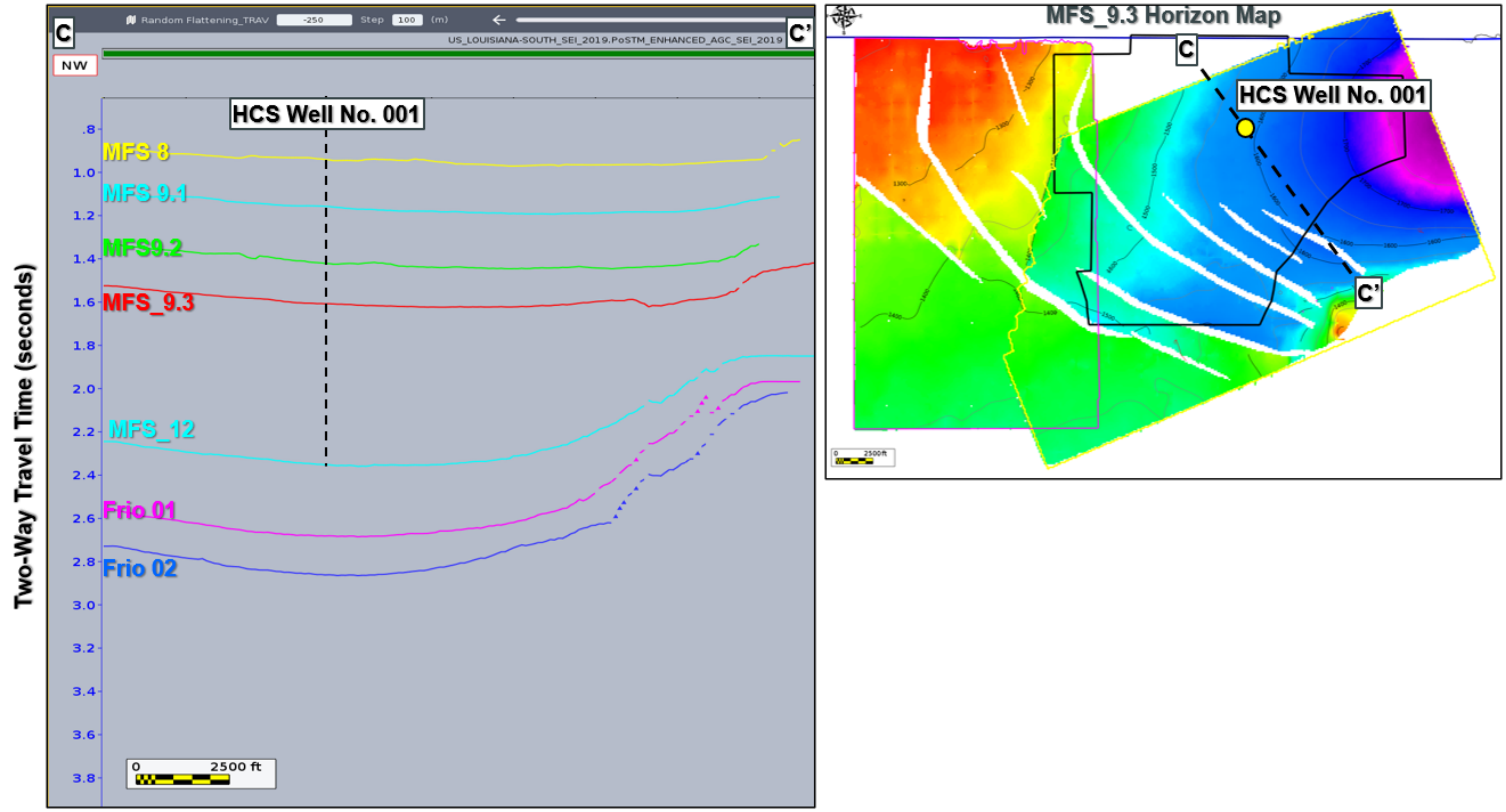


Figure 9 – A structural cross section C-C' that shows the notional area of the HCS Well No. 001 injection well. Note the lack of faulting in this area.

During the timeframe of this study, a large, east-west striking, normal fault was noted to possibly exist at the northern extent of the Sempra acreage, based on 2D seismic interpretation. With the licensing of the PSTM data in 2022, no major east-west striking fault was observed or interpreted.

Horizon Interpretation

Structural interpretation of seismic reflections differentiating layers of sedimentary rock was generally straight forward and considered to be of high confidence especially regarding the section from MFS 8 TO MFS 12. Just below the MFS 12 is the Anahuac shale, which has a distinctive seismic signature characterized by fewer seismic reflection cycles. The PSTM seismic quality is not high enough to confidently discern lateral sand continuity of the injection layers, nor differentiate between shale and sand layers, for much of the potential injection section. Horizons interpreted for this study were:

- MFS 8
- MFS 9 (Amphistegina B) – a surface created/modeled between MFS 8 and MFS 9.1
- MFS 9.1
- MFS 9.2
- MFS 9.3
- MFS 12 (Anahuac Shale top)
- Two sub-MFS 12 horizons (Frio_1 and Frio_2)

The deeper horizons such as the Frio, MFS 12, and MFS 9.3 are the most seismically visible and easiest to interpret, especially because of their continuity. Shallower horizons were more difficult because there was no diagnostic seismic character (no clear seismic packages). The SEI and Seitel seismic surveys were acquired/processed independently and with different processing sequence and thus, a depth-offset seam is present between the surveys. This offset introduces some uncertainty into the horizon interpretation. The above horizons were input for the geologic model but were not used directly. The horizons were bulk shifted slightly up or down to match the interpreted well log markers. Once in alignment, these new shifted surfaces were used as the geologic model input surfaces. An update of the horizons will likely be completed after the Hackberry Carbon Sequestration Well No. 001 is drilled and the well-to-seismic tie completed with new sonic and density logs, along with a potential vertical seismic profile (VSP) survey. At that time, a detailed interpretation update of the key maximum flooding surfaces and base of sand reservoirs will be performed.

A seismic attribute study was conducted from the top of the cubes (very shallow) to MFS 12 to attempt to see evidence for sedimentological features, such as channels, lobes, deltas, and shorefaces. Conventional amplitude extraction, time slices, and spectral decomposition techniques were used to visualize these features. After extensive searching, only sinuous channel features (Figure 1-10) were visible like the one in the MFS 9.2 interval. These features allow an estimation of fairway direction that was used in the geologic model.

[redacted]

Figure 1-10 – Spectral decomposition attribute at the MFS 9.2 surface showing a sinuous feature in the northeastern portion of the SEI Alligator Cove seismic cube.

During the evaluation and interpretation of the PSTM seismic data, a Pre-Stack Depth Migration (PSDM) reprocessing project was launched for a portion of the licensed data with the contractor CGG. Although the PSDM data was not incorporated into this interpretation, the goal is for learnings from this effort be utilized to improve the seismic image, making faults more visible and increasing the regularization of the ultra-shallow section (see better reflection continuity above MFS 8). This reprocessing project took place from July 2022 to March 2023. Key seismic processing flow steps were:

- Elevation statics
- 5D regularization to densify the ultra-shallow section
- Velocity model building
- Tomography / gather flattening
- Demultiple
- Post-processing denoise techniques

3D Seismic Survey Summary

The 3D seismic survey efforts confirmed the interpretations of the geological structure from the original 2D evaluation. The evaluation provided a better understanding of the location of offset faults and proved that faulting does not exist in the project area. No other significant features were identified that would indicate that the interpretation of the lateral continuity of the injection and confining zones has changed.