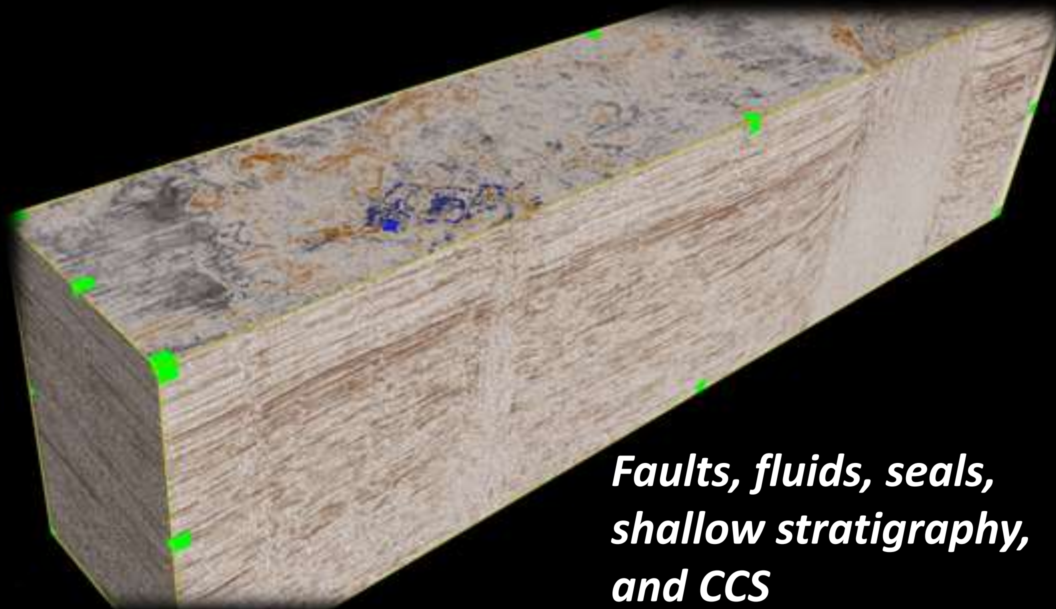
Overburden imaging using high-resolution 3D seismic: perspectives from 3 surveys in the Gulf of Mexico using P-cable technology

Dr. Tip Meckel
Research Scientist
TX BEG-GCCC

Tuesday, August 5
IEA-GHG Network Meeting
Morgantown, WV

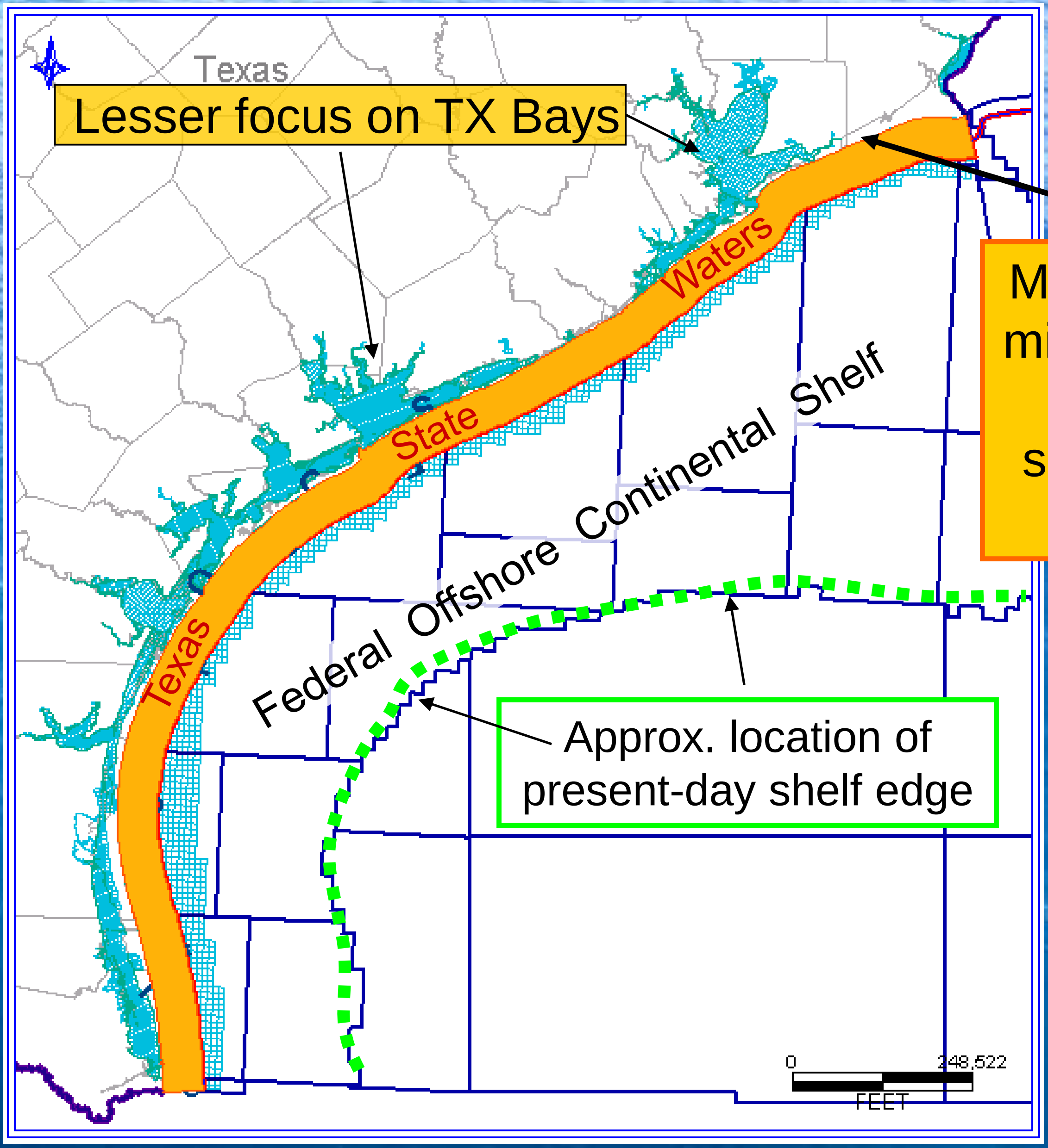


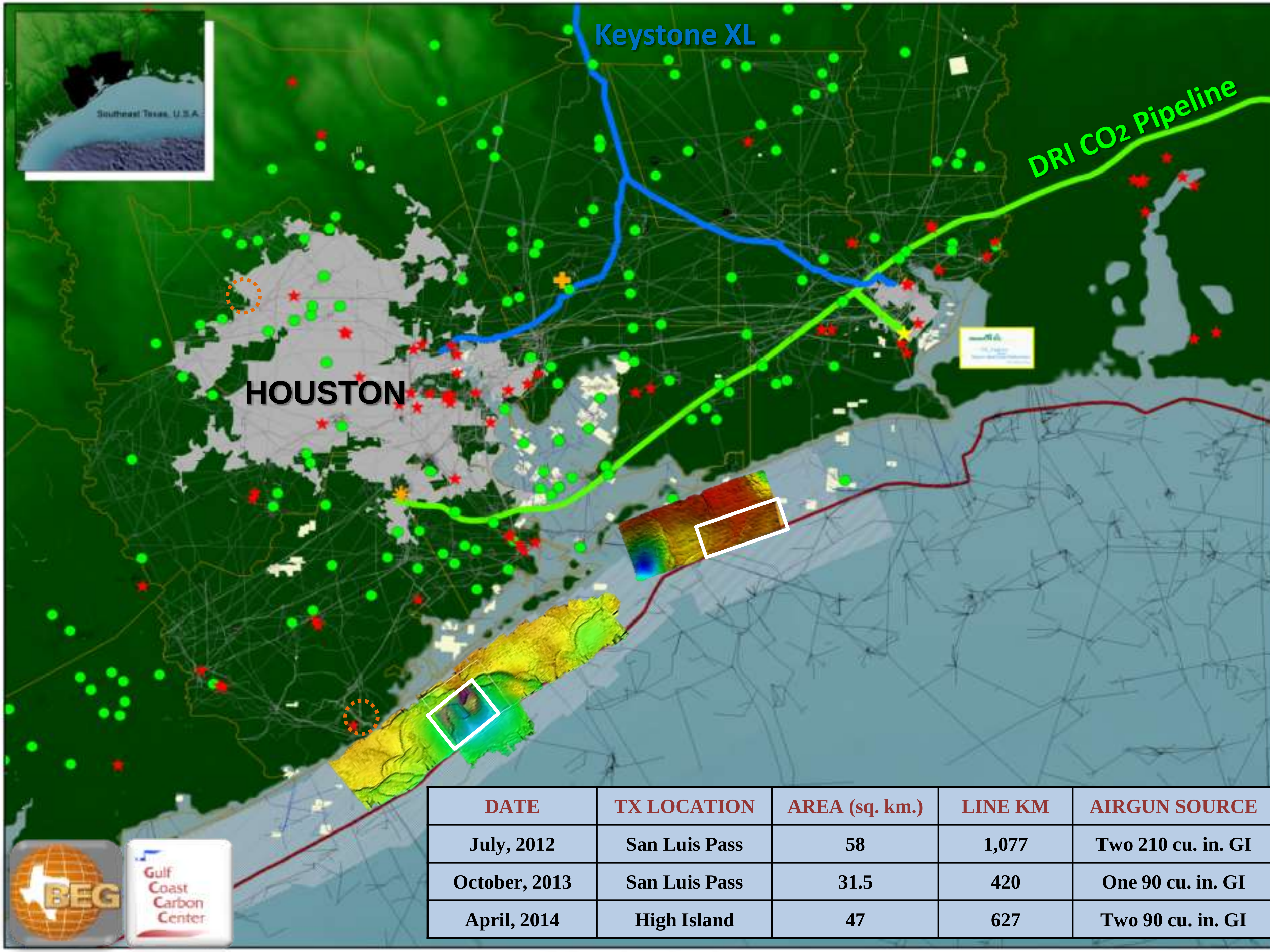
Faults, fluids, seals, shallow stratigraphy, and CCS

Primary Study Objectives

- **Refine Miocene capacity estimates in TX state waters.**
  - **Mapping, Formation Properties Database**
- **Identify regional CO_2 'plays' for prospective storage.**
- **Evaluate regional containment potential.**
  - **seal integrity; structural compartmentalization.**
- **Identify specific prospective 30 Mt+ site(s).**
- **Collect additional data to reduce barriers to near-term utilization of those sites.**
  - **P-Cable high resolution 3D seismic surveys**

Focus on innermost shelf: Texas State Waters

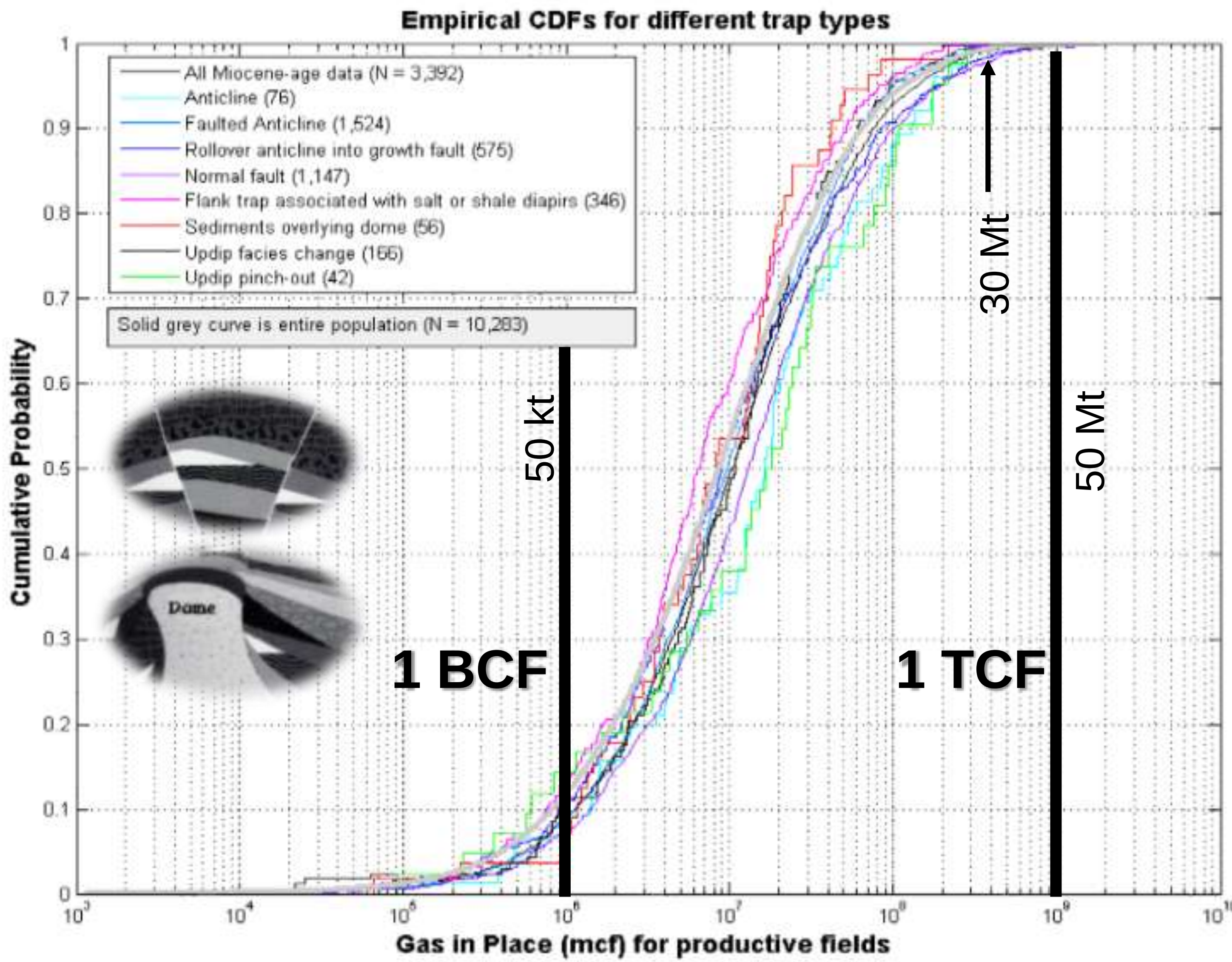


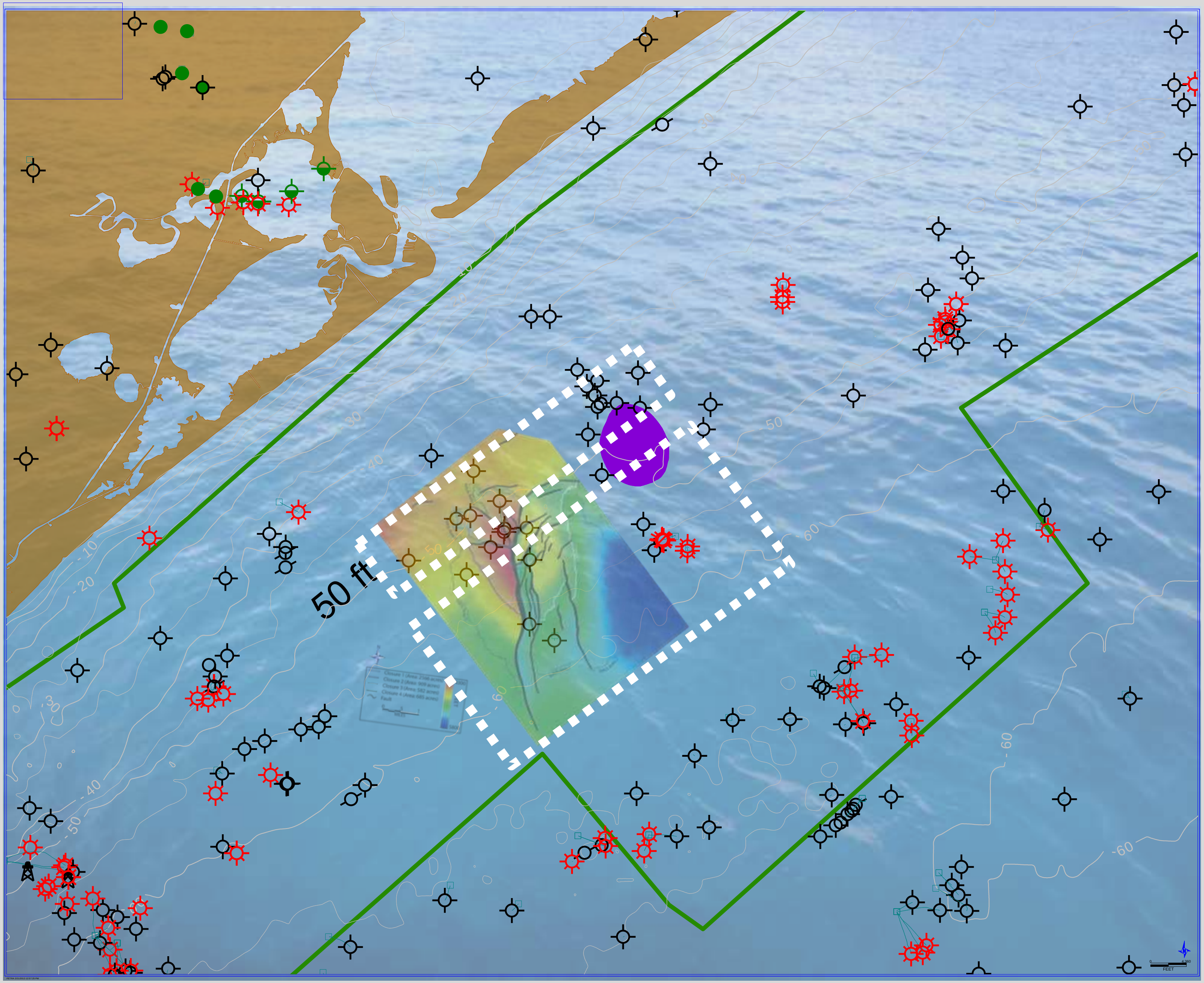


DATE	TX LOCATION	AREA (sq. km.)	LINE KM	AIRGUN SOURCE
July, 2012	San Luis Pass	58	1,077	Two 210 cu. in. GI
October, 2013	San Luis Pass	31.5	420	One 90 cu. in. GI
April, 2014	High Island	47	627	Two 90 cu. in. GI

Trap integrity: Miocene age reservoirs

Cumulative distribution of sizes for 3,400 gas fields
8 fundamental reservoir-seal trap types





San Luis Pass Salt Dome

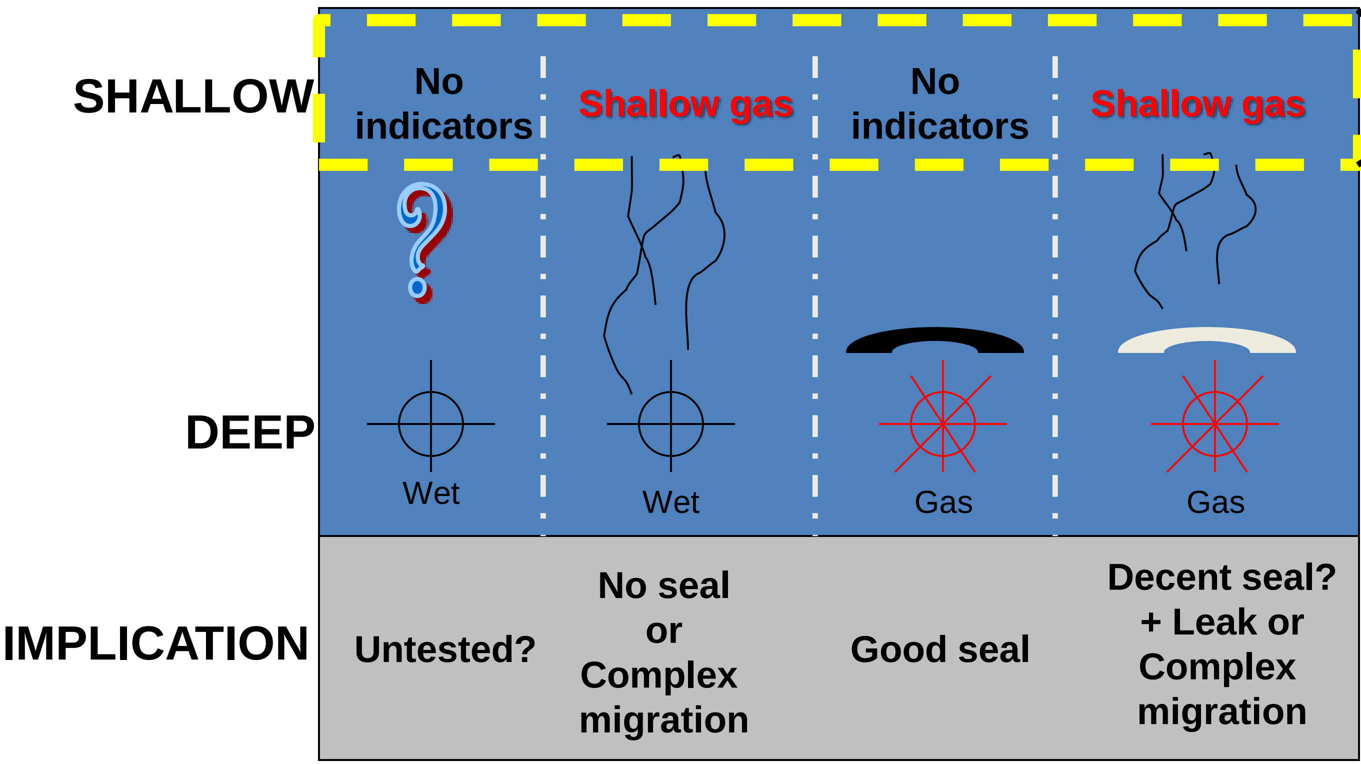
P-Cable Surveys 2012 & 2013

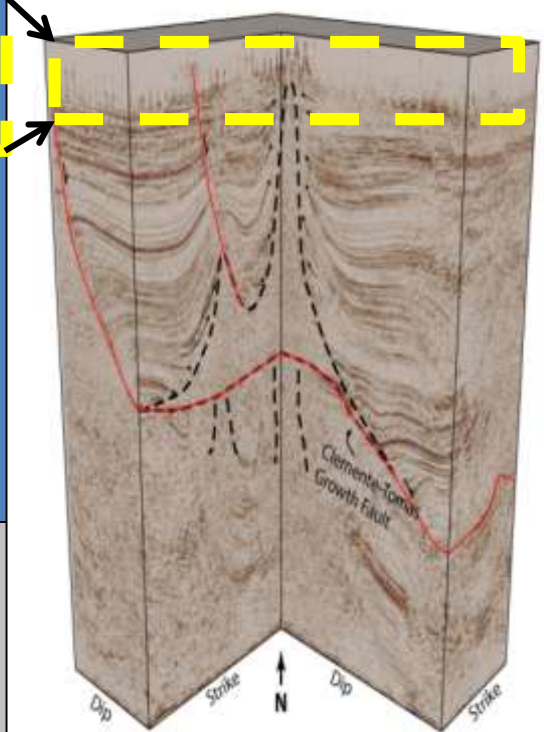
Map produced by Dave Carr

Fluid System Analysis Strategy using HR3D

Understand migration, traps and seals

HR3D insight:
Shallow interval
Poor conventional
coverage



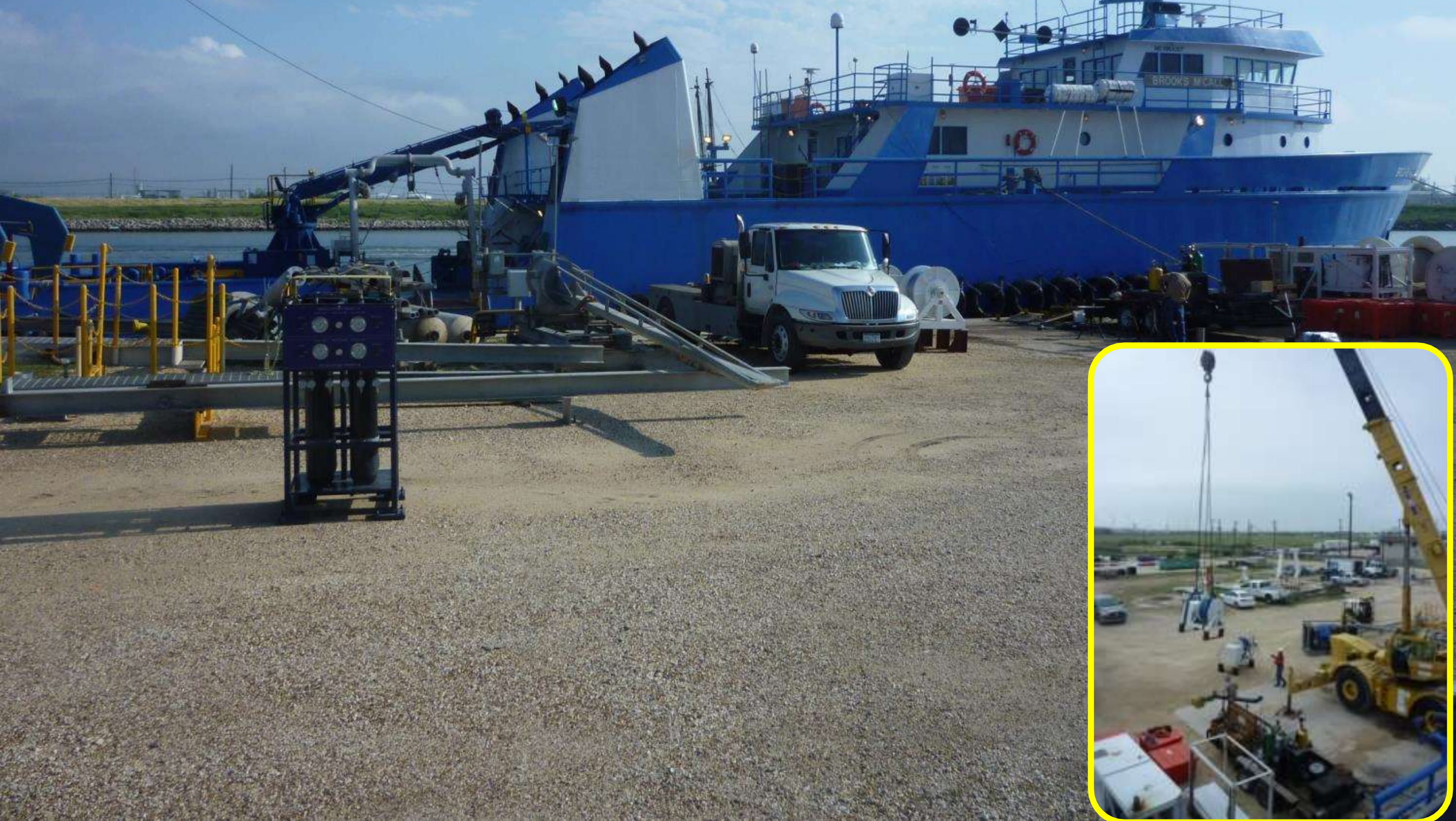


OCTOBER 2013 and April 2014

***R/V Brooks-McCall* based out of Freeport, TX**

50 m length, A-Frame

Primary operations: Sediment coring



Leased portable air compression
100 scfm units

ALPHA
SEISMIC COMPRESSORS
Offshore Rentals | Air Source Solutions

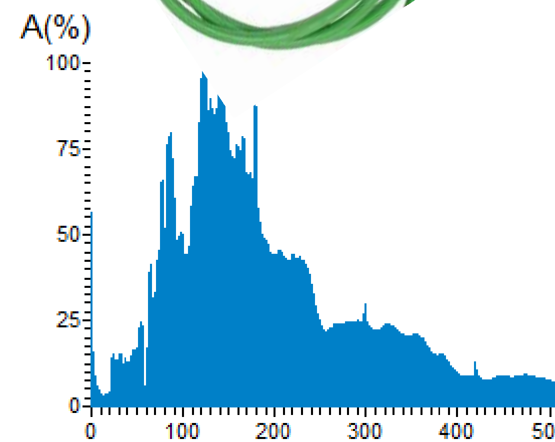

Sources
Starboard Paravane
Port Paravane
Cross Cable
Data Cable
Tow Winch
Tow Winch

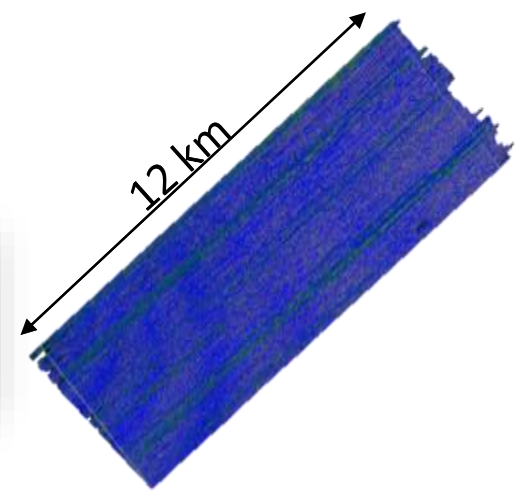
Deployment, Acquisition, Onboard QC

Photo by Eddie Tausch, courtesy of TDI-Brooks, Int.

System/Survey Specifications

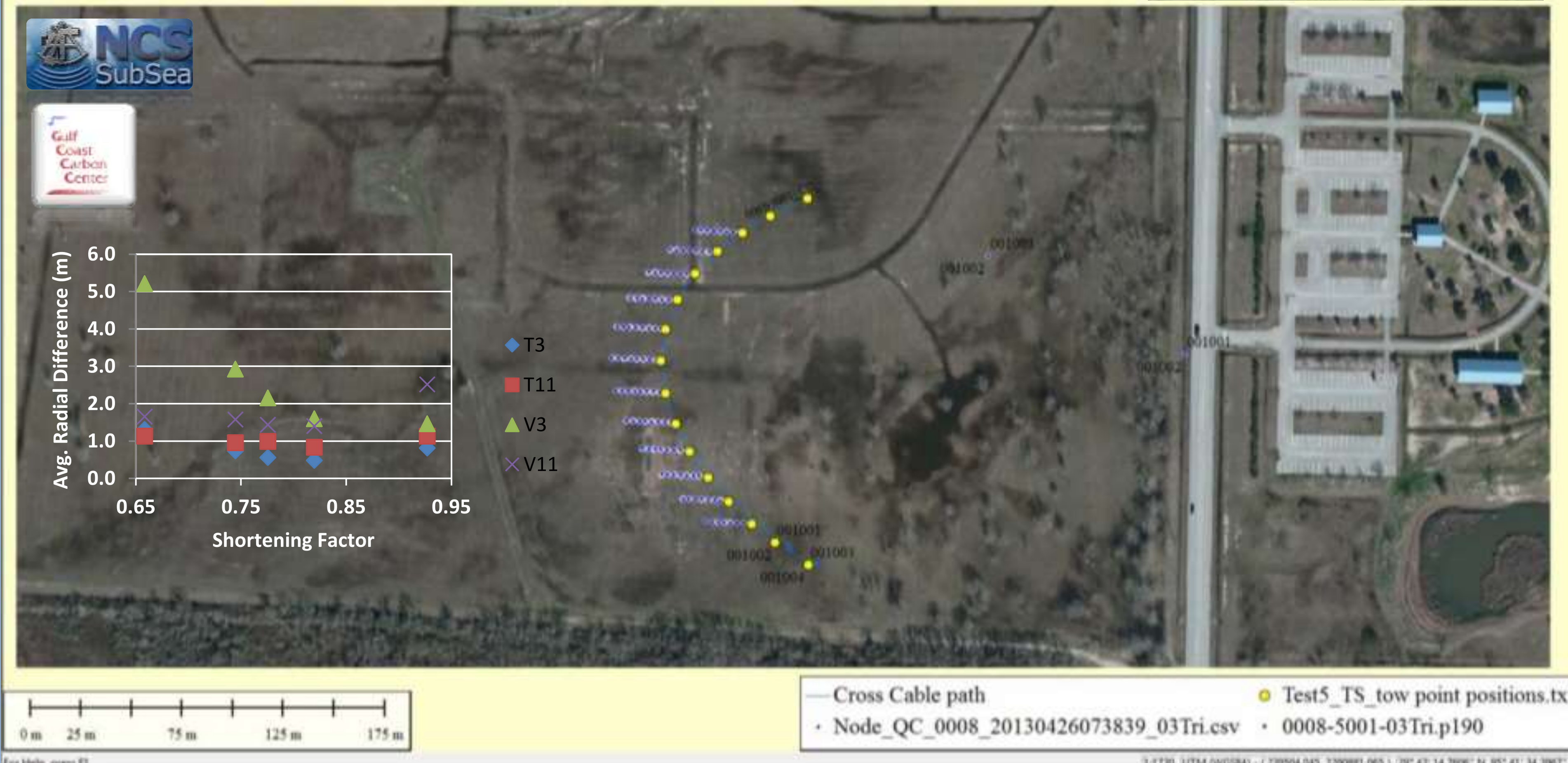
- 12 streamers: GeoEel Solid
- 25 m streamer length (short offset, low fold)
- 8 Channels per streamer (96 total)
- Streamer xline separation: ~12.5m
- Compasses for orientation, GPS positioning.
- Source: 90-420 in^3 Sercel GI (compressed air)
- 12.5 m shot spacing (6.25 m^2 bins)
- Dominant frequency: 150 Hz (50-250 Hz typical)
- Navigation and positioning: 3rd party navigation hardware/software with proprietary processing





Receiver Position Accuracy

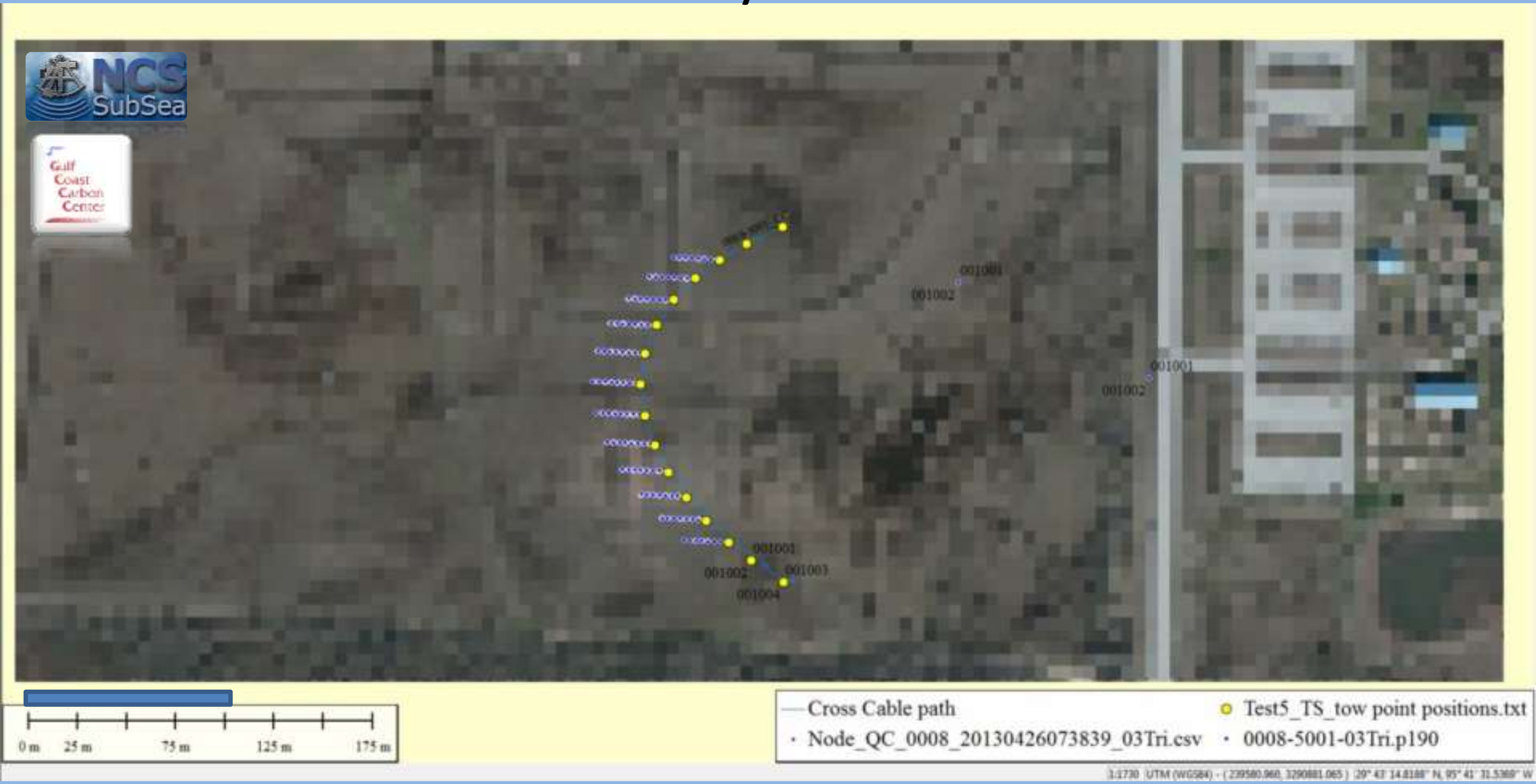
Pixels 0.5 m x 0.5 m



Horizontal Resolution?

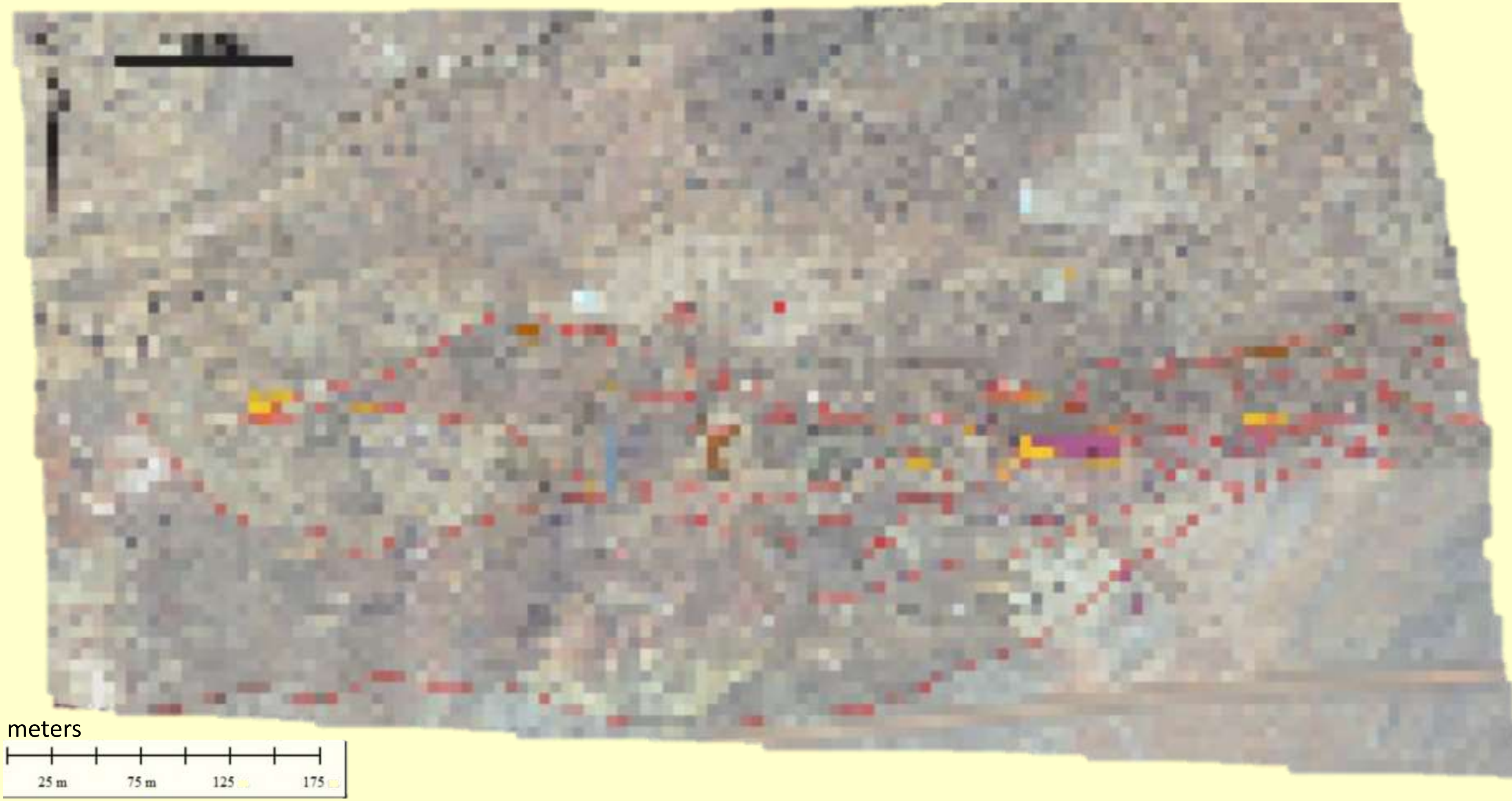
Pixels 6.25 m x 6.25 m

Survey bin size



Urquhart (2011) MS Thesis, UT-Austin:
Structural controls on CO_2 leakage and diagenesis in a natural long-term carbon sequestration analogue : Little Grand Wash fault, Utah

Little Grand Wash Fault System:
~6.25 m pixel resolution



Those features *may* be visible in overburden
Function(depth, frequency, Fresnel Zone, Moduli, etc.)

Conventional 3D

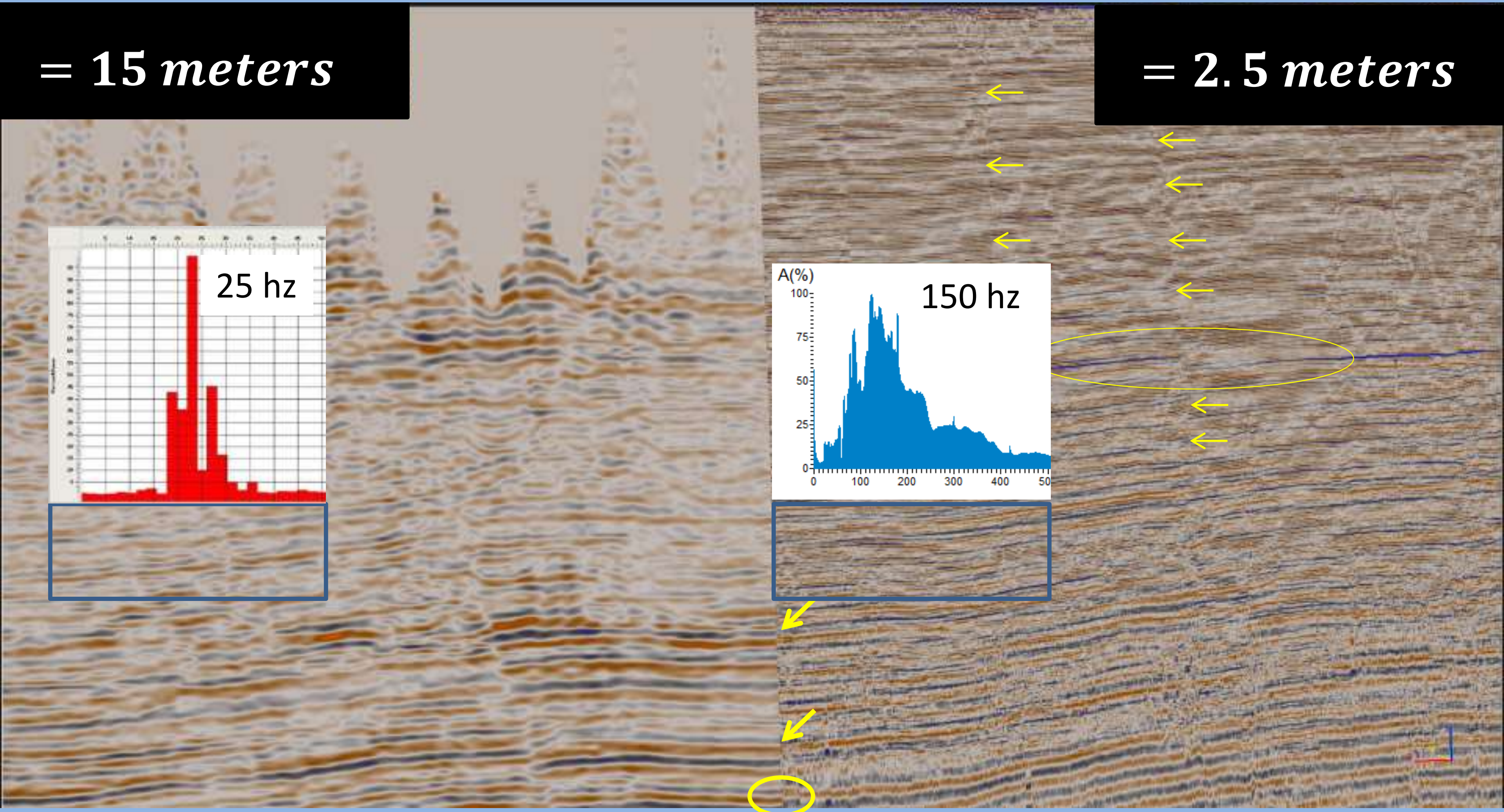
Vertical Resolution

HR3D - PCable

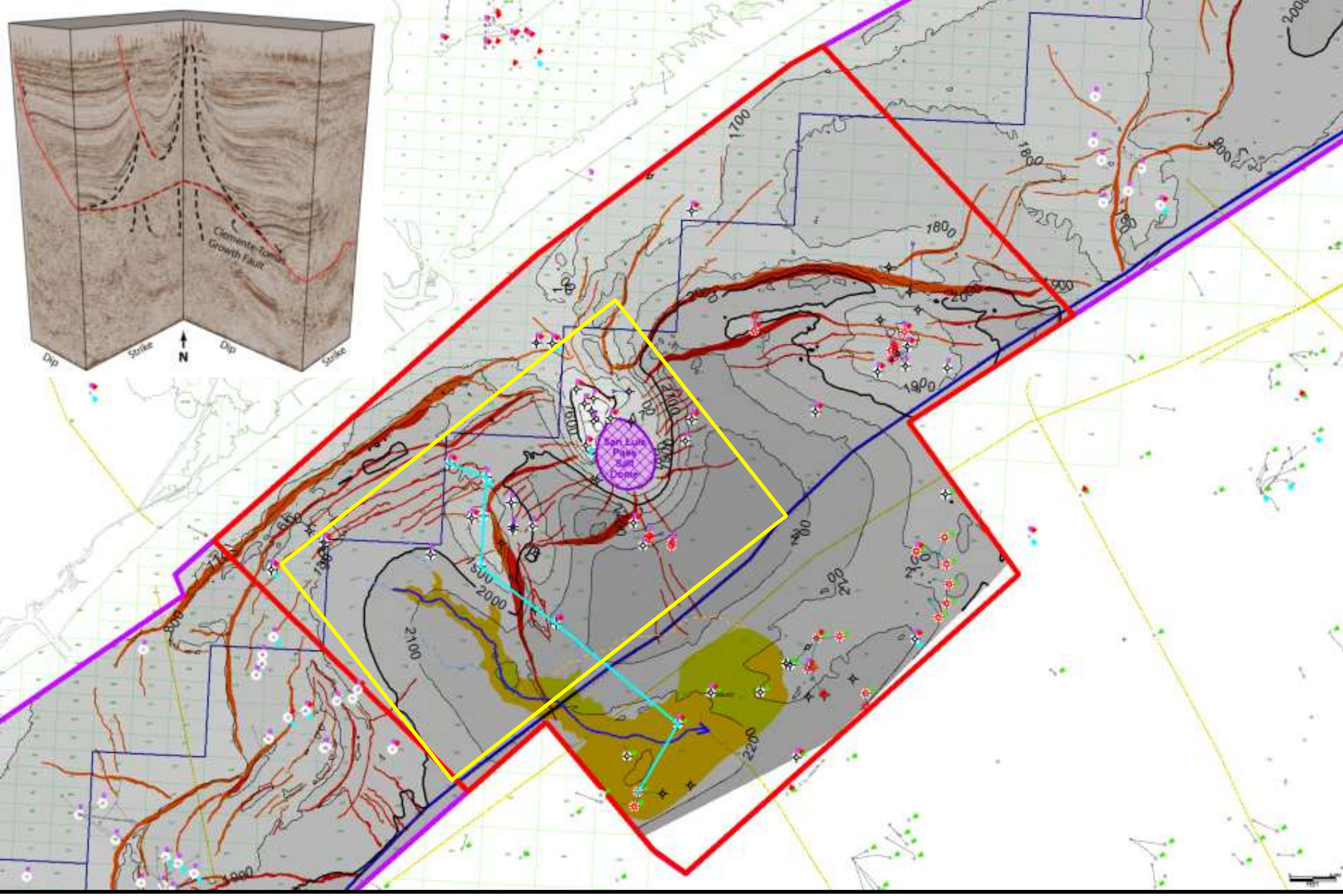
$$= \left(\frac{1}{25\ hz} * 1500\ m/s\right)/4$$

$$= \left(\frac{1}{f} * V\right)/4$$

$$= \left(\frac{1}{150\ hz} * 1500\ m/s\right)/4$$

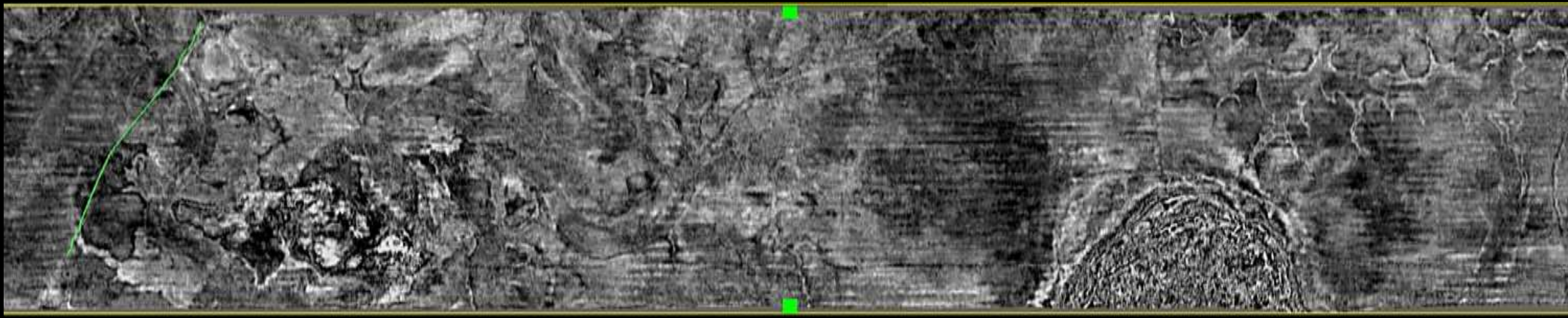


1500 ms ~ 2250 meters depth

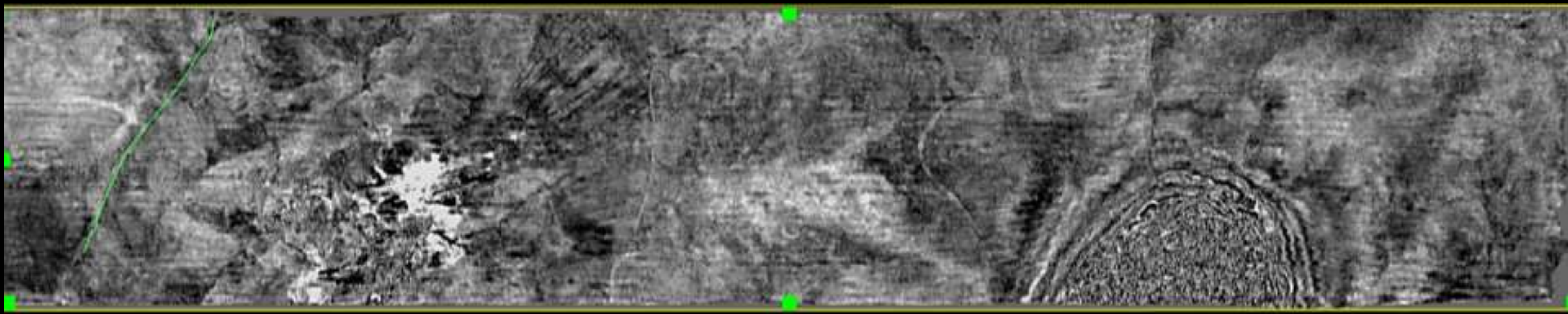

Clemente-Tomas
Growth Fault
Dip
Strike
N
Dip
Strike
San Luis
Pass
Salt
Dome
1700
1800
1800
1900
1900
2000
2000
2100
2100
2200

Stratigraphic morphologies: San Luis Pass

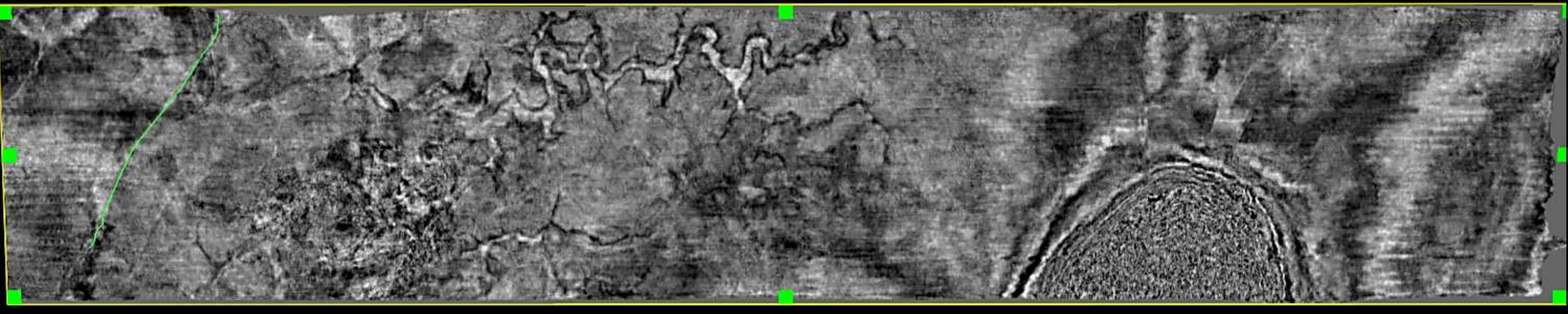
108 msec

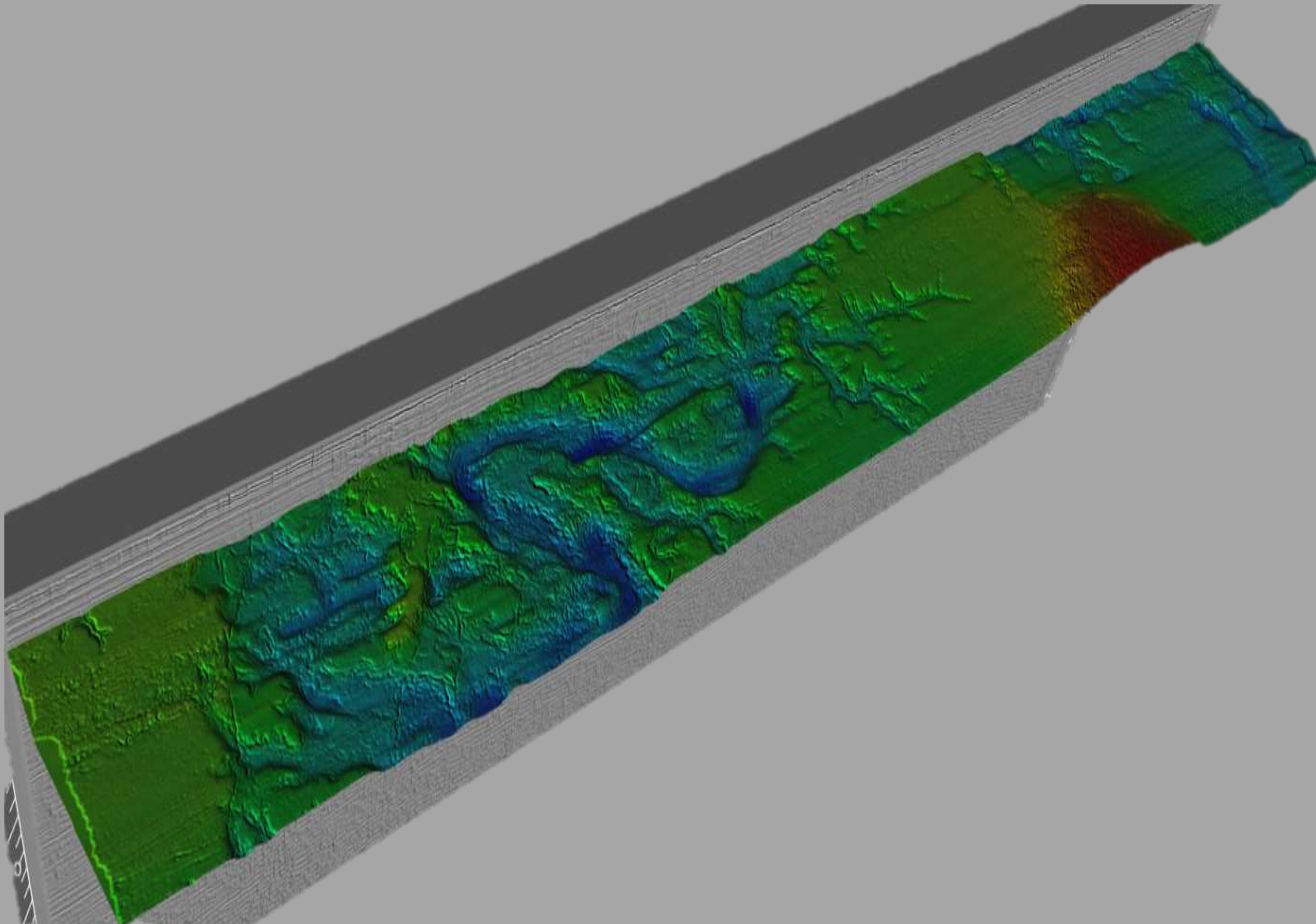


144 msec



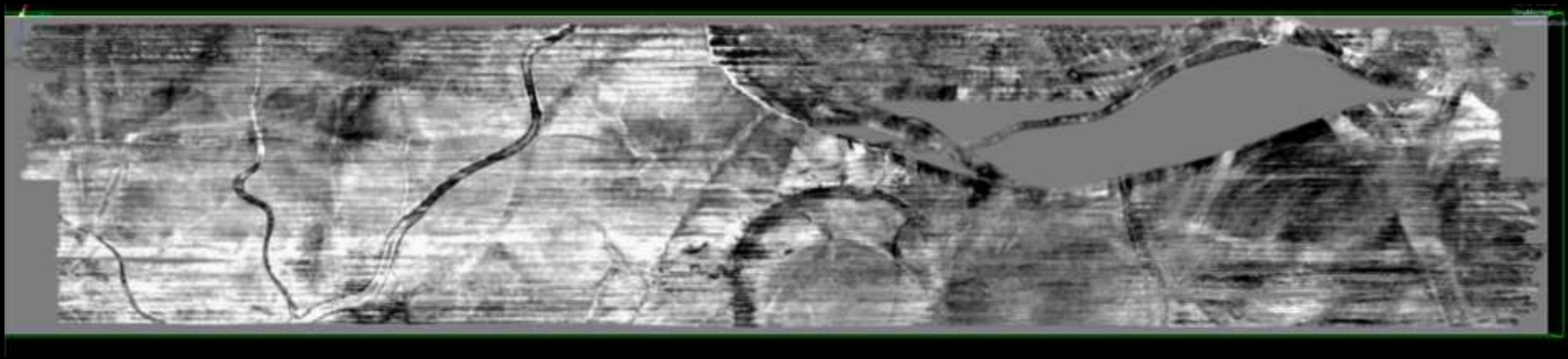
173 msec



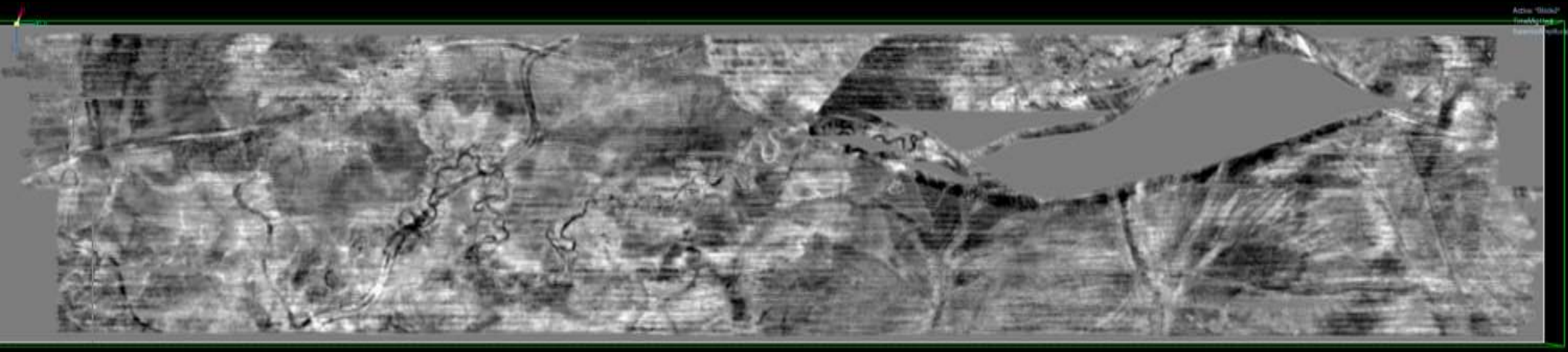


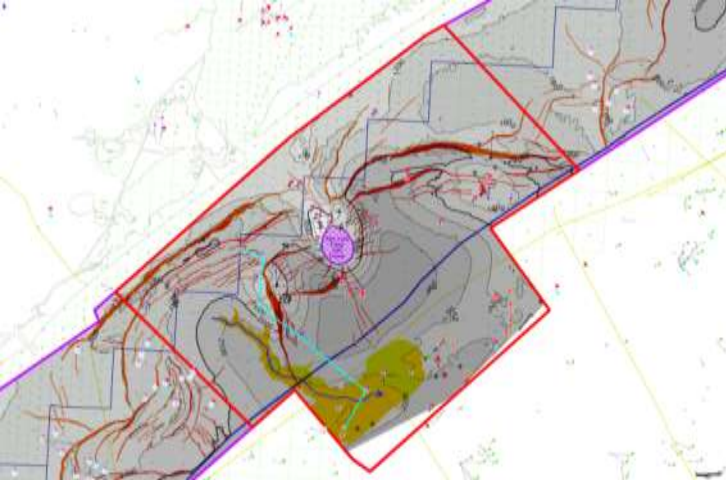
Stratigraphic morphologies 2014: High Island

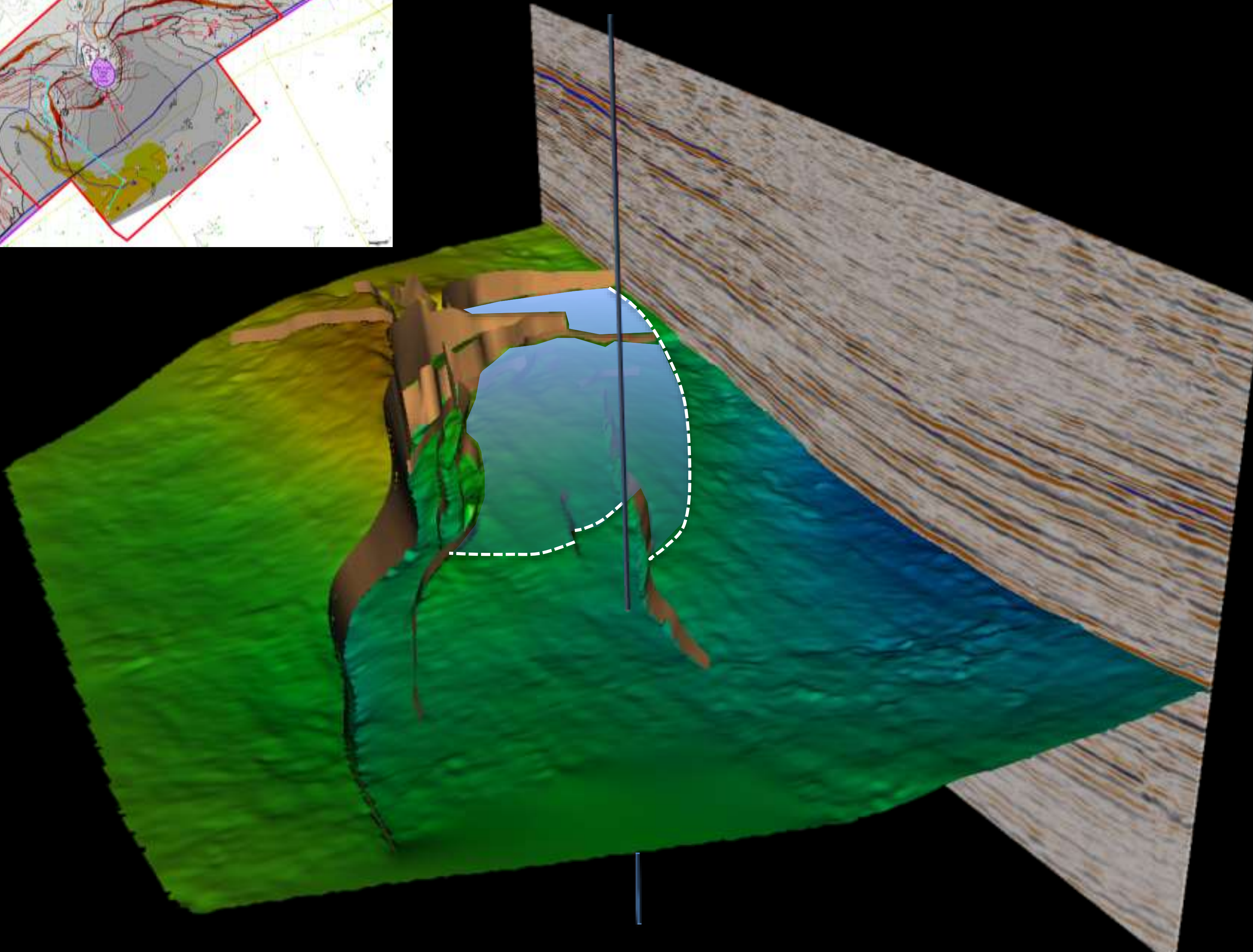
100 msec



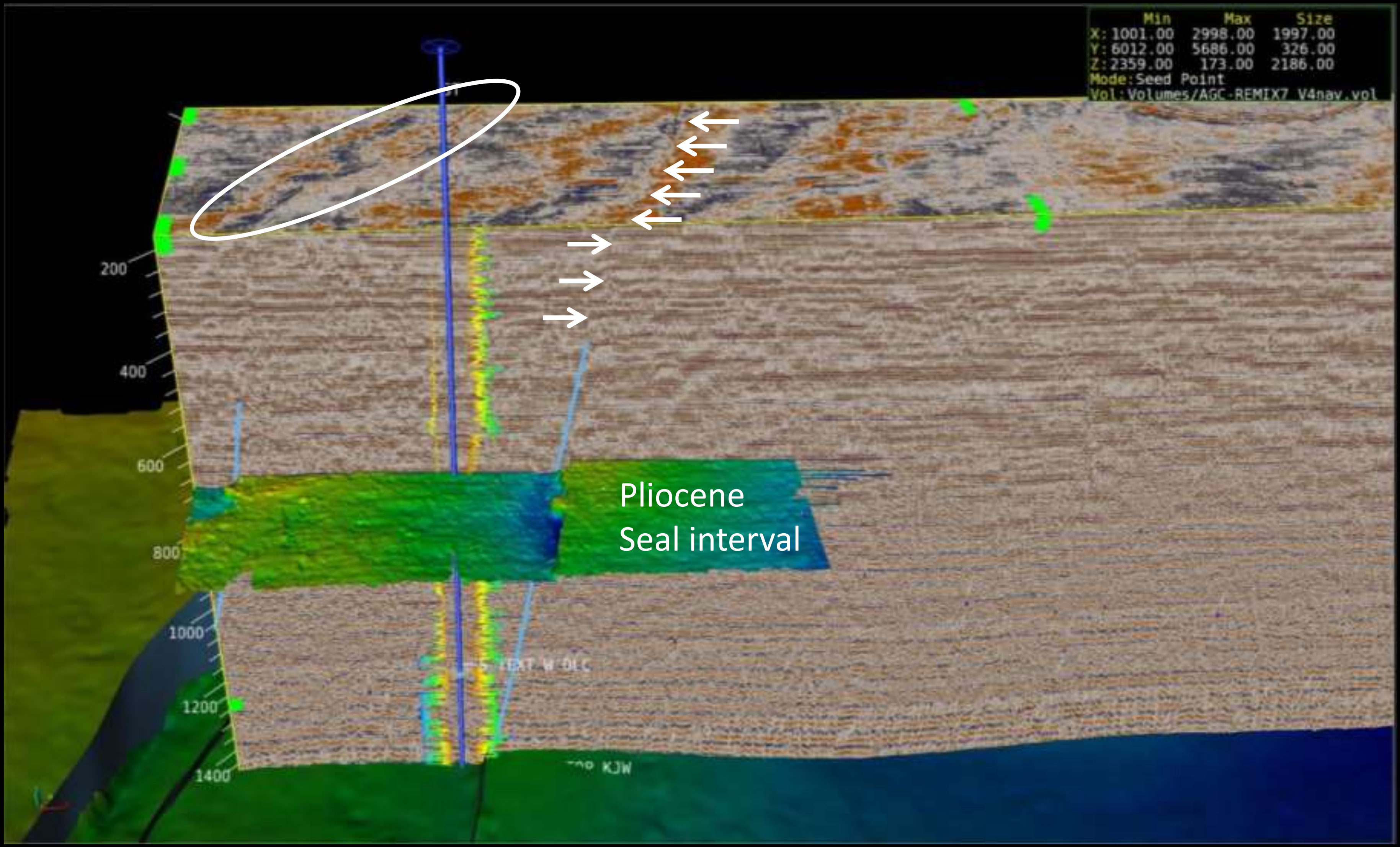
125 msec



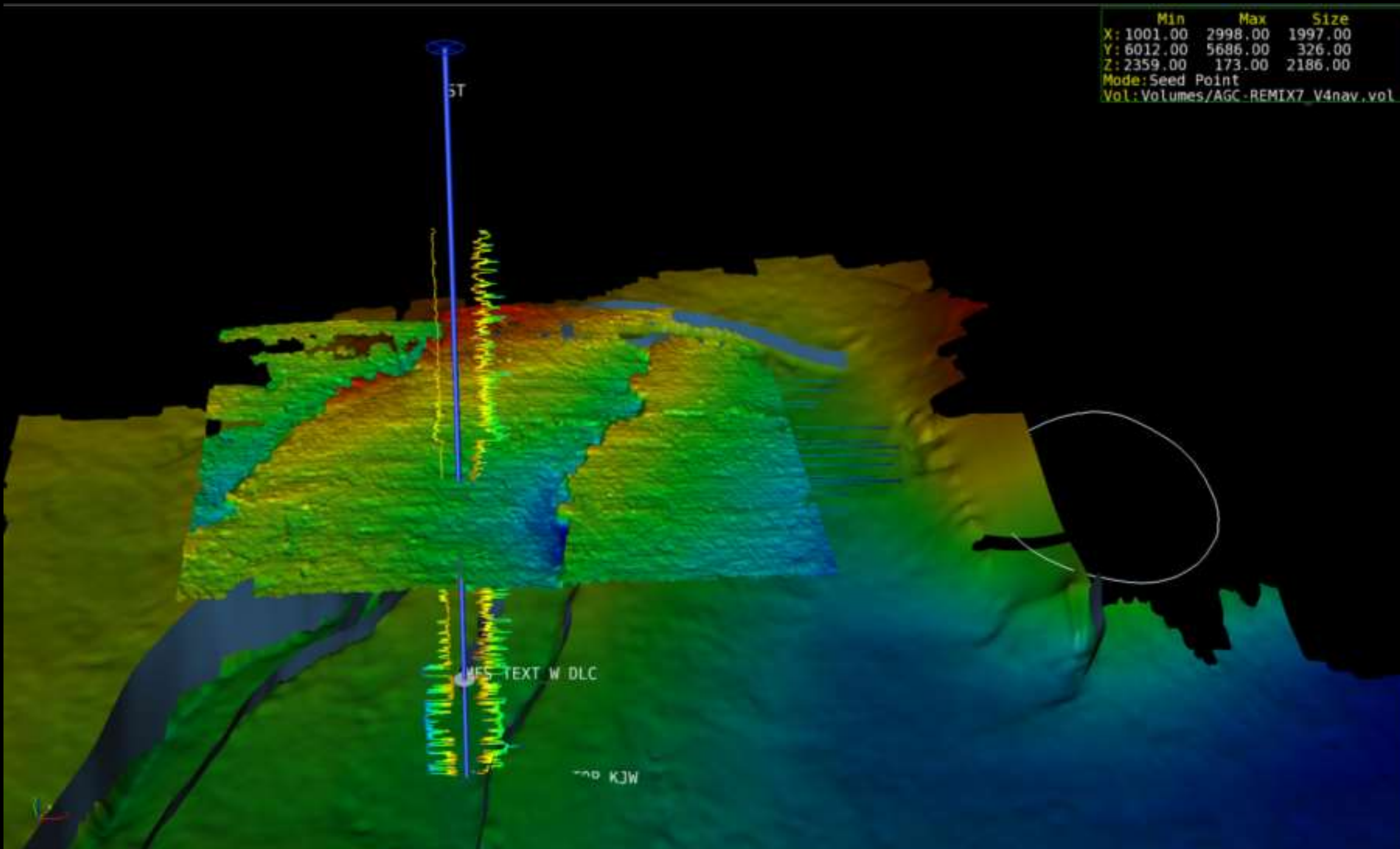




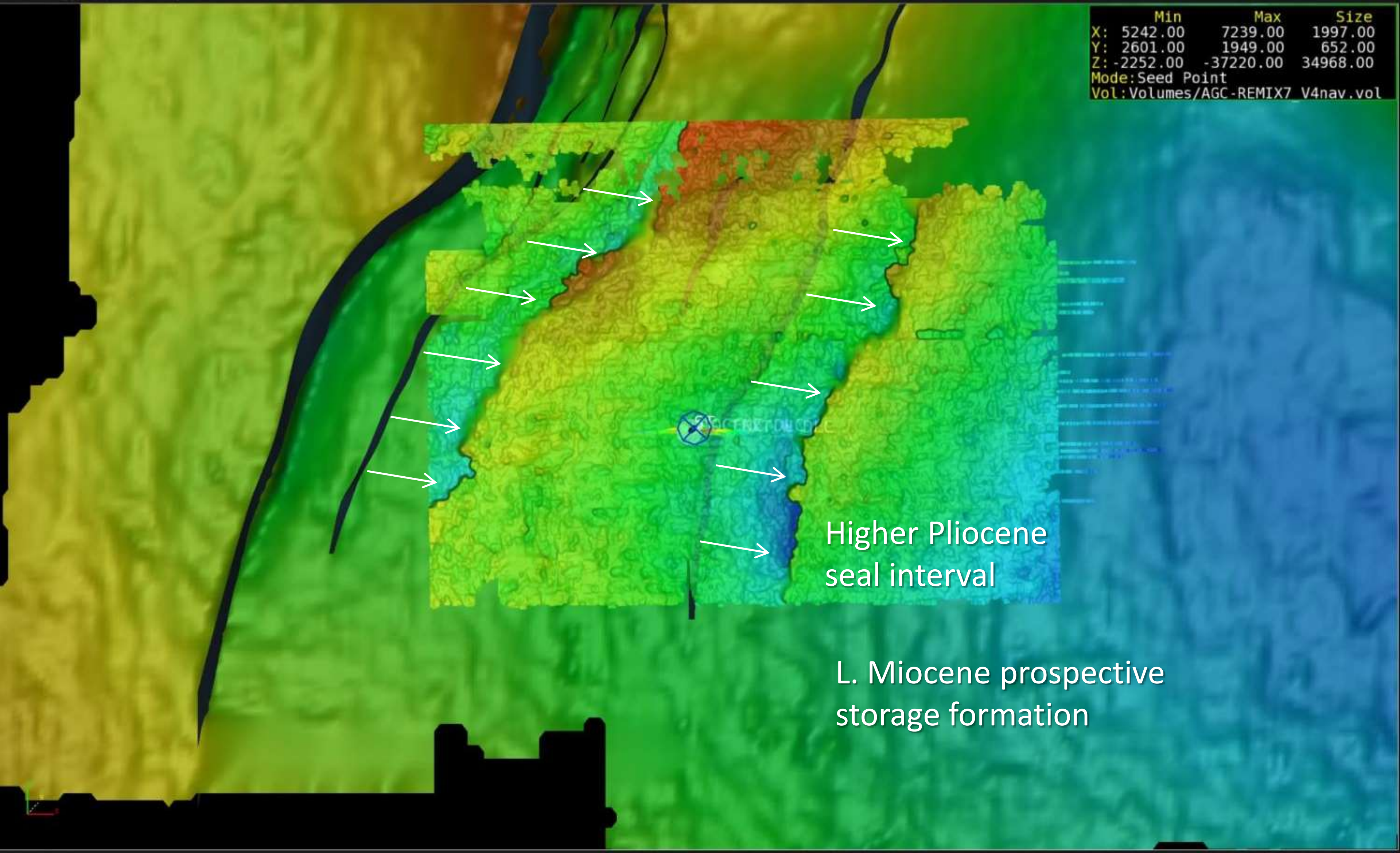
Pliocene Seal Interval

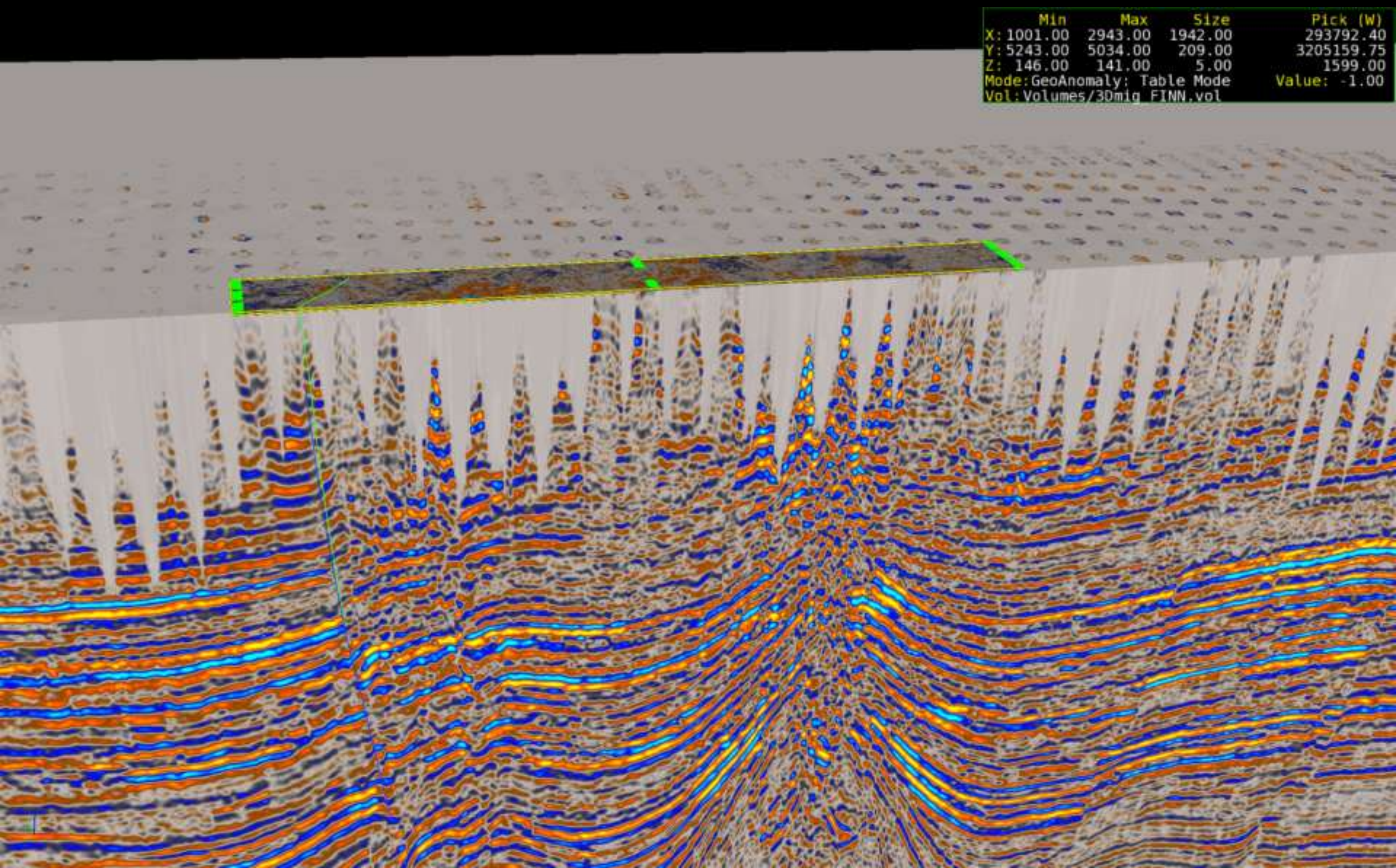


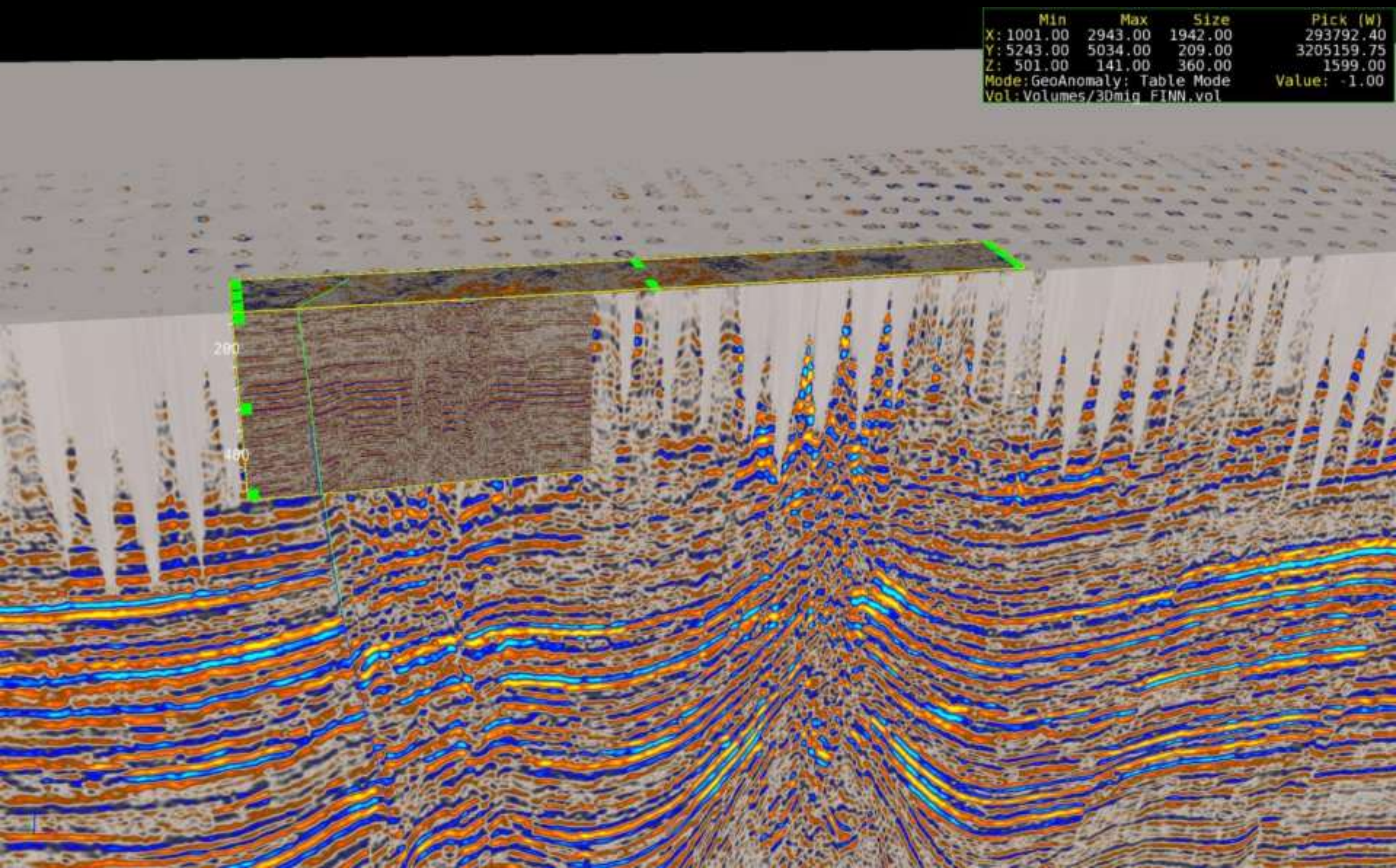
Pliocene Seal Interval



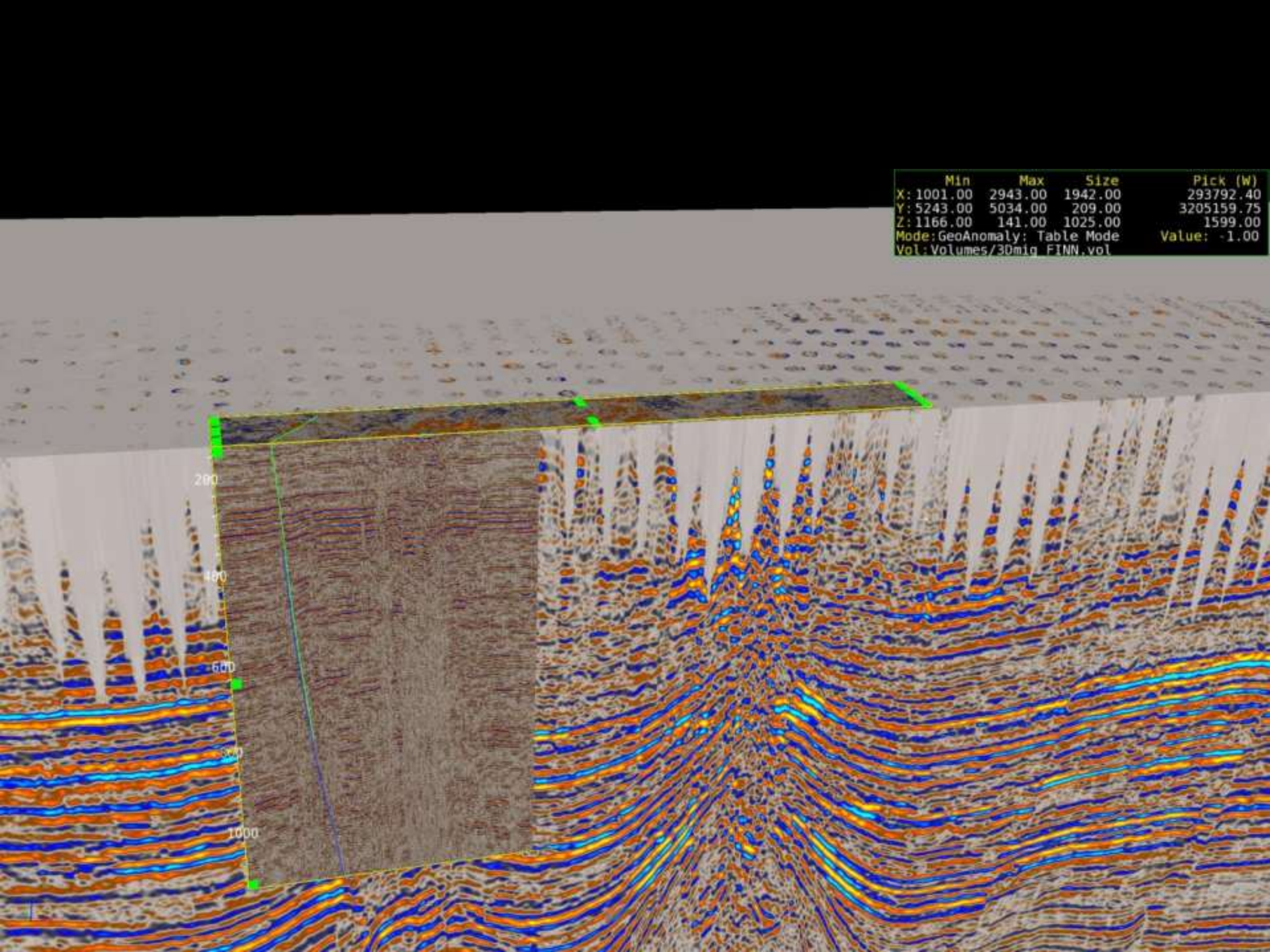
Pliocene Seal Interval

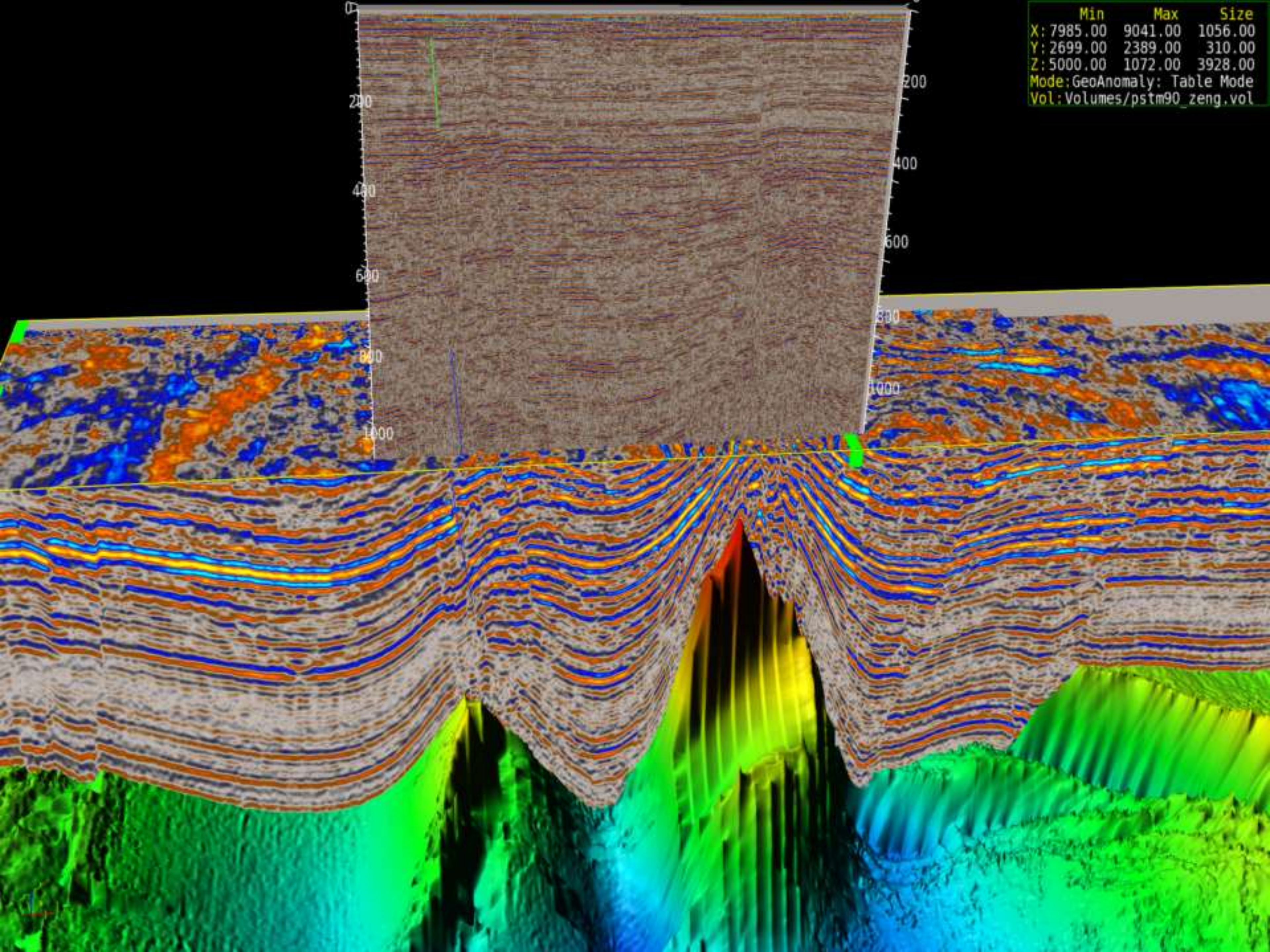


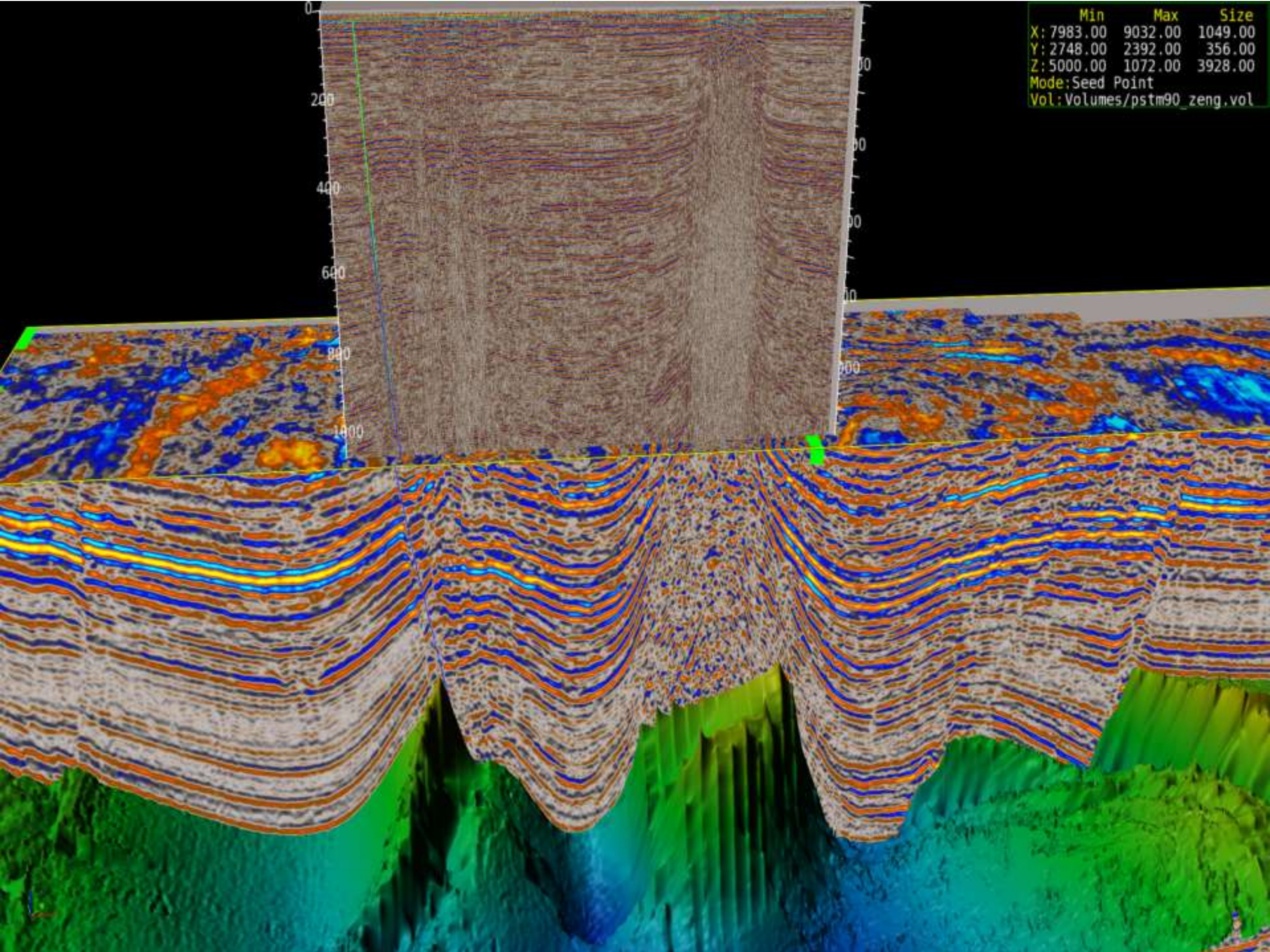

Min Max Size Pick (W)
X: 1001.00 2943.00 1942.00 293792.40
Y: 5243.00 5034.00 209.00 3205159.75
Z: 146.00 141.00 5.00 1599.00
Mode: GeoAnomaly: Table Mode Value: -1.00
Vol: Volumes/3Dmig_FINN.vol

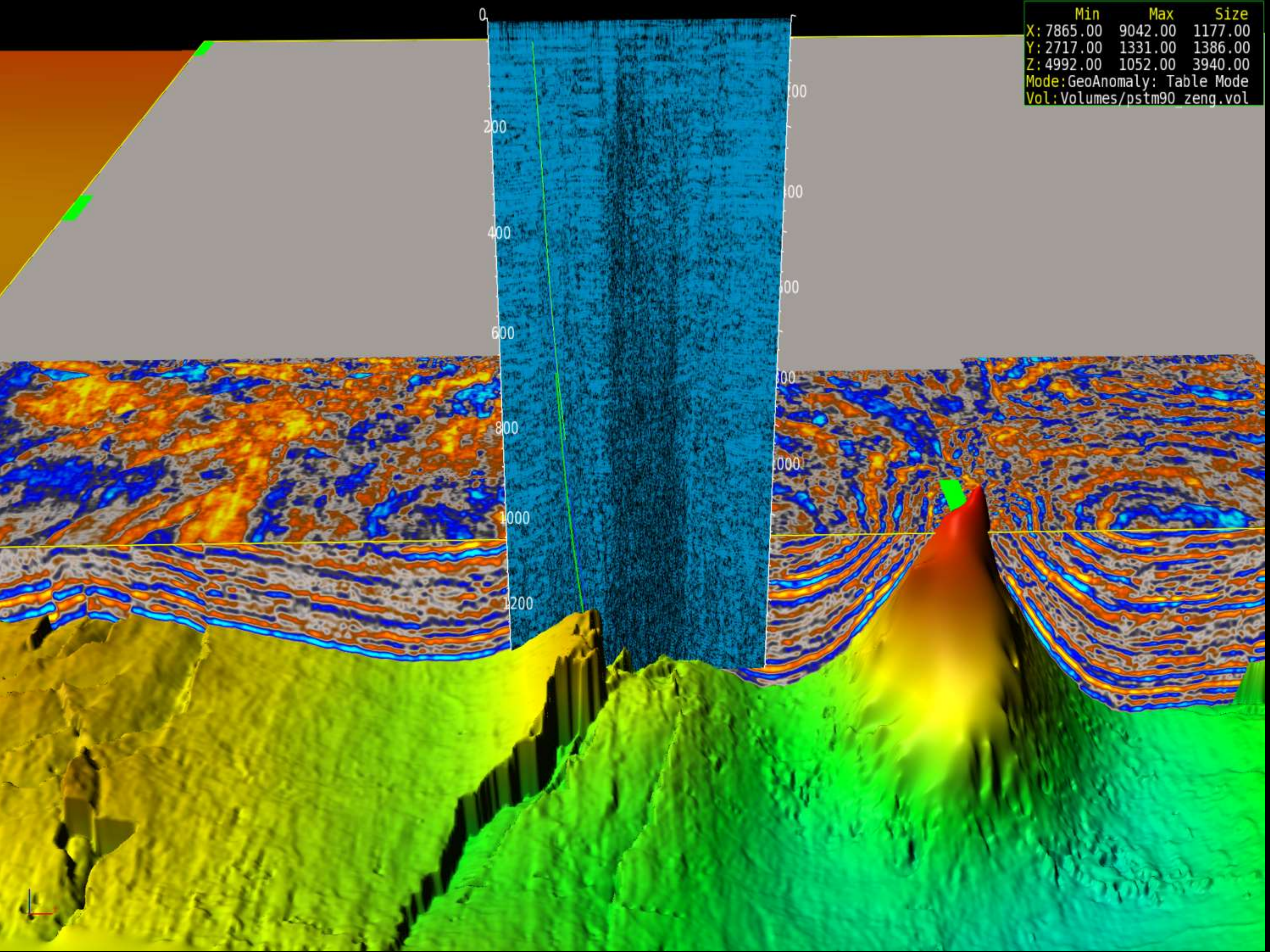


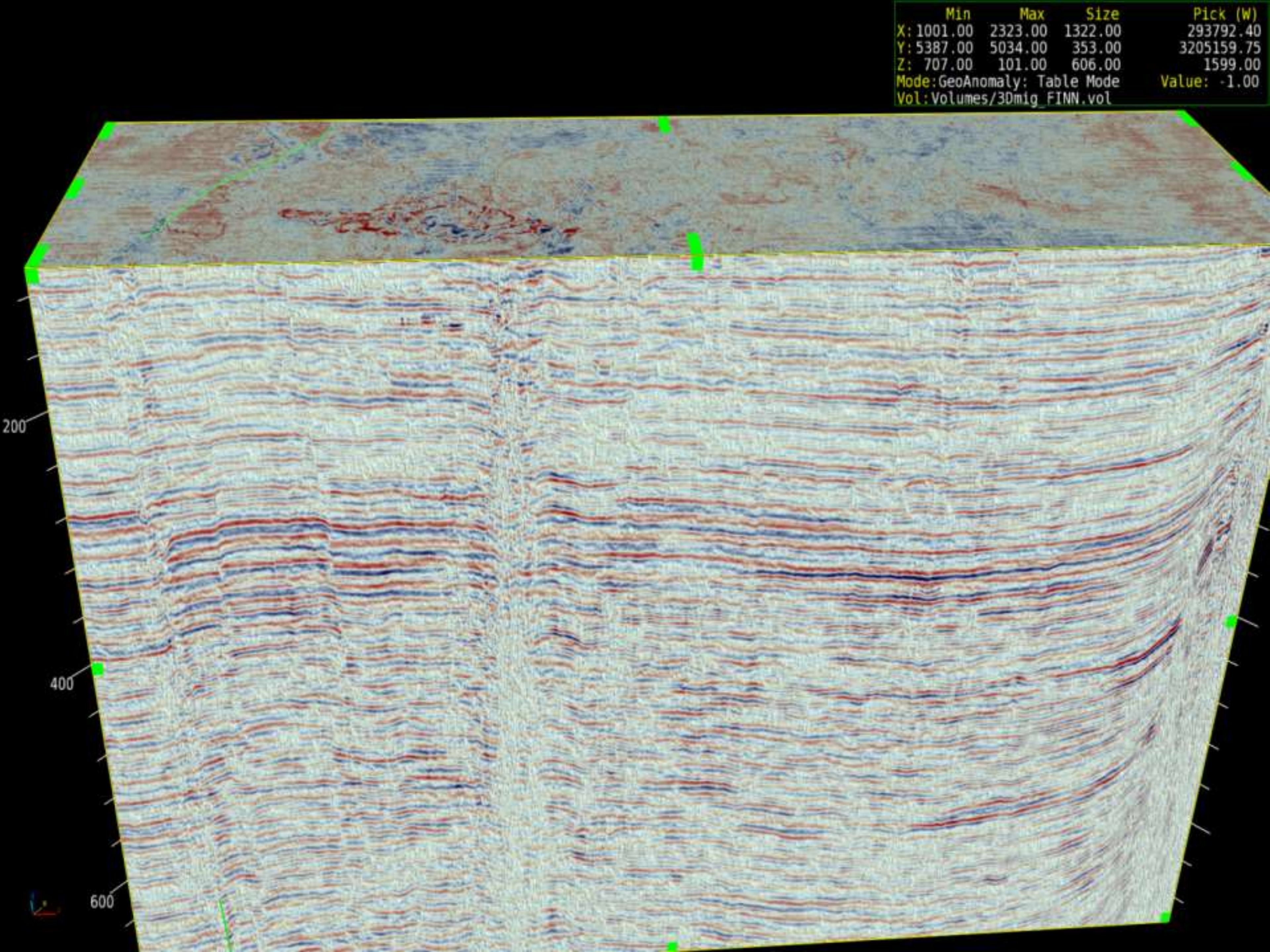
Min Max Size Pick (W)
X: 1001.00 2943.00 1942.00 293792.40
Y: 5243.00 5034.00 209.00 3205159.75
Z: 501.00 141.00 360.00 1599.00
Mode:GeoAnomaly: Table Mode
Value: -1.00
Vol:Volumes/3Dmig_FINN.vol
200
400


Min Max Size Pick (W)
X: 1001.00 2943.00 1942.00 293792.40
Y: 5243.00 5034.00 209.00 3205159.75
Z: 1166.00 141.00 1025.00 1599.00
Mode:GeoAnomaly: Table Mode Value: -1.00
Vol:Volumes/3Dmig_FINN.vol
200
400
600
1000

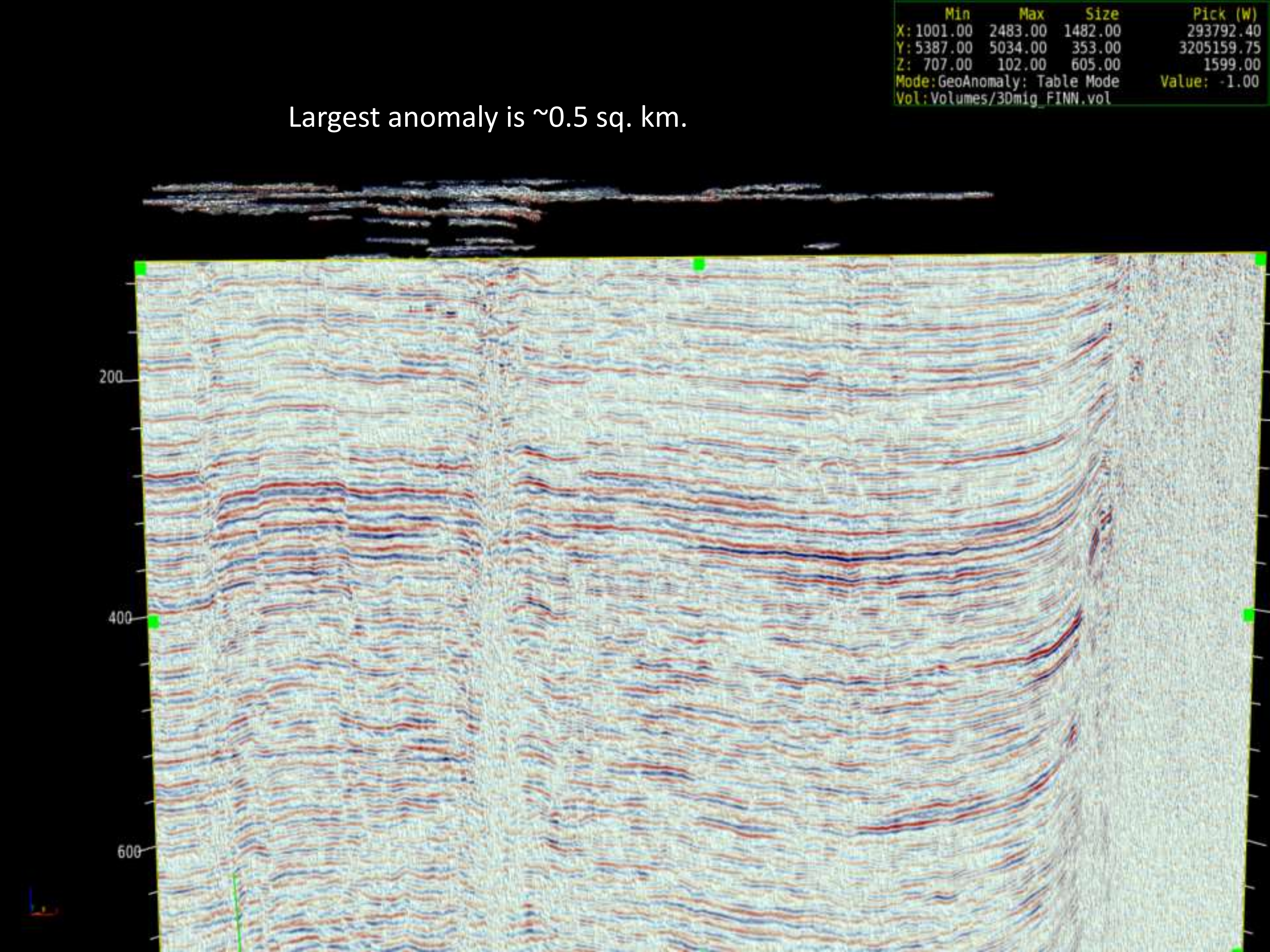

Min Max Size
X: 7985.00 9041.00 1056.00
Y: 2699.00 2389.00 310.00
Z: 5000.00 1072.00 3928.00
Mode:GeoAnomaly: Table Mode
Vol:Volumes/pstm90_zeng.vol
200
400
600
800
1000

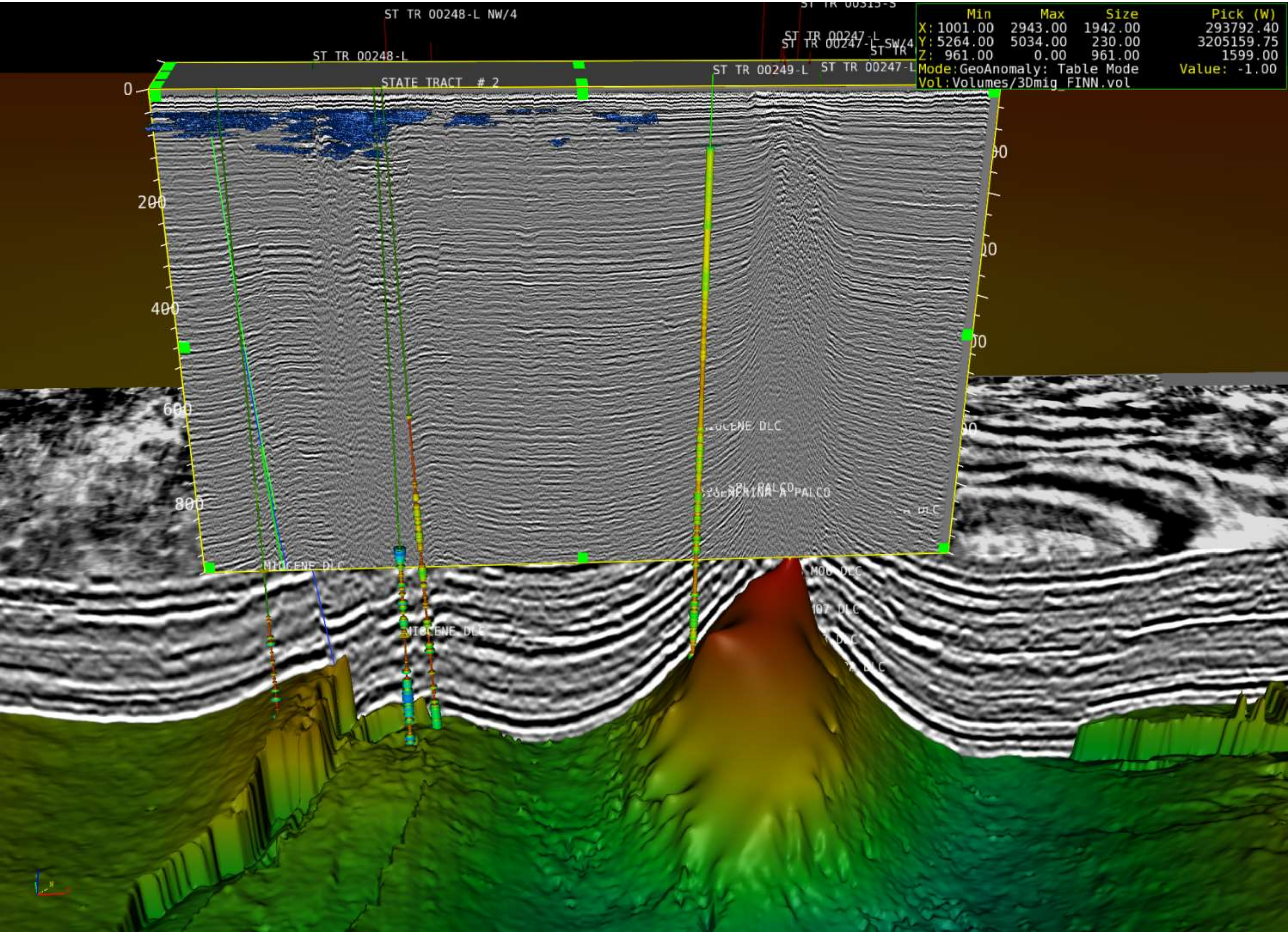

Min Max Size
X: 7983.00 9032.00 1049.00
Y: 2748.00 2392.00 356.00
Z: 5000.00 1072.00 3928.00
Mode: Seed Point
Vol: Volumes/pstm90_zeng.vol
0
200
400
600
800
1000


Min Max Size
X: 7865.00 9042.00 1177.00
Y: 2717.00 1331.00 1386.00
Z: 4992.00 1052.00 3940.00
Mode: GeoAnomaly: Table Mode
Vol: Volumes/pstm90_zeng.vol
0
200
400
600
800
1000
1200


Min Max Size Pick (W)
X: 1001.00 2323.00 1322.00 293792.40
Y: 5387.00 5034.00 353.00 3205159.75
Z: 707.00 101.00 606.00 1599.00
Mode:GeoAnomaly: Table Mode Value: -1.00
Vol:Volumes/3Dmig_FINN.vol
200
400
600

Largest anomaly is ~0.5 sq. km.




ST TR 00248-L NW/4
ST TR 00248-L
STATE TRACT # 2
ST TR 00249-L
ST TR 00247-L
ST TR 00247-L SW/4
ST TR 00247-L
Min Max Size Pick (W)
X: 1001.00 2943.00 1942.00 293792.40
Y: 5264.00 5034.00 230.00 3205159.75
Z: 961.00 0.00 961.00 1599.00
Mode:GeoAnomaly: Table Mode Value: -1.00
Vol:Volumes/3Dmig_FINN.vol
0
200
400
600
800
MIOCENE DLC
MIOCENE DLC

SUMMARY

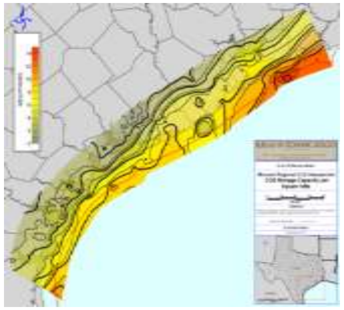
- **First acquisitions using HR3D system in GoM.**
  - Learnings from surveys:
    - Deployment, positioning, array geometry, source, processing
- **Datasets achieve 2 benchmark CCS goals:**
  1. **Characterization**: Success imaging overburden in detail
     - Well-resolved faults and stratigraphy down to 1 sec (90 cu. in. source)
       - Not seen in conventional data.
     - ID leaky/non-leaky geo-systems
       - Shallow salt dome feature appears non-leaky/uncharged, while deeper salt structure apparently is.
  2. **Monitoring**: Verification that fluid migration is likely to be observable (3D & 4D)
     - Fluid chimney identified, now need to understand migration processes & integrate expected saturations with seismic response.
     - Opportunity to integrate shallow sediment coring.
- **Modeling:** Dataset needed to characterize for modeling meso/deep migration.

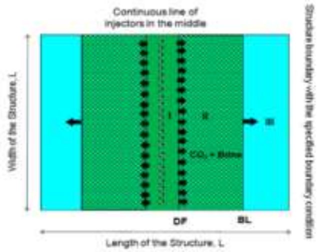
Acknowledgements

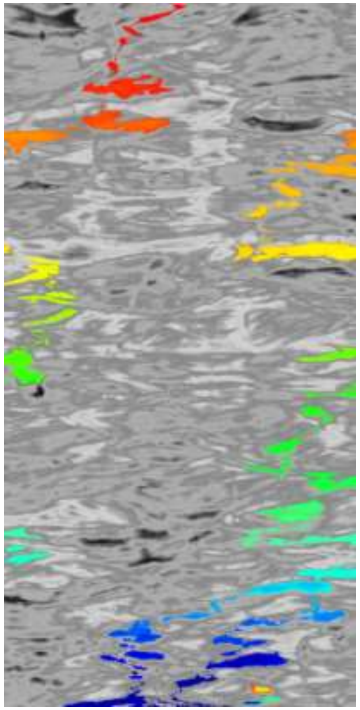
- Seismic Exchange, Inc.
- Ramon Trevino, BEG project manager
- Nathan Bangs, UTIG
- Tom Hess, JSG
- Lorena Moscardelli & Dallas Dunlap, BEG
- Finn Michelsen, Geo Survey Systems
- James Donnelly & CRC staff
- Randy McDonald & HRC staff

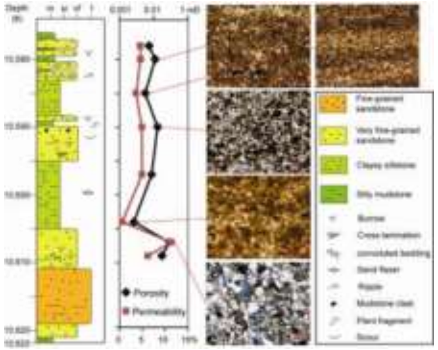
Research Scope

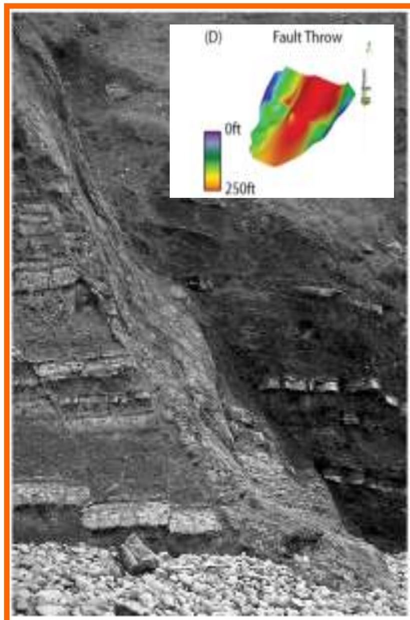
- Static capacity calculations
- Dynamic capacity calculations
- Geochemistry
- Mudrock sealing capacity
- Fluid migration
- Fault seal
- **Seismics**



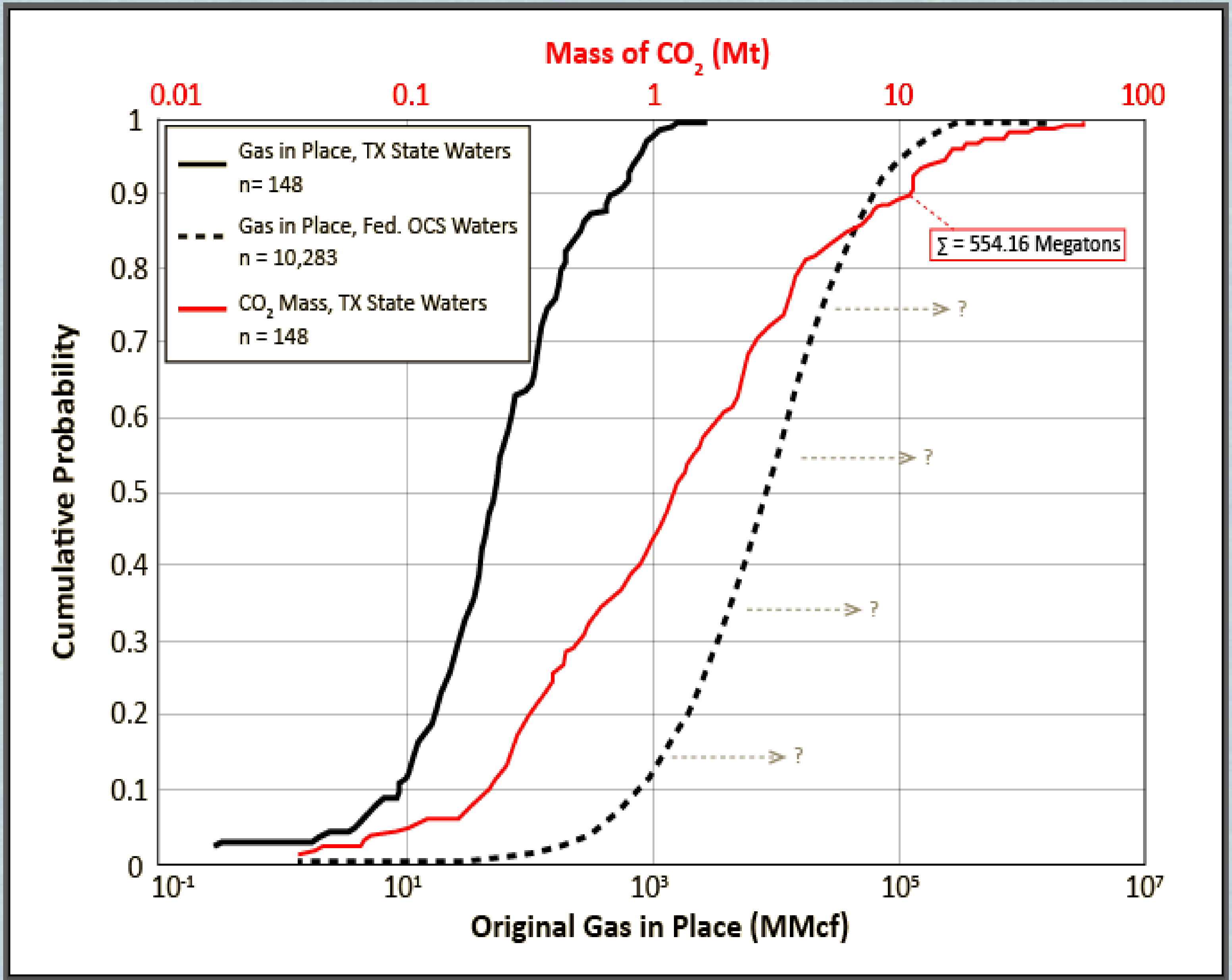






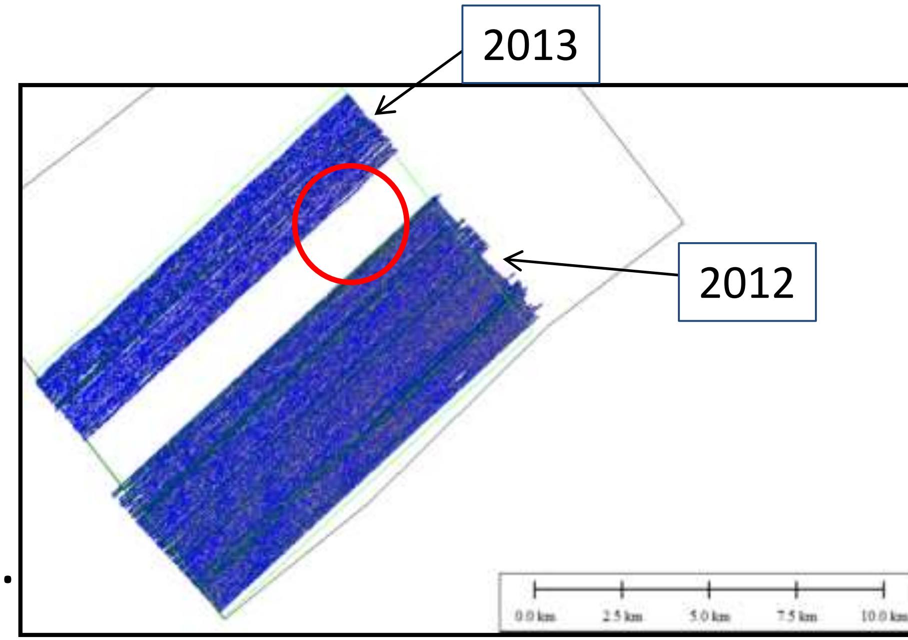


Static Gas Field Field Capacity



Example Survey Statistics

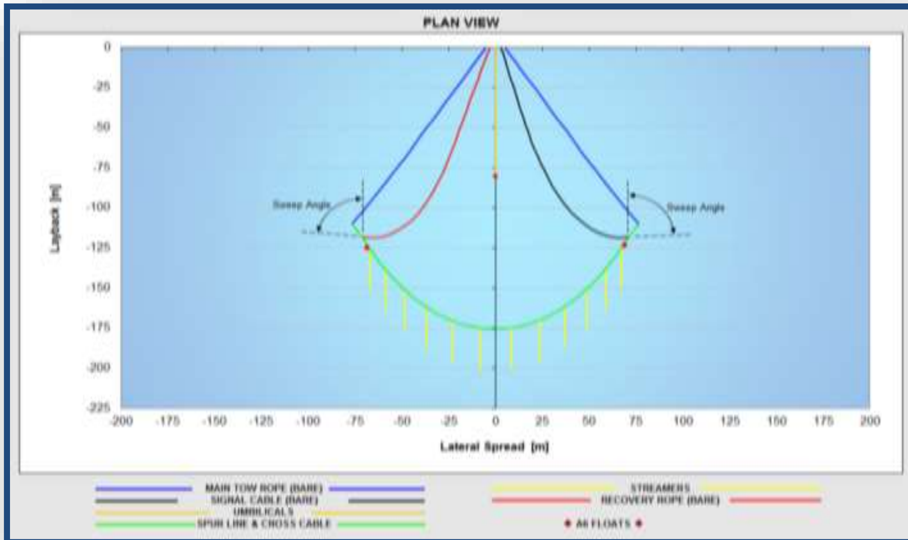
- 24 hour operations
- 27 crew aboard
  - 5 'science'
  - 6 support (Nav., guns, compr.)
  - 3 environmental monitors
  - 13 ship crew
- 3 day mobilization; 2 day demob.
- 2014: 630 line km; ~40 sq. km.



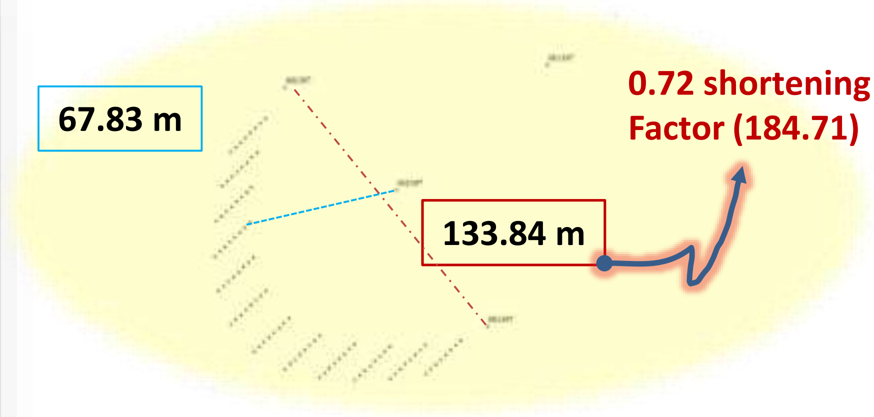
- Many Partnering Organizations: UT-JSG (BEG/UTIG), TDI-Brooks, NCS-Subsea, AlphaSeismic Compressors, GeoSurvey Systems.

Array Geometry

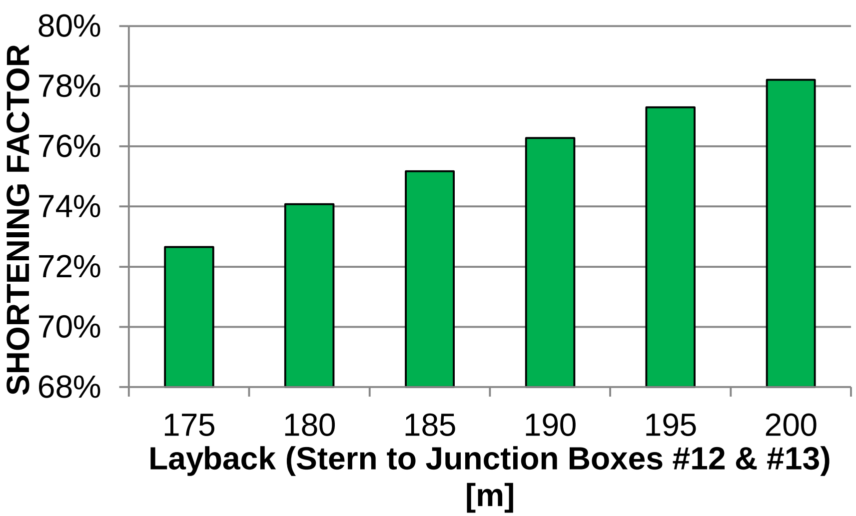
Modeling



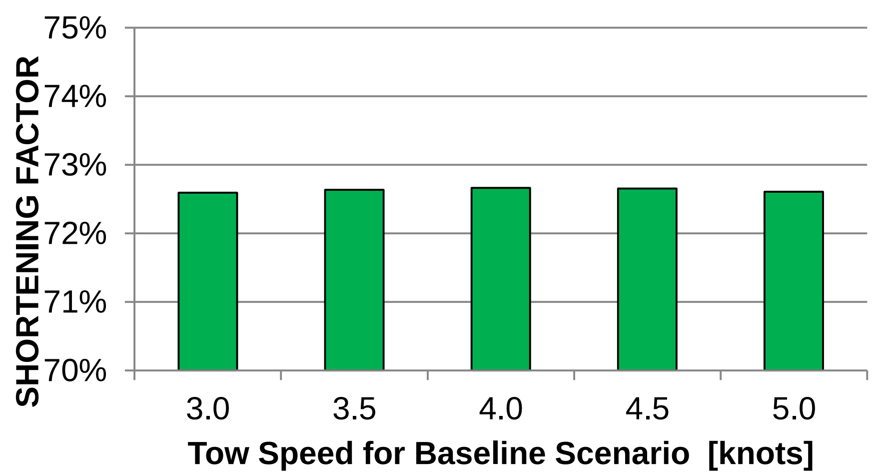
Field data



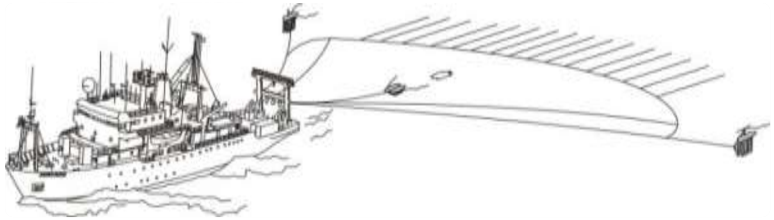
SHORTENING FACTOR VERSUS LAYBACK



SHORTENING FACTOR VERSUS TOW SPEED



P-Cable Development History



5 active systems globally

P-Cable systems are owned and operated by: IFM-Geomar, University of Tromsø, University of Texas, National Oceanography Center Southampton, P-Cable 3D Seismic AS and WGP Survey Ltd

2001: P-Cable concept testing

2004: P-Cable1 prototype; patent

2006: P-Cable2 system / 24 streamer digital system

2007: P-Cable2 Peon survey; better resolution than conventional 3D

2008: P-Cable 3D Seismic established

2009: Commercial P-Cable2 data on Peon, Statoil (188 km^2)

2010: P-Cable3 tested

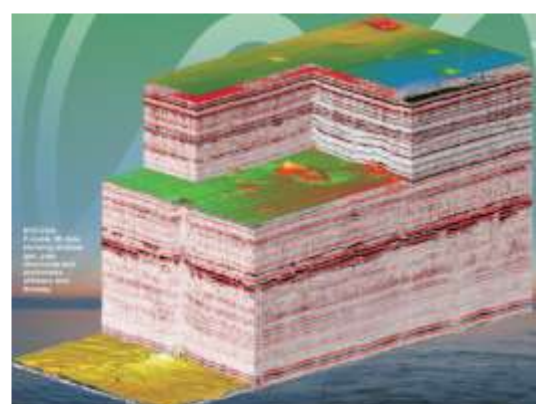
2011: Commercial P-Cable3 sales

2011: P-Cable3 Snøhvit survey

2011: P-Cable3 San Louis Obispo survey

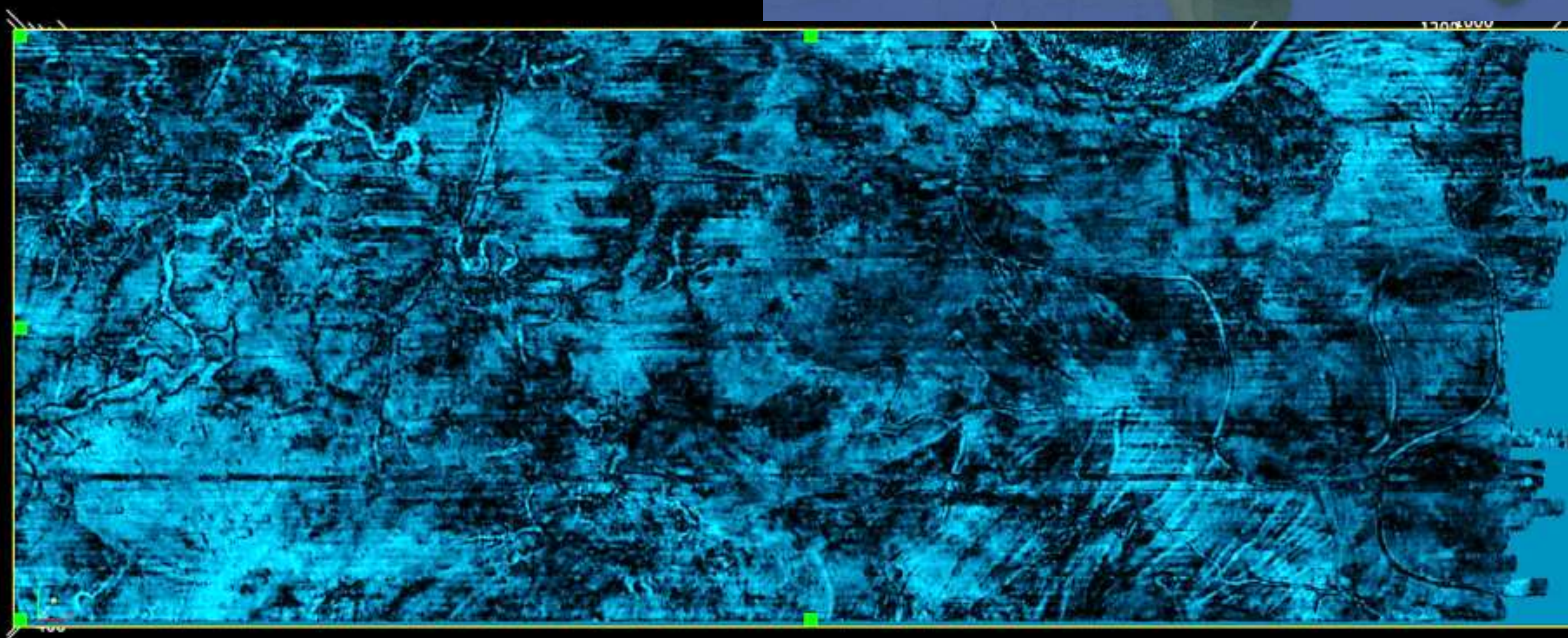
2012-14: UT-JSG GoM surveys

2014: NCS, WGP commercial system orders



Hustof et al., 2010
Nyegga pockmark field
Norway

Spectral decomposition
@ 500 ms
2012 dataset
D. Dunlap



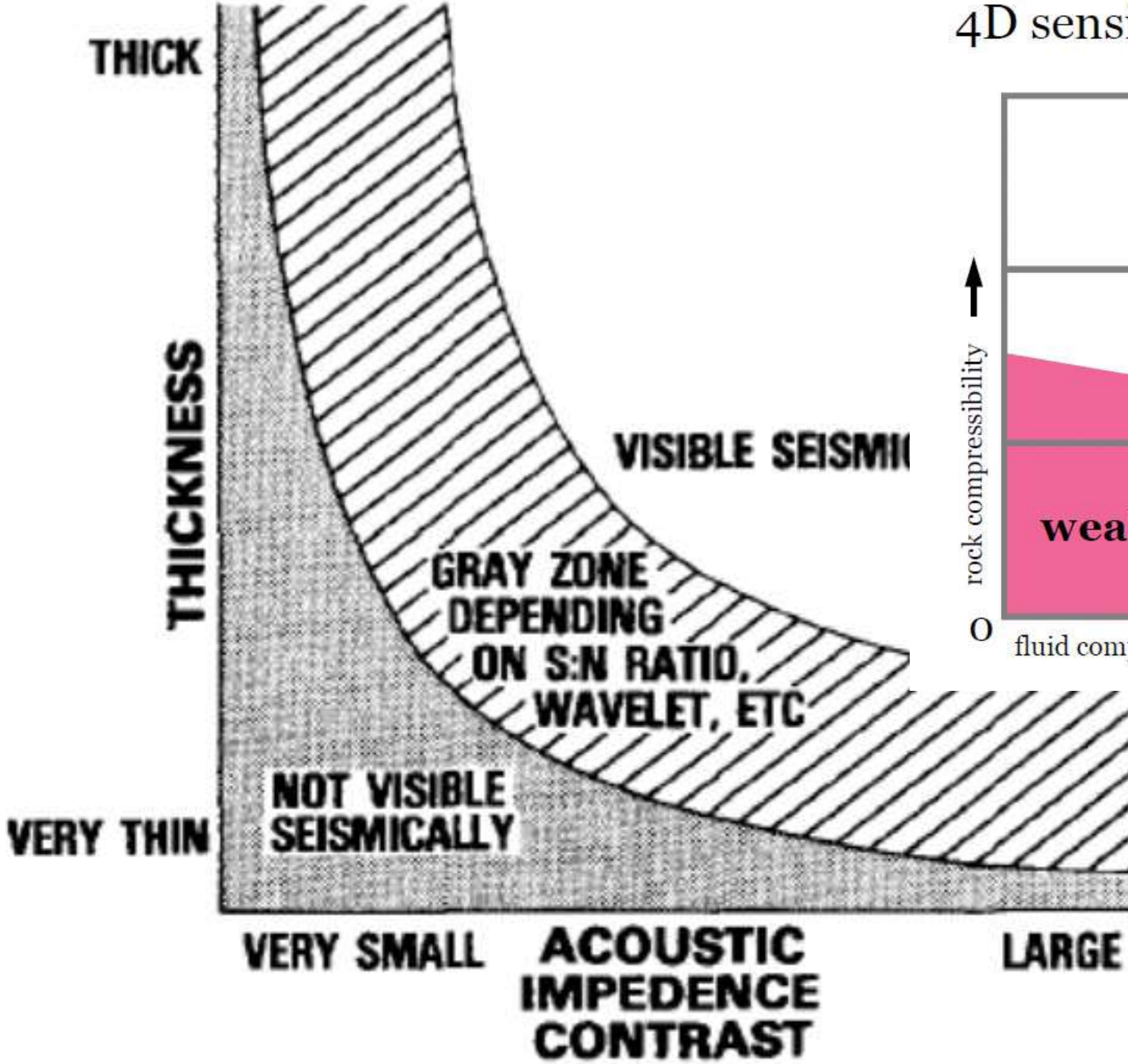
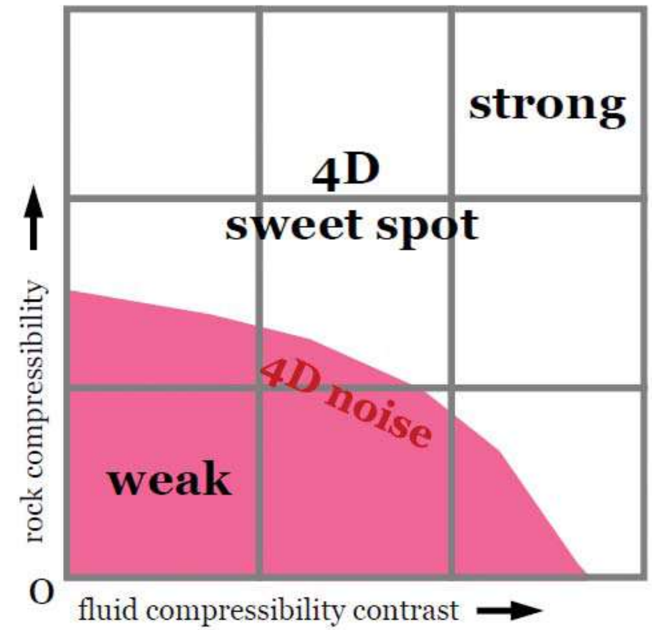
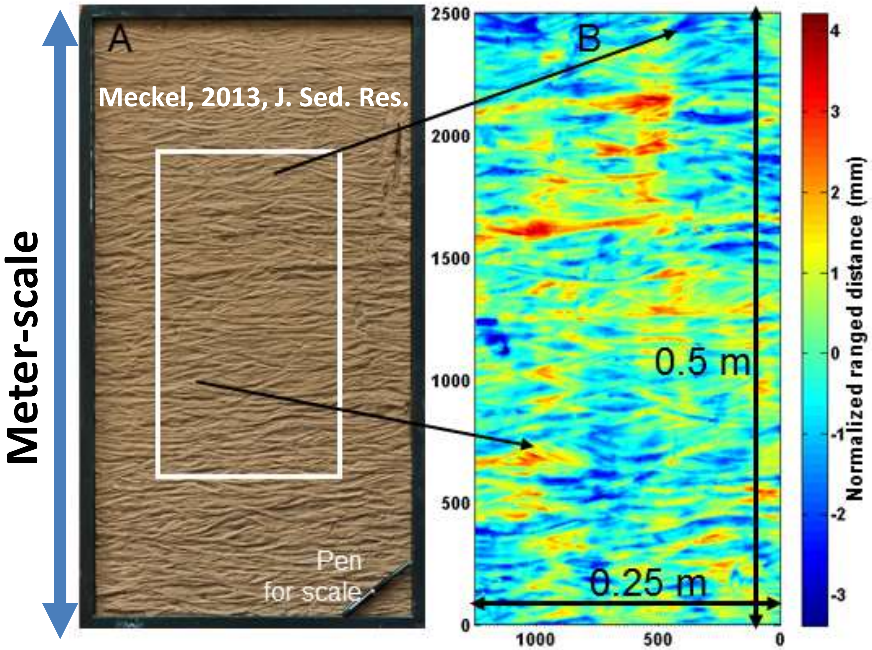


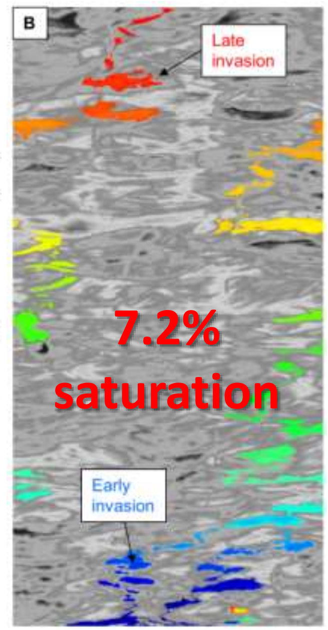
FIG. 32—Schematic graph showing seismic visibility of a unit.

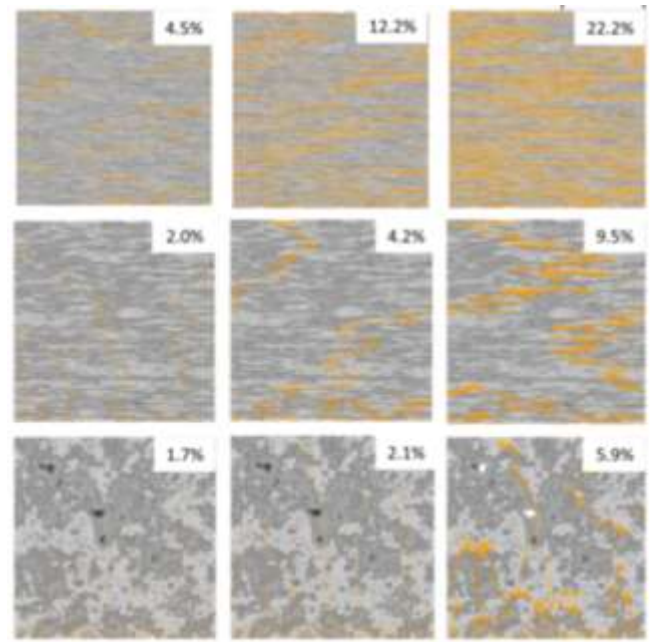
4D sensitivity to rocks & fluids



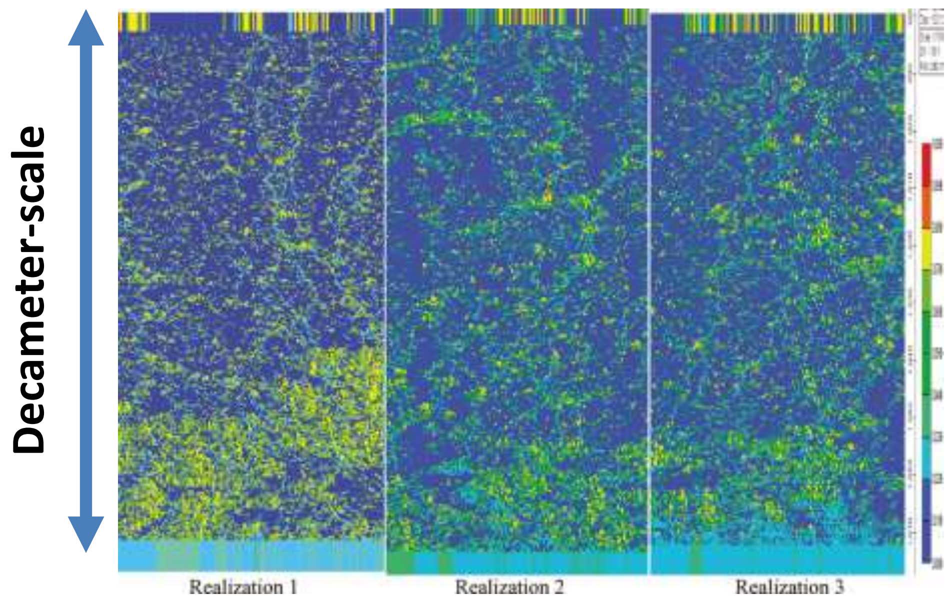
Low-saturation & seismic sensitivity (4D)

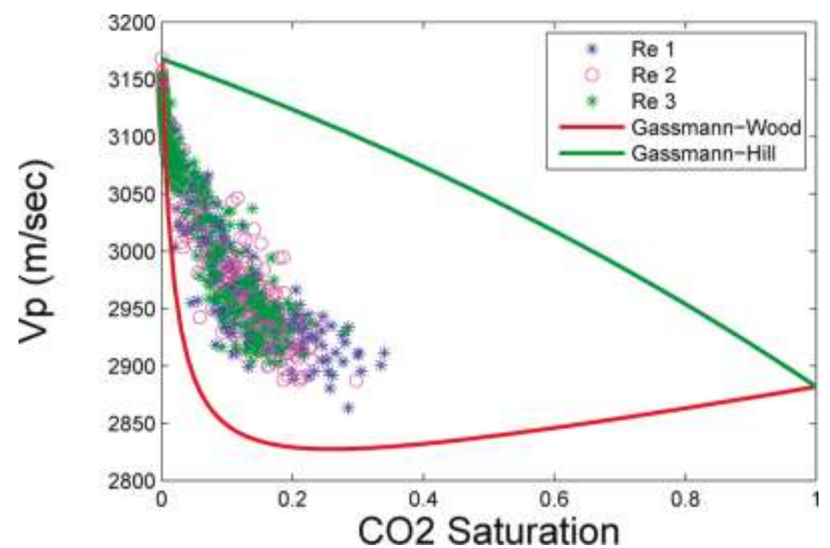




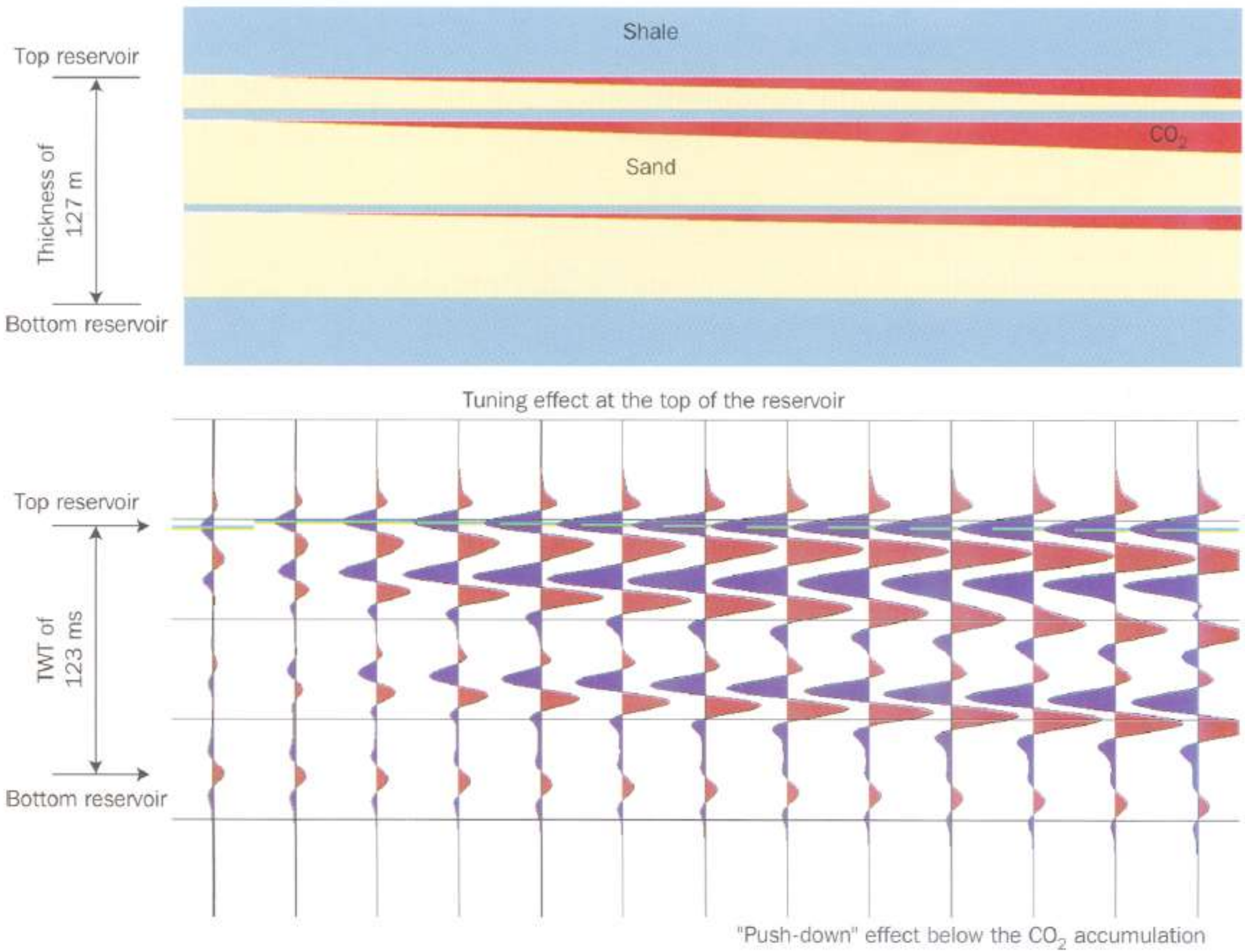


Meckel et al., in review, IJGGC

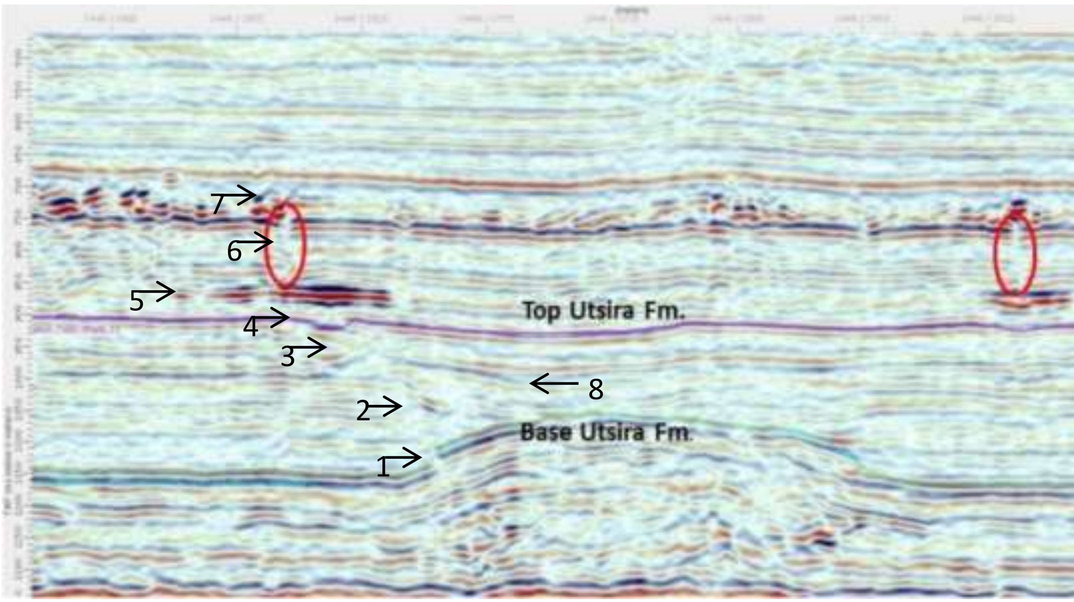




Behzadi et al., 2011, Env. Sci. & Tech.


Shale
Top reservoir
Thickness of 127 m
CO_2
Sand
Bottom reservoir
Tuning effect at the top of the reservoir
Top reservoir
TWT of 123 ms
Bottom reservoir
"Push-down" effect below the CO_2 accumulation

Hermanrud et al., in review
Utsira Fm



Petersen et al., 2010, M&PG
Vestnessa Ridge