Short-offset, multi-streamer 3D seismic arrays for overburden characterization and monitoring
Modified from Hill et al., 2015, Leading Edge
Geometry Detail: UT System

- 25 m
- 100 m
- ~300 m
- 85 - 110 m
- S-R Offsets
- 12.5 m
- GPS
- Compass
- Source
- 85 m
- 2 - 3 m towing depth
- 100 m
- Signal Cable
- 85 - 110 m
- Cross Cable
Conventional 3D

\[ \frac{1}{25 \text{ hz}} \times 1500 \text{ m/s} \times \frac{1}{4} = 15 \text{ meters} \]

Vertical Resolution

\[ \frac{1}{f} \times V \times \frac{1}{4} = 2.5 \text{ meters} \]

HR3D - PCable

\[ \frac{1}{150 \text{ hz}} \times 1500 \text{ m/s} \times \frac{1}{4} = 2.5 \text{ meters} \]

Existing conventional 3D

1500 ms \sim 1125 \text{ meters depth}

2012 UT Pcable HR3D
P-Cable Development History

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 km²)
2010: P-Cable3 tested
2011: Commercial P-Cable3 sales
2011: P-Cable3 Snøhvit survey
2011: P-Cable3 San Luis Obispo survey
2012-14: Three UT GoM surveys ~ 137 km²
2014: NCS, WGP commercial system orders
2015: NCS GoM SAFEBOARD
2016: NSF Langseth – New Jersey Shelf

~6 active systems globally; 70 surveys

<table>
<thead>
<tr>
<th>DATE</th>
<th>TX LOCATION</th>
<th>AREA (sq. km.)</th>
<th>LINE KM</th>
<th>AIRGUN SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>July, 2012</td>
<td>San Luis Pass</td>
<td>58</td>
<td>1,077</td>
<td>Two 210 cu. in. Gl</td>
</tr>
<tr>
<td>October, 2013</td>
<td>San Luis Pass</td>
<td>31.5</td>
<td>420</td>
<td>One 90 cu. in. Gl</td>
</tr>
<tr>
<td>April, 2014</td>
<td>High Island</td>
<td>47</td>
<td>627</td>
<td>Two 90 cu. in. Gl</td>
</tr>
</tbody>
</table>
UT System/Survey Specifications

- Water Depth = 10-15 m (CA, NS, NCS-SB much deeper)
- ~3-4 knots through water
- 12 streamers: GeoEel Solid
- 25 m streamer length (short offset, low fold)
- 8 Channels per streamer (3.125 spacing; 96 total)
- Streamer separation: ~12.5m
- CC compasses for orientation, positioning.
- Source: 90-420 in³ Sercel GI (compressed air)
- 12.5 m shot spacing (6.25 m² bins, 4 fold)
- Dominant frequency: 150 Hz (50-250 Hz typical)
- Coverage and positioning: 3rd party navigation hardware/software with proprietary processing

No ITAR restrictions
Interpreted Seismic-Section B to B’ - San Luis Pass Area, Offshore

Texas Offshore OBS 3-D

Key to Geologic Features and Symbols

- **R**: Recent through Pliocene Siliciclastics
- **UM**: Upper Miocene Siliciclastics
- **MM**: Middle Miocene Siliciclastics
- **Amph. B**: Amphistegina chiplensis Shale
- **LM2**: Lower Miocene 2 Siliciclastics
- **Marg. A**: Marginulina ascensionesis Shale
- **LM1**: Lower Miocene 1 Siliciclastics
- **O**: Oligocene Anahua Shale and Older
- **S**: Jurassic Allochthonous Louann Salt
- **OBS Amplitude**: Color scale for observed seismic amplitudes
- **SP Log**: Red for positive, blue for negative
- **Faults**: Black lines indicating faults

Clemente-Tomas Detachment
Subsurface Geology – Seismic Section

A-A’

Key to Geologic Features and Symbols:
- **R**: Recent through Pliocene Siliciclastics
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- **S**: Jurassic Allochthonous Louann Salt
- **Faults**: Faults
- **OBS Amplitude**: OBS Amplitude
- **SP Log**: SP Log

Depth (ft TVDSS):

- 0
- 5,000
- 10,000
- 15,000
- 20,000

Texas Offshore OBS 3-D

V.E. ~ 3x

5 mi
Primary Observations

• Structurally complex area.
• Evidence of charge.
• Non-economic well history locally.
• **Is this a good place to inject CO₂?**

• HR3-D seismic
  – Near-surface faults
  – Anomalies: chimney and shallow
  – (Quaternary stratigraphy)
OCTOBER 2013 and April 2014
R/V Brooks-McCall based out of Freeport, TX
50 m length, A-Frame
Primary operations: Sediment coring
2013 Survey: San Luis Pass, TX

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

A.)

Depth (ms TWT)

Texas Offshore OBS 3-D
Vertical Resolution: ~ 80 ft

B.)

Depth (ms TWT)

GCCP P-Cable 3-D
Vertical Resolution: ~ 24 ft

C.)

Depth (ms TWT)

UT CHIRP 2-D
Vertical Resolution: ~ 2 in

D.)

Key to Geologic Features and Symbols
- Seismic Amplitude Anomalies
  - Fault
  - V.E. ~ 15x
  - 0.5 mi

Vertical Resolution: ~ 80 ft
Vertical Resolution: ~ 24 ft
Vertical Resolution: ~ 2 in
Meckel and Mulcahy, 2016, INTERPRETATION

Variance Slice 181 ms

Geobody Elevation (ms)

-80
-125
-170

(a) Gas chimney zone

UC2 Surface

Surface Elevation (ms)

-50
-95
-130

Reservoir eroded by UC2

Anomalies sit at remnant topographic highs

(a) Strong negative amplitude

(b) Phase Shift

(c) Stacked Anomalies

Highly discontinuous zone below anomaly

Push down

Gaps in an anomaly where tributary valleys intersect
Interpreted Seismic-Section B to B' - San Luis Pass Area, Offshore

B)

050°

B

NO

YES

MAYBE

A - A'

42706300810000

Depth (ft TVDSS)

V.E. ~ 3x

5 mi
SUMMARY

- **3 acquisitions using P-Cable HR3D system in GoM.**
  - 2012 – 2014: 130 km$^2$ total to date.
  - Learnings from surveys:
    - Vessel, deployment, positioning, array geometry, source, processing.

- **Technology & datasets achieve 2 primary goals:**
  - Characterization: Success imaging overburden in detail.
    1) **GEOLOGY:** Well-resolved faults and stratigraphy down to 1+ sec (90 cu. in. source)
       - Complex stratigraphic heterogeneity (inner shelf)
       - Subtle fault expression toward seafloor.
    2) **FLUIDS:** Identification of leaky/non-leaky geo-systems.
       - Potential migration pathways & re-accumulations not seen in conventional data.
       - Integration with Coring.
TOMAKOMAI CO2 Injection Project

Onshore seismometer

Observation well OB-2 for Moebetsu Formation (vertical)

2 Injection wells (Deviated)

Observation well OB-1 for Takinoue Formation converted from survey well (Deviated)

Observation well OB-3 for Takinoue Formation (vertical)

Working area of 3D seismic survey

OBC (Ocean Bottom Cable): used for 2D seismic survey and monitoring of micro-seismicity and natural earthquakes.

OBS (Ocean Bottom Seismometer): used for monitoring of micro-seismicity and natural earthquakes.

Google Earth Image © 2013 DigitalGlobe

Data SIO, NOAA, U.S. Navy, NGA, GEBCO Image © 2013 TerraMetrics

Seismic Monitoring Program

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QUESTIONS?