March 27, 2020

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SECARB Offshore

Partnership for carbon capture & offshore geologic storage
GoMCarb

Experiencing Technical Difficulties?

Emily Moskal
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(281) 796-9834

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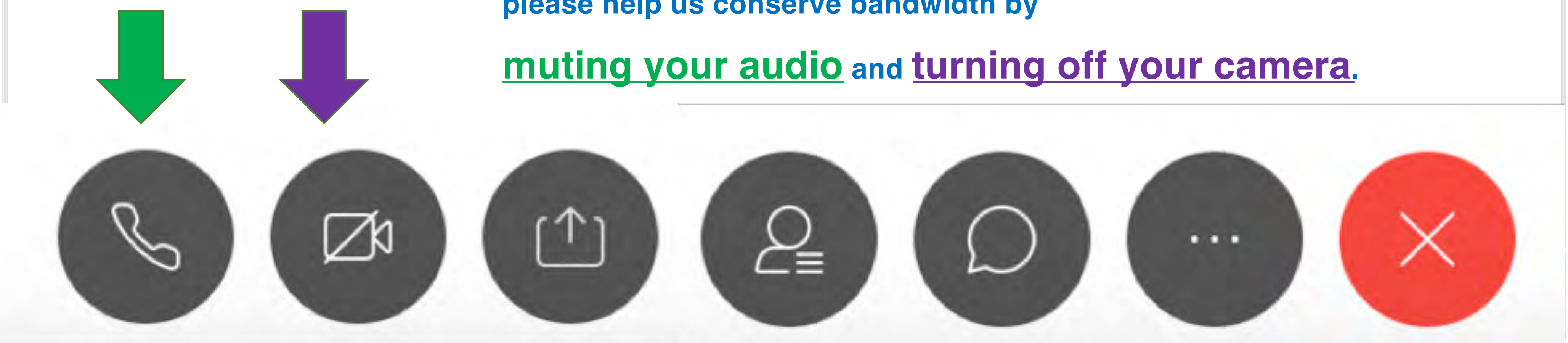

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March 27, 2020

SECARB Offshore GoM Project Updates and Discussion

9:45 AM – 10:00 AM
Log In and Trouble Shooting

10:00 AM – 11:00 PM
Status of Characterization of CO_2-EOR Offshore Resource Potential – Matt Wallace, Advanced Resources International, Inc.
Status of Risk Characterization Activities and Data Development – Michael Godec, Advanced Resources International, Inc.

11:00 AM – 11:15 AM | BREAK

11:15 AM – 12:15 PM
Status on Work on Characterizing Legal and Regulatory Frameworks and Key Considerations – Michael Godec, Advanced Resources International, Inc., and Ingvild Ombudstvedt, IOM Law
Overview of Offshore CO_2-EOR/Storage Case Studies – Vello Kuuskraa, Advanced Resources International, Inc.

12:15 PM – 1:15 PM | LUNCH BREAK

1:15 PM – 2:05 PM
Risk Assessment Gas Hydrates – Camelia Knapp, Oklahoma State University
SECARB Offshore evaluating the salt structures and deep-water reservoirs in the central Gulf of Mexico – Jack Pashin, Oklahoma State University

2:05 PM – 2:20 PM | BREAK

2:20 PM – 3:00 PM
Offshore Well Integrity – Andrew Duguid, Battelle Memorial Institute
45Q – Brian Hill, Crescent Resource Innovation

3:00 PM – 3: 15 PM
Wrap up and Comments

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Thank you for joining us!

Presentations are available online.

gulfcoastcarbon.org/news/2020

March 26-27: https://www.sseb.org/news-and-events/

After March 27: https://www.sseb.org/news-and-events/past-events/

SECARB Offshore

Partnership for carbon capture & offshore geologic storage

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Building the Foundation for Assessing GOM Offshore CO_2 EOR and Associated CO_2 Storage

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace
Anne Oudinot
Advanced Resources International, Inc.

March 26-27, 2020

Advanced Resources International, Inc.

Outline of Presentation

1	Purpose of the Case Studies
2	Petronius Offshore Oil Field Case Study
3	Cognac Offshore Oil Field Case Study
4	Observations and Findings

Purpose Of Case Studies

The primary purpose of the "Offshore Oil Field Case Studies" is to assess the ability of the NETL CO_2 PROPHET Model to represent the performance of an offshore CO_2 flood, including appropriately capturing the geologic complexity and irregular well spacings typical of offshore oil fields.

For this, the Study conducted seven tasks:

1. **Geologic Model.** Build representative geologic models for the oil fields, including capturing structural setting and associated aquifer.
2. **Reservoir Model.** Assemble the key reservoir properties of the oil reservoir, including its volumetric data, fluid flow capabilities, and oil composition.
3. **Field Development**. Establish the locations of the existing oil/gas production wells producing from the oil reservoir.

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Purpose Of Case Study (Cont'd)

4. **History Matching Using Compositional Simulations**. Use GEM compositional simulator to provide a "first-order" history match of fluid production from the oil reservoir.

5. **Assessing CO_2 Flooding Using Compositional Simulation**. With a calibrated geologic/reservoir description, appraise the performance of a post-primary CO_2 EOR project in the oil reservoir using the GEM compositional simulator.

6. **Assessing CO_2 Flooding Using CO_2 PROPHET**. In parallel with the GEM compositional simulator, use the NETL CO_2 PROPHET Model to appraise the performance of a post-primary CO_2 EOR project in the oil reservoir.

7. **Comparing GEM and CO_2 PROPHET Modeling.** Compare the results of GEM and CO_2 PROPHET modeling of CO_2 EOR to determine whether the NETL CO_2 PROPHET model could reasonably represent the performance of the CO_2 flood compared to the more sophisticated GEM compositional simulator.

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Petronius Offshore Oil Field Case Study

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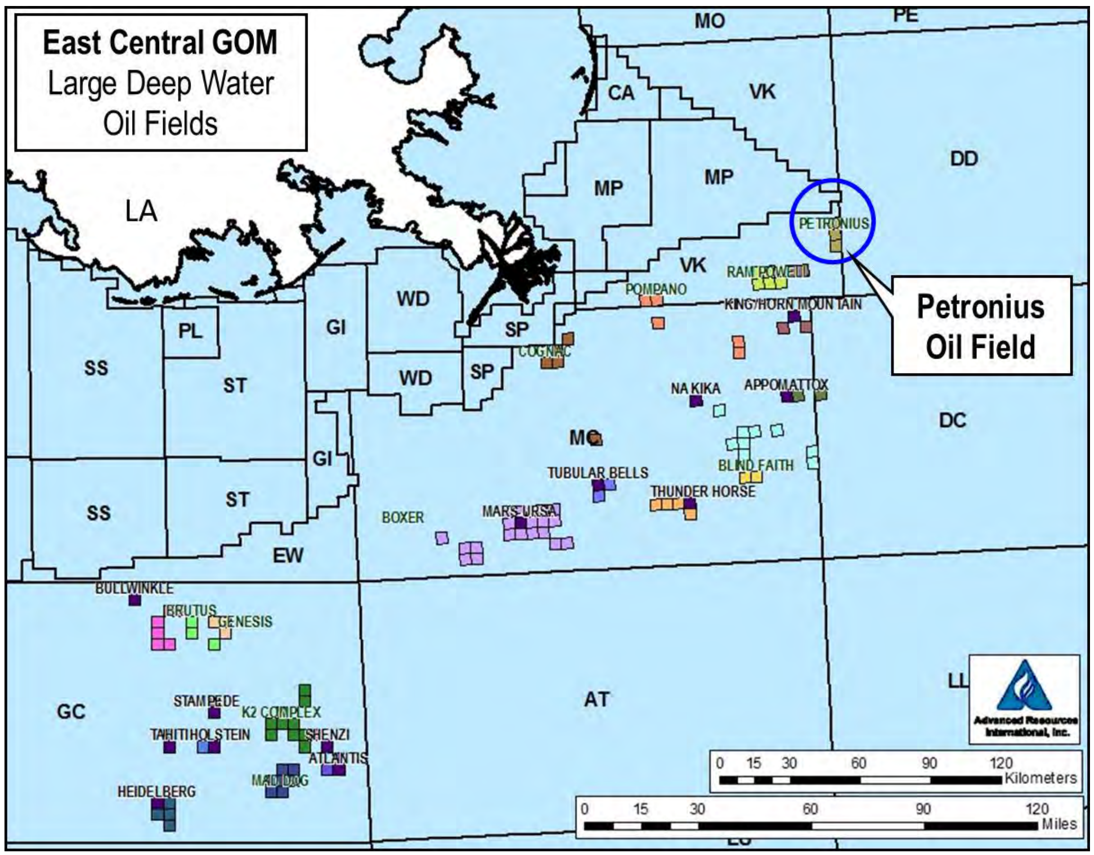
Background

The Petronius deepwater oil field (VK 786) is located in 1,790 feet of waters of the East Central Gulf of Mexico.

Location of Petronius Oil Field, Eastern Gulf of Mexico



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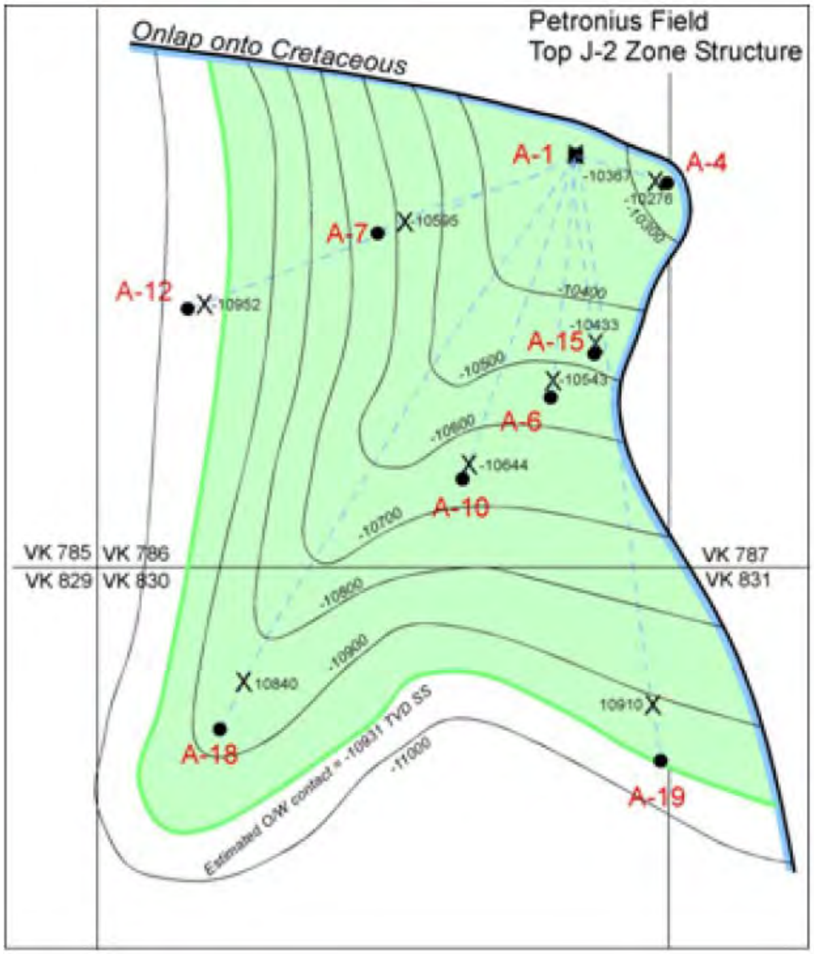
Petronius, with 162 million barrels of original oil reserves, has produced over 96% of its original reserves, as of the end of 2016.

Oil production that peaked at 70,000 B/D in 2003 but has declined to 6,600 B/D in 2016, placing Petronius on a list of oil fields facing near-term abandonment.

A notable feature of Petronius is its early installation of a waterflood due to a relatively weak underlying aquifer.

Petronius J-2 Sand Geologic Model

Structure of the Petronius J-2 Sand



Source: Duan, 2013

The Petronius J-2 Sand reservoir is a Middle Miocene sheet sand, providing a structurally simple setting.

There is little faulting within the Petronius oil field and the J-2 Sand reservoir is judged to be relatively continuous.

The illustration provides the structure of J-2 reservoir, its oil-water contact (OWC), and the location of its nine production wells.

The Petronius J-2 Sand

The Petronius oil field contains two major sands, the Miocene-age Upper (J-1) Sand and Middle (J-2) Sand, as well as a series of smaller oil sands, shown below.

Petronius Original Oil Resources, Production and Remaining Reserves

Sands		Area (Acres)	Original Oil In-Place (MMB)	Cumulative Oil Production* (MMB)	Remaining Oil Reserves* (MMB)
1. Major Sands					
▪	J-1	3,438	124.8	69.6	4.0
▪	J-2	5,288	104.7	52.0	1.3
2. Minor Sands					
▪	J-3	1,352	24.5	6.1	1.0
▪	J-4	1,398	39.2	17.8	0.9
▪	J-5	389	18.2	7.8	1.5
▪	Other (13)	-	0.7	0.2	-
Total		**11,865**	**312.1**	**153.5**	**8.7**

*As of end of 2016.

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Volumetric and Other Reservoir Properties: Petronius J-2 Sand

Reservoir Properties	Value
Oil Area	
▪ Total	5,288 Acres
▪ Quarter*	1,290 Acres
Porosity	30%
Depth	10,900 to 11,100 ft
Permeability	398 mD
Net Pay	16.5 ft
Oil Gravity	31 API
Swi	0.24
Boi	1.45
OOIP	104 MM bbls
Initial Pressure	5,287 psia
Pressure Gradient (@ 10,560 ft)	0.5 psi/ft
Initial Temperature	182 ^{o}F

*After including gas cap area.

The key volumetric and reservoir properties for the Petronius J-2 Sand are derived from information provided in the BOEM Offshore GOM database and from the technical literature on the Petronius oil field.

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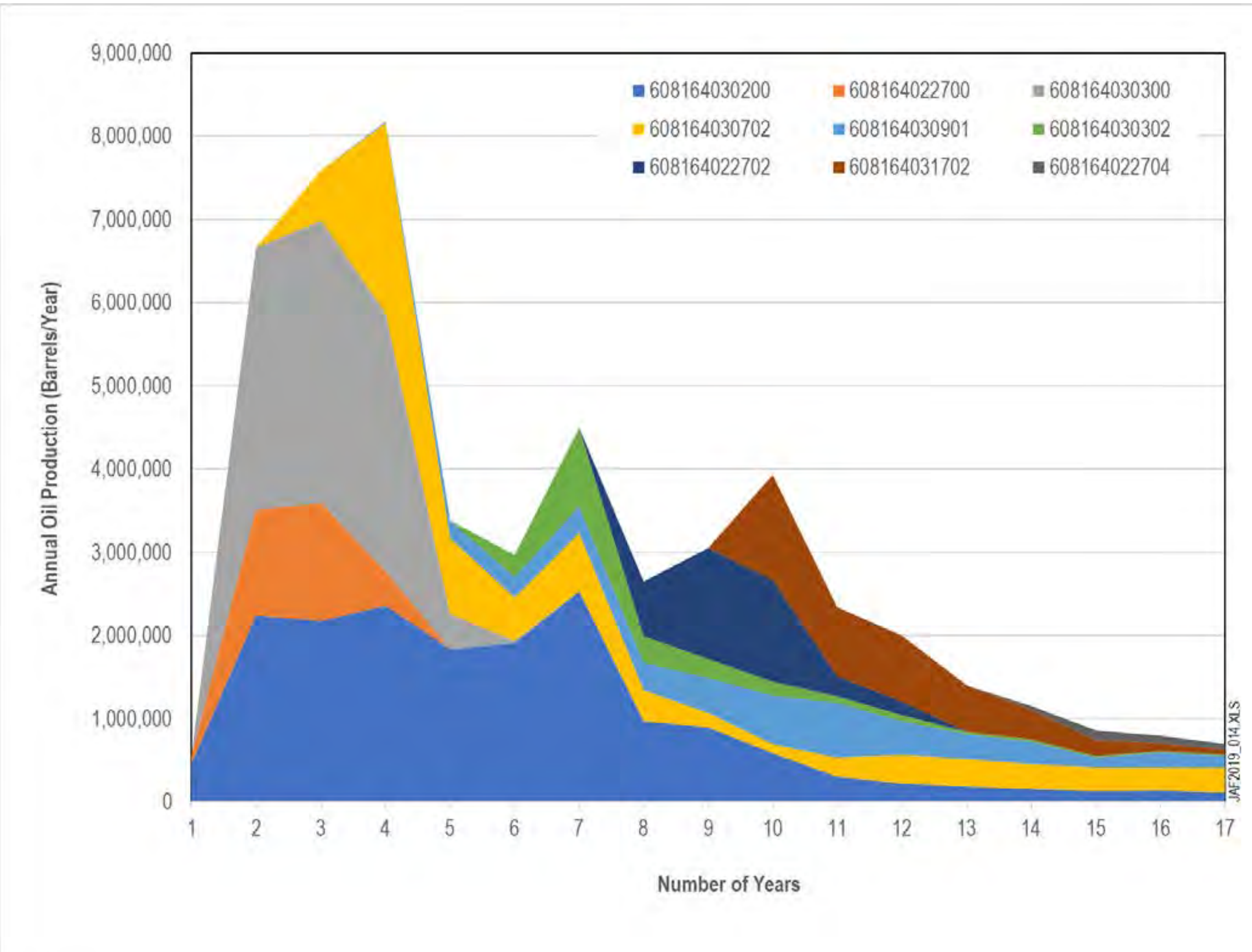
Petronius J-2 Sand

Annual Oil Production 2000-2016



After a peak of 22,400 B/D (8.2 MMBbl/yr) in 2003, oil production from the J-2 Sand declined to 1,900 B/D (0.7 MMBbl/yr) in 2016.

The oil production history for the nine production wells drilled into the Petronius J-2 Sand is shown.

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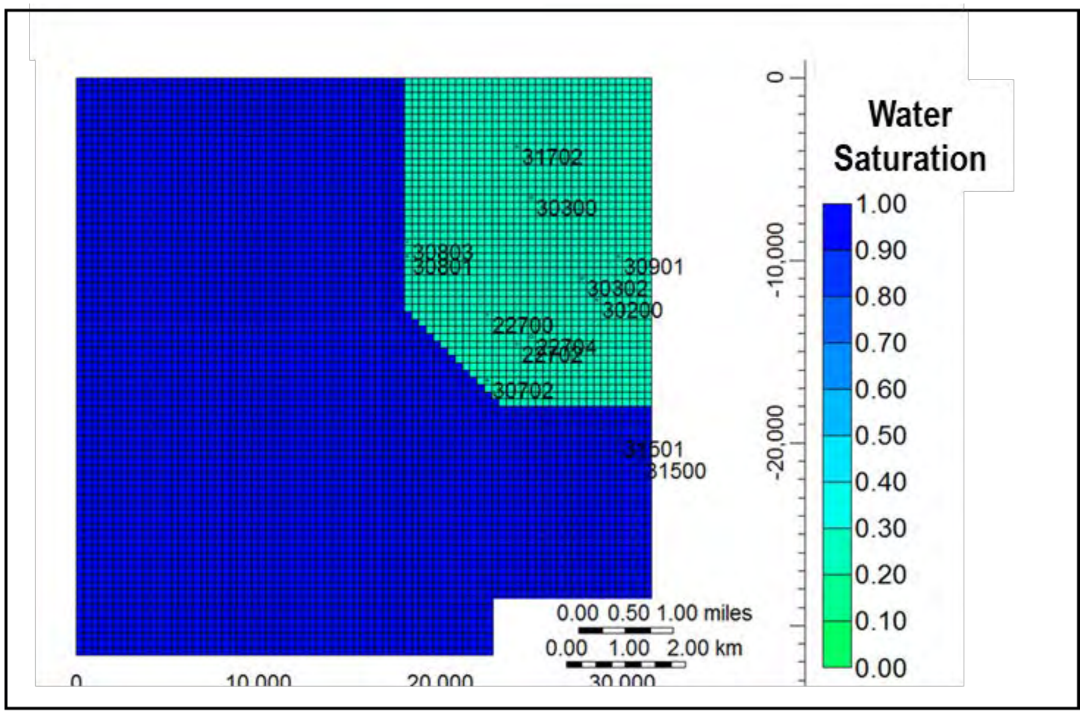
Reservoir Model for Petronius J-2 Sand

J-2 Sand Reservoir Model and Grid Blocks



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Source: Advanced Resources International, 2019

The reservoir model for the Petronius J-2 Sand contains 79 grid blocks in the X direction and 79 grid blocks Y direction, with each grid block set at 400 feet by 400 feet.

The up-structure portion of the reservoir model represents the oil reservoir. The down-structure portion of the reservoir model represents the underlying aquifer.

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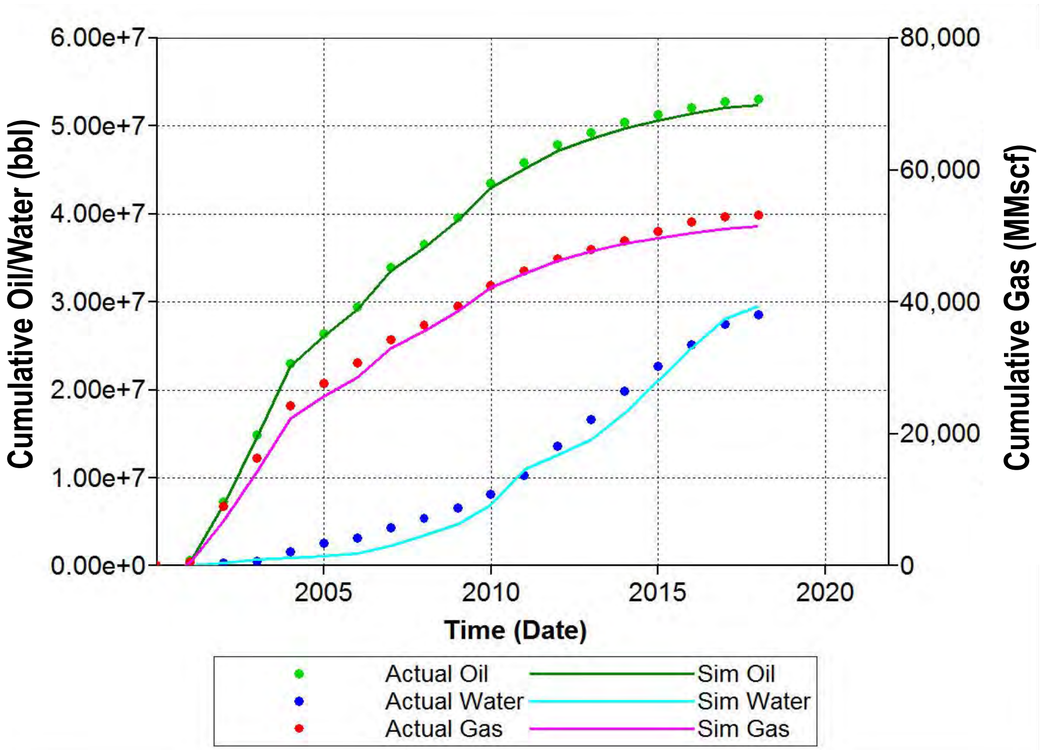
History Match of Fluid Production, Petronius J-2 Sand



Source: Advanced Resources International, 2019

Excellent history matched results were obtained for oil production, gas production and water production.

Fluid	Actual Data	History Matched Data
Oil	53 MM bbl	52.4 MM bbl
Gas	53 Bcf	51.4 Bcf
Water	28.5 MM bbl	29.4 MM bbl

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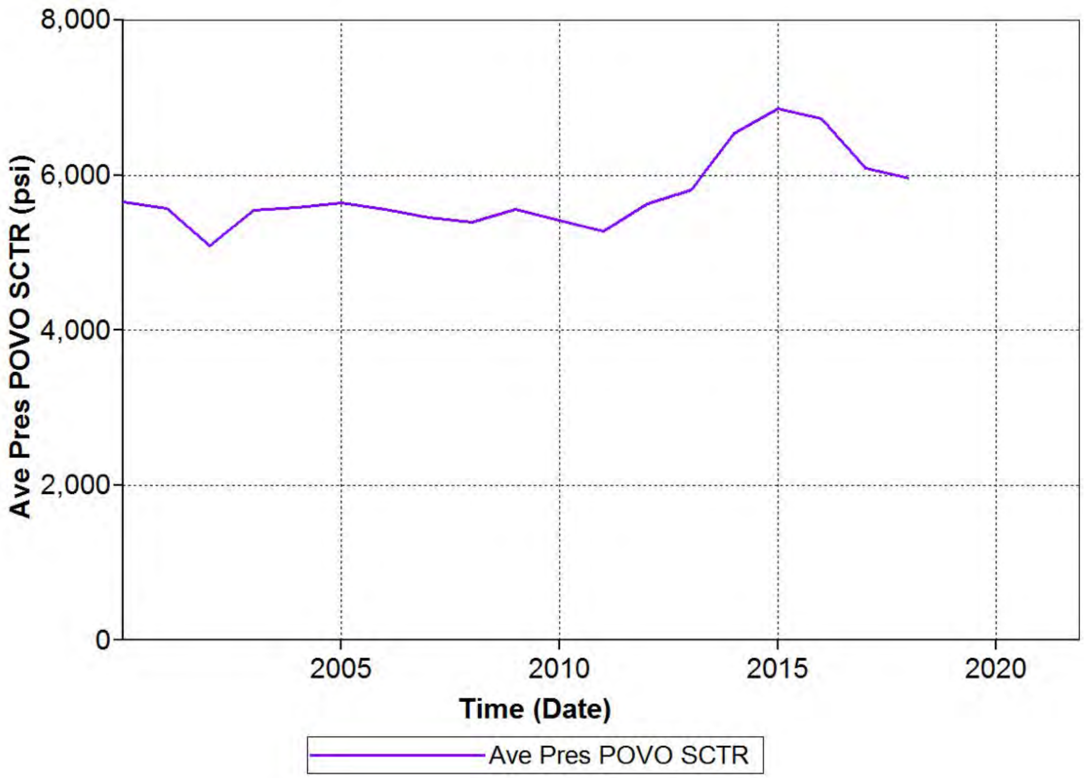
History Match of Fluid Production, Petronius J-2 Sand



An important output of the history match was the estimate of J-2 Sand reservoir pressure at the end of the waterflood.

Source: Advanced Resources International, 2019

GEM Compositional Modeling of the Performance of the CO_2 Flood, Petronius J-2 Sand

CO_2 Flood Design. Given the structural dip of the formation, its high permeability, and the strong bottom waterdrive, the design of the CO_2 flood was as follows:

- Drill an updip CO_2 injection well on the crest of the fault block.
- Inject continuous CO_2 at a rate of 25 MMcfd into the J-2 Sand for 40 years.
- Shut-in the one previously drilled, still active water injection well; operate the CO_2 flood using a bottom hole back pressure of 4,000 psi.
- Operate the CO_2 flood using a quarter of a five-spot pattern, with three closely spaced, active wells representing one production well and the other two closely spaced, active wells representing the second production well.

CO_2 PROPHET Modeling of the NETL CO_2 Flood, Petronius J-2 Sand

In parallel with the GEM compositional simulator, the study modeled the CO_2 flood in the Petronius J-2 Sand using NETL CO_2 PROPHET.

To capture the heterogeneity of the J-2 Sand, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the J-2 Sand were modeled (with CO_2 PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO_2 producer and operate the CO_2 flood using a quarter of a five-spot pattern.
- Inject continuous CO_2 at a rate of 25 MMcfd for forty years, reaching a cumulative injection of CO_2 of 365 Bcf, equal to CO_2 injected in the GEM Model.

Comparative Analysis of GEM and CO_2 PROPHET Modeling of CO_2 Flood, J-2 Sand

The CO_2 PROPHET streamtube model was able to reasonably represent the performance of the CO_2 flood compared to the GEM compositional simulator.

	CO_2 Flood Performance GEM Compositional Simulator	CO_2 Flood Performance CO_2 PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	106	106	106
CO_2 Injection (Bcf)	365	365	365
CO_2 Production (Bcf)	226	238	190
CO_2 Storage (Bcf)	139	127	175
Cumulative Oil Recovery			
▪ (million barrels)	14.3	10.8	17.4
▪ % of OOIP	13.5%	10.2%	16.4%
CO_2/Oil Ratio (Mcf/B)			
▪ Gross	25.5	33.8	21.0
▪ Net	9.7	11.8	10.1

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO_2 PROPHET model) provide results that bracket the performance of the CO_2 flood from the GEM compositional simulator.

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Cognac Offshore Oil Field Case Study

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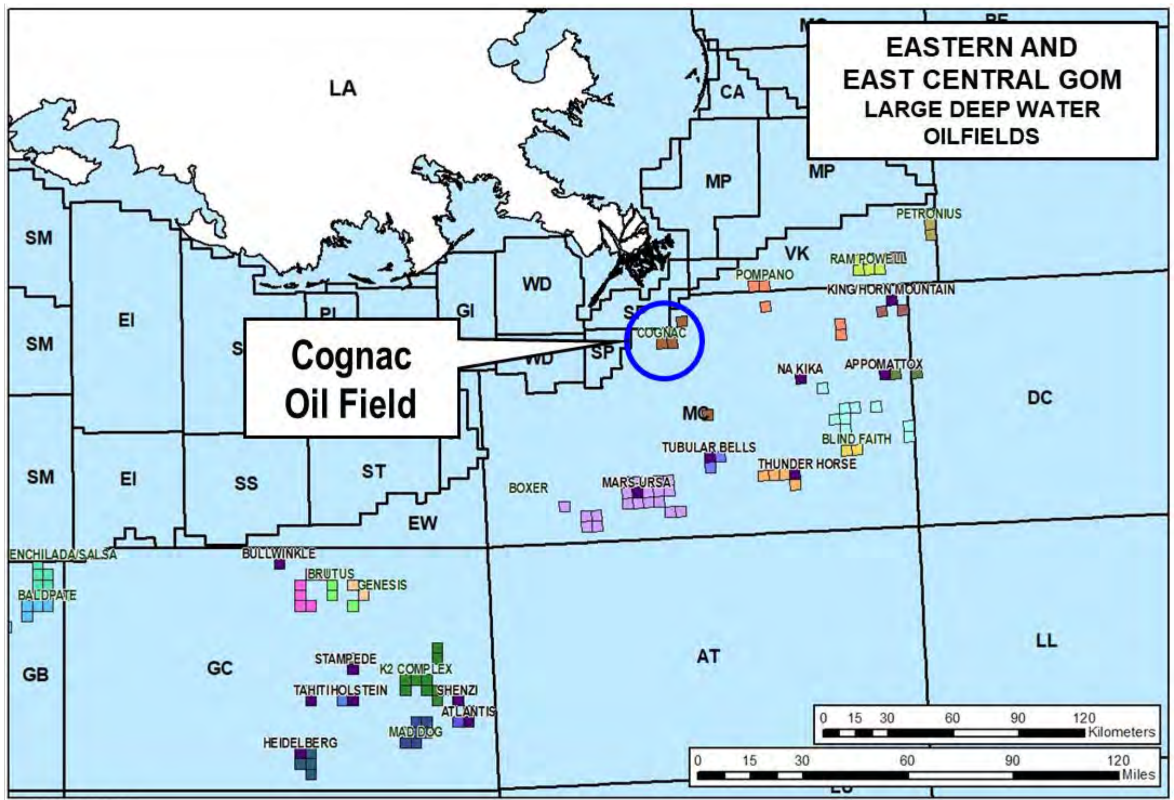
Background

The Cognac deepwater oil field (MC 194) is located in 1,022 feet of water in the Central Gulf of Mexico.

Location of Cognac Oil Field, Eastern Gulf of Mexico



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Cognac, with 184 million barrels of original oil reserves, has produced essentially all of its reserves, as of the end of 2017.

Oil production that peaked at 83,000 B/D of oil in 1983 has declined to about 2,000 B/D of oil in 2016, placing Cognac on a list of oil fields facing abandonment.

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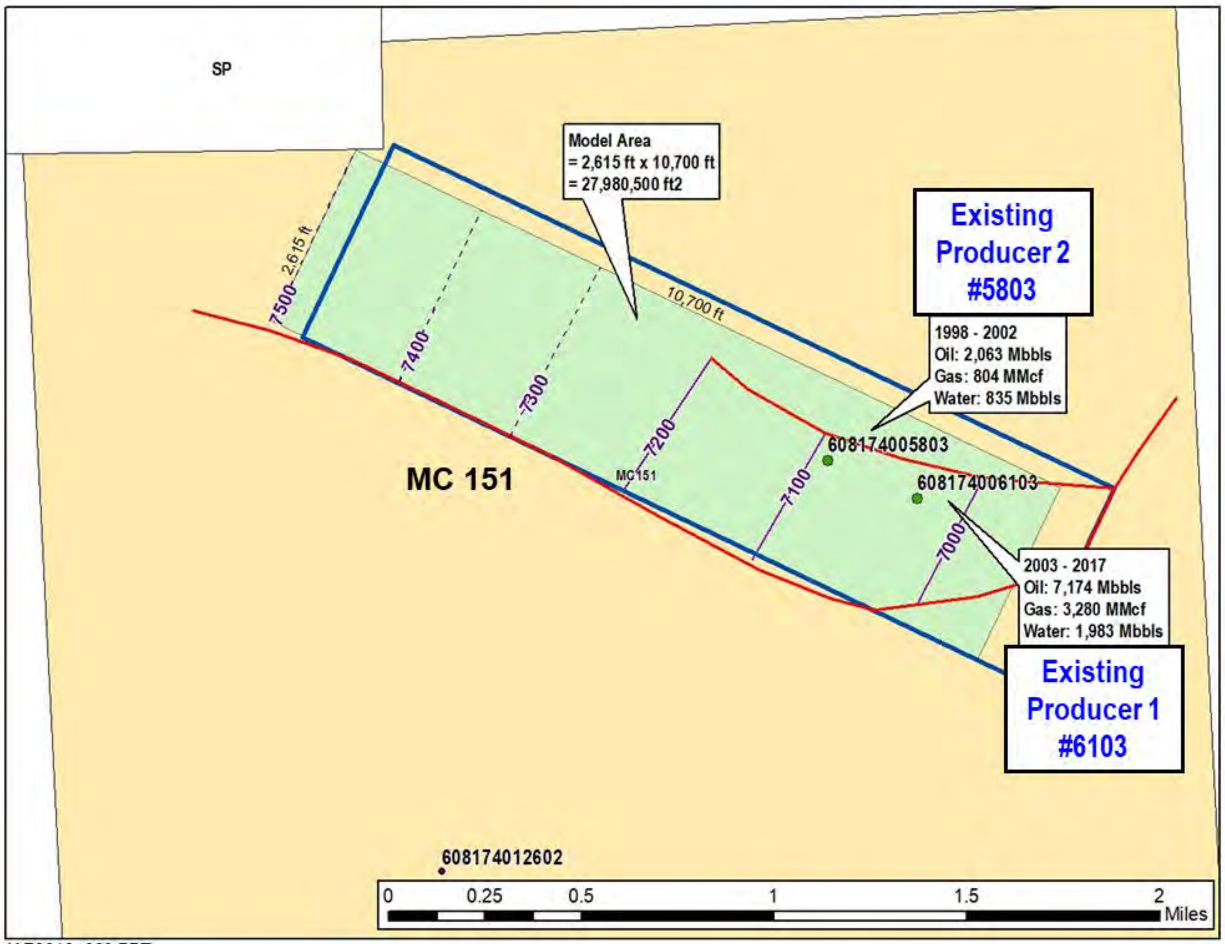
Cognac J Sand/NE Fault Block Geologic Model

Outline of NE Fault Block, Cognac Field



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The NE Fault Block in MC 151 contains two oil producing wells – Well #5803 and Well #6103 – producing from a fault bounded area of about 384 acres.

A simplified representation of the NE Fault Block, including its structure, the location of the bounding faults, and the location of the two producing wells is shown.

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Cognac J Sand

The J Sand in the Cognac oil field, selected for the Case Study, holds 136 million barrels of OOIP and has a remaining oil target of 79 MMB. The NE Fault Block (J Sand) holds about 18% of the OOIP in the total J Sand.

Cognac Original Oil Resources, Production and Remaining Reserves

Sands		Oil Area (Acres)	Original Oil In-Place* (MMB)	Cumulative Oil Production** (MMB)	Remaining Oil Reserves (MMB)
1. Major Sands					
▪	I	3,560	191.5	91.7	0.1
▪	J	2,240	135.6	56.9	0.3
2. Minor Sands					
▪	J-1	1,740	23.3	6.6	***
▪	Others	n/a	n/a	16.0	3.2
Total		**7,540**	**350.4**	**171.2**	**3.6**

*Volumetrically adjusted by Advanced Resources Int'l., **As of end of 2016.
***Less than 0.05 MMB.

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Volumetric and Other Reservoir Properties Cognac J Sand/NE Fault Block

Reservoir Properties	Value
Accessible Oil Area	384 Acres
Porosity	32%
Permeability	794 mD
Net Pay	42 ft
Oil Gravity	34.6 API
Soi	0.73
Sor	0.45
Boi	1.21
OOIP	24.2 MMbbls
Initial Pressure (@ 8,297 ft)	4,412 psia
Initial Reservoir Temperature	130 ^{o}F

The key volumetric and reservoir properties for the Cognac J Sand in the NE Fault Block are derived from information provided in the BOEM Offshore GOM data base and from the technical literature on the Cognac oil field.

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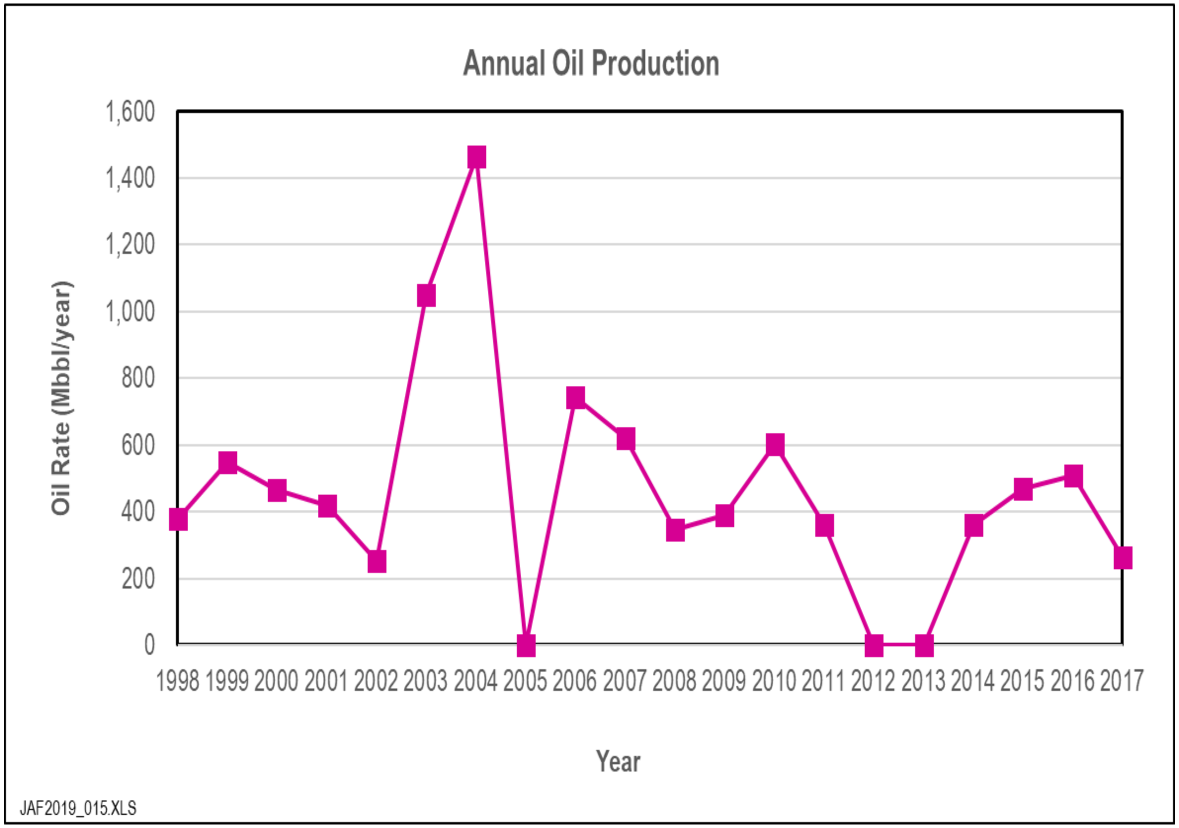
Cognac J Sand/NE Fault Block

Annual Oil Production, Cognac J Sand, NE Fault Block



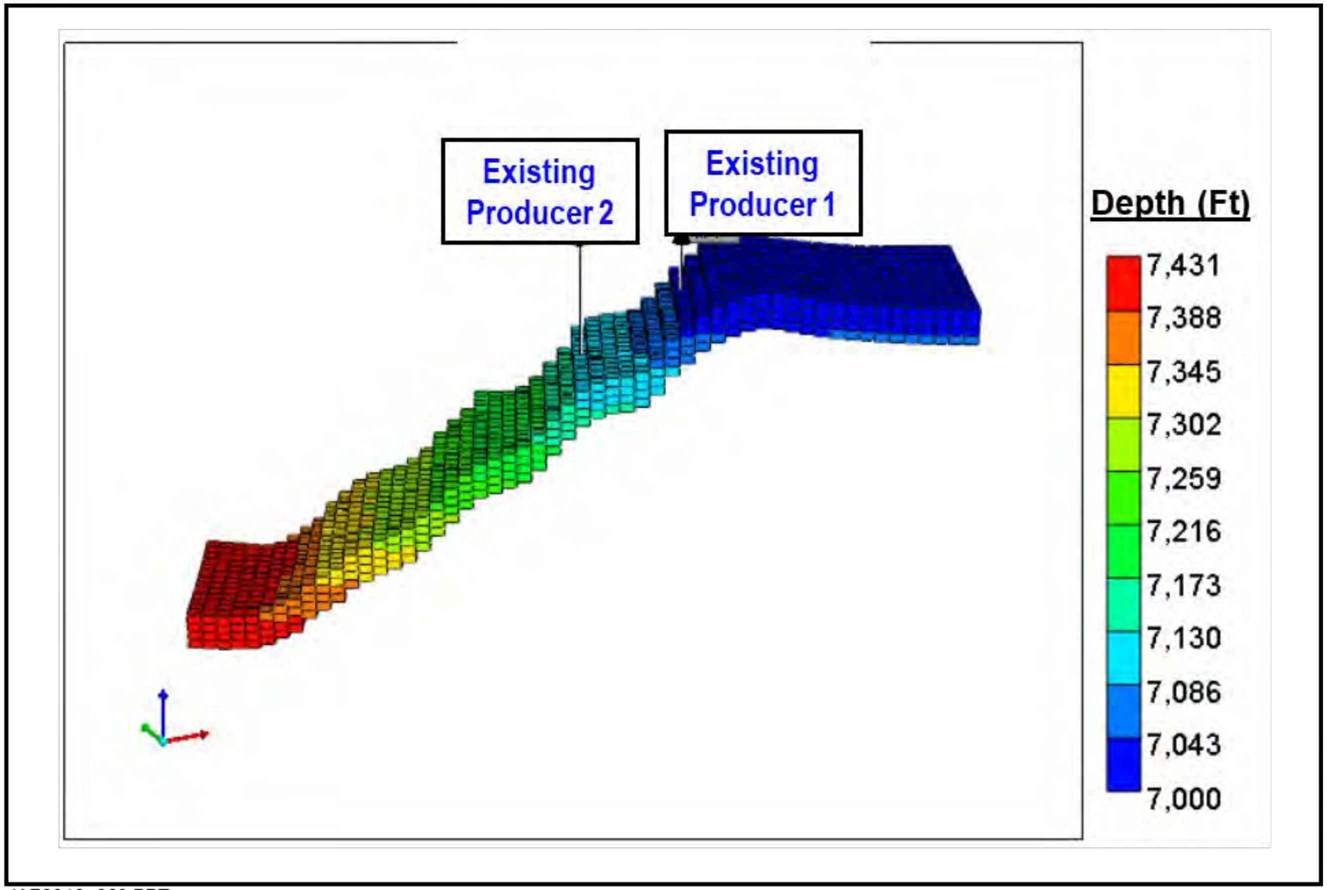
Source: Advanced Resources Int'l using DrillingInfo data, 2019

As of mid-2017, the J Sand of the NE Fault Block has produced 9.25 million barrels of oil, equal to 38 percent of OOIP.

The annual oil production history of the NE Fault Block J Sand from inception in mid-1998 to mid-2017 is shown.

Reservoir Modeling for Cognac J Sand

NE Fault Block, Cognac J Sand, 3D Model, Side View



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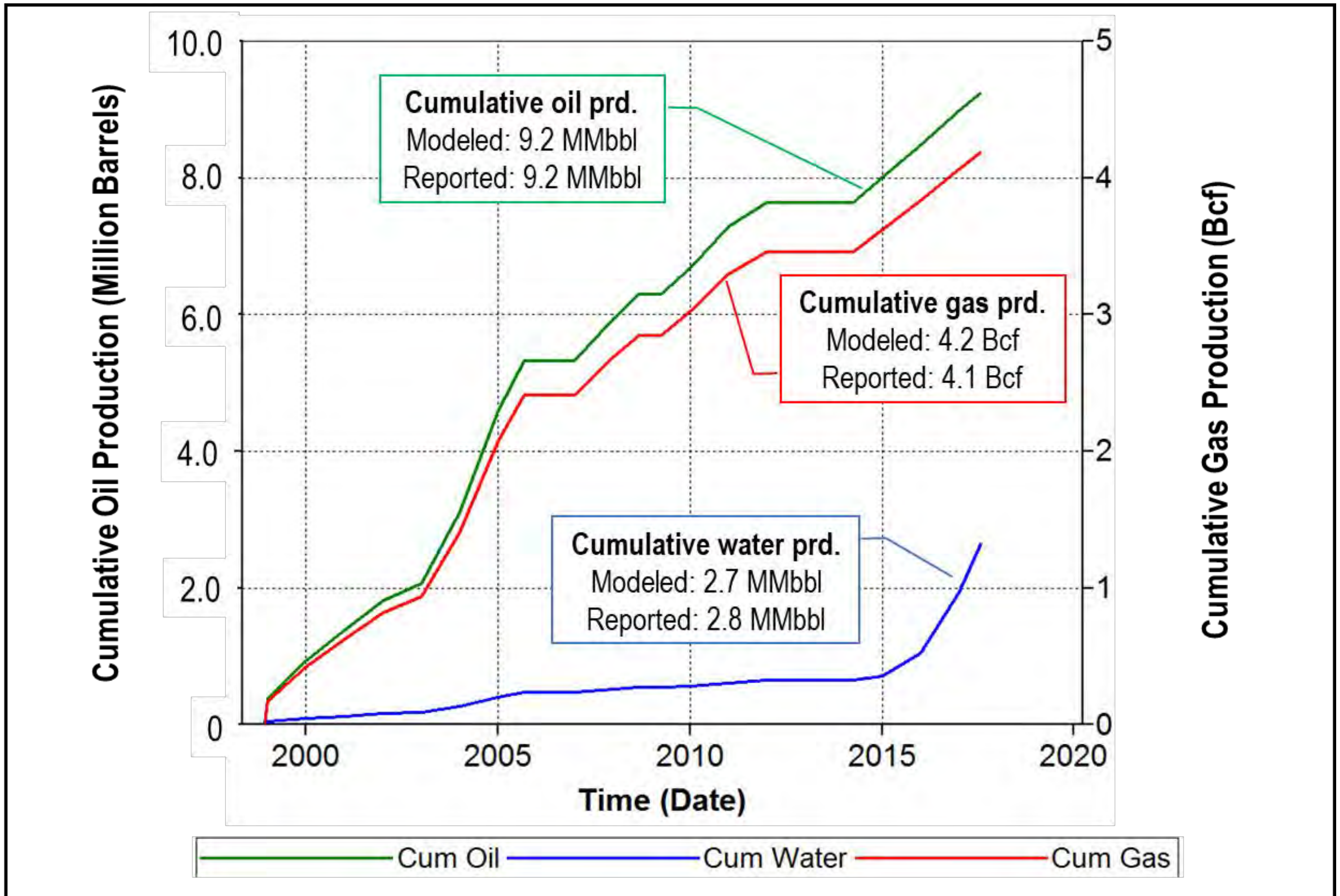
The reservoir model for the surface of NE Fault Block J Sand contains 702 grid blocks (54 x 13) each having a dimension of 200 ft in the X and Y directions.

The vertical dimension of the J Sand is represented by four layers (grid benches), each having a thickness of 10.5 feet.

History Match of Fluid Production, Cognac J Sand, NE Fault Block



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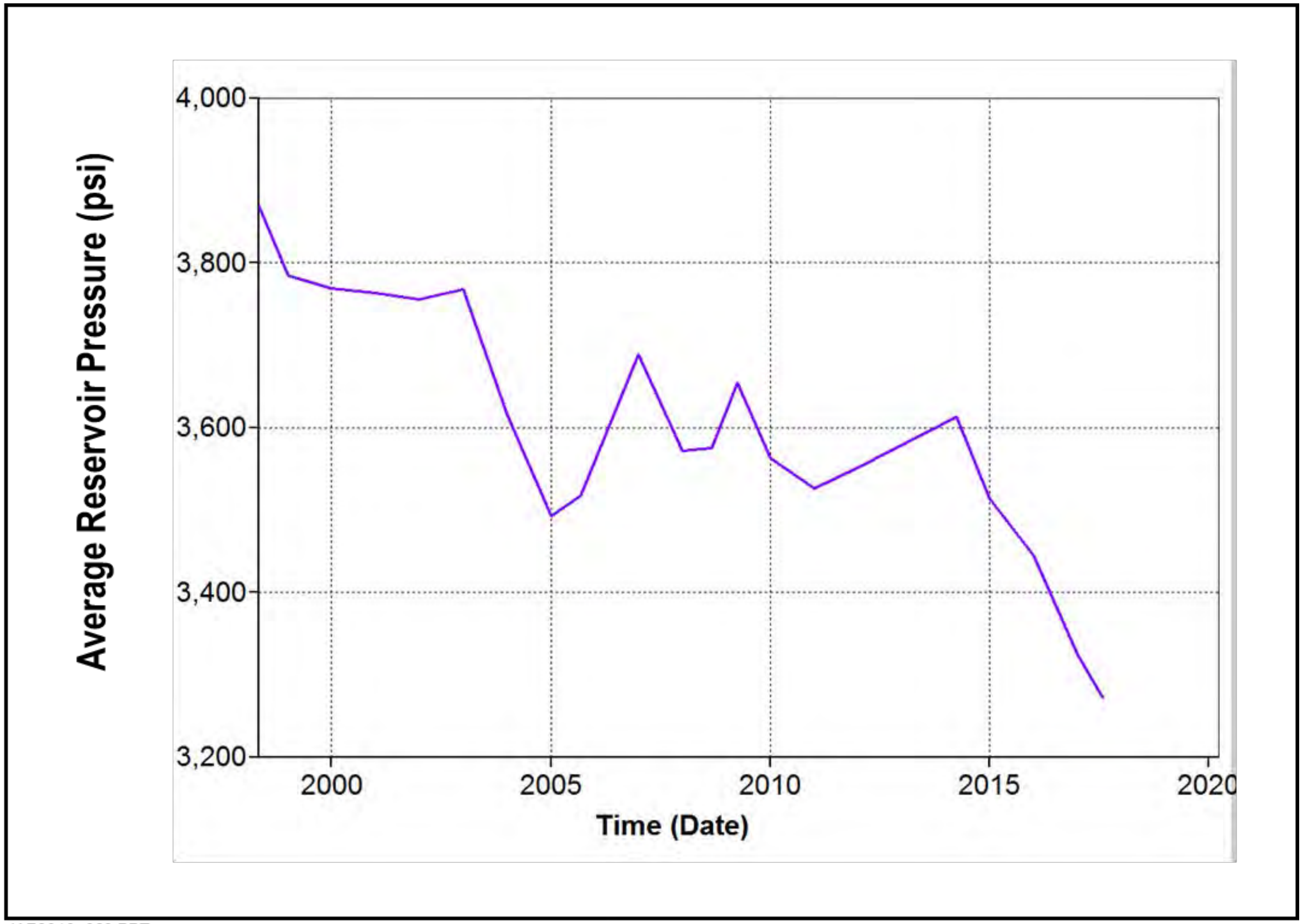
History Match of Fluid Production, Cognac J Sand, NE Fault Block



JAF2019_026.PPT

An important output of the history match was the estimate of J Sand reservoir pressure at the end of primary production.

GEM Compositional Modeling of the Performance of the CO_2 Flood, Cognac J Sand, NE Fault Block

CO_2 Flood Design. Given the structural dip of the formation, its high permeability and the strong bottom waterdrive, the design of the CO_2 flood was as follows:

- Drill an updip CO_2 injection well on the crest of the fault block.
- Inject continuous CO_2 at a rate of 24 MMcfd into the J Sand for 10 years and 20 years.
- Shut-in the producing wells for 12 months to raise reservoir pressure; operate the CO_2 flood using a bottom hole back pressure of 3,000 psi.
- Initially produce from updip production well (Prd #1) until CO_2 breakthrough; shut in updip production well and open downdip production well (Prd #2) and produce until end of the CO_2 flood.

CO_2 PROPHET Modeling of the NETL CO_2 Flood, Cognac J Sand, NE Fault Block

In parallel with the GEM compositional simulator, the study modeled the CO_2 flood in the Cognac J Sand, NE Fault Block, using NETL CO_2 PROPHET.

To capture the heterogeneity of the J Sand in the NE Fault Block, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the NE Fault Block's J Sand were modeled (with CO_2 PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO_2 producer and operate the CO_2 flood in a two well line drive configuration.
- Inject continuous CO_2 at a rate of 24 MMcfd for ten years, reaching a cumulative injection of CO_2 of 88 Bcf equal to CO_2 injected in the GEM Model (a HCPV of 1.2).

Comparative Analysis of GEM and CO_2 PROPHET Modeling of CO_2 Flood, NE Fault Block J Sand

The CO_2 PROPHET streamtube model was able to reasonably represent the performance of the CO_2 flood compared to the GEM compositional simulator.

	CO_2 Flood Performance GEM Compositional Simulator	CO_2 Flood Performance CO_2 PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	24.2	24.4	24.2
CO_2 Injection (Bcf)	89.5	87.7	87.7
CO_2 Production (Bcf)	52.3	55.7	45.3
CO_2 Storage (Bcf)	37.2	32.0	42.4
Cumulative Oil Recovery			
▪ (million barrels)	8.18	6.33	8.67
▪ % of OOIP	33.8%	26.2%	35.8%
CO_2/Oil Ratio (Mcf/B)			
▪ Gross	10.9	13.9	10.1
▪ Net	4.5	5.1	4.9

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO_2 PROPHET model) provide results that bracket the performance of the CO_2 flood from the GEM compositional simulator.

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Observations and Findings

A series of observations and findings have emerged from the GOM offshore case studies:

- Establishing a geologically representative data base for offshore oil fields is a challenge, but one that can be overcome with diligent effort.
- By defining the location and status of existing production and injection wells, reasonable spacing and CO_2 flooding designs can be established for offshore oil fields.
- Miscible CO_2 EOR can provide notable increases in oil recovery – 15% to 30% of OOIP – while storing significant volumes of CO_2.
- The NETL CO_2 PROPHET Model can provide realistic estimates of oil recovery and CO_2 storage in offshore oil reservoirs.

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Advanced Resources International, Inc.

Initial Risk Characterization and Data Development Activities

Presented at:

SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting

Presented by:

Michael Godec
Caroline Skidmore
Advanced Resources International

New Orleans, Louisiana, USA
March 25 – 27, 2020

Advanced Resources International, Inc.

Task 4.0
Risk Assessment, Simulation, and Modeling

- **Under Task 4.0, one activity is focused on assessing site-specific risks and developing mitigation strategies in the offshore GOM environment.**
  - Involves reviewing published efforts to evaluate onshore and offshore (North Sea, Australia, and Brazil) risk assessment and mitigation strategies and adapt or tailor them to our case.
- **Based on this, the project team will:**
  - Develop and/or adapt geologic and dynamic flow models that evaluate multiple physical and chemical processes
  - Describe the effects of the processes on CO_2 movement within the storage reservoir and potentially through the caprock, overburden, and water column, defined for representative prospects.
- **Among other objectives, the results of these modeling efforts will be used to identify and characterize potential geologic and CO_2 permanence risks and design monitoring programs.**

Proposed Approach for Risk Characterization

- **In this effort, we build on two previous risk assessment approaches.**
  - The CarbonSAFE ECO_2S Project Risk Assessment
  - The Shell Goldeneye “Bow-Tie” Risk Assessment
- **From these we have developed a proposed combination process that involves aspects of both.**

Project ECO_2S Approach

- Compile an initial risk register (pre-workshop)
  - Project ECO_2S used the SECARB Anthropogenic Test CCS project's risk register as their initial risk register.
- Identify and discuss project values (pre-workshop)
- Divide identified risks into topic groups (pre-workshop)
- Identify the elements of the project that fall under the "5 W's and H" -- Who, What, When, Where, Why, and How. (workshop)
- Evaluate each risk scenario in terms of Severity and Likelihood
- Determine a "risk" value for each risk scenario
- Develop plan for a monitoring program

Project ECO_2S Workshop

- **In October 2017, a workshop was conducted to identify and evaluate the principal risks to the Project ECO_2S storage site**
  - 18 project participants
- **102 unique risk scenarios were developed**
  - Encompassed five specific topic groups: 1) Geologic; 2) Monitor-Model; 3) Operations; 4) Project-Program Management; and 5) Public Acceptance
- **Discussion centered on known risks as well as unknowns that could potentially impede the achievement of project goals.**
- **Participants provided semi-quantitative risk-evaluation data for analysis and reporting**
  - Comprising 'Likelihood' and 'Severity' values measured on 5-point scales.
  - Aggregated values were displayed in real time during the workshop.
- **Scenarios not evaluated during the workshop were later completed through emailed correspondence.**

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Project ECO_2S Results

- 102 scenarios were ranked by risk. Strong group consensus identified five - seven program-management scenarios related to CO_2 supply as main sources of project risk.
- Technical risks ranked lower, with concerns about seal (caprock) continuity ranking highest (#23 out of 102, in the “most familiar with the topic” ranking).
- Induced seismicity risks were ranked low.
- Highest monitoring-modeling risks (ranked around #30) focused on prospect that the CO_2 plume might not be confidently observable using available monitoring techniques.
- Overall, risk rankings differed little among participants regardless of familiarity with the subject matter of specific scenarios.

How to select risks to treat? Multiple Screens

Scen ID	Risk	Rank by Risk (all)	Scenario
P01	12.17	1	Changes in the operational status or commercial viability of CO_2 source plant prevent meeting project objectives.
P09	12.16	2	Kemper energy facility does not become a source of CO_2.
P18	11.48	3	Insufficient CO_2 supply commitments to support regional storage hub.
U03	11.13	4	Changes in U.S. government personnel or policies result in removal of government support of the CarbonSAFE program.
O15	10.90	5	Operational problems at CO_2 source plant prevent delivering the CO_2 needed to show commercial-scale geological storage.
P13	10.10	6	MPC / SOPO management not interested in supporting a regional storage hub.
P12	10.06	7	MPC / SOCO management do not continue to support project during next 2-50 years.
P04	9.92	8	Existing pipeline network not designed to be used as a regional hub.
P14	9.43	9	Pore space rights are insufficient for the project.
P15	9.43	10	Potential CO_2 sources believe that no mature capture technology is available, so will not commit to project.
P11	9.09	11	Loss of pore space access (due to land sale or other cause) limits the overall storage capacity of the hub.
O14	8.88	12	Oilfield boom drives up project costs and increases lead time for equipment and services.
U11	8.75	13	Local animosity toward MPC leads to vocal opposition of ECO_2S project.
O10	8.48	14	Loss of surface access rights in area of existing or planned injection well.
U16	8.30	15	Permitting of a Class VI UIC permit for storage is delayed.
P07	8.17	16	Infrastructure development costs are considerably higher than expected.
O21	8.16	17	Uncertainty in CO_2 source(s) delays pipeline specifications (sizing, materials, pressure rating).

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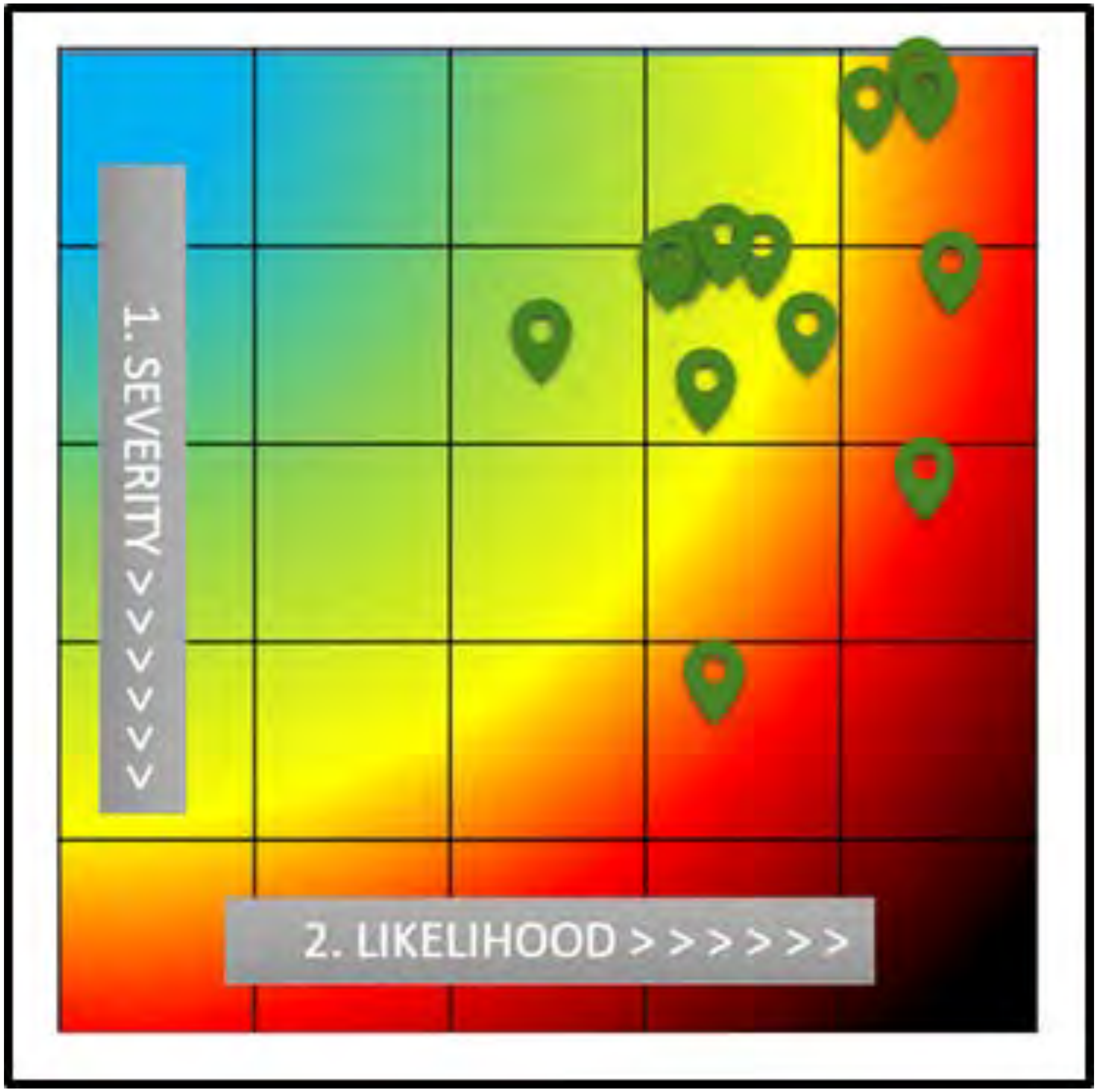
Example Severity-Likelihood Grid Live Poll Results (High-Risk Scenario)



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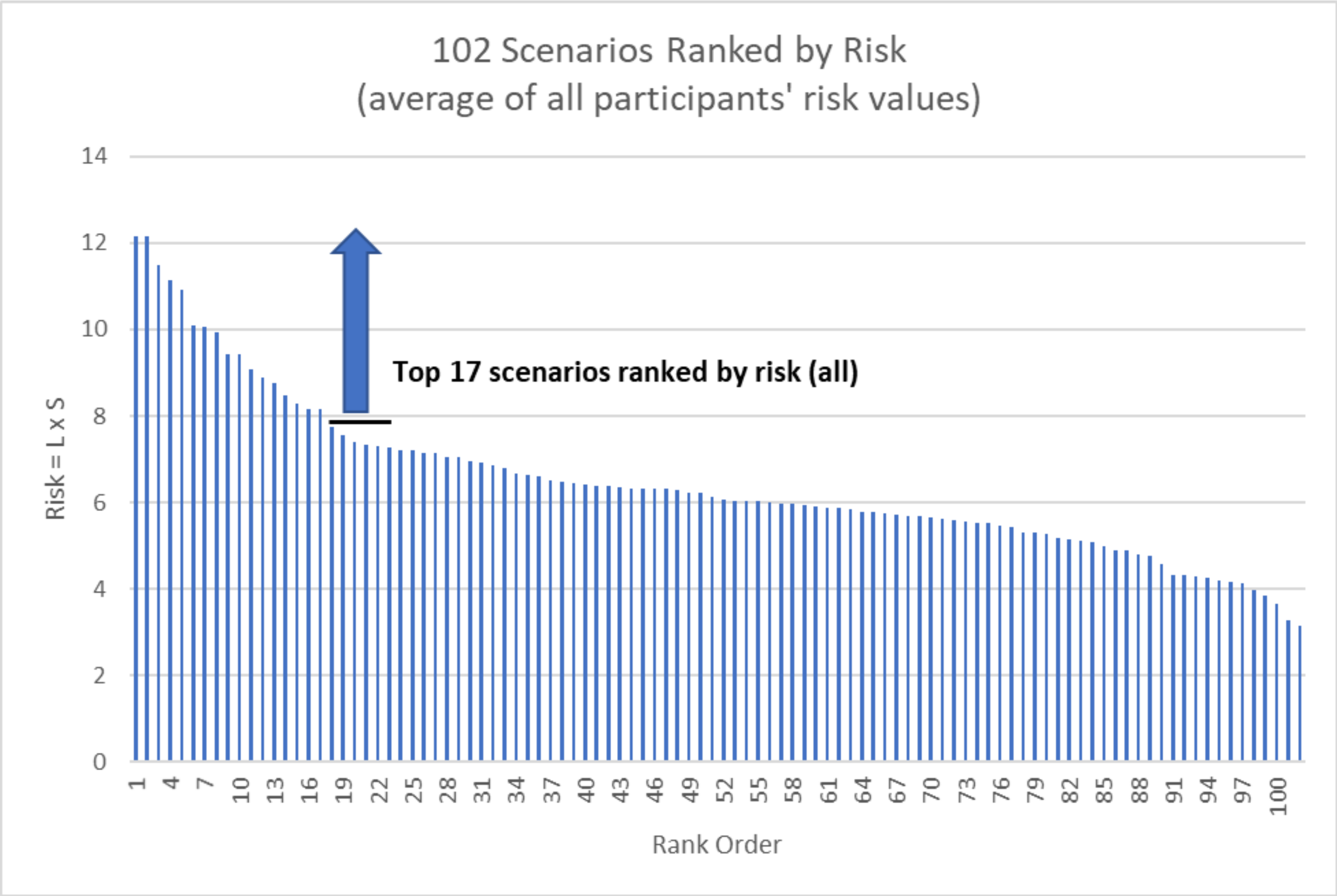
102 Scenarios Ranked By Risk



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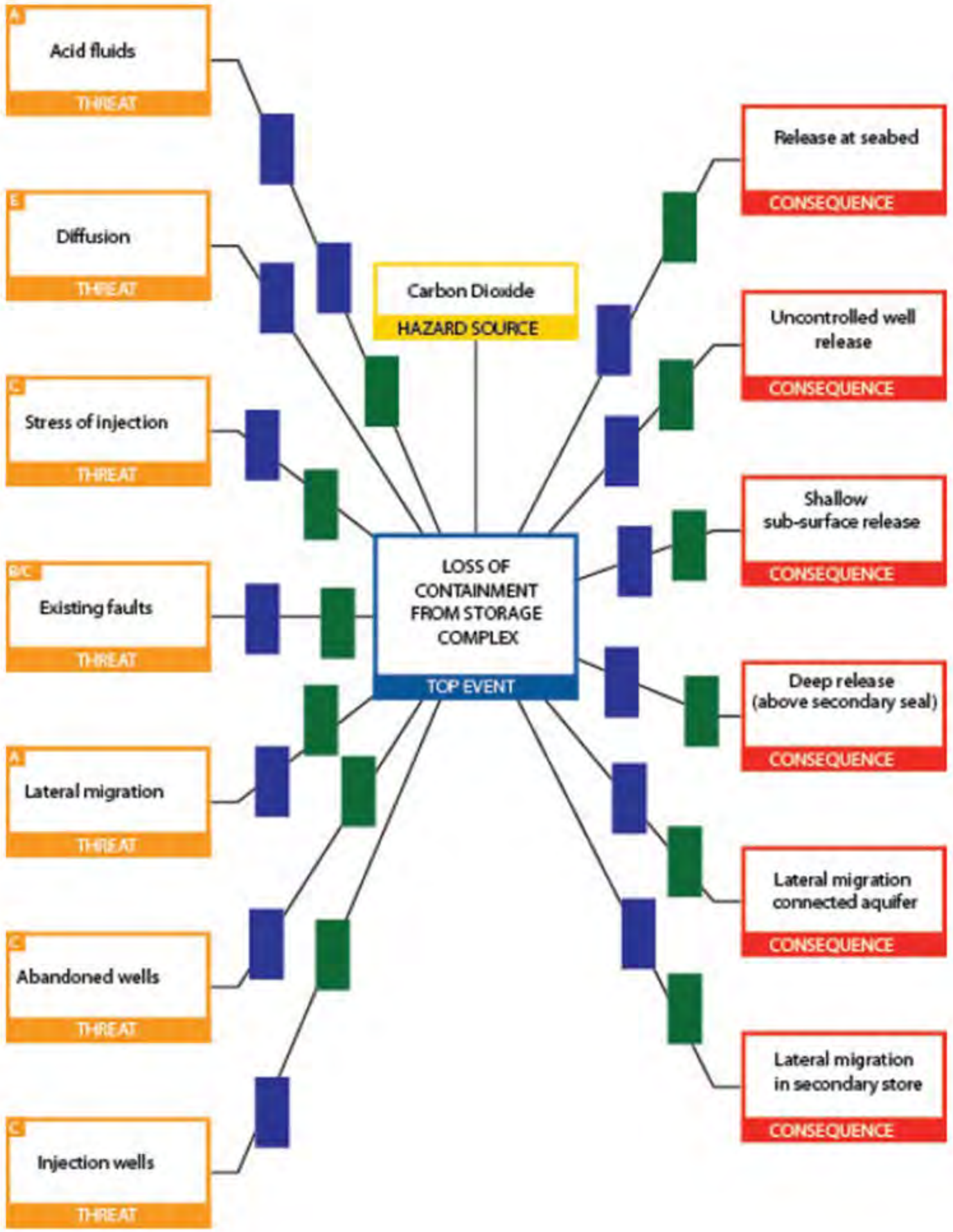
Shell Goldeneye "Bow-Tie" Approach

- **Identify and describe risks (pre-workshop)**
  - Based on risk identification workshops, experience, past project reviews, regular engagement with key external stakeholders
- **Conduct workshop where project members come together and discuss/create an initial bow-tie risk assessment**
- **Identify the top hazard event(s)**
  - Using initial risk register, identify 'threats, based on ways CO_2 could be released
  - Identify the consequence(s) for each threat
  - Identify 'barriers' that can prevent the 'threats' from causing CO_2 leakage
  - Identify 'controls' that can mitigate the consequences if CO_2 leakage does occur
- **Conduct initial bow-tie risk assessment**
- **Perform evaluation of risks**
- **Expand initial bow-tie risk assessment as monitoring program progresses**

Bow-Tie Model for Goldeneye Project



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Goldeneye's Risk Assessment Matrix

		Consequences/Severity Impact					Likelihood / Probability				
							Very Low	Low	Medium	High	Very High
							1	2	3	4	5
		Capex Cost	Schedule (First Injection)	Operability	HSSE	Reputation	Never heard of in the Industry	Heard of in the industry	Has happended in the organisation or more than once per year in the industry	Has happened at the location or more than once per year in the industry	Has happened more than once per year at the location
							0-10%	11-25%	26-50%	51-80%	>80%
Very High	5	>£30Million	> 6 months	One off >350k t deferment Annual >170t/d deferment Opex increase >£5 Million/Year	More than 3 fatalities Massive impact	Adverse international/ national media coverage Adverse international/ national political reaction Adverse reaction from regulator Organised protests					
High	4	£15 - £30 Million	<= 6 months	One off <350k t deferment Annual <170t/d deferment Opex increase <£5 Million/Year	PTD or up to 3 fatalities Major impact	Adverse national media Coverage Adverse national political reaction Adverse investor reaction Adverse reaction from regulator Organised protests					
Medium	3	£6-£15 Million	<= 4 months	One off <175k t deferment Annual <85 t/d deferment Opex increase <£2.5 Million/Year	Major impact/injury	Adverse regional political reaction Local protesting					
Low	2	£3-£6 Million	<= 2 months	One off <70k t deferment Annual <35 t/d deferment Opex increase <£1 Million/Year	Minor impact/injury	Adverse local media coverage Adverse Industry Press					
Very Low	1	<£3 Million	<= 1 month	One off <35k t deferment Annual <15 t/d deferment Opex increase <£0.5 Million/Year	Slight impact/injury	Complaints from Neighbours					
		No Impact	No Impact	No Impact	No Impact	No Impact					

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Proposed Approach for SECARB Offshore

The primary objective of this initial risk characterization workshop is to ensure that initial data acquisition and analysis activities are being conducted to ensure the best possible characterization.

****

- **Compile an initial risk register**
- **Establish one or more workshop working groups**
- **Assess risks that represent potential ‘real impacts’**
- **Determine data needs to characterize potential “real impacts,” possibly creating a bow-tie model**
  - **That includes the risks, the mitigation/controls and consequences that were discussed during their assessment of the risks as material impacts.**
  - **The overarching main concern initially will be release of CO_2 from the storage complex.**

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Proposed Approach for SECARB Offshore

(Cont.)

- Evaluate potential risks in terms of Severity and Likelihood
  - To discuss the highest-ranked risks and discuss if other risks should be ranked higher or vice versa.
  - These discussions will help pinpoint the data gaps and how those data gaps could be filled and which monitoring efforts would be the best to explore to ensure gaps are filled.
  - Discussions of risk evaluations are likely to continue after the workshop between project members as they determine the appropriate monitoring efforts.
- Discuss possible additional data acquisition activities
- Discuss possible monitoring plans and activities

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Initial Risk Registry

- An excel file has been created to document all potential risks that members of the SECARB Offshore project team identify as initial risks that should be looked into.
- The table will look similar to the table below.

Potential Risks	Severity of Risk	Likelihood of Risk	Data to Characterize Risk	Possible Monitoring Methods	Possible Mitigation Approaches	Links to Sources

Initial Risk Registry (Cont.)

- **Potential Risks:** identify potential risks from experience, past project reviews, and expertise.
- **Severity:** If the risk were to occur how serious are the impacts?
- **Likelihood**: The probability that the potential risk will occur.
- **Data to Characterize**: What data is already available to the project? And what data does the project team need to obtain to better characterize potential risks?
- **Monitoring Methods**: From past experiences and expertise what are the monitoring efforts that could be put in place for the potential risk?
- **Mitigation Methods**: What are the possible mitigation efforts that can diminish the negative impacts if the potential did occur?
- **Links to Sources**: If you have any PDFs, journal article, etc that could be helpful to better explaining/understanding your responses, please include the link(s).

Severity and Likelihood Scales

- We have chosen to use the Severity and Likelihood Scales from Project ECO_2S.
- Each potential risk's severity and likelihood should be evaluated in terms scales featured in the next slides, a 1 through 5 scale.
- After the severity and likelihood values have been determined, those two values will be added together to create the overall potential hazard score.
- Risks with potential hazard score of 7 or greater are considered to have the highest risk potential.
- As the project progresses and more data is collected, we expect the hazard scores to change.

Generic Likelihood Scale

LIKELIHOOD of Impact or Failure Occurring (L)				
1	2	3	4	5
Very Unlikely	**Unlikely**	**50/50**	**Likely**	**Very Likely**
In 50 ECO_2S-like commercial projects, might happen once.	Probably won't happen during this project. In ten such projects, once per decade.	May or may not happen during the project, with roughly equal likelihood.	Probably would occur during the pilot or commercial-scale ECO_2S Project. Once per several years.	Nearly sure to occur during the pilot or commercial-scale ECO_2S Project. Could happen yearly.

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Generic Severity Scale

Examples of negative impacts for generic project values, at each severity level						
	Health & Safety	**Environment**	**Regulatory**	**Economic-Financial**	**Reputation**	**CCS Validation**
1	First aid. Minor health effects. Public nuisance.	Insignificant and temporary impact. Small but recordable release of hazardous material.		Equipment damage or production costs <$5k.	Isolated individual concerns.	Temporary / fixable low injectivity. Ineffectiveness of one monitoring technique.
2	Medical aid, restricted work. Hospital visit. Temporary disability. 1-10 lost person-days. Brief facility evacuation or stand-down.	Reportable release of hydrocarbons or hazardous materials. Minor or one-time cleanup.	Nonconformance with stringent industry practice standards (e.g. ISO, API, ANSI).	$5k-100k	Local media coverage. Multiple informal complaints. Landowner or community concern.	Capacity somewhat limited for commercial CCUS. Moderate uncertainty in proving containment.
3	Intensive care. 10-100 lost days. Facility evacuation to 2 days.	Onsite release, large or with prolonged cleanup. Offsite release with quick cleanup.	Nonconformance with specific Regional or business unit requirements. Threat of sanctions.	$100k-1m	Broad media coverage or community concern. Repeated and/or formal complaints.	Injection takes 50% more wells. Models or monitoring questionably demonstrate creditable storage.
4	Permanent injury or disability. Lost days >100. Facility evacuation >2 days.	Offsite release, large or with long cleanup.	Nonconformance with operating company standards and/or rqmts. License suspension.	$1m-10m	Regional media coverage. Broad community outrage. Litigation.	Injection takes many wells. Suspected leakage; lack of data to show containment.
5	Fatality. Severe health effects. Facility and community evacuation.	Release on, to, or across moving water, potable water, wildlife, national park, state border.	Serious or flagrant nonconformance with regulations or license conditions. License revoked.	>$10m	National media coverage.	Persistent CO_2 leak to potable water or surface. Few wells usable at commercial rate.

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Next Steps

- **Our initial plan was to conduct a preliminary risk characterization workshop among the SECARB Offshore project team as part of this meeting.**
  - Of course, that plan has been overtaken by events
- **This was to use an initially developed risk registry, for participants to react to, add to, comment on, etc.**
- **We are in the process of evaluating options for continuing.**
  - Delay the preliminary workshop until we can get together again.
  - Conduct the preliminary workshop virtually via a webinar-type format
  - Facilitate input solicitation and data gathering via email communications.

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Characterizing Legal and Regulatory Frameworks

Presented at:
SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting

Presented by:
Michael Godec, Vice President
Advanced Resources International

New Orleans, Louisiana, USA
March 25 – 27, 2020

Subtask 6.3: Assessment of Legal and Regulatory Frameworks

- **"The Recipient will communicate with BOEM, BSSE, the Coast Guard and other Federal and State regulatory agencies to keep them informed on current project activities, to facilitate a dialogue on permitting requirements, and to compare and contrast with experience/lessons learned elsewhere.**
- **The project team also will engage with experts on regulatory oversight on offshore CO_2 storage projects from North Sea (UK and Norway and EU), Brazil, Japan.**
- **Further, the team will coordinate with BOEM, BSSE, DOE, Internal Revenue Service and other Federal and State agencies to develop recommendations to remove barriers and streamline the regulatory process to encourage subsea storage with or without enhanced hydrocarbon recovery and to enable projects to take advantage of any Federal or State incentives."**

Advantages of CO_2 Injection Offshore vs. Onshore?

- **May allow surface discharge of produced water.**
- **Avoids populated areas (minimal NIMBY concerns).**
- **Minimal issues with surface, pore space, and mineral rights ownership in federal or state waters.**
- **Avoids issues pertaining to potentially impacting underground sources of drinking water, at a minimum in federal waters.**
- **Regulatory processes could be more straightforward and expeditious in federal waters (may not he quite the case in state waters)**
- **E.g., Class VI regulatory requirements are not applicable in federal waters.**

BBA Enhancements to IRC Section 45Q -- Highlights

Previous 45Q	Bipartisan Budget Act of 2018
▪ 75 million metric ton cap	▪ Eliminates 75 million metric ton cap; applies to new facilities that **“break ground” by EOY 2023.**
▪ Credit based on “captured qualified CO_2”	▪ After enactment, credit based on captured “qualified carbon oxide” (CO_2 and **other carbon oxides**). ▪ Allows for the **transfer** of qualified credits
▪ $20/metric ton for CO_2 stored and not used for EOR ▪ $10/metric ton for CO_2 stored and used for EOR	▪ **$50/mt for geologic storage and $35/mt for EOR (each rate phases up over 10-year period from 2017 to 2026**). ▪ Existing qualified facilities would continue to receive the original inflation adjusted $20 and $10 credit rates.
▪ Available to <u>facility</u> with capture equipment capturing at least 500,000 metric tons CO_2/year.	▪ Capture > **500,000** metric tons CO_2/year for electric generating units; > **100,000** metric tons CO_2 /year for other. ▪ Credit goes to the **<u>owner of the capture equipment</u>**. ▪ Available to “**direct air capture” and “beneficial use** (with 25,000 metric ton threshold)”
▪ Credit available until the 75-million-ton cap is reached.	▪ Credit available for **12 years** from the date the carbon capture equipment is placed in service.

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Request for Comments by IRS on 45Q

- On 5/20, IRS issued Request for Comments on 45Q enhancements.
- Areas of comment included:
  - Establishing "secure geologic storage"
  - Leakage after credit award – "recapture"
  - Defining "qualifying facilities"
  - Defining "commence construction"
  - Credit transferability, timing, flexibility
  - Allowable structures/partnerships
  - 90+ comments received
- **Some limited guidance recently released; more pending**
- **Key question -- is 45Q, as it stands, enough for the offshore GOM?**

Form **8933** | **Carbon Oxide Sequestration Credit** | OMB No. 1545-0123 | **2018**

Department of the Treasury Internal Revenue Service

► Attach to your tax return.

► Go to *www.irs.gov/Form8933* for the latest information.

Attachment Sequence No. 165

Name(s) shown on return | Identifying number

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, nor utilized in a way described in section 45Q(f)(5).

1a Metric tons captured and disposed of

b Inflation-adjusted credit rate

c Multiply line 1a by line 1b — 1c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or utilized in a way described in section 45Q(f)(5).

2a Metric tons captured and used

b Inflation-adjusted credit rate

c Multiply line 2a by line 2b — 2c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, nor utilized as described in section 45Q(f)(5).

3a Metric tons captured and disposed of

b Section 45Q(a)(3) applicable dollar amount (see instructions)

c Multiply line 3a by line 3b — 3c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or used as described in section 45Q(f)(5).

4a Metric tons captured and disposed of

b Section 45Q(a)(4) applicable dollar amount (see instructions)

c Multiply line 4a by line 4b — 4c

Regulatory Oversight of CO_2 Storage in the Federal Offshore -- DOI

- **Outer Continental Shelf Lands Act (OCSLA), Dept. of Interior (DOI), Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) have authority to regulate development of mineral resources on the OCS:**
  - **Authority to permit the use and storage of CO_2 for EOR activities on existing oil and gas leases on the OCS.**
  - **Authority to permit the storage of CO_2 for certain types of projects; though the authority to issue leases for storage remains unclear.**
  - **No facilities/operations permitted to date**
- **BOEM finalized research on Best Management Practices (BMPs) for CO_2 offshore transportation and storage on the OCS**
  - **We are using some of the as a starting point for our study.**
  - **Specific categories of offshore issues (potential regulatory gaps) were identified.**

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CCS on the Outer Continental Shelf: Regulatory Framework

- **Under Section 8(p)(1)(C) of the OCSLA (43 U.S.C. 1337)(p)(1)(C)), BOEM may issue leases, easements, and rights-of-way for activities that:**
  - **"produce or support production, transportation, or transmission of energy from sources other than oil and gas"**
- **In certain circumstances, Section 8(p)(1)(C) allows BOEM to issue leases for sub-seabed CO_2 storage…**
  - **Only for CO_2 generated as a by-product of electricity production from an onshore coal-fired power plant.**
- **In 2010, the Presidential Interagency Task Force on CCS examined the existing U.S. regulatory framework and recommended the development of a comprehensive U.S. framework for leasing and regulating sub-seabed CO_2 storage operations on the OCS**
- **However, this comprehensive framework has yet to be established; therefore, the existing regulatory framework is shared across multiple Federal agencies, and there are several gaps.**

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IOM
·LAW·

Legal and regulatory analysis

Joint GoMCarb and SECARB Offshore meeting -- 26-27 March 2020

Ingvild Ombudstvedt, IOM Law

Approach

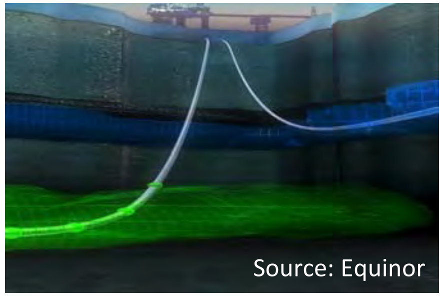
- Starting point: previous legal analysis of U.S framework
- Desktop review of recent developments
- Comparison with other legal and regulatory frameworks
- Test findings on SECARB Offshore case studies
- Recommendations

Previous legal analysis

- Storage of Carbon Dioxide in Geologic Structures: A Legal and Regulatory Guide for States and Provinces, 2007
- Interagency Task Force on Carbon Capture and Storage, 2010
- Preliminary evaluation of offshore transport and storage of carbon dioxide, 2013
- Best management practices for offshore transportation and sub-seabed geologic storage of carbon dioxide, 2017
- Overcoming Impediments to Offshore Carbon Dioxide Storage: Legal Issues in the U.S and Canada, 2019

The focus of our analysis

- Prioritized relevant barriers identified in the earlier cited reports
  - Lack of comprehensive legal and regulatory framework
  - Fragmentism
  - Monitoring, reporting, and verification pursuant to subparts RR and UU
  - Liability and long-term stewardship
  - CO_2 as hazardous waste



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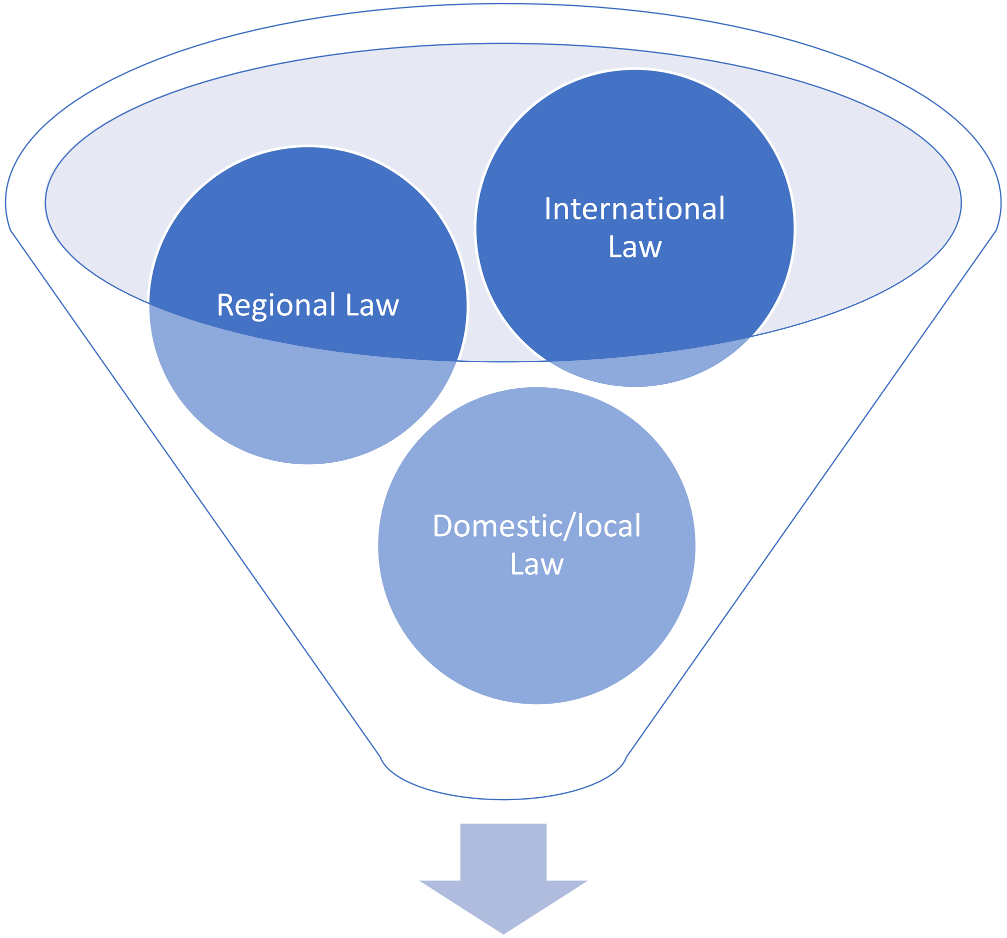


Legal Framework for CCUS

Building on existing U.S legal framework

Some of the most relevant instruments

- Outer Continental Shelf Lands Act
    - Oil and Gas Leasing Program
- Coastal Zone Management Act
- Submerged Lands Act
- National Environmental Policy Act
- Safe Drinking Water Act
    - Underwater Injection Control (UIC) Program
- Clean Air Act
    - Greenhouse Gas Reporting Rules

Comparison with International Legal Framework

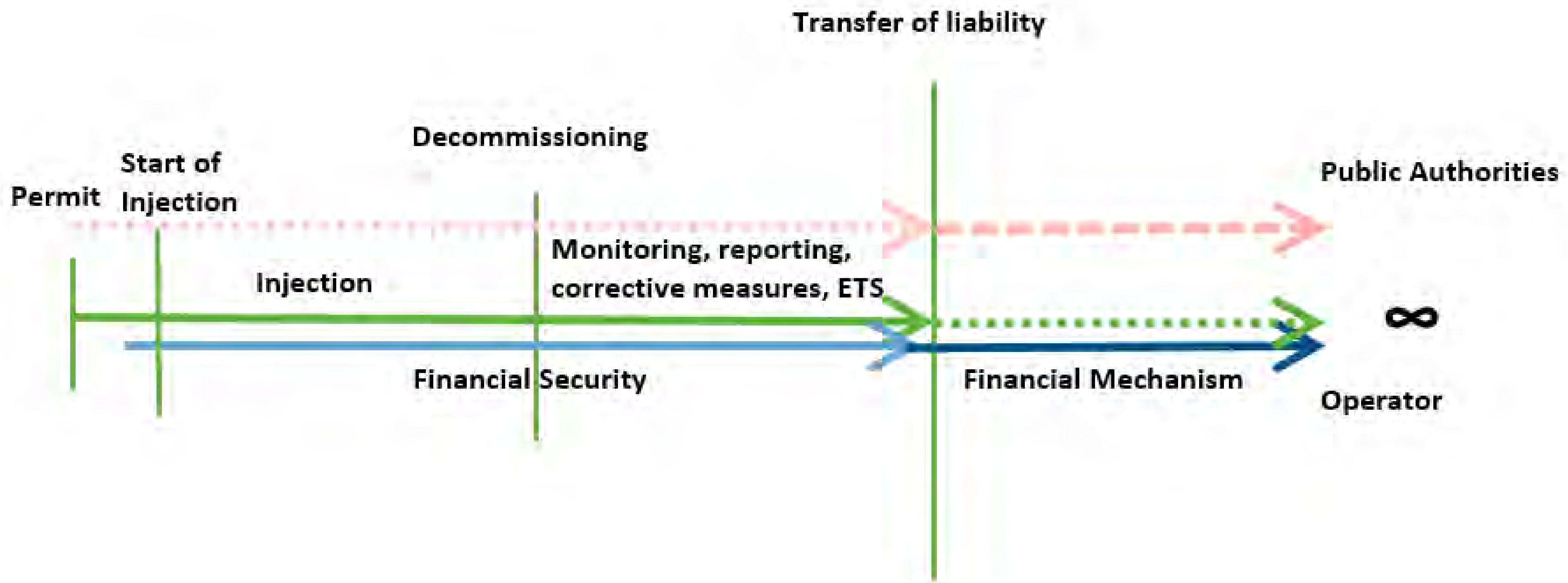
- The United Nations Convention on the Law of the SEA (UNCLOS)
- The London Convention
- The London Protocol
- OSPAR

Comparison with European Framework

- EU legal framework
  - CCS Directive (2009)
    - Guidance Document 2 (Characterization of the Storage Complex, CO_2 Stream Composition, Monitoring and Corrective Measures)
    - Guidance Document 3 (Criteria for Transfer of Responsibility to the Competent Authority)
    - Guidance Document 4 (Financial Security (Art. 19) and Financial Mechanism (Art. 20))
  - ETS Directive (2003)
  - Environmental Liability Directive (2004)

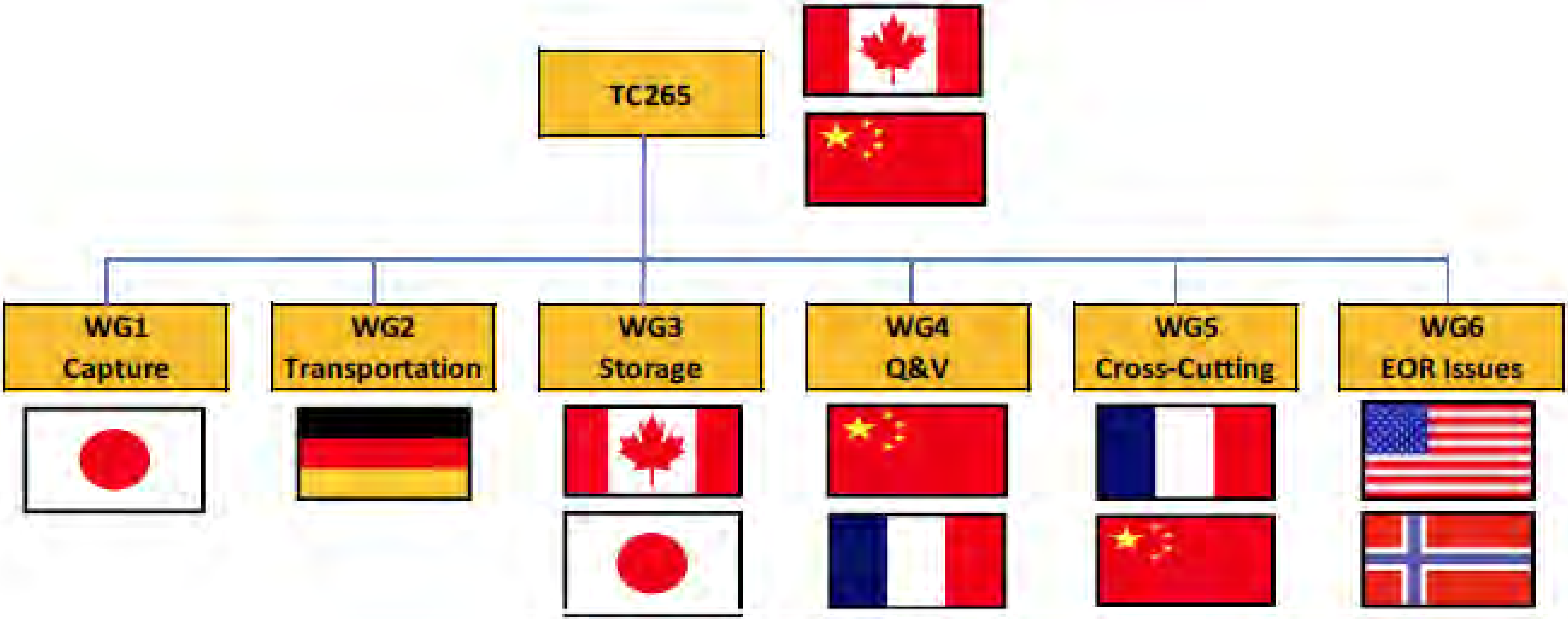
- Norwegian legal framework
  - Continental Shelf Act (1969)
    - Storage Regulations (2014)
    - Regulations related to safety and working environment in relation to transport and injection of CO_2 on the Norwegian Continental Shelf (2020)
  - Petroleum Act (1996)
    - Petroleum Regulations (1997)
  - Pollution Control Act (1981)
    - Pollution Control Regulations (2004)
      - Guidelines for financial security (2016)

EU liability framework for CO_2 storage at a glance



Other Documents

- EPA Guidance Documents for Class II and Class VI
- IEA Model Regulatory Framework
- ISO TC 265 documents
- European Commission opinions on draft permits for the Netherlands and the United Kingdom
- Norwegian exploitation permit for CO_2 storage (awarded January 2019)



ISO TC265 Carbon Dioxide Capture, Transportation and Geological Storage

General principles of the TC265 standards

- Technology neutrality
  - No patented rights
  - No explicit descriptions of technology or product
  - Fits both onshore and offshore

- Regulatory neutrality
  - Performance-based rather than descriptive
  - No time periods specified
  - No criteria for reporting
  - No criteria for decommissioning
  - No explicit references to, e.g., transfer of liability

- Complements other standards
  - TC265 standards
  - Other ISO standards
  - Specific technical standards from other standardization bodies

ISO standard for CO_2-EOR

- Standard for CO_2-EOR published 31 January 2019

- Provides important tools to
    - assuring containment
    - unlocking access to allowances under e.g. ETS
    - replacing natural with anthropogenic CO_2

- Applies to quantification and documentation of total CO_2 being stored in association with CO_2-EOR

- Contains background data and information about CO_2-EOR globally

- Allows for quantification calculation of natural, anthropogenic and in-situ CO_2

INTERNATIONAL STANDARD

ISO 27916

First edition
2019-01

Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery (CO_2-EOR)

Captage, transport et stockage géologique du dioxyde de carbone — Stockage du dioxyde de carbone au moyen de la récupération assistée du pétrole (RAP-CO_2)

Reference number
ISO 27916:2019(E)

© ISO 2019

Process for considering recommendations

- Contrast and compare previous work on legal analysis and recommendations
- Compare and contrast with other legal and regulatory frameworks
- Taking new legal and technical developments into consideration
- Taking policy considerations
- Filling gaps using technical international standards
- Reusing known models and mechanisms under US legal framework
- Consultation

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Thank you for your attention!

Building the Foundation for Assessing GOM Offshore CO_2 EOR and Associated CO_2 Storage

Prepared for:
Inaugural SECARB Offshore Conference

Prepared By:
Vello Kuuskraa, President
Matt Wallace
Anne Oudinot
Advanced Resources International, Inc.

March 26-27, 2020

Advanced Resources International, Inc.

Outline of Presentation

1	Purpose of the Case Studies
2	Petronius Offshore Oil Field Case Study
3	Cognac Offshore Oil Field Case Study
4	Observations and Findings

This work was completed under DOE NETL Contract Number DE-FE0025912. This work was performed under MESA Activity 205.002.

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Purpose Of Case Studies

The primary purpose of the "Offshore Oil Field Case Studies" is to assess the ability of the NETL CO_2 PROPHET Model to represent the performance of an offshore CO_2 flood, including appropriately capturing the geologic complexity and irregular well spacings typical of offshore oil fields.

For this, the Study conducted seven tasks:

1. **Geologic Model.** Build representative geologic models for the oil fields, including capturing structural setting and associated aquifer.
2. **Reservoir Model.** Assemble the key reservoir properties of the oil reservoir, including its volumetric data, fluid flow capabilities, and oil composition.
3. **Field Development**. Establish the locations of the existing oil/gas production wells producing from the oil reservoir.

Purpose Of Case Study (Cont'd)

4. **History Matching Using Compositional Simulations**. Use GEM compositional simulator to provide a "first-order" history match of fluid production from the oil reservoir.

5. **Assessing CO_2 Flooding Using Compositional Simulation**. With a calibrated geologic/reservoir description, appraise the performance of a post-primary CO_2 EOR project in the oil reservoir using the GEM compositional simulator.

6. **Assessing CO_2 Flooding Using CO_2 PROPHET**. In parallel with the GEM compositional simulator, use the NETL CO_2 PROPHET Model to appraise the performance of a post-primary CO_2 EOR project in the oil reservoir.

7. **Comparing GEM and CO_2 PROPHET Modeling.** Compare the results of GEM and CO_2 PROPHET modeling of CO_2 EOR to determine whether the NETL CO_2 PROPHET model could reasonably represent the performance of the CO_2 flood compared to the more sophisticated GEM compositional simulator.

Petronius Offshore Oil Field Case Study

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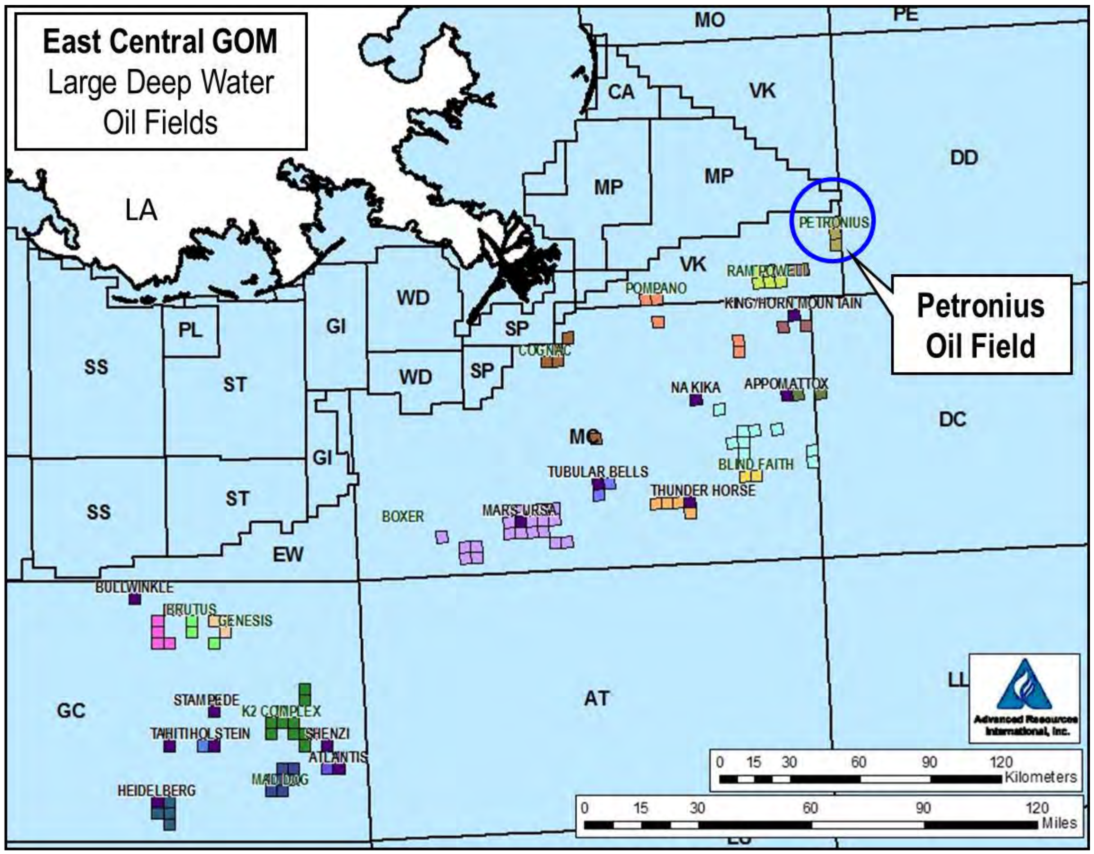
Background

The Petronius deepwater oil field (VK 786) is located in 1,790 feet of waters of the East Central Gulf of Mexico.

Location of Petronius Oil Field, Eastern Gulf of Mexico



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Petronius, with 162 million barrels of original oil reserves, has produced over 96% of its original reserves, as of the end of 2016.

Oil production that peaked at 70,000 B/D in 2003 but has declined to 6,600 B/D in 2016, placing Petronius on a list of oil fields facing near-term abandonment.

A notable feature of Petronius is its early installation of a waterflood due to a relatively weak underlying aquifer.

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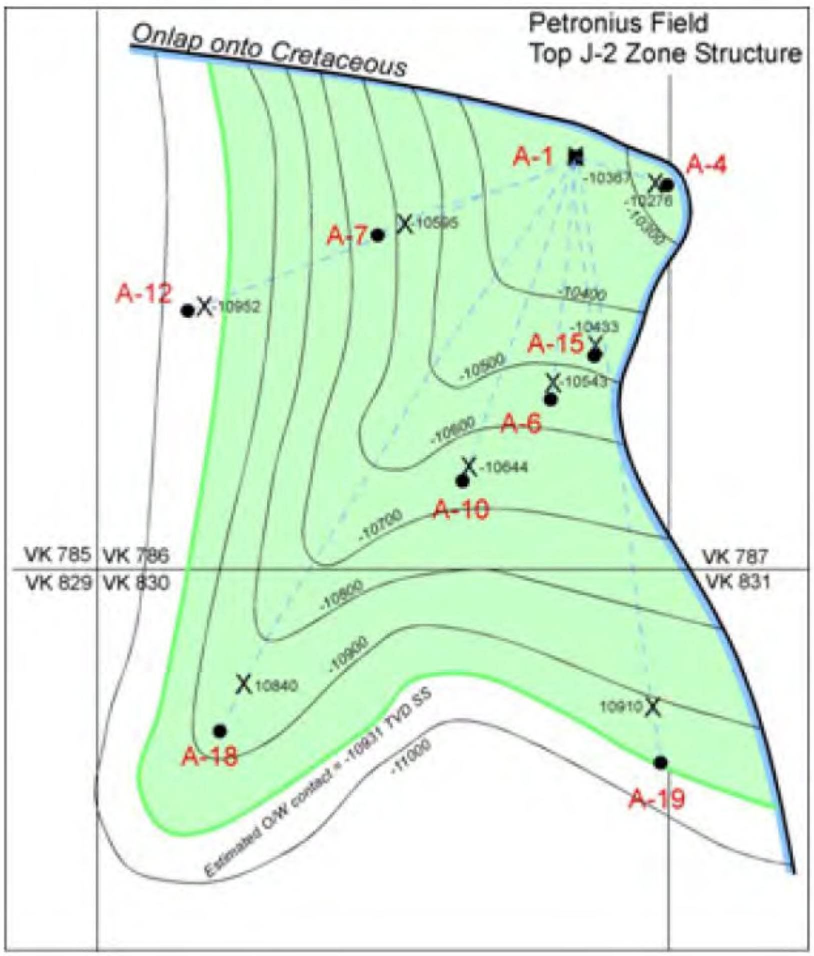
Petronius J-2 Sand Geologic Model

Structure of the Petronius J-2 Sand



Source: Duan, 2013

The Petronius J-2 Sand reservoir is a Middle Miocene sheet sand, providing a structurally simple setting.

There is little faulting within the Petronius oil field and the J-2 Sand reservoir is judged to be relatively continuous.

The illustration provides the structure of J-2 reservoir, its oil-water contact (OWC), and the location of its nine production wells.

The Petronius J-2 Sand

The Petronius oil field contains two major sands, the Miocene-age Upper (J-1) Sand and Middle (J-2) Sand, as well as a series of smaller oil sands, shown below.

Petronius Original Oil Resources, Production and Remaining Reserves

Sands		Area (Acres)	Original Oil In-Place (MMB)	Cumulative Oil Production* (MMB)	Remaining Oil Reserves* (MMB)
1. Major Sands					
▪	J-1	3,438	124.8	69.6	4.0
▪	J-2	5,288	104.7	52.0	1.3
2. Minor Sands					
▪	J-3	1,352	24.5	6.1	1.0
▪	J-4	1,398	39.2	17.8	0.9
▪	J-5	389	18.2	7.8	1.5
▪	Other (13)	-	0.7	0.2	-
Total		**11,865**	**312.1**	**153.5**	**8.7**

*As of end of 2016.

JAF2019_014.XLS

Advanced Resources International, Inc.

Volumetric and Other Reservoir Properties: Petronius J-2 Sand

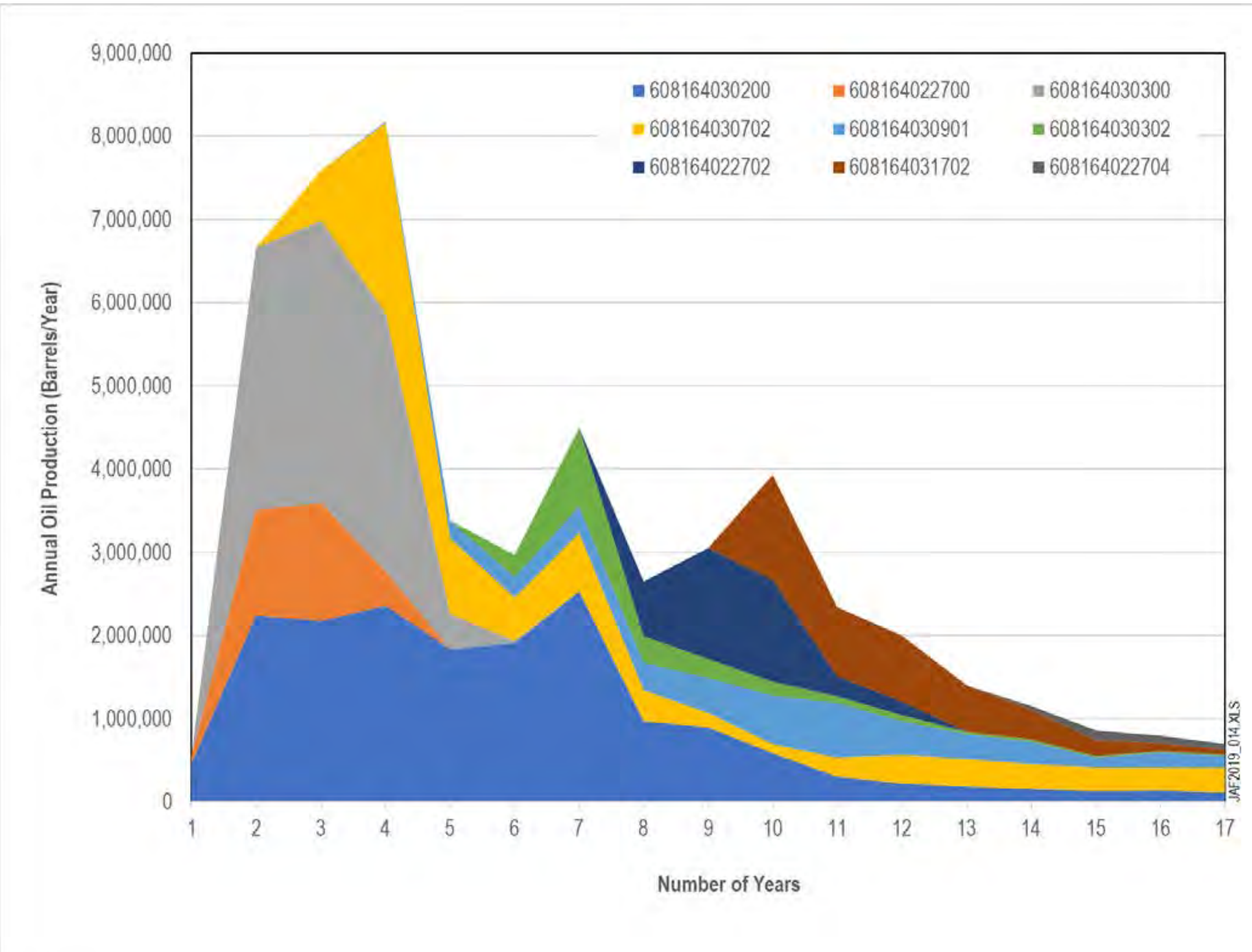
Reservoir Properties	Value
Oil Area	
▪ Total	5,288 Acres
▪ Quarter*	1,290 Acres
Porosity	30%
Depth	10,900 to 11,100 ft
Permeability	398 mD
Net Pay	16.5 ft
Oil Gravity	31 API
Swi	0.24
Boi	1.45
OOIP	104 MM bbls
Initial Pressure	5,287 psia
Pressure Gradient (@ 10,560 ft)	0.5 psi/ft
Initial Temperature	182 ^{o}F

*After including gas cap area.

The key volumetric and reservoir properties for the Petronius J-2 Sand are derived from information provided in the BOEM Offshore GOM database and from the technical literature on the Petronius oil field.

Petronius J-2 Sand

Annual Oil Production 2000-2016



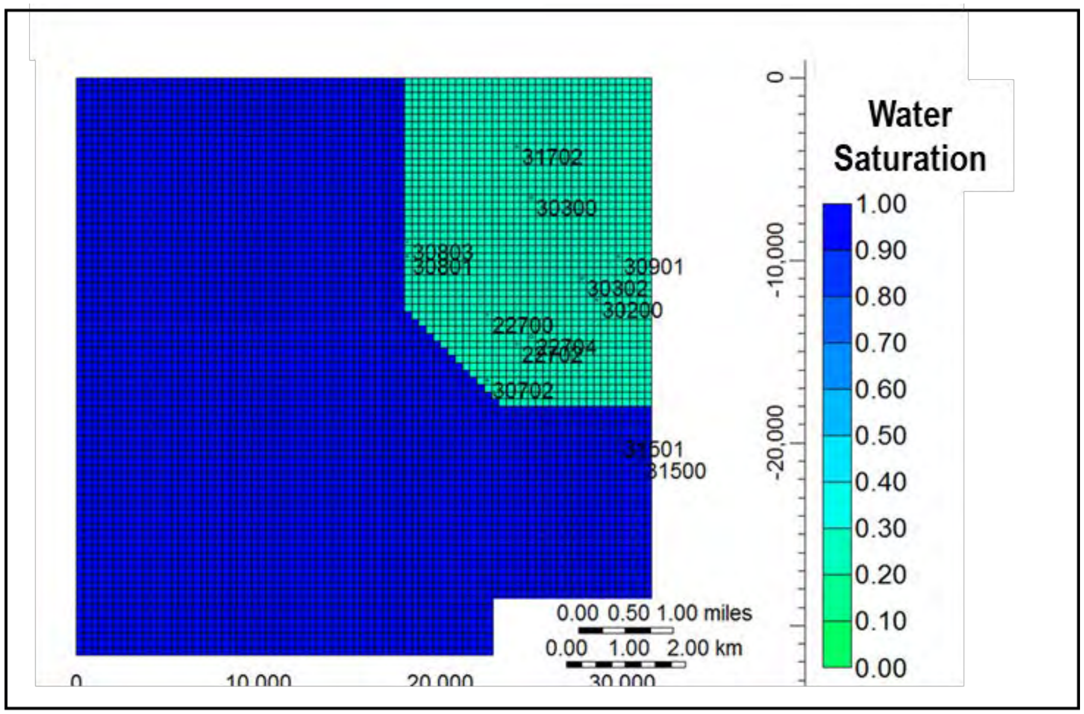
After a peak of 22,400 B/D (8.2 MMBbl/yr) in 2003, oil production from the J-2 Sand declined to 1,900 B/D (0.7 MMBbl/yr) in 2016.

The oil production history for the nine production wells drilled into the Petronius J-2 Sand is shown.

Advanced Resources International, Inc.

Reservoir Model for Petronius J-2 Sand

J-2 Sand Reservoir Model and Grid Blocks



JAF2019_025.PPT

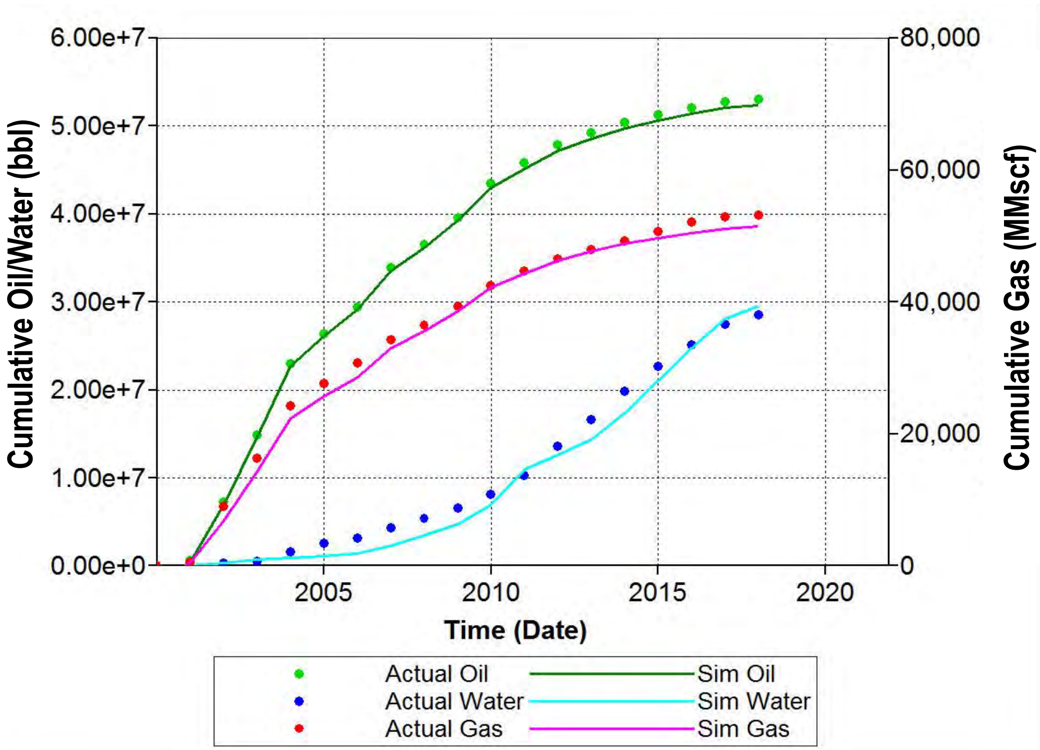
Source: Advanced Resources International, 2019

The reservoir model for the Petronius J-2 Sand contains 79 grid blocks in the X direction and 79 grid blocks Y direction, with each grid block set at 400 feet by 400 feet.

The up-structure portion of the reservoir model represents the oil reservoir. The down-structure portion of the reservoir model represents the underlying aquifer.

Advanced Resources International, Inc.

History Match of Fluid Production, Petronius J-2 Sand



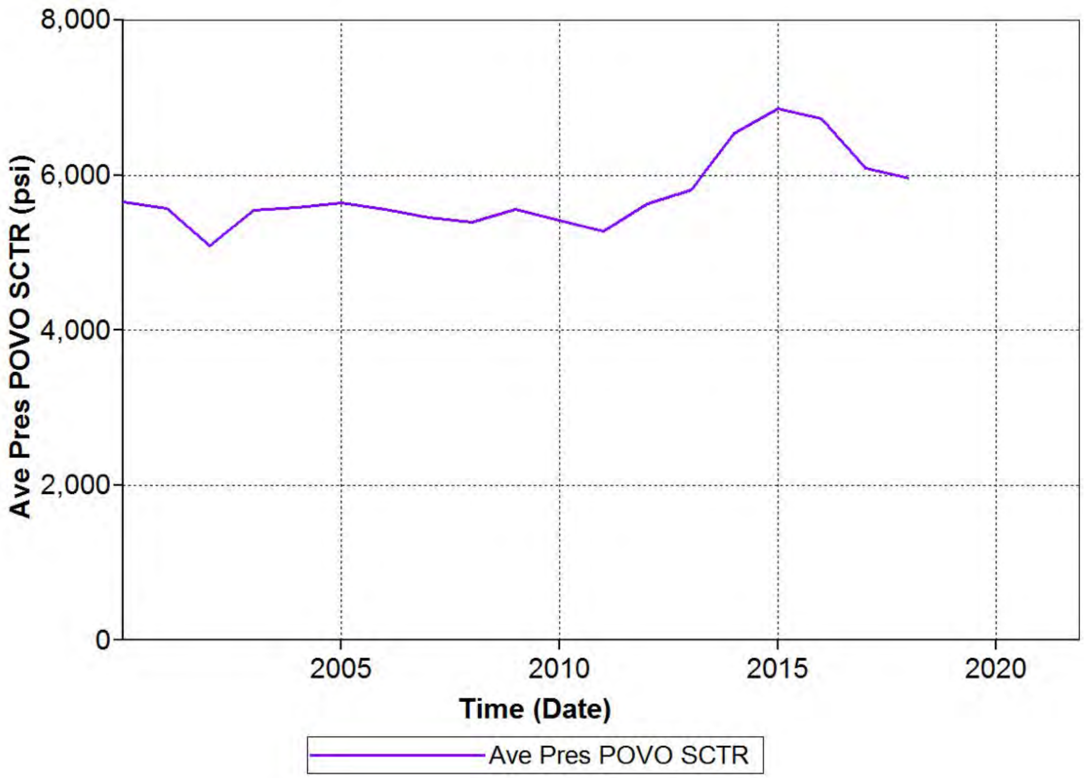
Excellent history matched results were obtained for oil production, gas production and water production.

Fluid	Actual Data	History Matched Data
Oil	53 MM bbl	52.4 MM bbl
Gas	53 Bcf	51.4 Bcf
Water	28.5 MM bbl	29.4 MM bbl

Source: Advanced Resources International, 2019

Advanced Resources International, Inc.

History Match of Fluid Production, Petronius J-2 Sand



An important output of the history match was the estimate of J-2 Sand reservoir pressure at the end of the waterflood.

Source: Advanced Resources International, 2019

GEM Compositional Modeling of the Performance of the CO_2 Flood, Petronius J-2 Sand

CO_2 Flood Design. Given the structural dip of the formation, its high permeability, and the strong bottom waterdrive, the design of the CO_2 flood was as follows:

- Drill an updip CO_2 injection well on the crest of the fault block.
- Inject continuous CO_2 at a rate of 25 MMcfd into the J-2 Sand for 40 years.
- Shut-in the one previously drilled, still active water injection well; operate the CO_2 flood using a bottom hole back pressure of 4,000 psi.
- Operate the CO_2 flood using a quarter of a five-spot pattern, with three closely spaced, active wells representing one production well and the other two closely spaced, active wells representing the second production well.

CO_2 PROPHET Modeling of the NETL CO_2 Flood, Petronius J-2 Sand

In parallel with the GEM compositional simulator, the study modeled the CO_2 flood in the Petronius J-2 Sand using NETL CO_2 PROPHET.

To capture the heterogeneity of the J-2 Sand, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the J-2 Sand were modeled (with CO_2 PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO_2 producer and operate the CO_2 flood using a quarter of a five-spot pattern.
- Inject continuous CO_2 at a rate of 25 MMcfd for forty years, reaching a cumulative injection of CO_2 of 365 Bcf, equal to CO_2 injected in the GEM Model.

Comparative Analysis of GEM and CO_2 PROPHET Modeling of CO_2 Flood, J-2 Sand

The CO_2 PROPHET streamtube model was able to reasonably represent the performance of the CO_2 flood compared to the GEM compositional simulator.

	CO_2 Flood Performance GEM Compositional Simulator	CO_2 Flood Performance CO_2 PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	106	106	106
CO_2 Injection (Bcf)	365	365	365
CO_2 Production (Bcf)	226	238	190
CO_2 Storage (Bcf)	139	127	175
Cumulative Oil Recovery			
▪ (million barrels)	14.3	10.8	17.4
▪ % of OOIP	13.5%	10.2%	16.4%
CO_2/Oil Ratio (Mcf/B)			
▪ Gross	25.5	33.8	21.0
▪ Net	9.7	11.8	10.1

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO_2 PROPHET model) provide results that bracket the performance of the CO_2 flood from the GEM compositional simulator.

Advanced Resources International, Inc.

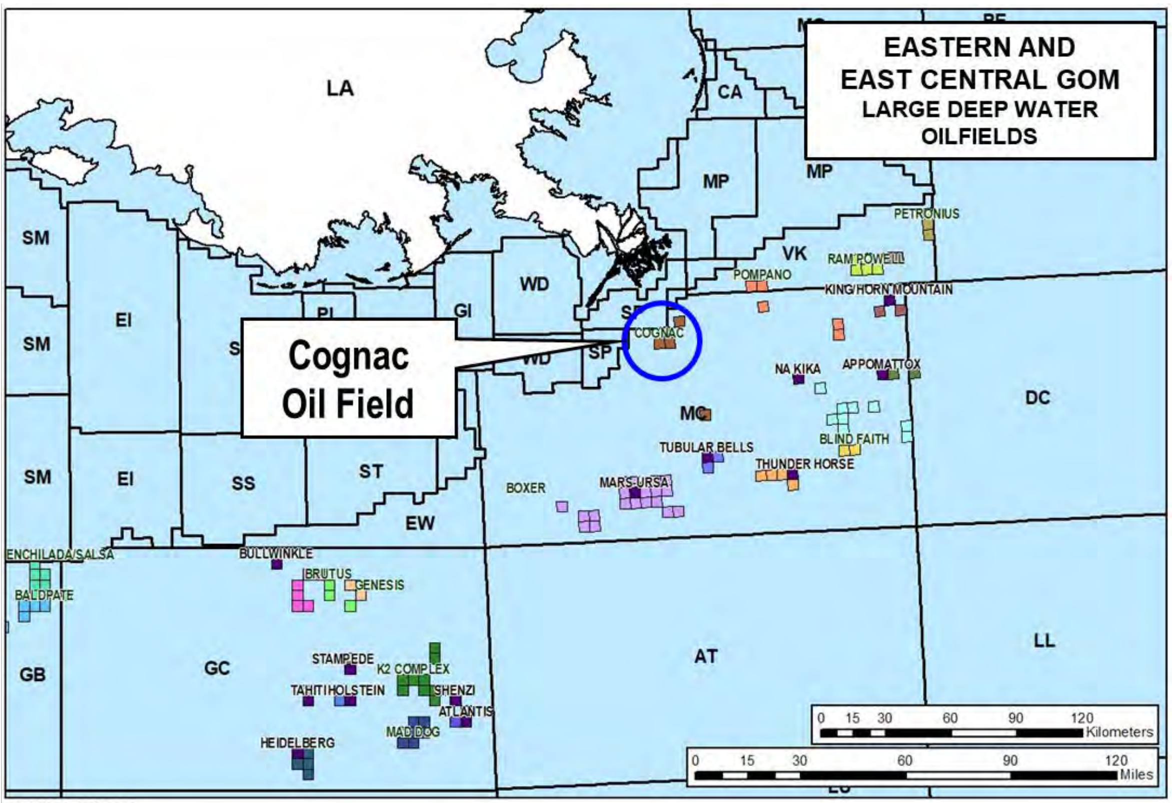
Cognac Offshore Oil Field Case Study

Advanced Resources International, Inc.

Background

The Cognac deepwater oil field (MC 194) is located in 1,022 feet of water in the Central Gulf of Mexico.

Location of Cognac Oil Field, Eastern Gulf of Mexico



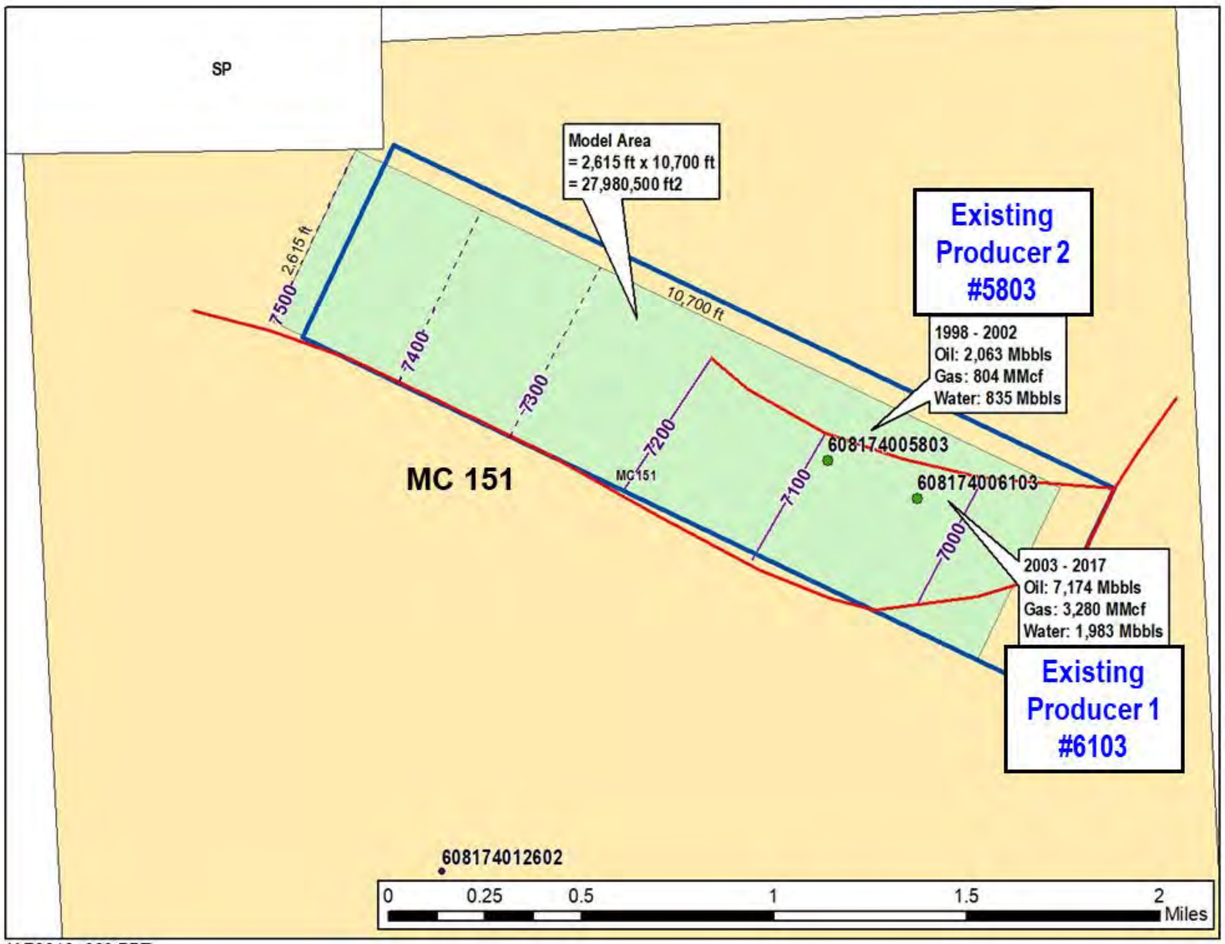
JAF2019_026.PPT

Cognac, with 184 million barrels of original oil reserves, has produced essentially all of its reserves, as of the end of 2017.

Oil production that peaked at 83,000 B/D of oil in 1983 has declined to about 2,000 B/D of oil in 2016, placing Cognac on a list of oil fields facing abandonment.

Cognac J Sand/NE Fault Block Geologic Model

Outline of NE Fault Block, Cognac Field



JAF2019_026.PPT

The NE Fault Block in MC 151 contains two oil producing wells – Well #5803 and Well #6103 – producing from a fault bounded area of about 384 acres.

A simplified representation of the NE Fault Block, including its structure, the location of the bounding faults, and the location of the two producing wells is shown.

Advanced Resources International, Inc.

Cognac J Sand

The J Sand in the Cognac oil field, selected for the Case Study, holds 136 million barrels of OOIP and has a remaining oil target of 79 MMB. The NE Fault Block (J Sand) holds about 18% of the OOIP in the total J Sand.

Cognac Original Oil Resources, Production and Remaining Reserves

Sands		Oil Area (Acres)	Original Oil In-Place* (MMB)	Cumulative Oil Production** (MMB)	Remaining Oil Reserves (MMB)
1. Major Sands					
▪	I	3,560	191.5	91.7	0.1
▪	J	2,240	135.6	56.9	0.3
2. Minor Sands					
▪	J-1	1,740	23.3	6.6	***
▪	Others	n/a	n/a	16.0	3.2
Total		**7,540**	**350.4**	**171.2**	**3.6**

*Volumetrically adjusted by Advanced Resources Int'l., **As of end of 2016.

***Less than 0.05 MMB.

JAF2019_015.XLS

Advanced Resources International, Inc.

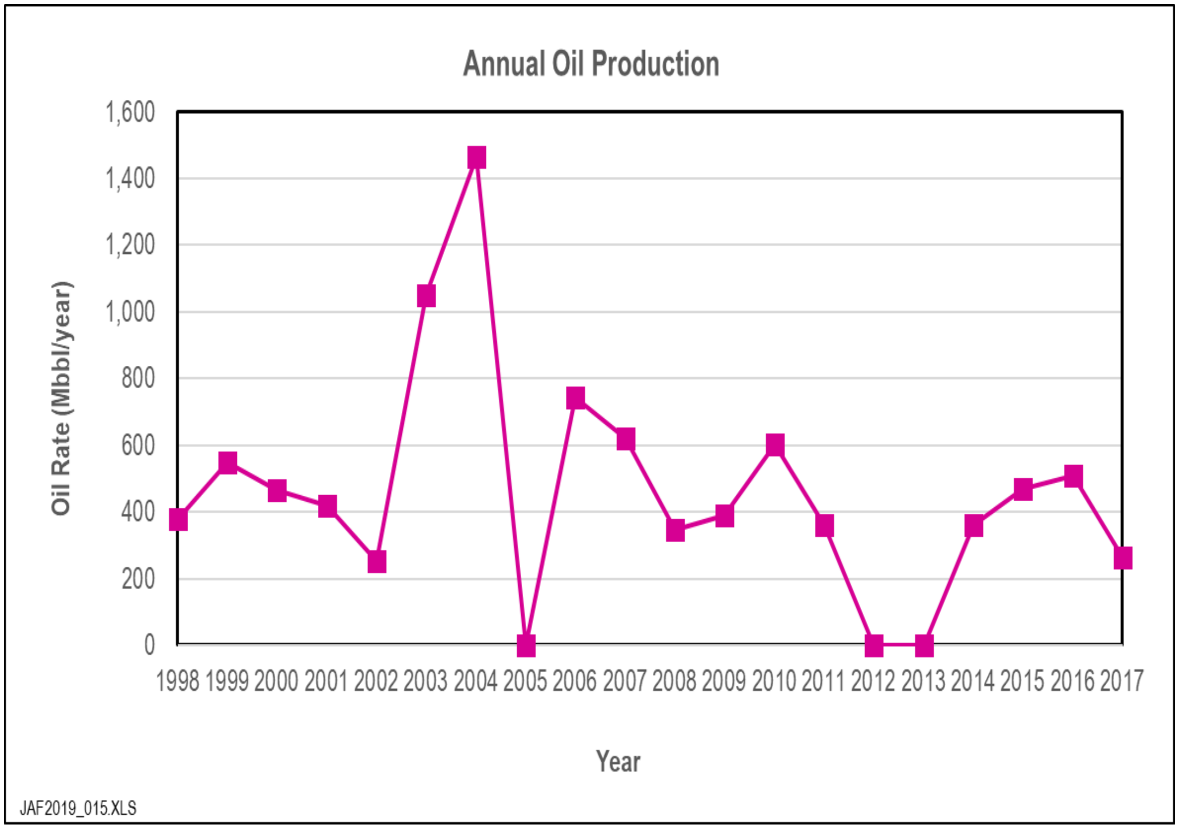
Volumetric and Other Reservoir Properties Cognac J Sand/NE Fault Block

Reservoir Properties	Value
Accessible Oil Area	384 Acres
Porosity	32%
Permeability	794 mD
Net Pay	42 ft
Oil Gravity	34.6 API
Soi	0.73
Sor	0.45
Boi	1.21
OOIP	24.2 MMbbls
Initial Pressure (@ 8,297 ft)	4,412 psia
Initial Reservoir Temperature	130 ^{o}F

The key volumetric and reservoir properties for the Cognac J Sand in the NE Fault Block are derived from information provided in the BOEM Offshore GOM data base and from the technical literature on the Cognac oil field.

Cognac J Sand/NE Fault Block

Annual Oil Production, Cognac J Sand, NE Fault Block



Source: Advanced Resources Int'l using DrillingInfo data, 2019

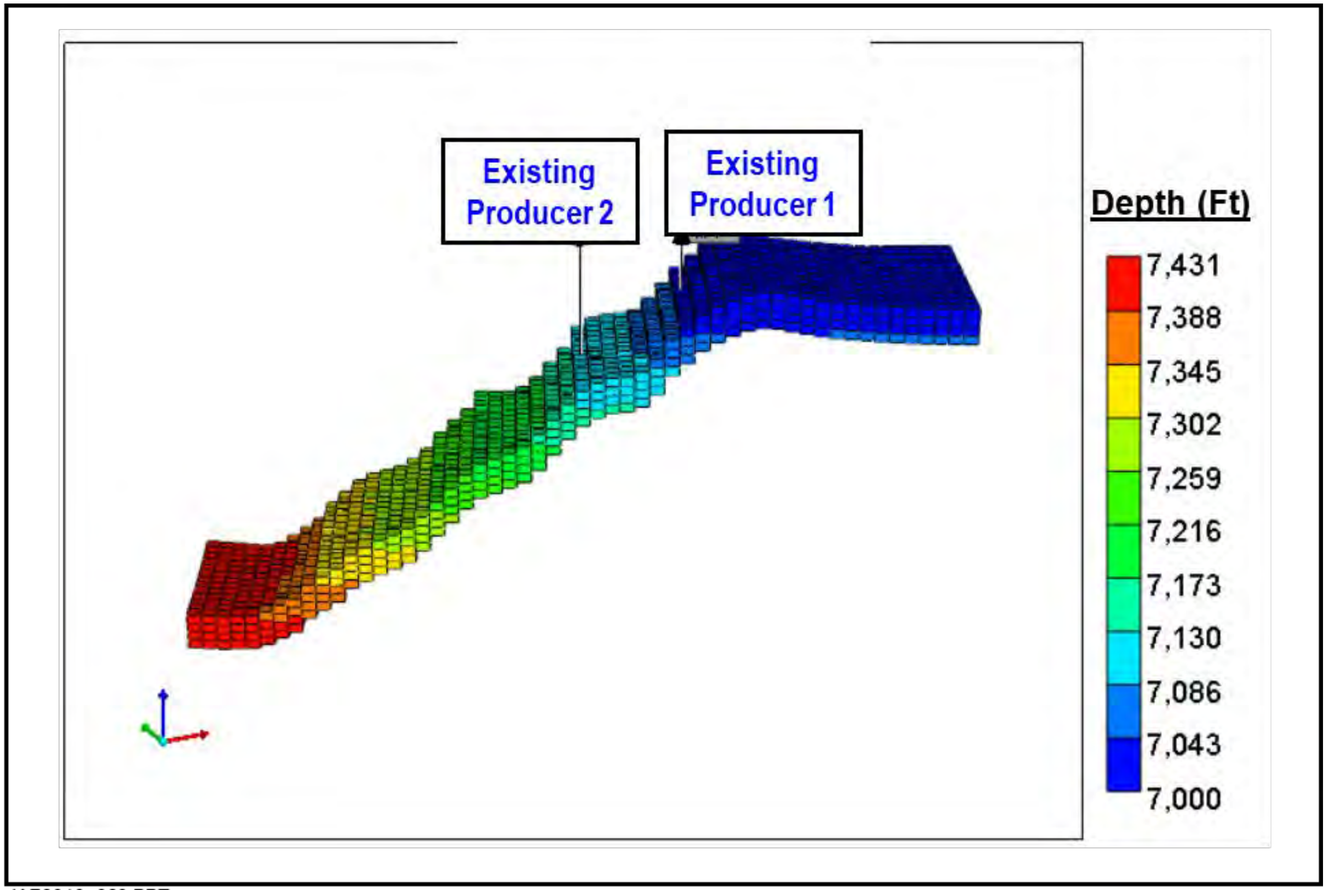
As of mid-2017, the J Sand of the NE Fault Block has produced 9.25 million barrels of oil, equal to 38 percent of OOIP.

The annual oil production history of the NE Fault Block J Sand from inception in mid-1998 to mid-2017 is shown.

Advanced Resources International, Inc.

Reservoir Modeling for Cognac J Sand

NE Fault Block, Cognac J Sand, 3D Model, Side View

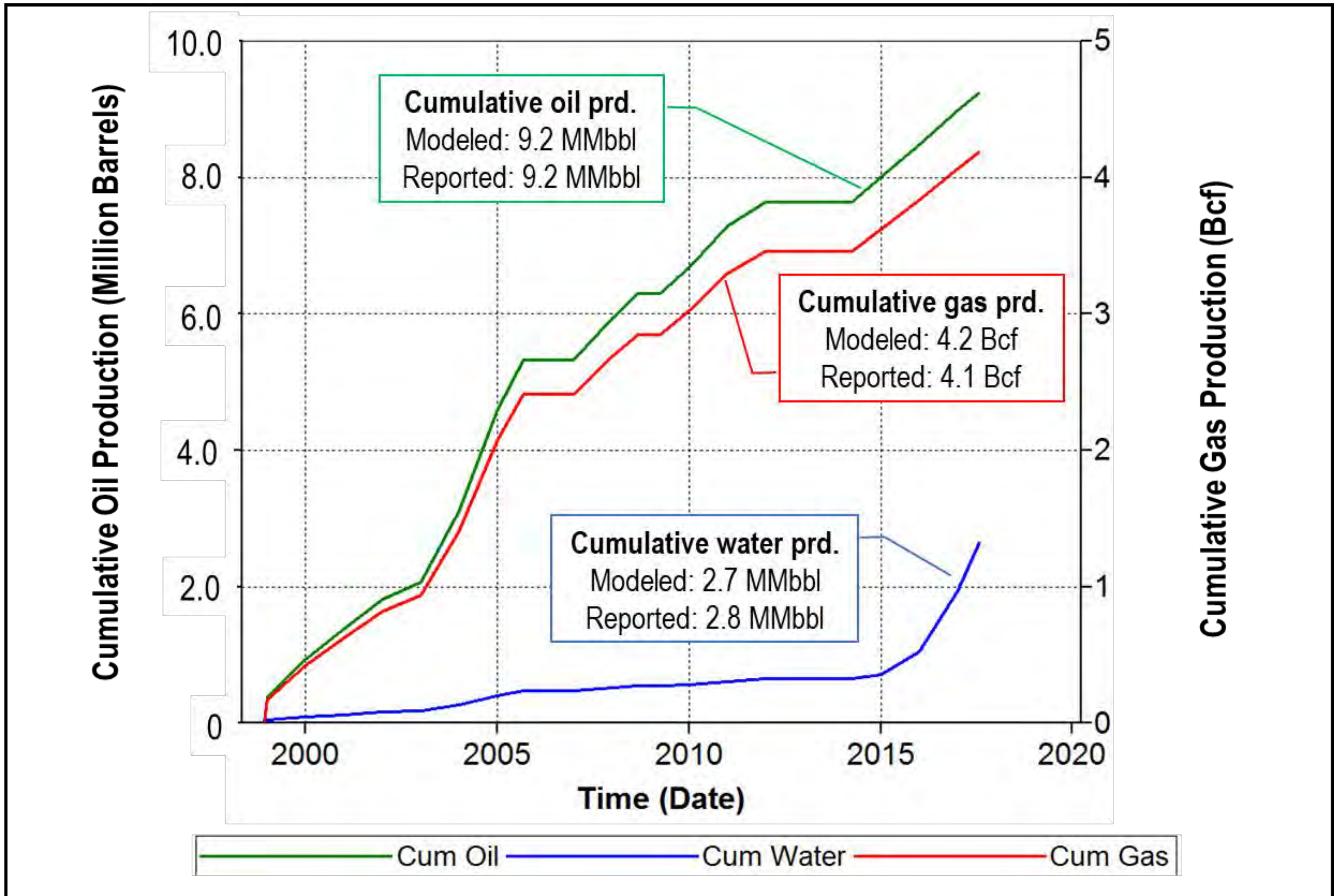


JAF2019_026.PPT

The reservoir model for the surface of NE Fault Block J Sand contains 702 grid blocks (54 x 13) each having a dimension of 200 ft in the X and Y directions.

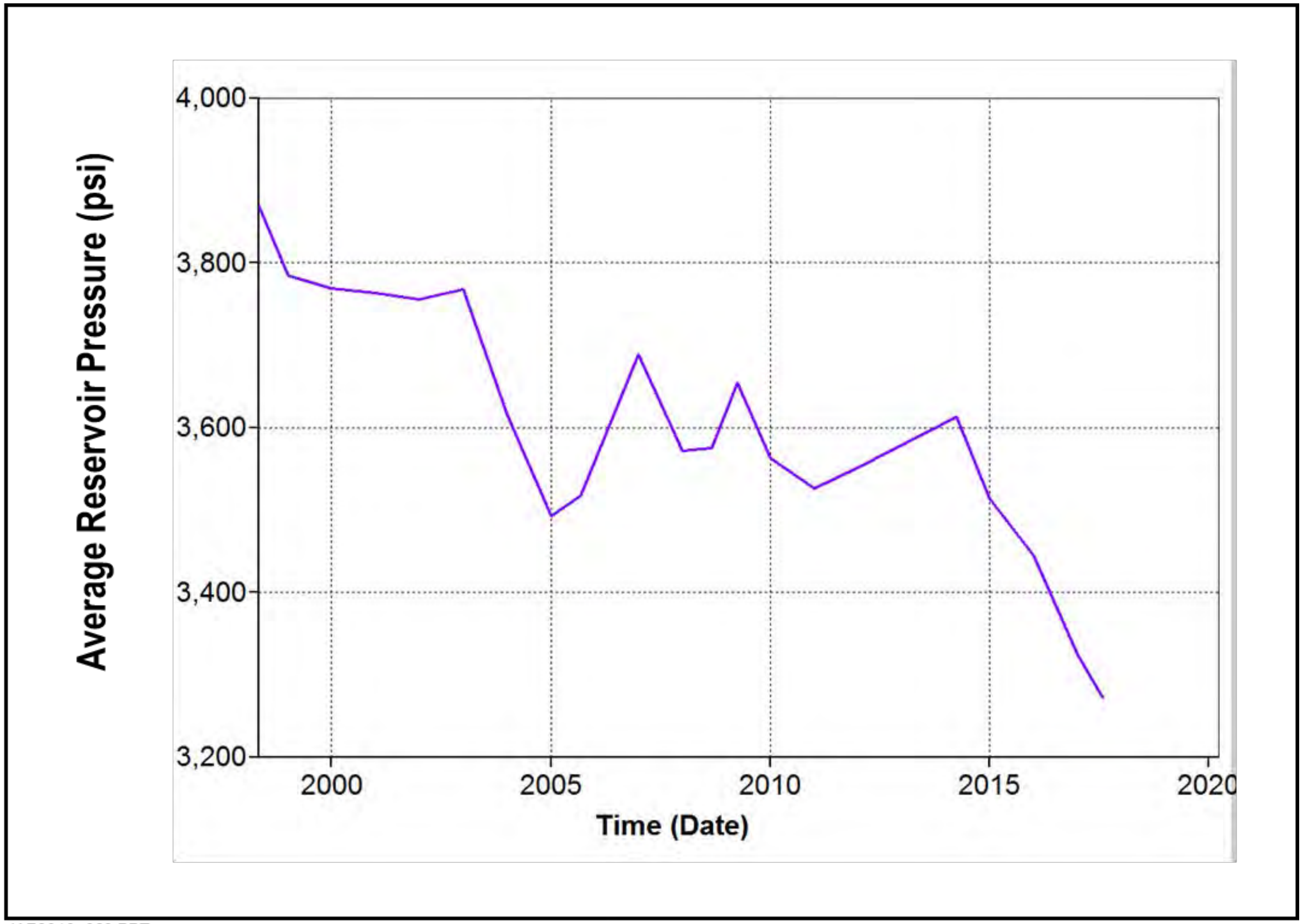
The vertical dimension of the J Sand is represented by four layers (grid benches), each having a thickness of 10.5 feet.

History Match of Fluid Production, Cognac J Sand, NE Fault Block



JAF2019_026.PPT

History Match of Fluid Production, Cognac J Sand, NE Fault Block



JAF2019_026.PPT

An important output of the history match was the estimate of J Sand reservoir pressure at the end of primary production.

Advanced Resources International, Inc.

GEM Compositional Modeling of the Performance of the CO_2 Flood, Cognac J Sand, NE Fault Block

CO_2 Flood Design. Given the structural dip of the formation, its high permeability and the strong bottom waterdrive, the design of the CO_2 flood was as follows:

- Drill an updip CO_2 injection well on the crest of the fault block.
- Inject continuous CO_2 at a rate of 24 MMcfd into the J Sand for 10 years and 20 years.
- Shut-in the producing wells for 12 months to raise reservoir pressure; operate the CO_2 flood using a bottom hole back pressure of 3,000 psi.
- Initially produce from updip production well (Prd #1) until CO_2 breakthrough; shut in updip production well and open downdip production well (Prd #2) and produce until end of the CO_2 flood.

CO_2 PROPHET Modeling of the NETL CO_2 Flood, Cognac J Sand, NE Fault Block

In parallel with the GEM compositional simulator, the study modeled the CO_2 flood in the Cognac J Sand, NE Fault Block, using NETL CO_2 PROPHET.

To capture the heterogeneity of the J Sand in the NE Fault Block, the study used Dykstra-Parsons (DP) coefficients of 0.5 and 0.75.

The geologic setting and well locations of the NE Fault Block's J Sand were modeled (with CO_2 PROPHET) using the following features.

- Incorporate reservoir properties from the BOEM Offshore data base.
- Drill a CO_2 producer and operate the CO_2 flood in a two well line drive configuration.
- Inject continuous CO_2 at a rate of 24 MMcfd for ten years, reaching a cumulative injection of CO_2 of 88 Bcf equal to CO_2 injected in the GEM Model (a HCPV of 1.2).

Comparative Analysis of GEM and CO_2 PROPHET Modeling of CO_2 Flood, NE Fault Block J Sand

The CO_2 PROPHET streamtube model was able to reasonably represent the performance of the CO_2 flood compared to the GEM compositional simulator.

	CO_2 Flood Performance GEM Compositional Simulator	CO_2 Flood Performance CO_2 PROPHET	
		DP of 0.75	DP of 0.5
OOIP (million Barrels)	24.2	24.4	24.2
CO_2 Injection (Bcf)	89.5	87.7	87.7
CO_2 Production (Bcf)	52.3	55.7	45.3
CO_2 Storage (Bcf)	37.2	32.0	42.4
Cumulative Oil Recovery			
▪ (million barrels)	8.18	6.33	8.67
▪ % of OOIP	33.8%	26.2%	35.8%
CO_2/Oil Ratio (Mcf/B)			
▪ Gross	10.9	13.9	10.1
▪ Net	4.5	5.1	4.9

The Dykstra-Parson (DP) reservoir heterogeneity values of 0.5 to 0.75 (CO_2 PROPHET model) provide results that bracket the performance of the CO_2 flood from the GEM compositional simulator.

Observations and Findings

A series of observations and findings have emerged from the GOM offshore case studies:

- Establishing a geologically representative data base for offshore oil fields is a challenge, but one that can be overcome with diligent effort.
- By defining the location and status of existing production and injection wells, reasonable spacing and CO_2 flooding designs can be established for offshore oil fields.
- Miscible CO_2 EOR can provide notable increases in oil recovery – 15% to 30% of OOIP – while storing significant volumes of CO_2.
- The NETL CO_2 PROPHET Model can provide realistic estimates of oil recovery and CO_2 storage in offshore oil reservoirs.

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RISK ASSESSMENT GAS HYDRATES

SECARB Offshore GoM

CAMELIA KNAPP, JIM KNAPP, GOKCE ASTEKIN, SAIFUL ALAM
Boone Pickens School of Geology
Oklahoma State University

Task 4.0

Task 4.0

- Risk Assessment, Simulation, and Modeling. Going beyond the traditional NRAP process, this Task encompasses activities related to the refinement and adaption of existing data mining, analysis, and machine learning tools (SAS Viya decision system; Subtask 3.2), simulation tools, geologic models, and risk assessment and mitigation strategies for site-specific assessments of storage prospects in the offshore environment. To aid in a formalized process for characterizing prospects with high potential for commercial CO2 storage development, supported, to the extent possible and practical, by the SAS Viya platform, the project team will perform a robust characterization of risk, geologic technical risk, operational risk, and commercial risk related to the full, integrated system (source, transport, and storage utilization). Results will be used to highlight possible physical regulatory and or commercial barriers, and mechanisms to overcome those barriers. This activity is directly dependent on the outcome of Task 3.0, namely the defined characteristics of representative storage opportunities.
- Subtask 4.3.2: Seismic Hazard Assessment and Earthquake Risk Analysis. Perform seismic hazard assessment and earthquake risk analysis in the study area, assess the evolution of gas hydrate-bearing systems and their temporal and spatial response to natural perturbations, based on lessons learned from the active Woolsey Mound cold seep at Mississippi Canyon 118.

Woolsey Mound - CSHS

McGee et al. 2009

- 900 m WD on the N continental slope of the GOM.
- Slope highly discontinuous, intersected by slumping, folding and faulting mainly driven by salt tectonics and sediment load delivered by the Mississippi River.
- Deepwater Horizon rig, Mississippi Canyon 252, April 22, 2010.

Woolsey Mound Hydrates

- Do not exhibit the classic regional BSRs on seismic sections.
- Seem to form around salt-related faults that provide likely migration pathways for the thermogenic hydrocarbons.
- Other methods need to be implemented in order to detect them and provide estimates of their volumetric extent.

MC 118, (Lutken et al., 2011)

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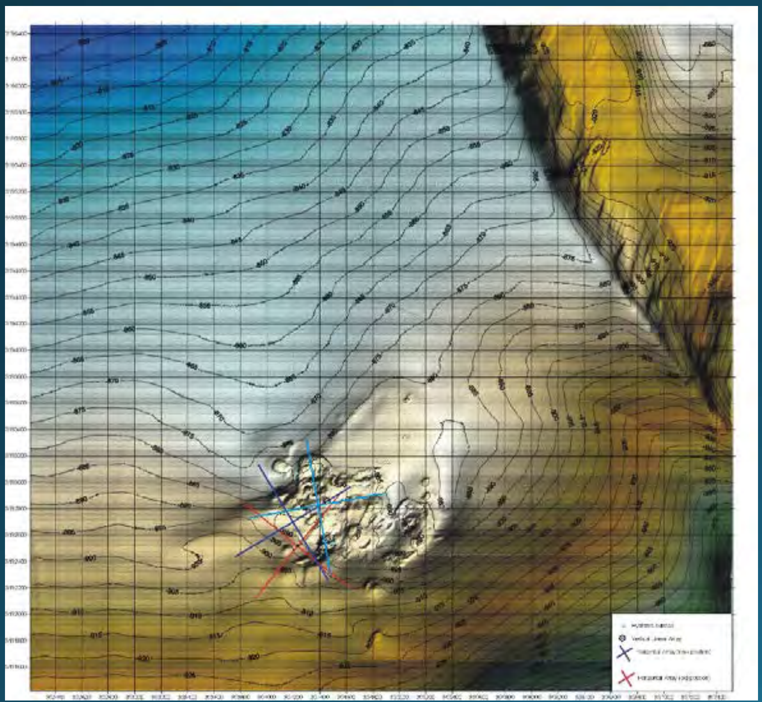
Woolsey Mound: Fault-Controlled, Transient, Thermogenic Hydrate System

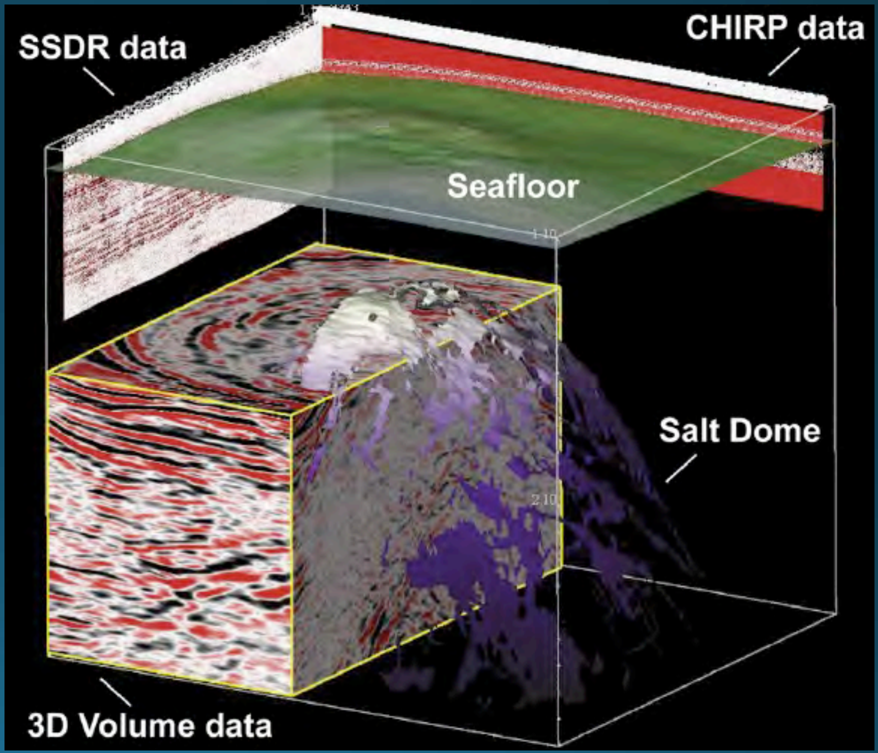


Macelloni et al., 2012

- Mid-slope of GOM
- Salt tectonically driven cold seep
- Gas venting at the seafloor
- Outcropping hydrate chemosynthetic communities, carbonate mounds, and bubble plumes
- Chemosynthetic communities
- Relatively shallow water depth (<1000 m).

Hypotheses

- GH are genetically related to the salt system through active normal faults, conduits for thermogenic gas
- GH formation and dissociation vary temporally in the vicinity of active faults, and can temporarily seal them as conduits for thermogenic fluids.
- GH at WM are controlled by a highly heterogeneous stability field leading to the general paucity of BSRs.
- AVO analysis is a good indicator of hydrates in the absence of well defined BSRs.
- Apparent temporal changes in seismic images of the subsurface are correlated with periodic fluid expulsion and hydrate dissociation.



Macelloni et al., 2012

Available Data

Standard 3-D data from TGS-Nopec, acquired in 2000; time domain data; 3 s TWTT

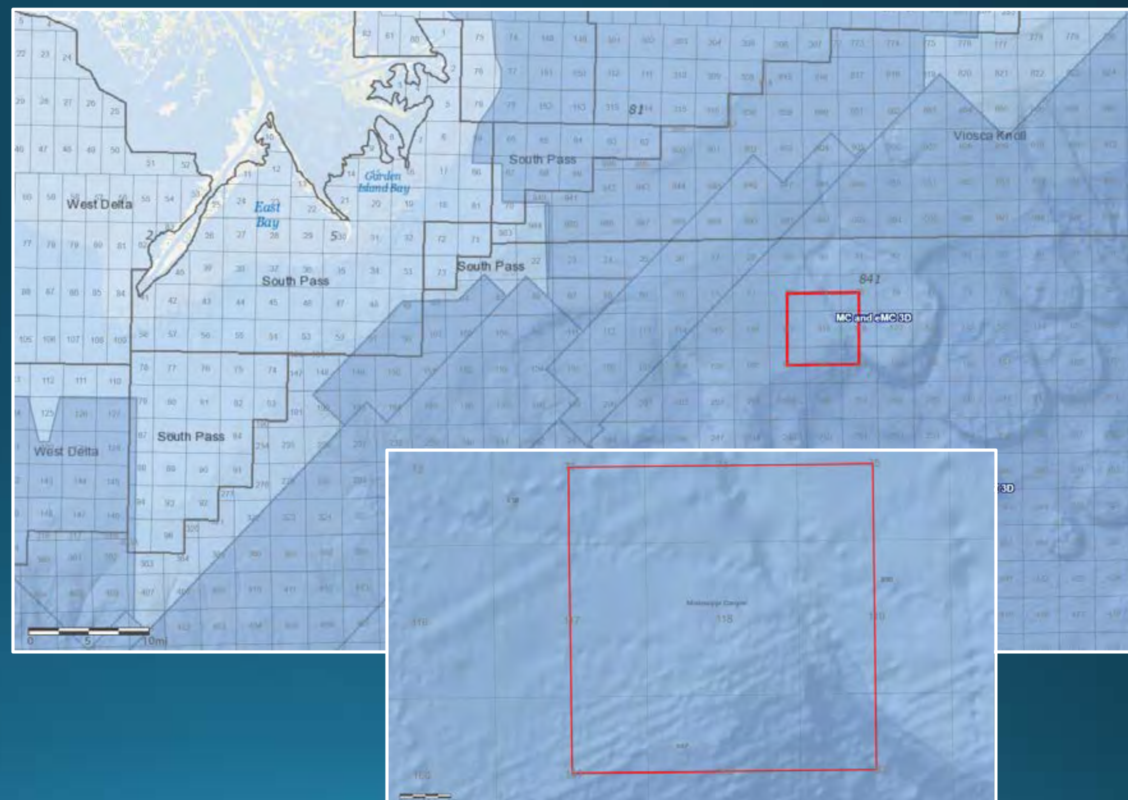
Standard 3-D data from Western Geco, acquired in 2003; time domain data; 10 s TWTT

Wide Azimuth (WAZ) 3-D data from TGS-Nopec, acquired in 2010; time and depth domain data; 10 s TWTT, 16 km depth

Wide Azimuth (WAZ) 3-D data from TGS-Nopec, acquired in 2014; time and depth domain data; 10.4 s TWTT, 18 km depth

Single-channel 2D AUV-borne Chirp Sub-bottom Profiler data, acquired in 2005;

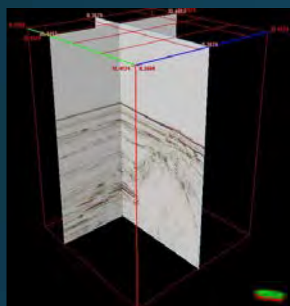
Single-channel pseudo 3D Surface Source Deep Receiver data (SSDR), acquired in 2006.



TGS Nopec

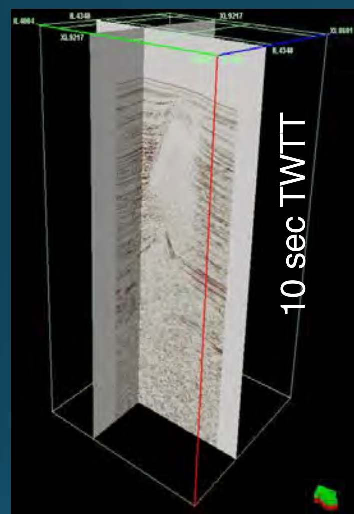
4-D SEISMIC ANALYSIS

3 sec TWTT

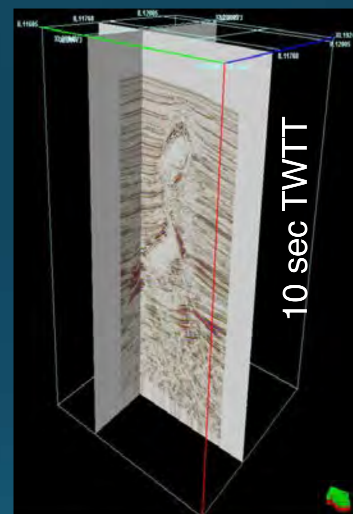


TGS 2000

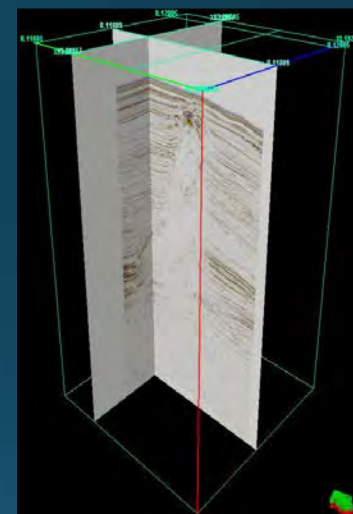
10 sec TWTT



WesternGeco 2003



Justice 2010



Declaration 2014

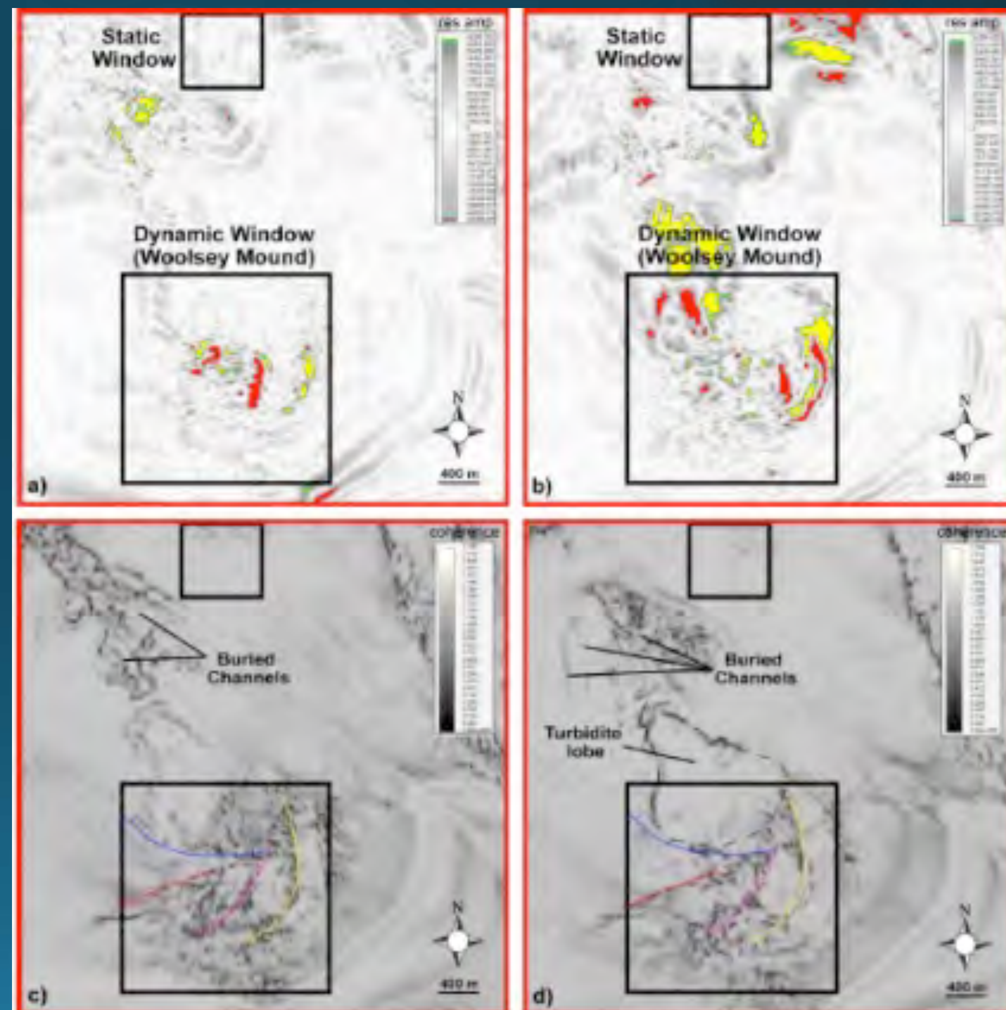
4-D PROCESSING SEQUENCE (cross-equalization):

- ✓ re-sampling
- ✓ 3D geometry re-binning
- ✓ phase matching
- ✓ shaping filter
- ✓ gain x-normalization
- ✓ residual amplitude map

Time-lapse seismic monitoring involves comparing the results of 3-D seismic surveys repeated at considerable time intervals: time is the fourth dimension.

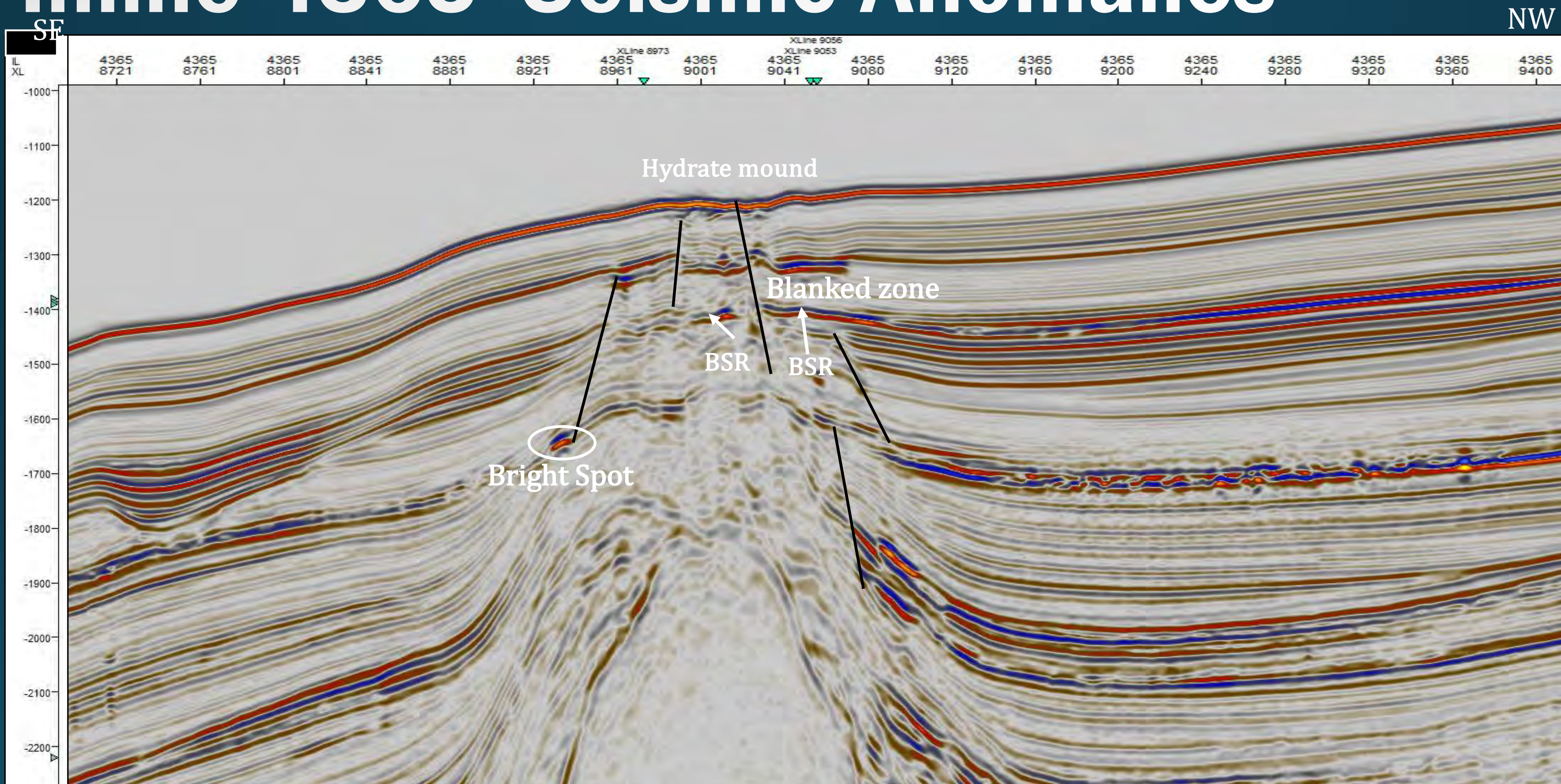
4-D seismic anomalies (time slices near the BHSZ)

Subsurface Structures
(time slices near the BHSZ)



Simonetti et al., 2015

Inline 4365- Seismic Anomalies



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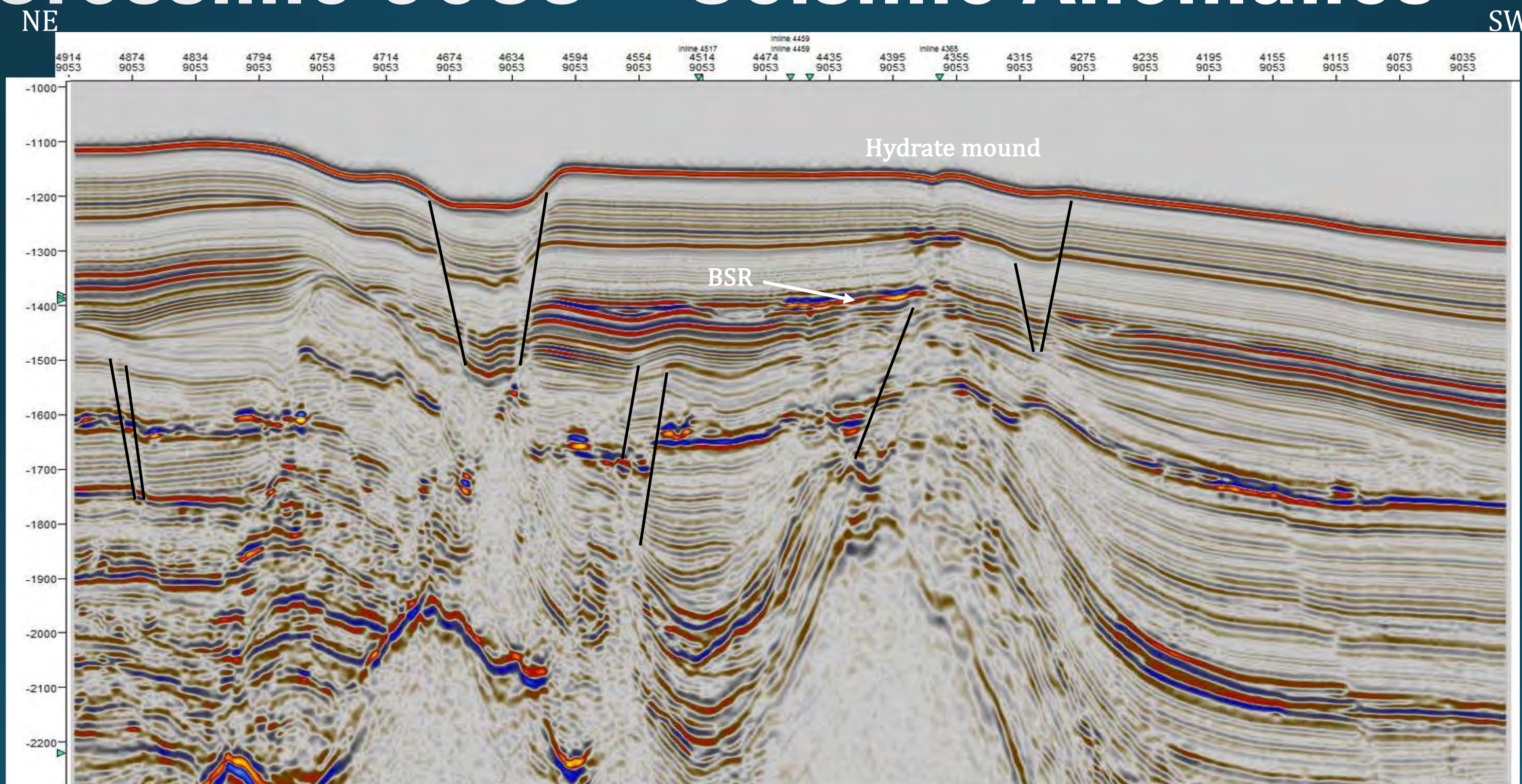
Crossline 9053 – Seismic Anomalies



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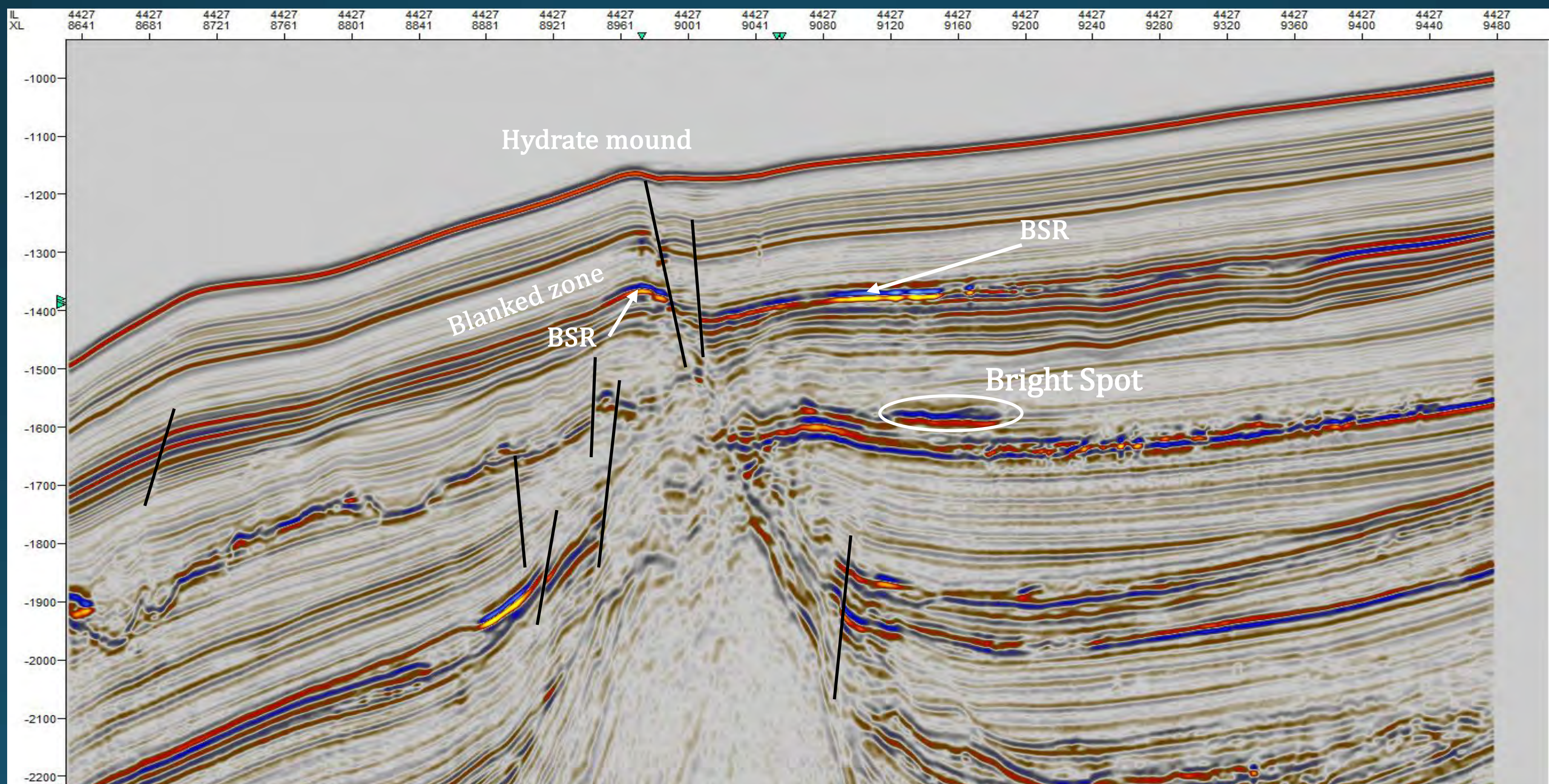
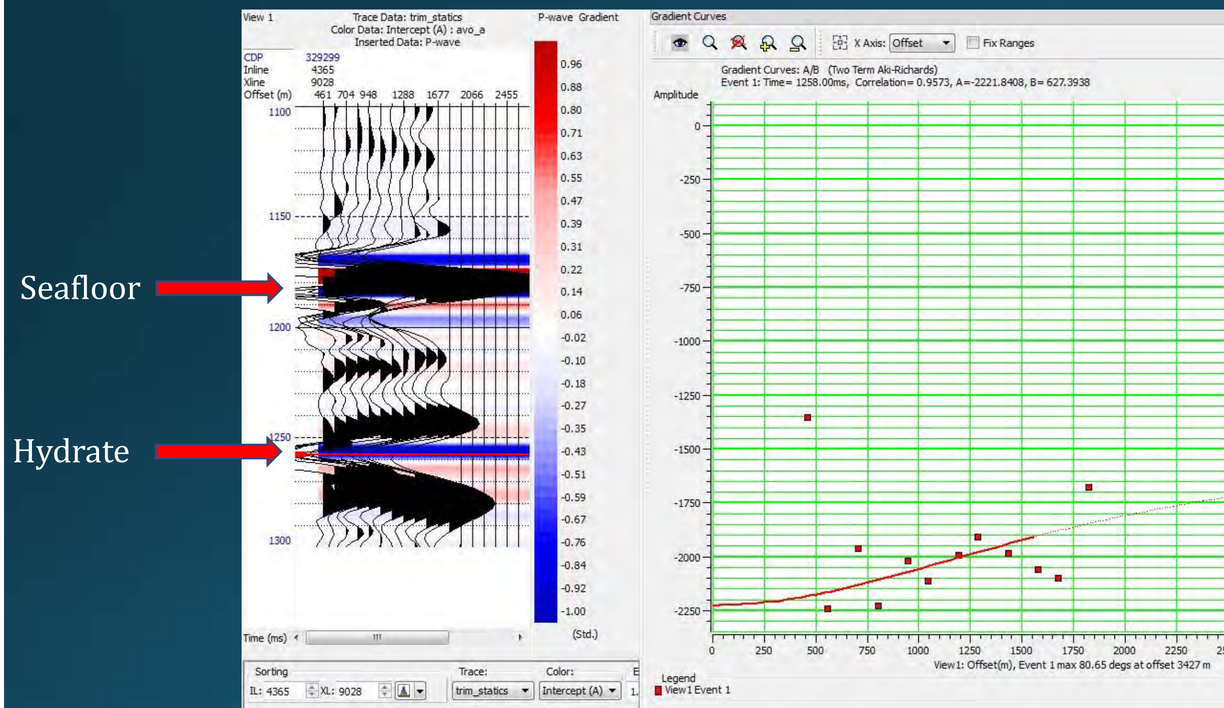
Inline 4427– Seismic Anomalies

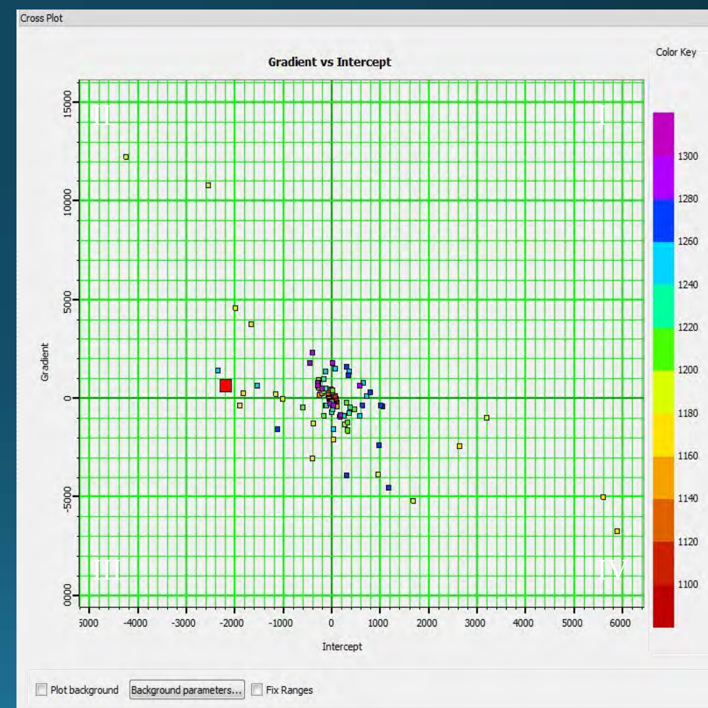
SE NW



Base of the Hydrate Layer 1 - Inline 4365

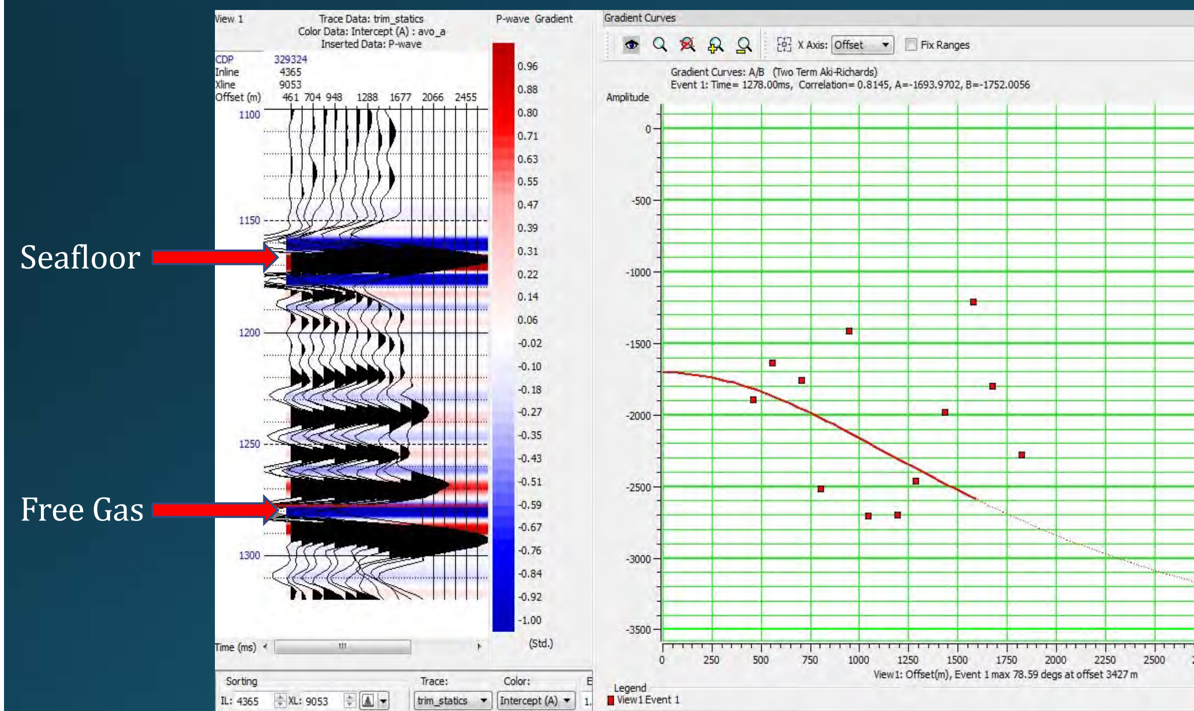


a)Variation of Reflected Amplitude with offset

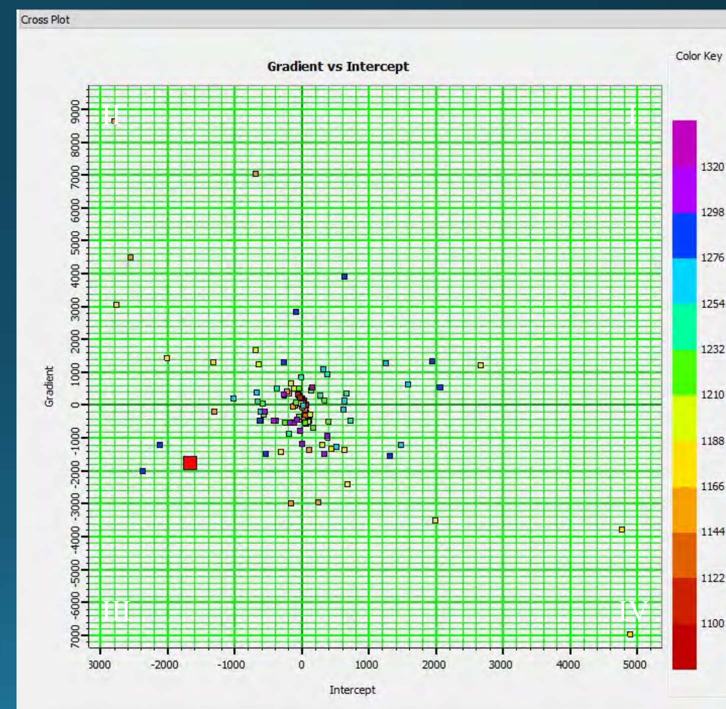


b) AVO Crossplot of data- Gradient vs Intercept

Free Gas Saturated Layer 1 - Inline 4365

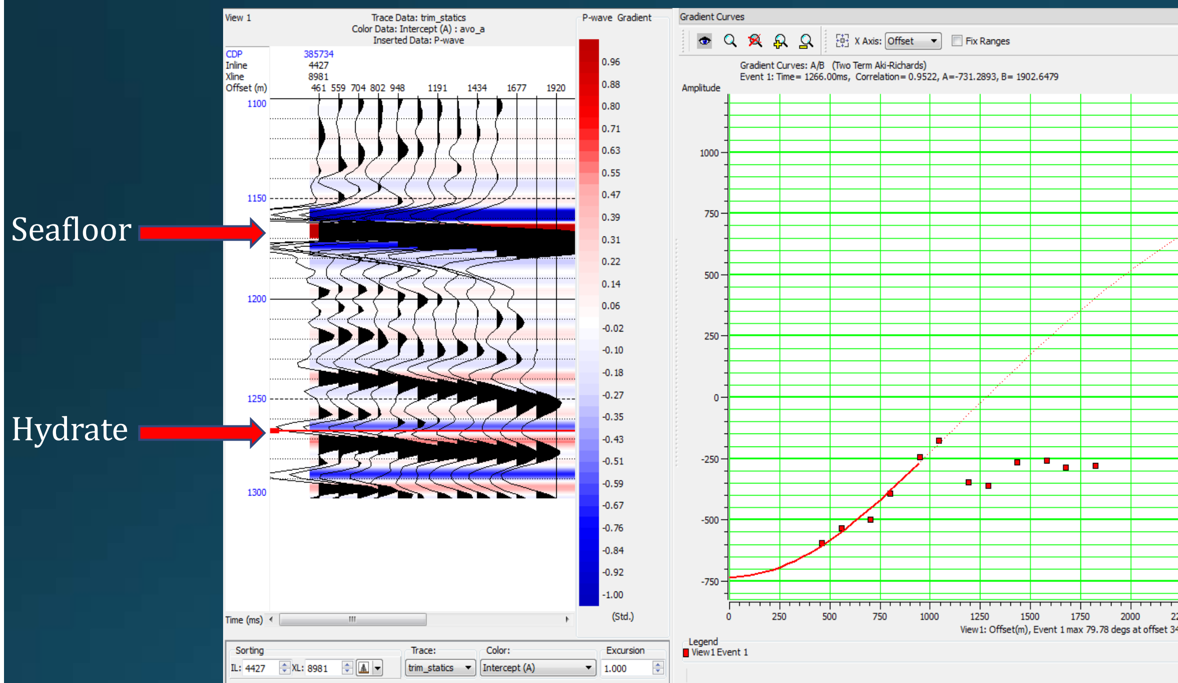


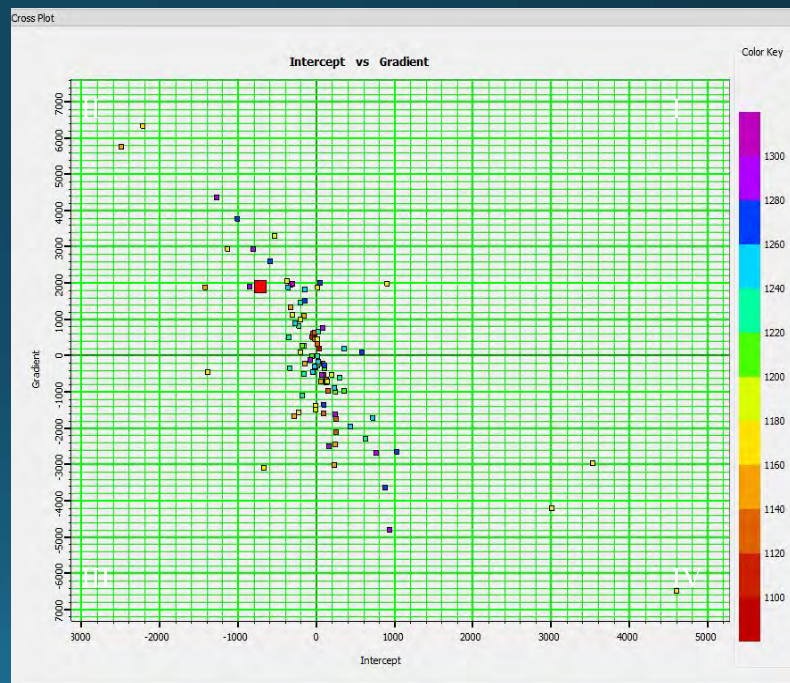
a)Variation of Reflected Amplitude with offset



b) AVO Crossplot of data- Gradient vs Intercept

Base of the Hydrate Layer 2 - Inline 4427

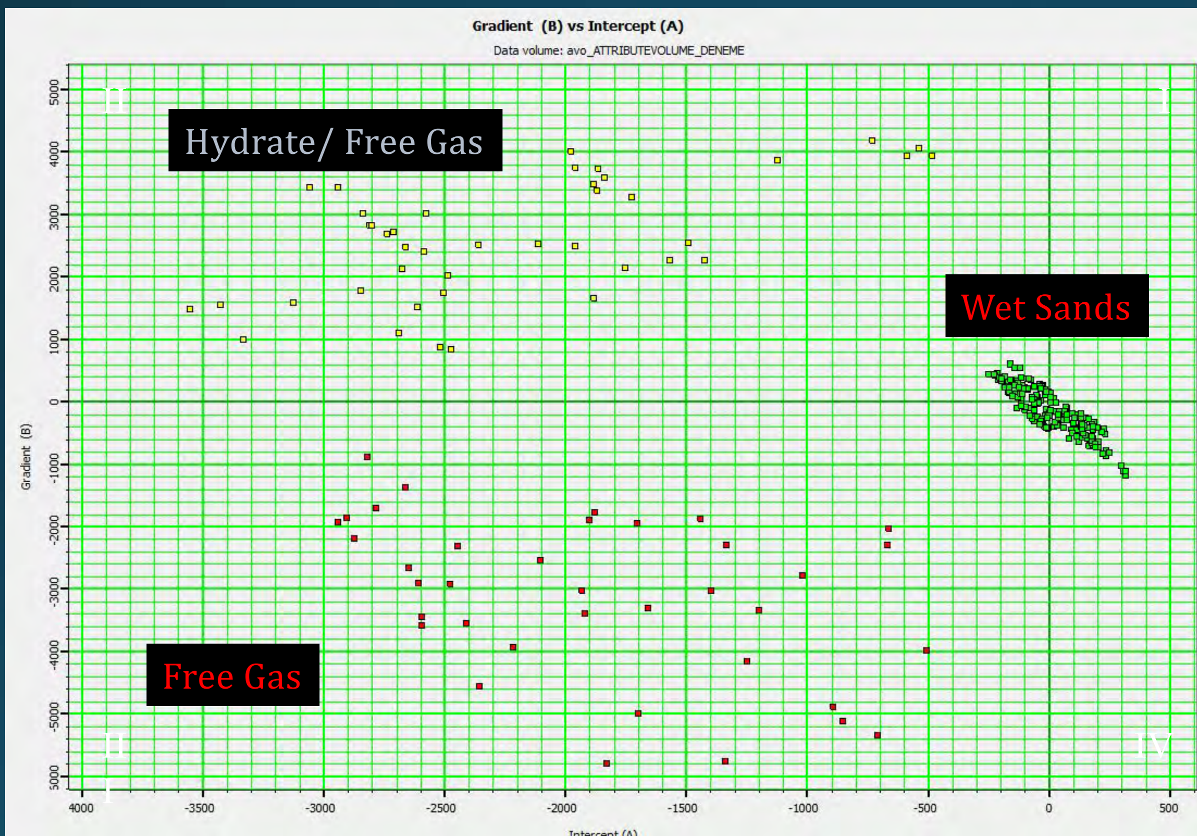




a)Variation of Reflected Amplitude with offset

b) AVO Crossplot of data- Gradient vs Intercept

Gradient vs Intercept Crossplots

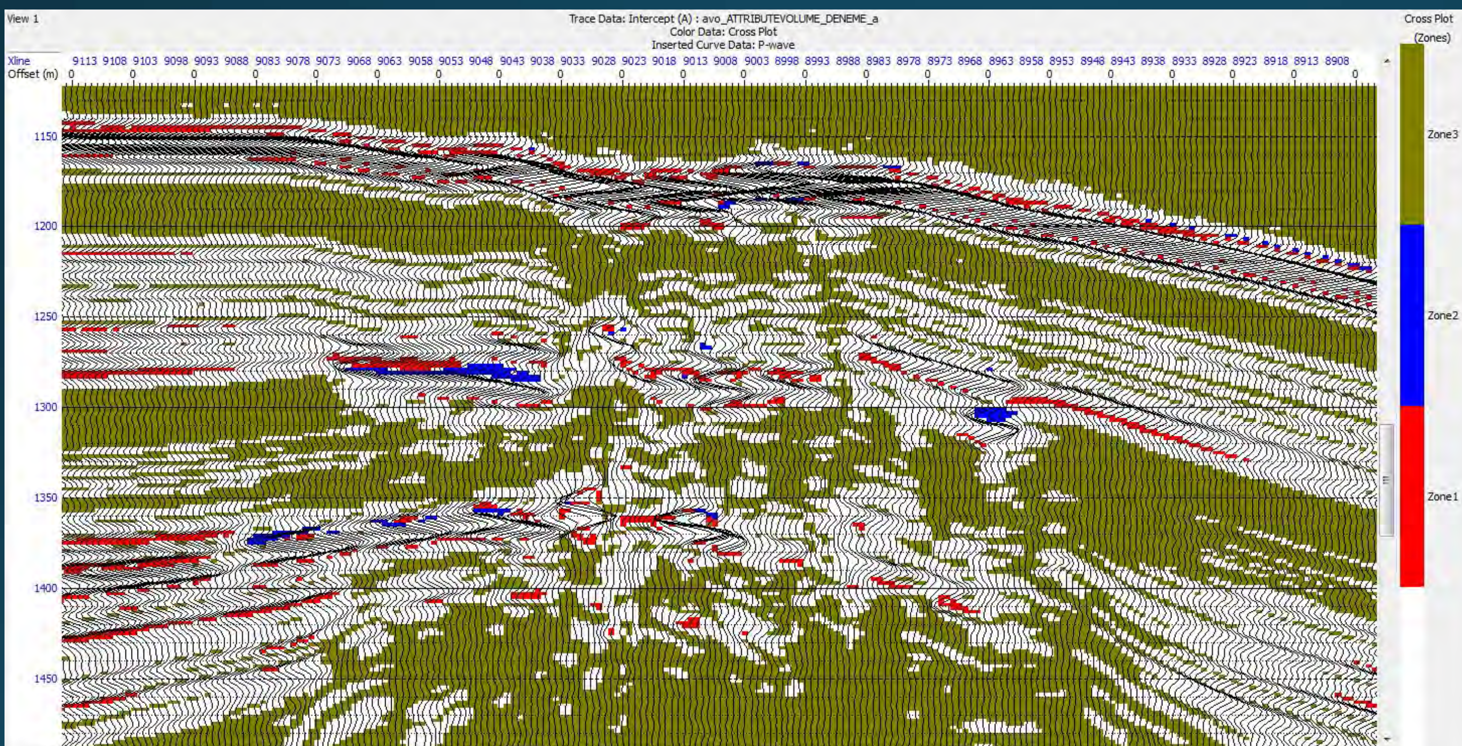


Yellow cluster: Hydrate/Free Gas
Located in Quadrant 2

Red cluster: Free Gas
Located in Quadrant 3

Green cluster: Wet Sands
Follows Background Trend

Defined Zones for AVO

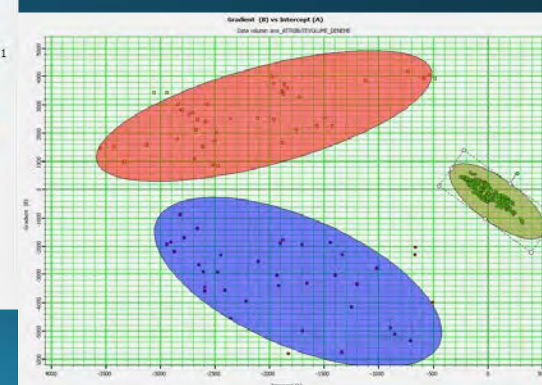


Zones of colors represent:

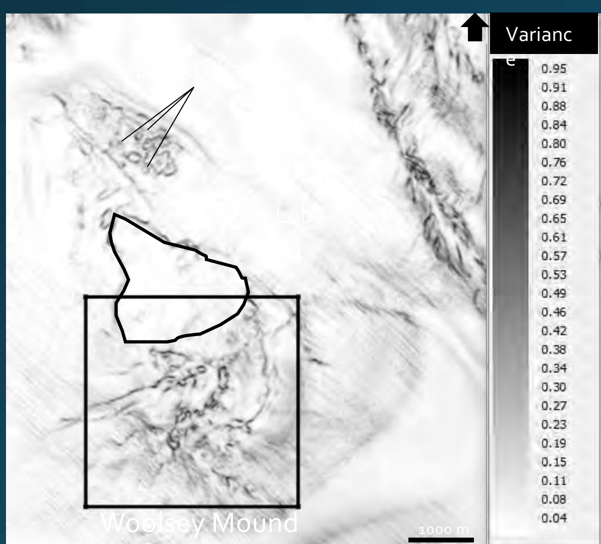
Red Zone: Hydrated sediments

Green Zone : Wet sands

Blue Zone: Gas sands

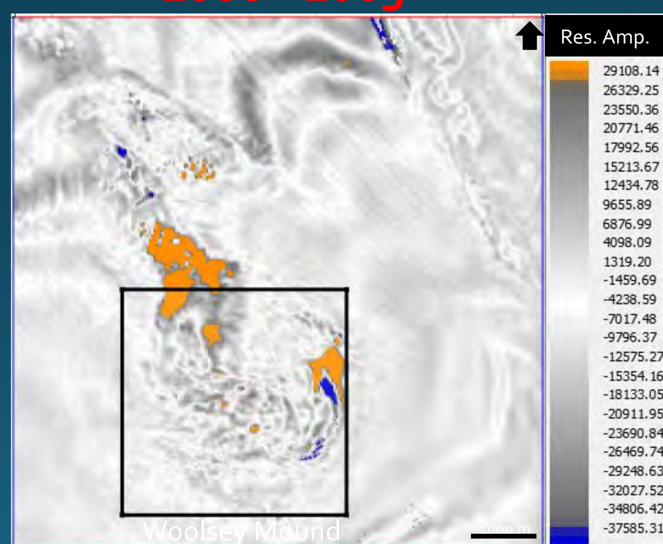


4-D SEISMIC – RESULTS



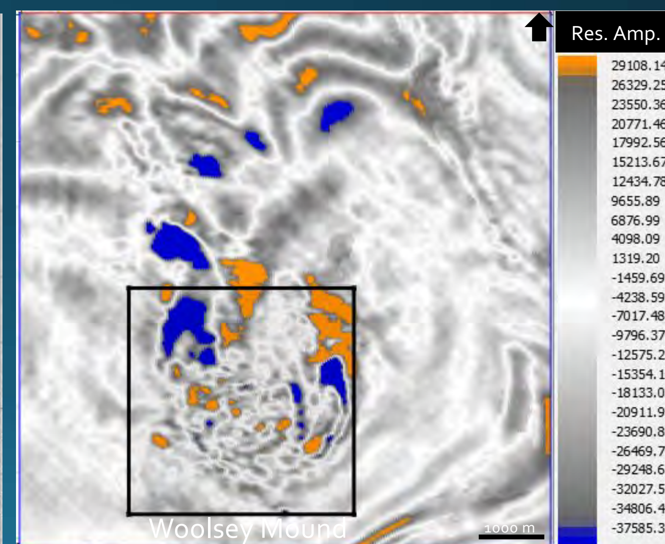
Variance slice

2000 - 2003



Residual amplitude slice

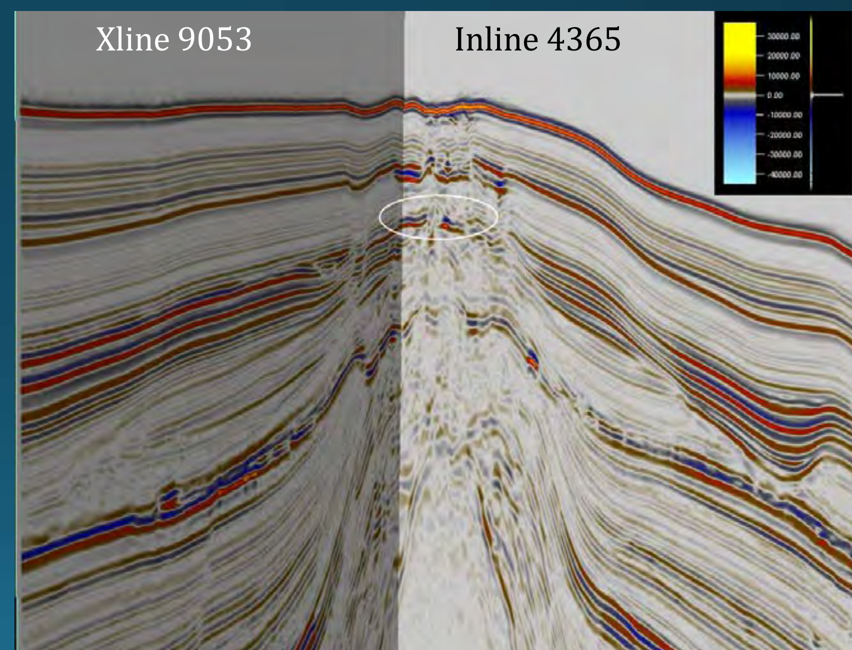
2000 - 2010



Residual amplitude slice

4-D SEISMIC – FUTURE WORK

- Apply 4-D processing sequence on Declaration 2014 data.
- Investigate the time-lapse changes that occur between year 2000 and 2014.
- Build a 4-D model that shows Gas Hydrate destabilization in Woolsey Mound between year 2000 and 2014.



Summary

- The hydrate stability field is highly fluctuating through time and space at Woolsey Mound.
- 4-D seismic anomalies are spatially associated with faults and may represent changes in the subsurface pore-fluid content.
- AVO analysis proves to be a reliable tool to identify hydrates in the absence of clearly defined BSRs.
- Results will provide fundamental numerical parameters of the development and evolution of a gas hydrate-bearing system and its response to natural perturbations over a time window comparable to human scale processes (14 years).

Acknowledgements

- Southern States Energy Board (SSEB)
- U.S. Department of Energy (NETL)
- Gulf of Mexico Gas Hydrate Research Consortium
- Geophysical Exploration/ Tectonics and Geophysics Labs
- TGS-Nopec; WesternGeco
- Bureau of Ocean Energy Management (BOEM)
- Seismic Micro-Technology, Landmark Graphics, Veritas Hampson-Russell, Schlumberger- Petrel

SECARB Offshore Partnership
Project Number: DE-FE0031557

SALT STRUCTURES, SHELF, AND DEEP-WATER RESERVOIRS, CENTRAL GOM

Jack Pashin, Ali Al-Janabi, Seyi Sholanke, and Justin Spears
Oklahoma State University

This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory.
Cost share and research support are provided by the Project Partners and an Advisory Committee.

GOMCarb-SECARB Offshore Partnership Web Meeting
March 26-27, 2020

Opening Questions

- How do storage and enhanced recovery strategies differ between shelf and continental slope settings?
- What are the critical depositional and tectonic factors that need to be understood when developing storage strategies in salt tectonic settings?
- In what ways can depositional and structural architecture be used to evaluate geologic storage security?
- What does a decision support system look like that integrates geology, engineering, and infrastructure?

NATIONAL ENERGY TECHNOLOGY LABORATORY

Objectives

- Geological Characterization (Stratigraphy, sedimentation, structure, hydrodynamic analysis).
- Analyze reservoir properties, storage volumetrics, potential storage mechanisms, migration pathways, and reservoir integrity.
- Understand pressure regime and implications for geologic CO_2 storage and enhanced recovery.
- Design heuristic decision support system using SAS Viya software.

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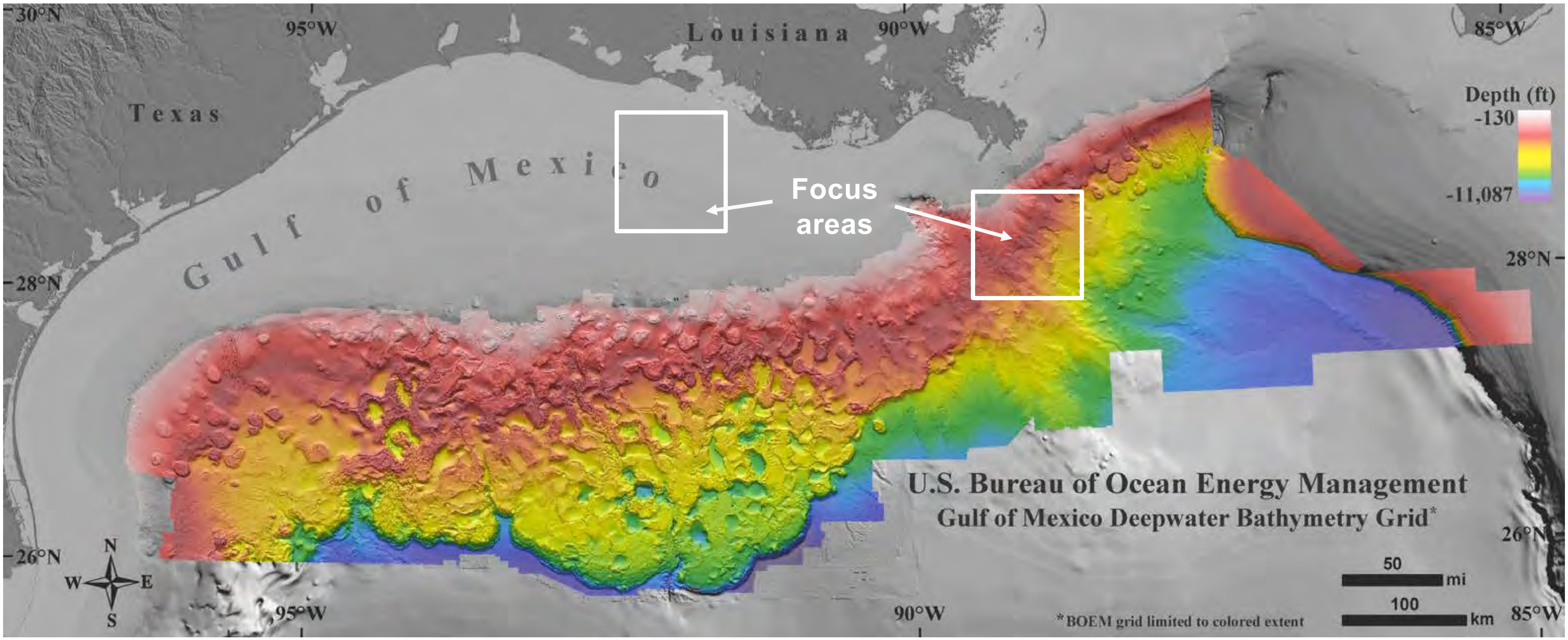
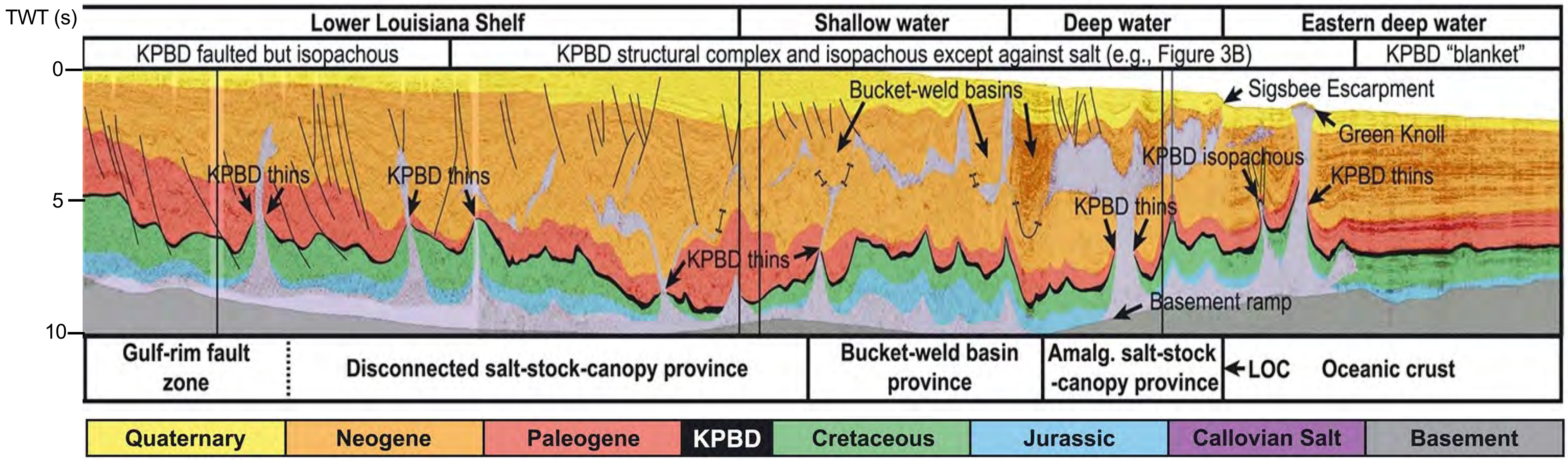
SECARB Offshore Project Area

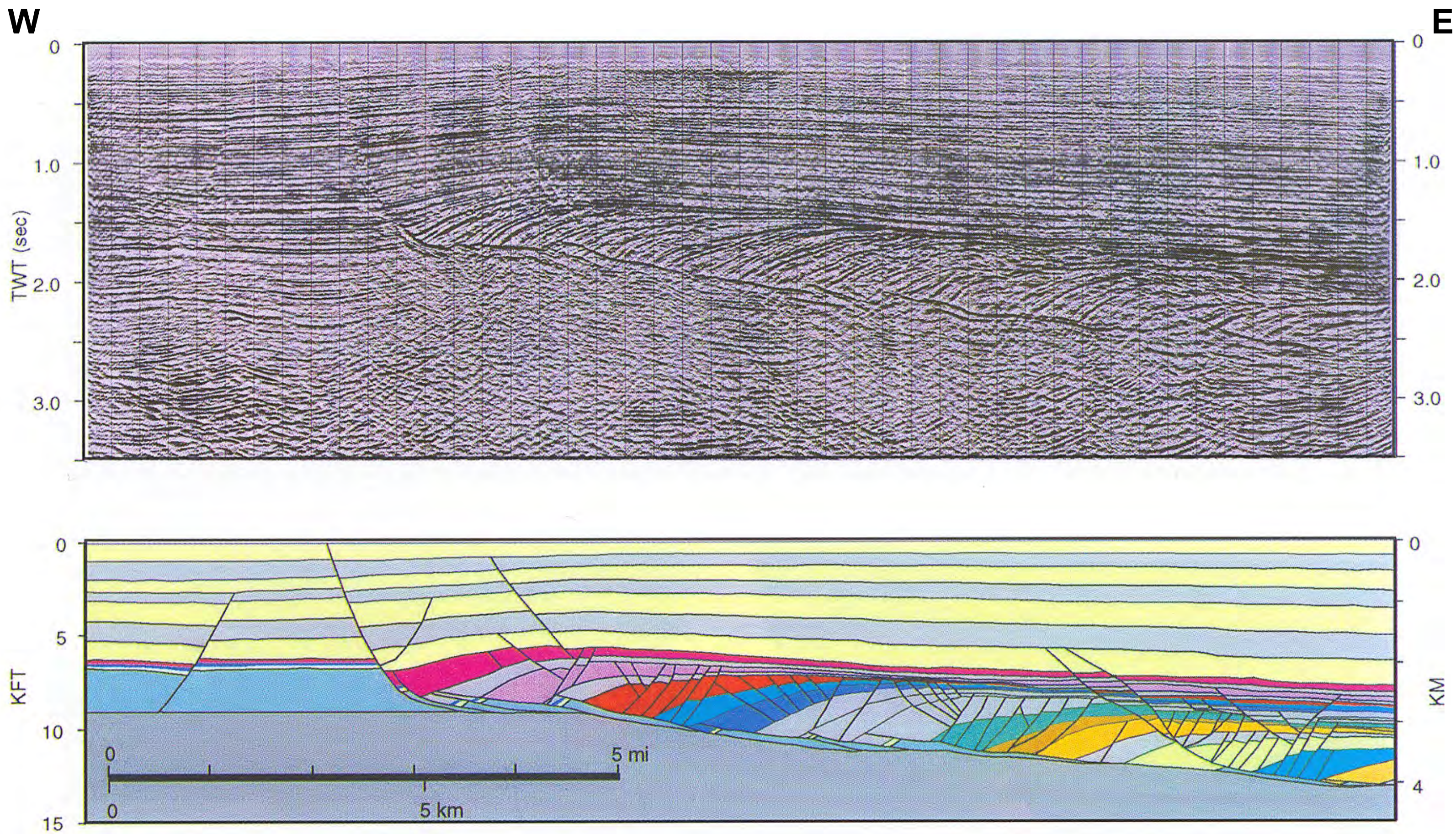


Shelf-Slope Transect



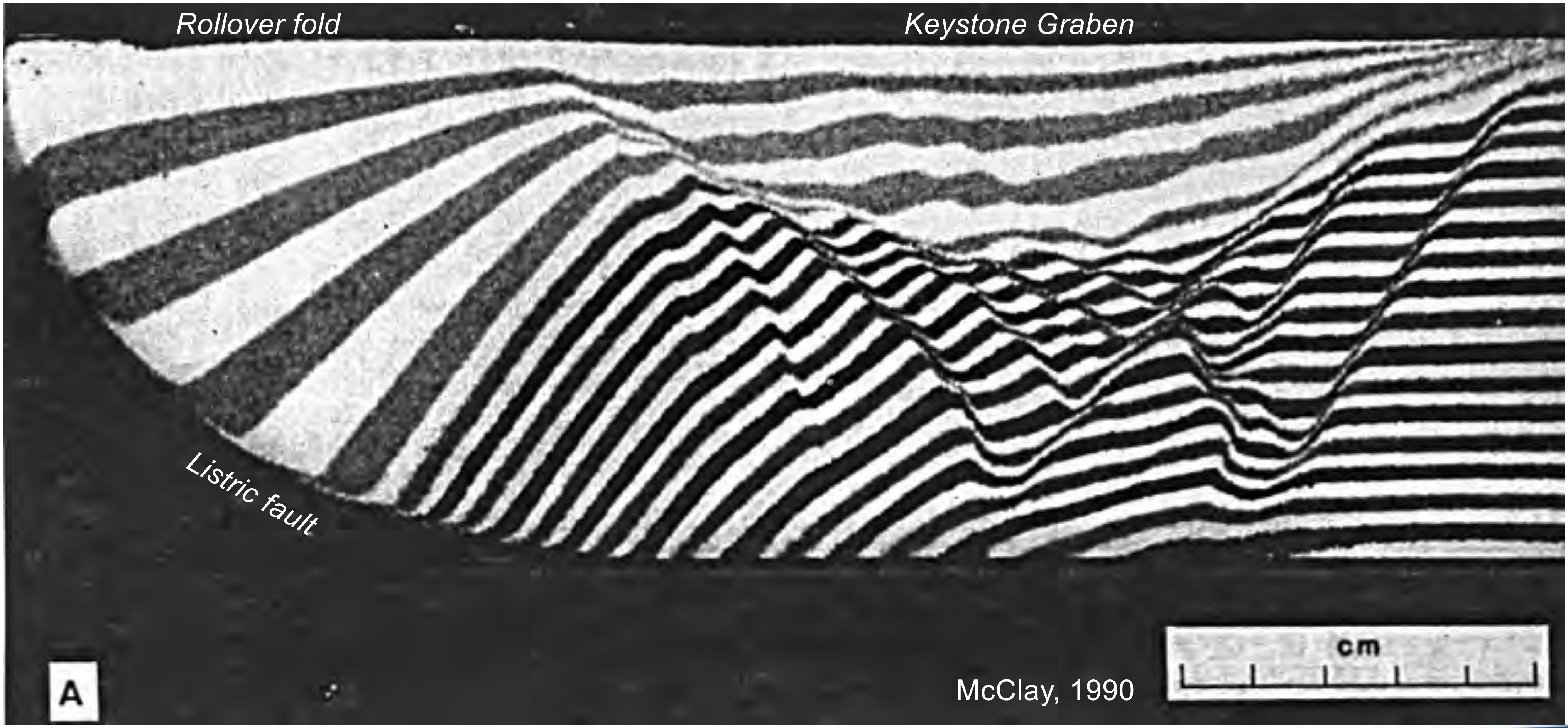
Sanford et al., 2016

Shelf Extension – Oligocene-Miocene Vicksburg Detachment, South Texas

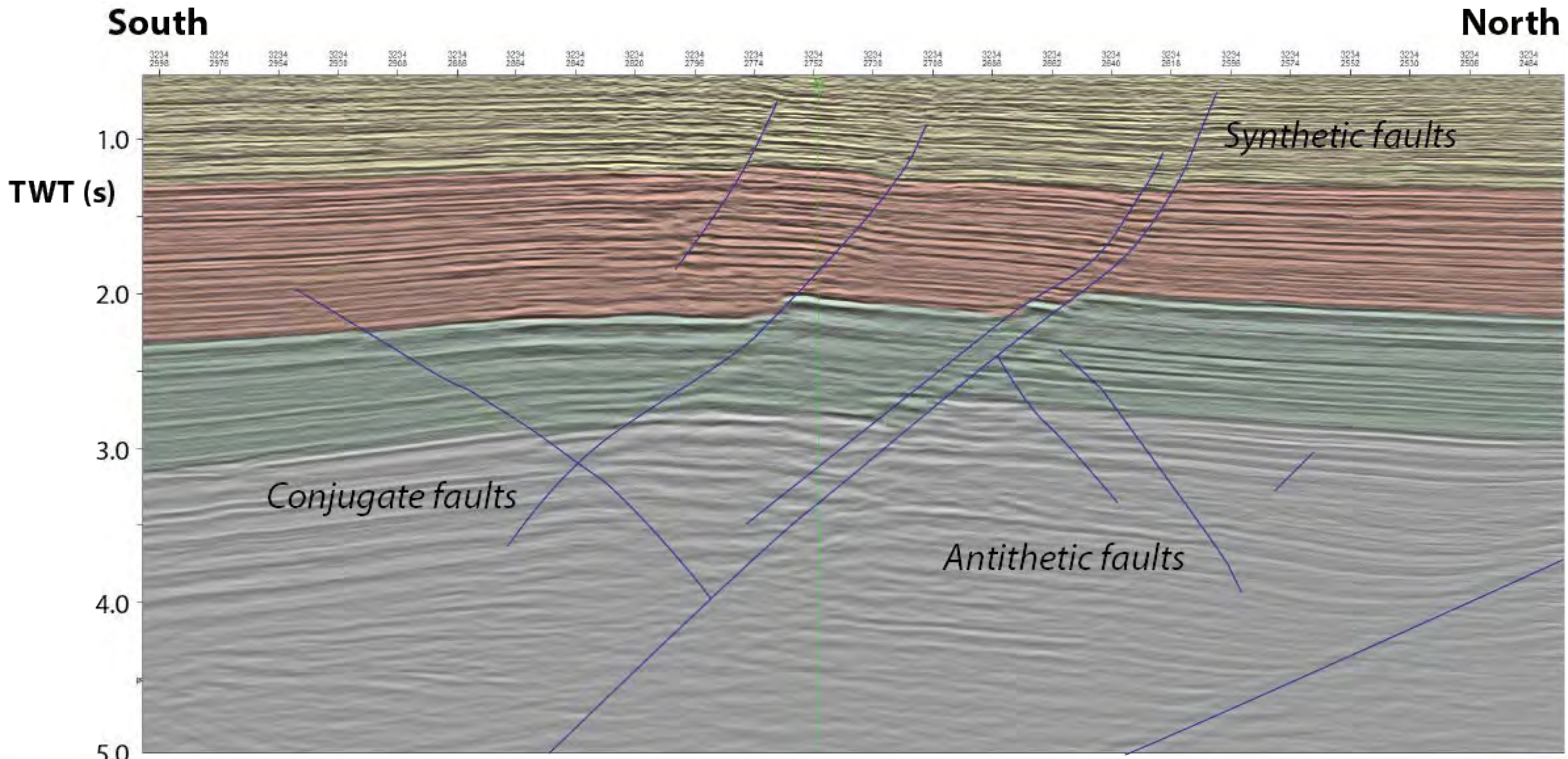


Diegel et al., 1995

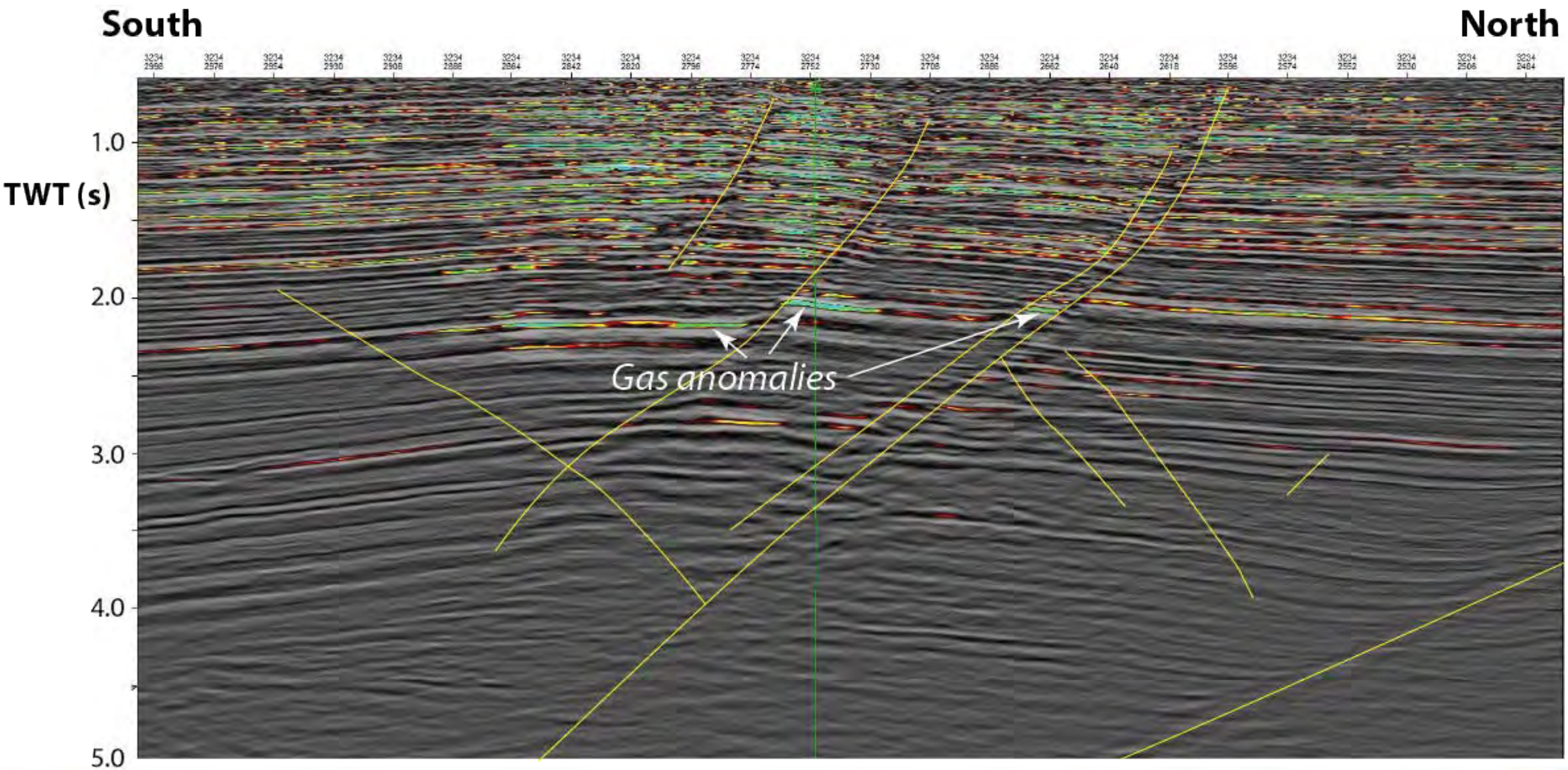
Sand-Box Model – Listric Fault, Rollover Fold, and Keystone Graben



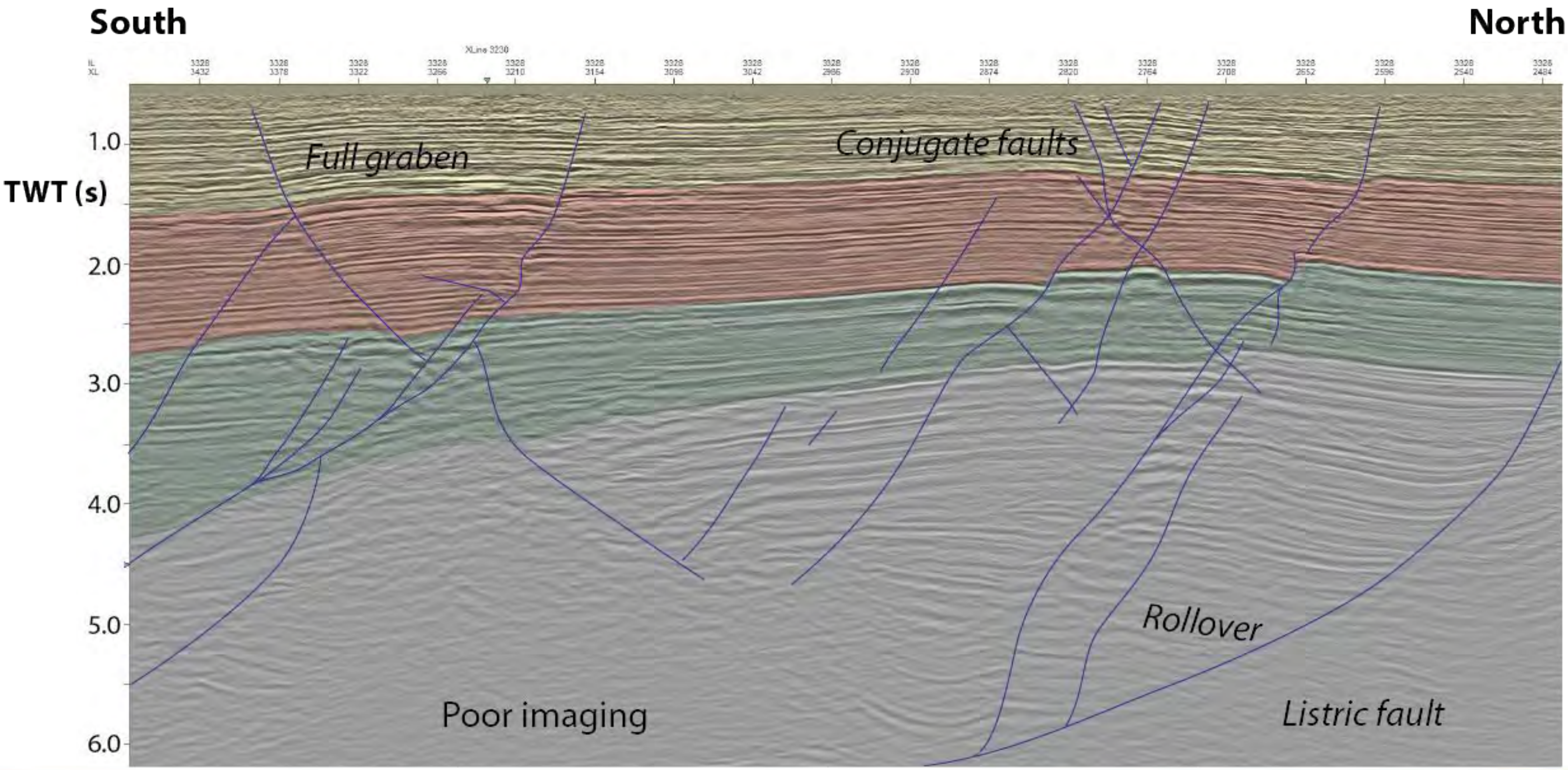
Seismic Interpretation: Louisiana Shelf Roho Province



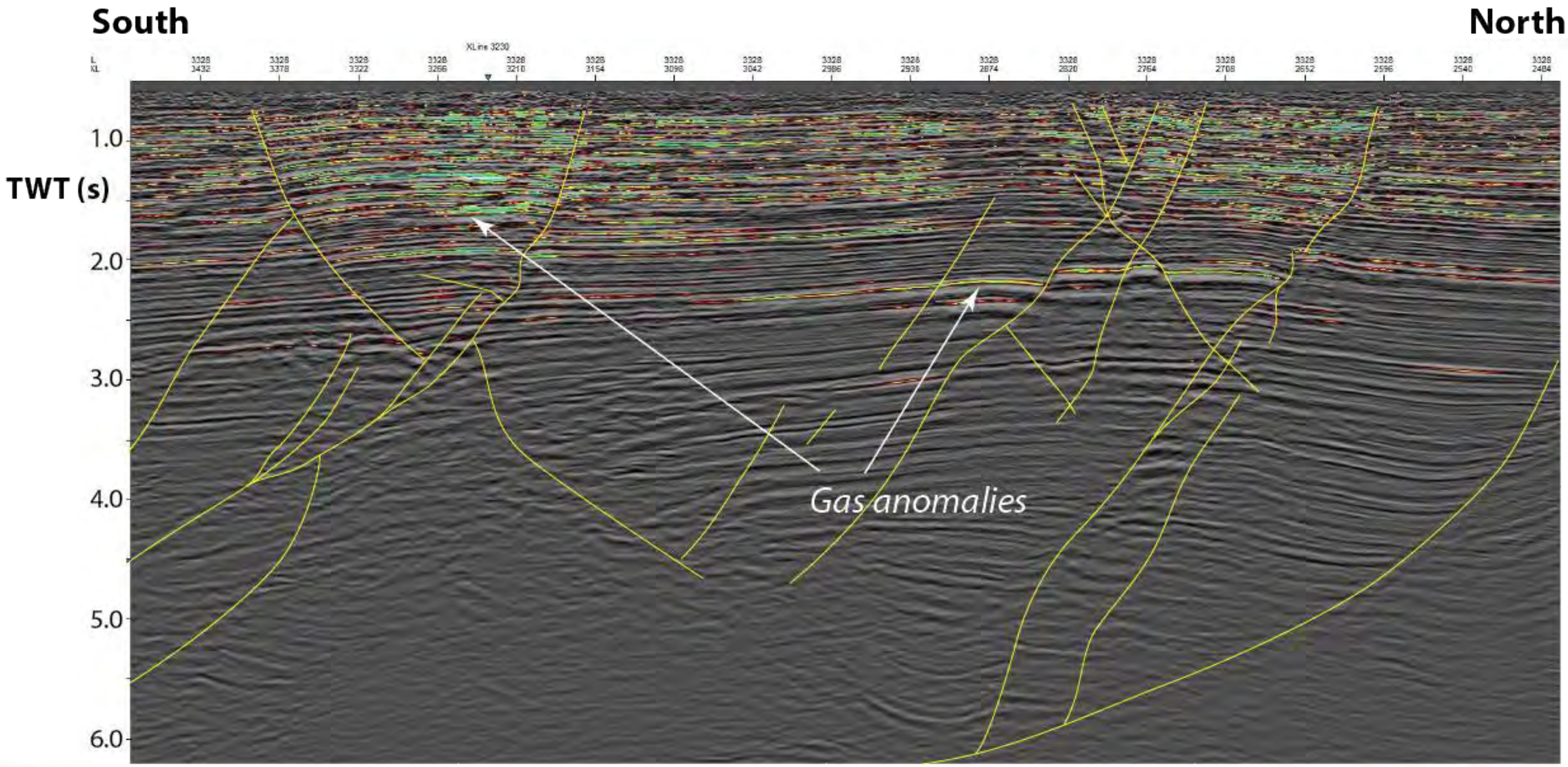
Seismic Interpretation: Louisiana Shelf



Seismic Interpretation: Louisiana Shelf

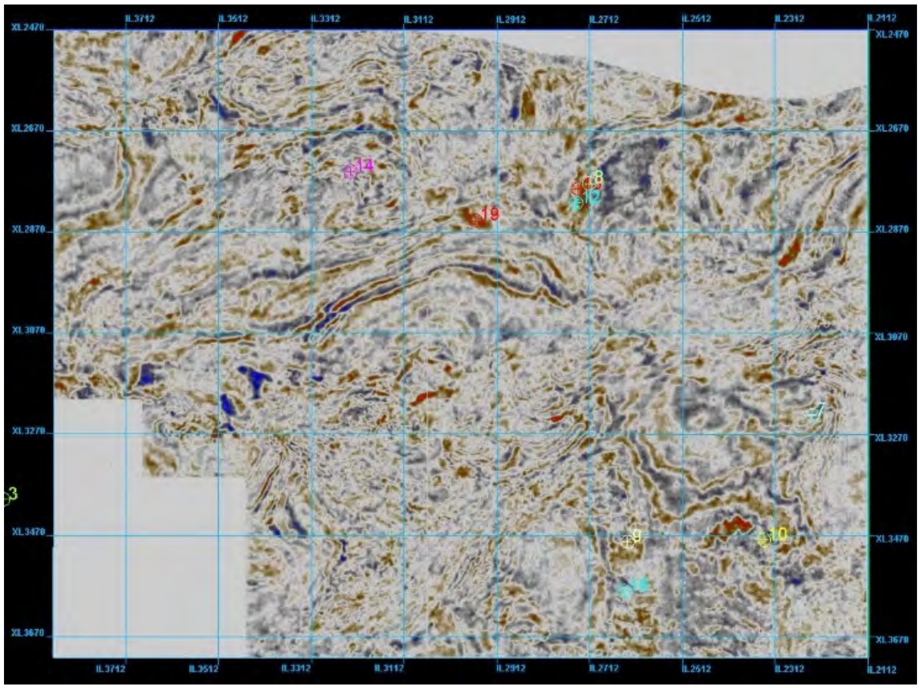


Seismic Interpretation: Louisiana Shelf



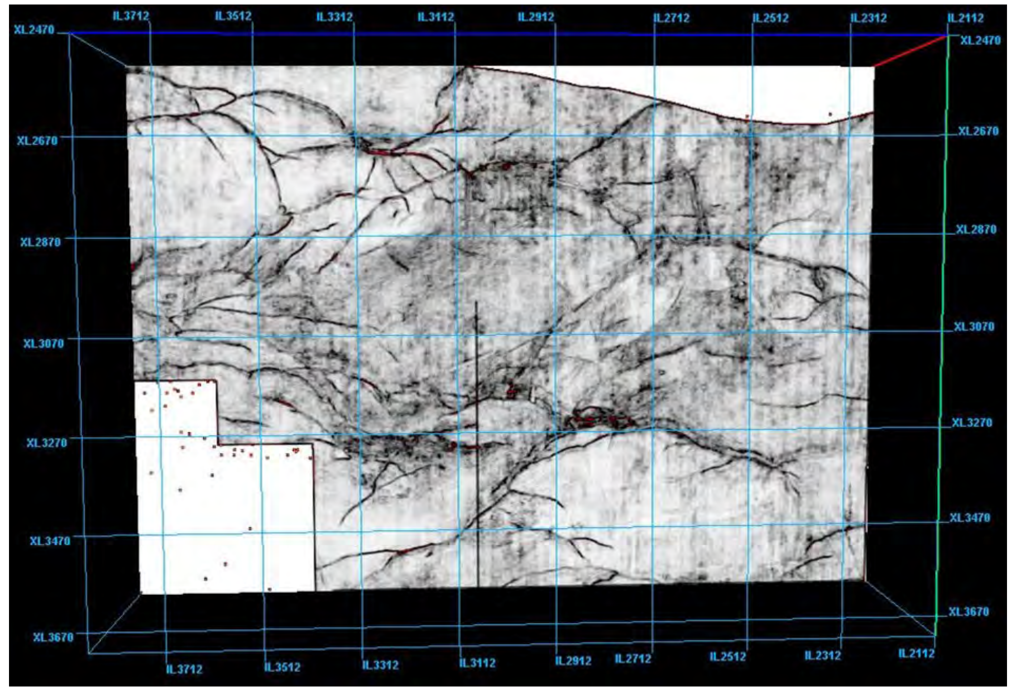
Seismic mapping

Amplitude, 3.0 s



Folds revealed

Coherency, 2.5 s

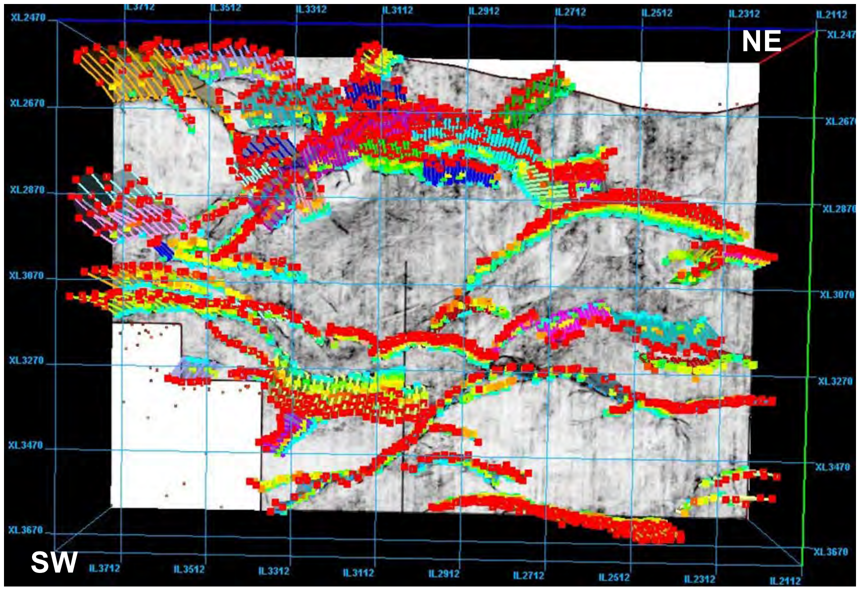


Faults revealed

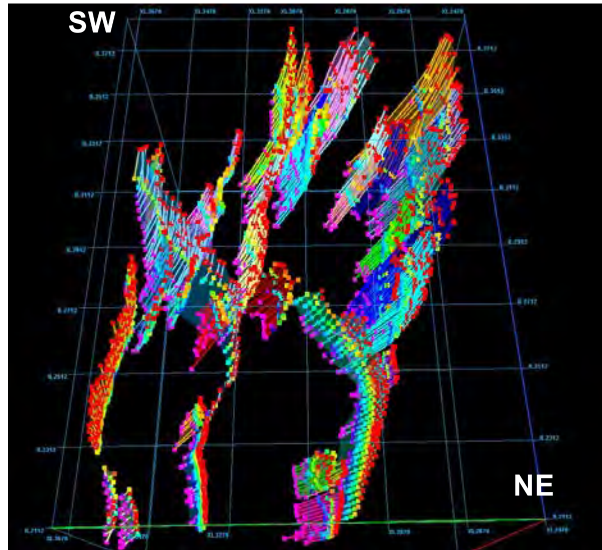
SEG
SOCIETY OF EXPLORATION GEOPHYSICISTS

Fault Modeling

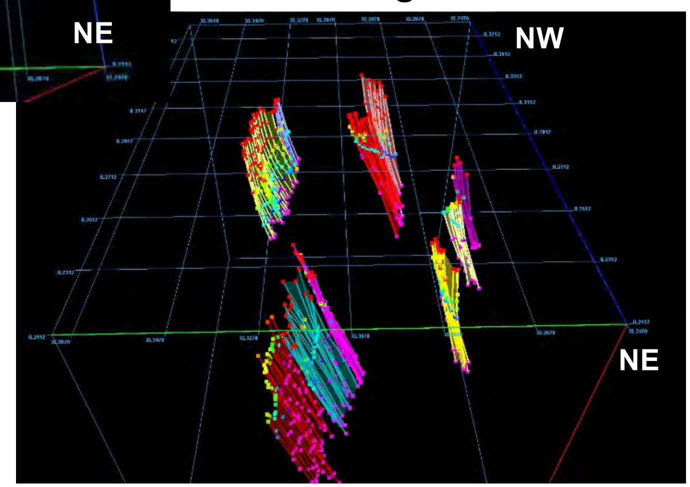
Mappable faults



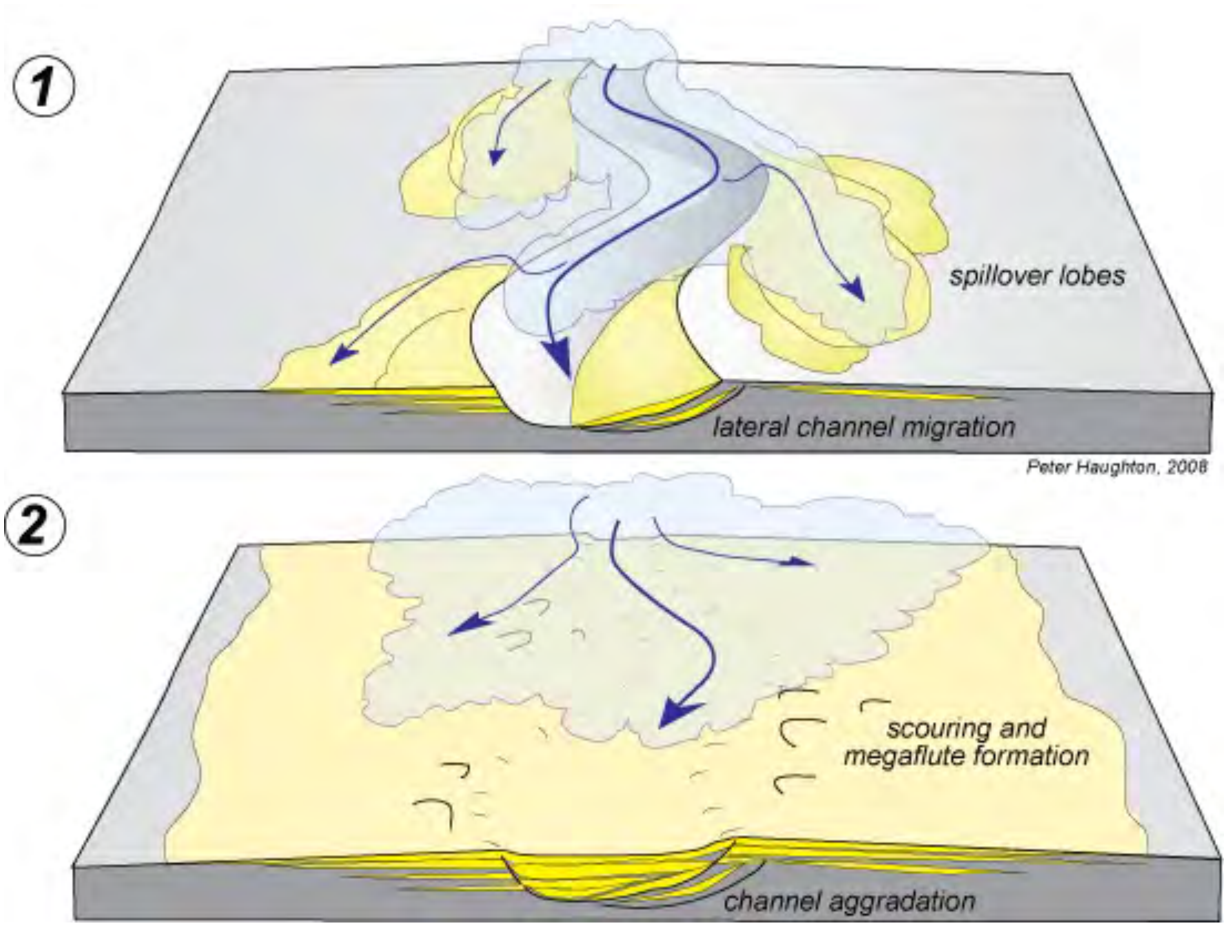
Regional faults



Counterregional faults



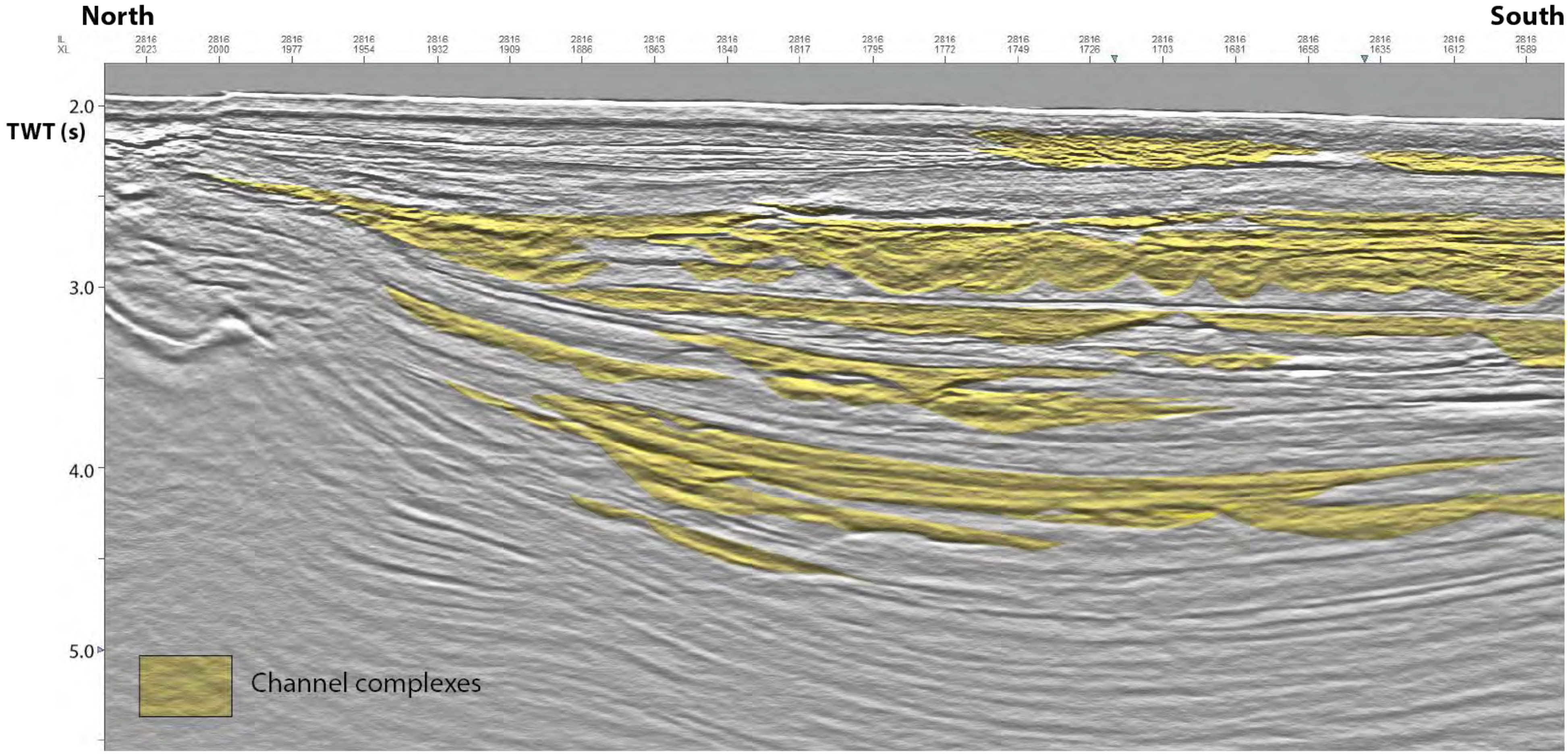
Turbidite Systems



Keathley Canyon bathymetry

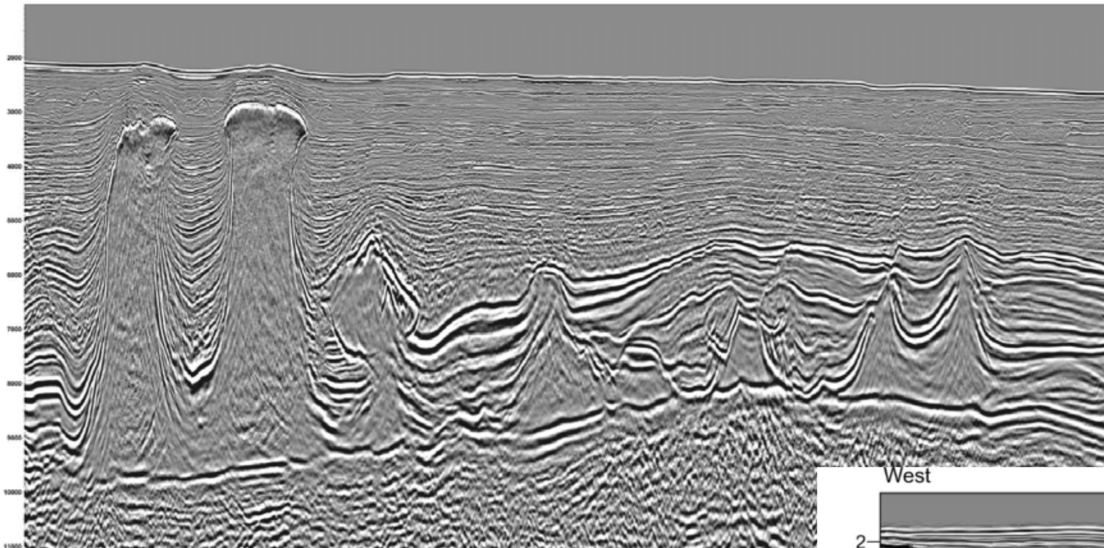
Source: BOEM

Seismic Interpretation: Submarine Channel Complexes, Mensa Region

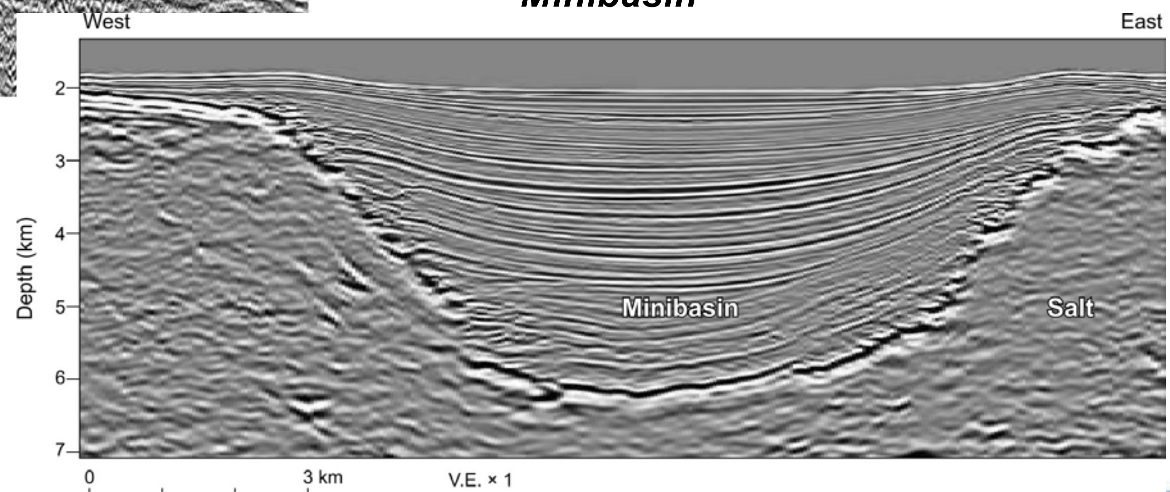


Deep-Water Salt Tectonics

Allochthonous salt sheet with diapirs



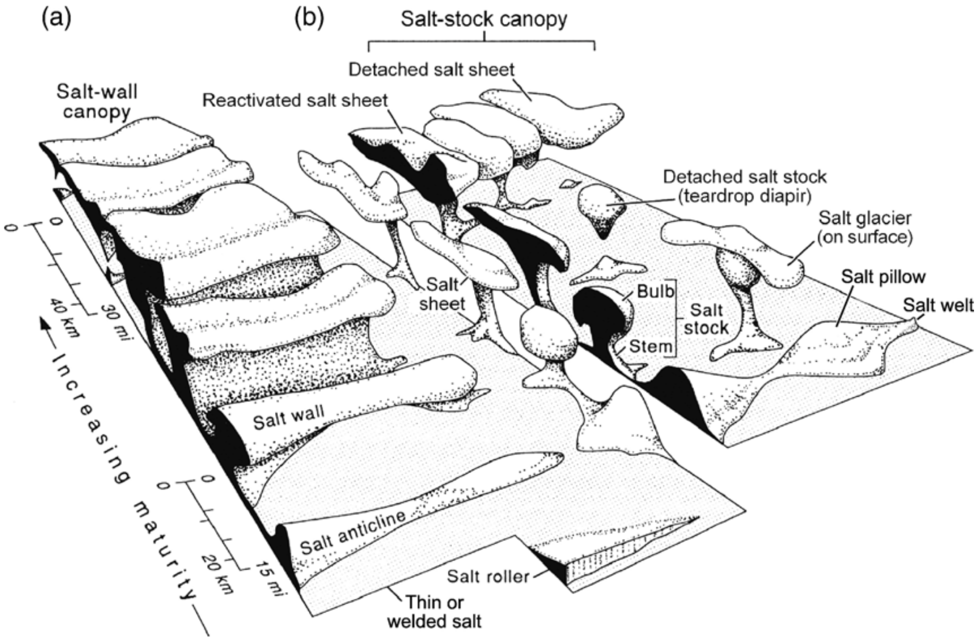
Minibasin



Hudec et al., 2009

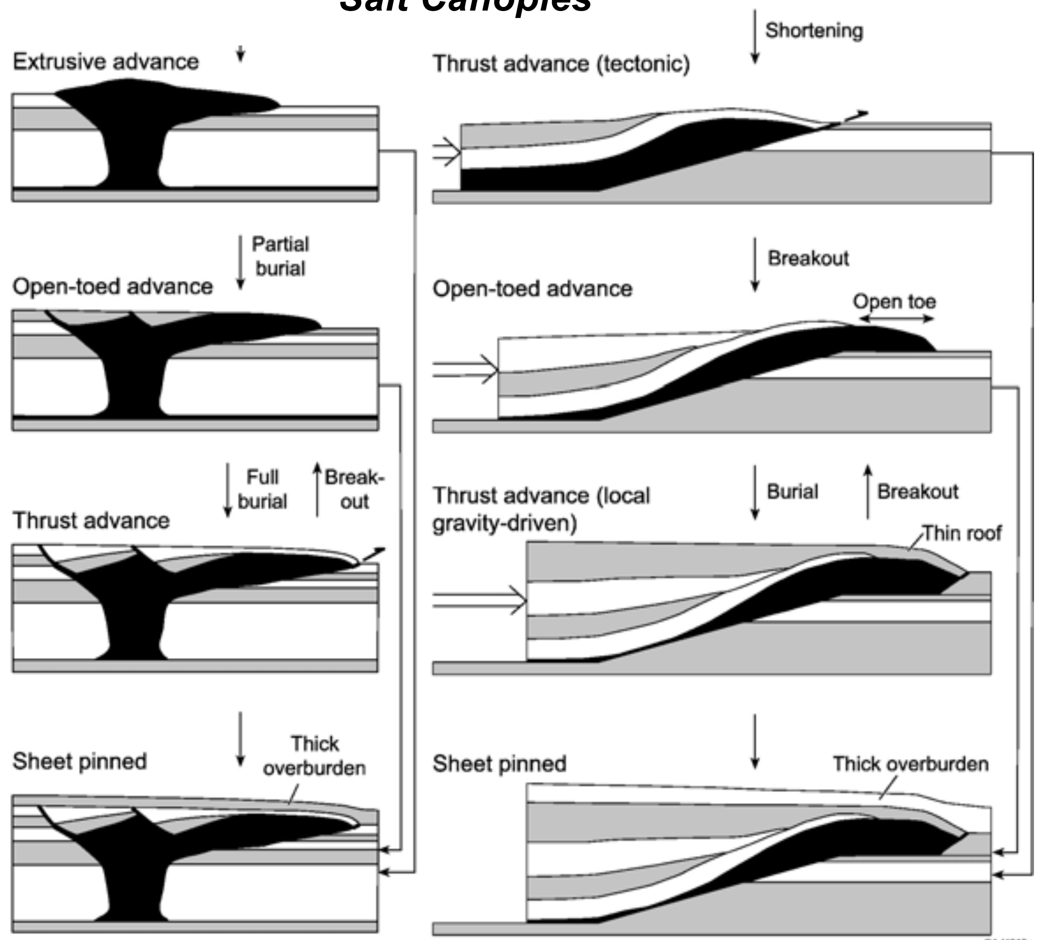
Salt Tectonics

Salt body geometry

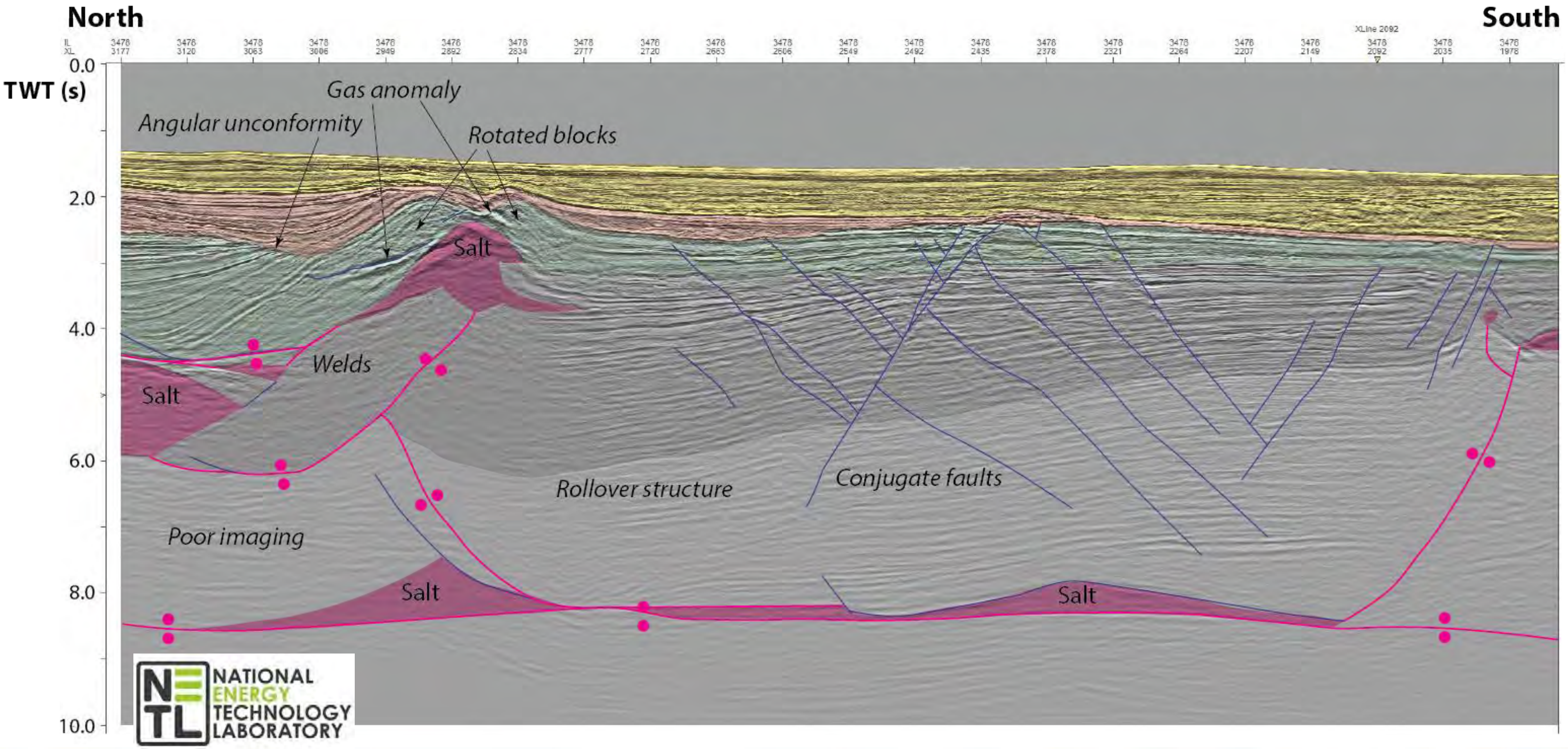


Hudec and Jackson (2007)

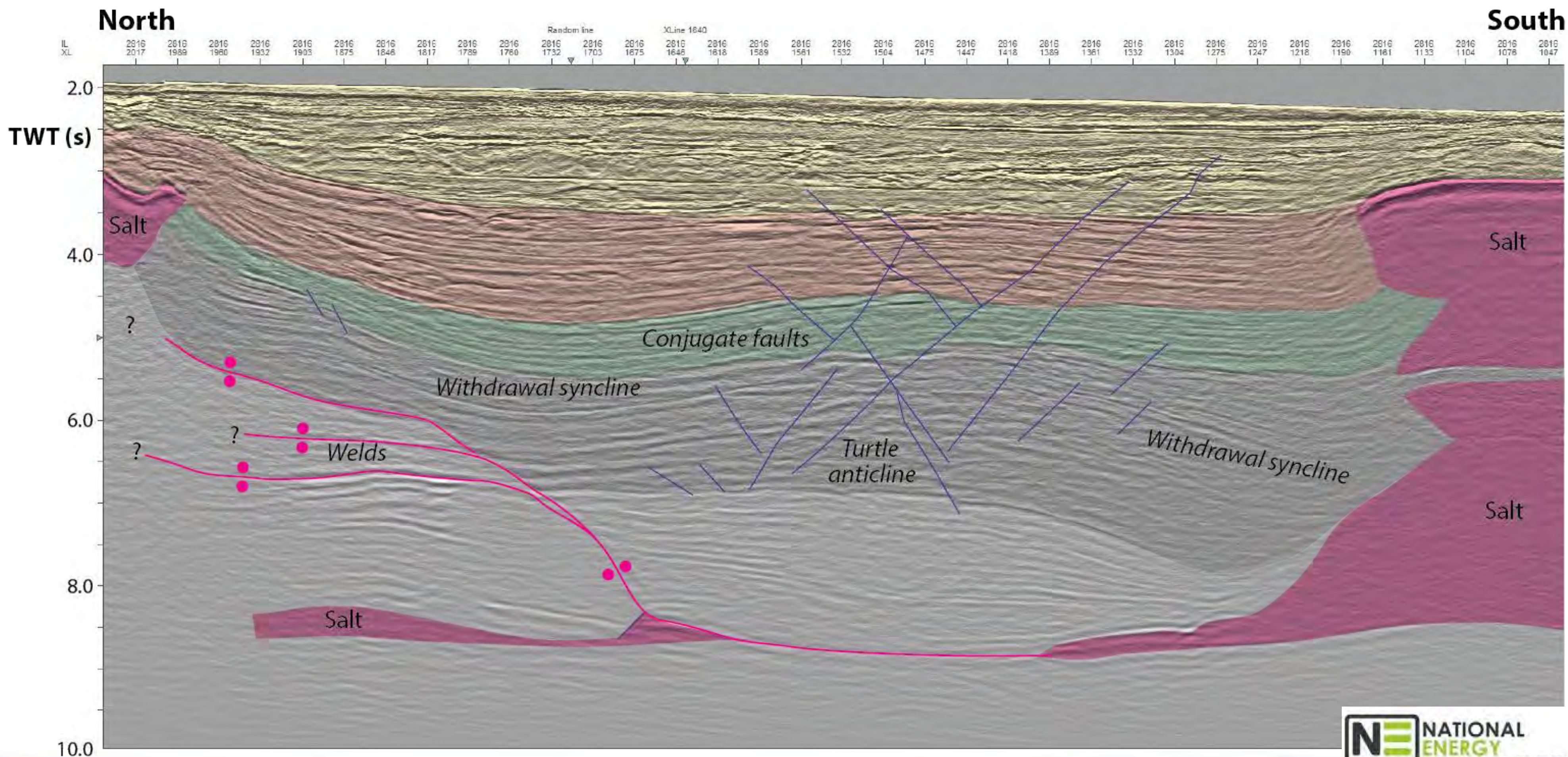
Salt Canopies



Seismic Interpretation: Rollover-Salt Withdrawal structure



Seismic Interpretation: Mensa Turtle Structure



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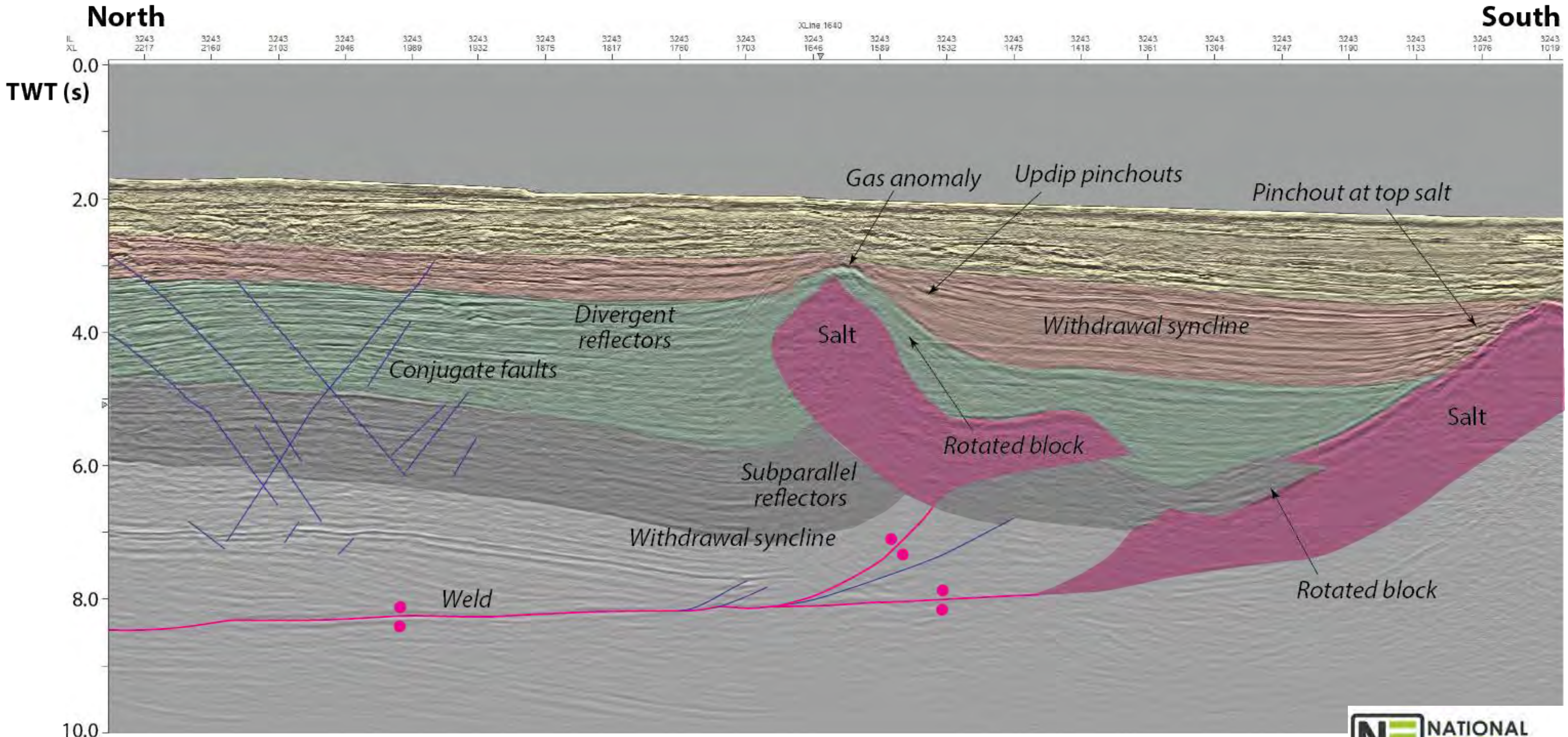
Seismic Interpretation: Devil's Tower Structure



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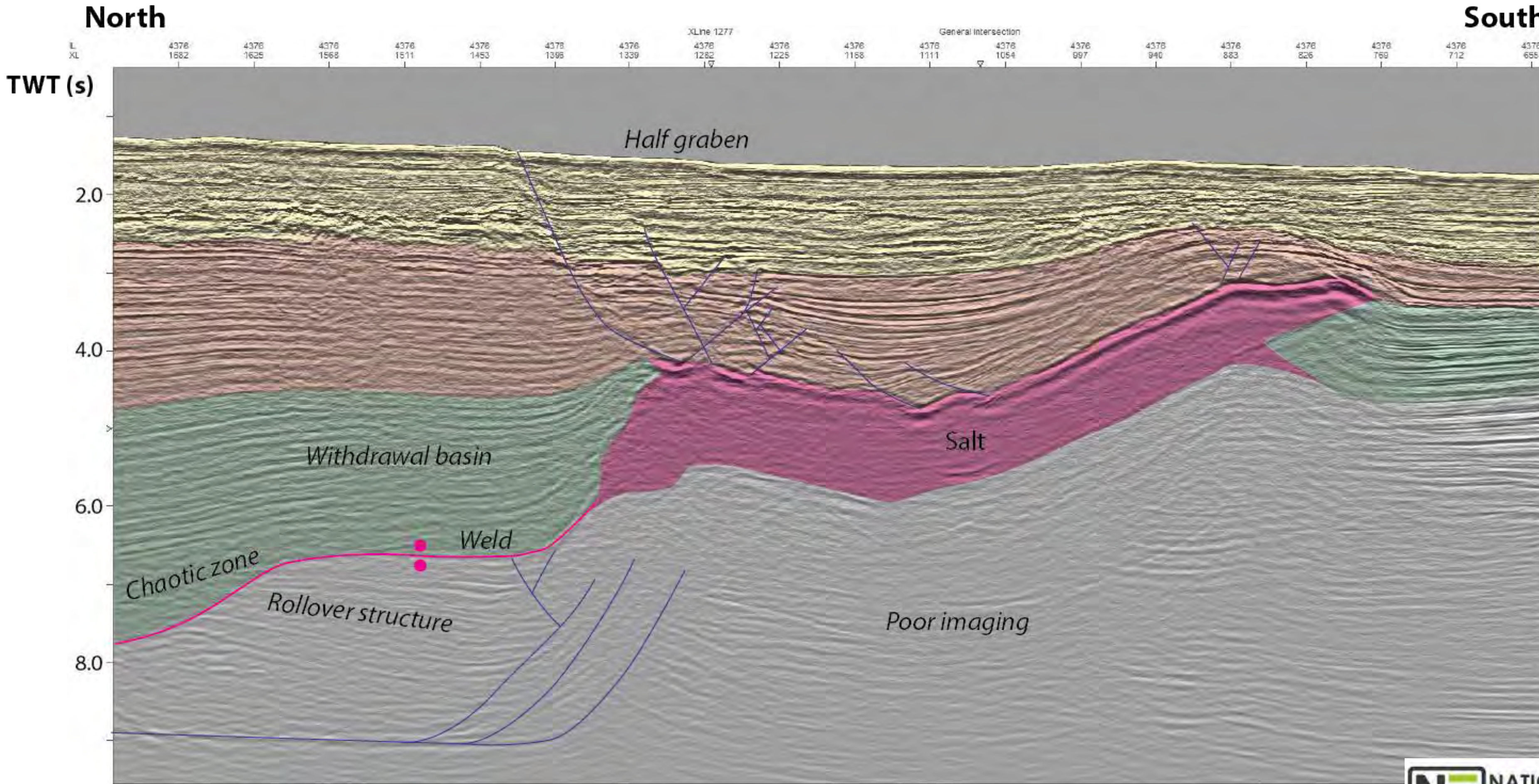
Seismic Interpretation: Ramp-Flat Weld, Allochthonous Salt



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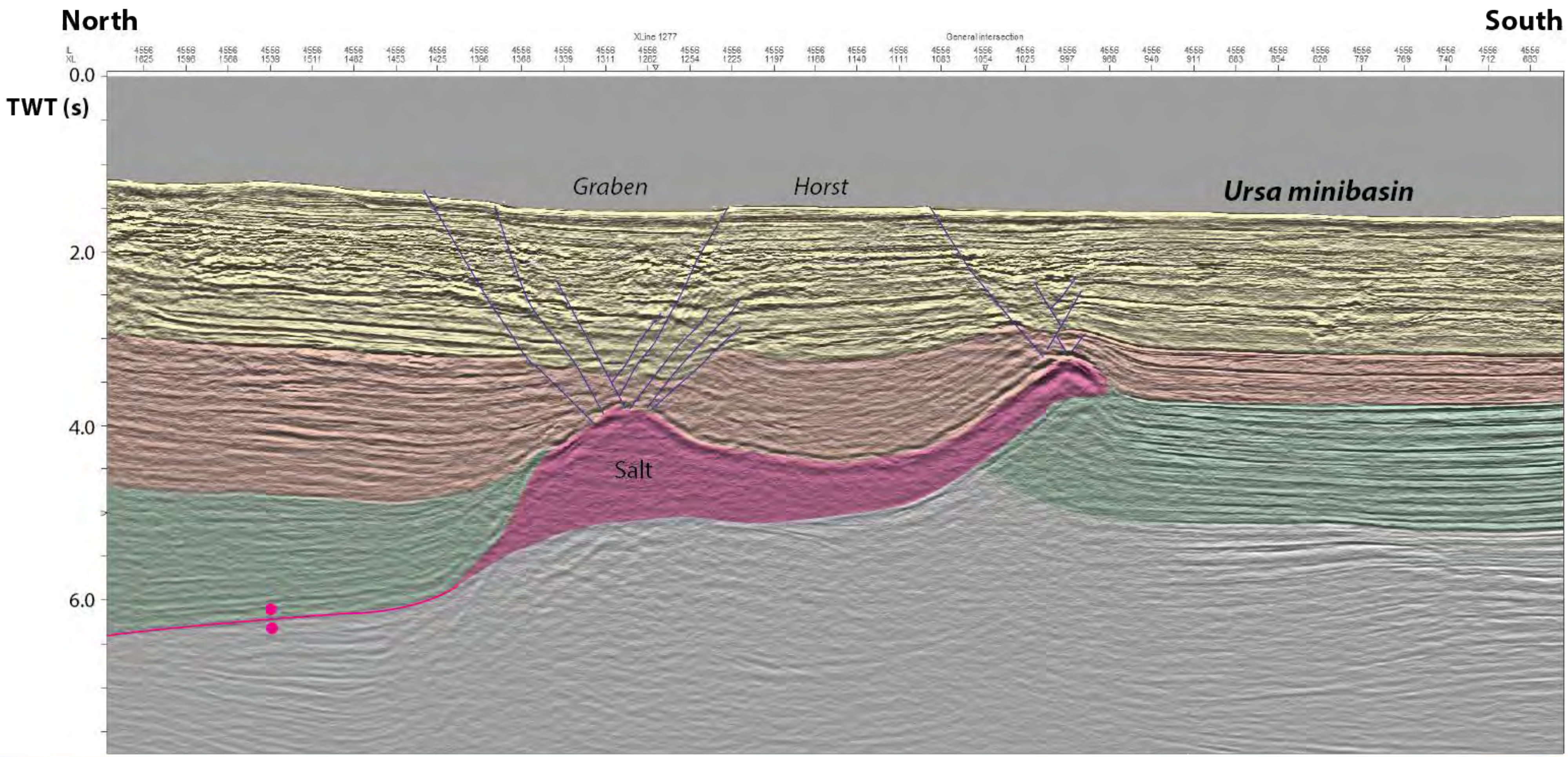
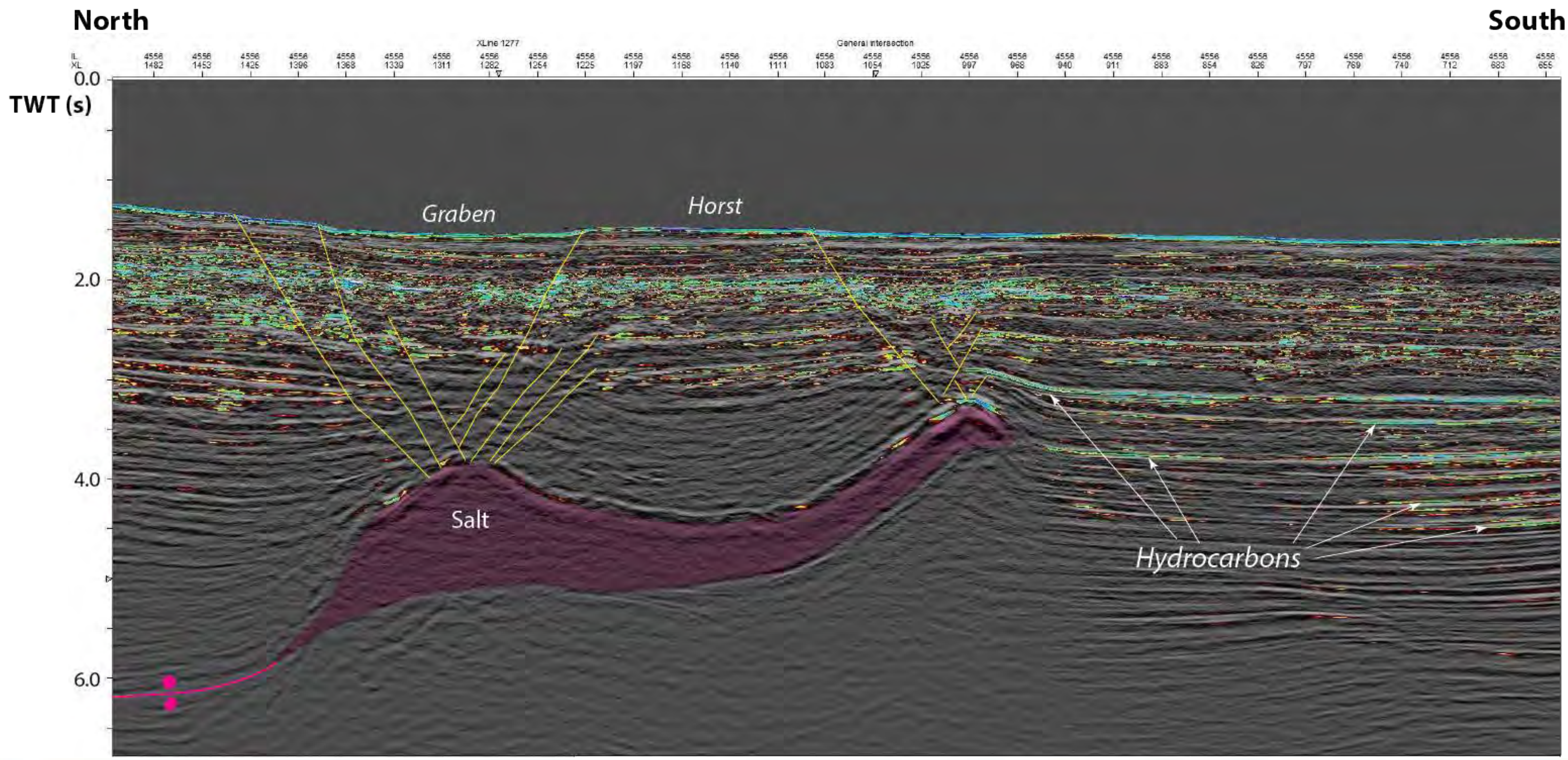
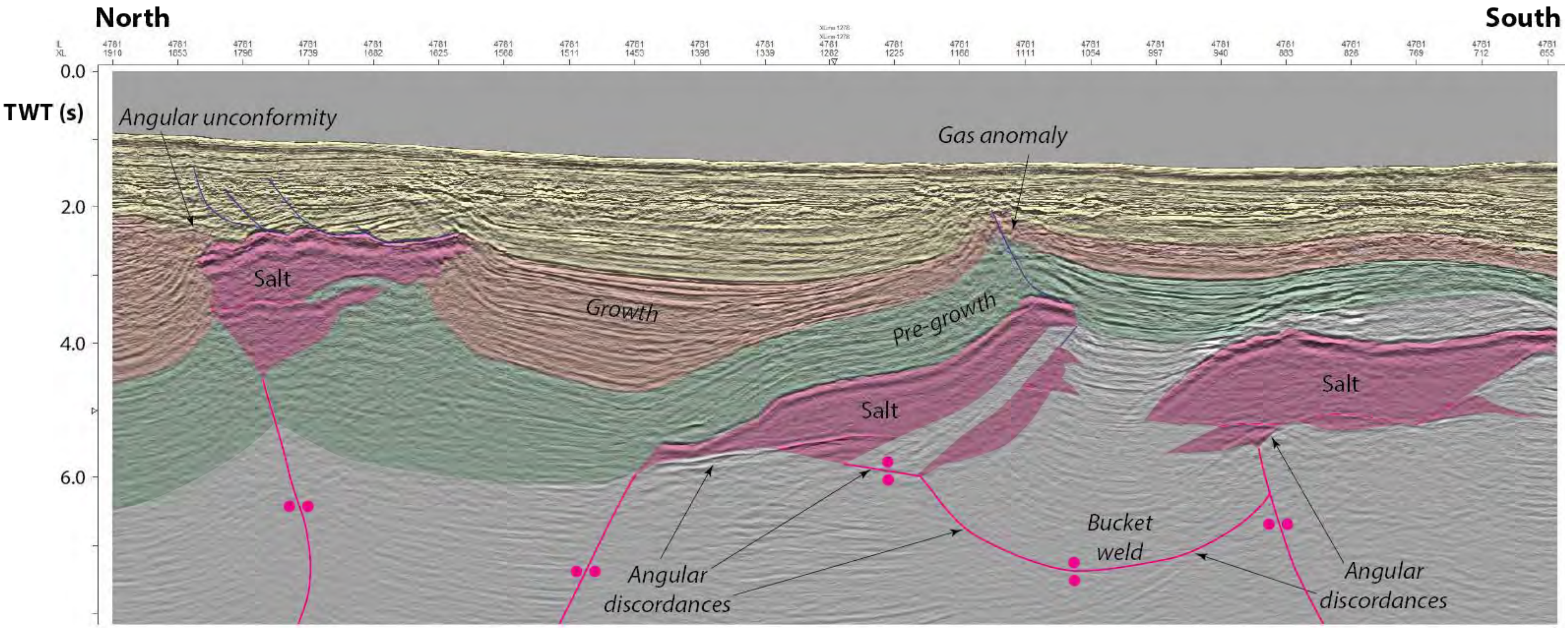
Seismic Interpretation : Ursa Structure



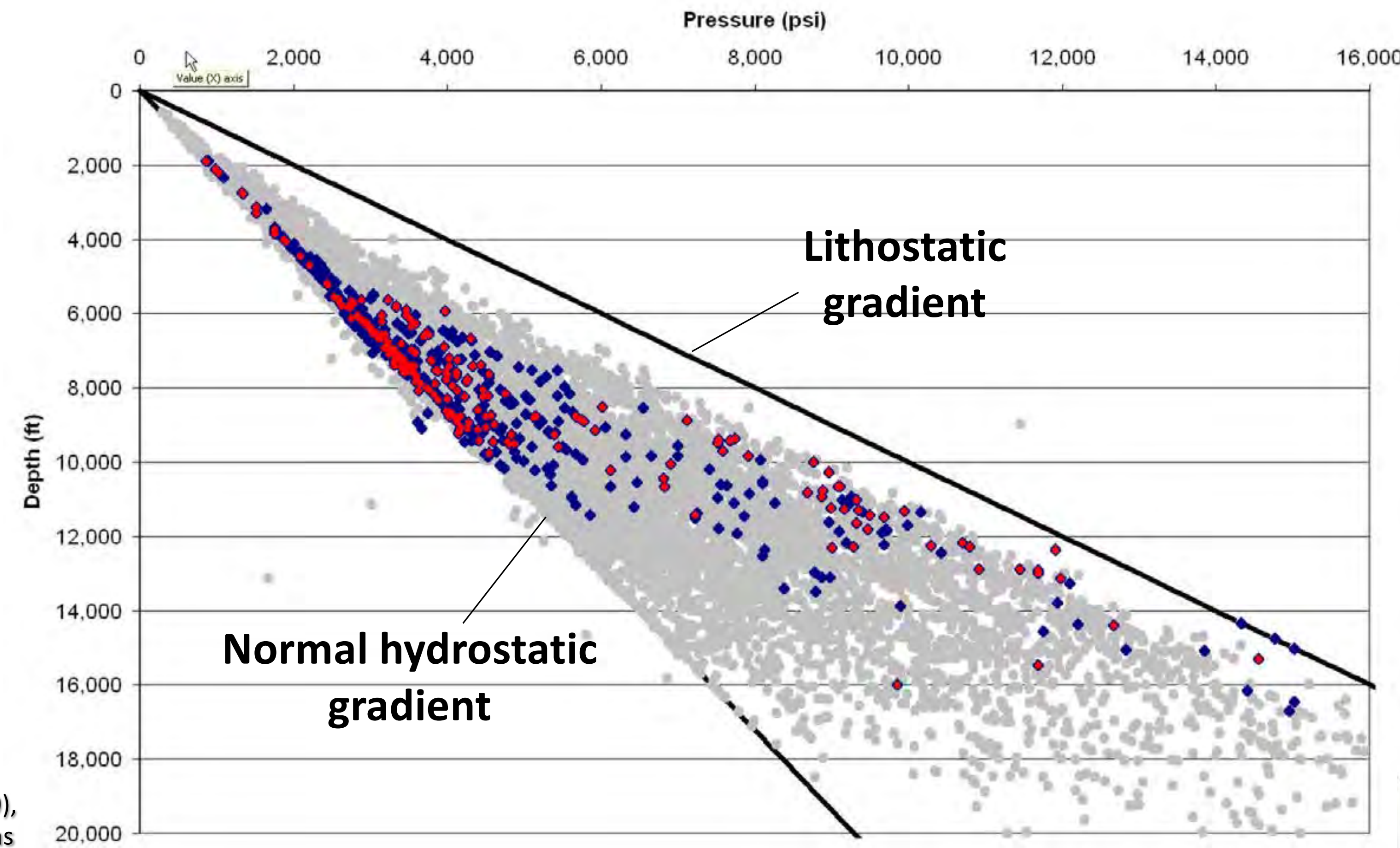
Seismic Interpretation: Ursa Structure



Seismic Interpretation: Mars Minibasin Complex



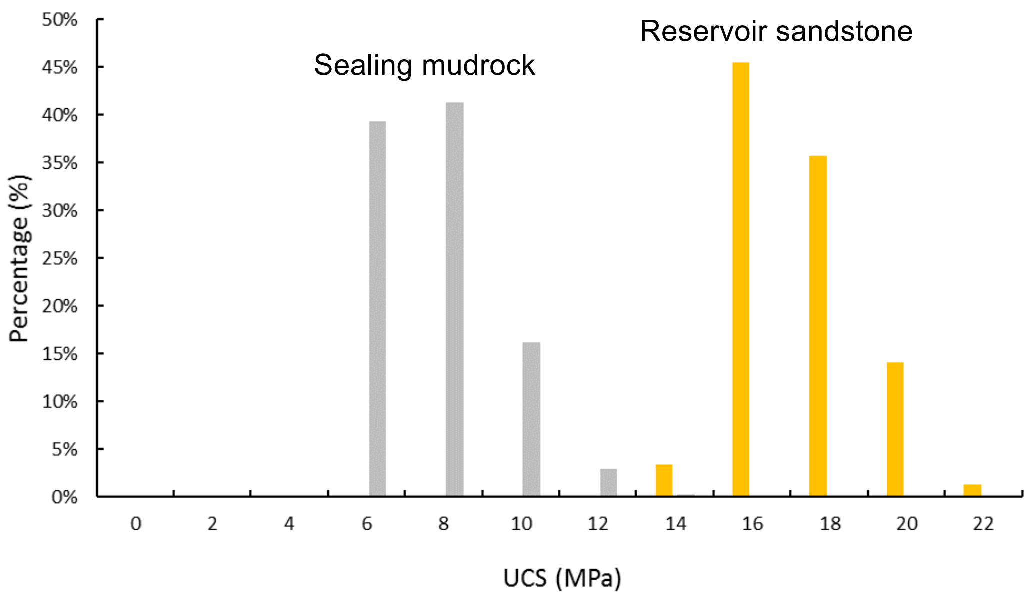
Reservoir Presssure Envelope



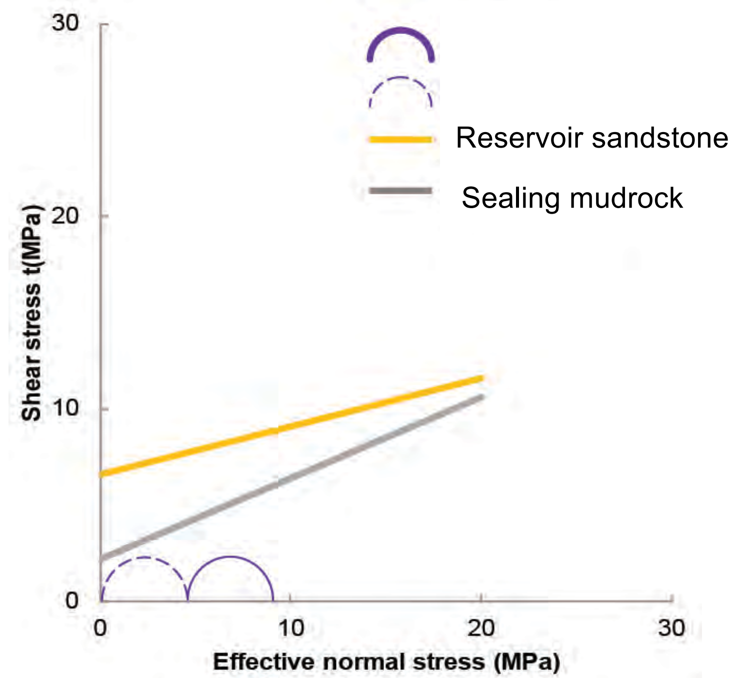
Meckel (2010), Offshore Texas Miocene

Rock Strength (Cenozoic Strata)

Unconfined compressive stress



Mohr failure analysis

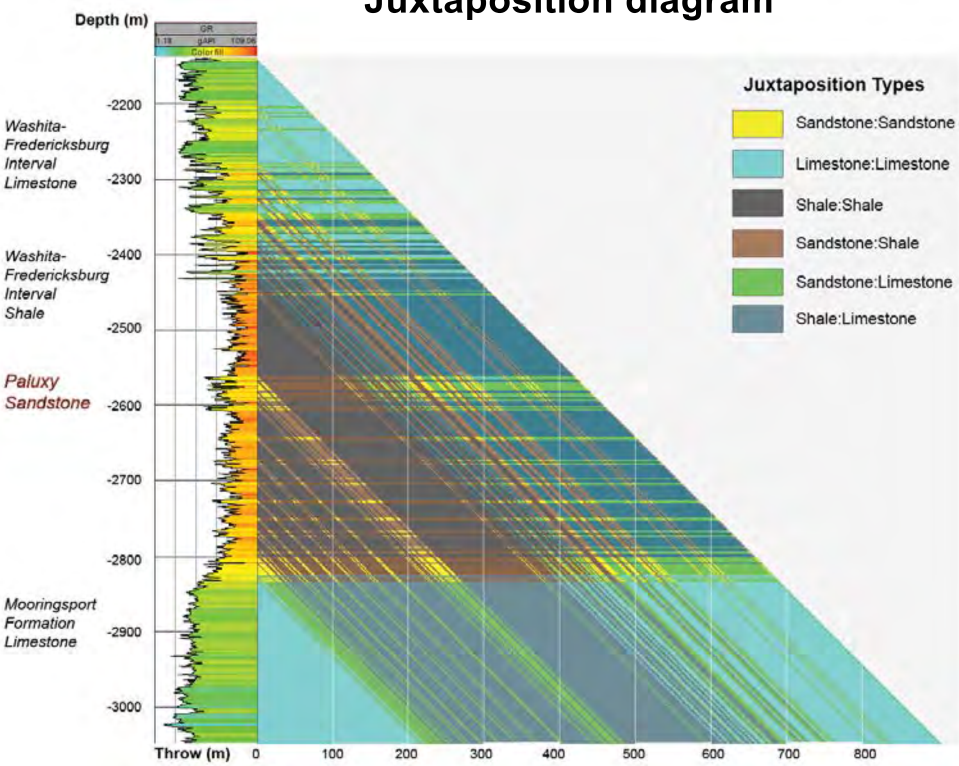


Meng et al., in press

NATIONAL ENERGY TECHNOLOGY LABORATORY

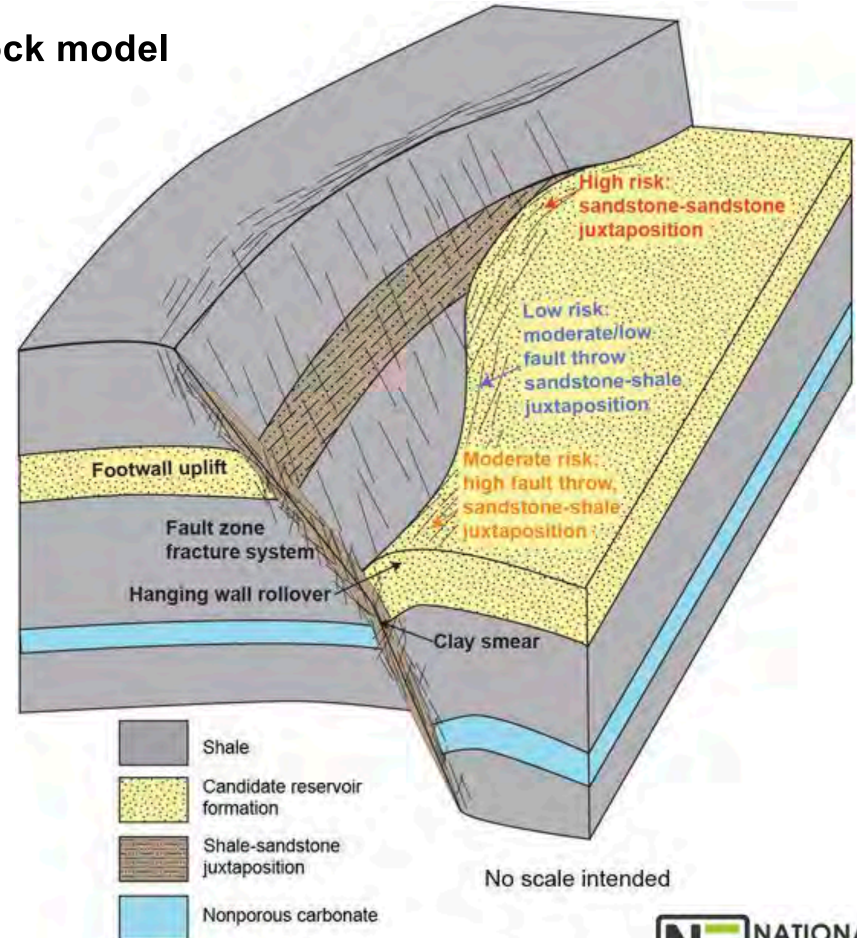
Fault Seal Analysis

Juxtaposition diagram



Meng et al., 2020

Block model



Heuristic Decision Support System Design

- **Geologic Information**
  - Reservoir location, dimensions
  - Rock type
  - Depth
  - Reservoir thickness
  - Structural and depositional geometry
  - Trap type
- **Reservoir properties**
  - Porosity
  - Permeability
  - Fluid composition and properties
  - Pressure
  - Storage resource
- **EOR/EGR information**
  - API gravity
  - Gas-oil ratio
  - Resource/reserve volumes
  - Production volumes
  - Production history
  - Drive type
  - Production systems

- **Considerations**
  - Quantified factors
  - Ranked factors
  - Infrastructure
  - Fluid transport options
- **What are your objectives?**
  - Saline formation storage
  - Depleted reservoir storage
  - Enhanced oil recovery
  - Pressure maintenance

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Observations

- Shelf has multiple storage/enhanced recovery options; slope focus on EOR
- Shelf potential principally in fluvial-deltaic, shelf sand, slope potential in turbidites.
- Faulting central consideration on shelf; bright spots show sealing potential.
- Slope presents broad range of subsalt, salt flank, and suprasalt options.
- Pressure envelope can be limiting; pressure depetion increases options in shelf.
- Mudrock weaker than sand, although sand consolidation variable.
- Fault seal analysis critical in many settings; structural position important.
- Data well suited for heuristic decision support system; many variables required for proper decision support; operation is context sensitive.

SECARB Offshore Gulf of Mexico Project: Well Integrity Analysis

SECARB Offshore GoM & GoMCarb Annual Joint Partnership Meeting
March 26 – 27, 2020

William Garnes, Laura Keister, Andrew Duguid
Battelle. Energy Division

Presentation Outline

Project Overview

- Study Area
- Initial Focus Areas

Methodology Development

- Required Data
- Data Collection
- Data Management

Next Steps

- Filling Data Holes
- Risk Assessment

Project Overview

Gulf Study Area

FEDERAL WATERS		
	Depleted Oil & Gas Fields, and Potentially Associated CO_2-EOR	**Deep Saline**
Western Planning Area	No	No
Central Planning Area	Study Area is East of Houma District's Western Boundary (includes Houma District)	Study Area is East of New Orleans District's Western Boundary (excludes Houma District)
Eastern Planning Area	All	All

STATE WATERS		
	Depleted Oil & Gas Fields, and Potentially Associated CO_2-EOR	**Deep Saline**
Texas	No	No
Louisiana	Partial, Includes State Waters East of Houma District Boundary Extension	Partial, Excludes Chandeleur Sound/Islands
Mississippi	Yes	Yes
Alabama	Yes	Yes
Florida (West Coast)	Yes	Yes

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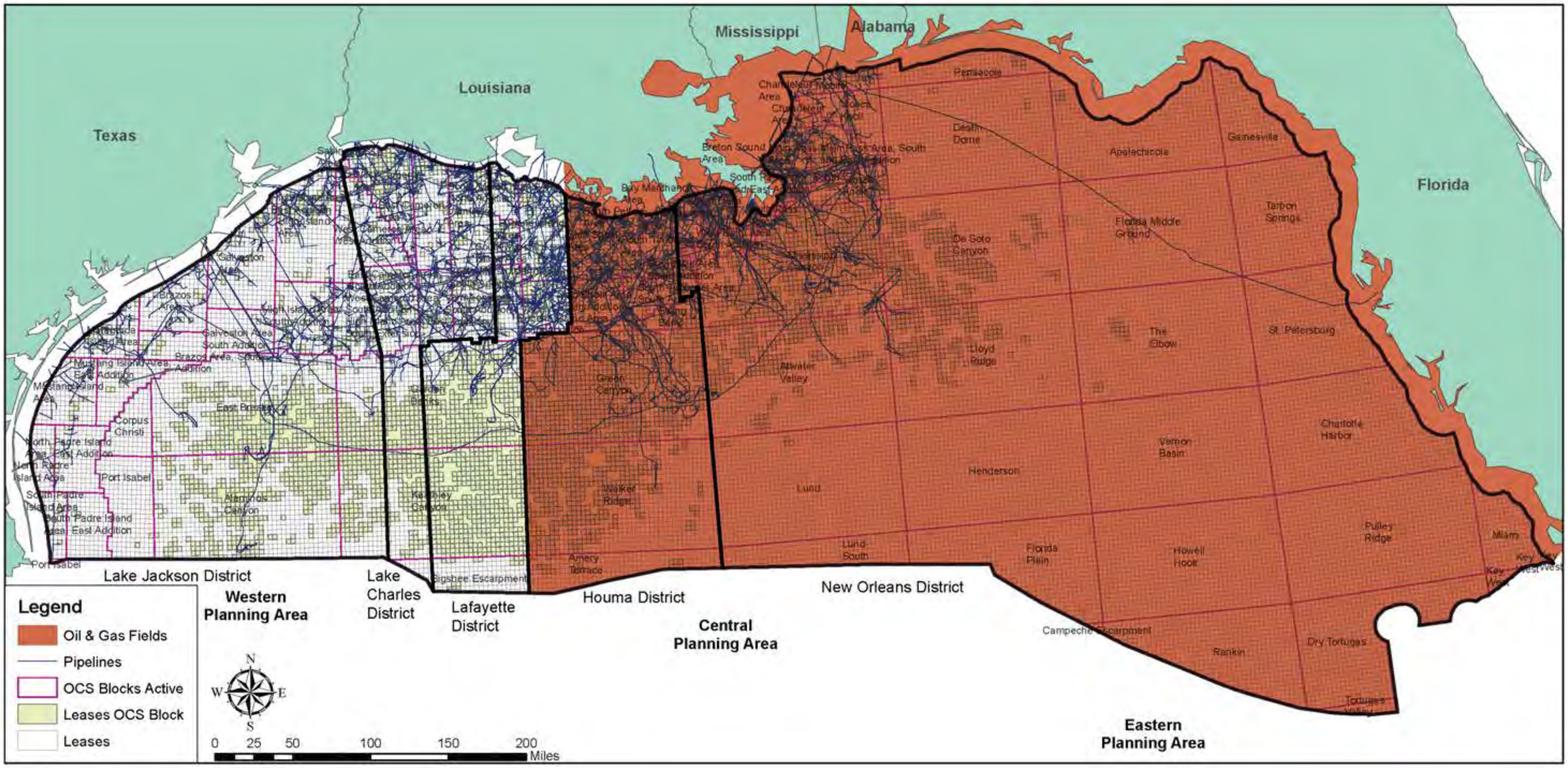
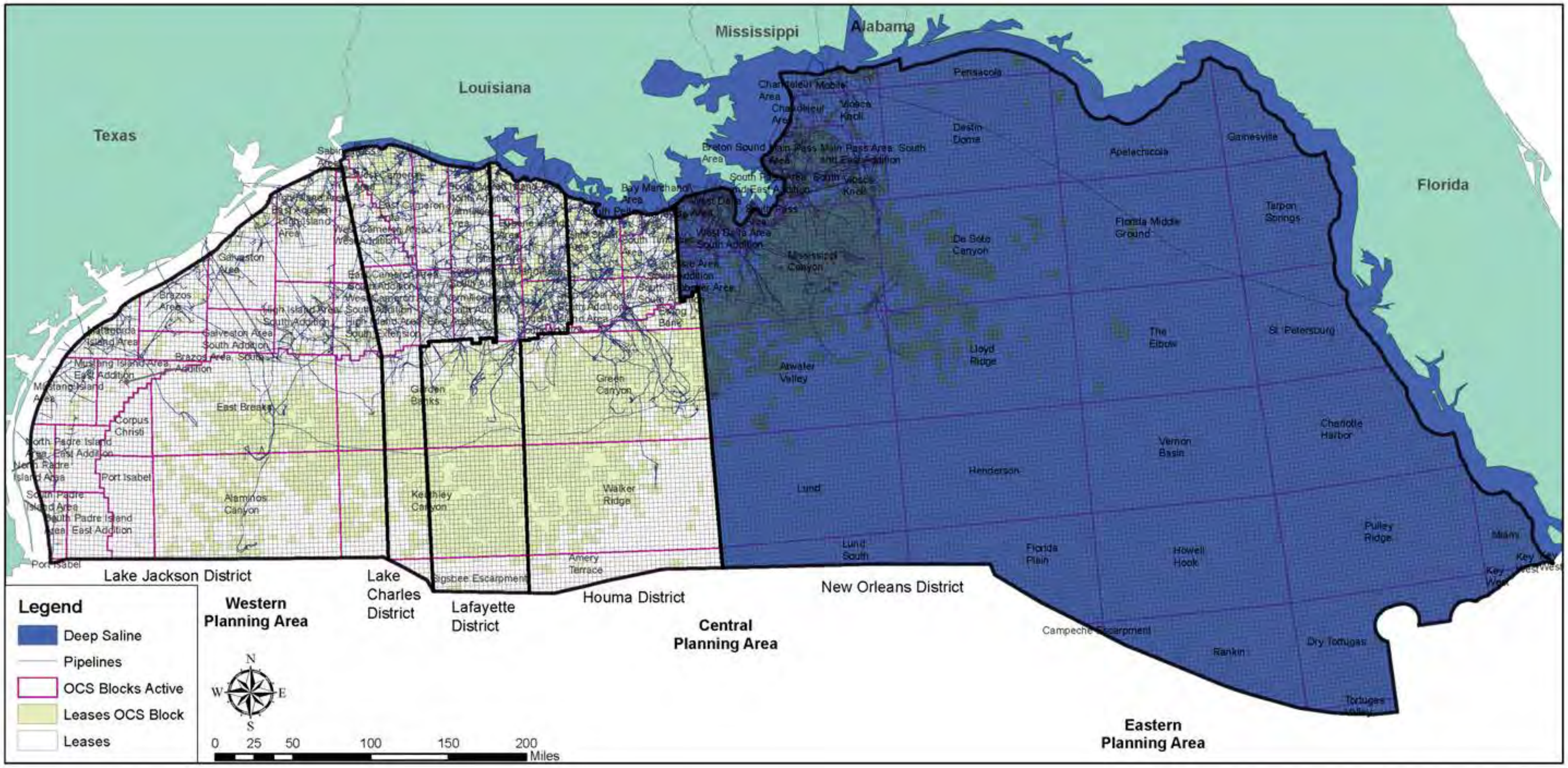
Oil and Gas Fields



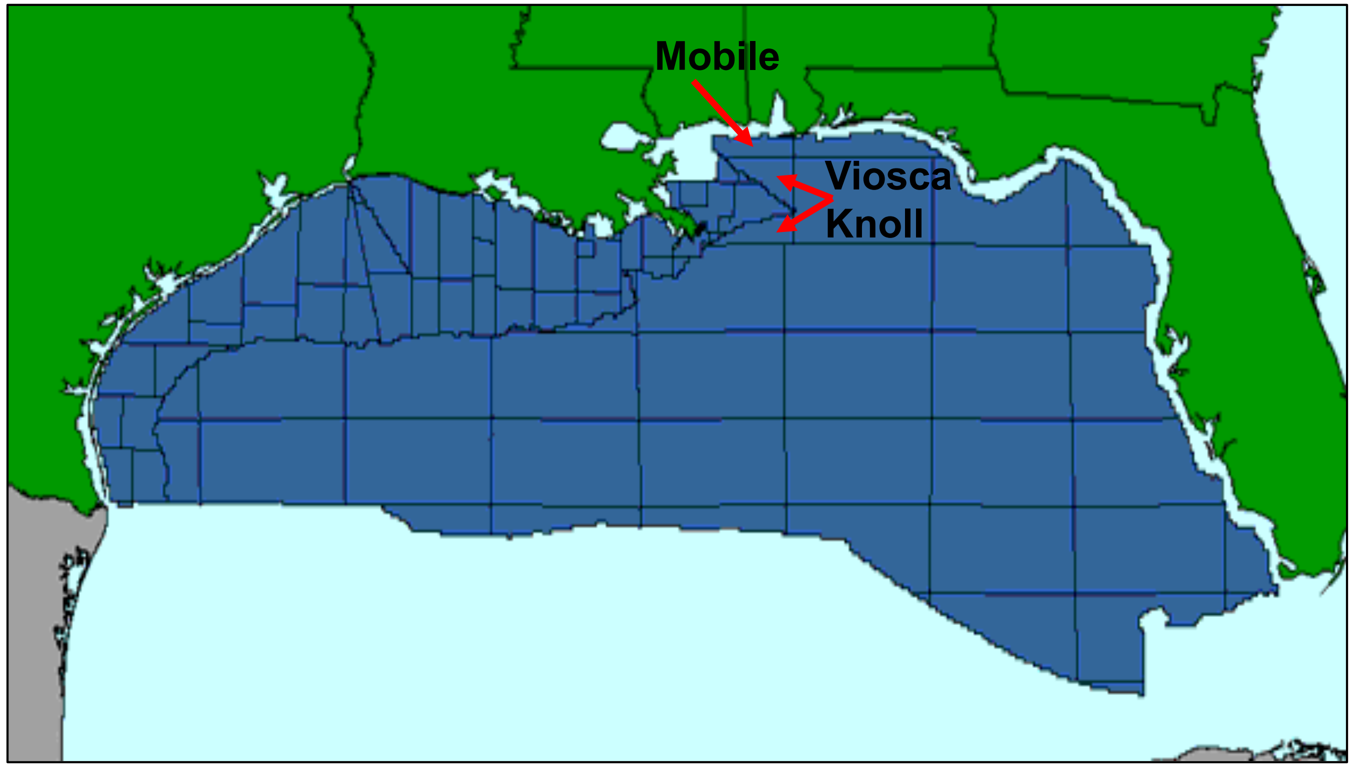
Deep Saline



Mississippi
Alabama
Louisiana
Texas
Florida
Lake Jackson District
Lake Charles District
Lafayette District
Houma District
New Orleans District
Western Planning Area
Central Planning Area
Eastern Planning Area
Legend
Deep Saline
Pipelines
OCS Blocks Active
Leases OCS Block
Leases
0 25 50 100 150 200 Miles

Initial Focus Areas

- Initial focus is on the Mobile and Viosca Knoll areas of the Gulf of Mexico.
- These areas were chosen to develop a methodology for collecting and analyzing data required for well integrity analyses.
- Once this methodology is established it can be used throughout the rest of the study area.



https://woodshole.er.usgs.gov/pubs/of2005-1071/htmldocs/catalog.htm

Methodology Development

Required Data

- Data requirements for a well integrity analysis were established.
- Geologic data
  - Reservoir formations
  - Reservoir characteristics (depth, porosity, permeability)
  - Presence of caprock
- Well ID and Location Data
  - Well API numbers
  - Geographic location of wells
  - Longitude and latitude
- Wellbore data
  - Well construction (age, depth, borehole diameter, casing, cement, BOP, etc.)
  - Well status (producing, abandoned, cement plugs, plug depths)
  - Well history (workovers, well corrosion, blowouts)

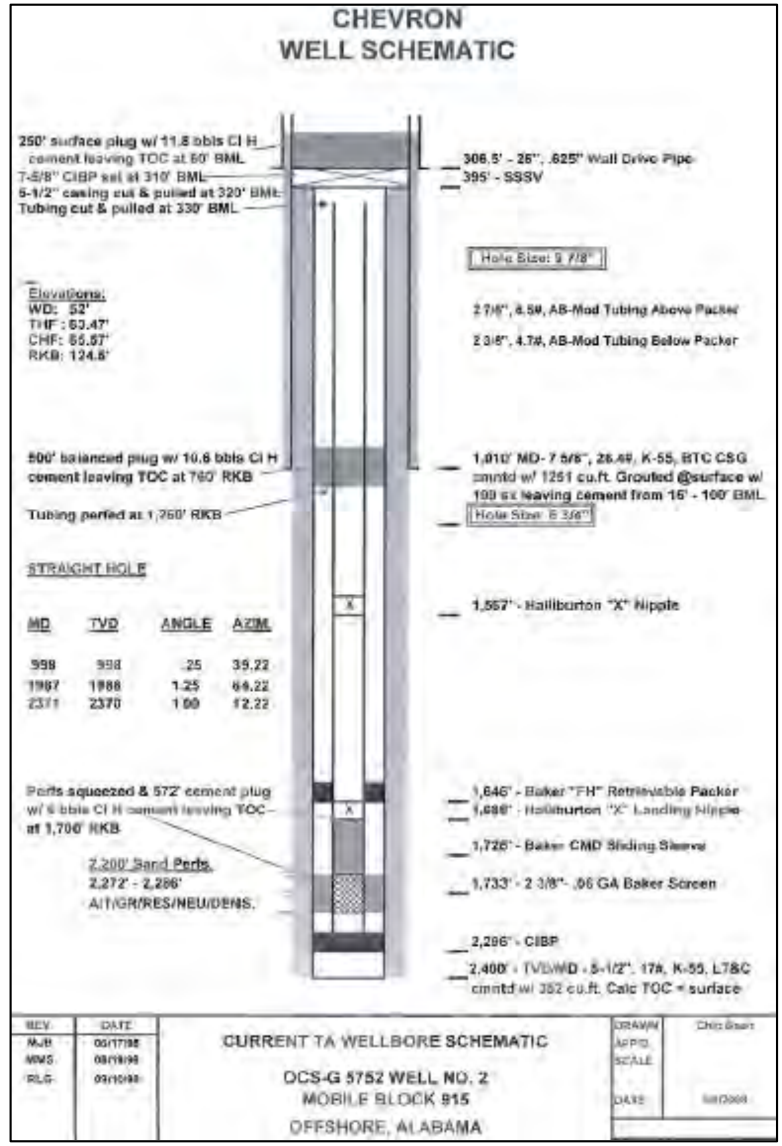
Data Collection

- Geologic data collection
  - Developing a generic geologic stratigraphy in the initial focus areas is being completed by project partners at Oklahoma State University.
- Well location and construction data
  - Provided by the Bureau of Safety and Environmental Enforcement (BSEE).
- Data types and formats
  - Completion reports, drilling permits, operations reports, geophysical logs, etc.
  - Excel files, PDF files, and image files.

BSEE
Bureau of Safety and Environmental Enforcement

Data Collection

- General Well Data
  - API number, long./lat., depth, age, and status data provided by BSEE in an excel file.
- Well construction data
  - Casing, cementing, BOPs, and workover history data was provided in PDF and image files.
- Additional Data Request
  - FOIA request was sent to BSEE to see if any additional well construction data is available in an excel file.



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Data Management

- Excel file well data provided by BSEE was organized by API number.

API	Spud Date	BH Total MD	TVD	TD Date	Status Date	Surface Lat.	Surface Long.	Bottom Long.	Bottom Lat.
608154000700	1983/04/14	21736	21736	1983/09/04	1983/11/24	-88.16313	30.189509	-88.16313	30.189509
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608154000901	1984/10/22	21575	21391	1984/11/03	1985/06/26	-87.985599	30.165922	-87.988766	30.164665
608154000902	1984/12/15	21728	21663	1985/03/05	1985/06/08	-87.985599	30.165922	-87.984414	30.167837
608154000970	1984/08/11	21628	21430	1984/10/15	1984/10/22	-87.985599	30.165922	-87.988938	30.164557
608154000971	1984/11/26	21583	21396	1984/12/07	1984/12/15	-87.985599	30.165922	-87.988791	30.164607
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608154001100	1984/03/14	22422	22420	1984/07/26	2015/10/11	-88.145588	30.148977	-88.145492	30.148895
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608154001300	1984/03/17	3620	3620	1984/03/20	2011/06/30	-88.272062	30.042356	-88.272103	30.042333
608154001400	1984/11/13	22092	22087	1985/07/13	1985/07/29	-88.078684	30.086074	-88.07817	30.086761
608154001500	1984/11/04	21645	21644	1985/03/22	1985/08/12	-88.442281	30.119052	-88.442012	30.119238
608154001600	1985/01/10	21995	21899	1985/09/24	2002/01/26	-88.187606	30.184783	-88.188741	30.185978
608154001700	1985/02/27	23153	23149	1986/01/08	1986/03/29	-87.825459	30.023703	-87.825435	30.024097

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Data Management

- Image and PDF files
  - Indexed by well API number and document type.
- Total files
  - Mobile: 7,575
  - Viosca Knoll: 23,443

API	File Name	File Type	Data Type	Data in File	Index File Order
608154004170	1332037	tif	WellData	Type=APD-Application for Permit to Drill"	1
	349914	tif	WellData	Type=APD-Application for Permit to Drill"	2
608154004200	295515	tif	WellData	Type=Well Completion Report"	3
	350526	tif	WellData	Type=Sundry Report"	4
	350527	tif	WellData	Type=Sidewall Core Analysis"	5
	350528	tif	WellData	Type=Sidewall Core Analysis"	6
	350530	tif	WellData	Type=Well Completion Report"	7
	350531	tif	WellData	Type=Sundry Report"	8
	350532	tif	WellData	Type=Sundry Report"	9
	350533	tif	WellData	Type=APD-Application for Permit to Drill"	10
	977764	tif	WellData	Type=Sundry Report"	11
	977811	tif	WellData	Type=Well Summary Report"	12
	977812	tif	WellData	Type=Sundry Report"	13
	977813	tif	WellData	Type=Sidewall Core Analysis"	14
	977814	tif	WellData	Type=Sundry Report"	15
	977815	tif	WellData	Type=Well Completion Report"	16
	977816	tif	WellData	Type=Sundry Report"	17
	977817	tif	WellData	Type=APD-Application for Permit to Drill"	18
	mo000522	tif	Logs	LogType=5in dual induction laterolog long spaced sonic"	19
	mo000523	tif	Logs	LogType=1in dual induction laterolog"	20
	mo000524	tif	Logs	LogType=5in dual induction laterolog long spaced sonic log"	21
	mo000525	tif	Logs	LogType=5in compensated density/neutron log"	22
	mo000526	tif	Logs	LogType=5in compensated density/neutron log"	23
	mo000527	tif	Logs	LogType=5in shiva computation six arm dipmeter survey"	24
	mo000535	tif	Logs	LogType=5in mud log"	25

Next Steps

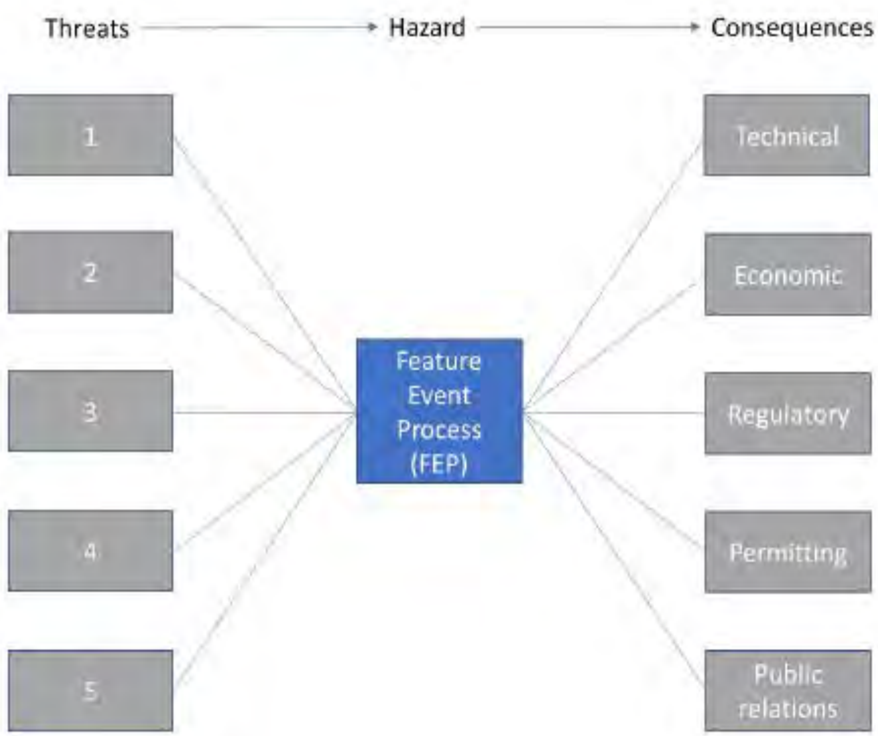
Filling Data Holes

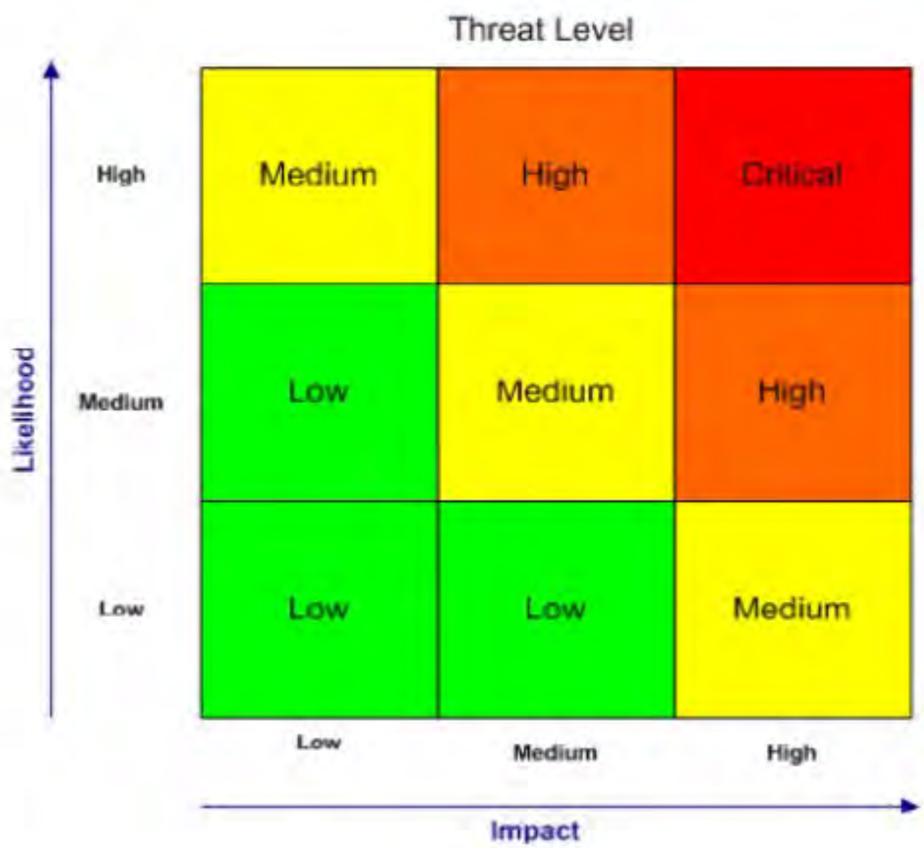
- Data holes
  - Missing data needs to be added.
  - Additional digitized well construction data to be added to the database when it is received from BSEE.
  - Referencing file indices and analyzing PDF and image files to find missing information and fill in the data gaps.

API	Spud Date	BH Total MD	TVD	TD Date	Status Date	Surface Lat.	Surface Long.	Bottom Long.	Bottom Lat.
608164005400	1978/10/20	5260	4524	1978/11/08	1978/11/14	-88.429876	29.227589	-88.42548	29.223335
608164005500	0000/00/00			0000/00/00	0000/00/00	-88.437277	29.271234		
608164005600	0000/00/00			0000/00/00	0000/00/00	-88.424134	29.27051		
608164005700	1978/12/01	10842	7461	1979/01/03	1979/01/12	-88.74278	29.062708	-88.734923	29.043967
608164005701	1979/03/03	10700	7439	1979/04/02	1979/04/02	-88.74278	29.062708	-88.724942	29.056218
608164005800	0000/00/00			0000/00/00	0000/00/00	-88.373232	29.064922		
608164005900	1979/04/03	7057	6843	1979/04/21	1989/03/23	-88.742775	29.062763	-88.739129	29.062641
608164006000	0000/00/00			0000/00/00	0000/00/00	-88.74272	29.062676		
608164006100	0000/00/00			0000/00/00	0000/00/00	-88.742793	29.062749		
608164006200	1979/11/06	5667	5666	1979/11/27	1979/12/06	-88.37949	29.125724	-88.379612	29.125717
608164006300	1980/07/12	15082	15014	1980/11/21	1980/12/05	-88.325986	29.14495	-88.323694	29.145448

Risk Assessment

- Risk = Likelihood * Impact





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SECARB Offshore Gulf of Mexico Available and Leading Practices

Presented by: Brian Hill, CrescentRI – SSEB Finance & Commercialization Consultant

U.S. Department of Energy | National Energy Technology Laboratory | DE-FOA-0001734

March 27, 2020

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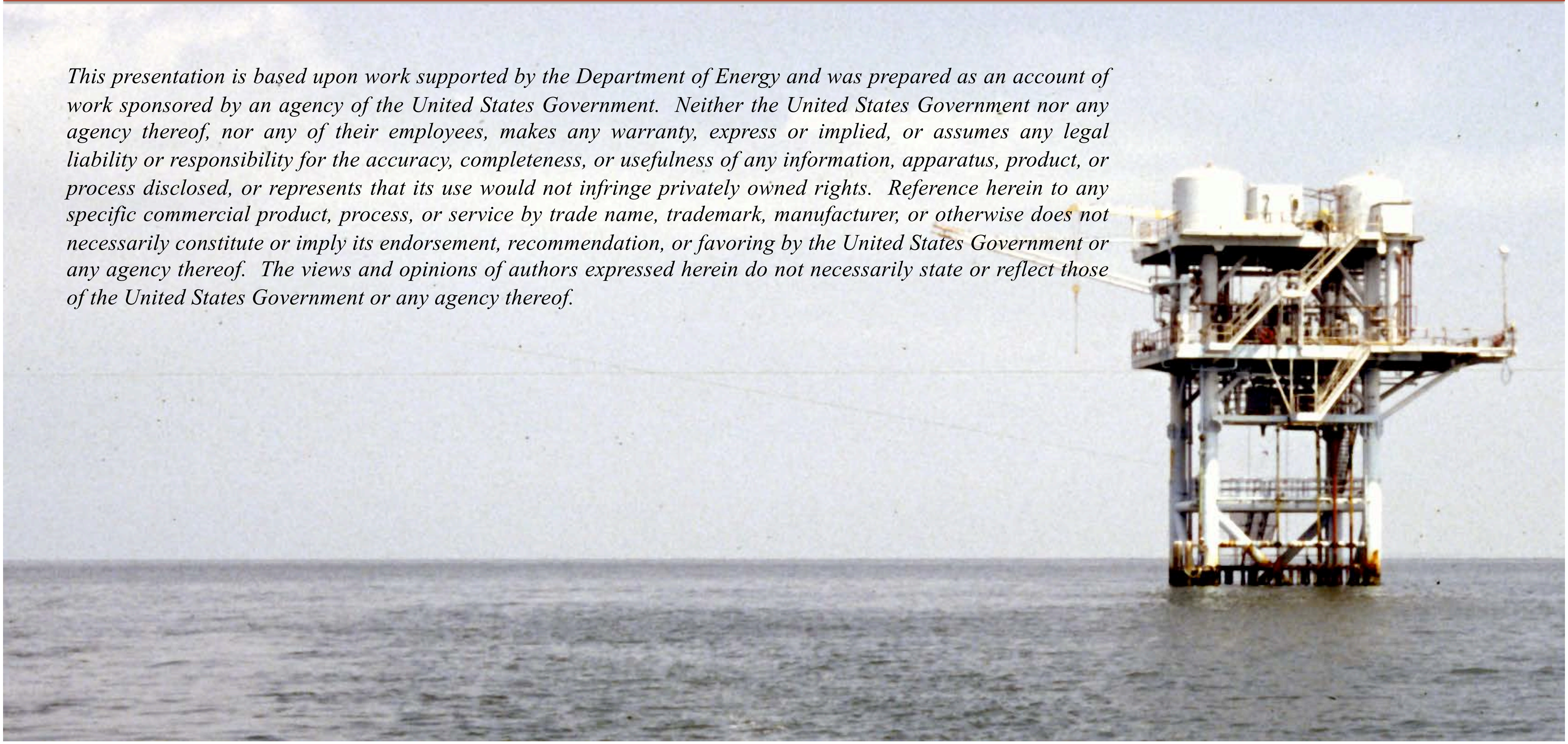
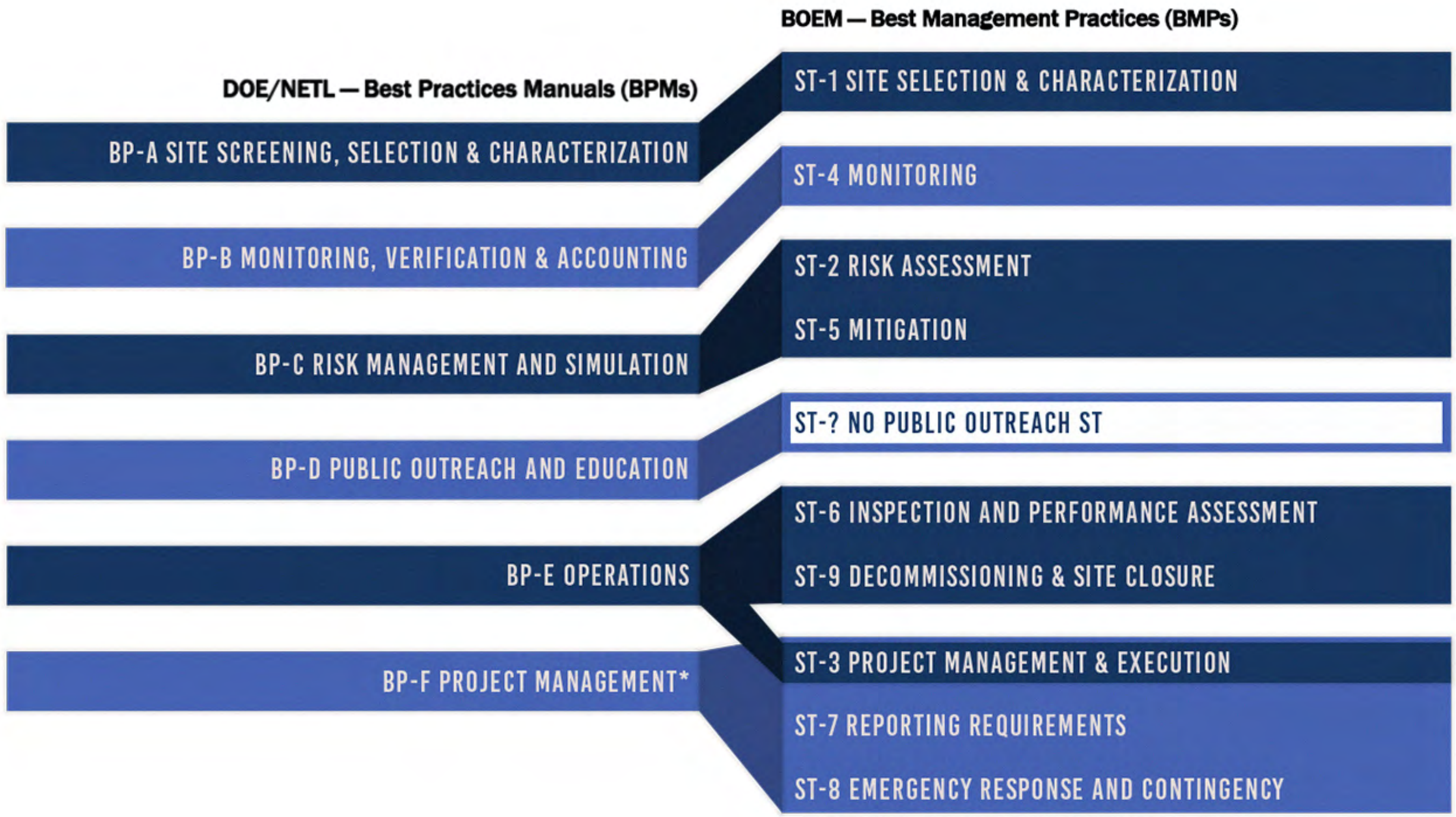


Best Practices: Recent Activities

- Offshore Best Practices for CO_2 Storage & Transportation
  - SSEB and the Interstate Oil and Gas Compact Commission (IOGCC) convened an Offshore Task Force that reviewed laws and regulations for CO_2 capture and storage (2012)
  - Texas BEG prepared a report for BOEM on best management practices for offshore transportation and sub-seabed geologic storage of CO_2 (2017)
  - SSEB prepared a SOSRA T6.1 report that compared DOE/NETL onshore best practices with the BOEM best management practices for offshore CO_2 transportation and storage (2019)
  - SSEB prepared SOSRA T6.2.a report formalizing Available and Leading Practices (2019) instead of Best Practices

DOE/NETL and BOEM Best Practices Comparison

*Project Management BPM not part of DOE/NETL 2017 update; Under review at SSEB (2020)



SECARB Offshore Planned Activities

- SECARB Offshore (BP1) Action Plan to Expand Available and Leading Practices Explicitly Applicable to the Gulf of Mexico (Mar 2020)
  - Create an action plan to advance offshore practices, based upon SOSRA 6.2 and BOEM work completed
  - Include existing infrastructure, logistical & regulatory obstacles, and decommissioning requirements
- SECARB Offshore (BP2) Final Report (Mar 2023)
  - Incorporate available and leading practices into a final report on *"Assessment of Legal and Regulatory Frameworks"*

SECARB Offshore Planned Activities

INVENTORY OF AVAILABLE PRACTICES: CONCEPTUAL DESIGN

INFRASTRUCTURE COMPONENTS	CHARACTERIZATION			RISK				MONITORING (Atmospheric, Aqueous,			
	SITE SELECTION	INITIAL SITE EVALUATION	DETAILED SITE EVALUATION	DEVELOPMENT	OPERATIONS	CLOSURE	POST CLOSURE	DEVELOPMENT	OPERATIONS	CLOSURE	POST CLOSURE
Landside Connections	C1	C2	C3	R1	R2	R3	R4	M1	M2	M3	M4
CO2 Transport & Corridors	C4	C5	C6	R5	R6	R7	R8	M5	M6	M7	M8
Platforms & Sea Floor Connections	C7	C8	C9	R9	R10	R11	R12	M9	M10	M11	M12
Well Bores & Wells	C10	C11	C12	R13	R14	R15	R16	M13	M14	M15	M16
Geological Seals & Barriers	C13	C14	C15	R17	R18	R19	R20	M17	M18	M19	M20
CO2 Storage & Utilization Formations	C16	C17	C18	R21	R22	R23	R24	M21	M22	M23	M24

	OUTREACH	
Integrate Public Outreach with Project Management	Identify Outreach Goals with Project Manangement	Identify Key Stakeholders
Conduct and Apply Social Characterization	Establish an Outreach Program	Develop Key Messages
Develop Outreach Materials Tailored to the Audiences	Implement and Manage the Outreach Program Needed	Asses the Performance of the Outreach Program

C16

SECARB Offshore Planned Activities

Inventory Of Available Practices – C16 CO_2 Storage and Utilization Formations

Phase	Onshore Action	Available Practices	Comparison to Offshore
Site selection	Subsurface Geological Data Analysis - Storage Reservoir	Identify storage reservoirs and injection zones within Selected Areas. Develop stratigraphic and structural framework diagrams that illustrate suitable storage reservoirs and injection zones of interest, using all available well and outcrop data.	No difference
Site selection	Subsurface Geological Data Analysis - Confining Zone	Analyze confining zones in Selected Areas. Create stratigraphic and structural framework diagrams to illustrate areal extent, thickness, lithology, porosity, permeability, capillary pressure, and structural complexity of suitable confining zones, based on existing data.	No difference
Site selection	Subsurface Geological Data Analysis - Trapping	Establish baseline geomechanical characteristics of targeted injection and confining zones.	No difference
Site selection	Subsurface Geological Data Analysis - Mechanism	Evaluate trapping mechanisms for Selected Areas using available well, outcrop, and seismic data.	No difference
Site selection	Subsurface Geological Data Analysis - Potential	Establish hydrogeological characteristics of injection and confining zones to assure reliable containment of injected CO2.	No difference
Site selection	Subsurface Geological Data Analysis - Injectivity	Perform initial estimate of injectivity of candidate injection zones in Selected Areas, using available production history data, hydrologic test data, and analyses of core plugs.	No difference
Site selection	Model development - Modeling parameters	Identify types of models and modeling parameters needed to characterize the storage reservoir, confining zone, and fluid properties for Selected Areas.	No difference
Site selection	Model development - Data Requirements and cost	Identify data requirements to optimize modeling results; conduct cost vs. benefit analysis to determine value of acquiring new data.	Data acquisition costs offshore tend to be significantly higher; data tends to be lower density due to higher cost
Site selection	Model development - Boundary conditions/uncertainty	Identify and characterize uncertainties in modeling results; select boundary conditions which minimize uncertainties in modeling results.	No difference
Site selection	Model development - Existing seismic data	If available, integrate existing seismic data in development of static and dynamic models for Selected Areas.	Offshore seismic data tends to be easier to work with due to no need for topographic corrections and easier avoidance of obstacles.

SECARB Offshore Planned Activities

MATRIX OF LEADING PRACTICES: CONCEPTUAL DESIGN

	Project Management										
INFRASTRUCTURE COMPONENTS	CHARACTERIZATION			RISK				MONITORING			
	SITE SELECTION	INITIAL SITE EVALUATION	DETAILED SITE EVALUATION	DEVELOPMENT	OPERATIONS	CLOSURE	POST-CLOSURE	DEVELOPMENT	OPERATIONS	CLOSURE	POST-CLOSURE
Landside Connections	C1	C2	C3	R1	R2	R3	R4	M1	M2	M3	M4
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Platforms & Sea Floor Connections	C7	C8	C9	R9	R10	R11	R12	M9	M10	M11	M12
Well Bores & Wells	C10	C11	C12	R13	R14	R15	R16	M13	M14	M15	M16
Geological Seals & Barriers	C13	C14	C15	R17	R18	R19	R20	M17	M18	M19	M20
CO2 Storage & Utilization Formations	C16	C17	C18	R21	R22	R23	R24	M21	M22	M23	M24
	Outreach and Education										

Onshore to Offshore Relationship
Very little to no difference

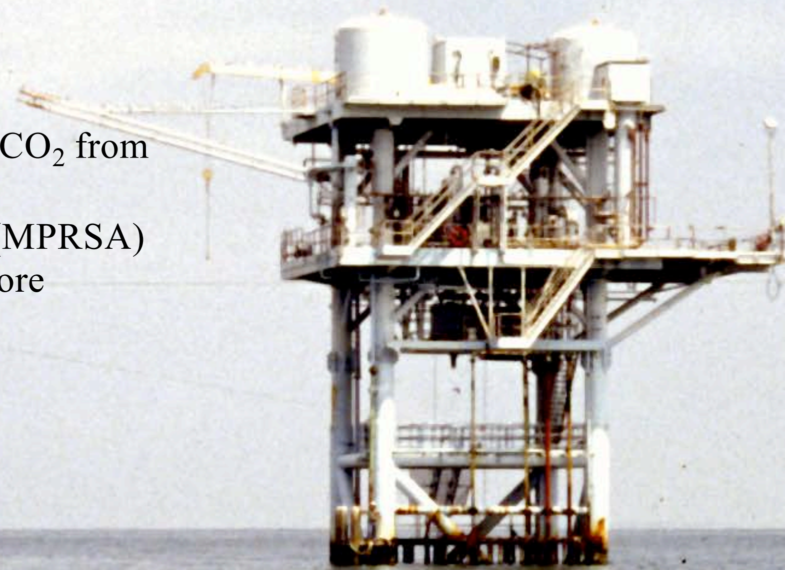
Onshore to Offshore Relationship
Small differences

Onshore to Offshore Relationship
Major differences

Onshore to Offshore Relationship
Not contemplated in Onshore

Challenges for Offshore

- Regulation
  - Regulation needed for offshore development
    - Bureau of Ocean Energy Management
    - Bureau of Safety and Environment Enforcement
      - Pore Space availability
      - Long term Liability
      - Monitoring requirements
  - Under the Outer Continental Shelf Lands Act (OCSLA) only CO_2 from coal fired power plants is allowed
  - Under the Marine Protection, Research, and Sanctuaries Act (MPRSA) CO_2 is considered a waste and prohibited from disposal offshore
- Timing
  - Limited window under existing 45Q
    - Commence Construction date of 12/31/2023
    - 6-year window to complete construction
- Economics
  - Higher costs to operate offshore
  - Current low oil prices
  - Economics of Storage after 45Q – only 12-year credit



THANK YOU!

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