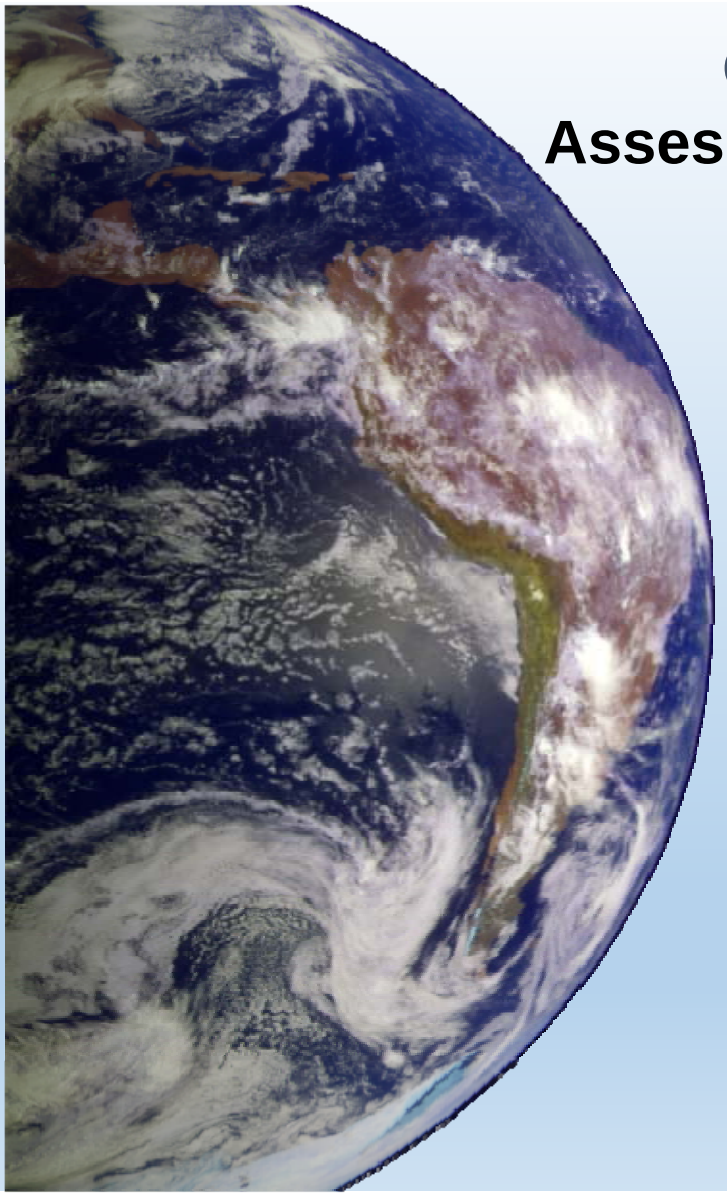


Global Opportunities for Offshore CCS :
Assessing Offshore Storage on Continental Shelves

International Workshop on Offshore Geological CO_2 Storage
Austin, Texas
April 19-20, 2016

Dr. Tip Meckel, Research Scientist

Gulf Coast Carbon Center

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Gulf Coast Carbon Center

carbon sequestration leadership forum

Three motivating messages:

1. **For CCS to be a technology with significant atmospheric benefit on desired timelines, rapid and broad global deployment needed.**
   - 6 Gt by 2050 (6,000 'Sleipners')
   - 2/3 of CCS potential will need to come from non-OECD countries (IEA)
   - Natural gas likely to be associated with many projects.

2. **The global offshore continental shelves broadly represent the largest near-term storage for Gigaton-scale CCS.**
   - CCS 'sweet spots' – source-sink match, ownership; thick, sand-prone, young (ductile seals), low stress.
   - **How assess storage potential?**

3. **Focus needs to be on capacity assessment, knowledge transfer, and *deployment of demonstration- and industrial-scale projects*.**
   - **This workshop!**

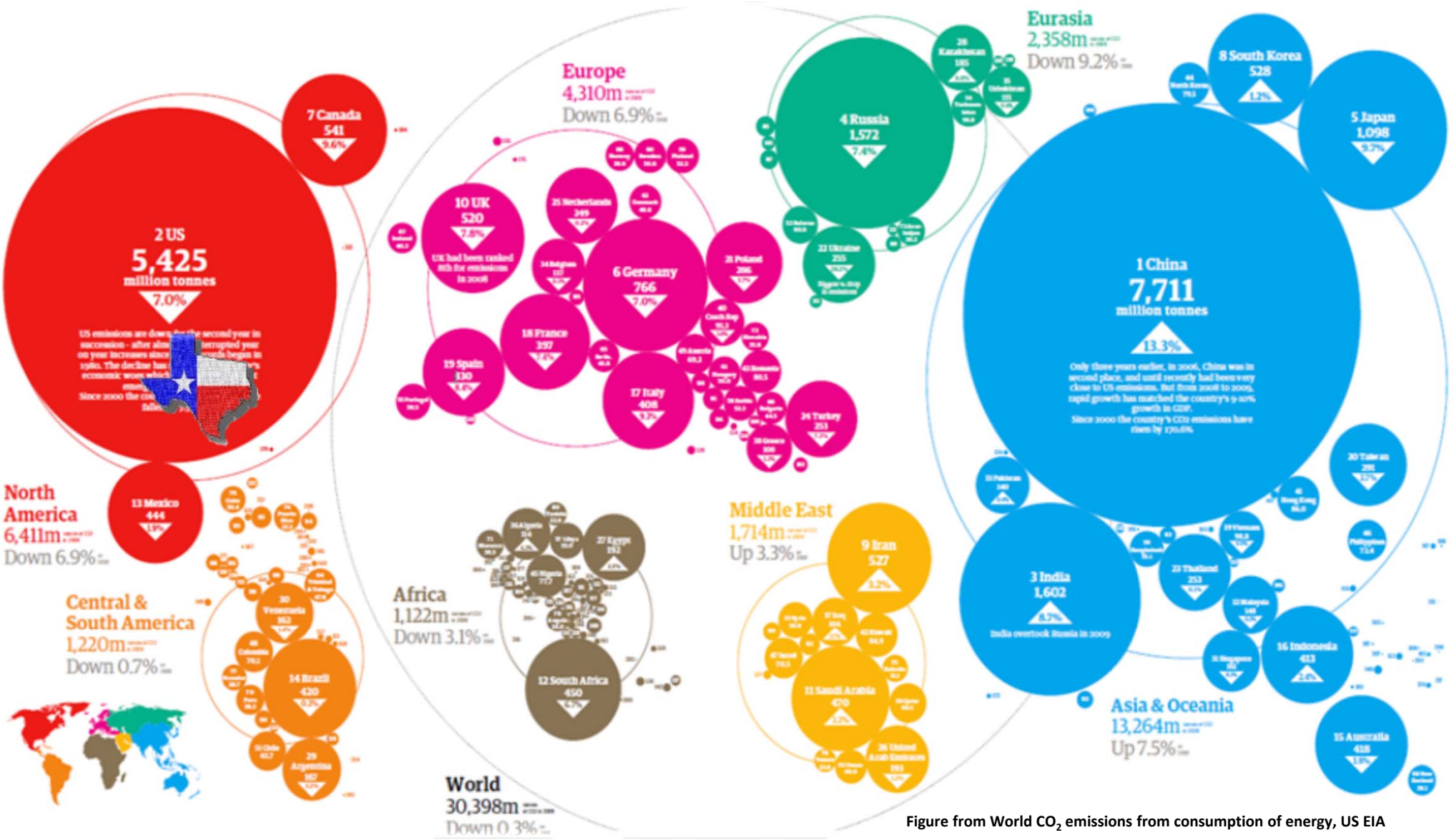
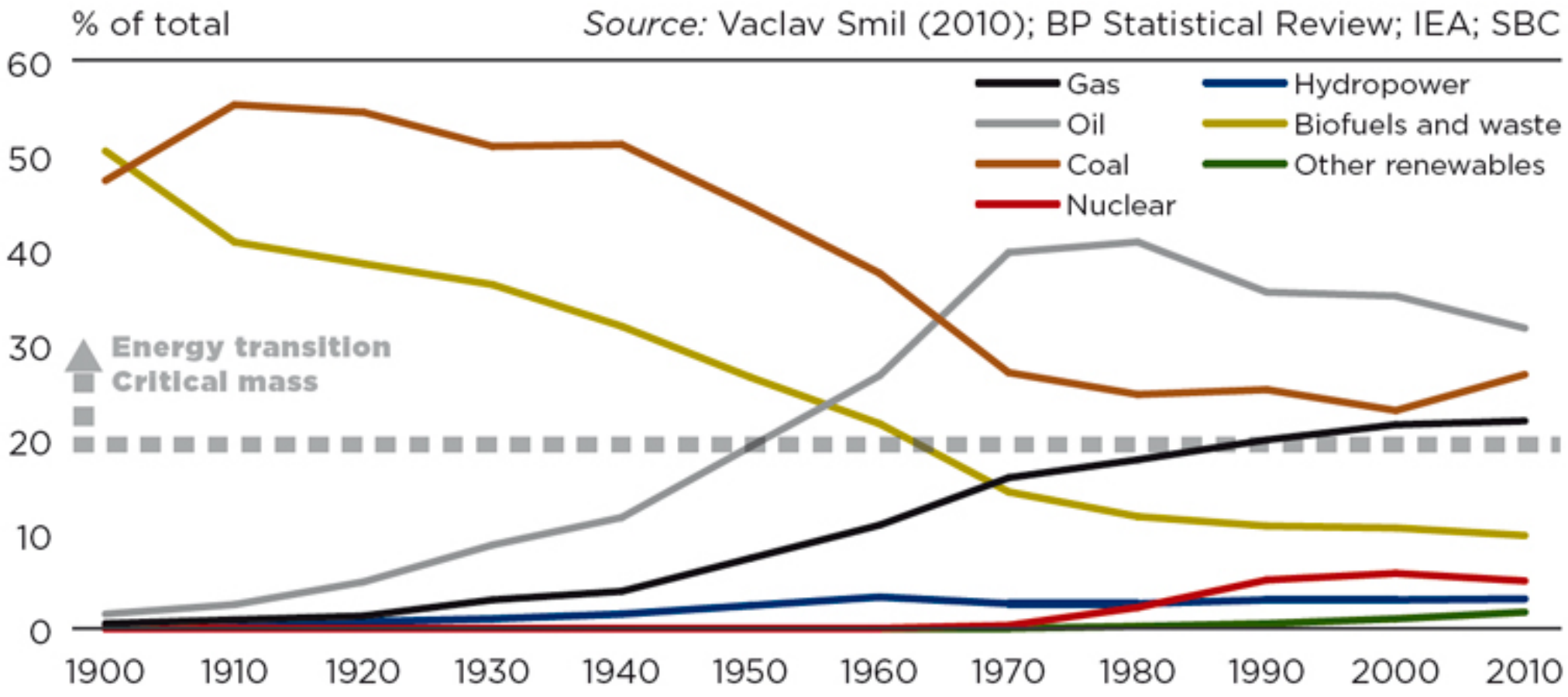


Figure from World CO_2 emissions from consumption of energy, US EIA

Figure 1: Global primary-energy demand by fuel type



Select Industrial CCS Projects

GAS PROJECTS!

- *Sleipner, Snohvit – North Sea*
- *In-Salah - Algeria*
- *Gorgon, NW Shelf Australia (15% CO_2)*
- *Lula – CO2/EOR*

World Gas Reserves

~2% production growth annually (IEA); international market
Gas quality problems are holding back investment

Approximately 40% (2600 Tcf) are estimated to be sour

To the degree that our energy future includes large gas fields, it includes CO_2 management.

Table 12.2 ● World proven sour gas reserves, end- 2006

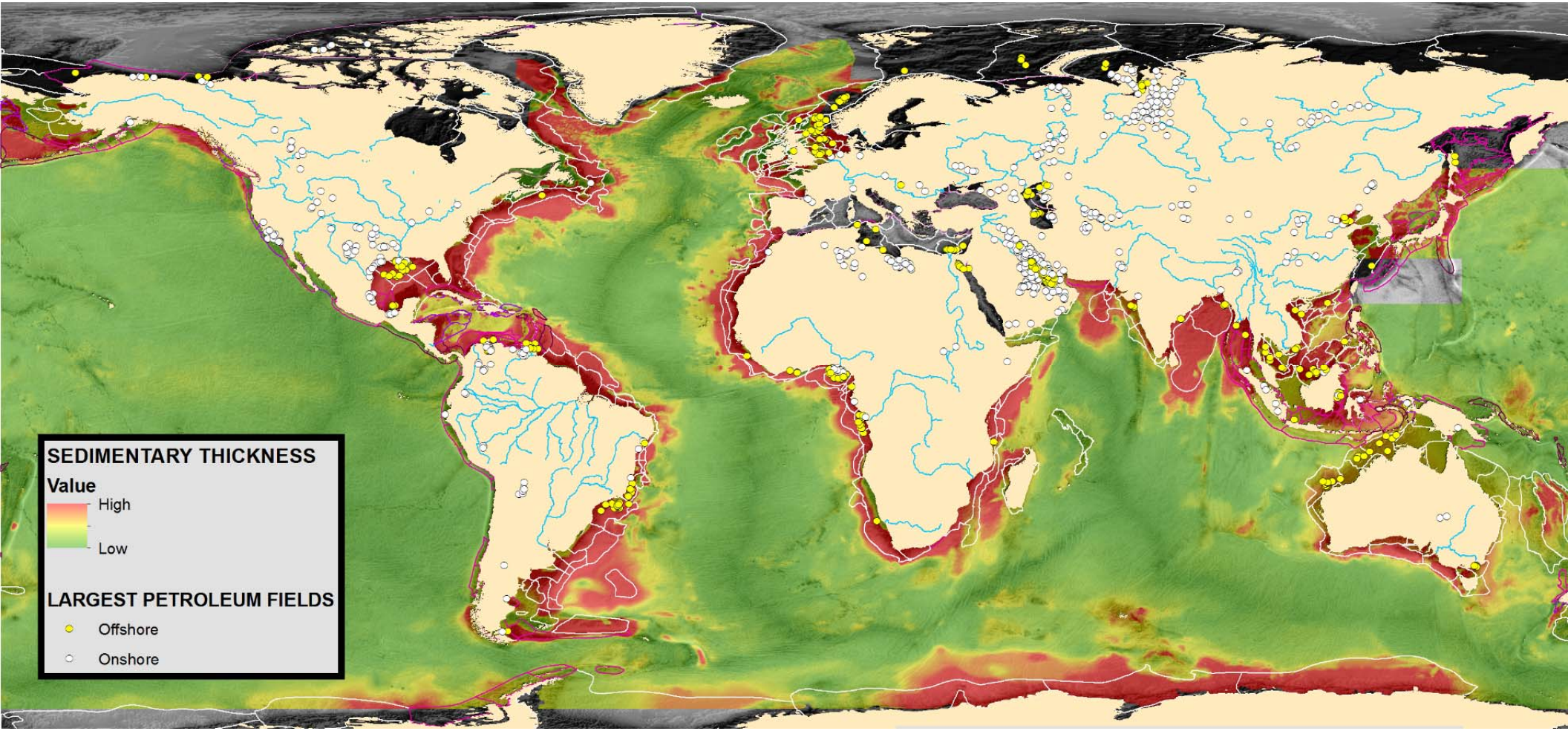
	High H_2S only (tcm)	High CO_2 only (tcm)	High H_2S and CO_2 (tcm)	Total (tcm)	Total % of total reserves
Mexico & Latin America	0.3	1.1	0.3	1.7	21
Europe	0.1	0.7	0.3	1.1	19
Former Soviet Union	0.8	10.1	7.3	18.2	34
Africa	0.0	0.5	0.5	1.0	8
Middle East	2.6	0.4	40.9	44.0	60
Asia-Pacific	0.3	4.4	2.3	7.1	46
World	4.2	17.2	51.6	73.1	43

Note: Excludes North America. High H_2S is more than 100 parts per million; high CO_2 is more than 2%.

Source: Bourdarot (2007).

SOURCE: US EIA

The global offshore continental shelves broadly represent the largest near-term storage for Gigaton-scale CCS.




Snøhvit
Peterhead / Goldeneye
Sleipner
TNO K12-B
White Rose
ROADS Project
Porto Tolle
New Jersey
(Schlumberger / SCS Energy)
Wilmington Graben
Carolinas
South Georgia
Gulf of Mexico
Miocene-Pliocene
Tomakomai
Korean Storage
Taiwan Straits – Taihsi Basin
Pearl River Delta
Malay / Penyu Basins
Indonesia
*Only Porous Media Studies – excludes coal-bed and basalts
Gorgon
Brazil Pre-Salt
Durbin Basin, South Africa
CarbonNet / Gippsland
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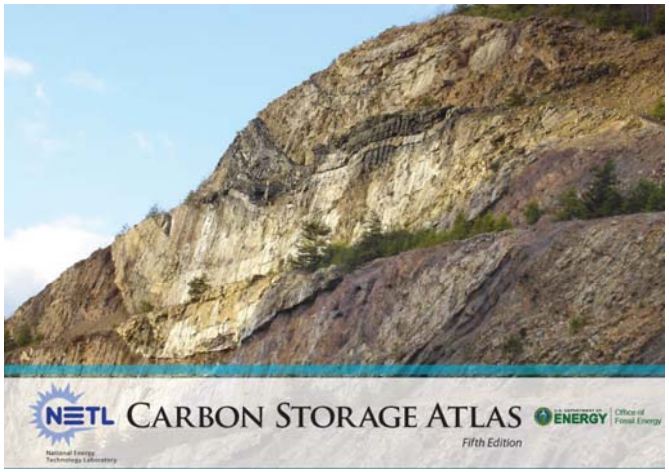
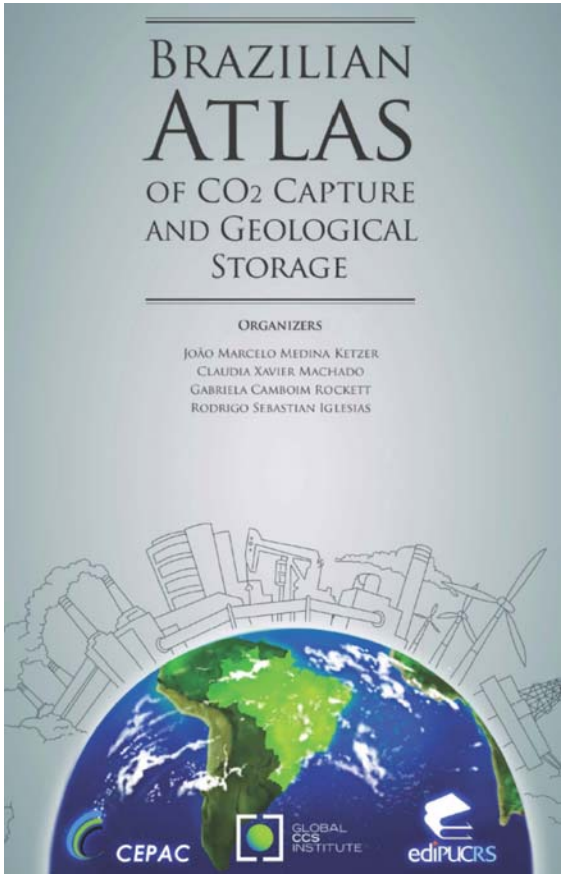
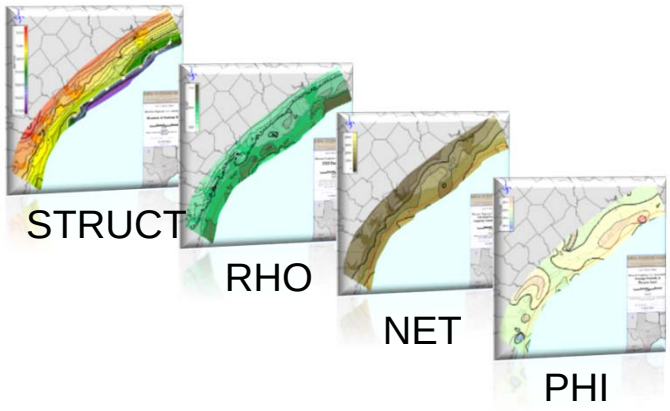
Very large regional static capacity estimates

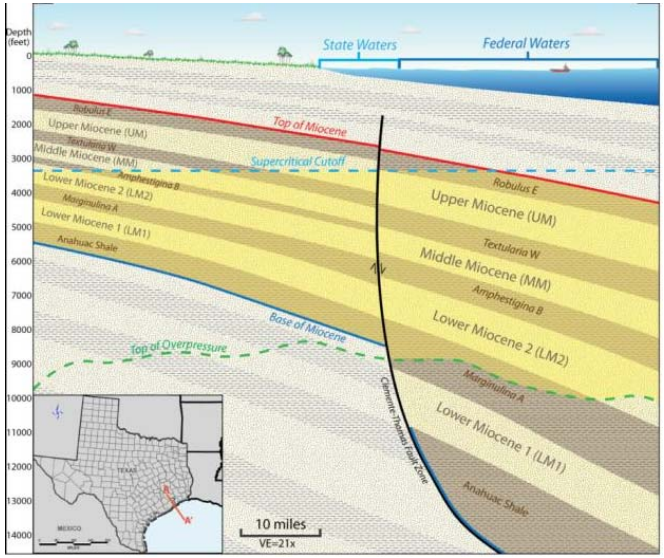


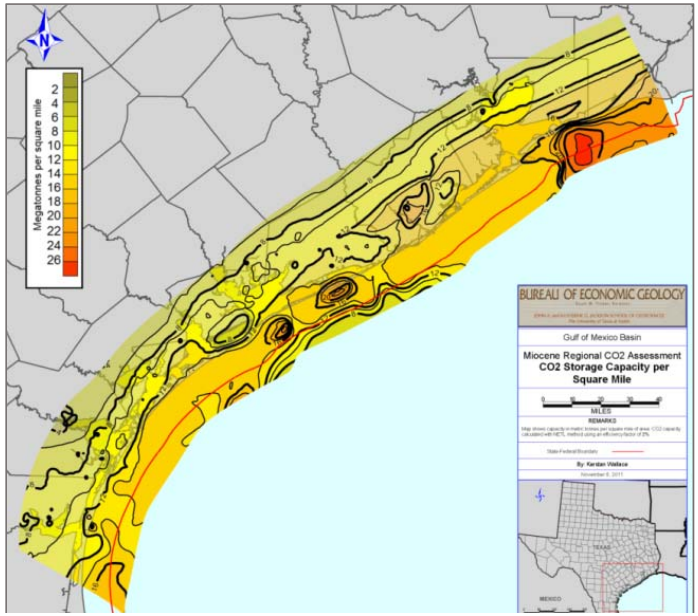


Static Regional Capacity Texas Example

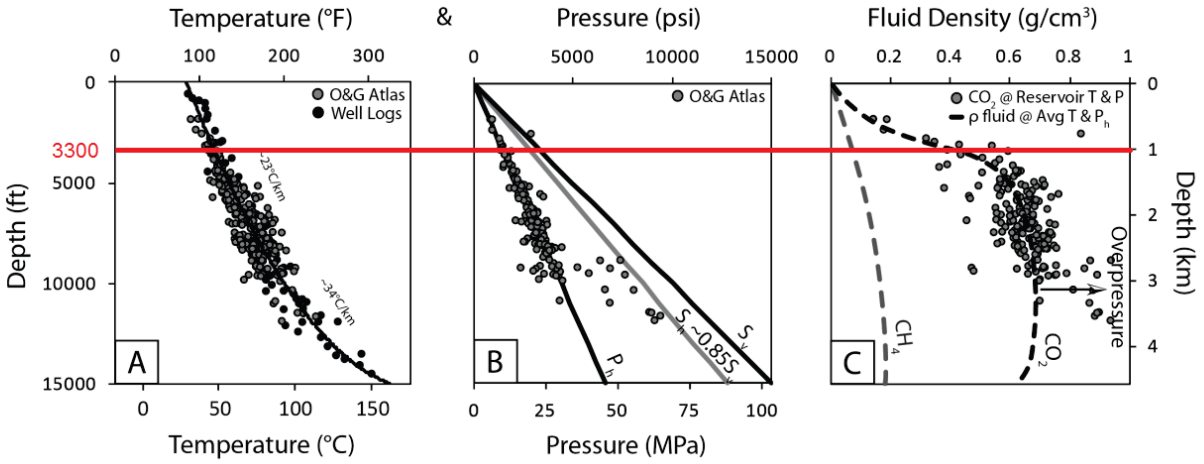
- NETL Methodology
- 40,000 sq. km.
- 3,300 logs
  - Tops, net sand, porosity
- 172 Gt total (TX State Waters)

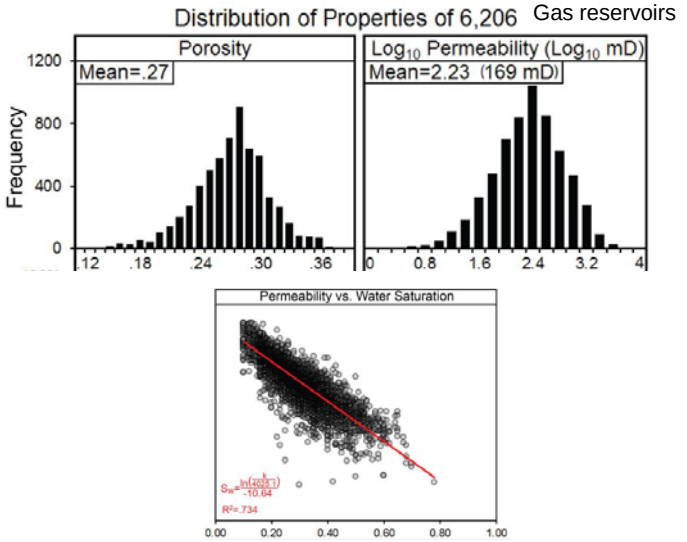


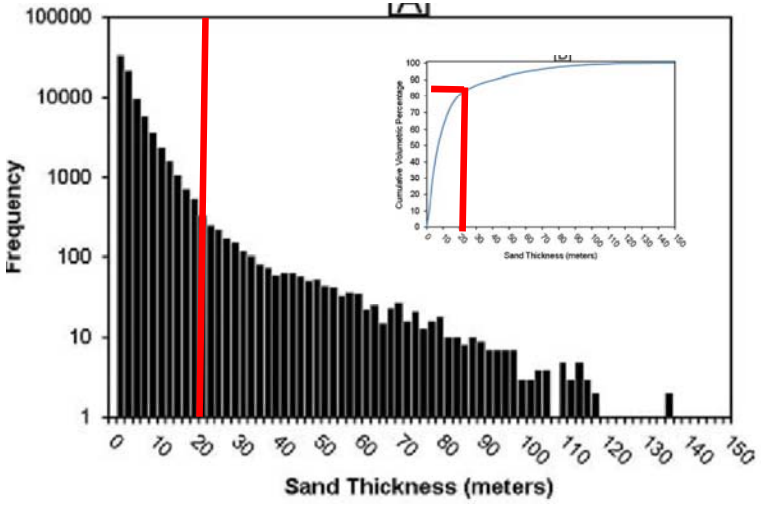


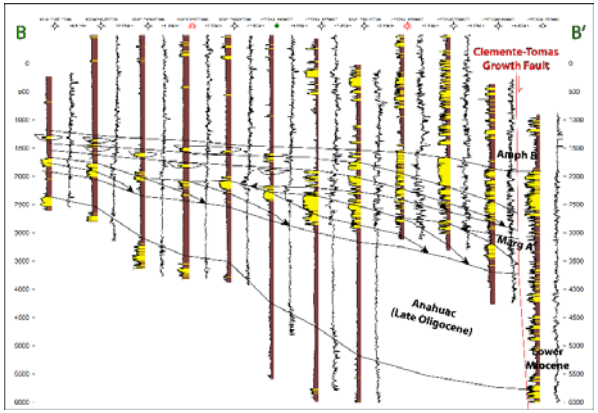


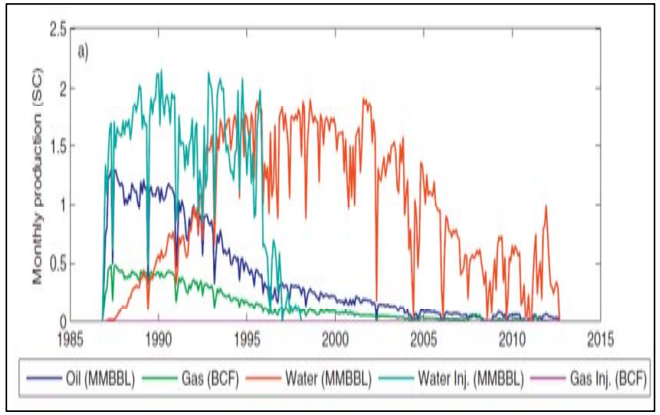
Geologic Characterization: What is typical? What is notable?







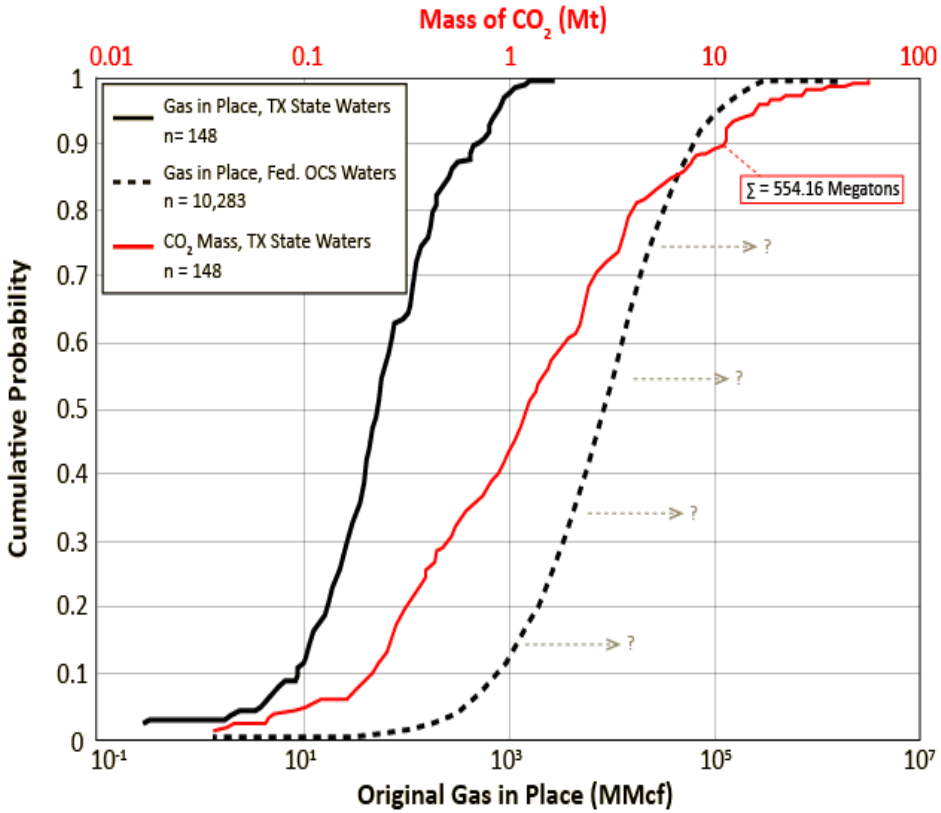


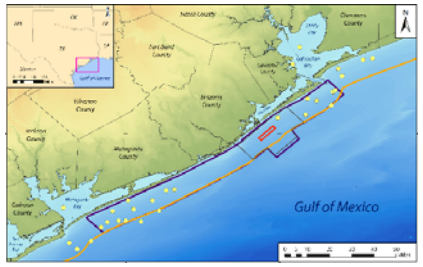


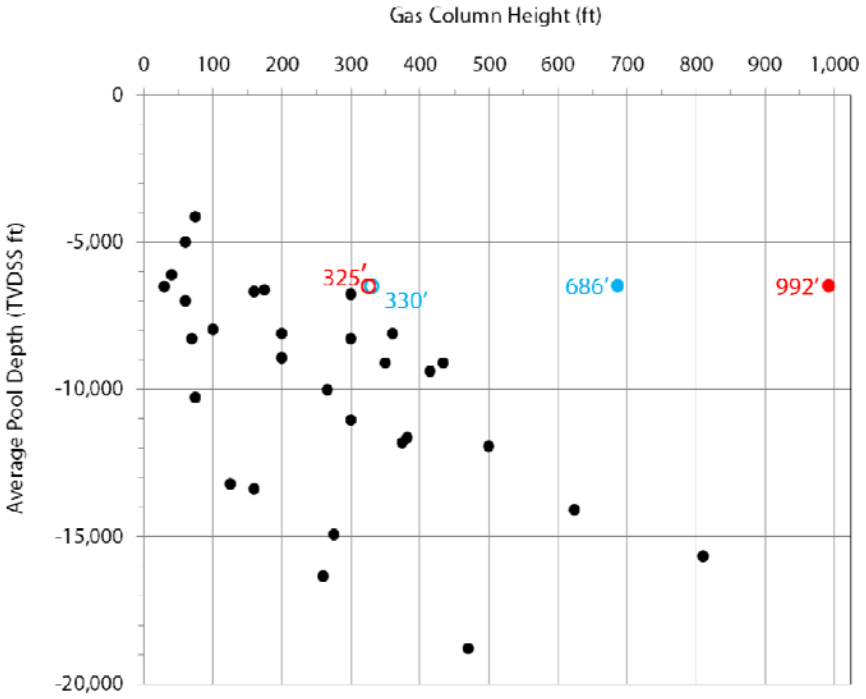
Gas field Characterization: What is typical? What is notable?

Gas Field Static Replacement Capacity

Depleted gas fields are major opportunity and part of solution

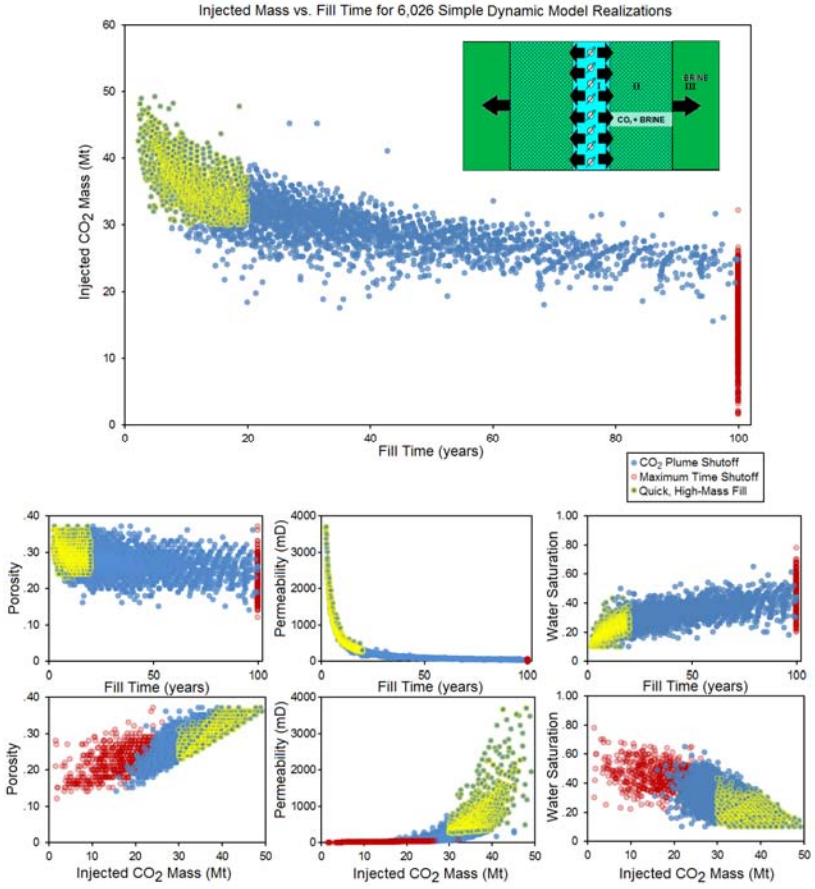




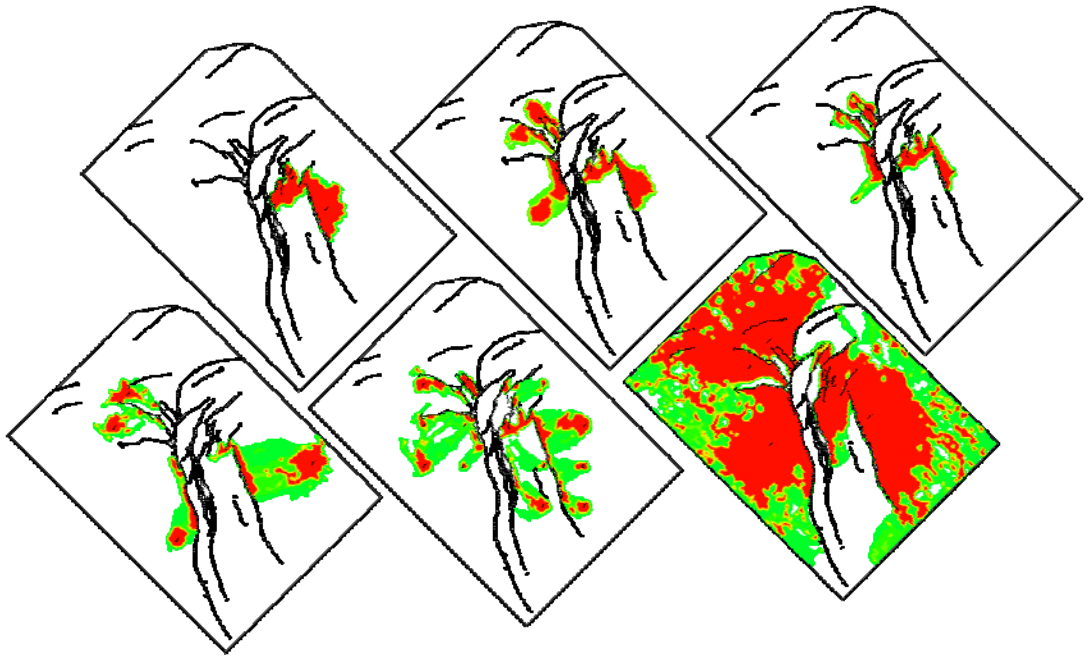


Injection Simulation: Theoretical/analytical, Numerical

Analytical = Expectations

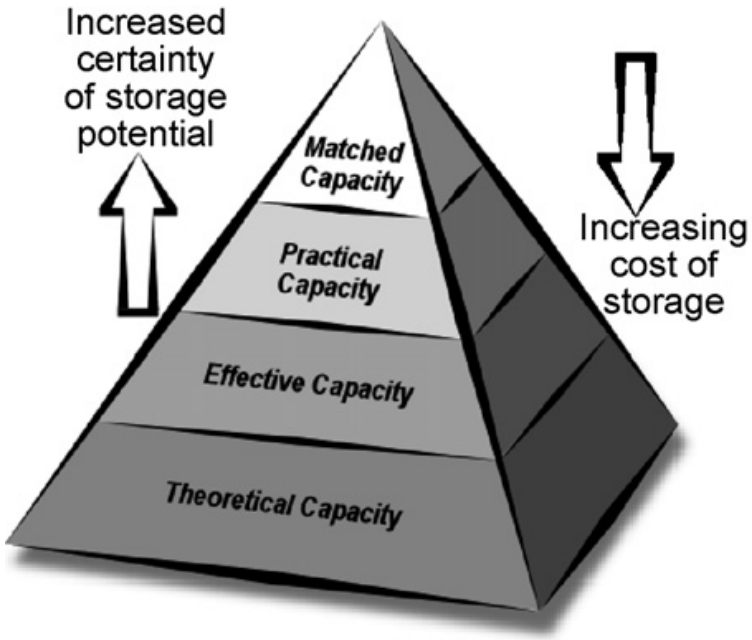


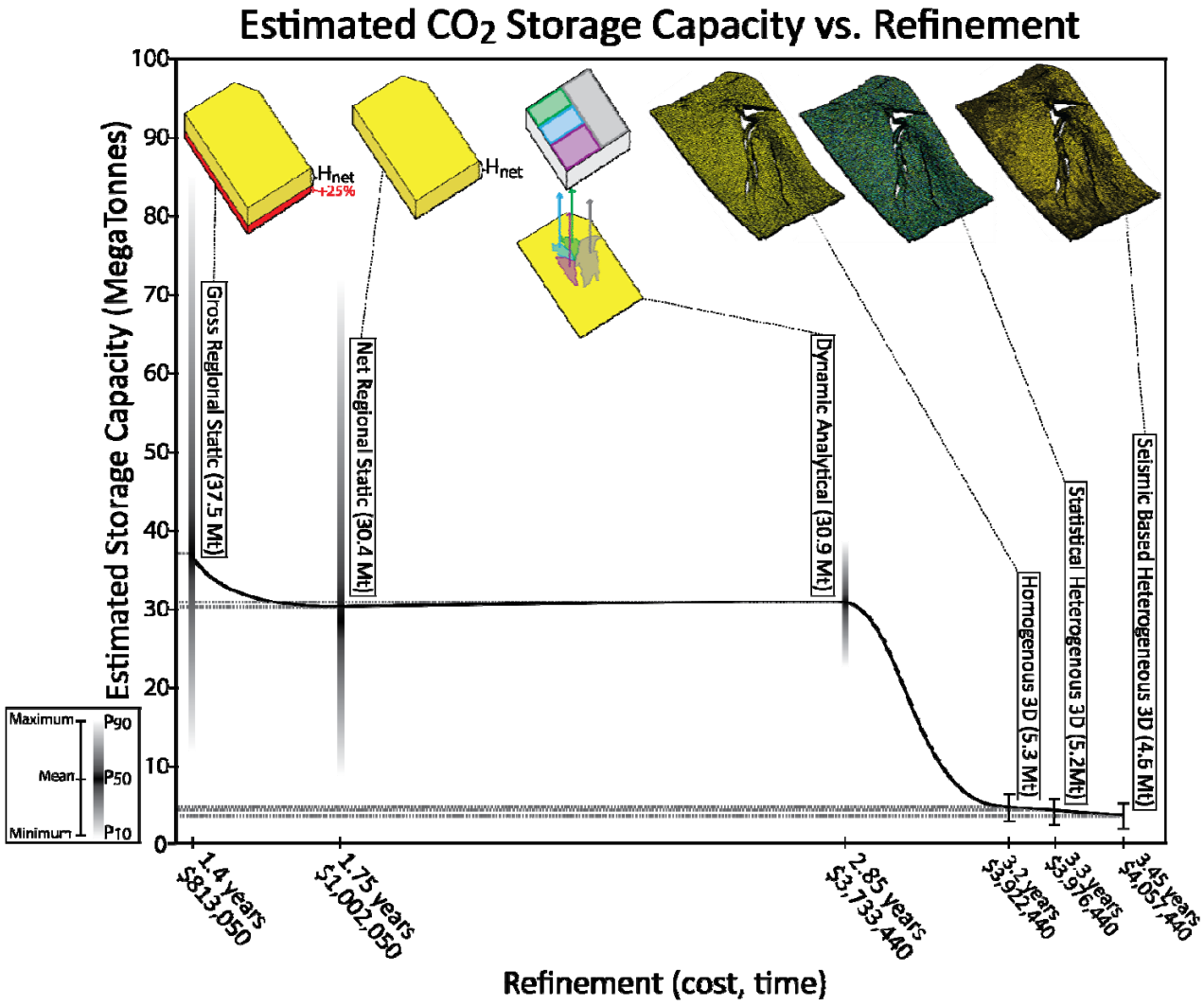
Numerical = Sensitivity

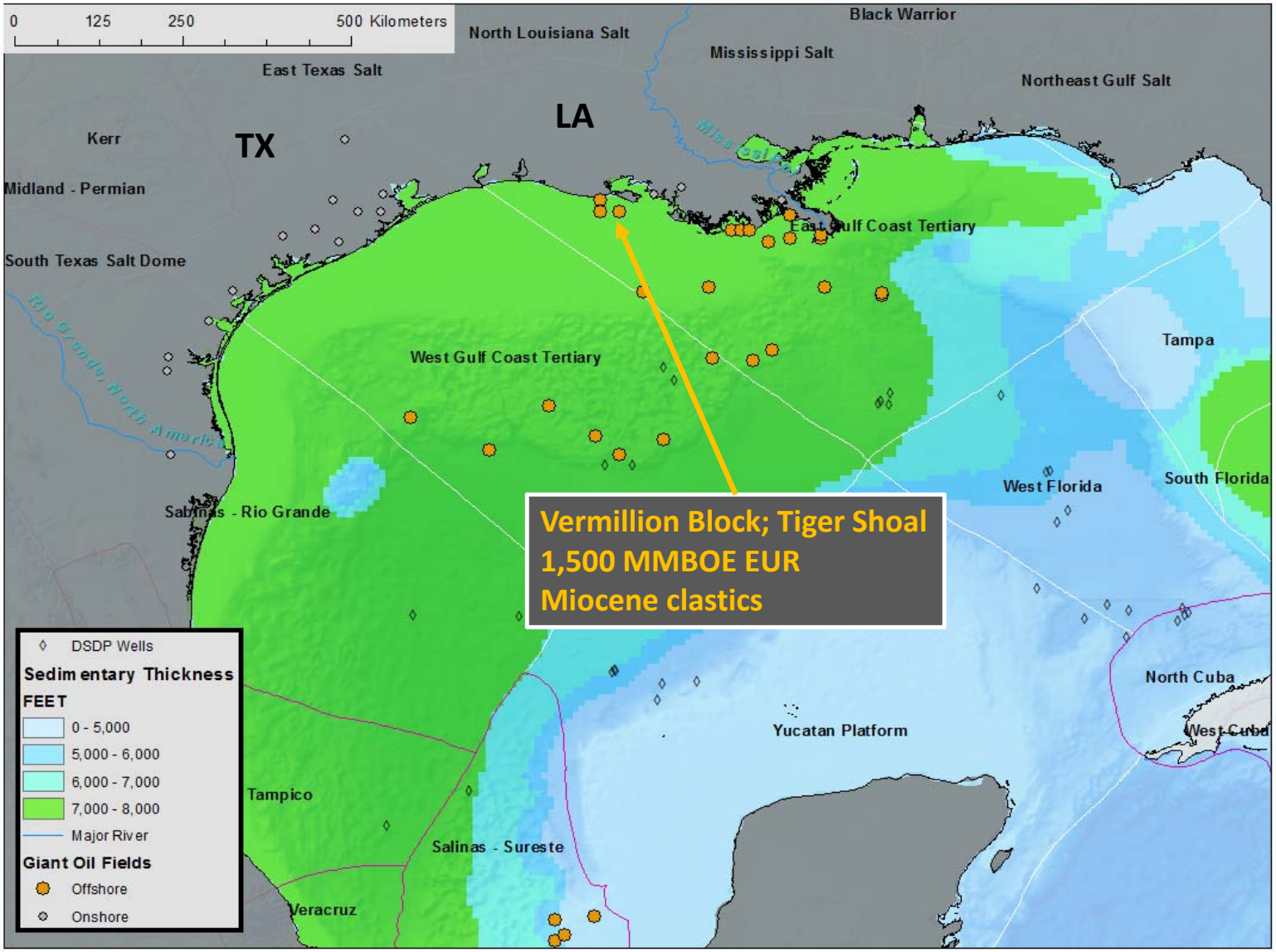


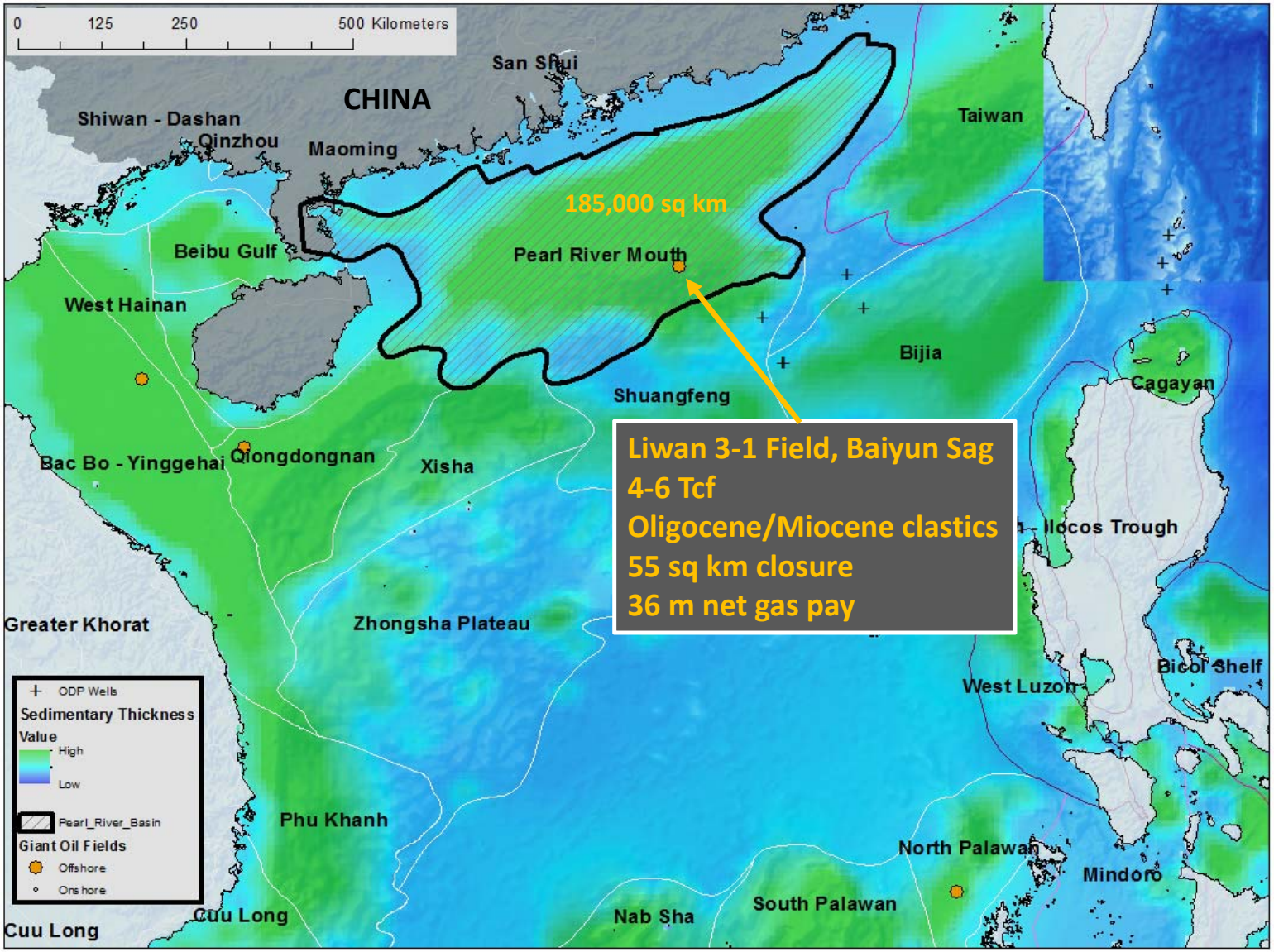
Which models lead to **undesirable** outcomes?
How can you avoid those scenarios?

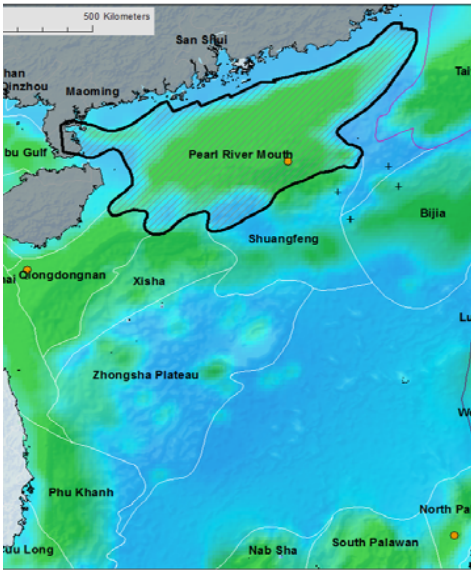
Capacity Refinement

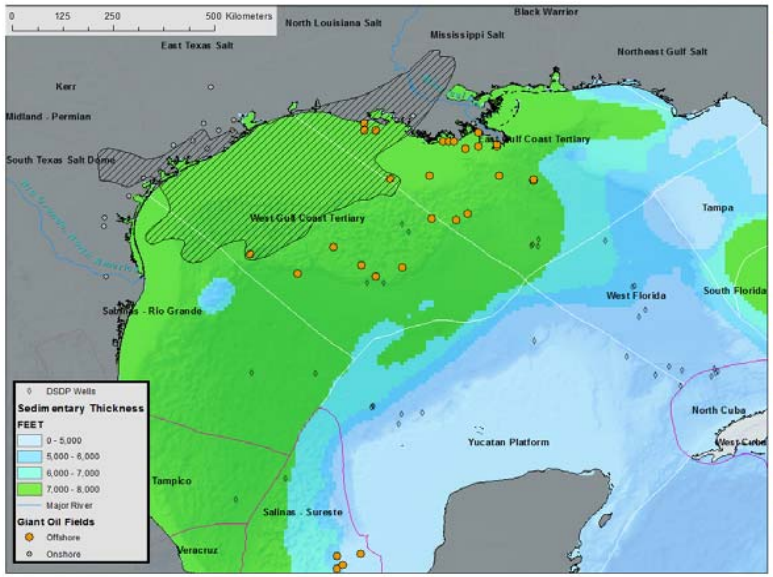


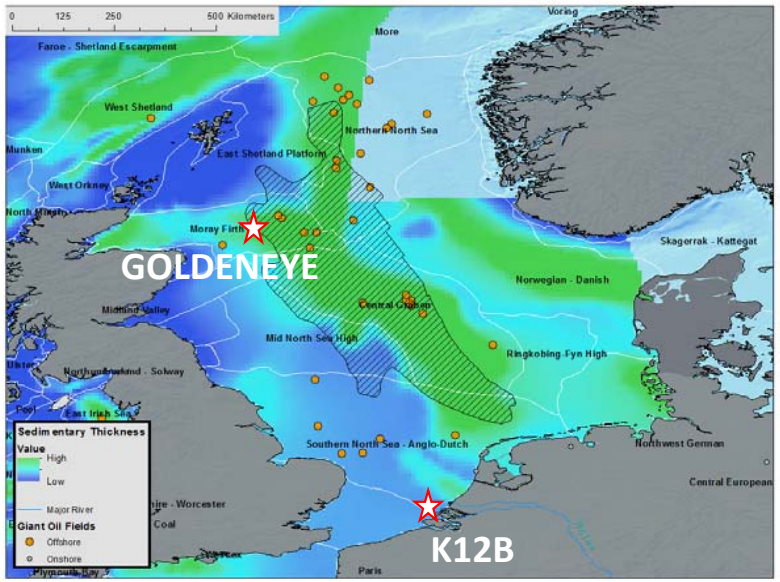


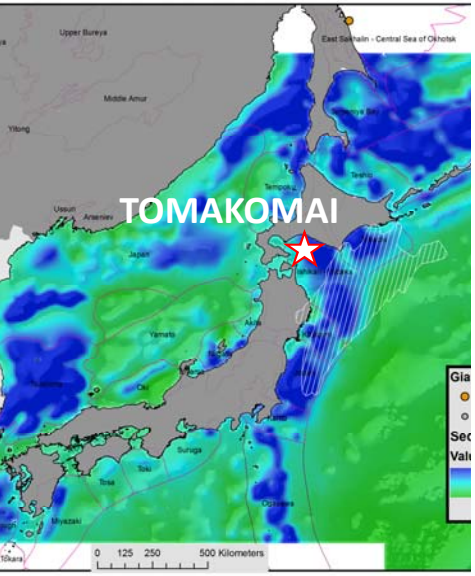

0 125 250 500 Kilometers
North Louisiana Salt
Black Warrior
Mississippi Salt
East Texas Salt
Northeast Gulf Salt
LA
TX
Kerr
Midland - Permian
East Gulf Coast Tertiary
South Texas Salt Dome
West Gulf Coast Tertiary
Tampa
West Florida
South Florida
Sabinas - Rio Grande
Vermillion Block; Tiger Shoal
1,500 MMBOE EUR
Miocene clastics
North Cuba
Yucatan Platform
Tampico
Salinas - Sureste
Veracruz
DSDP Wells
Sedimentary Thickness
FEET
0 - 5,000
5,000 - 6,000
6,000 - 7,000
7,000 - 8,000
Major River
Giant Oil Fields
Offshore
Onshore


0 125 250 500 Kilometers
CHINA
San Shui
Shiwan - Dashan
Qinzhou
Maoming
Taiwan
185,000 sq km
Pearl River Mouth
Beibu Gulf
West Hainan
Bijia
Shuangfeng
Cagayan
Liwan 3-1 Field, Baiyun Sag
4-6 Tcf
Oligocene/Miocene clastics
55 sq km closure
36 m net gas pay
Bac Bo - Yinggehai
Qiongdongnan
Xisha
Ilocos Trough
Greater Khorat
Zhongsha Plateau
Bicol Shelf
West Luzon
ODP Wells
Sedimentary Thickness
Value
High
Low
Pearl_River_Basin
Giant Oil Fields
Offshore
Onshore
Phu Khanh
North Palawan
Mindoro
South Palawan
Nab Sha
Cuu Long
Cuu Long


500 Kilometers
San Shui
Maoming
Pearl River Mouth
Bijia
Shuangfeng
Qiongdongnan
Xisha
Zhongsha Plateau
Phu Khanh
Nab Sha
South Palawan


0 125 250 500 Kilometers
North Louisiana Salt
Black Warrior
Mississippi Salt
East Texas Salt
Northeast Gulf Salt
Kerr
Midland - Permian
South Texas Salt Dome
East Gulf Coast Tertiary
West Gulf Coast Tertiary
Tampa
West Florida
South Florida
Salinas - Rio Grande
Yucatan Platform
Tampico
Veracruz
Salinas - Sureste
North Cuba
DSDP Wells
Sedimentary Thickness
FEET
0 - 5,000
5,000 - 6,000
6,000 - 7,000
7,000 - 8,000
Major River
Giant Oil Fields
Offshore
Onshore


0 125 250 500 Kilometers
Faroe - Shetland Escarpment
West Shetland
East Shetland Platform
Northern North Sea
West Orkney
Moray Firth
GOLDENEYE
Skagerrak - Kattegat
Norwegian - Danish
Central Graben
Mid North Sea High
Ringkobing Fyn High
Southern North Sea - Anglo-Dutch
Northwest German
Central European
K12B
Paris
Sedimentary Thickness
Value
High
Low
Major River
Giant Oil Fields
Offshore
Onshore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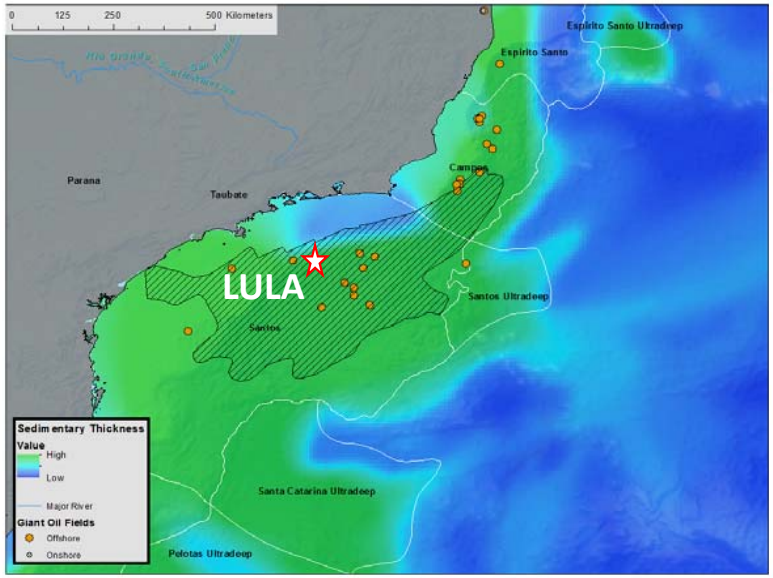
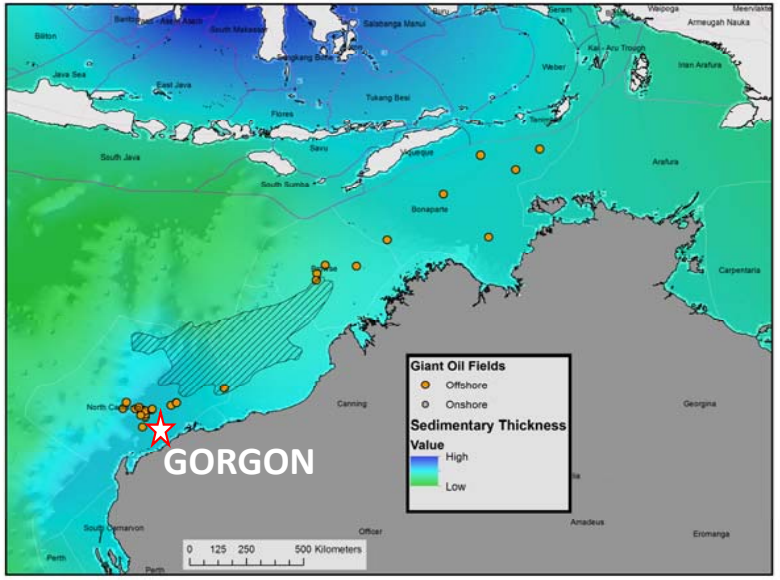
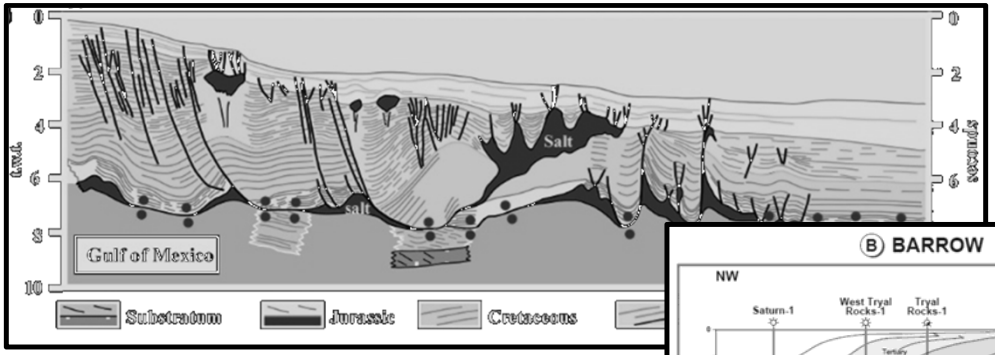
East Sakhalin - Central Sea of Okhotsk
Middle Amur
Japan
0 125 250 500 Kilometers

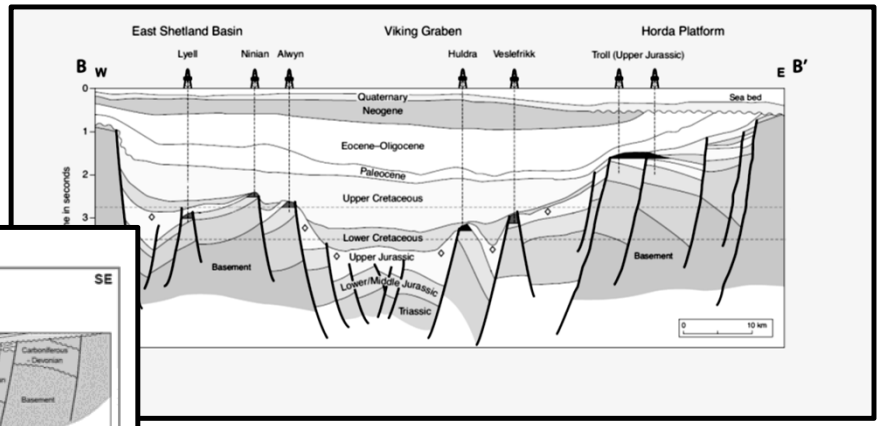

0 125 250 500 Kilometers
Espirito Santo Ultradeep
Espirito Santo
Parana
Taubate
Campos
LULA
Santos Ultradeep
Santos
Santa Catarina Ultradeep
Pelotas Ultradeep
Sedimentary Thickness
Value
High
Low
Major River
Giant Oil Fields
Offshore
Onshore


GORGON
Giant Oil Fields
Offshore
Onshore
Sedimentary Thickness
Value
High
Low
0 125 250 500 Kilometers

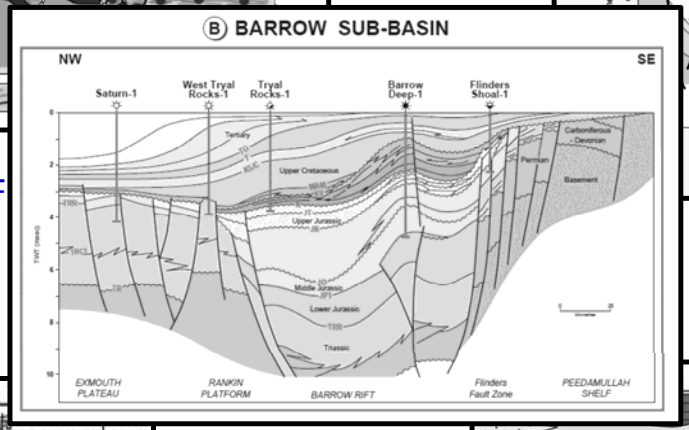
USA: GULF OF MEXICO



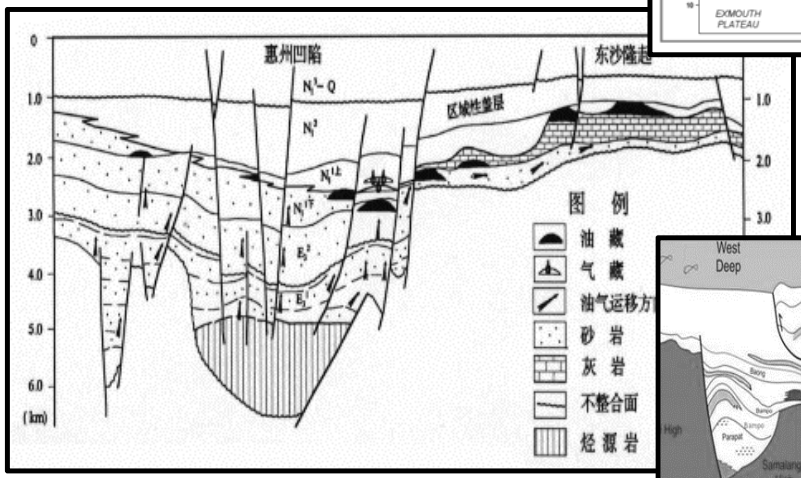
EUROPE: NORTH SEA



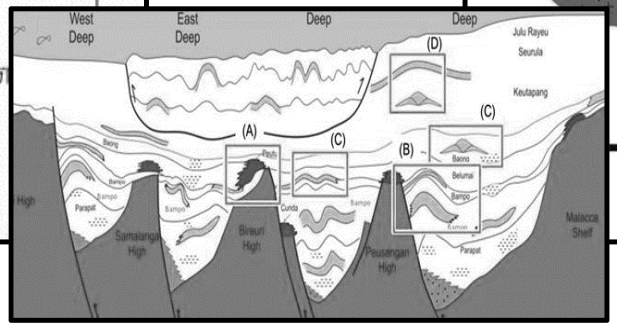
AUSTRALIA: NW SHELF



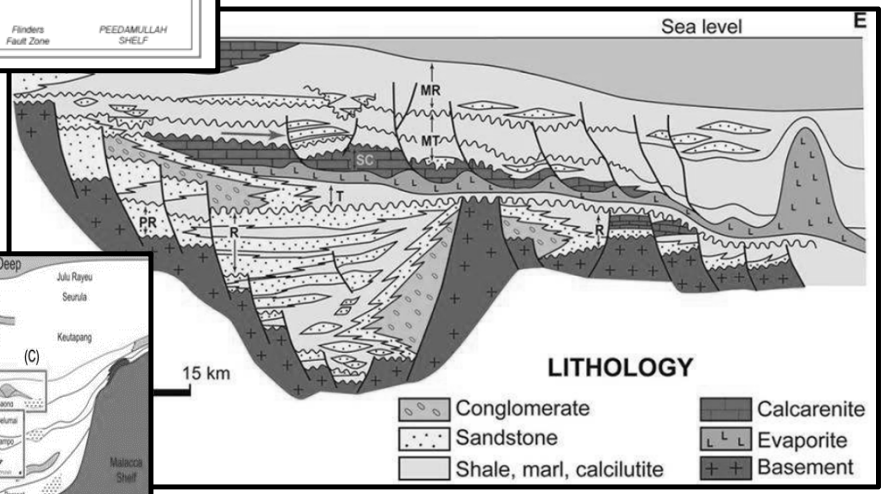
CHINA: PEARL RIVER MOUTH BASIN



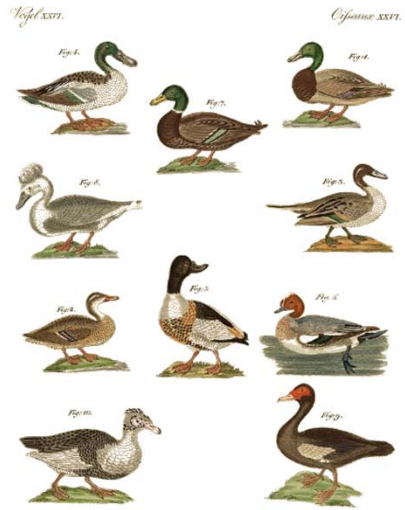
MALAYSIA



BRASIL: CAMPOS BASIN



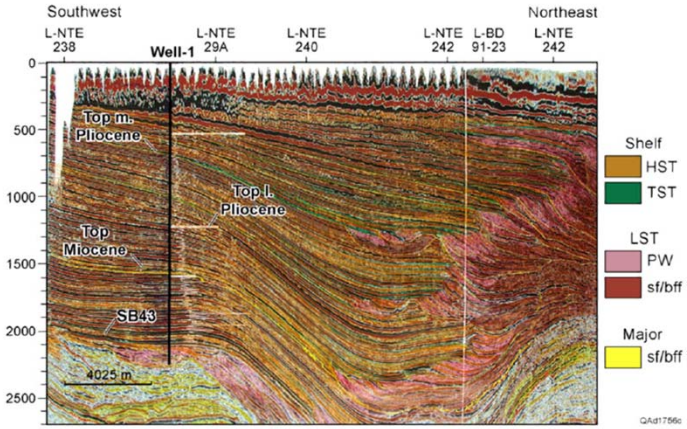
Geologic Similarities/Differences

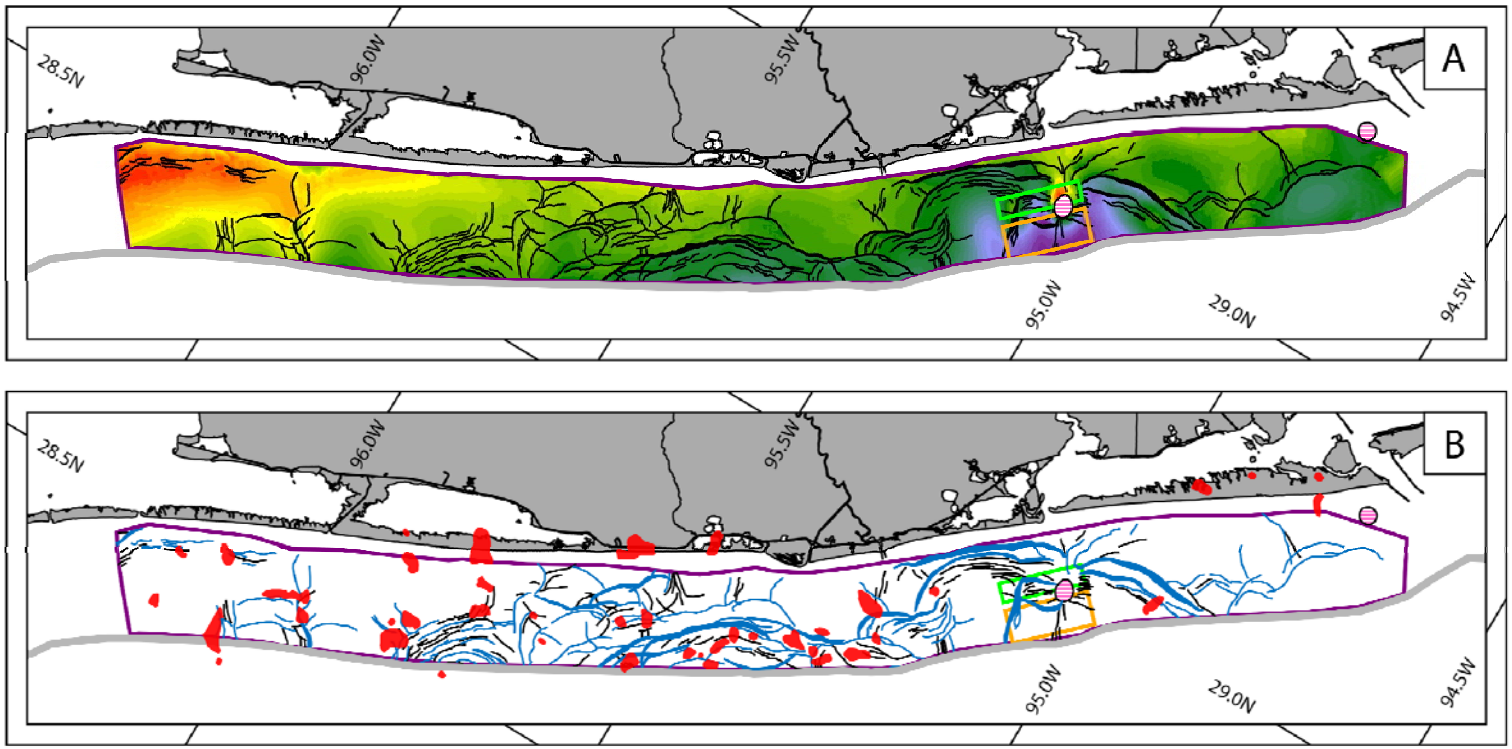


- Deeper rift sequence (‘CCS Basement’) overlain by prograding fluvial/deltaic/shelf systems.
  - Thick, sand-prone (+/- CO_3), young (limited diagenesis?)
- Regional unconformities, flooding surfaces (Global vs. relative SL change)
- Basement faults, overburden growth structures.
  - Fault seal, migration routes.
- Subsidence history: monotonic, punctuated, uplift?
  - Compaction, fluid pressure
- Provenance (sediment composition)

Basin Petroleum Systems and CCS

- Broad indication of basin fluid performance (if charged)
  - Reservoirs, faults, topseals, migration routes.
- Sequence Stratigraphy effective ‘tool’ for understanding basin geology.
- The question of rates: geologic vs. engineered.
  - North Sumatra Basin or Gulf of Mexico?
- Engineering: Re-commissioning of infrastructure
  - Best for HC = best for CCS?
- Hazards of generalizing
- Reservoirs vs. <u>Overburden</u>





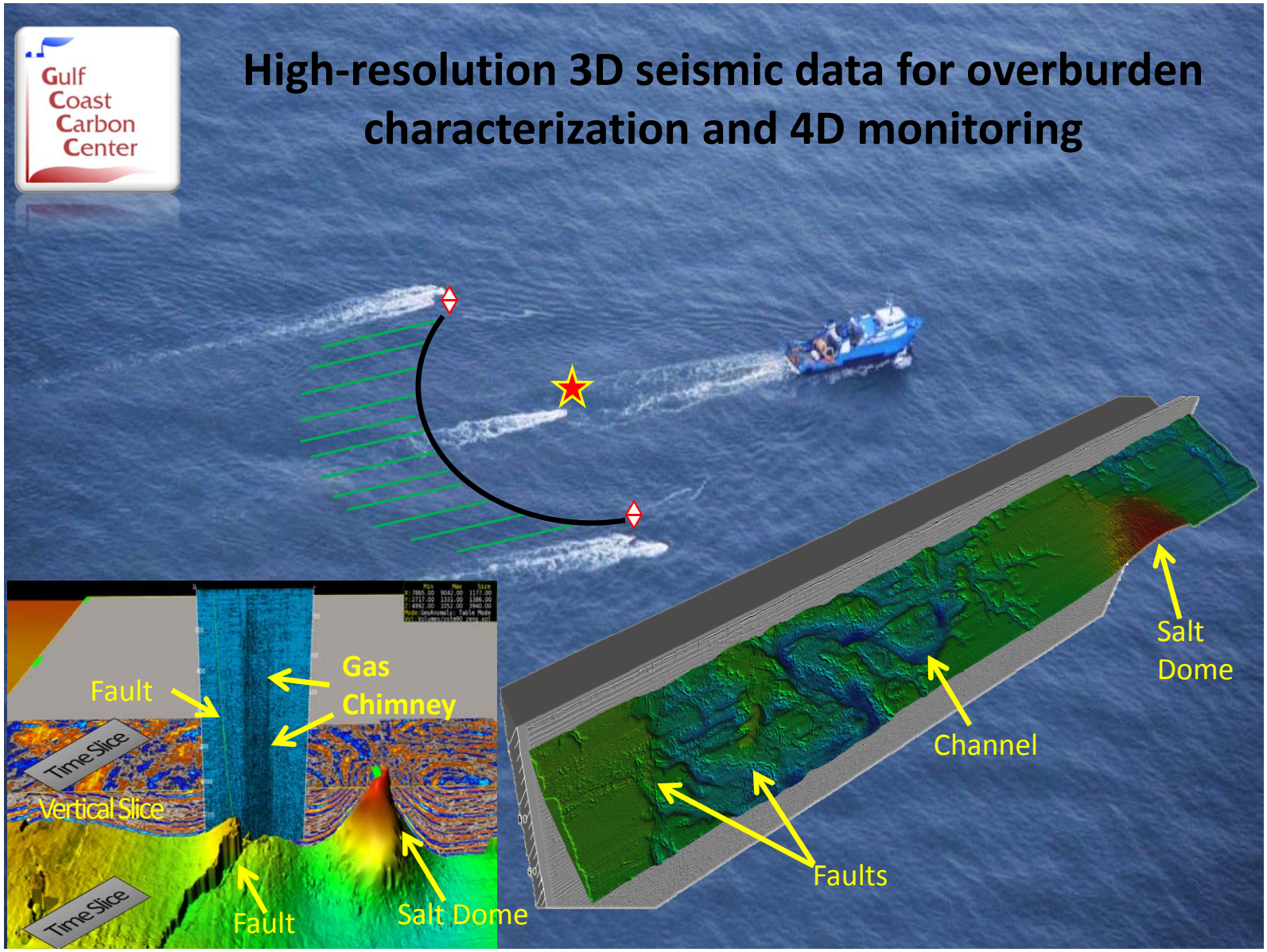
Key to Geologic Features and Symbols

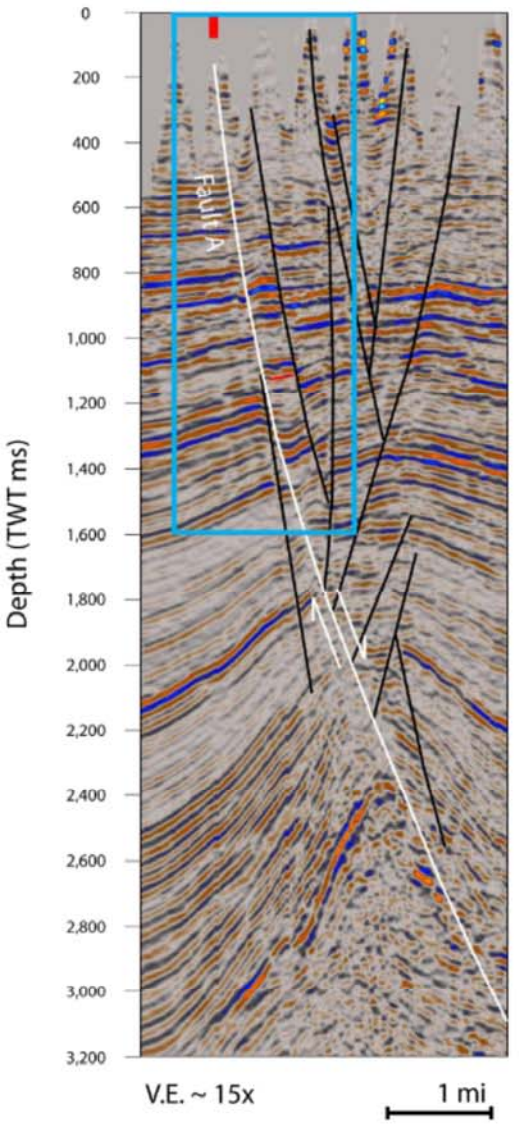
- Texas State Water Boundary
- SEI Offshore Texas OBS 3-D Seismic Data
- 2012 HR3D Data
- 2013 HR3D Data
- Lower Miocene Gas Fields
- Salt Dome
- Fault
- Near-Surface Fault (< 300 ms)

1.4
2.4
Top Lower Miocene 2 Depth (s)

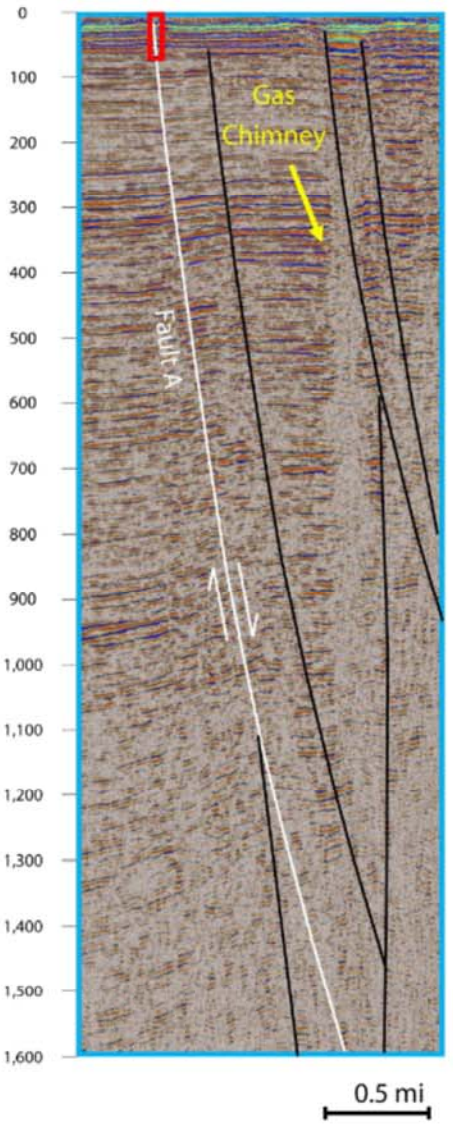
N
TEXAS

30 mi

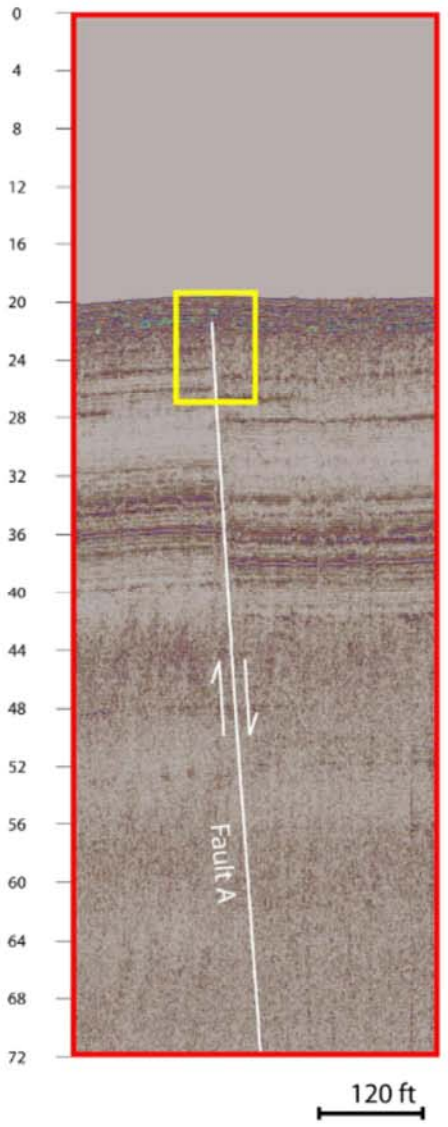

Gulf Coast Carbon Center
High-resolution 3D seismic data for overburden characterization and 4D monitoring
Fault
Gas Chimney
Time Slice
Vertical Slice
Time Slice
Fault
Salt Dome
Salt Dome
Channel
Faults



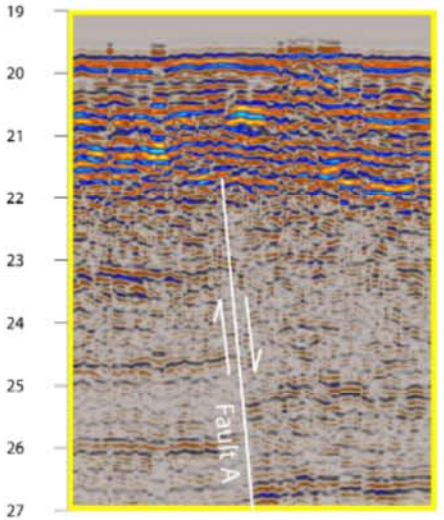
Texas Offshore OBS 3-D



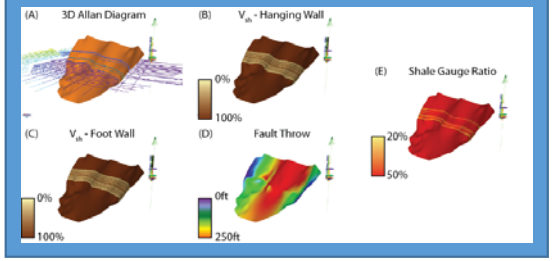
GCCC P-Cable 3-D



UT CHIRP 2-D



Data forces us to think very hard about things like faults



Focus needs to be on capacity assessment, knowledge transfer, and *deployment of demonstration- and industrial-scale projects*.

SNOHVIT

THIS WORKSHOP!

GCCC GULF COAST CARBON CENTER

sonedi

ieaghg

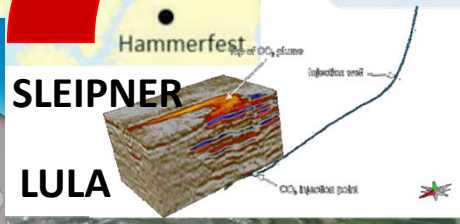
International Workshop on Offshore Geologic CO_2 Storage

CTCN CLIMATE TECHNOLOGY CENTRE & NETWORK

carbon sequestration leadership forum

PORT ARTHUR, USA

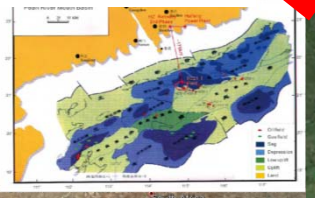
GORGON



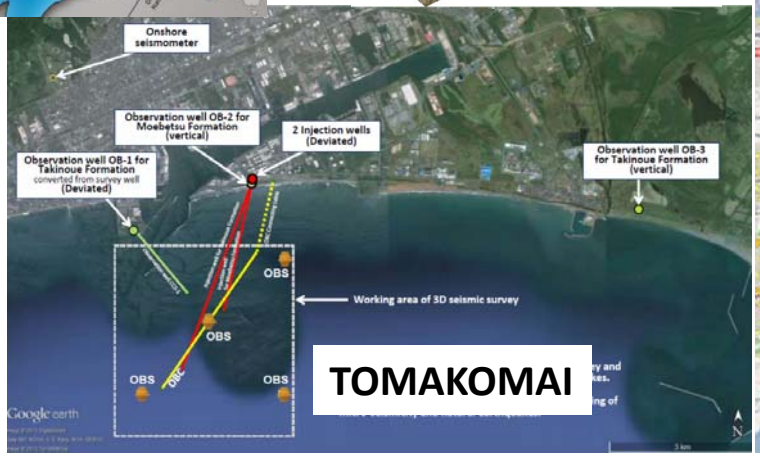
SLEIPNER

LULA

GUANGDONG



SOUTH AFRICA



TOMAKOMAI

Three motivating messages:

1. **For CCS to be a technology with significant atmospheric benefit on desired timelines, rapid and broad global deployment needed.**
   - **6 Gt by 2050 (6,000 'Sleipners')**
   - **2/3 of CCS potential will need to come from non-OECD countries (IEA)**
   - **Natural gas likely to be associated with many projects.**

2. **The global offshore continental shelves broadly represent the largest near-term storage for Gigaton-scale CCS.**
   - **CCS 'sweet spots' – source-sink match, ownership; thick, sand-prone, young (ductile seals), low stress.**
   - **How assess storage potential?**
3. **Focus needs to be on capacity assessment, knowledge transfer, and *deployment of demonstration- and industrial-scale projects*.**
   - **This workshop!**