Contrasting Styles of San Andres Reservoirs: Vacuum Versus Slaughter Fields, Middle Permian, West Texas and Southeast New Mexico*

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Abstract

Vacuum and Slaughter Fields contain two major San Andres (Middle Permian) reservoirs in west Texas and southeast New Mexico. Both are dolomitized. Vacuum has produced more than 355 million barrels of oil and Slaughter more than 1200 million barrels of oil (Koperna and Kuuskraa, 2006). However, the reservoirs are very different in their:

(1) paleogeographic position,
(2) stratigraphic position within the San Andres,
(3) internal reservoir geometries, and
(4) pore types and permeability.

Vacuum occurs at the San Andres shelf margin, whereas Slaughter is in the shelf interior. The San Andres Formation is ~1400 feet thick, and the main oil column in Vacuum is in the upper 500 feet of the San Andres; by contrast,the oil column in Slaughter is in the middle part of the San Andres, 450-750 feet below the top San Andres. The upper San Andres is dominated by nonporous, lagoonal evaporites at Slaughter. At Vacuum, the best reservoir is in basinward-prograding, oolitic grainstones, whereas the Slaughter reservoir is dominated by relatively flat-lying, burrowed wackestones and packstones. Molds, intercrystalline and intergranular pores are present at Vacuum, whereas Slaughter is dominated by small intercrystalline pores. Average porosity in the Vacuum reservoir is ~7.4% with permeability commonly varying from 1-100 mD. Slaughter has higher average porosity (~11%), and more uniform, but lower permeability, generally 0.2-30 mD. As a result, the two fields have different production characteristics.

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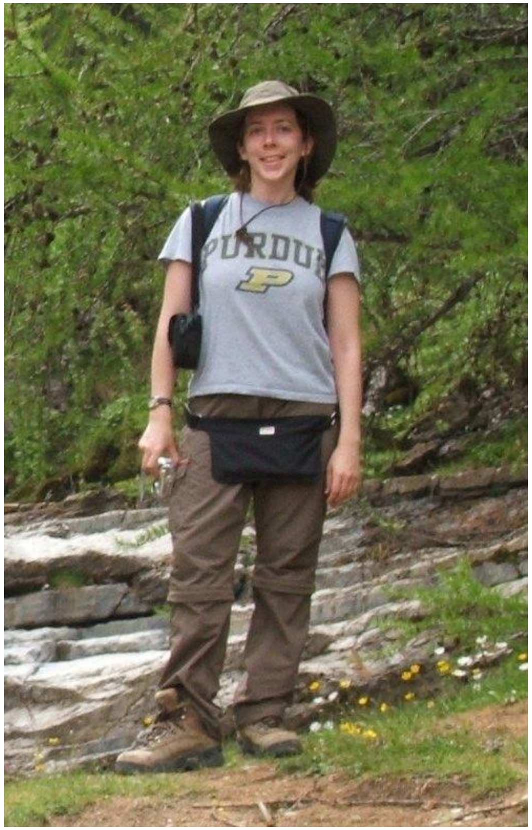


Lauren Bierly

Leigh Owens @ Algerita

Contrasting Styles of San Andres Reservoirs:
Vacuum Versus Slaughter San Andres Fields

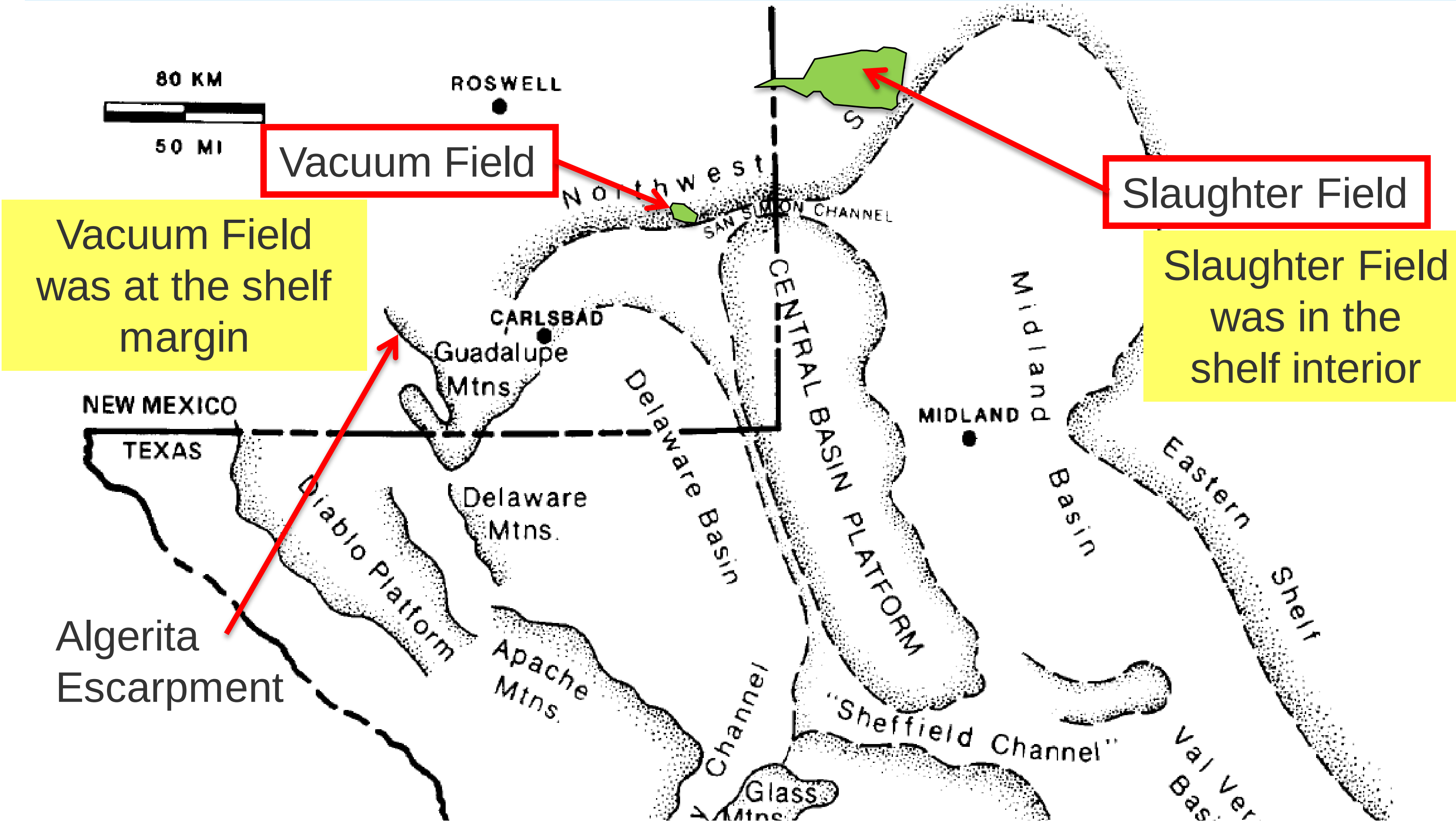
- San Andres reservoirs have produced >10 Billion barrels of oil (Dutton et al., 2005) with recovery efficiencies generally <40%*
- San Andres reservoirs at Vacuum & Slaughter are both Middle Permian dolomites with minor anhydrite
- Vacuum has produced >355 million barrels of oil*
- Slaughter has produced >1,200 million barrels of oil*
- The purpose of this presentation is to contrast these two fields relative to:
  - Paleogeographic position
  - Stratigraphic position within the San Andres
  - Internal reservoir geometries
  - Porosity
  - Pore types & permeability

* These production numbers are for the whole field (from Advanced Resources International, DOE Report [2006]). This talk will use geological data from Chevron operated units within those fields.

Comparison of Vacuum & Slaughter San Andres Fields

Vacuum Field	Slaughter Field
Paleogeographic Position	
Shelf Margin	Shelf Interior
Position within San Andres	
Upper	Middle
Reservoir Geometries	
Inclined/ Shingled	Parallel Layers
Porosity	
Variable (1-20%)	More Consistent (5-20%)
Pore Types & Permeability	
Many types; 0.01-1,000 mD	Mainly intercrystalline, some moldic; 5-40 mD

Paleogeographic Positions of Vacuum & Slaughter Fields



From: Ward, R.F., C.G. St. C. Kendall, Paul M. Harris, 1986, Upper Permian (Guadalupian) Facies and Their Association with Hydrocarbons--Permian Basin, West Texas and New Mexico: AAPG Bulletin, v. 70, p. 239-262,

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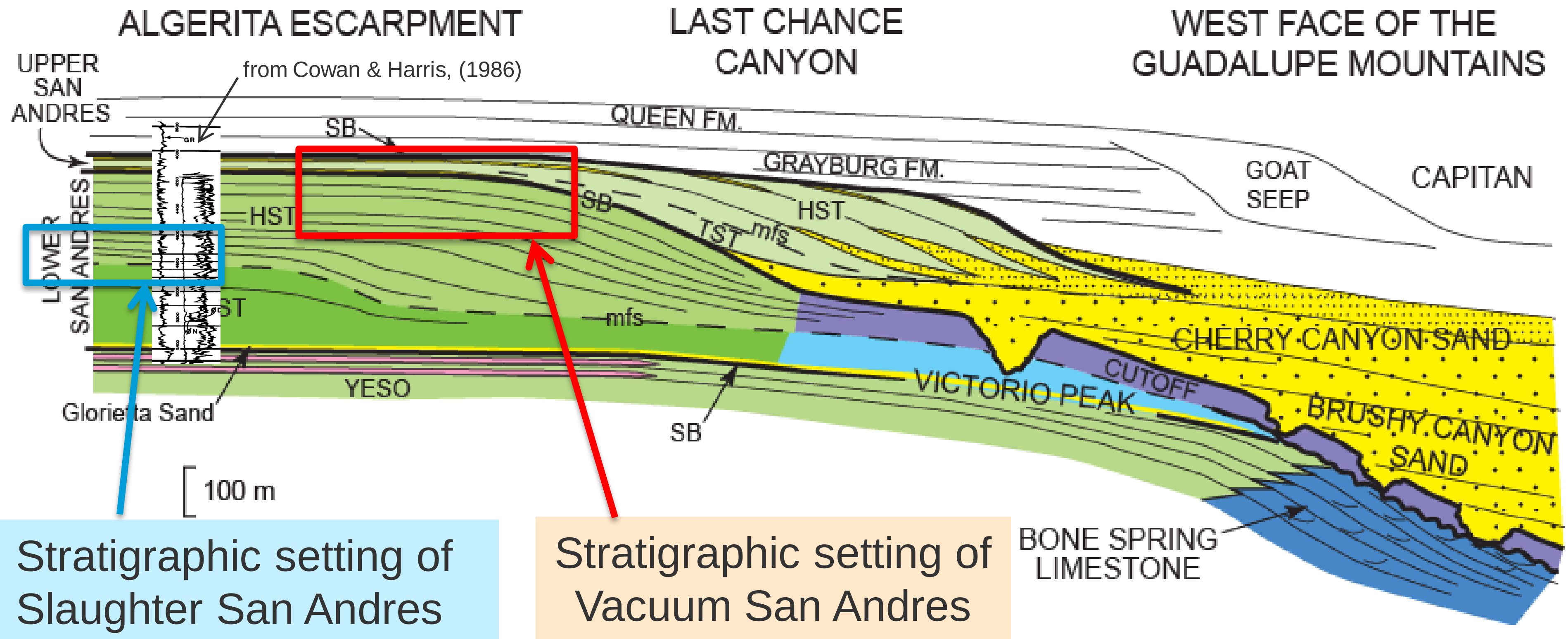
Reservoir Stratigraphy of Vacuum & Slaughter Fields

- San Andres Formation is ~1400 feet thick
- Vacuum: Main oil column in the upper 500 feet of the San Andres
- Slaughter: Main oil column in the middle part of the San Andres, 450-750 feet below the top San Andres
- Vacuum: Best reservoir is in basinward-prograding oolitic grainstones
- Slaughter: Upper San Andres is dominated by nonporous, lagoonal evaporites (not reservoir)
- Slaughter: Reservoir is dominated by relatively flat-lying burrowed wackestones and packstones

Stratigraphic Position of Vacuum & Slaughter Fields:
Relative to Outcrops in the Guadalupe Mountains



- San Andres Formation is ~1400 feet thick
- Vacuum oil column is ~ upper 500 feet of the San Andres
- Slaughter oil column in the middle San Andres, 450-750 feet below the top San Andres
- At Slaughter, the upper 450 feet of San Andres is dominated by nonporous, lagoonal evaporites & tidal flats

Well log is from Cowan, P.E., and P. M. Harris, 1986, Porosity Distribution in San Andres Formation (Permian), Cochran and Hockley Counties, Texas: AAPG Bulletin, v. 70, p. 888-897.
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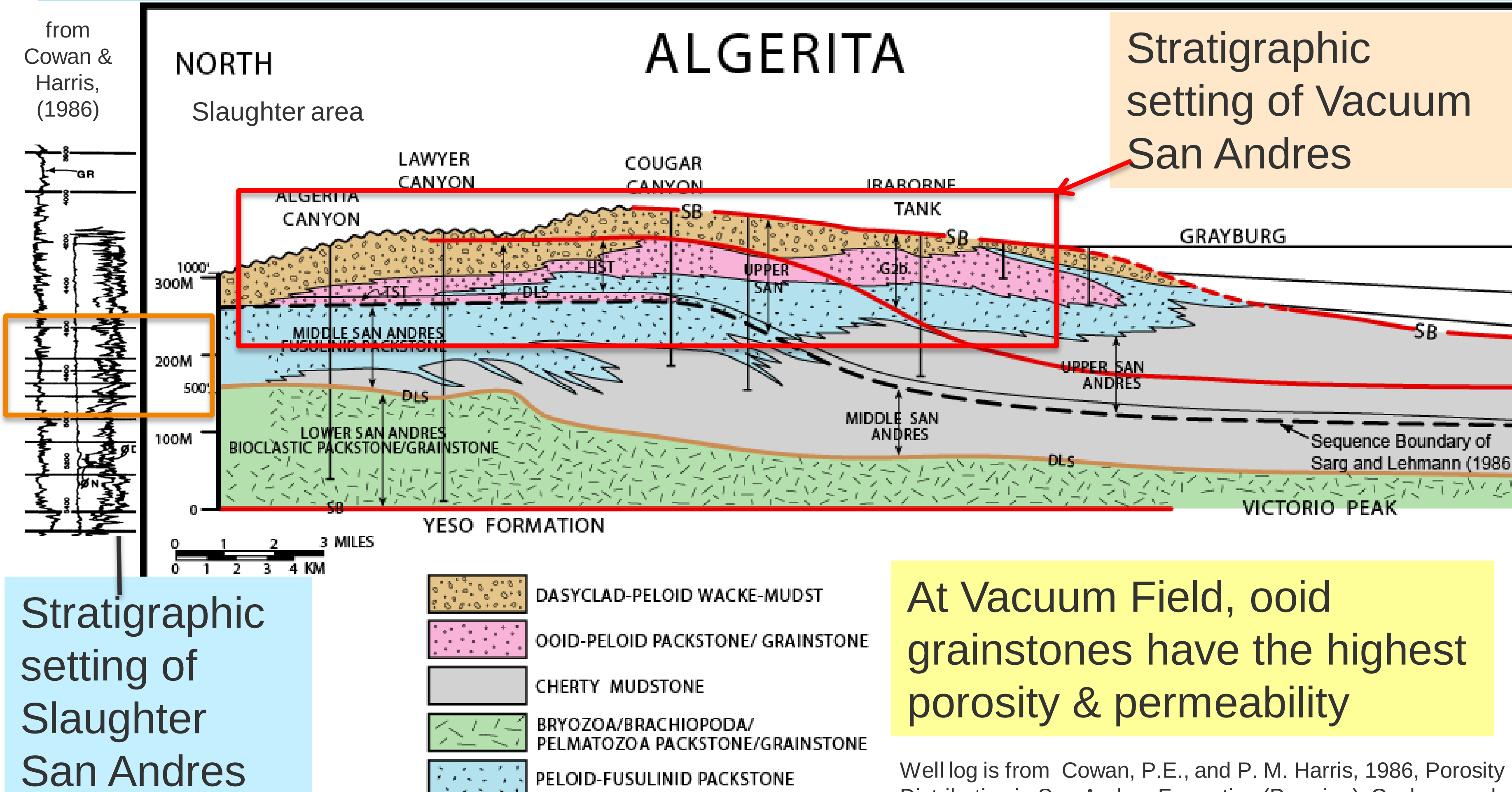
Stratigraphic Setting of Vacuum & Slaughter Fields relative to Outcrops on Algerita Escarpment, Guadalupe Mountains



Stratigraphic setting of Vacuum San Andres

Stratigraphic setting of Slaughter San Andres

At Vacuum Field, ooid grainstones have the highest porosity & permeability

Modified from Kerans, C., F.J. Lucia, and R.K. Senger, 1994, Integrated characterization of carbonate ramp reservoirs using Permian San Andres Formation outcrop analogs: AAPG Bulletin, v. 78, p. 181-216.

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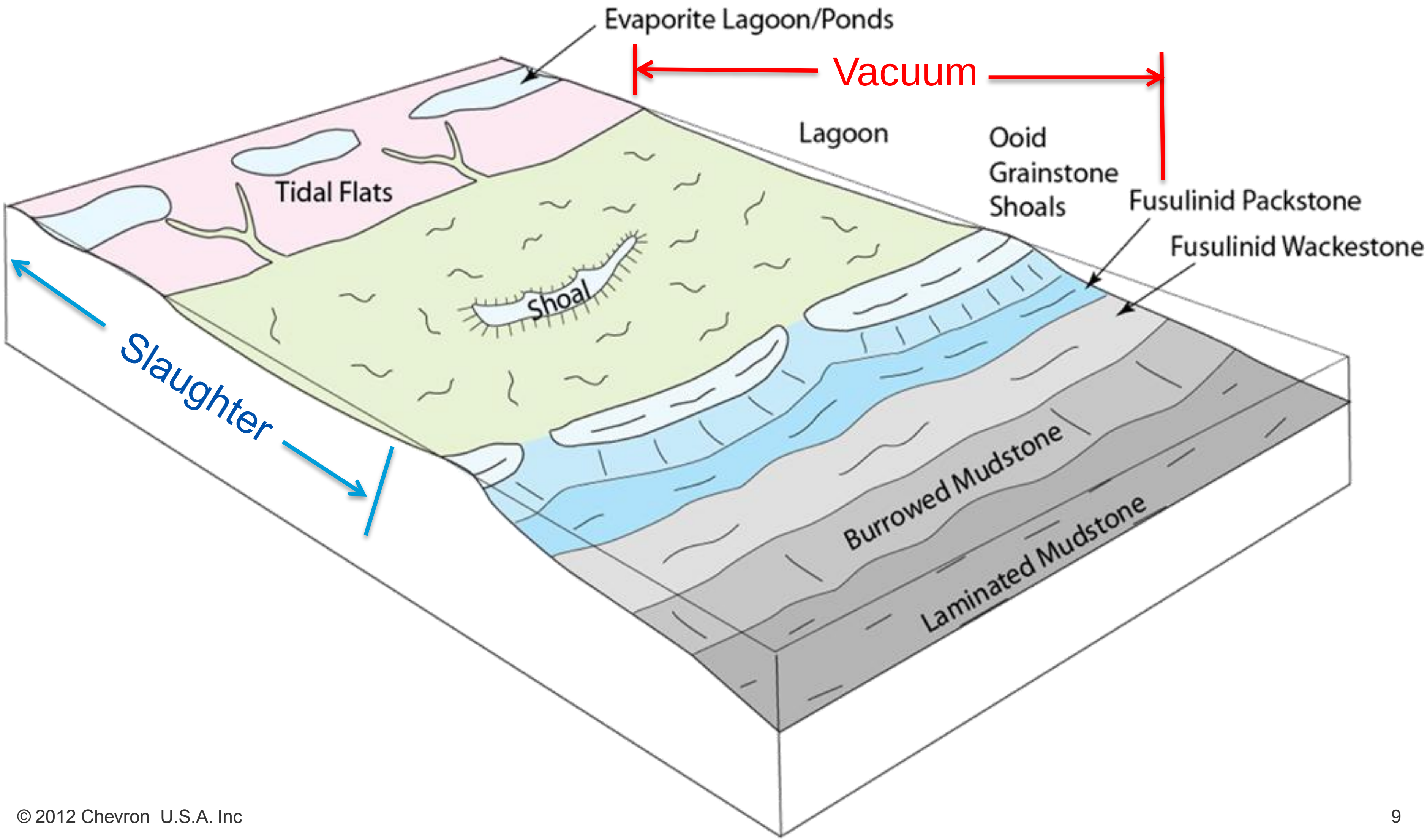
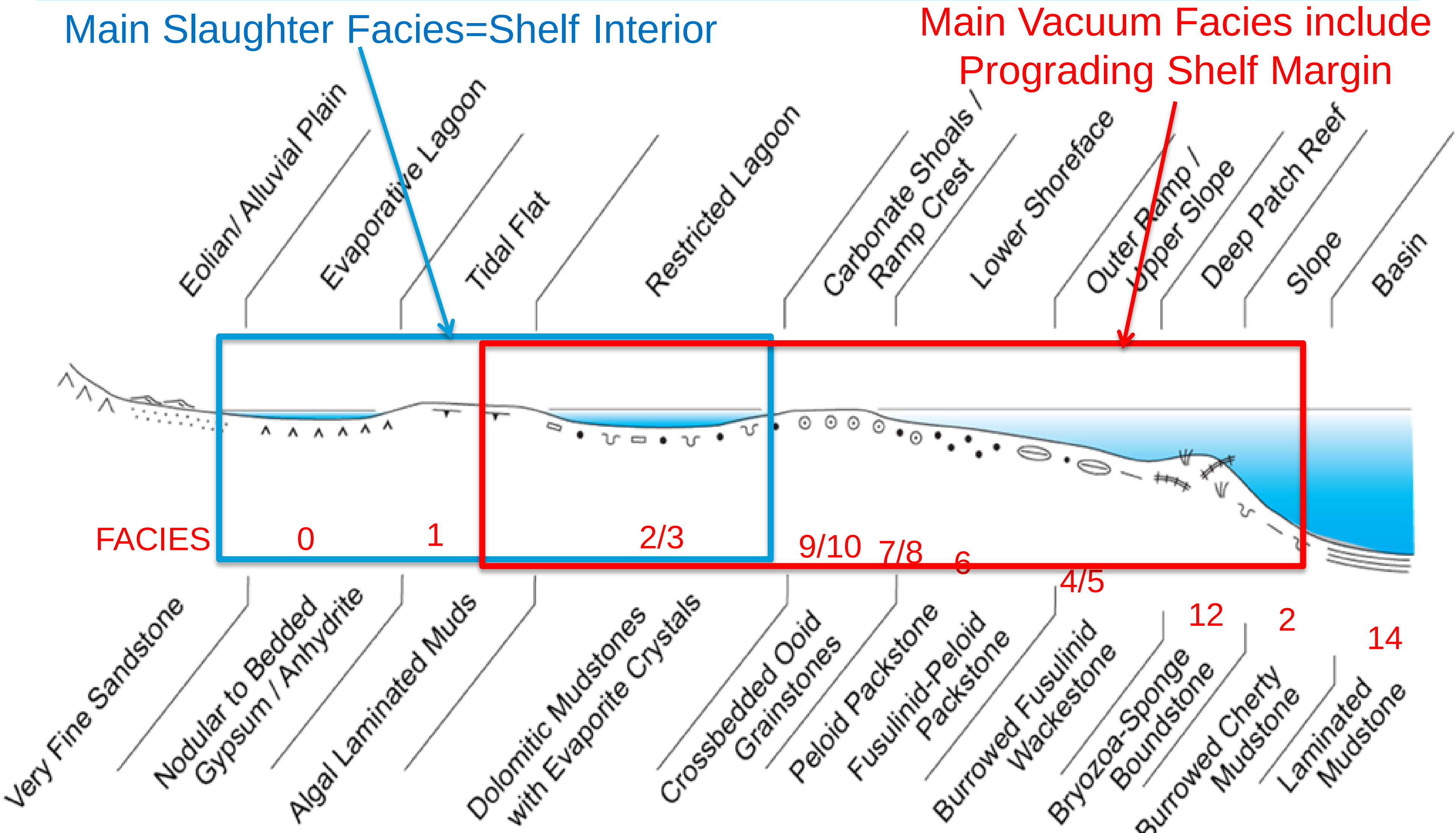
San Andres Depositional Model



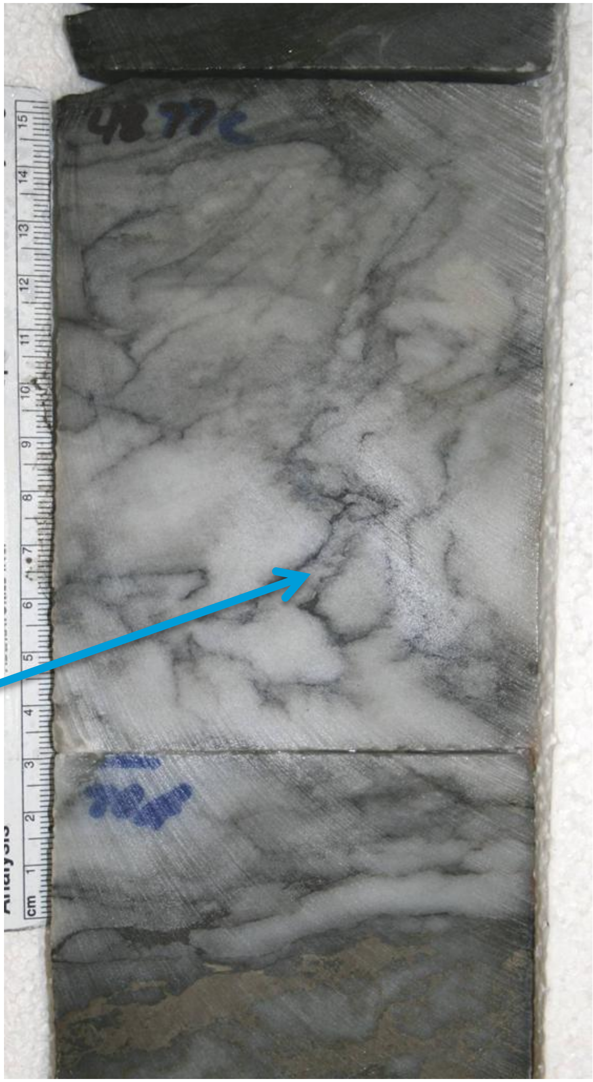
Reservoir Geometries Related to:
Paleogeographic Position & Associated Depositional Environments



Slaughter Field:
Facies 0. Anhydrite

- Depositional Environment: Saline lagoons & tidal flats
- Average Porosity: 3.1%
- Average Permeability: 0.2 mD
- Percent of Core Interval: 13%
- Amount of this Facies with >1 mD: 7.7%
- Percent Reservoir Rock (>1 mD): 0.1%

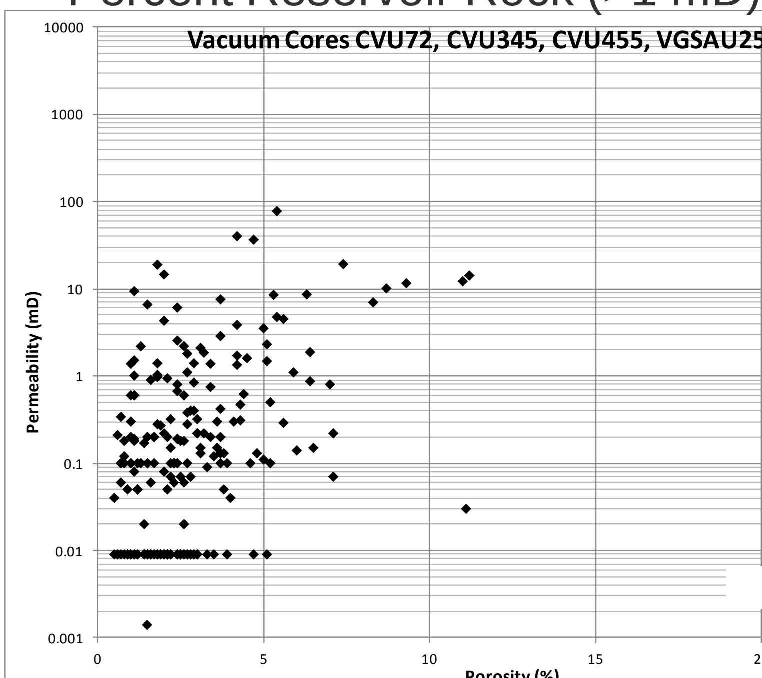
Vertical elongation formed by Recrystallized gypsum that precipitated on the floor of an evaporitic pond or lagoon



Vacuum Field

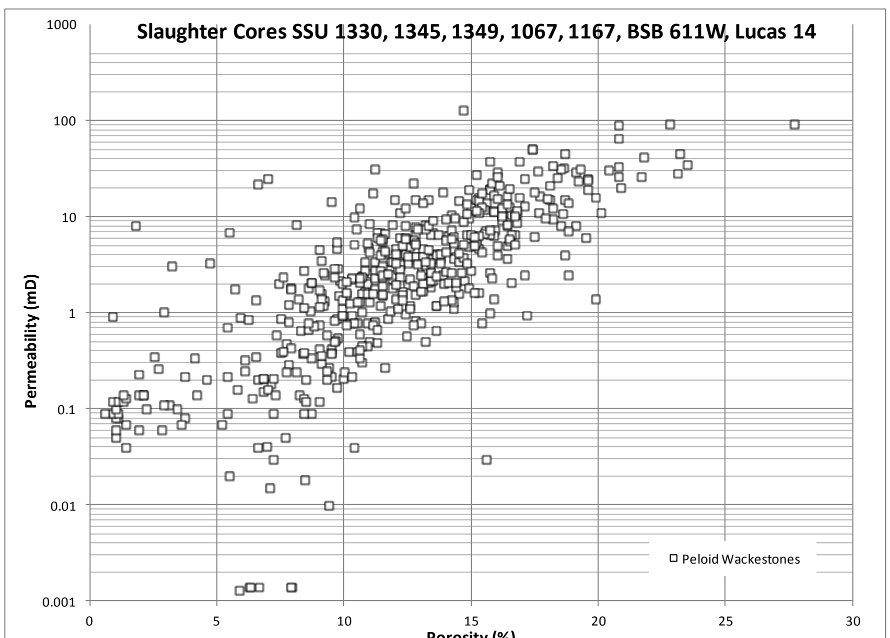
Facies 1. Laminated Mudstones, Wackestones, & Packstones

- Depositional Environment: Tidal Flats
- Average Porosity: 3.09%
- Average Permeability: 1.86 mD
- Percent of Core Interval: 12.2%
- Amount of this Facies with >1 mD: 11%
- Percent Reservoir Rock (>1 mD): 3%

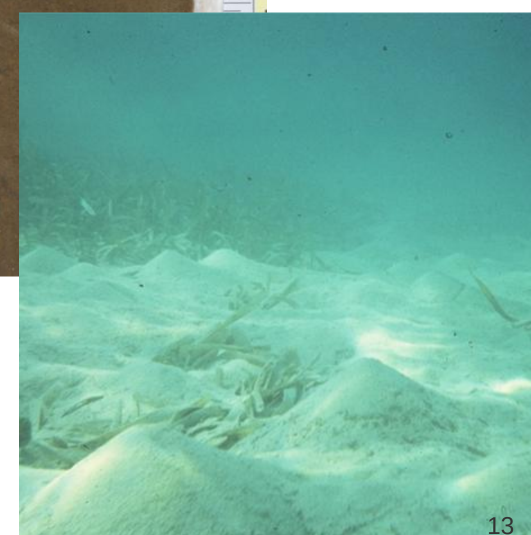


Slaughter Field:
Facies 3. Burrowed Peloid Wackestone-Packstone

- Depositional Environment: Restricted subtidal (below wave base)
- Average Porosity: 11.9%
- Average Permeability: 6.7 mD
- Percent of Core Interval: 35.4%
- Amt of this Facies with >1 mD: 70.8%
- Percent Reservoir Rock (>1 mD): 41.1%

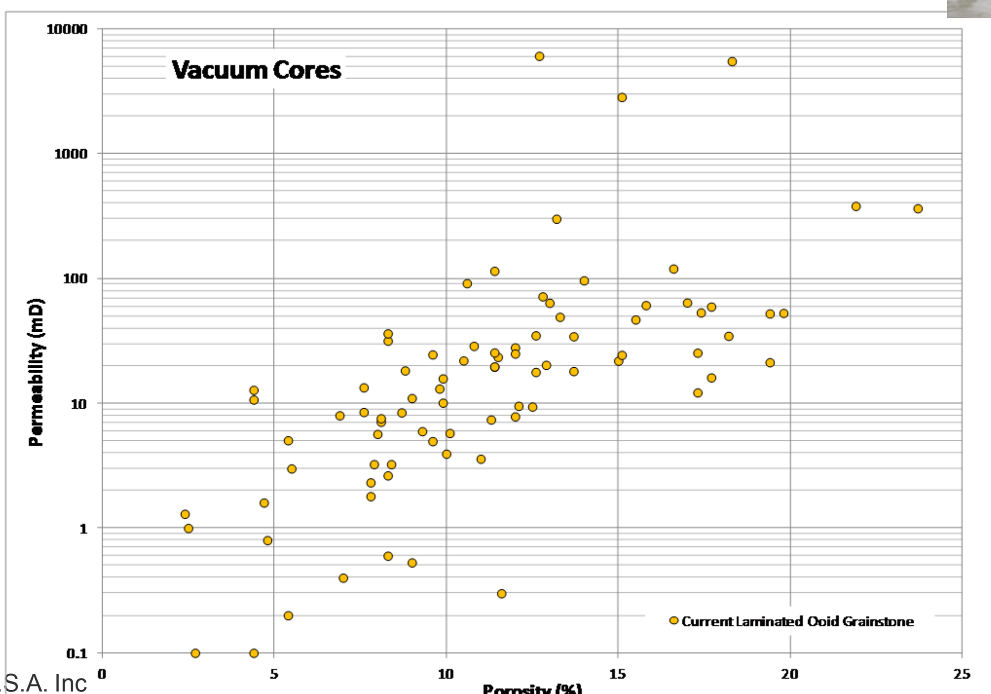


Burrows



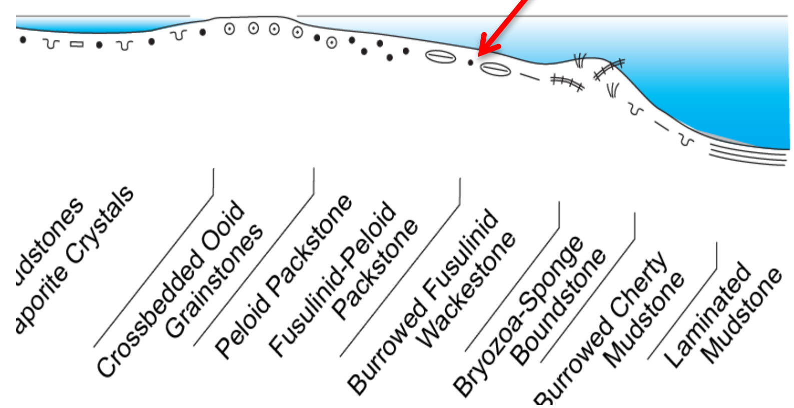
Vacuum Field:
Facies 10. Current-laminated Ooid Grainstone

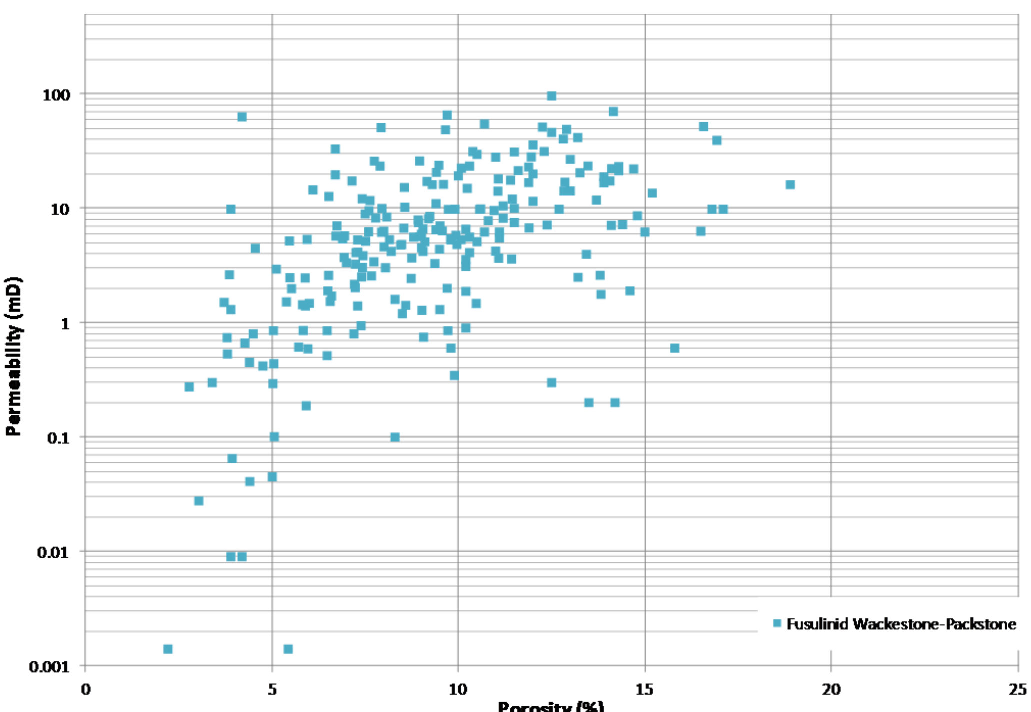
- Depositional Environment: Active shoal
- Average Porosity: 10.1%
- Average Permeability: 33.6 mD
- Percent of Core Interval: 6.4% (All Grnst ~25%)
- Amount of this Facies with >1 mD: 86%
- Percent Reservoir Rock (>1 mD): 9%

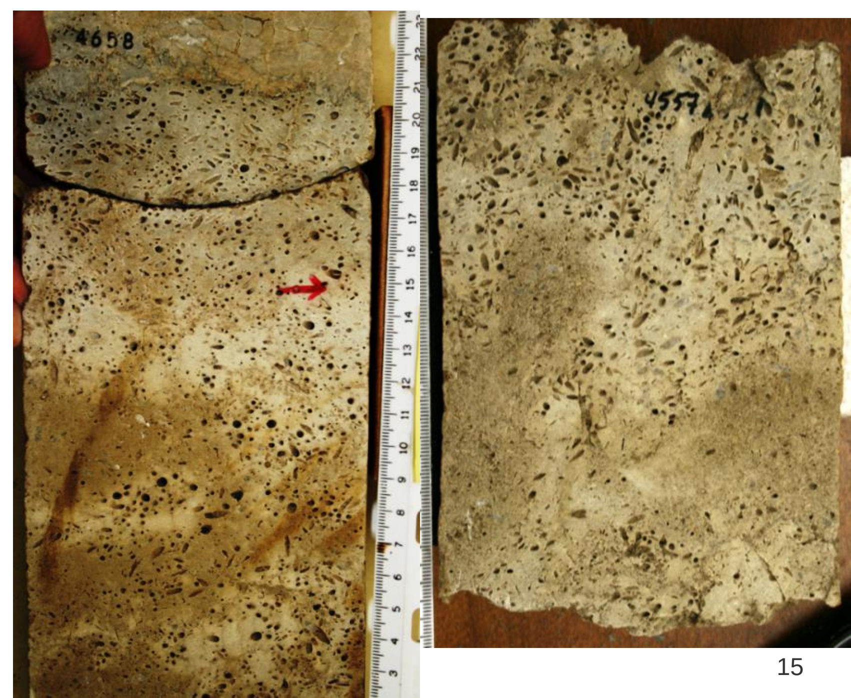


Vacuum Field:
Facies 5. Burrowed Fusulinid Wackestone-Packstone

- Dep. Environ: Open, low-energy subtidal
- Average Porosity: 9.5%
- Average Permeability: 11.2 mD
- Percent of Core Interval: 17.4%
- Amount of this Facies with >1 mD: 82%
- Percent Reservoir Rock (>1 mD): 23%

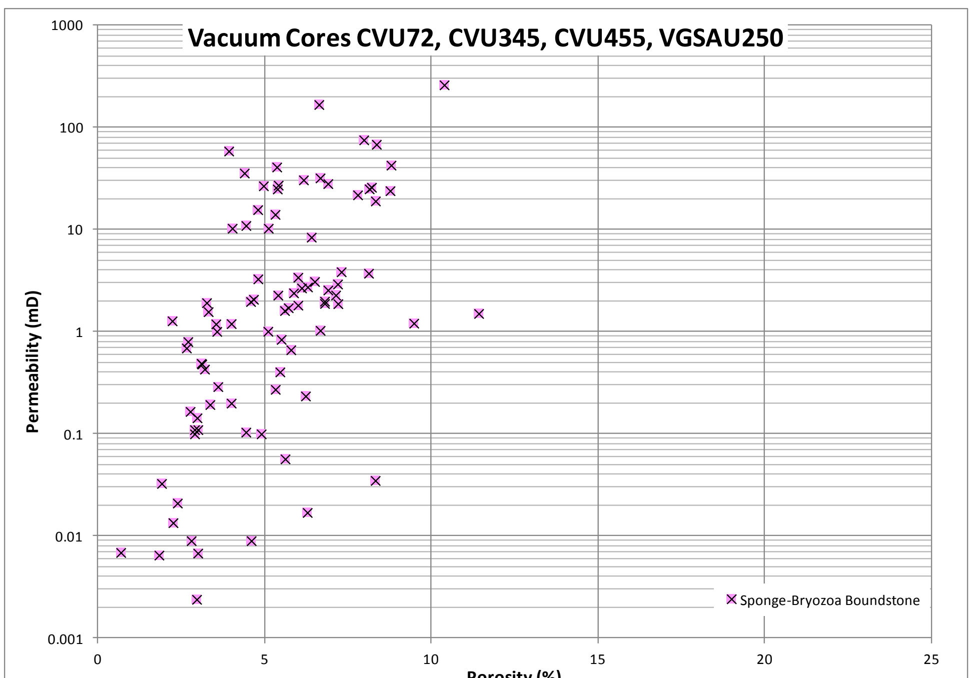


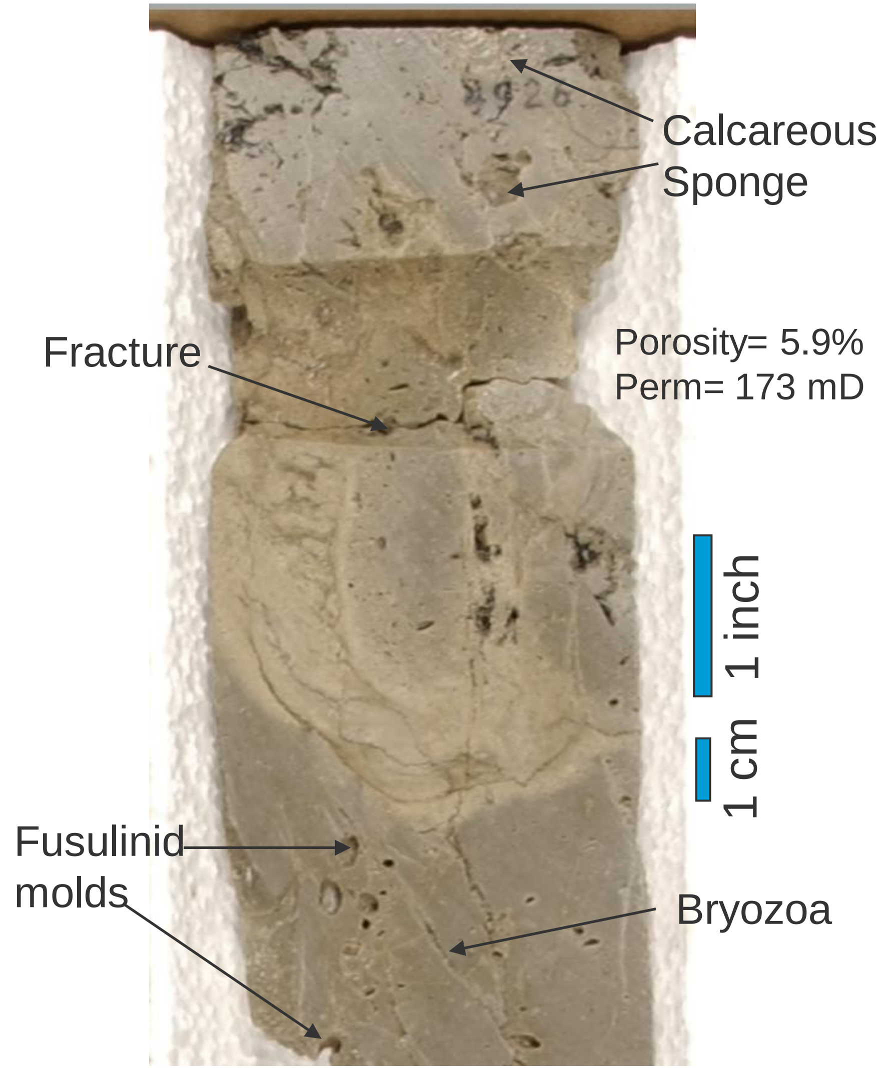




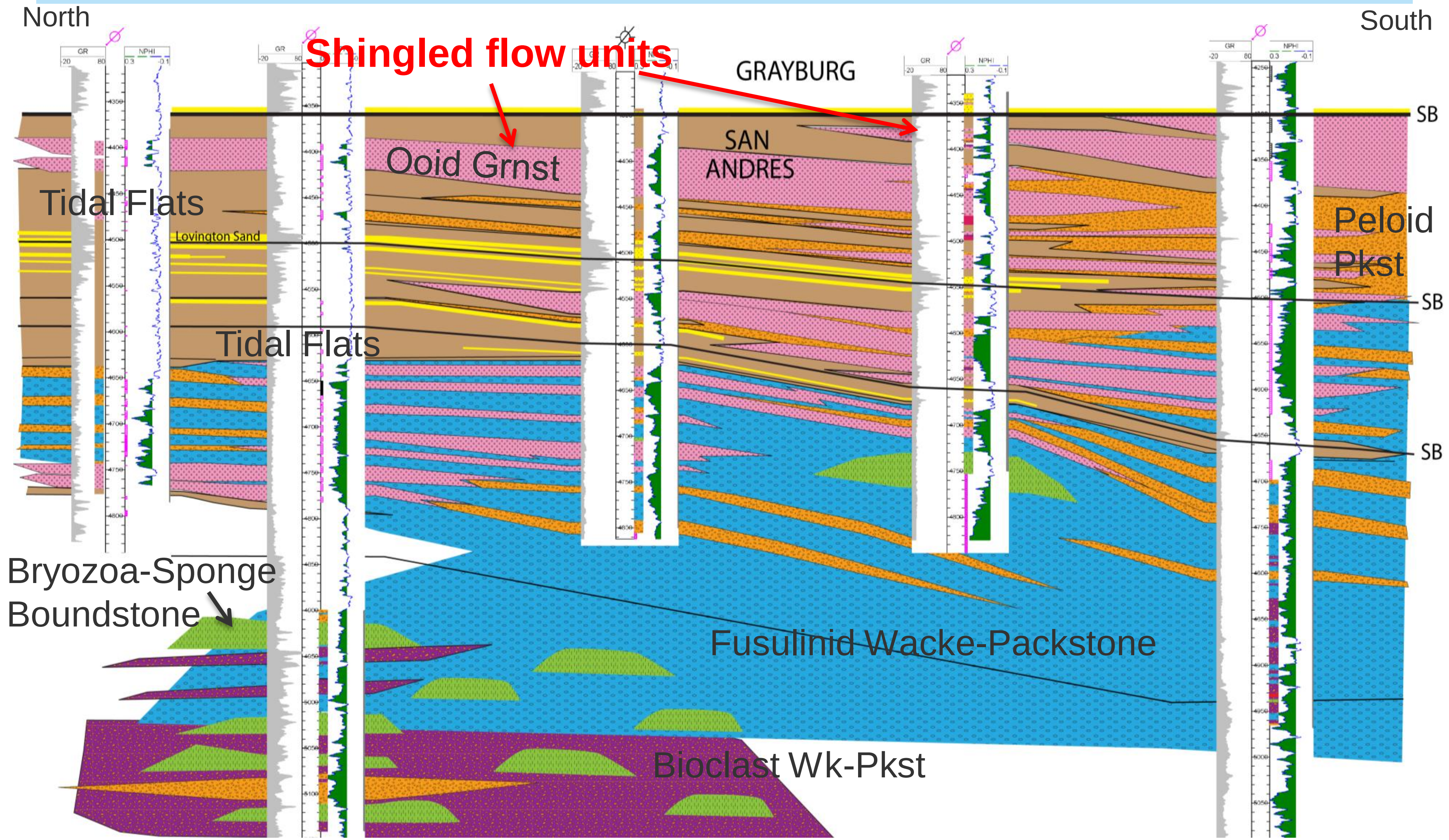
Vacuum Field:
Facies 12. Bryozoa-sponge Boundstone

- Dep. Environment: Transgressive mounds
- Average Porosity: 4.9%
- Average Permeability: 8.4 mD
- Percent of Core Interval: 6.7%
- Amount of this Facies with >1 mD: 60%
- Percent Reservoir Rock (>1 mD): 10%

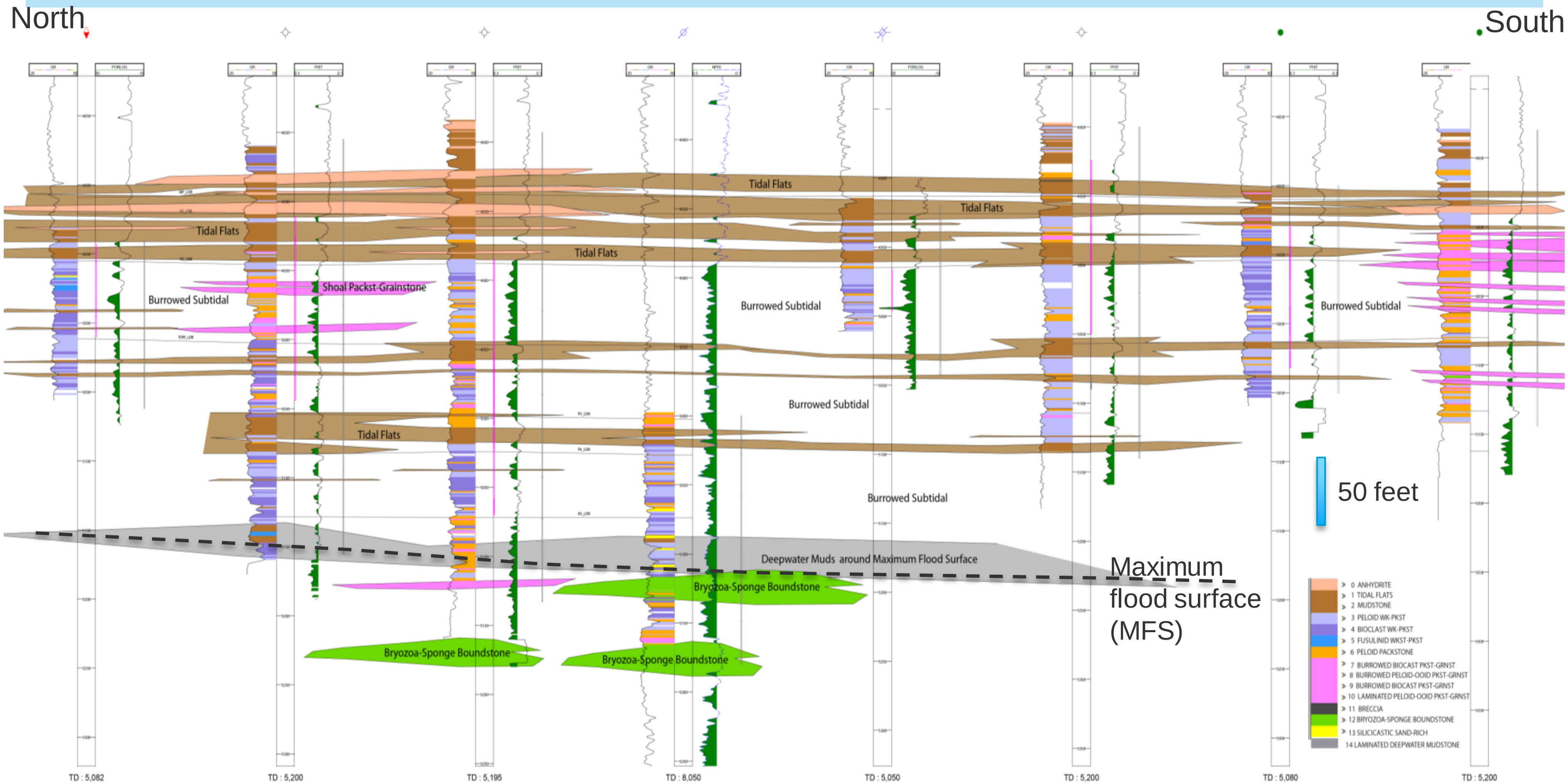




Vacuum Field Stratigraphic Cross Section:
Showing Relationships between Facies, Porosity & Flow Units

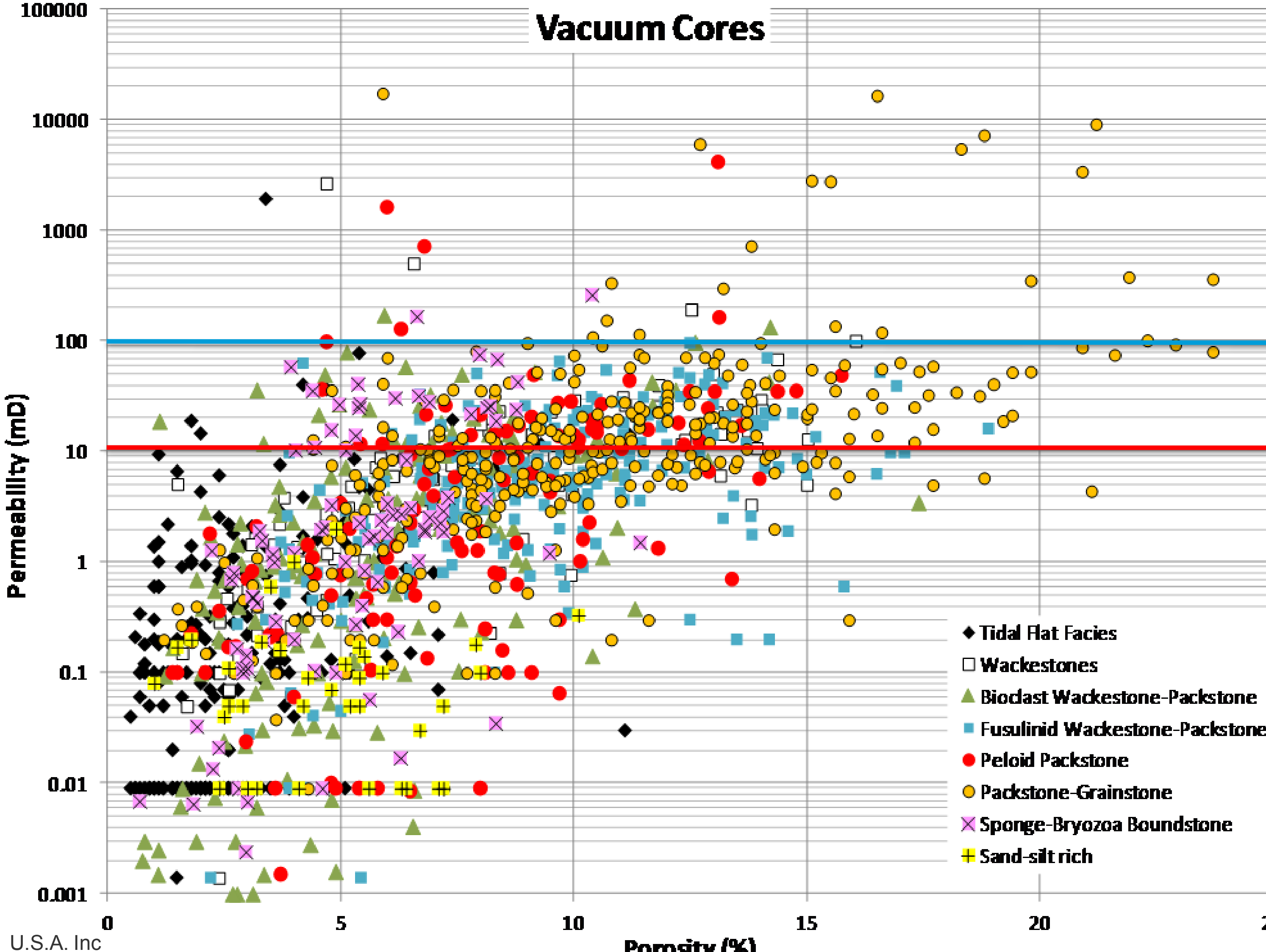


Stratigraphic Cross Section across Slaughter Field:
Porosity/Flow Units are Relatively Continuous Layers

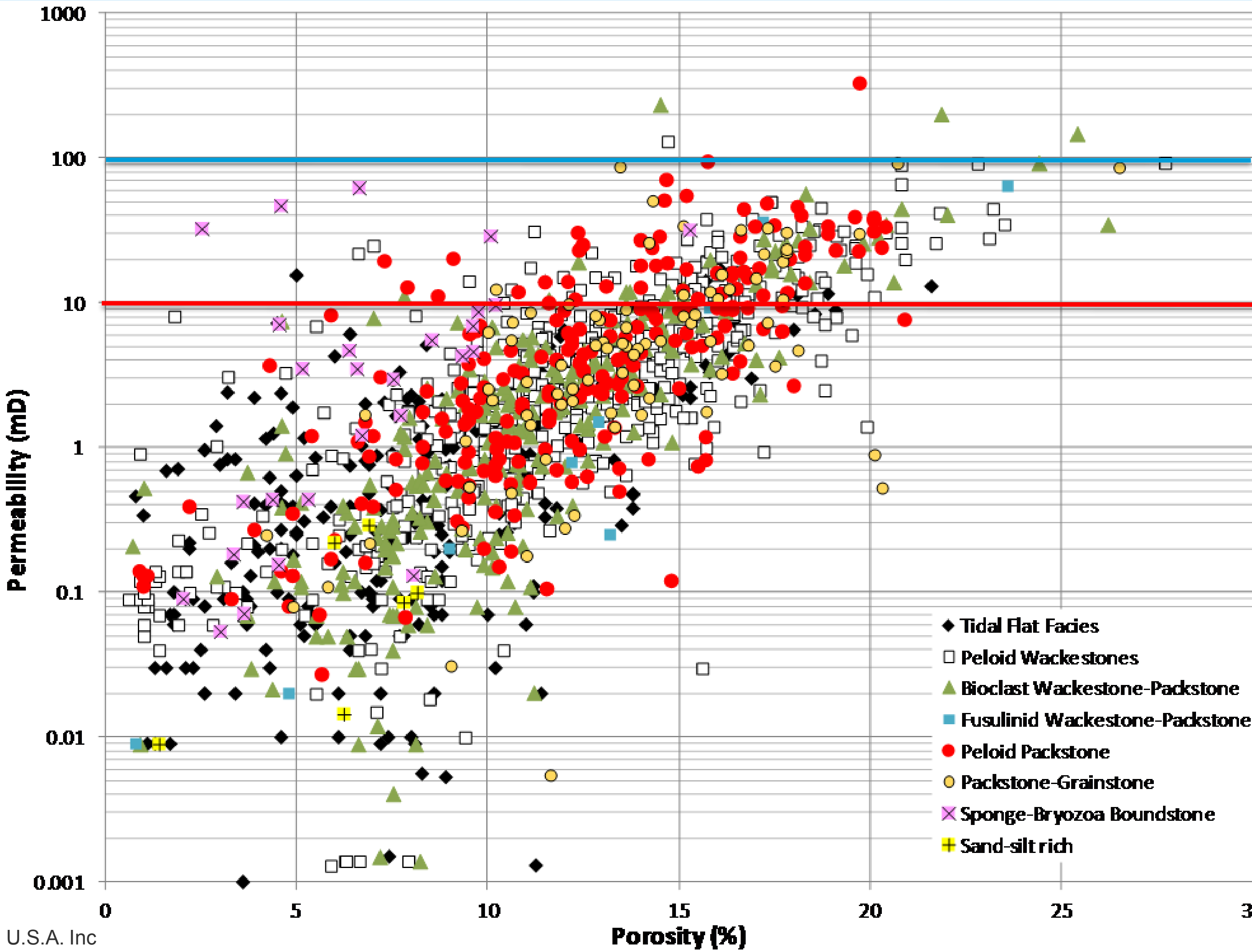


Vacuum Field:

Core Porosity & Permeability Relative to Facies



Slaughter Field:
Core Porosity & Permeability Relative to Facies



Comparison of Average Porosity and Permeability:

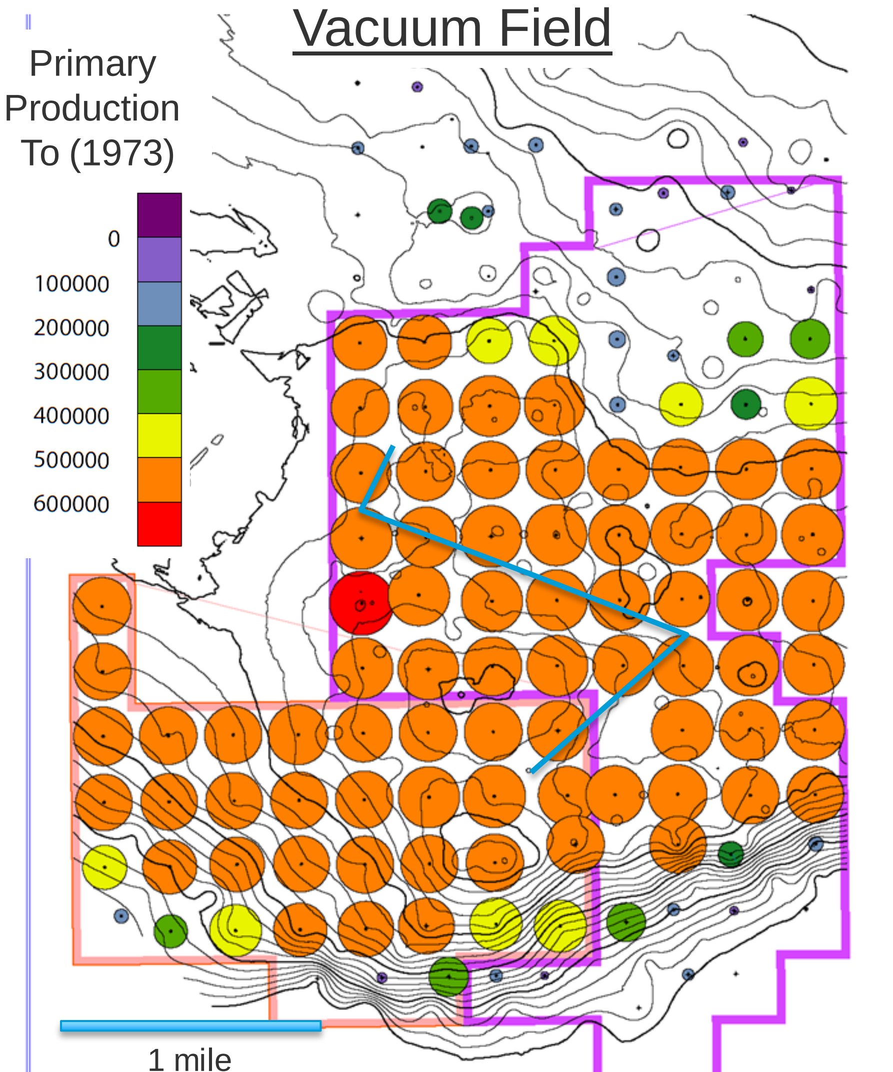
Results for Slaughter & Vacuum Cores

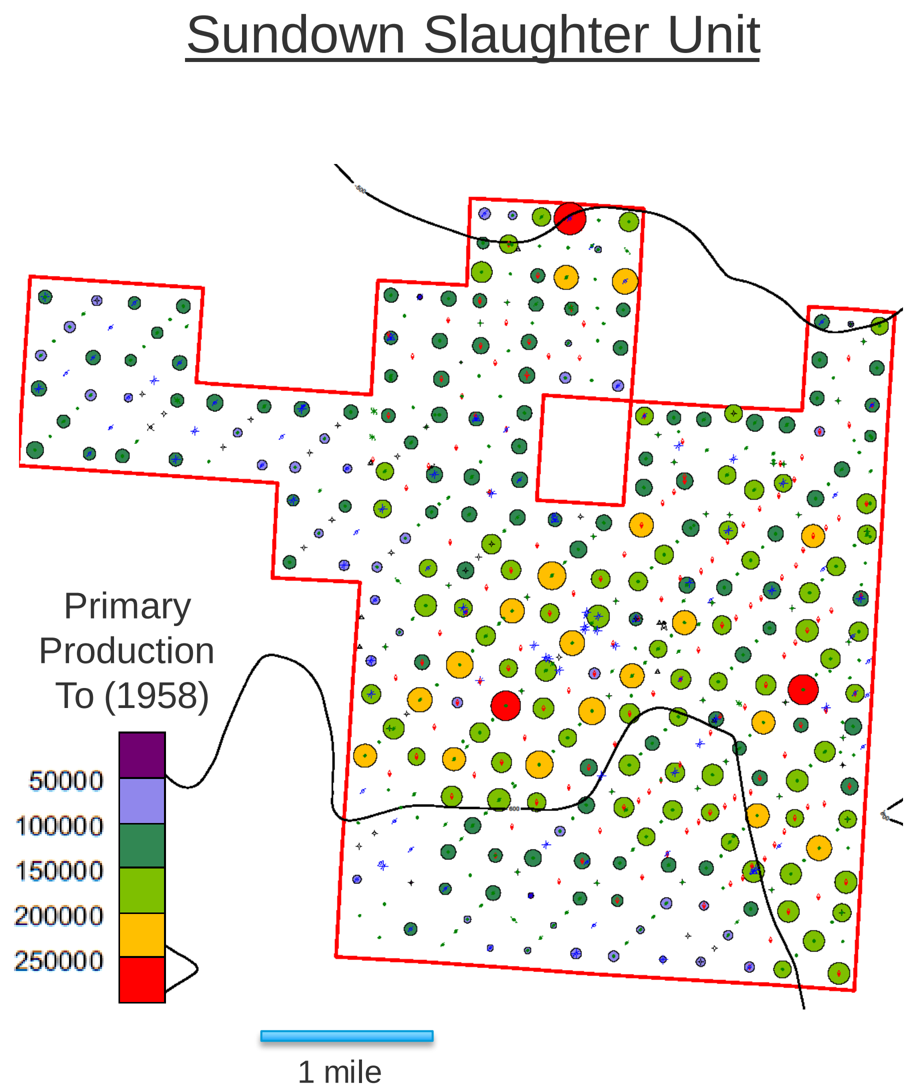
Facies	Slaughter Cores Porosity	Slaughter Cores Perm	Slaughter Cores % Core	Vacuum Cores Porosity	Vacuum Cores Perm	Vacuum Cores % Core
0. Anhydrite	3.1	0.2	0.9			
1. Laminated tidal flat	8.3	1.6	17.9	3.1	14.4	12.2
2. Burrowed mudstone-wackestone	8.9	3.0	3.8	5.2	5.5	4.1
3. Burrowed peloid wacke-packstone	11.9	6.7	35.4	6.8	18.1	7.0
4. Burrowed bioclastic wacke-packstone	11.1	7.3	17.1	6.5	9.7	13.1
5. Burrowed fusulinid wacke-packstone	11.9	11.2	0.7	9.5	11.2	17.4
6. Peloid packstone (WPG)	12.3	10.3	15.7	7.7	15.6	9.3
7. Burrowed bioclastic pack-grainstone	12.8	4.9	2.2	9.4	19.4	5.7
8. Burrowed peloid pack-grainstone	14.0	13.9	3.8	10.3	26.0	11.6
9. Current-lamin bioclastic grainstone				9.2	24.6	1.9
10. Current-laminated ooid grainstone				10.1	33.6	6.4
11. Breccia	15.6	1.8	0.1	5.6	14.2	2.0
12. Bryozoa-Sponge boundstone	6.6	10.0	1.9	4.9	8.4	6.7
13. Siliciclastic-rich	6.1	0.1	0.4	5.8	3.7	2.7
14. Dark laminated mudstone (deep)	9.1	1.3	0.2			
Total	11.0	6.6	100.0	7.4	15.7	100.0

6%

25%

Comparison of Primary Production:
From Vacuum & Slaughter Fields





Recovery Efficiency from Vacuum & Slaughter Fields:
Review from Published Sources

Vacuum Field

- East Vacuum
  - Primary = 25%*
  - Waterflood = 15%*

  *Brownlee & Sugg, 1987, SPE 16721

- All Units: Primary + WF = 35%*

*Advanced Resources International, DOE Report [2006])

Slaughter Field

- Mallett Unit(adjacent to SSU)
  - Primary = 16%*
  - Waterflood = 13%*

  *Behm & Ebanks, 1983 SPE12015

- Sundown Slaughter
  - Primary + WF = 42.7%*

  *Folger, 1996, SPE/DOE 35410

- All Units: Primary + WF = 35%*

*Advanced Resources International, DOE Report [2006])

Conclusion:
Comparison of Sundown Slaughter & Vacuum Fields

Vacuum Field

- Upper San Andres
- Shelf margin to shelf interior
- Main pay is highly stratified to shingled, and poorly stratified in the TZ/ROZ
- Wide scatter of matrix porosity & permeability (some porous/high perm & low porosity/low perm intervals)(more heterogeneous)
- Highly variable pore types
- Moderate to high permeability grainstone shoals are important
- Tidal flats are low porosity & perm
- Primary – 500K BO per well

Sundown Slaughter Unit

- Middle of Lower San Andres
- Restricted shelf interior
- Moderate parallel stratification of permeability in the main pays,
- Relatively homogenous, moderate to high porosity, moderate to low permeability clustering around 11%, 7 mD
- Generally fine intercrystalline pores
- Few grainstones
- Tidal flats are porous, but generally low permeability
- Primary < 250K BO per well