Using Old and New Data to Characterize the Lawrence Field, East-Central Illinois, for Alkaline-Surfactant-Polymer Flooding*

Suzanne Cluff¹, Robert Cluff¹, Catherine Murphy¹, Joe Alfano¹, Daniel Hallau¹, Ryan Sharma¹, Andrea Simenson¹, Stephen Whittaker², Bruce Schonert², and Bryan Clayton²

> Search and Discovery Article #40710 (2011) Posted March 14, 2011

*Adapted from oral presentation at AAPG Geosciences Technology Workshop, "New Ways to Look at Old Data: New Pay Zones, Increased Production, Expanded Regional Plays", Houston, Texas, November 8-9, 2010.

¹The Discovery Group Inc., Denver, Colorado (<u>suecluff@discovery-group.com</u>) ²Rex Energy Corporation, Bridgeport, Illinois

Conclusions

- Log data from various vintages needed to be normalized to be used
- If the old data is ignored, even ES logs, geological complexity would be difficult to identify
- Understanding the complex geology is essential to the success of the ASP flood

Using old and new data to characterize the Lawrence Field, east-central Illinois, for alkaline-surfactant-polymer flooding

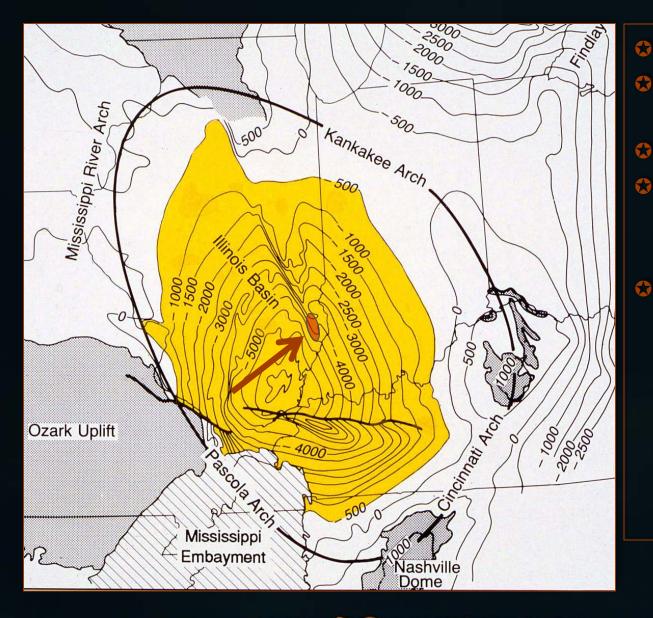
Suzanne Cluff, Robert Cluff, Catherine Murphy, Joe Alfano, Daniel Hallau, Ryan Sharma, and Andrea Simenson The Discovery Group Inc., Denver, Colorado

> Stephen Whittaker, Bruce Schonert, and Bryan Clayton Rex Energy Corporation, Bridgeport, Illinois

AAPG GTW Houston, TX November, 2010

Agenda

- Project overview and objectives
- Building the database
- Stratigraphy and correlations
- Define and map the sand bodies
 - get the container volumes right
- Log and core data analysis
 - get the pore volume right

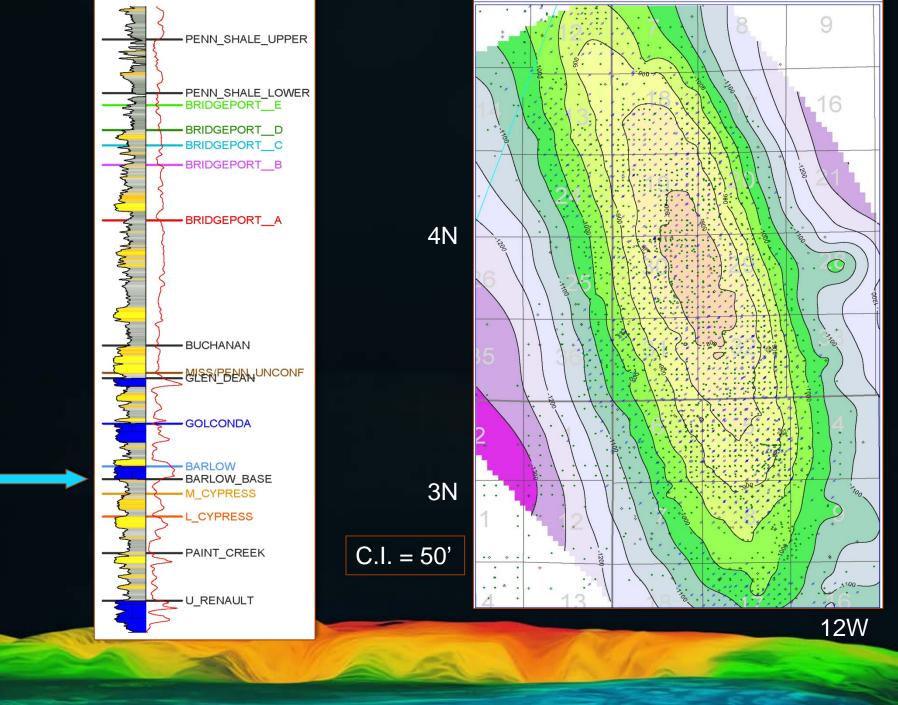


20 pay zones Penn. – Ord. Produced 400 MMBO **Rex Energy owns** ~12,500 acres Producing 1800 BOPD Penn. Bridgeport and Miss. Cypress are most significant pays Estimates of up to 40 million BO recoverable with EOR from Cypress and Bridgeport

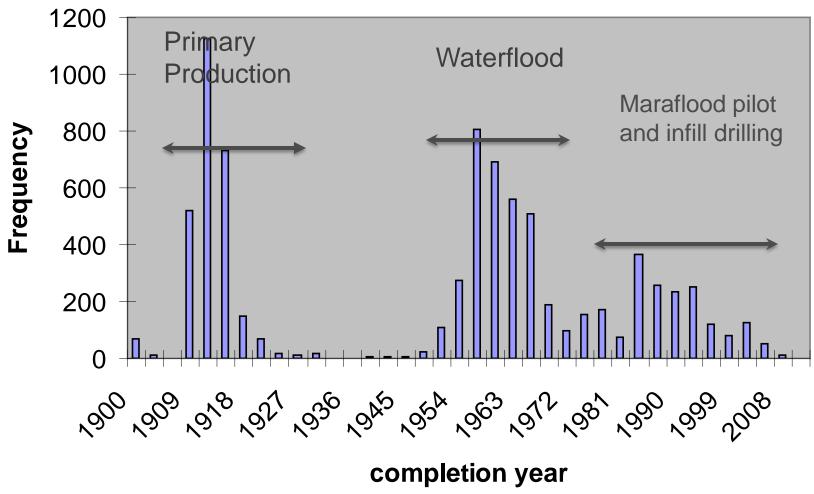
Discovered 1906

Project overview

- Rex Energy acquired Lawrence field in 2006 for its large residual oil in place and EOR potential
- Field was formerly owned an operated by Marathon Oil Company, sold in early 1990's
 - Marathon used Lawrence field as a test bed for chemical EOR methods in the 1960's-1980's
 - Two "proof of concept" surfactant polymer floods were technical successes, but uneconomic at the time



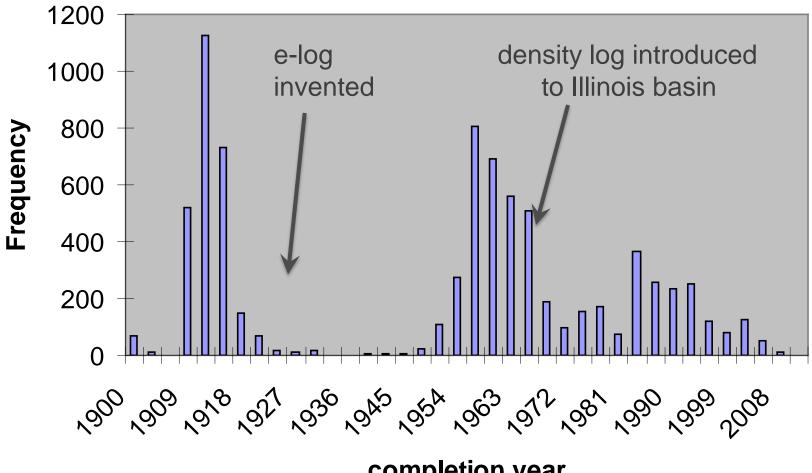
Drilling history



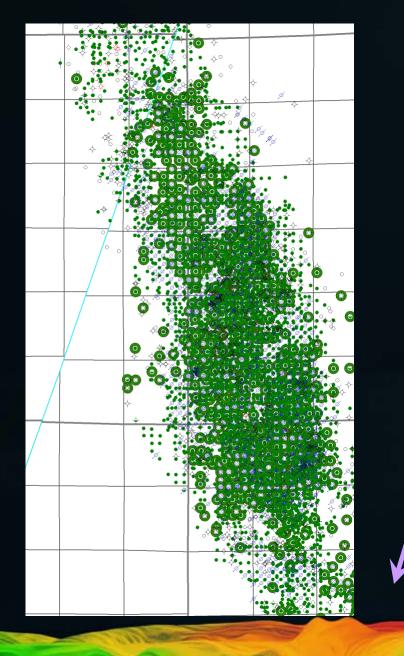
Building the database....

- Very old field, discovered in 1906
 - Lots of location problems
 - Mis-match of state records and commercial databases
 - Mostly paper records, had to scan/digitize logs & many other records
- Large well count (nearly 12,000 in the database)
 - Depth registered raster log images for 5600 wells
 - Digital logs for ~2400 wells
 - includes 900 wells with neutron or density logs, plus wells with core analysis data
 - Digitized core analyses and intervals for ~1500 wells
 - Perforations, tests, engineering data
 - Old operator tops were inconsistent & of minimal value

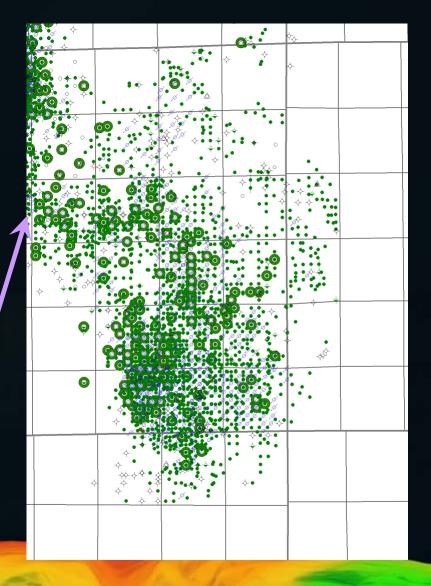
Drilling history



completion year



Modern porosity log control



Petrophysical process

- all GR, RhoB, and Nphi logs needed to be corrected and normalized
 - over 70 yrs of logging history, all vendors, all kinds of tools
- Developed separate petrophysical models for Bridgeport and Cypress
 - Varied Rw, ρ_g, etc.
- Every well with a porosity log was calculated for mapping

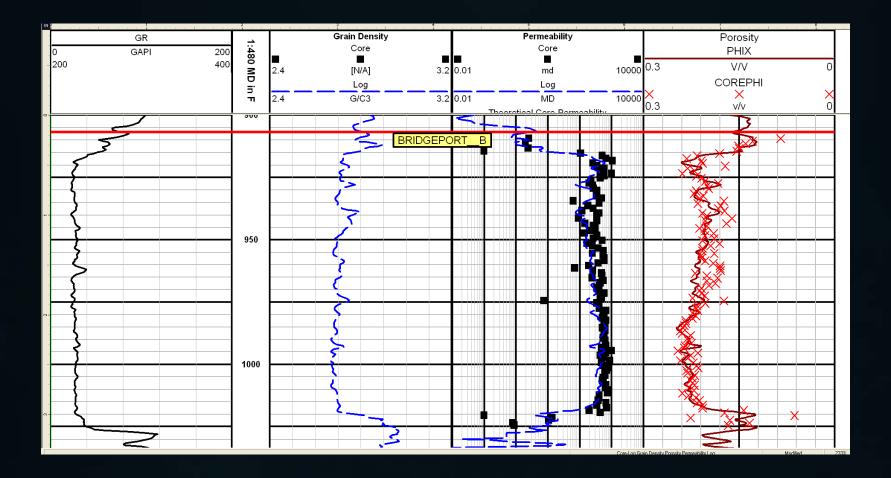
GR logs, un-normalized

	antistication of the second		Michael Innet and Mike			
		1	All maria and and	Lun when the	Comments of the second	ANAN ANAN
•			The share the state of the stat	Current C		A MARINA
		ļ	The second s		and Martinesser	
			Manhhadtanhadta		J	
A INTEN			March March and Alfre And		In the local	MMM MMM
ø						
= 8						
•••	and a second with the second se		and much hard control in			
•		And Contraction				
•						
			A CONTRACT OF A CONTRACT A MARKED A CONTRACT OF			
8 •					- Z.	
, Ø,		atar Internet	All and the second s		NAM MAN	
•				7		1
• •	and the second of the second s	And harden and harden	lt mel (f. france france and frank fran An and Market and Andrease and And	1 - 1		
•		an hiterature	1			
5 ø						
• ۶		Mark Manual	and the second secon			
•					- 5	
• 2	bril "Mittithe" "Ministithesite ad a furies with his constituents of hearing and the function of the function	and Minimum International	M. Mitthe Marine Ma	M. M. Martine		
ø					A MARKAN AND	
•••	and a first sector from the first from the matter of the first of the					
			With the With the state of the second states of the		-	
ø ø	arthold <mark>a beine ann an Anna an Anna an Arthold an Anna Anna Anna Anna Anna Anna Anna </mark>		anneti Maria – Martana – Arl Mari Handal Anana Anal Arasana an Martana – Arl Analana ana An			
•	White the induction of the Astronautic free and the second sector of the sector	A North Control of the	1			Charl Write
• • •	The first of the second se				~	
2	1101 The Control Manuard Manuar 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1111 - 1	addition and the second second	Antoninan harden and the			
					Ć	
	الا الكرام المركبية المستعمل وسعا المستعمل الت الكريسيين المركبين ومستعمل ومستركبة مستعمل الت	And a second	101 T. O'DAVI MARINA MARINA - MATA MARINA V. 101 Nationality Affaicational Marina Marina Marina Marina (de. 1 1944 - Transformational Marina - Marina Marina Marina Marina Marina - Marina Marina Marina Marina (de. 1944) - 1			
	-					
Ø)	and it is the first of the first of the first of the second state is a second state of the second secon	and a straight and a				
•		under minister of the	The function of the framework is a provide a size of the framework is the median of the second s	7	2	MANA AND
					1	
					_ 5	
			11) hitterterterterterterterterterterterterter			
	arthur hartmenter (M)	antibal settimentiterit have	hurth the Worth the Worth Standard and a sharehold a christian barrent that the second membrane of the Standard	Charl Carling		
	at the second		1	M. Manufactures	Mart Chan	
ø		and the second start of the start of the second start of the secon	" " " " " " " " " " " " " " " " " " "			

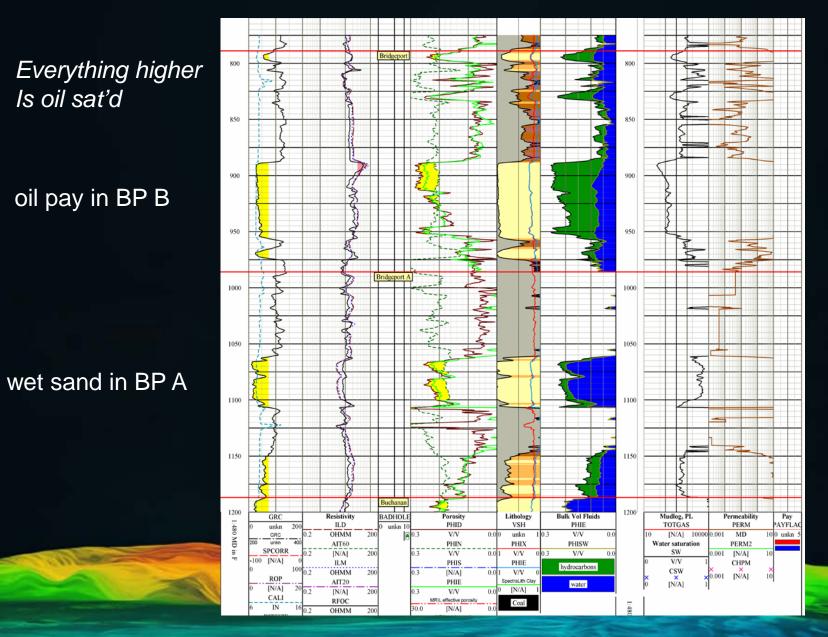
Normalized GR

Correction of the first of the	¢ J
10111111111111111111111111111111111111	·
1	
	·
and the second of the second second second with the second s	
	Ø
	ø
and the second of the second of the second of the second sec	·
	·
and the state of	Activity of
	· WWWWW
	• Multime
	A MANNE &
	•
a second de la constant de la const La constant de la cons	
	Ø WWW
	ø
A 14 March 1994 Annual 1994 Annual 1994 Annual	••
	•
DNA Whether Man State State State State State And the set of the state	ø. ,
C. M. C. M. Herrich Mitter C. M. Mither C. M. Mither M. Mit	
D.C. M.D. T. M. W. W. Manan M. Watara Master and a distribution of the Market State of the State	·
and model and the state of the	
a di anti di	
Manual Manual Control of the second s	•
ور <mark>از آن آن آن آن آن آن آن آن المعارفة من المعارفة المحالة المعارفة المعارفة المحالة ال المحالة المحالة المحالة</mark>	
Maketh Scatt as Walks Staff Annual Makether	
	•
direction and the second second	
1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	
And Presenting	A COMMIN
📒 11111 11 11 11 11 11 11 11 11 11 11 11	

Calibrated with Core Data



Example calculated log

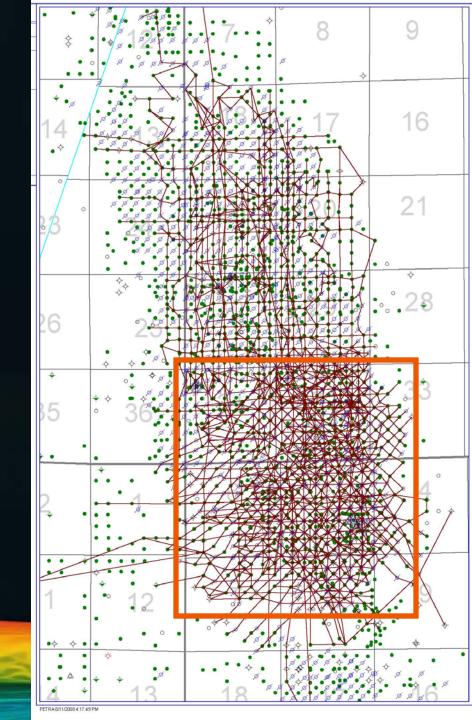


The Correlation Problem

- Massive correlation project, about 6000 wells with logs of various vintages to correlate
- Lots of location problems, bad API numbers, etc. to catch and correct on the fly
- Stratigraphically complex Pennsylvanian section with several cross-cutting incised valley fill (IVF) sequences
- Marginally simpler Upper Mississippian section with good marine limestone markers, but overlapping and shingled sand bodies with internal complexities

Stratigraphic xsection grid

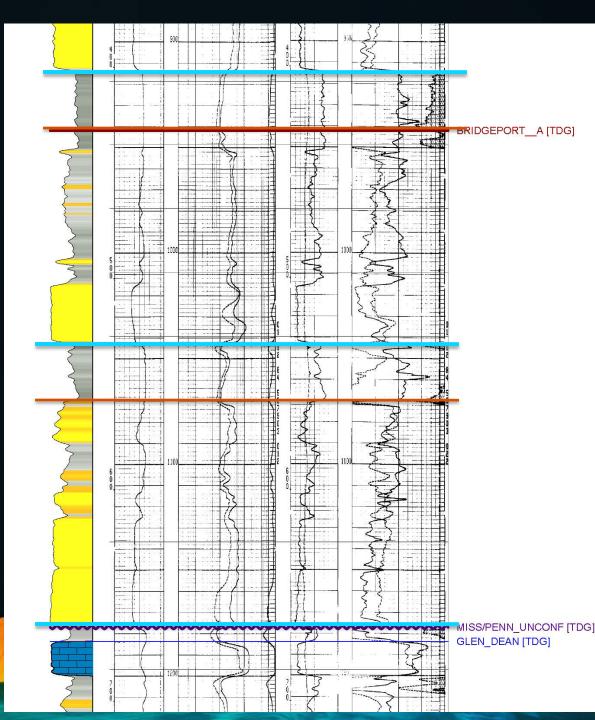
- NS, EW, and diagonal sections in both directions
- Mix of old and new logs because horizons look different on each
- Tight spacing between sections



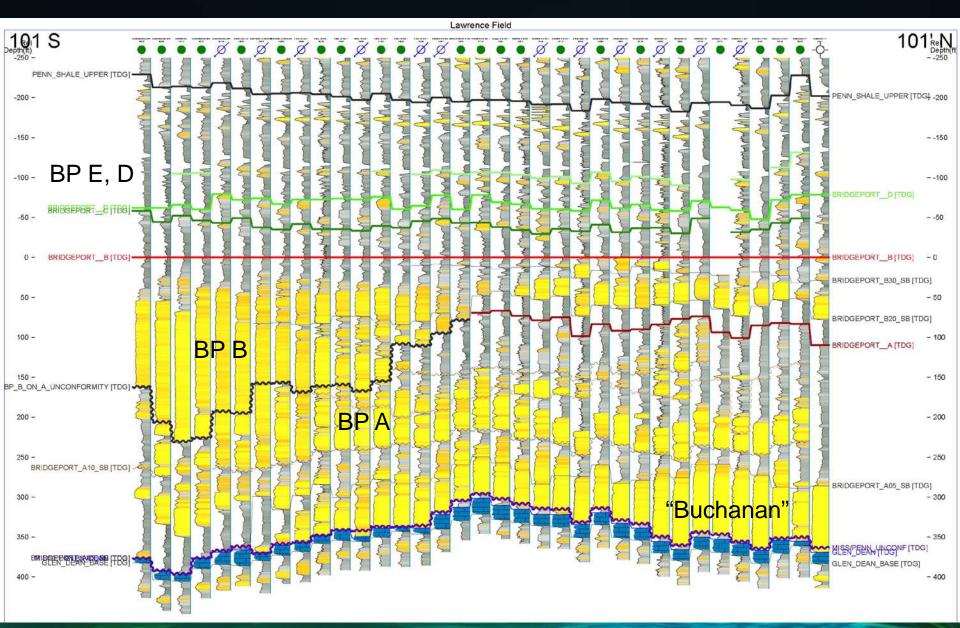
Sequence Stratigraphic Framework

flooding surfaces picked at resistivity log inflection points, usually maximum GR and maximum ϕd - ϕn separation

sequence boundaries placed at sharp bases of channel sand sections



Bridgeport normalized GR section

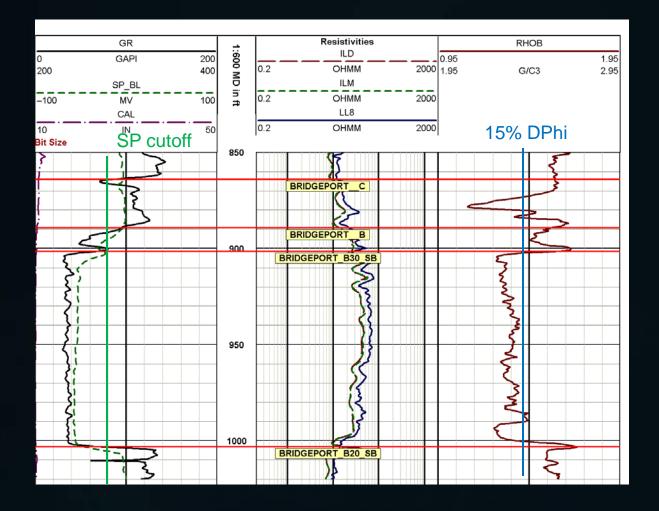


Reservoir property mapping

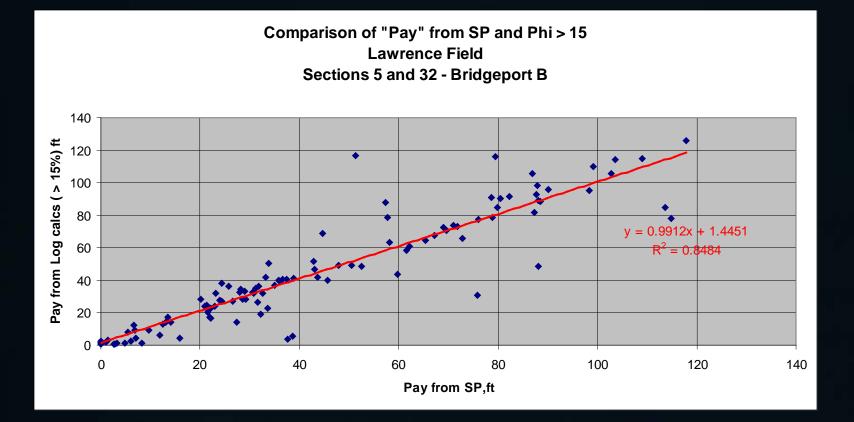
- mapped all key intervals (in 2D)
 - gross interval thickness
 - net sandstone above porosity cutoff (h)
 - average net porosity (φ)

 - average net water saturation (Sw)
 - net hydrocarbon pore volume (So-φ–h)

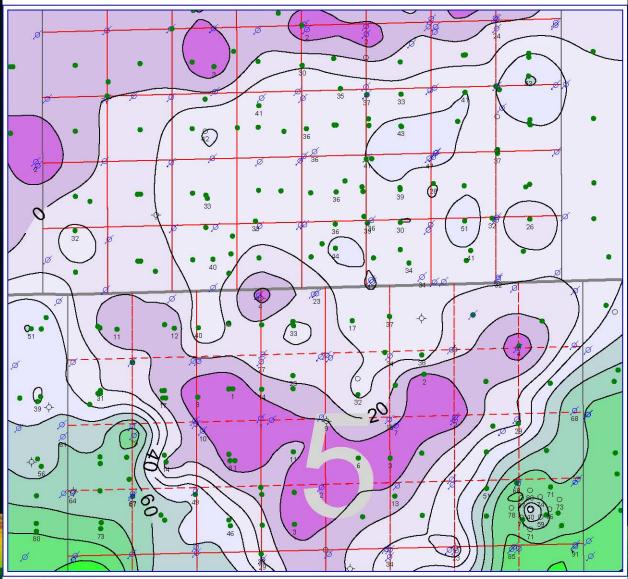
Comparison of SP and Density "Pay"



Comparison of Sand Counts

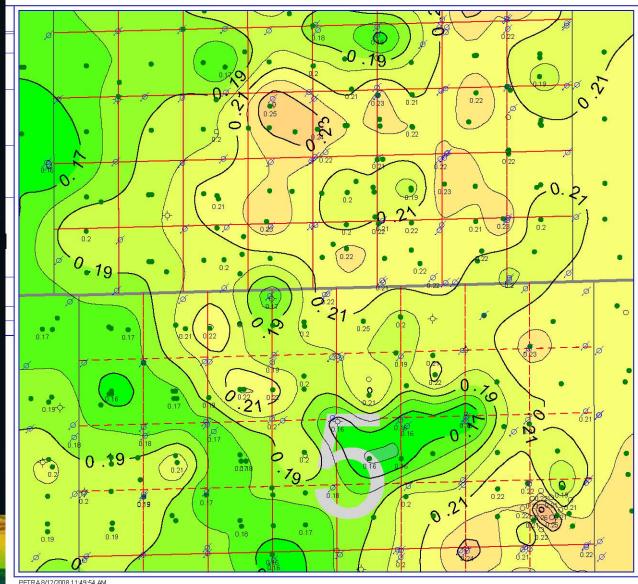


Bridgeport B Net Sand Thickness



PETPA 8/12/2008 11-4/4-49 AM

Average Porosity



Conclusions

- Log data from various vintages needed to be normalized to be used
- If the old data is ignored, even ES logs, geological complexity would be difficult to identify
- Understanding the complex geology is essential to the success of the ASP flood