What is net pay?

How we might re-assess the productive potential of tight carbonate reservoirs in the Illinois basin
Outline

• Short summary of the Illinois basin and history of carbonate reservoir exploration
• Review the Griffin bottoms activity from 2006-2015
• What are the options for explaining the high productivity of these low porosity wells?
• How can we better define “net pay” and map it to identify opportunities?
Illinois basin geology 101

- Interior cratonic basin, most similar to the Williston basin in comparison to Rockies/Midcontinent geology
  - No salt in the section, only very thin anhydrites
  - Open marine to the south through most of Paleozoic
- First production in early 1900’s, with a major drilling boom just before and during WWII.
- About 4 billion barrels of oil produced to date, mostly from Pennsylvanian and Mississippian reservoirs
  - Also Devonian, Silurian, and Ordovician reservoirs but the fields are generally small and are not material in the big picture
- Main source rock is the New Albany Shale, equivalent to the Bakken or Woodford
Howard, 1990, AAPG Mem 51

Mast & Howard, 1990, AAPG Mem 51
Most of 4 billion bbls since 1937

Focus since 1970
Illinois basin geology 102

- Long period of slow decline beginning in the early 1950’s as no new giant fields were discovered
- “Independents land” – the majors sold their holdings outside the giants by 1970, and divested those in the late 1980’s and 1990’s low price world
- Mostly small, locally based operators
  - Quite a few Texas, Oklahoma, and Colorado companies “dabble” in the basin but few have established a long term presence
- Starting about 1973, drilling focus shifted to “deeper” Middle Mississippian carbonates below 3300 ft
  - St Louis Limestone, Salem Limestone, “Warsaw” Limestone are the primary targets
  - Mostly carbonate grainstone reservoirs with preserved primary porosity
Middle Mississippian oil fields

Includes Ste Genevieve Ls, St. Louis Ls, Salem Ls, and "Warsaw" Ls

Barrows & Cluff, 1984, AAPG Mem 35
Map of Salem-Warsaw fields

9 township project area on Illinois-Indiana border, mostly in Gibson Co, IN

Howard, 1990, AAPG Mem 51
11,600 total wells in the area
4071 wells drilled post-1975
1071+ Salem-Warsaw tests
St Louis-Salem-Warsaw producers

Phillipstown, 1982-1984

Griffin Consolidated or "Griffin bottoms", 2008-2015

New Harmony, mostly 1990’s

New activity: ~80 producing wells, +/- 50 permits or active locs
Top of Barlow Ls structure
Summary production plot

“Typical” Salem-Warsaw wells make 10-20 MBO

72 PRODUCING WELLS
3.87 MMboe EUR
~54,000 bbls/well

30% De
The Discovery Group

500 ft gross perforated zone

Upper Salem interval

Middle Salem interval

Lower Salem + Warsaw interval
How can we explain the high productivity of these wells?

- Rex & Citation wells are making 2-4X the background productivity of Salem-Warsaw completions from the 1973-2007 timeframe in this same area
- Two explanations that I can see:
  - High volume fracs reach out to contact nearby, but disconnected lenses of high porosity conventional pay
  - High volume fracs create a high surface area region around the well with low porosity pay, increasing the net $S_o \phi h$ drained by a well
Reach out and touch someone.

New Jersey Bell
New Harmony field

Hallau, PTTC 2014 presentation
Griffin Consolidated

- ST_LOUIS
- SALEM
- WARSAW
- FT_PAYNE

Legend:
- > 7%
- 3% < x < 7%

Hallau, PTTC 2014 presentation
• Play works because carbonate sands are small, lenticular bodies
• When we frac a well, we reach out and touch the neighbor lenses
• Traditional pay cutoffs might still apply

NASA image, Eluthera area, Bahamas
Reach out and touch someone

- We want to look for areas with lots of thin, areally small conventional pay reservoir in fog of low porosity rocks
- Fracs should be optimized for “L” (length)
  - Simple geometry, reaching out as far as possible
- Horizontal wells would be drilled to cross as many small shoals as possible (depositional trend bias)
Fracs maximize length to reach nearby high porosity grainstone reservoirs
LIMBO
PARTY

"IVY" PETE and his LIMBOMANIACS
Limbo, or how low can you go?

- Experience in other basins says light oil can be produced from low porosity siltstones and carbonates
- A lot of oil.
- **But**, we have to honor the petrophysics of fluid flow in low porosity rock
  - and in particular the amount and distribution of irreducible water.
What do we mean by “net pay”? 

- **Gross** = everything. Applies to total interval thickness without any cutoffs.
- **Net sand** = clean formation below some shaliness cutoff, usually a GR cut.
  - But porosity doesn’t matter!
- **Net reservoir** = net sand above some porosity cutoff, usually picked to separate reservoir thought to be sufficiently permeable to flow fluids at commercial rates
  - But the fluid phase doesn’t matter – it can be salt water
  - And “sufficiently permeable” is an operational definition that moves with drilling and completion technology
Net pay = net reservoir that contains hydrocarbons, *in sufficient amounts to produce at commercial rates*

- Involves relative permeability to oil or gas
- Usually defined by an Sw cutoff, or in quick look work by a resistivity cutoff
- Pay = $$$$$. Payday, payroll, payoff, payola.
- Therefore it is an operational, economic definition that moves with pricing!
Net pay funnel

GR

Porosity

Water saturation

Net sand

Net reservoir

Net pay
“Net pay” in Illinois

- Operators traditionally use clean formation with > ~7% as a “net pay” cutoff in the Mississippian
- Saturation only considered to the extent of shows (either yes/no)
- Based on years of experience, 1000’s of DST’s and production tests
- “Searching for pay with a perforating gun”
The typical Illinois “mini-massive” frac

- Another factor setting the perception of net pay is how wells are completed
- A “typical” Illinois frac since 1970 was:
  - 210 to 500 barrels of fluid, with some HCl
  - Pumped at 10-14 bpm
  - 8,000 to 25,000 lb 20/40 sand
“Conventional” porosity perfs

- Relatively few and very thin high porosity streaks (<7%)
- Most perforations in Salem-Warsaw wells target these zones (~90% of them)
But if we add in low $\phi$ reservoir...

- Our work has shown that, in the Salem, only $\sim20\%$ of net reservoir is over $7\% \phi$ ("conventional pay").
- That means that $\sim80\%$ of the porous rock is below $7\% \phi$ (potentially, "tight pay").
- Question becomes – is this low porosity stuff productive or not???
• Wilbanks 1-6 Greer 4255 ft
• 12.0% φ, 47.3 mD, Swi 20.6%, Krg, Krg 0.993
• This sample is transitional to lower Salem with coated grains and a few ooids
- Rush Creek 1-C Klein 3888 ft
- 10.0% φ, 0.135 mD, Swi 31.2%, Krg 0.533
- **Tightest sample** – passes traditional porosity cutoff but is near the lower limit of acceptable perm
The experiment

• Collect representative suite of plugs over broad porosity range
• Measure porosity, perm, grain density
• Saturate plugs with brine, centrifuge down to “irreducible water saturation”
  – Defined here as $P_c = 200$ psi air-brine
• Measure $S_{wi}$ gravimetrically and effective permeability to gas at $S_{wi}$
  – Gas perm is easier/cheaper than oil
  – should be close, if anything slightly optimistic.
• Weatherford Labs, Houston, was our vendor on this study
• Two well **Warsaw Ls** core study
• n=10 samples
• Only intact cores at IGS and ISGS we found suitable for sampling for SCAL work

**Statistical disclaimer:** 10 samples is a small dataset – we need closer to 30 to get solid correlations!
• Nonetheless, we got 9 samples (one outlier) on a trend
• $R^2$ of 0.9997 –something real is here
• Only two samples had $K_{rg} < 1$ at 200 psi air-brine
• Suggestive of $K_{rg} = 3\%$ at 40\% $S_{wi}$
• In retrospect, we ran the samples to too high a $P_c$!
It takes roughly a 300 ft light oil column to drive saturations down to 40% $S_{wi}$. 
- Greer well points towards 40% $S_{wi}$ at 3% porosity
- But a pessimist could draw a steeper trend thru data
• We don’t have enough data to tell which model (or both) is correct
• Probably need at least 20 more samples to make it a solid call
How low can you go

• We want to look for as much net low porosity pay as possible, with shows indicating we have enough oil column height to fill the reservoir to $S_{wi}$

• Fracs should be optimized for “A” (surface area)
  – Complex fracs that break up the near wellbore region and contact as much low porosity rock as possible

• Horizontal wells would be drilled to optimize multistage frac geometry in the stress regime
Fracs seek complexity near wellbore to maximize surface area of the formation contacted
Map view – objective is to shatter the rock
Conclusions

- Low porosity carbonates can and do produce oil, in very large amounts.
- This is a potential pay opportunity we have not previously exploited in the Illinois basin.
- We don’t know what the lower pay limit is in these carbonates:
  -Primarily controlled by the pore size distribution in these rocks.
  -Which in turn controls $S_{wi}$ irreducible and the relative permeability to oil as you approach $S_{wi}$.
  -Directionally, it could be as low as 3% with a modern frac.
- If these rocks do produce at low porosity, it could work over a very large area of the Illinois basin.
- This is probably a common situation in “old basins”.
Other opportunities

- The Illinois basin is one of many “old” areas in the US and Canada approaching the tail end of the production curve.
- Lots of depleted, abandoned or almost abandoned fields that were developed on the 1950’s to 1980’s concept of “net pay”.
- The world has changed, thanks to the shale revolution, how many of these are scattered around out there waiting for you?
- These are low cost, shallow drilling opportunities ideal for a prolonged low price environment.