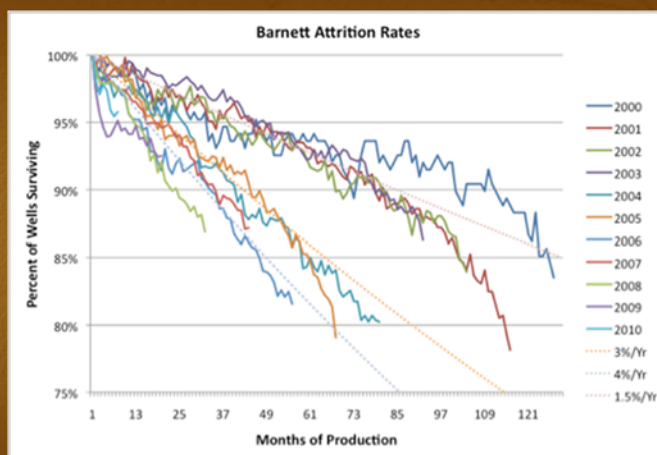# Sloan UT Shale Gas Project
Workflow Overview
Barnett Shale – first play addressed

Scott Tinker, John Browning, Svetlana Ikonnikova, Gurcan Gulen, Ken Medlock, Qilong Fu, Tad Patzek, Frank Male, Susan Horvath, Forrest Roberts, Bill Fisher, Eric Potter

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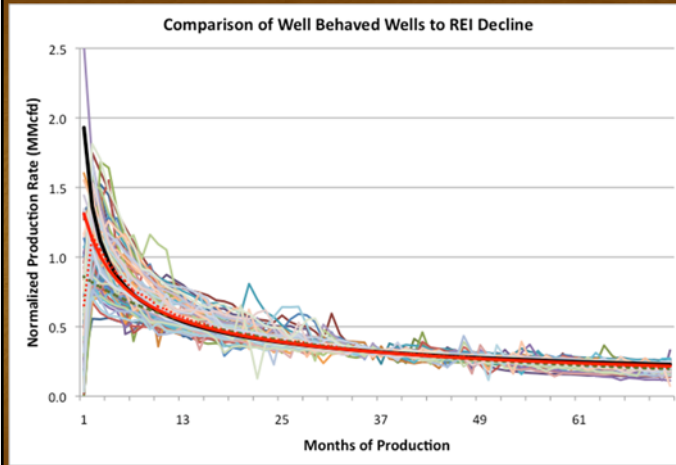
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Step 1: Compile Barnett Data

- Extracted production history for 16000+ wells
- Organized data to allow plotting, sorting and averaging wells quickly by any parameter
- For example well attrition (left) is worsening over time
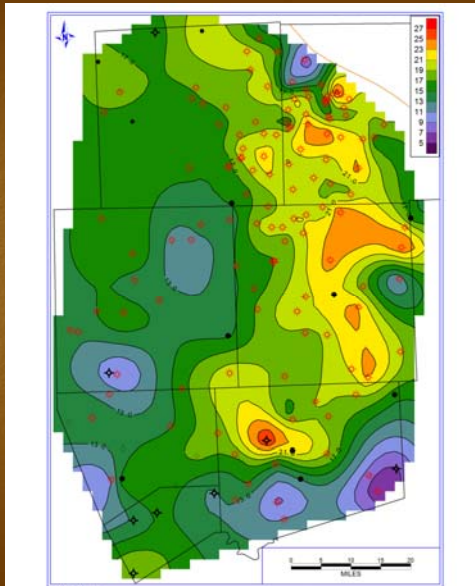- Attrition assumptions are a key driver in the Barnett supply outlook

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Step 2: A new decline approach

Comparison of Well Behaved Wells to REI Decline

- Industry uses hyperbolic, harmonic or exponential decline based on radial transient flow
- Transient test analysis indicates linear transient flow
- The Sloan REI approach assumes linear flow with production rate inverse to time squared
- Chart at left shows good match of REI (Black) with average well (red dashed)

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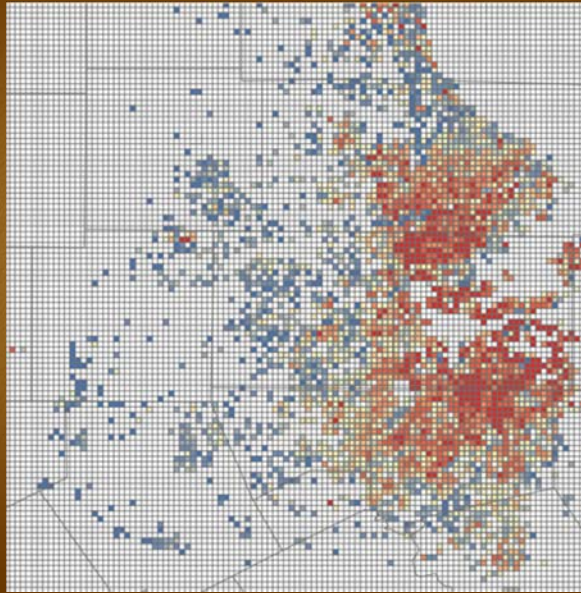## Step 3: Develop Geologic Model

- **Production sweet spot mainly driven by net-porosity thickness**
- **Density porosity values for 147 wells were corrected based on core porosity and mapped (left)**
- **TOC, thermal maturation and fracability also important factors**

PHI*H for the pay zone calibrated by a ratio of 0.53
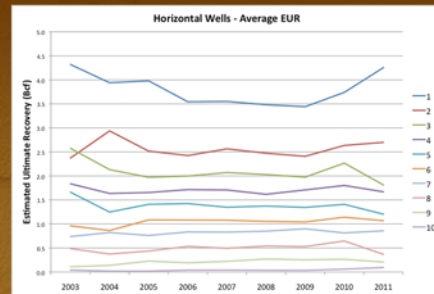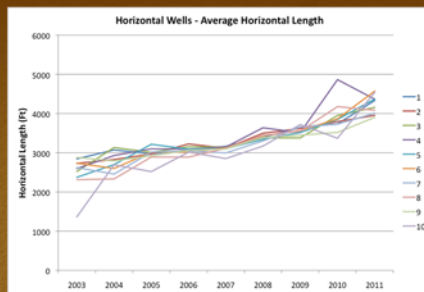
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Step 4: Divide Reservoir into Tiers

- Overlaid 1 square mile grid on Barnett (640 acre sections). Identified 3300+ blocks with an existing well.
- Identified the max REI achieved in each block and sorted the blocks into 10 tiers with ~330 blocks in each tier.
- Map closely resembles PhiH map developed by geologic team

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Step 5: Analyze performance by tier

- We are now well positioned to analyze many performance related issues by tier
- The example at left shows the average horizontal length of new Barnett wells segregated by tiers
- The chart at right shows the average EUR of new horizontal wells segregated by tiers
- The increased horizontal length has not led to improved well EUR's
- Total Barnett improvement is driven by tier mix and horizontal/vertical mix

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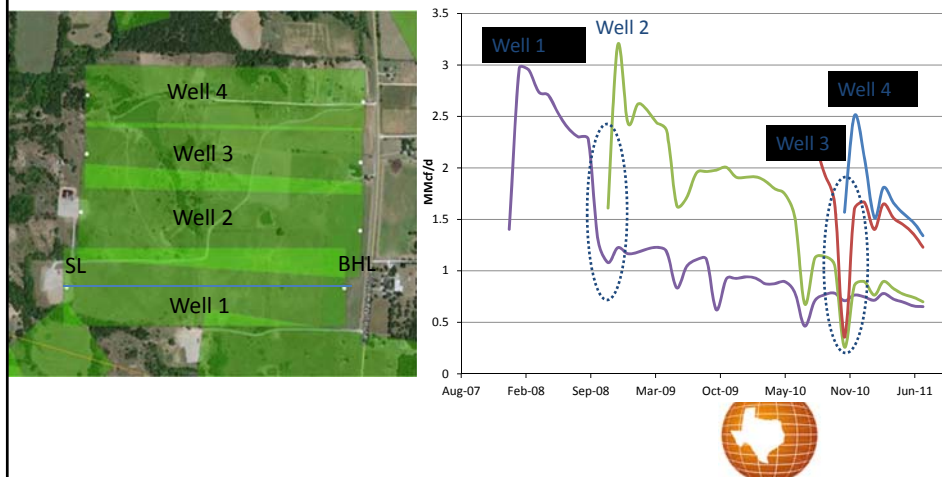GEOLOGY

Step 6: Determine drainage areas

- Drainage areas were calculated based on EUR for every well in the Barnett and plotted in Google Earth
- Wells showing overlap are typically confirmed to interfere; others do not interfere
- Using these maps, any area of Barnett can easily be inspected for drained and undrained acreage
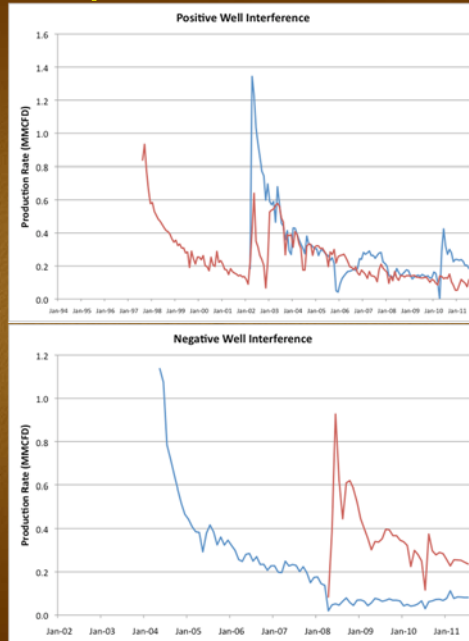
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Interference case

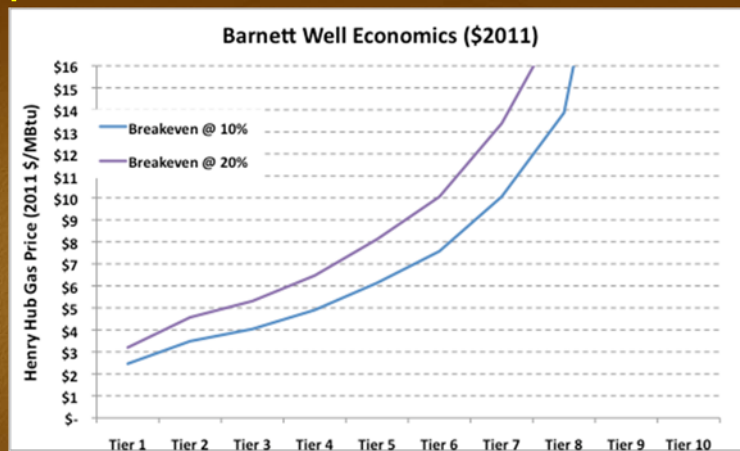We look at densely drilled 1-by-1 sq. mile blocks for interference.

Step 7: Confirm drainage areas

- The drainage areas were validated by comparing to actual well interference
- The top chart shows an original well production improving when a new well is drilled nearby
- The lower chart shows a less common occurrence where a nearby new well reduces production in the older well
- Resulting drainage areas are consistent with 50-60% recovery of original gas in place over relatively small areas

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Step 8: Determine well economics

- The chart shows the breakeven Henry Hub gas price to achieve 10% and 20% IRR for the current average well in each tier
- Current drilling is focused on the top 3 tiers that generate above 10% IRR

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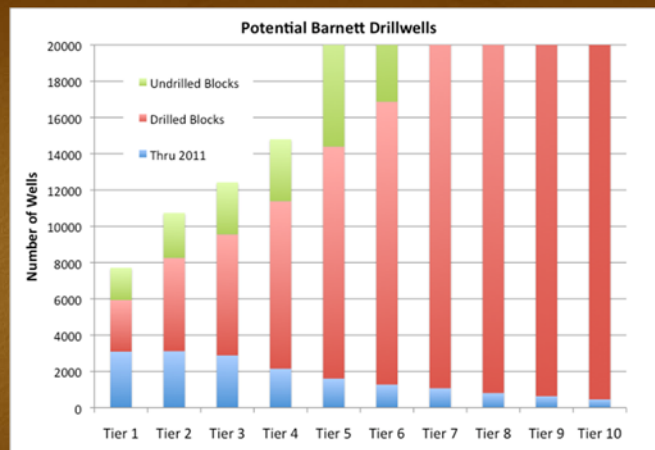
Step 9: Identify full field "reserves"

Summary Statistics for Barnett Tiers Based on Spacing Study Results

Tier	OGIP (TCF)	Wells	Cum Prod (TCF)	RUR (6/11)	EUR	RF %	Ac Drained	Ac Left	Well Prospects	Prospect EUR	BE HH	Field EUR @ BE
1	28	2940	2.9	7.1	9.8	35%	112504	123656	2996	11.2	2.35	40
2	27	2937	2.4	4.3	6.5	24%	76075	160085	5325	13.9	3.38	54
3	27	2769	2.0	3.1	4.9	18%	57379	178781	6786	15.3	3.94	69
4	27	2092	1.2	2.0	3.1	12%	36957	199203	9293	16.7	4.82	86
5	26	1563	0.7	1.2	1.9	7%	22747	213413	12830	18.1	6.06	104
6	25	1215	0.4	0.8	1.2	5%	14492	221668	15654	17.8	7.51	122
7	25	1069	0.3	0.5	0.8	3%	10044	226116	22664	17.0	10.02	139
8	23	802	0.2	0.3	0.4	2%	5124	231036	27772	16.6	13.87	155
9	23	641	0.1	0.1	0.2	1%	2151	234009	54523	13.3	28.42	169
10	21	449	0.0	0.0	0.0	0%	340	234540	150638	11.5	142.07	180
Total												

- Once EUR's and drainage areas are calculated for all wells the drained and undrained acreage can be totaled
- Breakeven economics are calculated for the undrained acreage prospect inventory
- The number of wells and field EUR can then be determined for each price level
- Field wide impact of all assumptions can quickly be tested generating full field statistics
- These numbers are in flux as we take input from key operators,
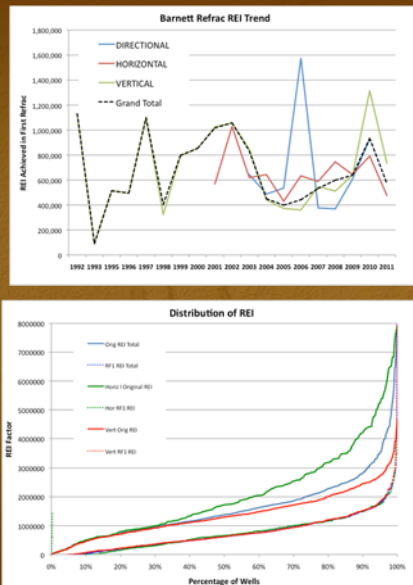- re: our assumptions!

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Step 10: Develop prospect inventory

Potential Barnett Drillwells

- The chart shows the number of drillwell prospects from the Barnett Spacing Study
- Drilling opportunities in the higher tiers will likely be a constraint in the coming decade.
- Remaining prospects in lower tiers are uneconomic at current gas prices

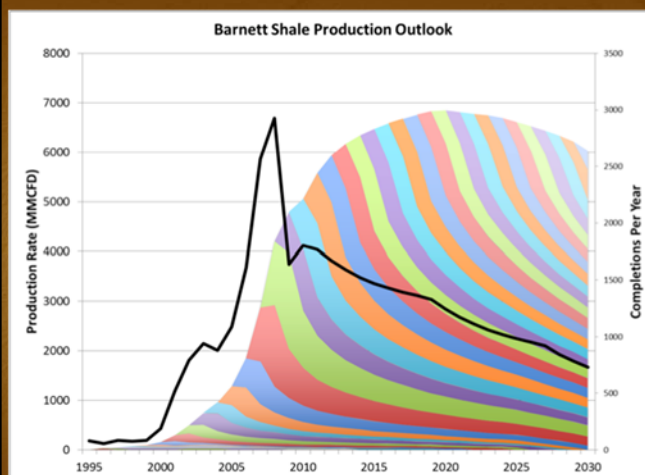BUREAU OF ECONOMIC GEOLOGY

Step 11: Determine impact of refractures

- Identified 1000+ inferred refractures based on well performance and determined reserves for each using REI
- The top chart shows average performance of refractures over time to be relatively stable
- The lower chart shows the distribution of refracture REI's similar regardless of well type
- Refractures currently occur about 100 per year and contribute about 60 MMcfd (< 2% of field production)
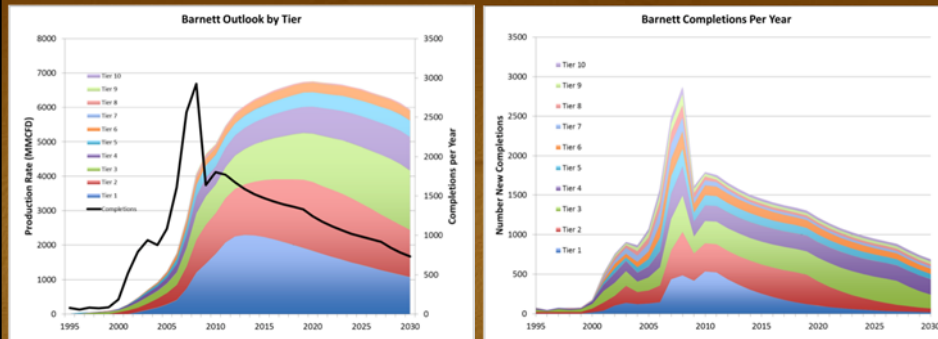
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Step 12: Develop Barnett supply model

- The chart shows the production outlook for the Barnett assuming
  - $4.00 Henry Hub
  - 90% of proven acreage
  - 20% of untested acreage
- The model EUR is 72 TCF with 40,000 wells drilled
- The annual production grows to ~7 Bcfd by 2020
- The well count steadily declines in the $4.00 price environment impacted by fewer higher tier prospects
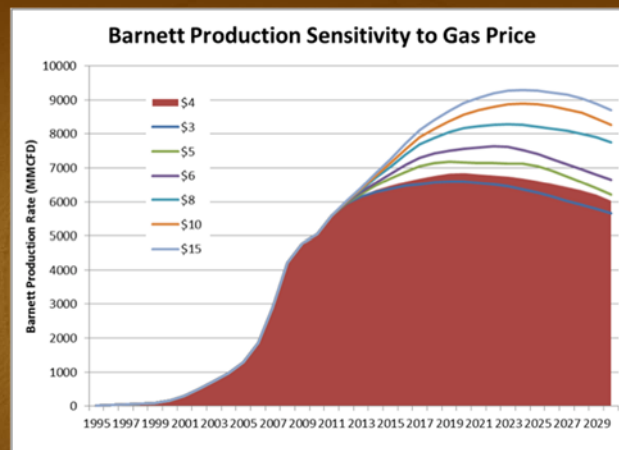
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Step 13: Model results by tier

- The left chart shows the production outlook for the Barnett split into tiers
- The higher tiers are fully developed over the next seven years driving production increases
- Low price environment hinders development of middle tiers driving field decline after 2020
- The well count in the right chart details depletion of prospect inventory in the top three tiers

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Step 14: Develop model sensitivities

- The chart shows the impact of Henry Hub gas price on Barnett production outlook
- Higher gas price accelerates development of tiers 3 through 6
- Poorer tiers are not developed in any case
- Best tiers are fully developed even at low gas prices

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Sloan Project Workflow Overview

Questions?

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Methodology

- Calculate $OGIP^{free}$ for the whole field and EUR for each well
- Examine production histories to find interfering wells and use these instances to calibrate the parameters of the drainage areas
- Assess the effective recovery factor, which explains overlapping drainage areas and the observed well interference
- Construct the Barnett drainage area map, with undrained spaces being interpreted as the inventory available for the future infill drilling.
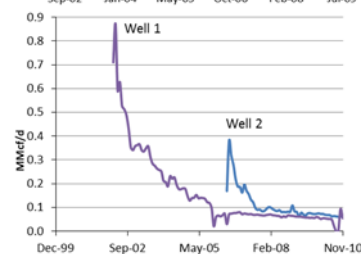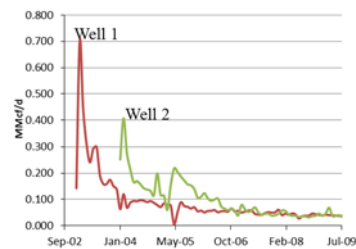
Approach I

$$EUR \approx (1-S_w) \cdot (Thickness \cdot Porosity)/B_g \cdot Area \cdot Recovery\ Factor$$

Well production based | *OGIP^{free}* | *Drainage area* | *Field wide estimate*

Based on available data we assess a full field model and determine acreage left undrained in the developed sections and EUR to be recovered.

No interference case

We test what recovery factor can best explain the observed (non)interferences

Looking into the future

- Technical, GIS, and economic characteristics of the developed areas are used to assign resource values to the undrained areas within drilled sections.

- Average well performance and economics are generated for each Tier.

- The HH breakeven gas prices, determined for an average well in each tier, allow us to assess the pace of activity to be expected in a given tier.

- We assess individual well recovery factor to be in the range of 50-60%; result is used to derive the future full field recovery.

From observations to analysis