SUCCESSES and FAILURES of HORIZONTAL WELLS IN TENNESSEE and WHY

Horizontal Shale Wells

- There have been approximately 76 horizontal shale wells drilled in Tennessee over a period of 6 years between 2007 – 2013.
- The first one drilled by CNX Gas had laterals of 2,500'. 4 ½' casing was cemented and perforated. The fracs were 3 stages foam frac with 1.5mmcf of Ni and 1,000# of sand per stage.
- The completions were very expensive. One zone would be perforated then fraced and a plug set and the process repeated.

Frac Jobs

- On at least some of the wells a coiled tubing unit was used to drill out the plugs. The foam fracs used water foamed with nitrogen. It took longer to get the wells cleaned up for production because of the water that came back.
- Later on the Packers Plus system was used which allowed up to 9 frac stages which later was advanced to 19-20 stages. I think now you can get up to 30 stages.
- The frac jobs were changed from foam fracs with sand to nitrogen only. The flowback of the frac was much easier using Ni only.

Frac Jobs

- During the time period of drilling the wells, 2008-2013, the performance and life of the down hole motors improved. The early motors had problems using air instead of fluid.
- The improved technology allowed the drilling of longer laterals 4,000' – 5,000', in less time that it took drill the earlier wells.
- As has been the case in other shale plays around the country, longer laterals and more frac stages resulted in more production per well.

Shale Thickness

- When horizontal shale wells first started to be drilled in Eastern Kentucky where the shale was 600'-1,000' thick, the general opinion was that they wouldn't work in Tennessee because the shale was not thick enough and therefore, didn't hold enough reserves or production potential.
- There had been shale gas production in the Big Sandy Field of Eastern Ky for many decades. Vertical wells would produce 100mcfd naturally with no treatment and of course decline but produce commercially for many decades.

Knox Energy/CNX Gas

- Knox Energy acquired approximately 300,000 acres in a deal with Jim Bruner around 2000-2001.
- They drilled several dozen vertical wells many of which were 6,000' deep to the Copper Ridge.
- While they were doing this they expanded the pipeline system they bought on the Coal Creek property that tied into the East Tennessee Natural Gas Pipeline between Wartburg and Harriman near Mossy Grove.
- By 2004 they decided they had not been successful enough and farmed out all their acreage to Atlas Energy.

Atlas Energy

- During the next three to four years, Atlas drilled some 300 wells on the CNX Farmout acreage. The farmout was to end at the end of 2007.
- But

Knox Energy/CNX Gas

- In 2007 CNX drilled the first horizontal shale well on the Coal Creek Property, permit # 11382. It was drilled with fluid and the lateral was about 2,500'.
- They perforated 4 zones but the first zone near the end of the lateral did not break down.
- I remember asking Kent Wright, the manager of the Oak Ridge office, how they decided where to perforate in that first well. He said it was where they lost circulation.

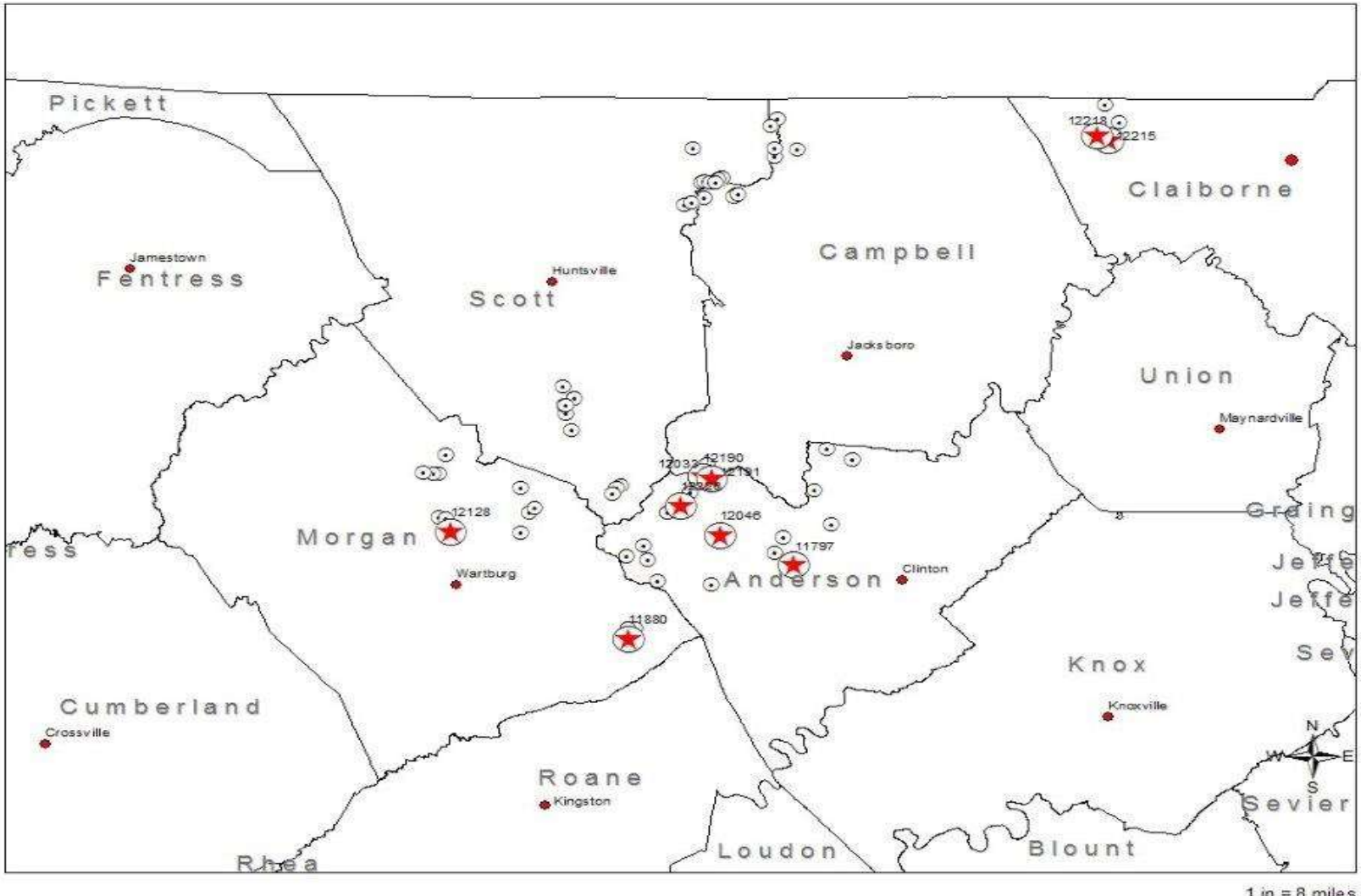
Knox Energy/CNX Gas

- Since they were drilling with fluid and since the Chattanooga Shale in this area is under pressured. This means that the shale will not support a column of fresh water.
- The lost circulation zones were naturally fractured zones that were intersected with the wellbore.
- This well has been one of the best producing wells. I will go into that in more detail later.

Atlas / CNX

- Because of the success of this first horizontal well, CNX changed the terms of a farmout extension with Atlas to exclude the rights to the Chattanooga Shale.
- The result was that the farmout was not renewed.
- In the next 5 years CNX drilled 50-60 horizontal shale wells.
- During the same period Atlas drilled 20 somenthing wells and Ngas/Magnum Hunter drilled 5.

Horizontal Shale Wells



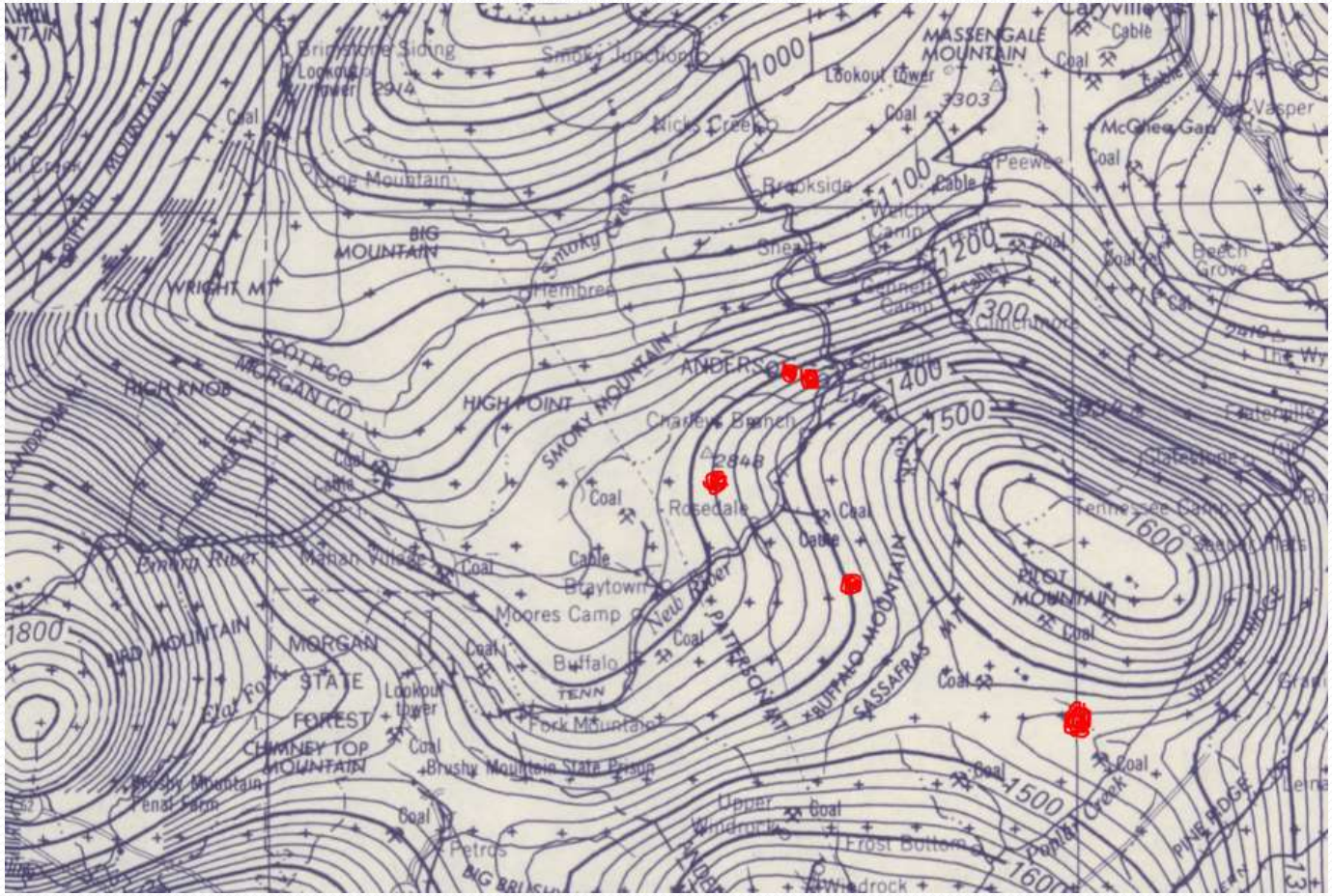
Top 10 Horizontal Wells

Permit #	Quad	Total	Well Name	Length	direction	stages	volume
		mmcf					
11797	Clinton	720	CH-2001	2200	NW	4 stages	foamed sand
12033	Duncan Flats	541	AH-1010	4400		15 stages	1mmcf/st
12326	Duncan Flats	437	AH-1040	4200	NW	22 stages	1mmcf/st
12191	Duncan Flats	394	AH-1038	4200		22 stages	1mmcf/st
12190	Duncan Flats	393	AH-1022	4200		22 stages	1mmcf/st
12218	Eagan	391	DPI-211	4900	NW	13 stage	1 mmcf/stage
12128	Gobey	388	HH-1034	5000	NW	22 stages	1mmcf/st
11880	Petros	384	WH-1004	3100	NW	9 stages	Ni
12046	Duncan Flats	384	AH-1024	4500	NW	15 stages	1mmcf/st
12215	Eagan	370	DPI-209	4400	NW	15 stage	1 mmcf/stage
Total		4402					
AVG Per Well		440.20					

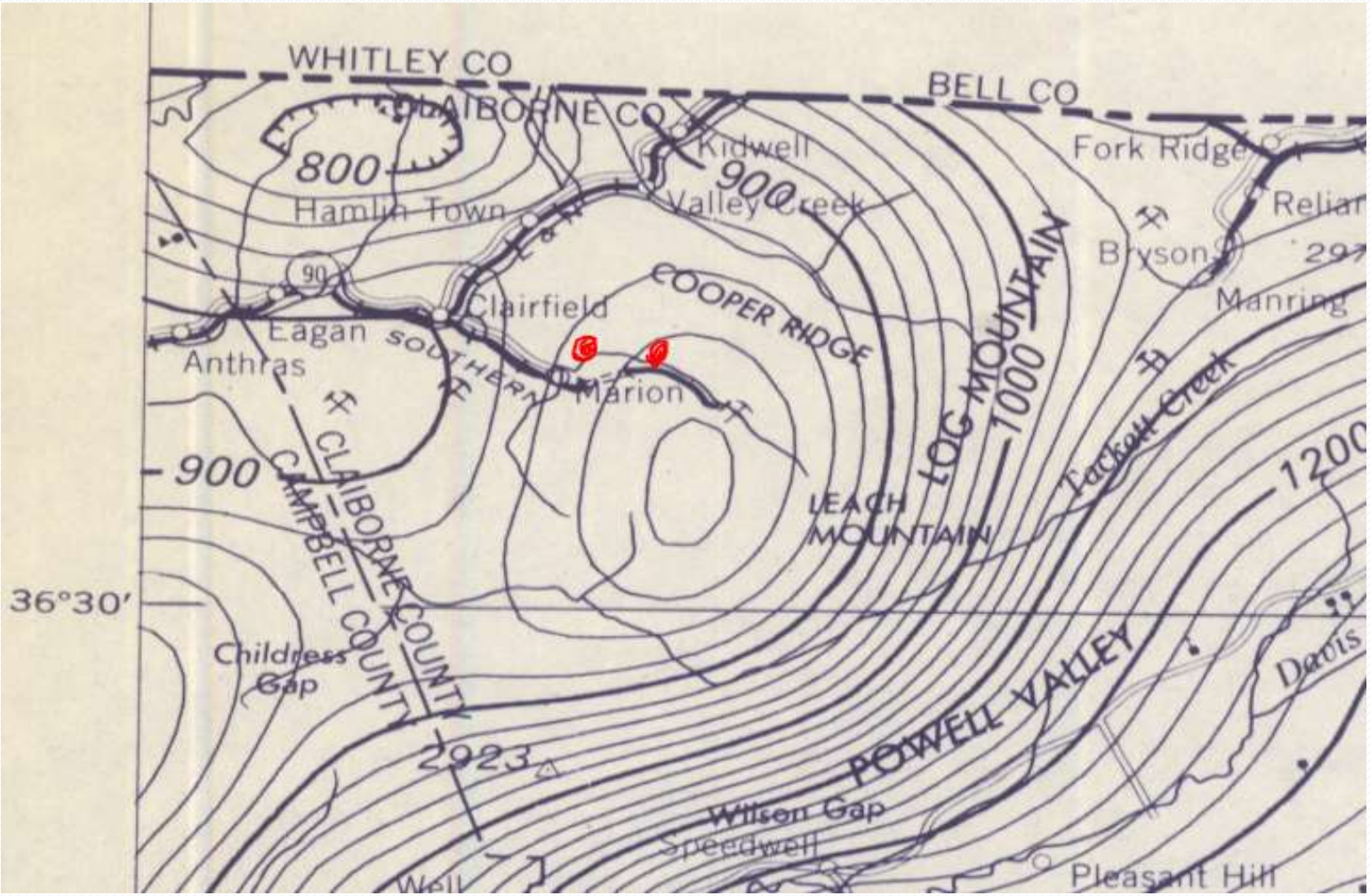
Worst 10 Horizontal Wells

Permit #	Quad	Total	Well Name	Length	direction	stages	volume
12049	Ketchen	65	BDH-003	2500		9 stages	1 mmcf Ni
12038	Ketchen	64	BDH-001	2700		9 stages	1 mmcf Ni
12059	Lake City	61	CH-2024	2500		9 stages	85Q foamed sand 1.2mmcf/st
11957	Ketchen	57	ELK-2H	3000			sand acid
11967	Ketchen	55	ELK-5H	2300			foamed sand
11994	Pioneer	52	ELK-22H2				foamed sand
12039	Ketchen	50	BDH-002	2700		9 stages	Foamed Sand
11933	Ketchen	49	KH-004	2500		9 stages	foamed sand
12003	Ketchen	40	ELK-44H2				foamed sand
12219	Lake City	14	CCLC-70H1	2800	NW	22 stages	100mcf/st
Total		507					
AVG Per Well		50.70					

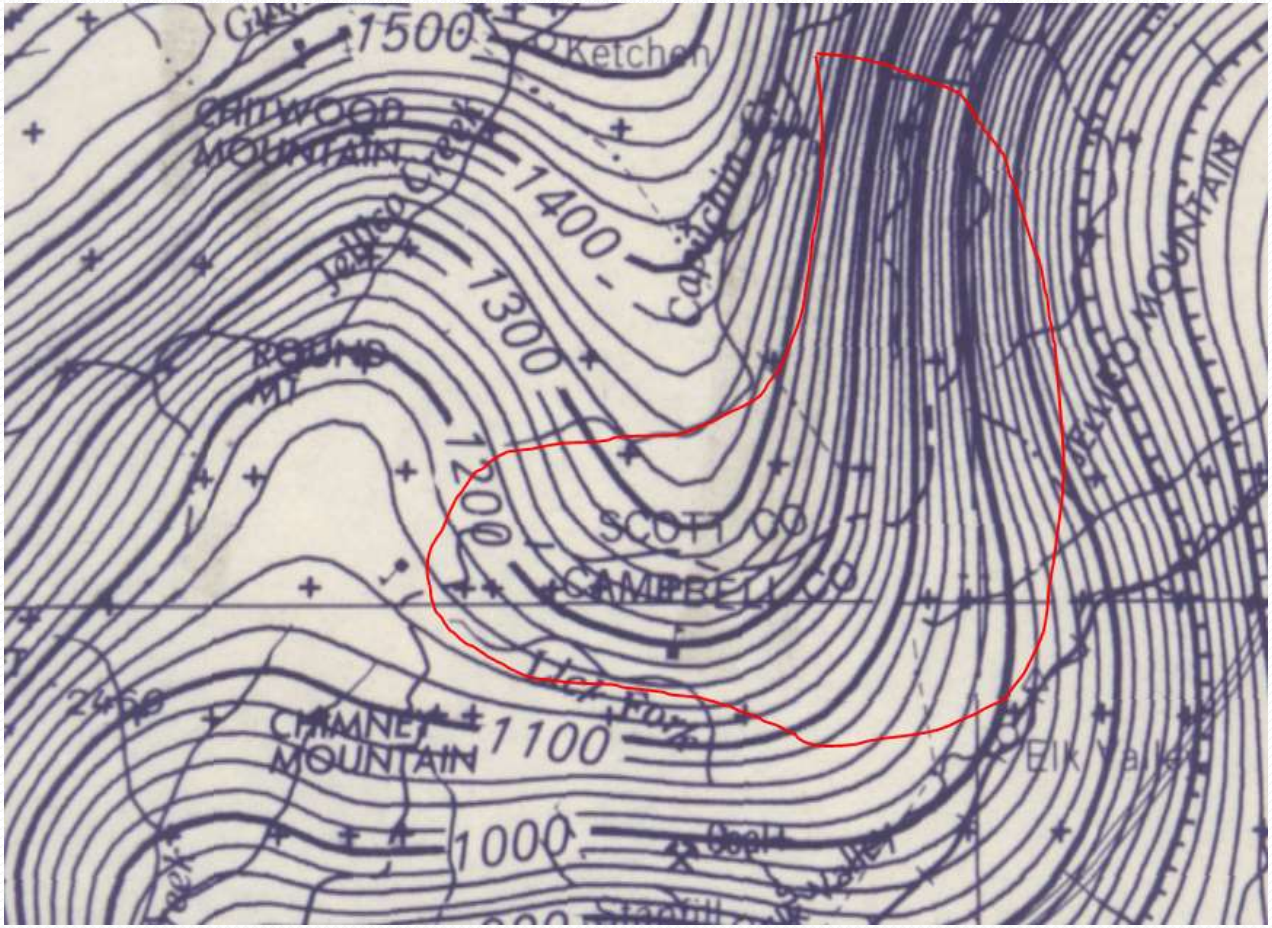
Mag map New River Area



Mag Map Claiborne



Atlas Wells


1500
Ketchen
CHITWOOD MOUNTAIN
1400
1300
ROUND MT
1200
SCOTT CO
CAMPBELL CO
CHANNEL MOUNTAIN
1100
1000
Elk Valley

Horizontal Shale Wells where and how

- Generally speaking, to get good production out of a horizontal shale well, you need longer laterals, more frac stages, larger fracs, and drill them in areas of magnetic lows .
- The best well in state was one of the first ones drilled was a short lateral with only 4 stages but was drill in a magnetic low.

Horizontal Shale Wells where and how

- Another factor in my opinion is picking the best zones to frac. The best zones, I think, are where the wellbore intersects natural fractures. As I mentioned earlier the first well, Permit #11382, used fluid for drilling and fraced the lost circulation zones, which were the natural fracture zones.
- That is probably not the best way to determine fracture zones but it worked. This well has produced 349mmcf in 9 years and is still making 30mmcf/year.

Horizontal Shale Wells where and how

- Another way to determine where the natural fracture zone is to have a mudlogger with a gas detector during the drilling.
- A geophysical log can be run but the cost is prohibitive.
- Using the Packers Plus type system with as many stages as practical assumes that fracing 20-30 different zones is going to hit some or all of the naturally fractured zones in the wellbore.

Wellbore Location

- One of the former employees of Knox Energy/Consol Energy told me that they learned that they got better results by directing the wellbore as close to the top of the shale as possible. This is easy to do since the bottom of the Fort Payne is hard dolomite and chert. Therefore, the bit with not drill up into the bottom of the Fort Payne.
- That same employee also said they found out that the better horizontal were located in areas that also had good production above in the Monteagle. I think that is related to magnetic lows.

Production

- The 79 horizontal shales wells have produced approximately 15bcf since 2009. That is roughly 1/3rd of the total production in the state.
- All of the best gas wells in Elaine's handout are horizontal shale wells.
- The top 15 wells have produced at least 300mmcf each and are still producing 30-60 mmcf/year after 6-9 years with a low decline rate.

Reserves

- When I put these spreadsheet together, I was surprised to see the production and low decline rate after 7-8 years.
- The decline rate on these wells is similar to that seen in vertical shale wells in Eastern Kentucky and West Virginia. Many of those have been producing for 50-80 years.
- A vertical shale well near Oliver Springs, Permit #10375, Vinland Energy/Coal Creek #14 has produced 379mmcf since 2005 and is still producing 12-13mmcf/year after 12 years.

Reserves

- I'm no reserve engineer nor have I seen any reserve reports on any of these wells, but I think the better wells would have reserves of over 1bcf with some up to 2bcf.
- I recently did an AFE for a horizontal well for Champ Oil Company. The total cost was approximately $1 million for a 4,000-5,000' lateral with 22 stages and 1mmcf of Nitrogen per stage.

Return on Investment

- 300mmcf of production receiving a price of $3/mcf results in an income of $900,000.
- Several of the better wells produced 300mmcf in the first 3 years of production.
- Assuming you drill new wells in the proper place, with a long lateral, many frac stages, and large gas fracs, you should achieve payout in 3-5 years which is attractive to most companies.
- For companies or individuals looking for long term investment over 10-20 years these wells should do fine.

Horizontal Oil Wells

- I think four horizontal oil wells have been drilled in Tennessee. Three were drilled in old depleted Fort Payne fields. The reservoir is a bio-hermal mound. The other was drilled into the chert and dolomite facies of the Fort Payne .
- None of these wells were commercial successes.
- The one well that I was involved in was in the Oneida West field.
- The well bore went through a part of the reservoir that had no vertical wells because of the airport. The well went under the runway.

Horizontal Oil Wells

- During the drilling of this well a lot of oil was produced. We sold 800bbls that was pumped out of the pit.
- My opinion is that some of the air from the rig which was 500-600PSI went into the formation which in turn forced oil into the wellbore behind the bit and was then blown out into the pit.
- We thought the well was going to be a monster, but once we started pumping the well the production gradually went down to 1bopd after a few months.

Horizontal Oil Wells

- One of Enrema's horizontal wells made Elaine's top 5 list, Permit #12404.
- According to the production report, it made 2,900 bbls, which is 8-9 bopd. This is better than 1 bopd but still not commercially profitable.
- When we drilled the well at Oneida West, I thought the wellbore would be like a drainage ditch. The oil would drain into the borehole then flow down hill into the heel of the well and to the pump.
- I was wrong.

Horizontal Oil Wells

- The problem is that something has to push that oil to the wellbore.
- If the original gas pressure is gone something else must serve that purpose.
- Bill talked about some of those options earlier; nitrogen, CO_2, Y grade NGL.
- This takes capital outlay, time, sometimes regulatory issues.