A Microseismic Case Study: Cotton Valley Taylor Sandstones, Overton Field, Texas

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ABSTRACT

Tanos Exploration II, LLC (Tanos) along with partner Breitburn Energy Partners (Breitburn) conducted a microseismic survey in 2015 at Overton Field, Smith and Cherokee counties, Texas. The survey was acquired in two horizontal wells drilled in opposite directions (north and south) from the same surface pad. Both wellbores targeted the same stratigraphic interval within the Taylor sandstone of the Jurassic-aged Cotton Valley formation. Stimulation spacing, perforation clusters, pump rates and proppant concentrations were fairly consistent between wells. The McElroy-Swann #1H, the northern lateral, was drilled between twelve existing vertical wells that were completed with single stage fracture stimulations over the entire Taylor interval approximately 10 yr earlier. In contrast the southern lateral, the Wilkinson-McElroy A #1H was drilled within a relatively undrained area of the field. The survey was conducted to compare and contrast the fracture stimulation results for the two wells, one drilled within "partially-drained" versus one drilled within "undrained" areas of the field.

The McElroy-Swann #1H was drilled with a total displacement of 6640 ft and an effective lateral length (first perforation to last perforation) of 5803 ft along a 358° azimuth to a total depth of 17,999 ft. Completion design utilized 5½ in. P110 casing cemented in place and a "plug and perf" methodology with three or four perforation clusters sixty feet apart per stage. The existing vertical wells ranged from 410 to 1265 ft away from the horizontal wellbore. Cumulative production from the existing vertical wells totaled over 4.6 billion cubic ft (BCF) of gas and 98,650 barrels of condensate (BC) (5.2 BCFE [BCF gas equivalent]). The microseismic event mapping for the northern lateral indicated the original stress field of the Taylor sandstone reservoir had been significantly altered by the fracture stimulations and associated production from the vertical wells. Instead of "well-behaved," predictable fracture propagation along a consistent orientation, results indicated a "random" orientation with different widths and half-lengths resulting in highly complex fracture patterns.

The Wilkinson-McElroy A #1H was drilled with a total displacement of 7253 ft and an effective lateral length of 6433 ft along a 169° azimuth to a total depth of 18,600 ft. Plug and perf methodology within 5½ in. casing was employed as above. In contrast to

the McElroy-Swann #1H, the southern horizontal wellbore drilled through a relatively undrained area of the field. Three wells along the wellbore, all completed in 2004, had produced less than one BCFE of gas combined. The Wilkinson-McElroy A #1H results indicated a more predictable fracture propagation orientation consistent with an earlier 2005 study at Overton Field.

A MICROSEISMIC CASE STUDY: COTTON VALLEY TAYLOR SANDSTONES, OVERTON FIELD

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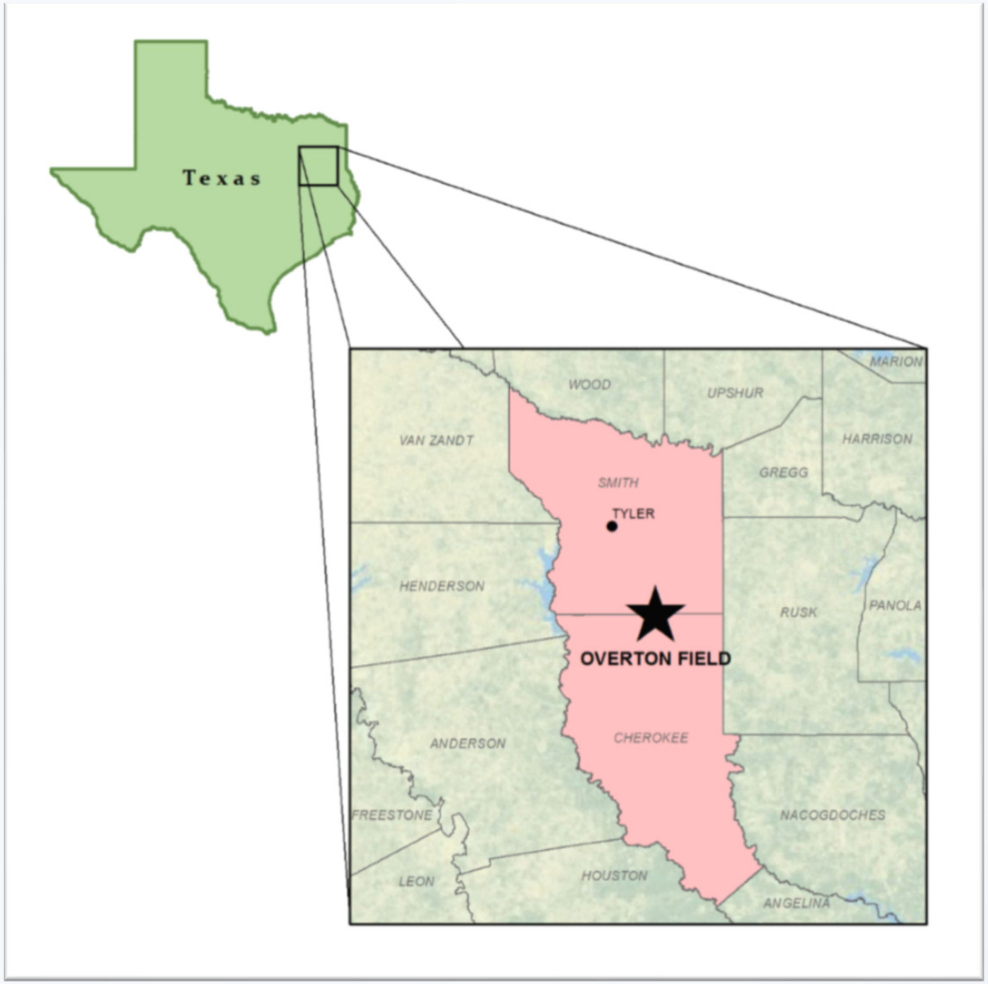
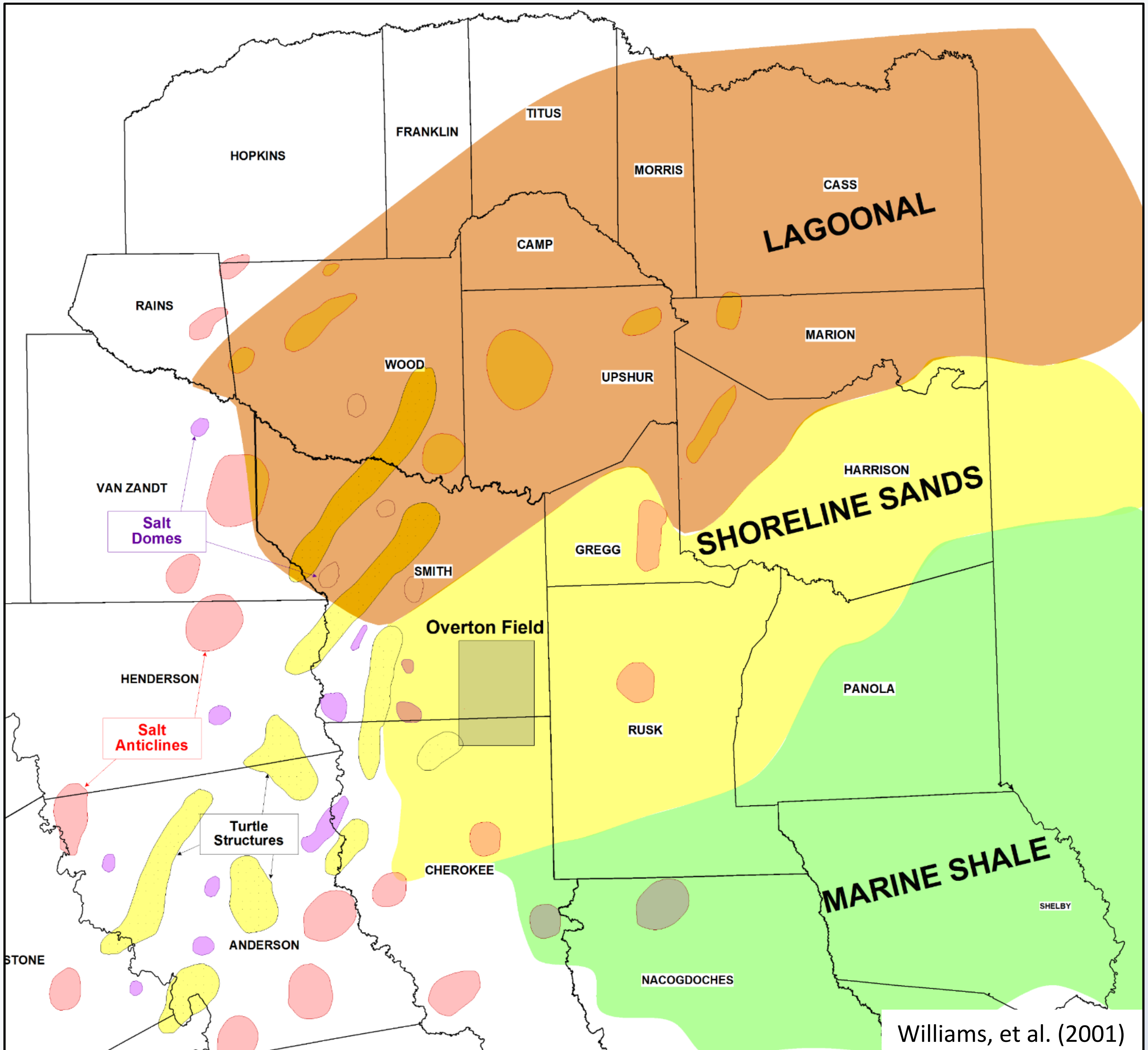
QUANTUM ENERGY PARTNERS



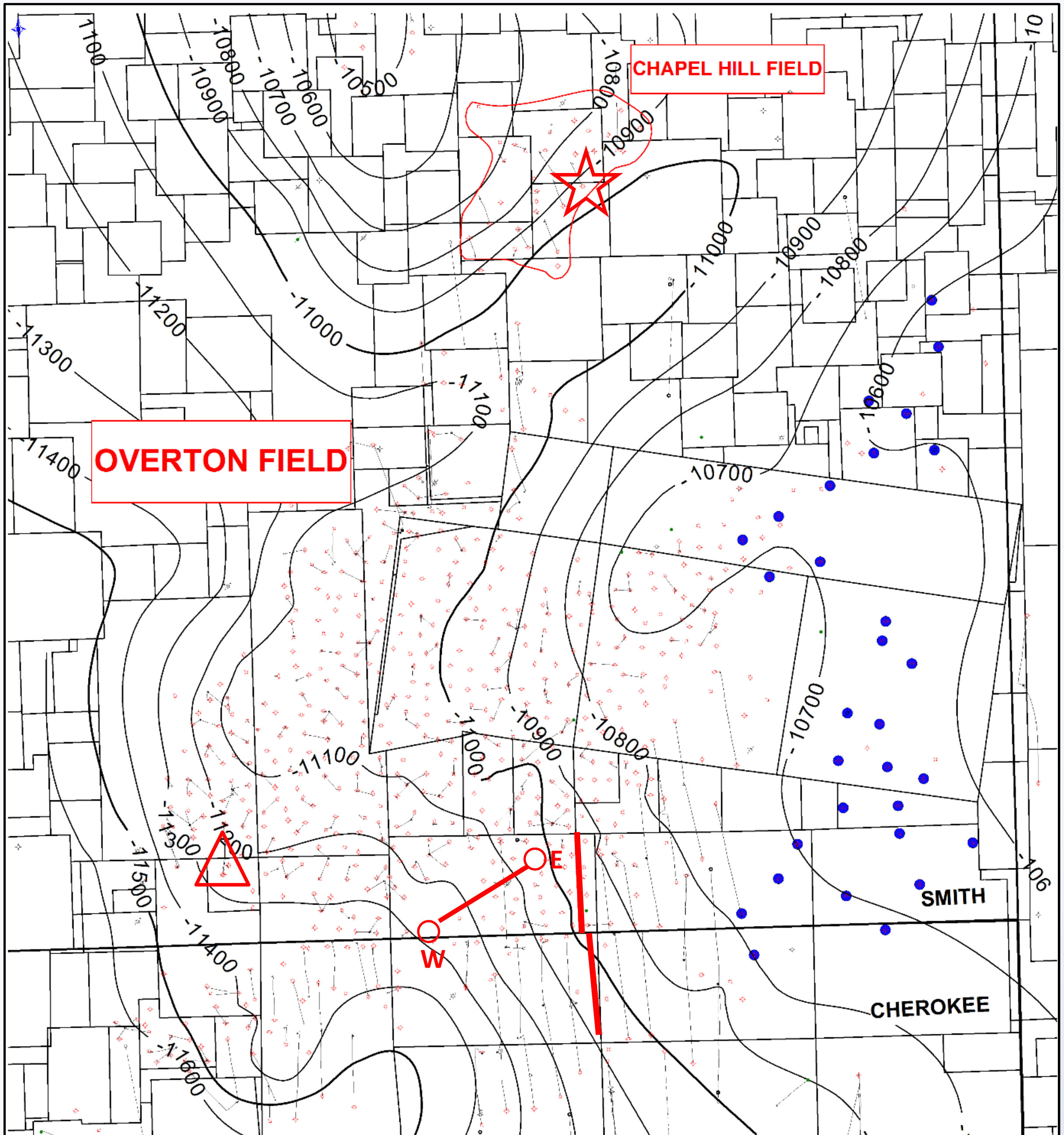
OVERTON FIELD

- Haynesville Lime discovered in 1974
- Cotton Valley Taylor Sands discovered in 1978
- Field development accelerated after Southwestern acquisition- 388 wells drilled from 2001 to 2005
- Cumulative Production > 530 BCF & 4.7 MMBC from Taylor Sands
- Currently over 600 active wells still producing in the field
- Gross Taylor interval averages 350 ft. in thickness across the field
- Condensate yields range from < 5 BC/MM to > 50 BC/MM in the field
- 1st horizontal well drilled in 2005, study wells drilled in 2015



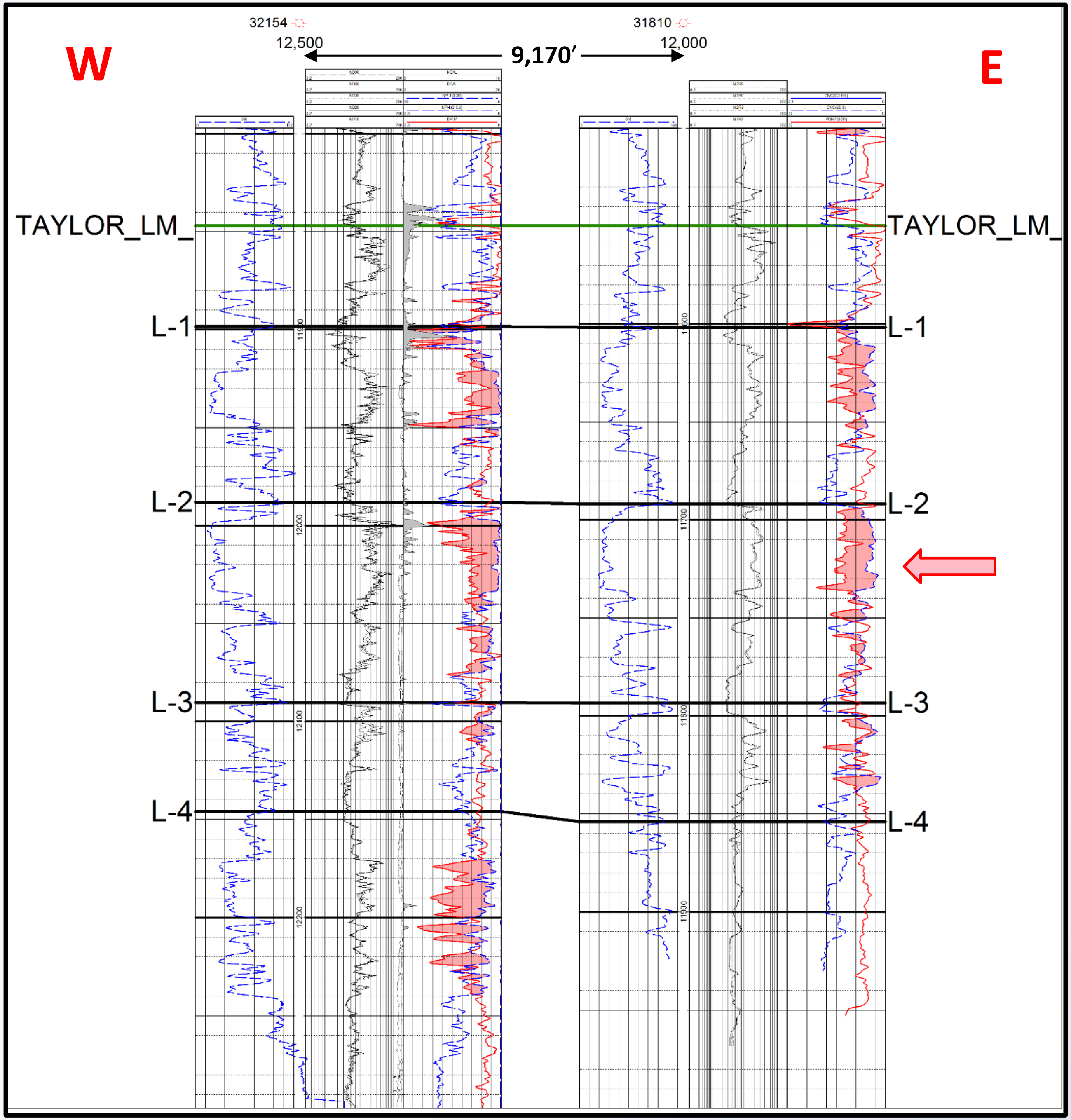
COTTON VALLEY STRATIGRAPHY

Williams, et al (2001) established a detailed sequence-stratigraphic interpretation of the Cotton Valley/Bossier depositional history. The Taylor sandstones are present in the BSB2 sequence, interpreted as part of a lowstand prograding complex that graded basinward into a predominantly shaly Bossier lithology



STRUCTURE MAP T/TAYLOR LIME

- Cotton Valley (Haynesville) Lime producers in blue
- Deepest Taylor production in the East TX Basin, produces at depths > 12,000
- Avg. porosity 8%, permeability 0.005 md & 27% Sw. Slightly overpressured @ 0.60 psi/ft
- First horizontal well drilled by J-W Operating in 2005 (red star), Mud Creek #2H (red triangle)
- Horizontal wells in this study identified by red laterals



TYPE LOGS

- Taylor sands generally perforated in L1-L3 + L4 when present and fracture stimulated in a single stage for most vertical wells in the field
- Gross thickness ranges from 250 – 350 ft
- L-4 generally present over the western half of the field and the best producing interval
- Taylor Lime provides a good barrier inhibiting upward frac growth, however some of the 80 bbl/min. frac jobs broke through this barrier in the vertical wells
- L-2 was target sand for both horizontal wells (red arrow)

HISTORICAL MICROSEISMIC FRACTURE MAPPING RESULTS

Vertical Well Example

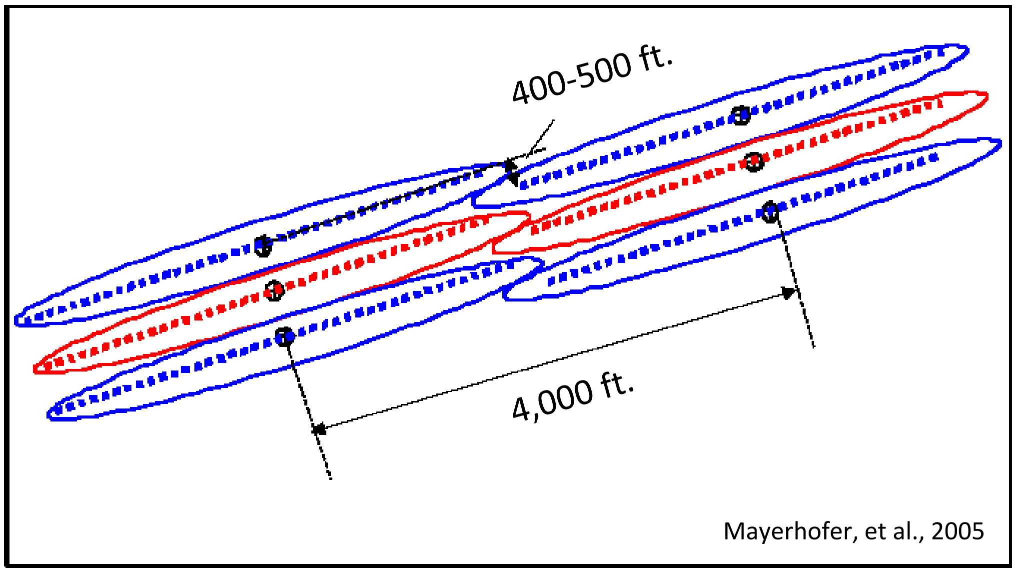
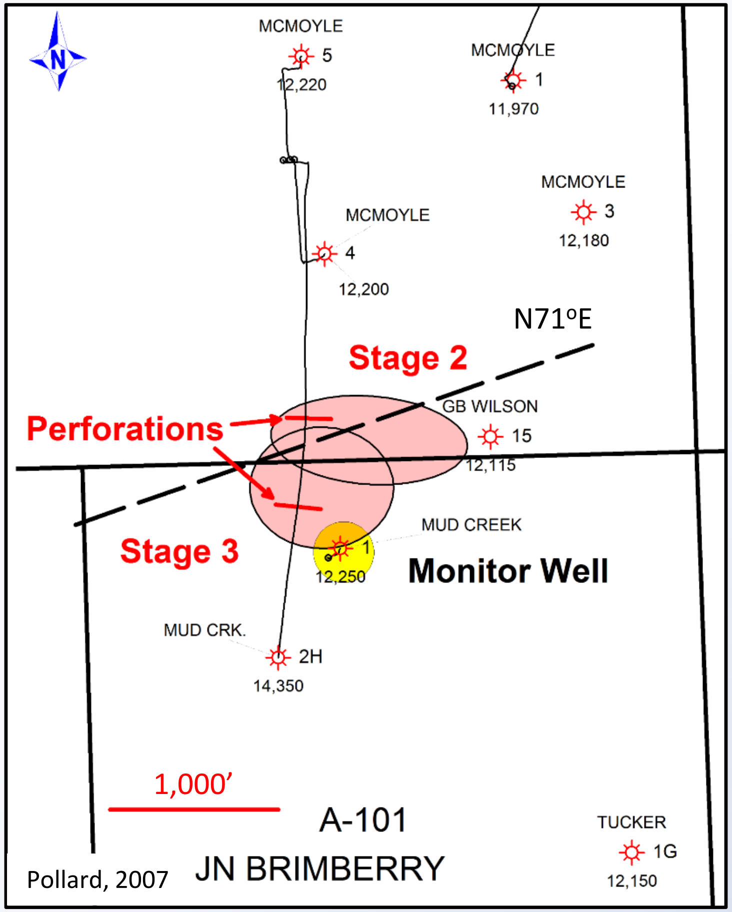


Figure 24 Conceptual sketch of future well placement strategy

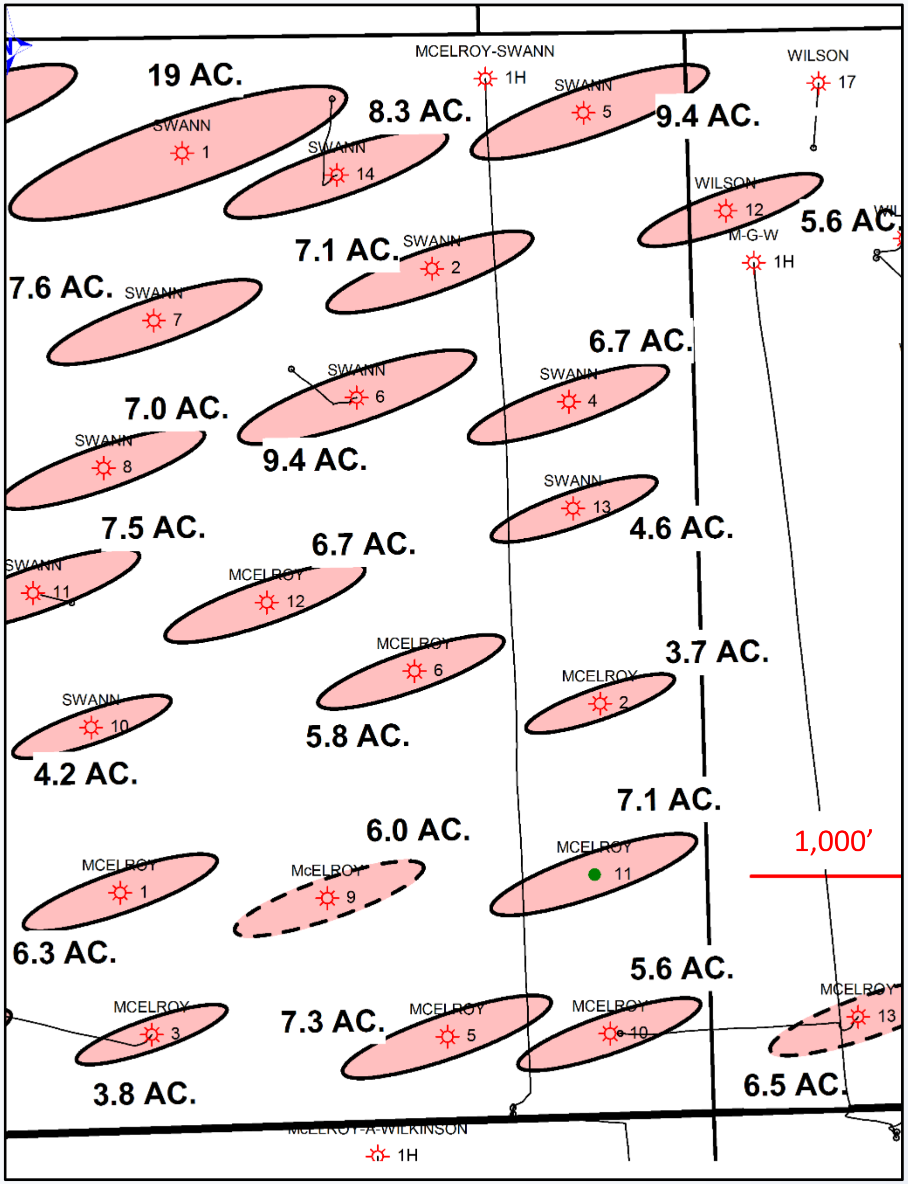
Mayerhofer, et al. (2005) concluded symmetric fracture wing lengths of 1,550 ft. on each side of the wellbore in a N71ºE azimuth, resulting in elongated "cigar-shaped" 27 acre drainage ellipses. Production interference was noted in wells as far as 2,450 ft. away along the fracture orientations

Horizontal Well Example



Mud Creek #2H targeted the L-4 sand & mapping displayed more oval and egg-shaped stimulation areas encompassing ~10 acres. Stage 2 asymmetry infers a pressure sink around the producing Wilson #15

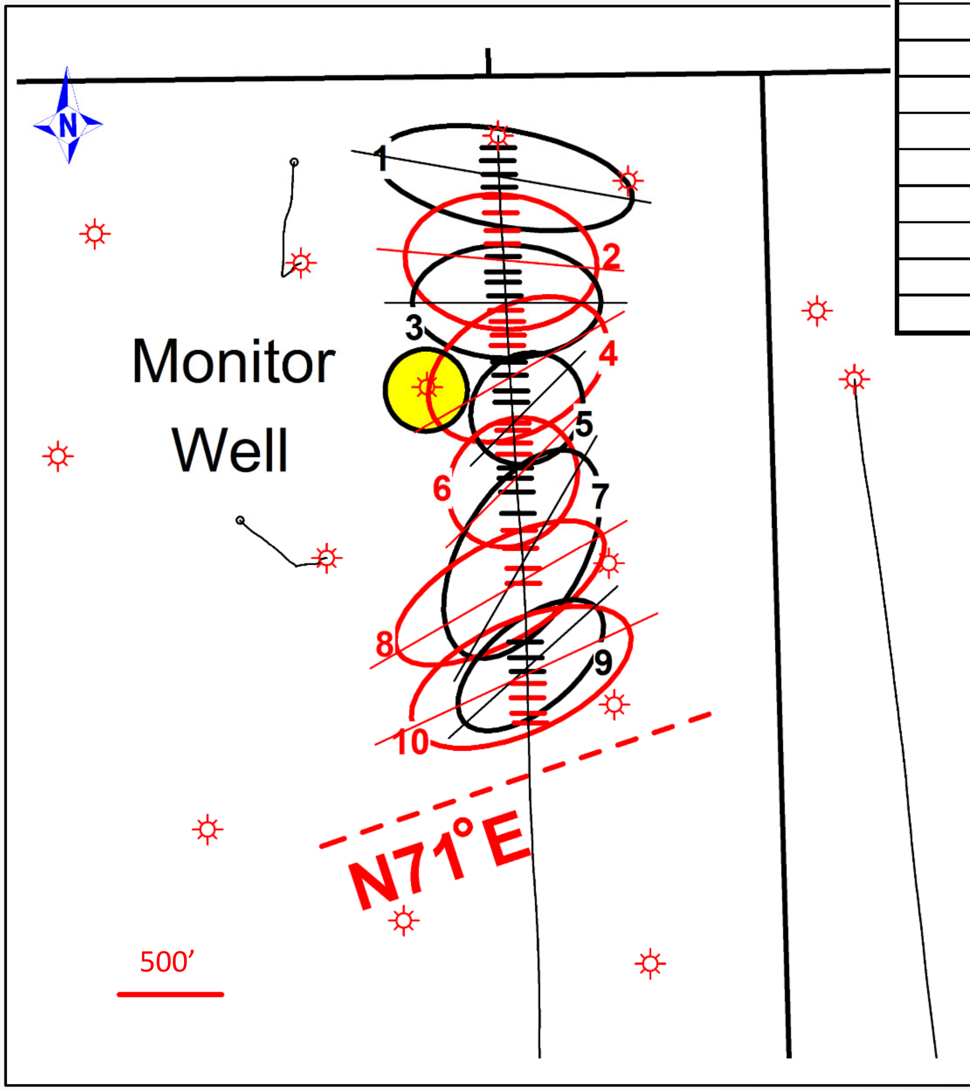
McElroy-Swann #1H Horizontal Well



NORTHERN LATERAL

- McElroy-Swann #1H was drilled with an ELL of 5,803 ft. and completed with 20 frac stages utilizing plug and perf methodology in 5 ½" casing
- The well was drilled between 12 vertical wells that had produced 4.6 BCF & 98,650 BC (5.2 BCFE) from the Taylor sands
- Wells ranged from 410 to 1,265 ft. from horizontal lateral, M-G-W #1H drilled later
- 12 vertical completions occurred from 2003 to 2006, with 9 wells completed during a 24 month span from 2005 to 2006
- Pre-drill analysis calculated inefficient drainage from the existing vertical wells. Drainage ellipses were assumed to be oriented N71ºE, consistent with the vertical microseismic study

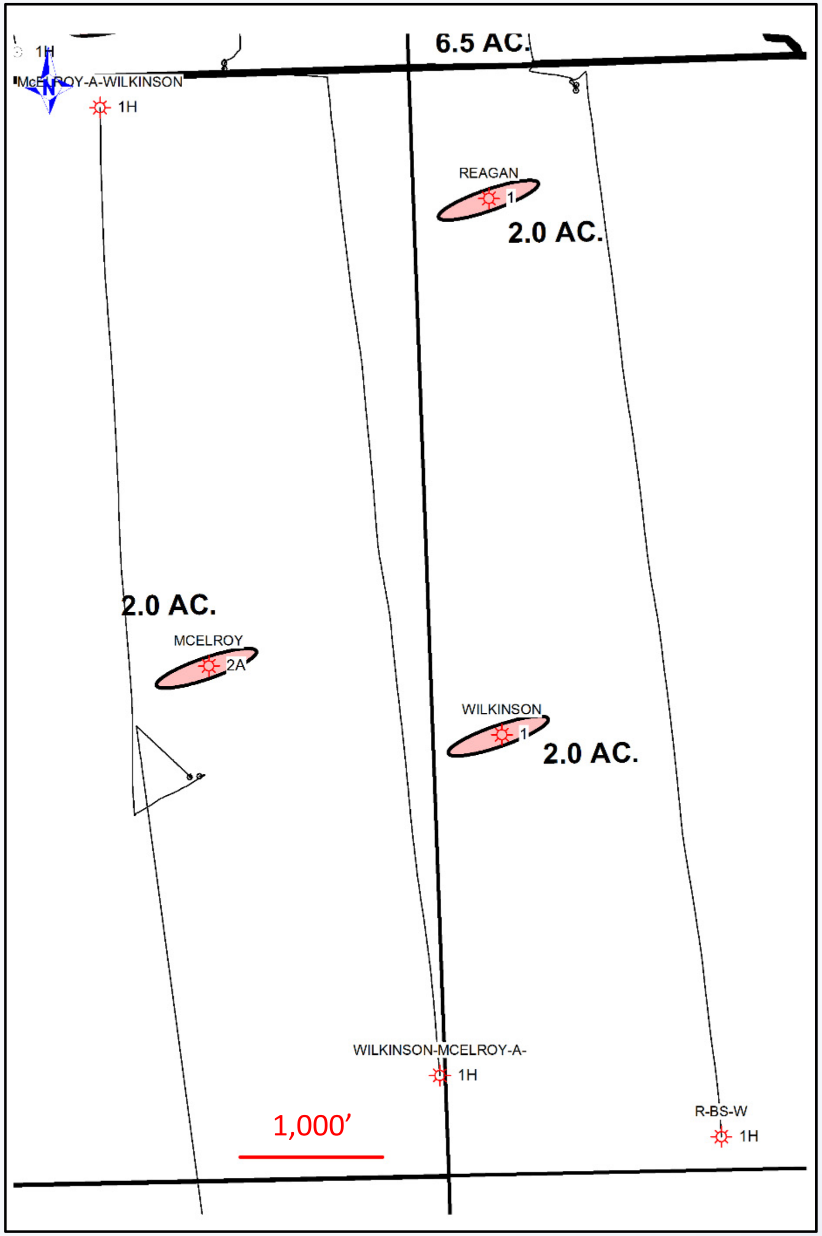
McElroy-Swann #1H (North Lateral) Microseismic Results



McElroy-Swann #1H		Azimuth	Half Length		Width	Avg Perf-Receiver
Stage	Events	(degrees)	East(ft)	West(ft)	(ft)	Distance(ft)
1	146	N100°E	671	591	470	1414
2	183	N95°E	460	477	647	1157
3	195	N90°E	455	465	577	1089
4	124	N60°E	513	425	614	1089
5	216	N45°E	392	182	499	982
6	173	N45°E	293	382	586	980
7	184	N30°E	575	550	597	1093
8	174	N60°E	576	571	475	1243
9	121	N50°E	460	393	426	1657
10	121	N65°E	579	574	542	1897

- Perfs and stimulated reservoir volume (SRV) for the 10 monitored stages are shown in alternating black and red colors. Lines through each stage indicate the mapped azimuth in comparison to the N71°E azimuth
- Microseismic indicated the entire Taylor interval was stimulated
- Results indicate the original stress field of the reservoir had been significantly altered by the fracture stimulations of the original vertical wells
- The result is a highly complex fracture pattern characterized by frac azimuths that vary by 70°, varied widths and half lengths & overlapping stimulation areas

Wilkinson-McElroy-A- #1H Horizontal Well

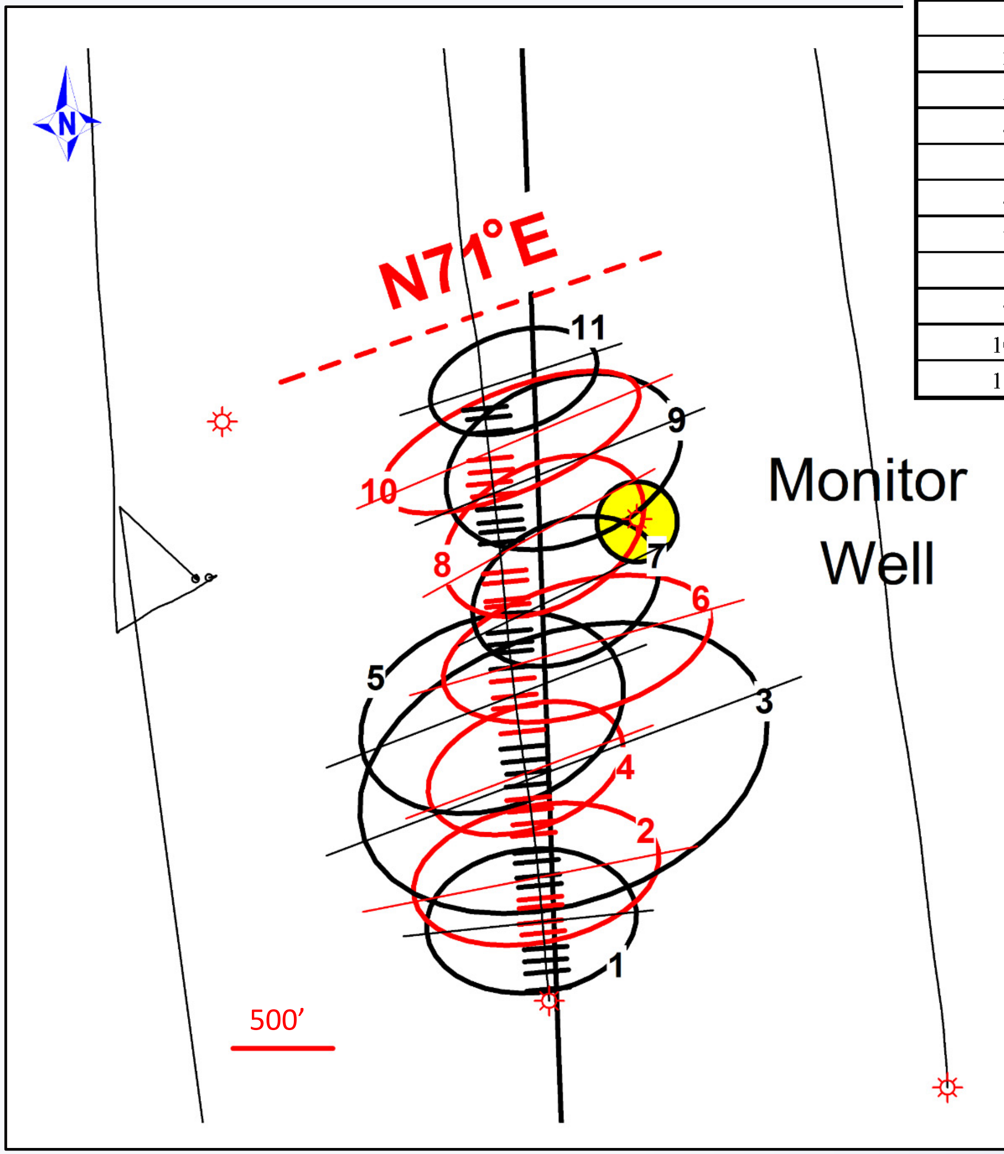


SOUTHERN LATERAL

- Wilkinson-McElroy-A- #1H was drilled with an ELL of 6,433 ft. and completed with 24 frac stages utilizing plug and perf methodology in 5 ½" casing
- In contrast to the McElroy-Swann #1H, the southern lateral was drilled in a relatively undrained section of Overton field
- The 2 vertical wells near the mapped well path were drilled in 2004 and had produced less than 0.5 BCF combined. The 3 offsetting horizontal wells were drilled after the monitored well
- Pre-drill analysis calculated insignificant drainage risk from the existing vertical wells. Drainage ellipses were again assumed to be oriented N71ºE

Wilkinson-McElroy-A- #1H (South Lateral) Microseismic Results

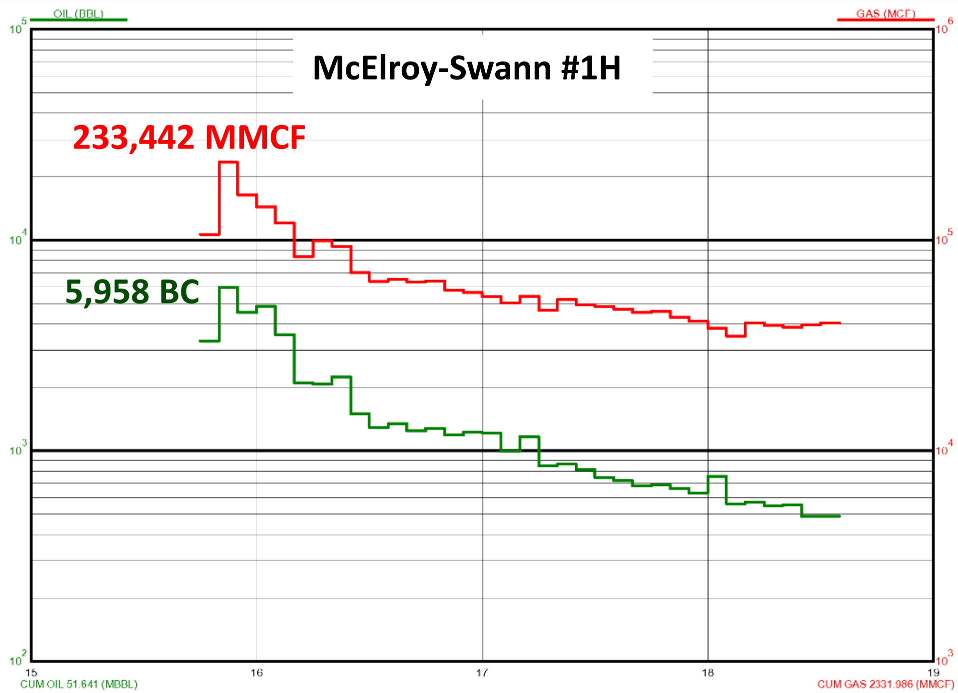
Wilkinson-McElroy-A- #1H		Azimuth	Half Length		Width	Avg Perf-Receiver
Stage	Events	(degrees)	East(ft)	West(ft)	(ft)	Distance(ft)
1	161	N84°E	484	565	715	2497
2	232	N79°E	604	635	682	2169
3	250	N70°E	1285	821	1340	2120
4	522	N70°E	502	58	620	1879
5	547	N70°E	571	780	964	1647
6	352	N74°E	1046	330	653	1453
7	530	N64°E	812	165	721	1322
8	540	N61°E	791	280	702	1196
9	228	N68°E	983	235	811	1128
10	322	N67°E	842	535	501	1151
11	745	N72°E	620	240	488	1276

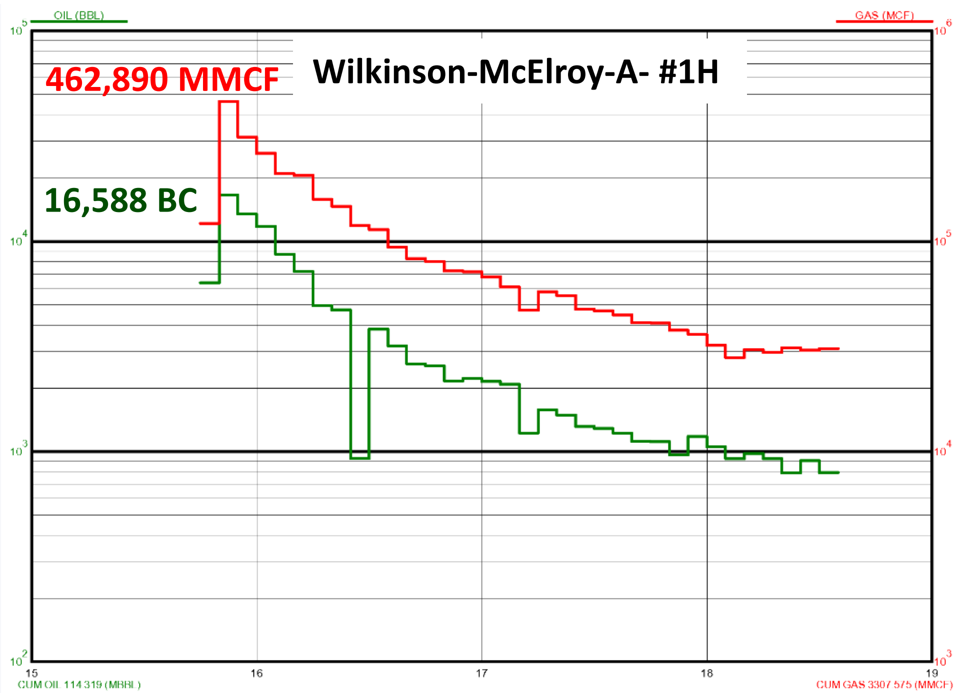


- Perfs and stimulated reservoir volume (SRV) for the 11 monitored stages are shown in alternating black and red colors. Lines through each stage indicate the mapped azimuth in comparison to the N71°E azimuth
- Microseismic indicated the entire Taylor interval was stimulated
- Mapped azimuths more closely aligned to the Mayerhofer, et al. study
- Fracture mapping reflected complex stimulation results with overlapping stages and asymmetric wing lengths when completing in an undrained area of the field

Fracture Stimulation Stage Statistics

McElroy-Swann #1H		Stage Interval	Prop. Pumped	Fluid pumped	Avg. Rate	Prop. Con.	Clusters/stage
Stage	Perf. Depths	(feet)	(lbs.)	(Bbls.)	(Bbl./min.)	#/ft.	
1	17750-17941	191	222960	7458	71	1167	3
2	17471-17697	226	228040	8520	71	1009	4
3	17218-17408	190	229000	7561	71	1205	4
4	16970-17150	180	227820	7710	71	1266	4
5	16700-16891	191	217060	7500	73	1136	4
6	16440-16598	158	258740	11277	80	1638	4
7	16150-16376	226	218200	7690	80	965	4
8	15806-16075	269	221900	7578	81	825	4
9	15381-15527	146	221240	7662	81	1515	3
10	15132-15319	187	218900	7459	81	1171	4
Wilkinson-McElroy-A- #1H							
Stage	Perf. Depths						
1	18335-18543	208	223260	7331	70	1073	4
2	18085-18263	178	162660	6892	70	914*	4
3	17850-18024	174	191900	7420	67	1103	4
4	17585-17768	183	229520	8863	72	1254	4
5	17330-17520	190	228560	8587	69	1203	4
6	16988-17251	263	261680	10508	82	995	4
7	16745-16931	186	159900	7103	80	860*	4
8	16449-16623	174	219900	6574	81	1264	4
9	16130-16303	173	219760	7543	81	1270	4
10	15880-16068	188	218960	7806	81	1165	4
11	15630-15748	118	222820	8118	80	1888	3





HORIZONTAL PRODUCTION

- Lower reservoir pressure resulted in lower flush production of almost 1/2 the W-M-A #1H gas & 2.5X less oil
- IP is 1.22 MMCF/1000' & EUR is 1.51 BCF/1,000'
- Shallower decline yields better EUR- 1.58 b factor
- Cum. Prod: 2.3 BCF & 51,600 BC- 22 BC/MM yield
- Current daily prod: 1.3 MMCF/D & 17 BC
- EUR: 8.2 BCF & 97,500 BC (8.8 BCFE)- 12 BC/MM yield

- First flush month of production almost 2X the M-S #1H gas & over 2.5X oil
- IP is 2.31 MMCFE/1000' & EUR is 1.12 BCFE/1,000'
- Steeper decline yields lower EUR- 1.08 b factor
- Cum. Prod: 3.3 BCF & 114,300 BC- 34 BC/MM yield
- Current daily prod: 1 MMCF/D & 27 BC
- EUR: 6.2 BCF & 173,000 BC (7.24 BCFE)- 28 BC/MM yield

CONCLUSIONS

McElroy-Swann #1H- Northern Lateral

Microseismic mapping indicated the original reservoir stress field had been significantly altered by the earlier vertical completions, resulting in complex and more compact stimulations

Drilled between 12 vertical wells drilled 9-10 years earlier completed with fracture stimulations in the same reservoir

Pre-drill analysis indicated inefficient drainage from vertical wellbores, but with the risk of sufficient remaining reservoir pressures

Maximum observed flowback pressures were ~1350# less than the southern lateral, indicating reservoir drawdown after 10 years of vertical production

Partial depletion reduces IP rates, but drilling in a higher OGIP area yields a higher EUR

Wilkinson-McElroy-A- #1H- Southern Lateral

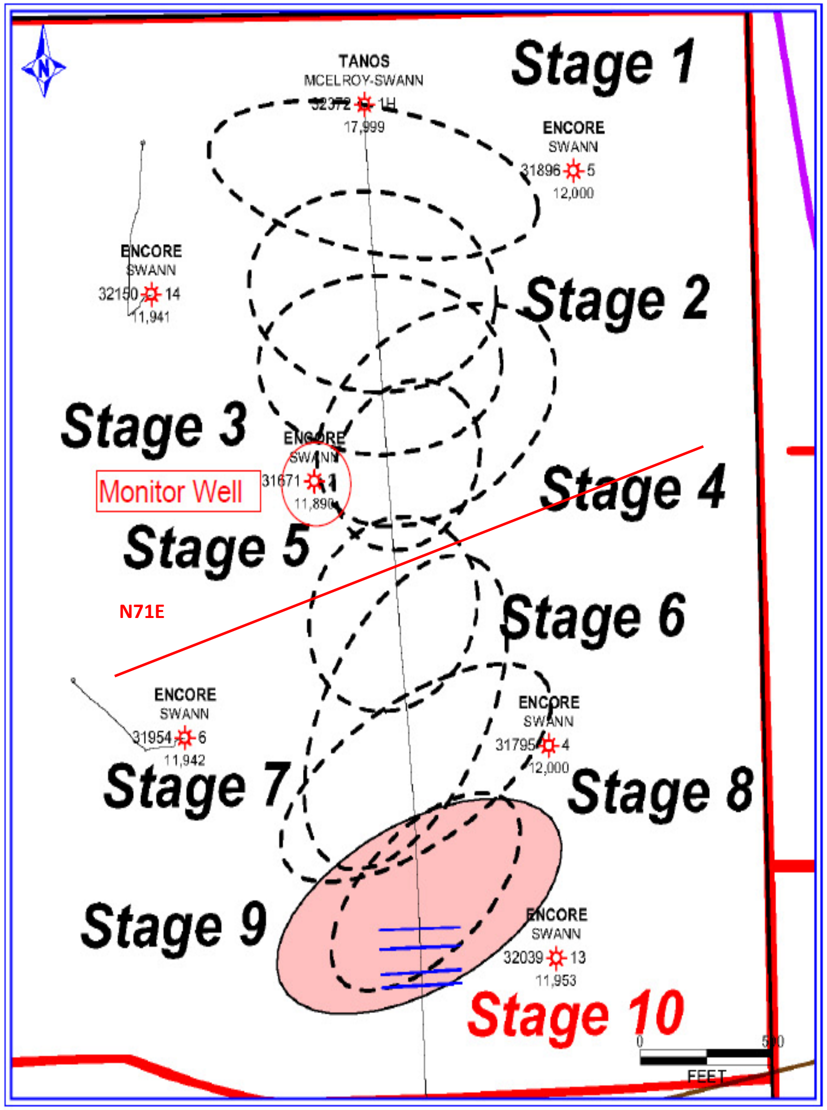
Microseismic mapping indicated fracture azimuths consistent with the earlier vertical study, longer frac half lengths and wider stimulated areas

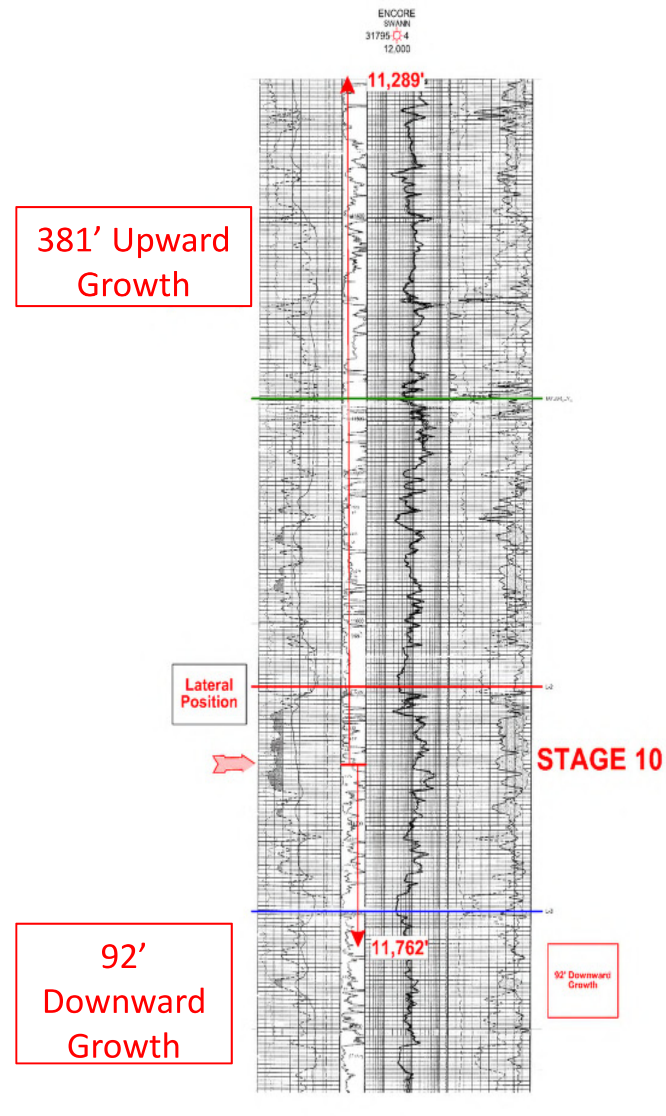
Drilled in a relatively undrained area of the field- 3 vertical wells completed in the same reservoir 11 years prior with marginal results (<1 Bcf total cum.)

Pre-drill analysis indicated no depletion risk, but a deliverability risk associated with poor vertical production

No reservoir pressure drawdown results in higher IP rates from the undrained area, but a lower EUR reflective of lower OGIP estimates

Bonus Slide detailing upward & downward frac growth





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