Mosser Dome Field, Yellowstone County, Montana: A Giant Stratigraphic Oil Accumulation*

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Abstract

Surface and subsurface mapping of a valley-fill depositional system in the Fall River Formation (Lower Cretaceous) in southern Montana reveals the presence of a giant oil accumulation that may have originally contained more than two billion barrels of oil. This major stratigraphic trap on the northeast flank of the Bighorn Basin is one of the largest in the Rocky Mountain region of the U.S. Except for a small area at Mosser Dome oil field, the oil contained in this trap is viscous heavy oil (<15° API). Extending a distance of twenty-two miles with a maximum width of four miles, the forty-eight square-mile accumulation is found in porous sandstone that reaches a thickness of over ninety feet. The sandstone reservoir, known as the Greybull Sandstone, was deposited in a westward-flowing valley-fill system. In the area of the Mosser Dome accumulation, two separate fault zones deflected the fluvial system to the northeast for a distance of sixteen miles before it resumed its westward flow direction. The large deflections of the valley-fill system combined with southward regional dip to form a giant stratigraphic oil trap. Geochemical analysis of the oil indicates a source in the Permian Phosphoria Formation. Subsequent introduction of bacteria-bearing fresh water caused the oil to be degraded, leaving relatively immobile asphaltic oil in the reservoir. The Mosser Dome stratigraphic trap is an excellent analog for non-degraded oil and gas accumulations in similar settings in the Fall River Formation in the deeper portions of the Bighorn Basin.

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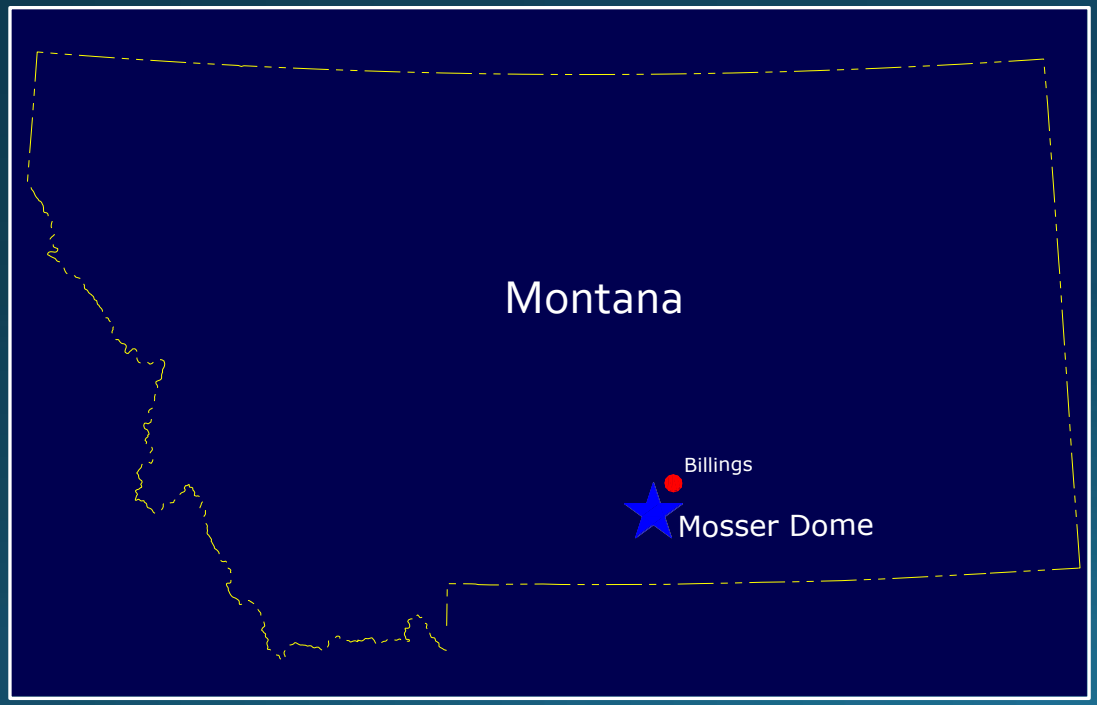
Mosser Dome Field, Yellowstone County, Montana: A Giant Stratigraphic Oil Accumulation



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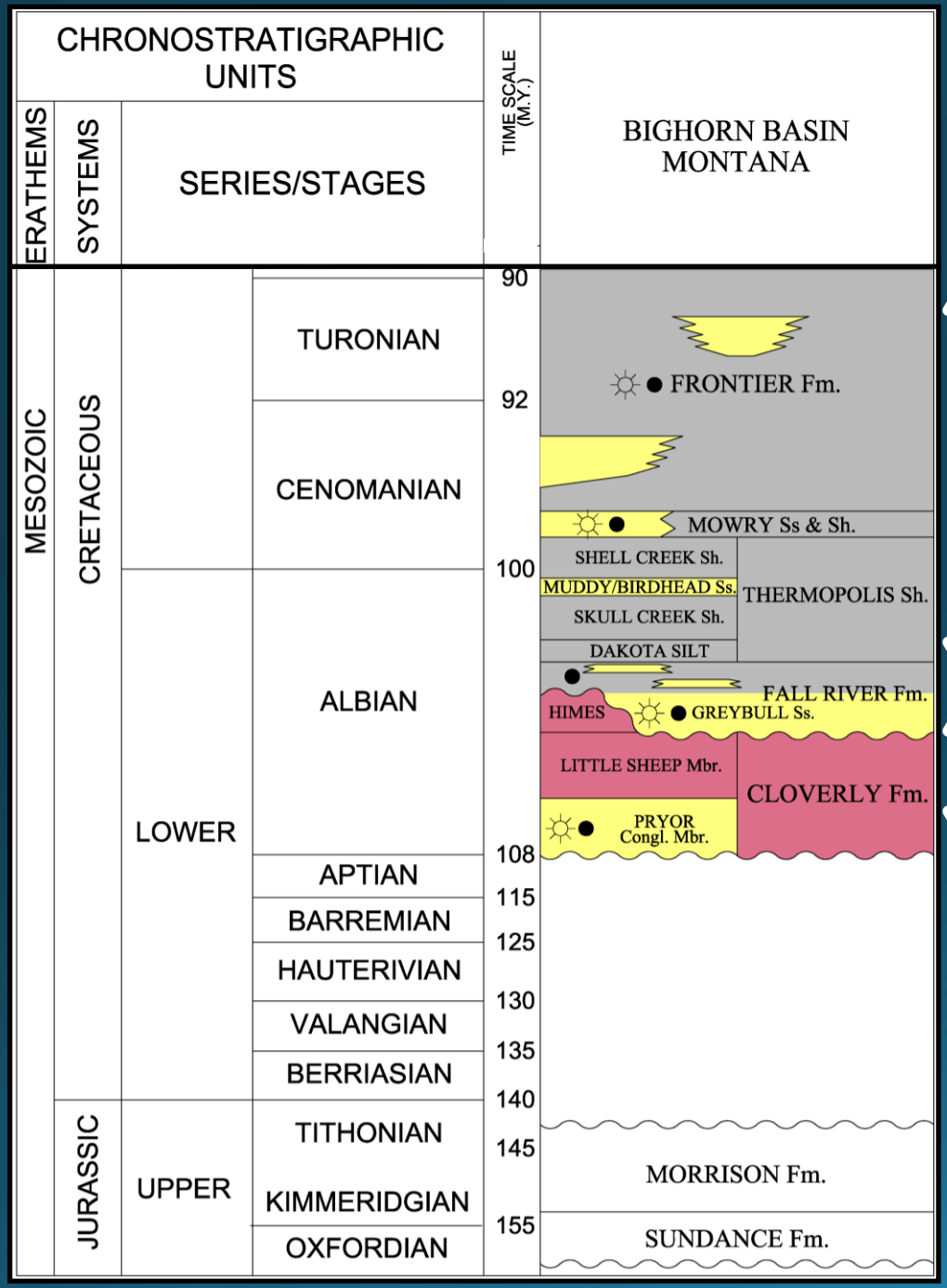
Key Points

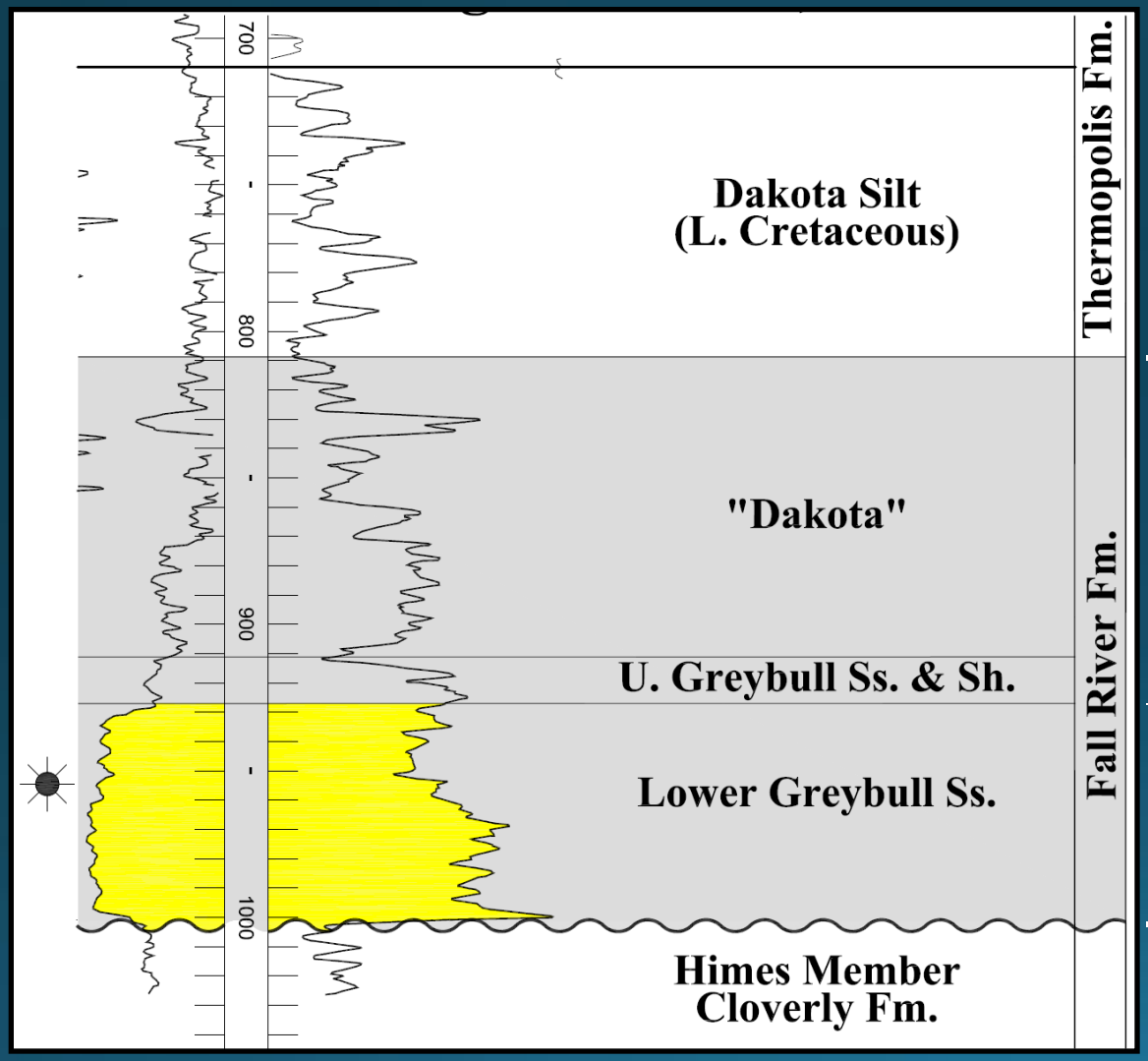
- A giant stratigraphic trap is present that **originally** contained 600 Million to 2 Billion barrels of oil in-place
- The reservoir rock is a thick valley-fill sandstone in the Greybull interval of the Lower Cretaceous Fall River Fm.
- Reservoir deposition was strongly influenced by faulting
- Present-day structural relief on oil column is >2300 feet
- Oil was generated from a carbonate source rock, probably from the Phosphoria Fm. (Permian)
- Oil has been moderately to severely degraded to 13-22° API gravity, destroying much of the original oil in-place
- Oil was degraded prior to formation of present-day structure, effectively locking the accumulation in-place
- The 22-degree API oil produced at Mosser Dome field is gravity segregated on the structural high and is the least degraded and most buoyant oil remaining in the trap

Cretaceous Stratigraphic Column

Bighorn Basin, Montana



Type Log: Fall River Fm. (L. Cretaceous) Mosser Dome



Black Shale

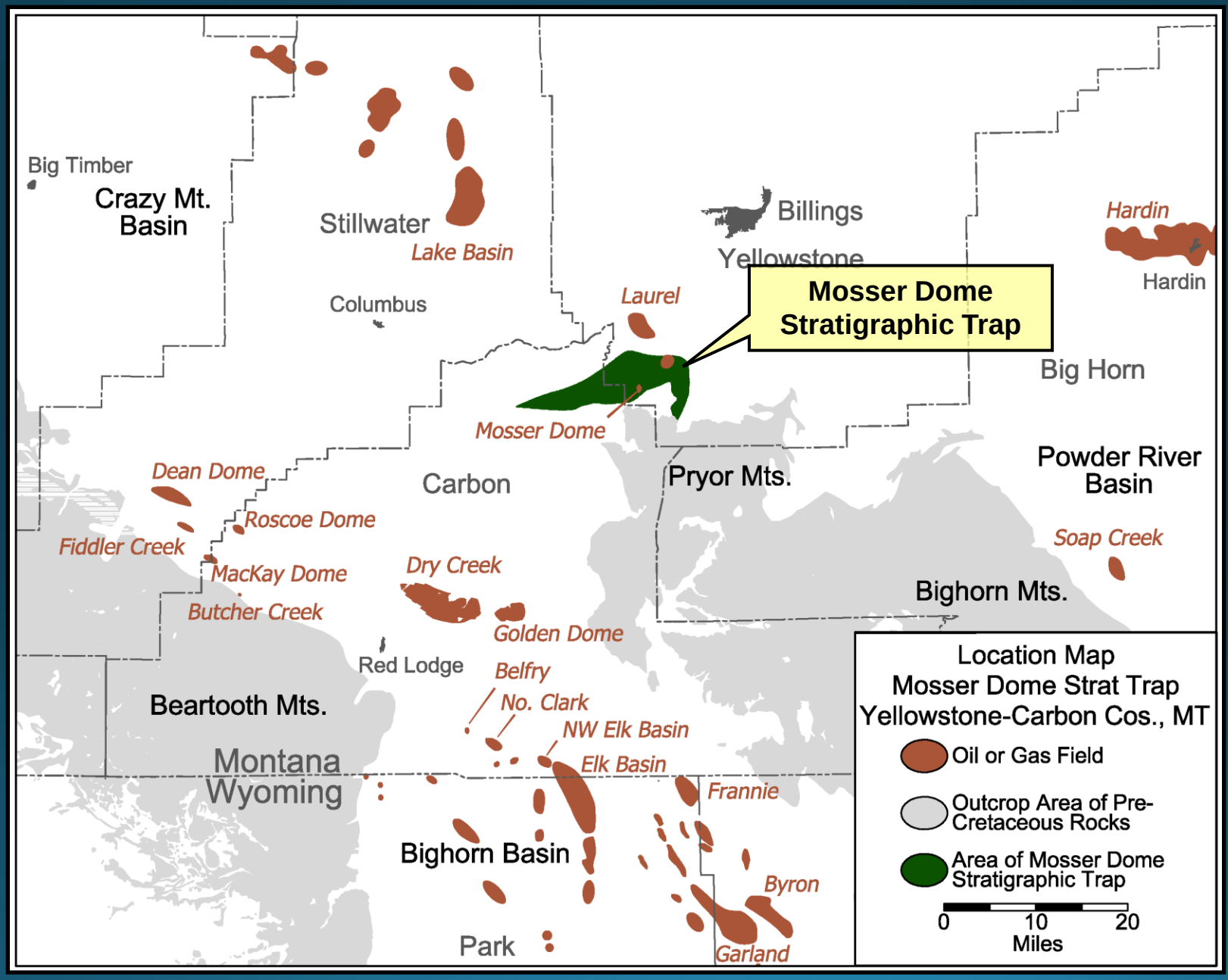
Black to Dark Grey Shale, Siltstone & Very Fine-Grained Sandstone

Sandstone, Quartz Arenite, Fine- to Medium-Grained, Well Sorted, Unidirectional Planar Cross Beds

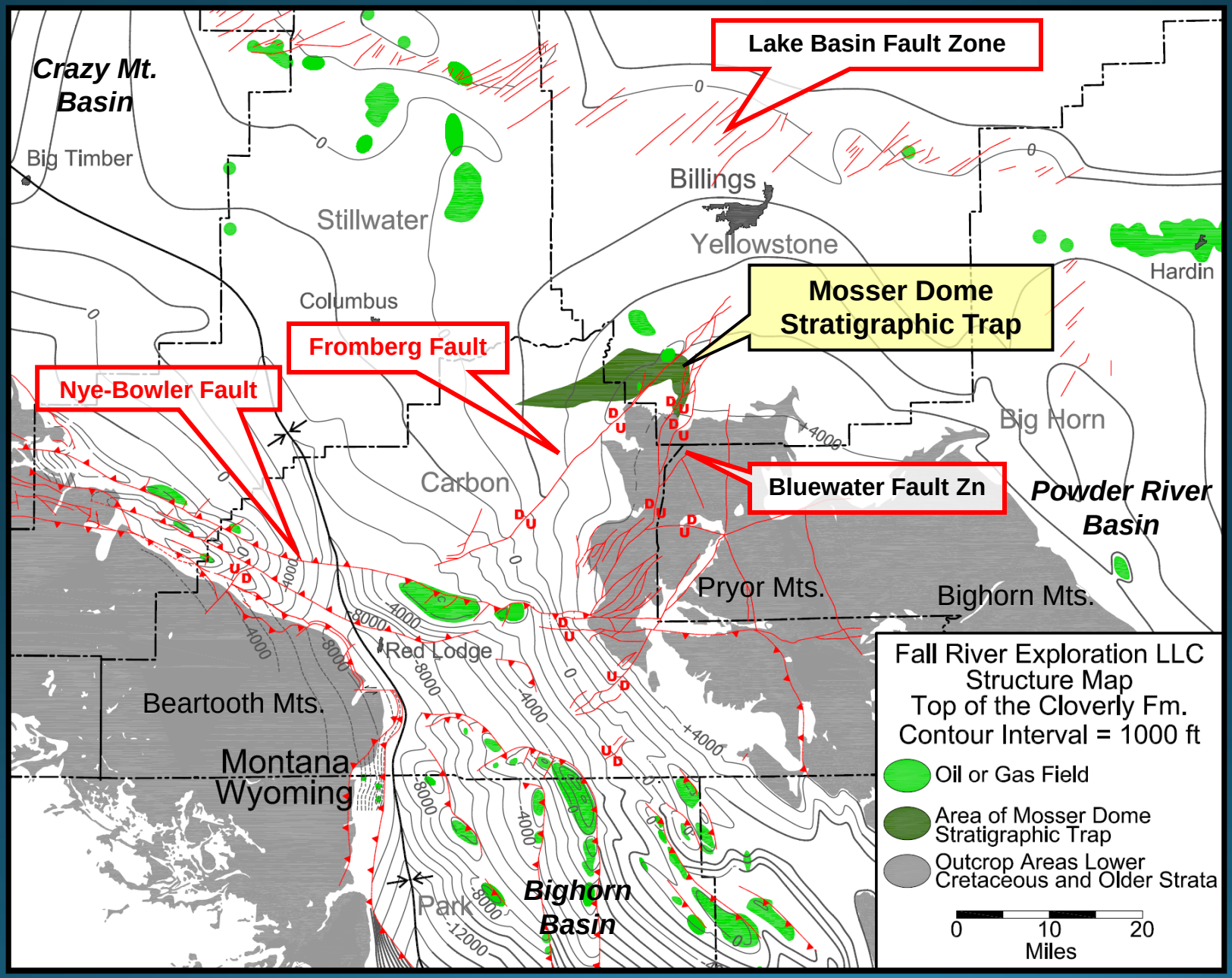
Grey to Yellow Brown Mudstone, Volcaniclastic Ss.

Regional Setting

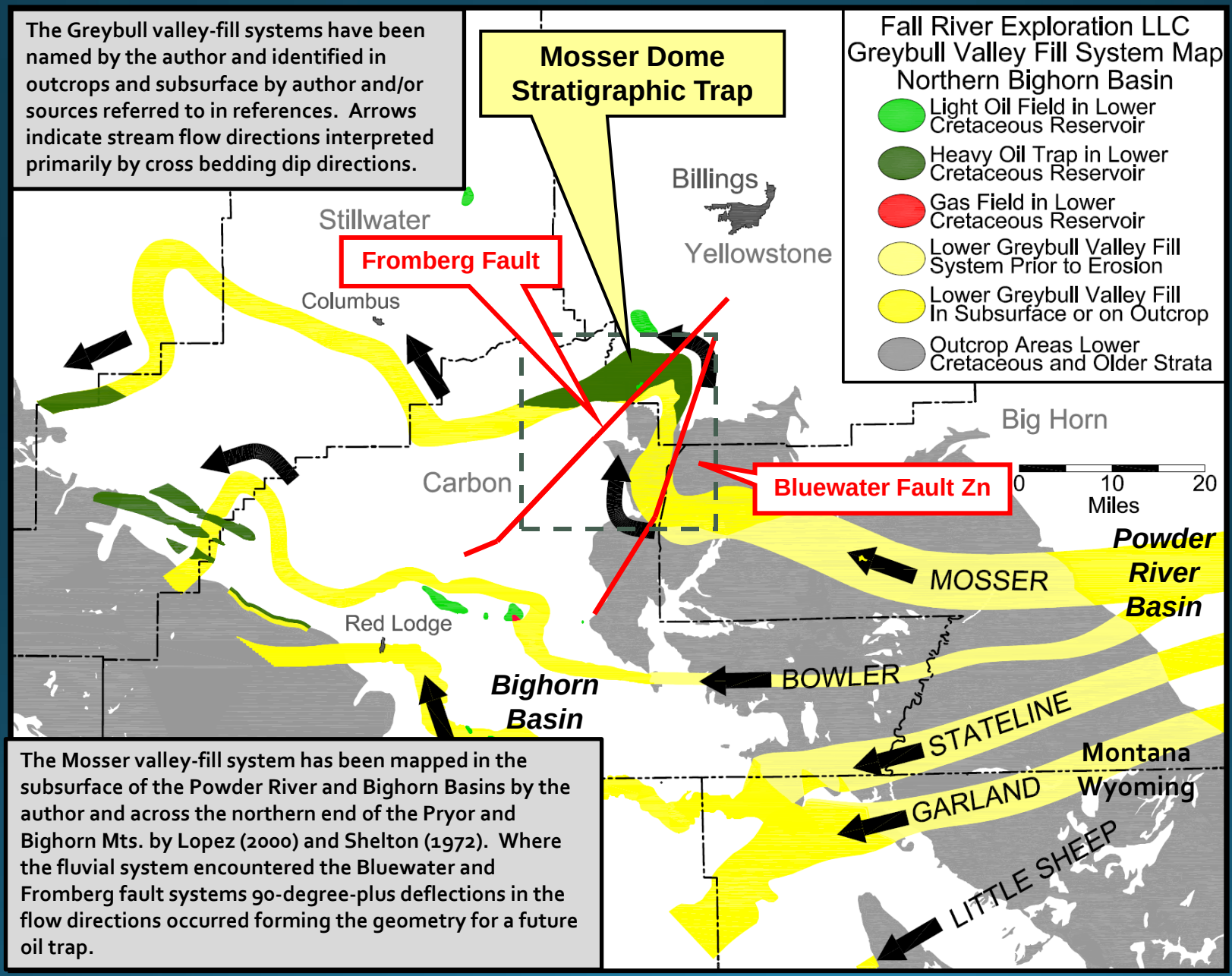
Location Map: Mosser Dome Stratigraphic Trap



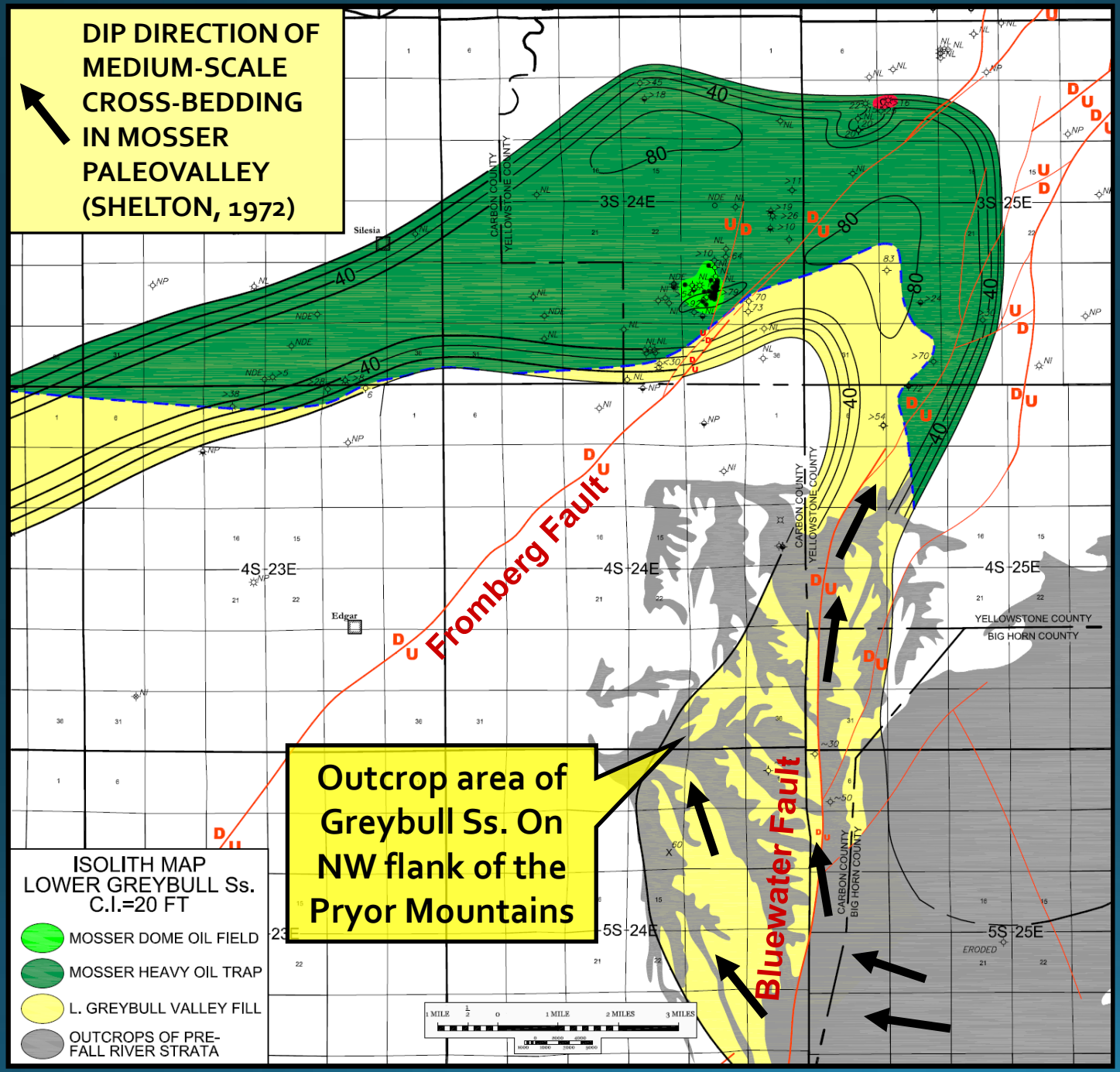
Structure Map: Top of the Cloverly Fm. (L. Cretaceous)



Paleovalley Map: Lower Greybull Ss. (L. Cretaceous)



The Mosser Dome Stratigraphic Trap

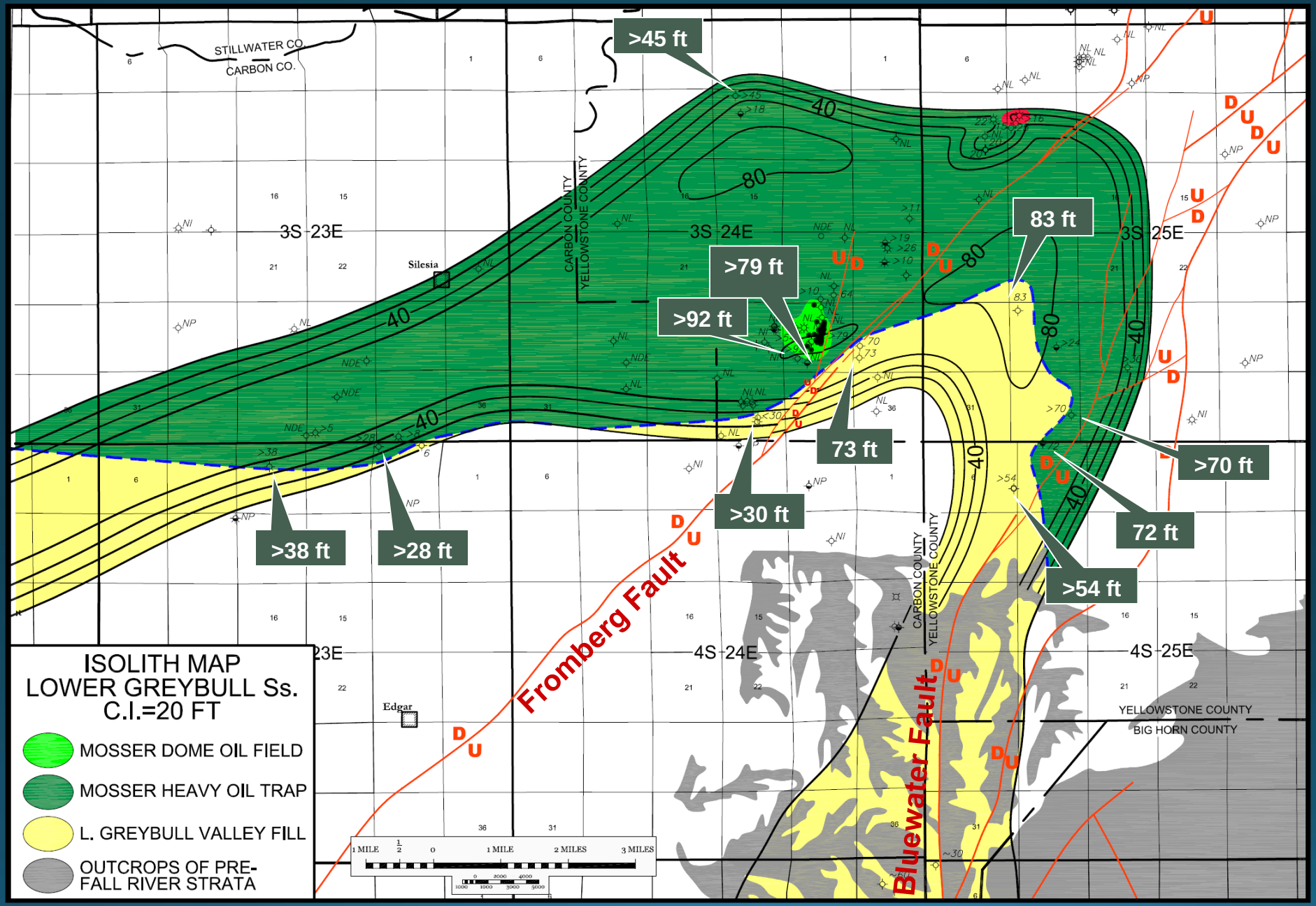


Isolith Map: L. Greybull Ss. Mosser Dome Strat Trap Area

Yellowstone & Carbon Cos., MT

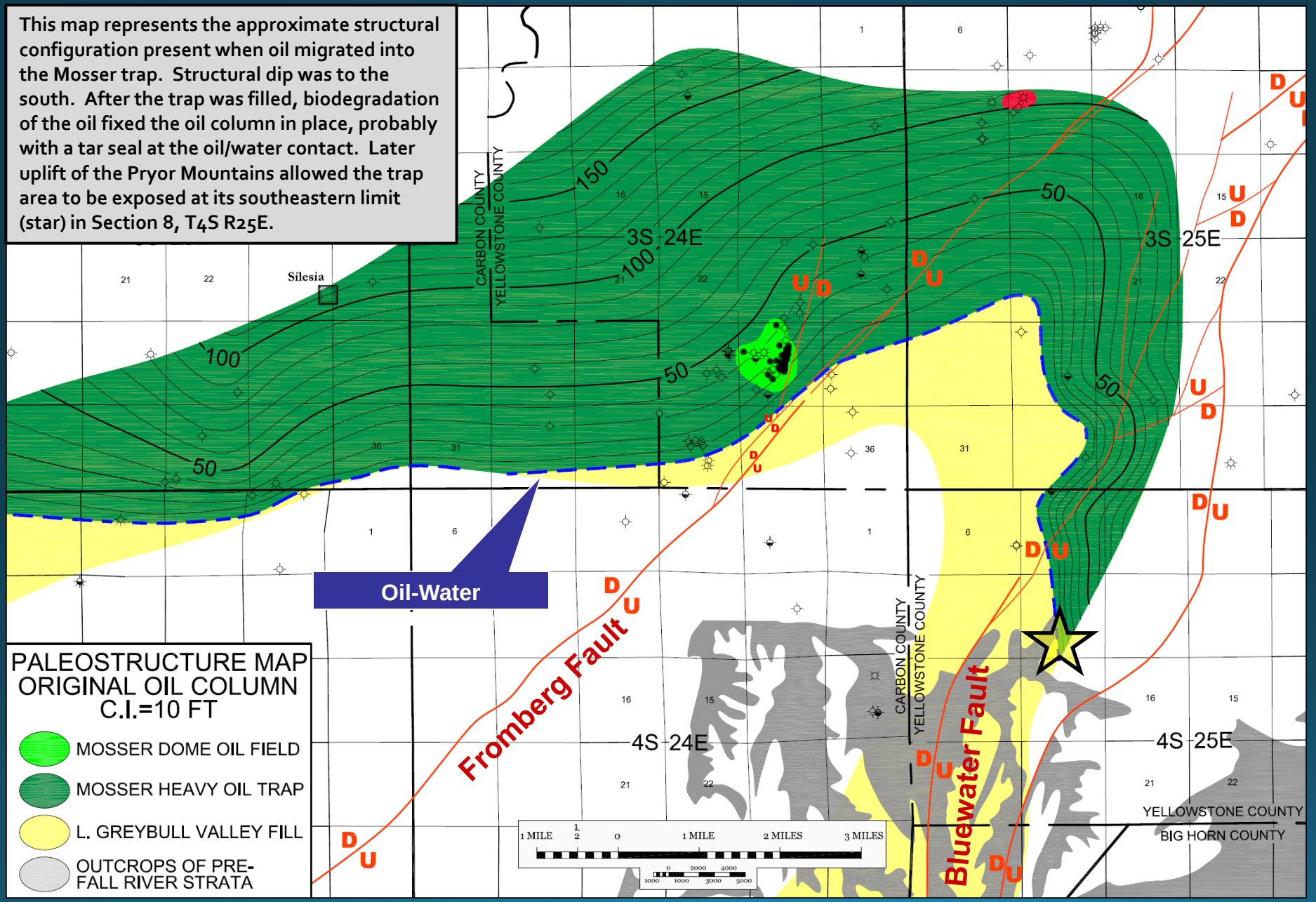
The Mosser valley-fill system has been mapped in the subsurface of the Powder River and Bighorn Basins by the author and across the northern end of the Pryor and Bighorn Mts. by Lopez (2000) and Shelton (1972). Where the fluvial system encountered the Bluewater and Fromberg fault systems 90-degree-plus deflections in the flow directions occurred, forming the geometry for a future oil trap

Isolith Map: L. Greybull Ss. - Mosser Dome Strat Trap Area

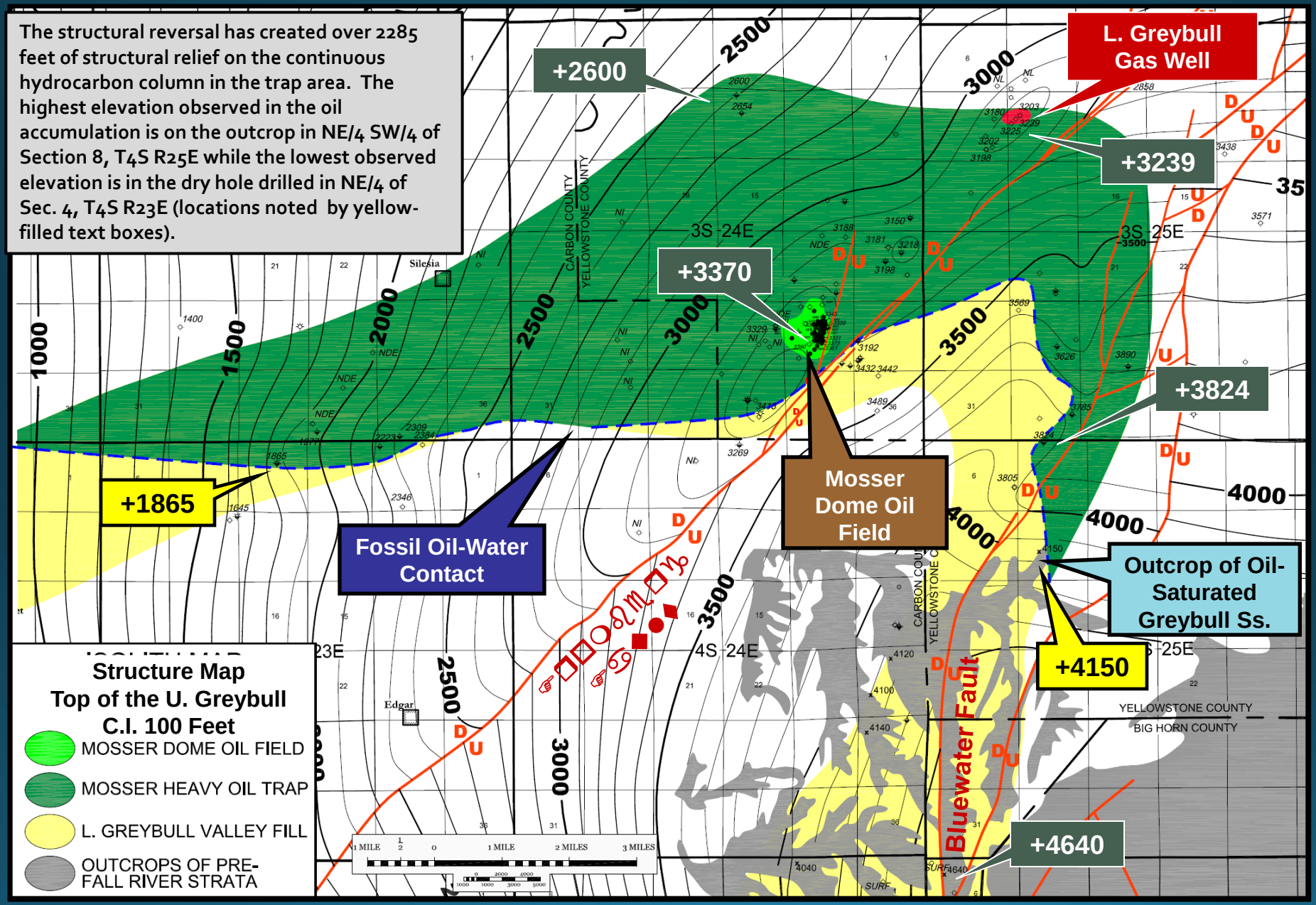


Paleostructure/Oil Column Height Map: Mosser Dome Strat Trap

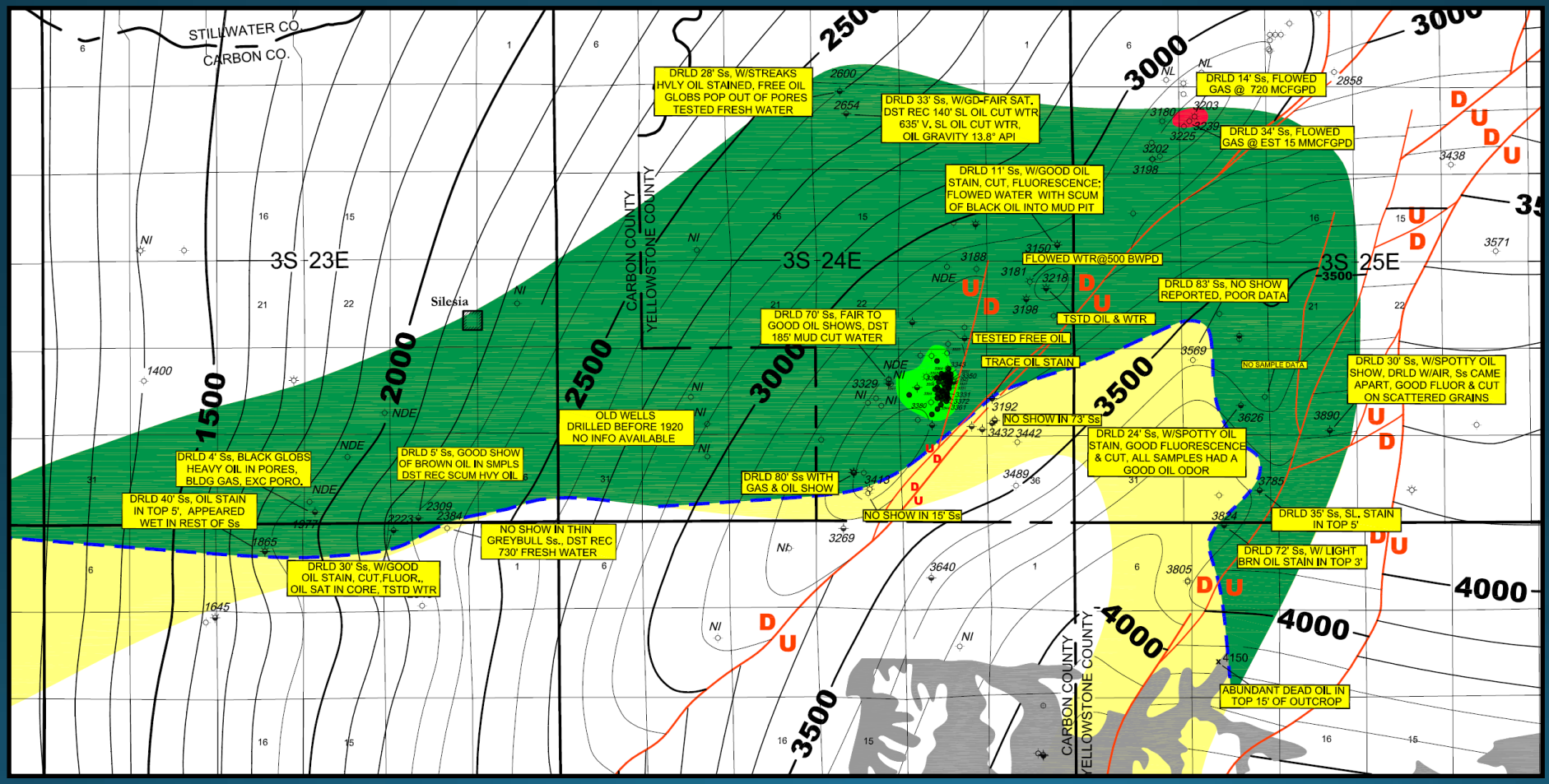
This map represents the approximate structural configuration present when oil migrated into the Mosser trap. Structural dip was to the south. After the trap was filled, biodegradation of the oil fixed the oil column in place, probably with a tar seal at the oil/water contact. Later uplift of the Pryor Mountains allowed the trap area to be exposed at its southeastern limit (star) in Section 8, T4S R25E.



Structure Map: Fall River Fm. - Mosser Dome Strat Trap Area

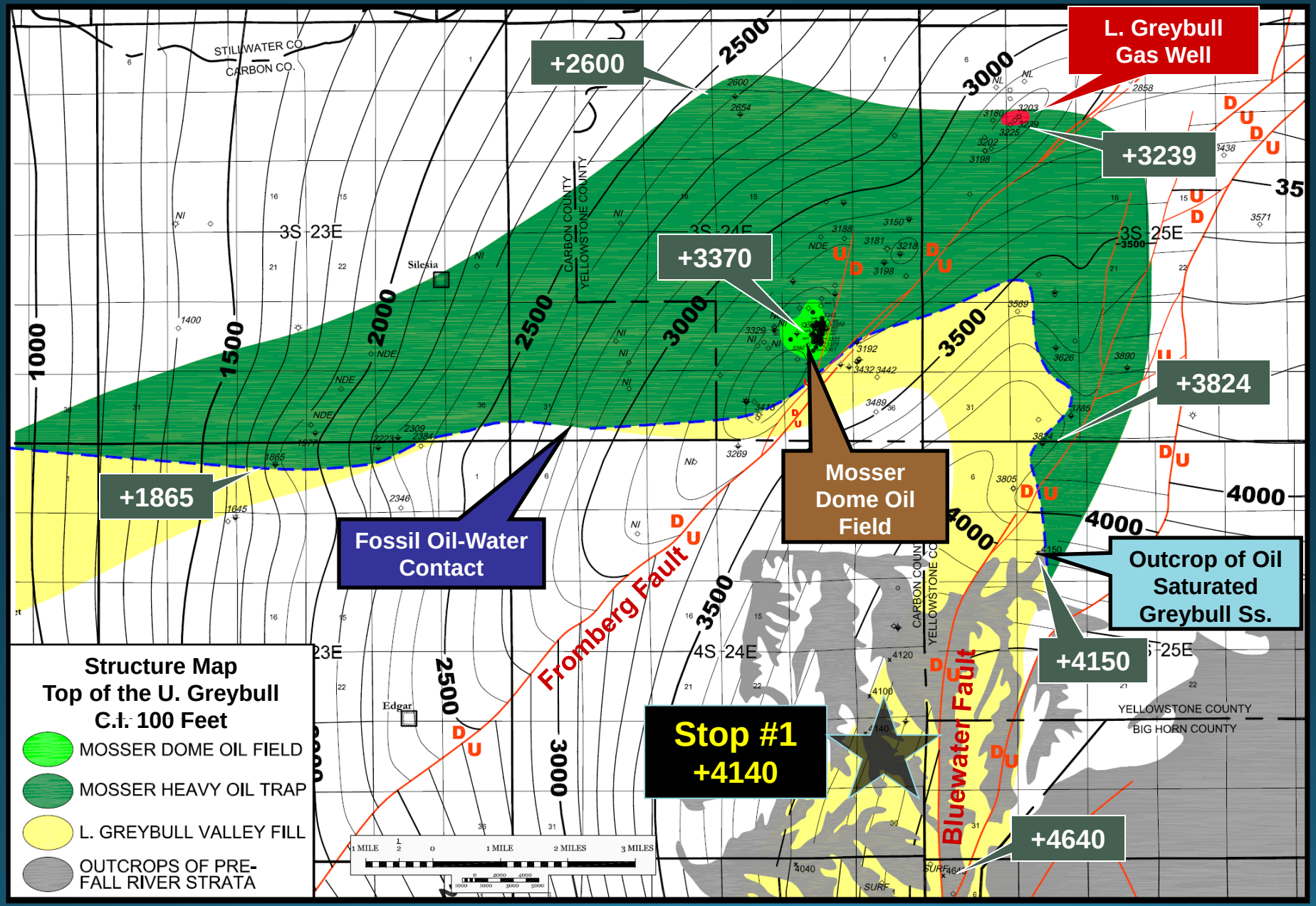


Structure Map: Mosser Dome Strat Trap Area with Detailed Oil Show and Test Information
Datum: Top of the Upper Greybull Ss.
Contour Interval=100 ft

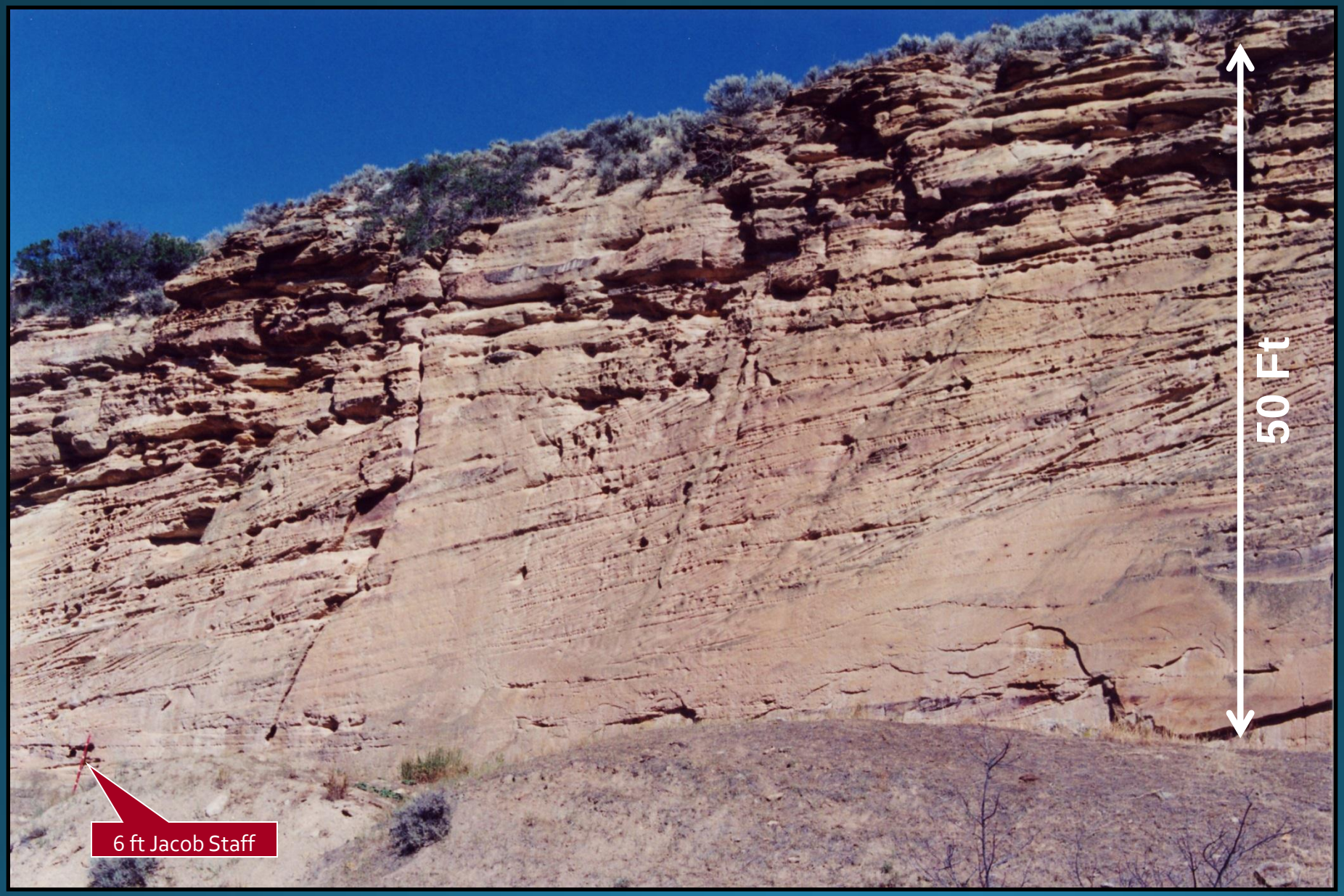


The Mosser Dome Stratigraphic Trap Virtual Field Trip

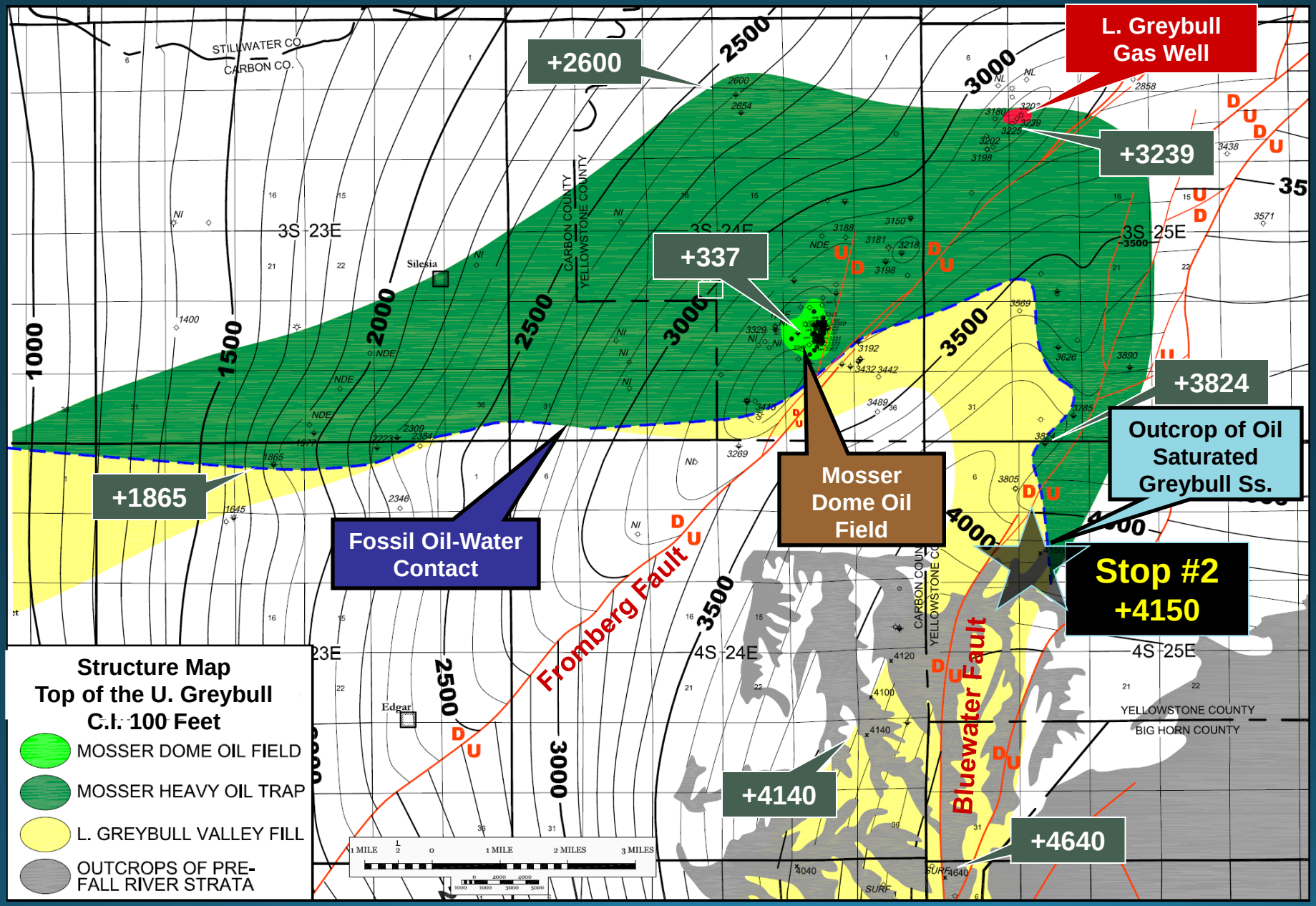
Stop #1 Wolf Creek Outcrop: Sec. 25, T4S R24E, Carbon Co., MT



Wolf Creek Outcrop: Lower Greybull Sandstone
Sec. 25, T4S R24E, Carbon Co., Montana



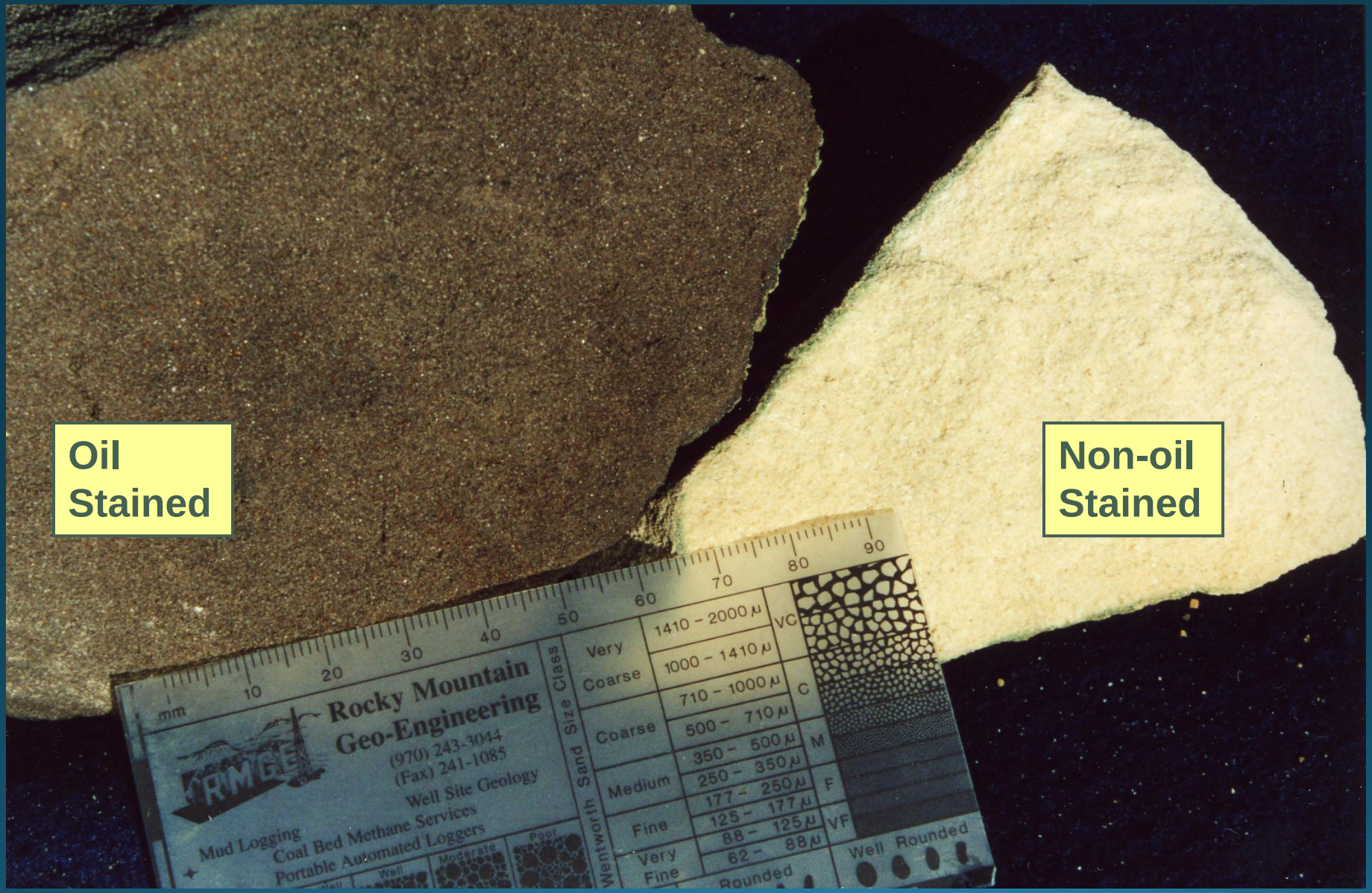
Stop #2: Cottonwood Creek Outcrop, Sec. 8, T4S R25E



Cottonwood Creek Outcrop: Cross Bedding, L. Greybull Ss. Sec. 8, T4S R25E, Yellowstone Co., MT

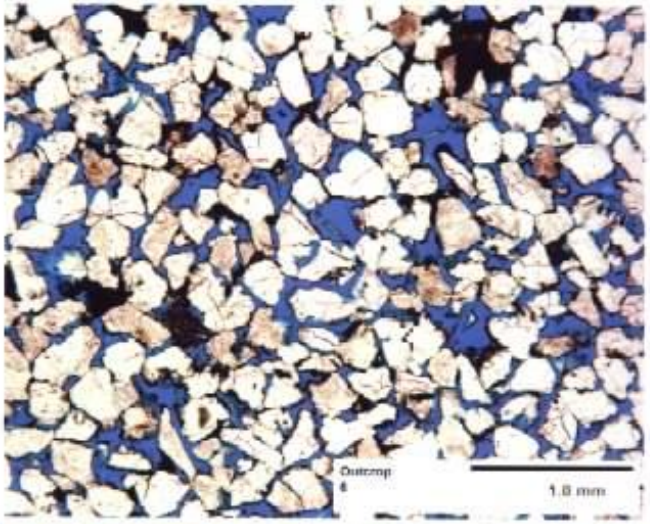
Cottonwood Creek Outcrop: Heavy oil saturation in L. Greybull Ss. Sec. 8, T4S R25E, Yellowstone Co., MT

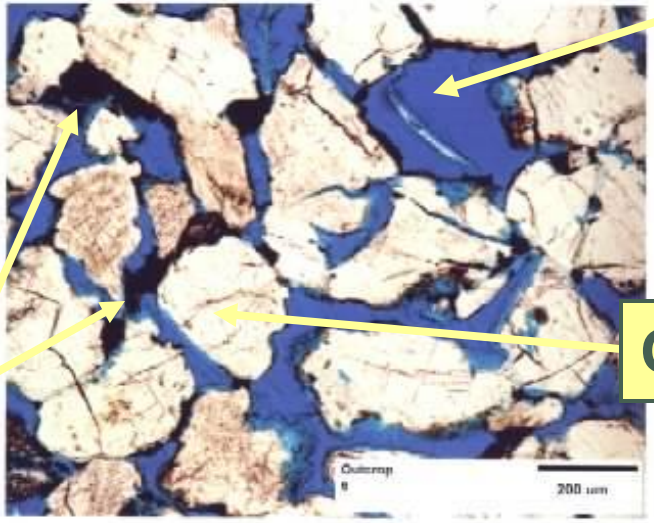
Cottonwood Creek Outcrop Samples: Lower Greybull Ss. Sec. 8, T4S R25E, Yellowstone Co., MT



Cottonwood Creek Outcrop Sample: Lower Greybull Sandstone - Mosser Paleovalley, Sec. 8, T4S R25E, Yellowstone Co., MT

Rocktell Porosity: 23.72% **Kmax: 2521 md**





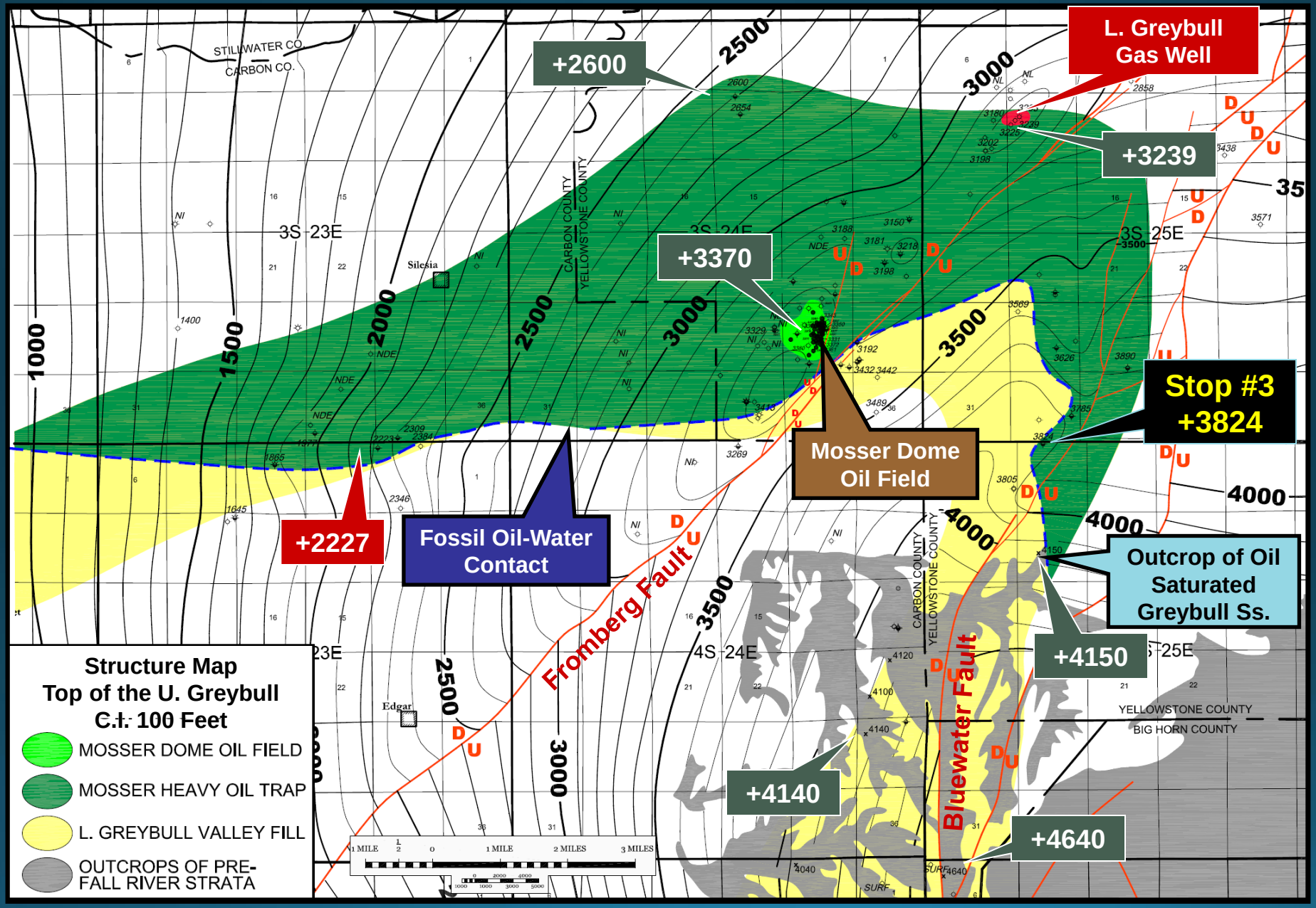
This rock sample is from outcrops on the southeast edge of the Mosser Dome stratigraphic trap. Note the abundant oil coating the quartz grains.

Porosity

Quartz grains

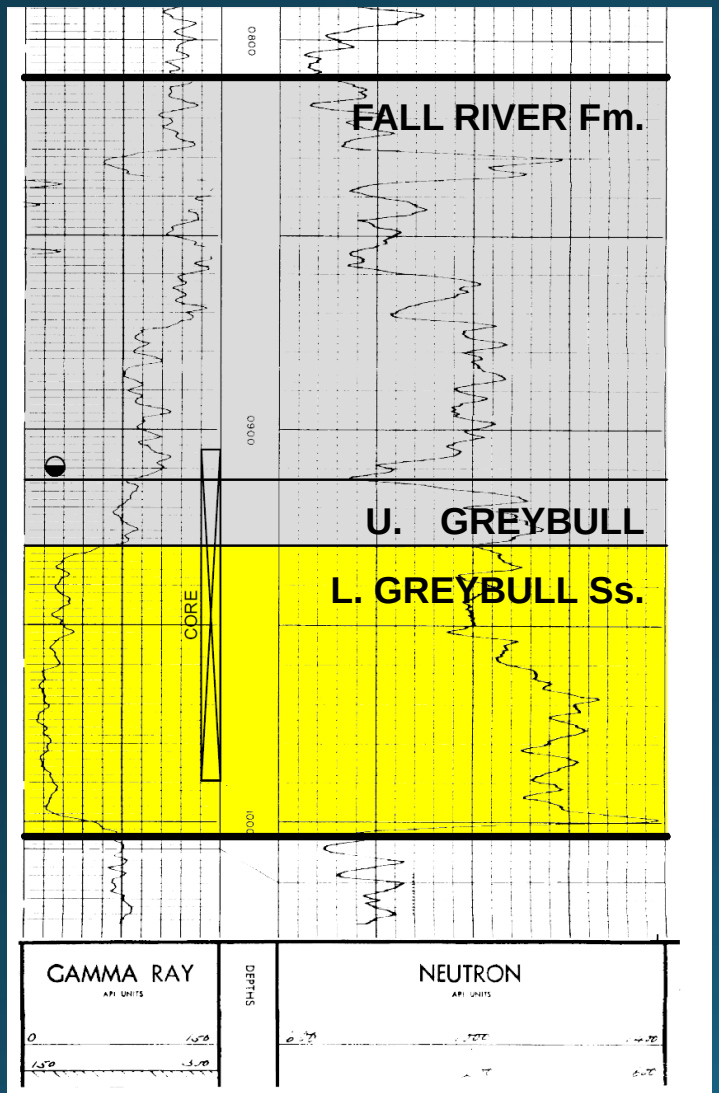
Oil

Stop #3 (Subsurface) : Shell Oil #1 Greeno NE NW Sec. 5, T4S R25E



Mosser Paleovalley: Lower Greybull Ss.

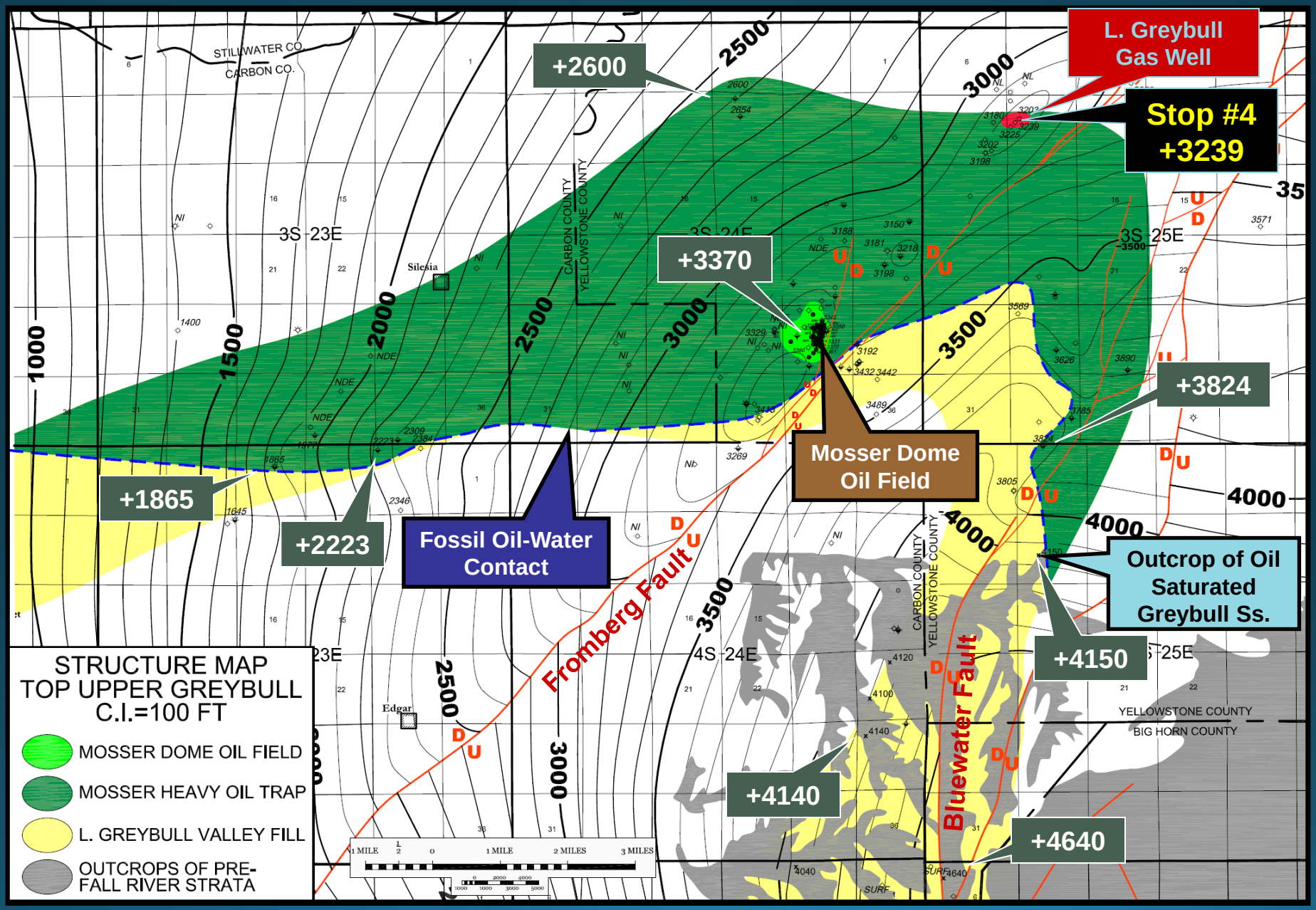
Well Log: Shell Oil #1 Greeno
NE NW Sec. 5, T4S R25E
Yellowstone Co., MT



CORE: 905-990' (GREYBULL Ss.) REC 80' SANDSTONE, FINE TO MEDIUM GRAINED, SLIGHTLY CALCAREOUS, WITH LIGHT BROWN OIL STAIN IN TOP 3 FEET

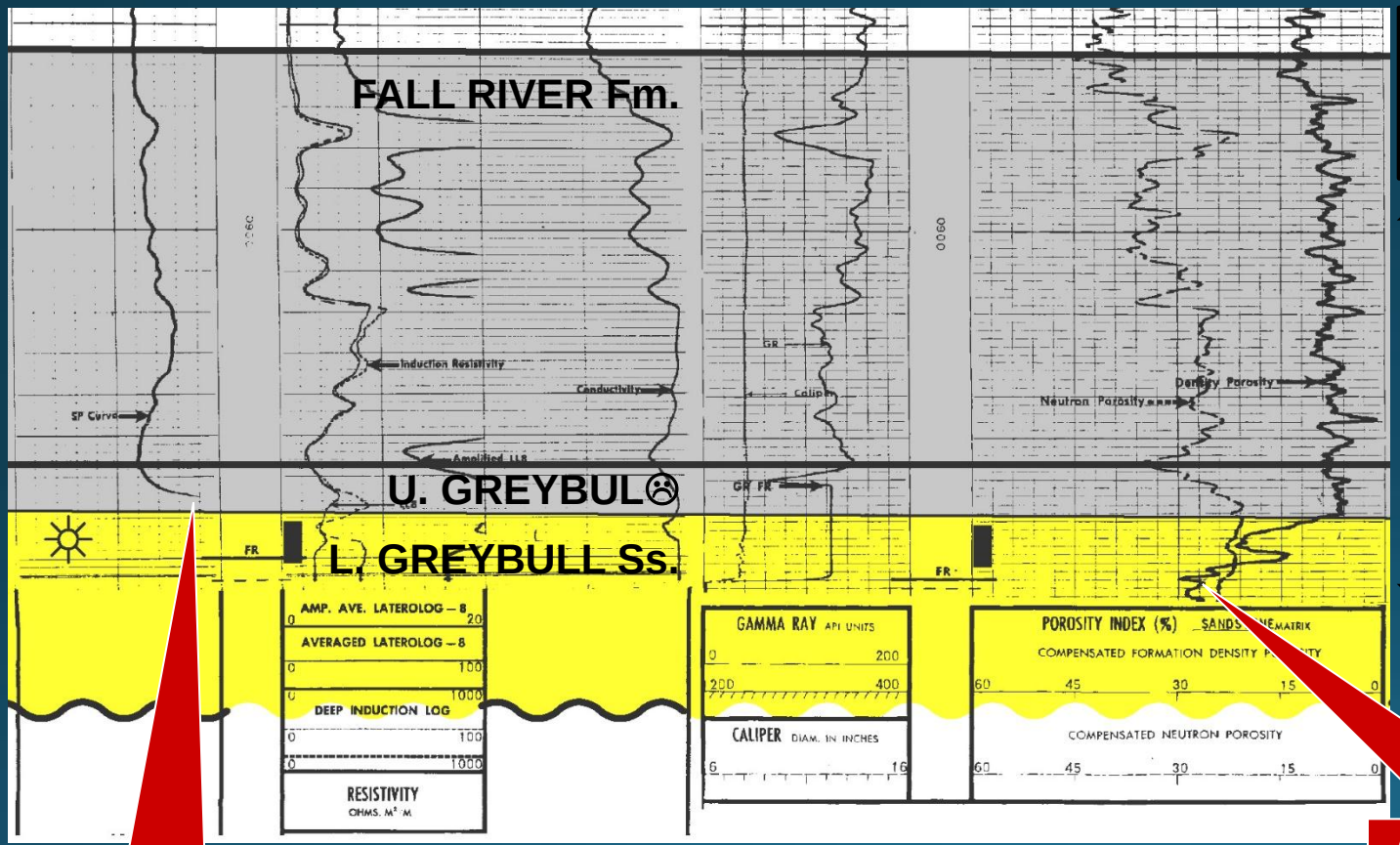
NO TESTS OR COMPLETION ATTTEMPT

Stop #4 (Subsurface): West Gas #5-8 Barber, SW NW Sec. 8, T3S R25E



Mosser Paleovalley: Lower Greybull Ss. Gas Well

Well Log: West Gas #5-8 Barber
SW NW Sec. 8, T3S R25E Yellowstone Co., MT



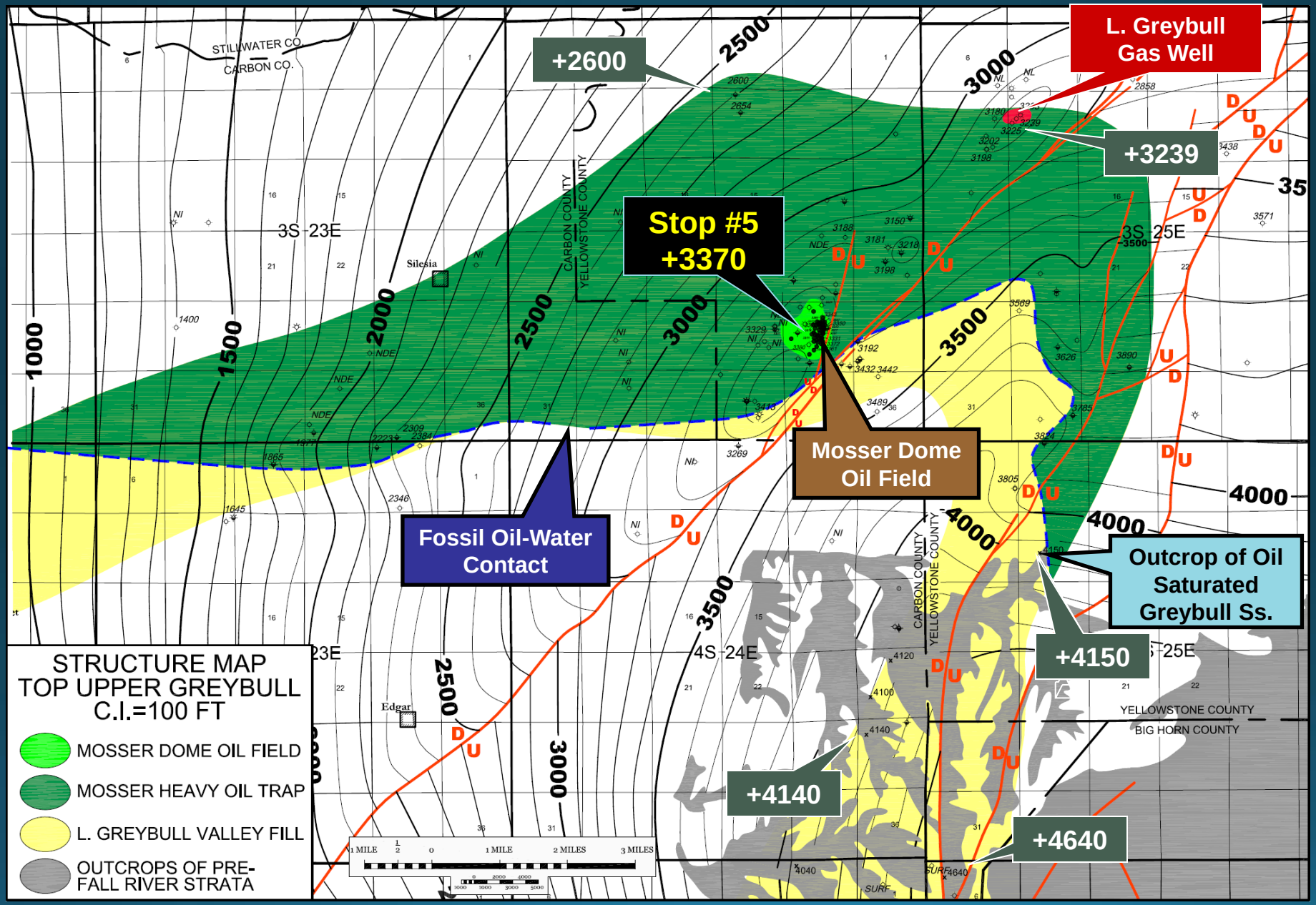
Perf: 971-981 ft
IPF: 780 MCFGPD
Natural

100 ft

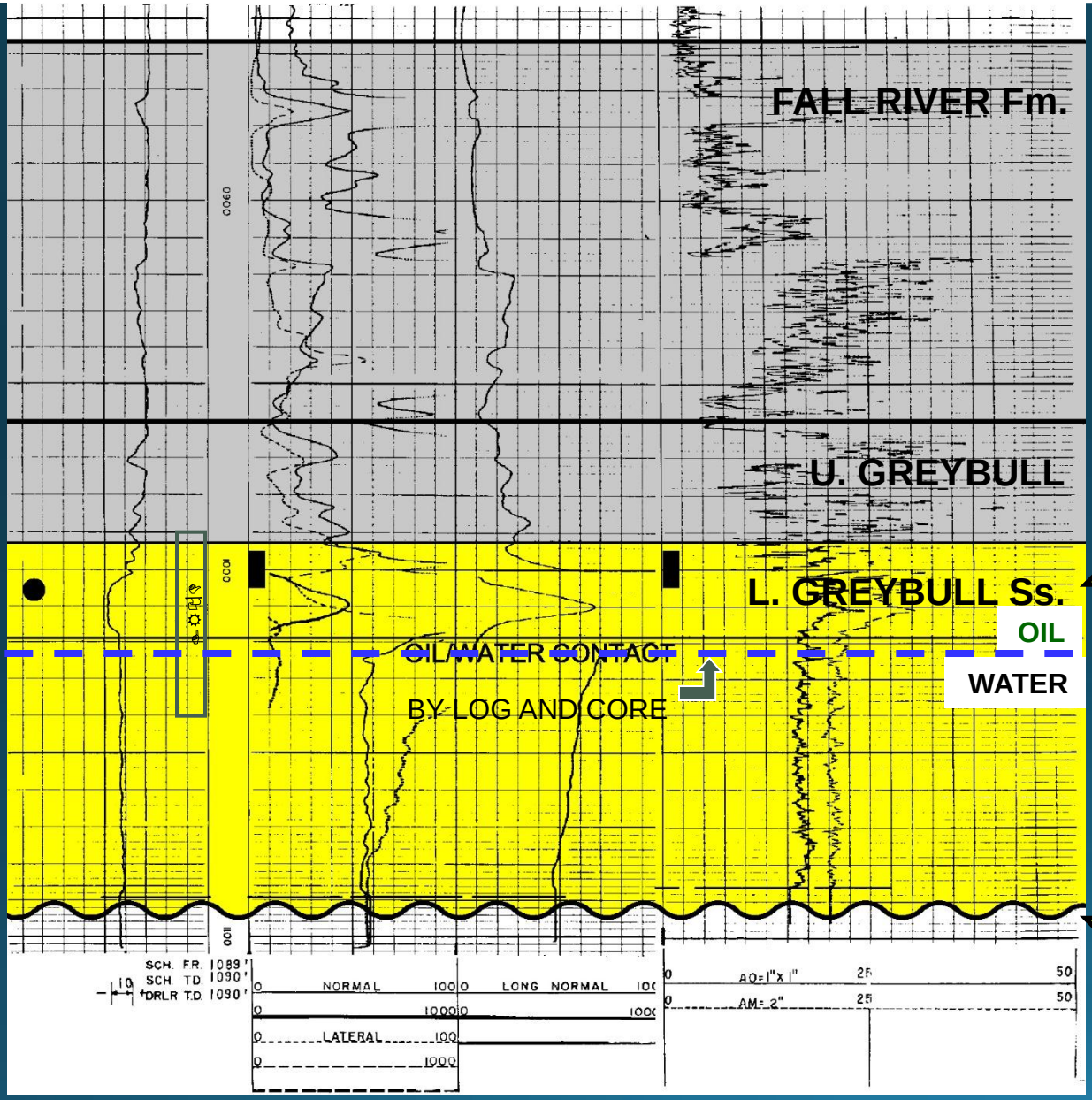
Reverse SP due to fresh water

28% Density Porosity, Gas Effect

Stop #5 (Subsurface): Mosser Dome Oil Field, Sec. 26, T3S R24E



Mosser Paleovalley: Lower Greybull Ss. Oil Well



Well Log:
Dawson #3 Spaeth
NE NE SW
Sec. 26, T3S R24E
Mosser Dome Field
Yellowstone Co.,MT

Perf: 995-1005 ft
IPP: 64 BOPD
22.5 API Oil

Mosser Dome Oil Field Fact Sheet*

(1) Mosser Dome Oil Field Discovered in 1936

(2) Producing Zone: Lower Greybull Ss., Fall River Fm.

(3) Average Depth: 1000 ft

(4) Cumulative Oil Production: 537,000 Barrels/25 Wells

(5) Oil Gravity: 22.5° API

(6) Oil Column: 25-30 feet

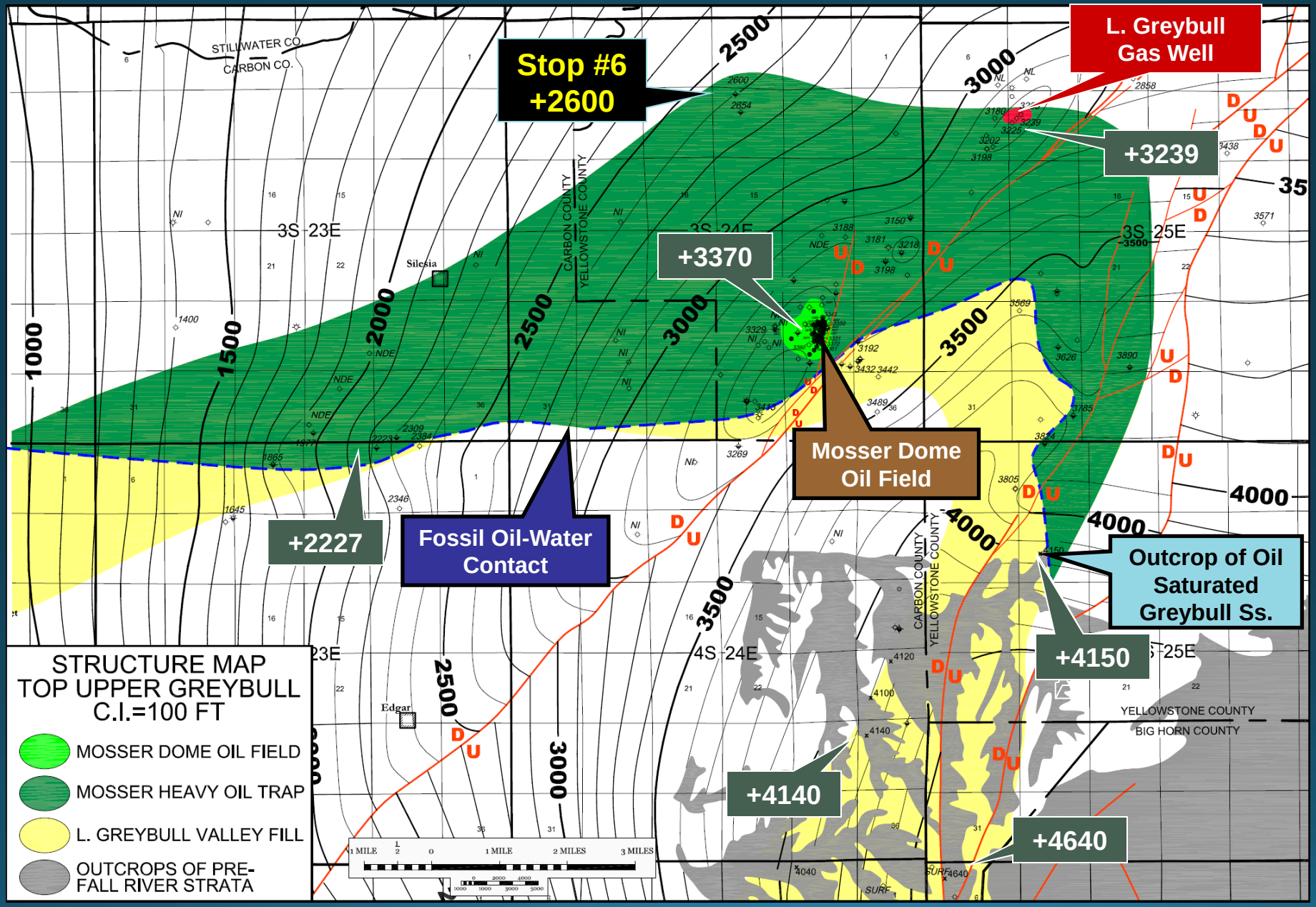
(7) Field Area: ~120 acres

(8) Reservoir: Avg. Porosity= 24%; Perm. =0.5-4 Darcies

(9) Salinity of Produced Water: 1700 ppm Total Dissolved Solids (Rw=5 Ohm/meters)

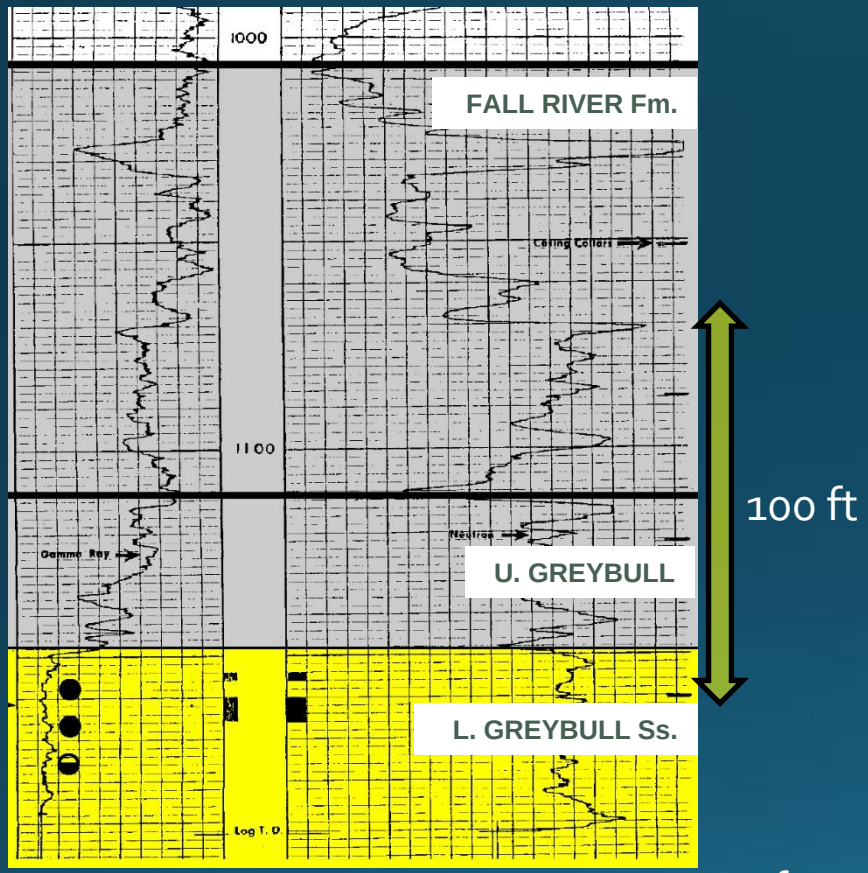
* Herb Hadley, MGS Oil & Gas Fields Symposium, 1985

Stop #6 (Subs.): Basso #1 Rawhouser-Krug, NE NW Sec. 10, 3S 24E



Mosser Paleovalley: Lower Greybull Ss. With Oil Shows

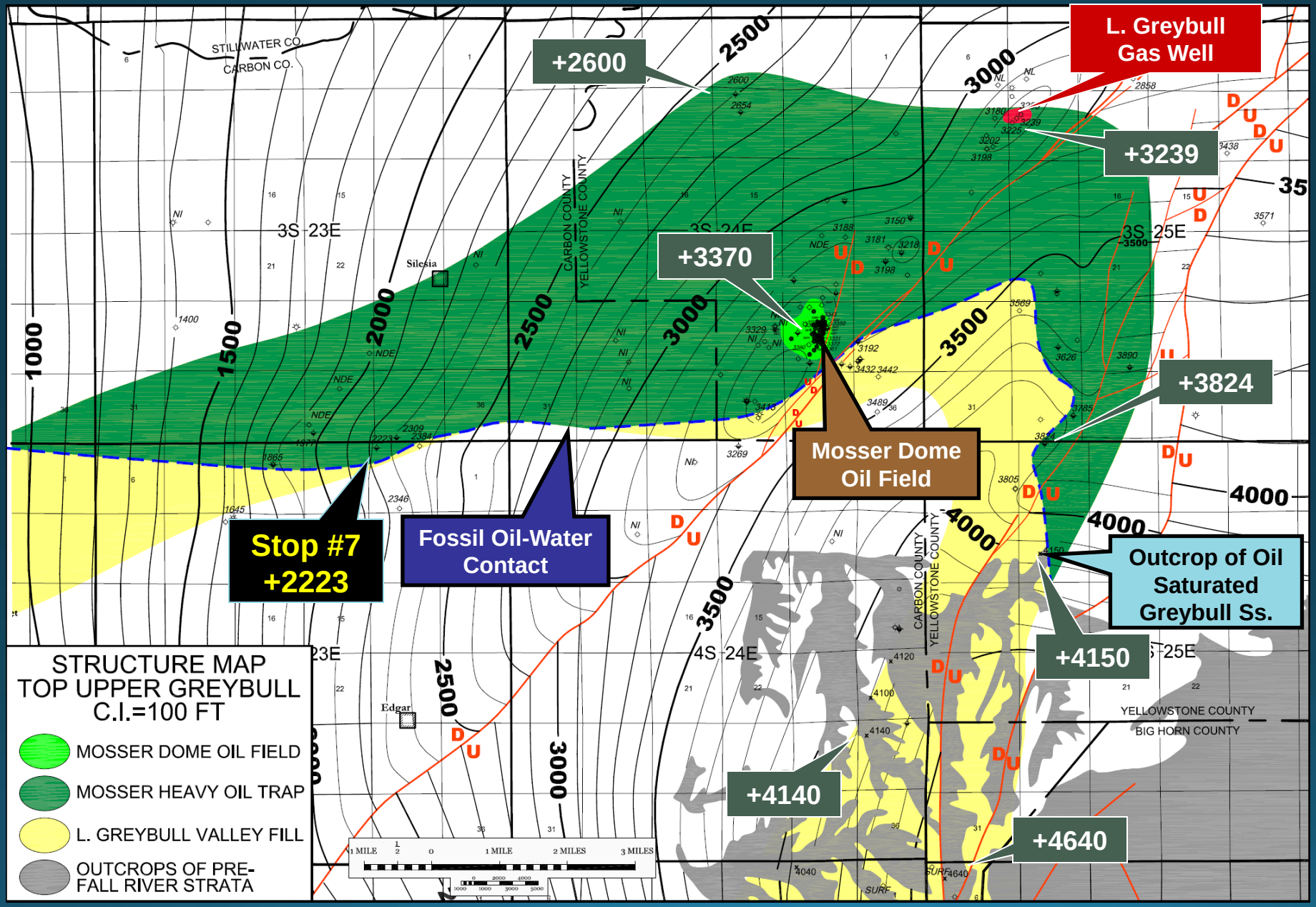
Well Log: Basso-Westwood-Lindberg #1 Rawhouser-Krug
NW NE NW Sec. 10, T3S R24E Yellowstone Co.,Montana



Three miles north and more than 700 feet downdip to the Mosser Dome oil field, this well is the key to whether the Mosser Strat Trap had 600 Million or 2 Billion barrels of original oil in-place. The samples from 1159-71 are heavily oil-stained. The oil shows decrease downward with the last 15 ft of sandstone being described as tight and silty with no show but with abundant loose sand grains. The lack of oil show could be due to tight, low permeability in this interval. If the lack of oil show reflects the original oil/water contact @1180 ft (32 ft into sand), then the trap had an original oil column of ~35 ft and calculates OOIP = 600 MMBO. If the entire porous portion of the sand was oil filled over a large portion of the trap area, forming an oil column of >100 ft, then OOIP was as much as 2 Billion barrels.

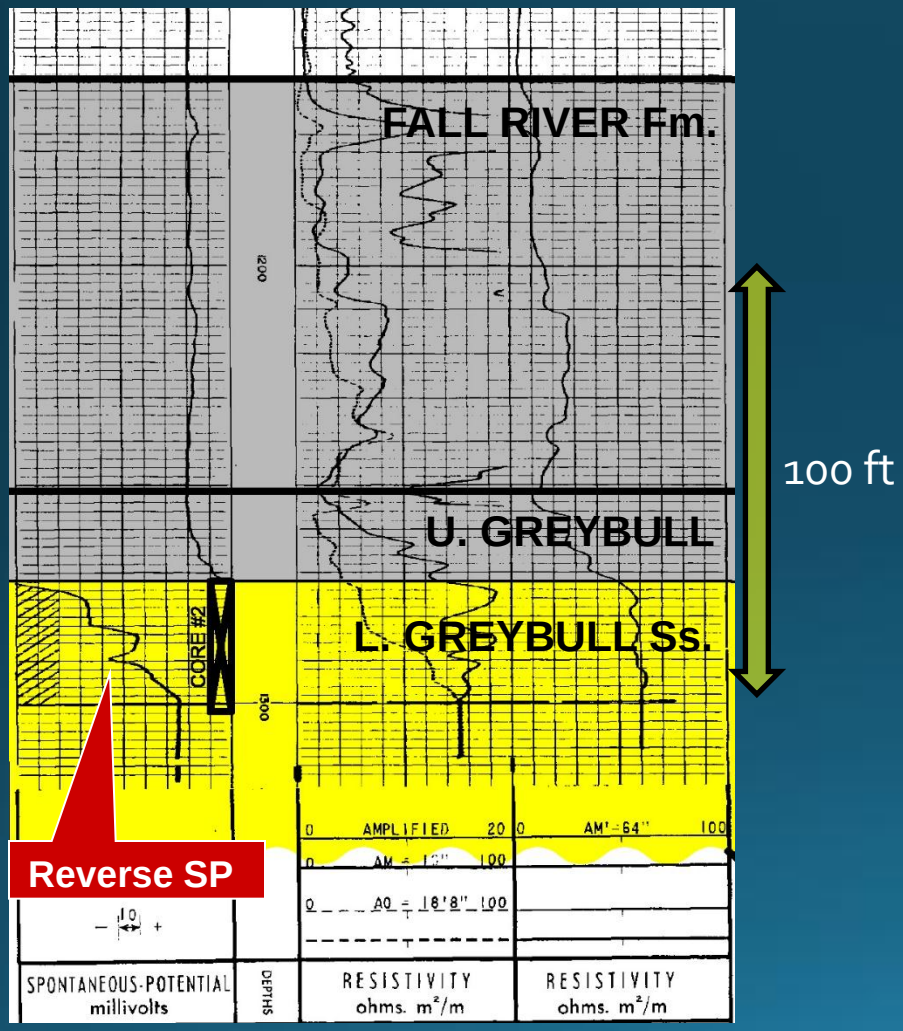
Perf: 1154-1156 ft
Perf: 1160-1166 ft
No Information
Completed as Water Well

Stop #7: Breuer & Curran #2 Olsen, NW/4 Sec. 2, T4S R23E



Mosser Paleovalley: Lower Greybull Ss. With Oil Shows

Well Log: Breuer & Curran #2 Olsen
NW NW Sec. 2, T4S R23E Carbon Co., Montana



Six miles west of and more than 1100 feet downdip to the Mosser Dome oil field, this well encountered abundant heavy oil saturation in the Lower Greybull sandstone as seen in the core description below.

Core: 1265-1295 ft: Rec 30 ft sandstone, abundant oil stain, cut and good to spotty fluorescence. Last 20 ft of core the oil was described as "low gravity to dead". Core analysis show residual oil saturations 14-18%, water saturations 33-51%. Oil gravities of oil retorted from core are 28-33° API. This well flowed water from the Greybull at a rate of 5 gallons/minute.

Oil Geochemistry

Results of Bighorn Basin Oil Geochemistry Study

- Two distinct oil groups have been produced from the Greybull Ss. in the Bighorn Basin

  (1) Phosphoria-Tensleep (Permo-Pennsylvanian) sourced oil

  (2) Cretaceous-sourced light oil

- Oil produced from the Phosphoria-Tensleep reservoirs at Elk Basin field and the oil produced from the Greybull Ss. at Mosser Dome field have a marine carbonate source of pre-Late Cretaceous age, based upon pristane-to-phytane ratios <1 and high sulfur contents
- Moderately elevated gammacerane in Mosser oil suggests a hypersaline source depositional environment
- Produced oil from Mosser Dome is moderately degraded (absence of intact *n*-alkane envelope)
- <u>Mosser Dome oil likely sourced from Phosphoria/Tensleep oil system</u>

Volumetrics

Volumetric Worksheet

Field/ Project	Producing Horizon	Planimiter Area	Ratio of Areas	Contour Interval	Equation Used	Acre-Feet	Reserve Oil MMBOOIP
Mosser Original Trap	Greybull	30710		10		0	
Mosser Original Trap	Greybull	28158	0.9169	30	Trap	588680	
Mosser Original Trap	Greybull	25040	0.8892677	50	Trap	531980	
Mosser Original Trap	Greybull	21676	0.865655	70	Trap	467160	
Mosser Original Trap	Greybull	1983	0.0914837	90	Trap	236590	
Mosser Original Trap	Greybull	0	0	92	Pyr	1322	
Mosser Original Trap	Greybull					0	
		Assume 22.00% por - 65% Oil Sat				1825732	
						1825732 ac-ft	2,025,456,126

Total Acre Feet

Original Barrels of Oil in Place

Volumetric Assumptions

(1) Assumed average porosity = 22%

(2) Assumed original average water saturation (Sw) = 35%

(3) Maximum reservoir thickness = 92 ft

(3) Maximum oil column height = 185 ft

Calculated Original Oil In Place: 2.025 Billion Barrels

Conclusions

- A giant stratigraphic trap is present that **originally** contained 600 Million to 2 Billion barrels of oil in-place
- The reservoir rock is a thick valley-fill sandstone in the Greybull interval of the Lower Cretaceous Fall River Fm.
- Reservoir deposition was strongly influenced by faulting
- Present day structural relief on oil column is >2300 feet
- Oil was generated from a carbonate source rock, probably from the Phosphoria Fm. (Permian)
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Thanks go to the following individuals for their work, ideas, or insights:

Dr. Ralph Moberly

Dr. Eric Kvale

Dr. John Shelton

Jack Warne

Dr. David Lopez

Joe Carlisle

Don French

Glen Luebking

Bob Schalla

Also, thanks to my family for their support and patience over my career and my many days in the field in the Bighorn Basin.

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