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

John R. Mitchell

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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.

Selected References


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.
<table>
<thead>
<tr>
<th>Era/Thems</th>
<th>Series/Stages</th>
<th>Time Scale</th>
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<td><strong>Albian</strong></td>
<td>100-108</td>
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<tr>
<td></td>
<td><strong>Aptian</strong></td>
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<td><strong>Barremian</strong></td>
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<td><strong>Hauterivian</strong></td>
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<td><strong>Valangian</strong></td>
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<td><strong>Berriasian</strong></td>
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<td><strong>Oxfordian</strong></td>
<td>150-155</td>
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<tr>
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<td><strong>Jurassic</strong></td>
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**Bighorn Basin, Montana**

- **Cretaceous Stratigraphic Column**
  - Marine
  - Non-Marine

- **Time Scale**
  - Cretaceous:
    - Turonian: 90-92
    - Cenomanian: 100
    - Albian: 100-108
    - Lower Cretaceous:
      - Aptian: 108-115
      - Barremian: 115-125
      - Hauterivian: 125-130
      - Valangian: 130-135
      - Berriasian: 135-140
    - Upper Cretaceous:
      - Tithonian: 140-145
      - Kimmeridgian: 145-150
      - Oxfordian: 150-155
  - Jurassic:
    - Morrison Fm.: 155
    - Sundance Fm.: 155

**Locations**
- **Frontier Fm.**
- **Mowry Ss. & Sh.**
- **Shell Creek Sh.**
- **Muddy Birdhead Sh.**
- **Skull Creek Sh.**
- **Dakota Silt**
- **Himes**
- **Greybull Ss.**
- **Little Sheep Mbr.**
- **Cloverly Fm.**
- **Pryor Congl. Mbr.**
- **Fall River Fm.**
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

Mosser Dome
Stratigraphic Trap

Location Map
Mosser Dome Strat Trap
Yellowstone-Carbon Cos., MT

- Oil or Gas Field
- Outcrop Area of Pre-Cretaceous Rocks
- Area of Mosser Dome Stratigraphic Trap

Miles
0 10 20
The Greybull valley-fill systems have been named by the author and identified in outcrops and subsurface by author and/or sources referred to in references. Arrows indicate stream flow directions interpreted primarily by cross bedding dip directions.

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.
The Mosser Dome
Stratigraphic Trap
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
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.
The structural reversal has created over 2285 feet of structural relief on the continuous hydrocarbon column in the trap area. The highest elevation observed in the oil accumulation is on the outcrop in NE/4 SW/4 of Section 8, T4S R25E while the lowest observed elevation is in the dry hole drilled in NE/4 of Sec. 4, T4S R23E (locations noted by yellow-filled text boxes).
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

Structure Map
Top of the U. Greybull C.t: 100 Feet
- MOSSER DOME OIL FIELD
- MOSSER HEAVY OIL TRAP
- L. GREYBULL VALLEY FILL
- OUTCROPS OF PRE-FALL RIVER STRATA

Fossil Oil-Water Contact

Mosser Dome Oil Field

Outcrop of Oil Saturated Greybull Ss.

Stop #1
+4140

L. Greybull Gas Well
+3239
+3824
+4150
+4640

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

Structure Map
Top of the U. Greybull
C.I.: 100 Feet

- MOSSER DOME OIL FIELD
- MOSSER HEAVY OIL TRAP
- L. GREYBULL VALLEY FILL
- OUTCROPS OF PRE-FALL RIVER STRATA

L. Greybull Gas Well

Outcrop of Oil Saturated Greybull Ss.

Mosser Dome Oil Field

Fossil Oil-Water Contact

Stop #2
+4150

+1865

+2600

+3239

+337

+3824

+4140

+4640

+4160

+3750

+3450

+3150

+2850

+2550

+2250

+1950

+1650

+1350

+1050
Cottonwood Creek Outcrop: Cross Bedding, L. Greybull Ss.
Sec. 8, T4S R25E, Yellowstone Co., MT

Unidirectional northeastward dipping planar-tabular cross bedding
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

Oil Stained

Non-oil Stained
This rock sample is from outcrops on the southeast edge of the Mosser Dome stratigraphic trap. Note the abundant oil coating the quartz grains.
Stop #3 (Subsurface) : Shell Oil #1 Greeno NE NW Sec. 5, T4S R25E

- **L. Greybull Gas Well**
  - +3239

- **Stop #3 +3824**

- **Mosser Dome Oil Field**
  - +3824

- **Fossil Oil-Water Contact**
  - +2227

- **Outcrop of Oil Saturated Greybull Ss.**
  - +4150

- **Top of the U. Greybull C.f.: 100 Feet**

  - MOSSER DOME OIL FIELD
  - MOSSER HEAVY OIL TRAP
  - L. GREYBULL VALLEY FILL
  - OUTCROPS OF PRE-FALL RIVER STRATA
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 ATTEMPT
Stop #4 (Subsurface): West Gas #5-8 Barber, SW NW Sec. 8, T3S R25E

L. Greybull Gas Well

Stop #4 +3239

Outcrop of Oil Saturated Greybull Ss.

Mosser Dome Oil Field

+3370

Fossil Oil-Water Contact

+2223

+1865

Fromberg Fault

+2600

Bluewater Fault

+3824

+4150

+4140

+4640

Structure Map Top Upper Greybull C.I. = 100 FT

MOSSER DOME OIL FIELD

MOSSER HEAVY OIL TRAP

L. GREYBULL VALLEY FILL

OUTCROPS OF PRE-FALL RIVER STRATA
Mosser Paleo valley: Lower Greybull Ss. Gas Well

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

L. GREYBULL Ss.
U. GREYBULL Ss.
FALL RIVER Fm.

Perf: 971-981 ft
IPF: 780 MCFGPD Natural

28% Density Porosity, Gas Effect

Reverse SP due to fresh water

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

L. Greybull Gas Well

Mosser Dome Oil Field

Fossil Oil-Water Contact

Outcrop of Oil Saturated Greybull Ss.

Outcrops of Pre-Fall River Strata

Stop #5
+3370

+2600

+3239

+4150

+4140

+4640

Structure Map
Top Upper Greybull C.I. = 100 ft

Mosser Dome Oil Field
Mosser Heavy Oil Trap
L. Greybull Valley Fill
Outcrops of Pre-Fall River Strata

MILE
0 2 4 0 2 4 6

MILES
0 2 4 6
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
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

Stop #6
+2600

L. Greybull Gas Well
+3239

Mosser Dome Oil Field
+3370

Fossil Oil-Water Contact
+2227

Outcrop of Oil Saturated Greybull Ss.
+4150

+4140

+4640

STRUCTURE MAP
TOP UPPER GREYBULL
C.I.=100 FT

MOSSER DOME OIL FIELD
MOSSER HEAVY OIL TRAP
L. GREYBULL VALLEY FILL
OUTCROPS OF PRE-FALL RIVER STRATA
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
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
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)

Mosser Dome oil likely sourced from Phosphoria/Tensleep oil system
Volumetrics
### Volumetric Worksheet

<table>
<thead>
<tr>
<th>Project</th>
<th>Horizon</th>
<th>Area</th>
<th>Ratio of Contour Areas</th>
<th>Equation</th>
<th>Reserve Oil</th>
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<td>Assume 22.00% por - 65% Oil Sat</td>
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**Total Acre Feet:** 1825732 ac-ft  
**Original Barrels of Oil in Place:** 2,025,456,126

### Volumetric Assumptions

(1) Assumed average porosity = 22%
(2) Assumed original average water saturation (Sw) = 35%
(3) Maximum reservoir thickness = 92 ft
(4) 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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- 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.
Thanks go to the following individuals for their work, ideas, or insights:

Dr. Ralph Moberly
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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.
References


