Abstract

The southern Denver basin has been undergoing a resurgence in drilling for conventional reservoirs in the past five years with the discovery of the Arikaree Creek and Great Plains fields. The area initially underwent exploration for carbonaceous shales of Atokan and Cherokee age and the laterally extensive thin Cherokee Formation carbonate conventional reservoirs. Several wells were drilled including at least two laterals to test the viability of these unconventional reservoirs and thin carbonate or dolomite reservoirs. The basin is significantly under-pressured, 0.24 to 0.28 psi per foot except locally, and reservoirs are found from 5,000 to 12,000 feet. The shale reservoirs have to date proven non-productive due to low permeability and difficulties of retaining hydraulic fracture stimulations within zone. Initially conventional drill rigs were used to target all reservoirs. Subsequent drilling used state-of-the-art top drive and slim-hole technology. Despite simplicity of the geologic section with historically minimal drilling problems, several operators have experienced multiple sidetracking, lost hole, and leaving several hundred feet of drill pipe in the well bore. In addition, evaluating the potential zones has been difficult in many wells. Mudlogs and mechanical logs have been misleading. DST’s are seldom used. Completion methods have been relatively simple. Fracture stimulation have been attempted they have not been successful. The presentation will be discussed the caveats and pitfalls of drilling, completing, and evaluating these reservoirs in an under-pressured environment.

References Cited


Comparison of completion and drilling techniques utilized in developing Paleozoic reservoirs in the Southern Denver basin, Mid-Continent, Colorado USA.
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Outline

• Geology of the Southern Denver Basin;

• Drilling Methods;

• Completion Methods;

• Reservoirs;

• Reserves

• Fields.
Geology in the Southern Denver Basin
Mississippian

Structure on top of the Mississippian. The Mississippian disappears in the northern part of the basin due to erosion at the Transcontinental Arch.
The Morrow is one of two prolific reservoirs of Paleozoic age in the Denver Basin, the other is the Mississippian. The valley fill channel sands can be highly productive for either oil or gas. Gas quality from the Morrow typically increases basinward in nitrogen.
Atoka

Structure on top of the Atoka Formation.
The Atoka disappears to the northeast and thickens into the basin center in to the southwest. The Atoka represents tin carbonates and shales, occasionally a localized coal. The sediments are lacustrine and terrestrial in origin.
Upper Atoka 4

Isopach of the Upper Atoka 4 shale. Note that the shale disappears to the west as it either was not deposited or removed by erosion. The Fountain Formation of Pennsylvanian and Paleozoic times. The Fountain Formation is a series of alluvial sands shred off the Ancestral Rockies.

There is a series of thinning in the Upper Atoka 4 that coincides with the Las Animas Arch suggesting it was a positive feature during deposition.
Isopach of the Cherokee Formation. As with previous formations the rocks thicken to the southwest and thin to the northeast.
Note no relationship on a regional scale between the thickness of the these two shale units and the presence of the Transcontinental and Las Animas archs.
Marmaton

Isopach of the Marmaton Formation. As with previous formations the rocks thicken to the southwest and thin to the northeast. Also this is the first Paleozoic unit to cover the entire basin suggesting the Transcontinental Arch no longer has an effect on deposition or is a positive feature.
East-West Cross-section
North-South Cross-section
Cherokee Shales
- Depths of 6,000 to 7,500 feet
- EUR range (est) 50 to 150 MBO
- IPs: 40 to 650 BOPD

Atoka Shales
- Depths of 6,300 to 7,800 feet
- EUR range (est) 50 to 150 MBO
- IPs: 10 to 200 BOPD

Cherokee A, B, C Dolomites
- Depths of 6,000 to 7,200 feet
- IPs: 40 to 120 BOPD

Morrow Sandstone
- Depths of 6,600 to 8,000 feet
- EUR range (est) 10 to 750 MBO
- IPs: 10 to 900 BOPD

Mississippian Carbonates
- Depths of 6,800 to 8,200 feet
- EUR range (est) 10 to 350 MBO
- IPs: 10 to 300 BOPD

All wells presently developed vertically
Cherokee and Atoka Shales

**Cherokee Shales**
- Low pour point
- 37 to 41 API Gravity
- Marine
- No sulfur
- Gas BTU 1300 to 1800
- 3 to 6 carbonaceous shales
- 2 to 10 feet thick individually
- 2% to 24% TOC, Ave 12%

**Atoka Shales**
- High Pour point
- 34 to 38 API Gravity
- Terrestrial
- Paraffin
- No sulfur
- Gas BTU 1400 to 2100
- 10 to 18 carbonaceous shales
- 1 to 2 feet individually thick
- 2% to 27% TOC, Ave 11%

**Maturity**
- 0.55 to 0.8 Ro
- Increase with depth
- Some oil may have migrated

**Carbonaceous Shales**
- 20% to 50% Clays
- Non swelling
- 30% to 50% Carbonate
- 30% to 50% Quartz
- Fractures common
- Bleeding cores and samples
Cherokee and Atoka Shales

**Cherokee and Marmaton Shale**
- Low pour point
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- 2% to 27% TOC, Ave 11%

**Maturity**
- 0.55 to 0.98 Ro
- Increase with depth
- Some oil may have migrated

**Carbonaceous Shales**
- 20% to 50% Clays
- Non swelling
- 30% to 50% Carbonate
- 30% to 50% Quartz
- Fractures common
- Bleeding cores and samples
FIELDS

Great Plains

Bolero

Manassas

Arikaree Creek
TYPICAL DRILLING PROBLEMS

- Cretaceous Pierre and Niobrara present lost circulation problems. Solution to 20 bbls of oil to minimize sluffing;
- Thickening of mud system minimizes shows and sample quality;
- DSTs are useful but can be misleading;
- Log analysis typically misleading in the Marmaton and Cherokee reservoirs.
The initial zone targeted was the Cherokee “A” that underlies the Excello Shale;

Found by using a single 2D seismic line;

Drilling requires drilling to TD using a typical double or triple rig;

Completion was perforation of the zone of interest and acid wash;

Reservoir structurally and stratigraphically controlled;

Other zones completed are the Marmaton “A” and Marmaton “B”, Ft. Scott and Morrow;

At least eight producers are uneconomic at $90 oil.

Production for the Great Plains Field;

17 wells, discovered in 2009;

8 uneconomic wells.

DST data indicates every new well is lower in reservoir pressure. Field results indicates the drill spacing should be greater than 40 acres.
Great Plains Field
Bolero Field

- Discovered in 1984
- Two wells in Cherokee “C” one foot thick;
- Abandoned for low prices, down hole mechanical problems;
- Produced approximately 40M BO up to 1985. Presently over 100 MBO
- Light acid wash;
- Reactivation in 2008;
- Completion in Atoka and Cherokee shales and carbonates;
- Small slick water, 10,000 gallon acid fracks and gel sand fracks;
- IPs varied from 70 to 180 BOPD;
- Completions in the Cherokee “A” and “C”, perforate and acid wash;
- Cherokee “A” is a fractured high porosity limestone related to structure;
- Cherokee “C” is a fractured dolomite is stratigraphic to structural in nature.
Bolero Field

Cherokee A Structure

Cherokee A Porosity
Bolero Cross-section
Manassas Field

- Field was discovered in 1986 by Petro-Lewis;
- Completed in an Atoka Sand;
- Produced 25 MMCFG and 5 MBO over 24 years;
- Oil is low pour-point green oil API 38 to 40;
- Well produces a high BTU gas that yields primarily propane;
- The field lies on a trend of valley fill or near shore channel sands that contain high BTU gas whereas the trend to the north is noted for its increasing low volume BTU gas;
- Drilling and completion similar to other fields. The Atoka sand may have been fractured stimulated;
Arikaree Creek Oil Field

- Discovered in 2012;
- Project developed by Running Foxes, partner bought out part of Company interest prior to drilling;
- Field found using:
  - Projection of reservoirs deeper into Denver Basin toward source of generated hydrocarbons;
  - Detail surface geochemical survey;
  - 3D seismic survey;
  - Identification of structure with associated wrench faulting.
Production

Field has made 1.1 MMBO
Iodine surface geochemistry in northern Lincoln county

Small area of the overall iodine survey in Lincoln County

Surface geochemistry done by Atoka Inc., 303 617 8919
Pre-drilling 3D seismic survey

3D Outline

Upper Horst
Middle Horst
Lower Horst

Mississippian Structure
Pop up structure
Areas where traps can form both in the up and down block position.
Hanson 8-10

**Discovery Well**

Completed in the Mississippian Spergen;
Upper Horst;
400+ BOPD;
Reservoir is low temperature hydrothermal dolomites;
High pour point oil;
Atokan oil;
No water.

- The well was drilled to the Precambrian;
- The well was drilled with top drive which increased rate of penetration and shortened drilling time. But damage to wellbore caused problems logging and running pipe;
- Perforation and production.

**Upper Horst Well**

- Pay

**Middle Horst**

oil and water zone
Erratic pay;
No predictability.

**Lower Horst**

Well: Whistler 16-21
33 meters lower then upper block
Iodine Survey and 3D Seismic

Anomalies related to fault leakage creating a halo anomaly

Surface geochemistry done by Atoka Inc., 303 617 8919
Steamboat Hanson 8-10

11/7/2012: Spergen. Perf 8055’ - 8065’

11/12/2012: Spergen. Perf 8027’ - 8014’

9/16/2013: Spergen. Perf 8018’ - 8027’

11/12/2012: Spergen. Tested 8027’ - 8065’ for 6 hrs, pumped 46 bbls Oil, 12 Mcf
Big Sky 4-11

Big Sky 4-11

![Graph showing production data for Big Sky 4-11](image)
Taos 1-10


6/7/2013: Spergen. Perf 8054' - 8100'

6/7/2013: Spergen. Tested 24 hrs, pumped 513 bbls Oil
Snowbird 9-15

7/3/2013: Spergen
Perf 8216’ - 8222’

7/8/2013: Spergen.
Perf 8148’ - 8156’

7/9/2013: Spergen.
Perf 8110’ - 8136’

7/10/2013: Spergen.
Perf 8084’ - 8100’

7/11/2013: Spergen.
Perf 8046’ - 8074’

7/27/2013: Spergen.
Tested 24 hrs, pumped 159 bbls Oil, 27 Mcf Gas, and
The Cherokee and Atoka Formations can be subdivided in intervals or cyclothems. The missing component is coal so the boundaries are the tops and bottoms of carbonaceous mudstones.
Stratigraphic Column
Morrowan and Mississippian
Morrow Isopach

Morrow Structure
Morrow- Mississippian Isopach

Results similar to the previous slide

Atoka-Morrow Isopach
Dividing the Atoka into the upper and lower indicates the thinning is more prominent in the Lower Atoka.
LA 1 and 2 are absent in the area; LA 3 rests directly on the Morrow.

LA3 interval has thin areas but is not as definitive as LA7 (younger) interval.
UPPER ATOKA ISOPACHS

The thin is more definitive in the UA 4 (older) then the younger UA 6.
Thinning is present in the Tebo and Excello intervals but this could be due to presence of or structural activity or the marine setting of topographic high creating an area of marine non-deposition.
The Marmaton is also a carbonate dominate formation. The thins could be related to a topographic feature or structural activity. The seismic does not support structural movement at this time.
Mississippian Production and Structure

Spergen Subsea

Total Production
Mississippian Production and Daily two to 13 Months

Two to 13 Months Total

Daily for two to 13 Months total Production
Total Oil and Water Production

Water Production

Total Production
Drilling and Completion Methods

- Drilling of wells in the Southern Denver Basin are typically vertical;
- Horizontals have had limited use;
- Completions are typically perforating, acid clean-up produce;
- Low psi per foot: .24 to 28 psi, have limited the use of fracture stimulation;
- Most reservoirs are a combination of fracturing and porosity.
SUMMARY

• The Paleozoic fields in the southern Denver Basin are typically thin to carbonates found in Mississippian, Cherokee, and Marmaton rocks. Morrow valley fill channel sands fields are also productive but more elusive;

• Many companies repeat the mistakes of previous operators;

• Horizontals have not been used to any great degree and where they have been used have not proven useful;

• Reservoirs are erratic and cannot be defined easily by seismic;

• Every well is almost a semi-wildcat;

• 3D seismic is critical to define structures.
The End

Thank You For Coming