Kyle E. Murray, PhD, Hydrogeologist

Presents:

Modeling of Pressure Propagation from Saltwater Disposal Wells Completed in the Arbuckle Group, northern Oklahoma
# Most Prominent Producing Zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Group</th>
<th>Formation</th>
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<tbody>
<tr>
<td>Permian</td>
<td>Chase</td>
<td>Brown Dolomite</td>
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<tr>
<td></td>
<td>Council Grove</td>
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<td></td>
<td>Admire</td>
<td>Belvial</td>
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<tr>
<td></td>
<td>Wabaunsee</td>
<td>Cisco Lime</td>
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<tr>
<td></td>
<td>Shawnee</td>
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<td>Kansas City</td>
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<td>Hogshooter</td>
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<td>Desmoinesian</td>
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<tr>
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<td>Middle Devonian</td>
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<td>Lower Dev - Silurian</td>
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<td>Oil Creek</td>
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<tr>
<td>Dev to Mid Ord</td>
<td>Arbuckle</td>
<td>West Spring Creek</td>
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<tr>
<td></td>
<td>Arbuckle Group</td>
<td>Kindblade</td>
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<td>Butterfly Dolomite</td>
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<tr>
<td></td>
<td>Basement &amp; Crystalline Rock</td>
<td>Reagan</td>
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<tr>
<td></td>
<td>Pre-Cambrian</td>
<td>Granite</td>
</tr>
</tbody>
</table>

O&G Wells Completed (2010 – May 2014)

Key to Symbols

OKCGS Shale Shaker (Murray and Holland, 2014)
Oil Production by Zone for 13 Study Area Counties, 2009–2014

Compiled from: Lasser Production Database

Prepared by:
Kyle E. Murray
OGS Hydrogeologist

(Murray, 2015 – in preparation)
Gas Production by Zone for 13 Study Area Counties, 2009–2014

Compiled from: Lasser Production Database

(Murray, 2015 – in preparation)
Kansas: not required to report produced water volumes
Oklahoma: not required to report produced water volumes
Texas: required to report produced water volumes annually to TX Railroad Commission
From 2000-2011, newly completed wells in OK’s Mississippian averaged:

- 7.4 bbl of H₂O produced for 1 bbl of oil
- 9.8 bbl of H₂O produced for 1 bbl oil equivalent gas

(Murray, 2013)
What do we do with the co-produced saltwater?

SaltWater Disposal (SWD) Wells

(Murray, 2015 – in preparation)
Drill-Stem Test Data for the Arbuckle Group, 1944–2006

BHP minus Hydrostatic
-7921 - -3040
-3039 - -500
-499 - 0
1 - 500
501 - 1000
1001 - 3840

Geologic Province
ANADARKO BASIN
ANADARKO SHELF
ARBUCKLE UPLIFT
ARDMORE BASIN
ARKOMA BASIN
CHEROKEE PLATFORM
CIMARRON ARCH
CRINER UPLIFT
HOLLIS BASIN
MARIETTA BASIN
NEMAH UPLIFT
OUACHITA MOUNTAINS UPLIFT
OZARK UPLIFT
WICHITA UPLIFT
Faults, OGS OF3-2015

Arbuckle Pressure vs. Time in northern Provinces

Prepared by:
Kyle E. Murray
OGS Hydrogeologist

(Carrell and Murray, 2015 – in preparation)
• Dilworth field, Kay County
• Model location criteria
  - Arbuckle SWD well locations and volumes
  - Mapped fault locations
  - Proximity of core and drill-stem test data

Legend

- Injection well
- Mapped fault
- Study area

(Carrell and Murray, 2015 – in preparation)
Hydraulic Properties

Legend

- OPIC core
- DST location
- OGS core plugs
- Model area
- Wellington field study

30 miles

(Carrell and Murray, 2015 – in preparation)
Cross-Section Through Dilworth Field, Kay County, OK

Legend:
- Post Simpson
- Simpson Group
- Arbuckle Group
- Precambrian Basement
- Model boundary
- Mapped fault
- Dry well
- Oil well
- Water injection well

Arbuckle Tops (ft):
- 4432 - 3915
- 3914 - 3455
- 3454 - 3081
- 3080 - 2806
- 2805 - 2627
- 2626 - 2516
- 2515 - 2393
- 2392 - 2287
- 2286 - 2166
- 2165 - 1607

(Carrell and Murray, 2015 – in preparation)
MODFLOW representation for simulating groundwater flow

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<th>API Text</th>
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<th>V10A</th>
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</tbody>
</table>

Simulated Injection Scenarios

1: Injection into Arbuckle w/ coincident production from Arbuckle
2: Injection into Arbuckle w/o coincident production from Arbuckle
3: Injection into Arbuckle w/ various hydraulic properties for Fault B
4: Injection into Arbuckle at various distances from Fault B
5: Injection into wells w/ commingled completions in Arbuckle and Simpson Groups
6: Injection into Precambrian Basement
7: Injection into different Arbuckle intervals
8: Injection into dense, unfractured Arbuckle dolomite
9: Injection into Arbuckle at various rates

(Carrell and Murray, 2015 – in preparation)
Injection into Arbuckle increases Pressure on east side of Fault B

- Decrease in hydraulic head of 250 ft (116 psi) around production wells within the horst block
- Increase in hydraulic head of 220 ft (102 psi) within the graben

(Carrell and Murray, 2015 – in preparation)
Case Study Area: Dilworth Field in Kay County in the Nemaha Uplift

(Carrell and Murray, 2015 – in preparation)
Lessons Learned

- Fault properties (barrier vs conduit) and vertical/horizontal permeability must be well characterized to understand propagation of fluid pressure.
- Under realistic/actual conditions injection into the Arbuckle increases fluid pressure in the Arbuckle and basement.
- An injection well’s radius of influence can be 6.2 miles (10 km) or more.

(Carrell and Murray, 2015 – in preparation)
The Oklahoma Geological Survey will present a one-day workshop on Petroleum and Co-Produced Fluid Extraction & Injection. The workshop will be held on November 11th at the Reed Conference Center, 5750 Will Rogers Road, in Midwest City, Oklahoma. The workshop is designed to cover recent developments of petroleum-rich carbonate reservoirs in the Mid-Continent which have led to large-scale water disposal practices. Understanding local and regional characteristics of reservoirs that produce hydrocarbons and the formations that are used for saltwater disposal is critical for continued development of oil and gas resources.

This workshop will examine development trends of the Hunton and Mississippian plays that have significant oil and water extraction histories. Another emphasis will be on the formations comprising the Arbuckle Group that are the primary saltwater disposal zones in Oklahoma. Scientific findings and operator case studies will supplement the workshop.

The field trip on November 10th or 12th will examine outcrop and/or quarry exposures of geologic and structural features that may be extrapolated to subsurface producing and disposal zones. These rock exposures exhibit porosity types, and fracture patterns that not only store hydrocarbons but also enable widespread and large-scale water disposal/migration into the Arbuckle Group.

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Sponsored by Oklahoma Geological Survey
University of Oklahoma
Mewbourne College of Earth & Energy
Sheraton Midwest City Hotel at the Reed Conference Center
Midwest City, Oklahoma