

# Basalt Characterization Test Update

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Richland, Washington*

Regional Carbon Sequestration Partnerships Initiative  
Review Meeting

*Pittsburgh, Pennsylvania  
December 13, 2007*

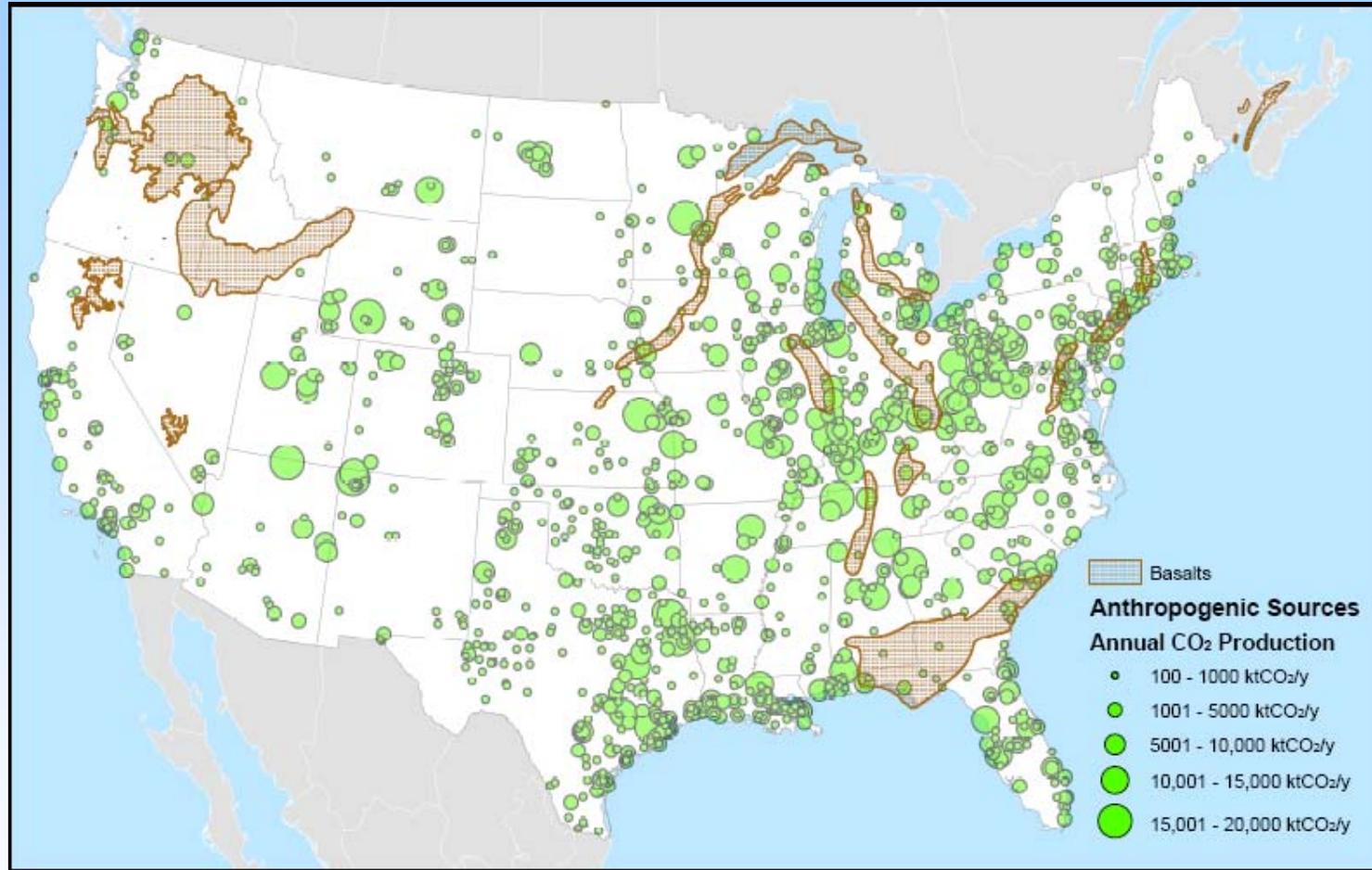
# Outline

- Sequestration in Basalts
- Big Sky Field Test

# Rationale for Basalts

- Major flood basalt formations exist throughout the world
  - Important role in global carbon cycle
  - Implicated in past climate change events
  - Not widely considered as a geological sequestration option
- Over 30 years and >\$400M of prior DOE investment in understanding basalt/aquifer systems that can be applied to carbon storage
- Capacity and Retention
  - Columbia River Basalt Group covers 164,000 km<sup>2</sup>, >174,000 km<sup>3</sup>
  - Chemical makeup favorable for mineralization reactions
- Water Resource Implications
  - Upper aquifers (<300 m) are major source of water
  - Deeper aquifers contain non-potable water
- Big Sky industry partners have IGCC projects in planning where sequestration in basalts is being considered to comply with recently passed state law limiting CO<sub>2</sub> emissions from new fossil power plants

# Major Basalt Formations in the U.S.



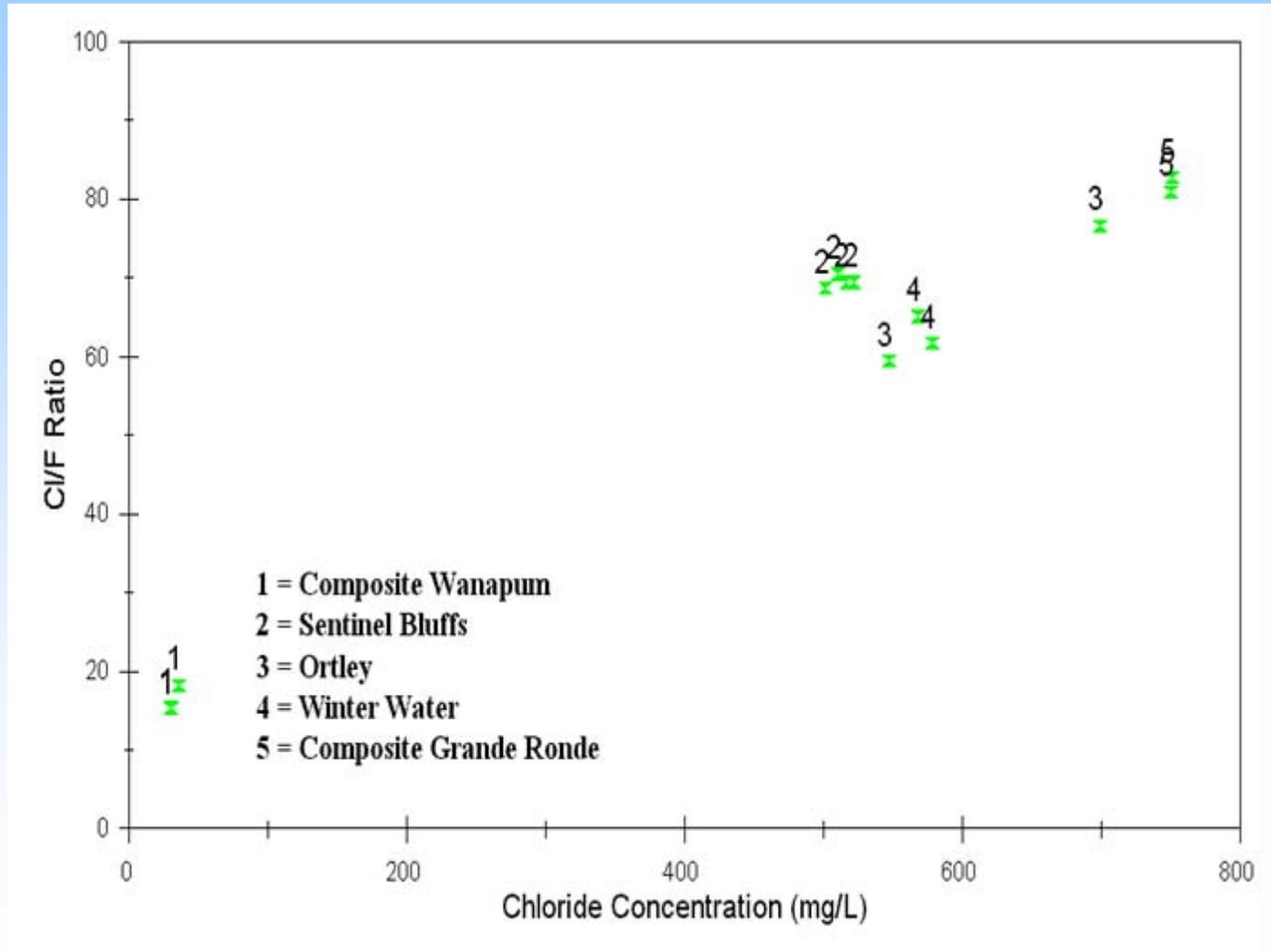
McGrail, B. P., H. T. Schaef, A. M. Ho, Y. Chien, J. J. Dooley, and C. L. Davidson. 2006. Potential for Carbon Dioxide Sequestration in Flood Basalts, *J. Geophys. Res.* **111**, B12201, doi:10.1029/2005JB004169

# Layered Basalt Flows

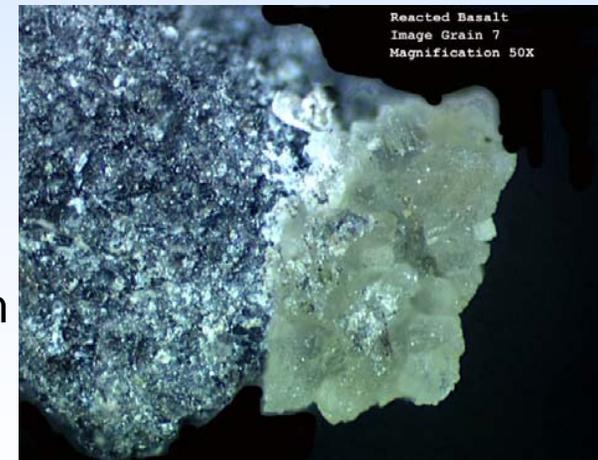
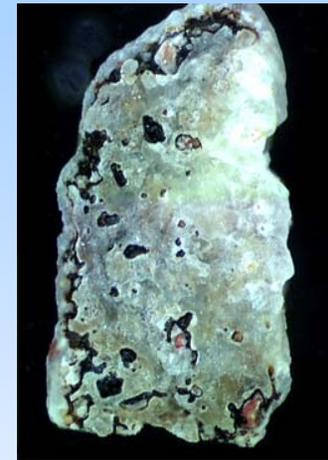
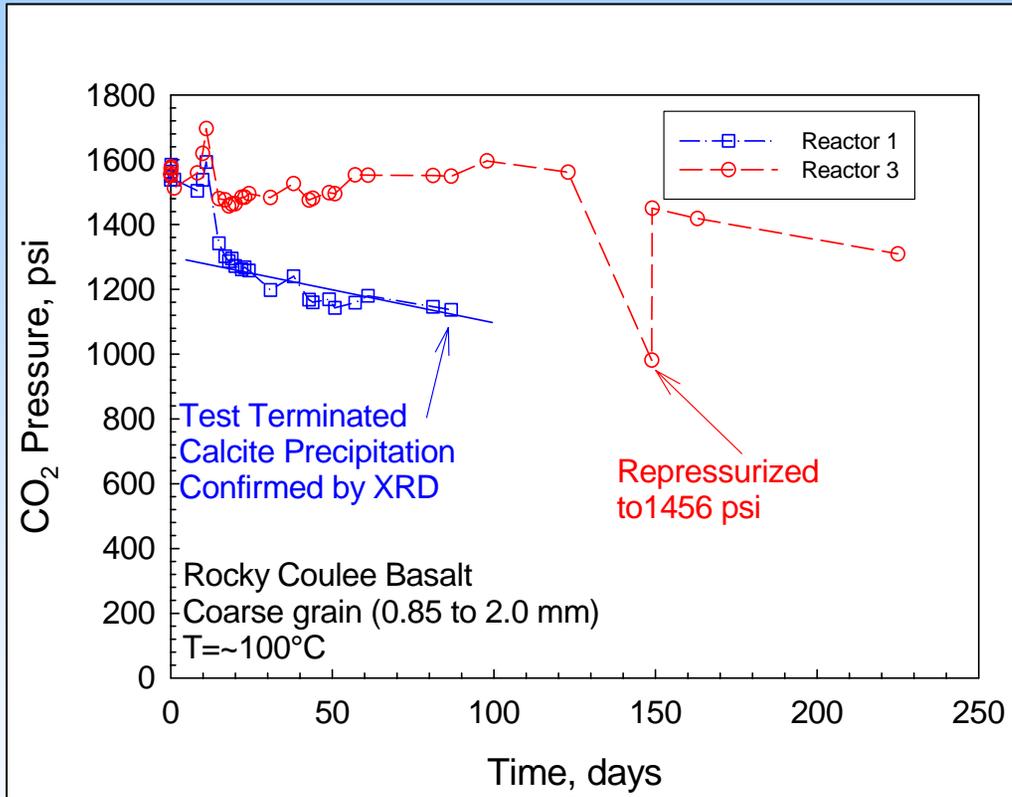


- Assume only 10 flows (3%) suitable for injection, thickness of only 10 m, 15% porosity, 1400 psi average pressure
- $\approx 50\text{-}100$  GtCO<sub>2</sub> storage capacity

# Water Chemistry Across Basalt Flows



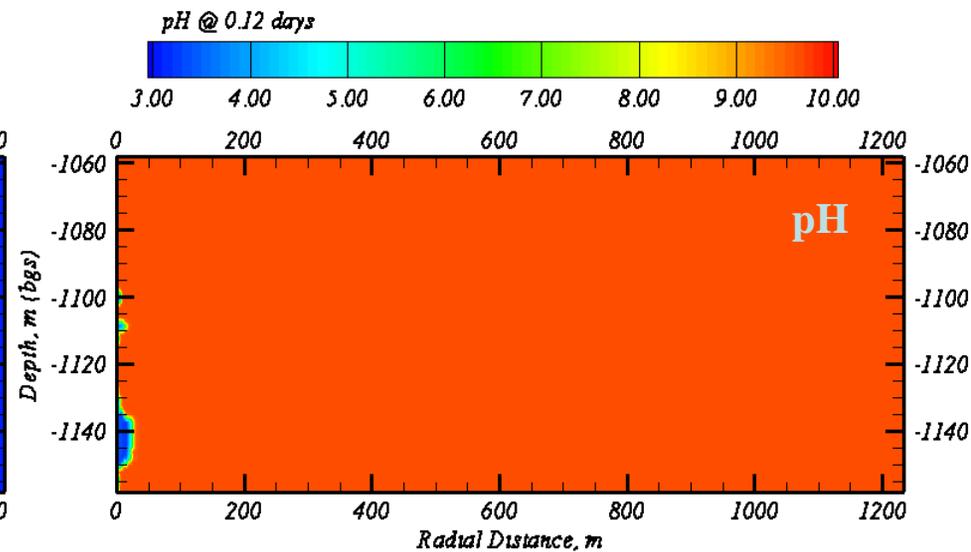
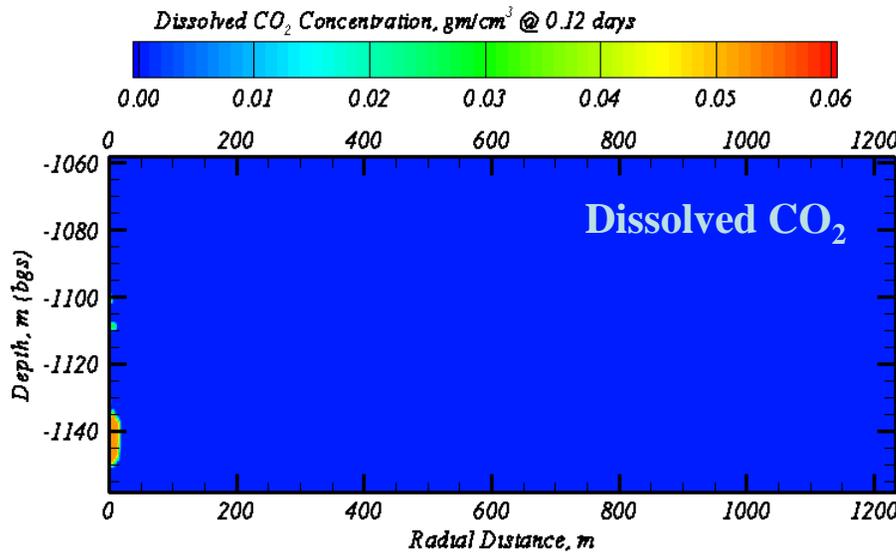
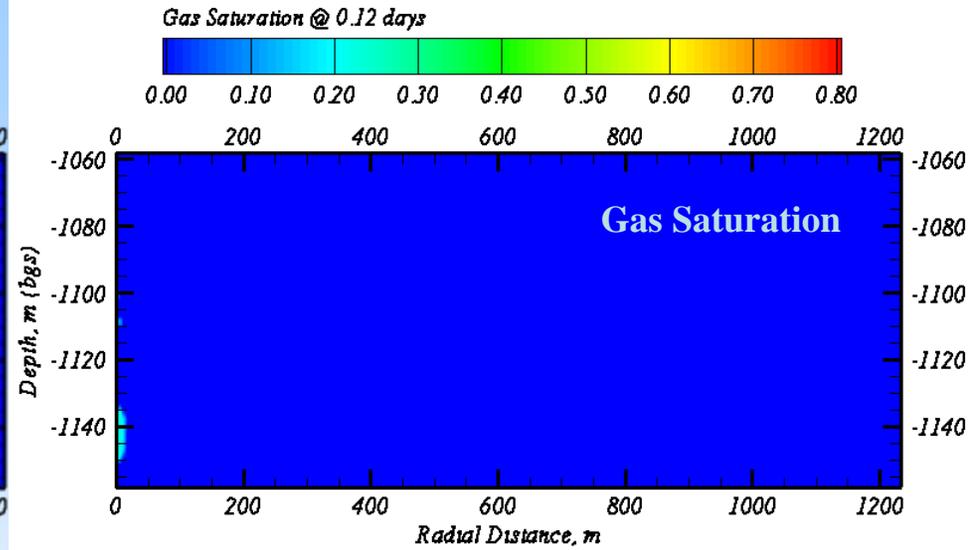
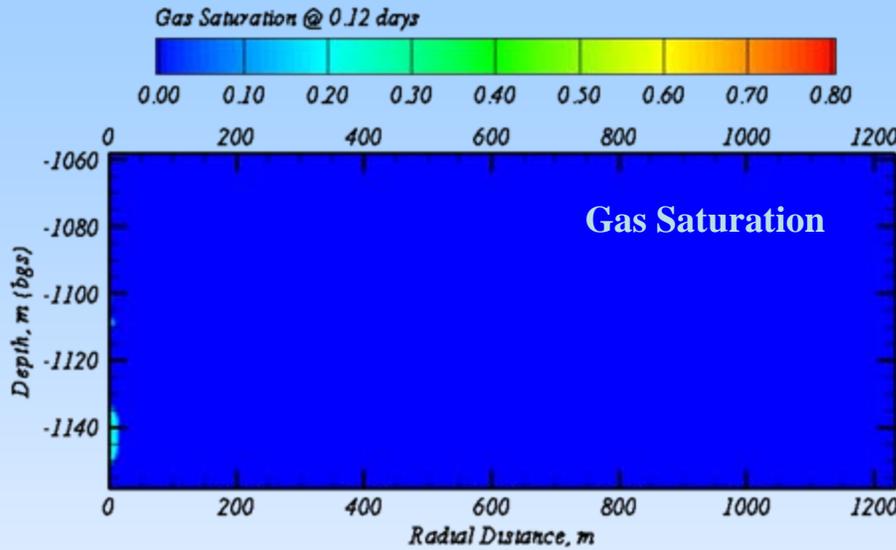
# Supercritical CO<sub>2</sub> Pressure Cell Experiments with Columbia River Basalt



Long-term experiments showing transition from calcite to ankerite,  $\text{Ca}(\text{Fe}, \text{Mg}, \text{Mn})(\text{CO}_3)_2$

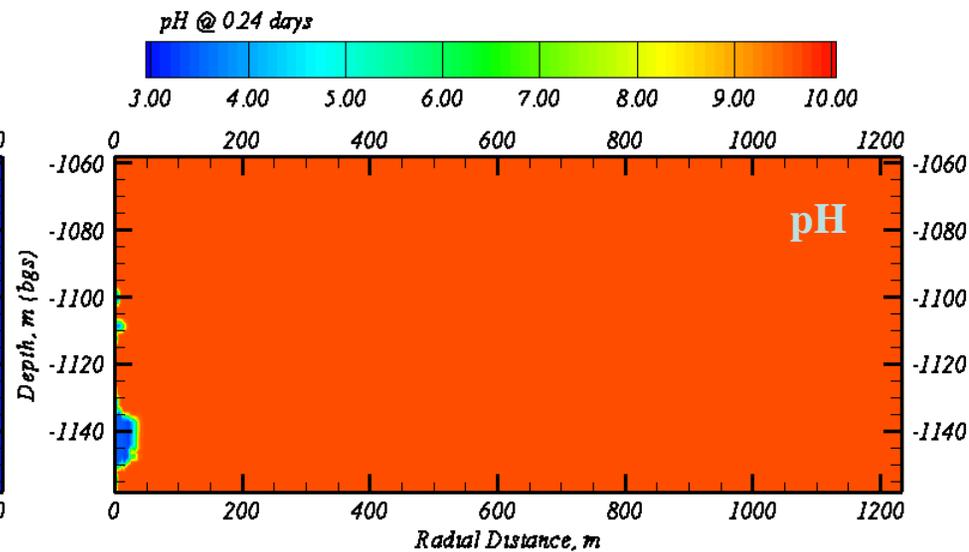
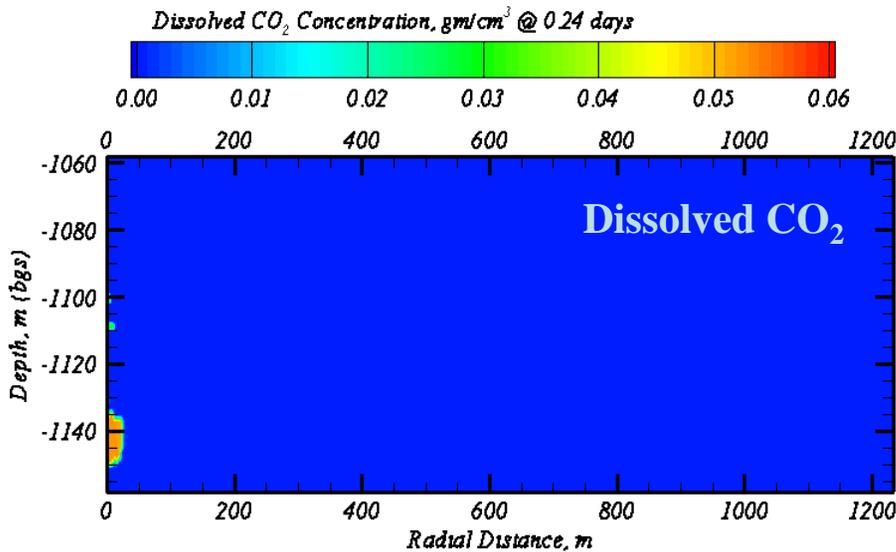
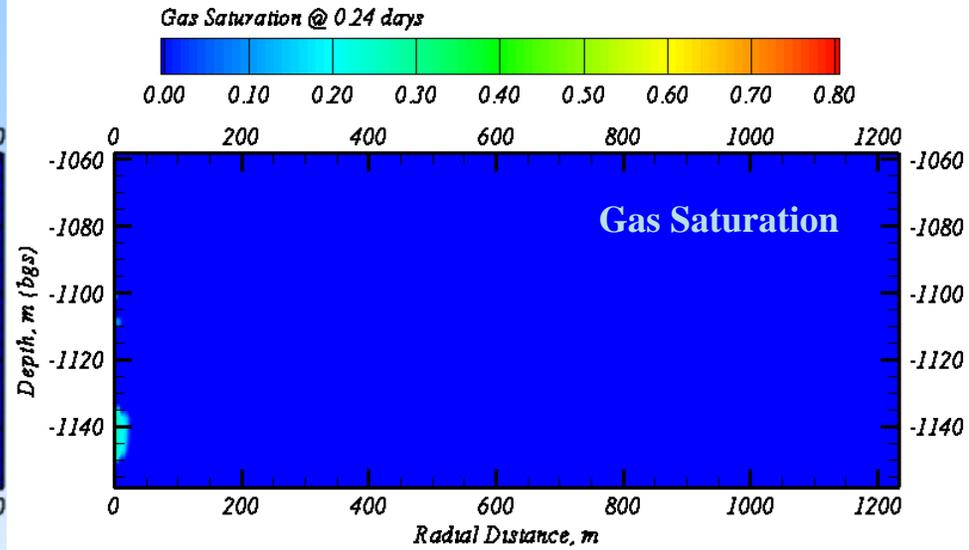
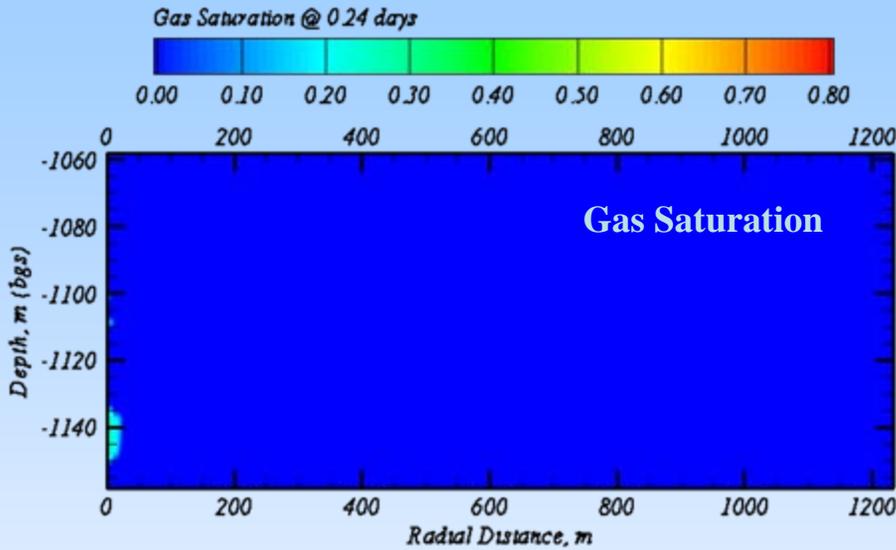
No Chemistry

Chemistry



No Chemistry

Chemistry



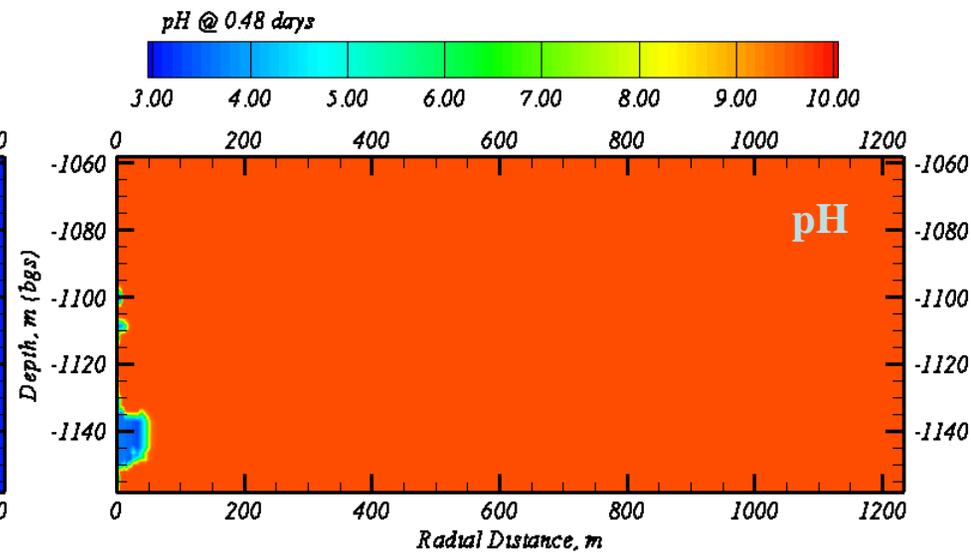
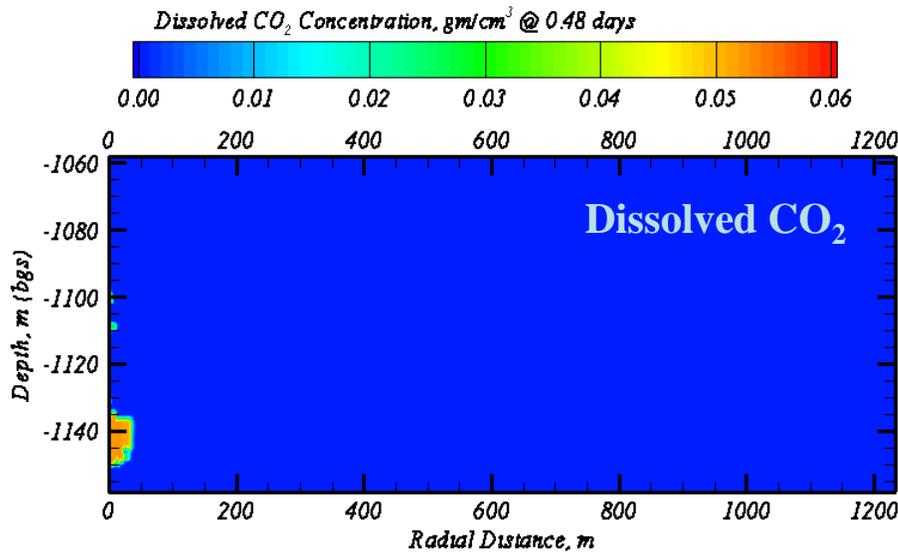
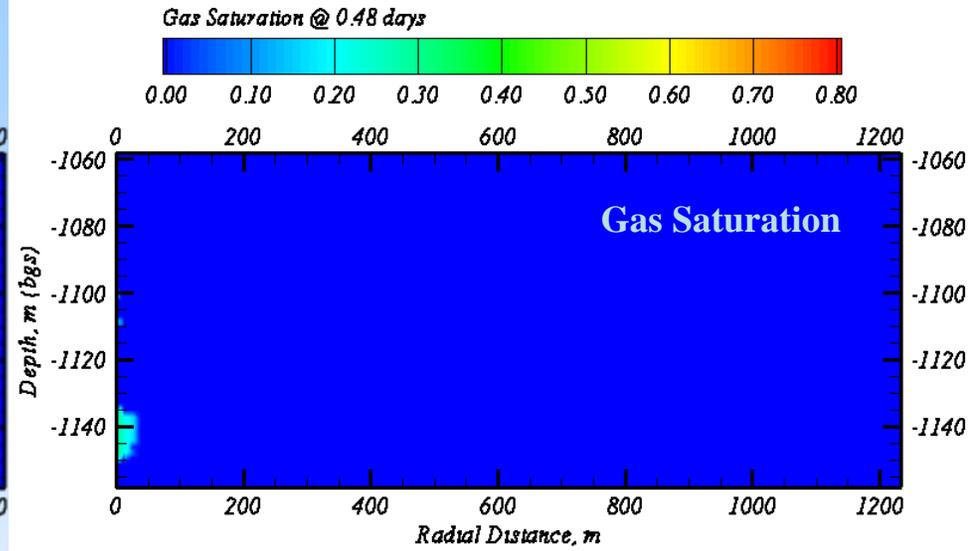
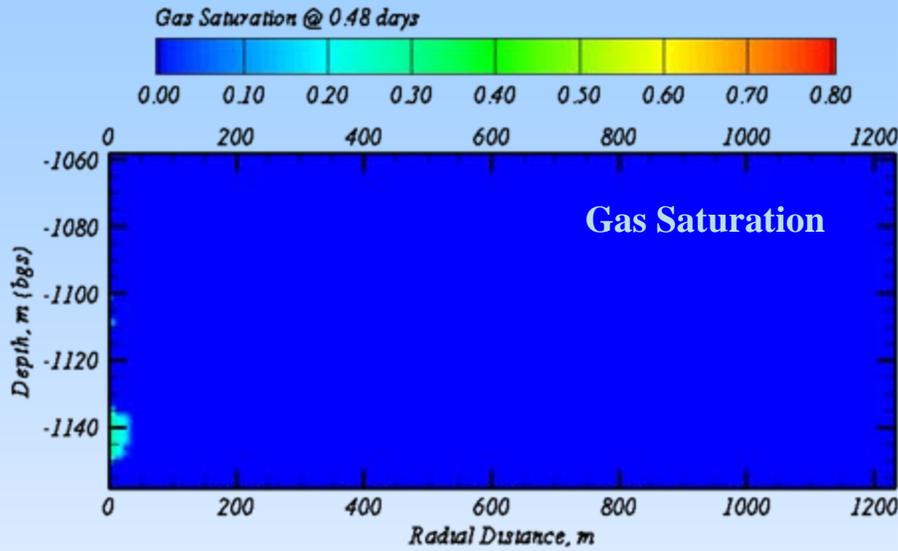
0.48 days

# Simulation Results

CMWRXXVI [246]

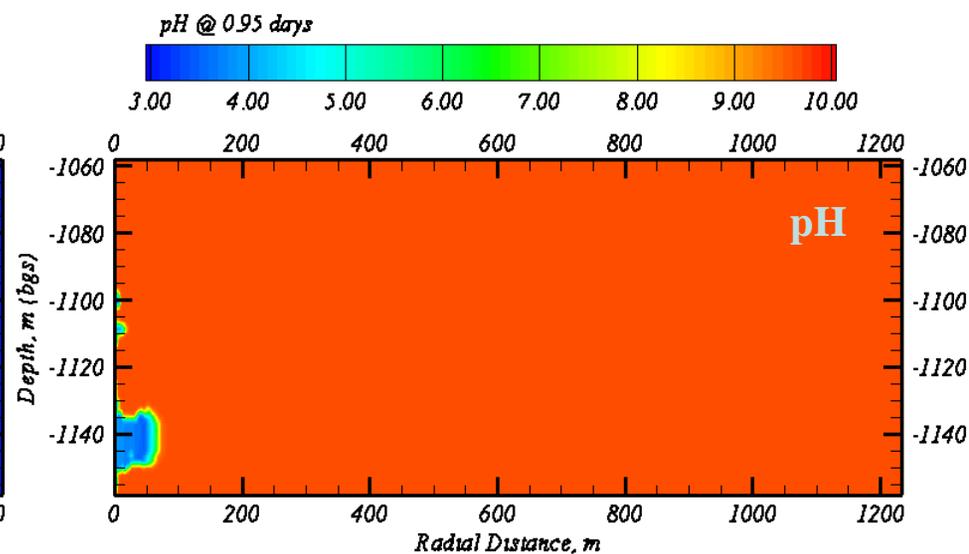
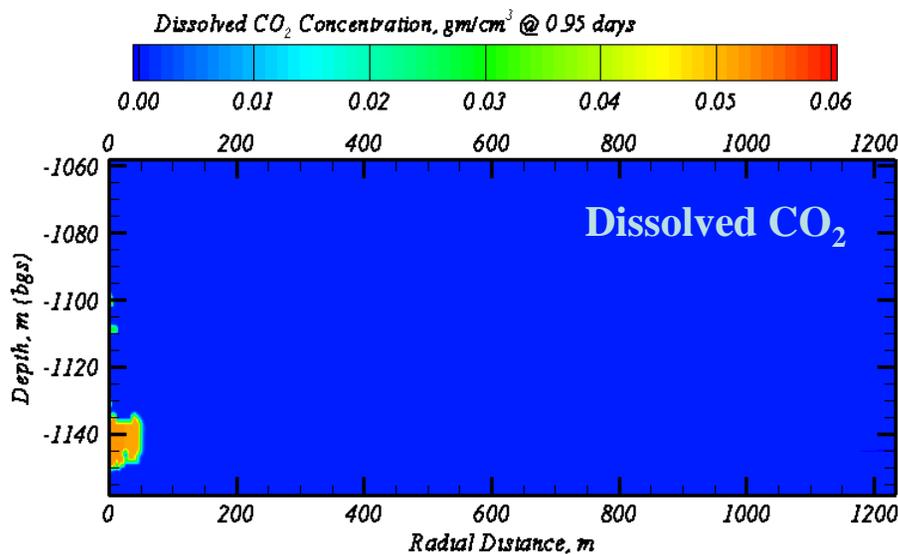
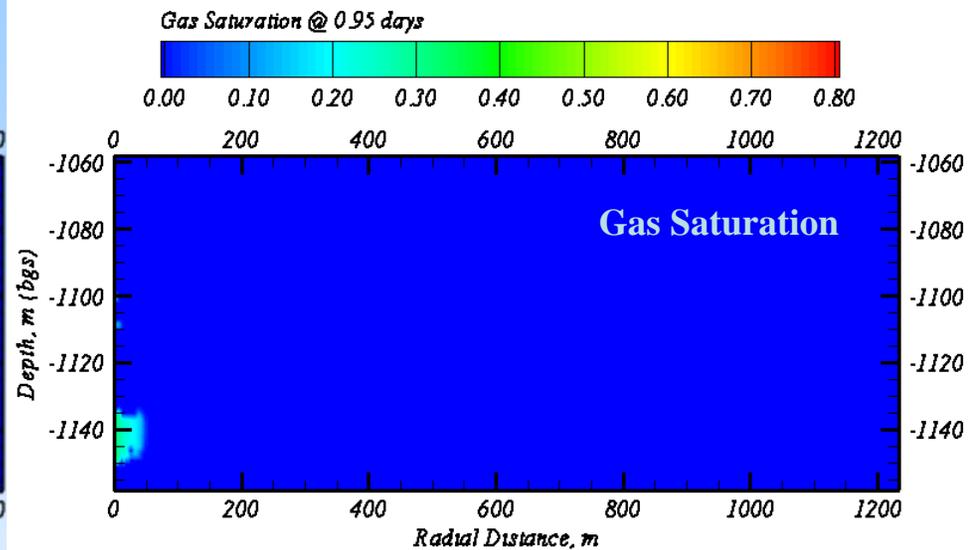
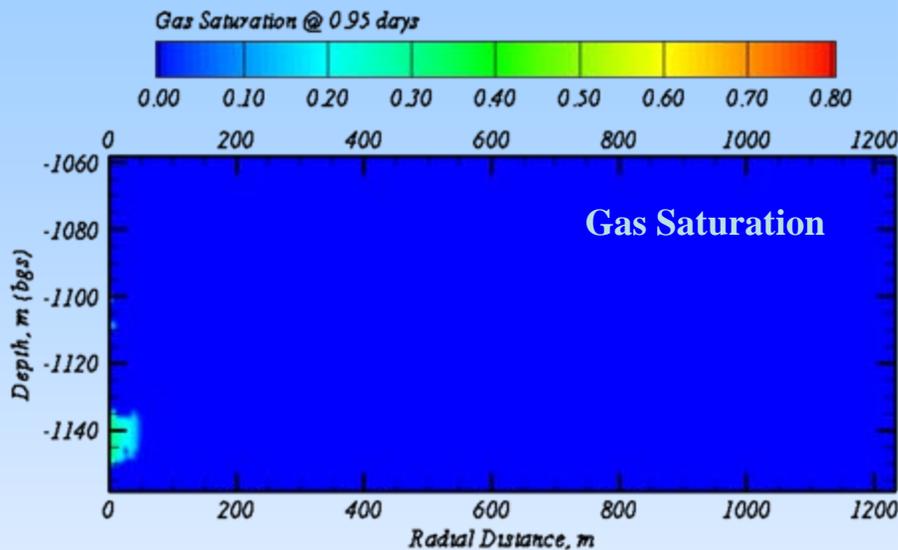
No Chemistry

Chemistry



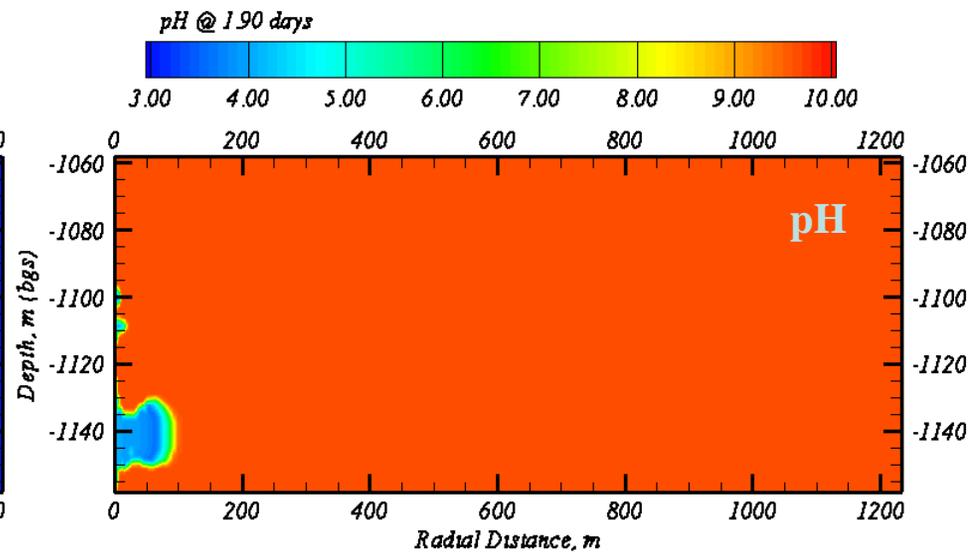
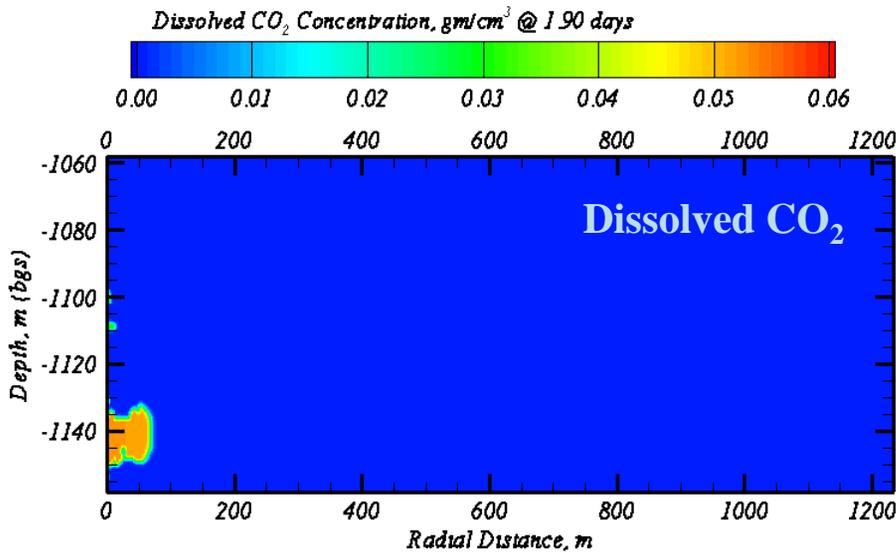
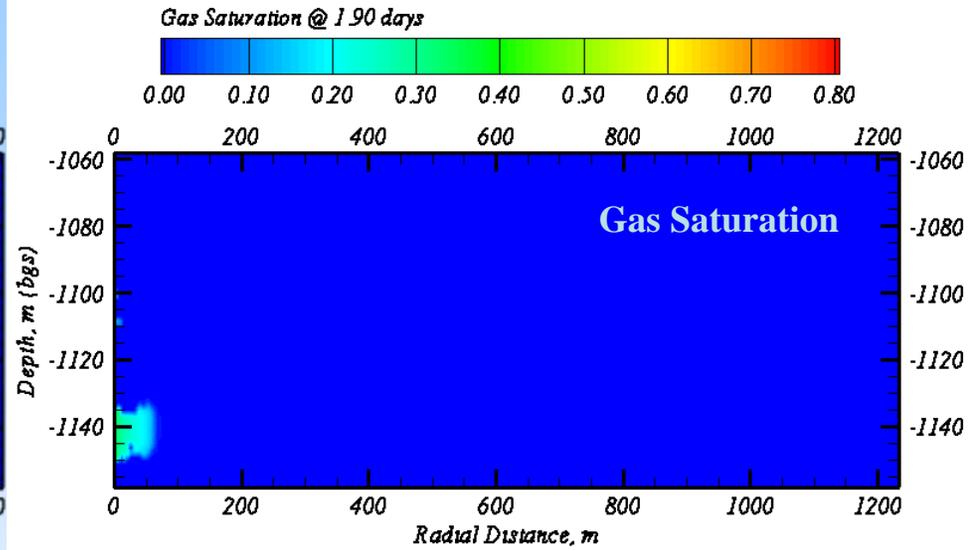
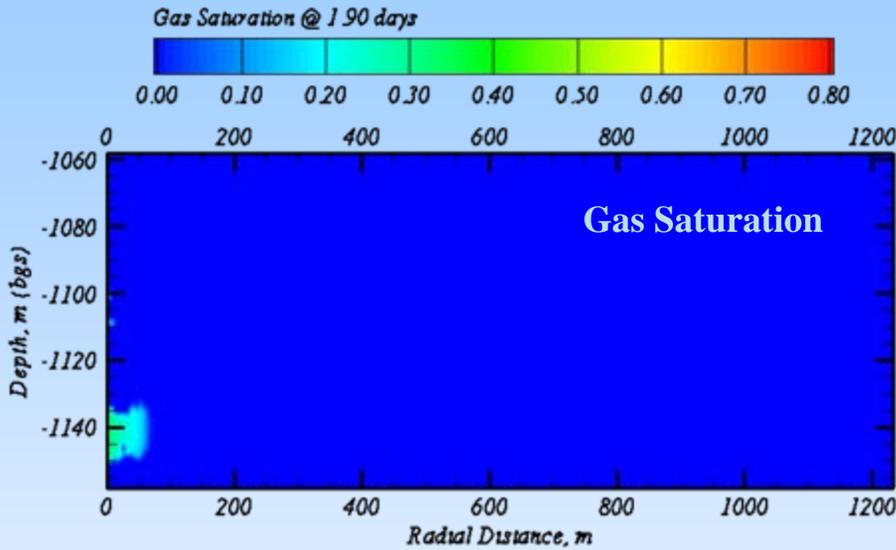
No Chemistry

Chemistry



No Chemistry

Chemistry



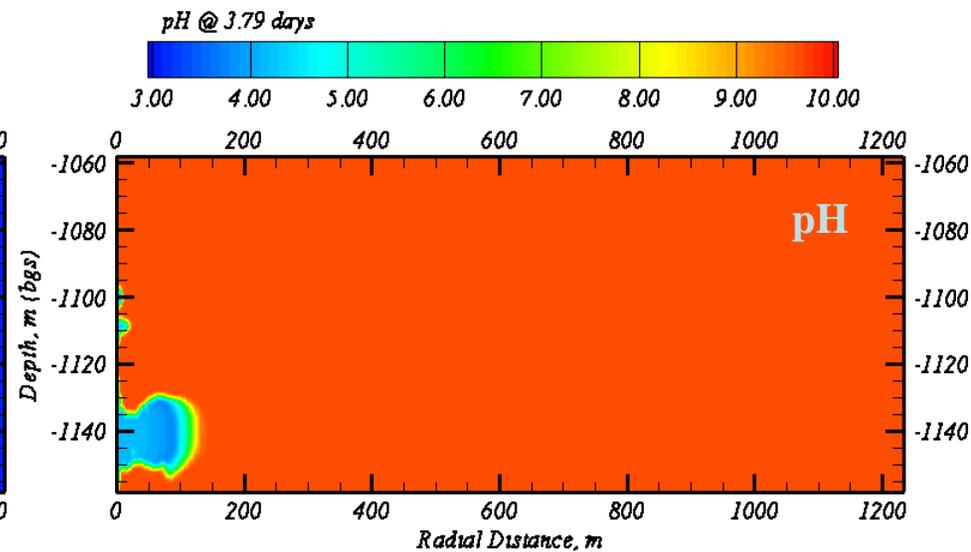
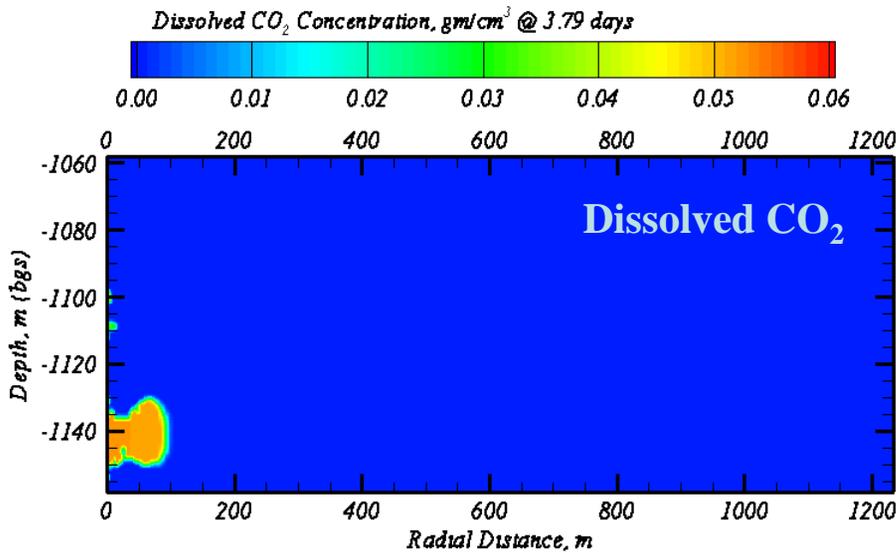
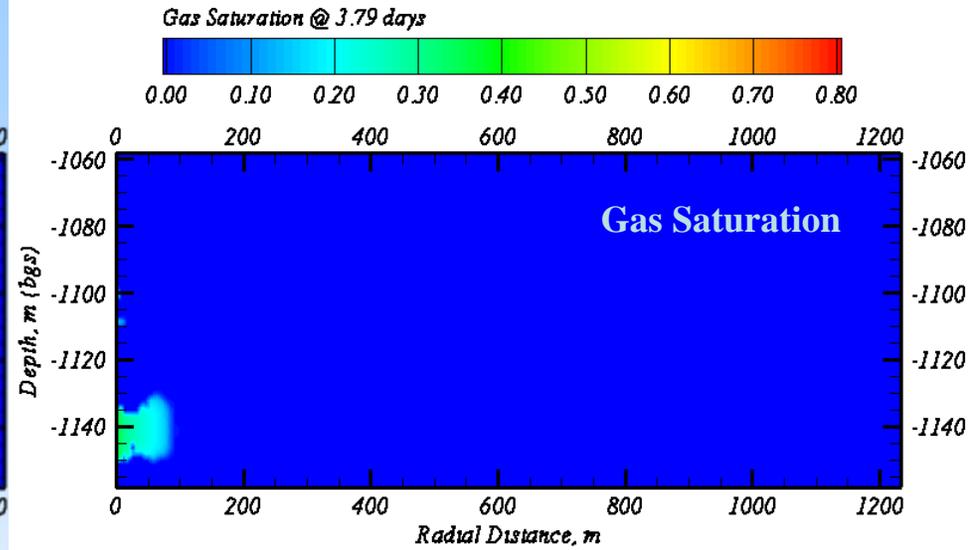
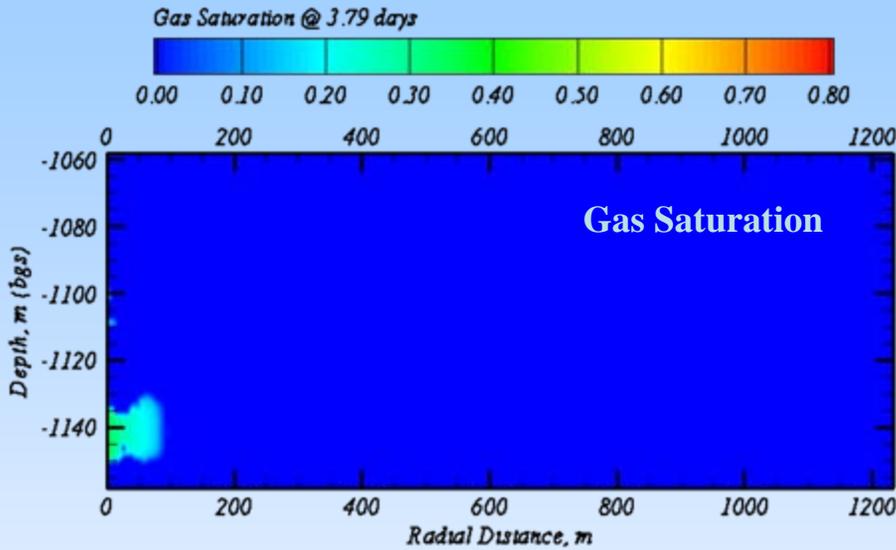
3.79 days

# Simulation Results

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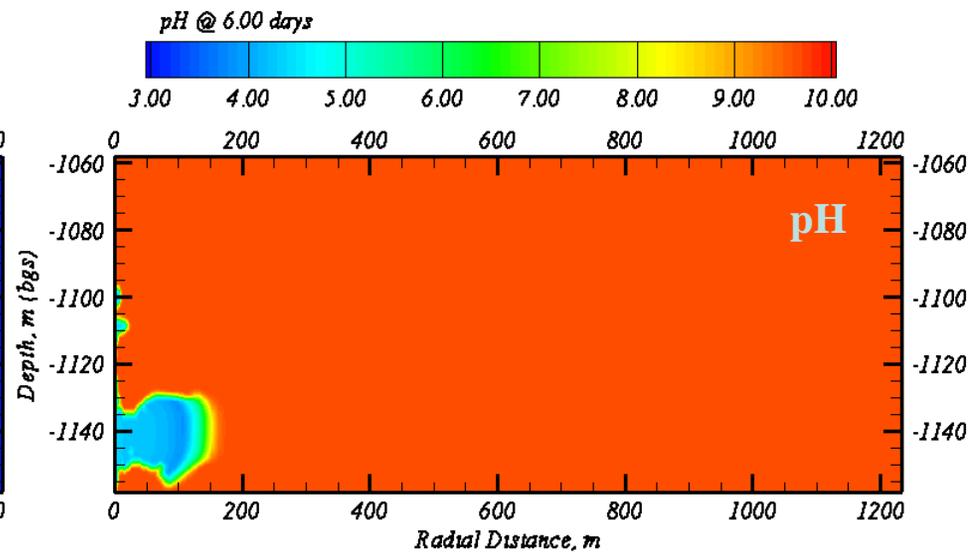
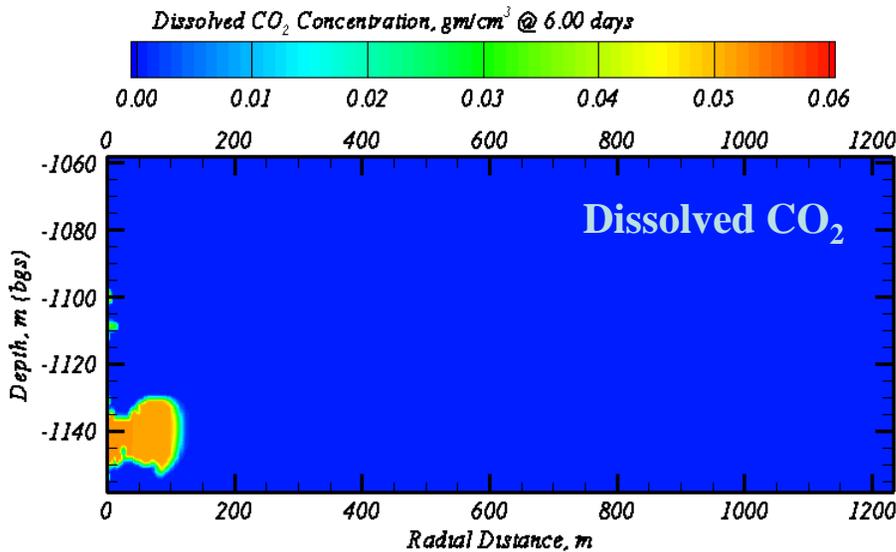
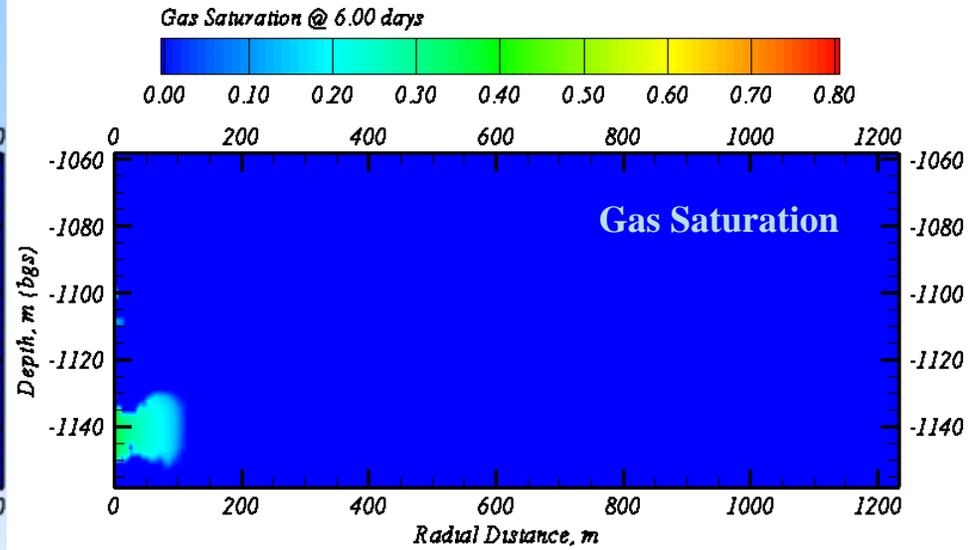
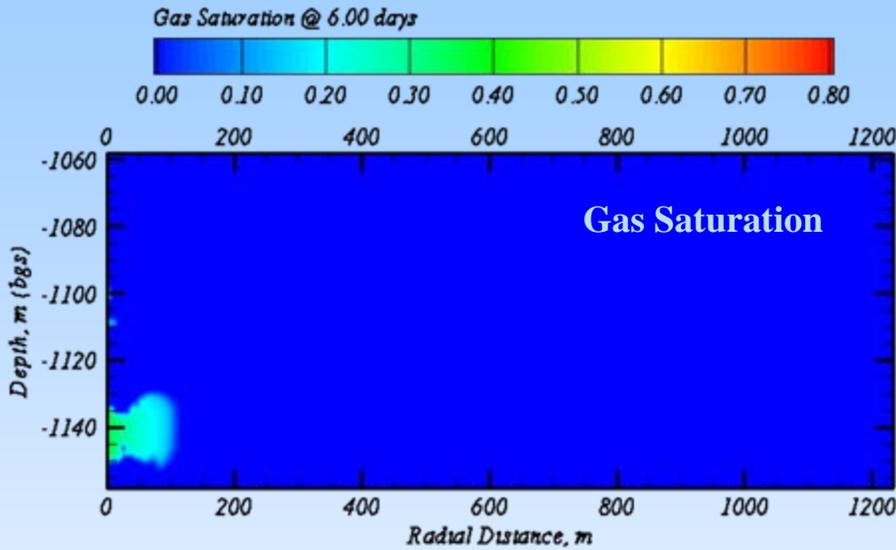
No Chemistry

Chemistry



No Chemistry

Chemistry



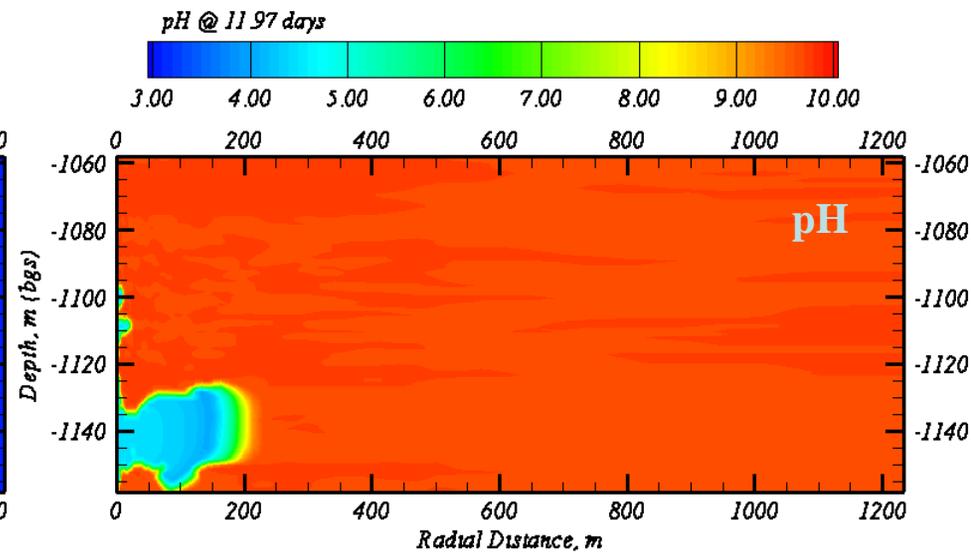
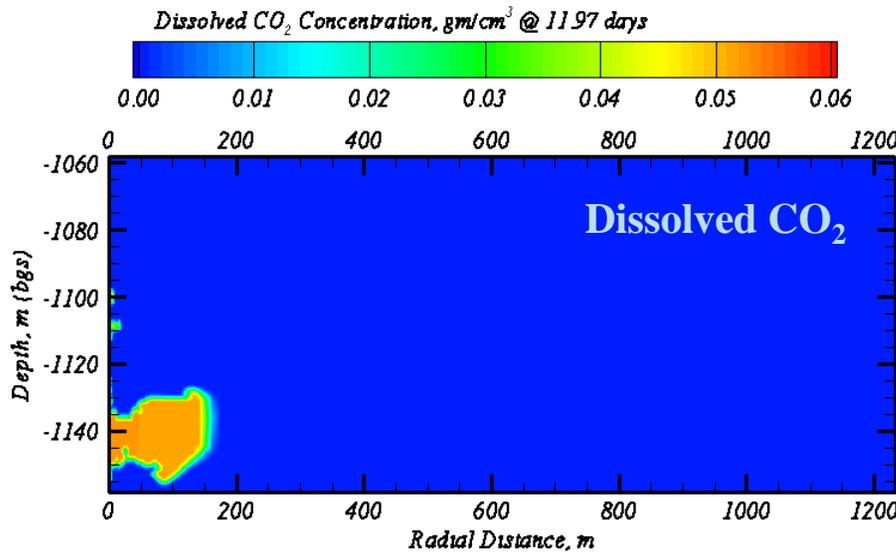
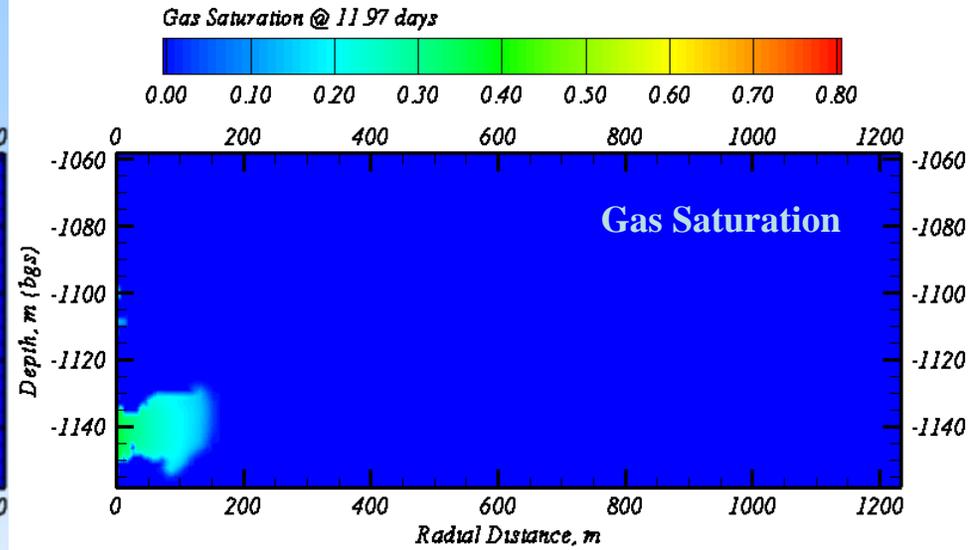
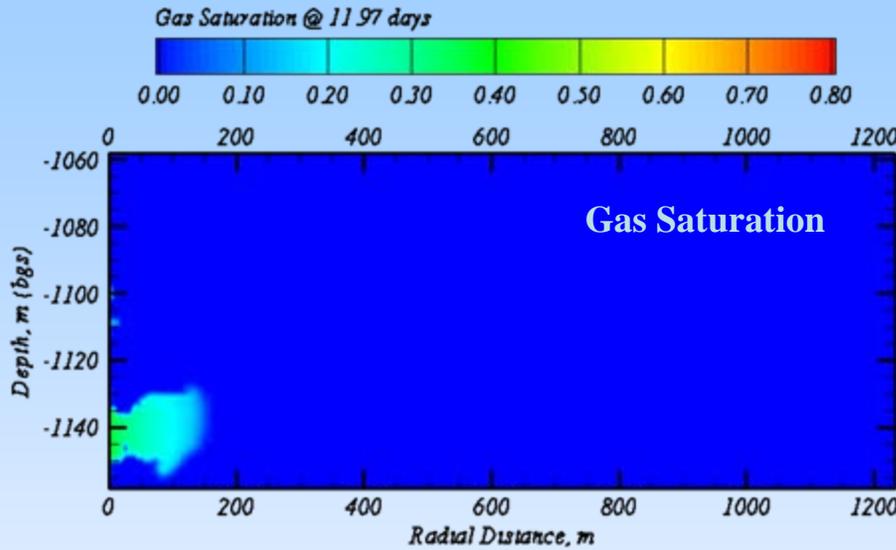
11.97 days

# Simulation Results

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No Chemistry

Chemistry



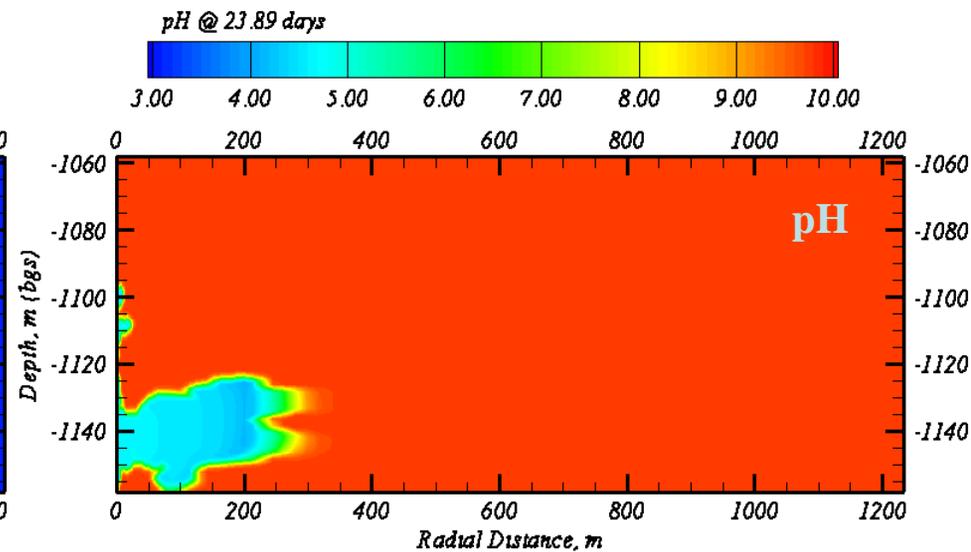
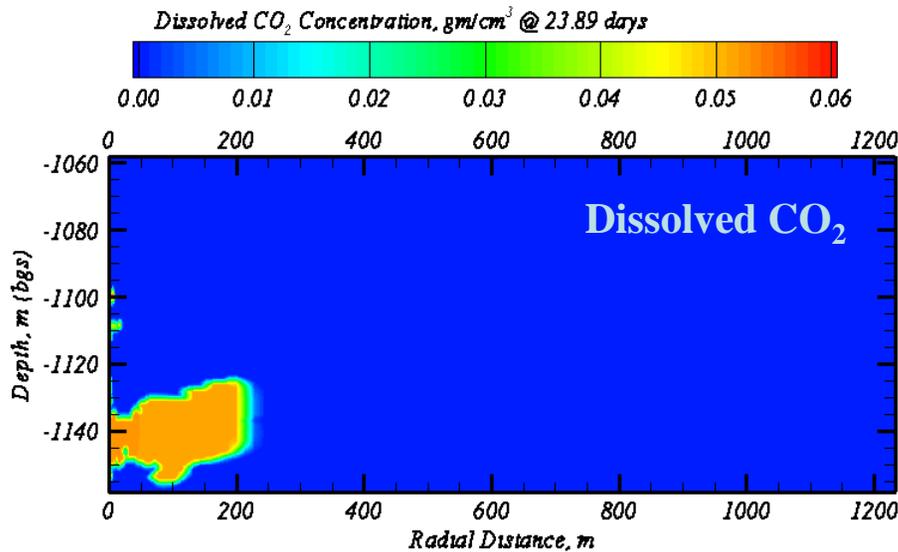
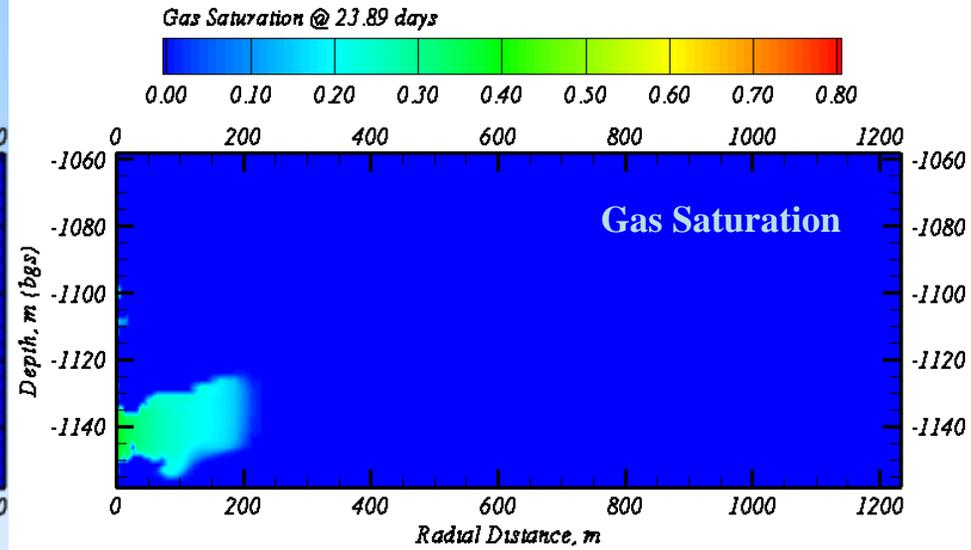
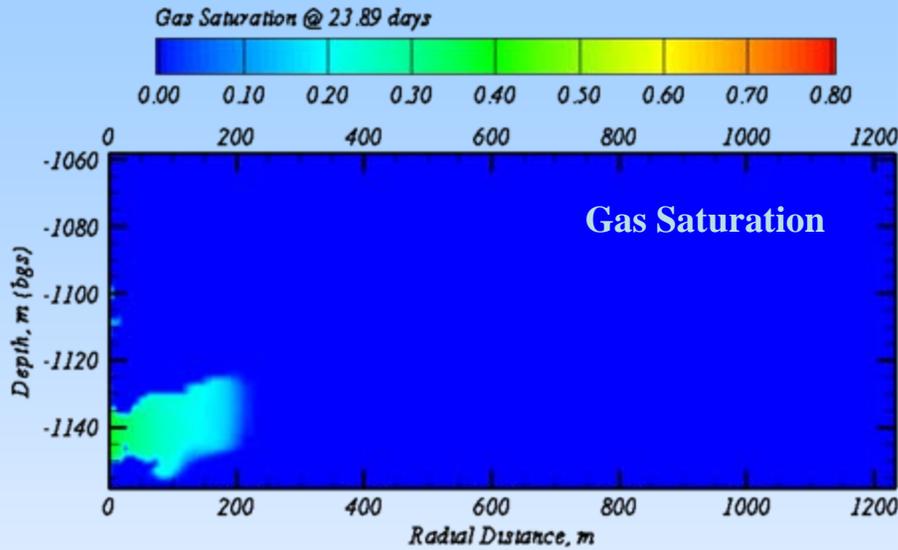
23.89 days

# Simulation Results

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No Chemistry

Chemistry



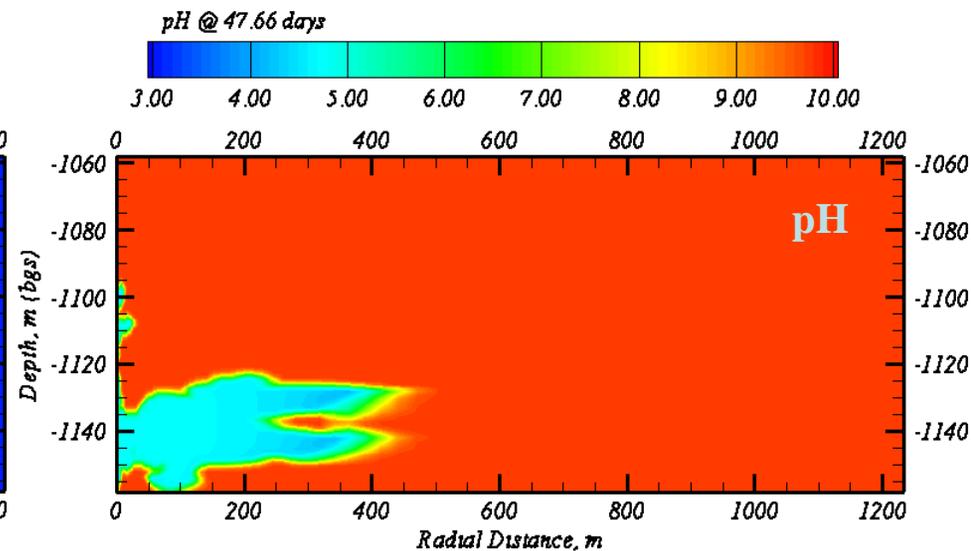
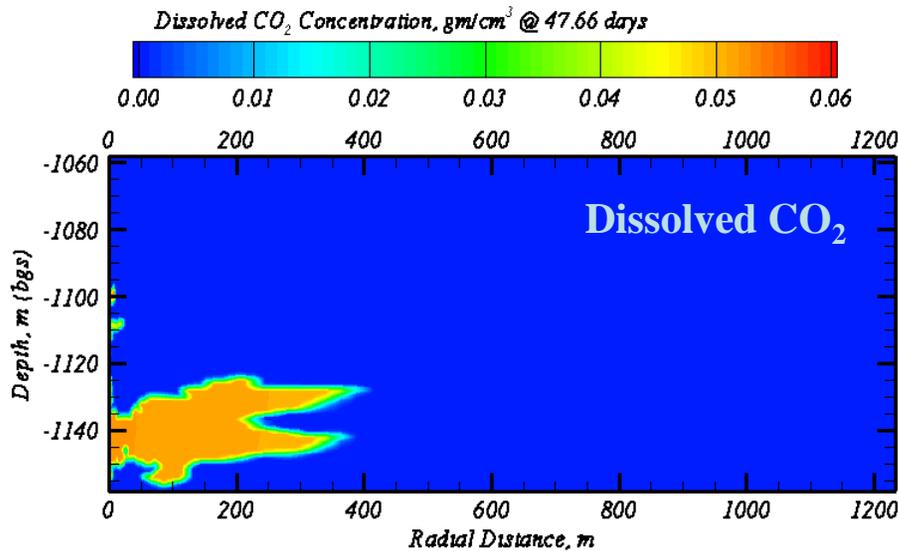
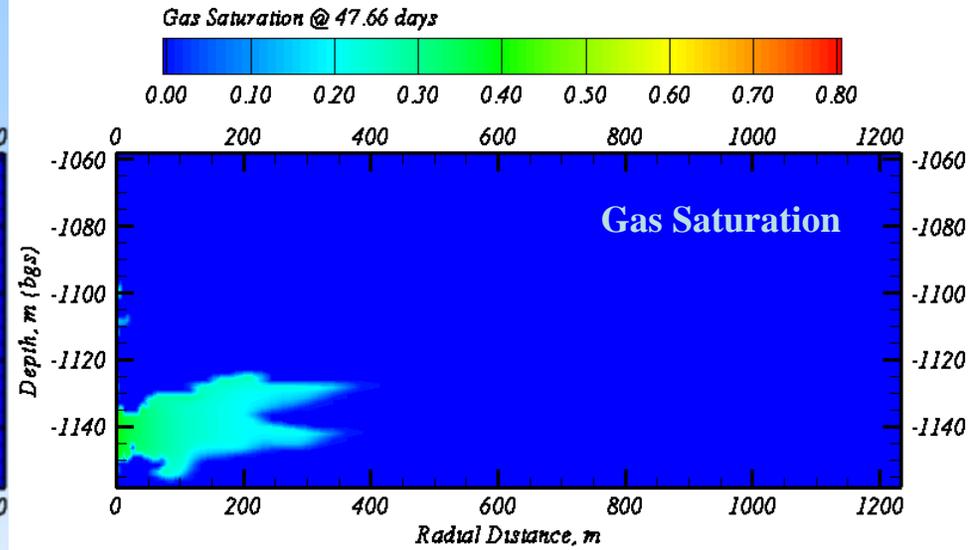
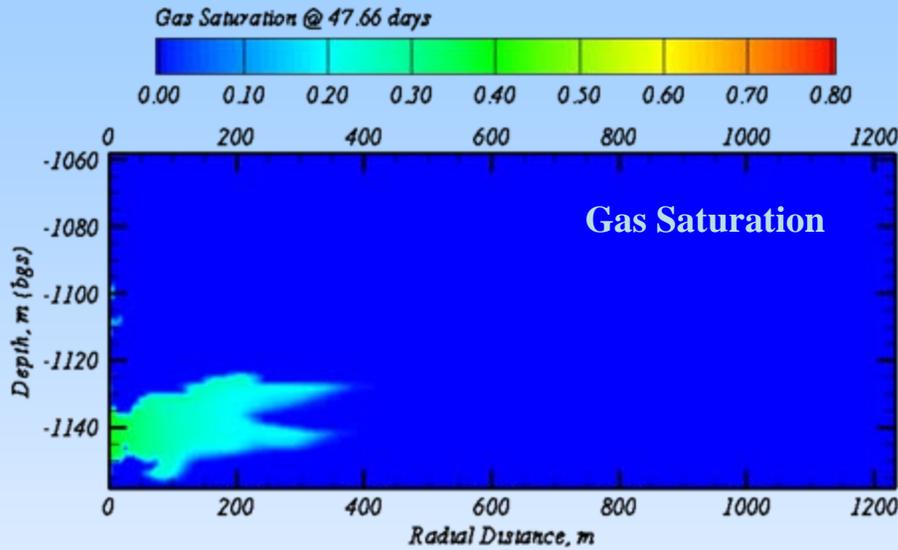
47.66 days

# Simulation Results

CMWRXXVI [246]

No Chemistry

Chemistry



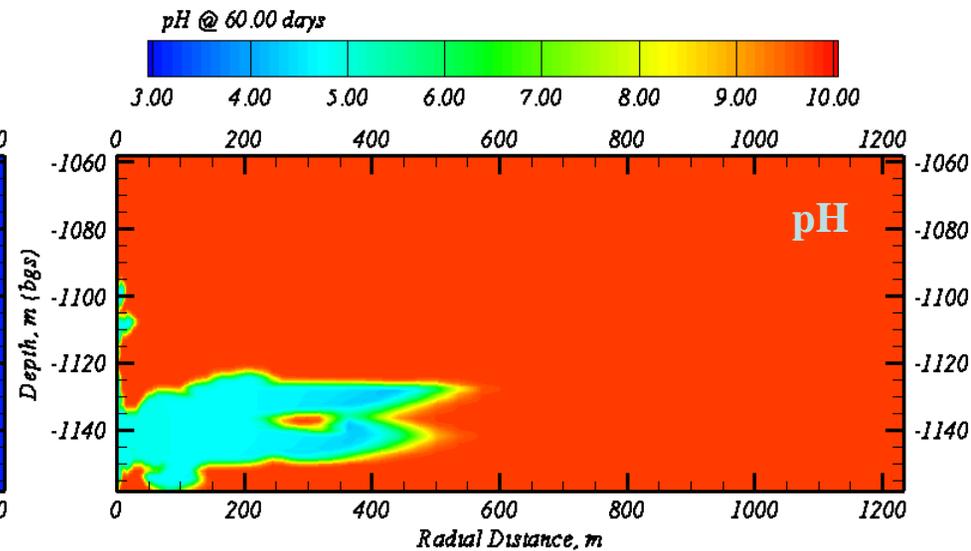
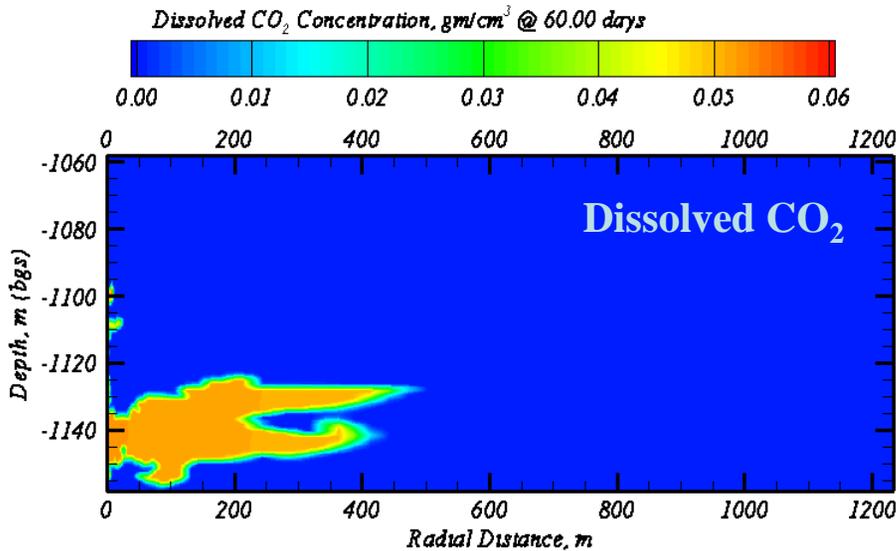
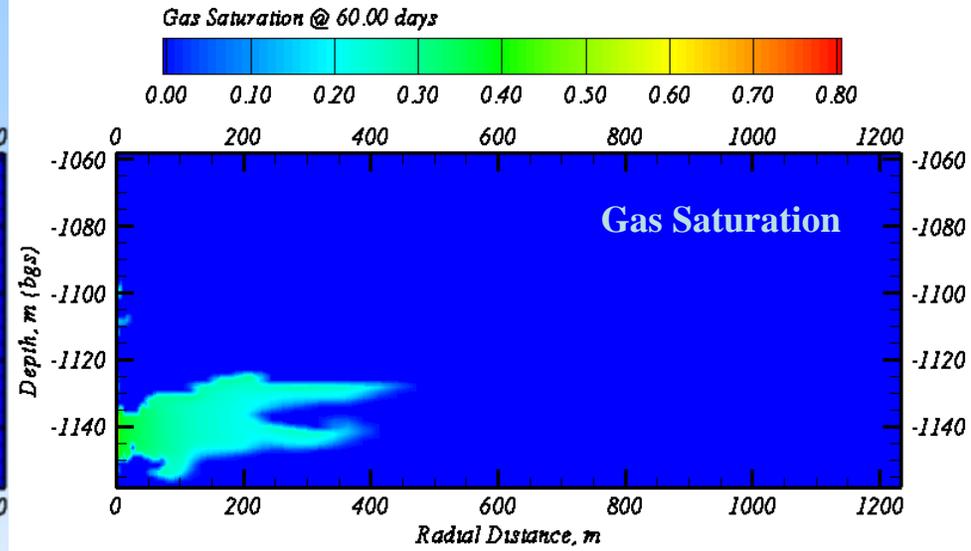
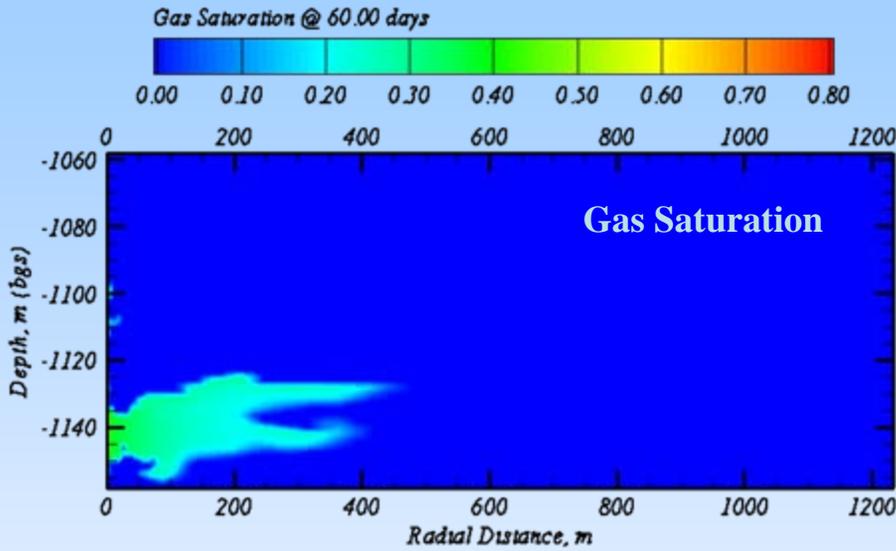
60.0 days

# Simulation Results

CMWRXXVI [246]

No Chemistry

Chemistry



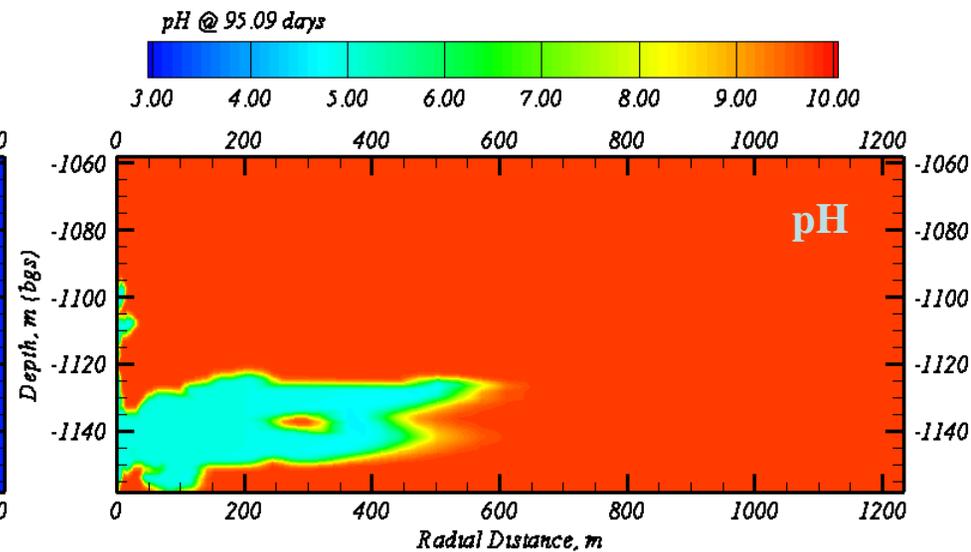
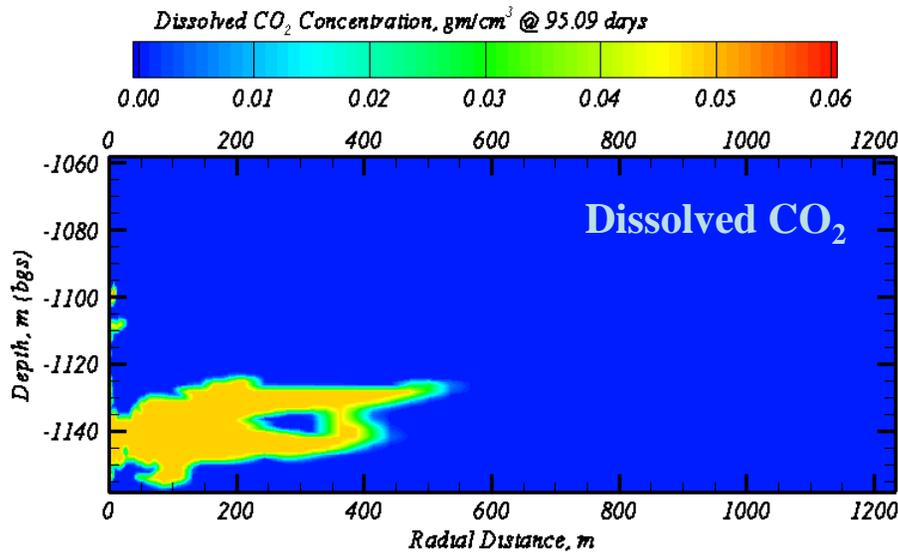
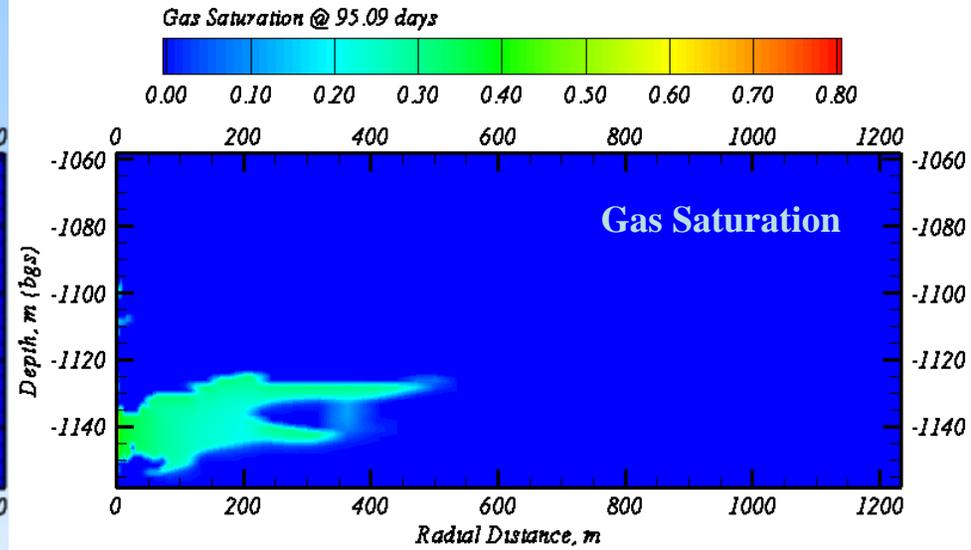
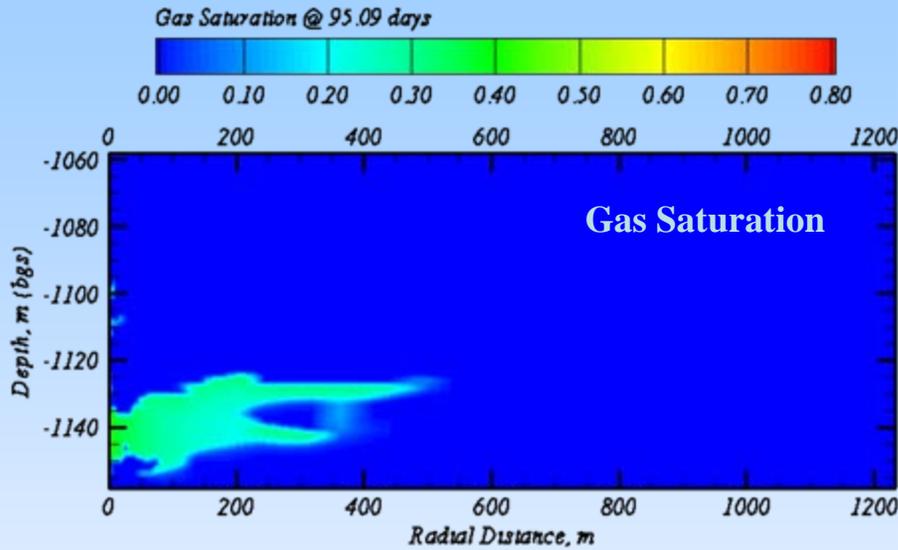
95.09 days

# Simulation Results

CMWRXXVI [246]

No Chemistry

Chemistry



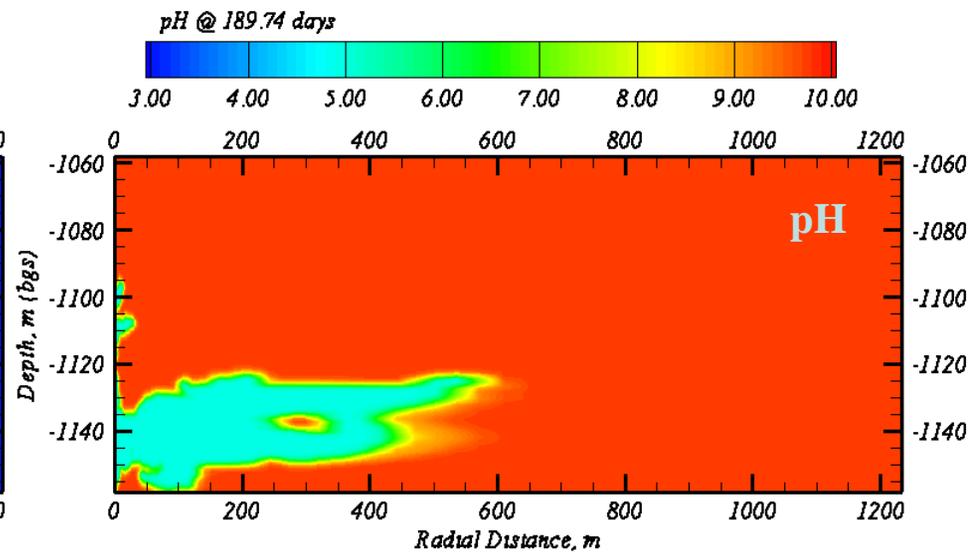
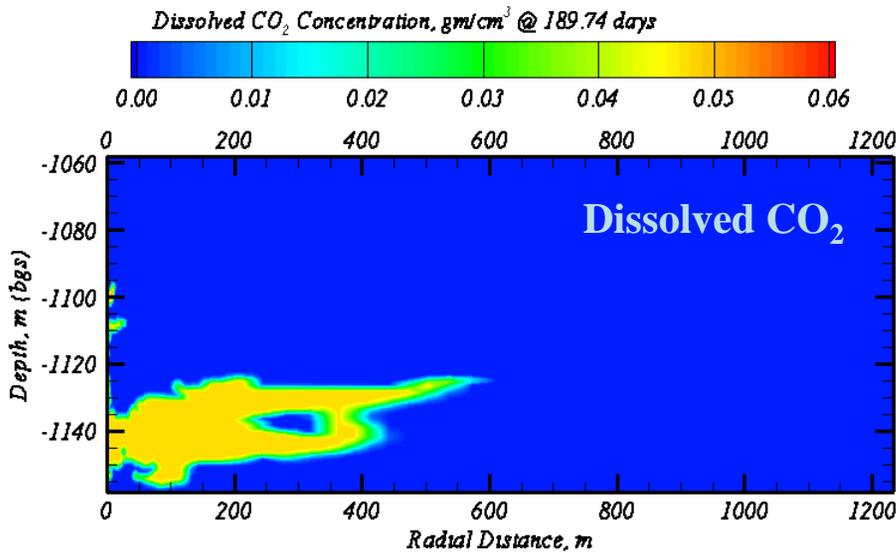
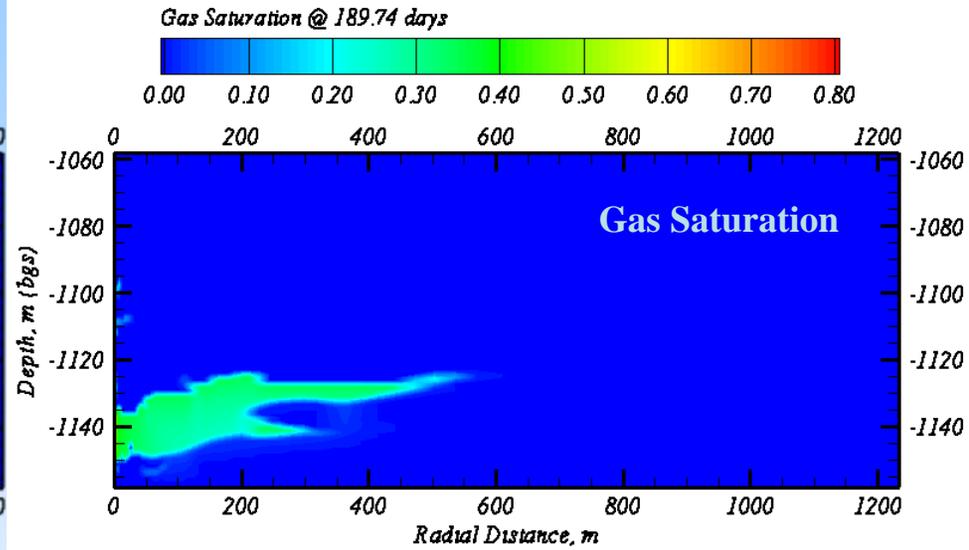
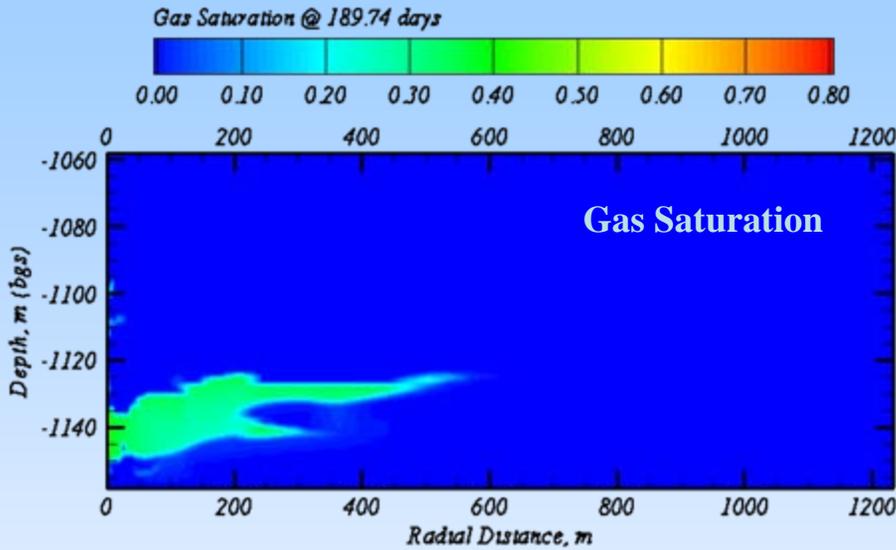
189.7 days

# Simulation Results

CMWRXXVI [246]

No Chemistry

Chemistry



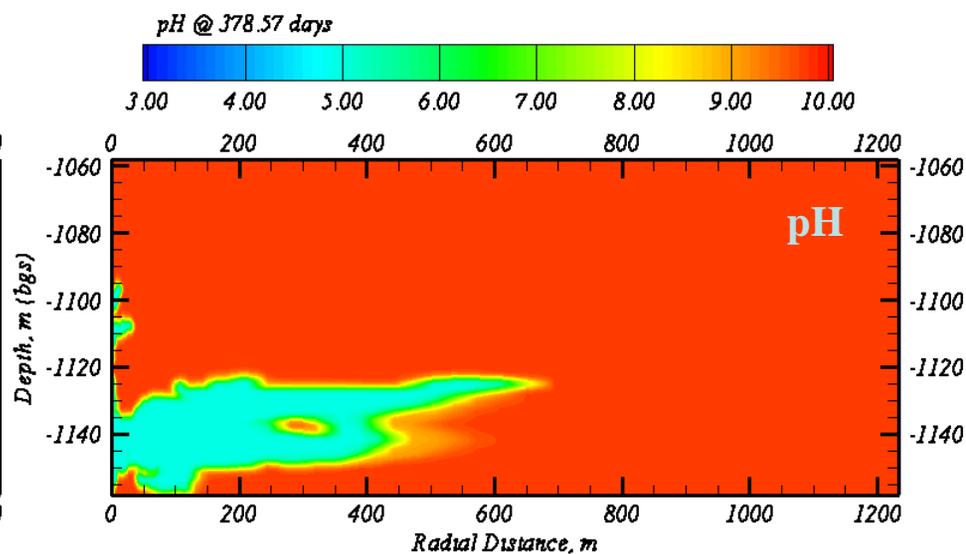
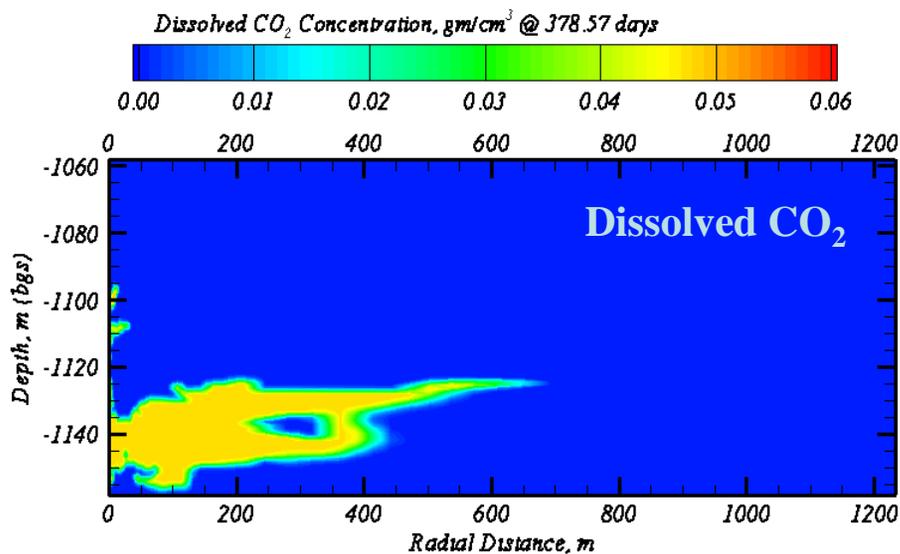
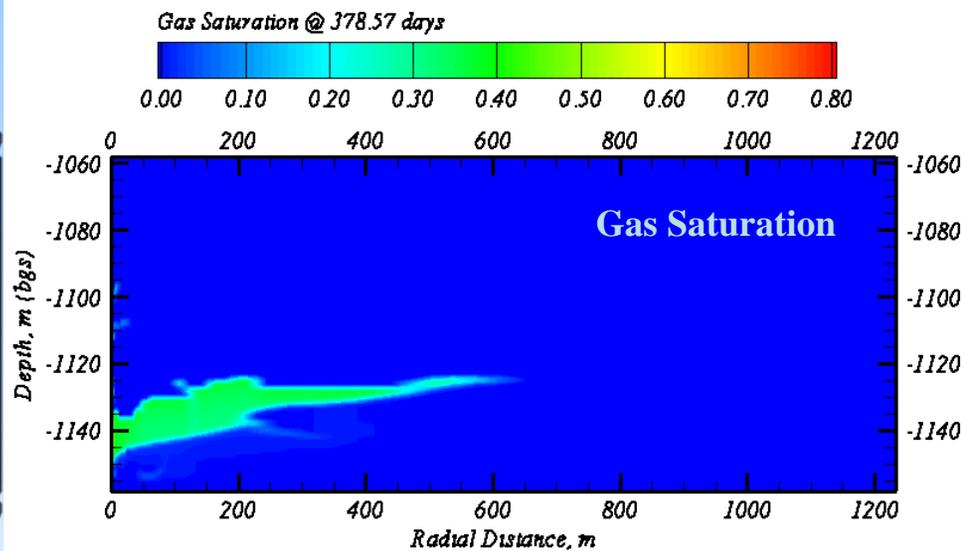
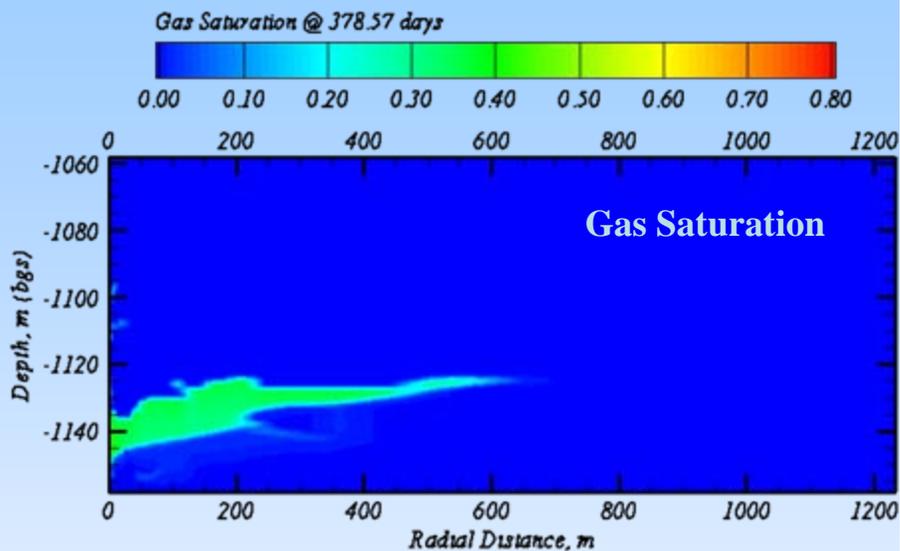
378.6 days

# Simulation Results

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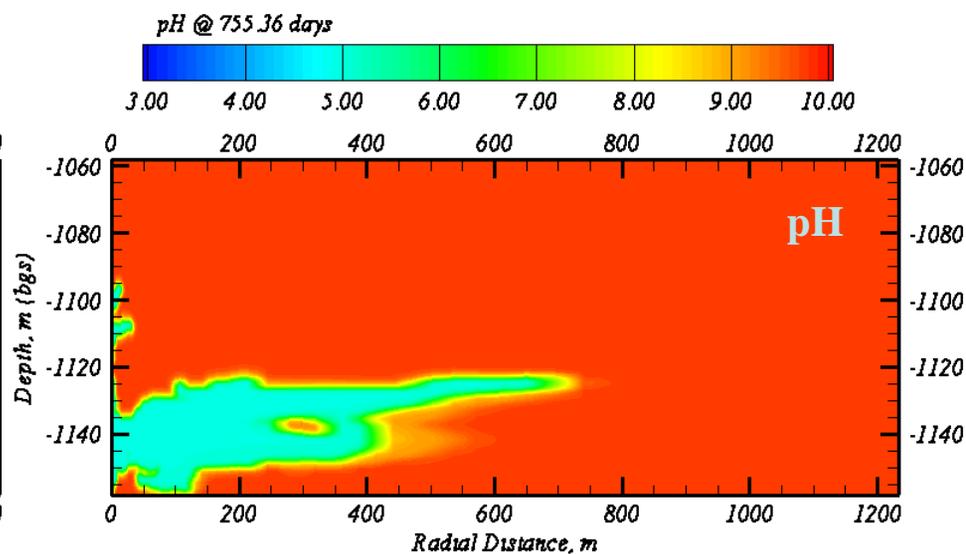
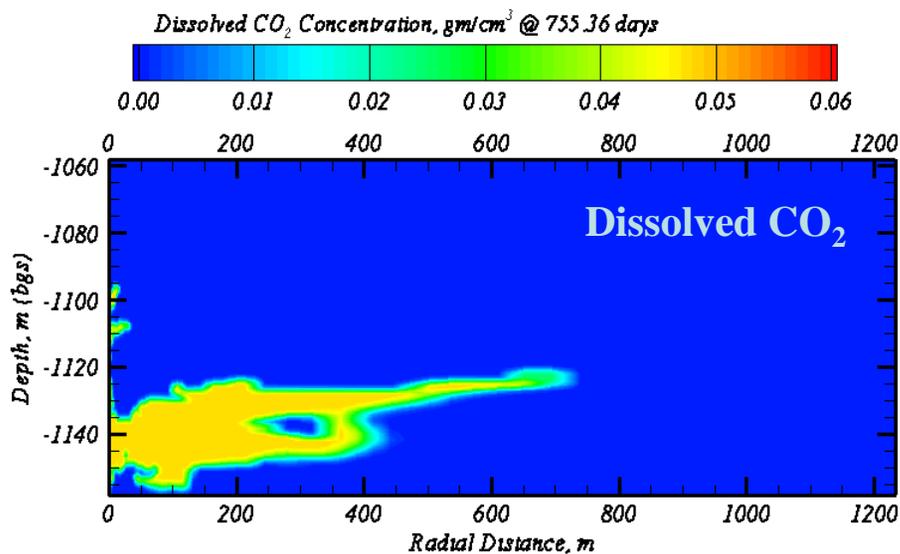
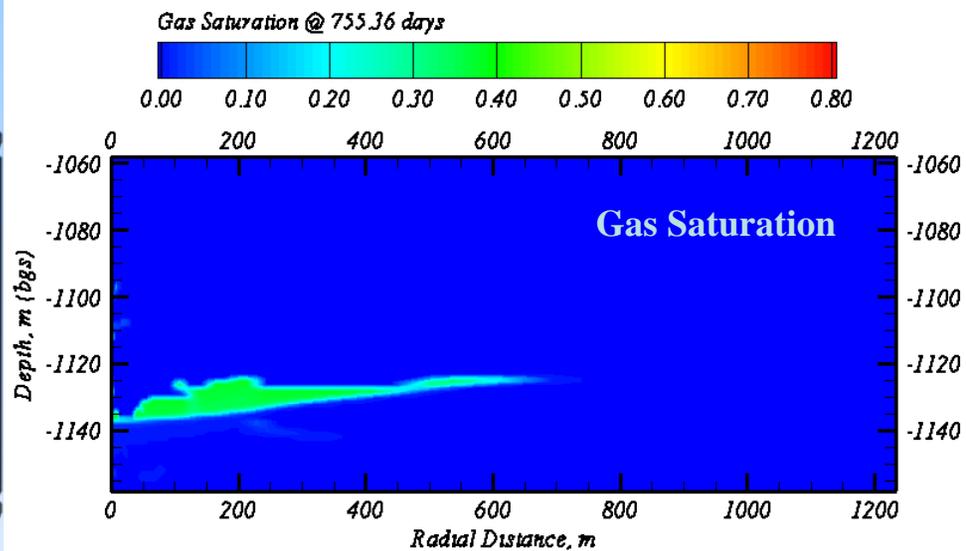
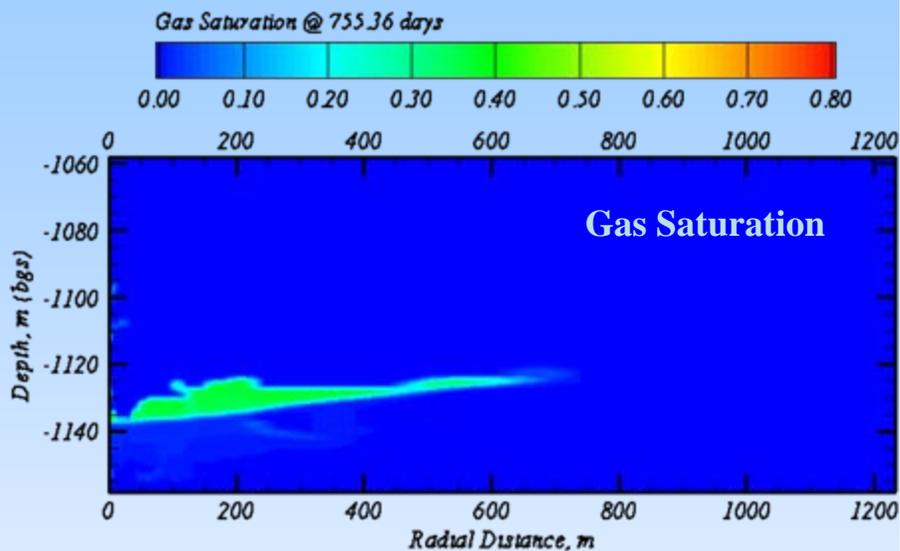
No Chemistry

Chemistry



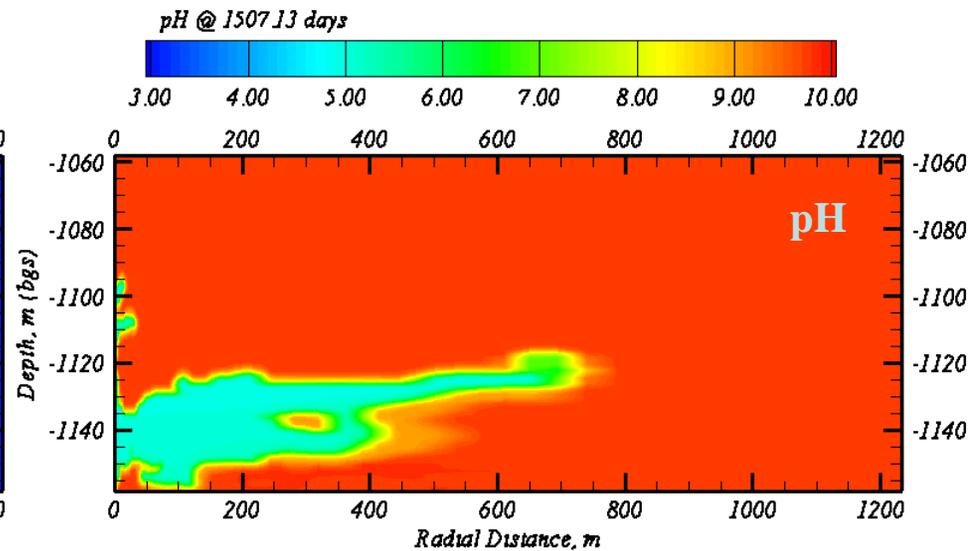
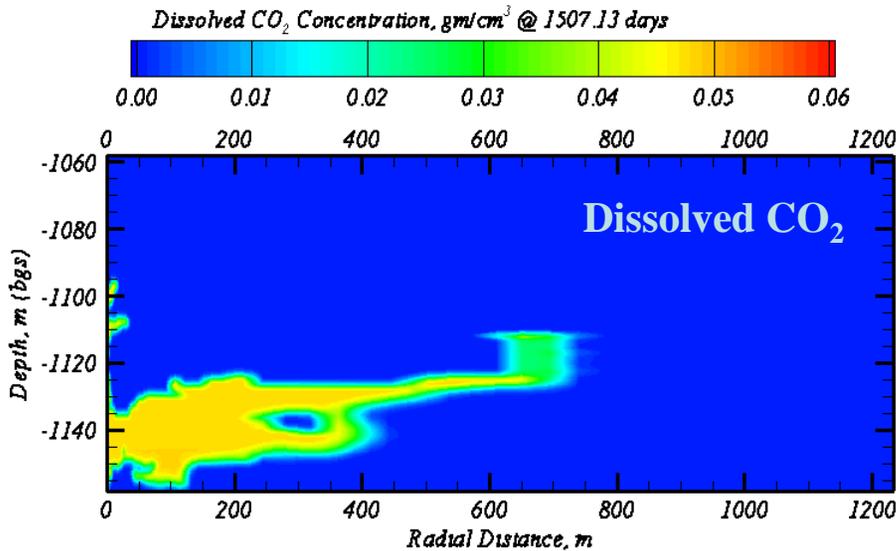
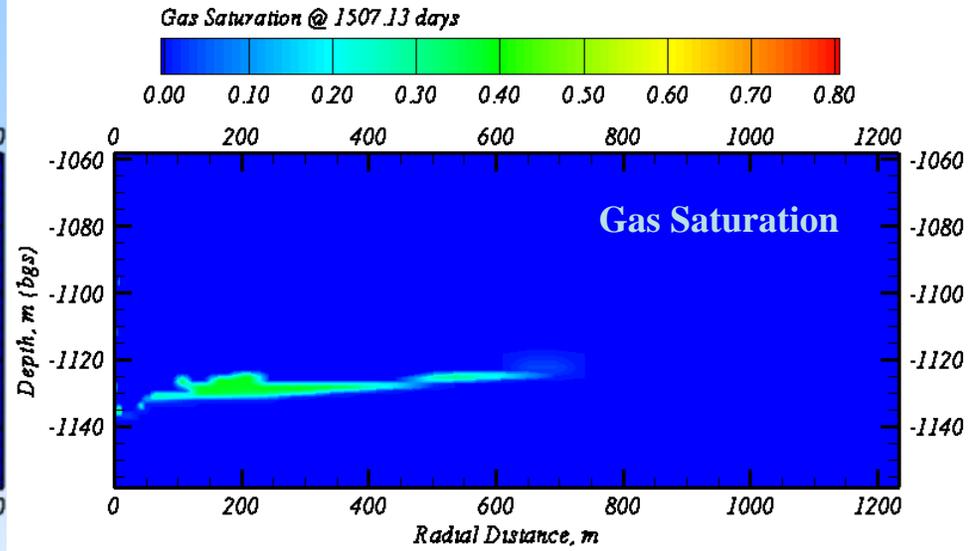
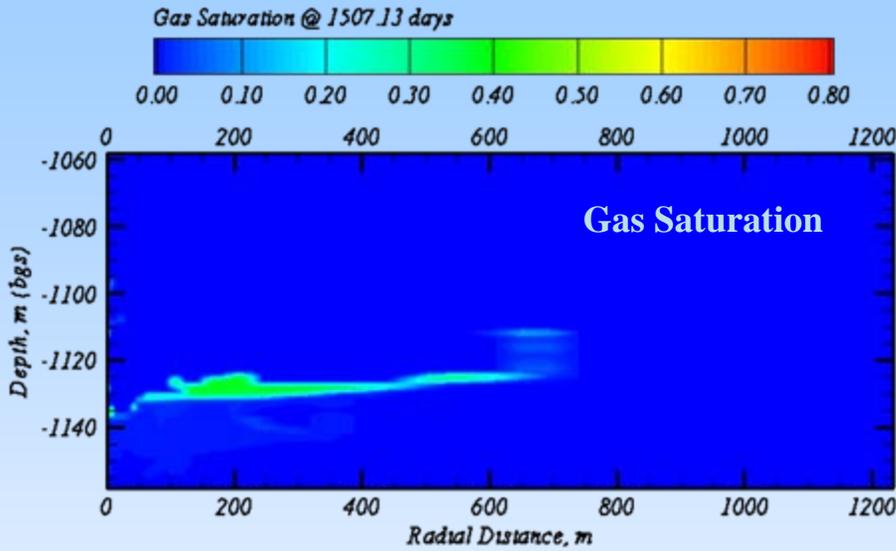
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Chemistry



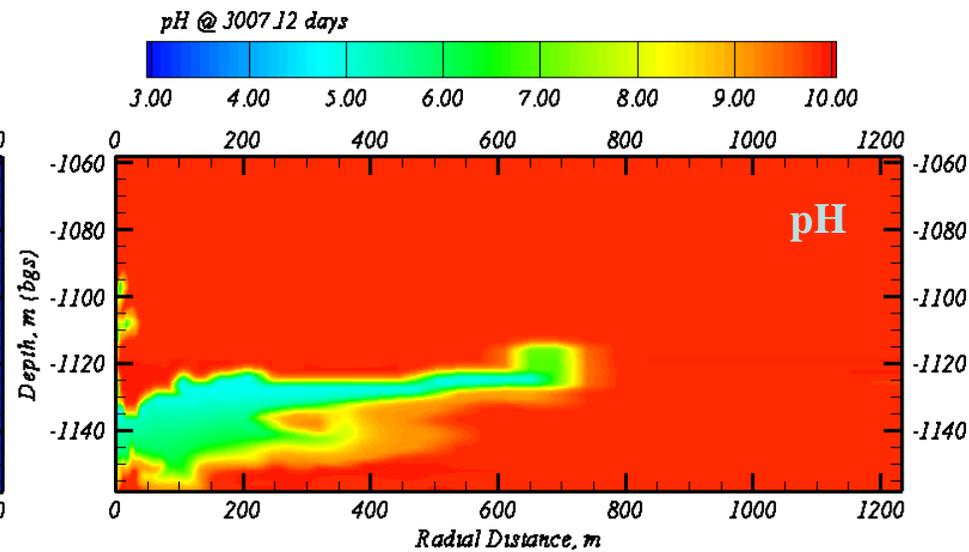
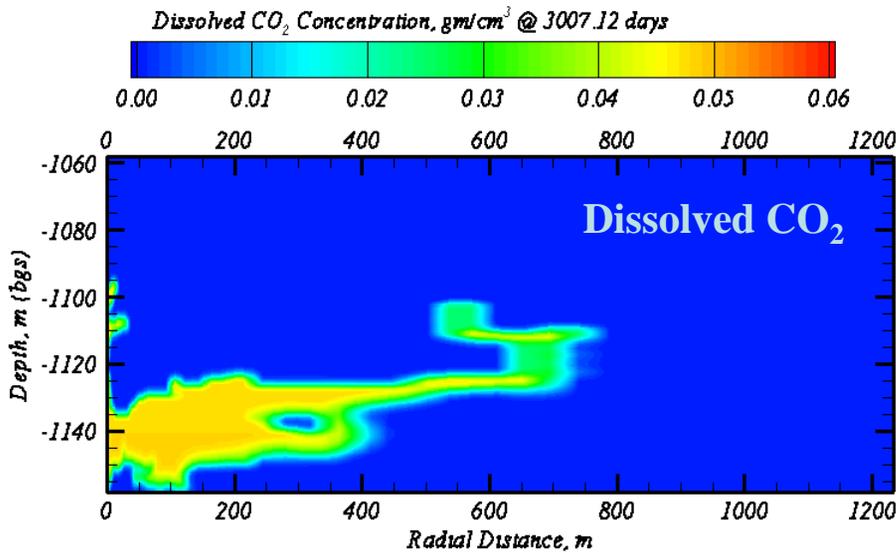
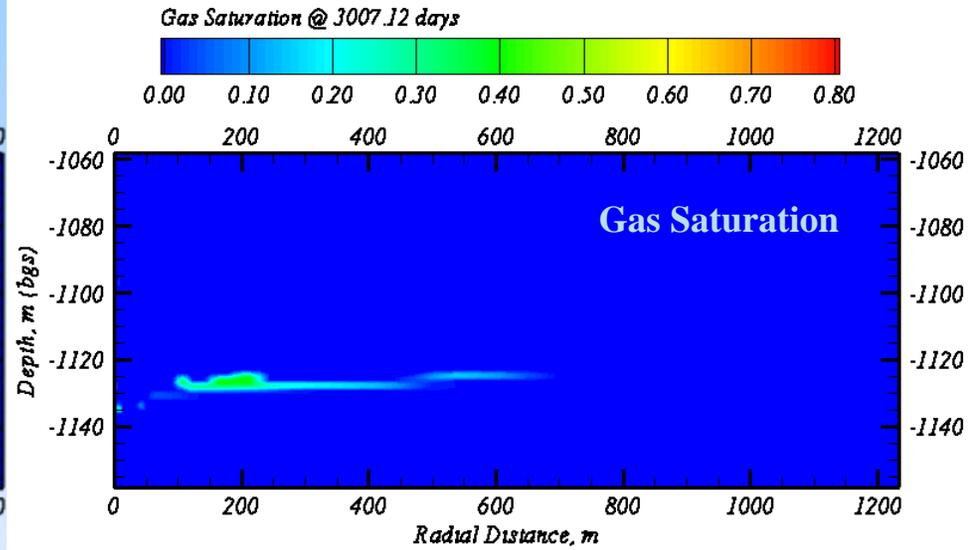
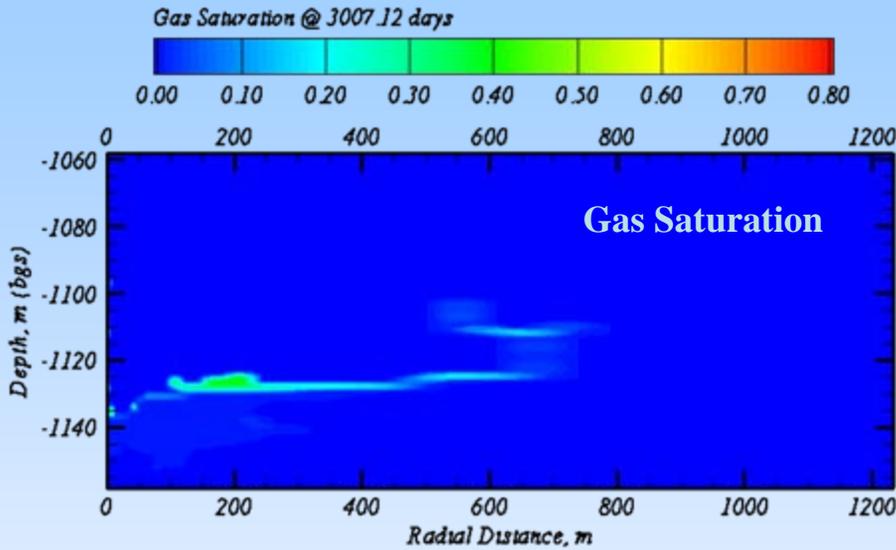
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Chemistry



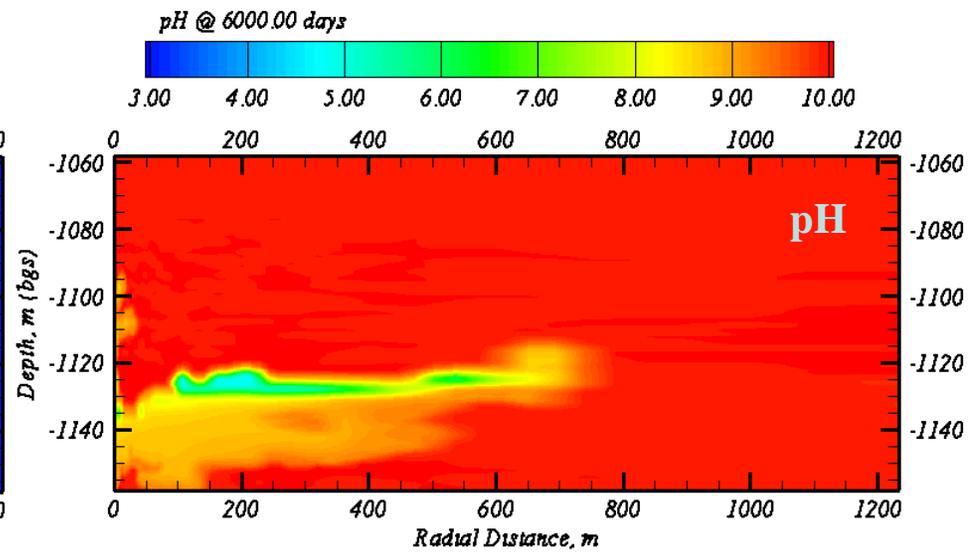
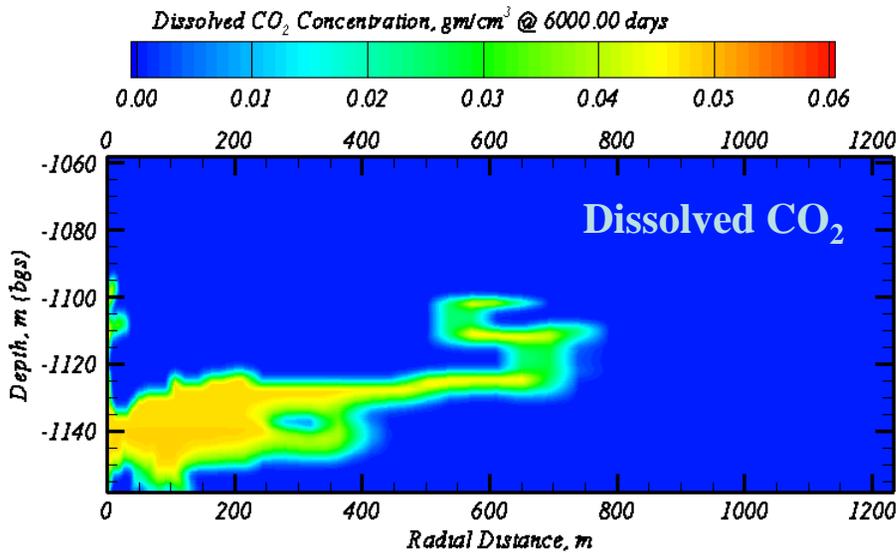
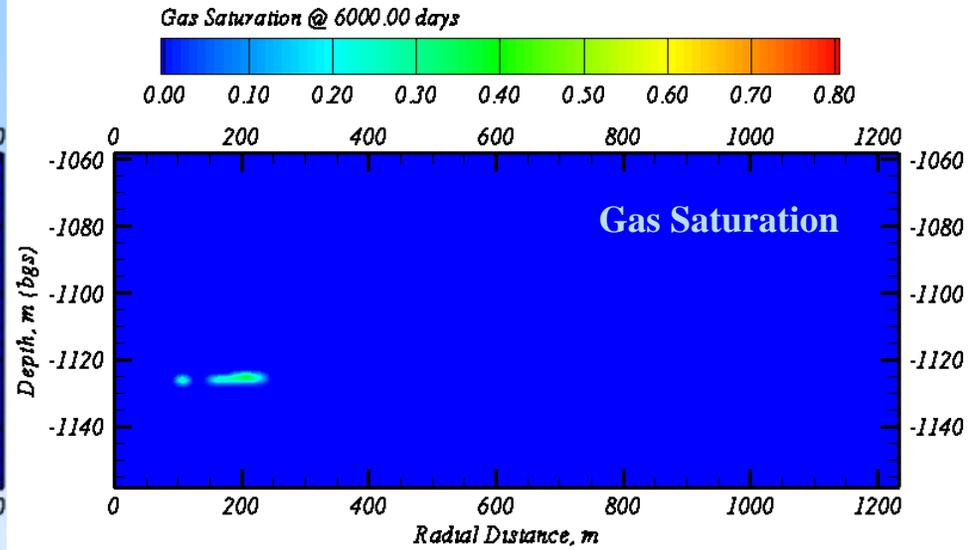
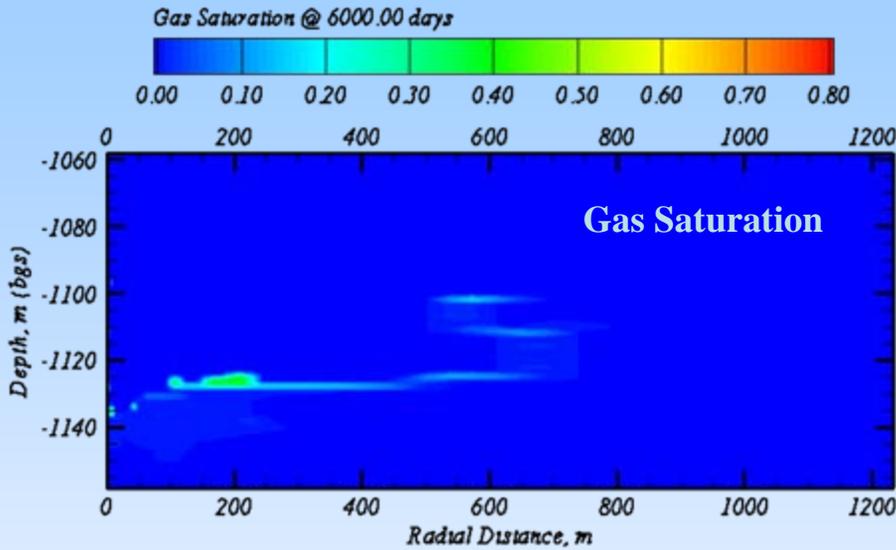
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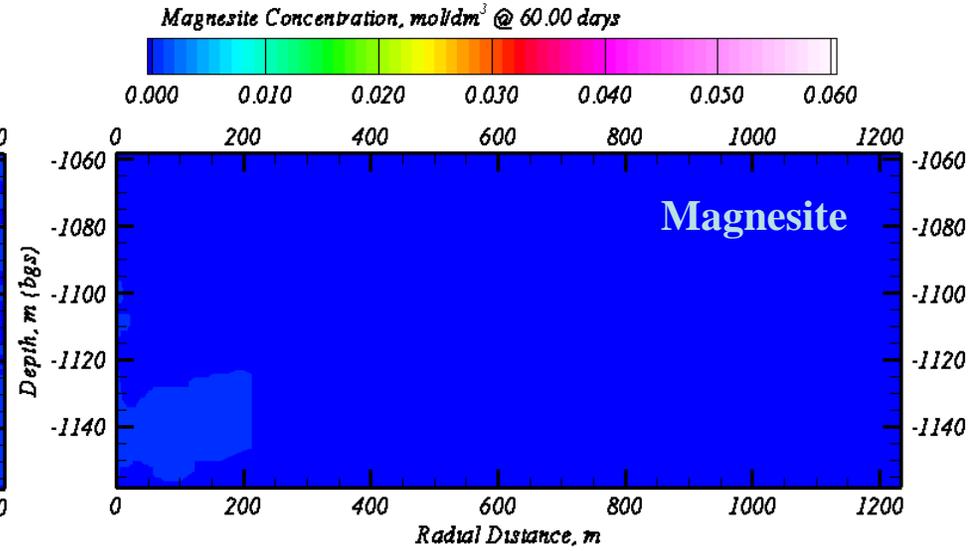
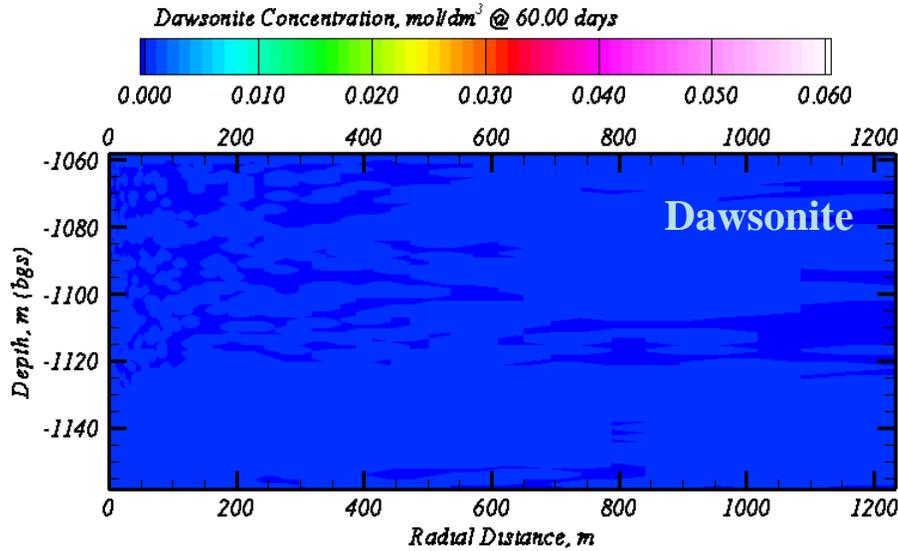
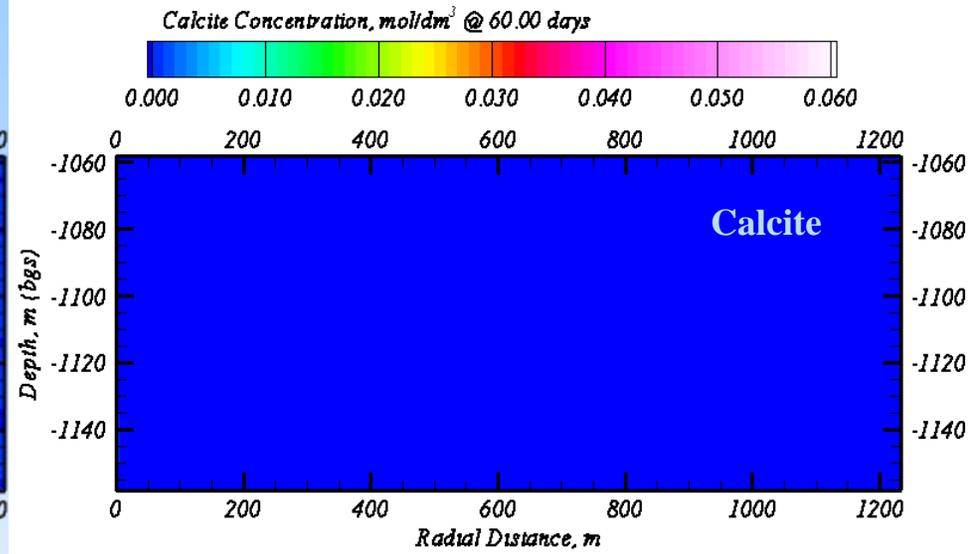
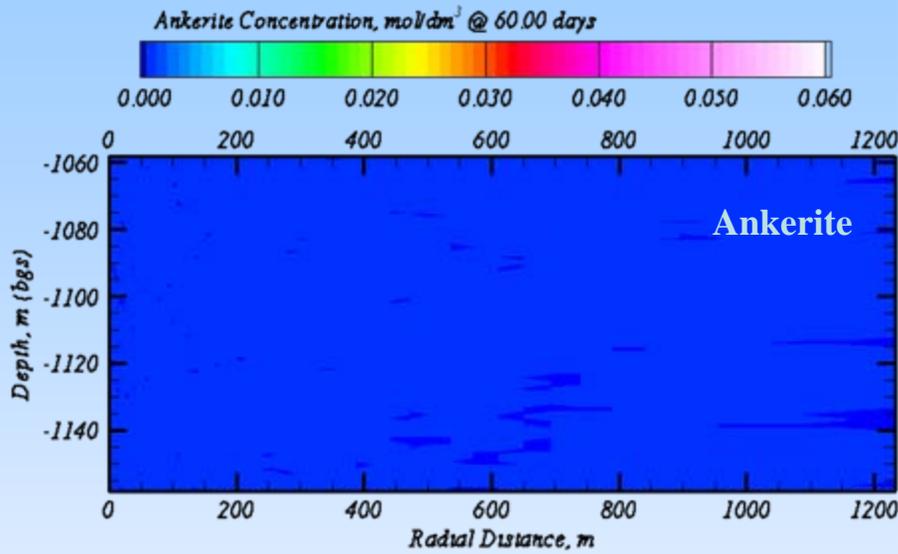
Chemistry

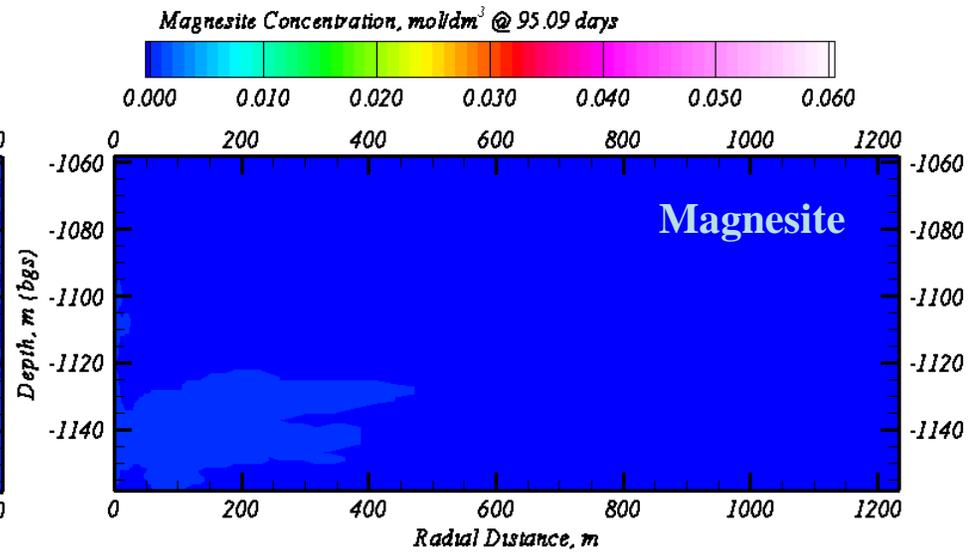
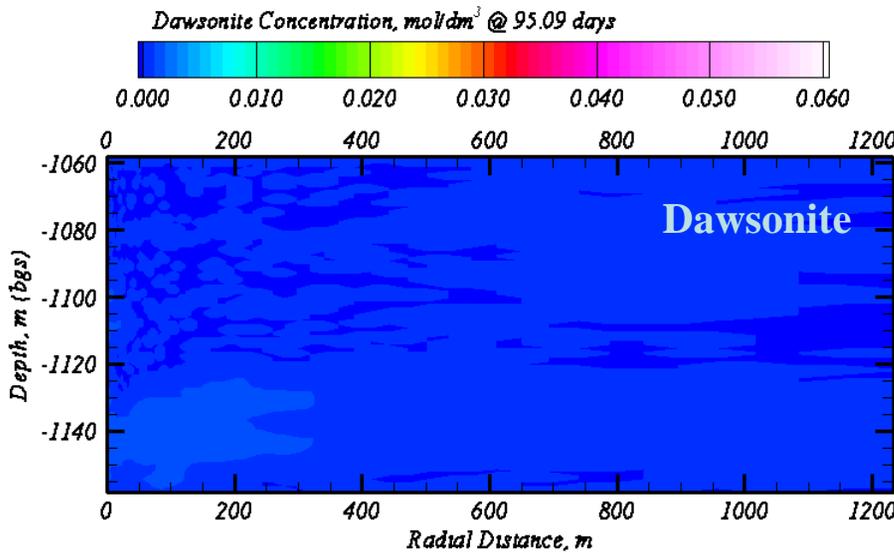
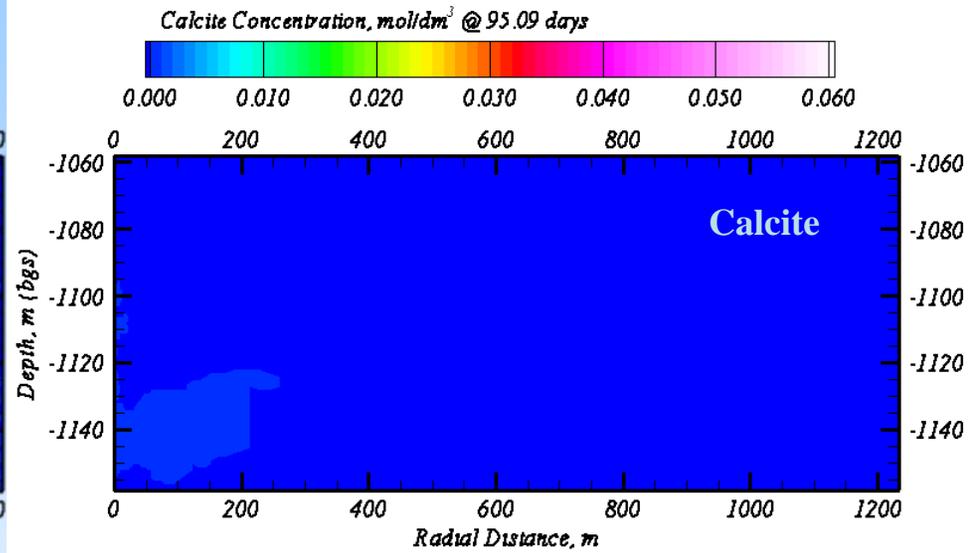
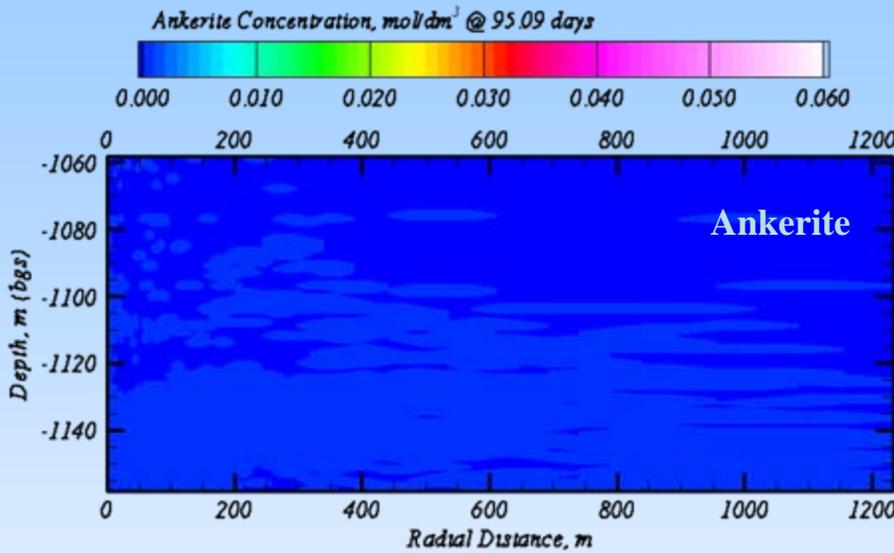


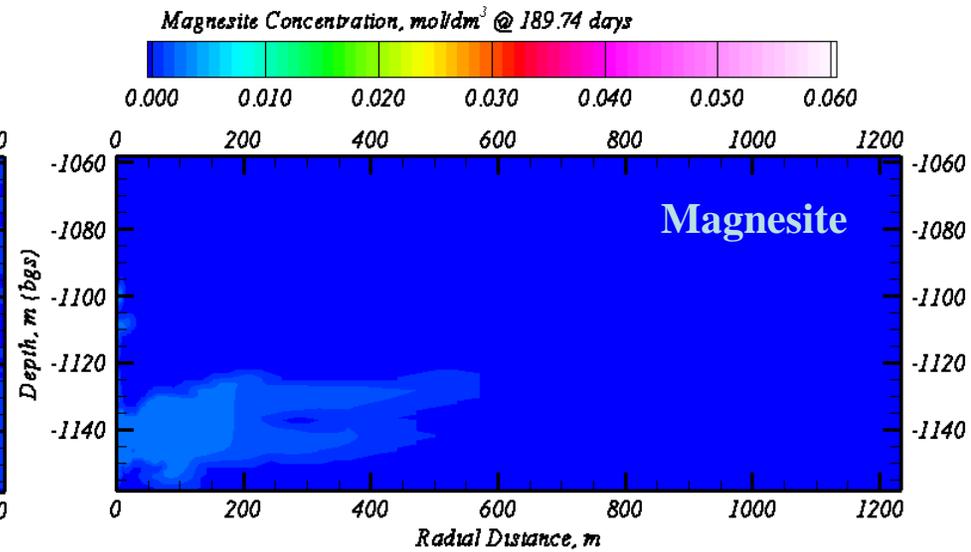
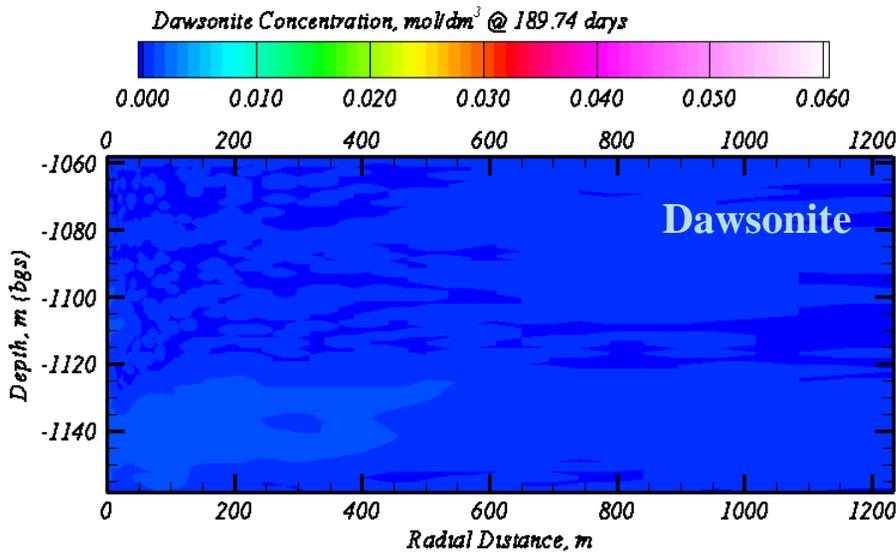
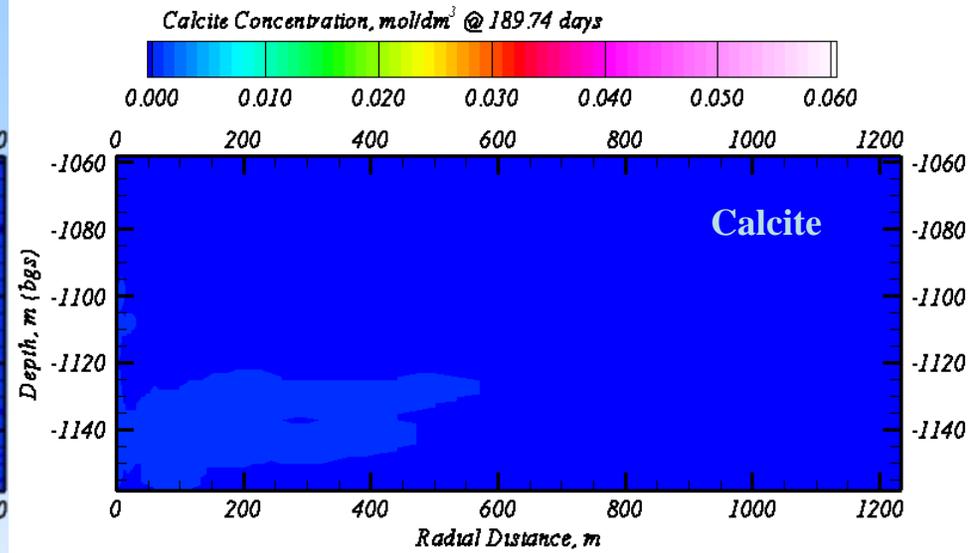
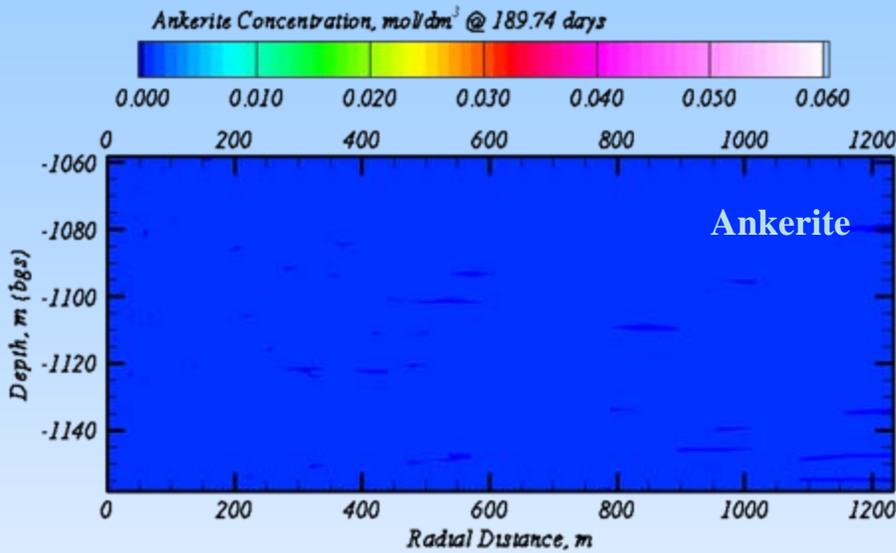
No Chemistry

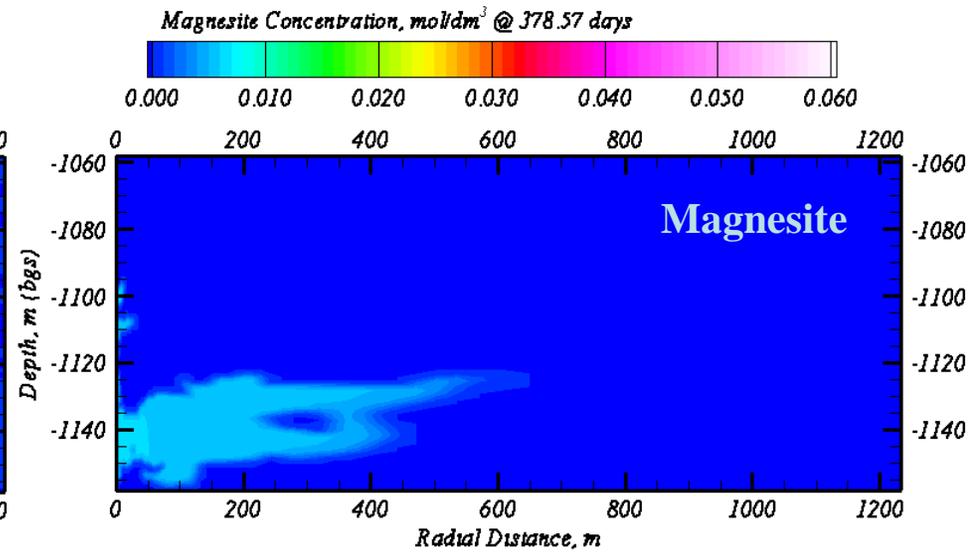
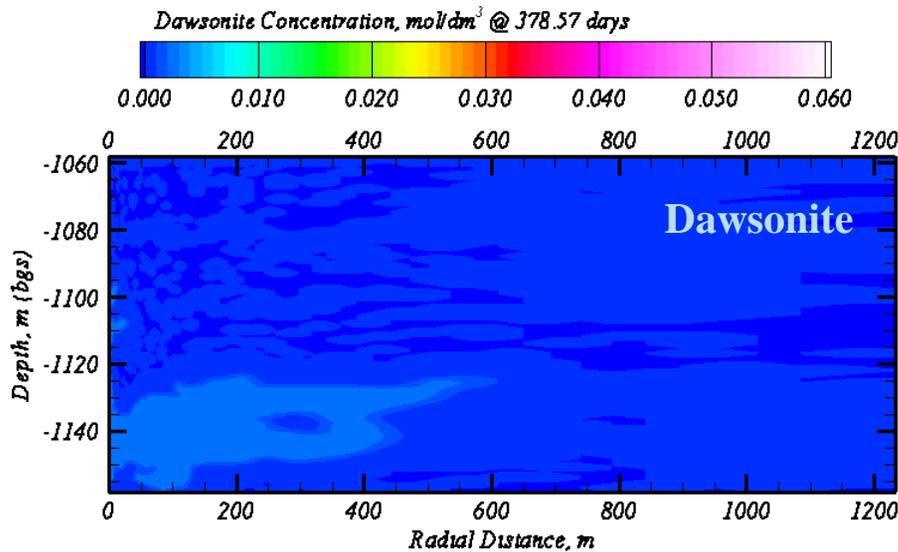
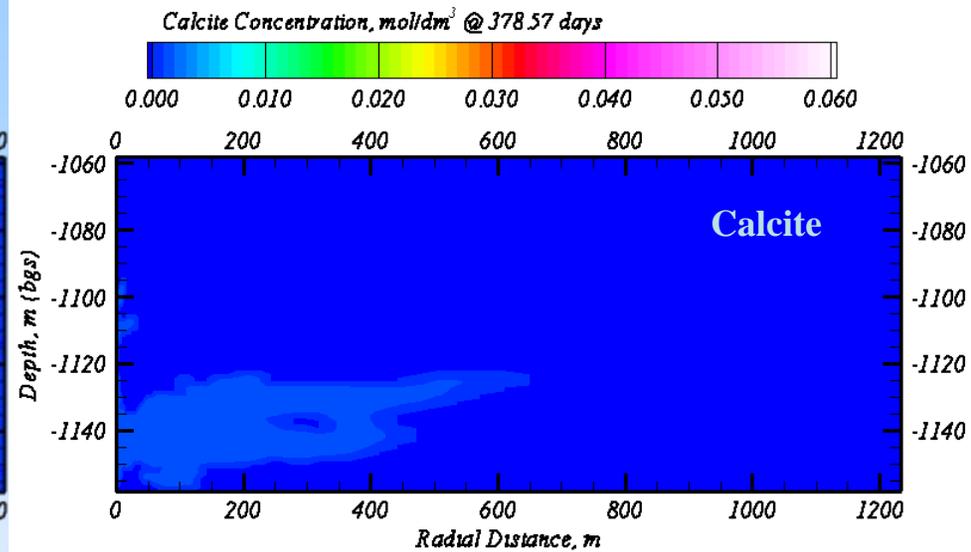
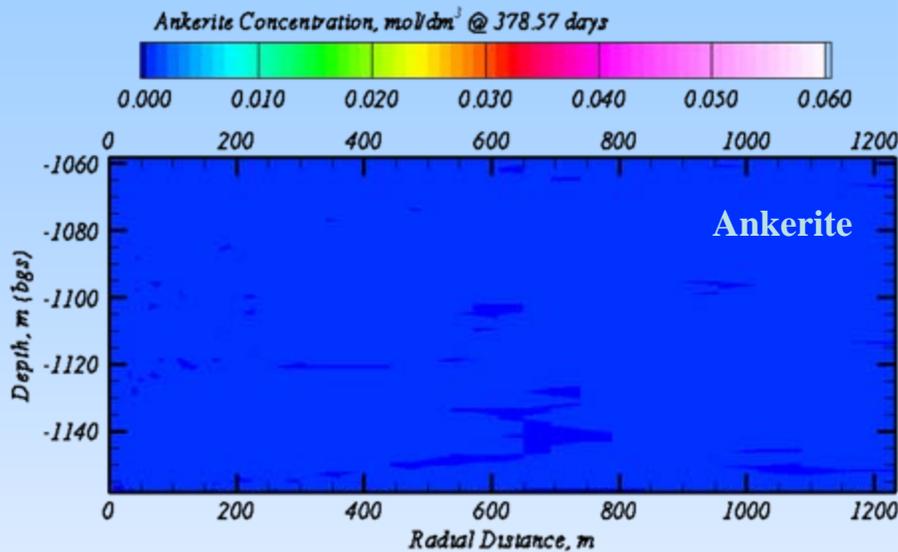
Chemistry

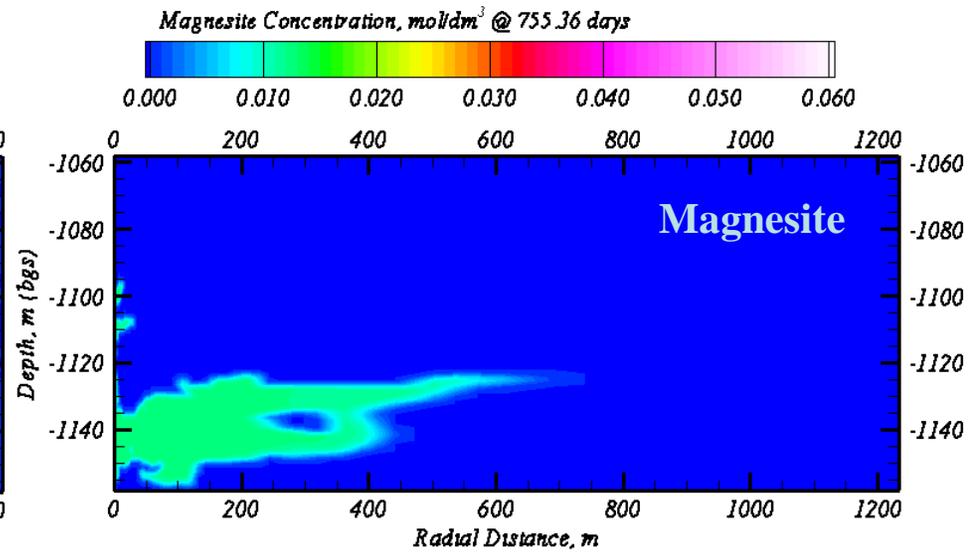
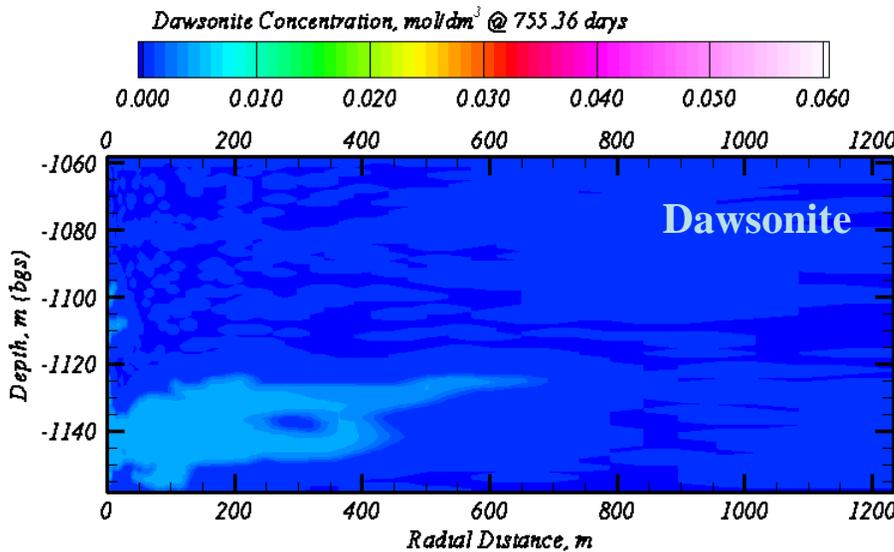
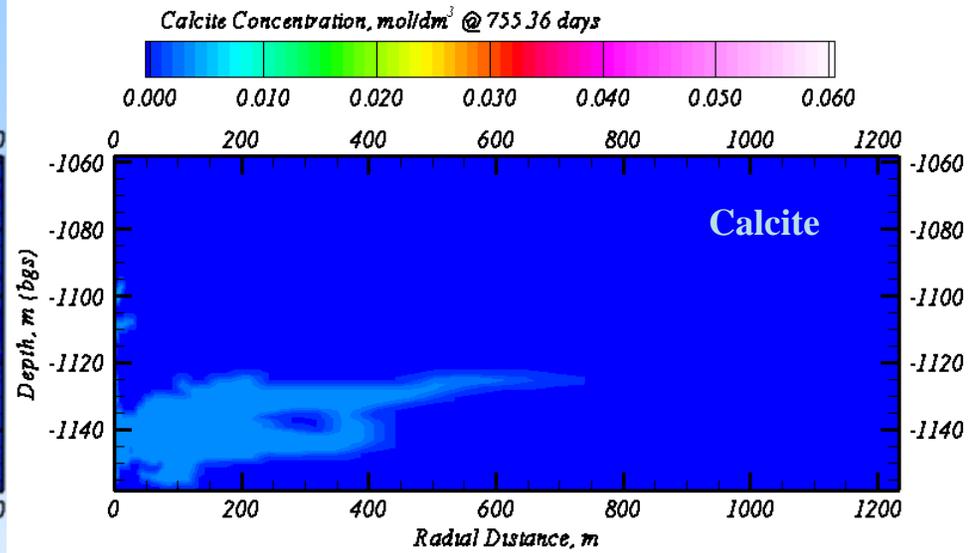
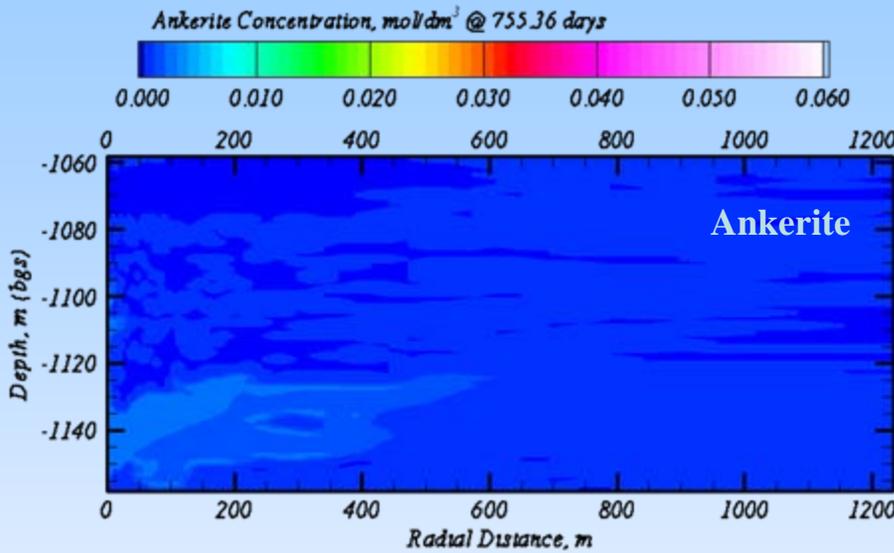


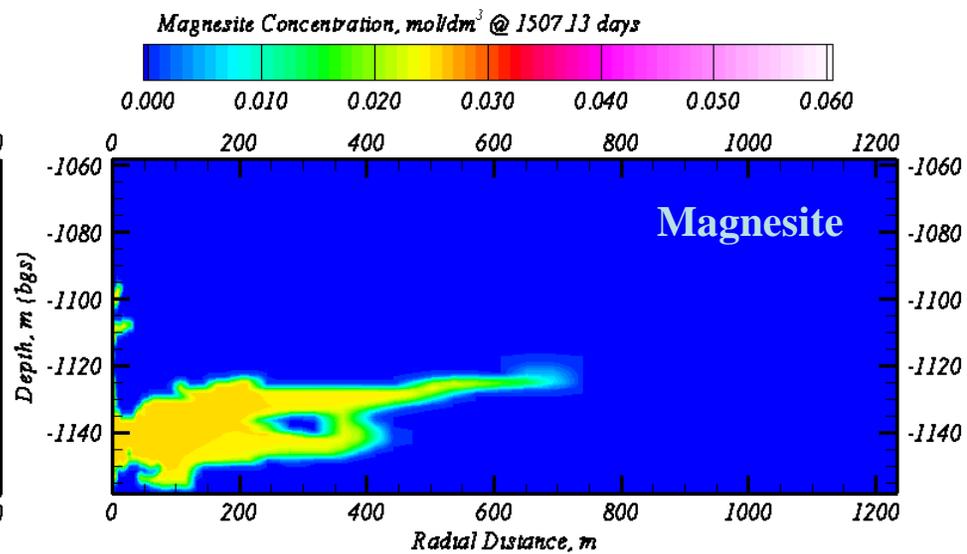
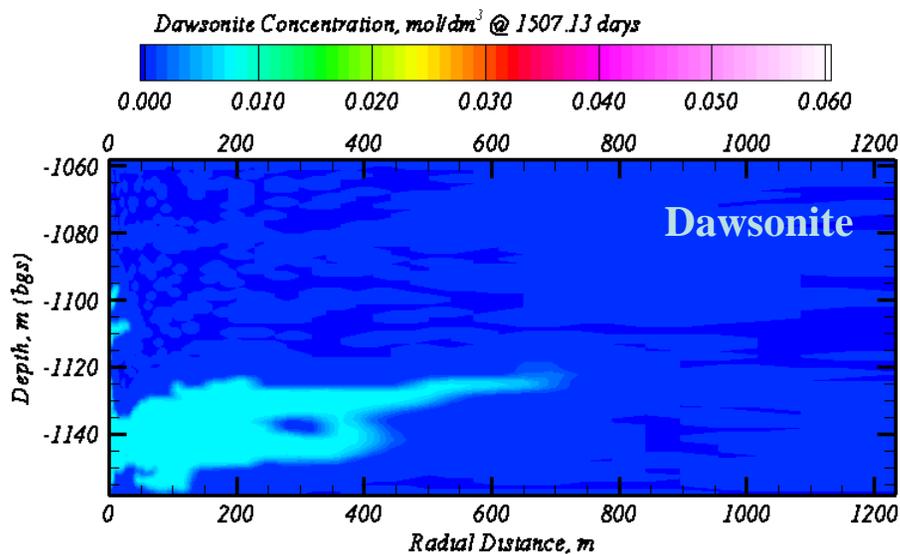
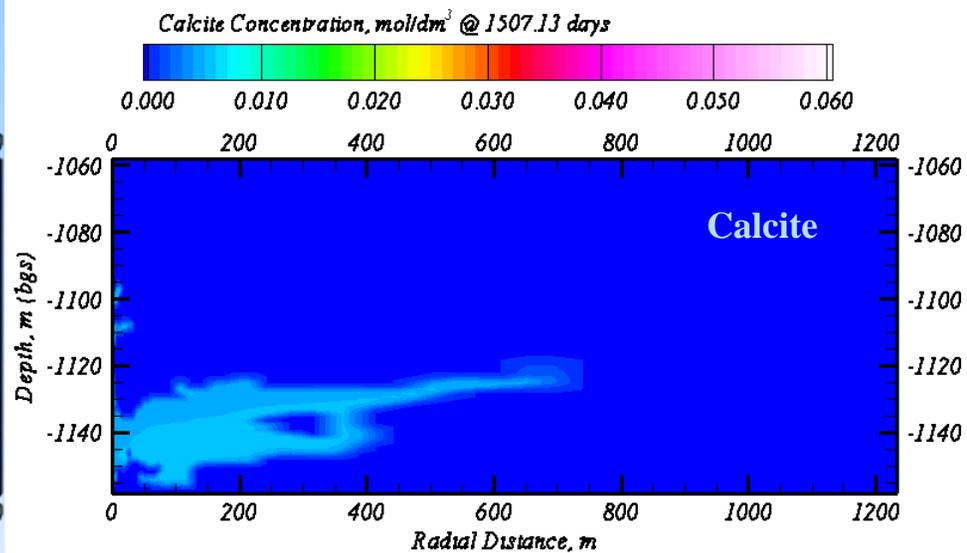
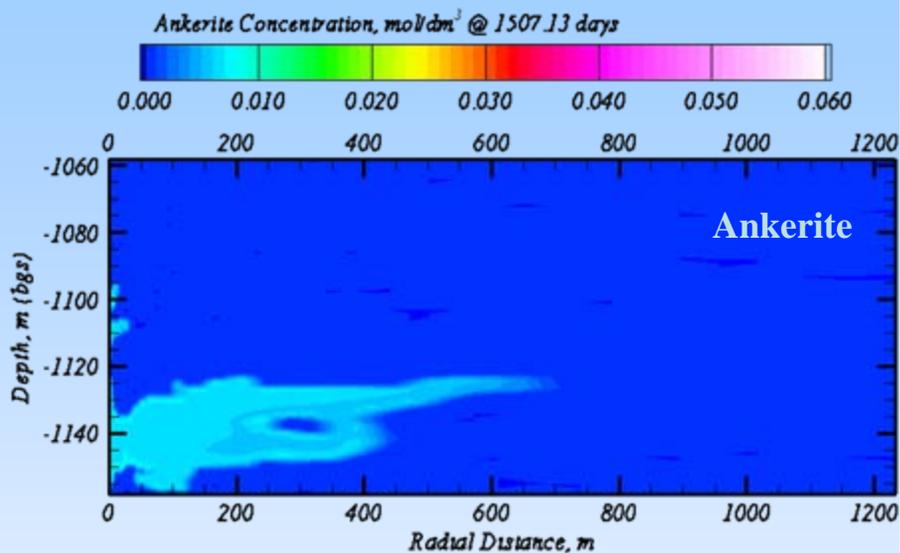


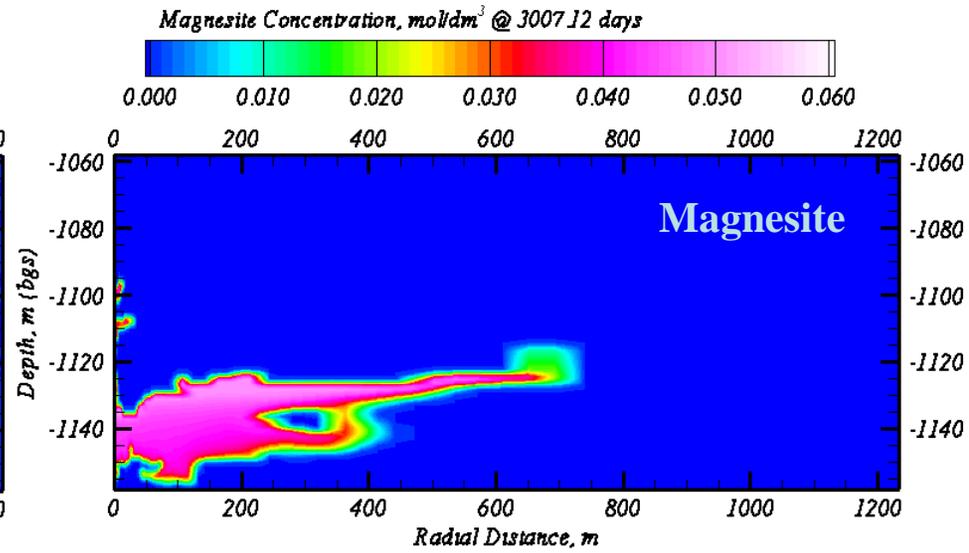
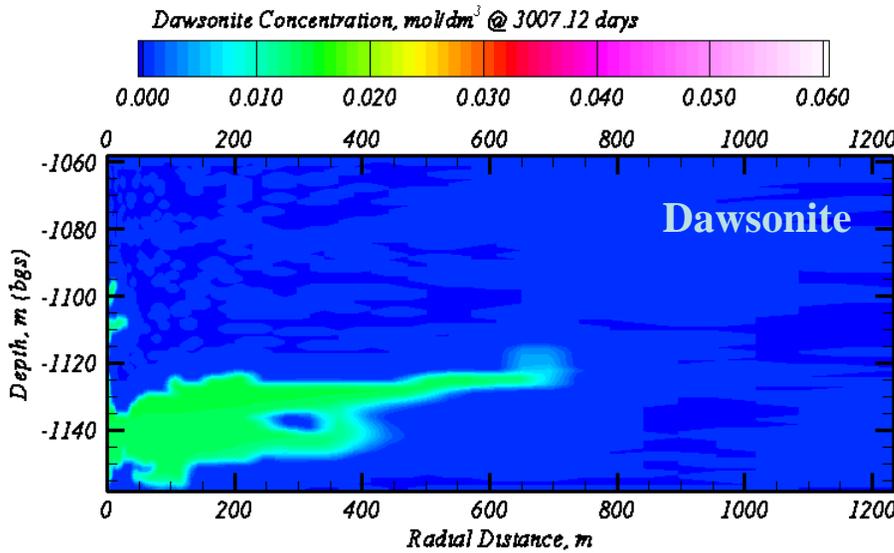
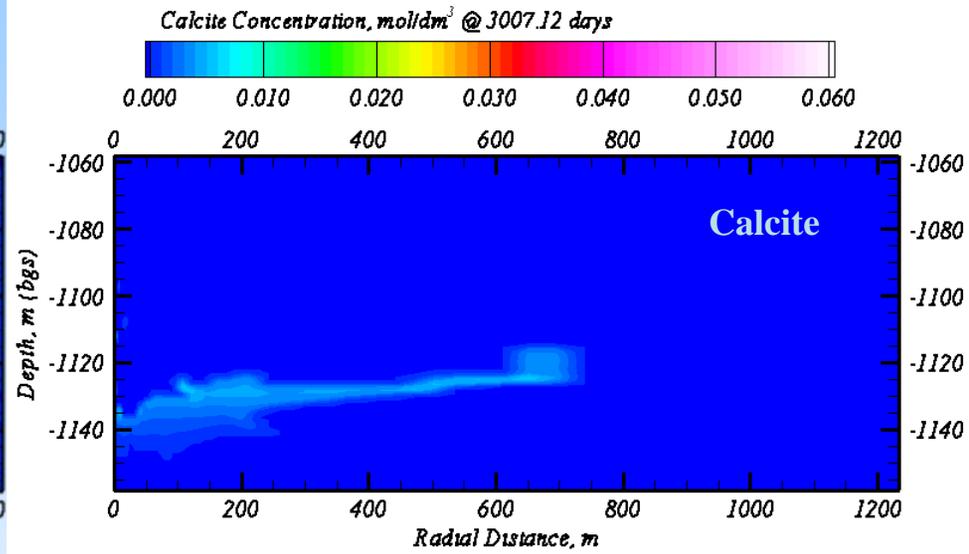
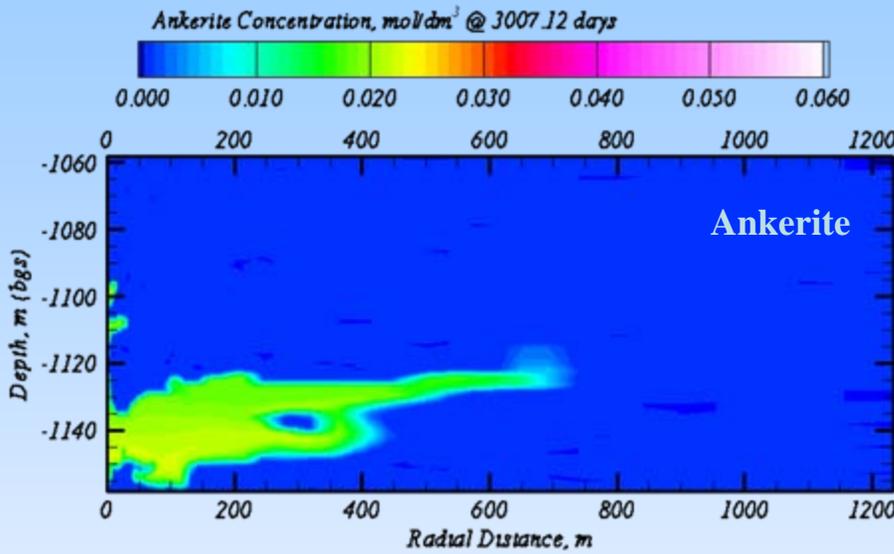




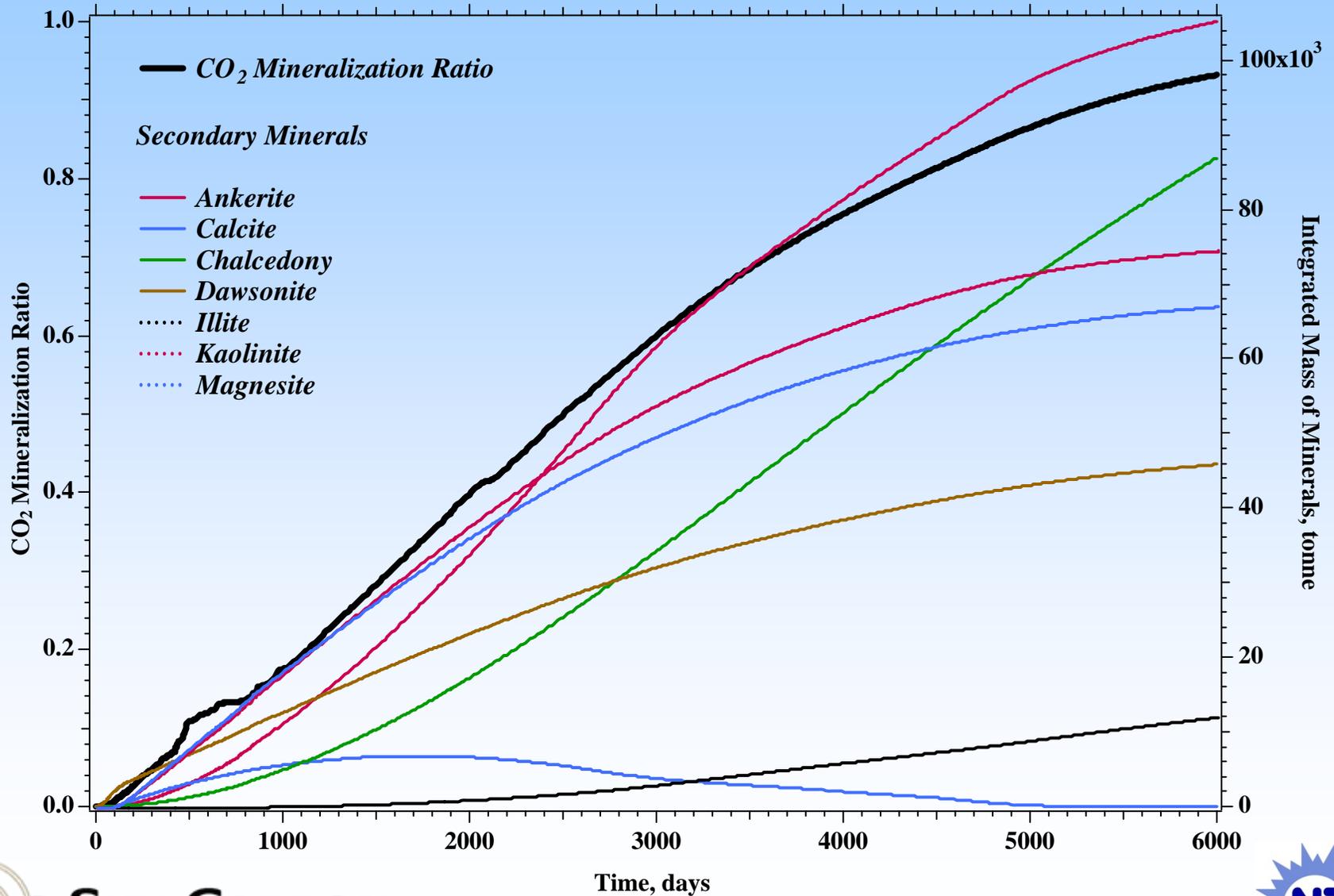




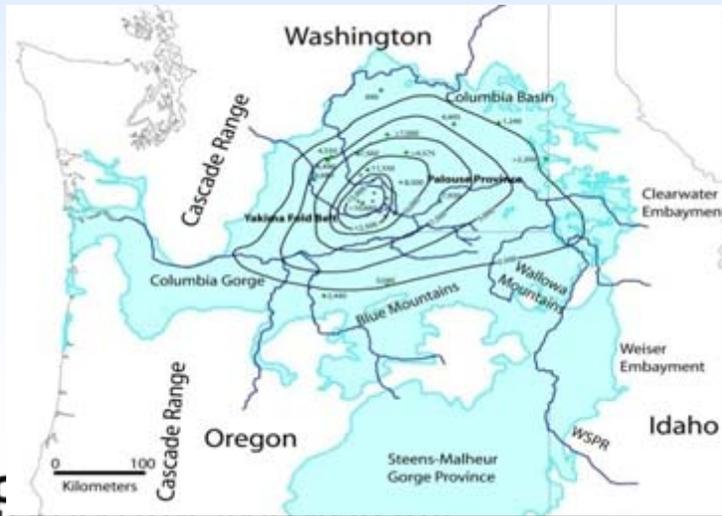




# Simulation Results: Mineralization



# Field Site Location/Characteristics

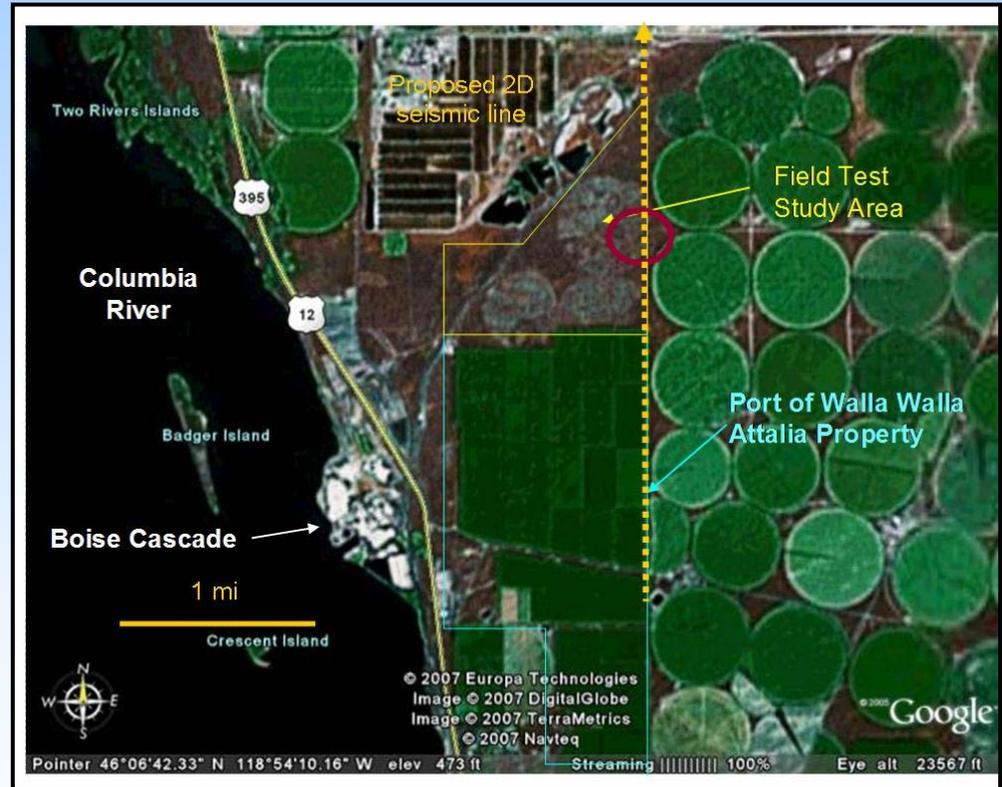


# Basalt Pilot Project Summary

- Pre-Injection Site Characterization
  - Seismic survey
  - Well logging and geochemical sampling during borehole drilling phase
  - Multiple multi-well hydrologic tests
- Injection Facts
  - 3000-5000 MT of CO<sub>2</sub> total (discussions with Praxair/BP and Shell underway)
  - Injection would occur over a 2 to 4 week period
  - Initial radius of CO<sub>2</sub> bubble is only about 100 ft. Maximum spread radius is about 500 ft (depending on total CO<sub>2</sub> used)
  - The CO<sub>2</sub> will dissolve in the formation water and eventually become mineralized over a period of several years
- Monitoring Program
  - An extensive monitoring program is planned that includes air, shallow subsurface, and deep monitoring components
  - Water samples will be obtained periodically to monitor geochemical changes
  - Core sample extraction (2-3 years post-injection)
- Closure
  - Wells would be plugged and abandoned according to state regulations
  - Site would be restored to pre-test condition
  - Closure option will depend on desire and feasibility of using these wells to support commercial operations

# Seismic Survey

- Four mile long multi-line swath
- Sufficient georeferencing to permit integration of VSP and cross-well seismic data
- Broad bandwidth, wide frequency energy spectrum
- Vibroseis source augmented with selected shot points
- 3C geophones
- P and converted S-wave (SV only) processing workflow designed to optimize information content and imaging

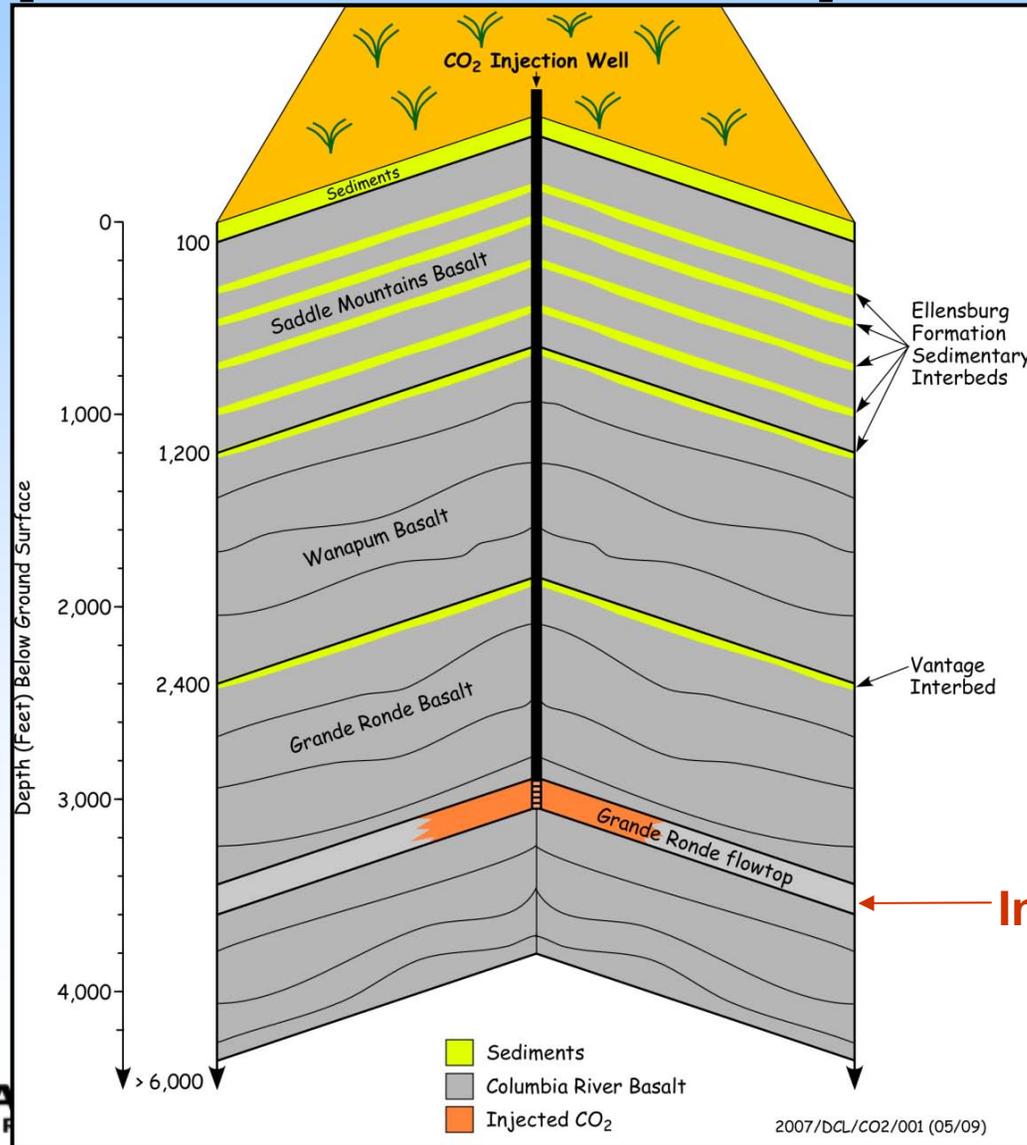


# Seismic Survey

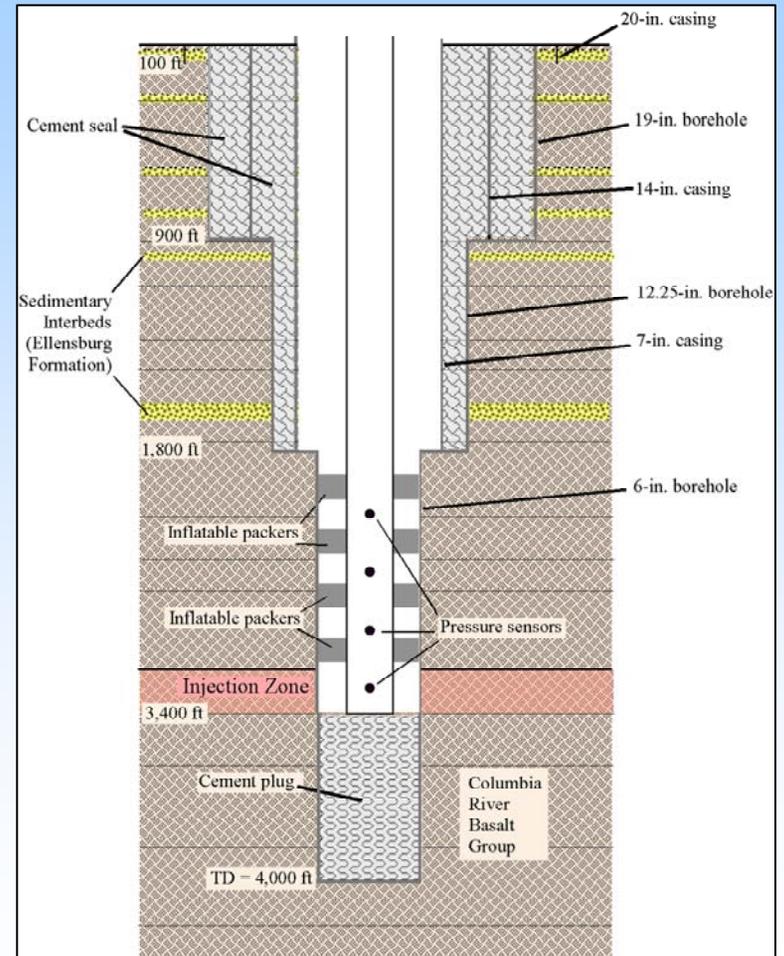
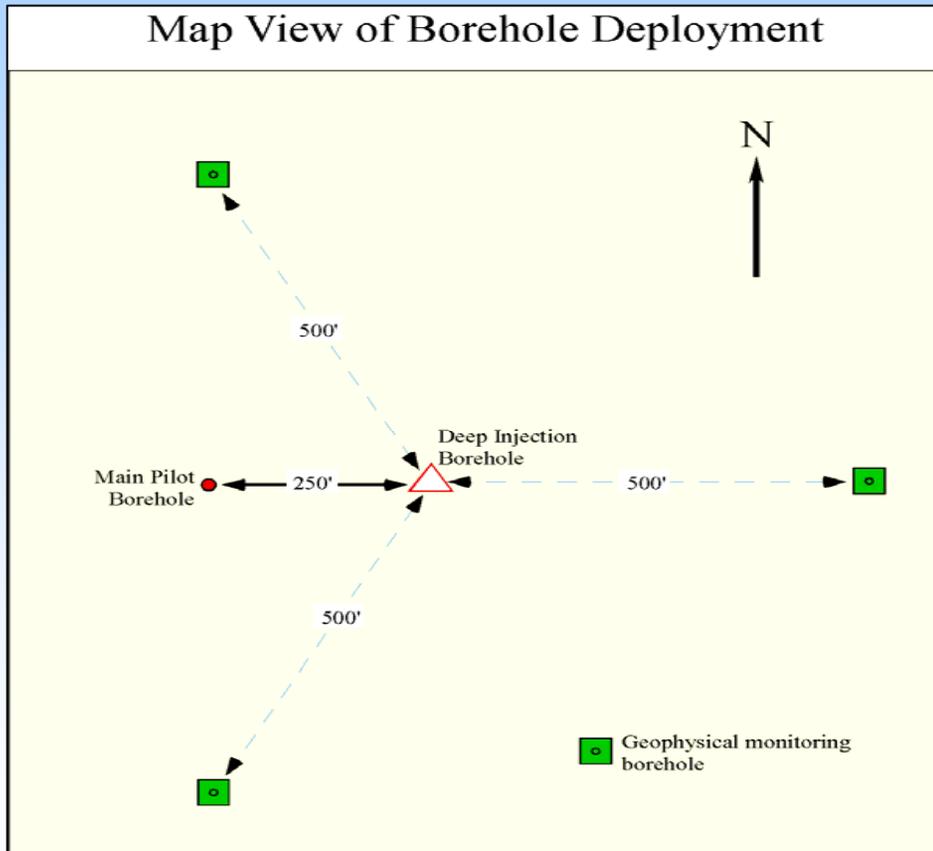
- Seismic survey completed 12/07/2007
- Field tests immediately prior to initiation of the seismic acquisition showed that ground roll could be suppressed by eliminating frequencies below 12 Hz, and by using (for each seismic source station) four vibroseis sweeps
- Optimized sweep resulted in longer production of high frequency source energy and a desirable flattened frequency spectrum
- The swath design of five receiver lines flanked by two source lines, together with the use of the optimized sweep design, results in a dominant frequency of 80 HZ at the target interval of 3,000-4,000 feet, and a fold of 200.
- Raw field records of the 2D data acquired confirm acquisition of P-wave and converted wave data
- Data processing in progress



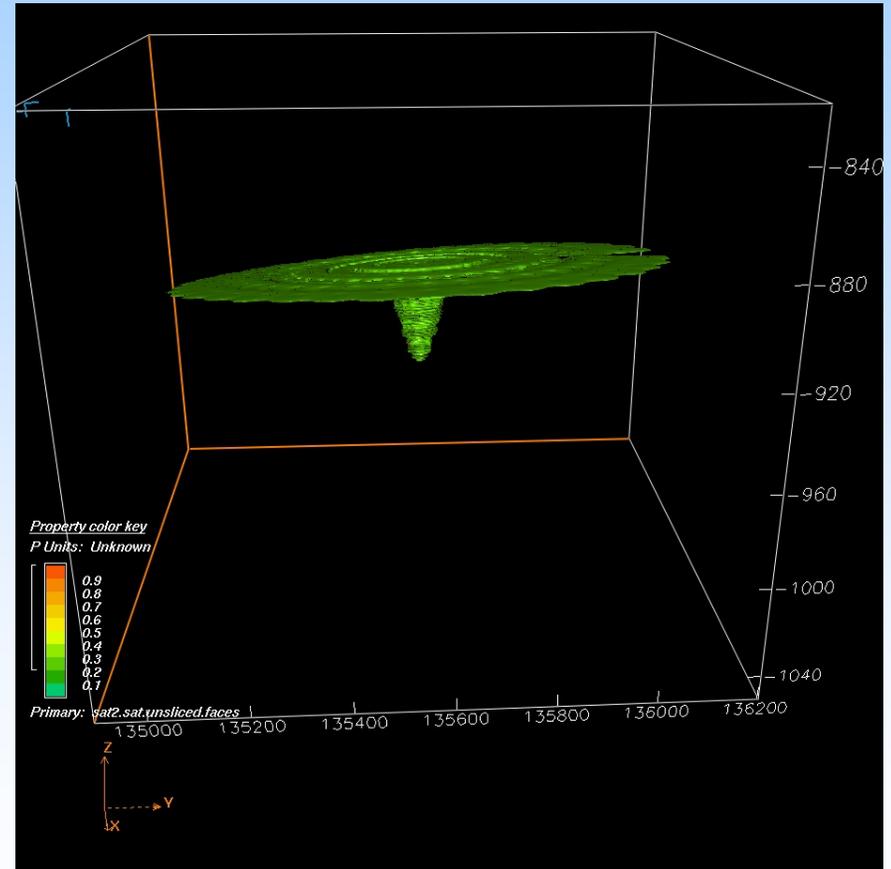
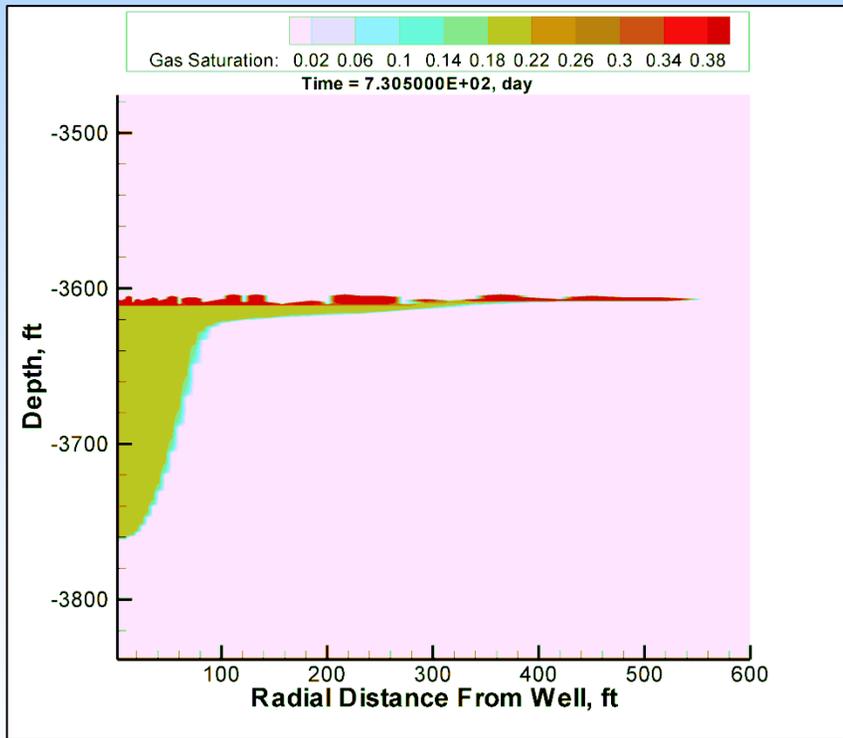
# Important Regional Stratigraphy for Sequestration in Deep Basalts



# Field Site Borehole Layout



# Supercomputer Modeling of Plume Behavior for Pilot



# Field Test Status

- Field Activity Plan completed
- Meeting with Washington State Department of Ecology, EPA Region 10, and Department of Natural Resources officials
  - Injection well to be permitted via Class V UIC registration and SEPA application
- Several meetings with public and state NGO groups have been held
  - Meeting with NWECC held in September
  - NWECC lab/site tour held in November
  - Public meeting in Walla Walla held in October
  - Additional public workshops scheduled for January 2008
- Drilling start scheduled for March 2008 contingent on contract approval

# Questions?

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# Basalt Characterization Test Objectives

- Determine reservoir zone suitability
  - Permeability
  - Storage capacity
- Assess caprock integrity
- Evaluate effectiveness of seismic imaging techniques for characterization and monitoring
- Validate reservoir simulations of CO<sub>2</sub> fate and transport and prediction of mineralization rates

# Grande Ronde Basalt Stratigraphic Realization

- Stochastic indicator simulation on four basalt descriptions

