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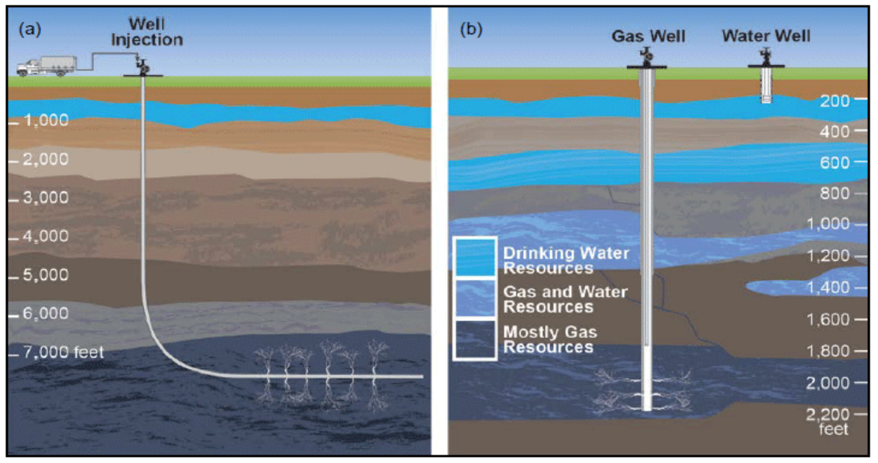
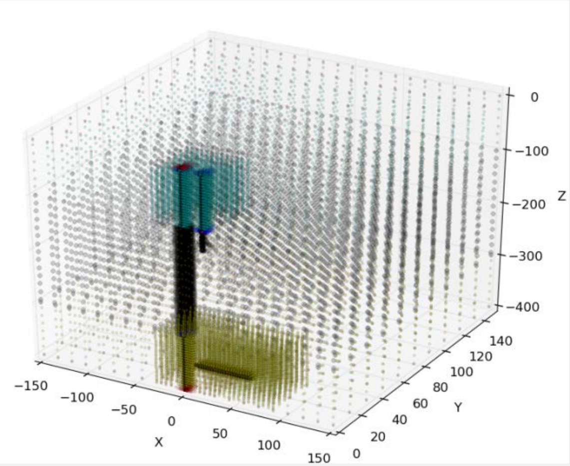
Modeling of Leakage in Potential Failure Scenarios in Shale Gas Systems

Technical Workshop Series:
Well Construction/Operation and Subsurface Modeling





Matt Freeman, LBNL

EPA-Research Triangle Park • April 17, 2013

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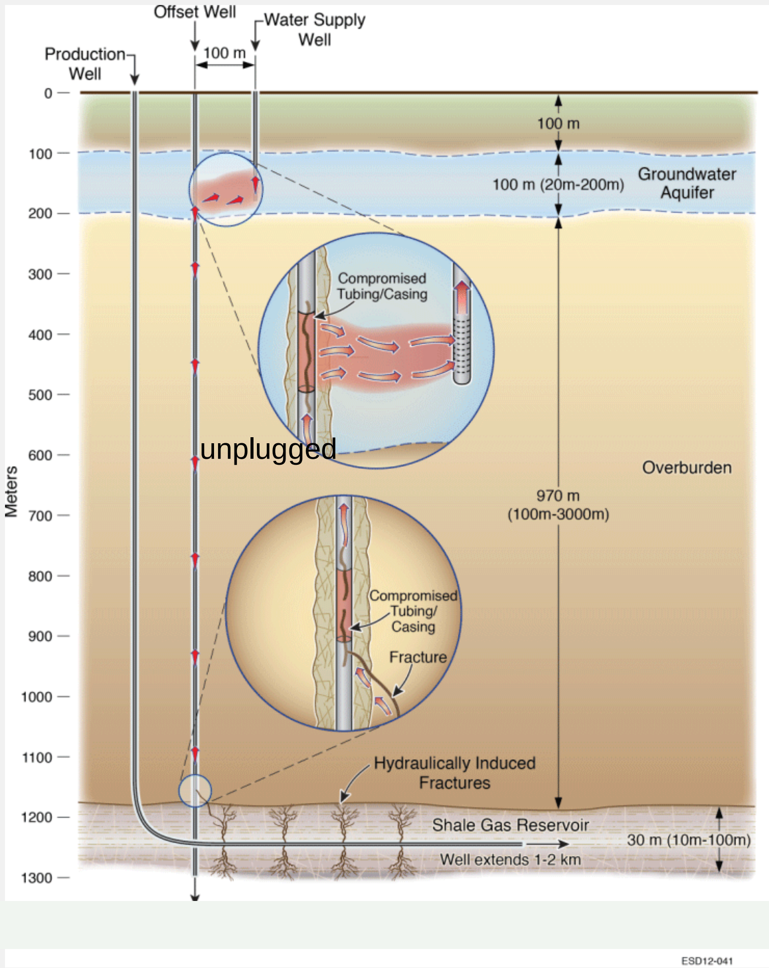
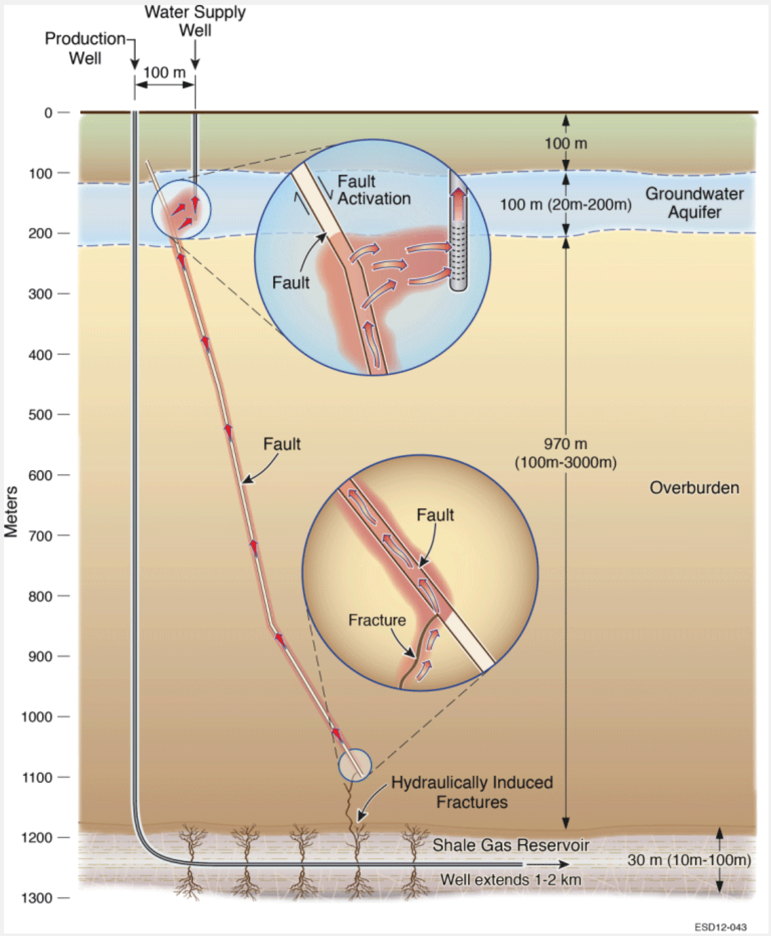
Background: Conceptual Failure Scenarios

Artificial Pathways: Well(s)



Natural Pathways: Faults or Fractures



(1) Physically possible? **(2) Potential for fluid migration?**

Mesh Generation Process

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MeshVoro code for unstructured mesh generation developed for complex 3D geometries.

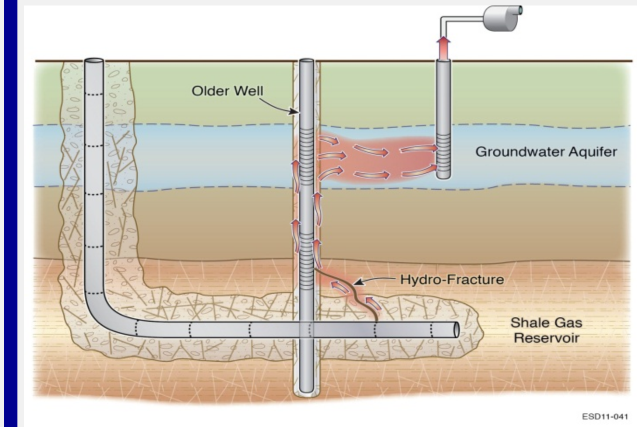

Figure 1.a: Conceptual schematic.

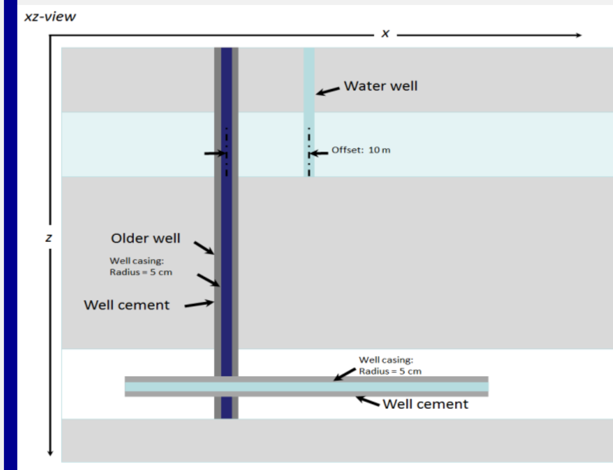

Figure 1.b: Engineering detail.

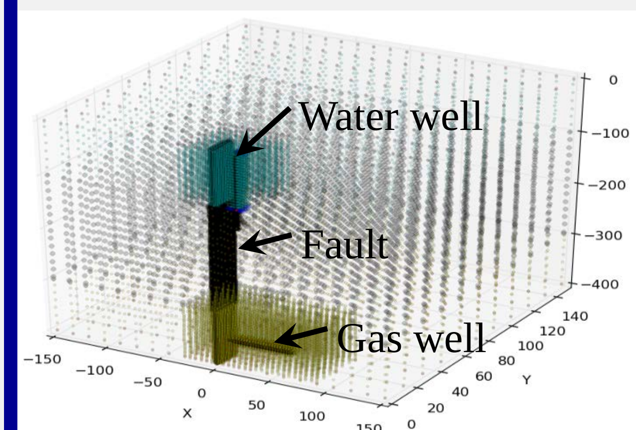

Figure 1.c: Pointcloud rendering.

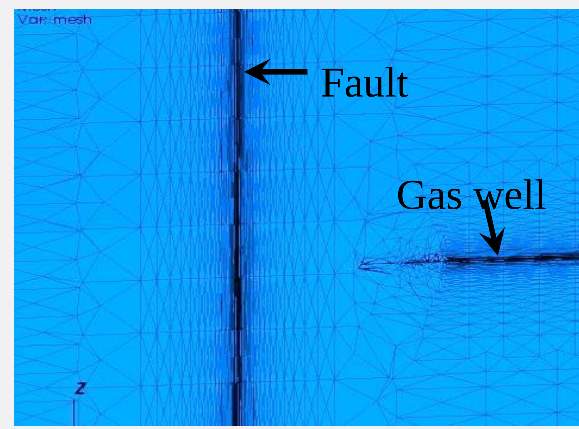

Figure 1.d: Close-up of Voronoi mesh.

Workflow for generation of complex Voronoi meshes using the MeshVoro code base. The generated meshes typically possess between 100,000 and 500,000 elements.

LBNL TOUGH: Transport of Unsaturated Groundwater and Heat

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FLOW & TRANSPORT

TOUGH+RGas
real gas mixtures

TOUGH+RGasH2O
real gas mixtures plus water

TOUGH+RGasH2OCont
real gas mixtures plus water plus dissolved contaminants

EOS
equations of state

coupling

GEOMECHANICS

ROCMECH
fracture creation and propagation

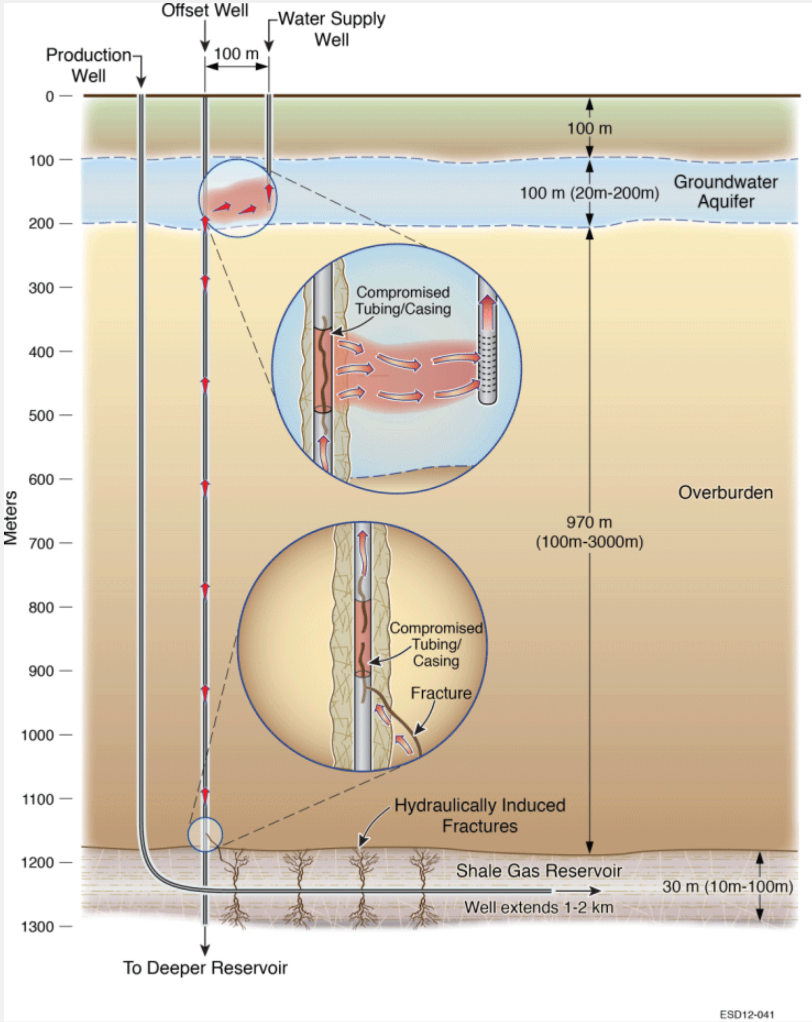
FLAC3D
fault reactivation

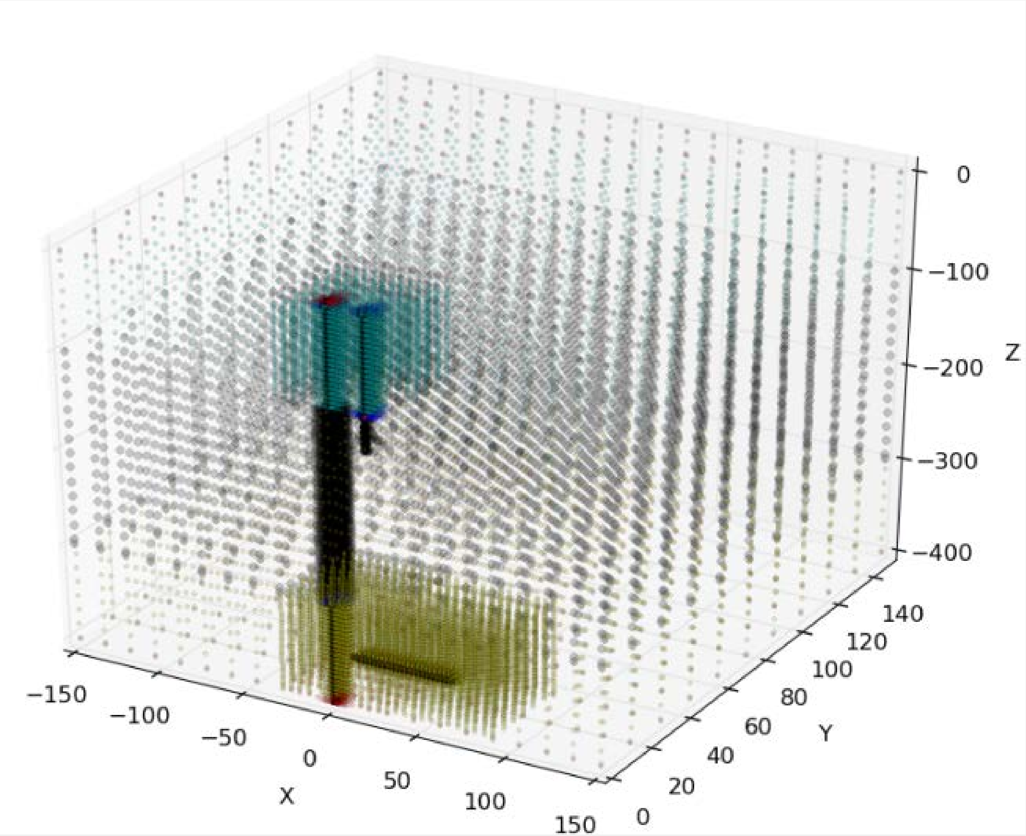
MESH GENERATION

MeshVoro
flexible unstructured gridding

Conceptual Model Building:

Scenarios: Well(s) as a Pathway

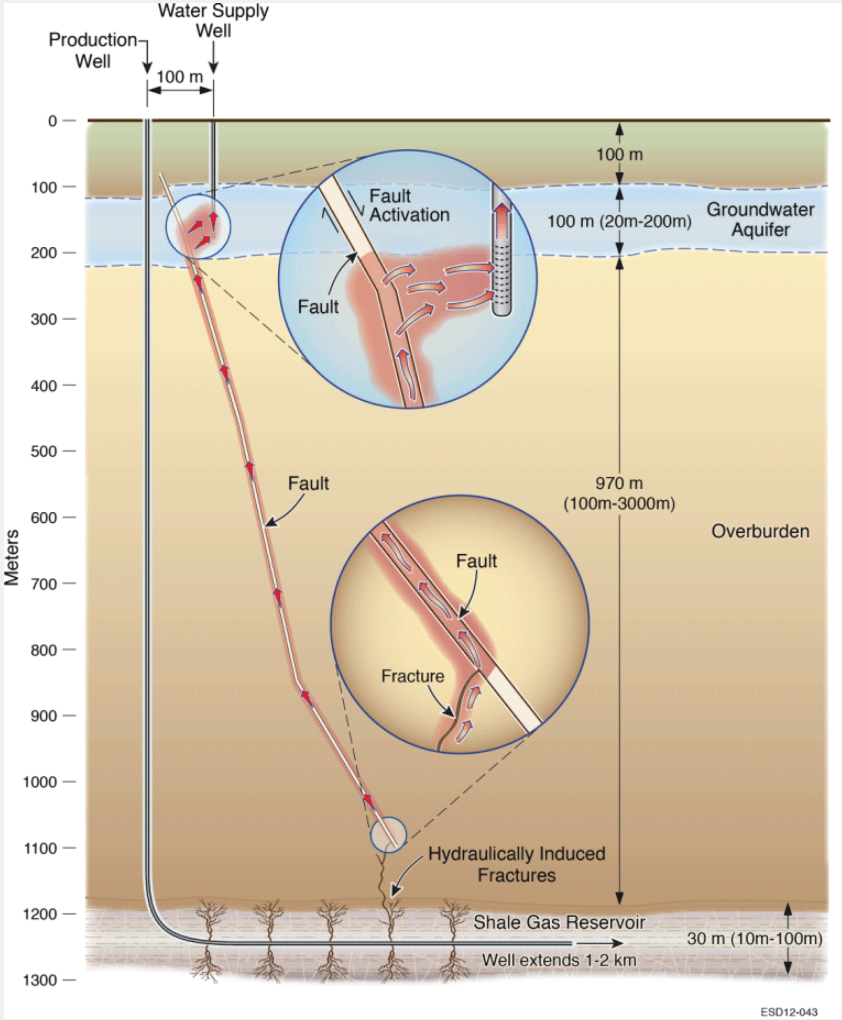


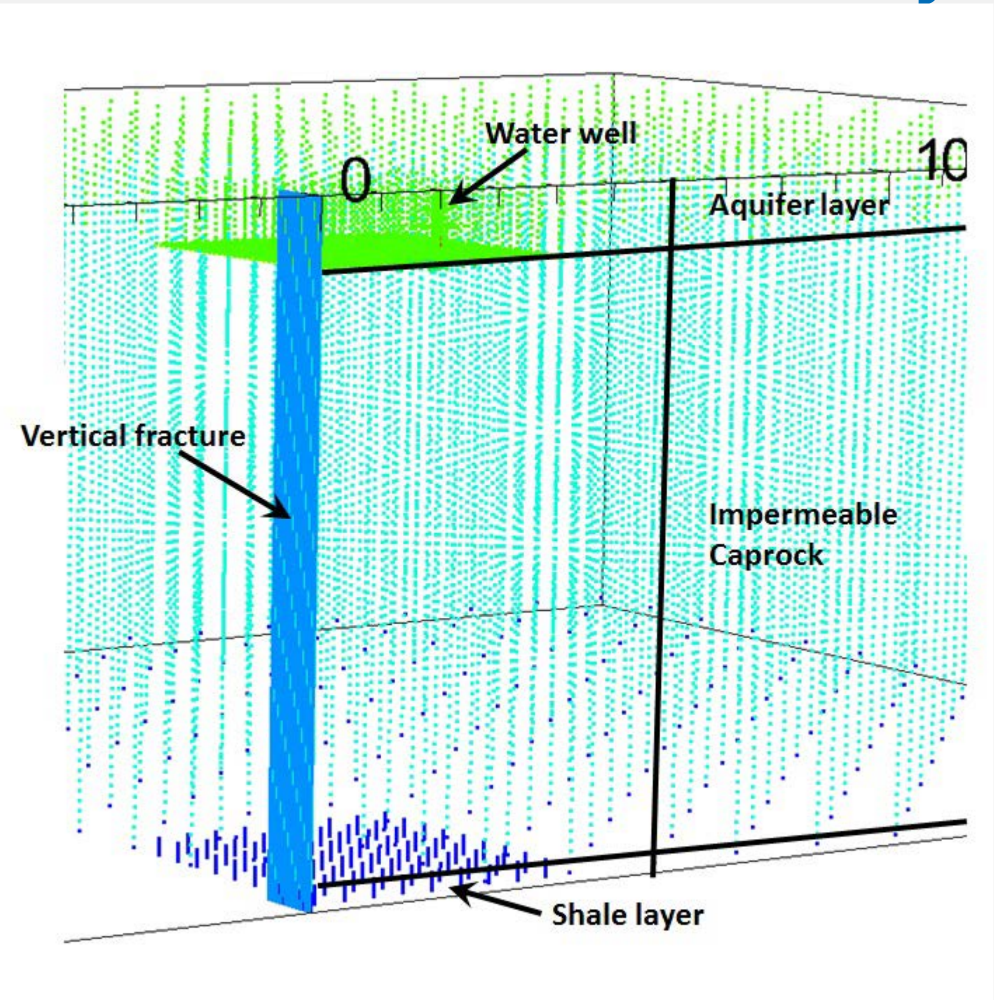


Various zones of the simulated system. Colors denote different material types.

Conceptual Model Building:

Scenarios: Fault/Fractures Pathway





Annotated view of the various zones of the simulated system. Colors denote different material types.

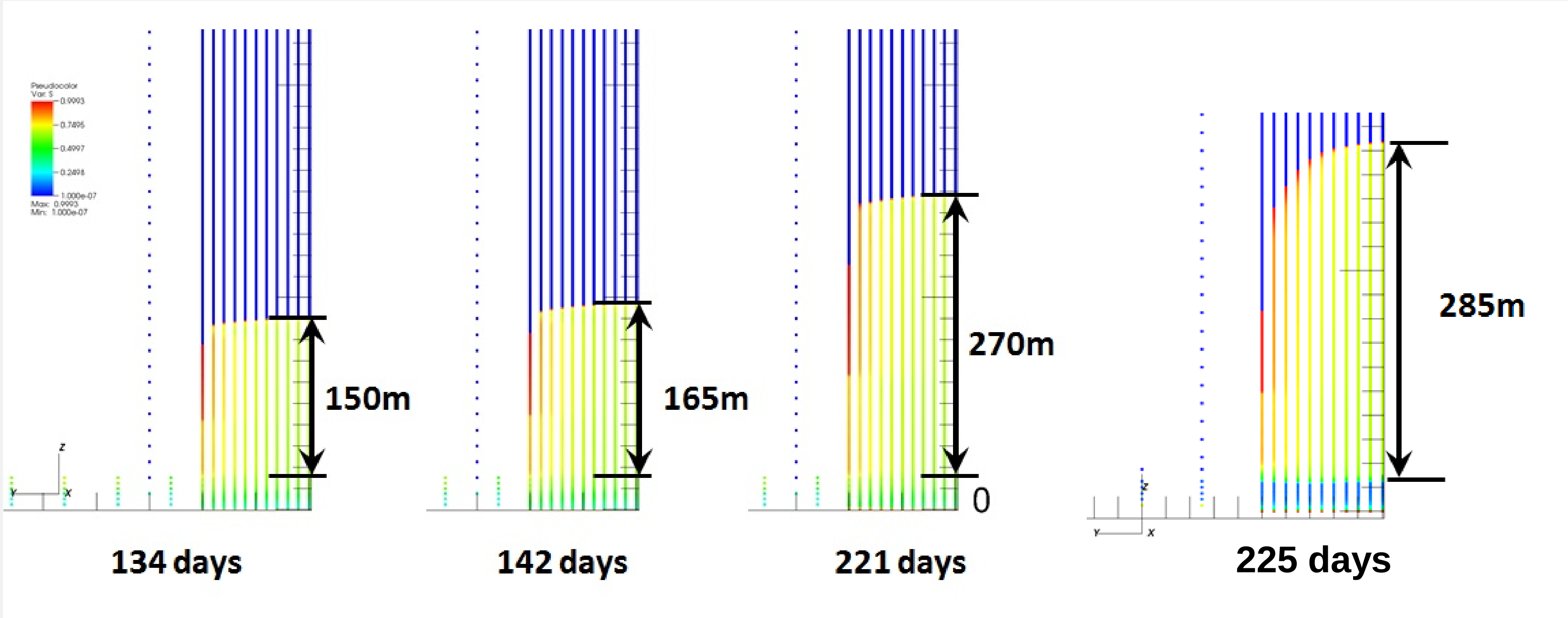
Sensitivity Analysis:

Characterize the problem space

1) Sensitivity parameters:
   - Conductivity of the leaking pathway (well/fault/fracture)
   - Production rate from **water** well
   - Production rate from **shale** well
   - Permeability of the shale
   - Vertical distance between gas-bearing shale and aquifer

Results:

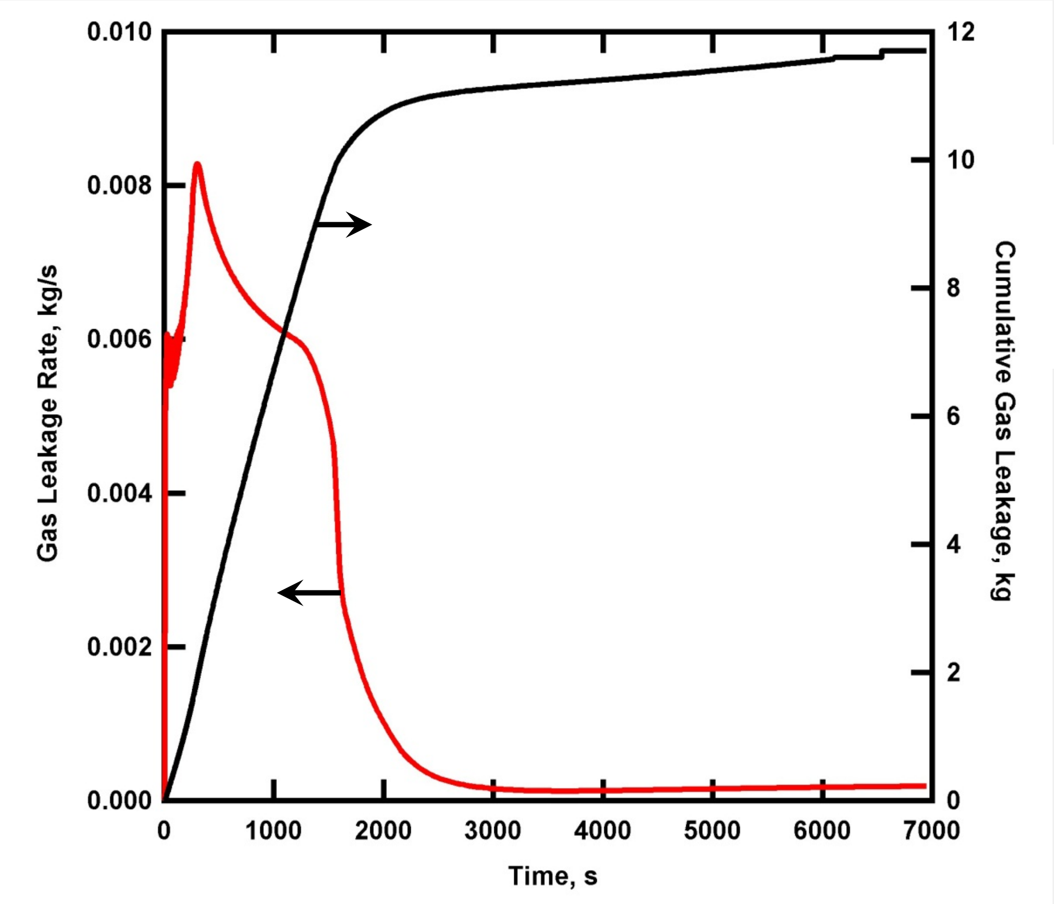
Gas plume rises through fracture



Saturation distribution at along the fracture at time snapshots of 134 days, 142 days, 221 days, and 225 days depicting the behavior of the gas plume over time with an overlying water well providing suction.

Some interesting results:

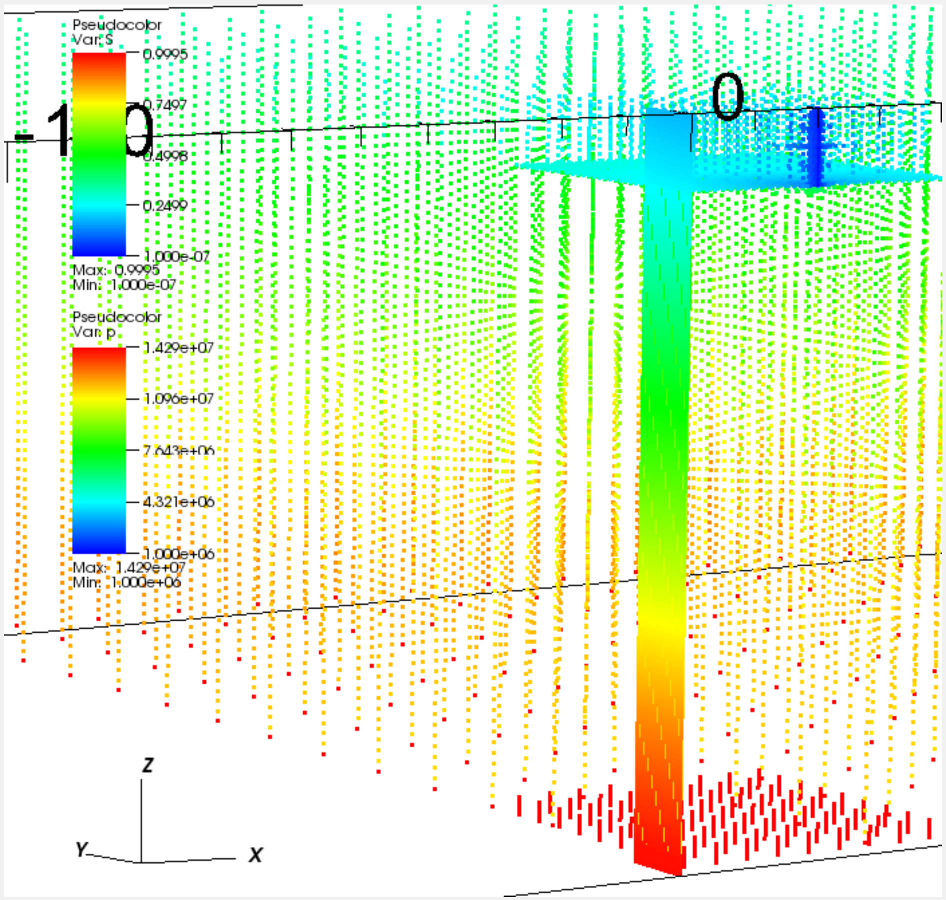
Gas plume rises through wellbore



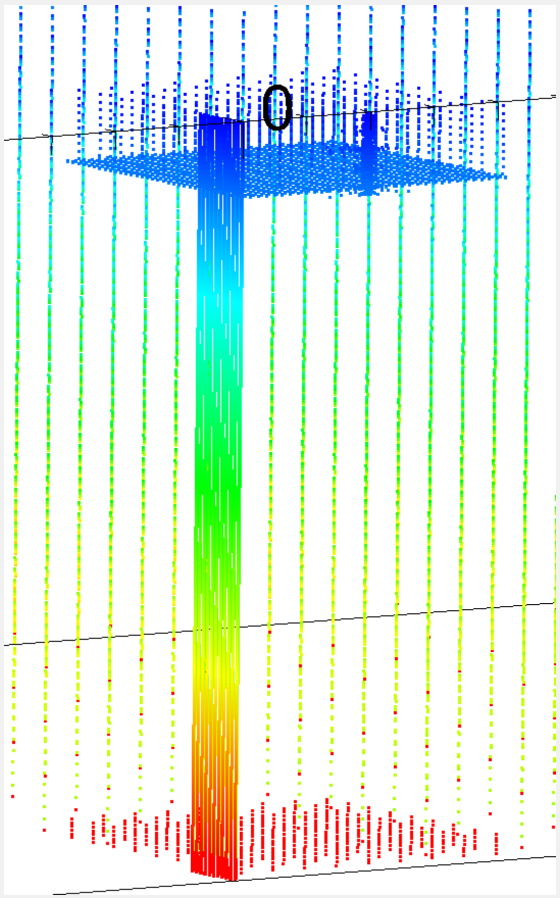
Gas leakage rate and cumulative leaked gas through an old abandoned well. After an initial "bubble" of gas percolates to the aquifer, the leakage rate drops before resuming a slow rise.

Results: Drawdown of aquifer

a.



b.



a. Pressure distribution at 134 days with water well producing at 1.0e6 Pa bottomhole pressure;
b. Pressure distribution at 221 days with water well producing at 1.0e6 Pa bottomhole pressure

Early Conclusions

1) Factors affecting gas leakage:
   - Conductivity of the leaking pathway
   - Relative pressure regimes in shale reservoir and aquifer
   - The shale matrix permeability

Future Plans

1) Consider further leakage scenarios
   - Improve mesh-generation capabilities

2) Perform more sensitivity simulations

3) Parallelization of our codes (a) for faster solutions and (b) to permit larger and more detailed simulations

END OF PRESENTATION

This work is partially funded through an EPA-DOE Interagency Agreements (DW-89-922359-01-0; DW-89-92235901-C). Information presented is part of the EPA's ongoing study. EPA intends to use this, combined with other information, to inform its assessment of the potential impacts to drinking water resources from hydraulic fracturing. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Some properties & conditions of systems under investigation

Abandoned leaking well

k_{shale} (m^2)	k_{well} (m^2)	Well Production Rates: Shale well (kg/s)	Well Production Rates: Water well (gpm)
3.00E-19	3.00E-09	**1.00E-03**	0.00E+00
3.00E-19	3.00E-09	**1.00E-04**	**1.00E-01**
3.00E-19	**3.00E-14**	0.00E+00	0.00E+00
3.00E-18	**3.00E-14**	0.00E+00	0.00E+00

Penetrating fracture

k_{shale} (m^2)	k_{frac} (m^2)	Shale well (kg/s)	Water well (gpm)
3.00E-18	3.00E-13	0.00E+00	0.00E+00
3.00E-19	3.00E-13	0.00E+00	0.00E+00

Partial lists