Comparison of Single and Multiphase Tracer Test Results From the Frio CO_2 Pilot Study, Dayton Texas

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Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Geologic – Frio Brine Field Project (1)

Comparison of Single and Multiphase Tracer Test Results from the Frio CO_2 Pilot Study, Dayton Texas

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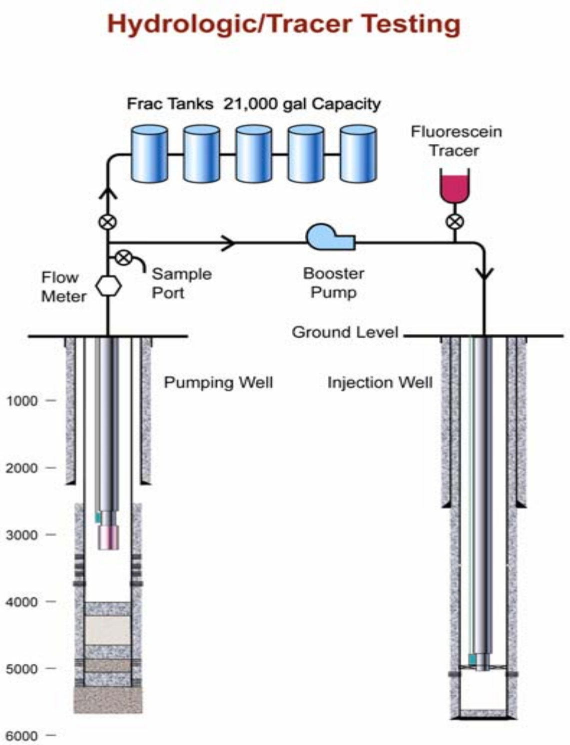
Outline

- Single-phase fluorescein tracer test
  - Field method
  - Description of dipole (or Doublet) model
  - Fluorescein data reduction and model match
- Gas-phase krypton tracer experiment
  - Field method/U-tube sampler
  - Description of radial dispersion model
  - Krypton data reduction and model match
- Comparison of single and multiphase tracer results
- Conclusions
- Recommendations & Acknowledgments

Single-Phase Fluorescein Tracer Test Prior to CO_2 Injection

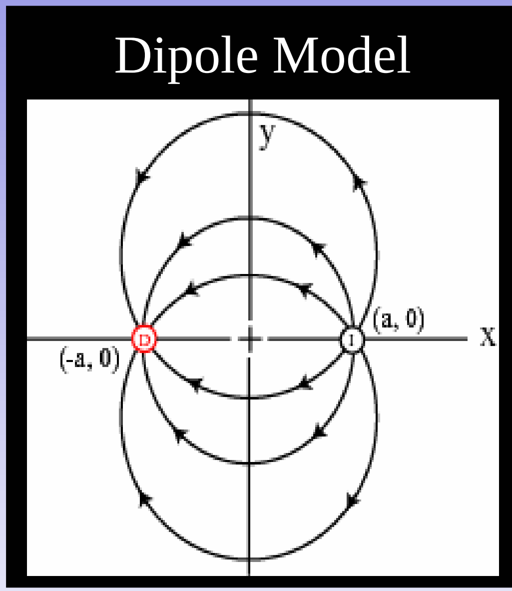


Balanced Dipole

FIELD METHOD

- Brine pumped at 51.4 gpm
- Steady flow was developed 24 hrs. prior to tracer injection
- Fluorescein tracer was added to injection water, c0 = 21.6 ppm
- Water samples collected every ½ hr. throughout test
- Water samples analyzed on site using a spectrophotofluorometer with detection level of ~ 6 ppb
- Test duration 15.7 days

Single-Phase Dipole Semi-Analytical Model Description
(Grove and Beetem, 1971)



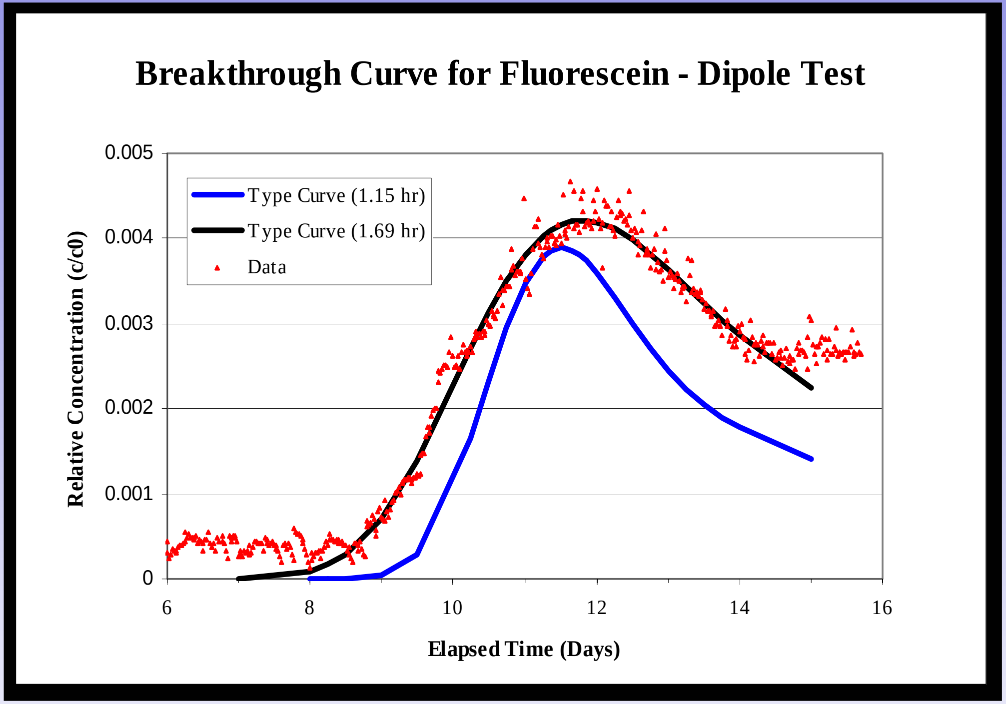
MODEL ASSUMPTIONS AND CONDITIONS

- Horizontal steady-state flow
- Homogeneous, isotropic aquifer of constant thickness
- Constant longitudinal dispersivity α_L
- Ignores diffusion, adsorption, retardation and transverse dispersivity α_T
- 1-D flow through a finite length column is used to model dispersion along individual streamlines.

ANALYTICAL PROCEDURE
- Analytical solution predicts travel time between wells for a dipole
- Travel time is used in 1-D dispersion solution to yield c/c0 for each streamline
- Each streamline contribution is added to produce total c/c0 at discharge well
- Superposition is used to calculate solution for finite length tracer pulse

Grove, D.B., and W.A. Beetem, 1971, Porosity and dispersion constant calculations for a fractured carbonate aquifer using the two well tracer method, *Water Resour. Res.*, *7*(1), pp. 128-134.

Fluorescein Data Match to Dipole Model

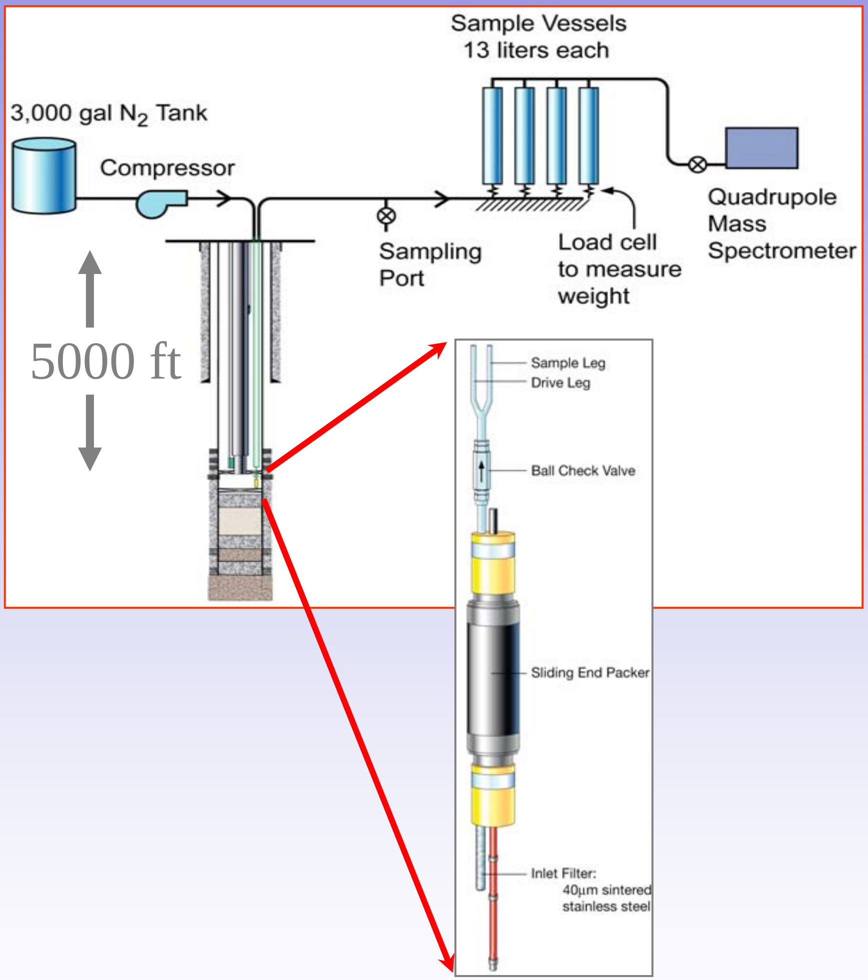


- Improved match using longer tracer injection period.
- First arrival predicted by model = 7 days
- First arrival based on data = 8.9 days
- Late time data confirms first arrival based on model prediction

Parameter Summary →

Tracer Inj. Time (hr)	Dispersivity, α_L (ft)	Effective Porosity (%)	Saturated Thickness (ft)
1.15	0.28	34.2	27.5
1.69	0.83	34.5	27.5

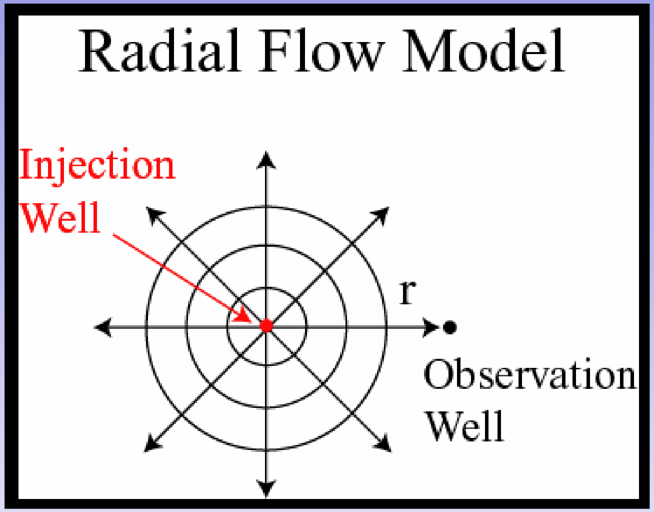
Gas-Phase Krypton Tracer Test During CO_2 Injection



FIELD METHOD

- CO_2 injected at 69.2 gpm
- CO_2 flow field was developed prior to tracer injection
- Krypton gas tracer was added to injected CO_2, c0 = 36.9 ppmV
- Gas samples collected every hour using U-Tube sampler
- Gas samples analyzed on site using a quadrupole mass spectrometer with method detection level of ~ 50 ppbV
- Test duration 3 days

Radial Analytical Dispersion Model Description
(Hoopes and Harleman, 1967)



MODEL ASSUMPTIONS AND CONDITIONS

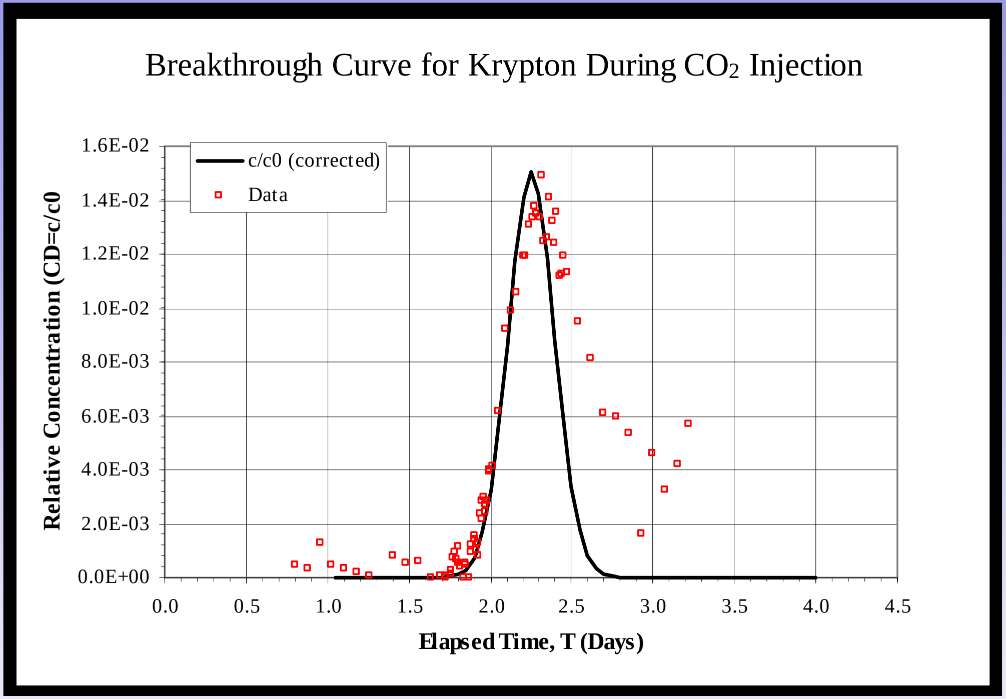
- Horizontal steady-state flow
- Homogeneous, isotropic aquifer of constant thickness
- Constant longitudinal dispersivity α_L
- Ignores diffusion, adsorption, retardation and transverse dispersivity α_T
- Solution is inaccurate near the injection well for early times
- Model does not account for buoyancy

ANALYTICAL PROCEDURE

- Analytical solution to the radial dispersion equation predicts c(t, r)/c0 for constant concentration source
- Superposition is used to calculate solution for finite length tracer pulse

Hoopes, J.A., and D.R.F. Harleman, Dispersion in radial flow from a recharging well, *J. Geophys. Res.*, *72*(14), 3595-3607, 1967.

Krypton Data Match to Radial Model



- First arrival in 53.47 +/-0.5 hours
- Departure of late-time data implies back diffusion of krypton into brine after peak concentration passes observation well

Parameter Summary →

Tracer Inj. Time (hr)	Dispersivity, α_L (ft)	Effective Porosity (%)	Saturated Thickness (ft)
0.13	0.16	8.4	10.3
No delay			

Comparison of Tracer Test Results

Single-Phase Dipole Fluorescein Test

Tracer Inj. Time (hr)	Dispersivity, α_L (ft)	Effective Porosity (%)	Saturated Thickness (ft)
1.15	0.28	34.2	27.5
1.69	0.83	34.5	27.5

Multi-phase Radial CO_2 /Krypton Test

Tracer Inj. Time (hr)	Dispersivity, α_L (ft)	Effective Porosity (%)	Saturated Thickness (ft)
0.13	0.16	8.4	10.3

- Saturation estimate = 24% (8.4/34.5)

Conclusions

- Dispersivity values and classic shape of the tracer breakthrough curves imply Frio is a relatively clean, homogeneous sandstone.
- Given the limitation of these simple models:
  - CO_2 moved along preferential pathways representing roughly 1/3 of the available saturated thickness.
  - CO_2 saturation along these pathways is estimated to be 24%.
  - The CO_2 injection efficiency, defined as the effective volume occupied by the CO_2 divided by the effective volume of the total reservoir, is about 9%
- Models are very sensitive to the porosity value
- Diffusion of gas into the brine could play an important role in sequestering additional quantities of CO_2

Recommendations

- Eliminate wellbore storage effect by collecting downhole samples during tracer injection
- Inject CO_2 containing tracers at different rates to determine corresponding saturations and optimum injection efficiency
- Quantify benefit of sequestering additional CO_2 by *in situ* diffusion mechanism

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