

Comparison of Single and Multiphase Tracer Test Results From the Frio CO₂ Pilot Study, Dayton Texas

GCCC Digital Publication Series #05-04t

R. Trautz
B. Freifeld
C. Doughty



Keywords:

Flow Paths, Tracer Tests, Radial Flow Model, Dipole Model, Fluid Displacement

Cited as:

Trautz, R., Freifeld, B., and Doughty, C., Comparison of single and multiphase tracer test results from the Frio CO₂ Pilot Study, Dayton, Texas: presented at the National Energy Technology Laboratory Fourth Annual Conference on Carbon Capture and Sequestration, Alexandria, Virginia, May 2-5, 2005. GCCC Digital Publication Series #05-04t, pp. 1-11.

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 CO₂ Pilot Study, Dayton Texas

Robert Trautz, Barry Freifeld and Christine Doughty

Lawrence Berkeley National Laboratory

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia

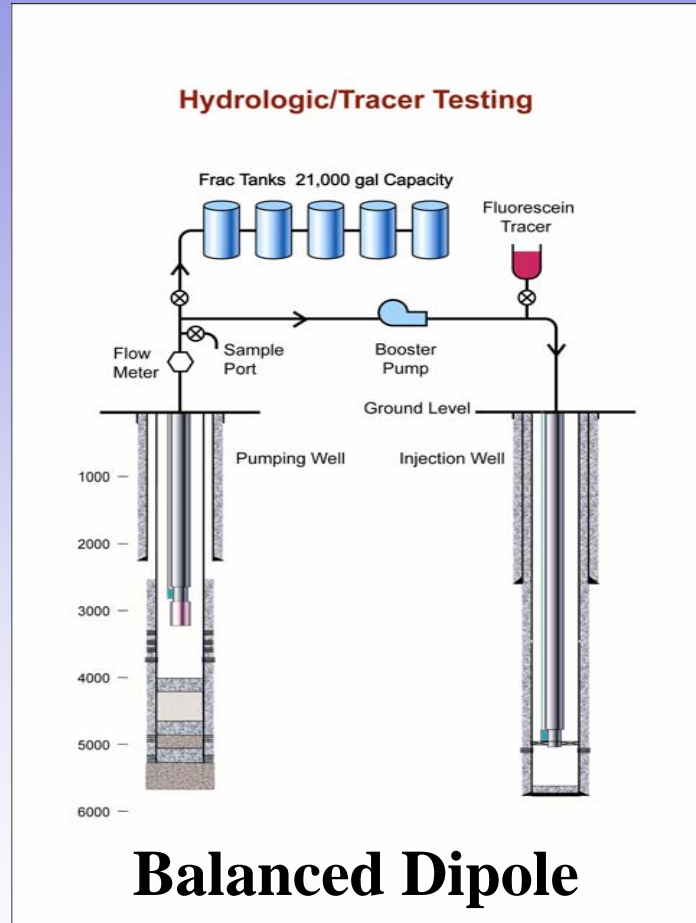


Outline

- 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 CO₂ Injection



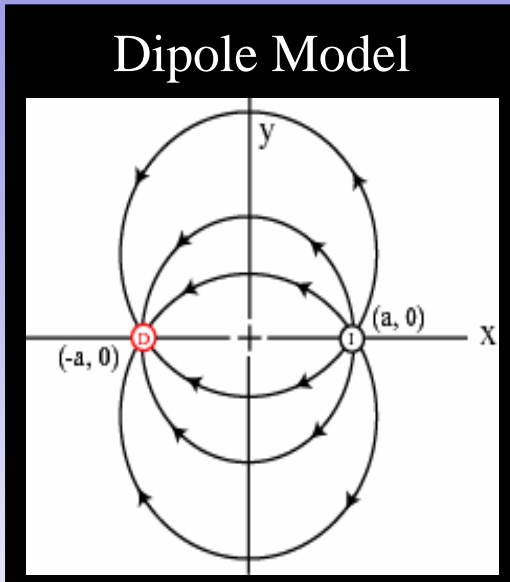
FIELD METHOD

- Brine pumped at 51.4 gpm
- Steady flow was developed 24 hrs. prior to tracer injection
- Fluorescein tracer was added to injection water, $c_0 = 21.6$ ppm
- Water samples collected every $\frac{1}{2}$ 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.

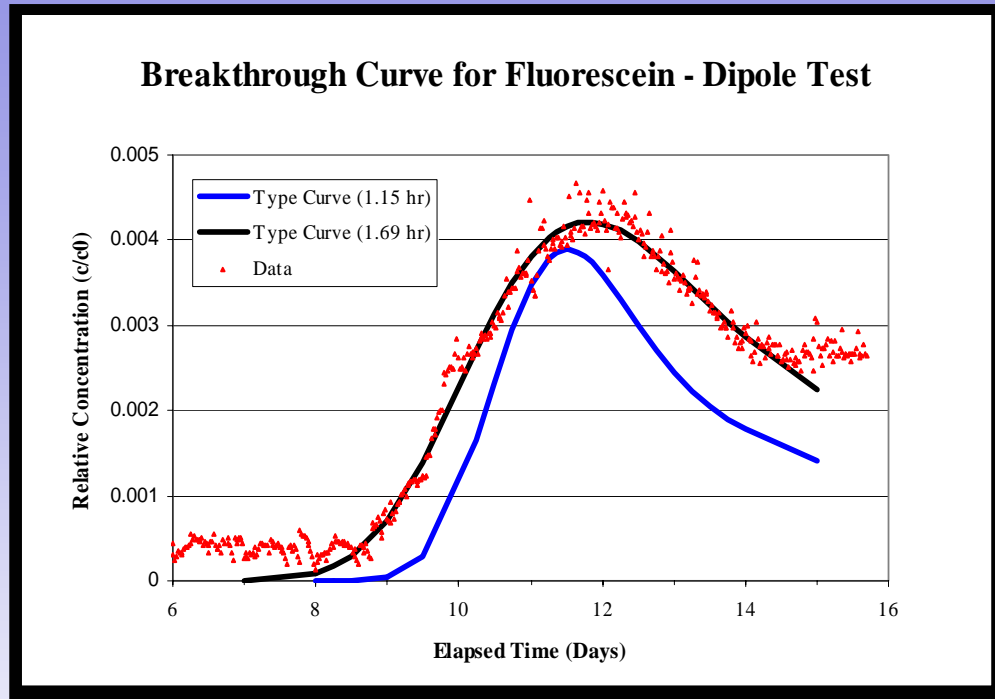
ANALYTICAL PROCEDURE

- Analytical solution predicts travel time between wells for a dipole
- Travel time is used in 1-D dispersion solution to yield c/c_0 for each streamline
- Each streamline contribution is added to produce total c/c_0 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

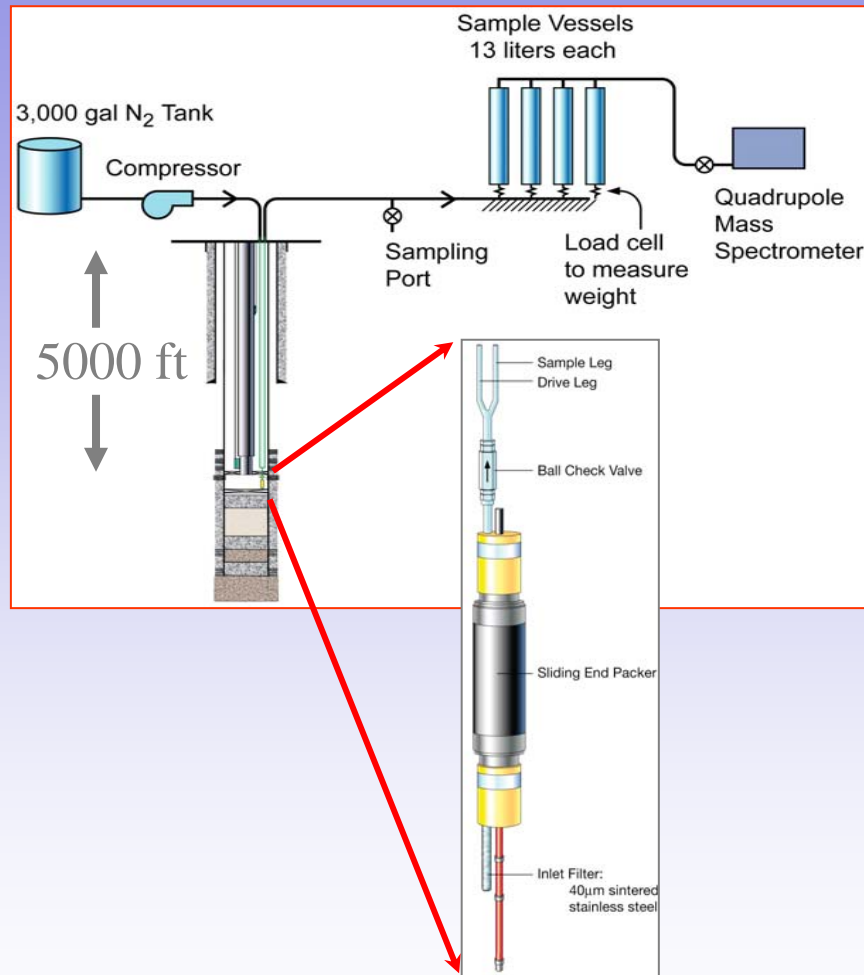
Parameter
Summary



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 CO₂ Injection



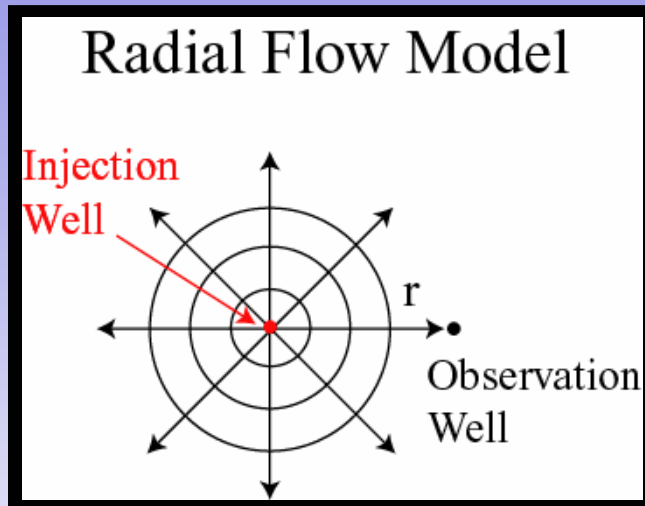
FIELD METHOD

- CO₂ injected at 69.2 gpm
- CO₂ flow field was developed prior to tracer injection
- Krypton gas tracer was added to injected CO₂, $c_0 = 36.9$ 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

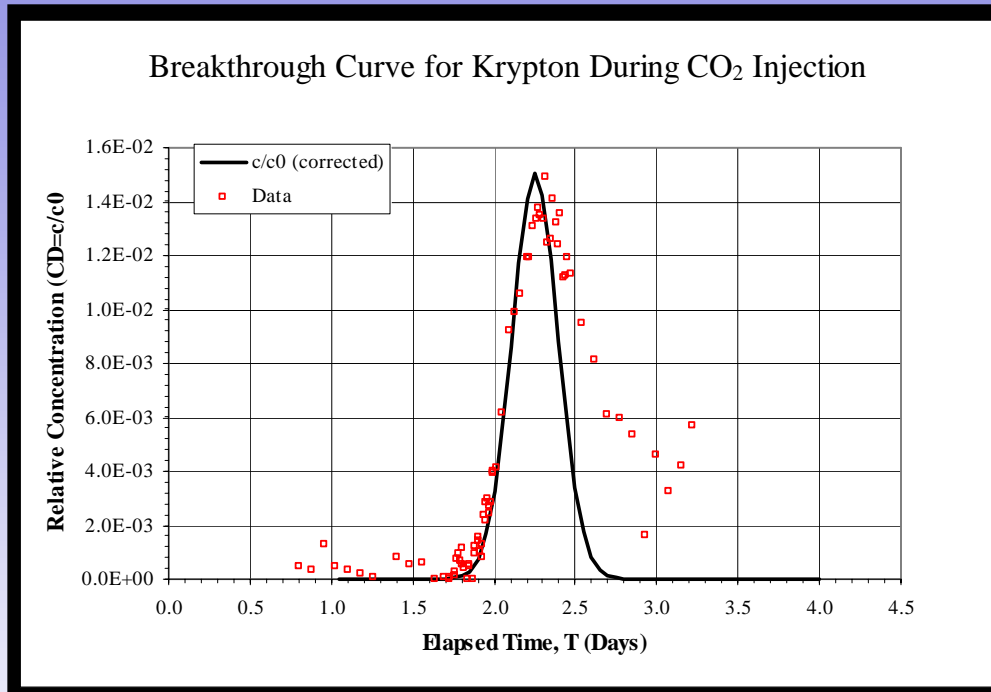
- Analytical solution to the radial dispersion equation predicts $c(t, r)/c_0$ for constant concentration source
- Superposition is used to calculate solution for finite length tracer pulse



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 CO₂ /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:
 - CO₂ moved along preferential pathways representing roughly 1/3 of the available saturated thickness.
 - CO₂ saturation along these pathways is estimated to be 24%.
 - The CO₂ injection efficiency, defined as the effective volume occupied by the CO₂ 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 CO₂



Recommendations

- Eliminate wellbore storage effect by collecting downhole samples during tracer injection
- Inject CO₂ containing tracers at different rates to determine corresponding saturations and optimum injection efficiency
- Quantify benefit of sequestering additional CO₂ by *in situ* diffusion mechanism

Acknowledgments

- U.S. Dept of Energy, NETL
- Field Operations:
Paul Cook and Alex Morales (LBL), Seah Nance (TBEG), and Ed “Spud” Miller, David Freeman, Bill Armstrong, and Dan Collins (Sandia Technologies)

