Gas Chemistry and Isotope Monitoring during the Lost Hills, CA CO_2 Injection Test

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Presentation Outline

Background: Lost Hills

Gas and Stable Isotope Results

Noble Gas Results

Preliminary Modeling

Summary

Questions Being Addressed in GEO-SEQ

Can stable isotope signals of CO_2 and other reservoir constituents (such as noble gases and their isotopes) be used to assess the fate of CO_2 in the subsurface?

Can isotope signals be used to assess leakage?

What factors most influence the isotopic signals over the short durations of a pilot test? Over longer periods of time after testing?

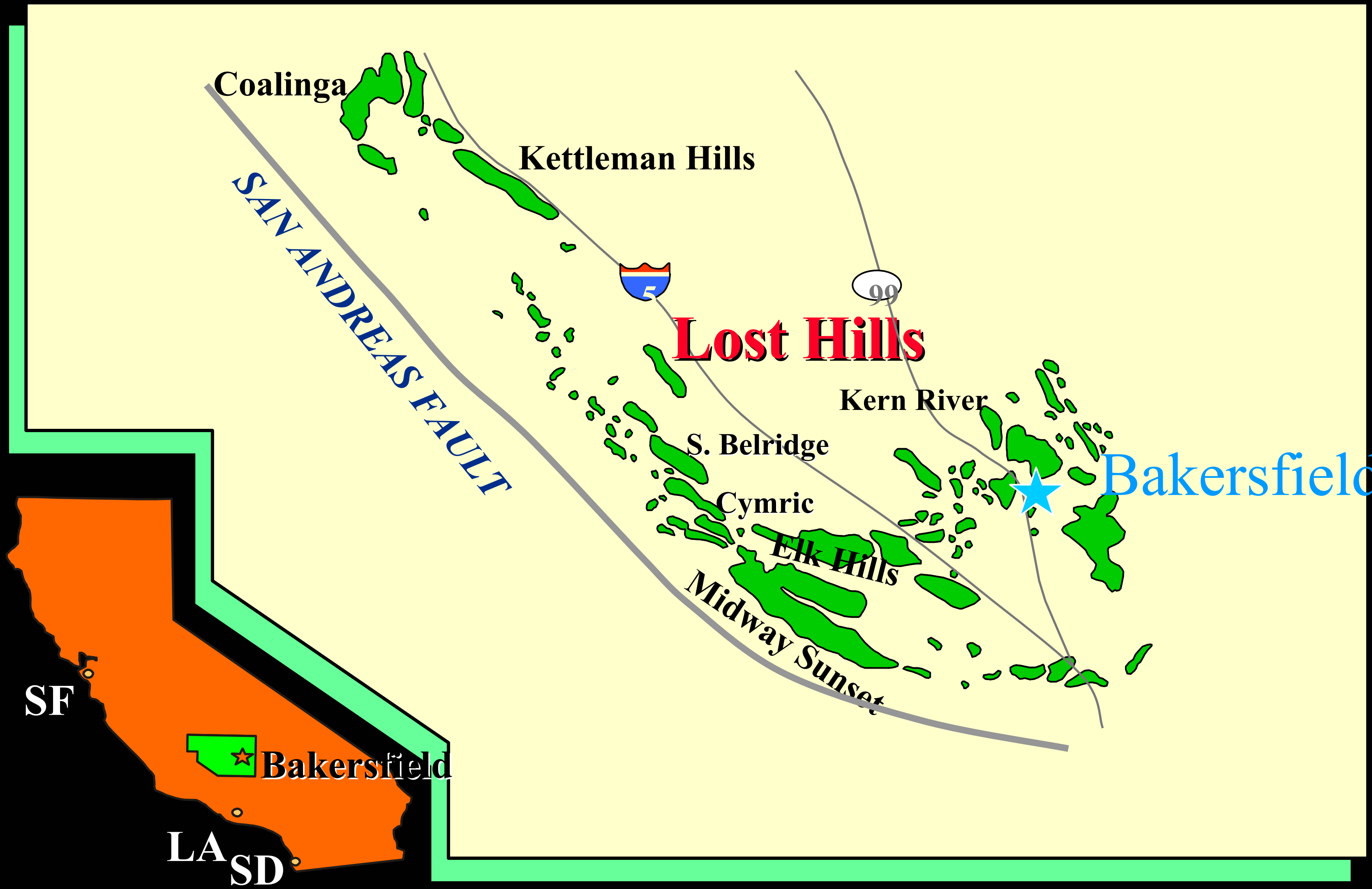
What gaps exist in our understanding of known isotope exchange pathways that influence the signals? How do we fill these gaps?

Processes Impacting Isotope and/or Tracer Behavior

Mixing with indigenous reservoir gas	fast
Dissolution and/or exsolution at the gas/brine interface	↓
Diffusion into brine	
Sorption onto mineral surfaces	
Partitioning into hydrocarbons: liquid or solid (e.g., kerogen)	
Microbial activity	
Dissolution and precipitation of carbonate minerals	
Reaction of CO_2 with silicates	slow

Possible consequence: chromatographic zoning along flow path.

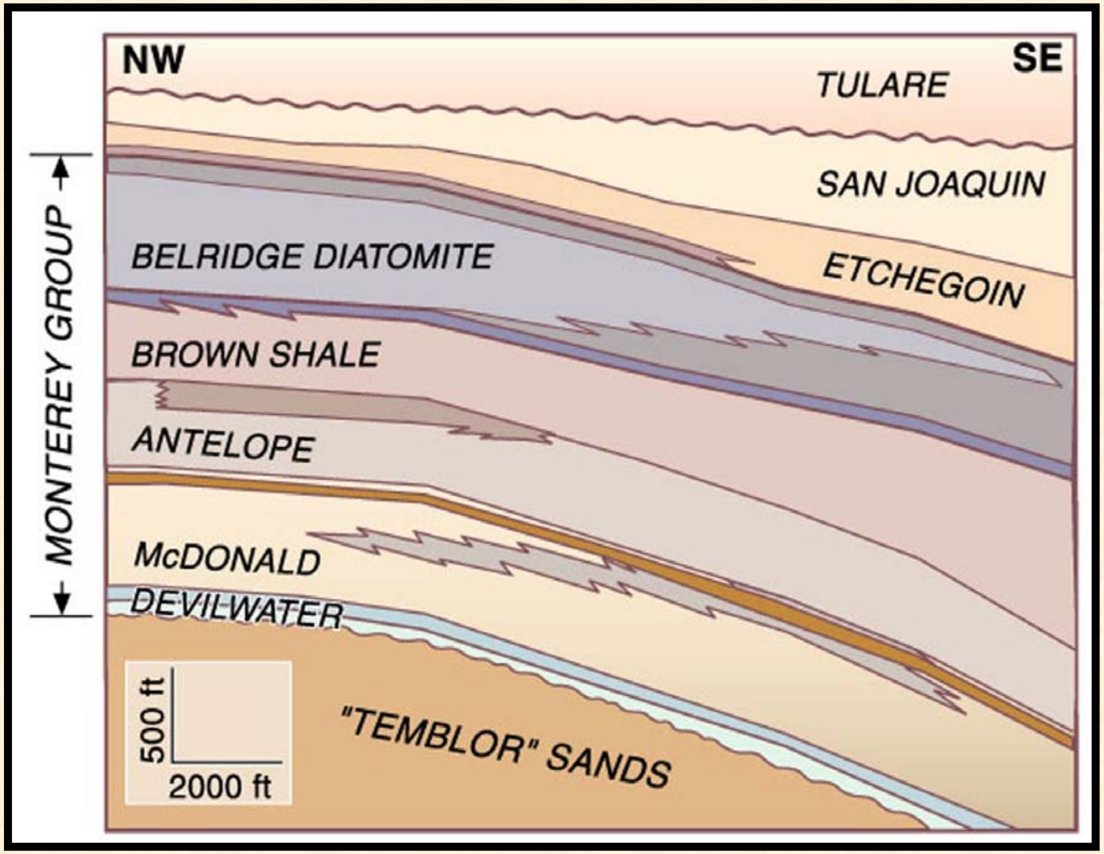
San Joaquin Valley Oil Fields



CO_2 Injection into Belridge Diatomite

Diatomite high porosity (40-60%), low permeability (<1-10 m darcies)

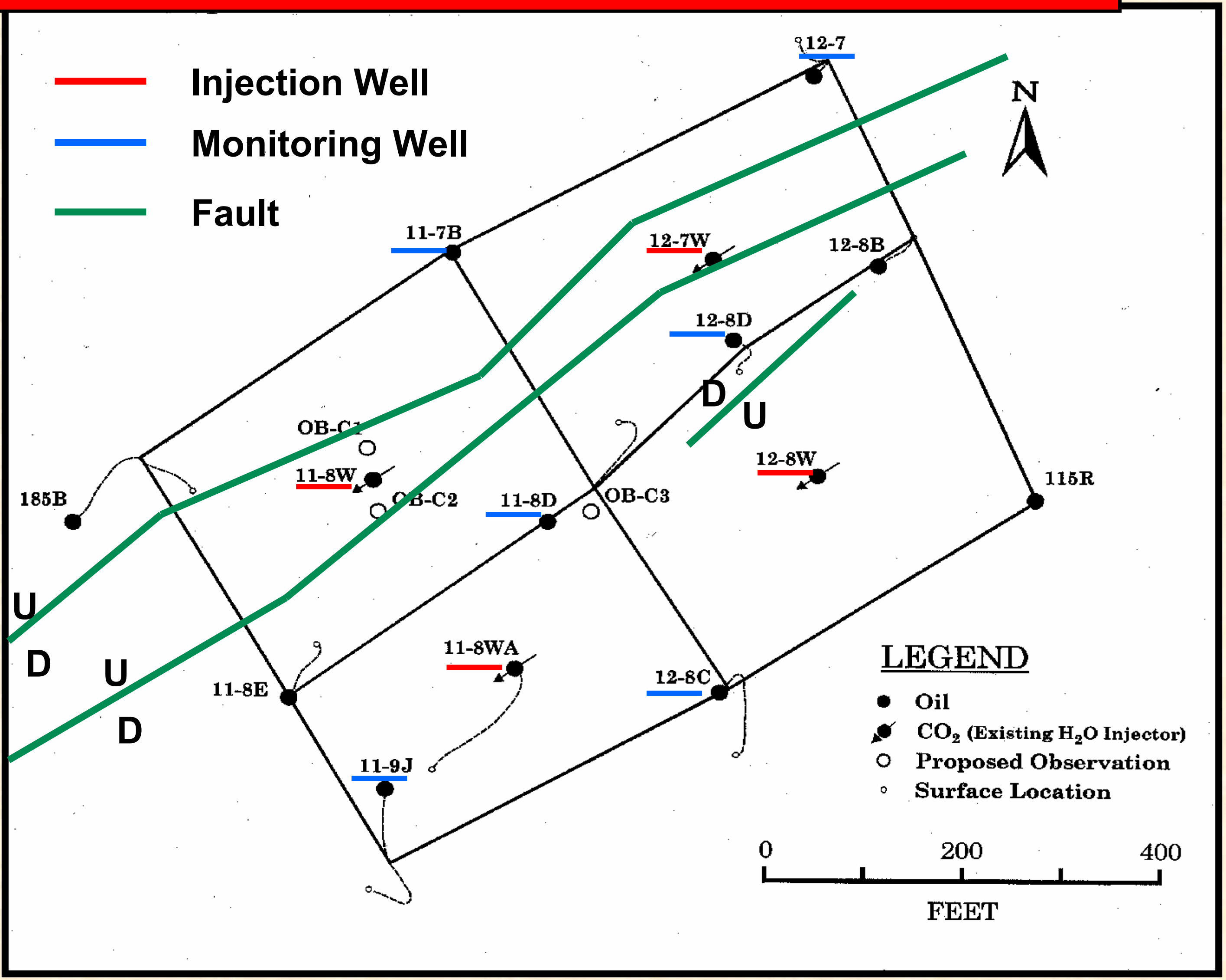
- 2.2 billion barrels of oil in place at Lost Hills



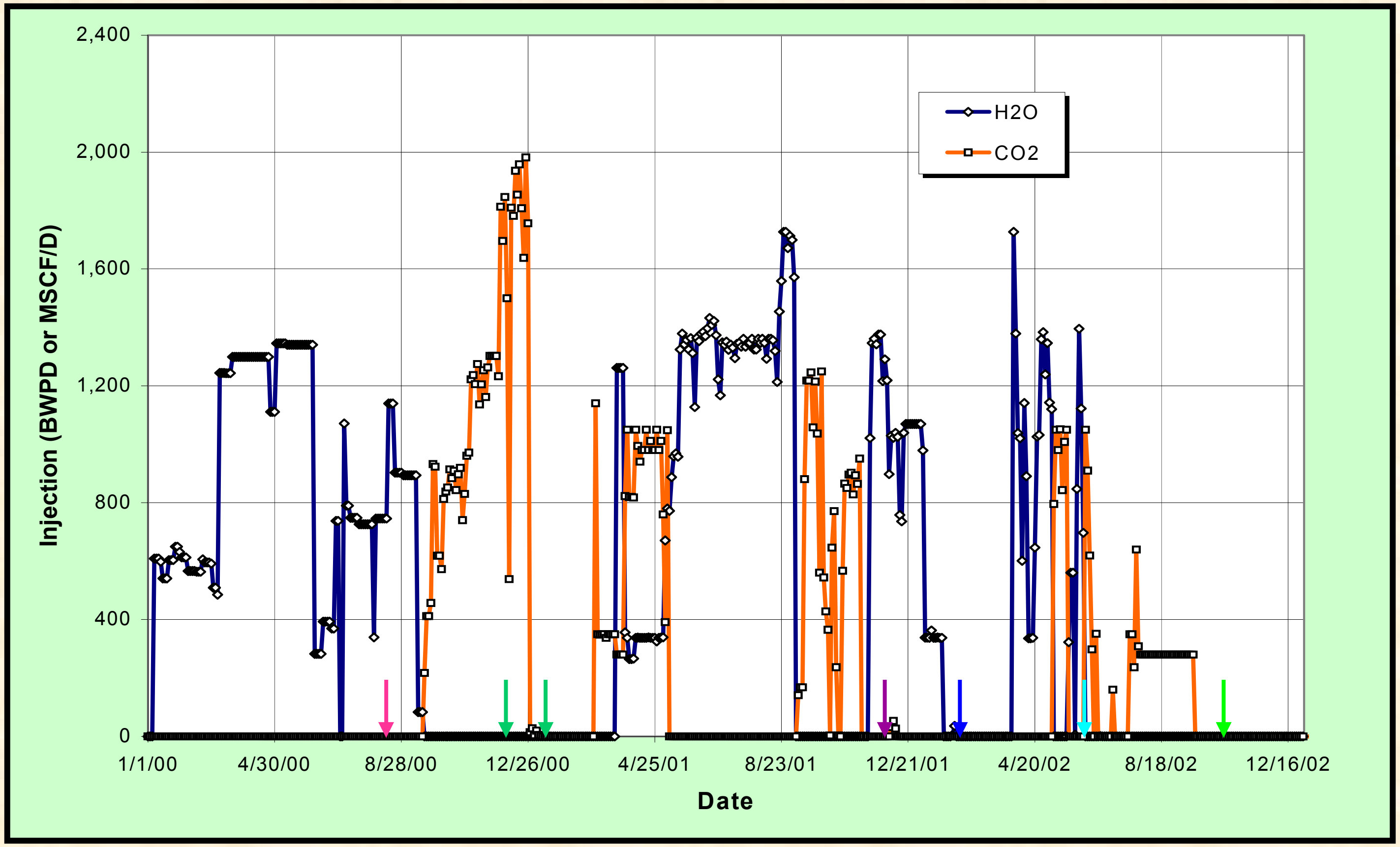
Hydrofracturing, water flood began in 1990

First CO_2 injectivity test completed in 1999; gain in oil production observed

Lost Hills: Four 2.5 Acre Patterns



Alternating Injection of CO_2 Gas and Water Over a Period of 33 Months



Pre- CO_2 injection sampling (8/11/00)

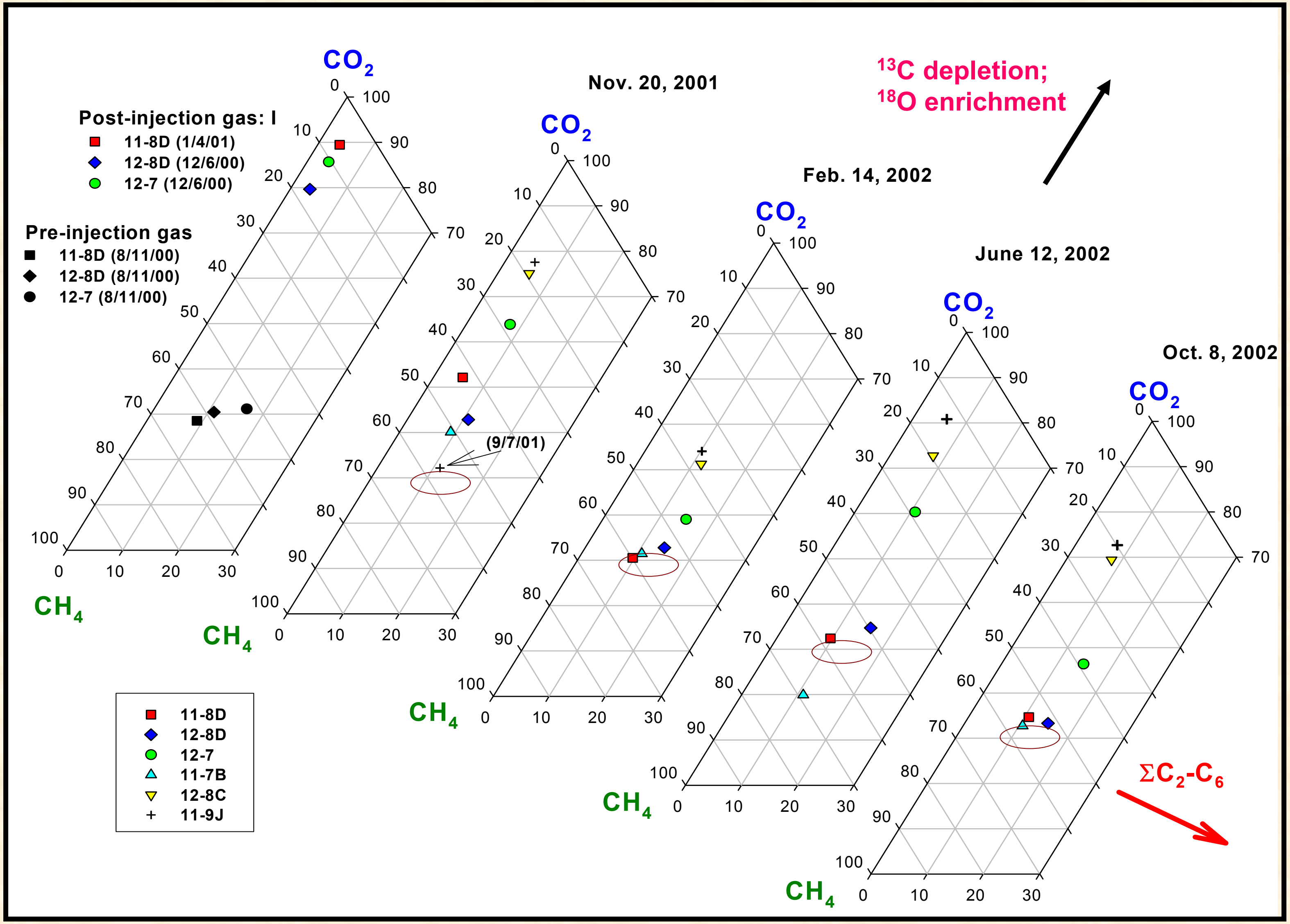
First sampling (12/6/00 &1/4/01)
(wells: 12-7, 12-8D, 11-8D)

2nd sampling (11/20/01); 3rd sampling (2/14/02)

4th sampling (6/12/02); 5th sampling (10/8/02)

Wells sampled: 11-7B, 11-8D, 11-9J, 12-7, 12-8C, 12-8D

Variations in Gas Chemistry versus Time



Based on mole %

Stable Isotope Notation

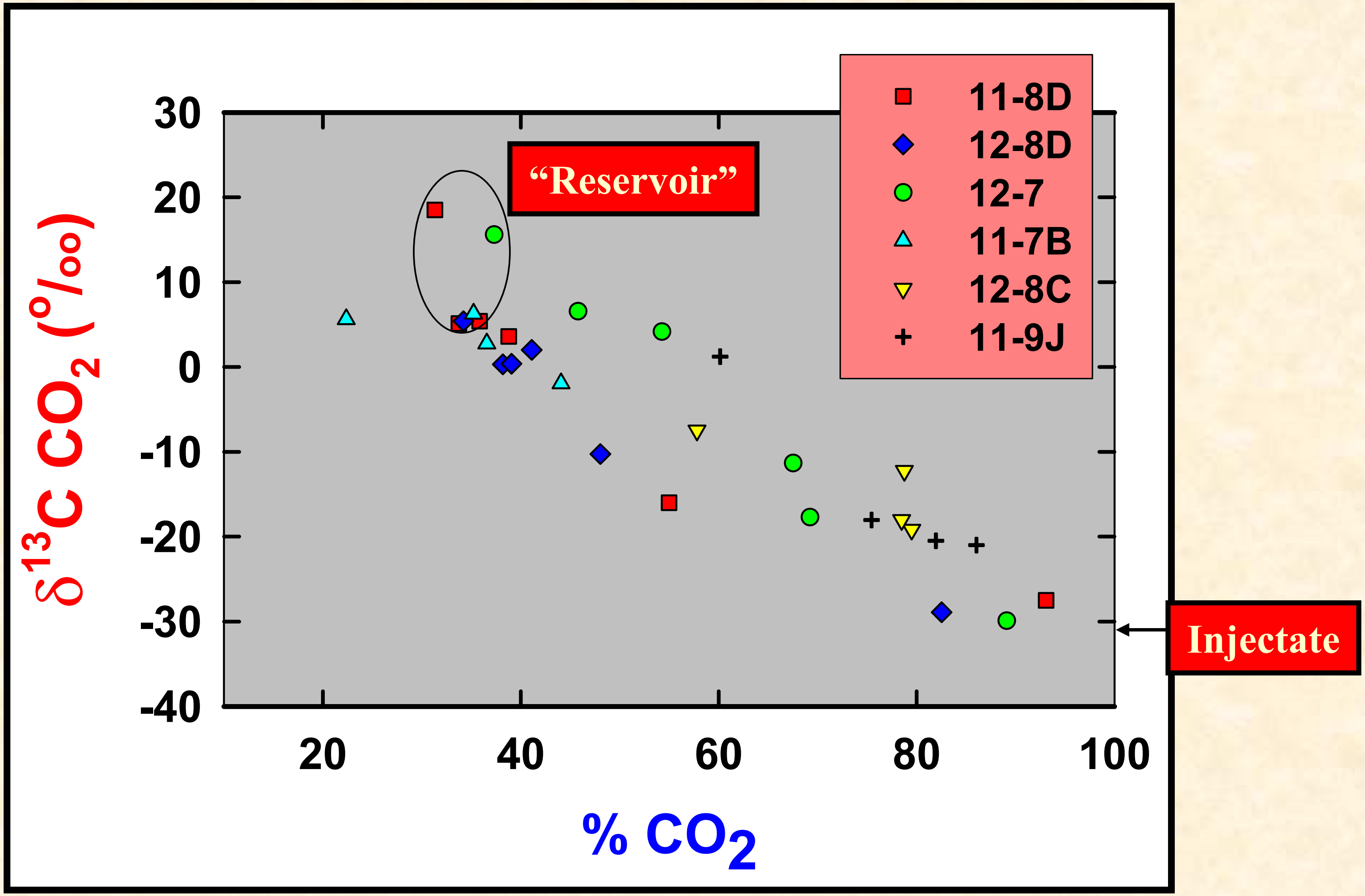
$$\delta\ (‰) = \left(\frac{R_x - R_{std}}{R_{std}}\right) 10^3$$

where $R_x = (D/H)_x$, $(^{13}C/^{12}C)_x$, $(^{18}O/^{16}O)_x$

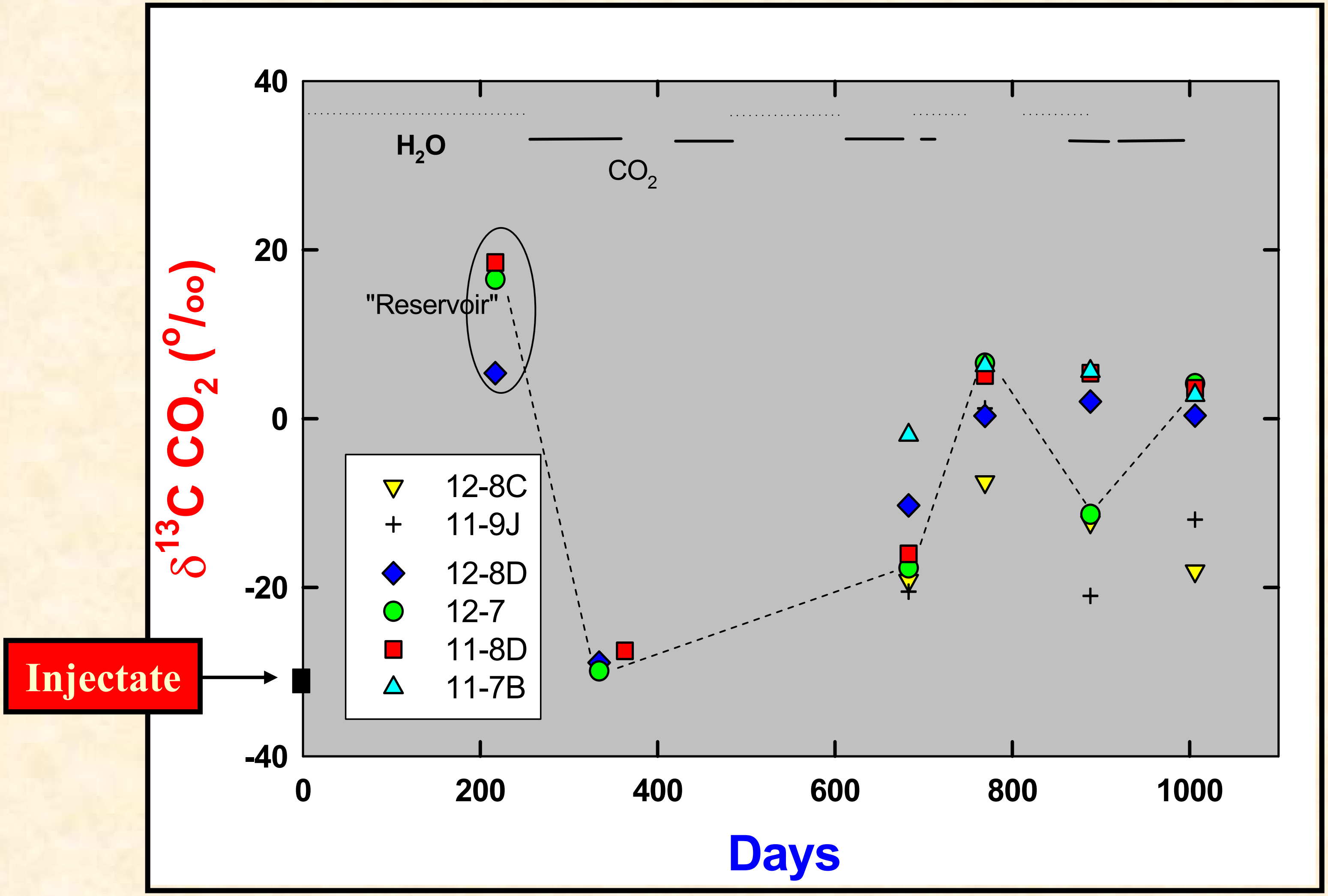
and R_{std} is the corresponding ratio in a standard

Gas Chromatograph-Combustion Isotope Ratio Mass Spectrometry

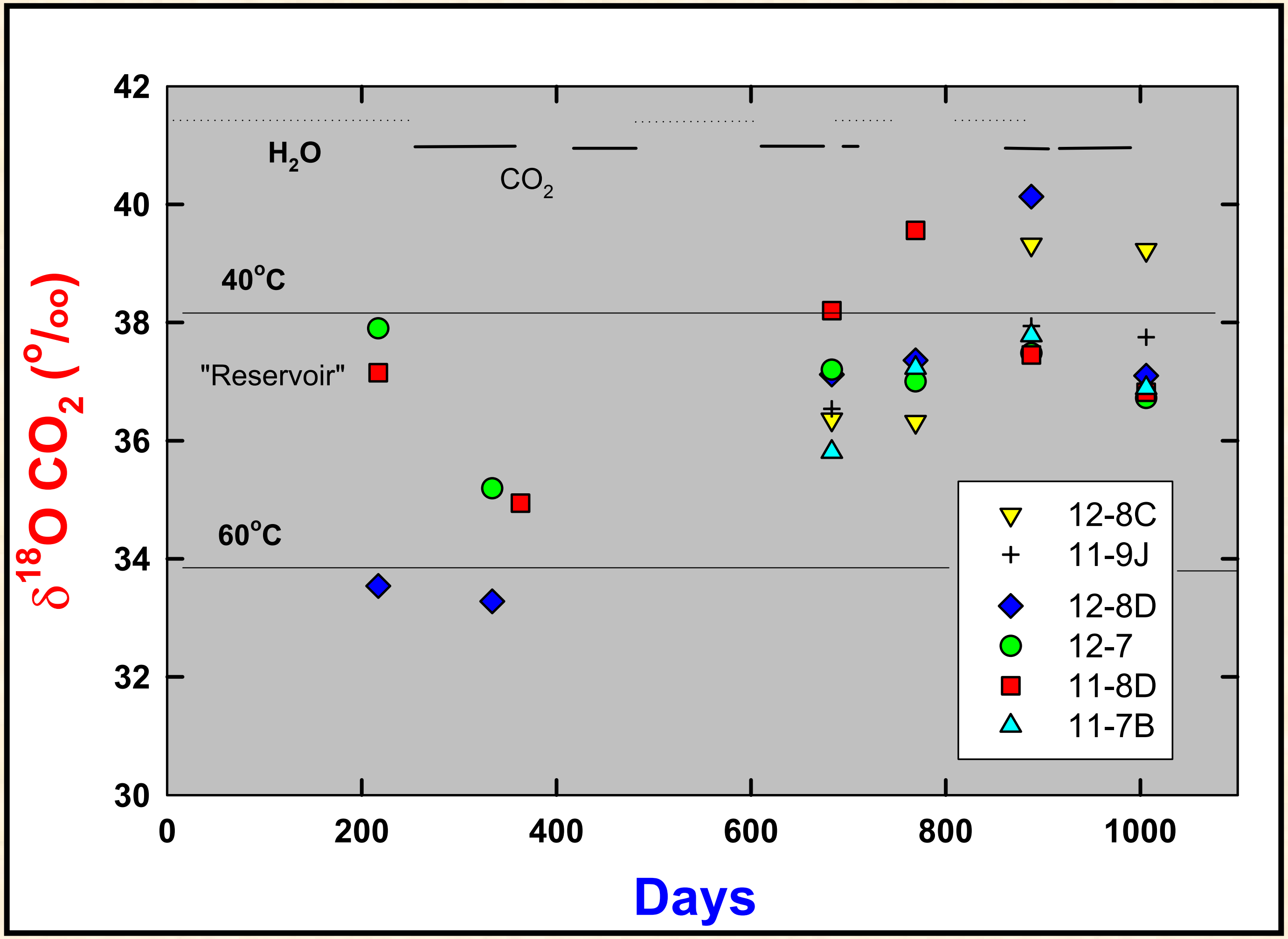
Carbon Isotope Composition of CO_2 versus % CO_2



Carbon Isotope Composition of CO_2 versus Time



Oxygen Isotope Composition of CO_2 versus Time



Injectate CO_2 = -1 to -2°/oo

Reservoir brines = -1 °/oo

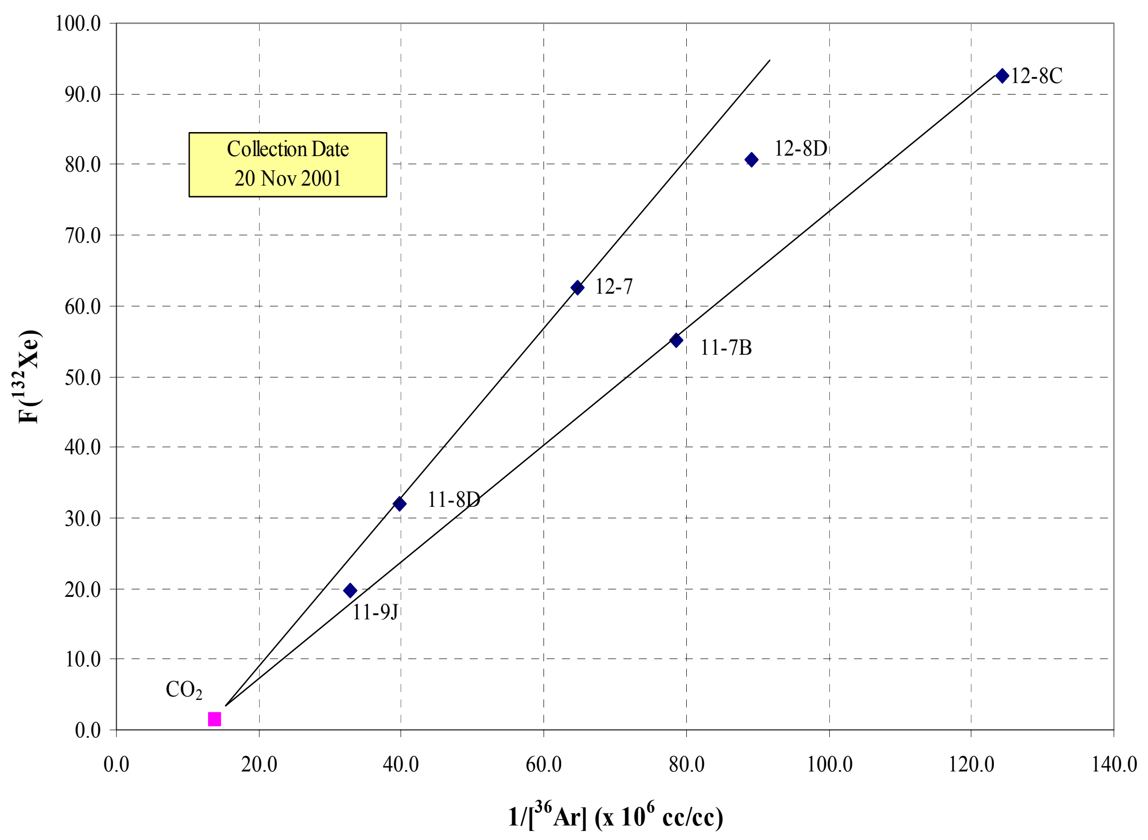
Preliminary Noble Gas Chemistry and Isotopes

Noble gases and their isotopes have been measured in samples obtained 11/20/01 during a CO_2 flood, 683 days after the beginning of the water injection in the field.

Plot shows F(Xe) where Xe/Ar ratio has been normalized to atm. ratio as a function of the inverse partial pressure of Ar.

High (>>1) F(Xe) ratios are indigenous to the reservoir.

The compositional trends confirms mixing between indigenous reservoir fluids and the injected CO_2.



CO_2 flood: sampled 11/20/01 (683 days)

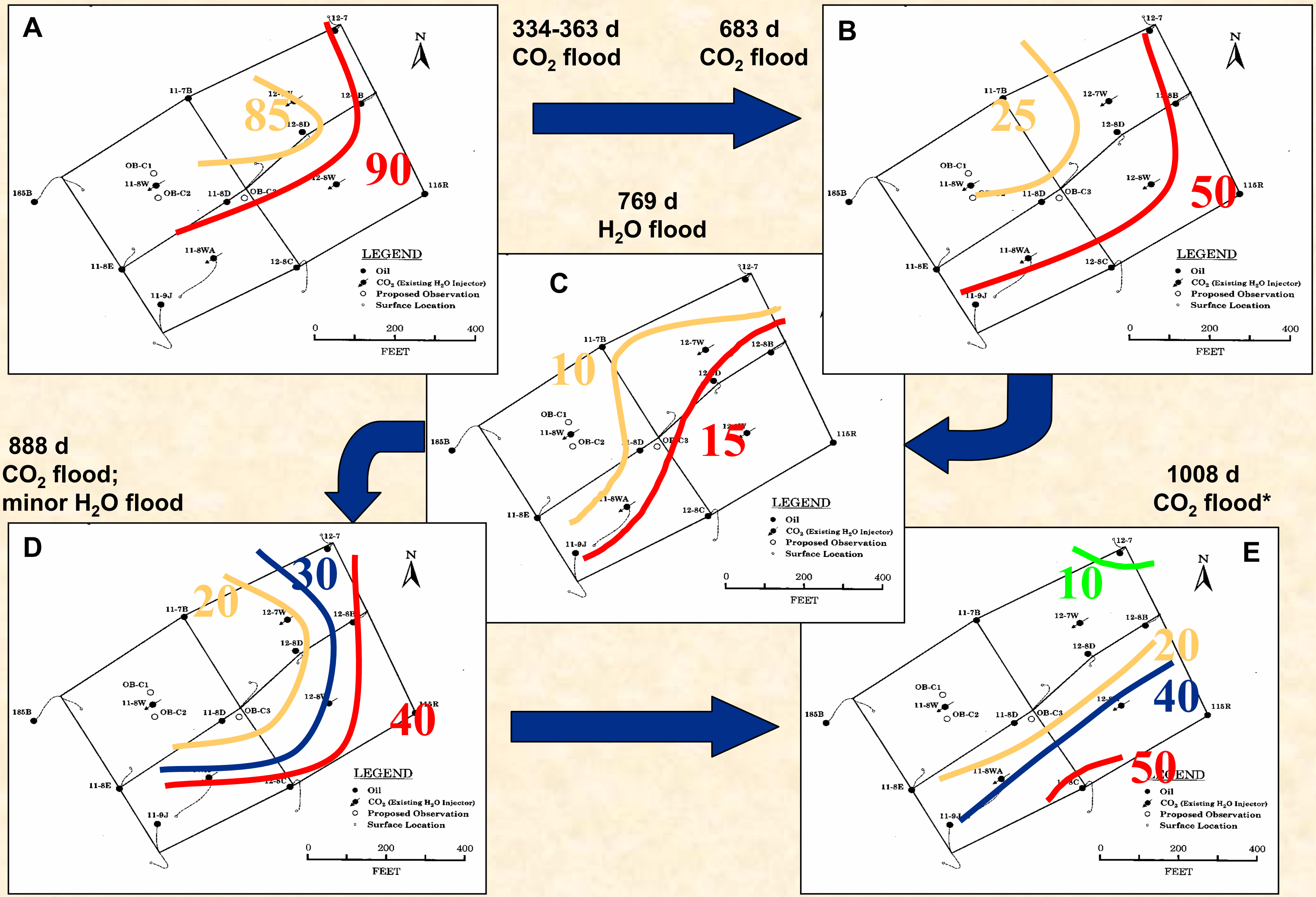
Mass Balance Relationships can be used to Quantify the Contribution of CO_2 Injectate to the System

Mass balance relation using gas chemistry is given as:

$$X_{CO_2}^{inj} = \frac{Y_{CO_2}^{mix} - Y_{CO_2}^{res}}{(1 - Y_{CO_2}^{res})}$$

Mass balance relation using isotope/gas chemistry is given as:

$$X_{CO_2}^{inj} = \frac{(Y_{CO_2}^{mix} \cdot \delta^{13}C_{CO_2}^{mix}) - (Y_{CO_2}^{res} \cdot \delta^{13}C_{CO_2}^{res})}{\delta^{13}C_{CO_2}^{inj} - (Y_{CO_2}^{res} \cdot \delta^{13}C_{CO_2}^{res})}$$



* CO_2 flood ended 23 d before sampling

Preliminary Conclusions from Lost Hills Study

(1) ^{13}C isotopes indicate that indigenous reservoir CO_2 is significantly different from the CO_2 injectate by as much as 50 per mil.

(2) The contribution of CO_2 injectate to the system can be quantified by mass balance modeling of gas and isotope (stable; noble) chemistry.

(3) This approach clearly demonstrates that increases in CO_2 and more depleted ^{13}C values correlate with periods of CO_2 injection.

(4) During water flood events, the CO_2 gas contents decrease and the ^{13}C values in CO_2 return to more “reservoir-like” in magnitude.

(5) Certain wells communicate with the injection wells far more readily than others, which may be controlled, in part, by faults that strike NE-SW.

(6) Disagreement between the % contribution of injectate estimated from gas chemistry vs. isotopes can be used to assess interaction among gas-rock-fluid.

(7) Oxygen isotope values in CO_2 demonstrate that the gas has equilibrated with reservoir water in the T range of ~40 - 60^{o}C.