Risks and Benefits of Geologic Sequestration of Carbon Dioxide - How Do the Pieces Fit?*

Susan Hovorka[1]

Search and Discovery Article #80058 (2009)
Posted September 30, 2009

*Adapted from oral presentation at AAPG Annual Convention, Denver, Colorado, June 7-10, 2009

[1]Bureau of Economic Geology, University of Texas at Austin, Austin, TX (susan.hovorka@beg.utexas.edu)

Abstract

Geologic sequestration of CO_2 as part of the carbon capture and storage (CCS) process has proven potential to provide the needed reduction in atmospheric emissions. Before this process is accepted as a dominant part of the solution, it is important to consider the possibility that hazards resulting from this action will create unacceptable damages. Capture of CO_2 from point sources would also create a significant revenue stream as CO_2 could be sold for enhanced oil recovery (CO_2 EOR). The benefit of CO_2 EOR to the economy would be significant, but it is important to examine how CO_2 EOR fits into the carbon balance and the long-term solution.

Techniques to assure that a sequestration site will retain stored CO_2 for geologically significant time periods include site characterization, modeling, and monitoring. Risks from failure of a sequestration site to perform properly include leakage to protected groundwater, impact on ecosystems, return to the atmosphere, and damage to other subsurface resources (gas reservoirs in particular). Assessment shows that maximum damage is limited and moderate, and that risks can be reduced by implementing a permitting process that favors high quality sites with adequate monitoring. CO_2 EOR is proposed as a valuable first step to prepare for following even larger volume sequestration in brine-bearing permeable units below and isolated from fresh water.

Bureau of Economic Geology Centennial Lecture Program

Risks and Benefits of Geologic Sequestration of Carbon Dioxide-How do the Pieces Fit?

Susan D. Hovorka
Gulf Coast Carbon Center
Bureau of Economic Geology,
Jackson School of Geosciences,
The University of Texas at Austin

100 Years of Scientific Impact

1909-2009

Bureau of Economic Geology - 100 Years of Scientific Impact

- First organized research unit of The University of Texas at Austin
- State Geological Survey of Texas
- One of three units of the

  Jackson School of Geosciences

- Staff—140, includes 80 researchers
  - Fossil energy
  - Environment
  - Outreach
- Advising state and federal government
  - Maintaining collections for research

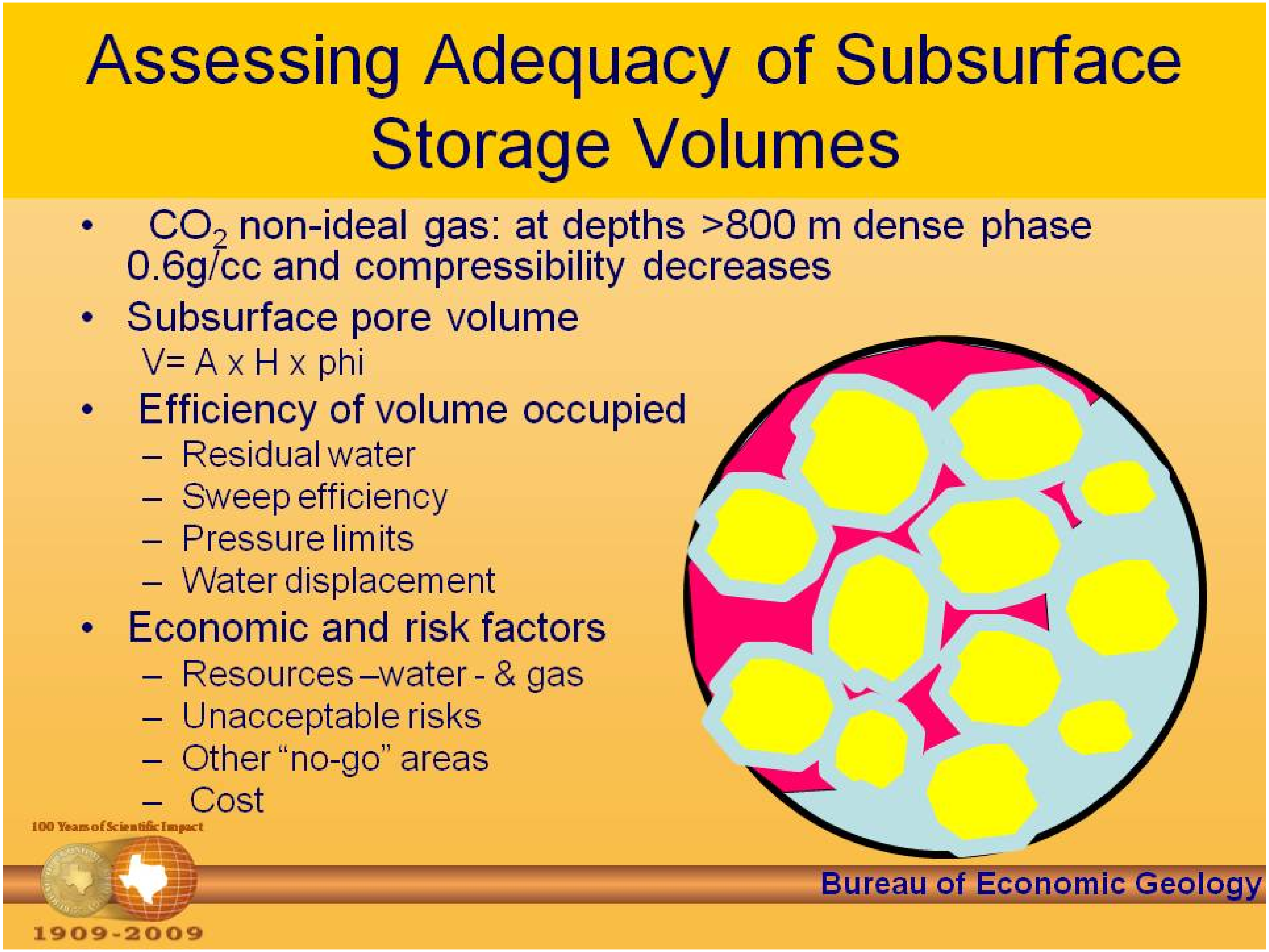
1909-2009

The “pieces” of geologic sequestration:

- Are subsurface volumes adequate to sequester the volumes needed to impact atmospheric concentrations?

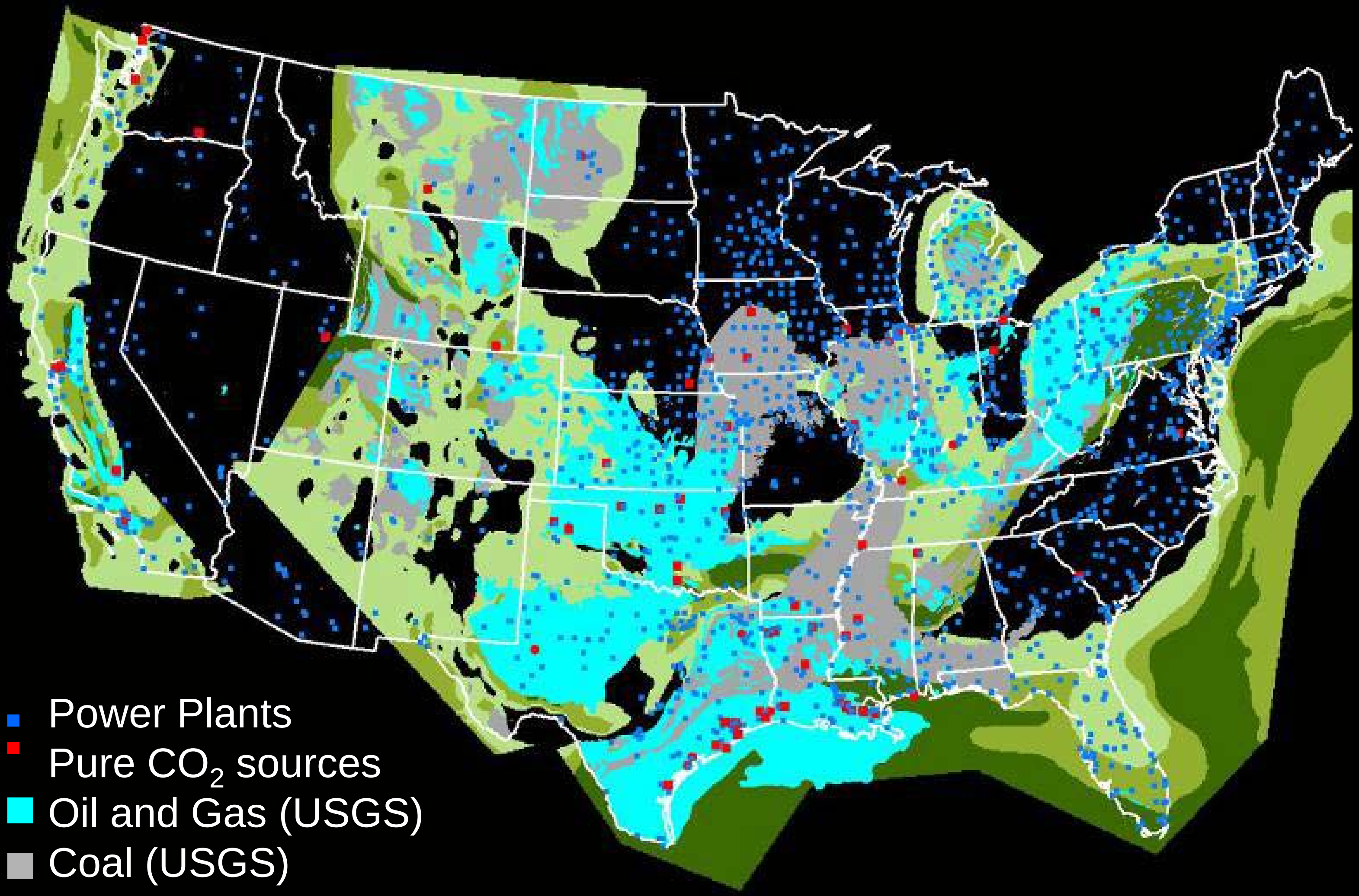
- Is storage security adequate to avoid inducing hazards and to benefit atmospheric concentrations?

- How does CO_2 EOR fit?



Compression is of great value in creating enough space for storage. However, we really cannot spread CO_2 evenly as a 0.4 mm sheet underground across the US.

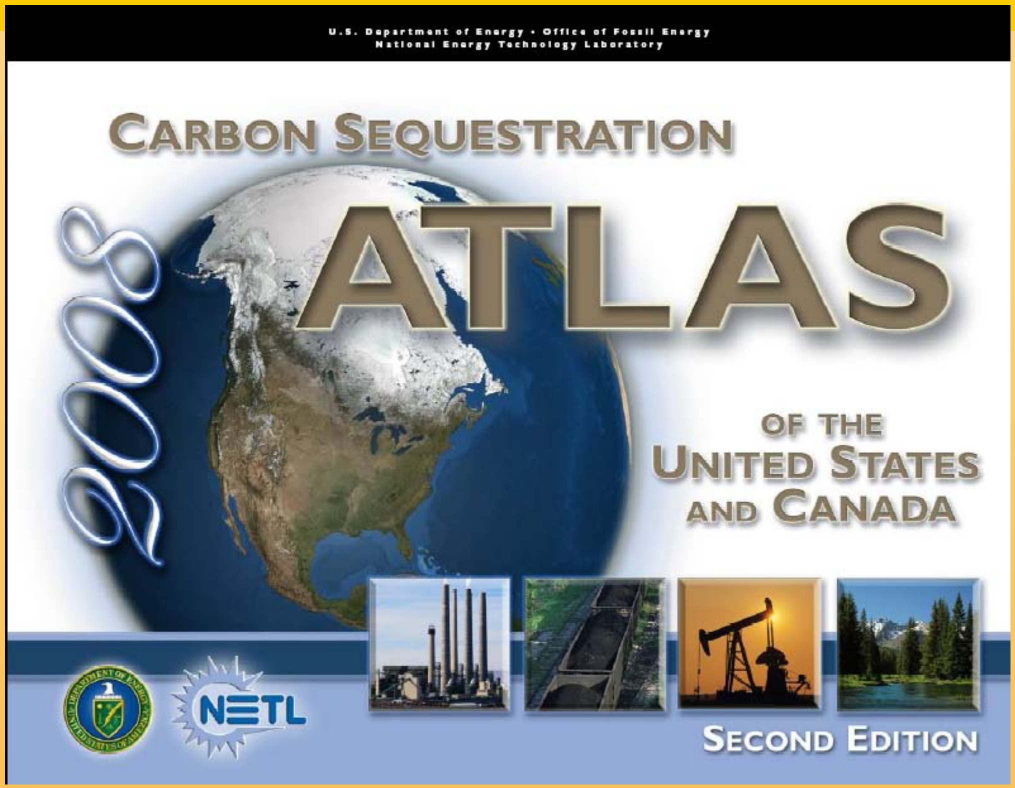
US CO_2 Sources and Sinks



- Power Plants
- Pure CO_2 sources
- Oil and Gas (USGS)
- Coal (USGS)
- Brine Aquifer> 1000m

Compiled from USGS data

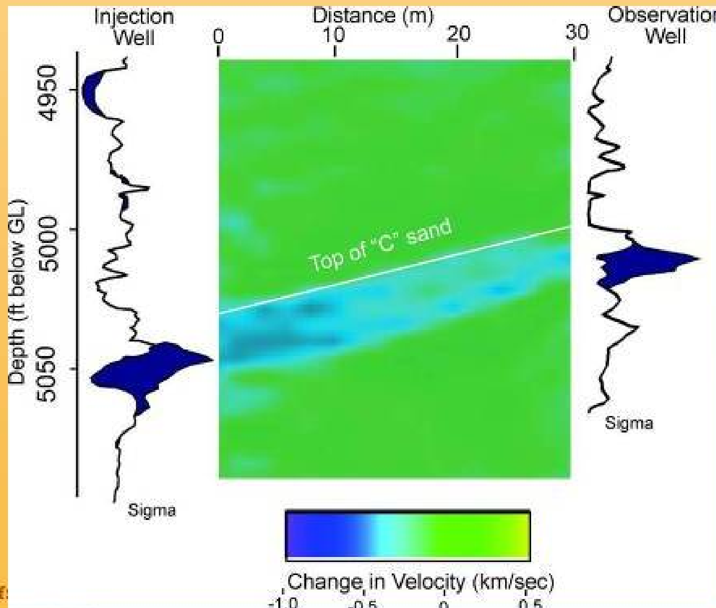
DOE NATCARB Atlas

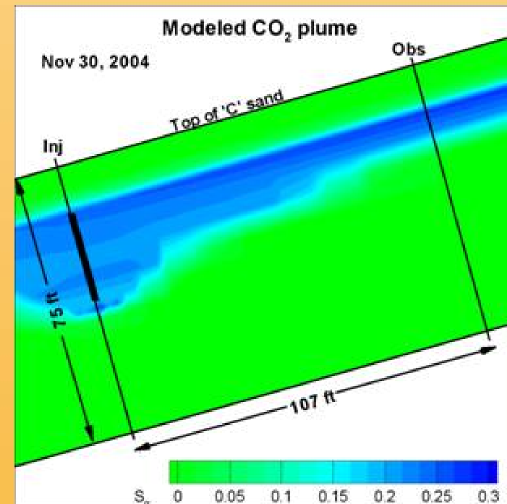


Saline aquifer

US current annual CO_2 emissions 7 billion metric tons
Estimated US storage volume 3,600 billion metric tons

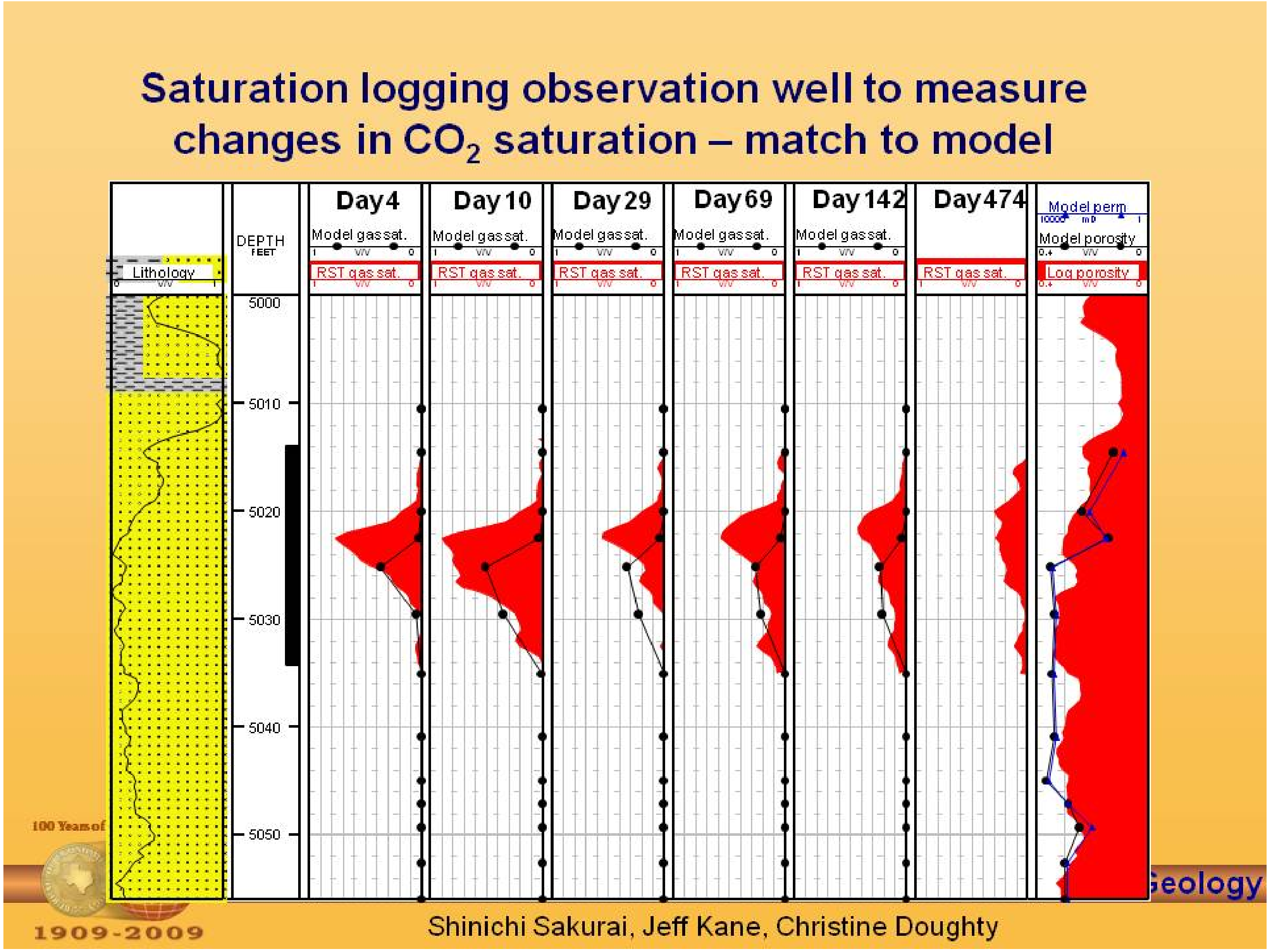
Documenting permanence of residual trapping CO_2 Saturation Observed with Cross-well Seismic Tomography vs. Modeled





Tom Daley and Christine Doughty LBNL

The plume imaged with cross–well seismic tomography is shown on the left. The RST log traces for the injection and observation wells are shown with the change in Sigma from pre-injection to maximum saturation shown in dark blue. The white line shows the seal that forms the top of the injection zone. The tomogram in this case shows CO_2 breakthrough, although the attenuation in the plume is stronger than observed with wireline logs. The diagram on the right shows the modeled geometry of the plume. With the blue colors showing the predicted CO_2 saturation. Comparison of the observed and predicted shows that heterogeneity is higher than modeled and more Co_2 was retained near the injection well (buoyancy effects appear to be more strongly expressed than they are in the model).



Saturation logging using Schlumberger RST measures changes in in saline brine saturation, and by inverse the displacement of brine by CO_2 during injection by drainage, and imbibition as CO_2 moves upgradient under gravity. Red areas show the measured gas saturation with depth in the observation well . You remember that CO_2 was first detected at the observation well on the 3rd day after start of injection, and this log measures the build-up on day 4. Day 10, end of injection, was close to maximum saturation. Post injection, the CO2 is decreasing as the plume spreads updip. The black lines show the modeled concentration of CO_2. In this realization, the CO_2 moved outward more rapidly than predicted, so the build-up during injection is more rapid. There is an offset in the location of the development of the plume, because reservoir heterogeneity was higher than modeled. It looks also that the buoyancy is more effective than modeled. In general, the match is quite good. Importantly, the CO_2 has not migrated laterally faster than predicted. Our current simulations and designed experiment will improve this match to document residual saturation.

Adequacy of Storage Security - Perceived Risks

Speculation about risks from geologic sequestration of CO_2 has been dominated by concerns such as:

- Escape leading to asphyxiation
- Escape leading to toxicity of drinking water
- Induced earthquakes

Perceived risk: CO_2 escape leading to asphyxiation

"CO_2 releases are deadly for communities:"

"….If the gases leak out they are **deadly to all living creatures** since CO_2 is lighter than air, and displaces air. When the gases are released they stay close to the ground, displace oxygen, and **suffocate everything in its path**. Two events in the relative recent history of CO_2 emissions from natural sources underscore the community health hazard created if CO_2 were to escape from sequestration:

- The largest recent disaster caused by a large CO_2 release from a lake occurred in 1986, in Cameroon, central Africa. A **volcanic crater-lake known as Nyos** belched bubbles of CO_2 into the still night air and the gas settled around the lake's shore, where it killed 1800 people and countless thousands of animals.
- The 15 August 1984 gas release at Lake Monoun that killed 37 people (Sigurdsson and others, 1987) was attributed to a rapid overturn of lake water with CO_2 that had been at the bottom coming to the surface, triggered by an earthquake and landslide. The emission of around 1 cubic kilometer of CO2 devastated a local village and killed animals for miles.

Environmental Justice objection to CA AB 705
Letter* to Assembly member Hancock, April, 2008
(emphasis mine)

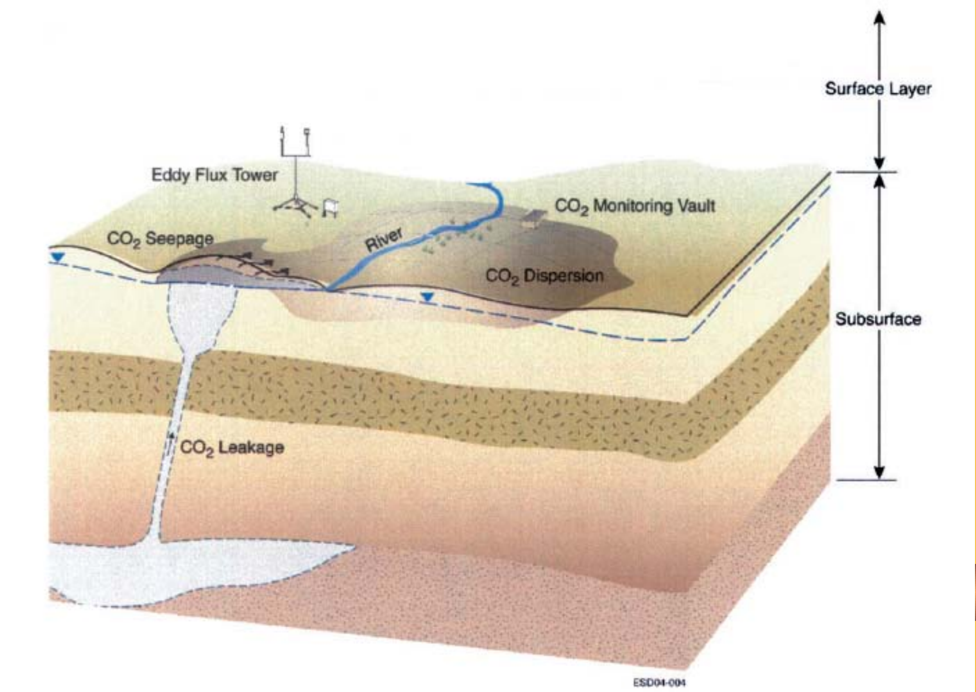
Risk Myth Explained: escape will not lead to asphyxiation

- CO_2 is a well known confined space risk – CO_2 is 1/3 denser than air (N_2 and O_2) therefore will effectively displace air from a tank, mine, cave, or crater.
- Air and CO_2 are miscible with no viscosity contrast, so CO_2 rapidly disperses in an open setting, on a slope, with breeze or circulation.

Cool CO_2 pooling on the ground in the still night air but at low concentrations Frio brine pilot, Houston, TX

–

No Danger



Topography or wind will cause CO_2 to spread and mix
Oldenburg and Unger, 2004, Vadose Zone Journal 3:848-857
No danger

Perceived Risk: escape leading to toxicity of drinking water

- "Carbon Sequestration….
  - Will require transformation of CO_2 gas to CO_2 liquid which is acidic
  - CO_2 liquid's acid nature is corrosive to the underground environment, contaminating the ground and would eventually leach to the surface.
  - When CO_2 leaches up to the surface, it will contaminate underground fresh drinking water aquifers, lakes, rivers, and the ocean"

Excerpts from "Carbon Sequestration Public Health and Environmental Dangers"
Researched by Coalition For a Safe Environment

`

Risk Myth Explained: CO_2 dissolved in aquifers has little ability to damage water quality

CO_2 dissolves in water = dissolution trapping

$CO_2(g) + H_2O \leftrightarrow H_2CO_3(aq)$
$H_2CO_3(aq) \leftrightarrow HCO_3(aq)^- + H^+$
$HCO_3(aq)^- \leftrightarrow CO_3(aq)^{--} + H^+(aq)$

Acid= tang in carbonated water

Acid is buffered by rocks

increase Ca, Mg, Fe, Na, Si, CO_3, SO_4, etc. in solution

What could the etc. be?

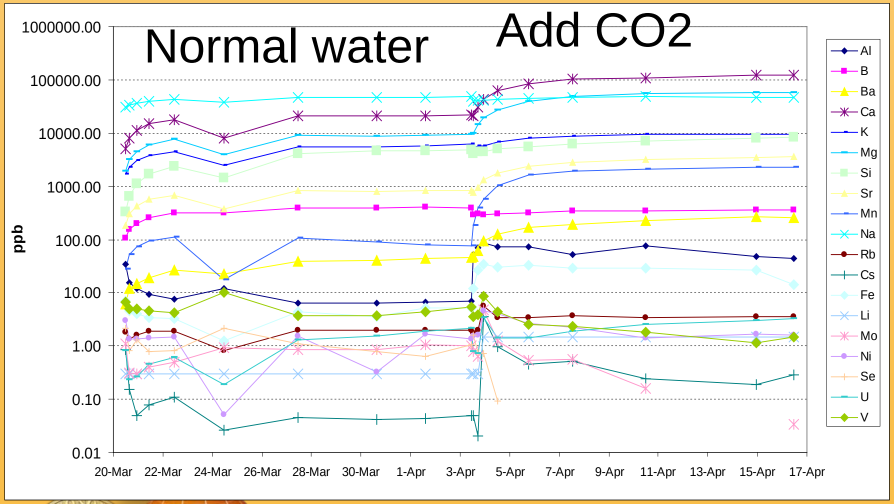
Mn, As, Pb, Sr, Ni, Zn, Ag, U, Ni, Cd……

So would leaked CO_2 be a risk to drinking water?

Carbonated water…

Otherwise known as sparkling water. Has variable mineral content but is potable

Results of adding CO_2 to aquifer system



- Add CO_2 to typical aquifer rocks + fresh water – increase in dissolved minerals – proportional to constituents already in water.
- No damage to fresh water from 37 years of CO_2 EOR at SACROC

GCCC staff Rebecca Smyth, Katherine Jiemin Lu, Changbing Yang

Perceived Risk: Injection causing earthquakes

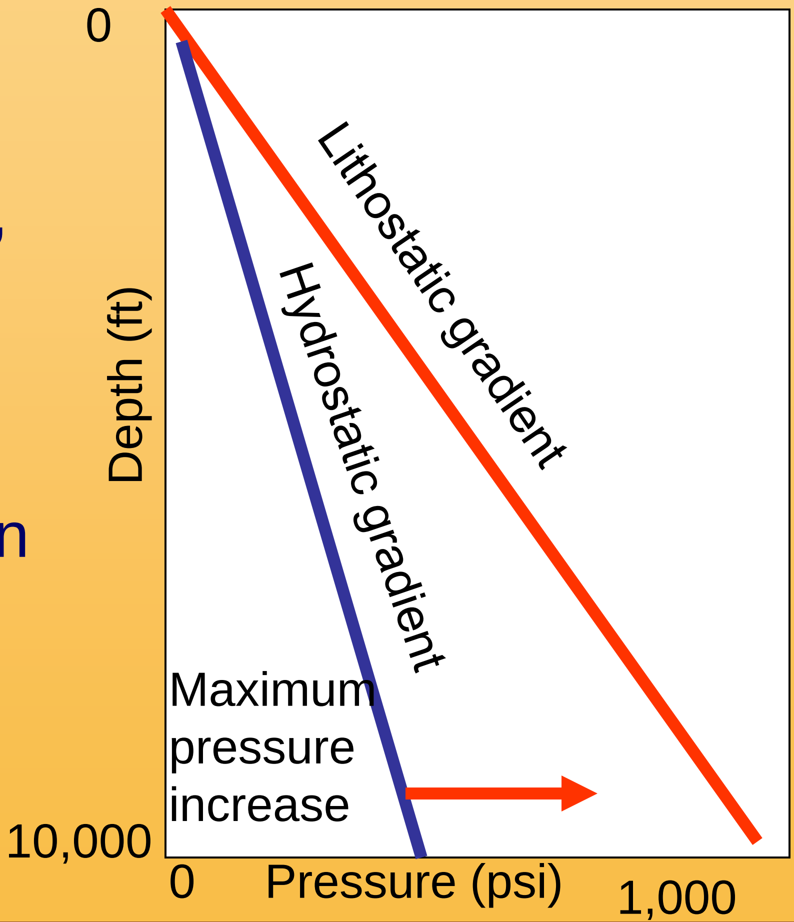
- In the first *Superman* movie, supervillain Lex Luthor plans to trigger a massive, California-detaching earthquake by detonating a couple of nuclear weapons in the San Andreas Fault.
- Crazy Lex! That scheme never would have worked, geologists will tell you. But, if he'd been serious about **creating an earthquake**, there are ways he could have actually done it. He would just have to **inject some liquid (as some carbon-sequestration schemes propose)** deep into the Earth's crust, or bore a few hundred thousand tons of coal out of a mountain.
- "In the past, people never thought that human activity could have such a big impact, but it can," said Christian Klose, a geohazards researcher at Columbia's Lamont-Doherty Earth Observatory.
- It turns out, actually, that the human production of earthquakes is hardly supervillain-worthy. It's downright commonplace: Klose estimates that 25 percent of Britain's recorded seismic events were caused by people.
- Most of these human-caused quakes are tiny, registering less than four on geologist's seismic scales. These window-rattlers don't occur along natural faults, and wouldn't have happened without human activity -- like mining tons of coal or potash. They occur when a mine's roof collapses, for example, as in the Crandall Canyon collapse in Utah that killed a half-dozen miners last year.

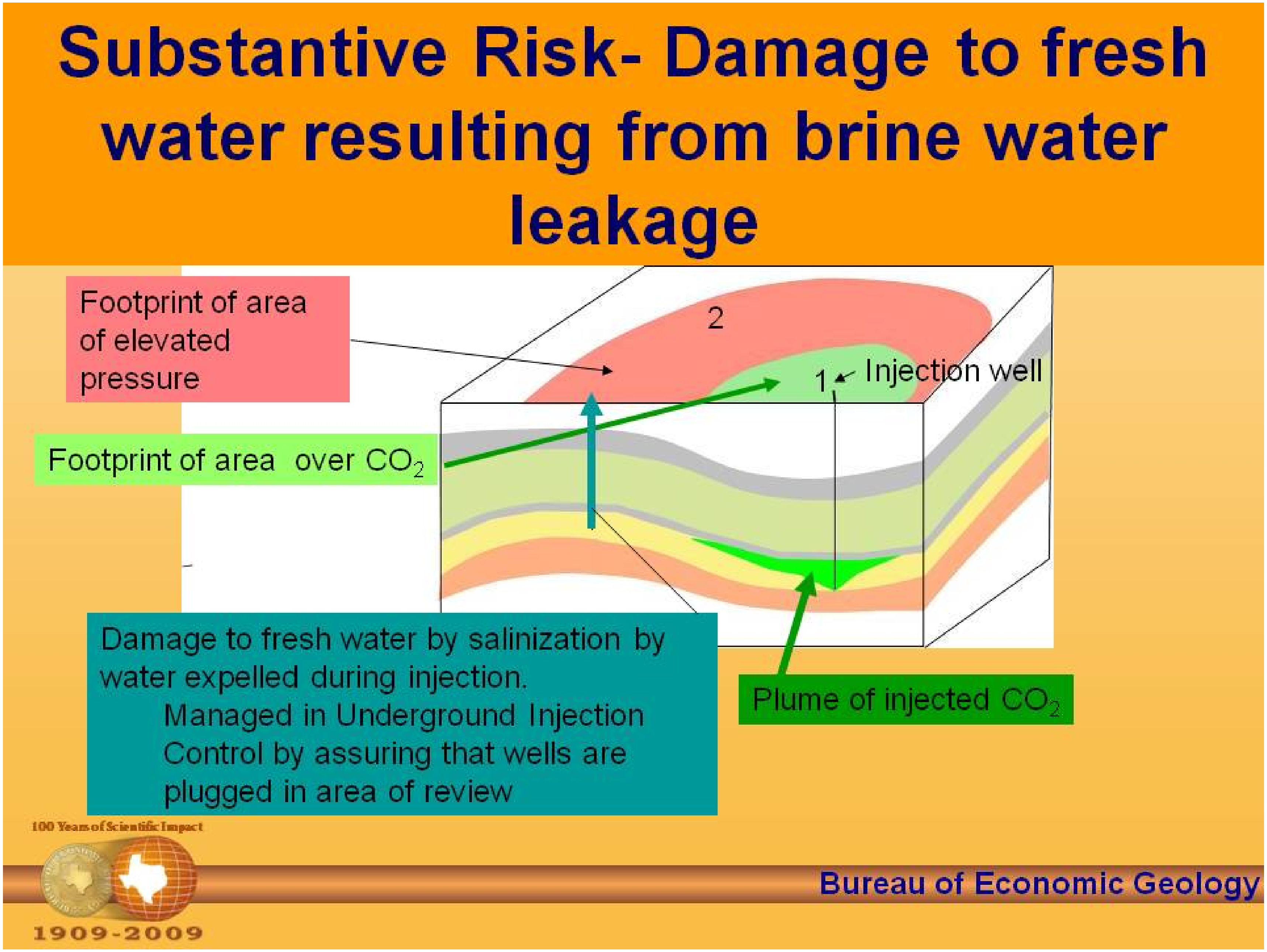
http://blog.wired.com/wiredscience/2008/06/top-5-ways-that.html

Emphasis added

Risk Myth Explained: Limiting injection pressure to avoid earthquakes

- Injection is used to cause “frac jobs” -- for reservoir stimulation. The pressure requirements are calculated, testable, and well documented.
- MASIP = Maximum Allowable Surface Injection Pressure is a main regulation of current EPA underground injection control program.
- Risk of accidental earthquake can be avoided by regulations in place.

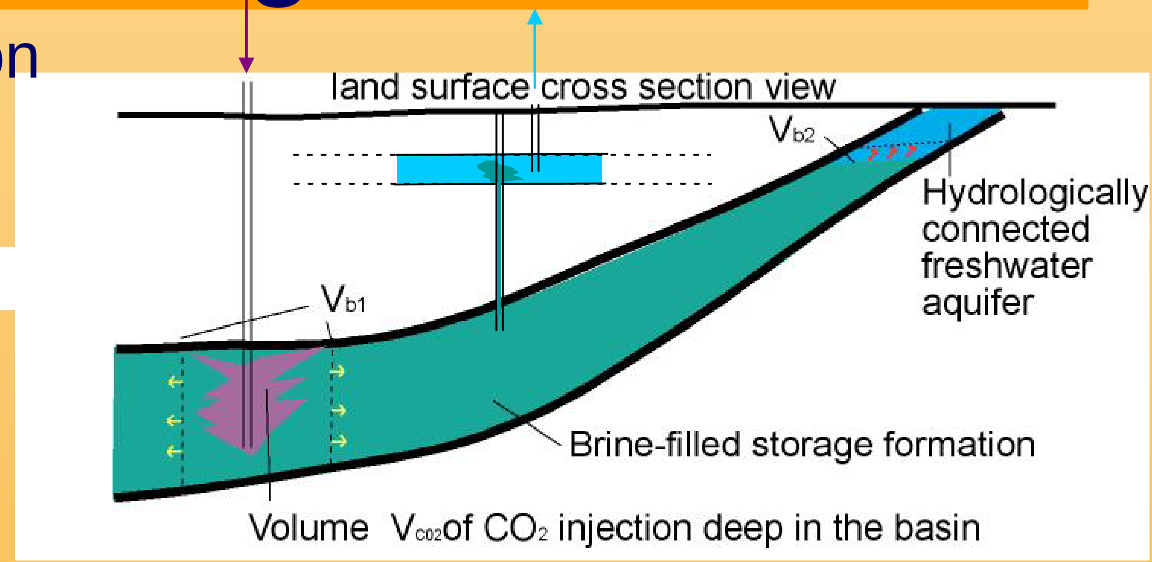




Many people in CCS have been concerned only with the issues of CO_2 leakage, but brine leakage resulting from elevated pressure is of concern also. Timing and process of leakage are somewhat different, but sources of risk (wells, flaws in seals) are similar. Good characterization is required to predict both parts of areas of review.

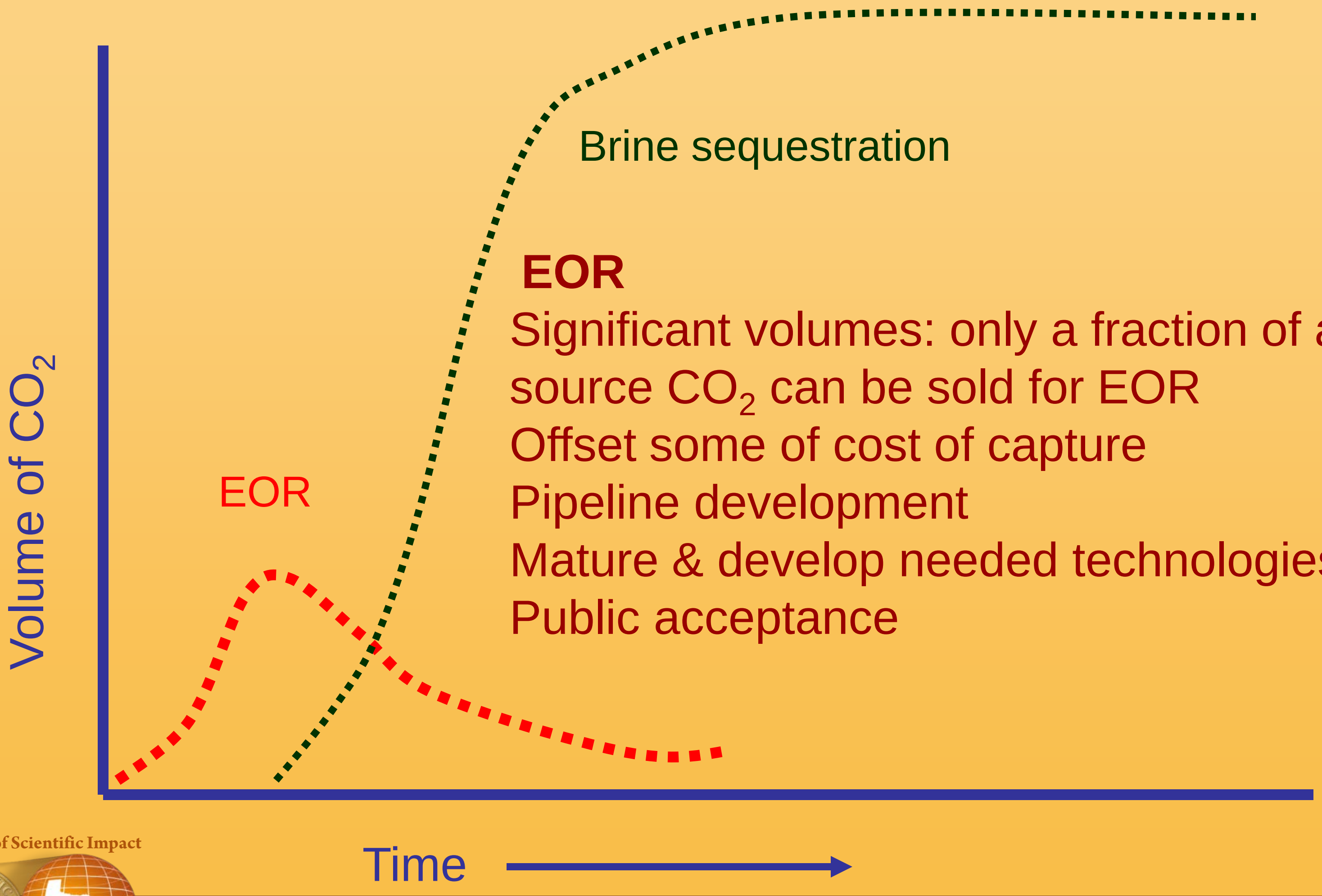
Substantive Risk- Damage to fresh water resulting from brine water leakage

Current GCCC work on Prediction of AoR and far field pressure



- Damage to surface freshwater (lakes) by increased acidity should CO_2 leak – e.g., fish kills when volcanogenic CO_2 leaked at Mammoth Lakes, CA.

Role of EOR in Sequestration



EOR

Significant volumes: only a fraction of all point source CO_2 can be sold for EOR

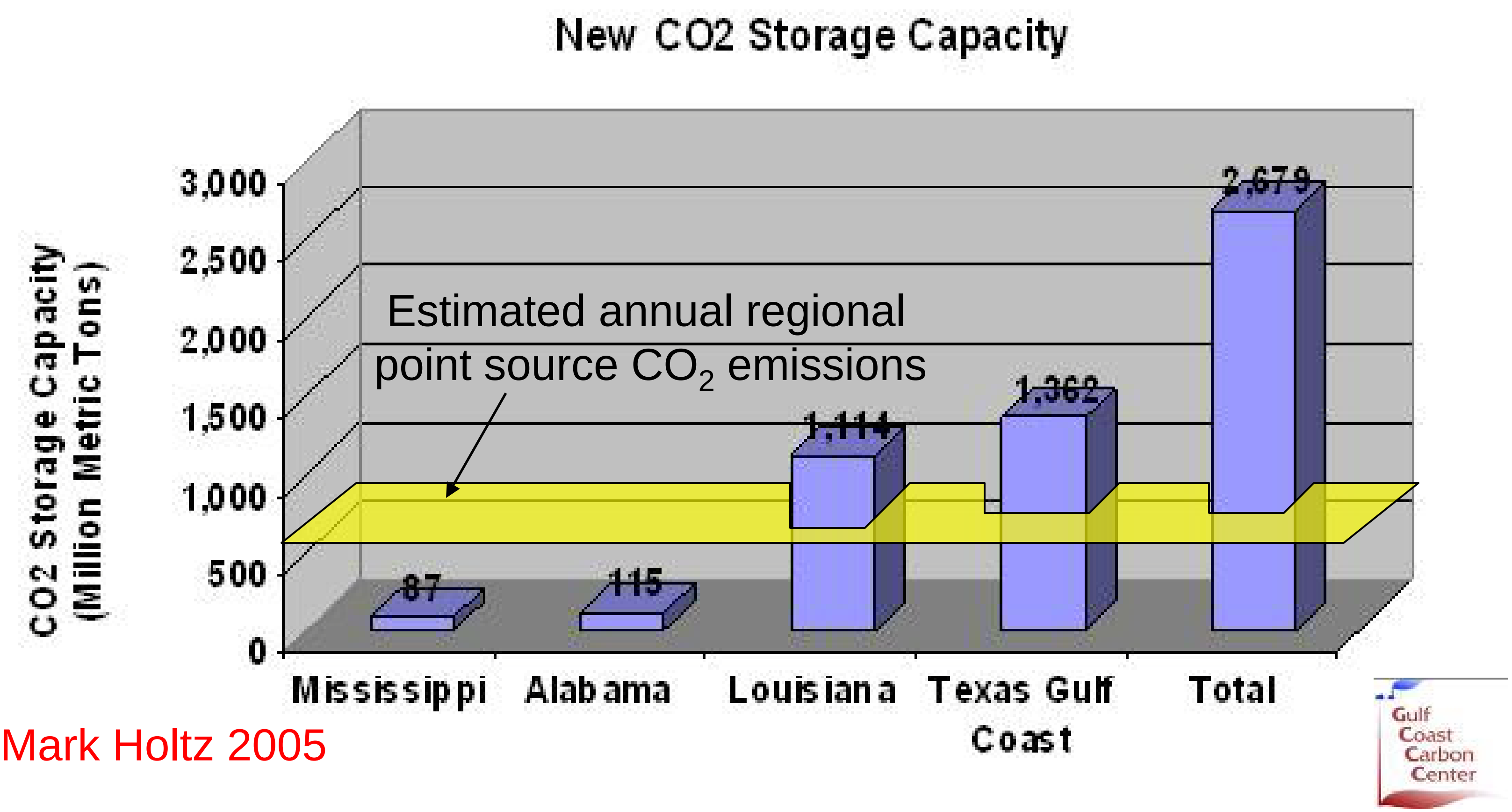
Offset some of cost of capture

Pipeline development

Mature & develop needed technologies

Public acceptance

CO_2 Sequestration Capacity in Miscible Oil Reservoirs along the Gulf Coast



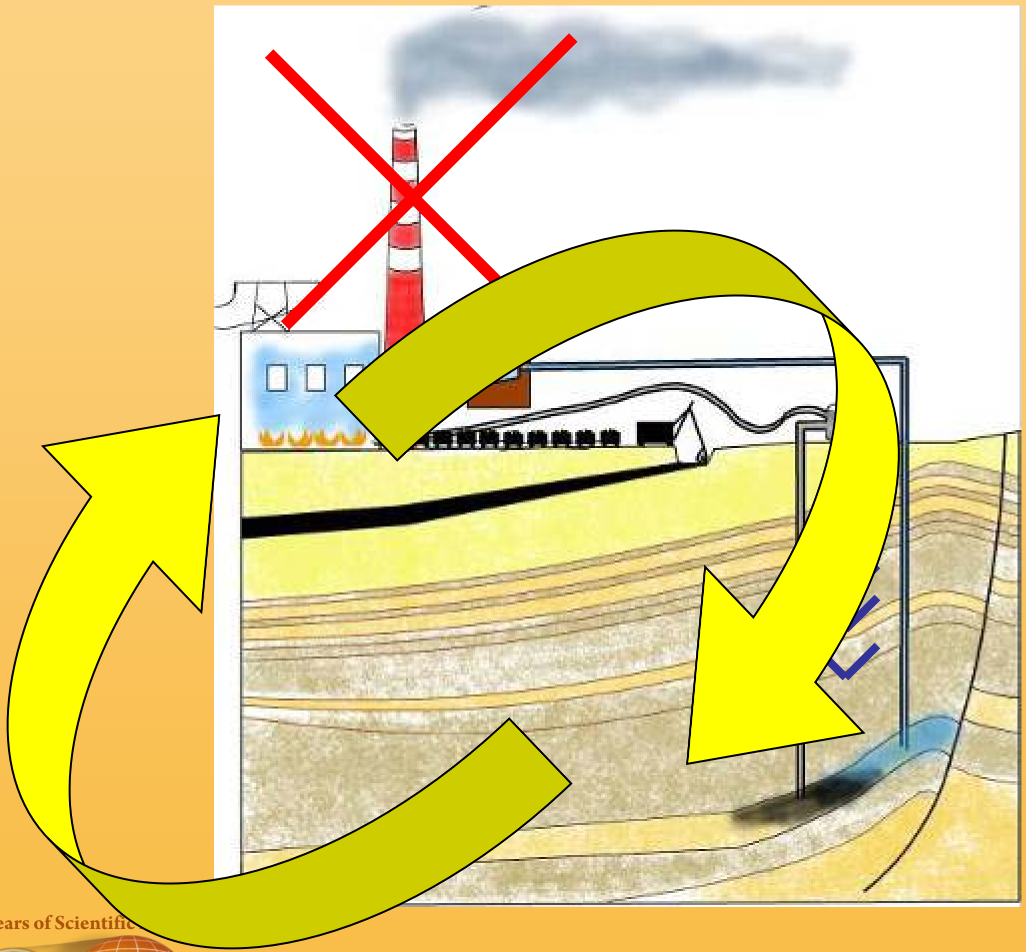
Mark Holtz 2005

Conclusions

- Subsurface volumes are adequate to sequester the volumes needed to impact atmospheric concentrations
- Using available technology, adequate storage security can be assured to avoid inducing hazards and to benefit atmospheric concentrations

Gulf Coast Carbon Center

Geologic Sequestration of Carbon – Put it back



Carbon extracted from coal or other fossil fuel…

Returned into the earth where it came from

Acknowledgements

- **Gulf Coast Carbon Center researchers:** **Susan Hovorka, Jiemin Lu, JP Nicot, Katherine Romanak, and Changbing Yang; BEG Associate Director: Ian Duncan; BEG Director: Scott Tinker**

Reference

Oldenburg, C.M., and A.J.A. Unger, Coupled vadose zone and atmospheric surface-layer transport of CO_2 from geologic carbon sequestration sites: Vadose Zone Journal, v. 3, p. 848–857.