Geological Sequestration of Greenhouse Gases: Opportunities for Industry Academe Research Partnerships

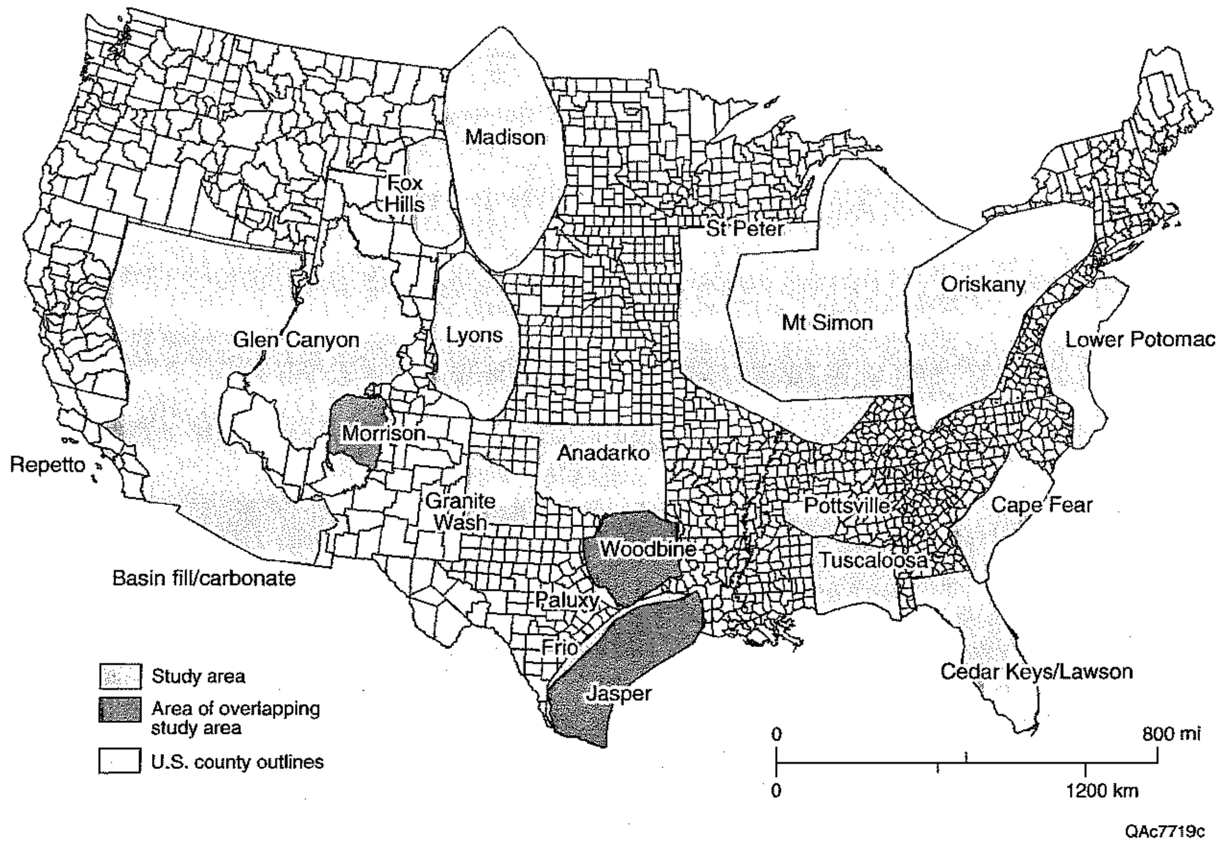
GCCC Digital Publication Series #01-02

P. R. Knox
S. D. Hovorka

Keywords:
Geologic Sequestration- Overview, Brine-Bearing Formations- Overview, EOR in Mature Fields

Cited as:
Knox, P. R., and Hovorka, S. D., 2001, Geological sequestration of greenhouse gases: opportunities for industry academe research partnerships: Houston Geological Society Bulletin, v. 43, no. 5, p. 26–33. GCCC Digital Publication Series #01-02.

Geological Sequestration of Greenhouse Gases: Opportunities for Industry Academe Research Partnerships



Abstract

The causes, effects, realities, and projections of global warming are currently highly contested and controversial issues. One approach under consideration by the U.S. Department of Energy (DOE) and the international community that has the potential to reduce atmospheric carbon dioxide (CO_2) concentrations is injection of CO_2 into the subsurface (geologic sequestration). Input from environmental and petroleum geoscientists is needed in order for society to clearly understand the costs and benefits of geologic sequestration.

Geologic targets for CO_2 sequestration include brine-bearing formations (those containing nonpotable waters) and mature or abandoned oil and gas reservoirs. Two possible benefits of geologic sequestration include safe storage of large volumes of CO_2 over long periods of time using existing technologies and also economic benefits from value-added approaches. Value-added approaches include enhanced oil recovery (EOR) through CO_2 flooding as well as injection of CO_2 for pressure maintenance, which might allow simultaneous production from oil legs and gas caps. Sequestration risks include (1) leakage of injected CO_2 through natural pathways (e.g., faults and fractures) over tens or hundreds of years; (2) pressurization of brine-bearing formations, resulting in leakage of brine into shallow, potable water sources; and (3) leakage through improperly abandoned or cemented well bores that could create asphyxiation hazards.

Research projects to identify constraints on successful geologic sequestration have been undertaken, as have initial studies on the economics of using CO_2 from power-plant exhaust streams in EOR. Further research is needed to plan and carry out field-scale pilot projects in both brine-bearing formations and oil and gas reservoirs. Such pilot projects would allow evaluation of engineering, safety, and economic issues.

Introduction

About 85% of U.S. energy comes from the combustion of fossil fuels. On the basis of current economic factors, these fuels are expected to continue to dominate energy sources well into the 21st century. Greenhouse gases, volumetrically dominated by carbon dioxide (CO_2) that is released by energy production (electricity generation, transportation, etc.), are an unavoidable byproduct of this process. In response to evidence suggesting a link between CO_2 emissions and global warming, the U.S. Department of Energy (DOE) has sponsored research into technologies that might reduce CO_2 emissions into the atmosphere.

Why should geologists and oil and gas companies be interested in these activities? Because one of the potential solutions to the CO_2 emission problem is to capture CO_2 from power-plant and refinery emissions and inject it into the subsurface, thereby "sequestering" the gas. Likely subsurface targets include brine-bearing formations adjacent to or under existing oil and gas reservoirs, brine-bearing formations that regionally underlie fresh-water aquifers, abandoned or mature oil and gas reservoirs (enhanced oil recovery, EOR), and unminable coalbeds (enhanced coalbed methane production). Now is the time for interested groups to provide input toward understanding these sequestration methods in order to guide safe practices and to evaluate the potential economic benefits of CO_2 sequestration.

Available Funding - The Carbon Sequestration Program, established by the DOE (U.S. Department of Energy, 2000), published anticipated requirements in funding to achieve its goals through 2015. The purpose of this funding is to build scientific understanding of the geologic sequestration process, upon which a national carbon sequestration policy could be built. To reduce the costs and risks, federal agencies (such as DOE) are partnering with industry, academe, foreign countries, and international organizations. The Bureau of Economic Geology, The University of Texas at Austin, has been involved in past partnering projects that have evaluated controls on geologic sequestration in both brine-bearing formations and abandoned or mature oil and gas reservoirs (through enhanced oil recovery involving CO_2 flooding). Future DOE partnerships regarding geologic sequestration will focus increasingly on modeling and design of field-scale pilot projects to demonstrate technologies and evaluate safety issues. Monitoring of air and aquifers around pilot sites is needed, as is investigation of impacts of CO_2-associated corrosion on pipelines and well casing and tubing and documentation of economic constraints on successful sequestration/EOR projects.

Current and proposed DOE funding supports partnering opportunities that target a combination of method assessment and public outreach, conceptual research and development, bench-scale prototype development, field-scale pilot testing, and large-scale project operation and monitoring. Funding will increase from about $9 million in 2000 to a maximum of $85 million in 2008, tapering off to $40 million in 2015. This funding will address research, not only in geologic sequestration, but also in CO_2 capture and separation technology, terrestrial and oceanic sequestration, advanced concepts, and crosscutting activities.

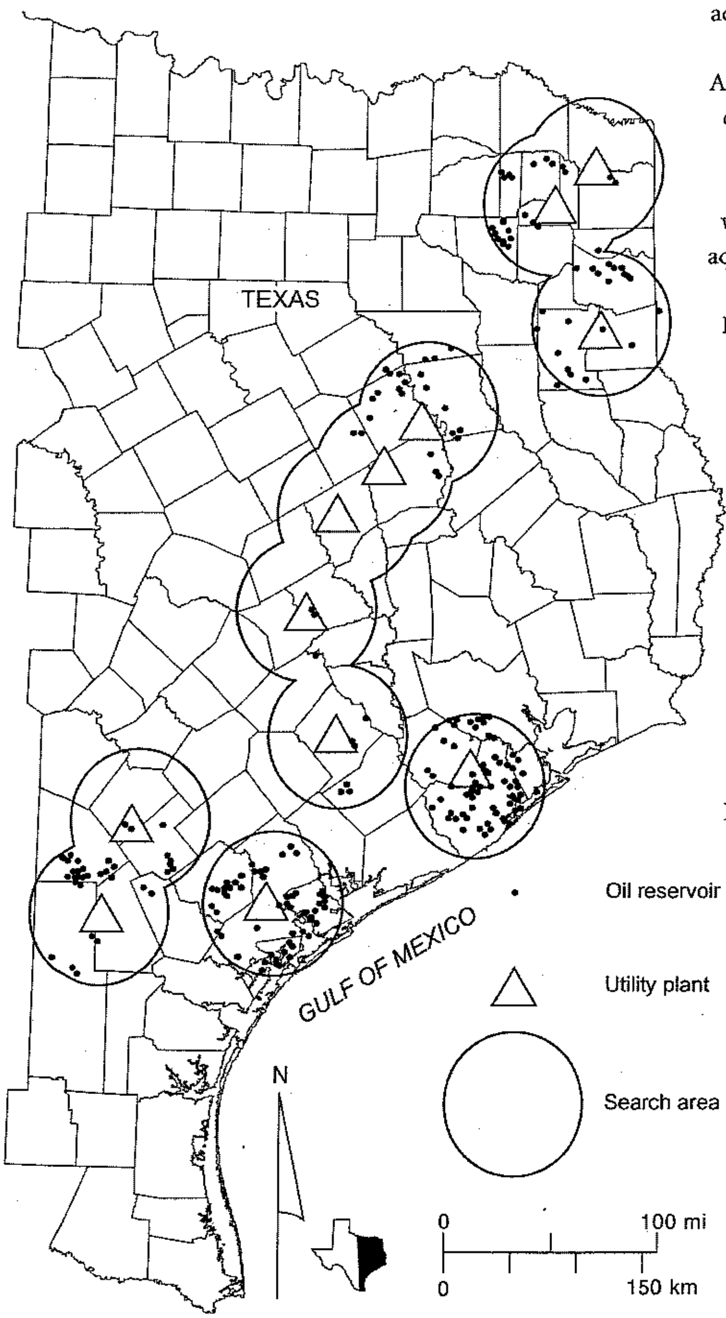
Sequestering CO_2 in the Subsurface

Benefits - Using existing technology, large volumes of CO_2 can be injected into the subsurface and effectively isolated from the atmosphere and potable ground water for long (geologic) periods. Between deep brine-bearing formations and depleted oil and gas reservoirs, as much as 1,000 years' worth of CO_2 emissions could be safely sequestered in an environment that is likely to remain stable over long periods (hundreds of thousands of years or more). And because of past activities in deep-well injection of waste and oil-field injection of CO_2 for EOR purposes, the mechanics and impact of these activities are well understood. Brine-bearing porous and permeable formations are an attractive and economic target for many CO_2 sources such as power plants because they underlie many parts of the United States. This allows injection at the site of the emissions, removing the need to construct a pipeline to transport the gas to another location for injection, such as an oil field. Because brine-bearing units are largely unused, subsurface rights to such formations should be available.

Where opportunities for injection into mature or abandoned oil and gas reservoirs exist, economic benefits can be derived from the injection of CO_2. Additionally, a study is being undertaken at Lawrence Berkeley National Laboratories to investigate whether injection of CO_2 at the gas-water contact of producing gas reservoirs might effectively maintain reservoir pressure and prevent edge-water influx. Success in this study may raise the question of whether injection at a gas-oil contact might allow simultaneous production of oil and an overlying gas cap while maintaining reservoir energy and preventing edge-water influx. Such a method may allow faster production of hydrocarbons, potentially increasing near-term cash flow and ultimate field economics.

Risks - Risks associated with subsurface sequestration of CO2 center mainly around possible leakage back into the atmosphere. Small leaks that persist for long periods can release significant volumes of CO_2 back into the atmosphere over a span of hundreds of years. Short-term high-volume leaks, such as occur when there is a failure of well casing cement bond, can potentially release a volume of CO_2 great enough to produce an asphyxiation hazard. Although gas leaks of dangerous volumes in oil and gas fields can be considered potentially analogous and

continued on page 29 →



Fgure 2. *Location of oil reservoirs within 30 mi of CO_2-generating utility plants in the Gulf Coast and East Texas Basins. From Holtz and others (1998).*

are rare, CO_2 injection raises different problems, which must be addressed through ongoing research.

Additionally, pressurization of brine-bearing formations might cause leakage of brine into shallower intervals, potentially contaminating potable ground water. Other unidentified risks might also exist, so careful preproject risk assessment, as well as long-term monitoring of injection sites and nearby aquifers, may be necessary.

Brine-Bearing Formations - Porous and permeable brine-bearing formations occur in nonreservoir intervals of structurally trapped oil and gas reservoirs, both between and below reservoir intervals. Such formations also exist in abundance away from known oil and gas reservoirs and need not be associated with a structural closure to be useful in sequestration.

Brine-bearing formations within existing oil and gas fields have the cost benefits of (1) significant subsurface data to guide modeling and project decision-making (porosity, permeability, architecture, etc.), (2) access to existing well bores for recompletions into CO_2 injectors, and (3) access to well bores that could be deepened for injection. Risks associated with these formations are related primarily to leakage of injected CO_2 into shallower intervals by way of improperly abandoned well bores or those having little or no cement above the injection target. Injection into deeper intervals that might contain fewer penetrations reduces the risk but may nonetheless complicate matters because of limited information regarding formation properties.

Although brine-bearing formations that are structurally isolated from oil and gas reservoirs have little risk of leakage through other well bores, they may have only regional information about rock properties and sand-body architecture to guide subsurface characterization. The benefit of such formations is that they are present in many regions and may directly underlie a CO_2 source, such that significant pipeline construction is not required to dispose of the CO_2. To facilitate evaluation by potential

continued on page 33 →

HGS Web Page
http://www.hgs.org

Jobs Hotline is on
Web Page or
at 713-785-9729

CO_2 emitters, we identified regional properties of major brine-bearing units in 21 sedimentary basins throughout the United States (Fig. 1) by compiling regional information. We then assembled these properties in a GIS framework (Hovorka and others, 2000, http://www.beg.utexas.edu/ environqlty/co201.htm).

EOR in Mature Fields - Sequestration of CO_2 can be accomplished within producing oil reservoirs by miscible and immiscible gas displacement during EOR projects. The benefit of such an effort is that ultimate oil recovery can be increased in mature or nearly abandoned reservoirs, providing an economic return while meeting national sequestration objectives.

A review of past CO_2 EOR projects in Texas was used to evaluate economic constraints on CO_2 sequestration (Holtz and others, 1998, http://www.beg.utexas.edu/environqlty/co201.htm). The study investigated geologic, engineering, and economic controls on past and current full-scale EOR projects and identified candidate reservoirs within 30, 60, and 90 mi of CO_2-emitting power plants (Fig. 2). The study (Holtz and others, 1998) identified 8 billion stock-tank barrels of oil that could be recovered through CO_2 sequestration in reservoirs within 90 mi of existing coal- and lignite-fired power plants in Texas.

West Texas carbonate reservoirs are the best-known targets of past CO_2 EOR projects. However, as many as 17 projects have been undertaken in sedimentary reservoirs along the Texas coast and in the East Texas Basin. Because projects in sandstone reservoirs are more economically marginal than typical West Texas carbonate projects, careful attention must be paid to oil price forecasts, CO_2 costs, and flood engineering design. A critical factor in any CO_2 EOR project is reservoir pressure, which must be above the minimum miscibility pressure (MMP) for CO_2 flooding to be effective in increasing oil mobility. In some cases, the target reservoir may require repressurization through water injection/flooding, especially if water drive is weak or the reservoir has not previously been waterflooded.

Because of the higher permeabilities typical in sandstone reservoirs, CO_2 is commonly injected either through water-after-gas (WAG) or alternating injection and recovery (huff-and-puff) methods. A recent project in the Marginulina sand of Port Neches field incorporated a horizontal injection well to improve CO_2 injection rates and sweep efficiency.

Gas Reservoirs and Gas-Cap Replacement - Abandoned gas reservoirs are also potential candidates for CO_2 sequestration. Although they would be effective in sequestration and would benefit from known subsurface properties, sequestration in abandoned gas reservoirs would not provide specific economic returns such as production of additional oil or gas.

Conclusions

Fossil energy will continue to be a significant part of the domestic and global energy mix in the foreseeable future. The global call for reduction of associated greenhouse gas emissions makes evaluation of costs, benefits, and feasibility of geologic sequestration of CO_2 a necessary step. Geoscientists and the oil and gas industry should be aware of the issues concerning geologic sequestration of CO_2 and actively participate in its assessment. Collaborative efforts from both environmental and oil and gas geoscientists will be required to evaluate topics ranging from the potential for contamination of aquifers to the possibility of improving cash flow from enhanced production of energy resources. The opportunity exists through partnership with DOE for geoscientists and industry to provide guidance and feedback regarding the safety or economics of geologic sequestration options. The best way to provide guidance and feedback is to address concerns through proposals to DOE outlining issues and methods to investigate these issues. More information can be found at the home page of the Carbon Sequestration Program (http://www.fetc.doe.gov/products/gcc/index.html).

Acknowledgments

Research into geologic sequestration of CO_2 has been supported by the U.S. Department of Energy and Electric Power Research Institute through contracts DE-AC26-98FT40417 and W04603-04. Publication authorized by the Director, Bureau of Economic Geology, The University of Texas at Austin.

References Cited

Holtz, M.H., P.K. Nance, and R.J. Finley, 1998, Reduction of Greenhouse Gas Emissions through Underground CO2Sequestration in Texas Oil and Gas Reservoirs, Final Contract Report prepared for Electric Power Research Institute through U.S. Department of Energy, under contract no. W04603-04, December, Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, 84 p., http://www.beg.utexas.edu/environqlty/co201.htm.

Hovorka, S.D., M. Romero, R. Treviño, A. Warne, W.A. Ambrose, P.R. Knox, and T.A. Tremblay, 2000, Project Evaluation: Phase II: Optimal Geological Environments for Carbon Dioxide Disposal in Brine-Bearing Formations (Aquifers) in the United States, Final Contract Report prepared for U.S. Department of Energy, National Energy Technology Laboratory, under contract no. DE-AC26-98FT40417, August, Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, 203 p.,http://www.beg.utexas.edu/environqlty/co201.htm.

U.S. Department of Energy, 2000, Carbon Sequestration: Overview and Summary of Program Plans (Draft), available in PDF format at http://fetc.doe.gov/products/gcc/indepth/carbseq/CseqOverview.PDF, April. □