

Preface

The primary purpose of this book is to assist future CCS, or CCUS investigations in characterizing potential geological CO₂ storage sites well enough so that all of the information required by regulators to permit commercial CO₂ storage facilities are provided. The Wyoming Carbon Underground Project (WY-CUSP) is part of the U.S. Department of Energy Geological CO₂ Storage Site Characterization Program. In 2010 DOE awarded funding to 10 CO₂ geological storage characterization projects. The WY-CUSP program under the direction of the University of Wyoming Carbon Management Institute (CMI) was one of the awardees (project DE-FE0002142: Site Characterization of the Highest-Priority Geologic Formations for CO₂ Storage in Wyoming; Principal Investigator, Ronald C. Surdam). The State of Wyoming through the U.W. School of Energy Resources generously provided matching funds for the WY-CUSP program. This book deals with most of the trials and tribulations required to achieve the ultimate goal of the WY-CUSP program: delivery of a certified commercial CO₂ storage site that could be used either as a surge tank for CO₂ utilization or for permanent sequestration of greenhouse gas (GHG) emissions, or for both.

The rationale for the WY-CUSP program is manifold: first is the effort to establish a mechanism that provides the potential to stabilize or reduce GHG emissions in order to reduce the rate of global warming; secondly to protect Wyoming's coal extraction and future coal-to-chemical industries by providing storage capacity for anthropogenic CO₂; thirdly to provide a source of anthropogenic CO₂ for enhanced oil recovery projects (at present rates of CO₂ production from gas processing plants it would take 150–200 years to recover Wyoming's stranded oil; fourthly to retrieve reservoir information essential for the expansion of natural gas storage in Wyoming; and lastly to establish more robust databases for two very important hydrocarbon reservoirs in Wyoming (substantially reduce uncertainty for all dynamic models of Tensleep/Weber Sandstone and Madison Limestone fluid-flow and rock/fluid systems).

To satisfy the WY-CUSP program rationale the following goals were set: to improve estimates of CO₂ reservoir storage capacity, to evaluate the long-term integrity and permanence of confining layers, and to manage injection pressures and brine production in order to optimize CO₂ storage efficiency for the most significant

storage reservoir (Tensleep/Weber and Madison Formations) at the Rock Springs Uplift (RSU), a premier CO₂ storage site in Wyoming.

To achieve this goal it was necessary to complete the following research objectives; (1) reduce uncertainty in estimates of CO₂ storage capacity of key storage reservoir intervals at the RSU; (2) evaluate and ensure CO₂ storage permanence at the RSU site by focusing on the sealing characteristics and 3-D interval heterogeneity of the Paleozoic and Mesozoic confining layers; (3) improve the efficiency of potential storage operations by designing an optimal coupled CO₂ injection/brine production strategy that ensures effective pressure management, and (4) improve the efficiency of brine treatment at the surface, including the effective use of the elevated temperature and pressure of the brines, recovery of potable water and extraction of metals.

Early efforts by the Wyoming State Geological Survey (WSGS) and the CMI determined that the Tensleep/Weber Sandstones and Madison Limestone were the highest priority CO₂ storage reservoirs in Wyoming. Regional studies also determined that the Rock Springs Uplift in southwestern Wyoming was a premier CO₂ storage structure/site in the state. The RSU is characterized by 4-way closure, with 10,000 ft of structural relief and extends from approximately 35 mi in an east-west direction, and 50 mi in a north-south direction. The WY-CUSP started with a large potential trap for storage of fluids, but with very little information regarding the nature of the reservoir intervals, distribution and continuity of confining layers or the rock/fluid properties of the reservoir and sealing lithologies. The original data available to CMI included 19 well reports that penetrated the Paleozoic stratigraphic interval in an area of approximately 2,000 mi², outcrops of key rock units 50–100 mi from the potential test area, well reports, regional maps and topical reports mainly housed in the Wyoming Oil and Gas Conservation Commission, WSGS, and the United States Geological Survey.

This book traces the steps taken by CMI and the WY-CUSP program to get from minimal regional data to a complete characterization of the Rock Springs Uplift as a certified commercial-level geological CO₂ storage site.

This trek will be described in 14 chapters covering the following subjects: (1) global warming and climate change: 45 million-year-old rocks in Wyoming support the concept (the context, need and role of CCUS in solving this global problem); (2) regional inventory and prioritization of potential CO₂ storage reservoirs in Wyoming: the origins of the WY-CUSP program—the search for the highest priority CO₂ geological storage site in the Rocky Mountain Region; (3) legal framework: carbon storage regulations, required permits and access to the study area; (4) the development of the WY-CUSP site characterization strategy—the role of 3-D seismic surveys and stratigraphic test wells; (5) storage site selection, with special emphasis on the proximity to sources of both anthropogenic and natural CO₂; (6) retrieval of crucial geologic data: the importance of a stratigraphic test well and 3-D seismic survey—key observations derived from core, well logs, borehole tests and seismic attribute acquisition; (7) utility of 3-D seismic attribute analysis and a VSP survey for assessing potential carbon sequestration targets (8) hydrologic data acquisition and observations—the importance of characterizing formation fluids; (9) predicting

spatial permeability in targeted storage reservoirs and seals on the RSU— a method that increases the accuracy of 3-D flow simulations of CO₂ storage applications; (10) advances in estimating the geological CO₂ storage capacity of the Madison Limestone and Weber Sandstone on the RSU by utilizing detailed 3-D reservoir characterization and geological uncertainty reduction (numerical simulations that include 3-D heterogeneity of reservoir petrophysical properties; displaced fluid/pressure management; (11) displaced fluid management—the key to commercial-scale geologic CO₂ storage; (12) illustration of the advantages of deploying innovative, multiple-resource development strategies designed to foster the sustainability of energy and environmental resources—strategies that greatly increase the value of CO₂ storage and utilization; (13) a feasibility study of the integration of geological CO₂ storage with enhanced oil recovery (CO₂ flooding) in the Ordos Basin, China and elsewhere; and (14) WY-CUSP integrated strategy for the detailed and accurate characterization of potential CO₂ storage reservoir and storage sites. Taken together these 14 chapters represent an effective and efficient process to improve estimates of CO₂ reservoir storage capacity, to evaluate the long-term integrity and permanence of confining layers, and the management of injection pressures and brine production and treatment in order to optimize CO₂ storage. Although the chapters in this book represent important steps to evaluating and optimizing CO₂ storage, each of the chapters is designed to stand alone.

Our aim in constructing the book was to positively affect and assist future global CO₂ storage and utilization projects. It is our firm belief that continued industrialization and global expansion of quality of life will require ever-increasing efforts to effectively store GHG emissions—without an exponential increase in the effort to store CO₂, neither further industrialization or global improvements in the quality of life and standard of living will be possible. Hopefully this book will expedite the global effort to retrieve energy, while sustaining environmental quality. Anyone interested in CCS, or CCUS should find this body of work helpful in executing their own projects to provide economic energy, while minimizing the development of undesirable environmental footprints. There is an old adage that, “a smart person learns from experience, but a wise person learns from the experience of others.” It is with that thought that we offer the WY-CUSP experience for the benefit of all others in their efforts to decrease or stabilize global GHG emissions by utilizing CO₂ geological storage.

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