

MAJOR OIL PLAYS IN UTAH AND VICINITY

QUARTERLY TECHNICAL PROGRESS REPORT

Reporting Period
Start Date: October 1, 2006
End Date: December 31, 2006

by
Thomas C. Chidsey, Jr., Principal Investigator
Utah Geological Survey



May 2007

Contract No. DE-FC26-02NT15133

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ABSTRACT

Utah oil fields have produced over 1.2 billion barrels (191 million m³) of oil and hold 256 million barrels (40.7 million m³) of proved reserves. The 13.7 million barrels (2.2 million m³) of production in 2002 was the lowest level in over 40 years and continued the steady decline that began in the mid-1980s. However, in late 2005 production increased due to the discovery of Covenant field in the central Utah Navajo Sandstone thrust belt play. The Utah Geological Survey believes this new upward production trend can continue by providing play portfolios for the major oil-producing provinces (Paradox Basin, Uinta Basin, and thrust belt) in Utah and adjacent areas in Colorado and Wyoming. Oil plays are geographic areas with petroleum potential caused by favorable combinations of source rock, migration paths, reservoir rock characteristics, and other factors. The play portfolios will include descriptions and maps of the major oil plays by reservoir; production and reservoir data; case-study field evaluations; locations of major oil pipelines; identification and discussion of land-use constraints; descriptions of reservoir outcrop analogs; and summaries of the state-of-the-art drilling, completion, and secondary/tertiary recovery techniques for each play.

This report covers research activities for the eighteenth quarter of the project (October 1 through December 31, 2006). This work included (1) gathering field data and analyzing best practices used in the Pennsylvanian Paradox Formation play, Utah Paradox Basin, and (2) technology transfer activities.

The most prolific oil and gas play in the Paradox Basin is the Pennsylvanian Paradox Formation play. The Paradox Formation has produced over 500 million barrels (80 million m³) of sweet, paraffinic oil and 650 billion cubic feet of gas (18 billion m³) from more than 70 fields. The main producing zones are referred to as the Cane Creek, Desert Creek, and Ismay. Traps types include stratigraphic, stratigraphic with some structural influence, combination stratigraphic/structural, structural, and diagenetic. The Paradox Formation has heterogeneous reservoir properties because of depositional lithofacies with varying porosity and permeability, carbonate buildup (mound) relief and flooding surfaces (parasequence boundaries), fracturing, and diagenetic effects. Best late-term development practices include waterflood, horizontal drilling, and carbon dioxide flood programs.

As part of technology transfer activities during this quarter, an abstract describing Covenant field in the central Utah thrust belt play was accepted for presentation at the 2007 American Association of Petroleum Geologists annual convention in Long Beach, California. Technology transfer activities also included a presentation and publication. The project home page was updated on the Utah Geological Survey Web site.

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EXECUTIVE SUMMARY

Utah oil fields have produced over 1.2 billion barrels (191 million m³) of oil and hold 256 million barrels (40.7 million m³) of proved reserves. The 13.7 million barrels (2.2 million m³) of production in 2002 was the lowest level in over 40 years and continued the steady decline that began in the mid-1980s. However, in late 2005 production increased due to the discovery of Covenant field in the central Utah Navajo Sandstone thrust belt play. The overall objectives of this study are to (1) continue adding new discoveries, (2) increase recoverable oil from existing field reservoirs, (3) prevent premature abandonment of numerous small fields, (4) increase deliverability through identifying the latest drilling, completion, and secondary/tertiary recovery techniques, and (5) reduce development costs and risk.

To achieve these objectives, the Utah Geological Survey is producing play portfolios for the major oil-producing provinces (Paradox Basin, Uinta Basin, and thrust belt) in Utah and adjacent areas in Colorado and Wyoming. This research is partially funded by the Preferred Upstream Management Program (PUMPII) of the U.S. Department of Energy, National Petroleum Technology Laboratory (NPTL) in Tulsa, Oklahoma. This report covers research activities for the eighteenth quarter of the project (October 1 through December 31, 2006). This work included (1) gathering field data and analyzing best practices used in the Pennsylvanian Paradox Formation play, Utah Paradox Basin, and (2) technology transfer activities.

A combination of depositional and structural events created the right conditions for oil generation and trapping in the major oil-producing provinces (Paradox Basin, Uinta Basin, and thrust belt) in Utah and adjacent areas in Colorado and Wyoming. Oil plays are specific geographic areas having petroleum potential due to favorable source rock, migration paths, reservoir characteristics, and other factors.

The most prolific oil and gas play in the Paradox Basin is the Pennsylvanian Paradox Formation play. The Paradox Formation has produced over 500 million barrels (80 million m³) of sweet, paraffinic oil and 650 billion cubic feet of gas (18 billion m³) from more than 70 fields. The main producing zones are referred to as the Cane Creek, Desert Creek, and Ismay. The Paradox Formation oil play area includes nearly the entire Paradox Basin. Traps in the Blanding sub-basin and Aneth platform regions include stratigraphic, stratigraphic with some structural influence, combination stratigraphic/structural, and diagenetic. The Paradox Formation has heterogeneous reservoir properties because of depositional lithofacies with varying porosity and permeability, carbonate buildup (mound) relief and flooding surfaces (parasequence boundaries), fracturing, and diagenetic effects. The extent of these factors, and how they are combined, affect the degree to which fluid flow barriers are created. Identification and correlation of depositional lithofacies, parasequences, and fracture trends in individual Paradox reservoirs is critical to understanding their effect on water/carbon dioxide injection programs, production rates, and paths of petroleum movement. Best late-term development practices include waterflood, horizontal drilling, and carbon dioxide flood programs.

Technology transfer activities during this quarter included a technical presentation describing the new central thrust belt, Utah Navajo Sandstone play to exploration geologists from various companies in Houston, Texas. An abstract describing Covenant field in the central Utah thrust belt play was accepted for presentation at the 2007 American Association of Petroleum Geologists annual convention in Long Beach, California. The project home page was updated on the Utah Geological Survey Web site. Project team members published a Quarterly Technical Progress Report detailing project work, results, and recommendations.

INTRODUCTION

Project Overview

Utah oil fields have produced over 1.3 billion barrels (bbls) (191 million m³) (Utah Division of Oil, Gas and Mining, 2006). The 13.7 million barrels (2.2 million m³) of production in 2002 was the lowest level in over 40 years. However, in late 2005 production increased (figure 1), due to the discovery of Covenant field in the central Utah Navajo Sandstone thrust belt play, and reversed the decline that began in the mid-1980s (Utah Division of Oil, Gas and Mining, 2006). Proven reserves are relatively high, at 256 million bbls (40.7 million m³) (Energy Information Administration, 2006). With higher oil prices now prevailing, secondary and tertiary recovery techniques should boost future production rates and ultimate recovery from known fields.

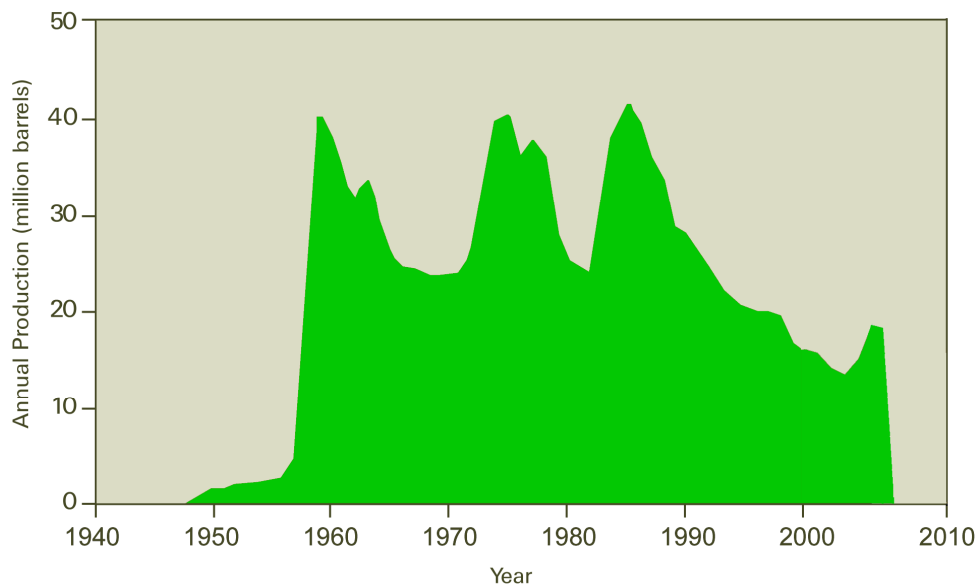


Figure 1. Oil production in Utah through 2006 showing an increase due, in part, to the discovery of Covenant field in the new central Utah thrust belt Jurassic Navajo Sandstone play. Source: Utah Division of Oil, Gas and Mining production records.

Utah's drilling history has fluctuated greatly due to discoveries, oil and gas price trends, and changing exploration targets. Utah has entered another boom period rivaling the early 1980s. In 2006, the Utah Division of Oil, Gas and Mining issued a record 2062 drilling permits and 889 wells were spudded. Sustained high petroleum prices are providing the economic climate needed to entice more high-risk exploration investments (more wildcats), resulting in new discoveries.

Utah still contains large areas that are virtually unexplored. There is also significant potential for increased recovery from existing fields by employing improved reservoir characterization and the latest drilling, completion, and secondary/tertiary recovery technologies. New exploratory targets may be identified from three-dimensional (3D) seismic surveys. Development of potential prospects is within the economic and technical capabilities of both major and independent operators.

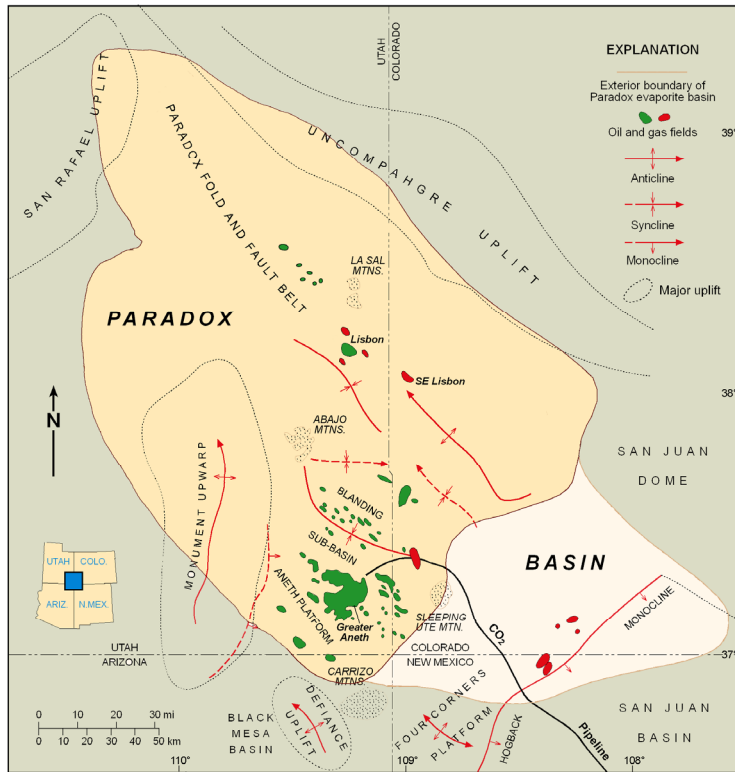
The primary goal of this study is to increase recoverable oil reserves from existing field reservoirs and new discoveries by providing play portfolios for the major oil-producing provinces (Paradox Basin, Uinta Basin, and thrust belt) in Utah and adjacent areas in Colorado and Wyoming (figures 2 and 3). These play portfolios will include descriptions (such as stratigraphy, diagenetic analysis, tectonic setting, reservoir characteristics, trap type, seal, and hydrocarbon source) and maps of the major oil plays by reservoir; production and reservoir data; case-study field evaluations; summaries of the state-of-the-art drilling, completion, and secondary/tertiary techniques for each play; locations of major oil pipelines; and descriptions of reservoir outcrop analogs for each play. Also included will be an analysis of land-use constraints on development, such as wilderness or roadless areas, and national parks within oil plays.

This report covers research activities for the eighteenth quarter of the project (October 1 through December 31, 2006). This work included (1) gathering field data and analyzing best practices used in the Pennsylvanian Paradox Formation play of the Paradox Basin, Utah, and (2) technology transfer activities.

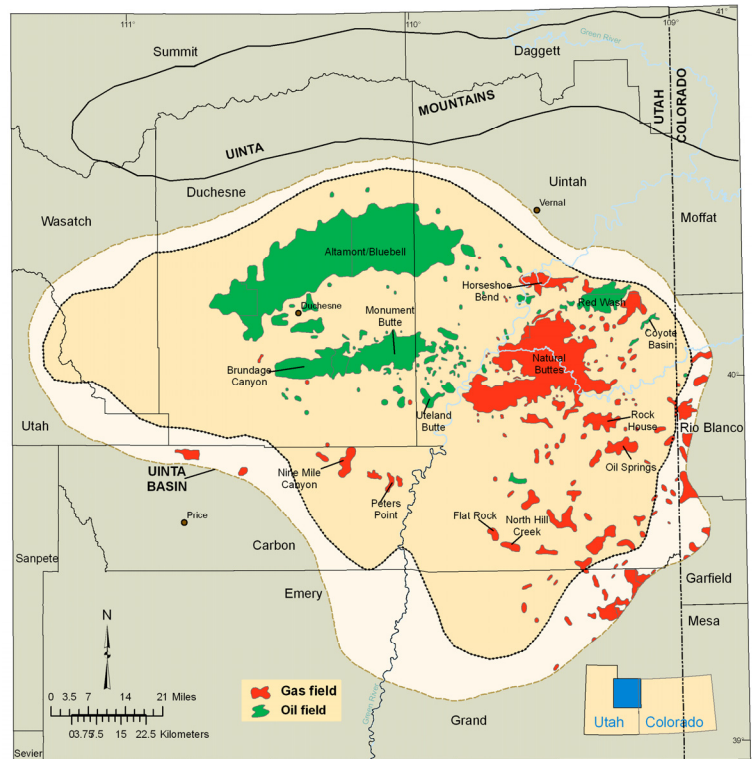
Project Benefits

The overall goal of this multi-year project is enhanced petroleum production in the Rocky Mountain region. Specific benefits expected to result from this project include the following:

- (1) improved reservoir characterization to prevent premature abandonment of numerous small fields in the Paradox and Uinta Basins,
- (2) identification of the type of untapped compartments created by reservoir heterogeneity (for example, diagenesis and abrupt facies changes) to increase recoverable reserves,
- (3) identification of the latest drilling, completion, and secondary/tertiary techniques to increase deliverability,
- (4) identification of reservoir trends for field extension drilling and stimulating exploration in undeveloped parts of producing fairways,
- (5) identification of technology used in other basins or producing trends with similar types of reservoirs that might improve production in Utah,
- (6) identification of optimal well spacing/location to reduce the number of wells needed to successfully drain a reservoir, thus reducing development costs and risk, and allowing more productive use of limited energy investment dollars, and
- (7) technology transfer to encourage new development and exploration efforts, and increase royalty income to the federal, state, local, Native American, and fee owners.

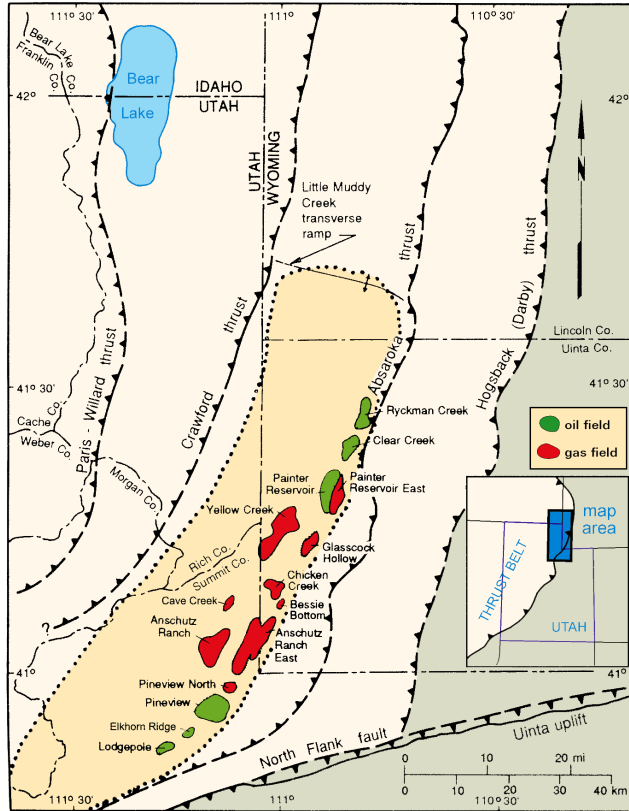


A

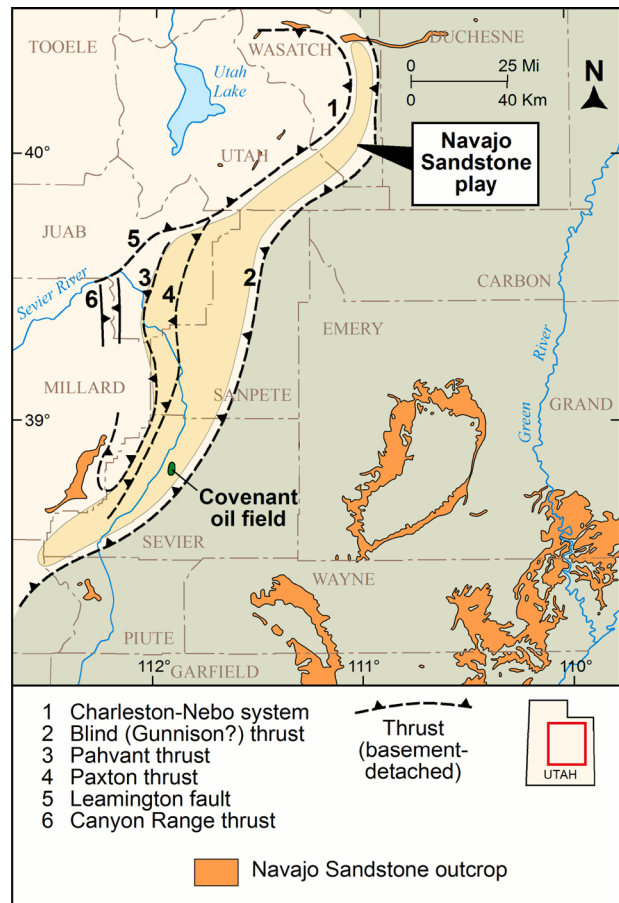


B

Figure 2. A - Oil and gas fields in the Paradox Basin of Utah, Colorado, and Arizona (modified from Harr, 1996). B - Oil and gas fields in the Uinta Basin of Utah (modified from Chidsey and others, 2004b). Colored (light orange) area shows present and potential of plays areas in the Paradox and Uinta Basins.



A



B

Figure 3. A - Oil and gas fields, uplifts, and major thrust faults in the Utah-Wyoming thrust belt. B - Location of Covenant oil field, uplifts, and selected thrust systems in the central Utah thrust belt province. Numbers and sawteeth are on the hanging wall of the corresponding thrust system. Modified from Hintze (1980), Sprinkel and Chidsey (1993), and Peterson (2001). Colored (light orange) area shows present and potential of plays areas in the thrust belt.

The Utah play portfolios produced by this project will provide an easy-to-use geologic, engineering, and geographic reference to help petroleum companies plan exploration, land-acquisition strategies, and field development. These portfolios may also help pipeline companies plan future facilities and pipelines. Other users of the portfolios will include petroleum engineers, petroleum land specialists, landowners, bankers and investors, economists, utility companies, manufacturers, county planners, and numerous government agencies.

The results of this project will be transferred to industry and other interested parties through establishment of Technical Advisory and Stake Holders Boards, an industry outreach program, and technical presentations at national and regional professional society meetings. All of this information will be made public through (1) the Utah Geological Survey (UGS) Web site, (2) an interactive, menu-driven digital product on compact disc, and (3) hard-copy publications in various technical or trade journals and UGS publications.

BEST PRACTICES FOR THE PENNSYLVANIAN PARADOX FORMATION, PARADOX BASIN PLAY – DISCUSSION AND RESULTS

Paradox Formation, Paradox Basin Play Description

The most prolific oil and gas play in the Paradox Basin is the Pennsylvanian Paradox Formation play (figure 4). The Paradox has produced over 500 million barrels of oil (BO [80 million m³]) and 650 billion cubic feet of gas (BCFG [18 billion m³]); however, much of the gas included in the production figures is cycled gas, including carbon dioxide, for pressure maintenance (Utah Division of Oil, Gas and Mining, 2006; Colorado Oil & Gas Conservation Commission, 2006). Greater Aneth field, Utah's largest oil producer, was discovered in 1956, and it has produced over 443 million BO (70 million m³) (Utah Division of Oil, Gas and Mining, 2006). The remaining production is from nearly 100 small fields in the basin.

The play outline represents the maximum extent of petroleum potential in the geographical area as defined by producing reservoirs, hydrocarbon shows, and untested hypotheses. The attractiveness of the Paradox Formation play (and other Paradox Basin plays) to the petroleum industry depends on the likelihood of successful development, reserve potential, pipeline access, drilling costs, oil and gas prices, and environmental concerns. When evaluating these criteria, certain aspects of the Paradox Formation play may meet the exploration guidelines of major oil companies while other aspects meet the development guidelines of small, independent companies. Prospective drilling targets in the Paradox Formation play are delineated using high-quality two-dimensional (2-D) and three-dimensional (3-D) seismic data, 2-D and 3-D forward modeling/visualization tools, well control, dipmeter information, facies mapping, and detailed analyses of the diagenetic history.

Rapid subsidence of the Paradox Basin, particularly during the Pennsylvanian and then continuing into the Permian, accommodated large volumes of evaporitic and marine sediments that intertongue with non-marine arkosic material shed from the highland area to the northeast. Deposition in the basin produced a thick cyclical sequence of carbonates, evaporates, and organic-rich shale in a subtropical arid environment. A shallow-water carbonate shelf on the south and southwest margins of the basin that locally contained carbonate buildups. These carbonate buildups, and the material shed from their flanks, formed petroleum traps where reservoir-quality porosity and permeability have developed.

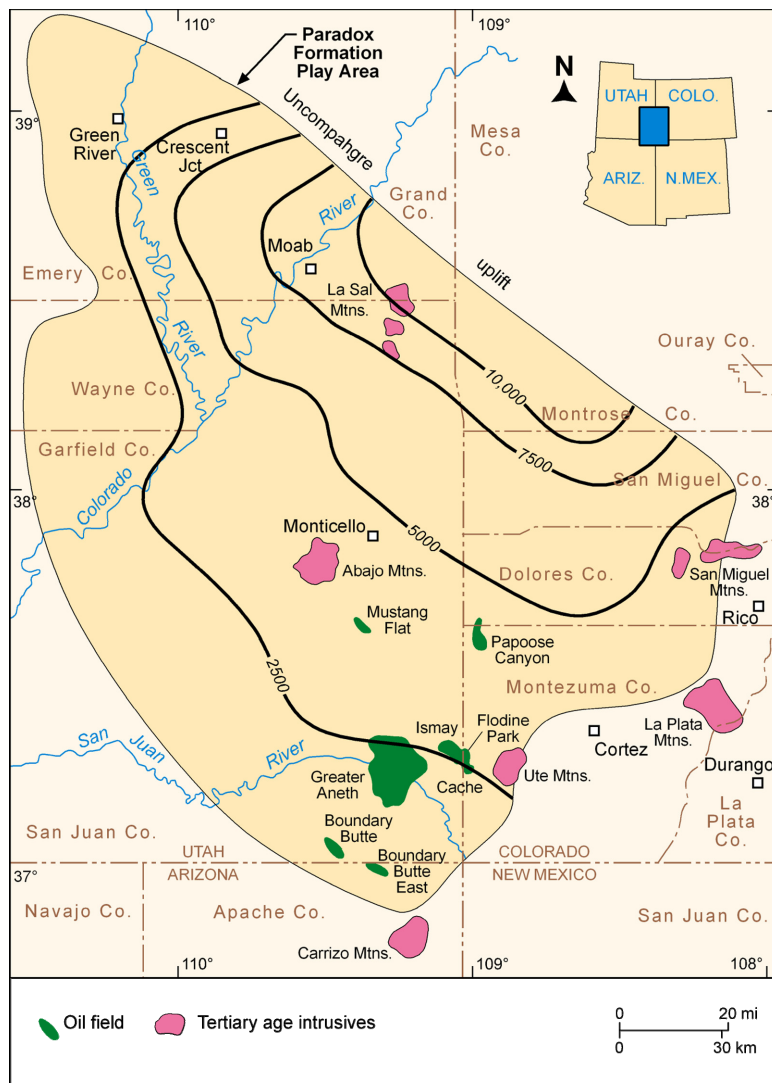


Figure 4. Pennsylvanian Paradox Formation play area and major fields, Utah, Colorado, and Arizona. Thickness of the Pennsylvanian rocks shown in feet. Modified from Choquette (1983).

The three main producing zones of the Paradox Formation are informally named the Cane Creek shale, Desert Creek zone, and Ismay zone (Hite, 1960; Hite and Cater, 1972; and Reid and Berghorn, 1981) (figure 5). In the fold and fault belt, the Cane Creek shale of the Paradox Formation is composed of marine carbonate, evaporite, and organic-rich shale beds. In the Blanding sub-basin, Ismay-zone reservoirs are dominantly limestones composed of small, phylloid-algal buildups; locally variable, inner-shelf, skeletal calcarenites; and rare, open-marine, bryozoan mounds. Desert Creek-zone reservoirs are dominantly dolomite comprising regional, nearshore, shoreline trends with highly aligned, linear facies tracts. On the Aneth platform, Desert Creek reservoirs include shallow-shelf buildups (phylloid algal, coralline algal, and bryozoan buildups [mounds]) and calcarenites (beach, dune, and oolite banks). Here, the Desert Creek and Ismay zones are predominately limestone, with local dolomitic units.

Traps in the Blanding sub-basin and Aneth platform regions include stratigraphic, stratigraphic with some structural influence, combination stratigraphic/structural, and diagenetic. Many carbonate buildups or fractured reservoirs developed on subtle anticlinal noses or structural closures. The Cane Creek is a fractured, self-sourced oil reservoir that is highly overpressured – an ideal target for horizontal drilling. Fracture data in the Cane Creek show a regional, northeast to southwest, near-vertical, open, extensional fracture system.

Vertical reservoir seals for the Paradox producing zones are shale, halite, and anhydrite within the formation; lateral seals are permeability barriers created by unfactured, off-mound (non-buildup) mudstone, wackestone, and anhydrite. Hydrocarbons in Paradox Formation reservoirs were generated from source rocks within the formation itself during maximum burial in the Late Cretaceous and early Tertiary. Organic-rich units, such as the Cane Creek, Chimney Rock, and Gothic shales, are composed of black, sapropelic shale and shaley dolomite.

The Paradox Formation has heterogeneous reservoir properties because of depositional lithofacies with varying porosity and permeability, carbonate buildup (mound) relief and flooding surfaces (parasequence boundaries), fracturing, and diagenetic effects. The extent of these factors, and how they are combined, affect the degree to which fluid flow barriers are created. Identification and correlation of depositional lithofacies, parasequences, and fracture trends in individual Paradox reservoirs is critical to understanding their effect on water/carbon dioxide injection programs, production rates, and paths of petroleum movement.

Fractured shale beds in the Cane Creek shale are oil productive in the Paradox Basin fold and fault belt. The Ismay mainly produces oil from fields along a trend that crosses the southern Blanding sub-basin. The Desert Creek produces oil in fields along a trend that crosses the central Blanding sub-basin and Aneth platform. Both the Ismay and Desert Creek buildups generally trend northwest-southeast.

The Paradox Formation oil play area includes nearly the entire Paradox Basin (figure 4); the formation produces only gas in the southeastern part of the basin in Colorado. The Paradox Formation Play is divided into four subplays (Chidsey and others, 2004a; Chidsey, 2006) (figure 6): (1) fractured shale, (2) Blanding sub-basin Desert Creek zone, (3) Blanding sub-basin Ismay zone, and (4) Aneth platform Desert Creek zone.

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"GOTHIC"
"CHIMNEY ROCK"

"CANE CREEK"

Figure 5. Pennsylvanian stratigraphic chart for the Paradox Basin; informal zones with significant production are highlighted with colors. Modified from Hite (1960), Hite and Cater (1972), and Reid and Berghorn (1981).

Data Collection

Three significant practices were or could be employed in the later development of fields in the Paradox Formation play to enhance the ultimate recovery of oil: (1) waterfloods, (2) carbon dioxide (CO₂) floods, and (3) horizontal drilling. During the quarter, data were collected from the files of the Utah Division of Oil, Gas and Mining, where there is a wealth of publicly available information, and from various publications for fields in the Utah portion of the Paradox Basin. This information includes structure maps and cross sections, production and pressure data, completion and injection reports, drilling and development plans, and testimony given at spacing hearings and other hearings before the Utah Division of Oil, Gas and Mining. The purpose of this data collection is to help determine the best drilling, completion, and secondary/tertiary recovery techniques for these and similar fields in the Paradox Basin. Analysis summarizing the best practices as determined from this information will be summarized in the next Quarterly Technical Progress Report.

TECHNOLOGY TRANSFER

The UGS is the Principal Investigator and prime contractor for this project under the U.S. Department of Energy (DOE) Preferred Upstream Management Program (PUMPII). All play maps, reports, databases, and other deliverables produced for the PUMPII project will be published in interactive, menu-driven digital (Web-based and compact disc) and hard-copy formats by the UGS for presentation to the petroleum industry. Syntheses and highlights will be submitted to refereed journals, as appropriate, such as the *American Association of Petroleum Geologists (AAPG) Bulletin* and *Journal of Petroleum Technology*, and to trade publications such as the *Oil and Gas Journal*.

The technology-transfer plan included the formation of a Technical Advisory Board and a Stake Holders Board. These boards meet annually with the project technical team members. The Technical Advisory Board advises the technical team on the direction of study, reviews technical progress, recommends changes and additions to the study, and provides data. The Technical Advisory Board is composed of field operators from the oil-producing provinces of Utah that also extend into Wyoming or Colorado. This board ensures direct communication of the study methods and results to the operators. The Stake Holders Board is composed of groups that have a financial interest in the study area including representatives from the State of Utah (School and Institutional Trust Lands Administration and Utah Division of Oil, Gas and Mining) and the federal government (Bureau of Land Management and Bureau of Indian Affairs). The members of the Technical Advisory and Stake Holders Boards receive all quarterly technical reports and copies of all publications, and other material resulting from the study. Board members also provide field and reservoir data, especially data pertaining to best practices. Project activities, results, and recommendations were presented at this meeting.

An abstract describing Covenant field and the potential for additional discoveries in the central Utah thrust belt play was accepted for presentation at a poster session during the 2007 AAPG annual convention in Long Beach, California.

Utah Geological Survey *Survey Notes* and Web Site

The UGS publication *Survey Notes* provides non-technical information on contemporary geologic topics, issues, events, and ongoing UGS projects to Utah's geologic community, educators, state and local officials and other decision-makers, and the public. *Survey Notes* is published three times yearly. Single copies are distributed free of charge and reproduction (with recognition of source) is encouraged.

The UGS maintains a Web site on the Internet, <http://geology.utah.gov>. The UGS site includes a page under the heading *Utah Geology/Oil, Coal, and Energy*, which describes the UGS/DOE cooperative studies (PUMPII, Paradox Basin [two projects], Ferron Sandstone, Bluebell field, Green River Formation), and has a link to the DOE Web site. Each UGS/DOE cooperative study also has its own separate page on the UGS Web site. The PUMPII project page, <http://geology.utah.gov/emp/pump/index.htm>, contains (1) a project location map, (2) a description of the project, (3) a reference list of all publications that are a direct result of the project, (4) poster presentations, and (5) quarterly technical progress reports.

Presentation

The following presentation was made during the reporting period as part of the technology transfer activities:

“Gas and Oil in Utah: Potential, New discoveries, and Hot Plays” by T.C. Chidsey, November 9, 2006, presented at the fall Utah Alumni Meeting sponsored by BP America Producing Company and Brigham Young University, Houston, Texas. An overview of major Utah oil plays, and the geology and potential of the new central Utah thrust belt play were included in the presentation.

Project Publication

Chidsey, T.C., Jr., and Sprinkel, D.A., 2006, Major oil plays in Utah and vicinity – quarterly technical progress report for the period July 1 to September 30, 2006: U.S. Department of Energy, DOE/FC26-02NT15133-17, 38 p.

CONCLUSIONS AND RECOMMENDATIONS

1. A combination of depositional and structural events created the right conditions for oil generation and trapping in the major oil-producing provinces (Paradox Basin, Uinta Basin, and thrust belt) in Utah and adjacent areas in Colorado, Wyoming, and Arizona. Oil plays are specific geographic areas having petroleum potential due to favorable source rock, migration paths, reservoir characteristics, and other factors.

2. The Paradox Basin is located mainly in southeastern Utah and southwestern Colorado with small portions in northeastern Arizona and the northwestern corner of New Mexico. The most prolific oil and gas play in the Paradox Basin is the Pennsylvanian Paradox Formation play. The Paradox Formation has produced over 500 million bbls (80 million m³) of sweet, paraffinic oil and 650 BCFG (18 billion m³) from more than 70 fields. The main producing zones are referred to as the Cane Creek, Desert Creek, and Ismay. The Paradox Formation oil play area includes nearly the entire Paradox Basin. The Paradox Formation Play is divided into four subplays: (1) fractured Cane Creek shale, (2) Blanding sub-basin Desert Creek zone, (3) Blanding sub-basin Ismay zone, and (4) Aneth platform Desert Creek zone.
3. Three significant late-term development practices were or could be employed in the later development of fields in the Paradox Formation play to enhance the ultimate recovery of oil: (1) waterfloods, (2) carbon dioxide (CO₂) floods, and (3) horizontal drilling.
4. Identification and correlation of depositional lithofacies, parasequences, and fracture trends in individual Paradox reservoirs is critical to understanding their effect on water/carbon dioxide injection programs, production rates, and paths of petroleum movement.

ACKNOWLEDGMENTS

Funding for this ongoing research was provided as part of the Preferred Upstream Management Program of the U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Oklahoma, contract number DE-FC26-02NT15133. The Contracting Officer's Representative is Virginia Weyland. Support was also provided by the UGS.

James Parker, Sharon Wakefield, and Cheryl Gustin of the UGS prepared the figures. Cheryl Gustin formatted the manuscript. This report was reviewed by David Tabet and Michael Hylland of the UGS.

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