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Start Date: October 1, 2007
End Date: December 31, 2007

MAJOR OIL PLAYS IN UTAH AND VICINITY

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MAJOR OIL PLAYS IN UTAH AND VICINITY

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

March 2008

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ABSTRACT

Utah oil fields have produced over 1.33 billion barrels (211 million m^3) of oil and hold 256 million barrels (40.7 million m^3) of proved reserves. The 13.7 million barrels (2.2 million m^3) 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, in part, 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 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 twenty-second quarter of the project (October 1 through December 31, 2007). This work included (1) preparing the Final Technical Report and interactive digital deliverable, and (2) technology transfer activities. The **Final Technical Report** will include play portfolios and best practices for the major oil plays in Utah and vicinity. The interactive, menu-driven digital product (deliverable) will contain the oil and gas field and pipeline map for Utah and vicinity linked by petroleum-producing provinces (thrust belt, Uinta Basin, and Paradox Basin) to the Final Technical Report and other features.

Technology transfer activities during this quarter consisted of exhibiting a booth display of project materials at the 2007 Rocky Mountain Section meeting of the American Association of Petroleum Geologists (AAPG); technical presentations describing the new central Utah thrust belt Navajo Sandstone play, and best practices in the Paradox and Uinta Basins; and publications. We also published a paper on the petroleum geology of Covenant field in the central Utah thrust belt play in the Utah Geological Association's (UGA) 2007 guidebook on the geology of central Utah. During UGA's annual field trip, we led a geologic stop at Covenant field and presented a short core workshop of Navajo Sandstone core from Covenant field in Manti, Utah. 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 1.33 billion barrels (211 million m^3) of oil and hold 256 million barrels (40.7 million m^3) of proved reserves. The 13.7 million barrels (2.2 million m^3) 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 Energy Technology Laboratory (NETL) in Tulsa, Oklahoma. This report covers research activities for the twenty-second quarter of the project (October 1 through December 31, 2007). This work included (1) preparing the **Final Technical Report** and interactive digital deliverable, and (2) technology transfer activities.

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. 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 Final Technical Report will include play portfolios and best practices for the major oil plays in Utah and vicinity (southwestern Wyoming, southwestern Colorado, and northeastern Arizona). The interactive, menu-driven digital product (deliverable) will contain the oil and gas field and pipeline map for Utah and vicinity linked by petroleum-producing provinces (thrust belt, Uinta Basin, and Paradox Basin) to the Final Technical Report and other features.

Technology transfer activities during this quarter consisted of exhibiting a booth display of project materials at the 2007 Rocky Mountain Section meeting of the American Association of Petroleum Geologists (AAPG) in Snowbird, Utah. Technical presentations describing (1) the geology of Covenant field and the central Utah thrust belt Navajo Sandstone oil play, (2) enhanced oil recovery potential in the Uinta Basin, and (3) recommendations for reservoir modelers in the Paradox Basin, were given at the AAPG meeting. We also published a paper on the petroleum geology of Covenant field in the central Utah thrust belt play in the Utah Geological Association's (UGA) 2007 guidebook on the geology of central Utah. During UGA's annual field trip, we led a geologic stop at Covenant field and presented a short core workshop of Navajo Sandstone core from Covenant field in Manti, Utah. The project home page was updated on the Utah Geological Survey Web site. Project team members published abstracts on the central Utah thrust belt Navajo Sandstone oil play and recommended best practices in the Uinta and Paradox Basins, and a Quarterly Technical Progress Report detailing project work, results, and recommendations.

INTRODUCTION

Project Overview

Utah oil fields have produced over 1.33 billion barrels (bbls) (211 million m^3) (Utah Division of Oil, Gas and Mining, 2007). The 13.7 million bbls (2.2 million m^3) 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, 2007). Proven reserves are relatively high, at 334 million bbls (53.1 million m^3) (Energy Information Administration, 2007). With higher oil prices now prevailing, secondary and tertiary recovery techniques should boost future production rates and ultimate recovery from known fields.

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 2007, the Utah Division of Oil, Gas and Mining issued 1553 drilling permits and record 1110 wells were spudded (Utah Division of Oil, Gas and Mining, 2008a, 2008b). Sustained high petroleum prices are providing the economic climate needed to entice more high-risk exploration investments (more wildcats), resulting in new discoveries.

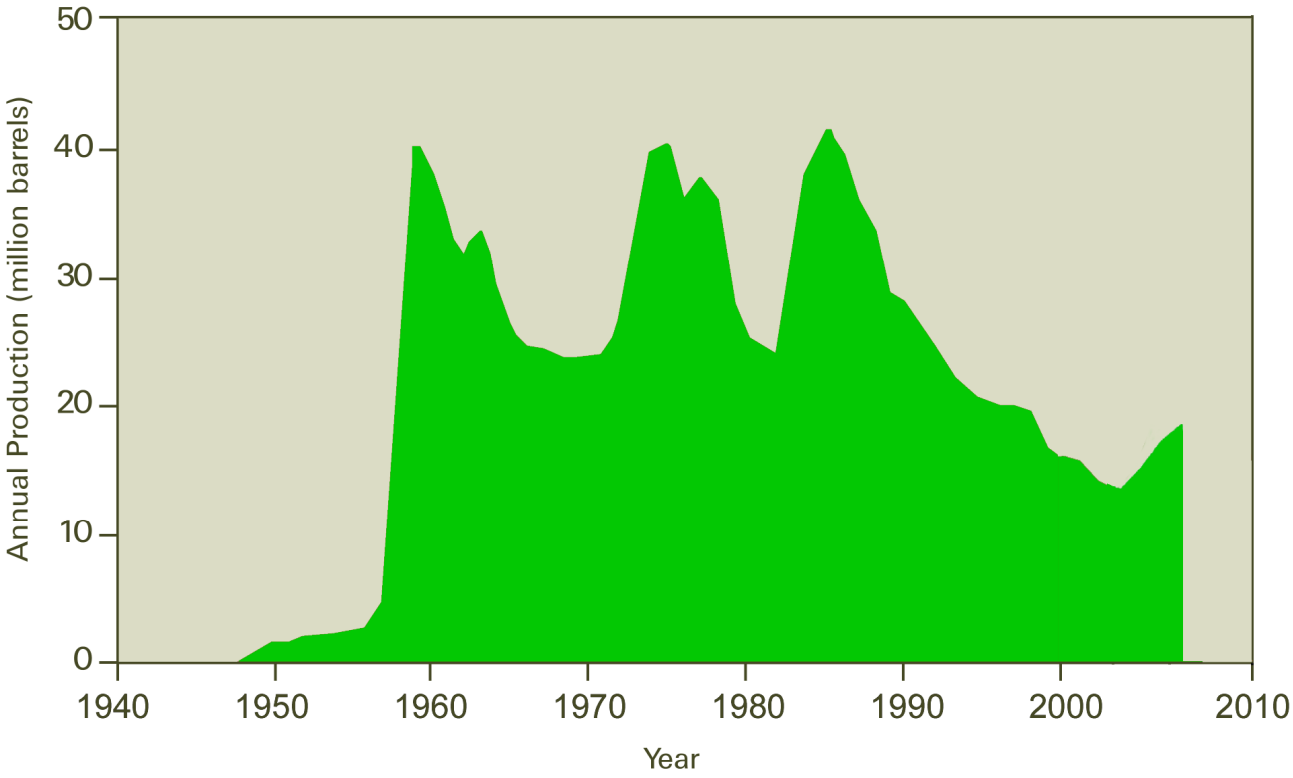


Figure 1. Oil production in Utah as of January 1, 2007 showing an increase due, in part, to the discovery of Covenant field in the new central Utah thrust belt Jurassic Navajo Sandstone play. Data source: Utah Division of Oil, Gas and Mining production records.

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).

This report covers research activities for the twenty-second quarter of the project (October 1 through December 31, 2007). This work included (1) preparing the **Final Technical Report** and interactive digital deliverable, 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,

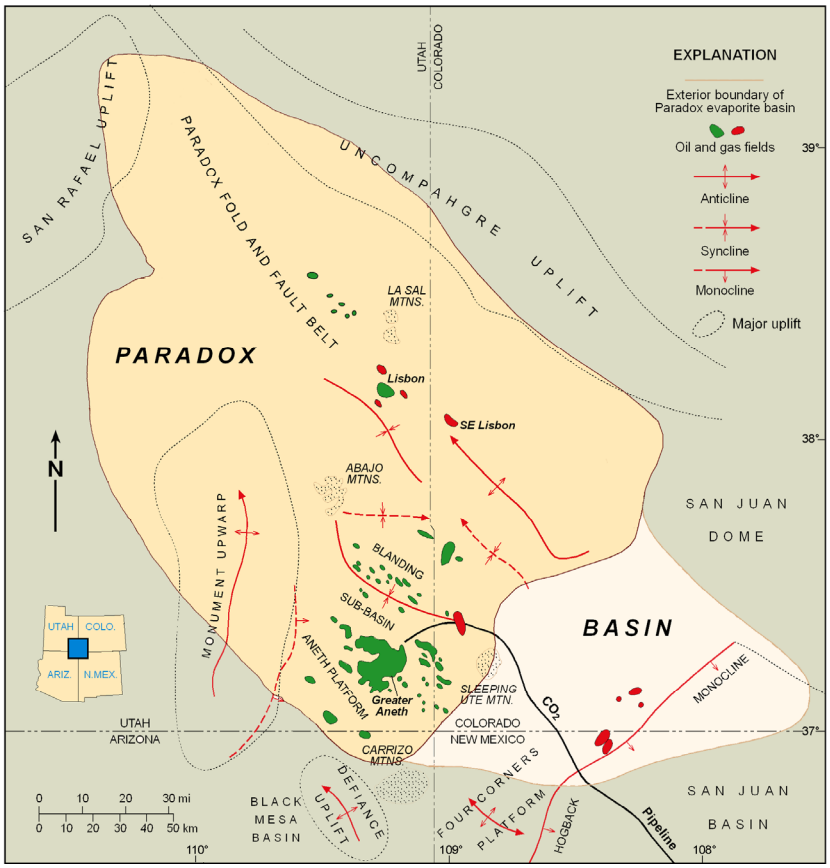
(5) identification of technology used in other basins or producing trends with similar types of reservoirs that might improve production in Utah,

(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.

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

A



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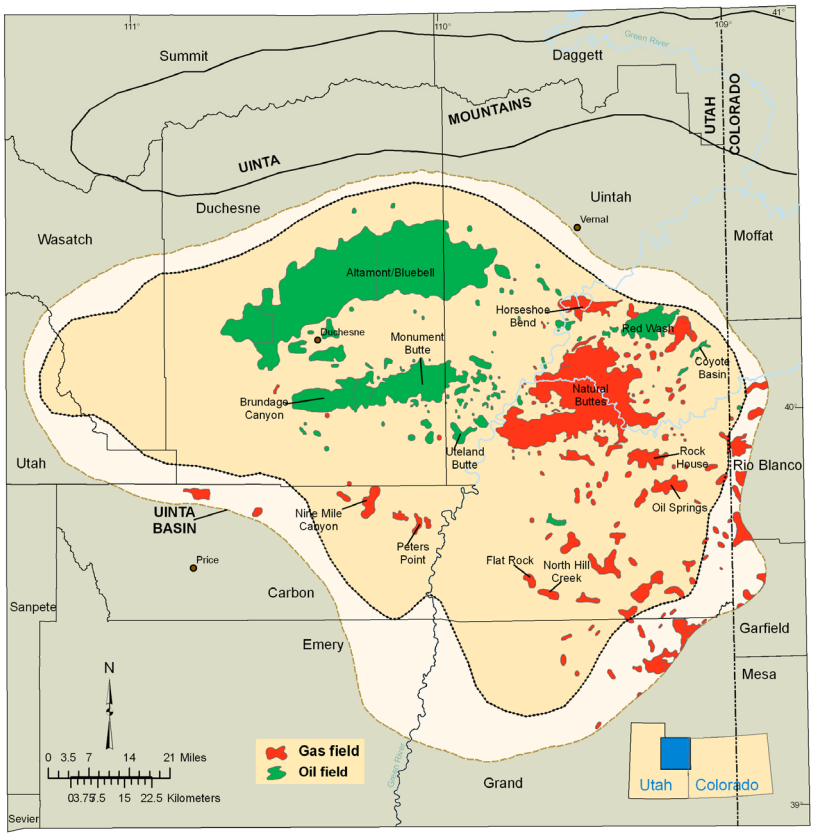
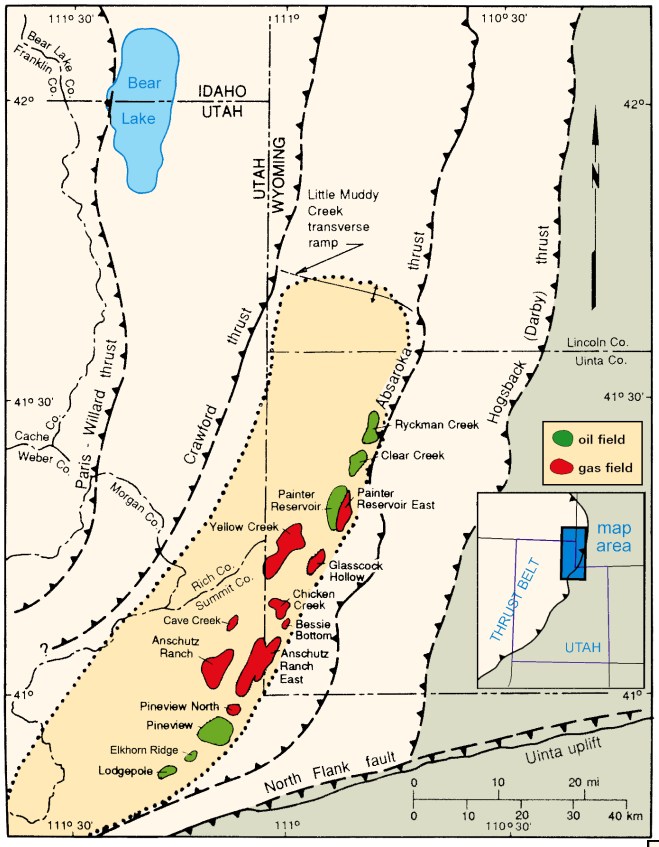


Figure 2. A - Oil and gas fields in the Paradox Basin of Utah, Colorado, and Arizona (modified from Harr, 1996). B - Oil and gas fields in the Uinta Basin of Utah (modified from Chidsey and others, 2004). Play areas in the Paradox and Uinta Basins colored light orange.

A



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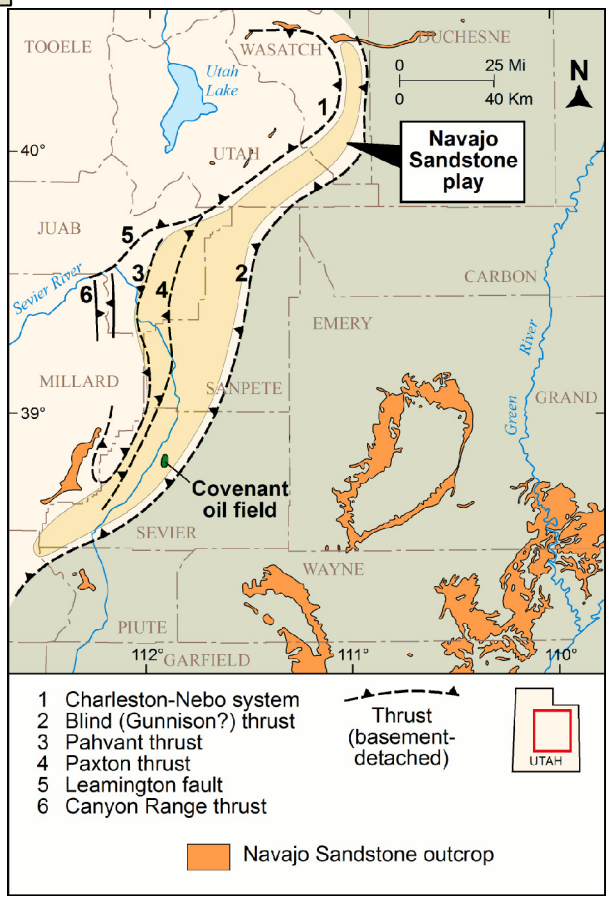

Figure 3. A - Oil and gas fields, uplifts, and major thrust faults in the Utah-Wyoming thrust belt. B - Location of Covenant oil field, uplifts, and selected thrust systems in the central Utah thrust belt province. Numbers and sawteeth are on the hanging wall of the corresponding thrust system. Modified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

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, technical presentations at national and regional professional society meetings, and publications.

FINAL TECHNICAL REPORT AND INTERACTIVE DIGITAL DELIVERABLE – DISCUSSION AND RESULTS

Review of Project Methodology

The U.S. Geological Survey defines "a play" as a set of known or postulated oil accumulations sharing similar geologic, geographic, and temporal properties such as source rock, migration pathway, timing, trapping mechanism, hydrocarbon type. This definition was the basis for the plays determined in the project. Analysis of the plays required evaluation of regional cross sections, correlation and mapping of reservoir facies, identification of wells with hydrocarbon "shows," use of geologic and engineering characteristics of each reservoir, and gathering field and production data from each reservoir. We also used current technology, primarily data from well logs, sample descriptions, tests, well completions, cores, publications, and outcrops.

Slabbed conventional core from available selected reservoirs was photographed with a digital camera and described. Selected geophysical logs from wells with cores were analyzed and compared to conventional core descriptions and/or petrophysical properties from core pugs. The logs were used to help determine the typical diagenetic processes, identify pore types, and estimate permeability trends in wells where conventional cores were not taken in the plays.

Reservoir data, cores and cuttings, geophysical logs, various reservoir maps, and other information from fields in the plays and/or regional exploratory wells were collected by the UGS. Various production reports, completion tests, core analysis and description, formation tops, and other data were compiled and entered in a database developed by the UGS. This geologic-information database linked a diverse set of geologic data to records and took geological information, such as lithology, petrophysical analyses, or depositional environment, and exported it to software programs which produced type strip logs, graphs, and cross sections, various reservoir maps, and other types of presentations to describe the individual plays.

Outcrop analogs for each play were described and photographed in the field. The state-of-the-art drilling, completion, and secondary/tertiary techniques for each play were summarized based on information obtained from the Technical Advisory Board, publications, other UGS projects, and other sources. The locations of major oil pipelines were delineated from available digital sources. Finally, the play boundaries and subplays were mapped (along with fields).

Final Technical Report

We are preparing the Final Technical Report for the project. The report includes play portfolios for the following major oil plays in Utah and vicinity (southwestern Wyoming, southwestern Colorado, and northeastern Arizona): (1) the Conventional Southern Uinta Basin (including six subplays), the Conventional Northern Uinta Basin (including two subplays) and the Deep Uinta Basin Overpressured Continuous plays in Utah, (2) the Jurassic Nugget Sandstone and Twin Creek Limestone thrust belt plays (including five subplays) in Utah and Wyoming, (3) the Mississippian Leadville Limestone and Pennsylvanian Paradox Formation plays (including four subplays) in Utah, Colorado, and Arizona, and (4) the Jurassic Navajo Sandstone "Hingeline" play in the central Utah thrust belt.

These play portfolios include the following descriptions: (1) tectonic setting; (2) reservoir stratigraphy, thickness, and lithology; (3) type of traps; (4) seals; (5) petrophysical properties; (6) diagenetic analysis; (7) oil and gas characteristics; (8) source rocks including timing, generation, and migration of oil; (9) exploration and production history; (10) case-study field evaluations; (11) summaries of the state-of-the-art current and potential best drilling, completion, and production practices, and potential for new secondary/tertiary enhanced oil recovery; (12) descriptions of reservoir outcrop analogs for each play; (13) exploration potential and trends; and (14) maps of the major oil plays and subplays. Also included are analyses of land-use constraints on development, such as wilderness or roadless areas and national parks within oil plays.

Interactive Digital Deliverable

An interactive, menu-driven digital product (deliverable) on compact disc (CD) is being prepared. The digital oil and gas field and pipeline map for Utah and vicinity will link the petroleum-producing provinces (thrust belt, Uinta Basin, and Paradox Basin) to the Final Technical Report. Other digital links will include (1) land ownership maps, (2) field boundary maps as defined by the Utah Division of Oil, Gas and Mining, (3) production, (4) oil analysis from the Utah oil sample bank (stored at the Utah Core Research Center [UCRC]), and (5) photographs and descriptions of type reservoir cores (also stored at the UCRC).

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 materials, plans, and objectives were displayed at the UGS booth during the AAPG Rocky Mountain Section meeting, October 7-9, 2007, in Snowbird, Utah. Four UGS scientists staffed the display booth at this event. Project displays will be included as part of the UGS booth at professional and other public meetings throughout the duration of the project.

Utah Geological Survey *Survey Notes* and Web Site

The Utah Geological Survey (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.

Presentations

The following presentations were made during the reporting period as part of the technology transfer activities:

> "Covenant Oil Field, Central Utah Thrust Belt – Possible Harbinger of Future Discoveries" by Michael D. Laine, Thomas C. Chidsey, Jr., John P. Vrona, and Douglas K. Strickland, at the AAPG Rocky Mountain Section meeting, Snowbird, Utah, October 8, 2007. Displays of Navajo Sandstone reservoir cores, the petroleum geology, reservoir facies, petrophysical properties, and oil source of the Covenant field discovery, and potential of the central Utah thrust belt Navajo Sandstone oil play were part of the presentation.

"Why Modelers Need to Look at the Rocks! – Examples from Greater Aneth Field, Paradox Basin, Utah" by Thomas C. Chidsey, Jr., David E. Eby, Michael D. Laine, and Thomas Dempster, at the AAPG Rocky Mountain Section meeting, Snowbird, Utah, October 9, 2007. Displays of Paradox Formation cores representing reservoir facies, baffles, and seals, and how they are needed in modeling and simulation studies were part of the presentation.

"Enhanced Oil Recovery Potential in the Uinta Basin, Utah" by Craig D. Morgan and Milind Deo, at the AAPG Rocky Mountain Section meeting, Snowbird, Utah, October 8, 2007. The presentation described waterflood operations, well spacing, carbon dioxide flooding, and reaming potential in the basin that requires enhanced oil recovery technology.

During the Utah Geological Association's annual fall field trip (October 10-12, 2007), the project team conducted a geologic stop at Covenant field (figure 4) that included the basic petroleum geology of the field (structure, reservoir/stratigraphy, drilling history, production, reserves, and oil source). The team later presented a short core workshop of Navajo Sandstone core from Covenant field in Manti, Utah (figure 5), emphasizing eolian facies and petrophysical properties.

Project Publications

Chidsey, T.C., Jr., 2007, Major oil plays in Utah and vicinity – quarterly technical progress report for the period July 1 to September 30, 2007: U.S. Department of Energy, DOE/FC26-02NT15133-20, 53 p.

Chidsey, T.C., Jr., DeHamer, J.S., Hartwick, E.E., Johnson, K.R., Schelling, D.D., Sprinkel, D.A., Strickland, D.K., Vrona, J.P., and Wavrek, D.A., 2007, Petroleum geology of Covenant oil field, central Utah thrust belt, *in* Willis, G.C., Hylland, M.D., Clark, D.L., and Chidsey, T.C., Jr., editors, 2007, Central Utah – diverse geology of a dynamic landscape: Utah Geological Association Publication 36, p. 273-296.

Chidsey, T.C., Jr., Eby, D.E., Laine, M.D., and Dempster, J.T., 2007, Why modelers need to look at the rocks! – examples from Greater Aneth field, Paradox Basin, Utah [abs]: American Association of Petroleum Geologists, Rocky Mountain Section Meeting Official Program, p. 35.

Laine, M.D., Chidsey, T.C., Jr., Sprinkel, D.A., Vrona, J.P., and Strickland, D.K., 2007, Covenant oil field, central Utah thrust belt – possible harbinger of future discoveries [abs]: American Association of Petroleum Geologists, Rocky Mountain Section Meeting Official Program, p. 45.

Morgan, C.D., and Deo, M., 2007, Enhanced oil recovery potential in the Uinta Basin, Utah [abs]: American Association of Petroleum Geologists, Rocky Mountain Section Meeting Official Program, p. 49.

Figure 4. Project team members explaining the basic petroleum geology of Covenant field during the Utah Geological Association's 2007 fall field trip in central Utah.

Figure 5. Core workshop displaying the Jurassic Navajo Sandstone core from Covenant field, Manti, Utah, during the Utah Geological Association's 2007 fall field trip in central Utah.

CONCLUSIONS AND RECOMMENDATIONS

1. 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.

2. 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.

3. We are preparing the Final Technical Report and an interactive, menu-driven digital product (deliverable) on CD for the project. The report includes play portfolios and best practices for the major oil plays in Utah and vicinity (southwestern Wyoming, southwestern Colorado, and northeastern Arizona). The CD will contain the digital oil and gas field and pipeline map for Utah and vicinity linked by the petroleum-producing provinces (thrust belt, Uinta Basin, and Paradox Basin) to the Final Technical Report and other features.

ACKNOWLEDGMENTS

Funding for this ongoing research was provided as part of the Preferred Upstream Management Program of the U.S. Department of Energy, National Energy Technology Laboratory, 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 Robert Ressetar of the UGS.

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