MAJOR OIL PLAYS IN UTAH AND VICINITY

QUARTERLY TECHNICAL PROGRESS REPORT

Reporting Period
Start Date: January 1, 2007
End Date: March 31, 2007

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

May 2007

Contract No. DE-FC26-02NT15133

Submitting Organization: Utah Geological Survey
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ABSTRACT

Utah oil fields have produced over 1.2 billion barrels (191 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 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 nineteenth quarter of the project (January 1 through March 31, 2007). This work included (1) continued analysis of the 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 m^3) of sweet, paraffinic oil and 650 billion cubic feet of gas (18 billion m^3) from more than 70 fields. The main producing zones are referred to as the Desert Creek and Ismay. Traps types 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), and diagenetic effects.

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As part of technology transfer activities during this quarter, abstracts describing Covenant field and petroleum potential in the central Utah thrust belt play were submitted to the Geological Society of America and American Association of Petroleum Geologists, for presentation at the 2007 Rocky Mountain Section meetings in St. George and Snowbird, Utah, respectively. We prepared a poster titled "Covenant Oil Field, Central Utah Thrust Belt – Possible Harbinger of Future Discoveries," for presentation at the 2007 American Association of Petroleum Geologists annual convention in Long Beach, California. We also prepared a draft manuscript on the geology of Covenant field in the central Utah thrust belt play for

inclusion in the Utah Geological Association's 2007 guidebook on the geology of central Utah. Technology transfer activities also included a presentation and publication, and the project home page was updated on the Utah Geological Survey Web site.

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Utah oil fields have produced over 1.2 billion barrels (191 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 Petroleum Technology Office (NPTO) in Tulsa, Oklahoma. This report covers research activities for the nineteenth quarter of the project (January 1 through March 31, 2007). This work included (1) continued analysis of the 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 m^3) of sweet, paraffinic oil and 650 billion cubic feet of gas (18 billion m^3) 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, carbon dioxide flood, and horizontal drilling programs.

Technology transfer activities during this quarter included a technical presentation describing the new central Utah thrust belt play to the Utah Association of Professional Landmen in Salt Lake City, Utah. Abstracts describing Covenant field and petroleum potential in the central Utah thrust belt play were submitted to the Geological Society of America and American Association of Petroleum Geologists, for presentation at the 2007 Rocky Mountain Section meetings in St. George and Snowbird, Utah, respectively. We prepared a poster titled "Covenant Oil Field, Central Utah Thrust Belt – Possible Harbinger of Future Discoveries," for

presentation at the 2007 American Association of Petroleum Geologists annual convention in Long Beach, California. We also prepared a draft manuscript on the geology of Covenant field in the central Utah thrust belt play for inclusion in the Utah Geological Association's 2007 guidebook on the geology of central Utah. Project team members published a Quarterly Technical Progress Report detailing project work, results, and recommendations, and the project home page was updated on the Utah Geological Survey Web site.

INTRODUCTION

Project Overview

Utah oil fields have produced over 1.3 billion barrels (bbls) (191 million m^3) (Utah Division of Oil, Gas and Mining, 2006). The 13.7 million barrels (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, 2006). Proven reserves are relatively high, at 256 million bbls (40.7 million m^3) (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.

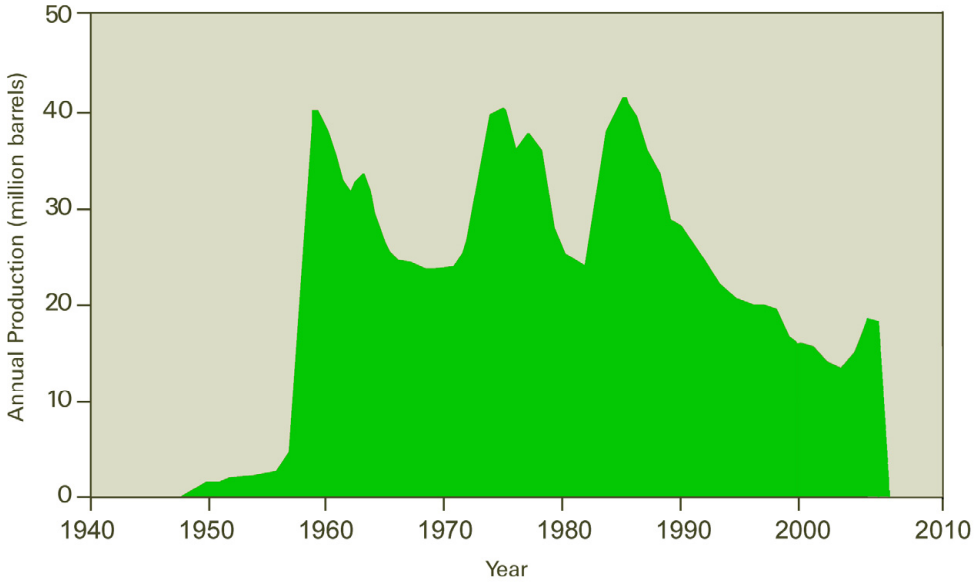

Figure 1. Oil production in Utah through 2006 showing a recent increase due, in part, to the discovery of Covenant field in the new central Utah thrust belt Jurassic Navajo Sandstone play. Source: Utah Division of Oil, Gas and Mining production records.

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 nineteenth quarter of the project (January 1 through March 31, 2007). This work included (1) continued analysis of the 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.

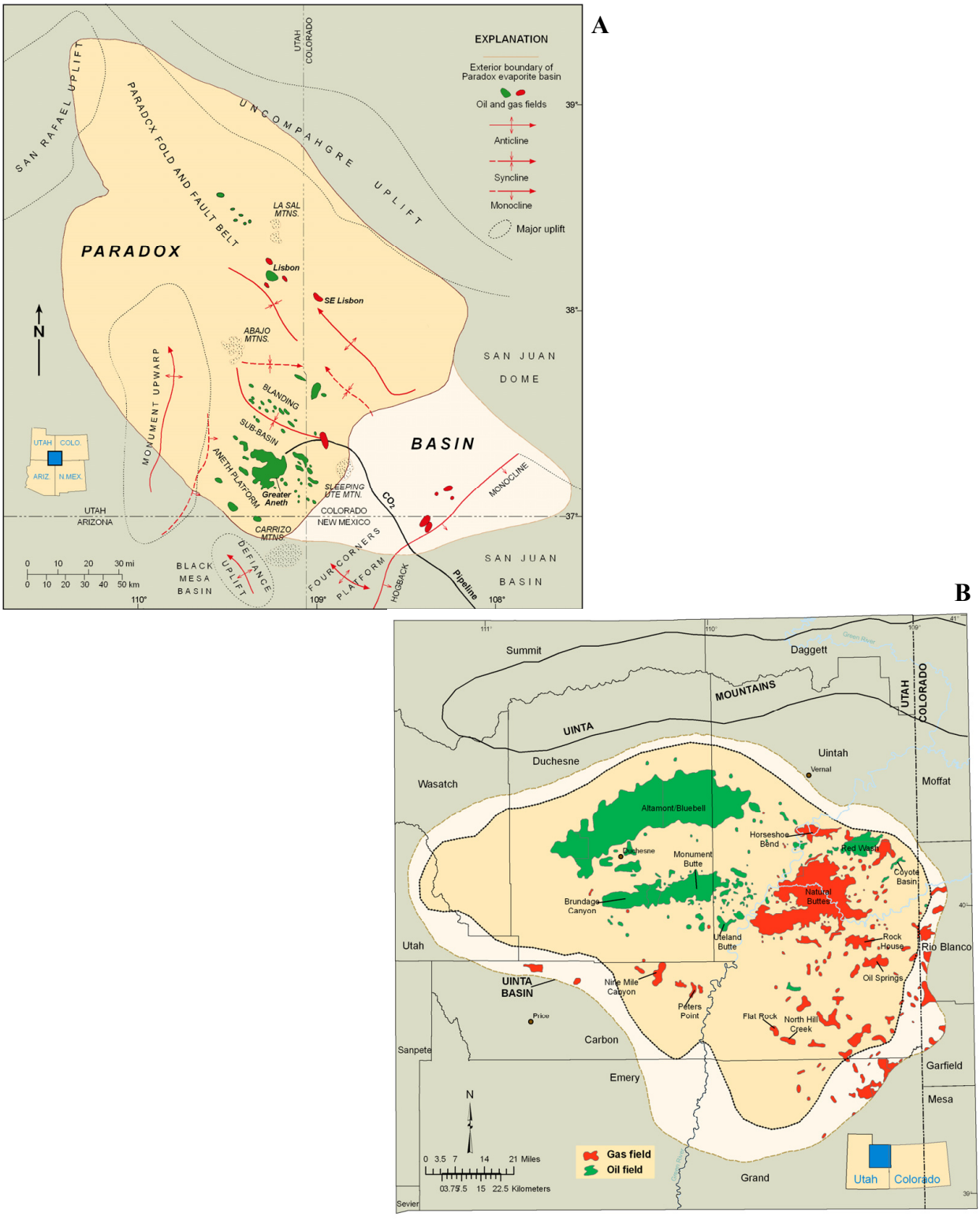

Figure 2. A - Oil and gas fields in the Paradox Basin of Utah, Colorado, and Arizona (modified from Harr, 1996). B - Oil and gas fields in the Uinta Basin of Utah (modified from Chidsey and others, 2004b). Play areas in the Paradox and Uinta Basins colored light yellow.

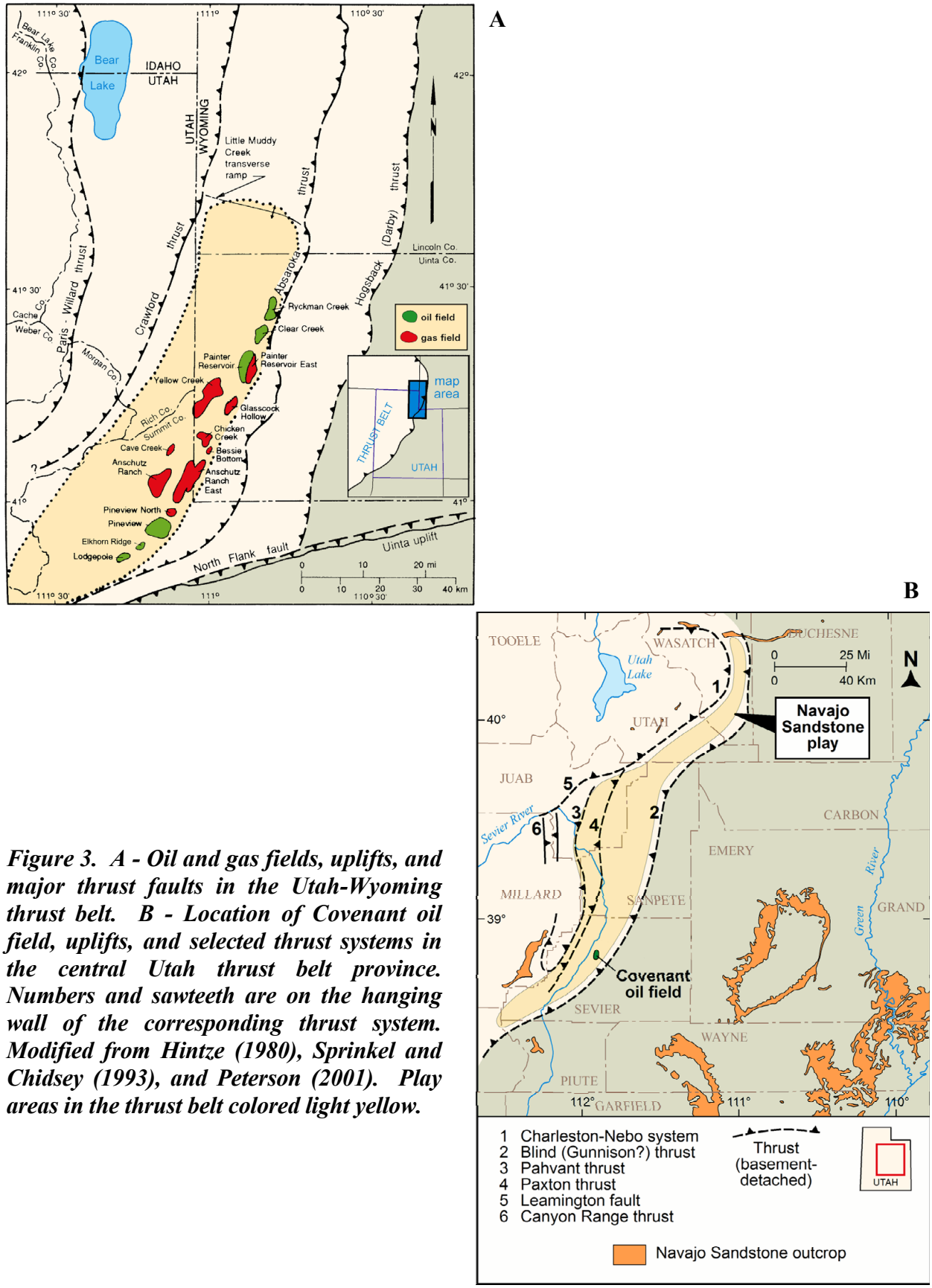

Figure 3. A - Oil and gas fields, uplifts, and major thrust faults in the Utah-Wyoming thrust belt. B - Location of Covenant oil field, uplifts, and selected thrust systems in the central Utah thrust belt province. Numbers and sawteeth are on the hanging wall of the corresponding thrust system. Modified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

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 m^3]) and 650 billion cubic feet of gas (BCFG [18 billion m^3]); 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 m^3) (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.

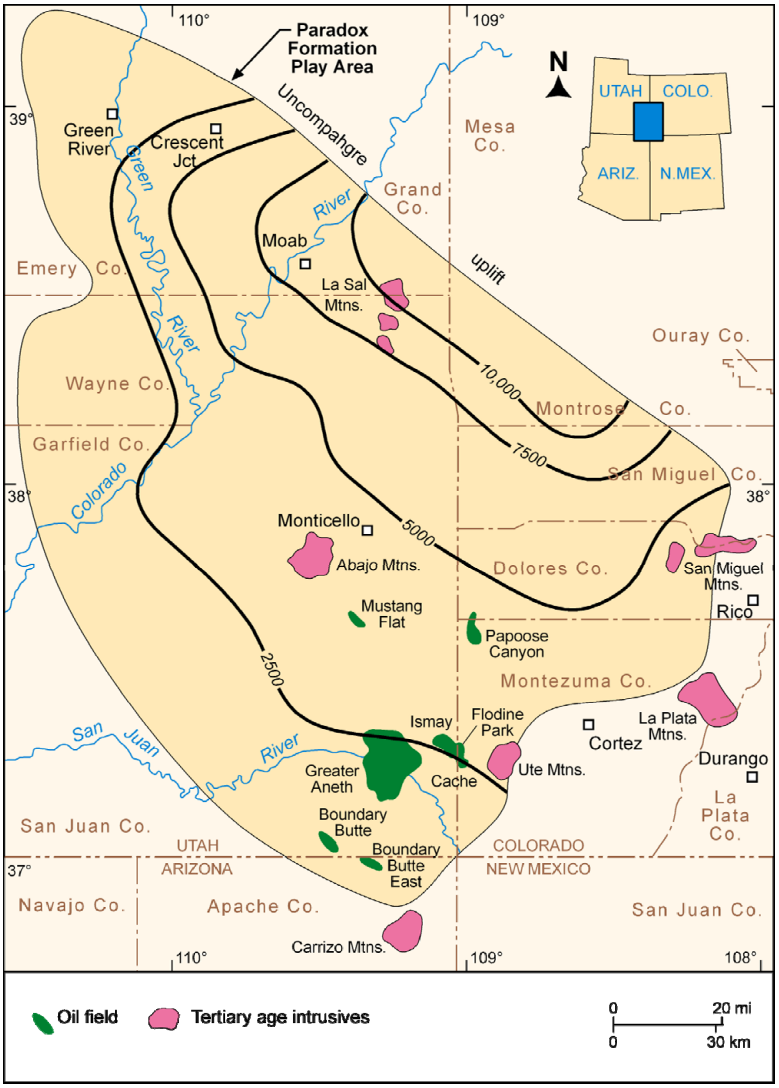

Figure 4. Pennsylvanian Paradox Formation play area and major fields, Utah, Colorado, and Arizona. Thickness of the Pennsylvanian rocks shown in feet. Modified from Choquette (1983).

The Paradox Basin can generally be divided into three areas: the Paradox fold and fault belt in the north, the Blanding sub-basin in the south-southwest, and the Aneth platform in southeasternmost Utah (figure 2A). The Paradox fold and fault belt was created during the Tertiary and Quaternary by a combination of (1) reactivation of basement normal faults, (2) salt flowage, dissolution, and collapse, and (3) regional uplift (Doelling, 2000). The relatively undeformed Blanding sub-basin and Aneth platform developed on a shallow-marine shelf. Each area contains oil and gas fields with structural, stratigraphic, or combination traps formed on discrete, often seismically defined, closures. Most Paradox Formation oil production comes from stratigraphic traps in the Blanding sub-basin and Aneth platform that locally contain algal-mound and other carbonate lithofacies buildups.

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; 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 unfractured, 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.

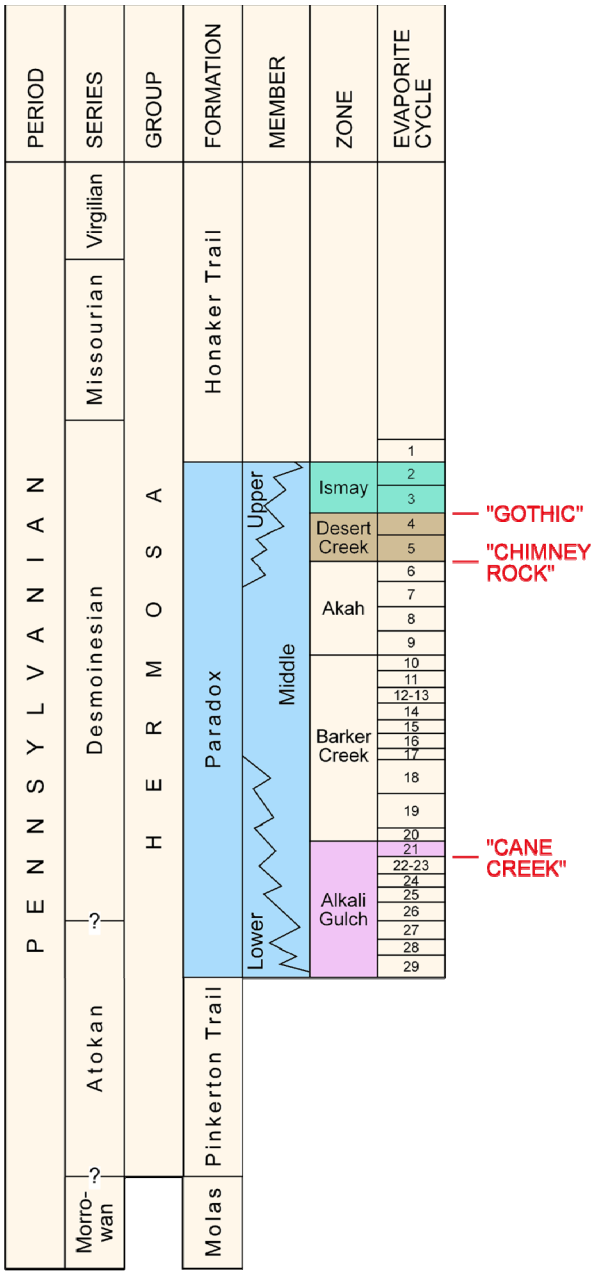

Figure 5. Pennsylvanian stratigraphic chart for the Paradox Basin; informal zones with significant production are highlighted with colors. Modified from Hite (1960), Hite and Cater (1972), and Reid and Berghorn (1981).

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. 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 (CO_2) floods, and (3) horizontal drilling.

Data Collection

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

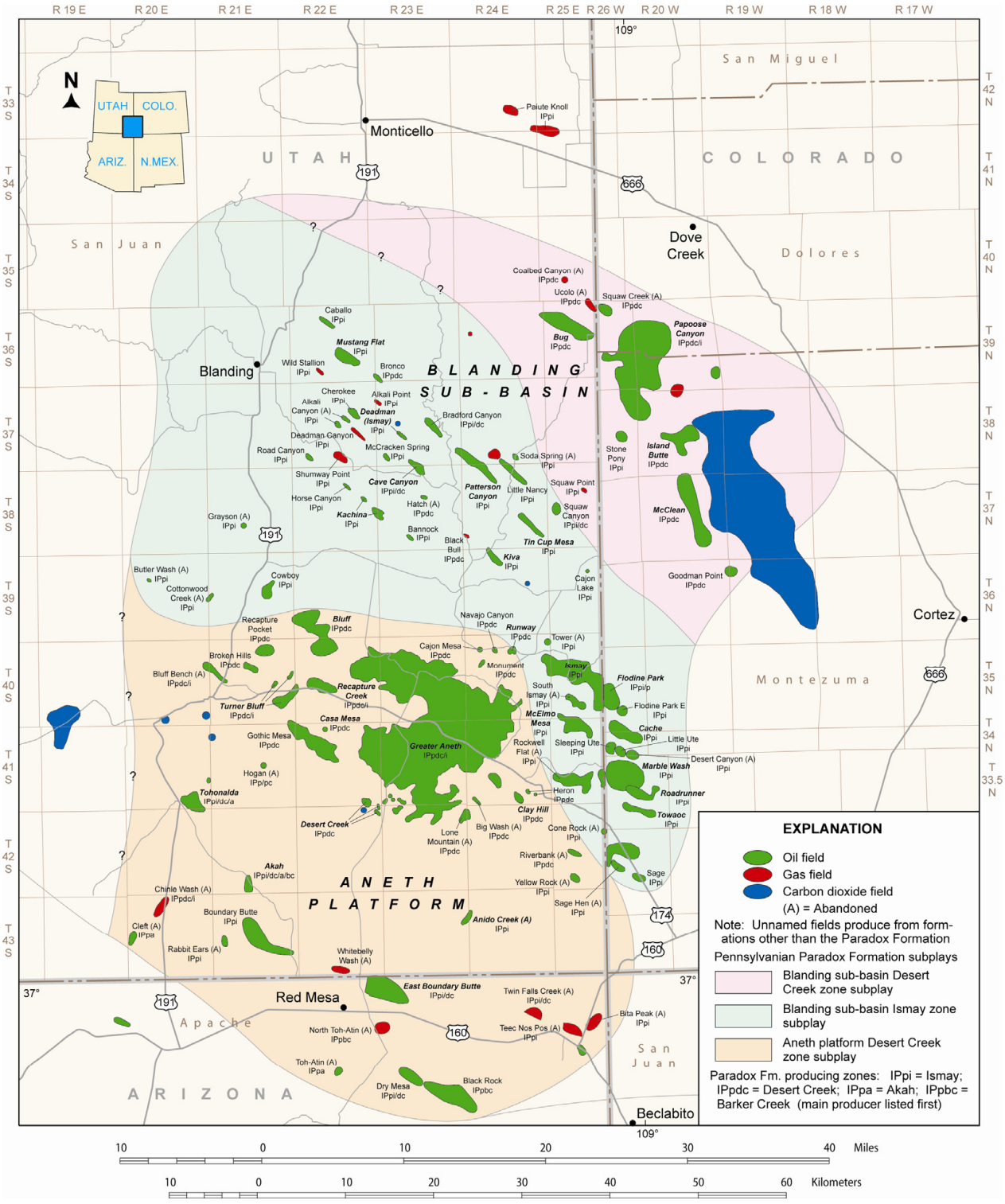

Figure 6. Location of the Paradox Formation Blanding sub-basin Desert Creek zone, Blanding sub-basin Ismay zone, and Aneth platform Desert Creek zone subplays, southeastern Utah, southwestern Colorado, and northeastern Arizona. Fields in italics have produced over 500,000 BO as of January 1, 2007. Modified from Chidsey and others (2004b); Wray and others (2002).

(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.

Abstracts describing Covenant field and petroleum potential in the central Utah thrust belt play were submitted to the Geological Society of America and American Association of Petroleum Geologists, for presentation at the 2007 Rocky Mountain Section meetings in St. George and Snowbird, Utah, respectively. We also prepared a poster titled "Covenant Oil Field, Central Utah Thrust Belt – Possible Harbinger of Future Discoveries," by T.C. Chidsey, Jr., M.D. Laine, J.P. Vrona, and D.K. Strickland, for presentation at 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:

> "Current Highlights of Major Oil and Gas Plays in Utah" by T.C. Chidsey, March 1, 2007, presented at the monthly meeting of the Utah Association of Professional Landmen in Salt Lake City, Utah. 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 Publications

Chidsey, T.C., Jr., 2007, Major oil plays in Utah and vicinity – quarterly technical progress report for the period October 1 to December 31, 2006: U.S. Department of Energy, DOE/FC26-02NT15133-18, 19 p.

We also prepared a draft manuscript on the geology of Covenant field in the central Utah thrust belt play for inclusion in the Utah Geological Association's 2007 guidebook titled "Central Utah – Diverse Geology of a Dynamic Landscape."

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 m^3) of sweet, paraffinic oil and 650 BCFG (18 billion m^3) 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 (CO_2) 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 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 Michael Hylland of the UGS.

REFERENCES

Chidsey, T.C., Jr., 2006, Major oil plays in Utah and vicinity – quarterly technical progress report for the period January 1 to March 31, 2006: U.S. Department of Energy, DOE/FC26-02NT15133-15, 67 p.

Chidsey, T.C., Jr., Morgan, C.D., and Bon, R.L., 2004a, Major oil plays in Utah and vicinity – quarterly annual technical progress report for the period April 1 to June 30, 2004: U.S. Department of Energy, DOE/FC26-02NT15133-8, 22 p.

Chidsey, T.C., Jr., Wakefield, S., Hill, B.G., and Hebertson, M., 2004b, Oil and gas fields of Utah: Utah Geological Survey Map 203DM, scale 1:700,000.

Choquette, P.W., 1983, Platy algal reef mounds, Paradox Basin, *in* Scholle, P.A., Bebout, D.G., and Moore, C.H., editors, Carbonate depositional environments: American Association of Petroleum Geologists Memoir 33, p. 454-462.

Colorado Oil & Gas Conservation Commission, 2006, Colorado oil and gas information system (COGIS) - production data inquiry: Online, <oil-gas.state.co.us/cogis/ProductionSearch2.asp>, accessed May 25, 2006.

Doelling, H.H., 2000, Geology of Arches National Park, Grand County, Utah, *in* Sprinkel, D.A., Chidsey, T.C., Jr., and Anderson, P.B., editors, Geology of Utah's parks and monuments: Utah Geological Association Publication 28, p. 11-36.

Energy Information Administration, 2006, Advance summary – U.S. crude oil, natural gas, and natural gas liquids reserves 2005 annual report: Online Petroleum Navigator, <tonto.eia.doe.gov/dnav/pet/pet_crd/pres_dcu_SUT_a.htm>, accessed October 5, 2006.

Harr, C.L., 1996, Paradox oil and gas potential of the Ute Mountain Ute Indian Reservation, *in* Huffman, A.C., Jr., Lund, W.R., and Godwin, L.H., editors, Geology of the Paradox Basin: Utah Geological Association Publication 25, p. 13-28.

Hintze, L.F., 1980, Geologic map of Utah: Utah Geological Survey Map M-A-1, 2 sheets, scale 1:500,000.

Hite, R.J., 1960, Stratigraphy of the saline facies of the Paradox Member of the Hermosa Formation of southeastern Utah and southwestern Colorado, *in* Smith, K.G., editor, Geology of the Paradox Basin fold and fault belt: Four Corners Geological Society, Third Field Conference Guidebook, p. 86-89.

Hite, R.J., and Cater, F.W., 1972, Pennsylvanian rocks and salt anticlines, Paradox Basin, Utah and Colorado, *in* Mallory, W.W., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists Guidebook, p. 133-138.

Peterson, J.A., 2001 (updated 2003), Carboniferous-Permian (late Paleozoic) hydrocarbon

system, Rocky Mountains and Great Basin U.S. region -- major historic exploration objective: Rocky Mountain Association of Geologists Open-file Report, 54 p.

Reid, F.S., and Berghorn, C.E., 1981, Facies recognition and hydrocarbon potential of the Pennsylvanian Paradox Formation, *in* Wiegand, D.L., editor, Geology of the Paradox Basin: Rocky Mountain Association of Geologists Guidebook, p. 111-117.

Sprinkel, D.A., and Chidsey, T.C., Jr., 1993, Jurassic Twin Creek Limestone, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 76.

Utah Division of Oil, Gas and Mining, 2006, Oil and gas production report, May: Online, <http://www.ogm.utah.gov/oilgas/PUBLICATIONS/Reports/PROD_book_list.htm>, accessed May 2, 2007.

Wray, L.L., Apeland, A.D., Hemborg, T., and Brchan, C., 2002, Oil and gas fields map of Colorado; Colorado Geological Survey Map Series 33, scale 1:500,000.