MAJOR OIL PLAYS IN UTAH AND VICINITY

QUARTERLY TECHNICAL PROGRESS REPORT

Reporting Period
Start Date: July 1, 2002
End Date: September 30, 2002

Edited and Compiled
by
Thomas C. Chidsey, Jr., Principal Investigator/Program Manager,
Utah Geological Survey

January 2003

Contract No. DE-FC26-02NT15133

Submitting Organization: Utah Geological Survey
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DISCLAIMER

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ABSTRACT

Utah oil fields have produced a total of 1.2 billion barrels (191 million m^3). However, the 15 million barrels (2.4 million m^3) of production in 2000 was the lowest level in over 40 years and continued the steady decline that began in the mid-1980s. The Utah Geological Survey believes this trend can be reversed 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; summaries of the state-of-the-art drilling, completion, and secondary/tertiary techniques for each play; locations of major oil pipelines; descriptions of reservoir outcrop analogs; and identification and discussion of land use constraints. All play maps, reports, databases, and so forth, produced for the project will be published in interactive, menu-driven digital (web-based and compact disc) and hard-copy formats.

This report covers research activities for the first quarter of the first project year (July 1 through September 30, 2002). This work included producing general descriptions of Utah's major petroleum provinces, gathering field data, and analyzing best practices in the Utah Wyoming thrust belt. Major Utah oil reservoirs and/or source rocks are found in Devonian through Permian, Jurassic, Cretaceous, and Tertiary rocks. Stratigraphic traps include carbonate buildups and fluvial-deltaic pinchouts, and structural traps include basement-involved and detached faulted anticlines. Best practices used in Utah's oil fields consist of waterflood, carbon-dioxide flood, gas-injection, and horizontal drilling programs.

Nitrogen injection and horizontal drilling programs have been successfully employed to enhance oil production from the Jurassic Nugget Sandstone (the major thrust belt oil-producing reservoir) in Wyoming's Painter Reservoir and Ryckman Creek fields. At Painter Reservoir field a tertiary, miscible nitrogen-injection program is being conducted to raise the reservoir pressure to miscible conditions. Supplemented with water injection, the ultimate recovery will be 113 million bbls (18 million m^3) of oil (a 68 percent recovery factor over a 60-year period). The Nugget reservoir has significant heterogeneity due to both depositional facies and structural effects. These characteristics create ideal targets for horizontal wells and horizontal laterals drilled from existing vertical wells. Horizontal drilling programs were conducted in both Painter Reservoir and Ryckman Creek fields to encounter potential undrained compartments and increase the overall field recovery by 0.5 to 1.5 percent per horizontal wellbore.

Technology transfer activities consisted of exhibiting a booth display of project materials at the Rocky Mountain Section meeting of the American Association of Petroleum Geologists, a technical presentation to the Wyoming State Geological Survey, and two publications. A project home page was set up on the Utah Geological Survey Internet web site.

EXECUTIVE SUMMARY

Utah oil fields have produced a total of 1.2 billion barrels (191 million m^3). However, the 15 million barrels (2.4 million m^3) of production in 2000 was the lowest level in over 40 years and continued the steady decline that began in the mid-1980s. The overall objectives of this study are to: (1) increase recoverable oil from existing field reservoirs, (2) add new discoveries, (3) prevent premature abandonment of numerous small fields, (4) increase deliverability through identifying the latest drilling, completion, and secondary/tertiary 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 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 first quarter of the first project year (July 1 through September 30, 2002). This work included: (1) producing general descriptions of Utah's major petroleum provinces, (2) gathering production, completion, and other field data, (3) analyzing best practices in the Utah-Wyoming thrust belt, and (4) technology transfer activities.

A combination of depositional and structural events created the right conditions for oil generation and trapping in Utah. Oil plays are specific geographic areas with petroleum potential due to favorable source rock, migration paths, reservoir characteristics, and other factors. These plays, to be delineated later during the project, are found in the three major petroleum provinces of Utah. The land ownership in Utah's oil provinces is complex, consisting of federal, state, Native American, and private lands.

Major Utah oil reservoirs are found in rocks of Devonian through Permian, Jurassic, and Tertiary age; outcrop analogs are found in Utah for most of these reservoirs. Trapping mechanisms include stratigraphic carbonate buildups and fluvial-deltaic pinchouts, and structural basement-involved and detached faulted anticlines. The oil found in these traps originates from Pennsylvanian, Permian, Cretaceous, or Tertiary source rocks. Over 125 fields have been discovered in these oil provinces with production from 4,300-plus wells. Best practices used in these fields include waterflood, carbon-dioxide flood, gas injection, and horizontal drilling.

Two significant ongoing practices are employed in Painter Reservoir and Ryckman Creek fields in the Wyoming portion of the thrust belt to enhance the ultimate recovery of oil from the Jurassic Nugget Sandstone, the major oil-producing reservoir in the province: (1) nitrogen injection and (2) horizontal drilling. Reservoir compositional simulation studies were conducted on Painter Reservoir field for a tertiary, miscible nitrogen-injection program. In this process, nitrogen and hydrocarbon gas are over-injected into the reservoir to raise the reservoir pressure to miscible conditions. The simulation indicated that when this program is supplemented with water injection, the ultimate recovery would be 113 million bbls (18 million m^3) of oil (a 68 percent recovery factor over a 60-year period). The miscible nitrogen-injection program began in 1981 and has been an ongoing success.

The eolian Nugget Sandstone has significant heterogeneity due to both depositional facies and structural effects. These characteristics create ideal targets for horizontal wells and horizontal laterals drilled from existing vertical wells. Horizontal drilling programs were conducted in both Painter Reservoir and Ryckman Creek fields to encounter potential undrained

compartments, reduce coning and cusping, reduce sand production, and increase sweep efficiency of the nitrogen and waterfloods. Optimally placed horizontal wellbores increase the overall field recovery by 0.5 to 1.5 percent for each horizontal well. Painter Reservoir field has produced over 44 million bbls (7 million m^3) of oil and serves as an excellent example of best practices for Nugget Sandstone reservoirs in the thrust belt.

Technology transfer activities included exhibiting a booth display of project materials at the 2002 Rocky Mountain Section meeting of the American Association of Petroleum Geologists in Laramie, Wyoming. An oral technical presentation was made to the Wyoming State Geological Survey describing project goals, tasks, and products. Two articles were published in the Utah Geological Survey's *Petroleum News* and *Survey Notes*. A project home page was set up on the Utah Geological Survey Internet web site.

INTRODUCTION

Project Overview

Utah oil fields have produced a total of 1.2 billion barrels (bbls) (191 million m^3) (Utah Division of Oil, Gas and Mining, 2001). However, the 15 million bbls (2.4 million m^3) of production in 2000 was the lowest level in over 40 years and continued the steady decline that began in the mid-1980s (figure 1) (Utah Division of Oil, Gas and Mining, 2001). Proven reserves are relatively high, at 283 million bbls (45 million m^3) (Energy Information Administration, 2001). With higher oil prices now prevailing, secondary and tertiary recovery techniques should boost future production rates and ultimate recovery from known fields.

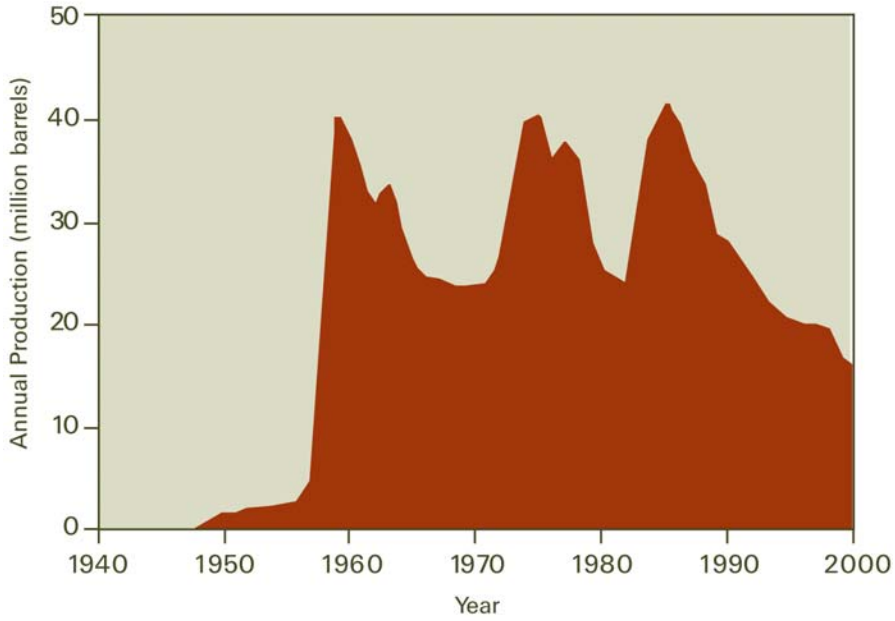
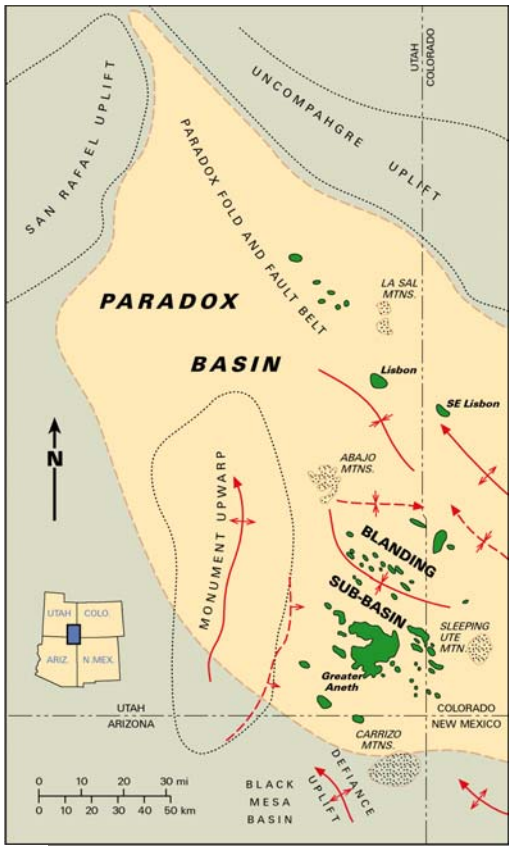


Figure 1. Oil production in Utah through 2000 (Utah Division of Oil, Gas and Mining, 2001).

Utah's drilling history has fluctuated greatly due to discoveries, oil price trends, and changing exploration targets. During the boom period of the early 1980s, activity peaked at over 500 wells per year. Sustained high prices are likely to entice less risk-averse exploration investment (more wildcats), resulting in new discoveries.

Utah still contains large, promising areas that are virtually unexplored. There is significant potential for increased recovery from existing fields by employing improved reservoir characterization and the latest drilling, completion, and secondary/tertiary 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 (figure 2). These play portfolios will include: descriptions (such as stratigraphic,



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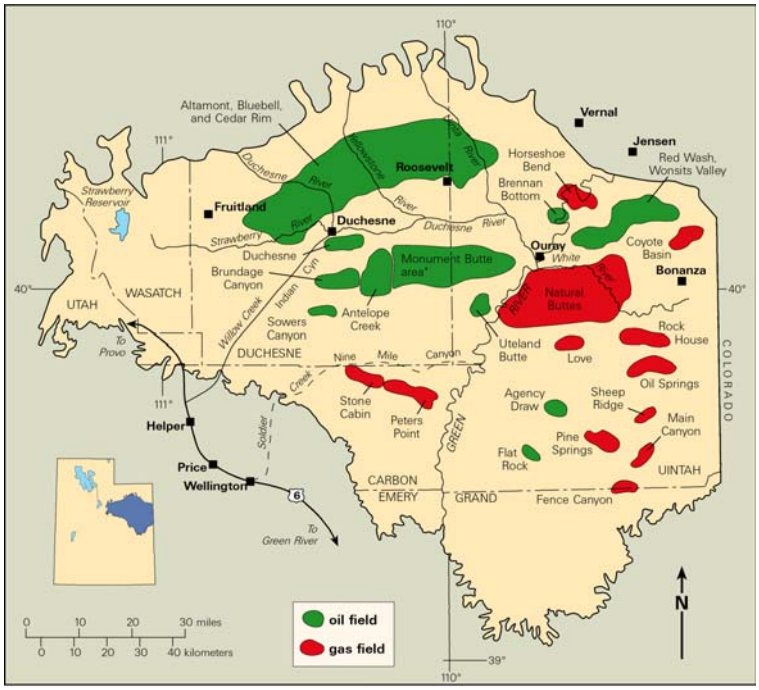

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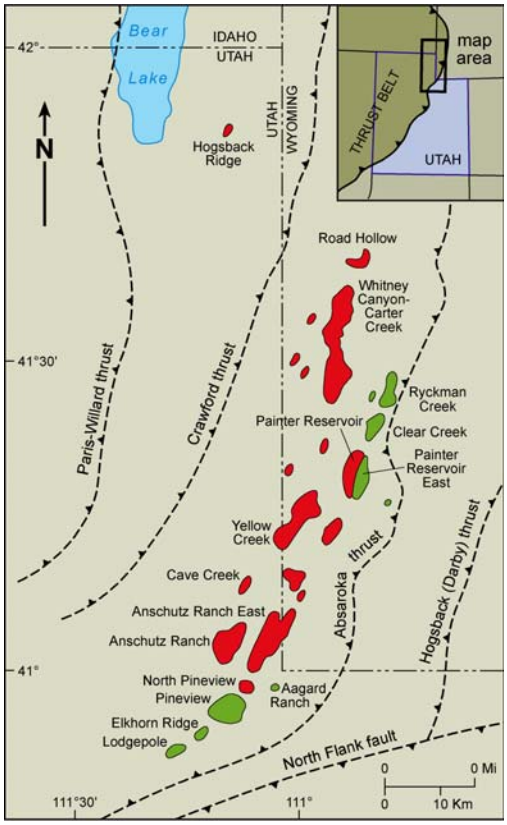


C

Figure 2. Major oil-producing provinces of Utah and vicinity. (A) Oil and gas fields in the Paradox Basin of Utah and Colorado. (B) Oil and gas fields in the Uinta Basin of Utah. (C) Oil and gas fields, uplifts, and major thrust faults in the Utah-Wyoming thrust belt.

diagenetic setting, 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 land use constraints to development such as wilderness or roadless areas, and national parks within oil plays.

Project Benefits

The overall benefits of this multi-year project will be enhanced petroleum production in the Rocky Mountain region. Specifically, the benefits expected from the project are:

(1) increasing oil production and reserves by improved reservoir characterization,

(2) preventing premature abandonment of numerous small fields in the Paradox and Uinta Basins,

(3) increasing recoverable reserves by identifying the type of untapped compartments created by reservoir heterogeneity (for example, diagenesis and rapid facies changes),

(4) increasing deliverability through identifying the latest drilling, completion, and secondary/tertiary techniques,

(5) identifying reservoir trends for field extension drilling and stimulating exploration in producing fairways,

(6) encouraging technology used in other identified basins or trends with similar types of reservoirs,

(7) reducing development costs and risk by reducing the number of wells needed to successfully drain the reservoir,

(8) allowing limited energy investment dollars to be used more productively, and

(9) increasing royalty income to the Federal Government; Utah, Wyoming, and Colorado state and local governments; the Navajo Nation and Ute Mountain Ute Indian Nation; 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 and land-acquisition strategies. 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 Holder Boards, an industry outreach

program, and technical presentations at national and regional professional meetings. All of this information will be made public (1) through the Utah Geological Survey (UGS) Internet web site, (2) as an interactive, menu-driven digital product on compact disc, and (3) as hard copy publications in various technical or trade journals.

MAJOR OIL-PRODUCING PROVINCES IN UTAH AND VICINITY

Geologic Setting

A combination of depositional and structural events created the major oil-producing provinces in Utah: Paradox Basin, Uinta Basin, and Utah-Wyoming thrust belt (figure 2). Oil production in the thrust belt and Paradox Basin extends into Wyoming and Colorado, respectively, but the bulk of the production is from Utah.

The ages of the rocks exposed in Utah include every geologic eon, era, period, and epoch. Many of these rocks have the qualities necessary to create the oil reservoirs, sources, and seals that make Utah a petroleum-producing state with large, relatively unexplored areas of hydrocarbon potential.

During the Pennsylvanian (figure 3A), the Paradox Basin developed in southeastern Utah where cyclic organic-rich shales, carbonates, and evaporites accumulated under restricted marine conditions in the rapidly subsiding basin. The Paradox Basin contains Utah's largest oil field, Greater Aneth. Renewed movement on deep, older basement faults in the basin formed structures which are now oil productive in Mississippian-age carbonates.

In Early Jurassic time, Utah had an arid climate and lay 15 degrees north of the equator (figure 3B). It was then that the most prolific oil reservoir in the thrust belt, the Nugget Sandstone, was deposited in an extensive dune field comparable to the present Sahara. Correlative rocks form many of the spectacular canyons in the parks of southern Utah.

During the Cretaceous, compressional forces of the Sevier orogeny produced highlands in western Utah and the Western Interior Seaway covered most of eastern Utah (figure 3C). Extensive coal-forming swamps near the coastline and fluvial and wave-dominated deltas migrated eastward across the state as the sea eventually retreated. The Sevier orogeny continued into the Paleocene producing the "thin-skinned" folds and faults of the thrust belt that have been such prolific oil producers in northern Utah (figure 3D). Concealed, deep exploration targets beneath the Sevier thrusts offer frontier-drilling opportunities in the poorly explored western half of Utah.

The Laramide orogeny, between latest Cretaceous and Eocene time, produced numerous basins and basement-cored uplifts in the Rocky Mountain states. In Utah, the Uinta Basin is the major oil contributor. During the Paleocene and Eocene (figure 3E), lakes Flagstaff and Uinta formed in the Uinta Basin where over 3,350 meters (11,000 feet) of alluvial, marginal lacustrine (fluvial, deltaic, beach), and open lacustrine sediments accumulated in an intertonguing relationship. Recent waterflood projects have been very successful in increasing oil production in the southern part of the basin.

The principal source rocks for these provinces were deposited during the Pennsylvanian, Permian, Cretaceous, and Tertiary as marine and lacustrine shale. The reservoir rocks were deposited in a variety of environments including deltaic, shallow-shelf marine, eolian-dune, coastal-plain, and river-floodplain settings.

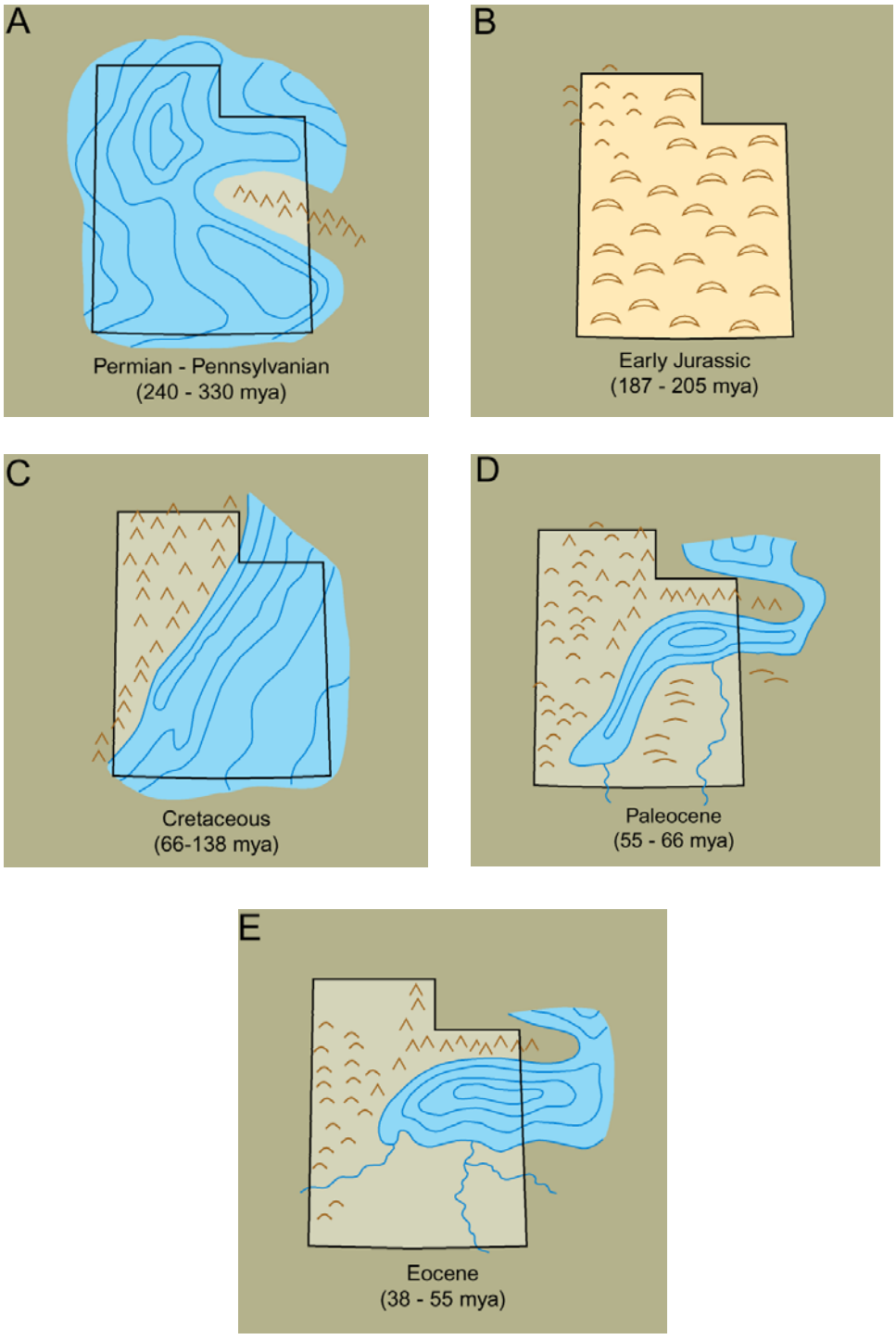


Figure 3. Paleogeographic maps of Utah during the Pennsylvanian-Permian, Early Jurassic, Cretaceous, Paleocene, and Eocene (modified from Stokes, 1986).

General Descriptions

Oil plays are geographic areas with petroleum potential caused by favorable combinations of source rock, migration paths, reservoir rock characteristics, and other factors. These plays, to be delineated later in the project, are found in the Paradox Basin, Uinta Basin, and thrust belt – the three major petroleum provinces of Utah (figure 2), two of which extend into Wyoming or Colorado. The following are general descriptions of these provinces in Utah.

Paradox Basin

- Major Oil Reservoirs: Devonian McCracken Sandstone Member of the Elbert Formation, subtidal to supratidal dolomite to delta-front sandstone; Mississippian Leadville Dolomite, shallow-shelf marine dolomite and limestone; Pennsylvanian Paradox Formation, shallow-shelf marine limestone and dolomite; Permian Coconino Sandstone, eolian sandstone.

- Trapping Mechanisms: stratigraphic – carbonate buildups (algal mounds, shoals, islands [figure 4]) sealed by anhydrite, salt, or organic-rich shale; structural – basement-involved faulted asymmetrical anticlines.
  Source Rocks: black, organic-rich marine shale within the Pennsylvanian Paradox Formation.

- First Commercial Discovery: Boundary Butte field, 1947.

- Number of Active Fields/Wells: 68 fields/779 wells (Utah Division of Oil, Gas and Mining, 2001).

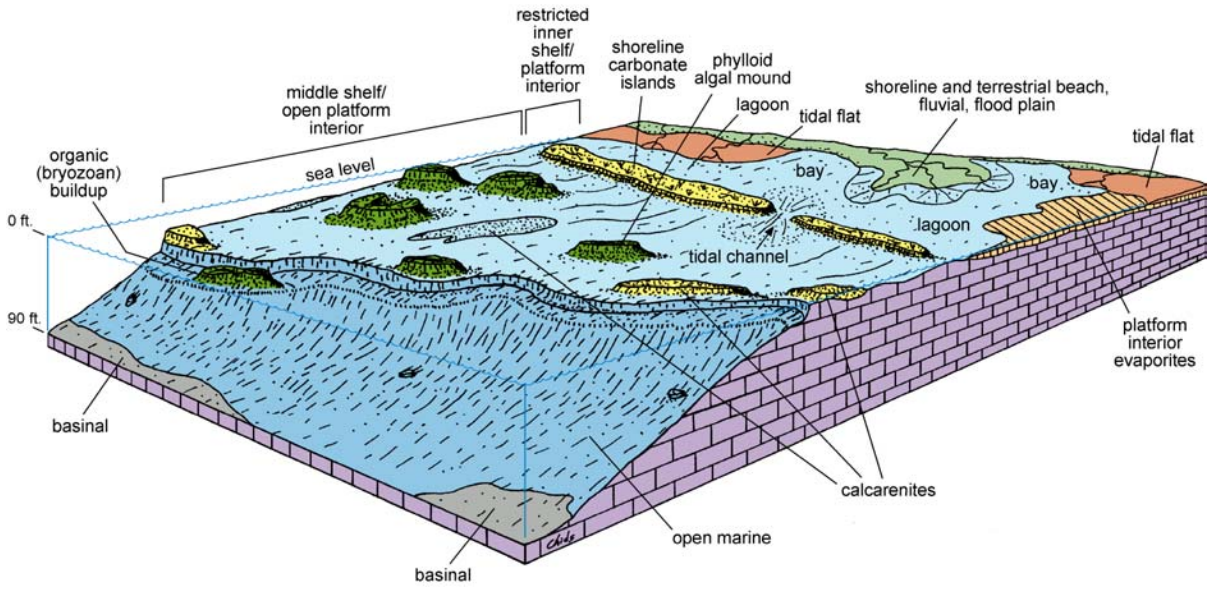


Figure 4. Block diagram displaying major depositional facies for the Pennsylvanian Paradox Formation, Paradox Basin.

- Recent Monthly Production: 525,000 bbls (84,000 m^3) of oil, 2.0 billion cubic feet (BCF) (0.06 BCM) of gas (Utah Division of Oil, Gas and Mining, 2001).

- Cumulative Production: 523 million bbls (83.2 million m^3) of oil, 1.3 trillion cubic feet (TCF) (0.04 TCM) of gas (Utah Division of Oil, Gas and Mining, 2001).

- Best Practices: waterflood, carbon-dioxide flood, gas injection, horizontal drilling.

- Major Pipelines: Four Corners Pipeline Co. (12-inch oil), Texas-New Mexico Pipeline Co. (16-inch oil), UNOCAL Pipeline Co. (10-inch oil), Western Gas Resources, Inc. (16-inch gas), Northwest Pipeline Corp. (26-inch gas), ExxonMobil (carbon dioxide), Mid-America Pipeline System (10-inch products).

- Land Ownership: 56 percent U.S. Bureau of Land Management (BLM), 11 percent National Parks, 9 percent Native American, 8 percent Utah School and Institutional Trust Lands Administration (SITLA), 8 percent private, 7 percent National Forest, 1 percent wilderness.

- Outcrop Analogs of Reservoir Rocks in Utah: Ismay and Desert Creek zone algal mounds, Pennsylvanian Paradox Formation, exposed along the San Juan River in southeastern Utah (figure 5).

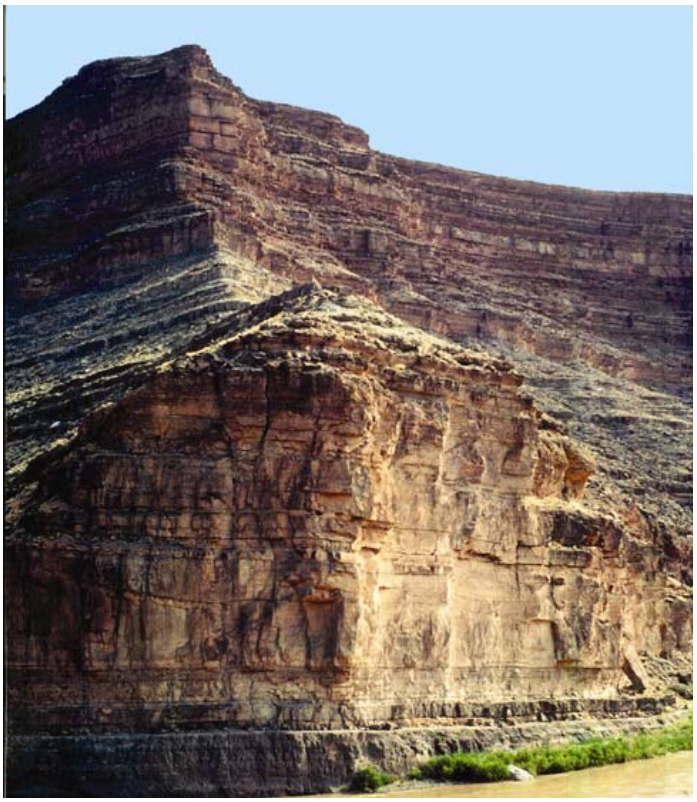


Figure 5. Paradox Formation algal mound, San Juan River Canyon, southeastern Utah. Photo by David E. Eby, Eby Petrography & Consulting, Inc.

Uinta Basin

- Major Oil Reservoirs: Eocene Green River and Colton Formations, lacustrine to alluvial channel and bar sandstone (figure 6); and Pennsylvanian Weber Sandstone, coastal eolian and littoral sandstone.

- Trapping Mechanisms: anticlinal at Ashley Valley field, stratigraphic conventional (fluvial-deltaic pinchouts) and basin centered.

- Source Rocks: Cretaceous coals and shale, Eocene lacustrine shale.

- First Commercial Discovery: Gas at the Ashley Valley field, 1925, and oil at Roosevelt field, 1949.

- Number of Active Fields/Wells: 51 fields/3,499 wells (Utah Division of Oil, Gas and Mining, 2001).

- Recent Monthly Production: 637,925 bbls (101,430 m^3) of oil, 8.8 BCF (0.25 BCM) of gas (Utah Division of Oil, Gas and Mining, 2001).

- Cumulative Production: 486 million bbls (77.3 million m^3) of oil, 1.9 TCF (0.05 TCM) of gas (Utah Division of Oil, Gas and Mining, 2001).

- Best Practices: waterflood in the Green River Formation.

- Major Pipelines: Chevron Pipe Line Co. (10-inch oil [2 lines]), Mid-America Pipeline System (10-inch LPG), Northwest Pipeline Co. (26-inch gas), Questar Pipeline Co. (16-inch and 20-inch gas).

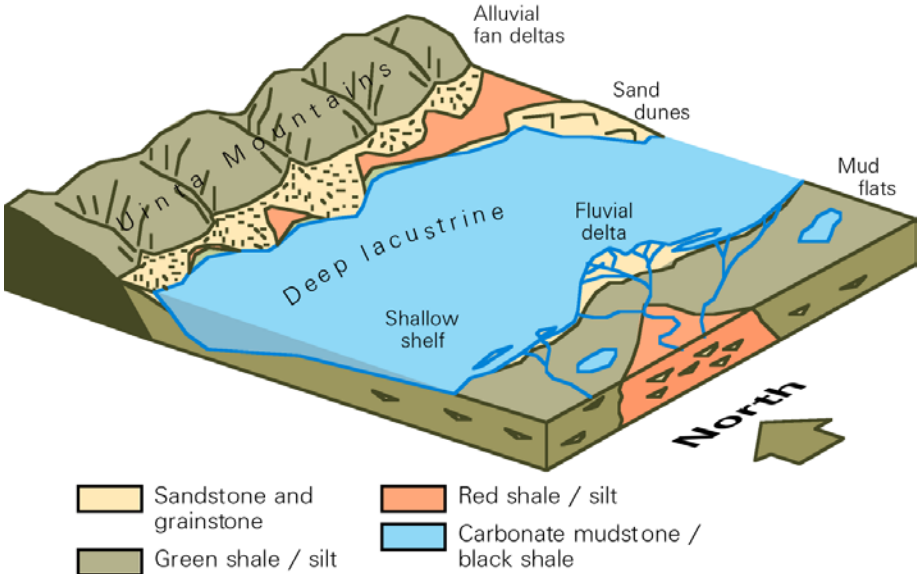


Figure 6. Block diagram displaying major depositional facies for the Tertiary Green River Formation, Uinta Basin.

- Land Ownership: 80 percent BLM, 7 percent National Forest, 6 percent Native American, 5 percent private, 1 percent SITLA, 1 percent wildlife refuge.

- Outcrop Analogs of Reservoir Rocks in Utah: Book, Roan, and Bad Land Cliffs, and Raven Ridge (figure 7).

Thrust Belt

- Major Oil Reservoirs: Jurassic Nugget Sandstone, eolian dune sandstone; Jurassic Twin Creek Limestone, shallow marine limestone.

- Trapping Mechanisms: anticlines in the hanging walls of detached (not involving basement rocks) thrust systems (figure 8), and untested subthrust structures (beneath detached and basement-cored faults).

- Source Rocks: Cretaceous Mowry Shale; possibly Permian Phosphoria Formation.

- First Commercial Discovery: Pineview field, 1975.

Figure 7. Fluvial channel deposits of the Green River Formation, Nine Mile Canyon, north of the Roan and Book Cliffs, east-central Utah.

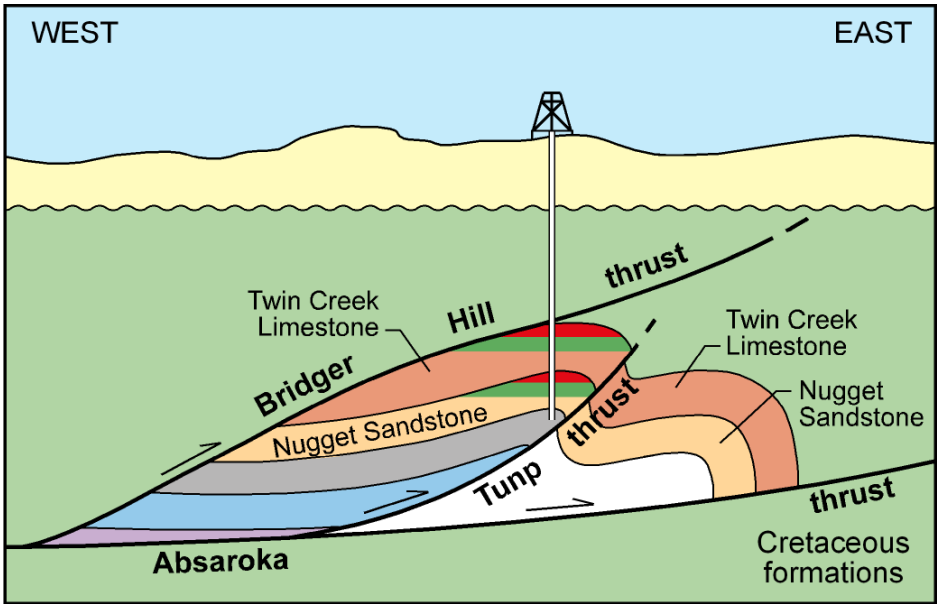


Figure 8. Diagrammatic west-east structural cross section showing typical hanging-wall anticline trap.

- Number of Active Fields/Wells: 10 fields/88 wells (Utah Division of Oil, Gas and Mining, 2001).

- Recent Monthly Production: 120,000 bbls (19,080 m^3) of oil, 6.4 BCF (0.18 BCM) of gas (Utah Division of Oil, Gas and Mining, 2001).

- Cumulative Production: 174 million bbls (27.7 million m^3) of oil, 3 TCF (0.08 TCM) of gas (Utah Division of Oil, Gas and Mining, 2001).

- Best Practices: gas re-injection to maintain pressure, horizontal drilling.

- Major Pipelines: BP Amoco (8-inch oil), Frontier Pipeline Co. (16-inch oil), Chevron Pipeline Co. (10-inch oil), Pioneer Pipeline Co. (8-inch oil), Phillips Pipeline Co. (6-inch oil, 6-inch products), Questar Pipeline Co. (24-inch, 20-inch, 18-inch, 16-inch gas), Kern River Gas Transmission Co. (36-inch gas), Anadarko (10-inch hydrogen sulfide).

- Land Ownership: Statewide thrust belt – 52 percent BLM, 25 percent private, 10 percent military reservations, 7 percent SITLA, 4 percent Forest Service, 1 percent Native American, 1 percent wildlife refuges; Northeast Utah – 70 percent private, 16 percent National Forest, 6 percent BLM, 3 percent SITLA, 3 percent wilderness, 2 percent Utah Division of Wildlife Resources.

- Outcrop Analogs of Structural Traps in Utah: northern Wasatch Range (figure 9), Crawford Mountains.

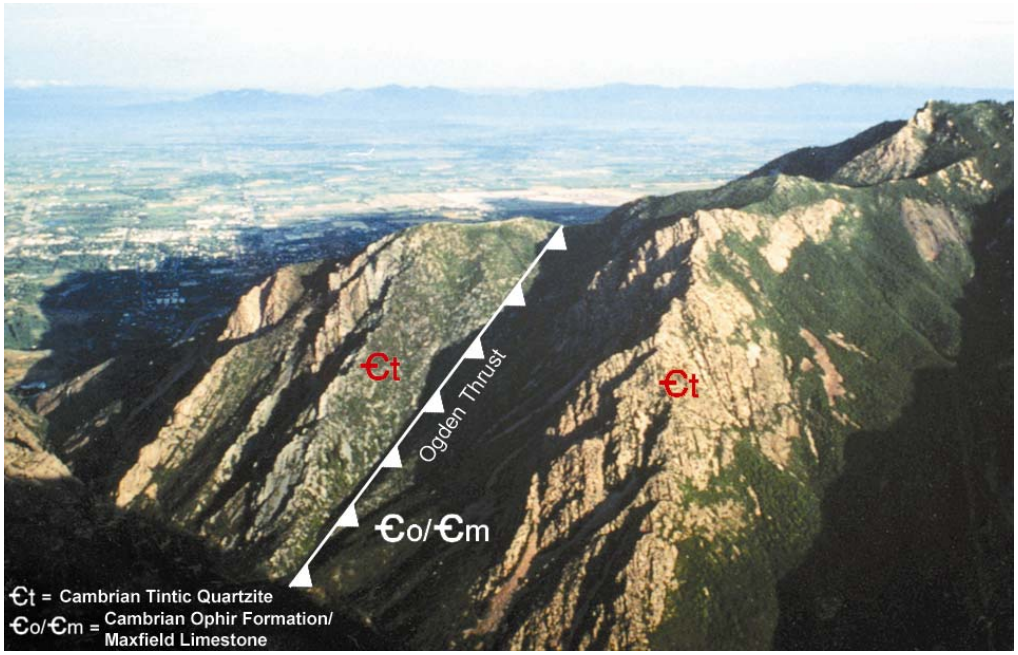


Figure 9. East-dipping Ogden thrust similar in structure to productive subsurface features. View to the northwest of Ogden Canyon, Wasatch Range, northern Utah.

BEST PRACTICES – THRUST BELT

Data were collected from the files of the Wyoming Oil and Gas Conservation Commission for two selected fields in the Wyoming portion of the thrust belt: Ryckman Creek and Painter Reservoir (figure 2C). The purpose of this data collection was to help determine the best drilling, completion, and secondary/tertiary recovery techniques for these and similar fields in the thrust belt. The principal reservoir for both fields is the Jurassic Nugget Sandstone. These fields were discovered early in the successful exploration of the thrust belt: Ryckman Creek in 1976 and Painter Reservoir in 1977 shortly after the initial thrust belt discovery in Utah of Pineview field (figure 2C). Nearly 90 wells have been drilled in the two fields and there is a wealth of publicly available information. This information includes structure maps and cross sections, production and pressure data, completion reports, drilling and development plans, and testimony given at spacing hearings and other hearings before the Wyoming Oil and Gas Conservation Commission.

Two significant practices were employed in the later development of these fields to enhance the ultimate recovery of oil: (1) nitrogen injection and (2) horizontal drilling. Reservoir compositional simulation studies were conducted on Painter Reservoir field. These simulation studies showed the field had an estimated ultimate recovery of 45 million bbls (7.2 million m^3) of oil under primary depletion of the 166 million bbls (26.4 million m^3) of original oil in place (a 27 percent recovery factor). A waterflood with gas-cap cycling increased the ultimate recovery to 88 million bbls (14 million m^3) of oil (a 53 percent recovery factor). This process uses nitrogen injection to cycle the gas out of the gas-condensate system while simultaneously waterflooding the oil zone. Ultimate recovery was also determined for a tertiary, miscible nitrogen-injection program. In this process, nitrogen and hydrocarbon gas are over-injected into the reservoir to raise the reservoir pressure to miscible conditions. This would yield an ultimate recovery of 97 million bbls (15 million m^3) of oil (a 59 percent recovery factor). The simulation further indicated that when the miscible nitrogen-injection program is supplemented with water injection, the ultimate recovery would be 113 million bbls (18 million m^3) of oil (a 68 percent recovery factor) (Wyoming Oil and Gas Conservation Commission, 1981a).

Painter Reservoir field, like most Utah-Wyoming thrust belt fields, is a hanging-wall anticline formed as a rollover into a thrust splay (figures 10 and 11). In the miscible nitrogen-injection program, nitrogen gas is injected into the gas cap at the crest of the structure. Over time, both the gas cap and the nitrogen are displaced downward into the oil-bearing part of the reservoir leaving little residual oil behind. Supplemental water is injected below the oil/water contact to minimize oil movement downward into the water-bearing part of the Nugget reservoir. The overall result is a very efficient miscible recovery of oil where nitrogen will affect all wells in the field whether they are below the original gas cap or to the side of it. The program was designed to extend over a life of 60 years (Wyoming Oil and Gas Conservation Commission, 1981a, 1981b).

In Painter Reservoir and Ryckman Creek fields, the lower third of the Nugget Sandstone typically has lower porosity and permeability when compared to the highly productive upper portion. Thus, this lower interval was avoided as a target for conventional vertical wells drilled during the early development of the field. However, the interval is oil saturated and has become a target of horizontal drilling techniques developed in the 1990s. This includes both new horizontal wells and horizontal laterals (less than 150 meters [500 feet]), economically

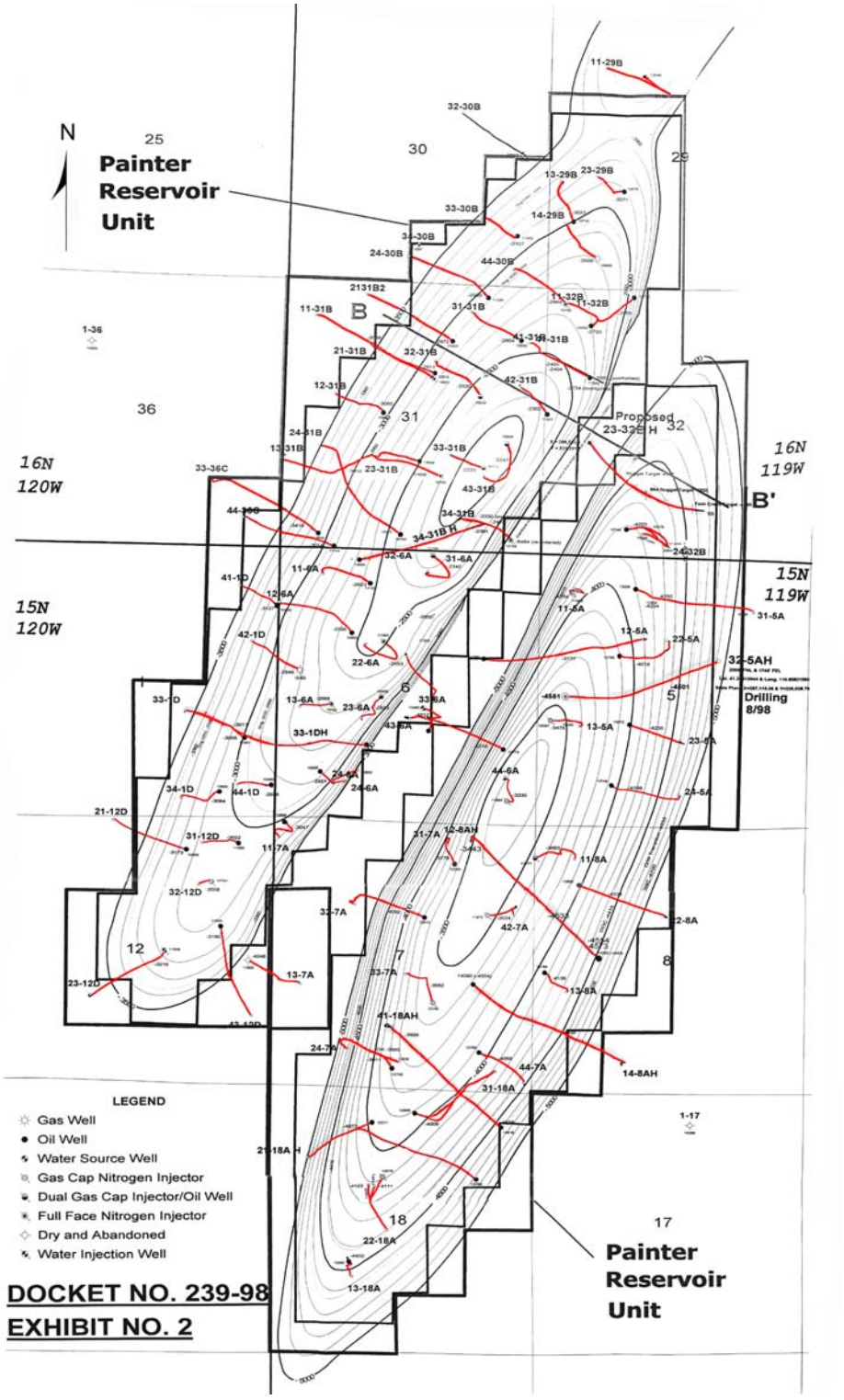


Figure 10. Structure contours on top of Nugget Sandstone, Painter Reservoir and East Painter Reservoir fields, Uinta County, Wyoming (after Wyoming Oil and Gas Conservation Commission, 1998b). East Painter Reservoir field is primarily a gas-condensate producer. Horizontal wells - completed, drilling, or proposed – are shown in red. Contour interval = 100 feet, datum = mean sea level.

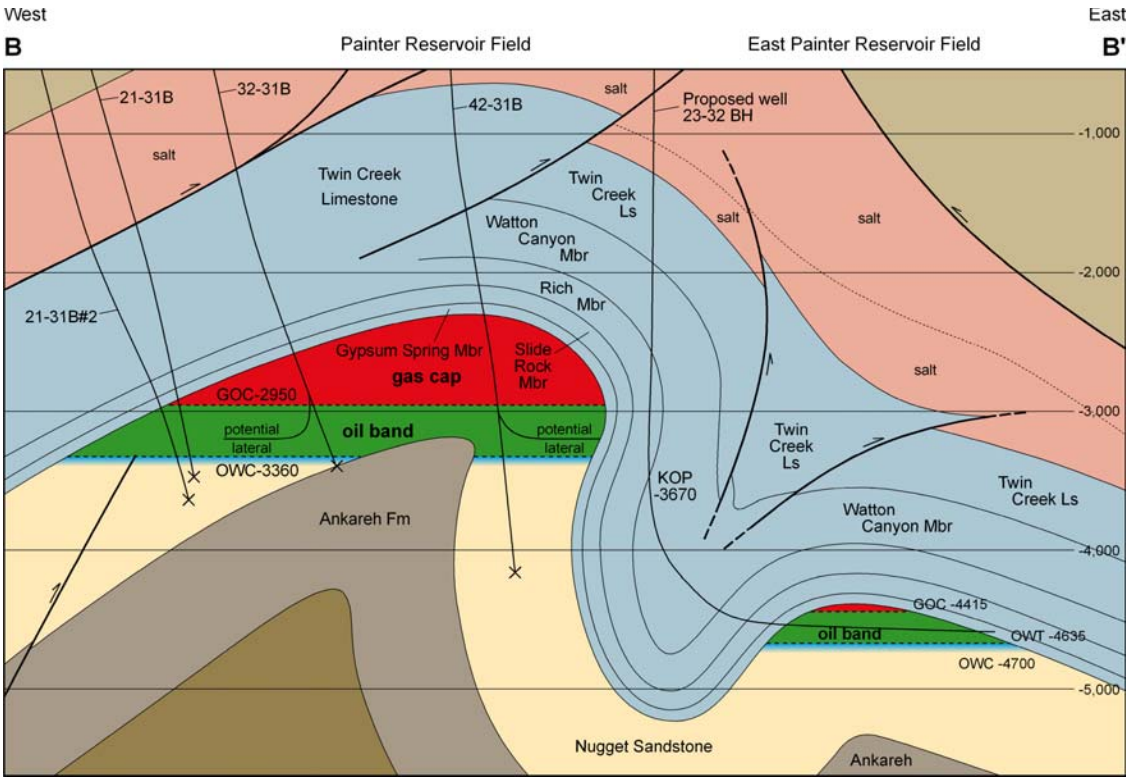


Figure 11. East-west structural cross section, showing potential horizontal drilling targets, Painter Reservoir and East Painter Reservoir fields, Uinta County, Wyoming (modified from Wyoming Oil and Gas Conservation Commission, 1998b). Depth in feet, datum = mean sea level.

drilled from existing vertical wells (figures 10 and 11). Because the Nugget was deposited in an eolian environment, the reservoir also displays a great deal of heterogeneity. Interdune, foresets, and avalanche-slope deposits have different directional permeabilites. Finally, the folding and faulting that create the hydrocarbon trap produced both open and closed fractures. The result is potential undrained compartments ideally suited to be encountered by horizontal drilling (Wyoming Oil and Gas Conservation Commission, 1998a).

Horizontal drilling in these thrust belt fields also improved areal connectivity of the wellbore and productive strata, improved drainage geometry, reduced coning and cusping, reduced the tendency to produce sand along with hydrocarbons, increased sweep efficiency of the nitrogen and waterfloods, and reduced field development costs, thus allowing increased oil recovery. Well-placed horizontal wellbores increase overall field recovery by 0.5 to 1.5 percent. Applying this technology to injection wells also helps improve pressure maintenance performance (Wyoming Oil and Gas Conservation Commission, 1998b).

Ryckman Creek field was shut-in in 2000 after producing 19,519,194 bbls (3,103,552 m^3) of oil. However in 2001, Painter Reservoir field remained one of most prolific active oil fields in Wyoming, ranking 12th in annual oil production – 891,237 bbls (141,707 m^3) from 33 wells (Wyoming Oil and Gas Conservation Commission, 2001). The gas-injection, pressure-maintenance program begun in 1978 and the tertiary, nitrogen-miscible program begun in 1981

both continue to perform well. Eight successful horizontal wells have also been drilled in Painter Reservoir field (one horizontal well was drilled in Ryckman Creek) and that program is ongoing (well records, Wyoming Oil and Gas Conservation Commission). The field has produced over 44 million bbls (7 million m^3) of oil and serves as an excellent example of best practices for Nugget Sandstone reservoirs in the Utah-Wyoming thrust belt.

TECHNOLOGY TRANSFER

The UGS is the Principal Investigator and prime contractor for the PUMPII project and three government-industry cooperative petroleum-research projects. These projects are designed to improve recovery, development, and exploration of the nation's oil and gas resources through use of better, more efficient technologies. The projects involve detailed geologic and engineering characterization of several complex heterogeneous reservoirs. Two Class II Oil projects include practical oil-field demonstrations of selected technologies in the Paradox Basin. The third project involves establishing a log-based correlation scheme for the Tertiary Green River Formation in the southwestern Uinta Basin to help identify new plays and improve the understanding of producing intervals. The DOE and multidisciplinary teams from petroleum companies, petroleum service companies, universities, private consultants, and state agencies are co-funding the three projects.

All play maps, reports, databases, and so forth, produced for the PUMPII project will be published in interactive, menu-driven digital (web-based and compact disc) and hard-copy formats by the Utah Geological Survey and presented 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*. This information will also be released through the UGS periodical *Survey Notes* and on UGS project Internet web pages.

The technology-transfer plan includes a Technical Advisory Board and a Stake Holders Board. 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 may 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 (SITLA and Utah Division of Oil, Gas and Mining) and the Federal Government (BLM and U.S. 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. They will also prove 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, September 8-10, 2002, in Laramie, Wyoming. Four UGS scientists staffed the display booth at this event. Project displays will be included as part of the UGS booth at professional meetings throughout the duration of the project.

Utah Geological Survey *Survey Notes* and Internet Web Site

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 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 (figure 12), 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, and (4) quarterly technical progress reports.

Technical Presentation

The following technical presentation was made during the quarter as part of the technology transfer activities:

"Major Oil Plays of Utah and Vicinity, " by Thomas C. Chidsey, Jr., presented to the Wyoming State Geological Survey, Laramie, Wyoming, September 12, 2002. Maps, cross sections, diagrams, and other information were part of the presentation.

Project Publications

Chidsey, T.C., Jr., 2002, UGS to produce play portfolios of major oil provinces: Utah Geological Survey Petroleum News, p. 6.

Chidsey, T.C., Jr., 2002, UGS awarded DOE grant to produce play portfolios of Utah's major oil provinces: Utah Geological Survey, Survey Notes, v. 34, no. 1, p. 6.

CONCLUSIONS

A combination of depositional and structural events created the right conditions for oil generation and trapping in Utah. Oil plays are specific geographic areas with petroleum potential due to favorable source rock, migration paths, reservoir characteristics, and other factors. These plays, to be delineated later during the project, are found in the Paradox Basin, Uinta Basin, and thrust belts – the three major petroleum provinces of Utah, two of which extend into Wyoming or Colorado.

ugs / utah geology / oil & energy / pump II

Preferred Upstream Management Practices (PUMP II)

Major Oil Plays of Utah and Vicinity
DOE Project

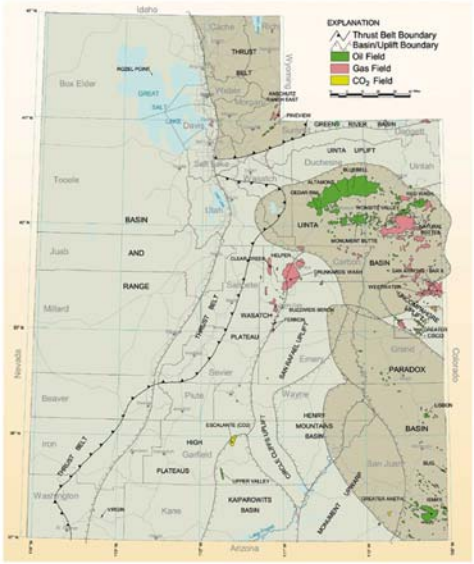
Reports || Project Area Map || Project Summary || Contact

Reports

- Abstract (pdf)
- Statement of Work (pdf)

Project Summary

- Project Description



Play Portfolios	Products	Technology Transfer
• Description of Reservoir Characteristics • Case Study Field Evaluations • Best Practices • Pipelines • Outcrop Analogs • Land Usage	• Play Maps • Reports • Databases • Digital and Hard Copy Format	• Technical Advisory Board • Stake Holders Board • Publications • Technical Presentations • Geologic Societies and Public Meetings

Contact

For more information on the DOE PUMP II project, contact Tom Chidsey, 801-537-3364, email: tomchidsey@utah.gov.

Figure 12. The PUMPII project page, http://geology.utah.gov/emp/pump/index.htm, from the UGS Internet web site.

Major oil reservoirs in Utah are found in rocks of Devonian through Permian, Jurassic, and Tertiary age; outcrop analogs are found in Utah for most of these reservoirs. Trapping mechanisms include stratigraphic carbonate buildups and fluvial-deltaic pinchouts, and structural basement-involved and detached faulted anticlines. The oil found in these traps originates from Pennsylvanian, Permian, Cretaceous, or Tertiary source rocks. Over 125 fields have been discovered in the Paradox Basin, Uinta Basin, and thrust belt provinces since the late 1940s with more than 1.2 billion bbls (191 million m^3) of oil produced from 4,300-plus wells. Monthly oil production averages 1.28 million bbls (205,500 m^3). Best practices used in these fields include waterflood, carbon-dioxide flood, gas injection, and horizontal drilling.

Two significant practices were employed in the later development of Painter Reservoir and Ryckman Creek fields in the Wyoming portion of the thrust belt to enhance the ultimate recovery of oil: (1) nitrogen injection and (2) horizontal drilling. Reservoir compositional simulation studies were conducted on Painter Reservoir field. Ultimate recovery was determined for a tertiary, miscible nitrogen-injection program. In this process, nitrogen and hydrocarbon gas are over-injected into the reservoir to raise the reservoir pressure to miscible conditions producing an excellent sweep of oil over a 60-year period. The simulation indicated that when this program is supplemented with water injection, the ultimate recovery would be 113 million bbls (18 million m^3) of oil (a 68 percent recovery factor).

The Jurassic Nugget Sandstone has significant reservoir heterogeneity due to both depositional facies and structural effects. These characteristics create ideal targets for horizontal wells and horizontal laterals drilled from existing vertical wells. Horizontal drilling programs were conducted in both Painter Reservoir and Ryckman Creek fields to: (1) improve areal connectivity of the wellbores and productive strata, (2) improve drainage geometry, (3) reduce coning and cusping, (4) reduce the tendency to produce sand along with hydrocarbons, (5) increase sweep efficiency of the nitrogen and waterfloods, and (6) reduce field development costs thus allowing increased oil recovery. A well-placed horizontal wellbore can increase the overall field recovery by 0.5 to 1.5 percent. Applying this technology to injection wells also helps pressure maintenance performance. Painter Reservoir field has produced over 44 million bbls (7 million m^3) of oil and serves as an excellent example of best practices for Nugget Sandstone reservoirs in the Utah-Wyoming thrust belt.

ACKNOWLEDGMENTS

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Data for the Uinta Basin were compiled by Craig Morgan, UGS, and production history compiled by Rick Allis, UGS. Jim Parker and Vicky Clarke of the UGS prepared the figures. This report was reviewed by Bryce Tripp and Mike Hylland of the UGS. Cheryl Gustin, UGS, formatted the manuscript for publication.

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