MAJOR OIL PLAYS IN UTAH AND VICINITY

QUARTERLY TECHNICAL PROGRESS REPORT

Reporting Period
Start Date: October 1, 2005
End Date: December 31, 2005

by
Craig D. Morgan
and
Thomas C. Chidsey, Jr., Principal Investigator
Utah Geological Survey

March 2006

Contract No. DE-FC26-02NT15133

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DISCLAIMER

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ABSTRACT

Utah oil fields have produced over 1.2 billion barrels (191 million m^3) of oil and hold 241 million barrels (38.3 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 fourteenth quarter of the project (October 1 through December 31, 2005). This work included (1) describing the Conventional Northern and Deep Overpressured Continuous Uinta Basin Plays and their outcrop analogs, and (2) technology transfer activities.

Oil and associated gas production in the Laramide-age Uinta Basin is mostly from the Paleocene and Eocene Green River and Colton/Wasatch Formations which were deposited in and around ancestral Lake Uinta. The Conventional Northern Uinta Basin and Deep Uinta Basin Overpressured Continuous Plays cover the northern Uinta Basin. The Conventional Northern Uinta Basin Play typically has drill depths ranging from 5000 feet (1500 m) to a maximum of 10,000 feet (3000 m). The play is divided into two subplays: (1) Conventional Bluebell subplay, and (2) Conventional Red Wash subplay. The Deep Uinta Basin Overpressured Continuous Play is where the lower 2500 to 3000 feet (750-900 m) of the Green River and intertonguing Colton Formations has a pressured gradient >0.5 pounds per square inch/foot (11.3 kPa/m); fracturing is also a key reservoir property. The source rocks for the Uinta Basin plays are kerogen-rich shale and marlstone of the Green River. Most of the oils are characterized as yellow or black wax. Reservoirs common in each play are well displayed on outcrop.

The Conventional Northern Uinta Basin and Deep Uinta Basin Overpressured Continuous Play areas are being explored for Mesaverde Group and Mancos Shale gas. The deeper drilling could result in the discovery of new oil fields in the overlying Green River Formation. However, the largest resource potential in may be in recompletions of the current wells. Well completions typically consist of perforating 40 or more beds. As a result, many of the beds never received adequate stimulation. We recommend using cased-hole logs to identify by-passed oil and selectively stimulating individual beds to recover significant amounts of additional oil.

Secondary and tertiary recovery methods have not been attempted in the Deep Uinta Basin Overpressured Continuous Play area. Fractures, the dominant reservoir property, can cause early breakthrough of any injected fluid or gas which can then move beyond the intended secondary recovery unit. Secondary and tertiary recovery methods generally require a high density of wells to be effective. The Deep Uinta Basin Overpressured Continuous Play area has

been developed with two wells per section and in many areas at least one of those wells has already been plugged and abandoned. As a result, any secondary or tertiary recovery method would require a significant amount of additional deep drilling.

Technology transfer activities during this quarter consisted of exhibiting a booth display of project materials at the 2005 Uinta Basin Energy Days Industry Exposition and Conference and a publication. Project team members joined Utah Stake Holders Board members in attending the Uinta Basin Oil and Gas Collaborative Group meeting in Vernal, 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 1.2 billion barrels (191 million m^3) of oil and hold 241 million barrels (38.3 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 fourteenth quarter of the project (October 1 through December 31, 2005). This work included (1) describing the Conventional Northern and Deep Overpressured Continuous Uinta Basin Plays and their outcrop analogs, 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.

Oil and gas production in the Laramide-age Uinta Basin is mostly from the Paleocene and Eocene Green River and Colton/Wasatch Formations. In early late Paleocene time, a large lake developed in the basin known as ancestral Lake Uinta. Deposition in and around Lake Uinta consisted of open- to marginal-lacustrine sediments that make up the Green River. Alluvial redbed and floodplain deposits that are laterally equivalent to, and intertongue with, the Green River form the Colton/Wasatch.

The Conventional Northern Uinta Basin Play (CNUBP) and Deep Uinta Basin Overpressured Continuous Play (DUBOCP) cover the northern Uinta Basin. The CNUBP typically has drill depths ranging from 5000 feet (1500 m) to a maximum of 10,000 feet (3000 m). The play is divided into two subplays: (1) Conventional Bluebell subplay, and (2) Conventional Red Wash subplay. The DUBOCP is where the lower 2500 to 3000 feet (750-900 m) of the Green River and intertonguing Colton Formations are overpressured (gradient >0.5 pounds per square inch/foot [11.3 kPa/m]). The most rapid increase in reservoir pressure and most of the high-volume, overpressured oil production is typically from 11,000 to 14,000 feet (3400-4300 m).

The source rocks for the crude oil produced from the Uinta Basin plays are kerogen-rich shale and marlstone of the Green River Formation, which were deposited in nearshore and offshore open-lacustrine environments. Most of the crude oils produced from the Uinta Basin plays are characterized as yellow or black wax. Production from the DUBOCP is dominantly yellow wax while most of the oil production from the CNUBP and Southern Uinta Basin Play (CSUBP) is black wax.

In the Conventional Bluebell subplay of the CNUBP sandstone reservoirs typically have low porosity (8 to 12 percent) and low matrix permeability (0.01 to 10 millidarcies). Sandstone reservoirs in the Conventional Red Wash subplay of the CNUBP have higher porosities (8 to 20 percent) and significantly higher matrix permeabilities, commonly 50 to 500 millidarcies. In the DUBOCP production is fracture controlled from rocks with typically very low (< 0.1 millidarcies) matrix permeability. The reservoir is fractured lenticular sandstone, shale, and marlstone deposited in the lacustrine and alluvial environments of Lake Uinta.

Fields in the CNUBP and DUBOCP produce crude oil with associated gas. Production from the Conventional Bluebell subplay cannot be accurately separated from the DUBOCP. The largest fields in the Conventional Red Wash subplay have produced 155.9 million barrels of oil (24.8 million m^3) and 474.6 billion cubic feet of gas (13.4 BCMG). The DUBOCP has produced nearly 300 million barrels of oil (50 million m^3) and 500 billion cubic feet of gas (14 BCMG) primarily from three large fields – Altamont, Bluebell, and Cedar Rim.

The largest untapped resource potential in the CNUBP and DUBOCP may be best exploited through recompletions of the current wells. Existing well completions typically consist of perforating 40 or more beds in a 1500-foot (450 m) or more, vertical section. As a result, many of the beds never received adequate stimulation. We recommend using cased-hole logs to identify by-passed oil and selectively stimulate individual beds to recover significant amounts of additional oil.

Secondary and tertiary recovery methods have not been attempted in the DUBOCP area. Fractures are the dominant reservoir property and can cause early breakthrough of any injected fluid or gas. Fractures can result in injected fluids or gases moving great distances, perhaps even beyond the intended secondary recovery unit. Secondary and tertiary recovery methods generally require a high density of wells to be effective. The DUBOCP area has been developed with two wells per section and in many areas at least one of those wells has already been plugged and abandoned. As a result, any secondary or tertiary recovery method would require a significant amount of additional deep drilling.

The CNUBP and DUBOCP areas are also being explored for deeper Mesaverde Group and Mancos Shale gas. The deeper drilling for gas could result in the discovery of new oil fields in the overlying Green River Formation.

An outcrop analog for the major oil reservoirs in the CNUBP is available in the northeastern Uinta Basin along Raven Ridge, which displays landward to lakeward facies transitions. Several locations offer excellent exposures of shoreline deposits that serve as reservoirs, and bay-fill deposits that provide organic-rich source rock for the play. Outcrop analogs for the DUBOCP are found in Sevier and Sanpete Counties, central Utah, and provide good examples of deposits shed off the western highlands into Lake Uinta. Many of the conglomerates were deposited as fan deltas extending into the lake. Other exposures include interbedded shale, sandstone, and limestone deposited in a marginal-lacustrine environment. The distal facies of the Flagstaff Limestone is composed of open-lacustrine shale and limestone.

Technology transfer activities during this quarter consisted of exhibiting a booth display of project materials at the 2005 Uinta Basin Energy Days Industry Exposition and Conference in Vernal, Utah. Project team members joined Utah Stake Holders Board members in attending the Uinta Basin Oil and Gas Collaborative Group meeting also in Vernal. The project home page was updated on the Utah Geological Survey Web site. Project team members published a Quarterly Technical Progress Report detailing project work, results, and recommendations.

INTRODUCTION

Project Overview

Utah oil fields have produced over 1.2 billion barrels (bbls) (191 million m^3) (Utah Division of Oil, Gas and Mining, 2005). 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, 2005). Proven reserves are relatively high, at 215 million bbls (34.2 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.

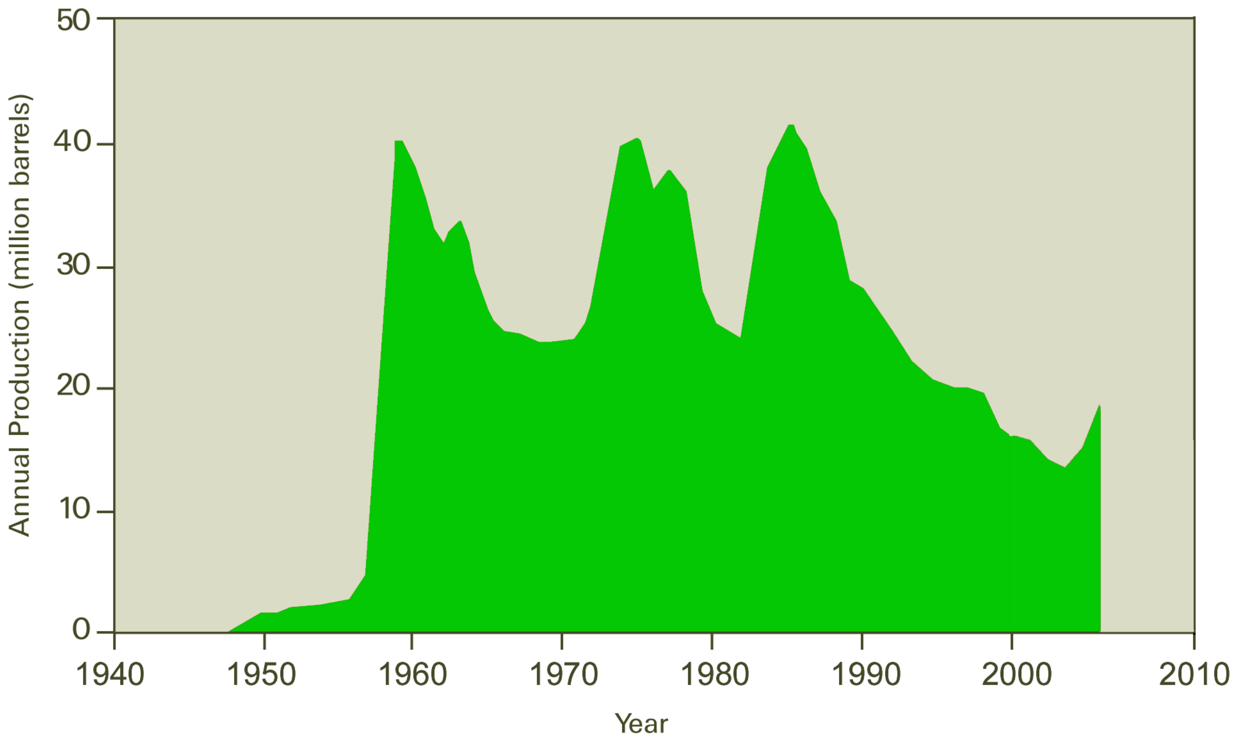


Figure 1. Oil production in Utah through 2005 showing an increase due, in part, to the discovery of Covenant field in the new central Utah thrust belt Jurassic Navajo Sandstone play. Source: Utah Division of Oil, Gas and Mining production records.

Utah's drilling history has fluctuated greatly due to discoveries, oil and gas price trends, and changing exploration targets. Utah has entered another boom period rivaling the early 1980s. In 2005, the Utah Division of Oil, Gas and Mining issued a record 1629 drilling permits and 876 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 (figure 2). 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 fourteenth quarter of the project (October 1 through December 31, 2005). This work included (1) describing the Conventional Northern Uinta Basin Play (CNUBP) and Deep Uinta Basin Overpressured Continuous Play (DUBOCP) and their outcrop analogs, and (2) technology transfer activities.

Project Benefits

The overall goal of this multi-year project is enhanced petroleum production in the Rocky Mountain region. Specifically, the project goal will benefit from the following:

(1) improved reservoir characterization to prevent premature abandonment of numerous small fields in the Paradox and Uinta Basins,

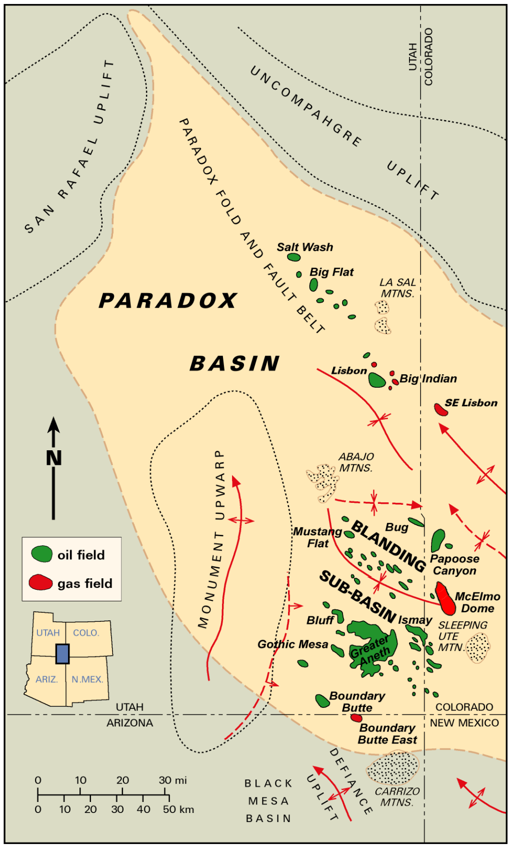
(2) identification of the type of untapped compartments created by reservoir heterogeneity (for example, diagenesis and abrupt facies changes) to increase recoverable reserves,

(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



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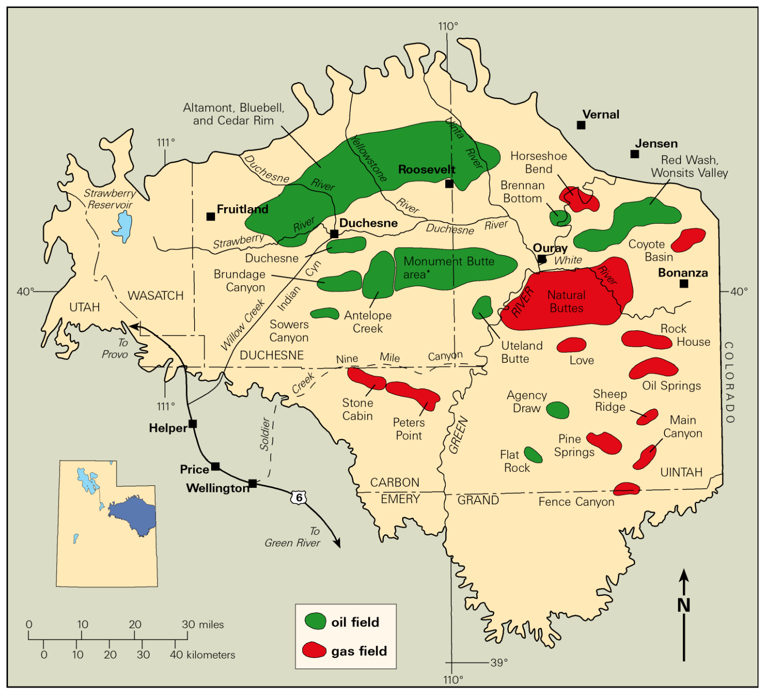

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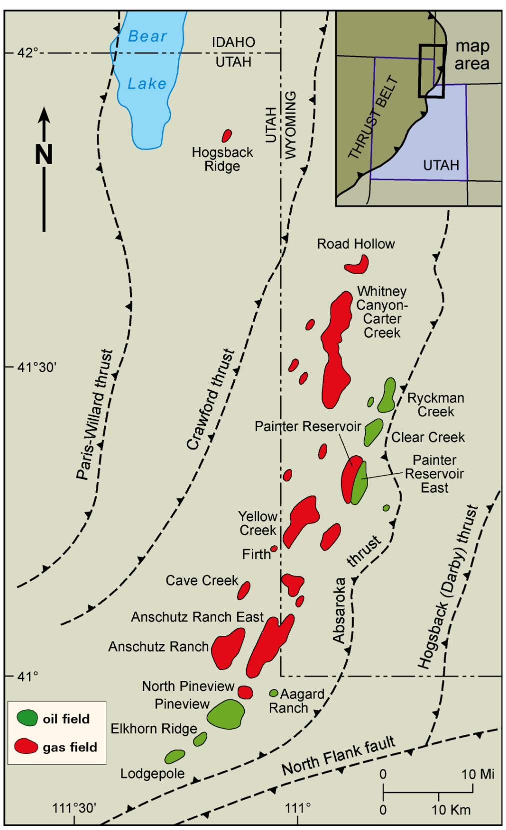

C

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.

(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 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.

CONVENTIONAL NORTHERN AND DEEP OVERPRESSURED CONTINUOUS UINTA BASIN PLAYS – DISCUSSION AND RESULTS

Uinta Basin Overview

The Uinta – Piceance Province in northeastern Utah and northwestern Colorado, as defined by the U.S. Geological Survey (USGS), contains the contiguous outcrops of the Maastrichtian and Tertiary rocks, and also includes the southwest- to northeast-trending Wasatch Plateau and Castle Valley (Dubiel, 2003). Our discussion will be restricted to the Uinta Basin portion of the province (figure 3), which incorporates a small portion of the western flank of the Douglas Creek Arch that separates the Uinta and Piceance Basins. The Uinta Basin area covers nearly 16,000 square miles (41,000 km^2). The Uinta Basin (excluding the Wasatch Plateau and Castle Valley) is a topographic and structural trough that is sharply asymmetrical, with a steep north flank bounded by the east-west-trending Uinta Mountains, and a gently dipping south flank (figure 4).

The Uinta Basin formed in Late Cretaceous (Maastrichtian) time, when a large structural sag with internal drainage formed. The earliest deposits in the intermontane basin were predominantly alluvial (Ryder and others, 1976) with some shallow lacustrine and paludal deposits that comprise the North Horn Formation. In early late Paleocene time, a large lake known as ancestral Lake Uinta developed in the basin (Francyk and others, 1992) (includes Lake Flagstaff of some workers). Deposition in and around Lake Uinta consisted of open- to marginal-lacustrine sediments that make up the Green River Formation. Alluvial redbed and floodplain deposits that are laterally equivalent to, and intertongue with, the Green River form the Colton (Wasatch) Formation (figure 5). The Eocene Uinta Formation and the Eocene to lower Oligocene Duchesne River Formation overlie the Green River.

The significant oil plays in the Uinta Basin are part of the Green River Total Petroleum System (TPS). The USGS defines the Green River TPS as a complex of entirely continental rocks (North Horn, Wasatch, Colton, Green River, Uinta, and Duchesne River Formations) that

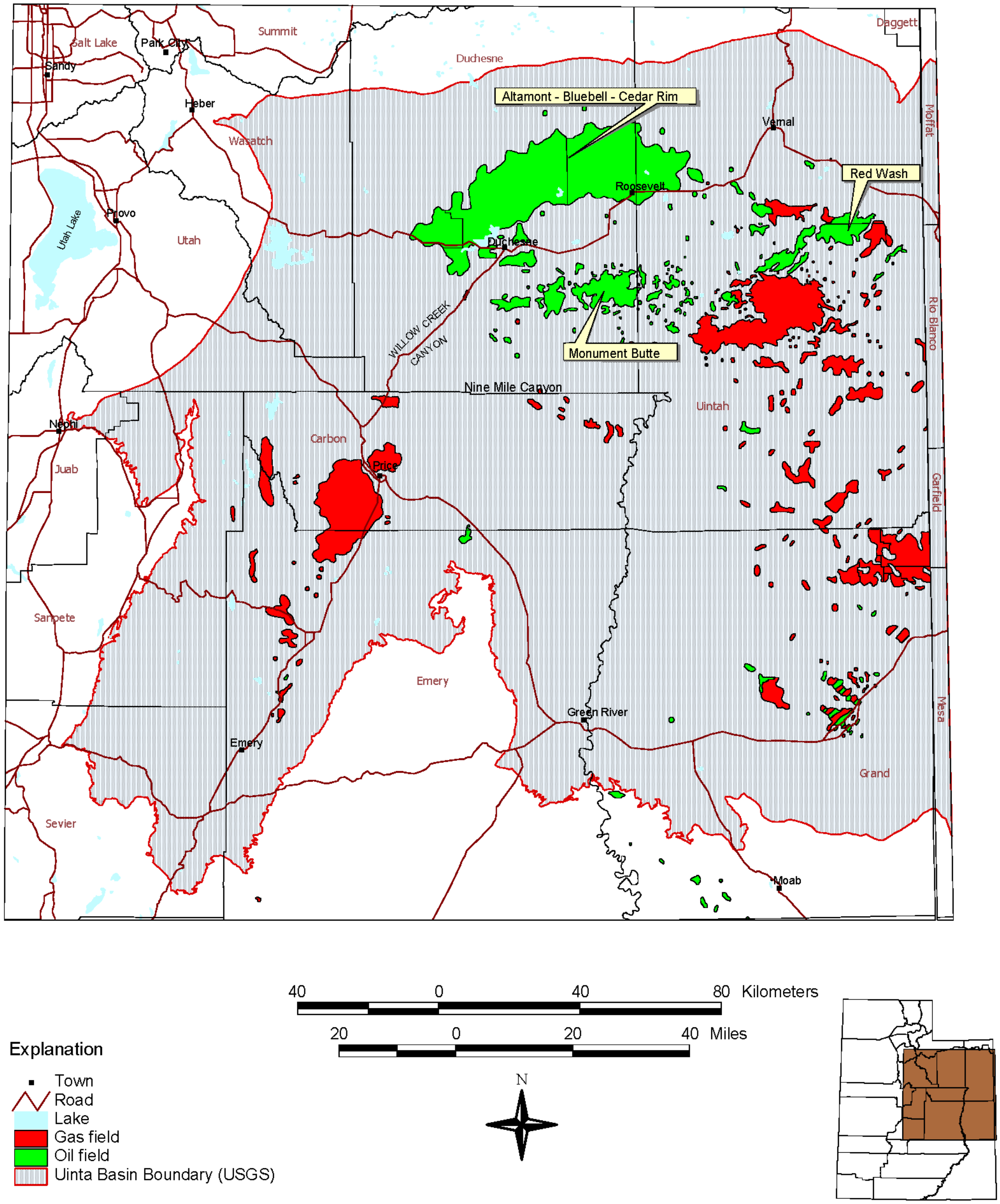

Figure 3. Map showing the location of the Uinta Basin and some of the major oil and gas fields.

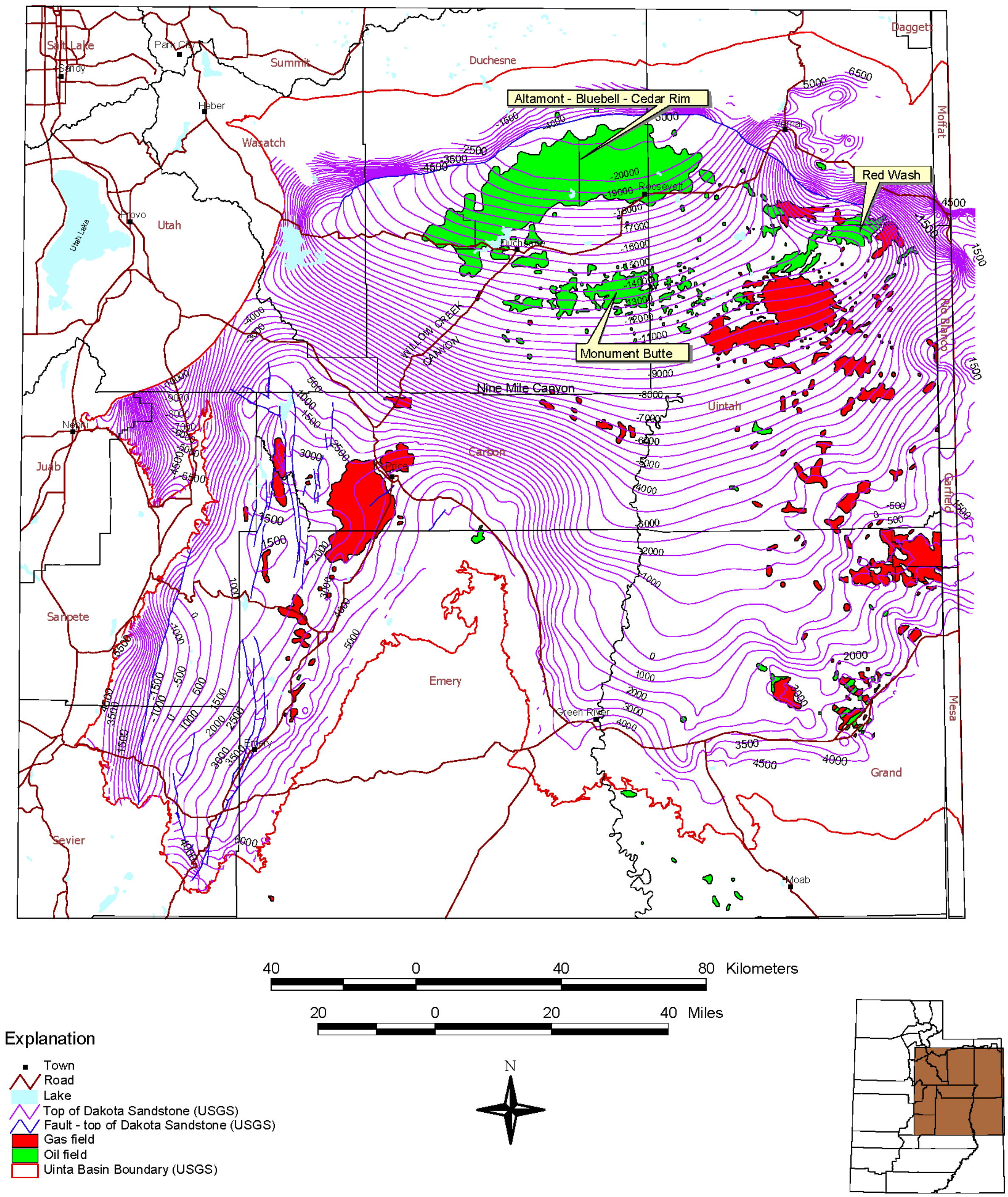

Figure 4. Structure contour map on top of the Cretaceous Dakota Sandstone, Uinta Basin. Contour interval is 500 feet sea-level elevation. Contours from Roberts (2003).

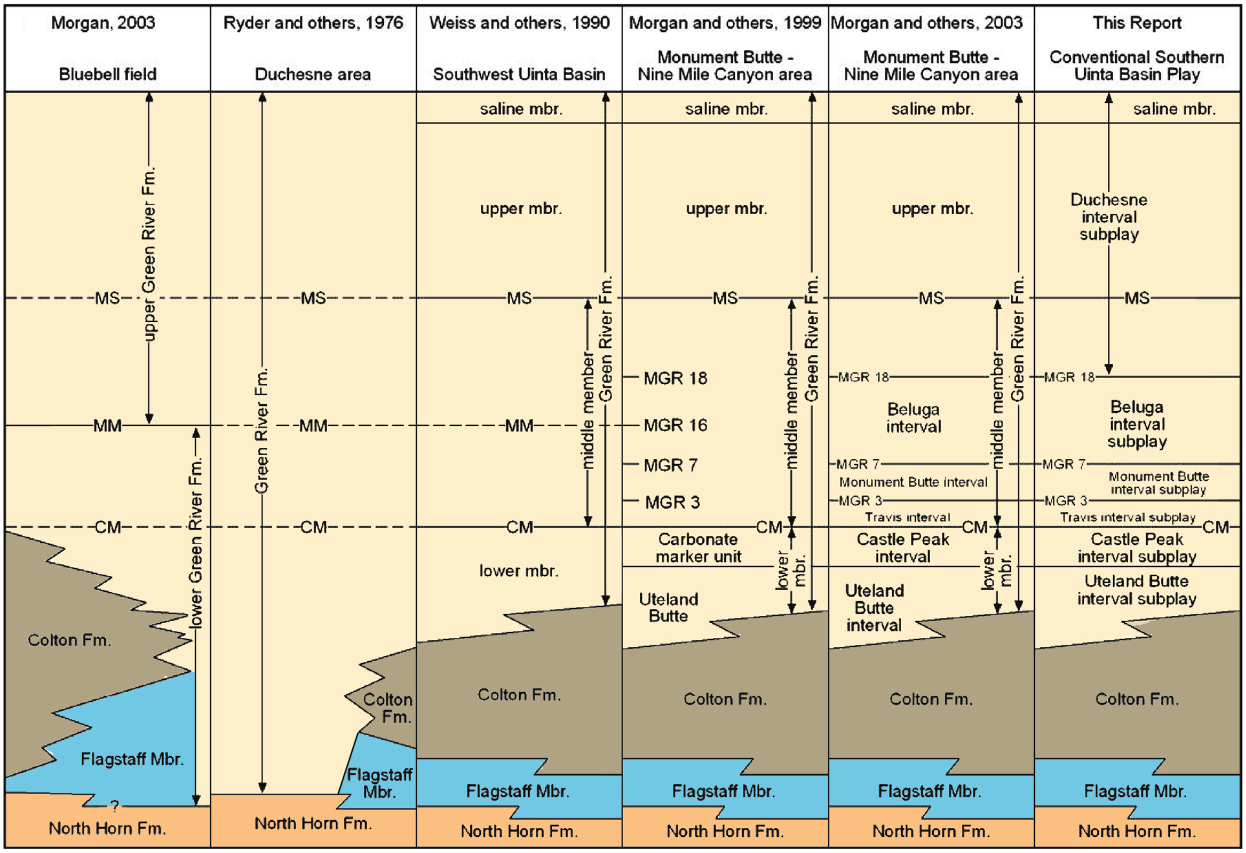

Figure 5. Generalized Uinta Basin nomenclature chart used in this report for the Green River through North Horn Formations. MS = Mahogany Shale, MM = middle marker, CM = carbonate marker, and MGR = middle Green River.

host gilsonite veins, oil shales, tar sands, and oil and gas, all sourced from lacustrine rocks within the Paleocene and Eocene Green River Formation (Dubiel, 2003). Source rocks are: (1) type I kerogen from the open-lacustrine facies, (2) type I, II, and III, kerogen from the marginal-lacustrine facies, and (3) type III kerogen from alluvial facies (Dubiel, 2003).

The maximum depth to the base of the Green River TPS is about 20,000 feet (6100 m) along the axis of the Uinta Basin (Fouch and others, 1994). Operators typically assign all strata containing red beds to the Wasatch or Colton Formations; however, oil and gas production is mostly from tongues of the Green River Formation within the alluvial Wasatch and Colton (Fouch and others, 1992; Fouch and others, 1994).

The dominant sediment source for the Green River and Colton Formations in the Cedar Rim, Altamont, Bluebell, and Red Wash fields was from the north, while the sediment source for the greater Monument Butte, Duchesne, Brundage Canyon, Sower Canyon, Antelope Creek, and Uteland Butte fields, was from the south (figure 6). As a result, the deposition and the resulting reservoir properties are significantly different between south-sourced and north-sourced depositional systems.

The USGS defines two assessment units in the Green River TPS within the Uinta Basin: (1) the Deep Uinta Overpressured Continuous Oil Assessment Unit (AU 50200561) and (2) the Uinta Green River Conventional Oil and Gas Assessment Unit (AU 50200501) (figure 7). The Green River Conventional Oil and Gas Assessment Unit extends farther west than the Uinta

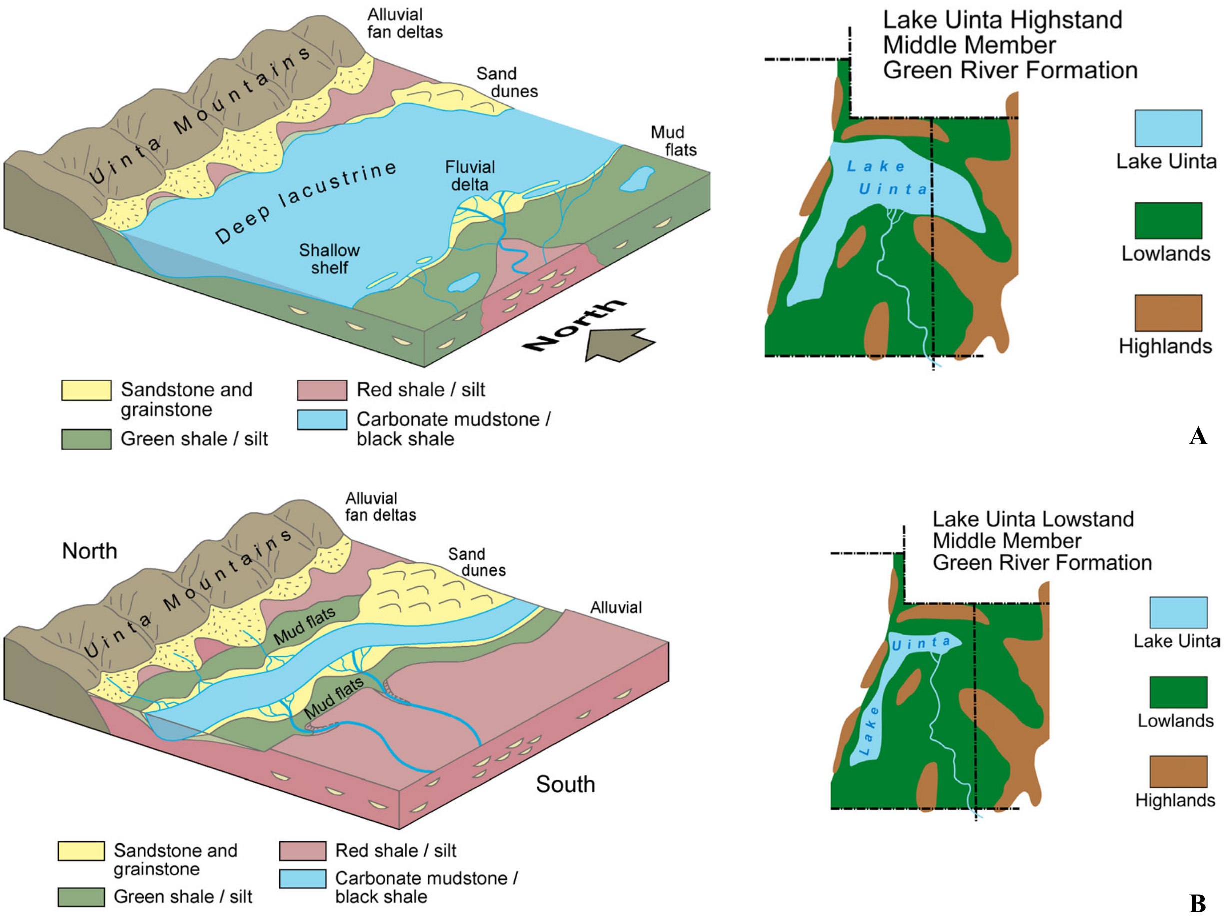

Figure 6. Diagrams showing the generalized depositional setting for Lake Uinta during high-lake levels (A) and low-lake levels (B). The Uinta Mountains were the source for the sediments in the northern portion of the lake while sediments in the southern portion of the lake were sourced from the much larger Four Corners area. Morgan and others, 2003.

Basin boundary. The western boundary of the Uinta Basin in Wasatch and Utah Counties is defined by the Charleston-Nebo thrust, and Maastrichtian and Tertiary rocks beneath the thrust define the assessment unit boundary. As a result, the assessment unit boundary extends beyond the basin boundary.

The USGS defines the Deep Uinta Overpressured Continuous Oil Assessment Unit by overpressured (gradient >0.5 pounds per square inch per foot [psi/ft]; 11.3 kPa/m) source and reservoir rocks in the Green River Formation (figure 8). The overpressuring is located near the basin center mostly in the Colton Formation and Flagstaff Member of the Green River in the Altamont, Bluebell, and Cedar Rim fields. The 0.5 psi/ft (11.3 kPa/m) gradient is encountered as shallow as 8500 feet (2600 m). However, most of the high-volume, overpressured oil production is typically from 12,000 to 14,000 feet (3600-4300 m) in the Flagstaff Member.

The USGS defines the Uinta Green River Conventional Oil and Gas Assessment Unit by the distribution of normally pressured (<0.5 psi/ft [11.3 kPa/m]) oil and gas accumulations in the Green River Formation typically at depths less than 8500 feet (2600 m) (Dubiel, 2003). The unit overlies the entire area of the Deep Uinta Overpressured Continuous Oil Assessment Unit.

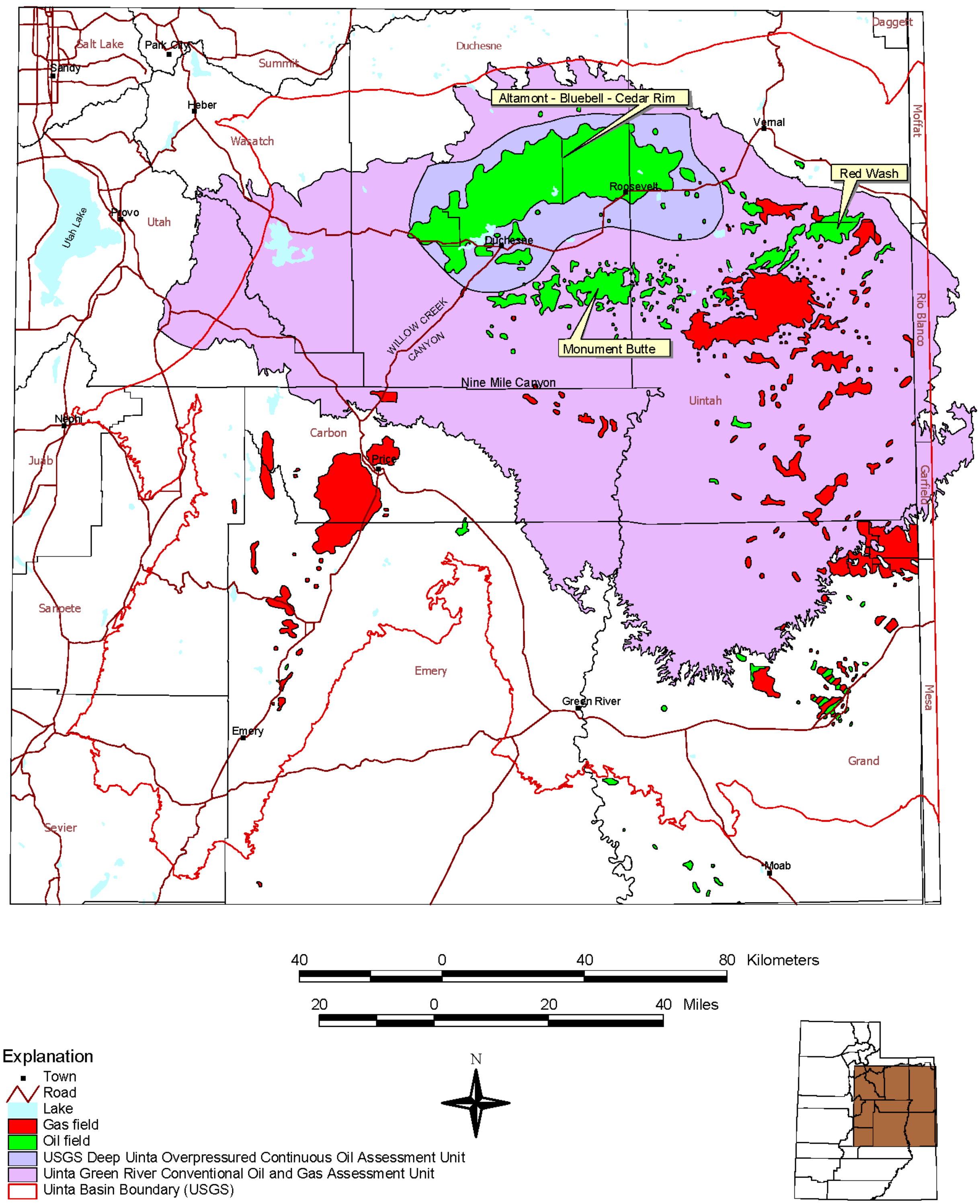

Figure 7. Map showing the USGS Deep Uinta Overpressured Continuous Oil Assessment Unit and the Uinta Green River Conventional Oil and Gas Assessment Unit of Dubiel (2003).

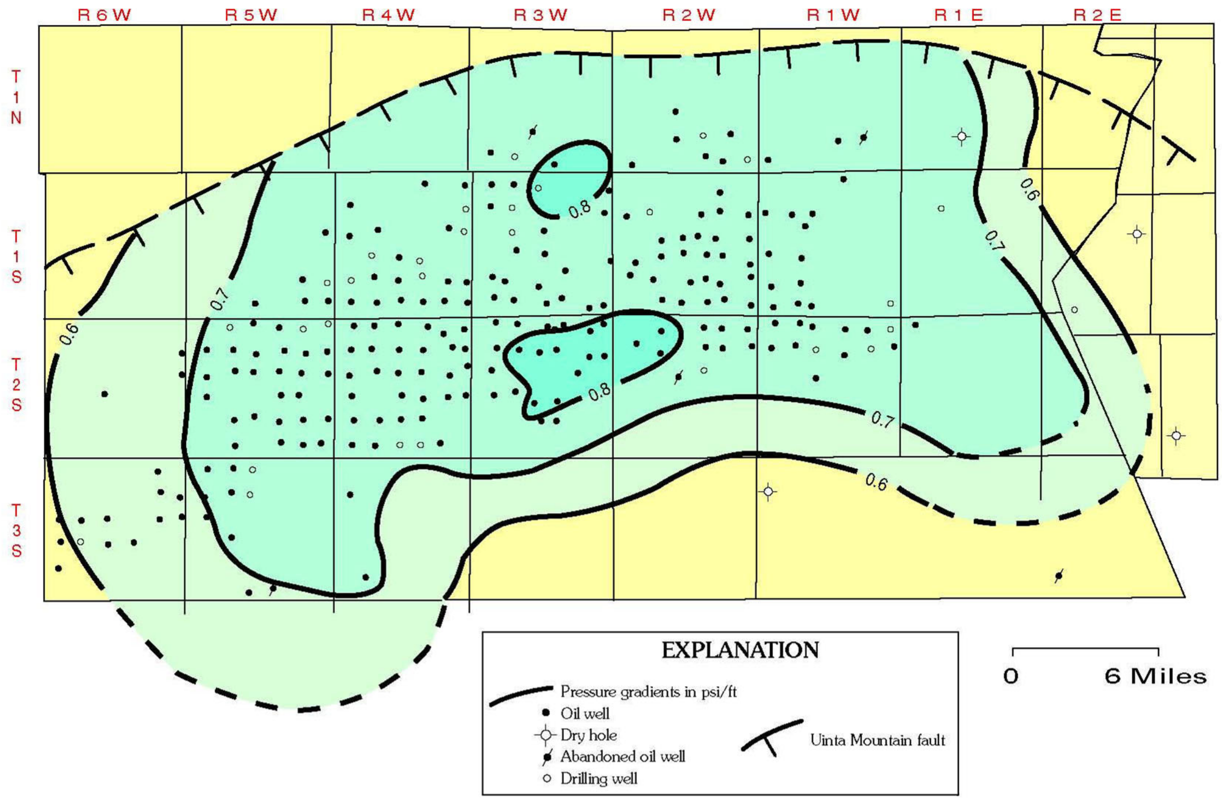

Figure 8. Distribution of wells and contours of pressure-gradient data in the Altamont – Bluebell field area from Dubiel (2003).

The Uinta Green River Conventional Oil and Gas Assessment Unit consists entirely of the part of the Green River that overlies the Colton and Wasatch Formations. A transitional interval from about 8500 to 11,000 feet (2600-3400) is slightly overpressured (0.50 to 0.55 psi/ft [11.3-12.4 kPa/m]) but many of the reservoir characteristics are more like the overlying CNUBP and is discussed in that play description.

The Deep Uinta Overpressured Continuous Oil Assessment Unit and the DUBOCP have the same boundaries. We divide the Uinta Green River Conventional Oil and Gas Assessment Unit into a Conventional Southern Uinta Basin Play (CSUBP) (see Morgan and Chidsey, 2003) and a CNUBP, which have some overlap (figures 9 and 10); each are further divided into subplays (table 1). The subplays are based on depositional environments of the reservoir rocks which were strongly influenced by the: (1) sediment source, (2) gradient of the depositional slope, and (3) energy regime of the environment which affected the amount of sediment reworking (figure 11).

Most of the crude oils produced from the Green River TPS in the Uinta Basin are characterized as yellow or black wax (table 2). Production from the DUBOCP is dominantly yellow wax while most of the oil production from the CNUBP and CSUBP is black wax. Asphaltine oil has been produced from a few shallow wells in the Duchesne interval of fractured shale/marlstone subplay in the CSUBP. Associated gas is produced from the Green River TPS and typically has a high heat value - greater than 1000 British thermal units (Btu/ft^3) (table 3).

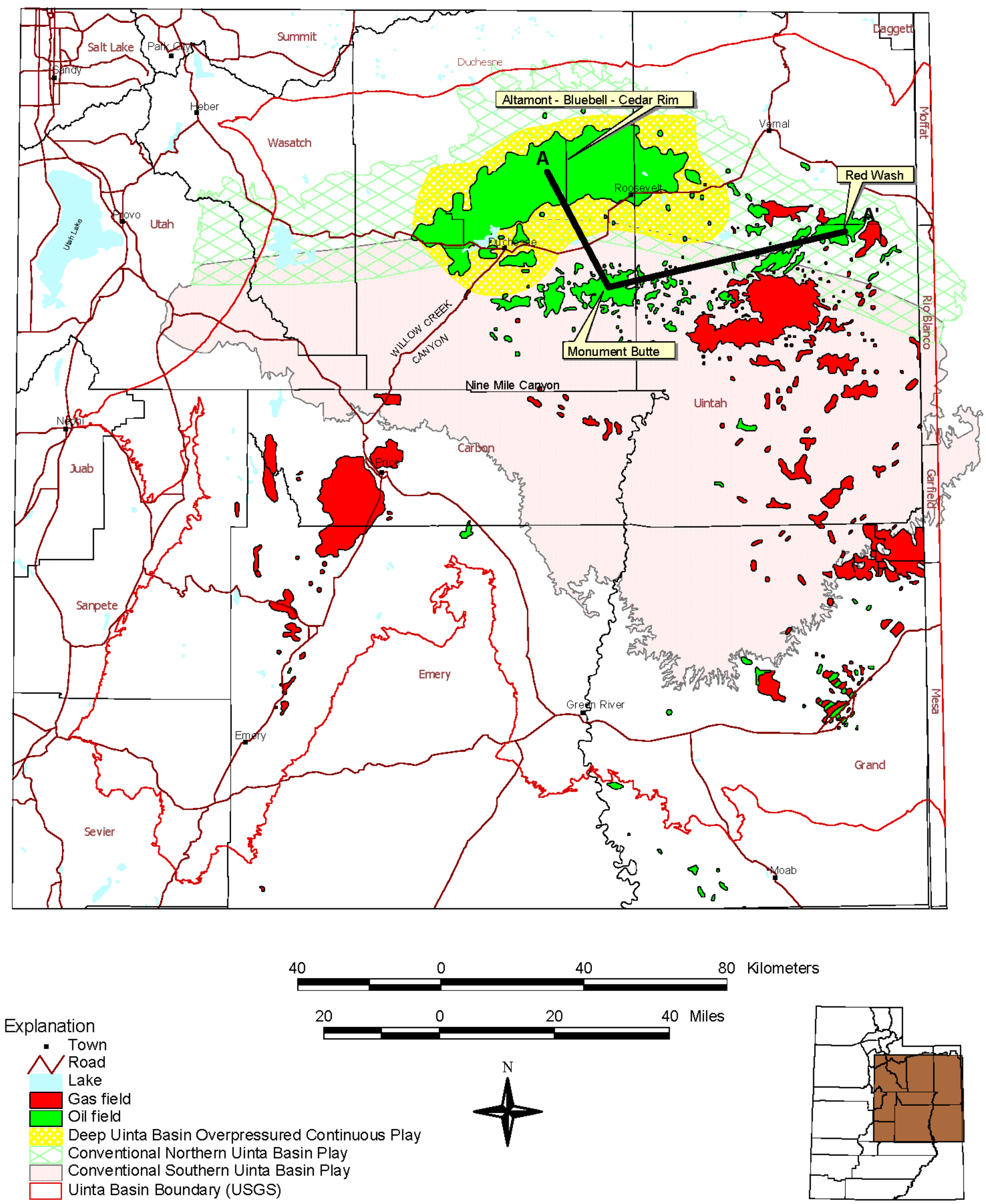

Figure 9. Map showing the Deep Uinta Basin Basin Overpressured Continuous Play which underlies the Conventional Northern and Conventional Southern Uinta Basin Plays; these plays overlap. Cross section A-A' shown on figure 10.

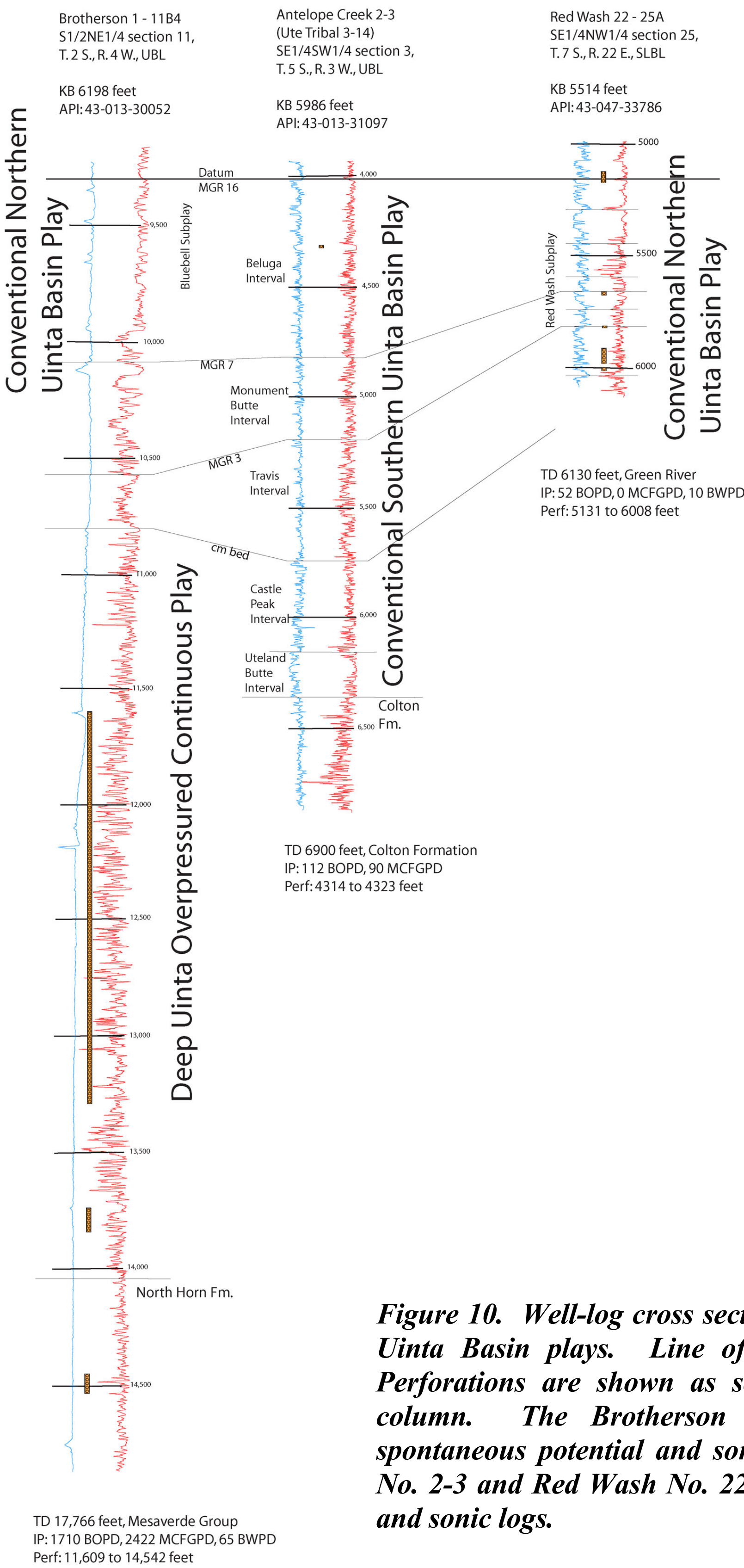

Figure 10. Well-log cross section showing correlation of the Uinta Basin plays. Line of section shown on figure 9. Perforations are shown as solid black lines in the depth column. The Brotherson No. 1-11 B4 well displays spontaneous potential and sonic logs. The Antelope Creek No. 2-3 and Red Wash No. 22-25A wells display gamma-ray and sonic logs.

Table 1. Plays and subplays in the Uinta Basin Green River Total Petroleum System.

GREEN RIVER FORMATION TOTAL PETROLEUM SYSTEM, UINTA BASIN
Deep Uinta Overpressured Continuous Oil Assessment Unit (AU 50200561)
Deep Uinta Basin Overpressured Continuous Play
Uinta Green River Conventional Oil and Gas Assessment Unit (AU 50200501)
Conventional Northern Uinta Basin Play
Conventional Bluebell Subplay
Conventional Red Wash Subplay
Conventional Southern Uinta Basin Play
Conventional Duchesne Interval Fractured Shale/Marlstone Subplay
Conventional Beluga Interval Subplay
Conventional Monument Butte Interval Subplay
Conventional Travis Interval Subplay
Conventional Castle Peak Interval Subplay
Conventional Uteland Butte Interval Subplay

Conventional Northern Uinta Basin Play (CNUBP) Description

The CNUBP covers the northern Uinta Basin and typically has drill depths ranging from 5000 feet (1500 m) to a maximum of 10,000 feet (3000 m). The play is divided into two subplays (figure 12): (1) Conventional Bluebell subplay, and (2) Conventional Red Wash subplay.

Depositional Environment

The CNUBP produces from the Eocene Colton and Green River Formations. Reservoir rocks in the Conventional Bluebell subplay consist of sandstone, shale, and marlstone deposited in intertonguing alluvial, marginal-lacustrine, to open-lacustrine environments. Reservoir rocks in the Conventional Red Wash subplay are dominantly sandstone deposited in shoreface lacustrine environment.

Conventional Bluebell subplay: The Conventional Bluebell subplay consists of the Altamont-Bluebell-Cedar Rim field area and land north and west of the fields. The Conventional Bluebell subplay overlies the DUBOCP. The Conventional Bluebell subplay produces from the lower Green River Formation and the Green River to Colton transitional facies at drill depths of 8000 to 10,000 feet (2400-3000 m). Most of the production is from sandstone shed from the Laramide-age Uinta uplift to the north and deposited in alluvial and marginal-lacustrine environments.

Conventional Red Wash subplay: The Conventional Red Wash subplay consists of several fields in the northeast portion of the Uinta Basin; the largest is the Red Wash field. The Conventional Red Wash subplay produces from the Douglas Creek Member in the lower

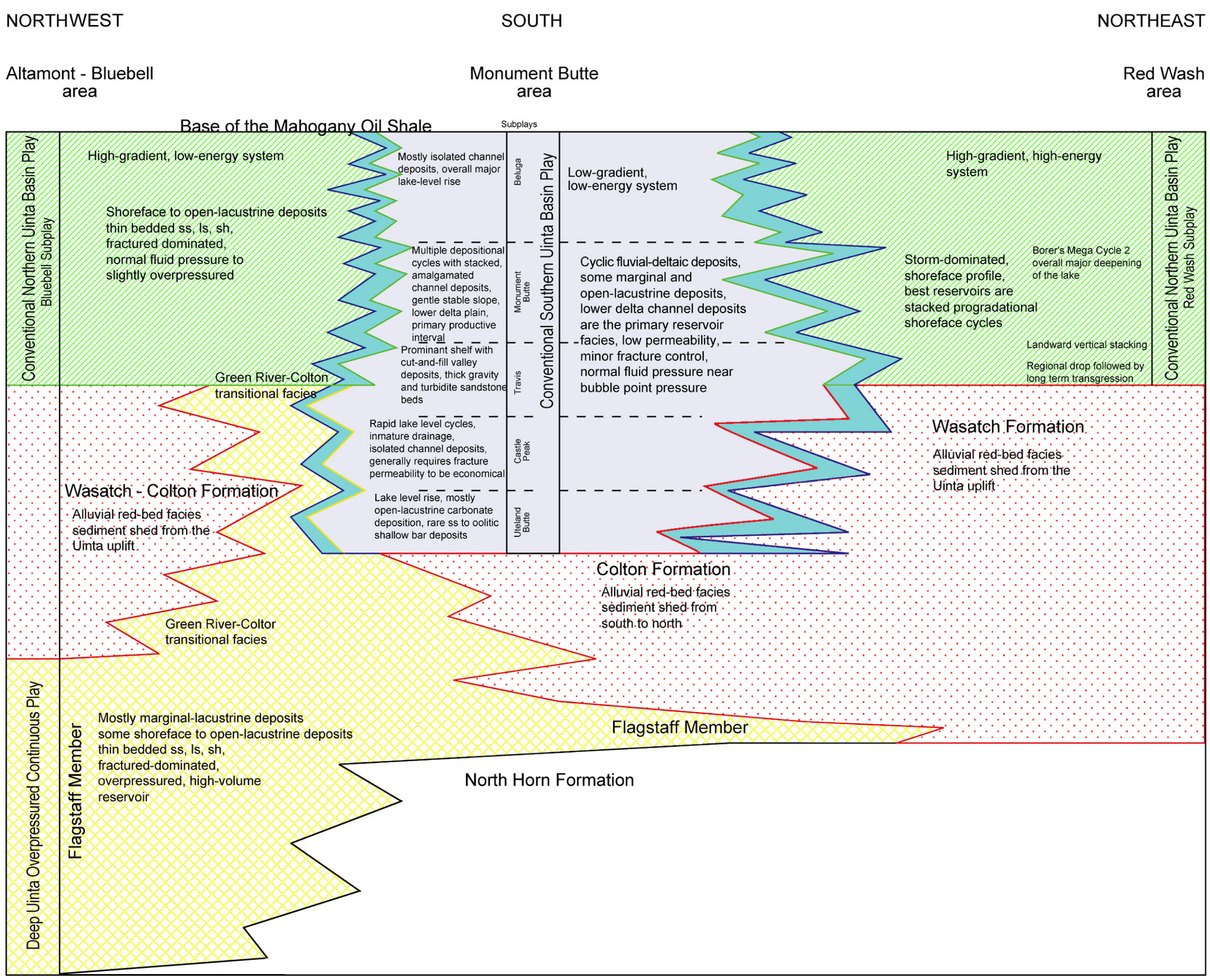

Figure 11. Diagrammatic correlation of the Green River plays in Uinta Basin. Sediment source and depositional energy systems resulted in varying reservoir characteristics in each of the plays and subplays.

Table 2. Comparison of Uinta Basin crude oils. Yellow-wax sample from John No. 2-7B2 well (section 7, T. 2 S., R. 2 W., Uinta Base Line and Meridian), black-wax sample from Leslie Taylor No. 24-5 well (section 24, T. 1 S., R. 1 W., Uinta Base Line and Meridian). The Monument Butte black wax is an average from three wells: Monument Butte Nos. 10-35, 8-35, and 12-35 (section 35, T. 8 S., R. 16 E., Salt Lake Base Line and Meridian). From Morgan (2003).

Oil Characteristics	Bluebell Yellow Wax (DUBOCP*)	Bluebell Black Wax (CNUBP*)	Monument Butte Black Wax (CSUBP*)
Paraffin Content	7.4% wt.	12.2% wt.	9.6% wt.
Cloud Point	132°F	157°F	122°F
Pour Point	95°F	120°F	95°F
API Gravity	39°	33°	34°

* DUBOCP = Deep Uinta Basin Overpressured Continuous Play, CNUBP = Conventional Northern Uinta Basin Play, CSUBP = Conventional Southern Uinta Basin Play.

Table 3. Comparison of associated gas from Uinta Basin oil plays. From Moore and Sigler (1987).

Play*	Field	Well	Methane	Ethane	Propane	Higher Fractions	Carbon Dioxide	Hydrogen Sulfide	Btu/ft^3
CNUBP	Red Wash	Unit 1	92.0	2.1	2.1	2.7	1.3	0.0	1096
CNUBP	Red Wash	Unit 32-27C	97.6	0.9	0.2	0.4	0.1	0.0	1026
CNUBP	Bluebell	Unit 2	96.0	1.1	0.9	1.1	0.1	0.0	1057
DUBOCP	Bluebell	Hamblin 1	73.7	14.4	7.2	4.2	0.4	0.0	1347
DUBOCP	Altamont	Brotherson 1	71.4	14.3	7.8	6.0	0.2	0.0	1409
CSUBP	Monument Butte	Unit 10-35	71.8	14.9	9.9	3.3	NA	NA	NA

* CNUBP = Conventional Northern Uinta Basin Play, DUBOCP = Deep Uinta Basin Overpressured Continuous Play, CSUBP = Conventional Southern Uinta Basin Play.

portion of the Green River Formation at drill depths of 5000 to 6000 feet (1500-1800 m). Production is from sandstone deposited in shoreface to shoreline environments. The Red Wash subplay has the highest average matrix permeability of any of the plays in the Green River–Colton Formations.

Borer and McPherson (1998) provide the following description of the depositional environment of the Green River Formation at Red Wash field.

> *In Red Wash, the overwhelming depositional overprint is that of wave/storm domination. It represents a high sediment supply and high accommodation regime. Middle and upper shoreface regimes are by far the most dominant reservoir facies. Sediment gravity flows, suspension fall out deposits and fluvial deposits are also of reservoir quality and can have a large impact locally on production and waterflood behavior. We consider many sediment gravity flows to be the result of high-energy storm impacts on the shoreline.*
>
> Borer and McPherson (1998)

Stratigraphy and Thickness

The Green River and Colton Formations have a combined thickness of more than 6000 feet (1800 m) in the northern Uinta Basin but only a portion of the stratigraphic interval is included in the CNUBP. The Bluebell subplay has a 2000-foot-thick (600 m) productive interval in the lower Green River and upper transitional Colton Formations. The Red Wash subplay has a 1000-foot-thick (300 m) productive interval in the Douglas Creek Member.

Lithology and Fracturing

The dominant oil-productive lithology is sandstone; some production is from fractured shale and marlstone in the Conventional Bluebell subplay. Fractures are encountered in both plays and generally enhance the reservoir quality, but are more common in the Bluebell subplay than in the Red Wash subplay.

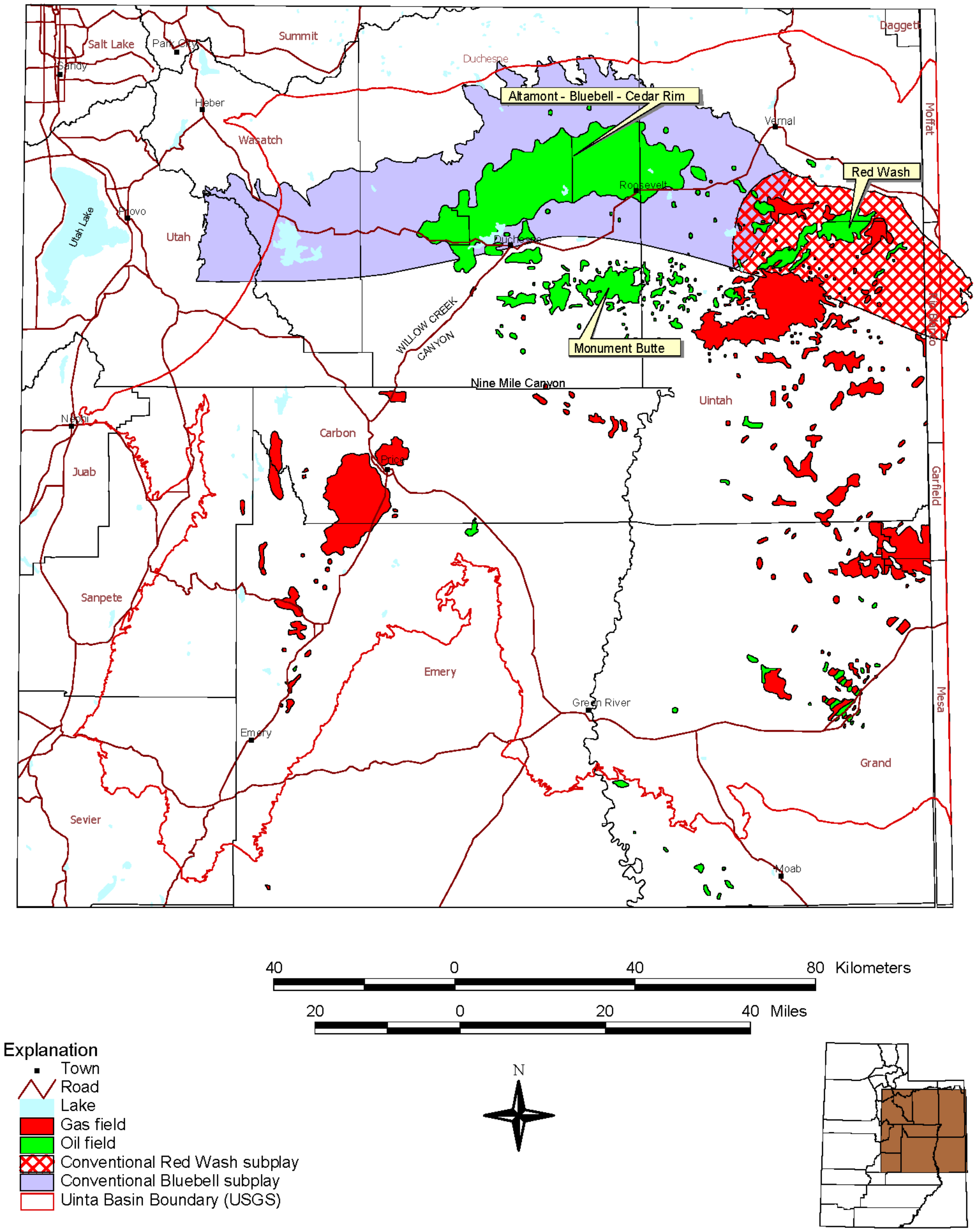

Figure 12. Location map showing the outline of the Uinta Basin and major oil and gas fields. Colored areas are the Conventional Red Wash subplay and the Conventional Bluebell subplay that make up the Conventional Northern Uinta Basin Play.

Fractures are an important part of the Conventional Bluebell subplay reservoir and the underlying DUBOCP in the Altamont, Bluebell, and Cedar Rim fields. The fractures in the Conventional Bluebell subplay generally have a different orientation and possibly a different origin than the fractures in the underlying DUBOCP. Based on limited data, fractures in the DUBOCP reservoirs generally trend east-west, whereas fractures in the overlying Conventional Bluebell subplay reservoirs trend northwest-southeast (Allison and Morgan, 1996; Harthill and Bates, 1996; Morgan, 2003). Fractures in the DUBOCP reservoirs are believed to be the result of rapid generation of hydrocarbons within the largely impermeable rock (Lucas and Drexler, 1975; Narr and Currie, 1982; Bredehoeft and others, 1994). The Conventional Bluebell subplay reservoirs are not overpressured (0.5 psi/ft [11.3 kPa/m]) to slightly overpressured, but have open fractures that are probably related to tectonic movement of the basin rather than hydrofracturing during oil generation. As a result, the fractures in the Conventional Bluebell subplay are not controlled by the distribution and thermal maturity of oil-source rock. Fractures in the Conventional Bluebell subplay are typically vertical to near vertical and often have significant calcite filling (Morgan, 2003).

Hydrocarbon Source and Seals

The source rocks for the crude oil produced from the CSUBP are kerogen-rich shale and marlstone of the Green River Formation, which were deposited in nearshore and offshore open-lacustrine environments (Hunt and others, 1954; Forsman and Hunt, 1958; Silverman and Epstein, 1958; Tissot and others, 1978; Ruble, 1996; Ruble and others, 1998). Anders and others (1992) showed that the 0.7 percent vitrinite reflectance level in the center of the Altamont and Bluebell fields is at about 8400 feet (2600 m) drill depth. The 0.7 percent reflectance level is the depth at which the onset of intense oil generation occurred. In most wells in Altamont and Bluebell, the 8400-foot (2600 m) depth is at or below the Mahogany oil shale, but above the middle marker of the Green River. As a result, only the lower Green River and the Flagstaff Member are in the oil-generation window.

Structure and Trapping Mechanisms

Stratigraphic traps are the primary trapping mechanism for reservoirs in the CNUBP. Structure is dominantly regional dip northward into the basin with minor flexures or plunging structural anticlinal trends with no four-way closure.

The trap in the Conventional Bluebell subplay is formed by the updip (north to south) pinchout of alluvial and marginal lacustrine sandstone beds into offshore marlstone and shale beds. A subtle west-plunging anticline is mapped at Bluebell field in the lower Green River Formation (figure 13), which is not present at deeper horizons. The Altamont and Cedar Rim fields also have a regional northerly dip.

The trap in the Conventional Red Wash subplay is formed by updip (northwest to southeast) pinchout of wave-dominated marginal lacustrine sandstone beds. A subtle west- to northwest-plunging anticline is mapped in the Red Wash field (figure 14).

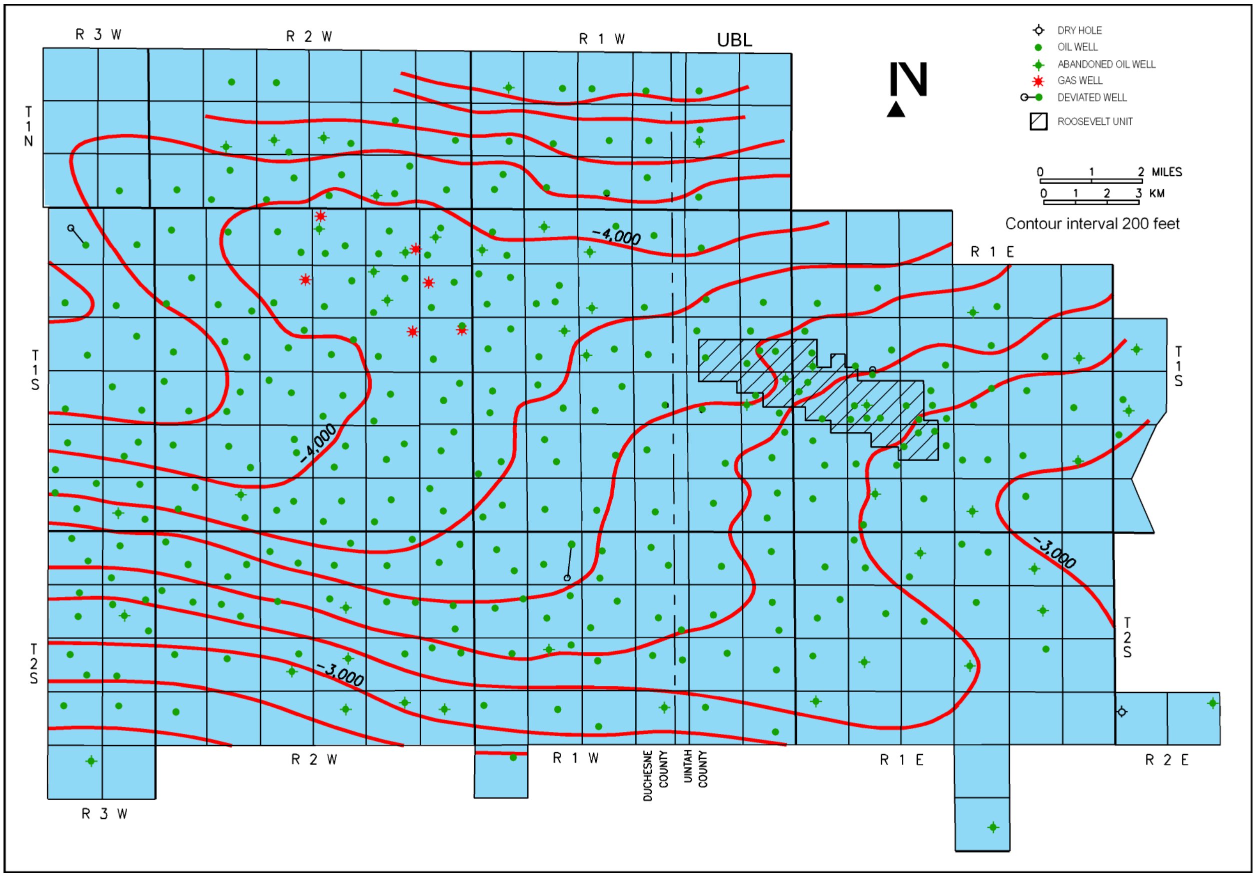

Figure 13. Structure contour map of the top of the middle marker of the Green River Formation, Bluebell field, Duchesne and Uintah Counties, Utah. Contour interval is 200 feet; datum = mean sea level. From Morgan (2003).

Reservoir Properties

Oil and gas production in the CNUBP is from the lower Green River Formation and upper Colton Formation (upper Green River/Colton transition). In the Conventional Bluebell subplay the sandstone reservoirs typically have low porosity (8 to 12 percent) and low matrix permeability (0.01 to 10 millidarcies [mD]). The sediment was shed from the Uinta uplift directly north of the play area, deposited as sandstone in alluvial channels and fans, shallow marginal-lacustrine channels and bars in a low-energy environment with very little reworking of the sediment. As a result, the sandstone reservoirs typically are high in clay content and well cemented.

In contrast, the sandstone in the Red Wash field area was derived from wind-deposited bars near the shoreline, was deposited in a shoreface environment on a steeper, higher energy shelf, and underwent greater reworking during deposition. As a result, the sandstone reservoirs in the Conventional Red Wash subplay have higher porosities (8 to 20 percent) and significantly higher matrix permeabilities, commonly 50 to 500 mD. Reservoir data for individual fields in the Conventional Red Wash subplay are summarized in table 4.

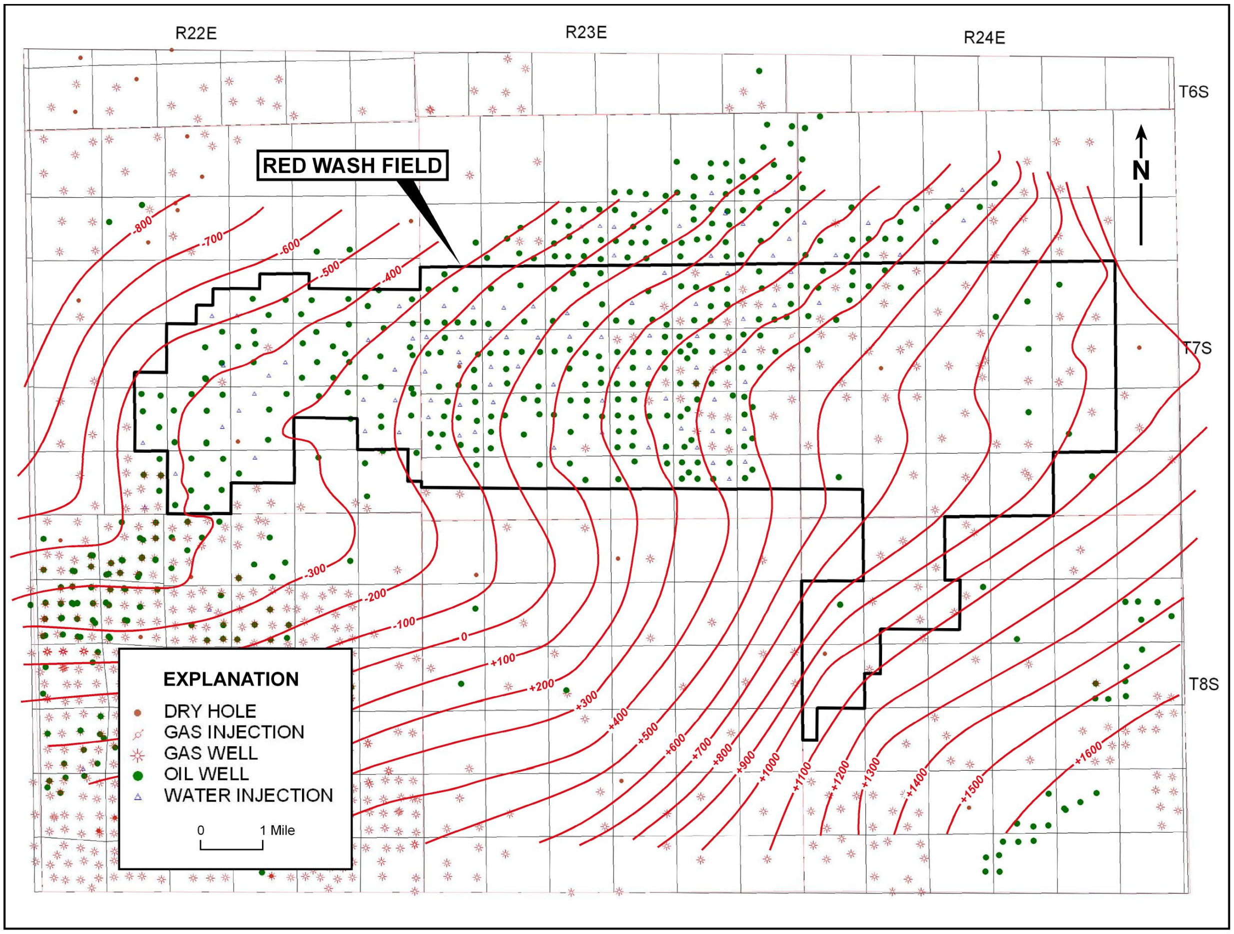

Figure 14. Structure contour map on the top of the Douglas Creek Member of the Green River Formation, Red Wash field. Contour interval is 100 feet; datum = mean sea level. From Schuh (1993).

Oil and Gas Characteristics

Most of the oil produced from the CNUBP is characterized as black wax. The black wax typically has a gravity of 28 to 32°API gravity. The crude at Red Wash field has a lower pour point 80 to 95°F (27-35°C) than the black wax at Bluebell field, which has a pour point of about 120°F (49°C).

Associated gas from the Red Wash field (table 3) contains an average of 95 percent methane, 1.5 percent ethane, 1.1 percent propane, 1.6 percent higher fractions, 0.7 percent carbon dioxide (CO_2), with an average heating value of 1060 Btu/ft^3 (Moore and Sigler, 1987). Associated gas from the Bluebell field (table 3) contains an average of 85 percent methane, 8 percent ethane, 3 percent propane, 2.6 percent higher fractions, 0.3 percent CO_2, with an average heating value of 1200 Btu/ft^3 (Moore and Sigler, 1987).

Production

Fields in the CNUBP produce crude oil and associated gas. Production from the Conventional Bluebell subplay cannot be accurately separated from the DUBOCP and is

Table 4. Geologic, reservoir, and production data for the largest fields in the Conventional Red Wash subplay of the Conventional Northern Uinta Basin Play. Data for the Conventional Bluebell subplay can not be accurately separated from the Deep Uinta Basin Overpressured Continuous Play, and is presented in that play. Production data is from Utah Division of Oil, Gas and Mining, June 30, 2005.

State	County	Field	Discovery Date	Active Producers	Abandoned Producers	Acres	Spacing (acres)	Pay (feet)	Porosity (%)	Perm. (mD)	Temp. (°F)	Initial Reservoir Pressure (psi)	Monthly Production		Cumulative Production	
													Oil (bbl)	Gas (MCF)	Oil (bbl)	Gas (MCF)
Utah	Uintah	Brennan Bottom	1954	8	3	1760	160	26	12	1.0	162	2580	2,508	1,800	1,709,082	2,256,049
Utah	Uintah	Coyote Basin	1964	21	3	1600	80	8	14	215	120	1559	2,334	2,107	1,913,057	904,908
Utah	Uintah	Red Wash	1951	116	21	31,000	40-80	170	13	42	149	1925	36,537	89,623	81,832,186	344,401,518
Utah	Uintah	Walker Hollow	1953	85	11	9040	40		13	42	107	NA	18,481	43,354	18,390,619	32,023,832
Utah	Uintah	White River	1964	4	2	1040	80	16	10	NA	150	2379	608	73,864	2,750,780	9307,231
Utah	Uintah	Wonsits Valley	1962	56	58	6240	40	90	12	22	149	2800	31,726	606,221	49,393,480	85,692,422

NA = data not available.

presented as production for that play. The largest fields (fields with >500,000 bbls of oil [79,500 m^3] cumulative production) in the Conventional Red Wash subplay have produced 155.9 million bbls of oil (BO) (24.8 million m^3) and 474.6 billion cubic feet of gas (BCFG) (13.4 BCMG) as of June 30, 2005. Monthly production from the play in June 2005 was 92,194 BO (14,659 m^3) and 817 million cubic feet of gas (MMCFG) (23 MMCMG). The Red Wash field has produced the most oil and continues to be the largest producer in the subplay. Data on production and number of wells are summarized for the fields in the play in table 4.

Exploration Potential and Trends

Conventional Bluebell subplay: Infill drilling will continue in portions of the Altamont-Bluebell-Cedar Rim field area where the Conventional Bluebell subplay play has not been developed on 320-acre spacing (130 ha). Down spacing to 160 acres (65 ha) has not been proposed but might be considered if oil prices remain high enough to make the additional drilling economical. However, the second well per section drilled on 320-acre spacing (130 ha) typically produces significantly less than the first well in the section (Morgan, 2003); as a result, down spacing to 160 acres (65 ha) will be financially risky.

The western portion of the Conventional Bluebell subplay is being explored for Mesaverde Group and Mancos Shale gas. The deeper drilling for gas could result in the discovery of new oil fields in the overlying Green River Formation.

Secondary and tertiary recovery methods have not been attempted in the Altamont-Bluebell-Cedar Rim field area. Several factors have discouraged operators from attempting any secondary recovery pilot projects. Fractures in the reservoir rock can cause early breakthrough of any injected fluid or gas. Fractures can result in injected fluids or gases moving great distances, perhaps even beyond the intended secondary recovery unit. Secondary and tertiary recovery methods generally require a high density of wells to be effective. The Altamont-Bluebell-Cedar Rim field area has been developed with two wells per section and in many areas at least one of those wells has already been plugged and abandoned. As a result, any secondary or tertiary recovery method would require a significant amount of additional drilling.

The largest resource potential in the Conventional Bluebell subplay may be in recompletions of the current wells. The wells in the Altamont-Bluebell-Cedar Rim field area were completed in a shotgun fashion with perforations in 40 or more beds in a 1500-foot (450 m) or greater vertical interval. As a result, many of the beds never received adequate stimulation. Using cased-hole logs to identify by-passed oil and selectively stimulating individual beds can recover a significant amount of additional oil. The potential to recomplete wells in the Bluebell field was the subject of a U.S. Department of Energy- (DOE-) funded study lead by the UGS (Morgan, 2003; also see Chidsey and others, 2004). The potential for increased oil recovery from recompletion of older wells has been demonstrated in the Roosevelt federal exploratory unit within the Bluebell field. Before recompletions, production from the unit had dropped to 561 BO (89.2 m^3) during the month of December 2002, but after recompletions, production has increased to >13,000 BO (2070 m^3) for the month of August 2005 (figure 15).

Conventional Red Wash subplay: Many of the fields in the Conventional Red Wash subplay are currently in secondary recovery waterflood operations and are not actively being drilled. Tertiary recovery techniques are not currently being tested, but may be considered in the future

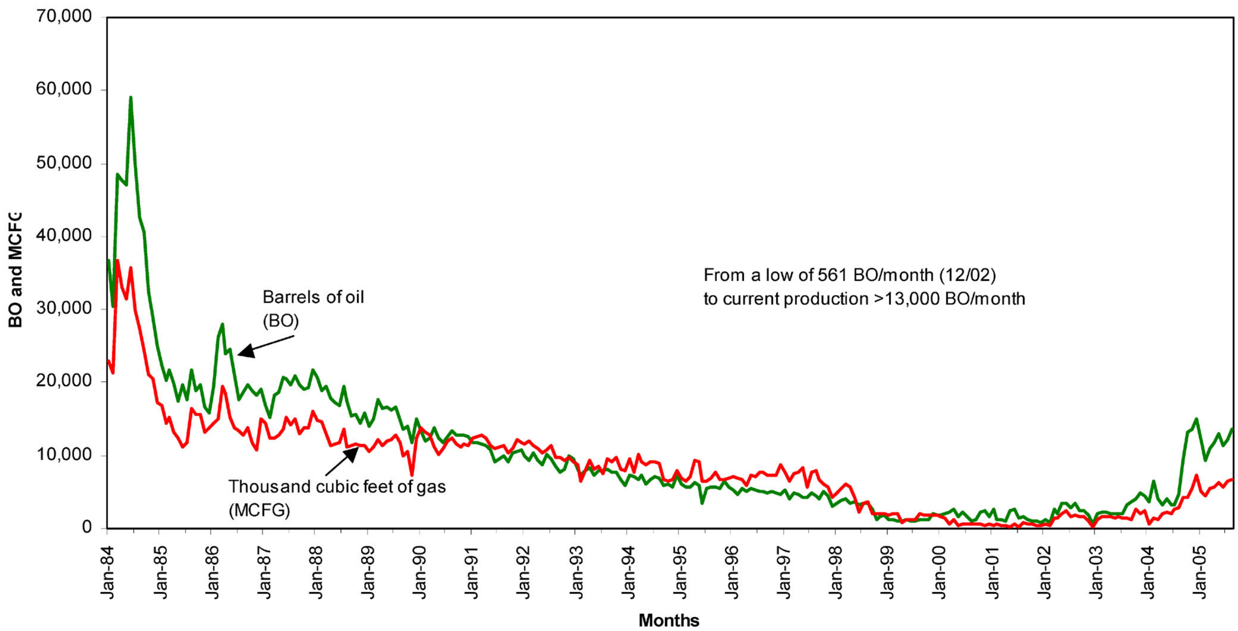

Figure 15. Monthly oil and gas production for the Roosevelt unit in the Bluebell field. Production from the unit had dropped to a low of 561 BO/month in December 2002, but a recent program of recompletions has increased production to more than 13,000 BO/month. This is an example of the potential that still exists in the Conventional Northern Uinta Basin Play. Data from Utah Division of Oil, Gas and Mining.

as production continues to decline. A pilot CO_2 injection test was conducted in the Red Wash and Wonsits Valley fields in the 1980s. The short injection tests had mixed results and no further testing was done. Much of the Conventional Red Wash subplay area is being actively explored for gas in the deeper Wasatch Formation, Mesaverde Group, and Mancos Shale. The deep drilling will likely identify new potential in the shallow Green River Formation that can be exploited in the wells when the deeper reservoirs are depleted or may lead to additional development drilling if the Green River potential is considered significant.

Deep Uinta Basin Overpressured Continuous Play (DUBOCP) Description

The DUBOCP is located near the basin center where about the lower 2500 to 3000 feet (750-900 m) of the Green River and intertonguing Colton Formations are overpressured (gradient >0.5 psi/ft [11.3 kPa/m]) (figures 16 and 17). The most rapid increase in reservoir pressure and most of the high-volume, overpressured oil production is typically from 11,000 to 14,000 feet (3400-4300 m) (figure 18). The drill depths given are averages, actual depth to the overpressured interval can vary greatly throughout the fields.

The play has produced nearly 300 million BO (50 million m^3) and 500 BCF (14 BCM) of associated gas from the three large fields – Altamont, Bluebell, and Cedar Rim. Production is fracture controlled from rocks with typically very low (< 0.1 mD) matrix permeability. The reservoir is fractured lenticular sandstone, shale, and marlstone deposited in the lacustrine and alluvial environments of Lake Uinta. Well completions typically consist of perforating 40 or more beds in a 1500-foot (450 m), or more, vertical section.

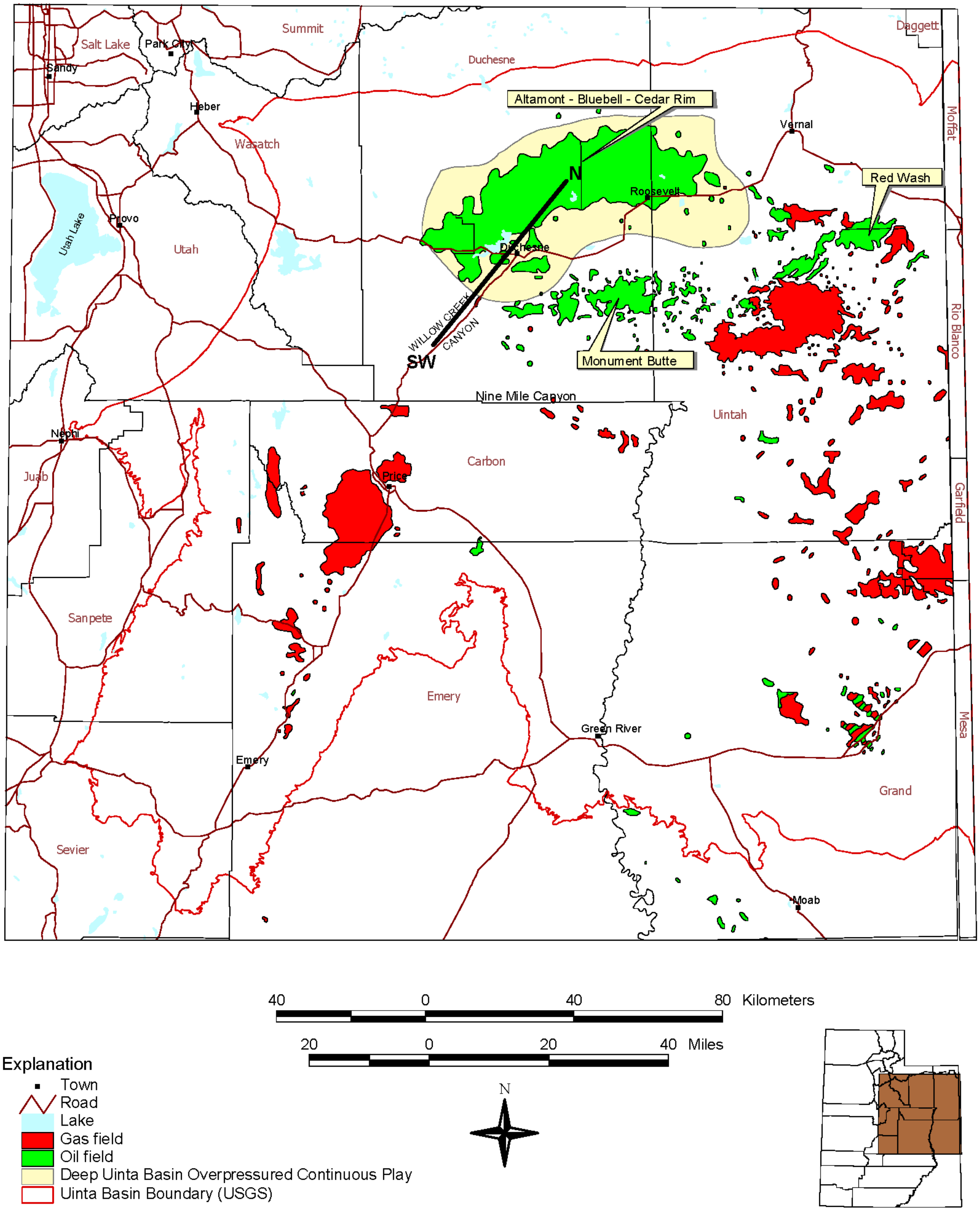

Figure 16. Location of the Deep Uinta Basin Overpressured Continuous Play in northern Uinta Basin. The play encompasses the Altamont, Bluebell, and Cedar Rim fields. North-southwest cross section shown on figure 17.

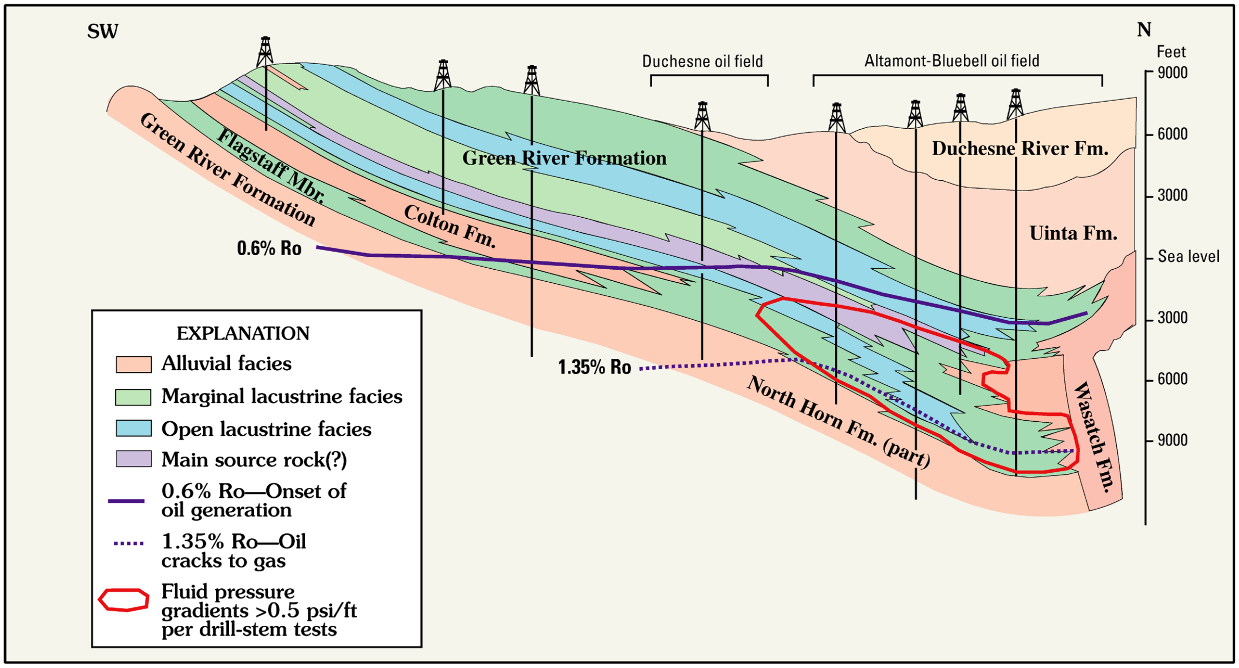

Figure 17. Generalized stratigraphic cross section of the Green River total petroleum system showing the overpressured interval of the Deep Uinta Basin Overpressured Continuous Play. Line of section shown on figure 16. From Dubiel (2003).

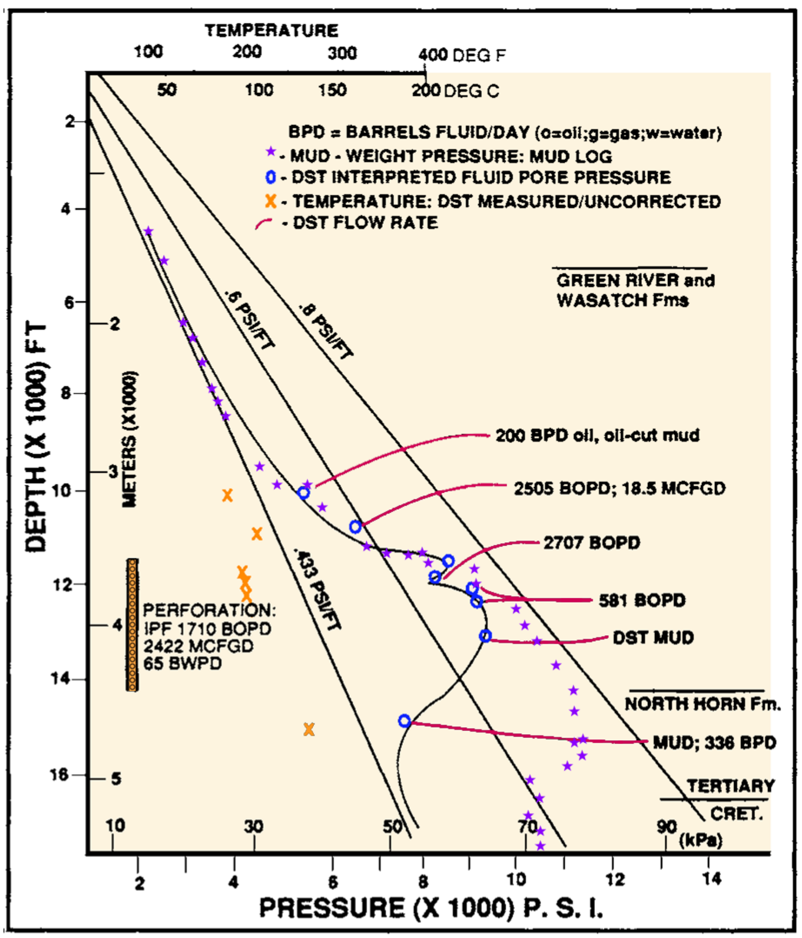

Figure 18. Plot of pressure versus depth for the Brotherson No. 1-11B4 well (section 11, T. 2 S., R. 4 W., UBL) at Altamont field. From Bredehoeft and others (1994).

Depositional Environment

The Uinta Basin began developing in middle Paleocene time. Shallow lakes and wetlands (the depositional facies of the Flagstaff Member of the Green River Formation) existed in the deep basin area by early Paleocene time. Ancient Lake Flagstaff, followed by Lake Uinta (both lakes will be referred to as Lake Uinta), were dominant features throughout most of the late Paleocene and Eocene in the deep basin area. In most of the basin the Flagstaff is separated from the main portion of the Green River by alluvial deposits of the Colton Formation. But in the central portion of the basin along the southern limits of Altamont and Bluebell fields, lacustrine deposits of Lake Flagstaff and Lake Uinta are continuous. Ryder and others (1976) defined three major depositional facies in the Colton and Green River Formations: (1) alluvial, (2) marginal lacustrine, and (3) open lacustrine. The depositional environments of the Colton and Green River are described in detail by Fouch (1975, 1976, 1981), Ryder and others (1976), Pitman and others (1982), Francyk and others (1992), and Fouch and Pitman (1991, 1992).

Abundant detritus was shed from the south flank of the Uinta uplift into the deep basin area from late Paleocene into earliest Eocene time (Franczyk and others, 1992). Alluvial deposits of the Colton Formation, laid down along Lake Uinta's northern margin, and intertongue with the deeper-basin, marginal-lacustrine deposits of the Green River Formation. The Colton thins rapidly from north to south in the deep basin play area. Expansion of Lake Uinta resulted in deposition of marginal-lacustrine and open-lacustrine sediments over the Colton (figure 19).

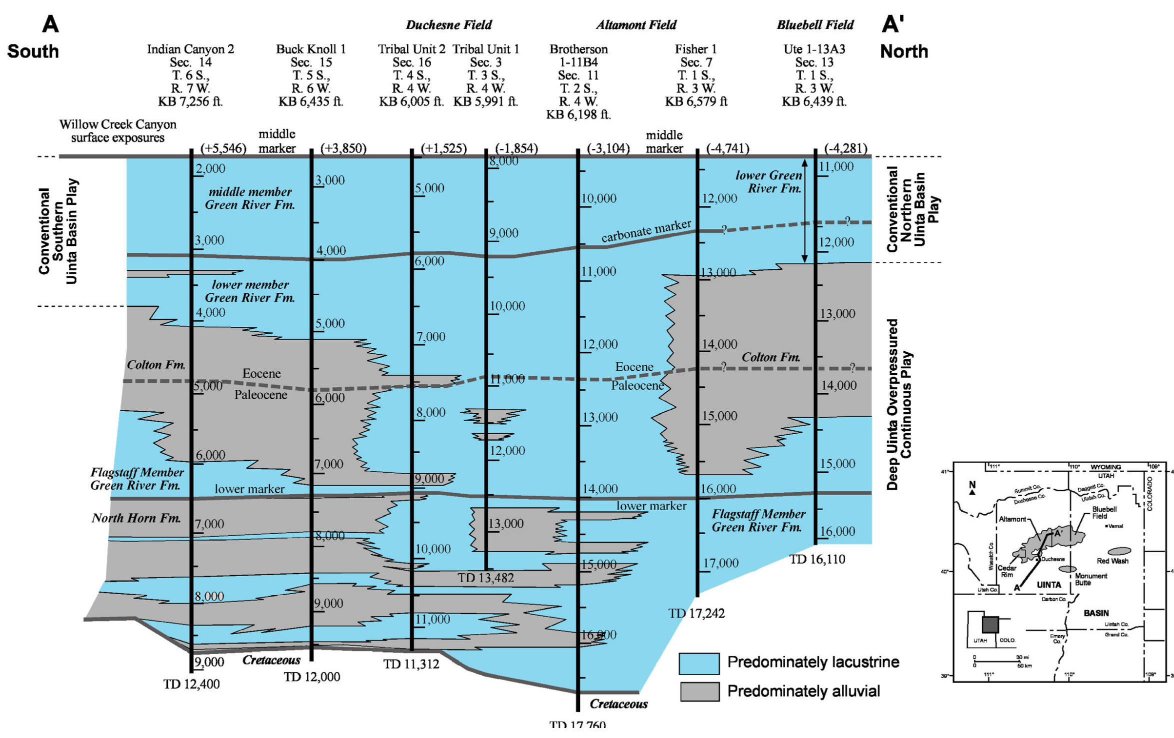

Figure 19. Generalized stratigraphic cross section which extends from outcrops in Willow Creek Canyon through Duchesne, Altamont, and Bluebell fields. Correlations of markers and depositional interpretations for many of the wells are from Fouch (1981). Datum is the middle marker with sea-level elevations in parentheses.

Stratigraphy and Thickness

The DUBOCP produces oil and associated gas, in ascending order, from the Flagstaff Member of the Green River Formation, the intertonguing Green River-Colton Formations, and the lower Green River Formation in the deepest portions of the play. The total thickness of the Green River, Colton, and Flagstaff Member strata can be more than 8000 feet (2400 m). The basal contact of the Flagstaff Member with the Paleocene part of the North Horn Formation is poorly defined and is rarely penetrated by wellbores. Typically the lower 2500 to 3000 feet (750-900 m) of the reservoir interval is overpressured and makes up the DUBOCP. The total depth of most wells in the deep basin play is 12,000 to 14,000 feet (3600-4300 m).

Lithology and Fracturing

Hydrocarbons are produced in the DUBOCP from the Paleocene- and Eocene-age Colton and Green River Formations. Most of the production is from sandstone, but some production comes from shale, limestone, and marlstone beds with open fractures. Most production in the deep basin play is dominated by fractures and the abnormally high fluid pressure, and to a lesser extent by facies and porosity distribution. Fractures in the DUBOCP reservoirs are believed to be the result of rapid generation of hydrocarbons within the largely impermeable rock (Lucas and Drexler, 1975; Narr and Currie, 1982; Bredehoeft and others, 1994).

A study of core from the Bluebell field by Wegner (1996) and Wegner and Morris (1996) showed that 78 percent of the sandstone beds and 43 percent of the clastic mudstone beds had at least one noticeable fracture. Fracture density, orientation, and filling vary with differing rock types; sandstone beds tend to have the lowest fracture density but the fractures are longer and generally have more separation than those found in other rock types (Wegner, 1996; and Wegner and Morris, 1996). Naturally occurring fractures in the sandstone beds are commonly perpendicular to near-perpendicular to bedding, with a measured vertical length greater than 3.3 feet (1 m) (although many fractures extend out of the sample). Fracture widths range from 0.03 to 0.13 inches (0.5-3.0 mm), and the openings are only partially calcite filled (Wegner, 1996; and Wegner and Morris, 1996; Morgan, 2003).

Hydrocarbon Source and Seals

The source rocks for the crude oil produced from the DUBOCP are kerogen-rich shale and marlstone of the Green River Formation which were deposited in nearshore and offshore open-lacustrine environments (Tissot and others, 1978; Ruble, 1996; Ruble and others, 1998). Anders and others (1992) showed that the 0.7 percent vitrinite reflectance level in the center of the Altamont and Bluebell fields is at about 8400 feet (2600 m) drill depth. The 0.7 percent reflectance level indicates the depth at which the onset of intense oil generation occurred. In most wells in Altamont and Bluebell fields, the 8400-foot (2600 m) depth is at or below the Mahogany oil shale, but above the middle marker of the Green River. As a result, only the lower Green River and the Flagstaff Member are in the oil-generation window.

Structure and Trapping Mechanisms

The DUBOCP is located near the center of the Uinta Basin. Structure in the Altamont, Bluebell, and Cedar Rim fields is dominated by north dip into the basin. Oil is trapped in natural pores and within fractures which were opened by the high fluid pressures during oil generation (Bredehoeft and others, 1994; McPherson, 1996). Interbedded sandstone, shale, and marlstone deposited in alluvial to marginal-lacustine environments pinch out updip into dominantly shale and marlstone deposited in an open-lacustrine environment. Updip facies changes, a reduction of fluid pressure, and associated closing of fractures in the structurally shallower strata direction combine to form the traps of the DUBOCP.

Reservoir Properties

Oil and gas production in the DUBOCP is from perforated intervals where the lower Colton Formation intertongues with the Flagstaff Member of the Green River Formation. In the Altamont-Bluebell-Cedar Rim field area, the Colton and Flagstaff contain an oil-bearing overpressured section that is up to 3000 feet (900 m) thick. The upper Colton and middle Green River are productive and locally overpressured, but are included in the Conventional Northern Uinta Basin Play. Sandstone in the DUBOCP has well-log porosities from 1 to 14 percent, with an average of 5 percent, and core-derived matrix permeabilities of 0.01 mD or less (Morgan, 2003). Open fractures are the primary reservoir property necessary for oil and gas production from the DUBOCP.

Well completions in the DUBOCP typically consist of perforating 40 or more beds in a 1500-foot (450 m), or more, vertical section and hydraulically fracturing them with hydrochloric acid. This is commonly referred to as a “shotgun” completion.

Reservoir pressure gradients in the DUBOCP vary from 0.5 to 0.8 psi/ft (11.3-18.1 kPa/m). Representative calculated reservoir pressures are 9600 psi (66,200 kPa) for Bluebell field (assuming 12,000-foot [3600 m] depth and a gradient of 0.8 psi/ft [18.1 kPa/m]), 8400 psi (58,000 kPa) for Altamont field (assuming 12,000-foot [3600 m] depth and a gradient of 0.7 psi/ft [15.8 kPa/m]), and 6000 psi (40,000 kPa) for Cedar Rim field (assuming 10,000-foot [3000 m] depth and a gradient of 0.6 psi/ft [13.5 kPa/m]). Bottom-hole temperature is typically greater than 210°F (99°C). The reservoir drive mechanisms include gas solution and pressure depletion. The wells yield a significant amount of water during the late stages of production but the water is not considered a major drive mechanism. Reservoir data for the individual fields in the DUBOCP are summarized in table 5.

Oil and Gas Characteristics

Most of the oil produced from the DUBOCP is characterized as yellow wax. The yellow wax from the John No. 2-7B2 well (section 7, T. 2 S., R. 2 W., Uinta Base Line and Meridian [UBL&M]) is a 39° API gravity crude with a paraffin content of 7.4 percent. Because of the high paraffin content, the yellow wax has a pour point of 95°F (35°C) and a cloud point of 132°F (56°C). The produced oil is stored on location in heated, insulated stock tanks to keep it above the pour-point temperature. Associated gas from the DUBOCP (table 3) contains an average of 73 percent methane, 14 percent ethane, 7.5 percent propane, 5.1 percent higher fractions, 0.3 percent CO_2, with an average heating value of 1380 Btu/ft^3 (Moore and Sigler, 1987).

Table 5. Geologic, reservoir, and production data for the largest fields in the Deep Uinta Basin Overpressured Continuous Play. Production data is from Utah Division of Oil, Gas and Mining, June 30, 2005; other data from Robertson and Broadhead (1993), Smouse (1993), and Morgan (2003).

State	County	Field	Discovery Date	Active Producers	Abandoned Producers	Acres	Spacing (acres)	Pay (feet)	Porosity (%)	Perm. (mD)	Temp. (^{O}F)	Initial Reservoir Pressure (psi)*	Monthly Production		Cumulative Production	
													Oil (bbl)	Gas (MCF)	Oil (bbl)	Gas (MCF)
Utah	Duchesne	Altamont	1970	250	165**	139,720	320	40+	5-12	0.1	217	8400	76,778	203,106	118,542,858	245,151,302
Utah	Duchesne/ Uintah	Bluebell	1971	297	**	129,040	320	40+	5-12	0.1	218	9600	181,778	291,718	156,904,340	216,687,418
Utah	Duchesne	Cedar Rim	1969	27	22	21,820	320	40+	5-12	0.1	212	6000	12,282	80,834	13,001,634	28,865,861

* Pressure data estimated based on 12,000 feet and a gradient of 0.8 psi/ft for Bluebell, 12,000 feet and 0.7 psi/ft for Altamont, and 10,000 feet and 0.6 psi/ft for Cedar Rim fields.
** Abandoned producers for the Altamont and Bluebell fields are combined.

Production

Fields in the DUBOCP produce oil with large amounts associated gas. Altamont-Bluebell-Cedar Rim fields have produced 288 million BO (45.8 million m^3) and 491 BCFG (13.9 BCMG). The three fields combined produced 271,000 BO (43,100 m^3) and 576 MMCFG (16.3 MMCMG) from 574 active wells during June 2004 (Utah Division of Oil, Gas and Mining production records). Many of the wells perforated in the deep overpressured interval also have perforations in the overlying CNUBP interval. As a result, the co-mingled production from the two plays cannot be accurately separated; therefore, all of the production from the Altamont-Bluebell-Cedar Rim fields is attributed to the DUBOCP.

Exploration Potential and Trends

The DUBOCP is well defined by drilling in the Altamont-Bluebell-Cedar Rim field area. It is highly unlikely that any new large field discoveries will be made in the Uinta Basin that produce from the overpressured portion of the Colton and Green River Formations. Drilling may result in some field extensions but even that will be limited by the well-defined overpressured region within the basin.

Infill drilling will continue in portions of the Altamont-Bluebell-Cedar Rim field area where the deep overpressured play has not been developed on 320-acre (130 ha) spacing. Down spacing to 160 acres (65 ha), or less, has not been proposed but might be considered if oil prices remain high enough to make the additional drilling economical. However, past experience indicates the second well per section drilled on 320-acre spacing (130 ha) typically produces significantly less than the first well in the section (Morgan, 2003). As a result, down spacing will be financially risky.

Secondary and tertiary recovery methods have not been attempted in the Altamont-Bluebell-Cedar Rim field area. Several factors have discouraged operators from attempting any secondary recovery pilot projects. Fractures are the dominant reservoir property and can cause early breakthrough of any injected fluid or gas. Fractures can result in injected fluids or gases moving great distances, perhaps even beyond the intended secondary recovery unit. Secondary and tertiary recovery methods generally require a high density of wells to be effective. The Altamont-Bluebell-Cedar Rim field area has been developed with two wells per section and in many areas at least one of those wells has already been plugged and abandoned. As a result, any secondary or tertiary recovery method would require a significant amount of additional deep drilling.

The largest resource potential in the DUBOCP may be in recompletions of the current wells. The wells in the Altamont-Bluebell-Cedar Rim field area were completed in a shotgun fashion with perforations in 40 or more beds in a 1500-foot (450 m) or greater vertical interval. Consequently, many of the beds never received adequate stimulation. Using cased-hole logs to identify by-passed oil, and selectively stimulating individual beds can recover a significant amount of additional oil. The potential to recomplete wells in the Bluebell field was the subject of a DOE-funded study lead by the UGS (Morgan, 2003; also see Chidsey and others, 2004). The Malnar Pike well in the field was recompleted as part of the UGS demonstration and is an example of increased oil production from just two beds (figure 20). A new operator took control of the Roosevelt unit in the Bluebell field and began a program of recompletions that has resulted in oil production increasing from 561 BO/month (89 m^3/month) to more than 13,000 BO/month (2100 m^3/month) (figure 15).

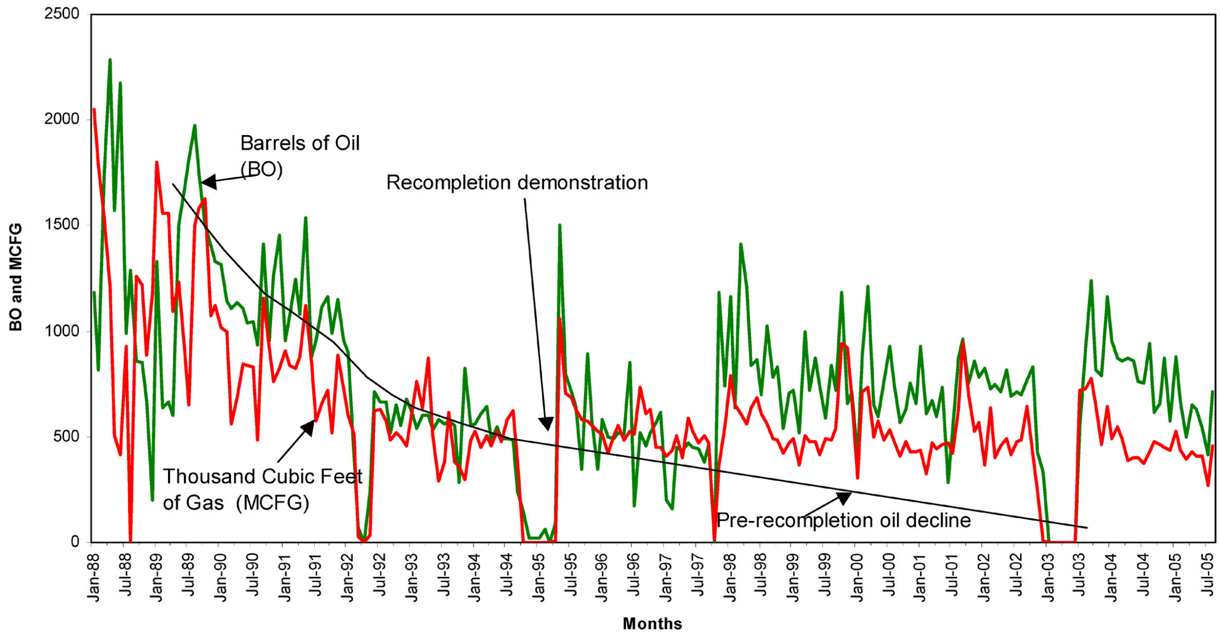

Figure 20. Monthly oil and gas production from the Malnar Pike well (section 17, T. 1 S., R. 1 E., UBL&M), Bluebell field, showing the increased oil production after recompleting in just two beds as part of the DOE-funded UGS demonstration project (Morgan, 2003). This is an example of potential that still exists in a well that has produced for many years in the Deep Uinta Basin Overpressured Continuous Play. Data from Utah Division of Oil, Gas and Mining.

Outcrop Analogs

Utah is unique in that representative outcrop analogs (depositional or structural) for each major oil play are present in or near the thrust belt, Paradox Basin, and Uinta Basin. Production-scale analogs provide an excellent view, often in 3D, of reservoir-facies characteristics, geometry, distribution, and nature of boundaries contributing to the overall heterogeneity of reservoir rocks. The specific objectives of this project are to: (1) increase understanding of vertical and lateral facies variations and relationships within major reservoirs; (2) describe the lithologic characteristics; (3) determine the morphology, internal geometries, and possible permeability and porosity distributions; and (4) identify potential impediments and barriers to fluid flow.

An outcrop-analog model, combined with the details of internal lithofacies characteristics, can be used as a "template" for evaluating data from conventional core, geophysical and petrophysical logs, and seismic surveys. When combined with subsurface geological and production data, the analog model will improve development drilling and production strategies, reservoir-simulation models, reserve calculations, and design and implementation of secondary/tertiary oil recovery programs and other best practices used in the oil fields of Utah and vicinity.

Conventional Northern Uinta Basin Play (CNUBP)

An outcrop analog for the major oil reservoirs in the Green River Formation in the CNUBP is available along Raven Ridge in the northeastern Uinta Basin (figure 21). The Raven Ridge outcrop belt is a 20-mile-long (32 km), dip-oblique transect. Shoreline trends in the Green River are generally east-west and therefore the northwest to southeast outcrop exhibits about 14 miles (23 km) of landward to lakeward facies transitions (Borer, 2003). Several locations offer excellent exposures of shoreline deposits (figure 22) that serve as reservoirs, and bay-fill deposits (figure 23) that provide organic-rich source rocks for the play. Borer and McPherson (1998), and Borer (2003) have done extensive work on the Raven Ridge outcrops and presented their results in two unpublished field trip guidebooks. Oil Gully is just one of their measured sections, although there are numerous other excellent exposures along Raven Ridge described by Borer and McPherson (1998), and Borer (2003). The following description of Oil Gully is taken largely from their work.

Oil Gully, named for the many tar sands in the exposed rocks, is a good outcrop analog for the reservoirs at Red Wash field. Borer measured 300 feet (100 m) of section in Oil Gully, which contains numerous depositional rise-to-fall cycles (figure 24). Some of the features that Borer describes at Oil Gully include landward-migrating bar forms that develop transgressive caps; gravity flow cycles; and lagoonal and high-energy, upper shoreface facies.

Deep Uinta Basin Overpressured Continuous Play (DUBOCP)

The depositional environments for the reservoirs in Altamont-Bluebell-Cedar Rim field area are, from north to south (proximal to distal): alluvial fans to fan deltas, and marginal lacustrine to open lacustrine. Sediment source was the Uinta uplift north of the field area. The Green River and Colton Formations do not crop out north of the field area, therefore a similar tectonic setting along the western arm of Lake Uinta is presented as a reservoir analog (figure 25).

No single outcrop or outcrop belt provides a view of the complete proximal to distal facies changes in the Flagstaff Limestone (equivalent to the Flagstaff Member of the Green River Formation) as the depositional environment of this unit changes from fan deltas to open lacustrine. Three different locations in Sevier and Sanpete Counties provide good outcrop examples of the various facies shed off the western highlands into Lake Uinta (figure 26). South Cedar Ridge Canyon contains exposures of proximal facies consisting of interbedded conglomerate, sandstone, and siltstone that were commonly deposited in water as fan deltas extending into Lake Uinta (figures 27 and 28). Exposures of medial facies in Lone Cedar Canyon have been described as interbedded shale, sandstone, and limestone deposited in a marginal-lacustrine environment. Another good exposure of the Flagstaff that is more accessible is in Price River Canyon (figure 29); here the medial facies of the Flagstaff is composed of open-lacustrine shale and limestone. Distal Flagstaff facies are also exposed at Musinia Peak on the Gunnison Plateau and in Manti Canyon (figure 30) on the Wasatch Plateau.

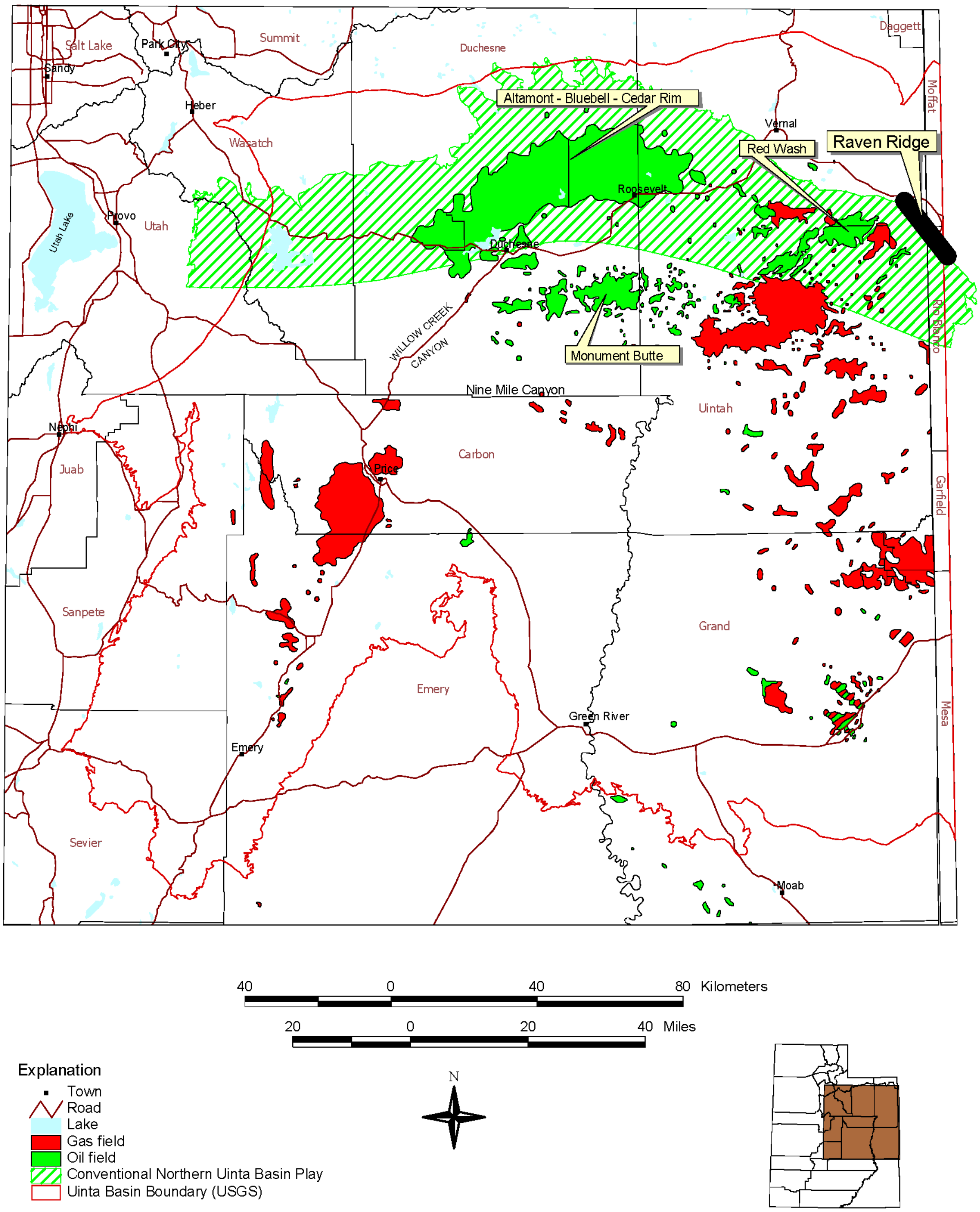

Figure 21. Location map showing the outline of the Uinta Basin and major oil and gas fields. The Conventional Northern Uinta Basin Play area is colored light green and the location of Raven Ridge where the Green River Formation is exposed is indicated.

Figure 22. Green River Formation and underlying Wasatch Formation exposed along Raven Ridge. The outcrop is a good analog to sandstone reservoirs in Red Wash field of the Conventional Northern Uinta Basin Play.

Figure 23. Organic-rich shale representing good oil source rock in the Green River Formation at Raven Ridge of the Conventional Northern Uinta Basin Play.

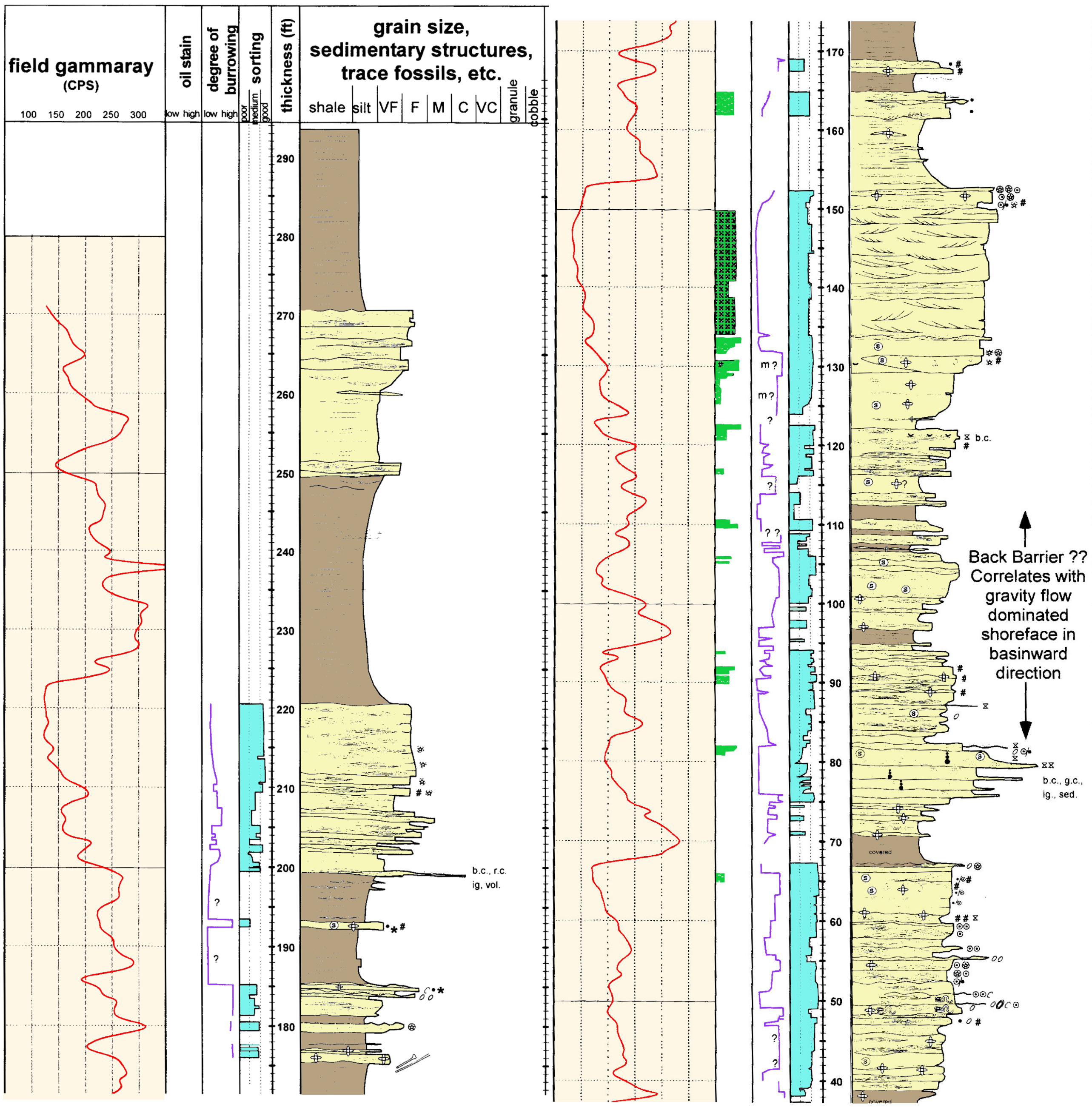

Figure 24. Stratigraphic measured section of the Green River Formation at Oil Gully, Raven Ridge, Uintah County, Utah. From Borer (2003).

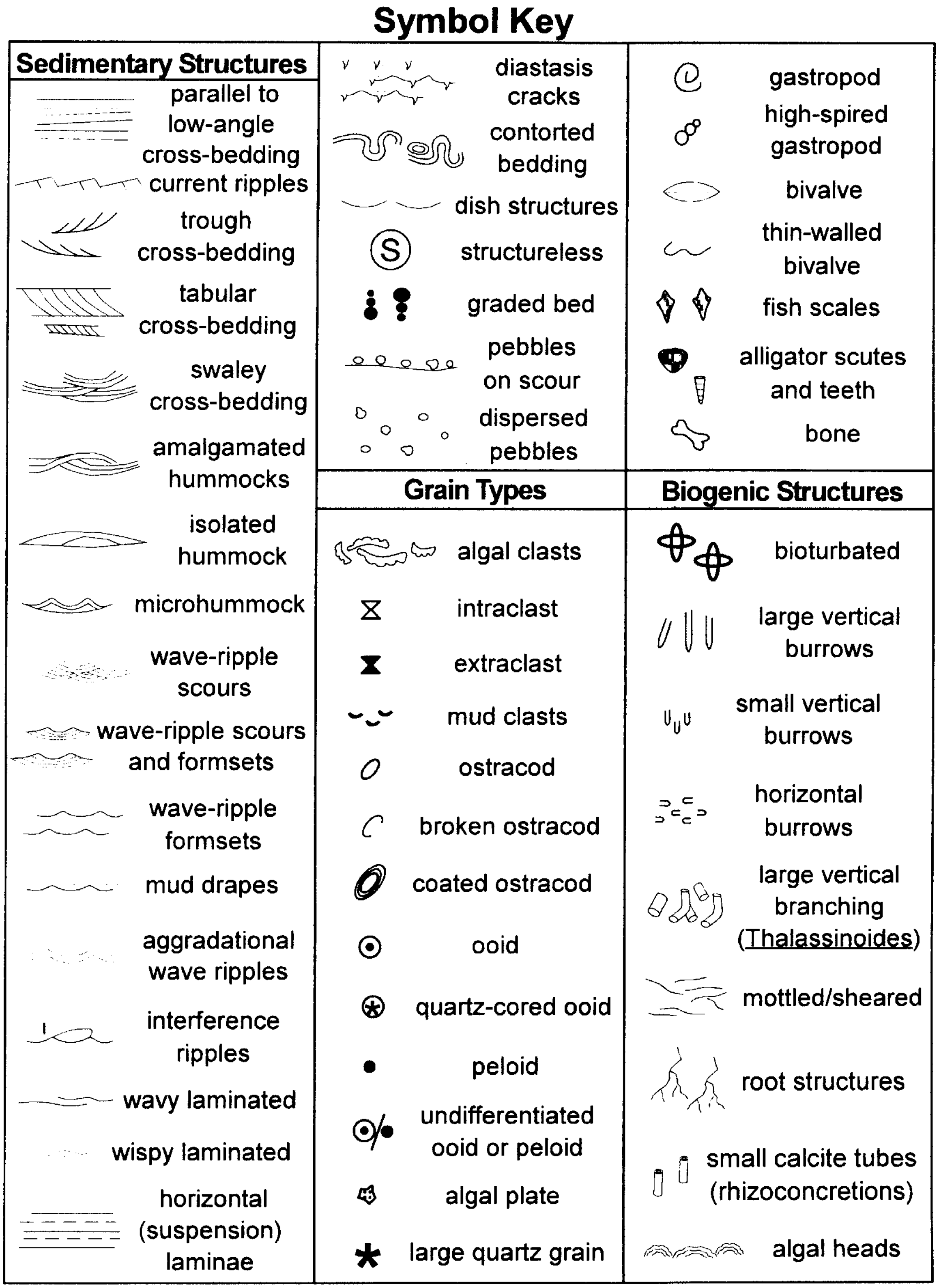

Figure 24 continued.

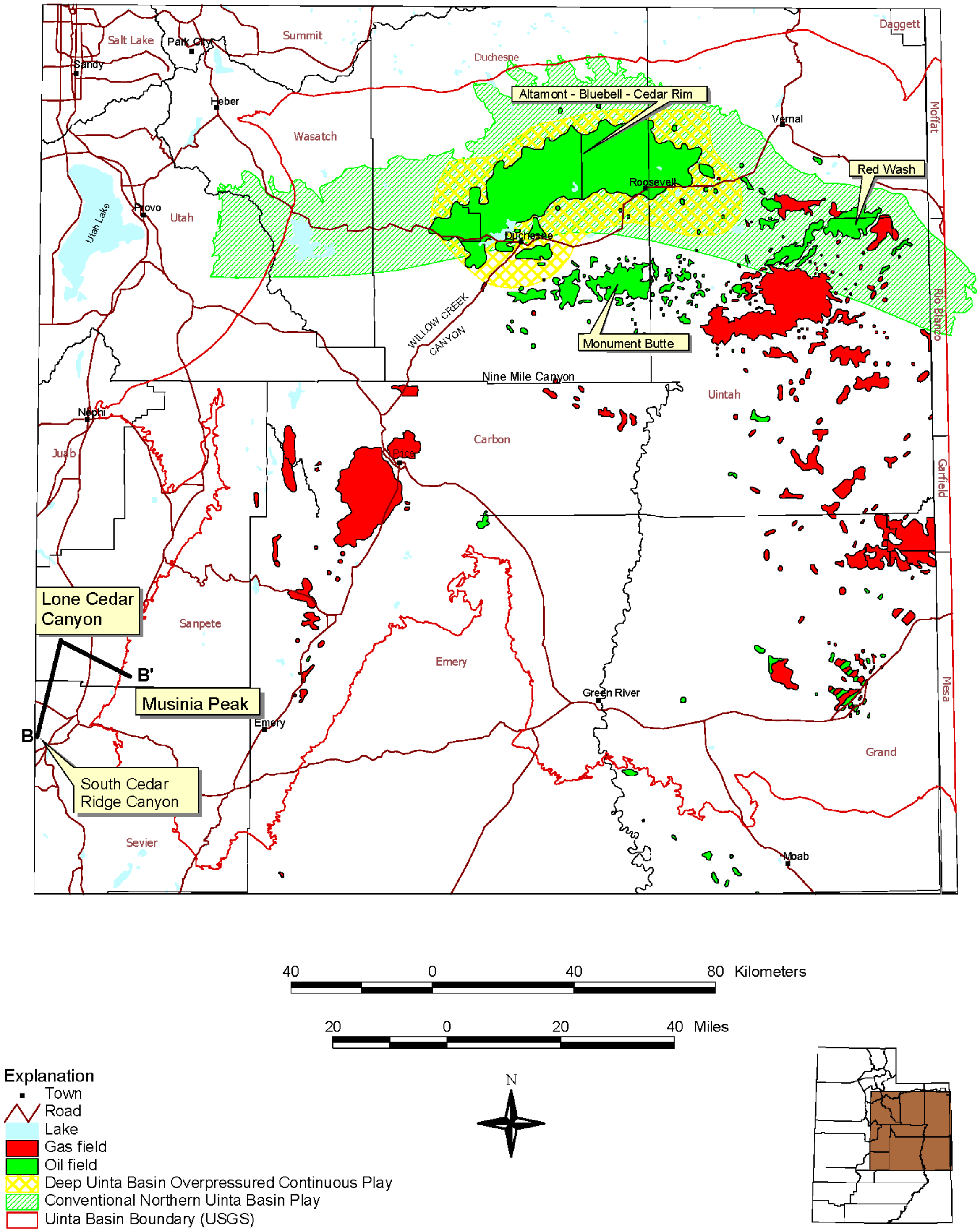

Figure 25. Location map showing the outline of the Uinta Basin and major oil and gas fields. The Conventional Uinta Basin Northern Play area and the Deep Uinta Basin Overpressured Continuous Play area are shown. Cross section B – B' (figure 26) is a series of outcrops in the Flagstaff Limestone demonstrating the proximal to distal facies change that is typical of the two plays.

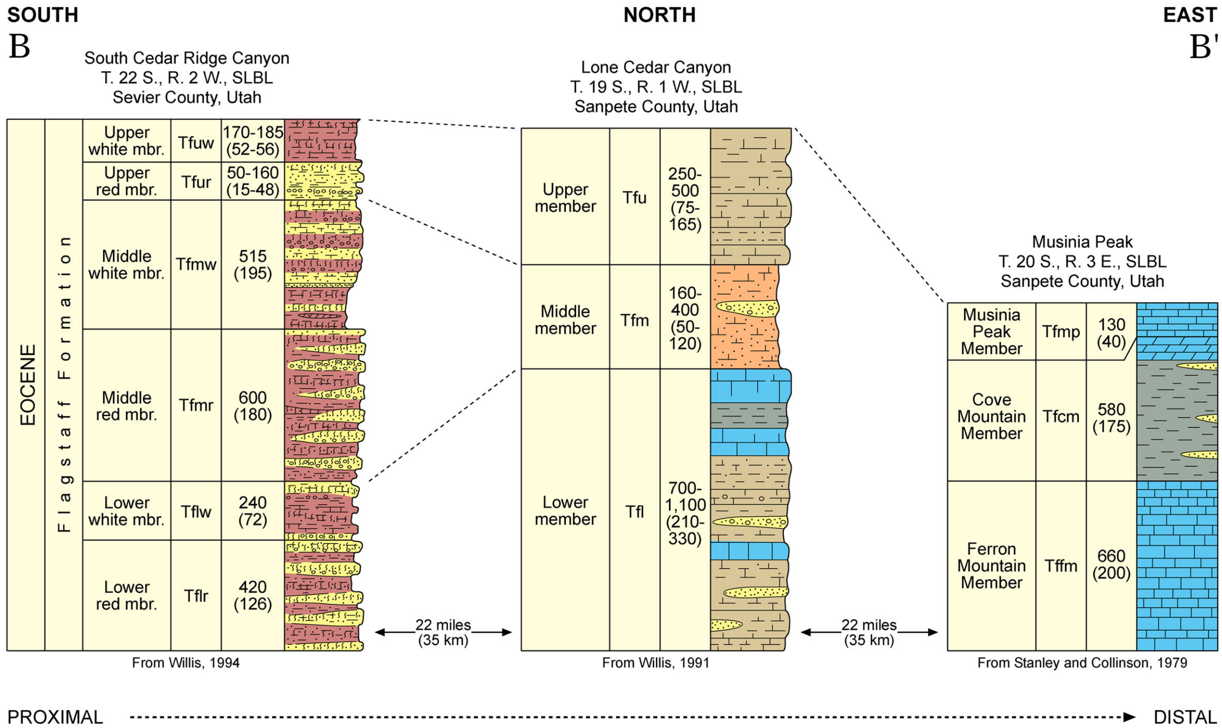

Figure 26. Cross section of measured stratrigraphic sections showing transition from proximal to distal facies in the Flagstaff Limestone, similar to the north-south facies change in the Altamont-Bluebell-Cedar Rim field area. Line of section shown on figure 25.

Figure 27. Proximal facies of the Flagstaff Limestone exposed along the east face of the Gunnison Plateau. At this location the Flagstaff is composed of sandstone and siltstone deposited as alluvial fans from the highlands to the southwest.

Figure 28. Sandstone and conglomerate beds in the proximal facies of the Flagstaff Limestone in South Cedar Ridge Canyon. Some of these beds appear to have been deposited in shallow lake water as fan deltas.

Figure 29. Marginal-lacustrine medial facies of the Flagstaff Member of the Green River Formation in Price River Canyon. The outcrop is composed of interbedded red and gray shale, sandstone, and some carbonate.

Figure 30. Distal facies of the Flagstaff Limestone exposed in Manti Canyon on the Wasatch Plateau. The outcrop is composed of open-lacustrine limestone and shale overlying the North Horn Formation (red beds).

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. During the quarter, project team members joined Utah Stake Holders Board members in attending the Uinta Basin Oil and Gas Collaborative Group meeting in Vernal, Utah, on December 1, 2005. Project activities, results, and recommendations were presented at this meeting.

Project materials, plans, and objectives were displayed at the UGS booth during the 2005 Uinta Basin Energy Days Industry Exposition and Conference, October 4-6, 2005, in Vernal, sponsored by the Vernal Area Chamber of Commerce and the Independent Petroleum Association of Mountain States. 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 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.

Project Publication

Chidsey, T.C., Jr., and Morgan, C.D., 2005, Major oil plays in Utah and vicinity – quarterly technical progress report for the period July 1 to September 30, 2005: U.S. Department of Energy, DOE/FC26-02NT15133-13, 27 p.

CONCLUSIONS AND RECOMMENDATIONS

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

2. Oil and gas production in the Laramide-age Uinta Basin is mostly from the Paleocene and Eocene Green River and Colton/Wasatch Formations. In early late Paleocene time, a large lake, known as ancestral Lake Uinta, developed in the basin. Deposition in and around Lake Uinta consisted of open- to marginal-lacustrine sediments that make up the Green River Formation. Alluvial redbed and floodplain deposits that are laterally equivalent to, and intertongue with, the Green River form the Colton/Wasatch.

3. The CNUBP and DUBOCP cover the northern Uinta Basin. The CNUBP typically has drill depths ranging from 5000 feet (1500 m) to a maximum of 10,000 feet (3000 m). The play is divided into two subplays: (1) Conventional Bluebell subplay, and (2) Conventional Red Wash subplay. The DUBOCP is delineated where the lower 2500 to 3000 feet (750-900 m) of the Green River and intertonguing Colton Formations are overpressured (gradient >0.5 psi/ft [11.3 kPa/m]). The most rapid increase in reservoir pressure and most of the high-volume, overpressured oil production typically occurs at depths ranging from 11,000 to 14,000 feet (3400-4300 m).

4. The source rocks for the crude oil produced from the Uinta Basin plays are also found in the Green River Formation and consist of kerogen-rich shale and marlstone which were deposited in nearshore and offshore open-lacustrine environments. Most of these oils are characterized as yellow or black wax. Production from the DUBOCP is dominantly yellow wax, while most of the oil production from the CNUBP and CSUBP is black wax.

5. In the Conventional Bluebell subplay, sandstone reservoirs typically have low porosity (8 to 12 percent) and low matrix permeability (0.01 to 10 mD). Sandstone reservoirs in the Conventional Red Wash subplay have higher porosities (8 to 20 percent) and significantly higher matrix permeabilities, commonly 50 to 500 mD. In the DUBOCP, production is fracture controlled in reservoir rocks which typically have very low (< 0.1 mD) matrix permeability. The reservoirs are fractured lenticular sandstone, shale, and marlstone deposited in the lacustrine and alluvial environments of Lake Uinta.

6. Fields in the CNUBP and DUBOCP produce crude oil with associated gas. Production from the Conventional Bluebell subplay cannot be accurately separated from the DUBOCP. The largest fields in the Conventional Red Wash subplay have produced 155.9 million BO (24.8 million m^3) and 474.6 BCFG (13.4 BCMG). The DUBOCP has produced nearly 300 million BO (50 million m^3) and 500 BCFG (14 BCM) primarily from three large fields – Altamont, Bluebell, and Cedar Rim.

7. The largest resource potential in the CNUBP and DUBOCP may be in recompletions of the current wells. Well completions have typically consisted of perforating 40 or more beds in a 1500-foot (450 m) or more, vertical section. As a result, many of the beds never received adequate stimulation. We recommend using cased-hole logs to identify by-passed oil and selectively stimulating individual beds to recover significant amounts of additional oil.

8. Secondary and tertiary recovery methods have not been attempted in the Altamont-Bluebell-Cedar Rim field area. Fractures are the dominant reservoir property and can cause early breakthrough of any injected fluid or gas. Fractures can result in injected fluids or gases moving great distances, perhaps even beyond the intended secondary recovery unit. Secondary and tertiary recovery methods generally require a high density of wells to be effective. The Altamont-Bluebell-Cedar Rim field area has been developed with two wells per section and in many areas at least one of those wells has already been plugged and abandoned. As a result, any secondary or tertiary recovery method would require a significant amount of additional deep drilling.

9. The CNUBP and DUBOCP areas are also being explored for Mesaverde Group and Mancos Shale gas. The deeper drilling for gas could result in the discovery of new oil fields in the overlying Green River Formation.

10. An outcrop analog for the major oil reservoirs in the CNUBP is exposed along Raven Ridge in the northeastern Uinta Basin; these exposures display landward to lakeward facies transitions. Several locations offer excellent exposures of shoreline deposits that serve as reservoirs, and bay-fill deposits that provide organic-rich source rock for the play. Outcrop analogs for the DUBOCP in Sevier and Sanpete Counties, central Utah, provide good examples of deposits shed off the western highlands into Lake Uinta. Many of the proximal conglomerates were deposited in water by fan deltas extending into the lake. Other exposures of medial facies include interbedded shale, sandstone, and limestone deposited in a marginal-lacustrine environment. The distal facies of the Flagstaff Limestone is composed of open-lacustrine shale and limestone.

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

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