WIND RIVER RESERVATION

List of Topics

Background
  Reservation Overview
  Petroleum System Overview
Geologic Overview
  Petroleum Systems
  Summary of play types
Conventional / Unconventional Play Types
  Play Type 1 - Basin Margin Subthrust Play
  Play Type 2 - Basin Margin Anticline Play
  Play Type 3 - Deep Basin Structure
  Play Type 4 - Muddy Sandstone Stratigraphic Play
  Play Types 5,6,7 - Phosphoria Stratigraphic, Bighorn Wedge Edge Pinchout
  Flathead-Lander and Equivalent Sandstone Play
  Play Types 8,9,10,12 - Madison Limestone, Darwin-Amsden Sandstone
  Triassic and Jurassic Stratigraphic, Cody and Frontier
  Play Type 11 - Shallow Tertiary/Upper Cretaceous Stratigraphic Play
  Play Type 13 - Basin-Center Gas Play
References
The Wind River Reservation, located in central Wyoming, is home to the Shoshone and Arapaho Tribes. It contains approximately 3,500 square miles of land, with notable geographic features including mountains and valleys. The reservation's location is significant for its natural resources, which have played a crucial role in the development of its economies.

### Tribal Governments

The Shoshone and Arapaho Tribes have their own tribal governments. Each tribe has a General Council that makes decisions about the tribe's affairs and elects the Business Council, which oversees the tribe's financial and business operations. The Black Hills communities, including the Shoshone, Arapaho, and Bannock Tribes, have their own tribal governments as well.

### Tax Structure and Revenue

The Wind River Indian Reservation Tax Structure is unique. In 1979, the Tribes enacted Ordinance Number 39, which imposed a one-half of one percent (0.5%) Privilege of Doing Business Tax on the market value of gas produced, saved, and/or sold or transported from the land or water where the production occurred. This tax was aimed at encouraging responsible development of the reservation's natural resources. In 1982, the Joint Business Council (JBC) amended Ordinance Number 39, increasing the tax rate from 0.5% to 4.0% on gas production. This significant increase was intended to ensure that a sufficient portion of the tax revenue flowed to the Tribes.

### Revenue Continuity

Despite the initial challenges, the Tribes have continued to develop their natural resource bases. The JBC has successfully managed to ensure that a portion of the revenue from these resources is directed towards the Tribes' economic development. This has been a crucial step in ensuring that the Tribes have the financial resources necessary to support their communities.

### Future Prospects

As the state and federal governments continue to explore new tax strategies, the Tribes are focusing on initiatives that will help them achieve their economic development goals. This includes projects aimed at increasing the number of businesses that can participate in the reservation's economic activities.

### Economic Development

The Tribes are committed to developing their economies in a sustainable manner. They are working closely with industry partners to ensure that new businesses are aligned with the Tribes' economic development goals. This includes developing targeted economic assistance programs and tax incentives that encourage responsible economic development in accordance with the Tribes' interests.
**Wind River Basin - Petroleum System Overview**

The Wind River Basin is a northwest-southeast trending asymmetrical intermontane basin of the Rocky Mountain foreland, located in central Wyoming. Province boundaries are defined by fault-bounded Laramide sub-basins that surround it. These include the Owl Creek Mountains to the north, Wind River Mountains to the west, Casper arch to the east, and the Sweetwater Uplift to the south. The Wind River Basin Province is about 200 mi. long and 100 mi. wide, encompassing an area of about 11,700 sq. mi. Actual basinal area not capped by eroded Precambrian and/or Paleozoic rock is approximately 7,500 sq. mi. The Wind River Reservation comprises almost half of this basinal area, 3,500 sq. mi. All of the major petroleum systems and play types have been encountered in the reservation area. Approximately 0.35 BBO, 35 MMBNGGL, and 2.9 TCFG are known to have been produced from the entire basin since 1884.

A nearly complete stratigraphic section, Cambrian through Tertiary in age fill the sub-basins located within the reservation area of the Wind River Basin. Sevier-aged and Cretaceous epicontinental sea-water basins have been completely folded, thrusted, and faulted during the Laramide orogenetic event (initiated latest Cret.-earliest Paleocene). Basement involved and detached structural features create intricate and complicated stratigraphic correlations throughout the Wind River Basin. Early paleozoic platform carbonates and fringing patch reefs of a mainly carbonate province become siliciclastic-dominated by latest Paleozoic time. Sandstone reservoirs of the Permian Phosphoria Formation and Pennsylvanian Tensleep produce the bulk of the petroleum within the reservation area. Locally, many of the other Cretaceous sandstone reservoirs produce significant quantities of oil and gas. Black shales of the Phosphoria and Mowry formations are considered the source of the petroleum for much of the Wind River basin reservoirs. Deeply buried Cretaceous and Tertiary coals are probably the source of significant amounts of thermogenic methane (gas) found in Cretaceous/Tertiary reservoirs.

**Stratigraphic Column for Wind River Basin**

- **Precambrian**
  - Undifferentiated Pre-Cambrian

- **Cambrian**
  - Undifferentiated

- **Ordovician**
  - Undifferentiated

- **Silurian**
  - Undifferentiated

- **Devonian**
  - Undifferentiated

- **Mississippian**
  - Undifferentiated

- **Pennsylvanian**
  - Undifferentiated

- **Permian**
  - Undifferentiated

- **Triassic**
  - Undifferentiated

- **Jurassic**
  - Undifferentiated

- **Cretaceous**
  - Undifferentiated

- **Tertiary**
  - Undifferentiated

**Figure WR 2.4**. These graphs depict the estimates for discovered and undiscovered hydrocarbons within the Wind River Basin. The bulk of new discoveries should be gas with over 100 MMBO added to production as well. Historic ratios of oil versus gas discovered will not apply in the future as exploration efforts will most likely target for new gas reserves (Willette, D., 1996).
Regional Geology

The Wind River Basin occupies the geographic center of Wyoming and is surrounded by some of Wyoming’s highest mountains. The Wind River Mountains (13,500+ feet in elevation) form the western boundary of the basin against which several major southwest verging thrust systems abut. The northern margin of the basin is constrained by the Owl Creek and southern Big Horn Mountains, while the southern basin margin is marked by the Granite Mountains. The eastern edge of the basin is delineated by the more subtle topography of the Casper arch which separates the Wind River basin from the Powder River basin. The basin is 180 miles long, northwest to southeast and is 75 miles wide north to south. The reservation area comprises most of the northwestern and central portions of the basin. The predominant patterns of deposition for both the Paleozoic and Mesozoic intervals consist of complexly interbedded sandstone and shales. Only the lower Paleozoic section contains carbonate and evaporite deposits.

Paleozoic and early Mesozoic Geologic History

During Paleozoic and early Mesozoic time all of central Wyoming was part of the stable shelf lying east of the Cordilleran orogenic belt. Deposition upon the shelf occurred primarily in shallow seas. Because of the broad shelfal area widespread facies changes and unconformities resulted from relatively minor sea level fluctuations.

Combined thickness of Cambrian-aged deposits range from 1025’ in the western edge of the basin to approximately 775’ in the east. The Flathead Sandstone and the Gros Ventre Formations consist of predominantly clastic deposits while the Upper Cambrian Gallatin Limestone provides the first evidence of carbonate depositional conditions within the shallow, shelfal environment.

Ordovician-aged sediments of the Wind River Reservation are represented only by the Bighorn Dolomite. Estimates in thickness range from 125-300 feet and the dolomite thins to the east and southeast and is absent in the southeast corner of the reservation due to an erosional unconformity.

Devonian rocks are thin to absent across the reservation area. The Madison Limestone comprises most of the Mississippian-aged sediments within the reservation. It ranges between 500-700 feet in thickness with the upper portion containing karst features.

During Pennsylvanian and Permian time, marine deposition became progressively more terrestrial influenced. The Amsden Formation consists of dolomite, shale, sandstone, and limestone ranging between 250-350 feet thick. The Tendefl Sandstone is a known reservoir interval containing massive to cross-bedded shelf and eolian sandstone deposits between 200-400 feet thick. By Permian time, the reservation area alternated between terrestrial shoreline and restricted carbonate depositional environments. The Phosphoria Formation contains an organic-rich source interval, dolomite, shale, and limestone deposits between 200-300 feet thick.

Lower Triassic deposits contain the Dinwoody Formation (50-150 feet thick), dominantly terrestrial Chugwater Group deposits (800-1000’) containing typical red bed’ continental sediments, and the Nugget Sandstone. The upper Triassic/lower Jurassic Nugget Formation is a known reservoir interval consisting of large-scale, cross-bedded eolian deposits. The formation is as thick as 300 feet, thins to the northeast, and is absent in the northern part of the reservation area. Jurassic deposition reflects both nearshore marine and fluvial conditions in the area. The Gypsum Spring and Sundance Formations contain colic limestone, glauconitic sandstone, gypsum, and anhydrite ranging between 250-350 feet thick. The Morrison Formation consists of fluvial sandstone, siltstones, and shales and contains well known dinosaur bone-beds.

Cretaceous Geologic History

Lower Cretaceous sediments reflect the first pulse of foreland basin development in the reservation area. Effects from the Sevier orogenic event located to the west are mainly restricted to relatively thin, fine-grained shale deposition in this area (Figure 3.1). The Cloverly Formation ranges between 250-450 feet thick and consists of ‘weathered’ thin sandstone deposits and paleosols representing coastal plain deposition. The Thermopolis and Mowry Shale Formations represent the initiation of clastic, marine epiclastic sea conditions.

Figure WR 3.1 - Generalized patterns of deposition in the Rocky Mountain area during Cretaceous time. A - Mid Atlantic spreading caused uplift, thrusting, and folding in the Sevier orogenic belt, synorogenic sediments were thick adjacent to the Sevier uplift and very thin elsewhere. B - Continued westward plate movement is reflected in uplifts on the western plate margin, thick deposits adjacent to the overthrust belt, and thin deposits over a wide area of the foreland. C - Early uppermost Cretaceous deposition is thickest adjacent to the overthrust belt; a thicker section of marine sediments may reflect a general downwarping of the foreland area. D - During latest Cretaceous and early Paleocene, the spreading rate between North America and Eurasia was greatly increased. Early Laramide buckling of the basement in the foreland began to occur, and foreland uplifts formed north-south parallel to the overthrust belt (after Gries, R. 1983).
Wind River Reservation
Wyoming

Geologic History

Cretaceous Geologic History (Continued)

As the foreland area developed and the basin began to down warp due to crustal loading, thick piles of sediment began to accumulate in front of the thrust sheets (Figure WR-3.1). The early Late Cretaceous Frontier Formation, an important oil/gas producing formation, ranges in thickness between 600-1000 feet. As downwarping continued, the clastic-marine Cody Shale was deposited. Accumulation ranges between 2500-5000 feet in thickness.

Terrestrial conditions were re-established in the reservation area by the time the Mesaverde Formation was deposited. Containing fluvial and shoreline sandstones, coal, and carbonaceous shale, the formation ranges between 1000-2000 feet in thickness but is absent in the southwest part of the reservation due to later uplift and erosion. The overlying Mancos shale Formation contains depositional environments similar to the Mesaverde, but the interbedded coal horizons are much thicker. Plant remains and dinosaur bones have been found in this formation and it can be up to 1400 feet in thickness.

As the basin buckled and uplifted during latest Cretaceous time, denudation of these highlands started to occur. The Lance Formation contains the first evidence of clasts from Paleozoic and Cambrian rocks deposited in lenticular conglomerate horizons. While the thickness of the interval is highly variable, it can range up to 1200 feet in thickness.

Cenozoic Geologic History

On the margins of the Wind River Basin the Paleocene Fort Union Formation unconformably overlies the Late Cretaceous Lance Formation but in the northern and central troughs, fluvial and alluvial fan deposition continued (Figure WR 4.1). Earliest Eocene deposits of the Indian Meadows Formation contain abundant alluvial fan and channel sandstones and conglomerates. Mesozoic and Paleozoic rock clasts are common and landslide/slide block masses from these thrust sheets are present as well. By the time of the Wind River Formation deposition, Precambrian rock fragments are abundant and reflect exposure of the igneous/metamorphic cores of the uplifts (Figure WR 4.1). The thickness of the Wind River Formation ranges from a few feet at the basin margin, to over 6000 feet in the northern part of the reservation area. Oligocene and younger sediments consist of a thin veneer of volcanic tuffs, volcanic breccia and sandstone deposits. Quaternary glacial till and outwash gravel are present in the southwestern part of the reservation.

Structural Evolution of Wind River Basin

Complex Laramide orogenic events produced a structural fabric in the Wind River area that produced polyphase structural re-orientations of major elements. However, studies of all the major Laramide Rocky Mountain basins and uplifts show similar patterns of development. The Laramide orogenic event was triggered by the opening of the mid-atlantic ridge and movement of the North American craton along a westward directed line of motion during latest Cretaceous time. The ridge-opening accelerated in Paleocene/Eocene time and movement of the craton became directed southward.

Most structural analyses indicate that little or no vertical movement occurred on east-west trending structures in latest Cretaceous/Paleocene time. However, substantial activity on northwest-southeast trending structures is likely and produced westward verging, linear thrust sheets (Figure WR-4.2). It is possible that east-west trending strike-slip faults also developed along zones of basement weakness. Development of east-west trending thrust sheets occurred during maximum compression (southward directed) in Eocene time. Detailed surface mapping has shown Eocene east-west trending thrusts and folds truncate or are superimposed on earlier Laramide north- and northwest-trending thrusts and folds (Figure WR-4.2).

Early Laramide (latest Cretaceous) erosion was mostly from north-south trending arches and ranges (Gries, R., 1983). Eroded material included previously deposited Mesozoic shale, limestone, dolomite, and sandstone. As uplift continued in early Paleocene, Paleozoic rock fragments became incorporated in fluvial/alluvial sedimentation. Thick sections of lower-middle Eocene coarse, boulder conglomerates adjacent to the east-west trending ranges are evidence of major uplift during the late phase of the Laramide orogeny (Fig. WR-4.1).

Most foreland basins have thicker sections of Eocene syn-orogenic sedimentary rocks than Paleocene and uppermost Cretaceous, an indication perhaps of greater tectonism at the end of the Laramide orogeny than during the earlier phases (Gries, R., 1983).
Petroleum Systems Overview

In the Wind River Basin area, there are three and possibly four source rock petroleum systems that have generated or are generating hydrocarbons. The reservation area is ideally situated to explore at least three of these systems. Thrusting during the Laramide orogenic event has obscured evidence regarding migration pathways, lithofacies relationships, and even a clear determination of geothermal gradient in some areas. However, some generalizations can be made.

A major source rock interval in the Wind River Basin is the Permain Phosphoria Formation which contains two organic-rich shale members called the Meade Peak and Retort intervals. These rocks were formed at the periphery of a foreland basin between the Paleozoic continental margin and the North American cratonic shelf (see Fig. WR-5.1). Restricted circulation patterns, increased biologic activity due to zones of upwelling, and resultant anoxia contributed to the preservation of algal organic matter.

Petroleum generation from the Phosphoria Formation ranges between 24.6 - 30.7x10⁶ metric tons according to various authors. Reservoirs such as the Tensleep, Chugwater Group, and Nugget Sandstone between 2.2 - 4.5 km. Relatively unimpeded migration pathways (both lateral and vertical) occurred during Late Cretaceous time just prior to the Laramide orogeny (Fig. WR-5.2).

The lower Cretaceous Mowry shales and their equivalents are major source rocks in the northern Rocky Mountain - Great Plains region. They are one of the major sources of hydrocarbon in the Jurassic Nugget Sandstone of southwestern Wyoming, lower Cretaceous Muddy Sandstone, and other Cretaceous sandstone reservoirs.

In the reservation area, the Mowry shale may range between 500 - 600 feet in thickness. A significant percentage of the interval includes non-source lithofacies such as oxic, bioturbated mudstone, sandstone and siltstone. Typically, only the basal Mowry can be considered a source facies due to the presence of anoxic, laminated mudstone.

The Mowry shales contain a mixture of predominantly type II and type III organic matter (see Fig. WR-5.4). These organic matter types represent a mixing of terrestrial and marine organic matter. Organic matter suites with this composition are typical of shallow, epicontinental seas. In general, the Mowry section within the reservation area contains a higher percentage of terrrestrially derived organic matter (more gas prone) than the shales deposited within the axial portion of the Mowry seaway.

Areas of anomalously low TOC values in the Mowry coincide with the deeper parts of Laramide structural basins which developed after the deposition of these shales. Regional variations in the TOC content may reflect in part a reduction of the TOC by thermal maturation or abrupt variations in the precursor organic facies (see Fig. WR-5.3).

Anomalously low TOC values may coincide with lithofacies variation or position with the deeper parts of Laramide structural basins where significant generation/ expulsion has occurred (from Burtner & Warner, 1984).
3) The Uppermost Cretaceous/Lower Tertiary section of the reservation area contains several potential source horizons, either organic-rich shales or thin-bedded coals. Oil and gas produced from the Fort Union reservoirs, as well as oil shows in the Wind River Formation were probably generated from these intervals. In addition, Lance Formation shows and reservoired hydrocarbons may also be source from these zones.

Figure WR-6.1 depicts the distribution of basins in which thermogenic gas has been generated from Tertiary or Upper Cretaceous coals, generally under deep burial conditions. These coals contain typical type II gas-generating kerogen. These coals could charge conventional sandstone reservoirs as well as unconventional ‘tight’ sandstones (basin-center accumulations). In addition, the coals may also provide a viable exploration target. Huminic coals are capable of both generating and storing significant amounts of dry methane gas. Methane generation commences within the high volatile bituminous A coal rank, where volatile matter content is 37.8% and vitrinite reflectance is 0.73% (Meissner, 1984). Lowland areas adjacent to the Cretaceous Seaway provided environments conducive to the formation of lagoonal swamps, shoreline paralic swamps, channel-overbank swamps, and restricted basinal swamps. Later Laramide orogenic activity has eroded some of these horizons while preserving others under thick volumes of Tertiary sediment (Figure WR-6.2).

In addition to coaly intervals, at least one shale horizon in the Tertiary section may have the organic richness to generate hydrocarbons (Figure WR-6.2). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.

The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale member of the Fort Union Formation. The Waltman Shale contains a mixture of both types II and III kerogen, with total organic carbon content values as high as 7.0 wt%. Mean Ro values for samples taken from the modeled well range from 0.61-.9% (Figure WR-6.1). In general, oil generation is thought to begin around the .60 Ro value. Mean Ro values for samples taken from the modeled well range from .61-.9% (Figure WR-6.1). In the reservation area, the Waltman Shale has been modeled using known well data and vitrinite measurements. Approximate location of this well is located in Figure WR-6.1.
Wind River Reservation

Figure 7.1 - Schematic illustration of play types showing distribution of hydrocarbons (modified from Willis & Groshong, 1993).

Table WR 7.2 - Summary of play information.

<table>
<thead>
<tr>
<th>Play Type</th>
<th>Description of Play</th>
<th>Known Accumulations</th>
<th>Undiscovered Resource (MMBOE)</th>
<th>Play Probability (chance of success)</th>
<th>Drilling depth (ft)</th>
<th>Favorable factors</th>
<th>Unfavorable factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin Margin Subthrust</td>
<td>Structural traps formed by trenching and basement involvement; gas seeps from multiple wedge; multiple reservoir horizons.</td>
<td>Basin, pools</td>
<td>5.1 MMBO (mean)</td>
<td>3.00-12.000 N</td>
<td>9,000 – 14,000</td>
<td>Processable; new, ongoing exploration; source rocks and reservoir present; seismic may be very useful.</td>
<td>Trapping mechanisms may be subtle, stratigraphic in part; increased depths enhances drilling difficulties/expense; increased depth may be required.</td>
</tr>
<tr>
<td>Basin Margin Anticline</td>
<td>Structural traps formed by trenching and basement involvement; gas seeps from multiple wedge; multiple reservoir horizons.</td>
<td>Anticline, domes</td>
<td>5.1 MMBO (mean)</td>
<td>3.00-12.000 N</td>
<td>9,000 – 14,000</td>
<td>Processable; new, ongoing exploration; source rocks and reservoir present; seismic may be very useful.</td>
<td>Trapping mechanisms may be subtle, stratigraphic in part; increased depths enhances drilling difficulties/expense; increased depth may be required.</td>
</tr>
<tr>
<td>Deep Basin Structure</td>
<td>Structural traps formed by trenching and basement involvement; gas seeps from multiple wedge; multiple reservoir horizons.</td>
<td>Dome, pools</td>
<td>5.1 MMBO (mean)</td>
<td>3.00-12.000 N</td>
<td>9,000 – 14,000</td>
<td>Processable; new, ongoing exploration; source rocks and reservoir present; seismic may be very useful.</td>
<td>Trapping mechanisms may be subtle, stratigraphic in part; increased depths enhances drilling difficulties/expense; increased depth may be required.</td>
</tr>
<tr>
<td>Play Type</td>
<td>Total Production (by province-1996)</td>
<td>Undiscovered resources and numbers of fields are</td>
<td>Wind River Basin 550 MMBO 2.8 TCFG 52 MMBOE</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undiscovered resources</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MMBOE)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural Gas</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(BCFG)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MMBNGL)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RESERVATION AREA**

**Reservoir Area:**

**Province Area:**

**Geologic Province:**

**Phosphoria Stratigraphic**

**Bighorn wedge-edge provinc**

**Portland Lintex & cephal sandstones**

**Maureen Lintex & cephal sandstones**

**Darwin - Amsden Stratigraphic**

**Tristan & Jurassic Stratigraphic**

**Shallow Tertiary-Upper Cretaceous**

**Cosby and Frontier Stratigraphic**

**Basin Center**

<table>
<thead>
<tr>
<th>Play Type</th>
<th>Total Production (by province-1996)</th>
<th>Undiscovered resources and numbers of fields are</th>
<th>Wind River Basin 550 MMBO 2.8 TCFG 52 MMBOE</th>
<th>Wind River Reservation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Undiscovered resources</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MMBOE)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural Gas</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(BCFG)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MMBNGL)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
</tbody>
</table>

**RESERVATION AREA**

**Reservoir Area:**

**Province Area:**

**Geologic Province:**

**Phosphoria Stratigraphic**

**Bighorn wedge-edge provinc**

**Portland Lintex & cephal sandstones**

**Maureen Lintex & cephal sandstones**

**Darwin - Amsden Stratigraphic**

**Tristan & Jurassic Stratigraphic**

**Shallow Tertiary-Upper Cretaceous**

**Cosby and Frontier Stratigraphic**

**Basin Center**

<table>
<thead>
<tr>
<th>Play Type</th>
<th>Total Production (by province-1996)</th>
<th>Undiscovered resources and numbers of fields are</th>
<th>Wind River Basin 550 MMBO 2.8 TCFG 52 MMBOE</th>
<th>Wind River Reservation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Undiscovered resources</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MMBOE)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural Gas</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(BCFG)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MMBNGL)</td>
<td>(by province-1996)</td>
<td>Wind River Reservation</td>
</tr>
</tbody>
</table>

**Table WR 3.1** Play summary information.
**PLAY TYPE 1**

**Basin Margin Subthrust Play**

Laramide basin-margin thrusting has trapped oil and gas in upturned, overturned, folded, and faulted Phanerozoic strata below the overthrust wedge. The limits of this demonstrated play are defined by the leading edge of basin-margin thrust faults and an assumed overhand displacement of 6 mi. This is a currently developing exploration play (Cave Gulch discovery) with previous exploration success limited to the Tepee Flats field. The Tepee Flats field is currently producing gas from the Frontier Formation at a depth of about 12,200 ft. with a known recoverable of 9.0 BCFG (see Figures WR 10.2 & 10.3). Since this play has only been marginally explored, significant new reserves could be anticipated from this play type. The Cave Gulch discovery attests to the economic viability of this concept with known recoverable estimates ranging from 50-200 BCFG (Fig. WR 10.1). Sparse information has been published regarding this new discovery but it is thought that relatively ‘shallow’ (>10,000 feet) Upper Cretaceous reservoirs contain the gas reserves. In the reservation area, little exploration has occurred over the potential subthrust areas.

Reservoir type and quality are highly variable since any of the buried Mesozoic and Paleozoic potential reservoir horizons could be involved. Principal reservoirs include the Pennsylvania Tensleep, Permian Phosphoria carbonates, and Upper Cretaceous Frontier, Mesaverde, and Lance Formations. Source horizons could be from the Phosphoria, Mowry, or Tertiary Fort Union Formations. It is likely that the shallower horizons would receive significant contributions from the Upper Cretaceous/Tertiary source intervals due to the simpler migration pathways. Because Laramide thrust faults have thrust thick wedges of Precambrian rocks over younger Paleozoic and Mesozoic intervals, the depth of burial of the source intervals is usually great enough for source rocks to have generated hydrocarbons locally or for hydrocarbons to have migrated from mature areas in deeper parts of the basin during/after Laramide deformation (Figure WR 10.3). Some pre-Laramide migration may have taken place, moving hydrocarbons into reservoirs before tectonic development of the basin-margin folds and faults. In this case, stratigraphic traps could have formed prior to basin-margin thrusting and folding. Subsequent structural development could have re-mobilized previously trapped hydrocarbons or kept the previous trap intact with a structural overprint enhancing the original trapping mechanism.

Petroleum is trapped where structures with closure occur beneath the basin-margin thrust and is sealed by associated rocks or by impermeable rocks of the hanging wall thrust sheet. In the thrusting process the underlying beds are folded and often upturned or overturned with fault slivers typically present (Figure WR-10.3). Oil and gas may also be trapped in these upturned, overturned, faulted, and folded strata. Depth of production is highly variable, ranging from more than 20,000 ft. on the structurally steepest side of the asymmetrical basin to less than 10,000 ft. in other basin-margin areas.
The mature exploration play is defined by the occurrence of oil and gas trapped in anticlines and domes, in many cases faulted, and in faulted noses that formed during major thrust movement in the Laramide orogeny. These structures are best developed along the shallow margins of the basin, with production ranging from about 1,000 ft. to 14,000 ft. The inner boundary of the play is located at the approximate basinward limit of basin-margin anticlines (Fig. WR-11.1). The outer boundary is drawn at the outcrop edge of the Tensleep Formation. Basement-involved and basement-detached thrusting has produced complex folded/faulted anticlines, domes, and synclines. These surface features were drilled early (1900-1950’s) in the exploration history of the Wind River Basin. Figure WR-11.4 shows an example of a typical basement-involved thrust/fold pair showing development of subsidiary faults and upturned fault sliver. In this case, the Sage Creek Anticline has only produced minimal hydrocarbons. Figure WR-11.5 shows the development of a typical detachment structure; detachments usually occur in Triassic or Jurassic-aged sediments.

Major fields have been discovered in these complex thrust/fold structures. Circle Ridge contains multiple reservoir horizons ranging from the Madison to Phosphoria Formations (Figure WR-11.2). This is typical for this play type. Because of the shallow nature of some of these structures and close proximity to outcrop, tilted oil/water contacts are common due to flushing from nearby recharge areas (Fig. WR-11.2). Care must be taken in evaluating the hydrodynamic conditions of potential targets in this play type.
PLAY TYPE 2 (continued)
Basin Margin Anticline Play

Examples from the Circle Ridge Field illustrate the nature of this particular play type within the Wind River Basin. Producing formations range in age from Mississippian through Cretaceous and include Madison, Tensleep, Phosphoria, Sundance, Nugget, Cloverly, Muddy, Frontier, Cody, and Mesaverde Formations (see Figure WR-12.3). Primary production has been from the Madison, Tensleep, and Phosphoria Formations. Many of the fields have multiple pay zones and some show common oil-water contacts involving several of the Paleozoic reservoirs. Sandstone is the dominant reservoir lithology.

Paleozoic reservoirs contain hydrocarbons derived from a distinct Phosphoria source facies. Two fields in the western part of the basin, Circle Ridge and Beaver Creek, produce oil from the Madison Limestone (see Figure WR-12.1). Properties of the oil in these two fields are nearly identical to those of the Tensleep and Phosphoria oil in the same area, indicating that the oil may have been derived from the younger Phosphoria source or re-mobilized from younger reservoir horizons. Figure WR-12.3 depicts the structural position of the Phosphoria in relation to other reservoir horizons; additional throw in the structure could easily juxtapose Madison against known source intervals or reservoirs.

Pre-Laramide generation and long-distance migration from western Wyoming prior to basin formation, followed by remigration during the Laramide Orogeny, is a possibility for charging lower Paleozoic reservoirs. However, local generation of deeply buried Cretaceous source rocks is a likely mechanism for charging reservoirs as well.

Structural closure in faulted anticlines, domes, and noses is the predominant trapping mechanism for this play. Figure WR-12.2 illustrates the typical thrust/fold structural pattern found in this play type. The shallower portions of these structures tend to become structurally more complex due to subsidiary fault development along the major thrust horizons. While the deeper, larger areas of structural closure may have been thoroughly explored, the smaller, shallower structural compartments should offer significant potential for future exploration.
This is a demonstrated gas play with entrapment in large intrabasin anticlinal, domal, and fold nose structures within the deep axial portion of the basin. The boundary of this play is defined on the north by the leading edge of the northern basin-margin thrust fault and on the south and west by the deep limit of the Basin Margin Anticline Play. Reservoir rocks range in age from Mississippian to Eocene. The bulk of the gas production has been from Lance, Fort Union, Wind River, and Mesaverde Formations. However, deeper drilling has encountered significant reserves in the Mississippian Madison and Pennsylvanian Tensleep Formations. Porosity and permeability reduced through compaction/cementation with deeper burial, may be re-enhanced by fracturing and secondary cement dissolution. Early migration and entrapment may have preserved some of the original porosity. Even if the hydrocarbons have been re-mobilized due to movement associated with the Laramide Orogeny, the porosity and permeability may have been preserved. This would allow subsequent migration into reservoir intervals from source rocks that initiated generation/expulsion in late Paleocene through to the present time.

Most fields have multiple pool production from a great range of depths and thicknesses. Most individual reservoir intervals range between 25.50 feet in thickness. Reservoirs may be overpressured; for example most Tertiary and Mesozoic strata on the Madden structure are overpressured but nearly normal pressure gradients occur near the top of the Paleozoic interval.

Most of the productive reservoir intervals are interbedded with source rocks. This facilitates migration and entrapment of the hydrocarbons. Indigenous source rocks are found in the Permian Phosphoria, Cretaceous Mowry, and Tertiary Fort Union (including Waltman shale) Formations. Early Paleocene generation from the Fort Union sources has been modeled using vitrinite reflectance data. Generation probably continues to present and accounts for some of the overpressured intervals encountered in some fields.

Potential for undiscovered resources may be good-excellent in this play due to deeper pool discoveries. Madden Field (825 BCFG), Pavillion (174 BCFG), Waltman-Bull Frog (96 BCFG), and Frenchie Draw (46.5 BCFG) all have the potential for deeper reservoir horizons. In fact, many of the currently discovered fields do not include Paleozoic units such as the Madison Limestone, which is a major new reservoir at Madden Field.
**PLAY TYPE 4**

**Muddy Sandstone Stratigraphic Play**

This is a stratigraphic play with anticipated entrapment of oil/gas in updip pinchouts of discontinuous Muddy Sandstone bodies, deposited as a complex series of coastal/valley-fill sandstone horizons whose distribution is controlled by paleotopography and sea-level fluctuations. Actual outline of play area may be unknown due to subtle nature of some channel/saltine complexes on seismic (Figure WR-14.1).

The Muddy Sandstone and equivalent strata have produced more than 1.7 billion bbl of oil-equivalent hydrocarbons in the Rocky Mountain region. Production is controlled principally by unconformities formed during a relative sea level lowstand. Reservoirs are found in paleohills of older marine sandstones, younger valley fill and associated alluvial plain channel sandstones, and infilling transgressive marine deposits (see Figures WR-14.3 and WR-14.4). Valley fill and channel reservoirs have produced at least 359 MMBOE, onlap cycles another 318 MMBOE, and older marine buried-hill reservoirs more than 269 MMBOE. The excellent reservoir characteristics and the high quality of oil (33-43 API gravity) make it a prime drilling objective. Porosity ranges from about 9% - 15% at depths to about 11,000 ft. Most reservoirs range between 20 - 52 ft. in thickness.

Migration from adjacent Mowry source rocks provides efficient pathways for fluid migration. This demonstrated play is heavily explored along the southern margin of the basin but is lightly explored in the central or western regions. Relatively new discoveries at Austin Creek (1988) and Sun Ranch (1987) indicate that additional exploration opportunities are possible. The reservation area is ideally situated to capitalize on new target possibilities within this play. Application of improved seismic processing techniques, sequence stratigraphic principles, and fluid migration modeling could greatly enhance the future potential within this play type.

Migration from adjacent Mowry source rocks provides efficient pathways for fluid migration. This demonstrated play is heavily explored along the southern margin of the basin but is lightly explored in the central or western regions. Relatively new discoveries at Austin Creek (1988) and Sun Ranch (1987) indicate that additional exploration opportunities are possible. The reservation area is ideally situated to capitalize on new target possibilities within this play. Application of improved seismic processing techniques, sequence stratigraphic principles, and fluid migration modeling could greatly enhance the future potential within this play type.
**Play Type 5**

**Phosphoria Stratigraphic Play**

High sulfur oil may be stratigraphically trapped in the Ervay Member of the Phosphoria Formation along a north-south transition zone from Phosphoria carbonates to the west and red shale and evaporites to the east (Fig. WR-15.2). The play area is located in the eastern Wind River Basin, limits of the play defined to the east by the estimated limit of viable carbonate porosity, and to the north and south by Phosphoria outcrops (Fig. WR-15.1).

Potential reservoir intervals occur in the Ervay Member of the Phosphoria Formation. They are typically dolomitized grainstones and packstones, along with algal framework laminations containing abundant fenestrate porosity. These reservoir intervals formed in high-energy tidal and shoreline environments. Reservoir matrix porosities average about 10 percent, but are fracture enhanced due to generation of hydrocarbons in-situ. Reservoir thicknesses range between 25 - 75 feet.

The interbedded nature of the carbonate facies with known source facies in the Phosphoria may create efficient migration pathways into reservoir horizons. Exploration in this interval was initiated back in 1953 with the discovery of the Cottonwood Creek Field in the Bighorn Basin.

**Play Type 6**

**Bighorn Wedge-Edge Pinchout Play**

This is a hypothetical play concept characterized by wedge-edge pinchouts of the Ordovician Bighorn dolomite against the base of the Madison Limestone (Fig. WR-15.3). This is a very high risk play with no known hydrocarbon occurrences or source rocks to occur near/within the potential trapping horizon.

Reservoirs in the Bighorn Dolomite could contain moderate-high porosities within an intergranular fabric. Dolomitized intervals within this formation are very common and anticipated to occur throughout most of the reservation area. Although regional truncation is demonstrated, the presence of traps at this unconformity horizon is undocumented.

**Play Type 7**

**Flathead-Lander and Equivalent Sandstone Stratigraphic Play**

This is a hypothetical play concept which involves hydrocarbons trapped in stratigraphic facies changes/resolution truncation horizons within the Cambrian Flathead and Ordovician Lander Sandstones (Fig. WR-15.3). No known hydrocarbon occurrences or source intervals are known within these formations.

Potential reservoir intervals could occur in sandstones which are probably present throughout much of the reservation area. Quality of potential reservoirs may be poor due to diagenesis and compaction. The absence of known source intervals near these reservoir horizons implies that the chance of exploration success is minimal.

---

**Stratigraphic Column for Wind River Reservation Area**

---

**UNCONVENTIONAL PLAY TYPES 5,6,7**

**Wind River Stratigraphic, Bighorn Wedge-Edge Pinchout, Flathead-Lander and Equivalent Sandstone Stratigraphic Plays**
Wind River Reservation
Wyoming

CONVENTIONAL / UNCONVENTIONAL PLAY TYPES
Madison Limestone, Darwin-Amsden Sandstone
Triassic and Jurassic, and Cody/Frontier Stratigraphic Plays

PAGE 15 of 18

Index map
topics

PLAY TYPE 8
Madison Limestone Stratigraphic Play

This hypothetical play encompasses possible hydrocarbons enclosed within or at the top of the Mississippian Madison Limestone. The trapping mechanism involves a combination of porosity variation and topography creation related to karst development.

Karstic, vuggy porosity carbonate intervals in the upper part of the Madison Limestone are expected throughout the play area (Figure WR-16.1). In some cases, these intervals may be fracture enhanced. The presence of sealing horizons above the Madison remains problematic. In addition, to charge these potential reservoirs require fault juxtaposition of Phosphoria source against Madison. This requires advantageous timing of hydrocarbon generation, structural development, and migration.

No production exists utilizing this play concept within the Wind River Basin and the presence of effective traps has not been demonstrated. As a result, this play type is classified as very high risk owing to poor charge and trap potential. Detailed mapping of the Madison karst surface is required to evaluate the exploration potential within the reservation area.

PLAY TYPE 9
Darwin-Amsden Sandstone Stratigraphic Play

This hypothetical play consists of stratigraphic entrapment of oil in discontinuous sandstone lenses of the Pennsylvanian Darwin and Amsden Formations. Although no known traps exist within the Wind River Basin, these formations are productive elsewhere in structural settings.

Potential reservoir intervals in poor-moderately porous sandstones are believed to be present over most of the reservation area. Total interval thickness ranges between 100 - 300 feet (Figure WR-16.2). Variable quality of porosity and permeability are expected and may be modified by burial diagenic processes. Hydrocarbon charging of this interval is problematic and would require complex, structurally modified, migration pathways. In addition, poor seal quality is expected immediately above the horizon.

No production exists within this play type and it is classified as a high risk exploration target. Considerable variation of sandstone distribution and porosity exists within the interval; detailed facies mapping of the Amsden as well as detailed structural modeling would be required to effectively explore for hydrocarbons.

PLAY TYPE 10
Triassic and Jurassic Stratigraphic Play

This hypothetical play encompasses stratigraphic plays within the Chugwater Group, Nugget Sandstone, Sundance, and Morrison Formations. The Nugget Sandstone provides the best opportunity for commercial production from wedge-edge pinchouts and truncations in the eastern and northern portion of the Wind River Basin.

Potential reservoirs would include mostly sandstone with good porosity and permeability. Sealing horizons remain problematic as well as the presence of effective hydrocarbon charge.

Numerous shows and non-commercial accumulations have been found in these zones. They may act as migration pathways into other horizons. This play is classified as high risk and would require detailed stratigraphic/charge modeling to effectively explore for hydrocarbons from these intervals.

PLAY TYPE 11
Cody and Frontier Stratigraphic Play

This hypothetical play would include deep oil and gas accumulations in stratigraphic traps from the Upper Cretaceous Cody and Frontier Formations. These sandstone/shale intervals are in thick marine sequences of shale and fine-grained sandstone.

Potential reservoir intervals of sheets of fine-grained sandstone are present throughout the reservation area. Although equivalent reservoirs are productive in structural settings, reservoir quality and effective traps in deeper, off-structural settings remain speculative.

Cretaceous source rock intervals in the Mowry Shale are interbedded with these potential reservoir horizons. A favorable hydrocarbon generation and migration history could charge these reservoirs if an effective trapping mechanism is present. The presence of traps of significant size have not been demonstrated. This play is characterized as high risk because of these issues.
PLAY TYPE 11
Shallow Tertiary/Upper Cretaceous Stratigraphic Play

Primarily a gas play, the shallow Tertiary and Upper Cretaceous reservoirs have also yielded liquids as well as these discontinuous, sandstone reservoirs. This play has been lightly explored for years and a number of small accumulations have been discovered within/outside the reservation area (Figures WR-17.1 and WR-17.2). In general, the proven reservoirs include the Wind River, Fort Union, Lance and Mesaverde Formations (Figure WR-17.3). These clastic sandstone reservoirs have good-excellent porosity and permeability, however, most exhibit discontinuous, fluvial reservoir architecture (Figure WR-17.4). Source horizons are underlying/interbedded Cretaceous/Paleocene shales and coals. Humic-rich coal horizons may be contributing to the gas charge as well as other shale zones with abundant Type III kerogen mixtures (Figure WR-17.2). In some instances, oil from the Waltman Shale has accumulated in reservoirs of Upper Cretaceous through Eocene age. Facies changes and local erosional unconformities associated with channel migration are the typical trapping mechanisms for these fluvial reservoirs. They are typically alluvial/fluvial sandstones that form localized channel bodies of limited areal extent (Figure WR-17.4). Traps are small and sometimes occur in combination with structural enhancement. Seals are provided by associated fine-grained overbank shales. Fluid migration is primarily vertical. Stacking of multiple reservoir horizons is enhanced when the underlying Cretaceous Mesaverde Formation is unconformably overlain by younger Paleocene reservoirs. This also allows more efficient migration from source horizons within Upper Cretaceous/Paleocene intervals (Figure WR-17.5).
Wind River Reservation
Wyoming

**Basin-Center Gas Play**

This play is characterized by an extensive and continuous overpressured gas accumulation trapped in low permeability Paleocene and uppermost Cretaceous sandstone reservoirs in the deep parts of the Wind River Basin (Figure WR-18.1). The play exists because the active generation of gas from source intervals in the deep part of the basin creates overpressuring. This allows reservoirs to be charged that would otherwise be non-reservoir intervals due to low permeability and porosity.

Principal reservoirs are sandstone beds in the Fort Union, Lance and Mesaverde Formations. They are generally arkosic or lithic in composition, with poor to modest porosity and low permeability (Table WR-18.1). Within the reservation area the reservoirs could be of three types; alluvial-fluvial sandstone bodies with channels of limited areal extent, marine sandstone intervals with a more blanket-like character, and overbank silty sandstone crevasse splay deposits.

Trapping mechanisms for this play concept are depicted in Figure WR-18.2. This play will only be viable if active generation is occurring to continuously replenish the reservoir intervals since most sealing intervals are "seeks" with respect to gas in these environments. Transient sealing mechanisms are common in deep, basin-center accumulations.

Since active generation is occurring from most of the Tertiary/Upper Cretaceous humic-rich coals and shales, timing is extremely favorable with reference to the interbedded potential reservoir intervals. Overpressuring which is one result of the active generation of gas appears to generally coincide with Ro=1.0% burial indicator. This maturation index is usually reached at about 10,000 feet. Therefore, those Tertiary and Upper Cretaceous intervals below this subsea elevation could be considered potential exploration targets.

The limiting factors regarding the development of these reservoirs are principally economic; the price of gas and expense associated in developing reservoirs with significant internal compartmentalization. Therefore, this play is considered high risk even though active generation from source intervals is occurring at the present time.

---

**Table WR-18.1**

<table>
<thead>
<tr>
<th>Conventional Gas</th>
<th>'Tight' Gas Blanket/Lenticular Sandstone (Low Pressure Reservoir)</th>
<th>'Tight' Gas Blanket Silstone, Silty Shale (High Pressure Reservoir)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity (%)</td>
<td>14 - 25+</td>
<td>3 - 12+</td>
</tr>
<tr>
<td></td>
<td>10 - 30% in individual siltstone laminations</td>
<td></td>
</tr>
<tr>
<td>Porosity Type</td>
<td>Primary, secondary</td>
<td>Common secondary</td>
</tr>
<tr>
<td></td>
<td>(interbedded), some</td>
<td>micaceous, some</td>
</tr>
<tr>
<td></td>
<td>secondary</td>
<td>interbedded</td>
</tr>
<tr>
<td>Porosity Communication</td>
<td>Good-excellent, short</td>
<td>Poor, relatively long, shelly</td>
</tr>
<tr>
<td></td>
<td>pore throats</td>
<td>ribbonlike capillary system</td>
</tr>
<tr>
<td>Relative Clay Content in Pores</td>
<td>Low</td>
<td>High to moderate</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Low to High</td>
</tr>
<tr>
<td>Water Saturation (%)</td>
<td>25 - 30</td>
<td>45 - 70</td>
</tr>
<tr>
<td></td>
<td>40 - 50 approximate</td>
<td></td>
</tr>
<tr>
<td>In-Situ Permeability to Gas (md)</td>
<td>1.0 - 1000+</td>
<td>0.1 - 0.0005</td>
</tr>
<tr>
<td></td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Capillary Pressure</td>
<td>Low</td>
<td>Relatively high</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Grain Density (g/cm³)</td>
<td>2.65</td>
<td>2.65 - 2.74 average</td>
</tr>
<tr>
<td></td>
<td>2.65 - 2.71 in siltstone</td>
<td></td>
</tr>
<tr>
<td>Reservoir Pressure</td>
<td>Usually normal-overpressured</td>
<td>May be under-overpressured</td>
</tr>
<tr>
<td></td>
<td>Overpressured (relative)</td>
<td></td>
</tr>
<tr>
<td>Recovery of Gas in-Place (%)</td>
<td>75 - 80</td>
<td>&lt;15 - 30 estimated low for individual reservoirs</td>
</tr>
<tr>
<td></td>
<td>Unknown, probably low</td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure WR-18.1** - Play outline for the Basin-Center Gas Play showing distribution of dry holes, oil and gas wells, and reservation outline (from U.S.G.S. 1995 National Hydrocarbon Assessment).

**Figure WR-18.2** - Generalized schematic cross-section showing general distribution of gas and water in conventional and 'tight' lenticular and 'tight' blanket reservoirs. Note that conventional reservoirs have gas-water contacts while the low-permeability reservoirs do not. A source interval that is still in the active generation stage is needed to charge and 'overpressure' the low-permeability reservoir horizons (after C.W. Spencer, 1989).
Wind River
General References


