ASSESSMENT OF OIL AND GAS POTENTIAL

CARIBOU NATIONAL FOREST AND CURLEW NATIONAL GRASSLAND

Located in portions of:

Bannock, Bear Lake, Bonneville, Caribou, Franklin, Oneida, and Power Counties, Idaho

Box Elder and Cache County, Utah

Lincoln County, Wyoming

Prepared by: Steve Robison, Caribou/Targhee NF Geologist

Prepared by: _____ Date: _____

Reviewed by Chuck Horsburgh and Bill Stout, BLM Geologists

INTRODUCTION

This report describes the oil and gas resource potential for the Caribou portion (which includes the Curlew National Grassland) of the Caribou-Targhee National Forest (CTNF), southeast Idaho, as shown on Figure 1. This evaluation will be used for the development a Reasonable Foreseeable Development scenario to be used in the environmental analyses that will assess the potential impacts associated with oil/gas leasing on the Caribou portion of the CTNF. This report was prepared based on a review of pertinent published scientific literature, unpublished reports, personal knowledge of the author, and a review of oil/gas potential reports prepared for adjacent National Forest System (NFS) lands.

REGIONAL GEOLOGY

Physiography

The Caribou portion of the CTNF (Caribou) lies within two different physiographic provinces. The eastern portion (essentially the Soda Springs and Montpelier Ranger Districts) lies within the Middle Rocky Mountain province, while the western portion (most of the Westside Ranger District and Curlew National Grassland) lies within the Basin and Range province. The dividing line for these provinces corresponds closely with the Wyoming Thrust Belt and Eastern Great Basin oil/gas province boundaries used by the US Geological Survey (USGS). The USGS boundaries will be used throughout this report for the sake of simplicity and clarity (see Figures 3 and 4). The names 'Middle Rocky Mountain' and 'Wyoming Thrust Belt' province will be used interchangeably throughout this report, but will refer to the same area. The names 'Great Basin' and 'Eastern Great Basin Province' will also be used interchangeably for the western portion of the Caribou.

The Caribou lands within the Middle Rocky Mountain province are characterized by often high, steep-sided mountains with deeply incised canyons. The Mountains are composed mainly of Paleozoic and Mesozoic aged sedimentary rocks, although Precambrian metasedimentary and Cenozoic igneous (mainly volcanic) rock units are also present (Bond, 1978). Most of the higher mountain peaks were glaciated during Pleistocene times. The major land features are generally controlled by the underlying geologic structure related to Sevier Orogeny thrust faulting and folding, overprinted by more recent uplifted movement along major displacement basin and range type faults. The Caribou Mountain area was uplifted by igneous intrusive activity during the Eocene. Volcanism, glaciation in the higher terrains, and continued erosion shaped the landscape to what it is today. Most of the Middle Rocky Mountain province lands of the Caribou drain into the Snake River drainage system; the remainder into the Great Basin.

Basin and Range province lands on the Caribou are dominated by relatively high, steep-sided mountains with broad intervening valleys. The mountain ranges, consisting mostly of Paleozoic marine sedimentary rocks (usually limestone, dolomite, and shale), have bounding fault systems along each side of the range. Some Precambrian metasedimentary rock units are present near the

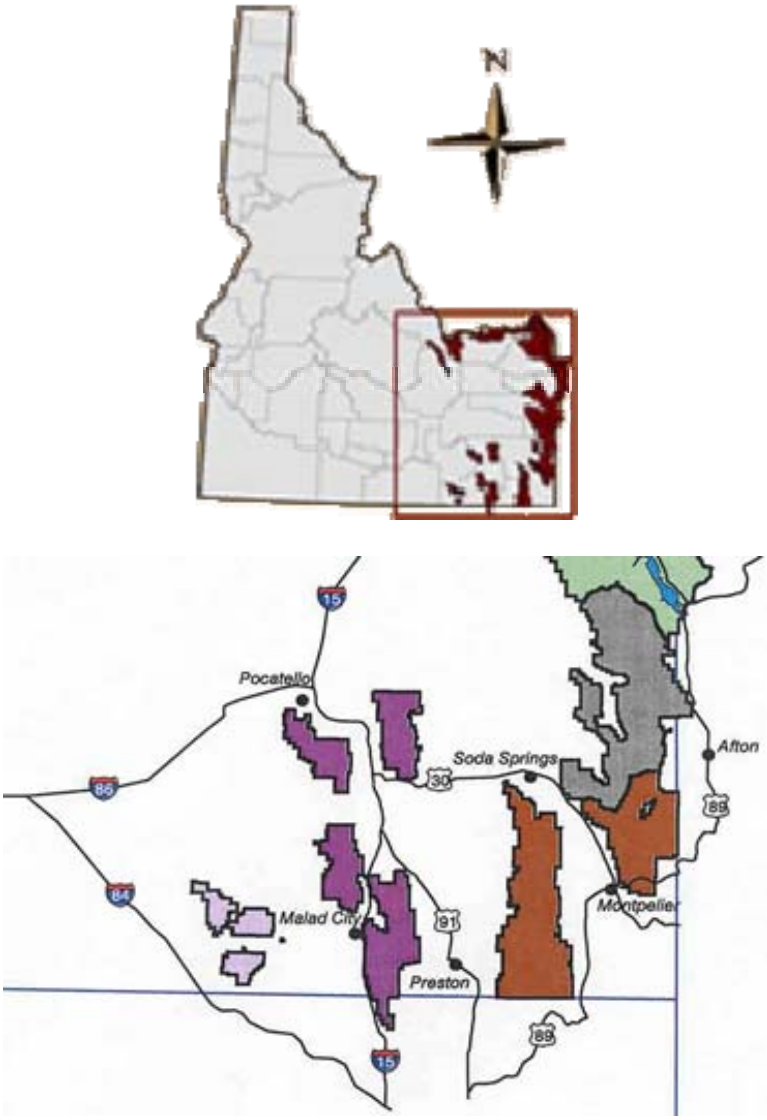

Figure 1. Map of Idaho showing the location of the Caribou-Targhee National Forest. Lower portion of the figure shows the individual Ranger Districts on the Caribou portion of the Forest. The gray area is the Soda Springs District, the brown area is the Montpelier District, the purple area is the Westside District, and the lavender area is the Curlew National Grassland.

bases of the mountain ranges; Cenozoic igneous rocks (mostly volcanic and volcaniclastic) are also present, and even dominate in some areas. The intervening valley bottoms (grabens) have been down-faulted relative to the mountain ranges, and have been partially filled with sediments, usually many thousands of feet thick. These sediments are often inter-layered with Cenozoic volcanic (often

ash) rock units. Continued uplift of the mountain ranges relative to the valley floors, volcanism, erosion, and glaciation in the higher elevations have produced the landscapes present today in the region. About half of the Caribou lands within the Basin and Range province drain into the Great Basin (Great Salt Lake), the remainder into the Snake River drainage system.

Geologic History

The geologic history of the southeast Idaho area follows closely that of the Cordilleran miogeosyncline. The miogeosyncline was created when rifting started in late Precambrian time along the western margin of the North American craton. This miogeosyncline received large amounts of sediment from the craton and carbonate precipitates in the form of limestone and dolomite during Cambrian and Ordovician time. Some of these sediments contained abundant organic remains. This seaway was apparently absent from the southeast Idaho area during most of Silurian and Devonian times, so that only minor amounts of sedimentary rocks of this age are present on or near the Caribou. Tens of thousands of feet of marine sediments and precipitates (limestone and dolomite) were deposited in this trough during Mississippian to Triassic times (Horsburgh, 1992). Paleozoic marine units are the most abundant rocks exposed at the surface on the southern portions of the Caribou, while Mesozoic sedimentary rocks predominate the surface in the eastern and northern portions.

This marine depositional system continued until Triassic times, when the area to the west of the craton started to rise. This uplift of land caused the seaway to retreat and allowed the deposition of terrestrial sediments (inter-layered with minor accumulations from marine impulses) through the late Cretaceous. A vast desert developed during late Triassic and early Jurassic times with extensive sand dunes being created throughout what is now part of the states of Arizona, New Mexico, Colorado, Utah, Nevada, Idaho, Montana, and Wyoming, as is evidenced by the Navajo, Aztec, and Nugget Formations.

A good synopsis and description of the tectonic history of the Cordilleran miogeosyncline during the late Jurassic through early Eocene times and how it affected the southeastern Idaho area is given by DeCelles (2004). As part of the tectonic events, the Sevier orogeny created uplift and great compressional forces that not only folded and deformed the rocks, but generated numerous thrust faults throughout the area, including southeast Idaho. This uplift also created a foredeep depositional basin centered in southeast Idaho, with up to 5,000 feet of Early Cretaceous non-marine sediment accumulation (Zaleha, 2006). During the Cretaceous period as a whole, up to 14,000 feet of sediment, consisting of terrestrial sediments intermingled with marine sediments from the epicontinental seaway lying to the east of this area, were deposited. Most of these sediments were shed from the Sevier uplift to the west. Many of the finer-grained sediments deposited had a high organic content that enhanced the potential for later hydrocarbon generation. Intrusive igneous activity in Early Tertiary time uplifted Caribou Mountain (Rains and Federspiel, 1993).

Beginning in Cenozoic times, and continuing to the present, the general area has undergone extensional forces, which created the Basin and Range physiographic province now present on much of the Caribou. This basin and range type of extensional faulting also affected the western parts of overthurst belt. Associated with the Basin and Range extensional faulting and migration of the

North American plate over the Yellowstone hotspot (trace seen across southern Idaho), abundant volcanic activity occurred mainly to the west and north of the Caribou. Volcanic activity to the west (mainly in northern Nevada, Oregon, California, and Washington) left deposits of volcanic ash in the western part of the Caribou. Some basalt flows and other volcanic rocks are present on and adjacent to the western and northwest portions of the Caribou.

Pleistocene glaciation helped shape some of the higher peaks of the Caribou. The filling of the Lake Bonneville basin in southern-most Idaho and eastern Utah left fine-grained lacustrine deposits over much of the Curlew National Grassland and courser deltaic deposits at the bases of the mountain ranges on the southwestern part of the Caribou. A loess blanket covers much of the Curlew National Grassland and other isolated small areas of the Caribou.

Stratigraphy

A generalized stratigraphic column for the Middle Rocky Mountain (Wyoming Thrust Belt) province of the Caribou area is displayed in Figure 2. Most of the rock units exposed at the surface consist of Paleozoic marine or Mesozoic terrestrial and marine sediments, with some basalts and intrusive igneous rocks present on the Soda Springs Ranger District. The Cambrian through mid Triassic age rocks are all of marine origin, with most of the other Mesozoic units of non-marine origin. Some of these sedimentary rocks contain a relatively high organic content, and thus provide a potential source of hydrocarbons for the Caribou (see discussion on source rocks). The upper Paleozoic and Mesozoic rock sequences are often repeated in the subsurface because of the thrust faulting and overturned structures present. The thickness of the composite section of Paleozoic and Mesozoic rocks in the southeast Idaho area exceeds 60,000 feet (Kaldenbach, 1990), although the total thickness is not always present because of differences in basin deposition, subsequent erosion, and faulting.

Rock units present in the Basin and Range province of the southeast Idaho area are generally extensions of the marine Paleozoic rocks present in the Wyoming Thrust Belt province shown in Figure 2, with the addition of a minor amount of Precambrian rock and more Tertiary volcanic units (Pope, 2002). The geologic units exposed in the valleys and lowlands are generally late Tertiary and Quaternary unconsolidated sediments shed from the mountain ranges intermixed with volcaniclastic units. The southwestern most part of the Caribou also has surficial accumulations of fine-grained lacustrine and courser deltaic sediments deposited in late Pleistocene Lake Bonneville. Loess deposits often cap the unconsolidated sediments in the intermontane valleys.

Structure

Middle Rocky Mountain Province (Wyoming Thrust Belt Province)

The Middle Rocky Mountain province in southeast Idaho is part of the geologically complex Wyoming thrust belt . This belt is part of a much larger tectonic province called the Cordilleran fold

Geologic Age		Formation or Group	Oil or Gas	Thickness Range
Tertiary		Green River Fm.		0–8,000′
		Wasatch–Evanston Fms.		
Cretaceous	Late	Adaville Fm.		6,000′–16,000′
		Hilliard Fm.		
		Frontier Fm.	RS ●	
	Early	Aspen Shale	RS ●	10,000′
		Bear River Fm.	RS ✸	
		Gannett Group		
Jurassic		Stump Fm.	R ●	500′–1,000′
		Preuss Ss. < Salt[1]	R ✸	
		Twin Creek Ls.	RS ✸	1,200′–3,500′
		Gypsum Spring Mbr.		
Jurassic (?) and Triassic (?)		Nugget Ss.	R ✸	500′–2,000
Triassic		Ankareh Fm.	R ✸	2,000′–7,000′
Early Triassic		Thaynes Fm.	RS ☼	
		Woodside Fm.		
		Dinwoody Fm.	R ☼	
Permian		Phosphoria Fm.[2]	RS ☼c	400′ – 5,000′
Pennsylvanian		Weber Ss.	R ☼c	750′–4,000′
Mississippian	Madison Group	Mission Canyon Ls.[3]	R ☼c	1,000′–7,000′
		Lodgepole Ls.	RS ☼c	
Devonian	Darby FM[4]	Three Forks Fm.	RS ☼c	500′–3,000
		Jefferson Fm.		
Ordovician		Bighorn Dolomite	RS ☼c	250′ – 2,000′
Cambrian		Gallatin Fm.		1,500′–5,000′
		Gros Ventre Fm.		
		Flathead Ss.		
Precambrian		Uinta Mtn. Group		>20,000′

● Oil productive

✸ Oil and gas productive

☼ Gas productive

[1] of Maher (1976)

[2] And equivalent strata

☼c Gas with condensate productive

R– Known or potential reservoir rock

S– Known or potential source rock

[3] Brazer limestone of some authors

[4] Locally in Wyoming

Figure 2. Generalized stratigraphic column for the Wyoming Thrust Belt Province showing potential source and reservoir rocks (Modified from Powers, 1983). The Bear River Formation has not been recognized on the Forest, but is represented by the equivalent upper Gannett Group and the Wayan Formation. Rock units above the Aspen have not been recognized on the Caribou.

belt, which extends from Alaska through Mexico. The Wyoming Thrust Belt is about 60 miles wide and is about 200 miles long, forming an easterly directed salient in the Cordilleran fold belt. It is bounded on the north by the Idaho Snake River Plain and on the south by the Uinta Mountain uplift in northern Utah (Banerjee and Mitra, 2005). The western boundary of the thrust belt was defined by Powers (1983) as the surface trace of the Willard-Paris thrust on the east side of the Bear River Range. Later evaluations and descriptions of plays (i.e. USGS, 2004) place the western boundary on the west side of the Bear River Range so that the trailing edge of the Willard-Paris thrust and portions of smaller thrust segments to the northwest near Pocatello, ID are included in the Wyoming Thrust Belt Province. The eastern boundary (Fig. 3) is defined as the surface trace of the Hogsback, Prospect, and Cache Creek thrusts in Wyoming (USGS, 2004).

The original description of the thrust faulting in southeast Idaho by Richards and Mansfield (as stated in Armstrong and Cressman, 1963) was termed the Bannock Overthurst. These early workers envisioned a single, laterally extensive thrust fault that had been folded and offset by faulting throughout the area. Later, Armstrong and Cressman (1963) demonstrated that it was not a single thrust fault, but a series of imbricate thrusts of differing ages, which they collectively termed the Bannock Thrust Zone. Continued exploration, mapping, seismic studies, and drilling have helped to refine these interpretations and names have been applied to the individual thrust faults and/or fault systems; the term Bannock Thrust Zone is no longer in common usage.

Compressional forces associated with the Sevier Orogeny caused extensive folding and the formation of thrust faults in the southeast Idaho area. The Wyoming Thrust Belt consists of four major thrust fault systems (from west to east - the Willard-Paris, Crawford-Meade, Absaroka, and Prospect-Darby-Hogsback) with numerous smaller associated ancillary thrusts (Anschutz, 1983). Thrust “systems” are still used because the lateral continuity of individual fault segments are generally not present on the surface and the desirability of retaining established thrust fault nomenclature. The thrust sheets have overridden one another, with the oldest (first emplaced) to the west. Younger thrusts then carry previously emplaced thrust sheets piggy-back fashion to the east (Holm, 1987). The individual major thrust sheets moved from the west to the east, at rates of 0.02 to 1.0 cm/year (Wiltschko and Dorr, 1983), and usually with total displacements of 10 to 30 miles (Chidsey, 1984).

Each thrusting event has the potential to distort the beds above and below the thrust plane, thus potentially creating structures that can act as traps for the accumulation of hydrocarbons. Movement on the individual thrust faults caused uplifts in the latest Jurassic and throughout the Cretaceous that provided the major source of sediment that was deposited in the associated foreland basin that developed east of the uplift, and includes most of the Cretaceous rocks on the Caribou. The same age rocks in Wyoming are almost always finer grained than the equivalent ones in Idaho, indicating the closer proximity of the Idaho deposits to their source.

The Caribou is on the western portion of the thrust belt, with the leading edge or outcrop of two of the major thrust systems (the Paris-Willard and Crawford-Meade) present on or adjacent to the Forest. The trace of the Willard-Paris thrust is continuous from southeast Idaho into northern Utah. However, the Meade thrust (surface exposed in Idaho only) has not been continuously mapped with the Crawford thrust in northern Utah and western Wyoming, and the two may represent two separate thrust faults (see Fig. 3). Portions of the Crawford thrust sheet (the leading edge is exposed east and

south of the Caribou in western Wyoming and northern Utah) are present at depth in the southern portion of the Caribou (Chidsey, 1984). Buried portions of the Absaroka thrust plate (the leading edge crops out in Wyoming and north of the Caribou in Idaho) are present in the northeastern part of the Caribou (Banerjee and Mitra, 2005). These imbricate thrust sheets overlap to some degree in the sub-surface, and get progressively younger to the east. Because these episodes of thrusting were not synchronous, and each thrust deformed the rocks above and below the thrust fault surface, several deformational events are present and have complicated the geologic structure present. These thrust faults are usually thousands of feet below the surface, and may be associated with smaller thrusts, folds, and normal faults, making the sub-surface, and more especially the sub-thrust geologic structures, very complex and difficult to interpret based on seismic and widely spaced exploratory drill hole data. It is sometimes these deep, complex structures that form the structural traps where oil/gas accumulations could occur. The recognition that surface structures are generally not continuous with sub-thrust structures greatly aided interpretation of the thrust belt. Most production in the thrust belt is from hanging wall anticlinal structures near the leading edge of the thrust sheet. Stratigraphic, anticlinal, and pinch-out traps also occur associated with footwall structures on some of the thrust faults in the area. The creation of structures/traps that could accommodate the accumulation of hydrocarbons also make the structural complexities which are difficult to interpret and have added significantly to the uncertainty, risk, and cost associated with oil/gas exploration drilling in southeast Idaho.

Although the Bear River Range is underlain by the Paris-Willard and possibly the trailing edge of the Crawford-Meade thrusts and is included in the Middle Rocky Mountain province, its surficial structure has been overprinted by and is much more typical of the Basin and Range province structure described below.

Basin and Range Province

The geologic structure of the Basin and Range province is generally much simpler than that of the overthrust belt. While compressional forces deformed the thrust belt, it has been mainly extensional forces (and uplift) that have deformed the Basin and Range province. These extensional forces, beginning in the Miocene, have caused large, normal, high-angle faults to form along a north-south trend. As further extension and uplift occurred (and continue), numerous grabens formed between the relatively uplifted horsts. This pattern is repeated numerous times to the west of the Caribou, creating the Basin and Range topography and geology typical of western Utah and most of Nevada. This process of extension with the displacement of the valley floors relative to the mountain ranges is continuing, as evidenced by the seismically active Intermountain Seismic Zone that extends through the Caribou. The strata in the Basin and Range province are not generally as complexly folded as those of the thrust belt, although normal faults are quite common. The faulting, especially the major mountain range bounding faults, associated with the Basin and Range province can create structures and pinch-out traps that can accommodate the accumulation of hydrocarbons.

FACTORS AFFECTING OIL AND GAS POTENTIAL

Several factors affect the oil/gas potential for any given area. At least five major parameters are necessary for the accumulation of oil and/or gas to occur in significant quantities: 1) Source rocks -

those that have sufficient organic content to generate hydrocarbons; 2) Thermal maturation that converts the organic materials into hydrocarbons and thus allows the migration of the hydrocarbons; 3) Reservoir rocks where the hydrocarbons can accumulate; 4) Traps (including tight impermeable caps or seals over the trap) that keep the hydrocarbons within the reservoir and prevent their escape or migration to the surface; and 5) Correct timing as to the generation and migration of hydrocarbons relative to the formation of traps and access paths for migration into the traps (Powers, 1983). These factors will be discussed individually below.

Source Rocks

The development and accumulation of hydrocarbons is dependant upon a sufficient amount of organic material becoming trapped and buried in sediments or precipitates (i.e. limestone or dolomite) to become source rocks. Figure 2 (Stratigraphic column) shows potential source rocks for the Caribou and surrounding area. Some of the Cretaceous rocks listed in Figure 2 are considered to be the most productive or have the highest potential for hydrocarbon generation (Chidsey, 1984). However, because these rocks units are not uniform in thickness, lithology, or organic content throughout the area, the potential to generate hydrocarbons generally diminishes from east to west (Holm, 1987). Most of the Cretaceous sediments were derived from uplift associated with the Sevier orogeny to the west with the courser sediments being deposited closer to the source (Wiltschko and Dorr, 1983). The courser grained terrestrial sediments generally represent more of an upland paleoenvironment that has a lower organic content than their finer grained lateral equivalents farther to the east. The marine formations represent deposits made at or near the western edge of the interior Cretaceous seaway. These marine rock units thin and become courser grained to the west. Although there are some limited coal beds associated with the marginal marine sediments, those coal units are very limited on the Caribou; they are much thicker and more widespread to the north and farther east in Wyoming. Further, Chidsey (1984), indicates these potentially more productive Cretaceous rocks are missing from both the hanging and foot walls of the Crawford and possibly the Meade thrust plates below the “thin skinned” portion of the Paris-Willard thrust. These factors reduce the potential for significant hydrocarbon accumulation on the Caribou. However, older potential source rocks, primarily the Permian Phosphoria Formation (with 1-6% organic carbon by weight) and Mississippian-aged formations (with 1.5-8% organic carbon) are still present in the general area (Chidsey, 1984), as are some of the lesser productive Cambrian and Ordovician potential source rock units.

The Basin and Range section of the Caribou has not been as heavily explored for oil and gas, so the subsurface geology is not as well known. Most of the Paleozoic rock units, or their lateral equivalents, that are present in the thrust belt section are also present in the Basin and Range portion of the Caribou, but the beds are generally a little thinner because they were not in the deepest part of the miogeosyncline. Potential source rocks in this area include, but are not limited to, the Permian Phosphoria Fm., Mississippian age rocks (including the Manning Canyon Shale – if present), and some Early Paleozoic rock units. The potentially highly productive Cretaceous source rocks present in parts of the Wyoming Thrust belt section are no present in the Basin and Range section of the Caribou.

Thermal Maturation

Temperature (and the length of time a rock unit is exposed to certain temperatures) is the most sensitive parameter in hydrocarbon generation and controls the amount and composition of hydrocarbons generated (Tissot, *et al*, 1987). Maximum temperatures and the duration of different temperature regimes are critical for hydrocarbon generation. Excessive heat (over maturation or over mature conditions) will destroy hydrocarbons; inadequate heat will not generate hydrocarbons even though sufficient organic materials may be present. Lower temperatures are more likely to generate oil, while higher temperatures are prone to develop gas (Tissot, *et al*, 1987). Paleotemperature (and temperature/time relationships) is often difficult to determine. Several indicators and models have been generated to try to unravel the complex thermal history of source rocks and hydrocarbons. Based on the conodont color-alteration index (CAI), some of the rocks in the southern part of the Caribou (Bear River Range) have a CAI of 3.0, placing them near optimum for hydrocarbon generation (Chidsey, 1984; Sandberg, 1983). The thermal history, and the timing of the maturation process, is not well understood for much of southeast Idaho.

Reservoir Rocks

Figure 2 shows the potential reservoir rock units in the southeast Idaho area. This list is a composite derived from the oil/gas potential reports prepared for NFS lands to the east, south and north of the Caribou. These units have produced oil and/or gas in anticlinal structural traps in the thrust belt in Wyoming and/or Utah (Horsburgh, 1992). Many of these rock units, or their equivalents, are known through exploration drilling to be present at depth in the southeast Idaho area. The presence of reservoir rocks is essential for the accumulation of hydrocarbons in extractable/economical quantities. The most prolific producer in adjacent areas is the Nugget Sandstone. This unit has been encountered in exploration drilling on the Caribou, mainly the eastern portions.

Traps or Seals

The fourth item necessary for the accumulation of hydrocarbons is traps or seals. Without some sort of trapping mechanism, migrating hydrocarbons would escape to the surface and be lost. Traps can be of two general types: structural or stratigraphic. For stratigraphic traps, a reservoir rock must be overlain by an impermeable layer that stops the upward migration of the hydrocarbons. In structural traps, seals of impermeable rock must also be present to keep the hydrocarbons in place in a structural trap that contains reservoir rocks. Because of the folding, faulting, and thrusting present throughout the Caribou, the likelihood of simple stratigraphic traps is very minor. Because of the complex geology of the Caribou, structural traps are present. The highest potential traps on the Caribou are associated with anticlinal structures just above or below thrust faults that were generally formed during movement on the thrust faults. Natural gas is very buoyant in the subsurface and tends to migrate easily through permeable strata and can even diffuse through seals that trap oil (Dyman, *et al*, 1997)

Timing

The final factor to be here considered in the formation of significant reservoirs of hydrocarbons is timing. In order for accumulations of oil or gas to occur, the source rocks have to have the correct amount of heat and pressure applied to convert the organic remains present in the rock to hydrocarbons. This has to have happened near reservoir rocks (sometimes the source and reservoir rock are the same geologic unit), and allowed the migration of the hydrocarbons into the reservoir rocks during or after the formation of traps. If any one factor is not optimum, significant accumulations of oil or gas will most likely not occur. Because of so many variables and limited windows of emplacement opportunity, coupled with the deeply buried and geologically complex nature of many of the structural traps that may lie beneath the Caribou, exploration has been and will continue to be risky and costly.

Most of the known producing fields in the Wyoming Thrust Belt appear to be the result of contact (through the thrust fault) of the Cretaceous footwall source rocks with the hanging wall reservoir rocks during (or after) hanging wall deformation created the traps occurring simultaneously with the maturation and migration of footwall source rock hydrocarbons. Timing is a critical element.

Plays and Assessment Units

The US Geological Survey (USGS) has been charged with developing a system to make appraisals of the potential for undiscovered petroleum resources. Schmoker and Klett (2005) discuss the differences between the 1995 National Assessment and the 2000 National Oil and Gas Assessment. For the 1995 National Assessment, the USGS divided the United States into eight regions and 72 provinces, with the basic level of assessment being the "play". A play was established primarily according to similarities of the rocks in which known petroleum accumulations occur. However, beginning with the National Oil and Gas Assessment (NOGA) series starting in the year 2000, the USGS used "total petroleum systems" with subdivisions termed Assessment Units (AU). A total petroleum system is the genetically related petroleum generated by a pod or closely related pods of mature source rocks with emphasis on the similarities of fluids in petroleum accumulations. As such, the AUs are more closely associated with hydrocarbon generation and migration than are plays. Schmoker and Klett (2005, p. 5) state: "The choice of play versus assessment unit probably does not result in significant systematic differences in assessed undiscovered resources." Both systems will be used in the following discussions. The Caribou falls in two oil/gas provinces: the Eastern Great Basin and the Wyoming Thrust Belt.

Eastern Great Basin Province

The Eastern Great Basin Province includes lands in eastern Nevada, western Utah, southeastern Idaho (south of the Snake River Plain and west of the Wyoming Thrust Belt province), and a very small part of northwest Arizona (see Figure 3). Most of the Westside Ranger District and all of the Curlew National Grassland lie in this province. Concerning the province, Peterson and Grow (1994) state that the region is one of exceptionally high heat flow. High heat flow can not only destroy organic remains that could have been converted to hydrocarbons under favorable circumstances, but can also effectively destroy existing hydrocarbon reserves.

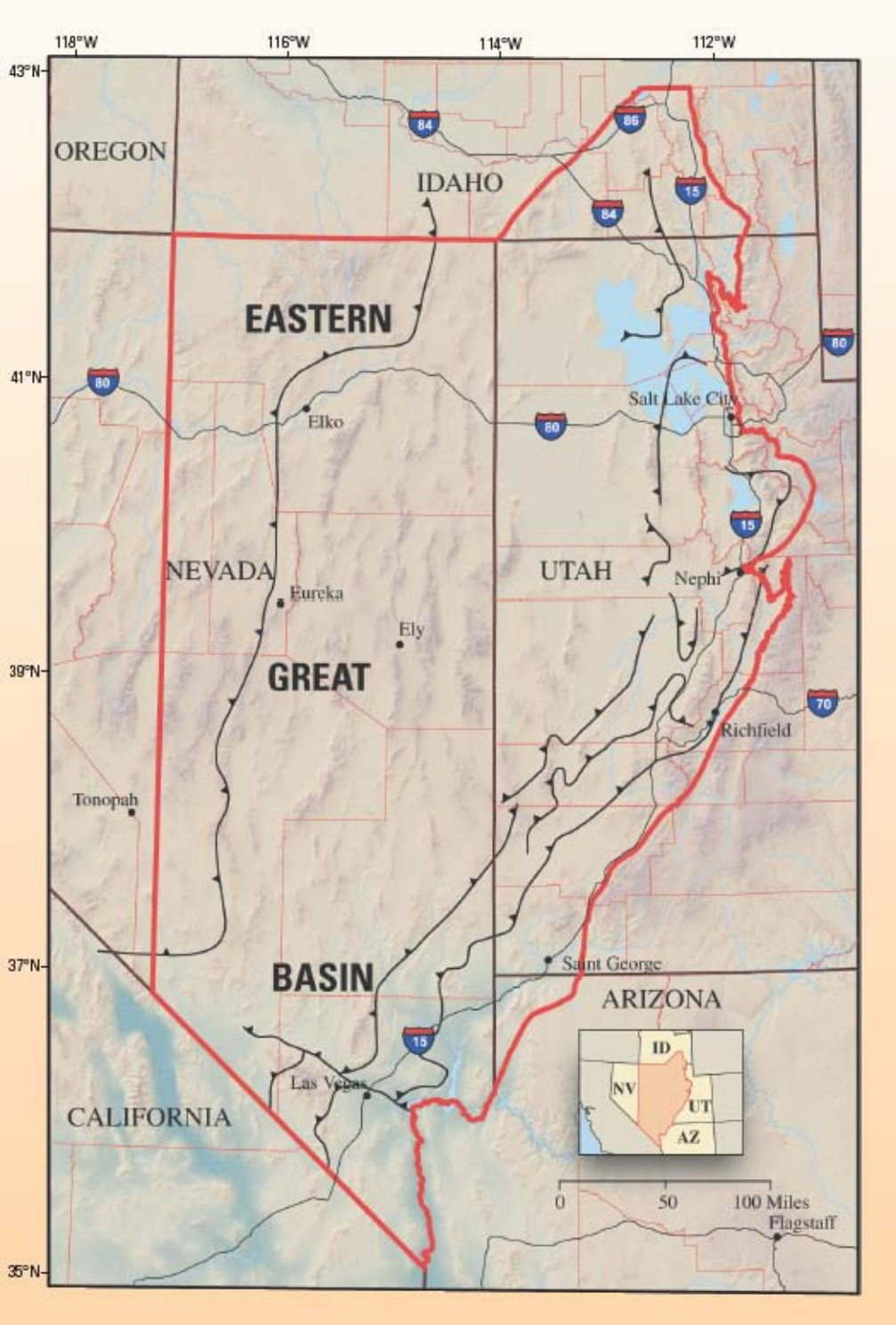

Figure 3. Eastern Great Basin Province (red line). Major thrust faults are shown with teeth on the thrust (upper) plate (Modified from USGS Fact Sheet FS-2005-3053, May 2005).

Although there are 10 known fields in the Eastern Great Basin Province (excluding the recently discovered Covenant field in central Utah), they are all in late Tertiary grabben basins in east central Nevada (Peterson and Grow, 1994). There are no past or present producing wells or known fields in or near the southeastern Idaho portion of this province.

The USGS developed seven plays in the Eastern Great Basin Province (USGS, 1993), with only two of them (both hypothetical) possibly present in the area of the Caribou. Peterson and Grow (1994) describe the Unconformity "A" play (play 1901) as having reservoirs in fractured and porous Paleozoic carbonate beds and Tertiary lacustrine and volcanic beds. Source rocks include organic-rich Paleozoic marine shales and Tertiary lacustrine rocks. Traps include folds, block-faulted beds, pinchouts, and hills buried beneath the valley fill. These units are producing hydrocarbons in east-central Nevada, but only minor shows have been reported from the southeast Idaho portion of the province.

The hypothetical Late Paleozoic Play (play 1902) is based on the possibility that early-formed traps (pre-Tertiary folds, thrusts, and fault blocks) in reservoirs have been buried and 'capped' to prevent loss of hydrocarbons (separate from the Unconformity "A" play). The presence of this play on the Caribou is uncertain. This play is based on reservoirs (Paleozoic sandstone and carbonate rocks) in traps formed prior to the late Cenozoic extensional faulting. Seals are the interbedded Paleozoic shales and the source rocks are organic-rich Missisippian, Permian, and Pennsylvanian shales. Peterson and Grow (1994) state, however, that the source rocks are over mature in much of the province. Typically the mountain ranges in this AU in the Caribou have been so broken up by faulting that traps and seals that may have been present in the past have probably been broken up and major accumulations of hydrocarbons that might have been present have presumably escaped to the surface.

The 2005 assessment of the Eastern Great Basin province has only the Paleozoic-Tertiary Total Petroleum System, with three assessment units: Neogene Basins, Ranges and Other Structures, and the Sevier Thrust System (USGS, 2005). Detailed data for the US Geological Survey 2003 General Assessment Results were not available on line. Only the Curlew National Grassland part of the Caribou lies in the Neogene Basins and Ranges and Other Structures AUs (the two AUs have identical boundaries), while the remainder of the Westside RD (except for a small section in the Haystack Mountain area) lies in the Sevier Thrust System AU.

The bulk of the undiscovered estimated reserves are in the Neogene Basins AU, which includes all of the known producing areas from the Eastern Great Basin province except the Covenant field in central Utah. Only a very small portion of the eastern Great Basin province, including this AU (as well as the Ranges and Other Structures AU) lies inside Idaho. These Neogene basins are the down-faulted basins between the mountain ranges. The only production from this AU is in east central Nevada. Seals that trap the hydrocarbons in the Nevada valleys do not appear to be effectively in place in Idaho. One wildcat well was drilled in the AU about 10 miles west of the Curlew in 1951. The well was drilled to a depth of almost 13,000 feet, but was plugged and abandoned, with no record of hydrocarbon shows.

The Ranges and Other Structures AU has the same geographic boundary as the Neogene Basins AU and also includes the Curlew National Grassland. However, the grasslands are all located in the valley bottoms between mountain ranges. There is no petroleum production from this AU in the entire Eastern Great Basin Province.

The Sevier Thrust System AU lies along the eastern edge of the Eastern Great Basin province, and includes almost all of the Westside Ranger District. It is this AU that contains the recently discovered Covenant field in central Utah. Only about 5% of this AU is in Idaho, with only a fraction of the Idaho portion included in the Caribou. Ten wildcat wells (none of them on the Caribou) were drilled in the Idaho portion of this AU between 1926 and 1982; all were plugged and abandoned as dry holes. Four of the 10 holes did have oil and/or gas shows. The deepest hole bottomed out at only 5,233 feet, and six of them had a total depth of 3,000 feet or less. Several wells were also drilled in the northern Utah portion of this AU, but they too were all plugged and abandoned as dry holes, except two wells that were reported as shut in gas wells (data are incomplete, but these wells were apparently drilled more than 30 years ago, yet were never developed, based on information present in Utah Division of Oil, Gas, and Mining's web site). Thrust fault structures similar to those of the Covenant field in Utah have not been found in the Sevier Thrust System AU in southeast Idaho.

Wyoming Thrust Belt Province (036)

All of the Montpelier and Soda Springs Ranger Districts and a very small portion of the Westside Ranger District (Northeastern most section of the District) in the Haystack Mountain area lie in the Wyoming Thrust Belt Province (see Figure 4). Although much has been said concerning the petroleum production and potential for the Wyoming Thrust Belt, to date all of the production has come from outside Idaho. Gautier and Varnes (1993) describe seven plays from the Wyoming Thrust Belt Province; only two of which are present on the Caribou. However, the best, most complete description found of the plays in this province is that of Powers (1994) for the USGS's 1995 oil and gas assessment. Highlights of Power's description are given below for the two plays he described that occur in southeast Idaho. A brief description of the USGS 2003 assessment of this province will also be given below.

<u>The Crawford-Meade Thrust hypothetical play (3602)</u> is characterized by probable hydrocarbon accumulations in footwall structures or truncation traps in Cretaceous reservoir rocks interbedded with Cretaceous source rocks, and gas accumulations in Paleozoic and Mesozoic reservoirs in tightly folded hanging-wall anticlines sourced by Paleozoic shales. Concerning this play, Powers (1994) states the following:

> "A few wells drilled in the northwestern one-third of the play had recorded elevated bottom-hole temperatures, indicating that higher geothermal gradients exist here in proximity to volcanics of the Snake River Plain of Idaho. This type of setting could be a deterrent to exploration. Any significant potential in the play, particularly for gas, would remain in the footwall Cretaceous section of the Crawford Thrust Plate in the southern half of the play."

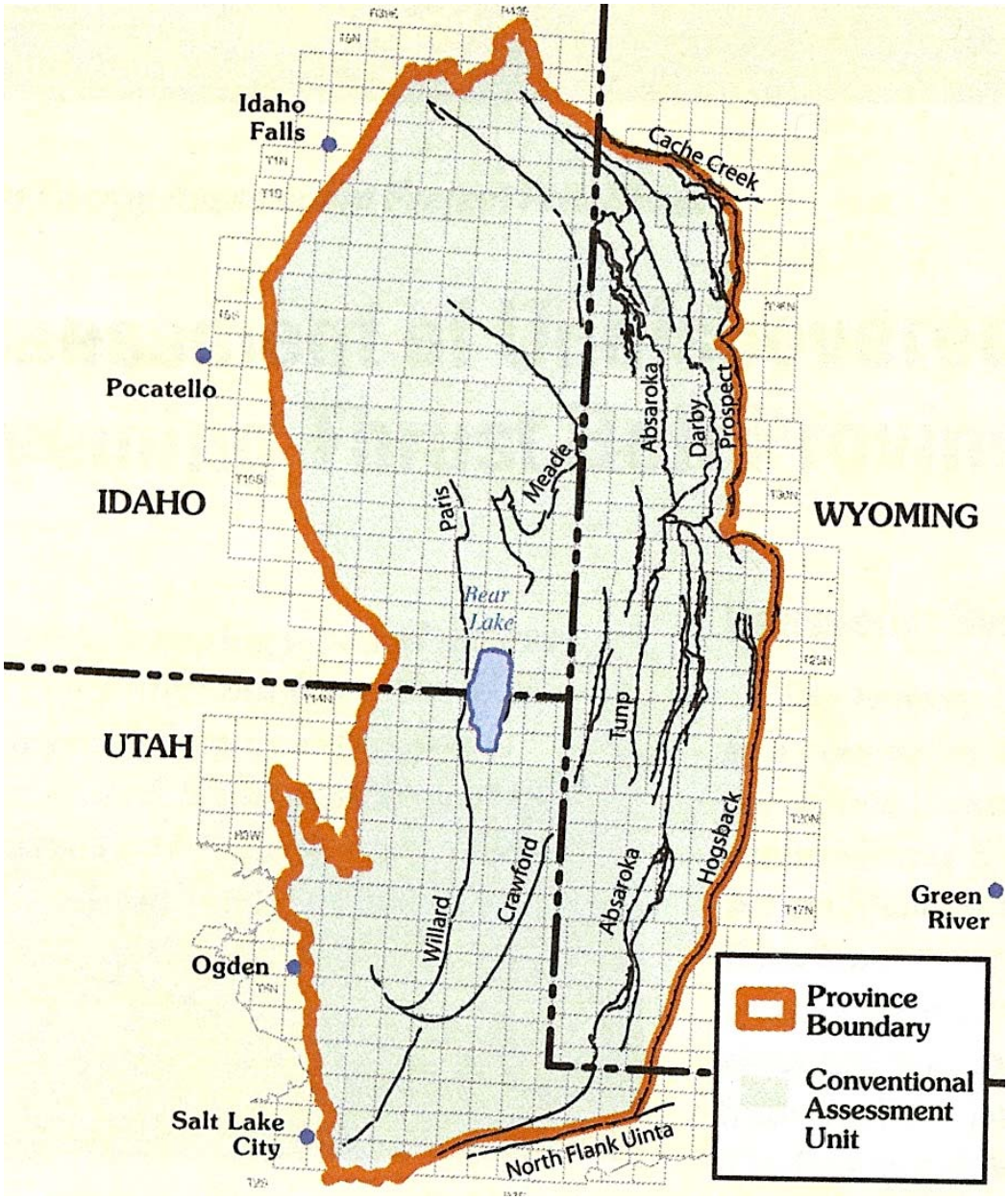

Figure 4. Wyoming Thrust Belt Province, Idaho, Wyoming, and Utah. Locations and names of major thrust faults (systems) are indicated (modified from USGS Fact Sheet 2004-3007, February, 2004).

The southern half of the play is the Utah portion and does not include the Caribou NF being evaluated in this report. The Hogback Ridge field, consisting of only one productive well located in northern Utah about 20 miles southeast of the southeastern most point of the Caribou on the Bear River Range, is the only known field within this play (see description below concerning the Hogback Ridge field). Twenty exploratory oil/gas wells (only two on the Caribou) have been drilled in the

Idaho portion of this play; they were all plugged and abandoned as dry holes, although some of them did have oil or, more often, gas shows. Dyman, *et. al*. (1997) mentioned a hypothetical deep gas play associated with the Crawford/Meade thrusts. Some of the Meade thrust portion of this play would lie beneath the Caribou, but no probability for the occurrence of deep gas in this play was given.

The Absaroka Thrust Gas play (3604) has gas and condensate accumulations in carbonate and sandstone reservoirs in hanging wall anticlines on the leading edge of the Absaroka thrust plate. The source of the hydrocarbons is Cretaceous shales in the footwall (Gautier and Varnes, 1993). All known production from this play is in Wyoming. The leading edge of the Absaroka and Darby thrusts do continue into Idaho, but it is several miles north of the Caribou (Pampeyan *et. al.,* 1967). They are also separated from the Caribou by the Grand Valley Fault system that produced a major grabben with thousands of feet of vertical displacement. The trailing edge of the Absaroka thrust sheet is apparently present at depth on the Caribou, but the known productive structures associated with the thrust plate are located near the leading edge of the thrust sheet or in associated smaller imbricate thrust sheets. Three surficial anticlinal structures have been drilled on the Caribou, that are presumably on or above the trailing portion of the Absaroka Thrust sheet. Of the six wells drilled on these structures, all were plugged and abandoned. Three of the holes were drilled deeper than 14,000 feet and at least three of them penetrated the Nugget Formation, a primary reservoir rock and drilling target in the area. Two of the wells were tite holes; at least three had gas shows. The wells were drilled between 1950 and 1985.

The US Geological Survey (2004) identified two assessment units in the Wyoming Thrust Belt Province, with only the Thrust Belt Conventional AU present in southeast Idaho. This AU covers the entire province. All of the known production from this AU is in Wyoming or Utah. The potentially large undiscovered reserves postulated in the AU most likely lie outside Idaho, based on known and inferred geology. Essentially all of the production from this AU is associated with hanging wall anticlines that are in contact with Cretaceous source beds on or near the leading edge of the Absaroka, Tump, Darby, and Hogsback thrusts. The leading edges of these thrusts are not located on the Caribou. One well drilled in this AU just a few miles west of the Caribou had a temperature of 360 degrees F at a depth of 9,500 feet. McLeod (1993) reported oil/gas exploratory well formation temperatures in the southeast Idaho portion of the Wyoming thrust belt in excess of 400 degrees F. Such high temperatures are not conducive to oil/gas accumulation.

Moulton and Pinnell (2006) state the following concerning the Wyoming salient (Wyoming Thrust belt):

> "In Canada, most similar thrusts contain economic hydrocarbons east of the Rocky Mountain Trench. However, in Wyoming [Wyoming Thrust Belt] only the eastern Absaroka thrust is economic with an undeniable symbiotic relationship with the Fossil basin providing required source rock depths. Other thrusted anticlines are essentially dry west of the Absaroka thrust because substantial quantities of oil and gas were unable to migrate to them from the east to the west. The migration pathway for the source of mature Cretaceous shales below and east of the Absaroka thrust plane was blocked…. On the other hand, west to east migration of Paleozoic oil and gas has never been noted in thrust layers in Wyoming [Wyoming Thrust Belt]."

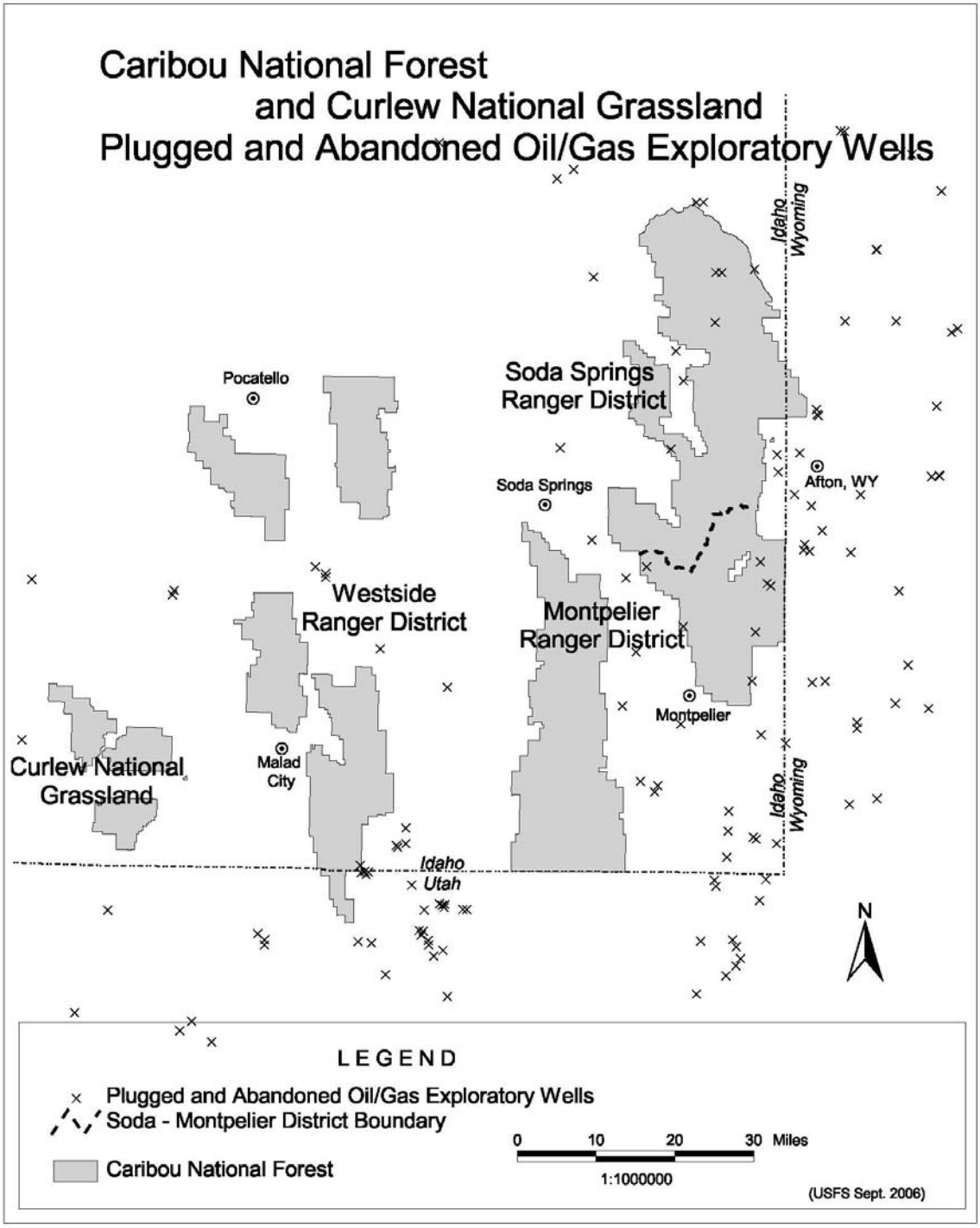

Figure 5. Location of oil/gas exploratory wells drilled in southeast Idaho and adjacent parts of eastern Wyoming and northern Utah (compilation of data from various sources – see text, this report).

PAST AND PRESENT OIL/GAS EXPLORATION ON THE CARIBOU

The first oil/gas exploratory wells in southeast Idaho were drilled in the 1920s; the most recent in 1988. Available drill data indicate that 54 wells have been drilled in southeast Idaho on or within 20 miles of the Caribou (Breckenridge, 1982), of which 11 were drilled within the National Forest boundary (Figure 5). Drilling record data were also searched for adjacent parts of Wyoming and Utah. Within 20 miles of the Caribou, records were found for 31 wells in Wyoming (Wyoming Oil and Gas Conservation commission web site, 2006) and 40 in Utah (Utah Division of Oil, Gas, and Mining web site, 2006). Of these 125 total wells drilled, all have been plugged and abandoned as dry holes except two shut-in gas wells in northern Utah (that have apparently been shut-in for more than 30 years - data are very incomplete) and one gas well in the Hogback Ridge field in northern Utah. The Hogback Ridge field (single well) produced a small amount of gas for about three years before it played out and was abandoned; total cumulative production was about 5.8 billion cubic feet of mainly sweet gas (Chidsey, 1984). Three offset wells in this field were drilled and all were plugged and abandoned as dry holes, indicating the small, limited size of the field. A few additional wells in northern Utah were suspended during drilling, and were not completed. Several other approved drill sites in northern Utah were abandoned before they were drilled. Table 1 below shows the reported well depths and the time period when the wells were drilled. Not all of the 125 wells mentioned above are included in Table 1 because some wells lacked sufficient data to place them in the Table.

Well Depth (in feet)	Pre 1950	1950s	1960s	1970s	1980s
< 1,000	U	I	U W	I U	U U U
1,000 - 4,000	I I I I I U W W W	I I I W W	I	**I** I U U U U	I U U U
4,000 - 7,000	I W	I I I I U W	**I** I I I W	W	U
7,000 – 10,000	W W	**I** U W	I U W W	I I U U W	**I** I I I U U W W
10,000 – 13,000		I		**I** I I I U U U U U W	I I I I U U W W
13,000 – 16,000				**I** I I IU W W W W	**I I I** I I U W W W W W W
16,000 - 19,000				**I** U U W	**I** I I W W W W W
>20,000					W

Table 1. Oil/gas well data for southeast Idaho and adjacent parts of Utah and Wyoming showing time period drilled (based on the well spud date), depth of drill hole, and state (I = Idaho, U=Utah, and W=Wyoming) drilled in. Each letter (I, U, or W) indicates one well. Additional wells were drilled, but available well data are insufficient to include them in the table. Each bold **I** represents a well drilled on the Caribou.

The geologic structure of the overthrust belt began to be better understood in the 1970s when it was realized that surface geologic structures did not generally continue below the thrust faults. This opened the door to better seismic exploration that included looking below the thrust plates for geologic structures that could host hydrocarbon reservoirs (Powers, 1983). Once oil/gas discoveries were made in other portions of the overthrust belt in Utah and Wyoming, more and deeper wells were drilled throughout the area, including southeast Idaho. Wildcat wells that penetrated the thrust faults were drilled – yet dry hole after dry hole in southeastern Idaho and adjacent areas of Utah and Wyoming were plugged and abandoned.

During the 1970s and early 1980s, hundreds of miles of seismic line exploration were run throughout southeast Idaho and surrounding area, including the Caribou. During the height of the energy boom in the 1970s and early 1980s, hundreds of miles of seismic line were run on an annual basis on the Caribou alone. However, there have been no seismic lines run in southeast Idaho (either on or off the Caribou) on NFS, BLM, or State of Idaho administered lands in the past 20 years (Horsburgh, personal comm., July, 2006; Gabardi, personal comm., July, 2006; Murray, personal comm., September, 2006). Relatively few wells were drilled on or adjacent to the Caribou, even during this flurry of exploration activity. No exploratory wells have been drilled in southeast Idaho since 1988.

Even though all of the wells drilled on the Caribou and surrounding area in Idaho and Wyoming and essentially all wells in adjacent parts of Utah were plugged and abandoned as dry wells, does not mean that there were no indications of oil/gas found. Several of the wells reported shows of oil and/or, more often, gas. One well on the northern edge of the Caribou (drilled on the Big Elk anticline – a hanging wall anticline on or above the trailing portion of the Absaroka thrust plate) reportedly flowed 5,000 MCFD of gas for an unspecified time. The hole was reentered about 13 years later and was then 'junked and abandoned'. According to a newspaper article (Idaho State Journal, 5-3-78), a test on a well drilled in Elk Meadows on the Montpelier Ranger District produced gas for about ½ hour before the well went "dead". Peak flow was only 265 MCFD for a few minutes. Oil from some of the shows in the western part of the area under consideration indicated that the oil there was over-mature or dead.

Oil/gas Leasing

At the height of the energy boom in the 1970s and early 1980s, more than 90% of lands available for oil/gas leasing on the Caribou were leased (similar numbers were also present on adjacent BLM lands). Currently, however, there are no existing oil/gas leases on the entire Caribou-Targhee NF and only two small existing Federal leases on BLM administered lands in southeast Idaho. The State of Idaho held an oil/gas lease sale on September 19, 2006. Included in that sale were two parcels totaling 1,280 of State lands in Bonneville County. Both of the tracts were bid on and leases will be issued (Murray, personal communication, September, 2006). One tract is a State section lying just inside the National Forest boundary, and the other is a State section lying immediately outside the Forest boundary on the northwestern corner of the Soda Springs Ranger District (Idaho Department of Lands, Bureau of Surface and Mineral Resources web site, 2006). These two parcels will be (are) the only oil/gas leases on State lands in southeastern Idaho (Murray, personal communication, August, 2006). There may be individual agreements for private lands/minerals in the area, but data are not available.

The following Federal leasing history (as of July, 2006) for the past 10 years for southeast Idaho was provided by the Idaho State Office of the BLM (Cron, personal comm., July 2006):

1) An expression of leasing interest (EOI) was received in February, 1998 for a total of 3,975 acres on the Caribou and surrounding area. A lease sale was held in November, 1998, with no parcels sold. One after-sale non-competitive 40 acre lease was issued effective February 1, 2000. This lease is still active (not on NFS lands).

2) An EOI for 10,605 acres of NFS lands (Targhee portion of the Caribou-Targhee NF) was received in October, 2000. No leases were sold at the subsequent August 2002, lease sale, but one after-sale lease for 1,495 acres was issued non-competitively, effective September 2002. This lease was terminated one year later for non-payment of rental.

3) An EOI for 14,298 acres of BLM lands was received in January, 2001. No parcels were sold at the subsequent lease sale, but two after-sale leases for 2,549 and 1,754 acres were issued non-competitively in April, 2002. The larger was terminated two years later for non-payment of rental; the other is still in effect.

4) An EOI for 2,830 acres of BLM land was received in April, 2002. No parcels sold at the sale, but a 671 acre non-competitive after-sale lease was issued, with an effective date of February 1, 2003. That lease was terminated three years later for non-payment of rental.

5) An EOI for about 230,000 acres of mostly NFS lands was received in August, 2005. No lease sale with any of these lands has occurred yet – a Forest Service leasing EIS must be completed for most of these lands prior to them being offered in a lease sale.

6) Three EOIs for a total of 7,430 acres were received in early 2006 for BLM administered lands and areas where Federal minerals are overlain by privately owned lands. No lease sale has been held yet for these lands.

As can be seen by the above history, there has been very little leasing interest in southeast Idaho for the past 10 years, with the exception of the one large request received in late 2005. Most of the lands in the large EOI are on the Caribou portion of the Caribou-Targhee NF, for which there is no current Forest Plan direction or decision to allow oil/gas leasing. It is assumed that the remaining lands in the 2005 EOI will be offered in a future lease sale once required approvals from land management agencies have been received.

ASSESSMENT OF Oil/GAS POTENTIAL

Several evaluations of the oil/gas potential for various parts of southeast Idaho and surrounding area have been made. A short review of selected published and unpublished references will be given here.

Eastern Great Basin Province

Describing the Eastern Great Basin Province, the USGS (2005) states: "The small number of drilled wells and producing wells compared to the total geographic area of the province indicates a frontier (or unproven) status."

Peterson (1988) states the following concerning the Eastern Great Basin province:

> "The eastern part of the Eastern Great Basin province in Utah and southeastern Idaho is considered to have very doubtful potential for significant hydrocarbon resources. The region contains organic-rich rocks of Devonian, Mississippian, Pennsylvanian, and Permian ages, but most of the area is affected by several negative factors: 1) deep burial; 2) excessive thermal effects and metamorphism; 3) severe tectonism, including thrusting, vertical faulting and fracturing and widespread exposure of the Paleozoic rocks extending into middle and late Tertiary time; 4) absence of effective seals to offset the adverse tectonic effects; 5) most of the valleys do not contain the thick valley-fill as is present in eastern Nevada; and 6) the post-Silurian section has been removed by regional erosion in much of the potentially favorable area." (it should be noted, however, that the recently discovered Covenant Field, a major discovery in central Utah, lies in the eastern part of the Eastern Great Basin province)

Perry (1997) states the following concerning potential deep gas accumulations in general: "Rift basins that fail to open into new ocean basins provide a third type of basinal setting within the conterminous United States; however, these are not a likely structural setting for major deep natural gas accumulations." This description applies to the eastern Great Basin area. Conversely, Dyman, *et. al*. (1997) state that the region as a whole has a fair potential for undiscovered deep natural gas accumulations. However, they only assign a probability of 0.2 (on a scale of 0.0 – 1.0) for the Late Paleozoic play (one of the two on the Caribou). USGS data lists a 0.24 probability for the Late Paleozoic play and a 1.0 probability for the Unconformity "A" play. The high probability in the Unconformity "A" play results from the 10 producing fields in this play in east central Nevada.

Dover and Bigsby (1980) stated the following about oil/gas potential for the Mt. Naomi roadless area, which lies on the southern portion of the Bear River Range on the Caribou, located in the Wyoming Thrust belt, and in adjacent northern Utah:

> "The oil and gas potential of the study area is unknown. Considering the nearby presence of potential petroleum source beds and the structure inferred for the study area, oil or gas concentrations could be present beneath the Willard allochthon. This possibility cannot be evaluated without seismic or drill-hole information. However, potential targets would probably be at depths greater than the 20,000 to 30,000 feet thickness estimated for the Willard allochthon – depths that may be prohibitive."

Wyoming Thrust Belt Province

Sandberg (1983) said the following about the petroleum potential for wilderness (proposed wilderness lands) in the Idaho portion of the Bear River Range: "Although little likelihood exists of finding structural traps in the fault plate at the surface, traps may be found in underlying thrust plates at depth. Hence the cluster is rated to have a medium potential." However, Molenaar and Sandberg (1983) rated the wilderness lands on the adjacent Utah portion of the Bear River Range as low (at least partly because of CAI values in Utah of 3.5).

Spencer (1983) rated the wilderness and proposed wilderness lands in the Wyoming portion of the Wyoming Thrust Belt as having a high potential for the accumulation of oil/gas. One of the proposed BLM wilderness areas (in the Sublette Range) evaluated lies just a few miles southeast of the Caribou. Another of the areas evaluated by Spencer (1983) lies within about 10 miles of the northeast corner of the Caribou.

In evaluating the mineral potential for an area just a few miles north of the northern end of the Caribou (north of the Soda Springs Ranger District), Fernette and Fredericksen (1983) state the following: "Wilderness Study Area 34-2 is classified as having a moderate potential for oil and gas resources based on minimal direct evidence. The reasons for the classification are the inferred favorable geologic processes, the reported hydrocarbon shows from underlying rocks elsewhere in southeastern Idaho, and the known hydrocarbon deposits within equivalent rocks in the Utah-Wyoming area."

Horsburgh (1992) rated the area adjacent to the northern part of the Caribou, northeast of the Soda Springs Ranger District, as having a moderate potential for the accumulation of oil/gas resources, with a C-2 confidence level. This rating was given because of the lack of significant oil/gas shows and because there are no leading edges of major thrust plates present in the area. Most of the known petroleum reserves in the Wyoming Thrust Belt are located along the leading edge of thrust sheets.

Kaldenbach (1990) made an assessment of the oil/gas potential for the Wasatch-Cache National Forest. The northern end of the Wasatch-Cache is adjacent to the southern end of the Montpelier Ranger District (on the Bear River Range), separated only by the Idaho – Utah state line. He assessed the oil/gas potential for the area as low, with a C-2 confidence level. This rating was based on a lack of significant shows from oil/gas wells drilled in the area, and because of the "Basin and Range" type faulting overprinted on the area that most likely destroyed the structural traps that may have been present in the area.

Holm (1987) evaluated the hydrocarbon potential for the Bridger-Teton National Forest in western Wyoming. Part of the Caribou is separated from the Bridget-Teton only by the Wyoming-Idaho state line, with other areas lying immediately east of the Caribou. In that assessment, the National Forest System lands in western-most Wyoming were all rated with a moderate potential for the economic accumulation of oil/gas resources. This rating was given because of a lack of significant shows of oil or gas in wells drilled in the area, and the lack of oil/gas exploration activity.

The Pocatello Field Office of the Bureau of Land Management recently developed a map showing oil/gas potential for much of the area covered by this assessment. That map showed the eastern

portion of the area (basically the Soda Springs and Montpelier Ranger Districts) as having a "highest" potential for the area. Other areas were of moderate, low, and unknown potential. A report that described the process to arrive at these conclusions was not made. In a conversation with Bill Stout of the BLM (the author of the map), he said his appraisal was made on the potential for the **occurrence** of oil/gas resources, not on the potential for the **accumulation** or occurrence of economically extractible of oil/gas resources (Stout, personal comm., June, 2006). Occurrence (minimal) has been demonstrated through shows in some of the wells drilled in southeast Idaho, but the lack of accumulation of commercial quantities based on the then economics and existing infrastructure of oil/gas has been demonstrated by the plugging and abandoning of all the wells drilled.

Area By Area Assessment

The following rating system was used to determine the potential for the accumulation of oil or gas resources on the Caribou and the certainty ratings associated with the potential ratings.

Potential for the Accumulation of Oil/Gas Ratings

High Potential: Geologic formations (including favorable source and reservoir rocks), the geologic structures (favorable for the accumulation and entrapment of hydrocarbons), and geologic processes (maturation, migration, and timing) necessary for the accumulation of hydrocarbons are known to exist.

Moderate Potential: Geologic formations, structures and processes (see above) necessary for the accumulation of hydrocarbons are thought to exist.

Low Potential: Geologic formations, structures, and processes necessary for the accumulation of hydrocarbons may or may not be present.

Certainty of Accumulation Ratings

C4: The available data provide abundant direct and indirect evidence to support or refute the possible accumulation of oil or gas resources.

C3: The available data provide direct evidence but are quantitatively minimal to support or refute the possible accumulation of oil or gas resources.

C2: The available date provide indirect evidence to support or refute the possible accumulation of oil or gas resources.

C1: The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible accumulation of oil or gas resources.

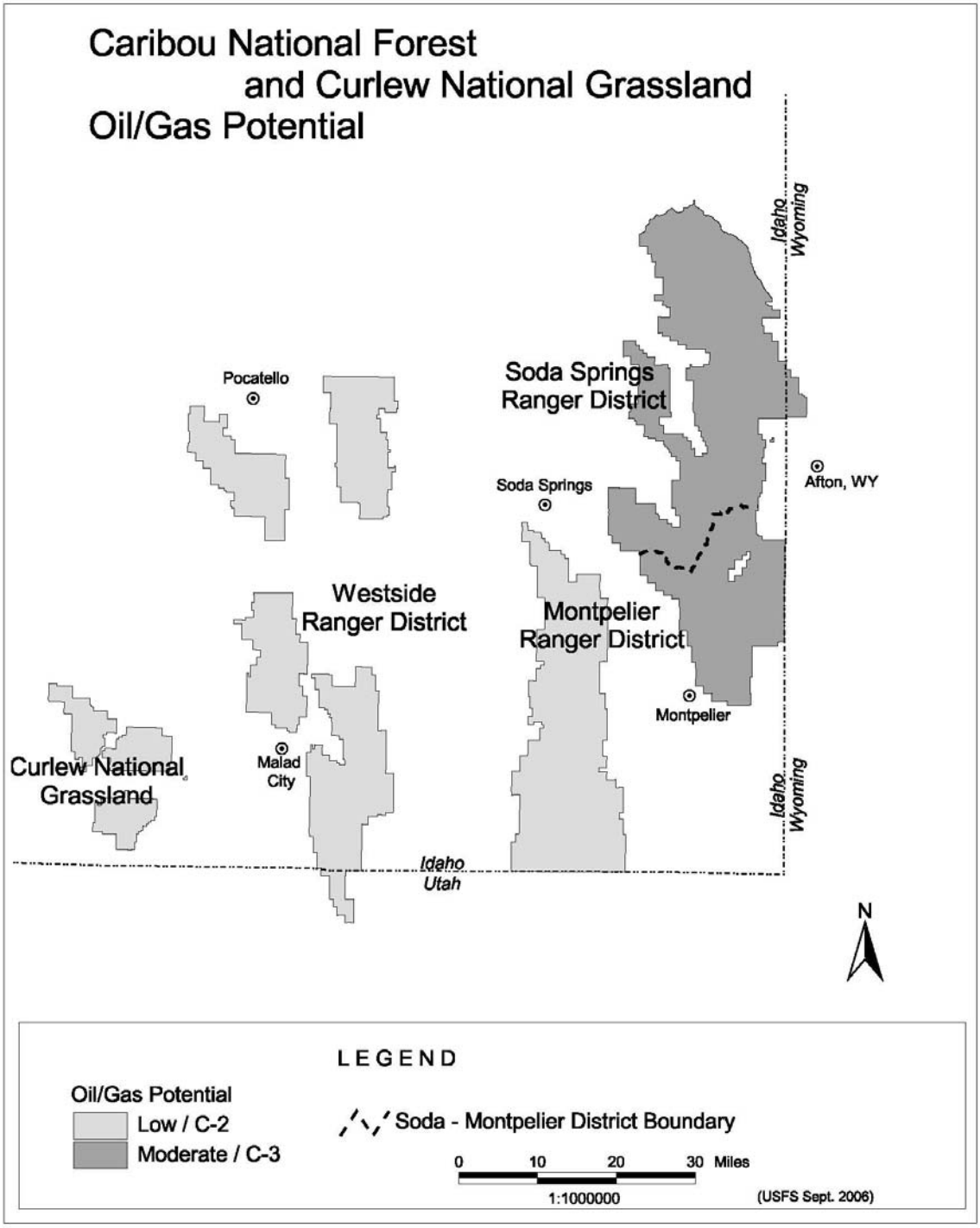

Figure 6. Oil/Gas Potential and Confidence Ratings for the Caribou National Forest and Curlew National Grassland.

Delineation of Potential Areas

The following narrative describes the delineation of the oil/gas potential and confidence ratings for the Caribou (see Figure 6):

The Soda Springs and eastern part of the Montpelier Ranger Districts are rated as having a moderate potential for the accumulation of oil/gas resources. This rating is based on several factors. The surface outcrop trace of the Meade thrust is present in the southern part of the area (see Fig. 4). The Absaroka and other thrusts are present in the subsurface in the northern part of the area. Exploratory wells have been drilled on and immediately adjacent to the Forest, with some of the more recent wells having penetrated at least one thrust sheet. Several of the wells in this area have also had oil/gas shows, or even limited gas flows for a time. The northern part of the area may be on or near the trend with producing structures to the southeast in Utah and Wyoming. Source and reservoir rocks that are known to produce/accumulate hydrocarbons in the Wyoming and Utah portions of the thrust belt are present on this portion of the Caribou.

However, the leading edges of the producing thrusts in Utah and Wyoming (Absaroka, Tump, Darby, Prospect, and Hogsback thrusts) are not present on the Caribou. It is generally the leading edge of the thrust sheets that has developed the structures, traps, and source rock/reservoir rock contacts that have allowed the accumulation of hydrocarbons in the known fields in the Wyoming Thrust Belt. Some Basin and Range type faulting is present in this eastern portion of the Caribou, which could have compromised the integrity of any structures/traps they may have intersected. High down-hole formation temperatures in wells drilled to the north and west of this area may continue into the Caribou and be a detriment to the accumulation of hydrocarbons. Drill holes on and immediately adjacent to the Caribou are widely scattered, and several of the exploratory wells were drilled when the thrust belt was poorly understood. This moderate rating is consistent with the oil/gas potential level assigned by Horsburgh (1992) and Holm (1989) for adjacent lands, but is lower than part of the rating shown on the oil/gas potential map prepared by the BLM Pocatello Field Office (Stout, 2006) for their Land Management Plan revision (in preparation).

A confidence rating of 3 was given to the Soda Springs and eastern portion of the Montpelier Ranger Districts mainly because of the number of wells drilled on or immediately adjacent to the Forest in this area.

The western portion of the Montpelier Ranger District (the Bear River Range) is rated as having a low potential for the accumulation of oil/gas resources. Potential source rocks and reservoir rocks may be present (mainly below the Paris Thrust). According to CAI values for the conodonts present in the Bear River Range, it appears that thermal maturation, at least above the thrust, is near optimal for hydrocarbon generation. The leading edge of the Paris Thrust crops out immediately east of the forest boundary, so that the leading edge portion of the thrust is presumably present under this portion of the Caribou. There are a few wells drilled near this portion of the Forest, but none on National Forest System Lands in the Bear River Range in Idaho.

The main reason for the low potential rating is that Basin and Range structure has been overprinted on the thrust belt structure. The bounding fault zone on the east side of the Bear River Range (which

is a horst) goes though the leading edge of the Paris Thrust, thus greatly reducing the potential for the accumulation of hydrocarbons in this typically productive portion of a thrust in the Wyoming Thrust belt. The surface structure of the range is a broad, southerly plunging syncline, again, not a very likely location for the accumulation of hydrocarbons. Although Chidsey (1984) stated that the trailing portion of the Crawford thrust sheet is present below the Paris thrust in southeast Idaho, wells drilled immediately east of the Forest (10,000 – 13,500 feet deep) apparently did not penetrate a thrust fault at, indicating that the trailing edge of the Crawford and/or Meade thrusts, if present in this area, are very deeply buried. These wells also did not report shows of oil or gas. Chidsey (1984) stated that the potentially most productive Cretaceous source rocks are missing from both the hanging and foot walls of the Crawford (and possibly the Meade) thrust fault beneath the Willard-Paris thrust fault. The low rating is in conformance with the oil/gas potential report completed by Kaldenbach (1990) for adjacent lands of the Bear River Range in Utah. This low rating is lower than that shown by the BLM Pocatello Resource Office for their revised Land Management Plan (Stout, personal comm., 2006).

Because of the lack of drilling data on the Bear River Range section of the Caribou, and the sparse and widely scattered drill data available from wells drilled near this range, a confidence rating of C-2 is assigned.

The Westside Ranger District is assigned a potential rating of Low. Most of the area is apparently not associated with thrust faults, but is in, and a part of, the Basin and Range Province. There are some potential source and reservoir rocks present. However, thermal maturation of these rocks may be too high for optimal generation and/or preservation of hydrocarbons; igneous rocks predominate in some areas, and the northern portion of the area is bounding on the trace of the Yellowstone hot spot (Snake River Plain). The area is also heavily faulted, with the mountain range bounding fault zones being well developed, which may have effectively broken up potential trapping structures. Although several wells were drilled to the southeast of the southern portion of the Ranger District, only one well was drilled just inside the Forest boundary (on private land). Two of the wells drilled to the southeast in Utah were apparently shut-in gas wells; more specific data was not available to the author for these wells.

Based on the meager drill data, the Westside Ranger District has a confidence rating of C-2.

The Curlew National Grassland is also rated as having a low potential. This area has very little rock outcrop, and what is present is mostly volcanic. Potential source and reservoir rocks are probably present at depth, but drill data for this area are very limited. Typical Basin and Range structure, with the development of horsts and grabens, is present in the area, with the Grassland occupying a graben between mountain ranges. This faulting may have compromised structural traps present. High subsurface heat regimes may also be present, as indicated by the quantity of volcanic rock present on the surface in the general area and its proximity to the trace of the Yellowstone hot spot.

A confidence rating of C-2 is given for the Curlew National Grassland because of the near lack of exploratory drill holes in the area.

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