3.0 DESCRIPTION OF MINERAL RESOURCES

Categorization of mineral resources as "locatable," "leaseable," or "saleable" is based upon provisions of the Act of May 10, 1872, otherwise known as the General Mining Law of 1872. The General Mining Law of 1872 declared "all valuable mineral deposits in lands belonging to the United States……to be free and open to exploration and purchase." The federal regulations further defined a "locatable mineral" or a "valuable mineral" as being whatever is recognized as a mineral by the standard authorities, whether metallic or other substance, when found in public lands in quantity and quality sufficient to render the lands valuable on account thereof.

Whether or not a particular mineral deposit is locatable depends on such factors as quality, quantity, mineability, demand, and marketability. Over time, the number of locatable minerals originally authorized by the General Mining Law of 1872 has been substantially reduced by several subsequent acts, with two of the primary acts being:

- the Mineral Leasing Act of 1920, as amended; and
- the Materials Act of July 31, 1947, as amended.

The Mineral Leasing Act of 1920, as amended, authorized that deposits of oil, gas, coal, potassium, sodium, phosphate, oil shale, native asphalt, solid and semi-solid bitumen and bituminous rock, including oil-impregnated rock or sands from which oil is recoverable only by special treatment after the deposit is mined or quarried, and the deposits of sulfur in Louisiana and New Mexico may be acquired only through a mineral leasing system.

The Materials Act of July 31, 1947, as amended by the Act of July 23, 1955, further excluded common varieties of sand, stone, gravel, pumice, pumicite, cinders and clay. However, uncommon varieties of sand, stone, gravel, pumice, pumicite, cinders, and clay remained as locatable minerals. Those minerals considered non-locatable generally have a normal quality and a value for ordinary use, and include ordinary deposits of clay, limestone, fill material (e.g., sand and gravel) (Maley, 1977).

The mineral resource potential for non-fluid minerals within the RMPPA also has been evaluated in detail. A wide range of non-fluid minerals is present within the RMPPA including leaseable, locatable, and saleable minerals.

In general, it can be stated that those non-fluid minerals of greatest economic significance within the RMPPA are aggregates and decorative stone. While a number of other non-fluid mineral commodities are known to be present within the RMPPA, virtually all other mineral types and occurrences are of sub-economic classification and, as such, are unlikely to be considered for development or exploitation within the projected planning period.

Aggregate occurrences are present throughout the RMPPA, and are subject to increasing consumptive demand as a result of increasing oil and gas development. This can generally be attributed to aggregate materials being utilized as roadway sub-base, base, and surfacing, with the increased demand being a result of the expanding infrastructure (i.e., collector, local, and resource roads) necessary to support the oil and gas industry. Similarly, decorative stone deposits that occur in localized areas within the RMPPA are being subjected to increasing demand for architectural and landscaping applications.

3.1 Leaseable Minerals

Leaseable minerals are governed by the Mineral Leasing Act of 1920. The Mineral Leasing Act of 1920, as amended, authorized that specific minerals no longer be locatable; but instead shall be disposed of through a leasing system. Minerals designated as leaseable under this law include:

- oil and gas;
- coal;
- native asphalt, solid and semisolid bitumen and bituminous rock including oil-impregnated rock or sands from which oil is recoverable only by special treatment after the deposit is mined;
- phosphate;
- sulfur (in the states of Louisiana and New Mexico); and
- chlorides, sulfates, carbonates, borates, silicates, or nitrates of potassium and sodium.

By far, the most significant leaseable minerals known to be present within the RMPPA are oil and gas (to include conventional natural gas and CBM), although other leaseable minerals are present to a significantly lesser degree. These other leaseable minerals include coal, oil shale, phosphate, and sodium brine (also referred to as black trona water).

3.1.1 Non-Coalbed Hydrocarbons

3.1.1.1 Origin, Occurrence, and Trapping

Origin of Petroleum

Crude oil and non-CBM gas are composed chiefly of hydrocarbon compounds and are primarily found in sedimentary rocks. The prevailing theory of the origin of petroleum hydrocarbons is that they are derived from organic matter of microscopic plants and animals. This is substantiated by the fact that the largest petroleum accumulations occur in sedimentary basins with widespread organic debris and that petroleum hydrocarbons have been found closely associated with organic matter. The organic matter accumulates in deposits that eventually become source rocks for petroleum. Source rocks are generally derived from organic-rich sediments that are deposited in sedimentary basins. Potential source rocks are subjected to increasing temperature and pressure as they become buried by other sediments and basin subsidence. Given high enough temperature and pressure, precursor petroleum compounds begin to form from the organic material in the rock. With increasing temperature and pressure, these organic compounds are thermally altered to form petroleum and natural gas. Hydrocarbons formed in this manner are termed thermogenic (Wiese and Kvenvolden, 1993). The hydrocarbons mobilize and may migrate away from the source rocks into more porous and permeable rocks called reservoir rocks. Methane, a large component of natural gas, also can be formed from the decomposition of organic material in the absence of oxygen. This type of methane is termed biogenic and is found in the earth at temperatures below about 200° Fahrenheit.

Four essential physical elements of a petroleum reservoir are reservoir rock, connected pore spaces that are able to store hydrocarbons, the presence of hydrocarbon fluids or gases in the connected pore space that can be moved through the rock, and a trap that prevents the further migration of hydrocarbons (Levorson, 1967).

Both source and reservoir rocks are widespread throughout the RMPPA as evidenced by the oil and gas fields discovered to date and the evidence of hydrocarbons in much of the stratigraphic section of rocks found in the area. Important source rocks are the Phosphoria Formation and Cretaceous shales.

Another element of a hydrocarbon reservoir can be stated in the following manner: A reservoir is "a rock from which oil or gas can be produced at a profit" (Berg, 1986). This definition is important because, in the history of petroleum exploration, known hydrocarbon-bearing strata have been bypassed or dismissed because either it was technologically or economically infeasible to produce them. Later, such strata may invite renewed interest because of either more favorable commodity prices, changes in technology, or the existence of a transportation infrastructure (natural gas pipelines). Development of natural gas resources in the RMPPA in the last decade is an example of the aforementioned principle in action.

Trapping Mechanisms

The fourth fundamental element of a petroleum reservoir is the trap. Water is the dominant subsurface fluid and hydrocarbons are lighter than water. Therefore, the tendency is for hydrocarbons to migrate vertically through the subsurface. Because of this tendency for vertical movement, any physical feature that impedes that movement will create a trap. There are three basic types of traps: structural traps, stratigraphic traps, and combination traps (Levorson, 1967). **Figure 3-1** portrays the most common trap types.

One type of structural trap is formed as a result of the folding of reservoir strata. Hydrocarbons migrate into the reservoir and are held there by less permeable rock on top of the reservoir. Anticlines are a common form of structural trap. Exposed structures are readily apparent and have received the earliest and most extensive exploration effort. Buried, or subsurface structures are more difficult to locate, requiring detailed geophysical and geologic analysis.

Another common form of structural trap forms when a reservoir is sealed by movement of a fault that places less permeable strata opposite the reservoir or the fault itself is the sealing agent. This presumes that the strata over the reservoir will not allow the hydrocarbons to escape. Anticlinal structures, possibly modified to some extent by faulting, are common traps in the RMPPA.

Another type of trap is the stratigraphic trap, which forms as a result of a lateral change in the physical characteristics of the reservoir or a change in the continuity of the rocks (Levorson, 1967). No matter what has caused the change in physical characteristic or change in continuity, ultimately it is the change of permeability that traps the hydrocarbons. Changes in permeability occur as a result of the complexity of the original depositional environment such as stream deposits or unconformities, which may result in the truncation of permeable strata with subsequent deposition of an overlying impermeable deposit. A change in permeability also may result from later alteration (diagenesis) that causes a reduction in pore sizes that decreases the potential flow paths through the reservoir to form a barrier to petroleum migration. Stratigraphic traps are not apparent at the surface as in the case of the surface anticlines, but in special cases may be indicated by geophysical data. The discovery of stratigraphic traps often depends upon detailed mapping of the subsurface using information derived from previously drilled wells to look for potential discontinuities or changes in rock types that may create traps. Under special conditions, modern geophysical methods also have the ability to identify changes in rock type that may be indicative of potential stratigraphic traps at depth.

Figure **3-1** Trap Types

Combination and Unconventional Traps

Many traps are not strictly structural or stratigraphic, but have elements common to both. There are all gradations of traps and often it is difficult to precisely determine the primary trapping mechanism.

Unconventional traps are those traps that do not fit into the classification scheme for conventional traps. Types of unconventional traps include fractured reservoirs, coal seams, and basin-centered gas accumulations. An unconventional trap with implications to the RMPPA is the basin-centered or continuous accumulation of natural gas (**Figure 3-1**). In the basin-centered model, there is no obvious seal or permeability barrier and the traditional concepts of structural and stratigraphic trapping are of lesser importance (Law, 1995). Instead of a continuous seal, hydrocarbons are trapped in widespread low-permeability reservoirs. Other attributes of basin-centered accumulations of gas include the following: the accumulations cover large areas of the deepest parts of basins, there is no gas-water contact below the accumulation, there is little or no water production, abnormal pressures are present (higher or lower than expected gradient), the gas is the pressuring agent, the gas originates from immediately adjacent rocks, and the gas also is thermogenic in origin.

3.1.1.2 Non-CBM Hydrocarbon Development and Production

The RMPPA has a history of oil production for many decades. Since the 1920s, the area has produced over 201 million barrels of oil and 5.6 trillion cubic feet (TCF) of gas from a number of oil and gas fields (WOGCC, 2002a,b). A list of fields and cumulative production for the RMPPA is presented in **Table 3-1**. The following discussion summarizes the major producing areas in the RMPPA. Based on year 2001 production figures, 7 of Wyoming's top 25 gas-producing fields are within or partially within the RMPPA (WOGCC, 2002a). The fields and year 2001 production rank are as follows: Jonah (2), Fogarty Creek (3), Lake Ridge (6), Tip Top (16), La Barge (21), Hogsback (22), and Birch Creek (23). Jonah Field was the state's second largest oil producer in 2001. A detailed discussion of oil and gas exploration and development is in Appendix A, Oil and Gas Operations.

Before an oil or gas well is drilled, the WOGCC must approve an Application for Permit to Drill (APD). If the well will be drilled on federal lands, an APD must be approved by the BLM. Historically, federal APDs have been 85 percent of the total number of applications filed in the RMPPA. Not every approved APD is actually drilled. In the RMPPA, 72 percent of the approved federal applications and 65 percent of the approved non-federal applications have actually been drilled. **Figure 3-2** illustrates the annual total of new wells drilled since 1970. This figure does not

Table 3-1
Oil and Gas Fields and Cumulative Production in the RMPPA[1]

Fields/Unit	Township/Range	Discovery Date	Number of Wells	Total Oil	Total Gas (MCF)	Remarks
Bald Mountain	31N-114W	1975	0	0	1,479	ABD 1981
Big Piney	28, 29N-113W	1964	179	6,752,461	190,996,175	
Big Piney P Sands	28N-114W	1938		2,659,892	13,542,244	
Big Piney Shallow	29N-113W	1938		56,801	28,102,407	
Birch Creek	27N-113W	1957	116	90,000,836	306,340,582	
Bird Canyon	27N-112W	1971	96	187,689	101,965,847	
Black Butte	37N-110W	1986	0	0	0	SI 1984
Buckhorn Canyon	25N-111W	1980	2	19,491	867,454	
Chimney Butte	28-29N-112-113W	1958	28	170,673	73,243,217	
Deer Hill	29N,30N-113W	1969	1	15,487	3,096,416	
Dry Piney	27,28N-114W	1957	17	15,199,160	89,727,224	
Figure Four Canyon	27N-112W	1959	17	7,224	24,091,157	
Fogarty Creek	28N-114W	1976	20	67,394	2,259,775,422	
Fontenelle	26N-112W	1974	243	439,237	218,187,098	
Goat Hill	30-31N-113-114W	1962	0	0	9,259,364	SI 1999
Graphite	27N-114W	1986	0	0	7,686,494	SI 1992
Green River Bend	26-27N-112-113W	1958	194	12,777,834	247,980,178	
Hogsback	26-27N-113-114W	1955	99	8,791,895	453,364,056	
Hogsback South	26-27N-113-114W	1984	34	313,518	60,023,053	
Isenhour	29N-112W	1983	0	601,815	1,138,209	SI 1994
Jonah	28N-108W	1977	384	5,723,773	543,082,565	
LaBarge	26-27N-113W	1925	415	29,447,095	510,599,744	
Lake Ridge	43N-91-92W	1981	5	0	87,657,602	
Lincoln Road	24N-111W	1977	110	3,872,146	196,155,961	
Little Monument	25N-111W	1983	31	23,321	19,534,474	
Long Island	28-29-30N-112W-113W	1961	1	855,915	1,760,250	
Maki Creek	33N-114W	1980	1	7,350	494,726	
Mason	31N-113W	1988	2	4,886	467,490	
McDonald Draw	28N-112W	1960	14	9,160,064	36,422,740	
Merna	36N-112W	1966	0	0	5,567	ABD 1978
Mesa Unit	32N-109W	1981	2	62,556	7,009,836	
Mickelson Creek	32N-114W	1960	14	195,510	6,983,159	
Monument Butte	26N-110W	1978	13	559,481	28,245,490	
Ote Creek	33N-114W	1976	0	8,864	283,602	SI 1993
Pinedale Anticline	30-31-32N-108-109W	1955	15	204,518	22,885,152	
Riley Ridge	29N-114W	1980	0	0	12,919	SI 1991
Ruben	30N-113W	1969	2	6,393,531	5,474,788	
Saddle Ridge	27-28N-113W	1962	11	2,869,867	9,765,007	
Soda	32N-115W	1982	2	9,675	177,072	
Spur Creek	26N-112W	1969	1	22,859	1,034,916	
Star Corral	30N-112W	1961	17	2,423,768	21,926,790	
Stead Canyon	26N-112W	1964	37	283,783	26,716,774	
Swan	25N-110W	1970	5	982,858	38,149,786	
Total				**201,173,227**	**5,654,234,486**	

[1] As of February 2002, WOGCC cumulative production figures do not give proportions of non-hydrocarbon gases produced.

Source: WOGCC (2002a,b).

Figure **3-2** Number of New Wells Drilled, by Year, in the RMPPA Since 1970 include workovers (i.e., maintenance operations), recompletions, or wells that were re-entered and deepened. Records indicate that before 1970 only 123 wells had been drilled. An appreciable increase in the number of wells drilled since 1992 has occurred. Much of this increased drilling activity was due to development of the Jonah Field, which began in earnest in 1997, and increased drilling around the Pinedale Anticline beginning in 2000.

As new wells are drilled and completed, wells are being plugged and abandoned. The great majority of these are wells, which are either unproductive (dry holes), or have become depleted and are no longer economic. Since 1990, approximately one well was plugged and abandoned for every four wells that were drilled.

The numbers of federal, fee, and state oil and gas wells drilled since 1950 are shown graphically in **Figure 3-3**. The available data indicate 428 wells were drilled in the RMPPA before 1950 (WOGCC, 2002a; IHS Energy Group, 2002). Eighty-four percent of the wells drilled since 1950 have been on federal leases.

Figures 3-4 and **3-5** show the results of new field wildcat wells and development wells drilled since 1970. In addition to wells shown graphically in **Figures 3-4** and **3-5**, 98 other wildcat wells of various types, and 107 service wells were drilled. The results of all wells drilled from 1970 to 2001 are summarized in **Table 3-2**.

Table 3-2
Summary of Wells Drilled in the RMPPA from 1970 to 2001

Well Class	Dry	Successful	Total	Success Rate
New Field Wildcat Wells	143	60	203	30%
Other Wildcat Wells	28	70	98	71%
Development Wells	115	1,933	2,048	94%
Service Wells	9	98	107	92%

Sources: WOGCC (2002a) and IHS Energy Group (2002).

Figure 3-6 shows the relative depths of wells drilled since 1990. The average TD of wells in the RMPPA has increased from 6,500 feet in 1990 to 10,200 feet in 2001 (IHS Energy Group, 2002). This reflects the greater drilling depths in the Jonah and Pinedale Anticline areas. The drilling depths can be categorized into three ranges; 2,000 to 4,000 feet, 7,000 to 9,000 feet, and 10,000 to 14,000 feet.

Figure **3-3** Wells Drilled in the RMPPA from 1950 to 2001

Figure **3-4** New Field Wildcat Wells in the RMPPA from 1970 to 2001

Figure **3-5** Development Wells Drilled in the RMPPA from 1970 to 2001

Figure **3-6** Well Depth Distribution for Wells Drilled in the RMPPA Since 1990

Within the RMPPA boundary, 3,722 wells in five categories are present (**Table 3-3**). To date, 88 percent of all wells have been drilled on federal lands, with the other 12 percent drilled on fee or state lands. Forty-one percent of all wells have been abandoned. Wells have been abandoned for the following reasons:

- no hydrocarbons were encountered in economically producible quantities;
- the wells initially were capable of producing hydrocarbons, but they became infeasible to produce at a later date; and
- mechanical difficulties within a wellbore prevented economic hydrocarbon production.

Table 3-3
Pinedale RMPPA Well Status as of April 1, 2002

Well Status	Federal	Fee or State	Total
Plugged and Abandoned	1,361	166	1,527
Dormant	100	3	103
Completed	1,705	258	1,963
Notices of Abandonment	19	3	22
Drilling	79	28	107
Total Wells	3,264	458	3,722

Source: WOGCC (2002a).

Figure 3-7 shows locations of all wells drilled in the RMPPA. For this map, wells were divided into two categories; active and abandoned. This map shows that drilling activity has been concentrated in three regions. The first region is in the Greater Big Piney – La Barge area, which has had the most activity. It is located in the southwestern part of the RMPPA and extends northward. The second area is the Jonah Field area, centered on T29N and R108W. In recent years, high levels of activity have occurred in the Jonah Field area and to the north of the Jonah Field in the third area, called the Pinedale Anticline. Outside these areas, little exploratory drilling and development activity has occurred. Many townships have not been tested with even one well.

Figure 3-8 illustrates RMPPA annual production of non-coalbed gas since 1974. Production was flat during the 1970s and early 1980s. However, production has increased steadily starting in 1985. Ninety percent of gas produced is from federal minerals. The abrupt six-fold increase in 1986 was due to start up of the Shute Creek gas plant. This plant processes gas from 21 deep wells (15,000 to 16,000 feet), which produce high volume, poor quality gas from the Madison

Figure **3-7** Wells Drilled for Oil and Gas

Figure **3-8** Yearly Total Non-coalbed Gas Production, Production from Federal and Non-federal Lands, and Production Without Madison Limestone Production in the RMPPA

Limestone. This gas only contains about 24 percent methane. However, it also contains about 0.6 percent helium. Yearly gas production from these deep wells has remained relatively steady since 1986.

Since 1990 gas production, excluding the Madison Limestone, has increased at a nominal rate of 4.5 percent per-year. Wells in the RMPPA produce at an average rate of 410,000 cubic feet of gas per day (IHS Energy Group, 2002). This rate has increased steadily since 1996. Gas production from the RMPPA is presently 27 percent of total Wyoming gas production. Non-federal gas production has been flat, with a slight increase in 1986 and flat rate after that. Again, the slight increase in 1986 was as a result of the Shute Creek gas plant start-up.

Oil production (**Figure 3-9**) in the RMPPA is relatively minor compared to gas production. Federal mineral lands account for 93 percent of the oil produced. Although production has increased sharply since 1994, it is only 4.7 percent of the state's total oil production. Most of the increase in production shown in **Figure 3-9** is due to condensate produced in association with gas from the prolific Jonah Field.

Producing oil and gas wells in the RMPPA have increased steadily since 1974 (**Figure 3-10**). Eighty-five percent of the producing wells are federal. Average well depths have increased from 6,381 feet for wells drilled in 1980-1990 to 10,143 for wells drilled in 2001.

The following sections summarize the historical development in the major producing areas in the RMPPA. In addition, there are discussions on deep wells (wells deeper than 15,000 feet), secondary and tertiary recovery units, pipelines and processing infrastructure, and federal units.

Big Piney – La Barge Area

In the region encompassed by the RMPPA, commercial oil and gas development began in the Big Piney – La Barge area. Oil seeps were discovered in the Big Piney – La Barge area in 1907 (Dunnewald, 1969). In the early 20th century, attempts at finding commercial quantities of oil and gas were unsuccessful until the discovery of the La Barge Field in 1924, which initially produced oil from shallow lower Tertiary reservoirs. The first significant gas was encountered in 1938 when a well drilling in Tertiary rocks at a depth of about 1,700 feet "blew out" (i.e., uncontrolled flow to the surface) at a rate of between 22 to 77 million cubic feet of gas per day (MMCFGPD). Development continued in the area from the 1930s until after World War II, but it occurred in the deeper Frontier Formation. In the 1950s and 1960s, deeper production from the lower Cretaceous Bear River and the Nugget Sandstone was developed (Shipp and Dunnewald, 1962).

Figure **3-9** Yearly Total Oil Production and Production from Federal and Non-federal Wells in the RMPPA

Figure **3-10** Yearly Total Producing Wells and Federal and Non-federal Producing Wells in the RMPPA

In 1962, Mobil drilled the deepest well on the platform up to that time (over 15,000 feet deep) to Cambrian Limestone. Numerous zones below the Cretaceous were tested in the well, but it was found that much of the gas was non-methane, mostly carbon dioxide. The Madison Limestone had the greatest potential resource. It was not until 1986 that Exxon Corporation began to develop carbon dioxide resources with the construction of a facility to process methane, carbon dioxide, nitrogen, helium, and hydrogen sulfide (DeBruin, 2001).

The Madison Limestone produces gas from a thick, extensive section of carbonate sediments. It averages 850 feet thick on the crest of the La Barge Platform and contains an alternating sequence of dolomite and limestone with dolomite as the dominant rock type (Stilwell, 1989). The Madison appears to be productive over an area of about 21 miles by 65 miles. **Figure 3-11** shows the approximate outline of the potential Madison Limestone Reservoir and its relation to the RMPPA boundary. It is a structural trap that appears to have some stratigraphic implications (Stilwell, 1989). Approximately 71 percent of this trap lies within RMPPA boundaries.

The traps along the La Barge Platform are a combination of structural and stratigraphic traps. The La Barge Platform is essentially a large anticline. Much of the tertiary production comes from stratigraphic traps. Reservoirs in the Tertiary Almy (or Fort Union Formation) “pinch out” (i.e., end of a stratum) against the La Barge structure (Dunnewald, 1969). Hydrocarbons are produced from Cretaceous reservoirs from complex folded and faulted traps. The geology is further complicated by the Darby Thrust Fault, which has overridden the La Barge Platform from the west (Shipp and Dunnewald, 1962). The deeper Madison reservoir is largely an anticlinal structural trap that is below the Darby Thrust.

There are a number of fields in the Big Piney – La Barge vicinity that have coalesced into one large producing area. To date, these fields (which may lie partially outside of the RMPPA) have produced most of the oil and gas in the RMPPA. Production of carbon dioxide by the end of 2001 was 3.17 TCF of gas (IHS Energy Group, 2002). The primary market for the carbon dioxide is for use in oil production operations to enhance recovery of oil.

Pinedale Anticline Field

The Pinedale Anticline, located in the northeastern portion of the RMPPA, is 35 miles long and 6 miles wide. The California Company first drilled the structure in 1939; the “wildcat test” (i.e., a well drilled in an area or stratum with no previously established production) was drilled to a depth of about 10,000 feet (Law and Spencer, 1989). The well was drilled on the basis of reflection seismic geophysical work conducted in by the California Company (Chevron) in 1936 (Berg, 2002). The seismic survey was the second geophysical survey conducted for hydrocarbon

Figure **3-11** Deep Reservoir Potential, Deep Wells, and Location of Deep Madison Limestone Reservoir exploration in Wyoming. No commercial production was established at that time. In the 1950s, El Paso Natural Gas Company (EPNG) drilled a number of wells on the anticline. One of wells, the EPNG Wagon Wheel No. 1, was drilled to a TD of 19,000 feet and reached TD in the Baxter Shale (Law and Spencer, 1989). Up until 1989, 20 wells had been drilled on the anticline and production was hampered by the low permeability reservoirs and hydraulic fracturing used to stimulate the wells had not provided the expected results. By the early 1990s, industry operators began to understand that previous well fracturing and treatment techniques were actually reducing productivity of the reservoirs (BLM, 1999). New treatments at Jonah Field (adjacent to the anticline) spurred operators to redesign well treatment and stimulation at the anticline. The sandstones have low permeability because of high clay content. The older completion methods were actually reducing permeability by injecting fluids that reacted with the clays.

As of February 2002, there were 21 active producing wells and 12 shut-in wells on the anticline (WOGCC, 2002a). Spacing in the anticline area is 40 acres per well. Since the end of 2000, the cumulative production nearly doubled from slightly over 12 billion cubic feet (BCF) of gas to 22.9 BCF at the end of February 2002. Until 1995, production from the field came from the lower Tertiary Fort Union Formation. In 1995, production came on-line from the upper Cretaceous Lance Formation and in October 2000, gas was initially produced from the Mesaverde Group. Although production from the Fort Union actually declined from a peak in the year 2000, the added incremental production from the Lance Formation and the Mesaverde Group was a significant addition to production from the field.

Jonah Field

The first well in the Jonah Field area was the Wardell Federal Unit #1 (Section 9, T28N, R108W) drilled by Davis Oil Company in 1975 (Robinson, 2000). The well was drilled to a TD of 11,324 feet. Drill stem tests indicated that gas was present in low-permeability sandstones in the Lance Formation. The well was completed and fracture stimulated and flowed gas at rates that were not commercial. Because of the low-flow rates and absence of a pipeline connection, the well was “shut-in” (i.e., production temporarily ceased). The WOGCC assigned the name Jonah Field in 1977 although there was no active production.

The successor to Davis Oil Company was Home Petroleum Corporation (HPC). HPC drilled another well in the area in 1986, the Jonah Federal 1-4 (Section 4, T28N, R108W) (Robinson, 2000). Based upon good shows (i.e., evidence) of gas during drilling, casing was set. Well problems prevented testing of the entire interval that was drilled, but test results encouraged HPC to drill a second well, but it also had marginal production. Eventually lease rights were purchased by McMurry Oil Company (McMurry) in 1991. McMurry tested the 1-4 well and the flow rates were better than when it was originally tested in 1986. The operator suspected that the original fracture stimulations had actually impeded the flow of gas into the wells. McMurry then drilled the Jonah Federal 1-5 (Section 5, T28N, R108W) in order to employ better drilling and completion techniques in an effort to increase productivity. The results were successful and in March 1993, the well had a stabilized flow rate of 3.7 MMCFGPD and 40 barrels of oil per day after a week production testing (Robinson, 2000).

Initially, it was thought that the Jonah Field was essentially a basin-centered gas accumulation. However, step-out wells on the south side of the unit and geophysical data indicated that there was an element of fault trapping to the field (Robinson, 2000; Warner, 2000). The field is bounded on the south and west by arcuate faults defined by three-dimensional (3-D) geophysical seismic surveys. Jonah Field is essentially a fault-bounded pressure compartment in that over-pressuring occurs at depths that are 3,000 feet less than areas outside of the bounding faults. In addition to the bounding faults, the producing sandstones in the field area may be of limited extent and there are fault compartments in the area inside of the bounding faults, further adding to the complexity and reservoir heterogeneity of the field.

As of November 2002, 435 wells had been completed in the Jonah Field, 416 of those were on Federal lands (WOGCC, 2002a). Of the total number of completed wells, there are about 430 active producers and 5 plugged and abandoned wells. Cumulative production as of November 2002 was 645 BCF of gas, 7.3 million barrels of oil, and 2.2 million barrels of water. Ultimate recovery from the field is estimated to be 1.5 TCF of gas based on 40-acre well spacing (Robinson, 2000), but could be as high as 3.0 TCF (DeBruin, 2002). Additional significant reserves of gas may be present in untested zones on the field.

Deep Wells

Deep wells are those wells that have been drilled to depths greater than 15,000 feet (Dyman and others, 1990). Deep wells drilled in the RMPPA are shown on **Figure 3-11**. Information relating to these wells is presented in **Table 3-4**. Forty-six deep wells have been completed. The deepest well drilled was the Wagon Wheel No. 1, which was drilled to a TD of 19,000 feet on the Pinedale Anticline Field.

Thirty-five of the 46 wells (76 percent) were originally completed as gas wells. Twenty-five of those 35 wells (71 percent) produce from zones deeper than 15,000 feet. All production in these deep wells has been from the Madison Limestone. No deep wells produce oil (IHS Energy Group, 2002).

Table **3-4** Summary of Data for all Deep Wells (>15,000 Feet) Drilled in RMPPA page 2

La Barge Platform

Most of the 33 deep wells are concentrated in the Fogarty Creek, Lake Ridge, Riley Ridge, Tip Top, Graphite, and Hogback III fields that lie on the crest of the La Barge Platform in the southwestern part of the RMPPA. Most of these wells were drilled to test the Madison Limestone.

Other Deep Wells

Other deep wells are widely scattered across the RMPPA. The first deep test was the Unit No. 1 completed by Phillips Petroleum Company to a TD of 16,531 feet in 1956. Upper Cretaceous sediments were tested below 15,000 feet, but only small quantities of gas were recovered and the well was abandoned. An additional 12 wells have been drilled; however, only one was completed as a producer at a depth of more than 15,000 feet. The Unit No. 5 and Wagon Wheel No. 1 were completed as productive wells in zones less than 15,000 feet.

The Cutlass Unit No. 1 was completed in 1981 as the only deep producing well outside of the Big Piney – La Barge area. It was completed in the Lower Cretaceous Frontier Formation in a 16,538-to 16,779-foot interval. Tests indicated that it could produce with an initial potential of 1.67 million cubic feet of gas per day, but this well never produced to a pipeline and was abandoned in 1988.

Outside of the La Barge Platform area, the exploration targets have been cretaceous sandstones. Tests of the upper Cretaceous section down to the Frontier Formation (the lowest part of the upper Cretaceous) have indicated the presence of gas in these deep intervals and the potential for the discovery of economically recoverable reservoirs in the future.

Secondary and Tertiary Recovery Projects

Primary production is characterized by initial stages of reservoir production whereby the hydrocarbons can be fairly easily moved to the wellbore either by the natural forces in the reservoir or through artificial lift (pumping). Primary recovery sometimes only recovers a fraction of the hydrocarbons originally in place in the reservoir. In order to more efficiently extract the oil as the reservoir energy is depleted, often oil and gas operators conduct secondary recovery operations (Baars and others, 1993). Secondary recovery involves the injection of water, gas, or steam to help push the oil to production wells. Beyond secondary recovery, there are tertiary recovery methods that often involve the injection of miscible fluids to combine with the oil to try to move the oil to production wells. However, a point is reached at which additional oil cannot be recovered under existing technologies. There are a number of secondary and tertiary recovery projects in the RMPPA and they are listed on **Table 3-5**.

Table **3-5** Secondary and Tertiary Recovery Units in the RMPPA

Pipelines, Natural Gas Storage, Natural Gas Processing

There is an extensive system for gas processing and transportation within the RMPPA as would be expected with the level of production. There are several gas gathering systems within the production areas that connect with gas transmission pipelines. Associated with the gas gathering pipelines are compressor and gas processing facilities. Compressors are used to move the gas through the pipelines and the processing facilities are used to remove liquid hydrocarbons (condensate and natural gas liquids) and excess water. There are a number of gathering systems in the Big Piney – La Barge area (DeBruin, 2002). In addition to the gathering systems, there is a 200 MMCFGPD compression facility at Big Piney and several smaller compressor stations in the Big Piney – La Barge area and at the Jonah Field.

In the northeastern portion of the RMPPA, there are gathering systems for the Pinedale and Jonah Fields. Gas from Pinedale Anticline and Jonah is placed into pipelines that tie into facilities in the Big Piney – La Barge area. Gas from Jonah Field originally tied into the gathering system at the Pinedale Anticline through a 4.5-inch-diameter pipeline, but by 1996 production in the field exceeded the capacity of the line and a new 8-inch-diameter pipeline was constructed that moved gas directly to the La Barge area (Robinson, 2000). There are no gas gathering pipelines into the northern part of the RMPPA despite some small fields that have been discovered over the years in the area (e.g., Merna and Black Butte)

Exxon/Mobil operates a 28-inch-diameter pipeline to move carbon dioxide-rich gas from the Lake Ridge and Fogarty Creek Fields. The gas is treated at Exxon/Mobil's Shute Creek Gas Plant (located 25 miles south of La Barge, Wyoming and outside of the RMPPA) where the gas stream is processed to remove hydrogen sulfide and methane. The Shute Creek Plant processes about 435 MMCFGPD (DeBruin, 2001). The carbon dioxide is then transported via pipeline to Baroil in northeastern Carbon County, Wyoming and to northwestern Colorado at Rangley. The carbon dioxide is used for enhanced oil recovery at oil fields in those locations.

The WOGCC (2002a) lists one gas storage project in the RMPPA at the Chimney Buttes Field north of La Barge. The facility was approved to store gas in the lower Tertiary Almy "P" Sandstone and is operated by FMC Corporation.

Federal Units

Forty active federal unit agreement areas lie within or partially within the RMPPA boundaries (**Figure 3-12**). See Appendix A for a detailed discussion of federal units. Federal units in the RMPPA cover an area of 358,499 acres, or about 12 percent of the area. Companies operating

Figure **3-12** Federal Unit Agreement Areas these units include EOG Resources, Inc., Exxon/Mobil Production Company, Ultra Resources, Inc., Shell Rocky Mountain Production, BP America Production Company, Questar Exploration and Production Company, ChevronTexaco, Herbaly Petroleum Corp., XTO Energy, Inc., Griggs Oil, Inc., Wold Oil Properties, Inc., Alpine Gas Company, Kerr-McGee Rocky Mountain Corporation, Burlington Resources, and EnCana Energy.

Most of the older units are located in the Greater Big Piney – La Barge area in the southwestern portion of the RMPPA. These units are generally at a mature stage of development. In recent years, many new exploratory units have been proposed and approved to the northwest and southeast of the Jonah Field. The approximate center of the Jonah Field is T29N, R108W. These newer units are in early stages of exploratory activity.

3.1.2 Coalbed Methane

The presence of methane in coal seams has long been recognized as a potential hazard in the mining of coal (Diamond, 1993). The extraction of methane from coal was originally practiced to provide a margin of safety for coal mining by removing as much methane as possible prior to mining. It was recognized that there was a potential significant gas resource in coals. In the early 1980s, Congress considered CBM as an “unconventional” gas resource and enacted tax incentives for the production of gas from coal seams. The tax incentives were extended, but eventually expired in 1991. The tax incentive spurred industry to develop technologies to produce the resource and major coalbed producing areas resulted in the Black Warrior Basin of Alabama and the San Juan Basin in southwestern Colorado and northwestern New Mexico (Rice and others, 1993).

CBM occurs as a result of the process that turns plant material into coal (DeBruin and others, 2001). The process of turning peat and other plant material into coal is called coalification. As accumulated plant material is buried and subjected to increasing temperature and pressure, it is transformed into varying ranks of coal. The coal rank is reflective of the amount of burial and, therefore, temperature and pressure that a coal has been subjected. The gas in the coal can either be biogenic and thermogenic, depending on the particular circumstances of the burial history of a coal seam. In addition to methane, other gases generated in the coalification process are nitrogen and carbon dioxide. The nitrogen and carbon dioxide are generated under thermogenic conditions. Other heavier hydrocarbon gases may be generated depending on the organic materials in a particular coal deposit (Rice and others, 1993).

The methane generated in the coalification process can be stored in several ways: as free gas in tiny pores and fractures in the coal, as a dissolved phase in interstitial water in the coal, or is adsorbed on to the surface of the coal. Because most coals have abundant microfractures, or cleat, there is a large amount of surface area on which gas can be adsorbed. This feature of gas storage allows coals to store a much higher volume of gas than conventional gas reservoirs (Rice and others, 1993).

In order to extract the gas from the coal, it is necessary to lower the hydrostatic pressure in the coal. Lowering the pressure is accomplished by producing the water that is in the coal. Extraction of the gas often involves the pumping of large amounts of water in the initial stages of development. **Figure 3-13** shows a production profile for a typical CBM well showing relative production rates of gas and water production over time. According to Rice and others (1993) as much as 6,000 barrels of water per day have initially been produced from a single well, but once wells reach economic production, water production rates can be substantially lower. Water quality can range from less than 200 milligrams per liter (mg/l) of total dissolved solids to exceeding 90,000 mg/l (Rice and others, 1993). Water quality may be better if the coal seams are closer to the surface, indicating potential recharge from meteoric water. Water disposal options, which are highly dependent on water quality and economics, can include discharge to the surface or subsurface injection into disposal wells or in aquifer recharge wells. Surface disposal options may require pre-treatment prior to disposal to meet discharge permit requirements. All disposal options require permits.

Coal deposits in the RMPPA are generally limited to the Mesaverde Formation. As discussed in Section 2.2.3.3, the Tertiary Fort Union Formation, a common coal-bearing formation, lacks abundant coal in this part of the Green River Basin. The coals in the Mesaverde are described in Section 3.1.3.1 in the discussion of the Green River Coal Region. Coals that are favorable for development of CBM are located in the Riley Ridge area in T28-30N and R114W.

Although no commercial quantities of CBM have been produced to date in the RMPPA, there are indications that CBM may be an important resource. In 1992, DeBruin and Jones (1992) indicated that coal from a drill hole in the Mesaverde Formation in the Riley Ridge area Section 30, T28N, R113W had methane values ranging from 434 to 539 cubic feet per ton (CFPT). The CFPT range compares to a gas content in Powder River Basin coals of 65 CFPT and a Greater Green River Basin average of 275 CFPT (DeBruin, 2001).

In 2000, Infinity Oil and Gas proposed a CBM project in the Riley Ridge area in T29-30N, R114W. To date, five wells have been drilled and have only recently begun to produce gas (Rocky Mountain Oil Journal, 2002).

Figure **3-13** Typical CBM Well Production Profile

3.1.3 Coal

Sub-bituminous coals are present along the westernmost portion of the RMPPA. In addition, the RMPPA is abutted to the west by a significant active mining area of the Hams Fork Coal Region (e.g., Kemmerer and Skull Point mines), and to the south by formerly active coal mining areas (e.g., the Rock Springs Coal Field).

Coal occurrences within the RMPPA are generally considered to be within the western part of the Green River Coal Region (**Figure 3-14**). In addition, portions of coal fields designated as being within the eastern part of the adjoining Hams Fork Coal Region also fall within the western portion of the RMPPA.

Coal is classified by rank, in accordance with standard specifications of the American Society for Testing Materials (ASTM). Most of the Wyoming coals are of bituminous and sub-bituminous rank. The reader is referred to ASTM D-388 for detailed information regarding coal classification specifications and considerations. While it should be noted that there are minor variants on classification on the basis of certain physical properties, a brief synopsis of the classification system (in general decreasing order of rank) is as follows:

I. Anthracitic	
1. Meta-anthracite	
2. Anthracite	
3. Semi-anthracite	
II. Bituminous	
1. Low volatile bituminous	(> 78% but < 86 percent Fixed Carbon)
2. Medium volatile bituminous	(> 69% but < 78 percent Fixed Carbon)
3. High volatile “A” bituminous	(> 31% but < 69 percent Fixed Carbon)
4. High volatile “B” bituminous	(> 13,000 but < 14,000 Btu/lb1 moist)
5. High volatile “C” bituminous1	(> 11,000 but < 13,000 Btu/lb moist)
II. Sub-bituminous	
1. Sub-bituminous “A”2	(> 11,000 but < 13,000 Btu/lb moist)
2. Sub-bituminous “B”	(> 9,500 but < 11,000 Btu/lb moist)
3. Sub-bituminous “C”	(> 8,300 but < 9,500 Btu/lb moist)

[1]British thermal units per pound.
[2]Classification varies on the basis of agglomerating and/or weathering properties.

Figure **3-14** Wyoming Coalfields

Within the Green River Basin west of the Rock Springs Uplift, the coal-bearing rocks are covered by younger rocks, except for a few scattered outcrops along the western edge of the basin. It should be noted that the formation names used in the western part of the region differ from those used for the eastern part of the region; the nomenclature utilized in the following sections is that of the Hams Fork Coal Region.

3.1.3.1 Green River Coal Region

The only named coalfield located in the western portion of the Green River Basin is the La Barge Ridge Field (T26-28N, R113-114W), which occupies portions of Lincoln and Sublette Counties. It is bounded on the west by a major thrust fault. To the east, non-coal bearing Tertiary rocks overlie the coal-bearing rocks unconformably and restrict the area of coal occurrence to two small areas that cover a total of less than 25 square miles. The coal is probably in the Adaville Formation of the upper Cretaceous, a formation that is approximately 2,800 feet thick and composed of clay, shale, sandstone, and numerous beds of coal present throughout. The Adaville is equivalent to the Mesaverde Group. At several locations, as many as 7 to 10 coalbed outcrops are apparent, which range from 1 to 5 feet thick. The average coal thickness measured in 12 stratigraphic sections, in various parts of the field is 4.7 feet, with the maximum thickness being 8.3 feet. A partly concealed anticline trends northwest through the field and is the cause of dips that range from 20° to 50°. The coal is of sub-bituminous “B” rank. Analysis, on an as-received basis, shows coal quality parameters of 3.0 percent ash, 1.9 percent sulfur, and 9,640 Btu/lb (Berryhill and others, 1950).

A small area in the Fall River Basin also contains coal of mineable thickness. The Fall River Basin is in the extreme northwestern portion of the Green River Basin (T36-39N, R113-114W), which lies within Sublette County. The coal occurs at or near the surface in the Paleocene Evanston Formation. The Evanston is equivalent to the Fort Union Formation. This formation, which unconformably overlies older rocks, consists of about 9,500 feet of shale, clay, and sandstone, and several coal beds. In general, the coal is poorly exposed and ranges from sub-bituminous “B” to sub-bituminous “A” in rank. A 3.8-foot-thick bed of coal was historically mined in T39N, R114W.

In the vicinity of Riley Ridge (T28N-29N, R114W-115W), deep coal beds (approximately 2,500 to 3,400 feet deep) also are present within the Mesaverde Group. In this area, the Tertiary Wasatch Formation is approximately 800 feet thick, and overlies the approximately 1,700-feet-thick Fort Union Formation, the 900-feet-thick Mesaverde (coal-bearing) Group, and the non-coal bearing upper Cretaceous Baxter (Hilliard) Shale, which is encountered at a depth of about 3,400 feet (TRC-Mariah, 2000). Due to its extreme depth, this coal occurrence is considered sub-economic for purposes of coal extraction or mining, but it may be of potential interest for CBM development (see Sections 3.1.2 and 4.1.2).

3.1.3.2 Hams Fork Coal Region

The Hams Fork Coal Region is located in the extreme western part of Wyoming, west of the Green River Basin. It extends southward from southwestern Teton County into Lincoln County, western Sublette County, and the western half of Uinta County.

The coal-bearing formations exposed in the northern portion of the Hams Fork Region are (lowest to highest) the Bear River, Frontier, Adaville, and Evanston Formations. Non-coal bearing rocks include the Aspen Shale and Baxter Shale.

The structure of the Hams Fork Coal Region is somewhat complex and includes several northward-trending major folds and associated faults. As a result of these structural features, the coal-bearing rocks are exposed in long, narrow parallel belts.

In the northern part of the Hams Fork Coal Region, where these features are particularly noticeable, the ranges and fields have been named from west to east, as follows: Salt River Range, Greys River Coal Field, Wyoming Range, and McDougal Coal Field. Of these, the McDougal Coal Field is present along the northwestern portion of the RMPPA. A major fault, the Darby Fault, extends along the eastern side of the Wyoming Range and forms the western boundary of the McDougal Coal Field, which extends south-southeasterly (at depth) into the RMPPA (T29-34N, R114W).

The McDougal Coal Field, which is located immediately east of the Wyoming Range in Lincoln and Teton counties, includes coalbeds believed to belong to the Frontier Formation, but many of the outcrops are concealed. The coal has not been correlated with any coal zones to the south, partly because the only good horizon marker, the Oyster Ridge Sandstone Member, has not been observed in the area. A few widely-spaced sections, located in townships south of the Snake River, include coalbeds that range in thickness from 1.2 to 20.0 feet; but the majority of the coalbeds are less than 5 feet thick. No specific information is available for the area of complex structure located west of the Snake River, where the Frontier Formation occurs and is likely to be coal-bearing. A number of small mines have operated in the McDougal Field in three different coalbeds, which range from 2.5 to 8.3 feet in thickness (Berryhill and others, 1950).

The southern part of the Hams Fork Coal Region contains the Kemmerer Coal Field, which extends northward into the extreme southwestern portion of the RMPPA. While economic mineable coal is exploited in the Kemmerer Coal Field, areas of mining activity are geographically situated within the BLM's Rock Springs Planning Area. However, the delineated extent of the northern portion of the Kemmerer Coal Field is located within the RMPPA.

The Kemmerer Coal Field is underlain by a long narrow syncline, known as the Lazeart Syncline, which extends northward from near the southern border of Wyoming, into the general vicinity of Oyster Ridge and Commissary Ridge (T29N, R115W and R116W). Coal is found in both the Frontier and Adaville Formations. Most mining has been in the Kemmerer Coal Zone, the highest of three such zones in the Frontier Formation. The other coal zones are the Willow Creek (near the middle of the formation) and the Spring Valley (near the base of the formation).

Within the Frontier Formation, the Kemmerer Coal Zone is situated above the Oyster Ridge Sandstone Member. Mines in the immediate area of the Town of Kemmerer (which is outside the RMPPA) exploit the main Kemmerer coalbed, which ranges from 5 to 20 feet thick, dipping approximately 12° to 16° in a westerly direction. The thickness of coal has been measured at various locations within the area (extending from the south border of T15N, R118W northward into T26N, R116W), with most sections indicating beds greater than 3 feet in thickness with a few being more than 10 feet thick. Information as to the extent and exact stratigraphic location of the coalbeds is not available (Berryhill and others, 1950).

3.1.3.3 Historic Coal Production

There is no known current (or recent) coal mining activity within the RMPPA. The known historic coal production within the RMPPA occurred intermittently from 1929 to 1963, and was small-scale, typically resulting in the production of 1,000 tons per year or less. Produced coal was primarily utilized for domestic purposes.

There are approximately eight locations within the RMPPA that are known or believed to have been associated with historic small-scale underground coal mining. These former mines and/or prospects are all located within the La Barge Ridge Coal Field (**Table 3-6**).

Table 3-6
Former Mines or Prospects Within the La Barge Coal Field

Mine/Prospect	General Location
Twitchell Mine	SW¼ SE¼ Section 29, T27N, R113W (2 miles northwest of Calpet)
Salli Mine	Section 7, T26N, R113W (vicinity of Viola)
Unnamed Prospect	SE¼ NE¼ Section 32, T27N, R113W (2 miles west of Calpet)
Unnamed Prospect	NW¼ NW¼ of Section 5, T26N, R113W (2 miles southwest of Calpet)
Unnamed Prospect	SE¼ of Section 12, T28N, R113W (north of Cretaceous Mountain)
Unnamed Prospect	NE¼ of Section 12, T28N, R113W (Deloney Canyon, north of Cretaceous Mountain)
Unnamed Prospect	NW¼ of Section 1, T28N, R113W (north of Cretaceous Mountain)
Unnamed Prospect	Section 7, T28N, R113W (east of Cretaceous Mountain)

Reports indicate that the Salli Mine, near Viola, operated in a coal seam 6 feet thick or less, within the Adaville Formation. When operational (exact dates not indicated), it produced a locally used domestic coal. The coal was apparently of poor quality and slacked quickly when exposed to air (Hamilton, 1985).

Production data obtained from annual reports of the Wyoming State Inspector of Coal Mines for the period 1926-1999 indicate that annual coal production from Sublette County typically did not exceed 1,000 tons per year (Lyman and Hallber, 2000). No production is reported for the period 1926 through 1928; a total of 1,067 tons was reported for the 4-year period 1929 to 1932, inclusive; and mines were apparently idle again for the period 1933 through 1937. Production recommenced in 1938 and continued on a relatively consistent basis through 1963. It appears that there has been no coal production from Sublette County since 1963. [Note: Although portions of the RMPPA extend into Lincoln and Sweetwater Counties, coal production attributable to mines, if any, within the RMPPA incorporated into production totals for those areas is likely to be nominal, and cannot be readily separated from county production statistics.] Recorded annual production data for Sublette County is provided in **Table 3-7**.

Table 3-7
Annual Coal Production Data – Sublette County

Year	Coal Production (tons)	Year	Coal Production (tons)
1926	0	1945	0
1927	0	1946	0
1928	0	1947	800
1929	610	1948	668
1930	101	1949	997
1931	200	1950	1,797
1932	156	1951	1,128
1933	0	1952	1,016
1934	0	1953	1,000
1935	0	1954	942
1936	0	1955	610
1937	0	1956	235
1938	311	1957	372
1939	1,254	1958	920
1940	685	1959	983
1941	594	1960	0
1942	401	1961	0
1943	439	1962	125
1944	511	1963	284

Source: Lyman and Halliber (2000).

3.1.4 Oil Shale

The Eocene Green River Formation contains thin deposits of oil shale in the southern part of the RMPPA. In this area, there are three named members of the Green River Formation; the Fontenelle Tongue, Wilkins Peak, and Laney Shale. The richest oil shale beds are concentrated in the lower part of the Middle Tongue (Oriel, 1969). Numerous exposures of the Wilkins Peak Member can be observed along Muddy Creek near Facinelli Ranch, and in cliff exposures around the Fontenelle Reservoir and along the Green River near the Town of La Barge.

The lower Wilkins Peak Member is composed mainly of carbonate rock, consisting of oil shale and laminated marlstone (a fine-grained limestone), massive marlstone, algal limestone, and lesser amounts of sandstone and conglomeritic limestone. Total thickness of the lower Wilkins Peak Member averages 55 feet, or which about 35 feet is oil shale and laminated marlstone. The oil shale occurs in thin (6 to 12 inches thick) persistent beds, displaying a light-gray surface weathering.

Oil shale in the Green River Formation of Wyoming is thickest and richest in the southern part of the Greater Green River Basin. Westward, southward, and northward from this part of the basin, the oil shale deposits grade into tongues of detrital (sand) material. Along the basin margins, the Green River Formation is thin and contains only small amounts of oil shale, most of which is low grade (Culbertson, 1969).

3.1.5 Phosphate

Phosphate rock is the source for calcined phosphate compounds, roughly 90 percent of which are used as the major component of fertilizer. The remaining 10 percent of phosphate production is used to produce industrial chemicals such as elemental phosphorous or phosphoric acid (Stowasser, 1989). Primary phosphate production in the United States (U.S.) centers in southeastern Idaho, where phosphatic ores are mined from the Permian Phosphoria Formation.

Phosphate rock is classified by grade, on the basis of tri-calcium phosphate or bone phosphate of lime (BPL) content, as follows: “low grade” (30 to 49.9 percent BPL); “medium grade” (50 to 69.9 percent BPL); or “high grade” (70 percent or greater BPL). Phosphate beds containing over 65 percent tri-calcium phosphate or $Ca_3(PO_4)_2$, otherwise referred to as the BPL, are generally considered to be of potential commercial grade.

The principal constituents of phosphate rock are lime, phosphate, silica, carbon dioxide, organic matter, magnesia, alumina, iron oxide, and fluorine (listed in approximate order of abundance). In addition, appreciable quantities of vanadium are found in thin beds within the Phosphoria

Formation. Investigation by the Geological Survey of Wyoming has determined that the phosphatic shales can contain as much as 0.01 percent to 0.02 percent uranium oxide (U_3O_8) (Cochran, 1950; McKelvey, 1946).

The subsurface presence of the Phosphoria Formation within the RMPPA has been well established by exploration and drilling programs. The Phosphoria Formation at Deadline Ridge is on the east limb of a large northwest-trending synclinal fold, and is bounded by stratified rocks of Triassic Age at Rock Creek and by Pennsylvanian Age immediately east of Deadline Ridge. Phosphate beds are exposed along the western slope of Deadline Ridge, and bedding planes dip at about 40°, approximately parallel to the slope of the ridge hillside. A surface section bearing relatively rich phosphate beds at Deadline Ridge (Sections 5, 8, and 11 of T27N, R114W and Sections 1 and 2 of T27N, R115W) has been described as having a total thickness of about 360 feet (Sheldon, 1954).

The Phosphoria Formation consists of three units in this area: the Phosphatic Shale Member, Rex Chert Member, and the Upper Shale Member. The Upper Shale Member contains a phosphate horizon of nearly commercial grade near its base. The Basal Horizon, which is about 4 feet thick, has three beds averaging 1 foot each with an average assay of about 63 percent BPL. Two commercial grade beds have been identified, a 1.7-foot-thick bed (high grade – 70.6 percent BPL) near the base of the Rex Chert Member, and a 1-foot-thick bed (69.1 percent BPL) within the phosphate horizons near the base of the Upper Shale Member. There are two medium grade beds within the Phosphatic Shale Member, one near the top (1.3 feet thick, 58.2 percent BPL) and another in the middle of the member (1.4 feet thick, 52.7 percent BPL).

3.1.6 Sodium

The Wilkins Peak Member of the Green River Formation is rich in sodium carbonate-bicarbonate, or trona, an evaporite mineral deposit. In all, some 42 beds of the Green River Formation contain trona resources in an area (outside of the RMPPA) generally defined by T14-21N, R107-112W and situated west of the Town of Green River. A total of 5 underground mines produce trona [$Na_2(CO_3) \bullet Na(HCO_3 \bullet 2H_2O)$] from depths as great as 1,700 feet in this area.

An occurrence of sodium carbonate and/or sodium sulfate is reported near Soda Lake, north of Pinedale (U.S. Geological Survey [USGS] Missouri Basin Studies Map No. 9); however, the nature of the occurrence is unknown. Sodium-sulfate-rich soda lakes also are found elsewhere in Wyoming; however, none of these are being commercially exploited at the present time (Harris and others, 1985).

3.2 Locatable Minerals

Locatable minerals within the RMPPA are not considered to be of particular economic significance due to limited occurrences and general sub-economic grades where present. Those locatable minerals that have been shown to have an indicated or confirmed presence within the RMPPA are generally limited to uranium, gypsum, gold, copper, jade, and bentonite (which can be either a locatable or a saleable mineral, dependent on its end-use classification). Mineral resource occurrences are described in the following sections.

3.2.1 Uranium

Uranium deposits in Wyoming are known to occur in rocks of Precambrian Age and in at least 33 different formations ranging in age from Cambrian to Pliocene. Most of the commercial uranium production to date has been from the Eocene Wind River Formation in the Gas Hills area of Fremont and Natrona Counties. Additional production has originated from the Madison Formation (Mississippian) in Big Horn County, Fall River and Lakota Formations (Lower Cretaceous) in Crook County, Wasatch Formation (Eocene) in Campbell, Converse, and Johnson Counties, and Browns Park Formation (Miocene) in Carbon County.

The non-Precambrian uranium occurrences within southwestern Wyoming are of Tertiary origin. The origin of Tertiary uranium mineralization is subject to controversy; however, the majority of evidence supports a volcanic ash leach hypothesis as opposed to theories that the uranium-bearing solution is of hydrothermal origin. The volcanic ash leaching theory is based on the supposition that sufficient volcanic ash accumulated over much of the state in middle to late Tertiary, and that the uranium-bearing ash was subsequently leached by meteoric waters. The uranium was then carried in solution by groundwaters to a favorable host zone (Wilson, 1955).

The Tertiary uranium occurrences within the RMPPA are typically of the roll-front type and are found within the sandstone members of the Wasatch Formation, where prospecting programs have been carried out in portions of T34-35N, R110-111W (Hamilton, 1985). Other Wasatch Formation occurrences have been noted in central portion of the RMPPA (T29-33N, R107-109W), generally in areas situated some distance south and west of the Town of Boulder. Additionally, the literature indicates an occurrence of uranium within T28N, R105W, or roughly 20 miles north of the Town of Farson (Gaffke and others, undated).

Occurrence of uranium also has been noted in Precambrian granite at a location (Sections 17 and 21; T32N, R107W) roughly 6 to 8 miles east of the town of Boulder in the Fremont Butte area (Harris and others, 1985). However, assays of these specimens are relatively low in uranium content (Wilson, 1960).

Airborne anomalies indicative of uranium occurrence have also been reported from an area (outside of the RMPPA) of southeastern Sublette County (T28N, R105W), which is east of Road 118 and northeast of Big Sandy Reservoir (Wilson, 1955).

3.2.2 Gypsum

Gypsum is an evaporite mineral originating from the deposition of calcium sulfate minerals by precipitation from aqueous solution. Gypsum, the dihydrate form of calcium sulfate ($CaSo_4{\cdot}2H_20$) and anhydrite (the anhydrous form [$CaSO_4$]) are typically found in close association, and it is rare that a calcium sulfate deposit would consist exclusively of one mineral or the other. Most commercial gypsum production in the U.S. originates from deposits that are in the 80 to 95 percent purity range (Jorgensen, 1994).

In Wyoming, gypsum is found in the Pennsylvanian Amsden Formation, Permian-Triassic Goose Egg and Spearfish Formations and their equivalents, Jurassic Gypsum Spring Formation, and locally (within the RMPPA) in the Jurassic Sundance and Tertiary Wasatch Formations.

Quaternary deposits of gypsite are often found near outcrops of these units. The gypsite mineralization results from solubilization of the existing gypsum deposit by groundwater, which in turn is drawn toward the surface by capillary action where it evaporates leaving the dissolved sulfate precipitated as a porous aggregate of impure gypsum.

There are two known gypsum occurrences within the RMPPA: one deposit is located in the extreme northern portion of the RMPPA (T37N, R110-111W), and the second deposit is located in the central portion of the RMPPA, along the western extent of Ross Ridge and Ross Butte (T30N, R109-110W).

The northern occurrence (Harris and others, 1985) is indicated to be of Jurassic origin, associated with outcroppings of the Sundance and Gypsum Spring Formations. This locale can be generally defined as the southeastern extent of the Gros Ventre Range. There is no indicated commercial exploitation associated with this occurrence.

The Ross Ridge/Ross Butte occurrence (Hamilton, 1985) is within in a 75-foot-thick red and green shale interval in the New Fork Tongue of the Wasatch Formation (Donovan, 1950). The interval can be visually traced laterally along Ross Ridge and Ross Butte, generally occupying a zone approximately 50 feet below the ridge top. The gypsum is reported to be thin-bedded (4 inches or less), fibrous and crystalline, and exhibiting a distinctive yellow, white, and amber color. There is evidence of limited, small-scale extraction of the mineral having occurred at the southwestern portion of Ross Butte (Hamilton, 1985).

3.2.3 Metallic Minerals

Due to the primarily sedimentary geology within the RMPPA, the occurrence of metallic minerals is limited. However, the literature indicates potential or confirmed presence of gold and copper mineralization within the RMPPA.

3.2.3.1 Gold

A number of gold occurrences are known to exist along the extreme northern portions of the RMPPA, at locations adjacent to the southwestern flank of the Gros Ventre Range. These are considered to be Paleo-placer deposits originating from the Pass Peak Formation (Cenozoic). Outcrops of the Pass Peak Formation are found adjacent to the northernmost extent of the RMPPA. The eroded detritus has subsequently been carried into the RMPPA resulting in alluvial placer deposits. These placer deposits are principally concentrated within T37-38N, R111W and are referred to locally as the Griggs Placer deposits (Harris and others, 1985). No information concerning grade or tonnage has been located; however, it is noted in Section 4.2.3.1 that unpatented claims, associated with this deposit were allowed to lapse in the early 1990s.

Early prospecting reports from the Green River area indicate that placer gold has been produced along the river course from as far south as Big Piney, which is situated in the central portion of the RMPPA (Antivieler and others, 1977). Texaco, Inc., reportedly carried out limited activity (in the form of assessment work) in 1983 on placer claims situated along the Green River (location not indicated).

Other occurrences of gold have been noted in the Phosphoria Formation and various upper Jurassic and lower Cretaceous rocks in the Overthrust Belt. Nearby historic gold producing areas that are located outside of, but proximal to, the RMPPA include the Lewiston District or South Pass locale (approximately 20 miles east).

3.2.3.2 Copper

There has been no known production of copper within the RMPPA, nor are there published accounts of known copper occurrences. However, the literature suggests that, due to the presence of nearby historic mining activity, there is a remote possibility for copper occurrence in the southwestern portion of the RMPPA in the vicinity of upper La Barge Creek.

A number of prospect pits occur along La Barge Creek Road (Section 21 of T27N, R115W) associated with unpatented claims reportedly located (on the basis of copper values) by I. Lewis, and others, in 1941. Observed green staining of sandstone specimens within the pits could suggest the possible presence of oxide copper mineralization; however, this interpretation has not been verified, and no assay data is available (Hamilton, 1985).

The former copper-producing district that is proximal to the RMPPA is known as the Lake Alice Mining District. Although approximately 3 to 5 miles outside of the RMPPA boundary, the Lake Alice Mining District (copper-silver-zinc) is situated immediately west, within the Wyoming Range (T27-28N, R116W). The Lake Alice deposits are localized in an anticline formed of bleached red beds of the Nugget sandstone, capped by the Gypsum Spring Member of the Twin Creek Limestone. The District produced copper-silver-zinc ores during the period 1914-1920 and again in 1942 from the Griggs Mine, the principal mine in the district. Situated in the northern portion of the district, the Griggs Mine exploited mineralized sandstone at least 300 feet thick. Active exploration of the district was carried out in the 1970s by Bear Creek Exploration (Hausel, 1994). Lake Alice District has the potential for a deposit or series of deposits containing over 100 million tons of ore grading 0.5 percent to 1.0 percent copper and 2 to 5 ounces per ton silver (Boberg, 1984).

3.2.4 Jade

Jade is a semi-precious gemstone found in one of two mineral forms – jadeite (a pyroxene mineral of sodium aluminum silicate composition) and nephrite (an amphibole mineral of calcium magnesium silicate composition). The type of jade found in Wyoming is of the nephrite, or tremolite-actinolite variety, which typically exhibits coloration ranging from white to dark, olive green. There also is a “snowflake” jade, which has mottled coloration due to the intermixing of other minerals with the nephrite. Generally, it is the lighter colors of nephrite that are more highly valued (Hausel, 1986).

Tremolite and actinolite are common minerals of low and medium grade metamorphic rocks, tremolite being characteristic of metamorphosed dolomitic limestones, and actinolite occurring in rocks richer in iron.

The nephrite form consists of submicroscopic, intricately interwoven, tremolite-actinolite mineral fibers that produce a massive and extremely tough gemstone. Actinolite-tremolite mineral fibers can occur as prismatic asbestos-form masses, coarse crystalline grains, or as the tough compact masses known as nephrite. The division between tremolite and actinolite is an arbitrary one, tremolite being the low-iron end of the series (white in color) and actinolite comprising the iron-bearing members (green in coloration) (Berry and Mason, 1959).

The occurrence of Wyoming, or nephrite jade has been reported in the Prospect Mountains (southernmost portion of the Wind River Range) and at various locations along the Wind River Range (which forms the eastern edge of the RMPPA).

Veins of jade are rarely found in the mountainous terrain, and pebbles and boulders of jade in alluvial fans also are uncommon. However, random discoveries continue to be made; a 7-ton boulder of black jade was discovered in the early 1970s in the Prospect Mountains (15 miles northeast of Big Sandy Reservoir).

3.2.5 Bentonite

Bentonite is a clay mineral. As described in the introduction to Chapter 3.0, bentonite can be classified as either a locatable or saleable mineral, dependent on its end use (value). Typically, Wyoming bentonites are considered to be locatable minerals, whereas other common or industrial use clays produced in Wyoming are categorized as saleable.

Bentonite is a sedimentary rock that contains 75 percent of the montmorillonite group of clay minerals. It has widely varying properties, due to its many possible mineralogical and chemical combinations. Montmorillonite minerals are comprised of sheet-like layers of hydrous aluminum silicate, between which are layers of water molecules containing exchangeable ions, usually either sodium or calcium. Bentonites can be divided into two classes: 1) those that absorb large quantities of water, thus “swelling” greatly in the process – with sodium being the predominant exchangeable ion; and 2) those that absorb only slightly more water than ordinary plastic clays and do not “swell” noticeably – with calcium being the predominant exchangeable ion. Freshly quarried bentonite typically contains approximately 40 percent moisture, and is commonly creamy or greenish grey, but may be cream, gray, off-white, pink, dark green, buff, brown, black, or a mixture of these colors. When dried, its color is lighter, usually cream or buff (Ross, 1964).

Bentonite is formed by the alteration and devitrification of volcanic ash and the crystallization of montmorillonite minerals in depositional environments. It occurs in sedimentary successions as lens-like beds which vary considerably in lateral extent, and in thickness from a fraction of an inch up to many feet. Only rarely are bentonite beds in excess of 10 feet thick. Most of the commercially important bentonite deposits within Wyoming occur along the outcrop traces of the Frontier Formation and the Mowry Shale. Major bentonite mining areas are located in the Black Hills, the Bighorn Basin, and near Kaycee, in Big Horn, Crook, Weston, Johnson, and Natrona Counties.

Bentonite clay deposits within Sublette County have been noted northwest of Riley Ridge, in Sections 15 and 21 of T29N, R115W (Bridger-Teton National Forest). It is reported that bentonite beds up to 2 feet thick have been found in the Aspen Shale in Section 15, and in Section 21 the bentonite beds are described as being 2 to 8 inches thick, occurring within the Hilliard Shale (Fruchy, 1962; Furer, 1962). Also, it is reported that the Hilliard Shale likely contains bentonite within areas further west of the RMPPA boundary in T28-29N, R116W (Hauf, 1963; Suydam, 1963).

In addition to the above, thin beds of bentonite occur within a sequence of dark gray mudstones of the Bear River Formation, and within a few thin layers of bentonite in the Frontier Formation, both of which are present within the southwestern part of the RMPPA.

3.3 Saleable Minerals

Saleable minerals disposition is addressed under the Materials Act of July 31, 1947, as amended by the Acts of July 23, 1955, and September 28, 1962. These Acts authorized that certain mineral materials be disposed either through a contract of sale or a free-use permit. This group of mineral materials, commonly known as “saleable minerals” includes, but is not limited to common varieties of sand, stone, gravel, pumice, pumicite, cinders, clay, and petrified wood in public lands of the U.S. (Maley, 1977).

Saleable minerals known to be present within the RMPPA include aggregates (sand and gravel), decorative stone, boulders, and to a very limited extent, common clay. [Note: Bentonitic clays have been addressed under the category of locatable minerals due to unique end uses, whereas common varieties of clay are categorized as saleable.] Review of published data indicative of saleable minerals occurrence and exploitation indicates that there are no known occurrences of pumice, pumicite, or cinders within the RMPPA (Harris and King, 1986). To the extent petrified wood may be present within the RMPPA, it has been considered a paleontological resource rather than a mineral resource.

3.3.1 Aggregates (Sand and Gravel)

By far, the most significant saleable mineral (both in terms of occurrence and demand) within the RMPPA is aggregates, or sand and gravel. Aggregate resources typically occur in one or more of the following forms:

- natural gravel deposits (unconsolidated gravel or loosely or partially cemented gravel that can be removed without benefit of blasting or cutting);

- alluvial sand and gravel deposits (stream channel and flood plain deposits);
- terrace sand and gravel deposits (braided stream and sheet flood deposits of glacial and non-glacial materials derived from mountain ranges);
- glacial gravels;
- older gravel deposits (conglomerate); or
- windblown (dune) deposits.

Within the RMPPA, the aggregates resource base is generally present as terrace or alluvial deposits (**Figure 3-15**), with the terrace type of deposit being predominant over the northwestern portion of the RMPPA (T29-35N, R111-115W). The southeastern portion of the RMPPA is generally devoid of identified significant aggregate deposits except for limited areas of windblown sand deposits, which are present at T27-28N, R108W (northwest of Sublettes Flat). However, random occurrences of limited to sizeable aggregate deposits would be expected to be present along secondary drainage courses in this portion of the RMPPA.

The Quaternary terrace deposits present within the northwestern portion of the RMPPA were formed during the Pleistocene in basin areas near the present mountain ranges. Braided streams and sheet floods from the mountains provided materials derived from various sources. The changing climate of the Pleistocene (glacial and non-glacial intervals in the higher mountains, dry and wetter cycles in the lower parts) resulted in terrace gravel deposition in certain areas (Harris, 1986). These depositional areas are located on the tops of benches and terraces and frequently form a surface layer more resistant to erosion than the surrounding deposits, however, the quality of gravel deposits can be highly variable.

Alluvial deposits generally follow the trace of the Green River and its major tributaries from upper stream source areas downstream to Fontenelle Reservoir. It is important to note that, for the large part, the alluvial deposits along the Green River and its tributaries are located on land with private surface ownership, whereas the terrace deposits are primarily located on land with BLM surface ownership.

The alluvial deposits that are present along the Green River and its major tributaries are recent stream deposits that contain varying proportions of sub-rounded to sub-angular clasts of gravel, sand, silt and clay. Sizeable outcrop areas of glacial sand and gravel are present in the area north and west of Cora (T35-36N, R111W), where Pleistocene glacial moraine, outwash, and related deposits typically contain a high proportion of coarse material.

Figure **3-15** Surficial Geology

In general, extensive deposits of commercial grade sand and gravel can be found along all major drainages in the RMPPA (Welder, 1968), with lesser deposits of a non-commercial nature present along minor drainages.

Relatively extensive glacial sand and gravel deposits also are present along the western flank of the Wind River Range, extending northwesterly into Teton County and southeasterly to the Big Sandy area; however, the majority of these deposits are situated within the Bridger-Teton National Forest.

3.3.2 Decorative Stone

Decorative stone is any rock product (exclusive of aggregate) that is used for its color or appearance. Although color and appearance are important criteria in selecting decorative rock, the rock must frequently meet strength, durability, and other specifications. These specifications can include the absence of sulfides or minerals that could oxidize and stain or discolor the rock.

Decorative rock that is present and in demand within the RMPPA is generally limited to moss rock (utilized for building and architectural purposes) and boulders (utilized primarily for landscaping purposes).

3.3.2.1 Moss Rock

The moss rock occurs as a moss-covered, salmon-pink sandstone, and is generally found on steep talus slopes at the base of massive cliffs in the Nugget Formation (Triassic-Jurassic in age), which occurs along the western extent of the RMPPA. Due to its desirable properties of fracture, color, and hardness, this moss rock makes an excellent facing or structural building stone. It is laminated sandstone that tends to break along bedding planes, leaving blocks 2 to 4 inches thick with a flat base and top. Prolonged exposure and weathering of the debris rock results in a rough, moisture-bearing surface that induces the growth of lichen. The resulting orange-, green-, and silver-colored lichen rock presents a pleasing decorative look and is in high demand.

Although the sandstone can be considered a suitable building material, it is apparently the attached lichen that provides the rock with its appeal for decorative use. Numerous business and government buildings, churches, and homes in Sublette, Lincoln, and Teton Counties utilize moss rock for exterior structural and decor applications.

Although extensive quantities of the moss rock material likely exist within the western extent of the RMPPA, much of it occurs in relatively remote areas with limited existing access and oftentimes, characteristically rugged terrain. Accessibility (proximity to existing roadways) and obtainability (the rock typically requires manual labor to minimize the potential for damaging the lichen surfacing) are key to determining the areas that would be subject to exploitation.

Significant deposits of accessible moss rock material are present along the La Barge Creek Road and in the Miller Mountain Area (T26-27N, R115W and in parts of T25N, R114-115W). Intermittent attempts at commercial exploitation of these deposits have been carried out in recent years. This has been done from an area along La Barge Creek (Hamilton, 1985). In order to minimize damage to the lichen growth on the rock, most “quarrying” activity is carried out utilizing manual labor.

In addition, small volume removal (via unauthorized trespass) at roadside locations along La Barge Creek Road has occurred. This type of removal has been attributed to individuals seeking small amounts of stone for personal use.

3.3.2.2 Boulders

The boulder occurrences are typically limited to the northeastern fringe areas of the RMPPA, along the western flank of the Wind River Range where glacial deposits are evident. In those areas, glacial action has resulted in the deposition of sizeable, rounded boulders along lateral and terminal moraines. Subsequent (post-glacial) erosional and deposition processes have transported and scattered the boulders downslope where they are sometimes present at the surface. Surface distribution is generally of a random nature; however, there are areas of concentration that may be suitable for pit extraction.

One significant and accessible boulder field is located along either side (right-of-way) of the Boulder Lake Road, which traverses an area of concentrated boulder deposition south of Boulder Lake. The boulder field commences at a point approximately 4 miles north of Wyoming State Highway 353 and continues up to the BLM/Bridger-Teton National Forest Boundary, encountered northeast of the BLM boat ramp at the west end of Boulder Lake. This area (generally within Sections 18 and 19, T33N, R107W) has been field-delineated with signage, and has been designated as a common-use area, allowing for limited extraction of boulders from areas alongside the roadway.

Additional boulder resources have been identified along the Soda Lake Road right-of-way, which extends north of Pinedale, and along rights-of-way of access roads enroute to Burnt Lake. It is probable that exploitable surface boulder occurrences are present along the rights-of-way of most roadways traversing BLM surface in and around the morainal terraces along the northeastern edge of the RMPPA.

3.3.3 Common Clay

Clay minerals are hydrous aluminosilicate minerals with a sheet-like structure. Common clay is an industrial classification (by use) of clay, and it consists of clay or clay-like material that is sufficiently plastic to permit molding (Ampian, 1985). It is composed of the minerals illite, smectite, and kaolinite (Patterson and Murray, 1983). Common clay was produced in almost every county in Wyoming during the early years of statehood, typically for the manufacture of bricks that were used locally (Harris and King, 1987). At present, common clay is mined in Uinta County and shipped to Utah for the manufacture of brick. Occasionally, clay pits are opened for an immediate local need (e.g., landfill or lagoon liner material, etc.).

Quaternary common clay (non-bentonitic) deposits that are mostly derived from the weathering of underlying shales, are noted as being present immediately west of the RMPPA in the Mammoth Hollow area, or approximately 25 miles west of Fontenelle Reservoir (T25-27N, R115W and T23-24N, R116W). The underlying shales in Mammoth Hollow are associated with the Hilliard Shale (Cretaceous). These clays were apparently utilized in the manufacture of brick at Glencoe, Wyoming. However, the quality of brick and location of the clay pit is unknown (Schultz, 1907). The suitability of the Hilliard Shale clays for fired clay products is uncertain (Van Sant, 1961).

Although the literature identifies no specific occurrences of common clay within the RMPPA, it is likely that limited quantity localized occurrences are present along the western edge where shale outcrops are present.

3.3.4 Petrified Wood

Petrified wood is organic woody material that has been replaced by microcrystalline quartz or opal. Most Wyoming petrified wood formed 30 to 40 million years ago, a result of trees being buried under volcanic ash. It is mainly considered to be of value to specimen collectors. While it is technically a saleable mineral (obtainable subject to limitations under a “free-use” designation), it has no significant commercial value. It is, however, considered a paleontological resource, and collection is subject to terms and conditions consistent with the preservation of significant deposits as a public recreational resource.

Occurrences of petrified wood within the RMPPA have been reported at various locations, including the vicinities of Ross Ridge and Ross Mesa, Blue Forest and areas northeast of Farson. In fact, some of the most attractive petrified wood in the state is reportedly found northeast of Farson, immediately south of the Wind River Range. This occurrence is known as the Eden Valley petrified wood, and it is black to dark grey in coloration (Hausel, 1986).