MINERALS AND PALEONTOLOGY TECHNICAL REPORT

1988

For Amoco CO_2 Projects
Environmental Impact Statement

Prepared For:

U.S. Department of the Interior
Bureau of Land Management

Prepared By:

Planning Information Corporation
1801 Broadway, Suite 920
Denver, Colorado 80202
(303) 298-0919

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

AMOCO CO_2 PROJECTS
MINERALS AND PALEONTOLOGY
TECHNICAL REPORT
CHAPTER ONE:
INTRODUCTION

1.1 PURPOSE

Amoco Production Company has proposed the development of five separate and distinct projects in the State of Wyoming. An Environmental Impact Statement (EIS) is being prepared to analyze the potential impacts associated with construction, operation, maintenance and abandonment of these five separate projects. This technical report was prepared to support the EIS analysis of potential impacts to mineral and paleontological resources.

1.2 OVERVIEW OF THE PROJECTS

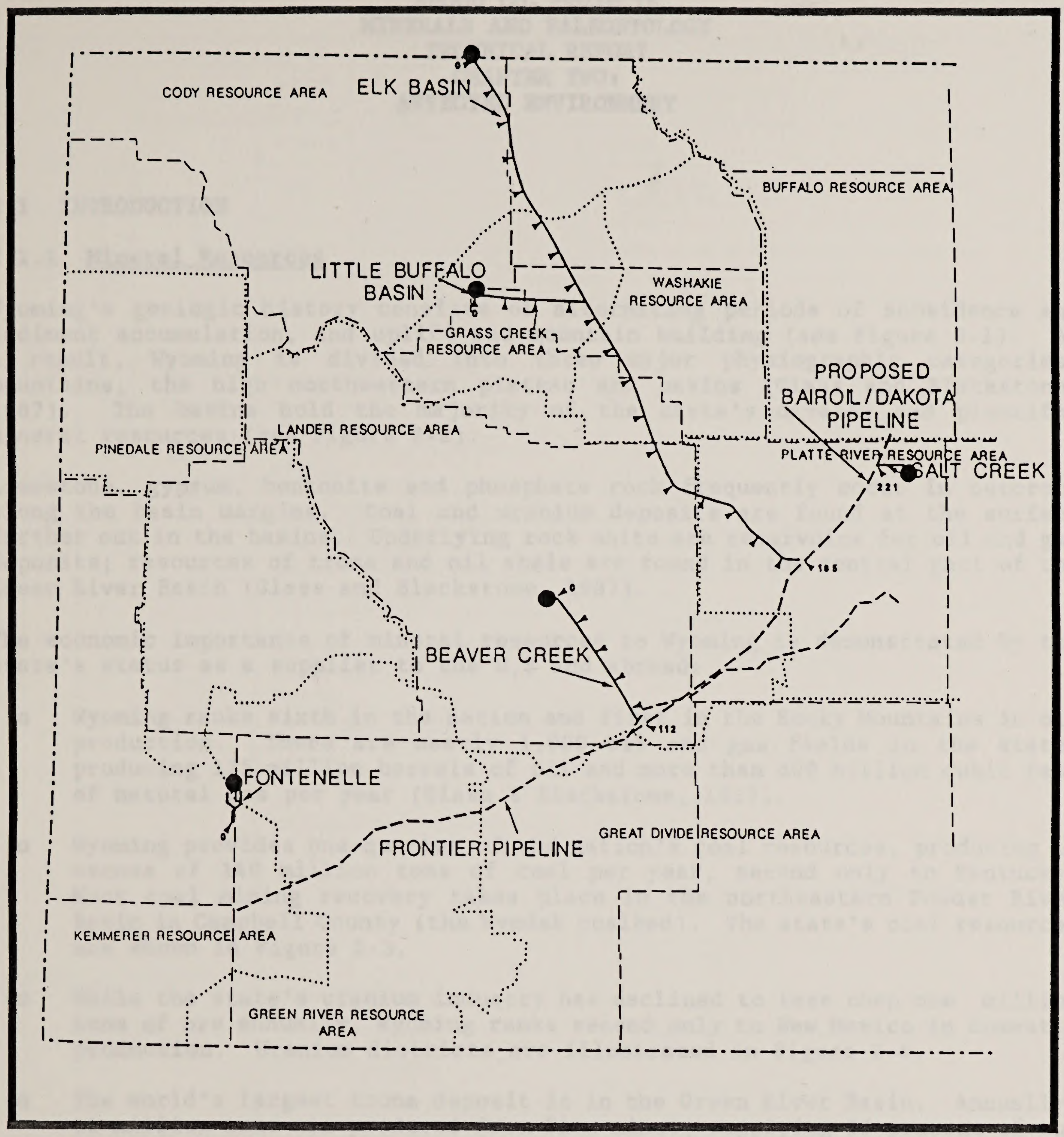
Amoco proposes to implement enhanced oil recovery, through the injection of CO_2, in four established fields: Elk Basin, Beaver Creek, Little Buffalo Basin and Salt Creek (Figure 1-1). The CO_2 would be supplied by the Fontenelle Project, which would obtain CO_2 from the nearby Raptor Field and process it for transport. Pipelines (16 or 18 inch) would be constructed to deliver the CO_2 in conjunction with existing CO_2 pipelines, to the four fields. A plant to recycle injected CO_2 would be constructed in each of the four fields.

The Fontenelle CO_2 Supply Project would be constructed in 1989 and 1990. Construction of the Elk Basin CO_2 Project would occur in 1990 and 1991. The Beaver Creek CO_2 Project is proposed for 1991, 1992 and 1993. The Little Buffalo Basin CO_2 Project is proposed for 1992, 1993 and 1994. The Salt Creek CO_2 Project's proposed construction is scheduled for 1993 through 1997.

Details of each project and schedules are included in Chapter 2 of the EIS.

1.3 SCOPE OF THE ENVIRONMENTAL IMPACT STATEMENT

The scope of the EIS is primarily restricted to analyzing the impacts associated with construction of CO_2 spur and trunk pipelines and the proposed gas processing and CO_2 recycle plants. While impacts of wellfield activities are discussed, precise plans and locations for wellfield-related activities are not available at this time. Analysis and mitigation of specific impacts associated with individual wellfield-related activities will be conducted after preparation of field development plans.



········· BLM RESOURCE AREA BOUNDARY

——— PROPOSED PIPELINE ALIGNMENT

— — — EXISTING FRONTIER PIPELINE

— — — PROPOSED BAIROIL / DAKOTA PIPELINE

— — — COUNTY LINE

● OIL OR CO_2 FIELDS

► MILEPOST (10 MILES)

Figure 1—1. Location of Proposed Pipeline Alignments.

2.1 INTRODUCTION

2.1.1 Mineral Resources

Wyoming's geologic history consists of alternating periods of subsidence and sediment accumulation, and uplift and mountain building (see Figure 2-1). As a result, Wyoming is divided into three major physiographic categories: mountains, the high northwestern plateau and basins (Glass and Blackstone, 1987). The basins hold the majority of the state's diverse and plentiful mineral resources (see Figure 2-2).

Limestone, gypsum, bentonite and phosphate rock frequently occur in outcrops along the basin margins. Coal and uranium deposits are found at the surface farther out in the basins. Underlying rock units are reservoirs for oil and gas deposits; resources of trona and oil shale are found in the central part of the Green River Basin (Glass and Blackstone, 1987).

The economic importance of mineral resources to Wyoming is demonstrated by the state's status as a supplier to the U.S and abroad:

- Wyoming ranks sixth in the nation and first in the Rocky Mountains in oil production. There are nearly 1,000 oil and gas fields in the state, producing 125 million barrels of oil and more than 600 billion cubic feet of natural gas per year (Glass & Blackstone, 1987).

- Wyoming provides one-quarter of the nation's coal resources, producing in excess of 140 million tons of coal per year, second only to Kentucky. Most coal mining recovery takes place in the northeastern Powder River Basin in Campbell County (the Wyodak coalbed). The state's coal resources are shown in Figure 2-3.

- While the state's uranium industry has declined to less than one million tons of ore annually, Wyoming ranks second only to New Mexico in domestic production. Uranium districts are illustrated in Figure 2-4.

- The world's largest trona deposit is in the Green River Basin. Annually, 11 million tons are produced from five mines, supplying 90 percent of the nation's demand. Wyoming also exports trona to other countries.

- Wyoming is the nation's leading producer of bentonite, which occurs primarily in Cretaceous shales.

Additionally, many other minerals, including limestone, gypsum, crushed rock, jade, sand, gravel, gold, copper, iron ore, phosphate rock and diamonds, are mined in various regions of Wyoming,

ARCO CO2 PROJECT
MINERALS AND PALEONTOLOGY
TECHNICAL REPORT
CHAPTER TWO
AFFECTED ENVIRONMENT

2.1 INTRODUCTION

2.1.1 Mineral Resources

Wyoming's geologic history consists of alternating periods of subsidence and sediment accumulation, and uplift and erosion, building [illegible] (see Figure 2-1). As a result, Wyoming is divided into [illegible] major physiographic categories: mountains, the high intermontane plateaus and basins (Knight and [illegible], 19[illegible]). The basins hold the majority of the state's reserves and potential mineral resources (see Figure 2-2).

Limestone, gypsum, bentonite and phosphate rock frequently occur in outcrops along the basin margins. Coal and uranium deposits are found at the surface farther out in the basins. [illegible] rock [illegible] are [illegible] for oil and gas deposits, [illegible] of sodium and oil shale are found in the central part of the Green River Basin (Glass and Blackstone, 1987).

The economic importance of mineral resources to Wyoming is demonstrated by the state's status as a supplier to the U.S. and abroad:

- Wyoming ranks sixth in the nation and first in the Rocky Mountains in oil production. There are nearly 1,900 oil and gas fields in the state, producing 112 million barrels of oil and more than 600 billion cubic feet of natural gas per year (Glass & Blackstone, 1987).

- Wyoming contains one-quarter of the nation's coal reserves, producing in excess of 140 million tons of coal per year, second only to Kentucky. Most coal mining activity takes place in the northeastern Powder River Basin in Campbell County (the Gillette area). The state's coal resources are shown in Figure 2-3.

- While the state's uranium industry has declined to less than one million tons of ore annually, Wyoming ranks second only to New Mexico in domestic production. Uranium districts are illustrated in Figure 2-4.

- The world's largest trona deposit is in the Green River Basin. Annually, 11 million tons are produced from five mines, supplying 90 percent of the nation's demand. Wyoming also exports trona to other countries.

- Wyoming is the nation's leading producer of bentonite, which occurs primarily in Cretaceous shale.

Additionally, many other minerals, including limestone, gypsum, crushed rock, jade, sand, gravel, gold, copper, iron ore, phosphate rock and diamonds, are mined in various regions of Wyoming.

TIME[1]	ERA	PERIOD	EPOCH	EVENTS IN WYOMING	MINERAL RESOURCES IN WYOMING
0	CENOZOIC	QUATERNARY	Holocene	Present climate.	Sand and gravel, placer gold.
			Pleistocene	Ice Age, glaciers.	
1.6		TERTIARY	Pliocene	Teton Mountains formed, terrestrial deposition.	Gypsum.
5.3			Miocene	Intense volcanic activity in Yellowstone area, temperate climate.	Copper-molybdenum porphyries in Absaroka Mountains; uranium in Baggs area.
24			Oligocene	Terrestrial deposition of great amounts of volcanic ash, warm temperate climate.	Copper-molybdenum porphyries in Absaroka Mountains.
37			Eocene	Green River lake and terrestrial deposition, subtropical climate.	Uranium and coal in basins; trona and oil shale in the Green River Basin; clinker.
58			Paleocene	Terrestrial deposits, tropical climate.	Uranium and coal in basins; clinker; gas.
66	MESOZOIC	Cretaceous		Transgression and regression of seas, Rocky Mountains begin to rise, abundant cephalopods.	Bentonite along flanks of mountain ranges; some coal; oil and gas; and uranium in Black Hills.
135		Jurassic		Seas withdrew, broad flood plains, many dinosaurs.	Copper-silver-zinc in the Overthrust Belt; oil and gas; gypsum.
180		Triassic		Fluctuation of shore line, wide tidal flats, mild climate.	Gypsum; oil and gas.
245	PALEOZOIC	Permian		Shallow seas in western Wyoming, invertebrates common.	Phosphate in Overthrust Belt; gypsum; oil and gas.
270		Pennsylvanian		Local uplift in south-central and southern Wyoming.	Limestones along flanks of mountain ranges; oil and gas; copper.
		Mississippian		Entire state submerged in warm tropical seas.	Thick limestone deposits; oil and gas.
350		Devonian		Seas in northwestern and western Wyoming.	Diamond-bearing kimberlites; oil and gas.
400		Silurian		Probably emergent (record incomplete in Wyoming).	----
440		Ordovician		State inundated by shallow warm waters.	Oil and gas.
500		Cambrian		Seas transgressed from west across entire state.	"Rawlin's red" hematite quartzites in the Rawlins uplift; oil.
570	Major unconformity			Long interval of erosion at close of era.	
1000	PRECAMBRIAN	PROTEROZOIC		Land reduced to broad plains of low relief. Mountain building. Widespread ancient seas. Continents in existence. Atmosphere becoming more oxygen-rich.	Anorthosite in the Laramie Range. Gold, copper, platinum (?) veins and shears in the Medicine Bow Mountains. Beryl, lepidolite, feldspar, copper sulfide pegmatites at Copper Mountain. Numerous beryl and feldspar pegmatites in Laramie Range and at South Pass. Copper in the Silver Crown district, Laramie Range. Volcanogenic copper-zinc silver sulfide deposits in the Sierra Madre. Copper-bearing quartzites in the Sierra Madre. Uranium paleoplacers in the Medicine Bow Mountains and Sierra Madre, becoming less common as earth's atmosphere gets more oxygen rich.
2500		ARCHEAN		Reducing atmosphere (low oxygen). Formation of primitive continents.	Banded magnetite iron formation at South Pass, Copper Mountain and Seminoe Mountains. Gold-bearing veins and shears at South Pass. Tungsten deposits at Copper Mountain.
4500					

[1] In millions of years before the present.

Figure 2—1. Geologic Time Chart of Wyoming (Glass and Blackstone, 1987).

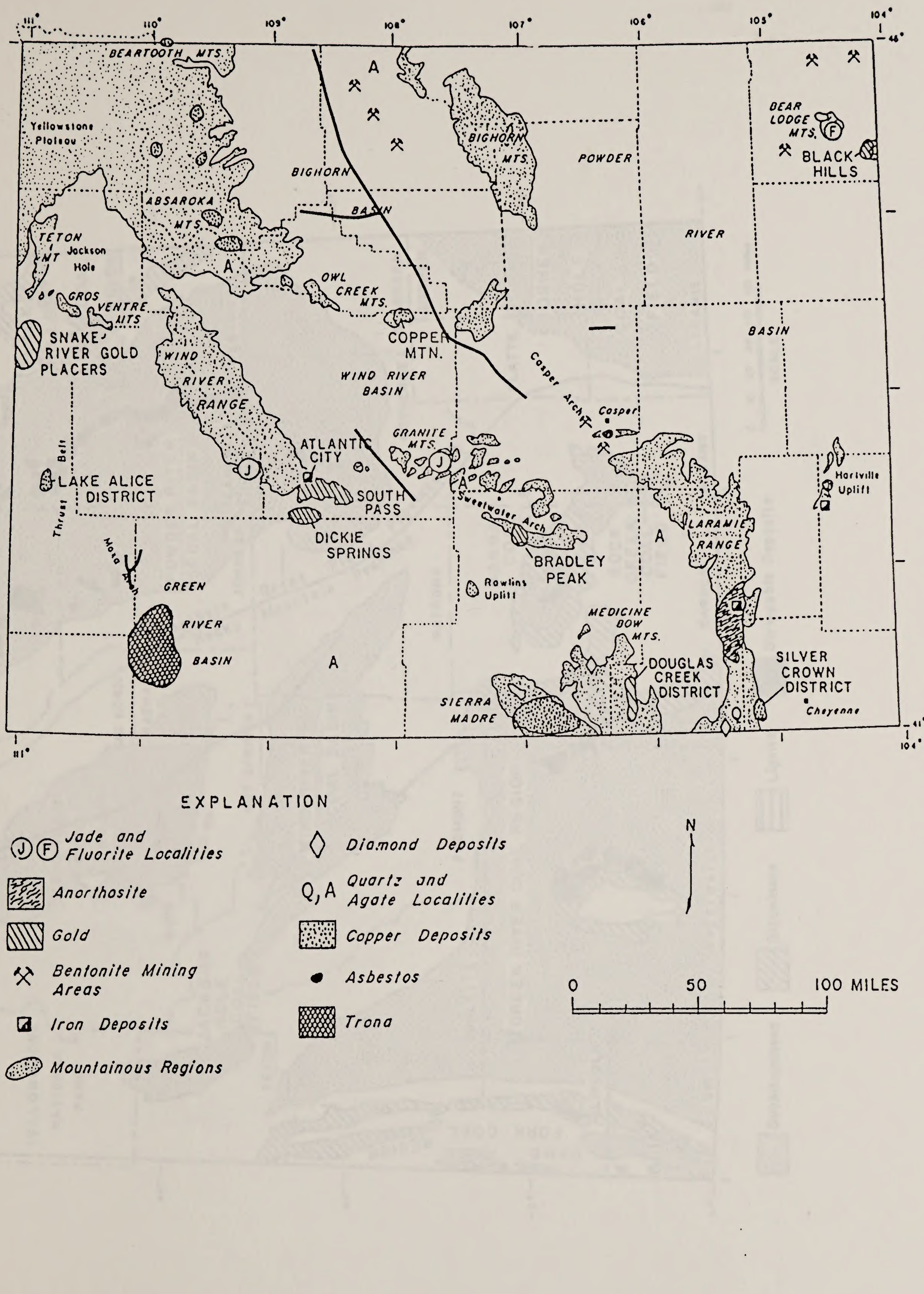


Figure 2—2. Mineral Resources in Wyoming (Hausel et al., 1987).

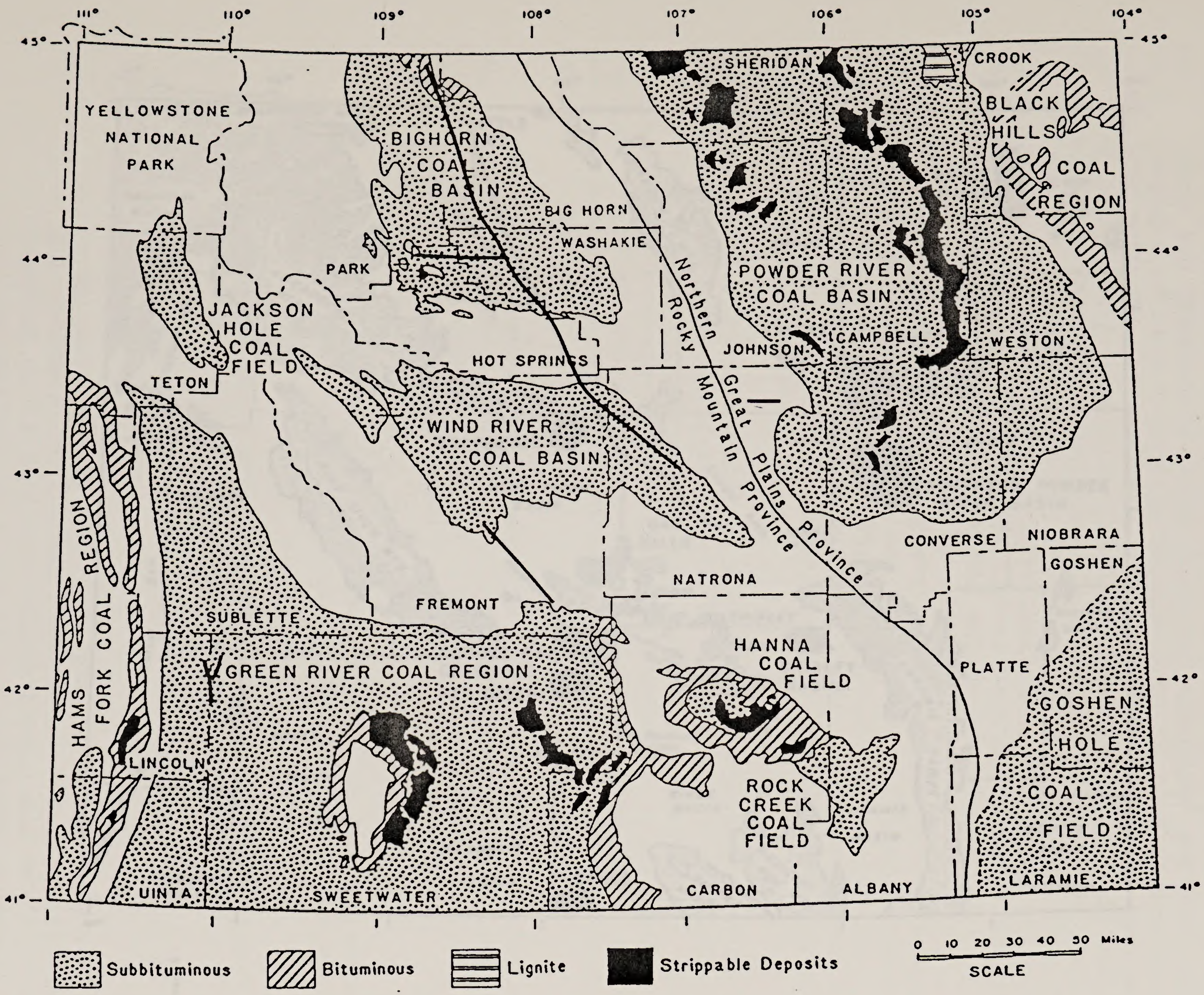


Figure 2—3. Coal—bearing Regions of Wyoming (Hausel,1987).

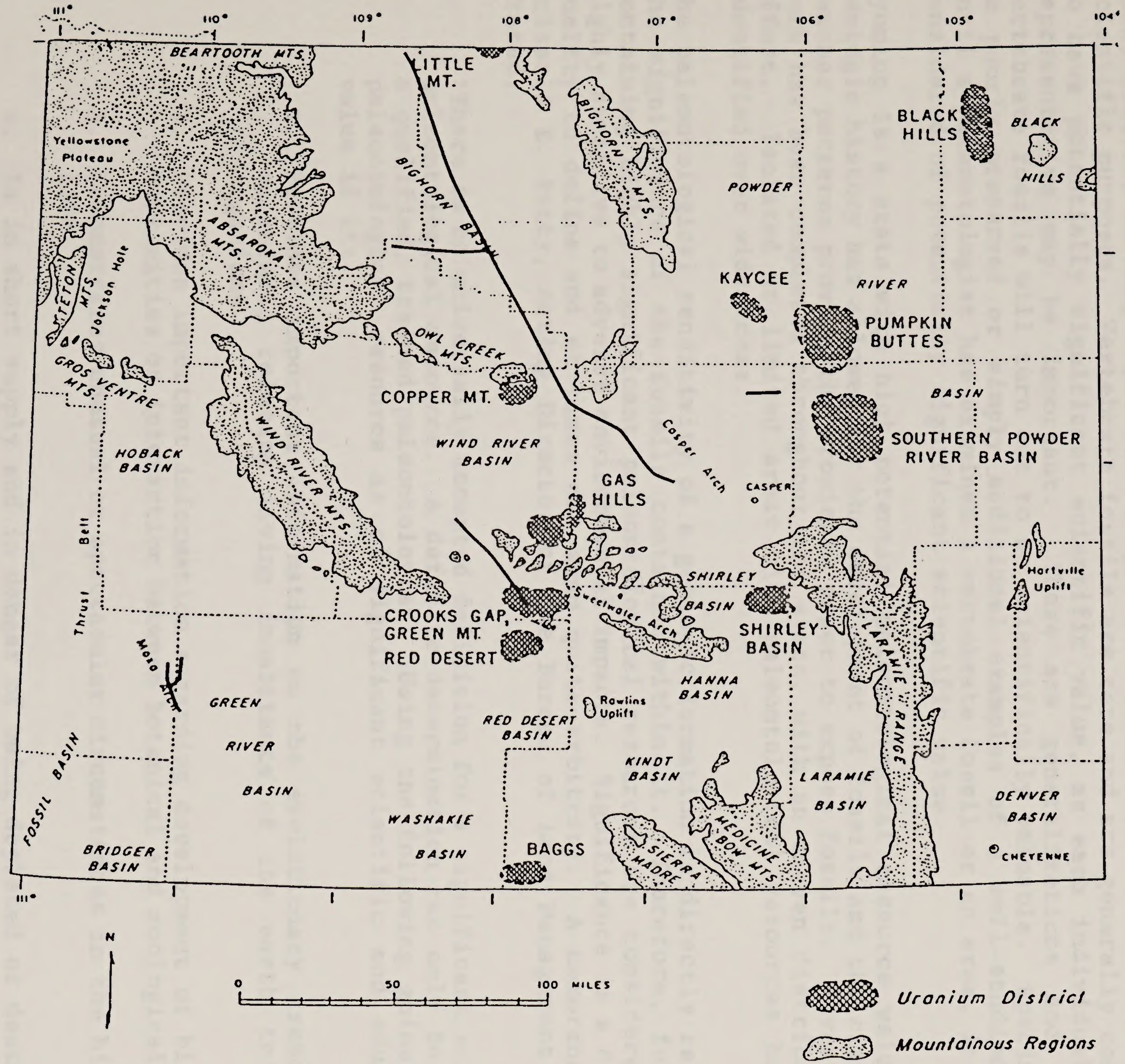


Figure 2—4. Uranium Districts in Wyoming (Hausel, 1987).

2.1.2 Paleontological Resources

Paleontology is the geologic science dealing with the plant and animal life of past geologic periods as known from fossil remains (BLM, 1986). Fossils are rarely distributed homogeneously throughout a geological formation. Formations can indicate only a potential for fossils in any given area.

Invertebrate fossils are generally formed from organisms living in lakes or seas. They are frequently found in great abundance and over large areas. As such, recovery of only a portion of specimens in an area can be sufficient for scientific purposes. Vertebrate fossils are rare and are generally considered to have potentially significant scientific value, as each individual fossil representative may be important. These are generalizations and not all vertebrate fossils will turn out to be scientifically valuable. Specimens may be poorly preserved or simply additional examples of a well-studied group. Until a paleontologist has examined a vertebrate fossil or an area, it must be considered of potentially significant scientific value.

Wyoming is a state with high potential paleontological resource value. Its geologic history has allowed for the development of fossils and the climate and weather patterns provide the erosional power to expose fossils. Investigative work has been completed throughout the state, with an uneven distribution of effort. Isolated or limited areas with paleontological resources have been identified over wide areas.

The paleontological sensitivity of a geologic formation is directly related to the significance of the fossils contained within it. Therefore, formations containing highly significant paleontological resources are considered to be highly sensitive to adverse environmental impacts. Significance is a difficult quality to define and at times can seem quite arbitrary. A memorandum from Grissold E. Petty, Acting Director of the Bureau of Land Management (1978), stated,

> "There is no universally accepted definition for a significant scientific paleontological resource. A definite determination can only be made by a qualified, trained paleontologist. Using the following guidelines, a paleontological resource is of significant scientific and educational value if it:
>
> 1. Provides important information on the evolutionary trends among organisms, relating living inhabitants of the earth to extinct organisms.
>
> 2. Provides important information regarding development of biological communities or interaction between botanical and zoological biotas.
>
> 3. Demonstrates unusual or spectacular circumstances in the history of life.
>
> 4. Is in short supply and in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation, and is not found in other geographic locations. All vertebrate fossils have been categorized as being of a significant scientific value."

Based in part on the BLM criteria cited above, the following levels of paleontological sensitivity are used in this report and the EIS.

2.1.2 Paleontological Resources

Paleontology is the geologic science dealing with the plant and animal life of past geologic periods as known from fossil remains ([illegible], 1983). Fossils are rarely distributed homogeneously throughout a geological formation. Formations can indicate only a potential for fossils in any given area.

Invertebrate fossils are generally formed from organisms living in oceans or seas. They are frequently found in great abundance and over large areas. As such, recovery of only a portion of specimens in an area can be sufficient for scientific purposes. Vertebrate fossils are rare and are generally considered to have potentially significant scientific value, as each individual fossil representative may be important. There are exceptions, and not all vertebrate fossils will turn out to be scientifically valuable. Specimens may be too fragmented or simply additional examples of a well-studied group. Until a paleontologist has examined a vertebrate locality in person, it must be considered of potentially significant scientific value.

Wyoming is a state with high potential paleontological resource value. Its geologic history has allowed for the preservation of fossils and the climate and weather patterns provide the erosional power to expose fossils. Investigations over the area have been completed throughout the state, this research has shown distribution of extant. Instances of limited areas with paleontological resources have been identified over wide areas.

The paleontological sensitivity of a geologic formation is directly related to the significance of the fossils contained within it. Therefore, formations containing highly significant paleontological resources are considered to be highly sensitive to adverse environmental impacts. Significance is a difficult quality to define and it varies for each paleo discipline. A memorandum from Edward E. [illegible], Acting Director of the Bureau of Land Management (1978), states,

> "There is no universally accepted definition for a significant scientific paleontological resource. A scientific determination can only be made by a qualified, trained paleontologist. Using the following guidelines, a paleontological resource is of significant scientific and educational value if it:
>
> 1. Provides important information on the evolutionary trends among organisms, relating living inhabitants of the earth to extinct organisms.
>
> 2. Provides important information regarding development of biological communities or interaction between botanical and zoological biotas.
>
> 3. Demonstrates unusual or spectacular circumstances in the history of life.
>
> 4. Is in short supply and in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation, and is not found in other geographic locations. All vertebrate fossils have been categorized as being of a significant scientific value."

Based in part on the BLM criteria cited above, the following levels of paleontological sensitivity are used in this report and the EIS

High sensitivity formations are those containing known paleontological resources of high significance. Generally speaking, these formations have produced vertebrate fossil remains or are considered to have the potential to produce such remains.

Moderate sensitivity formations rarely contain paleontological resources either within or adjacent to the study area.

Low sensitivity formations are those with no known paleontological resources, but generally have a resource potential based on their sedimentary origin.

2.1.3 Geologic Environment

The proposed spur and trunk CO_2 pipeline routes would cross several local physiographic provinces (Figure 2-5) including the Bighorn Basin, the Owl Creek Mountains, the Wind River Basin, the Casper Arch, the Granite Mountains and the Green River Basin. Folding and faulting related to the late Cretaceous/early Tertiary Laramide Orogeny has produced this complex setting of basement uplifts and intervening sedimentary basins. In general, Mesozoic sedimentary rock units occur in the uplifts and Tertiary rock units in the basins.

Sedimentary rock formations along the proposed spur and trunk CO_2 pipeline routes range primarily from late Cretaceous through mid-Tertiary in age and contain a fairly complete record of the prehistoric land life of western North America during this time span from approximately 100 to 15 million years ago. This fossil record preserves the end of the age of dinosaurs as well as the beginning of the age of mammals.

Many of the geologic formations crossed by the proposed pipeline routes are known to contain paleontological resources. For individual formations, this is a general assessment of the resource potential of the entire formation both within and outside the study areas. Table 2-1 lists and briefly describes the geologic formations that may be affected by all of the proposed projects. Project-by-project discussions of mineral and paleontological resources identify existing and potential mineral resources and summarize the paleontological sensitivity of the formations along each proposed pipeline at proposed plant sites and within the fields. Sensitivity ratings, by nearest milepost, are also noted for each of the projects. The milepost markings are close approximations. If particular sections are to be examined in the field, a more accurate separation, if feasible even on the ground, of formations would be determined at that time.

2.2 FONTENELLE CO_2 SUPPLY PROJECT

The proposed Fontenelle Gas Gathering System and Raptor Field are located in the Green River Basin at the southern end of the Fontenelle Reservoir. The project area is in the northeast corner of the Kemmerer Resource Area and the northwest corner of the Green River Resource Area. The pipeline would transport CO_2 between the Raptor Field and the proposed Fontenelle Gas Processing Plant, to be constructed adjacent to the existing Exxon Shute Creek Gas Processing Plant (Figure 2-6). Geologic formations and other stratigraphic units that would be crossed by the proposed pipelines are listed in Table 2-2.

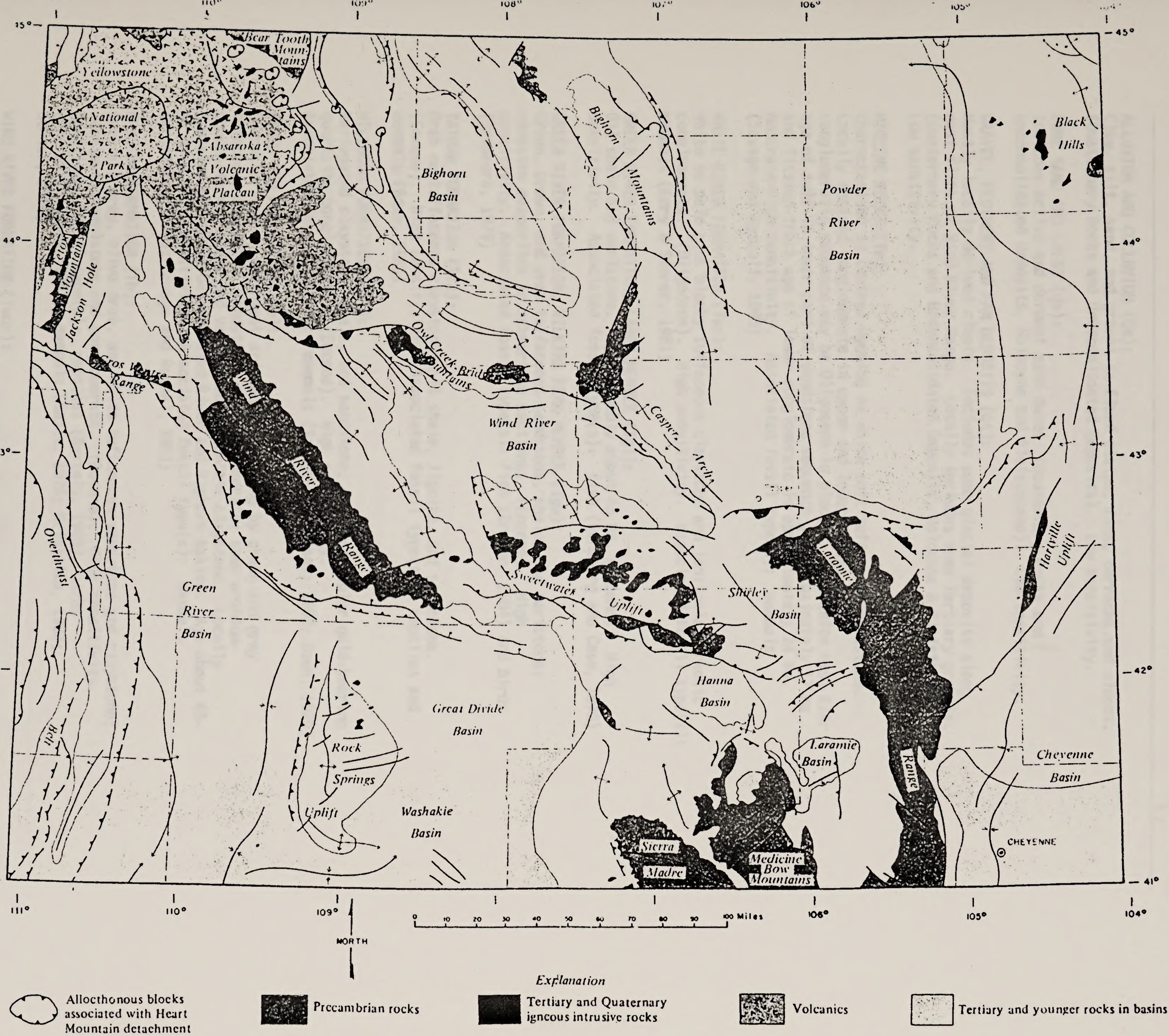


Figure 2—5. Major Structural Elements in Wyoming (Glass and Blackstone, 1987).

Table 2-1. Geologic Formation Background Information, Paleontological Sensitivity and Associated Fossil Types.

ALLUVIUM AND COLLUVIUM (Qa):
Clay, silt, sand, and gravel in flood plains, fans, terraces,and slopes. (Quaternary Rocks and Unconsolidated Deposits). Low sensitivity.

DUNE SAND AND LOESS (Qs):
Includes active and dormant sand dunes (Quaternary Rocks and Unconsolidated Deposits, Holocene and Pleistocene). Low sensitivity.

GRAVEL, PEDIMENT AND FAN DEPOSITS (Qt):
Mostly locally derived clasts. Includes some glacial deposits along east flank of Wind River Range. Locally includes some Tertiary gravels. (Quaternary Rocks and Unconsolidated Deposits, Holocene & Pleistocene). Low sensitivity.

MIOCENE ROCKS (Tm):
Characterized in Central Wyoming as white soft tuffaceous sandstone. Locally derived conglomerate in upper and lower parts; lower conglomeratic sequence may be Oligocene in places. In Granite Mts, K/Ar age of tuff in lower part of sandstone sequence is approximately 17 Ma and fission-track age of lower conglomerate is approximately 24 Ma. Moderate-High sensitivity. Associated fossil type(s): mammals (Savage and Russell, 1983)

WHITE RIVER FORMATION (Twr):
White to pale pink blocky tuffaceous claystone and lenticular arkosic conglomerate. (Oligocene). High sensitivity. Associated fossil type(s): mammals (Emry & Storer, 1981)

GREEN RIVER FORMATION, LANEY MEMBER (Tgl):
Oil shale and marlstone. Age probably about 45 Ma. (Eocene). High sensitivity. Associated fossil type(s): fish (Lundberg and Case, 1970)

GREEN RIVER FORMATION, WILKINS PEAK MEMBER (Tgw):
Green, brown, and gray tuffaceous sandstone, shale, and marlstone; contains evaporites in subsurface sections. (Eocene). High sensitivity. Associated fossil type(s): fish (Grande, 1984) and birds (Brodkorb, 1970)

TATMAN FORMATION (Tta):
Drab nontuffaceous claystone, oil shale, lignite, and sandstone. (Eocene). High sensitivity. Associated fossil type(s): reptiles and mammals (Bown, 1983)

WILLWOOD FORMATION (Twl):
Variegated claystone, shale, and sandstone; some lenticular gold-bearing quartzite conglomerate. (Eocene). High sensitivity. Associated fossil type(s): mammals (Savage and Russel, 1983; Bown, 1979)

WAGON BED FORMATION (Twb):
Characterized in southwest and central Wyoming by green and gray tufaceous claystone, sandstone, and conglomerate; some uranium-phosphate marlstone and variegated bentonitic claystone. Locally contains oil shale between Wind River and Bighorn basins. Age about 45-49 Ma. High sensitivity. Associated fossil type(s): mammals (Kristalka, 1983; Savage and Russel, 1983)

BRIDGER FORMATION (Tb):
Greenish gray, olive drab, and white tuffaceous sandstone and claystone; lenticular marlstone and conglomerate. (Eocene). High sensitivity. Associated fossil type(s): reptiles (Bartels, 1983), birds (Mourer-Chauvire, 1983); mammals (Gazin, 1976; Kristalka, 1983; Schoch, 1983)

WIND RIVER FORMATION (Twdr):
Variegated claystone and sandstone, lenticular conglomerate. Age of tuff at top 49 Ma. (Eocene). High sensitivity. Associated fossil type(s): mammals (Kristalka and Stucky, 1983)

Table 2-1. Continued.

BATTLE SPRING FORMATION (Tbs):
Equal to and lithologically similar to locally derived basin-margin conglomerate of Wasatch Formation and merges southward into main body of the Wasatch Formation. (The main body of the Wasatch Formation is drab sandstone, drab to variegated claystone and siltstone with locally derived conglomerate around basin margins. The lower part is Paleocene). Lower part is Paleocene, upper is Eocene. Moderate sensitivity.

FT. UNION FORMATION (Tfu):
Brown to gray sandstone, gray to black shale, and thin coal beds. (Paleocene). High sensitivity. Associated fossil type(s): reptiles Bartels, 1983), mammals (Gazin, 1976; Gingerich, 1983; Dristalka, 1983; Rigby, 1980; Savage and Russell, 1983)

LANCE FORMATION (Kl):
Thick-bedded buff sandstone and drab to green shale; thin conglomerate lenses. (Upper Cretaceous). High sensitivity. Associated fossil type(s): amphibians (Fox, 1976), reptiles (Estes, 1964), dinosaurs (Brown, 1983), mammals Savage and Russell, 1983)

FOX HILLS SANDSTONE (Klm):
Light-colored sandstone and gray sandy shale containing marine fossils. (Upper Cretaceous). High sensitivity. Associated fossil type(s): marine invertebrates, dinosaurs (Horner, 1979); mammals (Savage and Russel, 1983)

MEETEETSE FORMATION (Km):
Chalky white to gray sandstone, yellow, green, and dark gray bentonitic claystone, white tuff, and thin coal beds. Age about 733 million years (Ma.) (Upper Cretaceous). Moderate sensitivity.

MESAVERDE FORMATION (Kmv):
Light colored massive to thin-bedded sandstone, gray sandy shale, and coal beds. North of North Fork of Powder River east of the Bighorn Mts, consists solely of Parkman Sandstone Member. (Upper Cretaceous). Moderate sensitivity.

CODY SHALE (Kc):
Dull gray shale, gray siltstone, and fine-grained gray siltstone. Age about 78 to 83 Ma. Moderate sensitivity.

FRONTIER FORMATION (Kf):
Gray sandstone and sandy shale. Oyster coquina in upper part in Thrust Belt. (Upper Cretaceous). Moderate sensitivity.

THERMOPOLIS SHALE (Kmt):
Black soft fissile shale; Muddy Sandstone Member at top. (Lower Cretaceous). High sensitivity. Associated fossil type(s): marine invertebrates, dinosaurs (Moodie, 1932; Horner, 1979)

CHUGWATER FORMATION (Trcd):
Red siltstone and shale. Alcova Limestone Member in upper and middle part in N. Wyoming. Thin gypsum partings near base in N. Wyoming. (Upper and Lower Triassic). High sensitivity.

PHOSPHORIA FORMATION AND RELATED ROCKS (Pp):
Brown sandstone and dolomite, cherty phosphatic and glauconitic dolomite, and greenish-gray to black shale. Intertonguing equivalents of parts of phosphoria are Park City Formation (primarily cherty dolomite, limestone, and phosphatic gray shale) and Shedhorn Sandstone. Moderate sensitivity.

Note: Formations are listed by geologic age, youngest to oldest.
Descriptions of formations are from Love and Christiansen, 1985.

Table 2-2. Geologic Formations or Stratigraphic Units Crossed by the Proposed Actions and the Dominant Units in the Wellfields. (a)

Formation/ Stratigraphic Unit	Paleontological Sensitivity	Fontenelle	Elk Basin	Beaver Creek	Little Buffalo Basin	Salt Creek
Dune Sand & Loess	Low	x	x			
Phosphoria Formation	Moderate		x			
Chugwater Formation	High		x			
Thermopolis Shale	High		x			
Frontier Formation	Moderate		x			
Meeteetse Formation	Moderate		x (a)			
Battle Spring Formation	Moderate			x		
Cody Shale	Moderate		x (a)	x	x (a)	x (a)
Miocene Rocks	Moderate-High			x		
Wagon Bed Formation	High		x	x		
Wind River Formation	High		x	x		
Alluvium & Colluvium	Low	x (a)	x	x (a)		
Mesaverde Formation	Moderate		x (a)		x (a)	
Lance Formation	High		x (a)		x	
Ft. Union Formation	High		x		x	
Tatman Formation	High				x	
Willwood Formation	High				x	
Gravel, Pediment & Fan Deposits	Low	x	x		x	
Green River Formation, Laney Member	High	x				
Bridger Formation	High	x (a)				
White River Formation	High			x		

a = Formations or stratigraphic units are dominant in the wellfield.

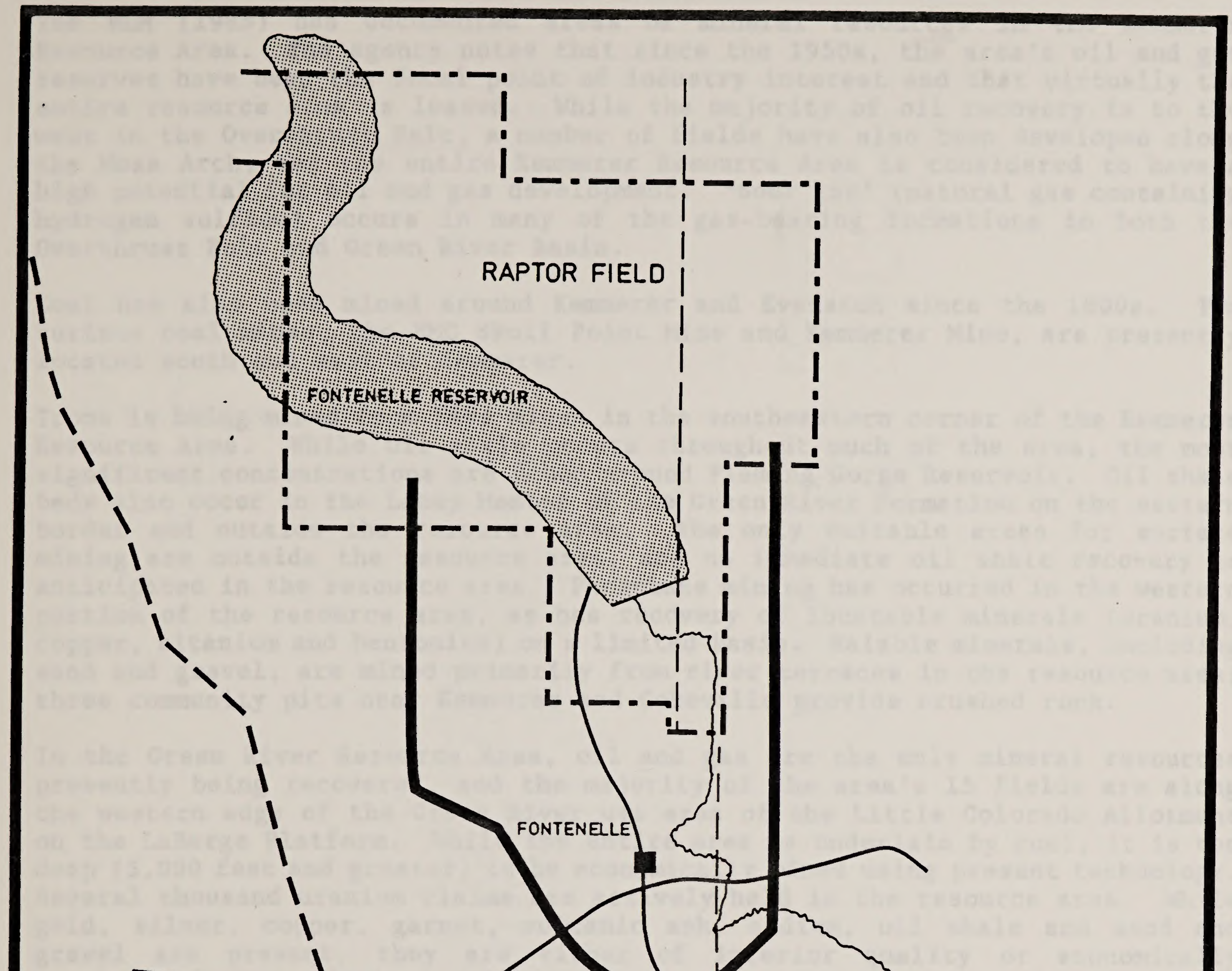


Figure 2—6. Proposed Fontenelle Project.

The BLM (1985) has documented areas of mineral resources in the Kemmerer Resource Area. The agency notes that since the 1950s, the area's oil and gas reserves have been the focal point of industry interest and that virtually the entire resource area is leased. While the majority of oil recovery is to the west in the Overthrust Belt, a number of fields have also been developed along the Moxa Arch, and the entire Kemmerer Resource Area is considered to have a high potential for oil and gas development. "Sour gas" (natural gas containing hydrogen sulfide) occurs in many of the gas-bearing formations in both the Overthrust Belt and Green River Basin.

Coal has also been mined around Kemmerer and Evanston since the 1800s. Two surface coal mines, the FMC Skull Point Mine and Kemmerer Mine, are presently located south and west of Kemmerer.

Trona is being mined from five mines in the southeastern corner of the Kemmerer Resource Area. While oil shale occurs throughout much of the area, the most significant concentrations are found around Flaming Gorge Reservoir. Oil shale beds also occur in the Laney Member of the Green River Formation on the eastern border and outside the resource area. The only suitable areas for surface mining are outside the resource area, and no immediate oil shale recovery is anticipated in the resource area. Phosphate mining has occurred in the western portion of the resource area, as has recovery of locatable minerals (uranium, copper, titanium and bentonite) on a limited basis. Salable minerals, including sand and gravel, are mined primarily from river terraces in the resource area; three community pits near Kemmerer and Cokeville provide crushed rock.

In the Green River Resource Area, oil and gas are the only mineral resources presently being recovered, and the majority of the area's 15 fields are along the western edge of the Green River use area of the Little Colorado Allotment on the LaBarge Platform. While the entire area is underlain by coal, it is too deep (3,000 feet and greater) to be economically mined using present technology. Several thousand uranium claims are actively held in the resource area. While gold, silver, copper, garnet, volcanic ash, sodium, oil shale and sand and gravel are present, they are either of inferior quality or economically precluded from development (BLM, 1978).

Existing mines and minerals in the project's vicinity have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). While the area is underlain by bedded trona, few other mineral resources have been located. There are several construction aggregate pits/quarries located on both the east and west sides of Fontenelle Reservoir. These are sources of crushed rock, sand, sand and gravel, baked rock (clinker or scoria) or limestone mined for aggregate (see Map 1 in Appendix A). There are no oil fields immediately adjacent to the proposed gas gathering system, but there are a number of existing gas fields (Table 2-3, Figure 2-7).

The Kemmerer Resource Area is noted for its paleontological resources. The Bridger Formation has produced at least 25 families of fossil mammals and the Green River Formation has yielded an extremely diverse assemblage of vertebrates and invertebrates (BLM, 1985).

Vertebrate fossils have also been recovered in the Green River Resource Area. Fossil fish have been found in the Laney Member of the Green River Formation northeast of Farson, and the potential for fossils is considered high throughout the areas underlain by the Green River and Bridger formations (BLM, 1978).

The BLM (1983) has documented areas of mineral resources in the Kemmerer Resource Area. The agency notes that since the 1920s, the area's oil and gas reserves have been the focal point of industry interest and that virtually the entire resource area is leased. While the majority of oil recovery is to the west in the Overthrust Belt, a number of fields have also been developed along the Moxa Arch, and the entire Kemmerer Resource Area is considered to have a high potential for oil and gas development. "Sour gas" (natural gas containing hydrogen sulfide) occurs in many of the gas-bearing formations in both the Overthrust Belt and Green River Basin.

Coal has also been mined around Kemmerer and Evanston since the 1800s. Two surface coal mines, the FMC Skull Point Mine and Kemmerer Mine, are presently located south and west of Kemmerer.

Trona is being mined from five mines in the southeastern corner of the Kemmerer Resource Area. While oil shale occurs throughout much of the area, the most significant concentrations are found around Flaming Gorge Reservoir. Oil shale beds also occur in the Laney Member of the Green River Formation in the western portion and outside the resource area. The most favorable areas for surface mining are outside the resource area, and no immediate oil shale recovery is anticipated in the resource area. Phosphate mining has occurred in the western portion of the resource area, as has recovery of locatable minerals (uranium, copper, titanium and bentonite) on a limited basis. Salable minerals, including sand and gravel, are mined primarily from river terraces in the resource area; three community pits near Kemmerer and Cokeville provide crushed rock.

In the Green River Resource Area, oil and gas are the only mineral resources presently being recovered, and the majority of the area's 15 fields are along the eastern edge of the Green River use area of the Little Colorado Allotment on the [illegible] Platform. While the entire area is underlain by coal, it is too deep (3,000 feet and greater) to be economically mined using present technology. Several thousand uranium claims are actively held in the resource area. While gold, silver, copper, garnet, soda ash, sodium, oil shale and sand and gravel are present, they are either of inferior quality or economically precluded from development (BLM, 1978).

Existing mines and minerals in the project's vicinity have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). While the area is underlain by bedded trona, few other mineral resources have been located. There are several construction aggregate pits/quarries located on both the east and west sides of Fontenelle Reservoir. These are sources of crushed rock, stone, sand and gravel, baked rock (clinker or scoria) or limestone mined for aggregate (see Map 2 in Appendix A). There are no oil fields immediately adjacent to the proposed gas gathering system, but there are a number of existing gas fields (Table 2-3, Figure 2-7).

The Kemmerer Resource Area is noted for its paleontological resources. The Bridger Formation has produced at least 25 families of fossil mammals and the Green River Formation has yielded an extremely diverse assemblage of vertebrates and invertebrates (BLM, 1983).

Vertebrate fossils have also been recovered in the Green River Resource Area. Fossil fish have been found in the Laney Member of the Green River Formation northeast of Farson, and the potential for fossils is considered high throughout the areas underlain by the Green River and Bridger formations (BLM, 1978).

Table 2-3. Oil and Gas Fields Within Ten Miles of the Proposed Projects. (a)

Project	Oil Fields	Gas Fields
Fontenelle		Fontenelle Emigrant Springs Opal Mesa Blue Forest Lincoln Road Shute Creek Storm Shelter Horn Canyon
Elk Basin	Elk Basin Silver Tip Badger Basin Silver Tip South Elk Basin South Bearcat Big Polecat Little Polecat Coon Creek Foster Gulch Pullium Neiber Water Creek Murphy Dome Zimmerman Butte Corley Tumbler Ridge Lake Creek Northwest Lake Creek Black Mountain Kirby Creek Blue Spring Wild Horse Butte Mud Creek Kirby Creek East	North Danker Whistle Creek South Bridger Trail Emblem Bench Fourteen-Mile Dolis Hills Madden Lost Cabin Badwater Teepee Flats Arminto (b) Waltman Bullfrog Boone Dome Hells Half-Acre Smith Canyon Powder River Lox (b)
Beaver Creek	Crooks Gap Sheep Creek Golden Goose Happy Springs Kohler Draw Sand Draw South Big Sand Draw Kirby Draw	Kirk Mt Rodgers Riverton Dome
Little Buffalo Basin	Grass Creek Buffalo Rim	Fourteen Mile Little Grass Creek
Salt Creek	Smokey Gap Salt Creek West Salt Creek East Teapot Castle Creek	

a = Source: Stephenson et al., 1984.
b = Abandoned.

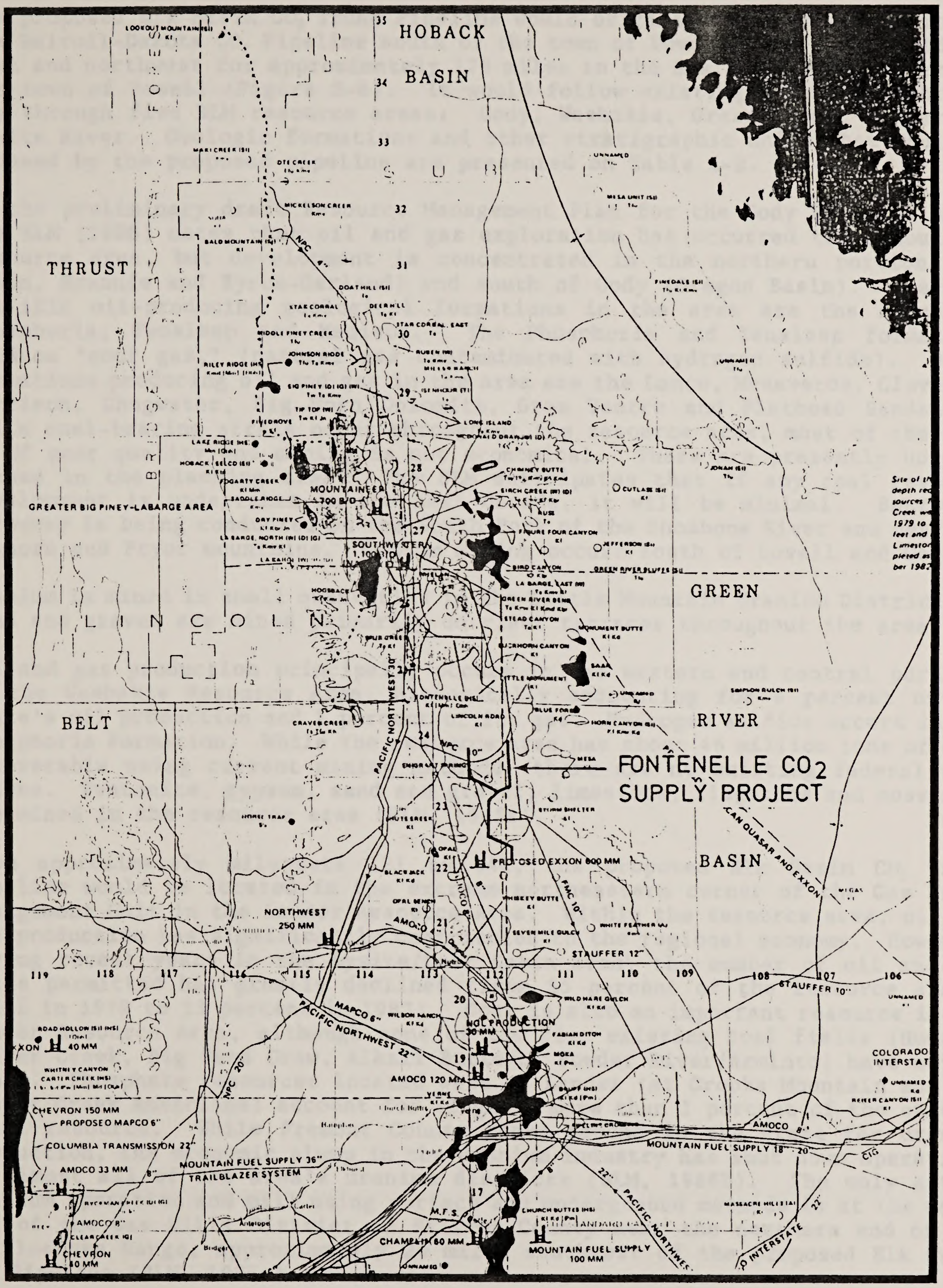


Figure 2—7. Oil & Gas Fields Near the Fontenelle CO_2 Supply Project (Stephenson et al., 1984)

2.3 ELK BASIN CO_2 PROJECT

The proposed Elk Basin CO_2 Trunk Pipeline would originate from the extension of the Bairoil-Dakota CO_2 Pipeline south of the town of Powder River. It would run west and northwest for approximately 178 miles to the Elk Basin Field, north of the town of Powell (Figure 2-8). It would follow existing pipeline right-of-way through five BLM resource areas: Cody, Washakie, Grass Creek, Lander and Platte River. Geologic formations and other stratigraphic units that would be crossed by the proposed pipeline are presented on Table 2-2.

In the preliminary draft Resource Management Plan for the Cody Resource Area, the BLM (1988) notes that oil and gas exploration has occurred throughout the resource area, but development is concentrated in the northern portion (Elk Basin, Frannie and Byron-Garland) and south of Cody (Oregon Basin). The most prolific oil-producing geological formations in the area are the Frontier, Phosphoria, Tensleep and Madison. The Phosphoria and Tensleep formations produce "sour gas," (natural gas contaminated with hydrogen sulfide). Other formations producing oil and gas in the area are the Lance, Mesaverde, Cloverly, Morrison, Chugwater, Big Horn Dolomite, Gros Ventre and Flathead Sandstone. While coal-bearing strata occur throughout the resource area, most of the coal is of poor quality and mining is not economical. There are presently no coal leases in the planning area. The BLM anticipates that if any coal resource development is undertaken in the next decade, it will be minimal. Bentonite recovery is being conducted on the South Fork of the Shoshone River and near the Bighorn and Pryor mountains. Gypsum mining occurs south of Lovell and Cody.

Uranium is mined in small quantities in the Little Mountain Uranium District and sand and gravel are mined primarily on river terraces throughout the area.

Oil and gas production principally occurs in the western and central portions of the Washakie Resource Area, historically accounting for 4 percent of the state's oil production and 1 percent of its gas. Hydrogen sulfide occurs in the Phosphoria Formation. While the resource area has about 46 million tons of coal recoverable using current mining methods, there are no existing federal coal leases. Bentonite, gypsum, sand and gravel, limestone, flagstone and moss rock are mined in the resource area (BLM, 1986a).

From approximately mileposts 121 to 141, the proposed Elk Basin CO_2 Trunk Pipeline would be located in the extreme northeastern corner of the Gas Hills Management Unit in the Lander Resource Area. Within the resource area, oil and gas production has significantly contributed to the regional economy. However, during recent years in the Lysite/Lost Cabin area, the number of oil and gas wells permitted has greatly declined (from 35 percent of the resource area's total in 1979 to 13 percent in 1983). Coal is also an important resource in the Lander Resource Area, although none of the five existing coal fields (Hudson, Beaver Creek, Big Sand Draw, Alkali Butte or Powder River/Arminto) have active mines. Phosphate resources located west of Lander (at Crooks Mountain and the Conant Creek Anticline) account for slightly more than 1 percent of the state's total resource. While Fremont County ranks second in the state for uranium production, the economic slump in the uranium industry has shut down operations in almost all of the area's uranium districts (BLM, 1986b). The only active uranium operation and mill using surface and underground methods is at the north end of the Gas Hills District in Natrona County near the northern end of the Rattlesnake Range, approximately 20 miles southwest of the proposed Elk Basin CO_2 Pipeline (BLM, 1984a).

2.3 ELK BASIN CO2 PROJECT

The proposed Elk Basin CO2 Trunk Pipeline would originate from the extension of the [illegible] CO2 pipeline south of the town of [illegible] River. It would run west and northwest for approximately 173 miles to the Elk Basin Field, north of the town of Powell (Figure 2-4). It would follow existing pipeline rights-of-way through five BLM resource areas: Cody, Washakie, Grass Creek, Lander, and Platte River. Geologic formations and other stratigraphic units that would be crossed by the proposed pipeline are presented on Table 2-2.

In the preliminary draft Resource Management Plan for the Cody Resource Area, the BLM (1988) notes that oil and gas exploration has occurred throughout the resource area, but development is concentrated in the northern portion (Elk Basin, Frannie and Byron-Garland) and south of Cody (Oregon Basin). The most prolific oil-producing geological formations in the area are the Frontier, Phosphoria, Tensleep and Madison. The Phosphoria and Tensleep formations produce "sour gas" (natural gas concentrations with hydrogen sulfide). Other formations producing oil and gas in the area are the Lance, Cloverly, [illegible], [illegible], Big Horn Dolomite, Gros Ventre and Flathead Sandstone. While coal-bearing strata occur throughout the resource area, most of the coal is of poor quality and mining is not economical. There are presently no coal leases in the planning area. The BLM anticipates that if any coal resource development is undertaken in the next decade, it will be minimal. Bentonite [illegible] is being [illegible] on the south fork of the Shoshone River and near the Bighorn and Pryor mountains. Gypsum mining occurs south of Lovell and Cody.

Uranium is mined in small quantities in the Little Mountain Uranium District and sand and gravel are mined primarily on river terraces throughout the area.

Oil and gas production principally occurs in the western and central portions of the Washakie Resource Area, historically accounting for 4 percent of the state's oil production and 1 percent of its gas. Hydrogen sulfide occurs in the Phosphoria formation. While the resource area has about 46 million tons of coal reserves, there are no existing federal coal leases. [illegible] bentonite, gypsum, sand and gravel, limestone, [illegible] and [illegible] are mined in the resource area (BLM, 1988a).

From approximately milepost [illegible] to 152, the proposed Elk Basin CO2 Trunk Pipeline would be located in the extreme northwestern corner of the Gas Hills Management Unit in the Lander Resource Area. Within the resource area, oil and gas production has significantly contributed to the regional economy. However, during recent years [illegible], the number of oil and gas wells permitted has greatly declined (from 35 percent of the resource area's total in 1979 to 13 percent in 1983). Coal is also an important resource in the Lander Resource Area, although none of the five existing coal fields (Hudson, [illegible], Big Sand Draw, [illegible]) have active mines. [illegible] located west of Lander [illegible] and the [illegible] account for slightly more than 1 percent of the state's total [illegible]. [illegible], the [illegible] in the uranium industry has shut down operations in [illegible] of the area's uranium districts (BLM, [illegible]). The only active [illegible] mill, using surface and underground methods is at the north end of the Gas Hills District in Natrona County near the northern end of the [illegible], approximately 20 miles southwest of the proposed Elk Basin CO2 Pipeline (BLM, [illegible]).

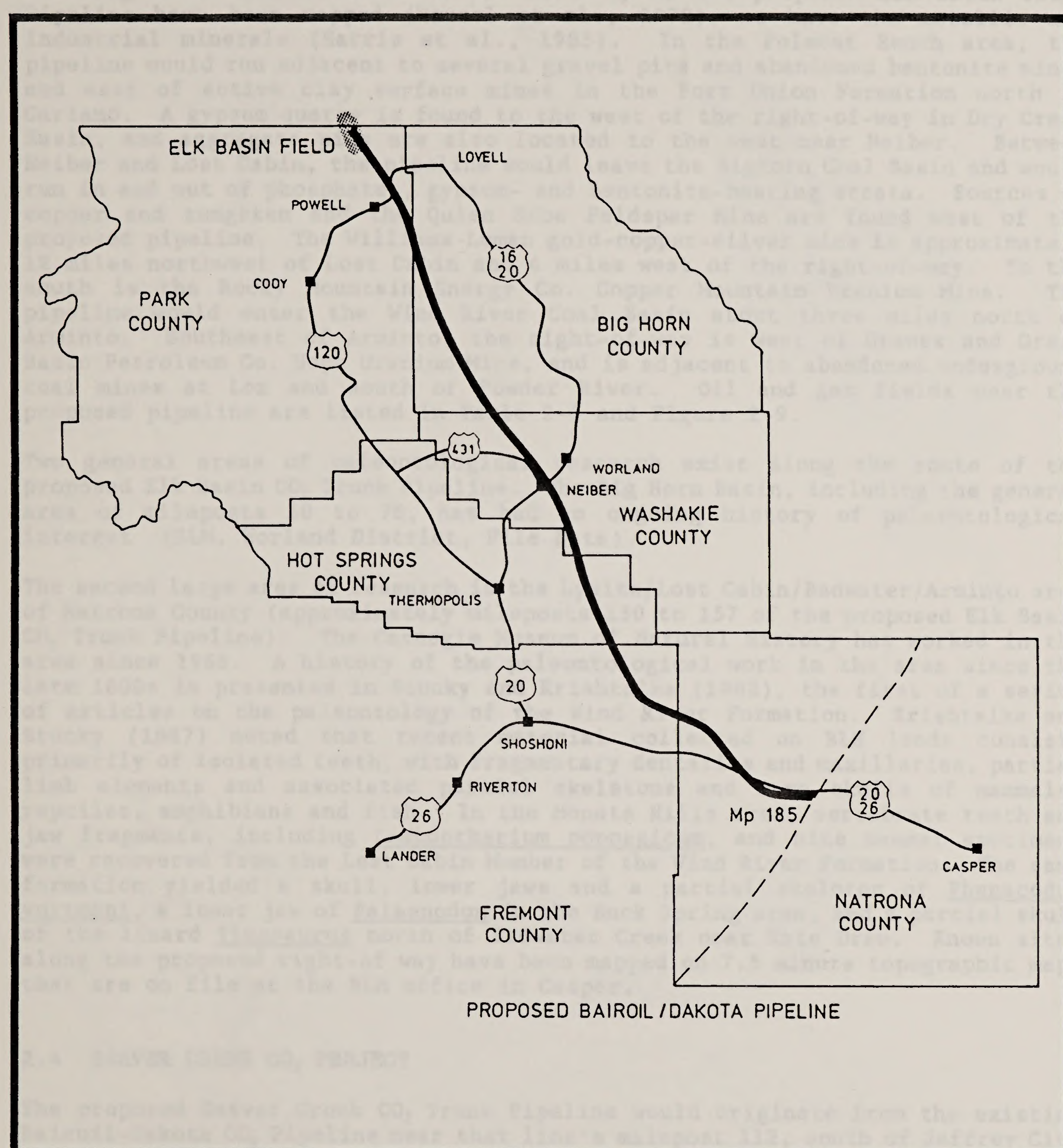


Figure 2—8. Proposed Elk Basin Project.

The pipeline would originate south of Powder River in the Platte River Resource Area and would cross the South Bighorns Resource Management Unit (RMU) and the Platte River Resource Area RMU 14.

Existing mines and minerals in the vicinity of the proposed Elk Basin Trunk Pipeline have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). In the Polecat Bench area, the pipeline would run adjacent to several gravel pits and abandoned bentonite mines and east of active clay surface mines in the Fort Union Formation north of Garland. A gypsum quarry is found to the west of the right-of-way in Dry Creek Basin, and aggregate pits are also located to the west near Neiber. Between Neiber and Lost Cabin, the pipeline would leave the Bighorn Coal Basin and would run in and out of phosphate-, gypsum- and bentonite-bearing strata. Sources of copper and tungsten and the Quien Sabe Feldspar Mine are found west of the proposed pipeline. The Williams Luman gold-copper-silver mine is approximately 12 miles northwest of Lost Cabin and 4 miles west of the right-of-way. To the south is the Rocky Mountain Energy Co. Copper Mountain Uranium Mine. The pipeline would enter the Wind River Coal Basin about three miles north of Arminto. Southeast of Arminto, the right-of-way is west of Uranex and Great Basin Petroleum Co. Hope Uranium Mine, and is adjacent to abandoned underground coal mines at Lox and south of Powder River. Oil and gas fields near the proposed pipeline are listed in Table 2-3 and Figure 2-9.

Two general areas of paleontological research exist along the route of the proposed Elk Basin CO_2 Trunk Pipeline. The Big Horn Basin, including the general area of mileposts 50 to 76, has had an ongoing history of paleontological interest (BLM, Worland District, File Data).

The second large area of research is the Lysite/Lost Cabin/Badwater/Arminto area of Natrona County (approximately mileposts 130 to 157 of the proposed Elk Basin CO_2 Trunk Pipeline). The Carnegie Museum of Natural History has worked in the area since 1968. A history of the paleontological work in the area since the late 1800s is presented in Stucky and Krishtalka (1982), the first of a series of articles on the paleontology of the Wind River Formation. Krishtalka and Stucky (1987) noted that recent material collected on BLM lands consists primarily of isolated teeth, with fragmentary dentaries and maxillaries, partial limb elements and associated partial skeletons and rare skulls of mammals, reptiles, amphibians and fish. In the Moneta Hills area, vertebrate teeth and jaw fragments, including Lambdotherium popoagicum, and nine mammal specimens were recovered from the Lost Cabin Member of the Wind River Formation. The same formation yielded a skull, lower jaws and a partial skeleton of Phenacodus vortmani, a lower jaw of Palaenodon in the Buck Spring area, and a partial skull of the lizard Tinosaurus north of Badwater Creek near Rate Draw. Known sites along the proposed right-of way have been mapped on 7.5 minute topographic maps that are on file at the BLM office in Casper.

2.4 BEAVER CREEK CO_2 PROJECT

The proposed Beaver Creek CO_2 Trunk Pipeline would originate from the existing Bairoil-Dakota CO_2 Pipeline near that line's milepost 112, south of Jeffrey City in Southeastern Fremont County. It would run northwest for approximately 44 miles to the Beaver Creek Field, south of Riverton (Figure 2-10). The project area is within the Beaver Creek Resource Management Unit (RMU) of the Lander Resource Area. Geologic formations and other stratigraphic units that would be crossed by the proposed pipeline are listed in Table 2-2.

The pipeline would originate south of Powder River in the Platte River Resource Area and would cross the South Bighorns Resource Management Unit (RMU) and the Platte River Resource Area RMU 14.

Existing mines and minerals in the vicinity of the proposed Elk Basin, Trunk Pipeline have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). In the Salt Creek/Teapot Dome areas, the pipeline would run adjacent to several gravel pits and abandoned bentonite mines and east of active clay surface mines in the Fort Union Formation south of Garland. A gypsum quarry is found to the west of the right-of-way in the Crown Butte, and vermiculite mine site also located to the east near Kaycee. Between Kaycee and Lost Cabin, the pipeline would leave the Bighorn Coal Basin and would run in and out of phosphate-, gypsum- and bentonite-bearing strata. Traces of copper and tungsten near the Quien Sabe Feldspar mine are found east of the proposed pipeline. The Williams Lemon gold-copper-silver mine is approximately 12 miles northwest of Lost Cabin and 4 miles west of the right-of-way. To the south is the Rocky Mountain Energy Co. Copper Mountain Uranium mine. The pipeline would enter the Wind River Coal Basin about three miles south of Arminto. Southeast of Arminto, the right-of-way is west of Uranus and Great Basin Petroleum Co. Hope Uranium mine, and is adjacent to abandoned underground coal mines at Lox and south of Powder River. Oil and gas fields near the proposed pipeline are listed in Table 2-3 and Figure 2-9.

Two general areas of paleontological research exist along the route of the proposed Elk Basin CO_2 Trunk Pipeline. The Big Horn Basin, including the general area of mileposts 30 to 45, has had an ongoing history of paleontological interest (BLM, Worland District, file data).

The second large area of research is the Lost Cabin/Badwater/Arminto area of Natrona County (approximately mileposts 150 to 185 of the proposed Elk Basin CO_2 Trunk Pipeline). The Carnegie Museum of Natural History has worked in the area since 1958. A history of the paleontological work in the area since the late 1800s is presented in Stucky and Krishtalka (1983), the first of a series of articles on the paleontology of the Wind River Formation. Krishtalka and Stucky (1985) noted that fossil material collected on BLM lands consists primarily of isolated teeth, with fragmentary mandibles and maxillaries, partial limb elements and associated partial skeletons and rare skulls of mammals, reptiles, amphibians and fish. In the Beaver Rim area, vertebrate teeth and jaw fragments, including Hyopsodus wortmani, and nine mammal specimens were recovered from the Lost Cabin member of the Wind River Formation. The same formation yielded a skull, lower jaws and a partial skeleton of Phenacodus wortmani, a lower jaw of Palaeosyops in the Hells Spring area, and a partial skull of the lizard Glyptosaurus south of Badwater Creek near Hare Draw. Known sites along the proposed right-of-way have been mapped on 7.5 minute topographic maps that are on file at the BLM office in Casper.

2.4 BEAVER CREEK CO_2 PROJECT

The proposed Beaver Creek CO_2 Trunk Pipeline would originate from the existing Bairoil-Dakota CO_2 Pipeline near that line's milepost 112, south of Jeffrey City in southwestern Fremont County. It would run northwest for approximately 56 miles to the Beaver Creek Field, south of Riverton (Figure 2-10). The project area is within the Beaver Creek Resource Management Unit (RMU) of the Lander Resource Area. Geologic formations and other stratigraphic units that would be crossed by the proposed pipeline are listed in Table 2-2.

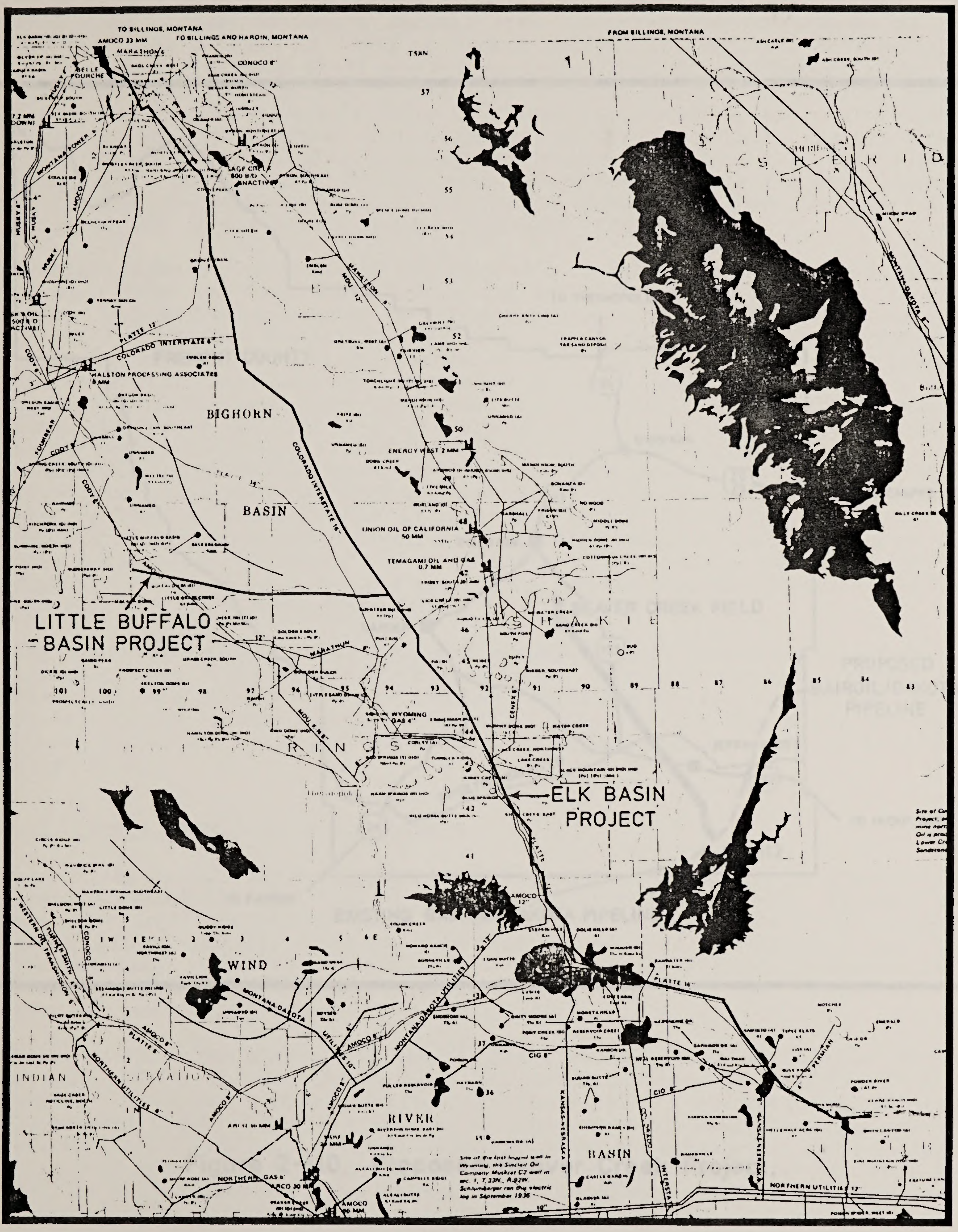


Figure 2—9. Oil and Gas Fields Near the Elk Basin CO_2 Project and the Little Buffalo Basin Project (Stephenson et al., 1984).

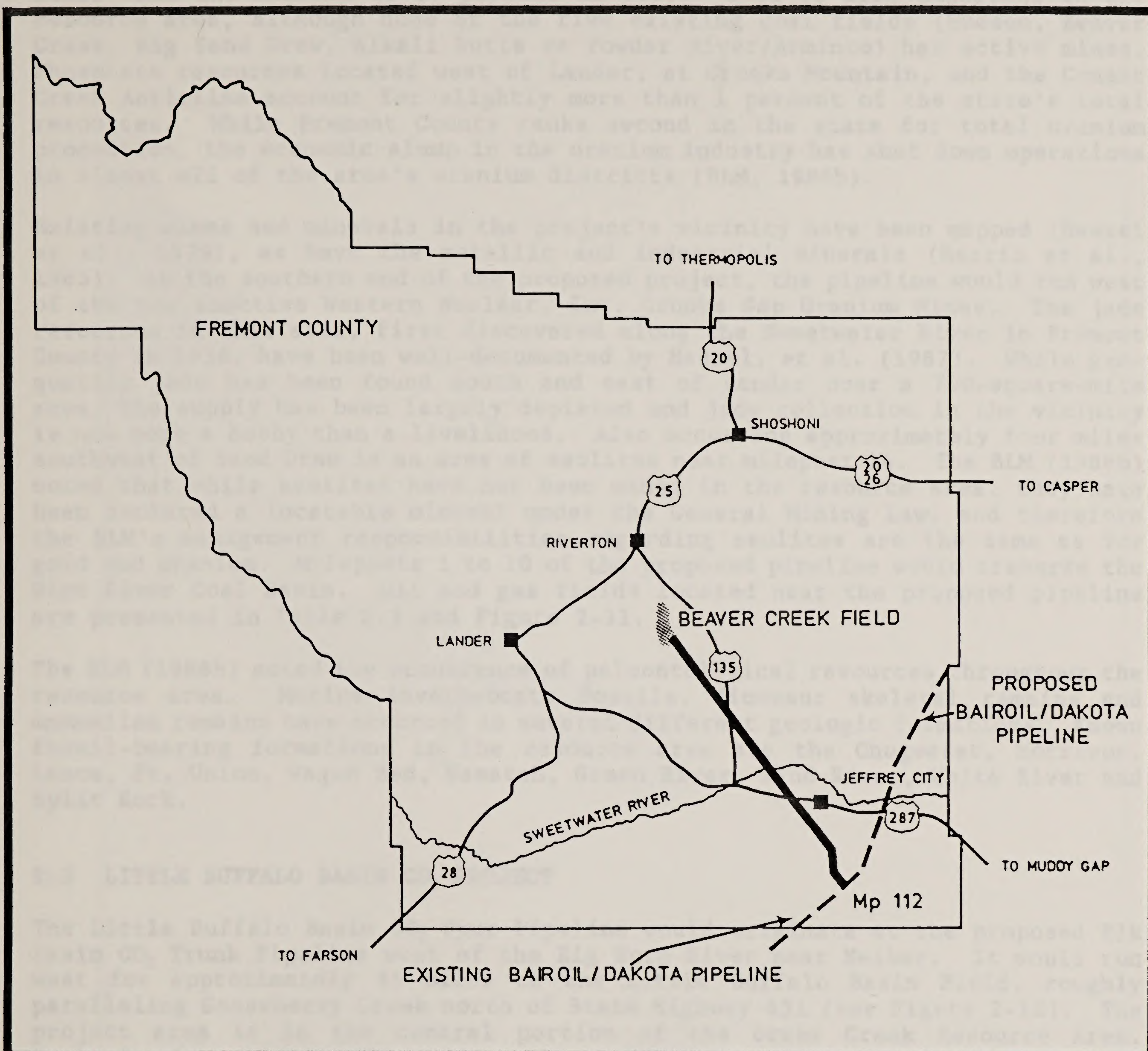


Figure 2—10. Proposed Beaver Creek Project.

The development of oil and gas resources has been a significant economic force in the resource area. The number of wells permitted in the Beaver Creek, Big Sand Draw, Crooks Gap/Happy Springs area accounted for 13 percent of the resource area's total in 1983, up from 8 percent in 1982, but substantially lower than the maximum of 37 percent in 1980. Coal is also important in the resource area, although none of the five existing coal fields (Hudson, Beaver Creek, Big Sand Draw, Alkali Butte or Powder River/Arminto) has active mines. Phosphate resources located west of Lander, at Crooks Mountain, and the Conant Creek Anticline account for slightly more than 1 percent of the state's total resources. While Fremont County ranks second in the state for total uranium production, the economic slump in the uranium industry has shut down operations in almost all of the area's uranium districts (BLM, 1986b).

Existing mines and minerals in the project's vicinity have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). At the southern end of the proposed project, the pipeline would run west of the now inactive Western Nuclear, Inc. Crooks Gap Uranium Mines. The jade resources in this area, first discovered along the Sweetwater River in Fremont County in 1936, have been well-documented by Hausel, et al. (1987). While gem-quality jade has been found south and east of Lander over a 700-square-mile area, the supply has been largely depleted and jade collection in the vicinity is now more a hobby than a livelihood. Also occurring approximately four miles southwest of Sand Draw is an area of zeolites near milepost 14. The BLM (1986b) noted that while zeolites have not been mined in the resource area, they have been declared a locatable mineral under the General Mining Law, and therefore the BLM's management responsibilities regarding zeolites are the same as for gold and uranium. Mileposts 1 to 10 of the proposed pipeline would traverse the Wind River Coal Basin. Oil and gas fields located near the proposed pipeline are presented in Table 2-3 and Figure 2-11.

The BLM (1986b) noted the occurrence of paleontological resources throughout the resource area. Marine invertebrate fossils, dinosaur skeletal remains and mammalian remains have occurred in several different geologic formations. Known fossil-bearing formations in the resource area are the Chugwater, Morrison, Lance, Ft. Union, Wagon Bed, Wasatch, Green River, Wind River, White River and Split Rock.

2.5 LITTLE BUFFALO BASIN CO_2 PROJECT

The Little Buffalo Basin CO_2 Spur Pipeline would originate at the proposed Elk Basin CO_2 Trunk Pipeline west of the Big Horn River near Neiber. It would run west for approximately 35 miles to the Little Buffalo Basin Field, roughly paralleling Gooseberry Creek north of State Highway 431 (see Figure 2-12). The project area is in the central portion of the Grass Creek Resource Area. Geologic formations and stratigraphic units that would be crossed by the proposed project are presented in Table 2-2.

Existing mines and minerals in the project's vicinity have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). There are two construction aggregate pits or quarries located along Gooseberry Creek; these are sources of crushed rock, sand, sand and gravel, baked rock (clinker or scoria) or limestone mined for aggregate. Two gas fields (Fourteen Mile and Little Grass Creek) and two oil fields (Grass Creek and Buffalo Rim, Figure 2-9) are within ten miles of the proposed Little Buffalo Basin pipeline (Stephenson et al., 1984).

The development of oil and gas resources has been a significant economic force in the resource area. The number of wells permitted in the [illegible] Basin, Big Bend Draw, [illegible] areas accounted for 15 percent of the statewide total in 1983, up from 8 percent in 1982, but substantially lower than the maximum of 37 percent in 1980. Coal is also important in the resource area, although none of the five existing coal fields ([illegible], [illegible] Creek, Big Sand Draw, [illegible] or Powder River [illegible]) has [illegible] mines. [illegible] located west of Lander at Crooks Mountain, and the [illegible] Creek [illegible] account for slightly more than 1 percent of the state's total [illegible]. While Fremont County ranks second in the state for total uranium production, the economic slump in the uranium industry has shut down operations in almost all of the area's uranium districts (BLM, 1983b).

Existing mines and minerals in the project's vicinity have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). At the northern end of the proposed project, the pipeline would run west of the [illegible] Western Nuclear, Inc. [illegible] Gap Uranium Mines. The [illegible] in this area [illegible] along the Sweetwater River in Fremont County [illegible] have been well documented by Hausel, et al. (1985). While [illegible] jade has been found north and east of Lander near a [illegible] area, the supply has been largely depleted and jade exploration in the vicinity is now more a hobby than a livelihood. [illegible] approximately four miles southeast of [illegible] is an area of [illegible] been [illegible]. The BLM (1983a) states that while [illegible] have not been mined in the resource area, they have been declared a locatable mineral under the General Mining Law, and therefore the BLM's management responsibilities regarding [illegible] are the same as for gold and uranium. [illegible] 1 to 10 of the proposed pipeline would traverse the [illegible] Coal Basin. Oil and gas fields located near the proposed pipeline are presented in Table 2-5 and Figure 2-11.

The BLM (1983b) notes the occurrence of paleontological resources throughout the resource area. [illegible] invertebrate fossils, dinosaur skeletal remains and [illegible] have occurred in several different geologic formations. [illegible] fossil-bearing formations in the resource area are the [illegible], Morrison, [illegible], Wagon Bed, [illegible], [illegible], Wind River, White River and Split Rock.

2.3 LITTLE BUFFALO BASIN CO, PROJECT

The Little Buffalo Basin [illegible] Pipeline would originate at the proposed [illegible] [illegible] Pipeline west of the Big Horn River near Worland. It would run west for approximately [illegible] miles to the Little Buffalo Basin Field, roughly paralleling [illegible] Creek north of State Highway 431 (see Figure 2-12). The project area is in the central portion of the [illegible] Creek Resource Area. Geologic formations and stratigraphic units that would be crossed by the proposed project are presented in Table 2-6.

Existing mines and minerals in the project's vicinity have been mapped (Hausel et al., 1979), as have the metallic and industrial minerals (Harris et al., 1985). There are two construction aggregate pits or quarries located along [illegible]. These are sources of crushed rock, sand, sand and gravel, [illegible] or [illegible] used for aggregate. Two gas fields ([illegible] and Little [illegible] Creek) and two oil fields ([illegible] Creek and [illegible], Figure 2-12) are within ten miles of the proposed Little Buffalo Basin pipeline ([illegible] et al., 1984).

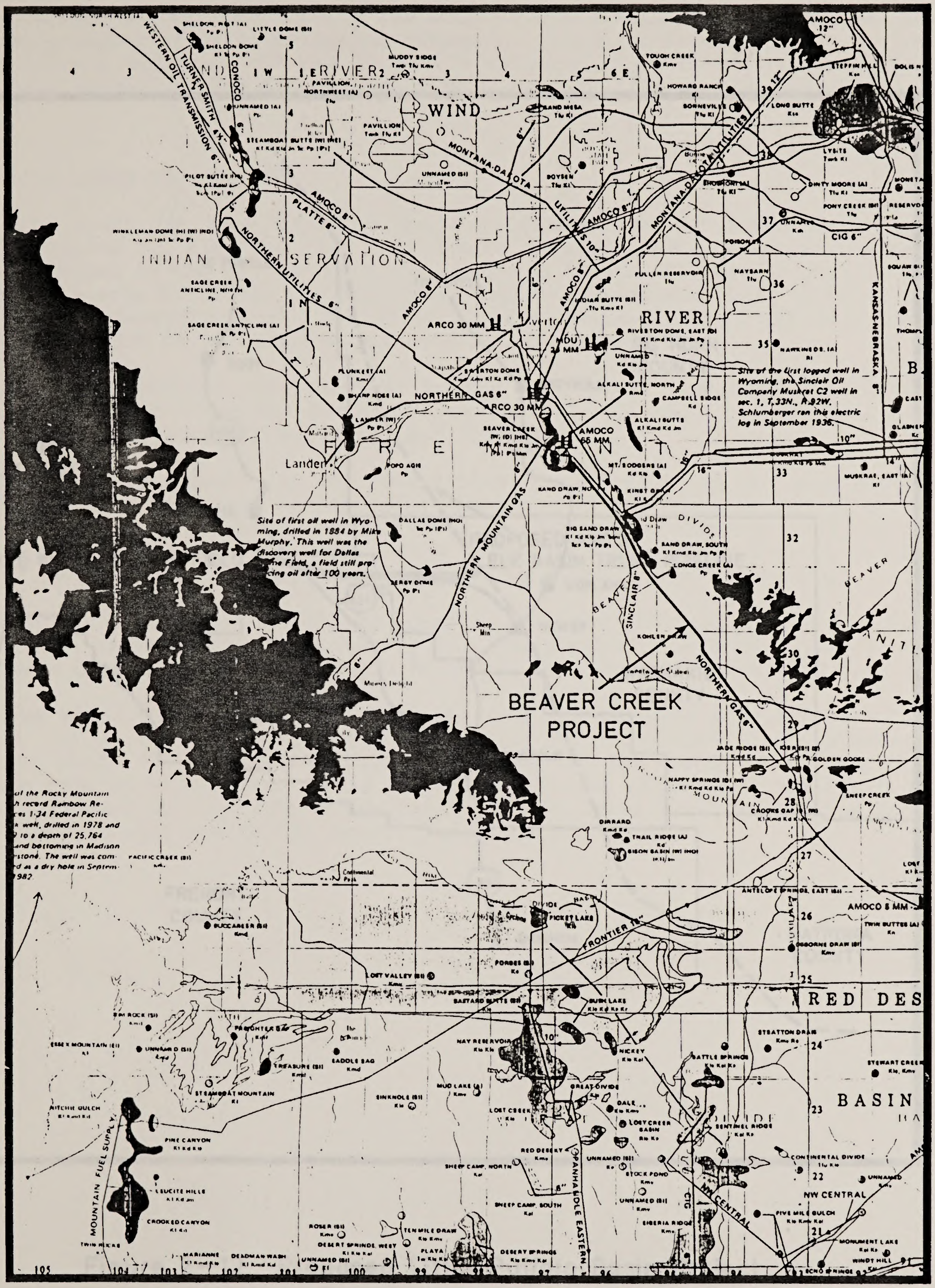


Figure 2—11. Oil & Gas Fields Near the Beaver Creek CO_2 Project (Stephenson et al., 1984)

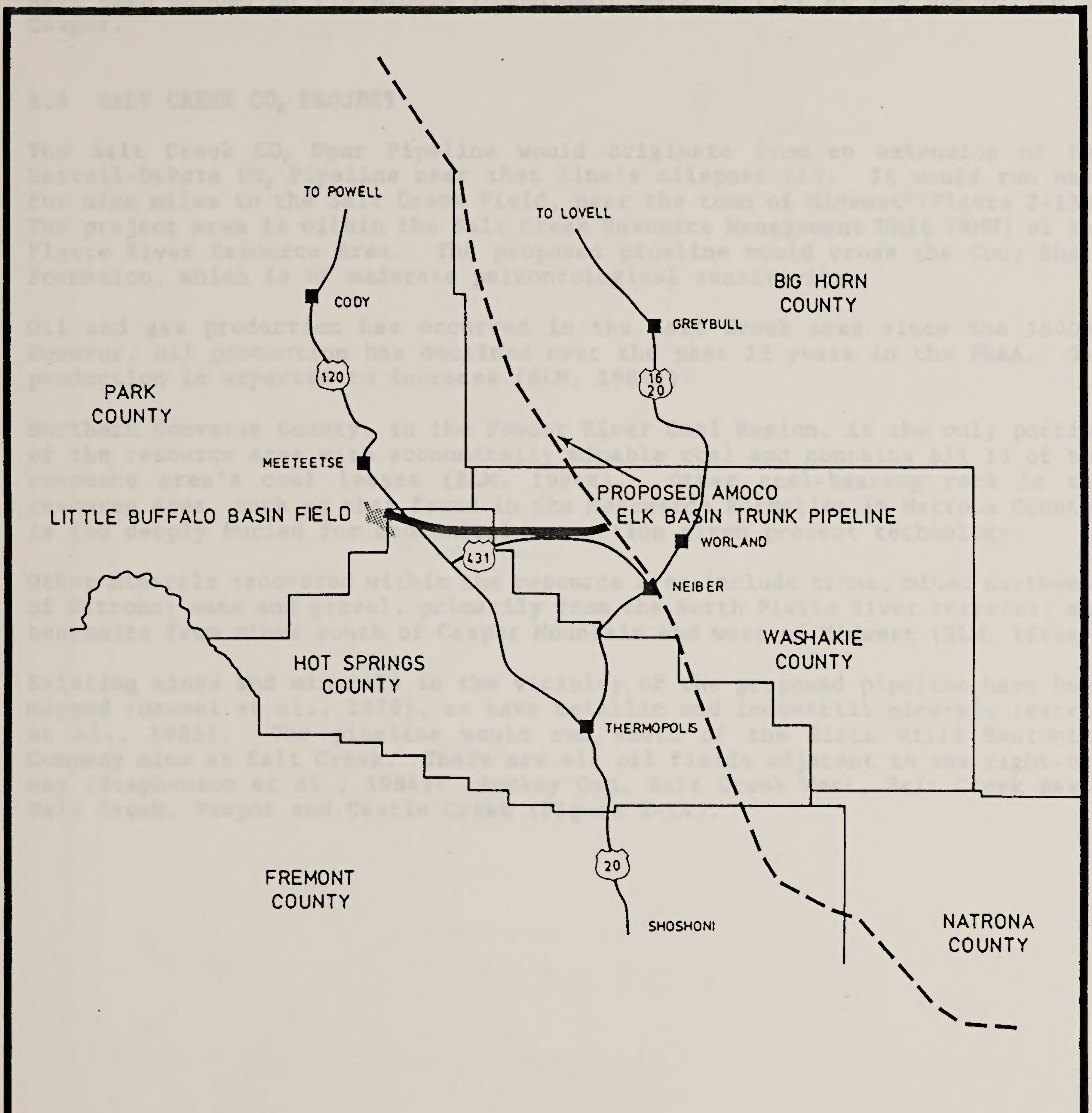


Figure 2—12. Proposed Little Buffalo Basin Project.

The area surrounding the origin of the Little Buffalo Basin CO_2 Spur Pipeline has yielded a number of paleontological resources. Areas of known fossil resources occur between mileposts 20 and 35 of the proposed right-of-way. These sites have been mapped on 7.5 minute topographic maps on file at the BLM office in Casper.

2.6 SALT CREEK CO_2 PROJECT

The Salt Creek CO_2 Spur Pipeline would originate from an extension of the Bairoil-Dakota CO_2 Pipeline near that line's milepost 213. It would run east for nine miles to the Salt Creek Field, near the town of Midwest (Figure 2-13). The project area is within the Salt Creek Resource Management Unit (RMU) of the Platte River Resource Area. The proposed pipeline would cross the Cody Shale Formation, which is of moderate paleontological sensitivity.

Oil and gas production has occurred in the Salt Creek area since the 1800s. However, oil production has declined over the past 12 years in the PRRA. Gas production is expected to increase (BLM, 1984a).

Northern Converse County, in the Powder River Coal Region, is the only portion of the resource area with economically minable coal and contains all 13 of the resource area's coal leases (BLM, 1984a). Other coal-bearing rock in the resource area, such as that found in the Mesaverde Formation in Natrona County, is too deeply buried for economical extraction given present technology.

Other minerals recovered within the resource area include trona, mined northwest of Natrona; sand and gravel, primarily from the North Platte River terraces; and bentonite from mines south of Casper Mountain and west of Midwest (BLM, 1984a).

Existing mines and minerals in the vicinity of the proposed pipeline have been mapped (Hausel et al., 1979), as have metallic and industrial minerals (Harris et al., 1985). The pipeline would run south of the Black Hills Bentonite Company mine at Salt Creek. There are six oil fields adjacent to the right-of-way (Stephenson et al., 1984): Smokey Gap, Salt Creek West, Salt Creek East, Salt Creek, Teapot and Castle Creek (Figure 2-14).

The area surrounding the origin of the Little Buffalo Basin Oil Spur Pipeline has yielded a number of paleontological resources. Areas of known fossil resources occur between mileposts 20 and 23 of the proposed right-of-way. These areas have been mapped on 7.5 minute topographic maps on file at the BLM office in Casper.

3.4 SALT CREEK OIL PROJECT

The Salt Creek Oil Spur Pipeline would originate from an extension of the Belfield-Sakota CO₂ Pipeline near that line's milepost 225. It would run east for nine miles to the Salt Creek Field, near the town of Midwest (Figure 2-12). The project area is within the Salt Creek Resource Management Unit (RMU) of the Platte River Resource Area. The proposed pipeline would cross the Fort Union Formation, which is of moderate paleontological sensitivity.

Oil and gas production has occurred in the Salt Creek area since the 1900s. However, oil production has declined over the past 10 years in the field. Gas production is expected to increase (BLM, 1984a).

Northern Converse County, in the Powder River Coal Region, is the only portion of the resource area with economically mineable coal and contains all 1% of the resource area's coal leases (BLM, 1984a). Other coal-bearing rock in the resource area, such as that found in the Mesaverde Formation in Natrona County, is too deep or thin for economical extraction given present technology.

Other minerals recovered within the resource area include trona, mined northwest of Natrona, sand and gravel, primarily from the North Platte River terraces, and bentonite from mines south of Casper Mountain and west of Midwest (BLM, 1984a).

Existing mines and prospects in the vicinity of the proposed pipeline have been mapped (Hausel et al., 1979), as have metallic and industrial minerals (Harris et al., 1985). The pipeline would run south of the Black Hills Bentonite Company mine at Salt Creek. There are six oil fields adjacent to the right-of-way (Stephenson et al., 1980): Sussex East, Salt Creek West, Salt Creek East, Salt Creek, Teapot and Castle Creek (Figure 2-12).

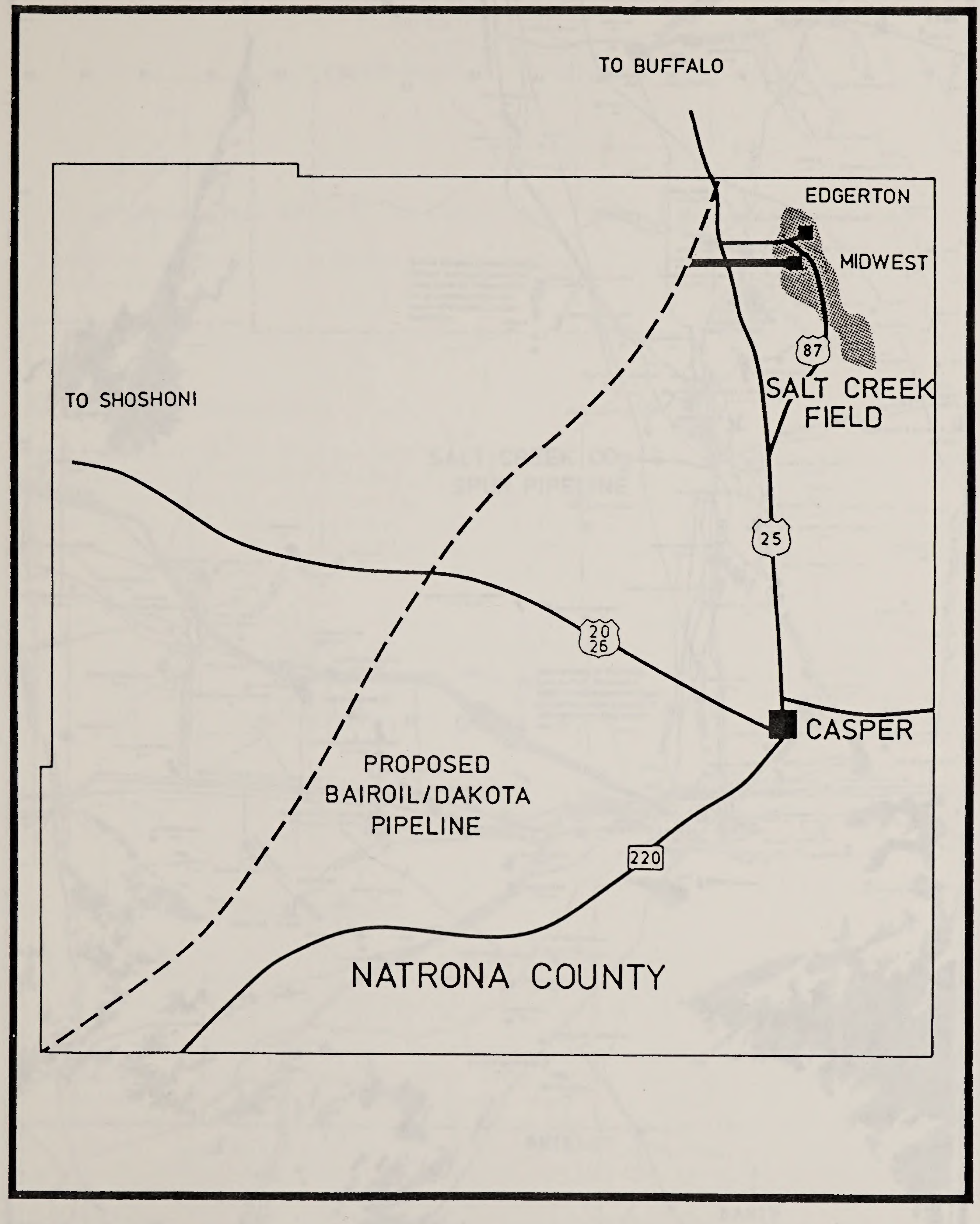


Figure 2—13. Proposed Salt Creek Project.

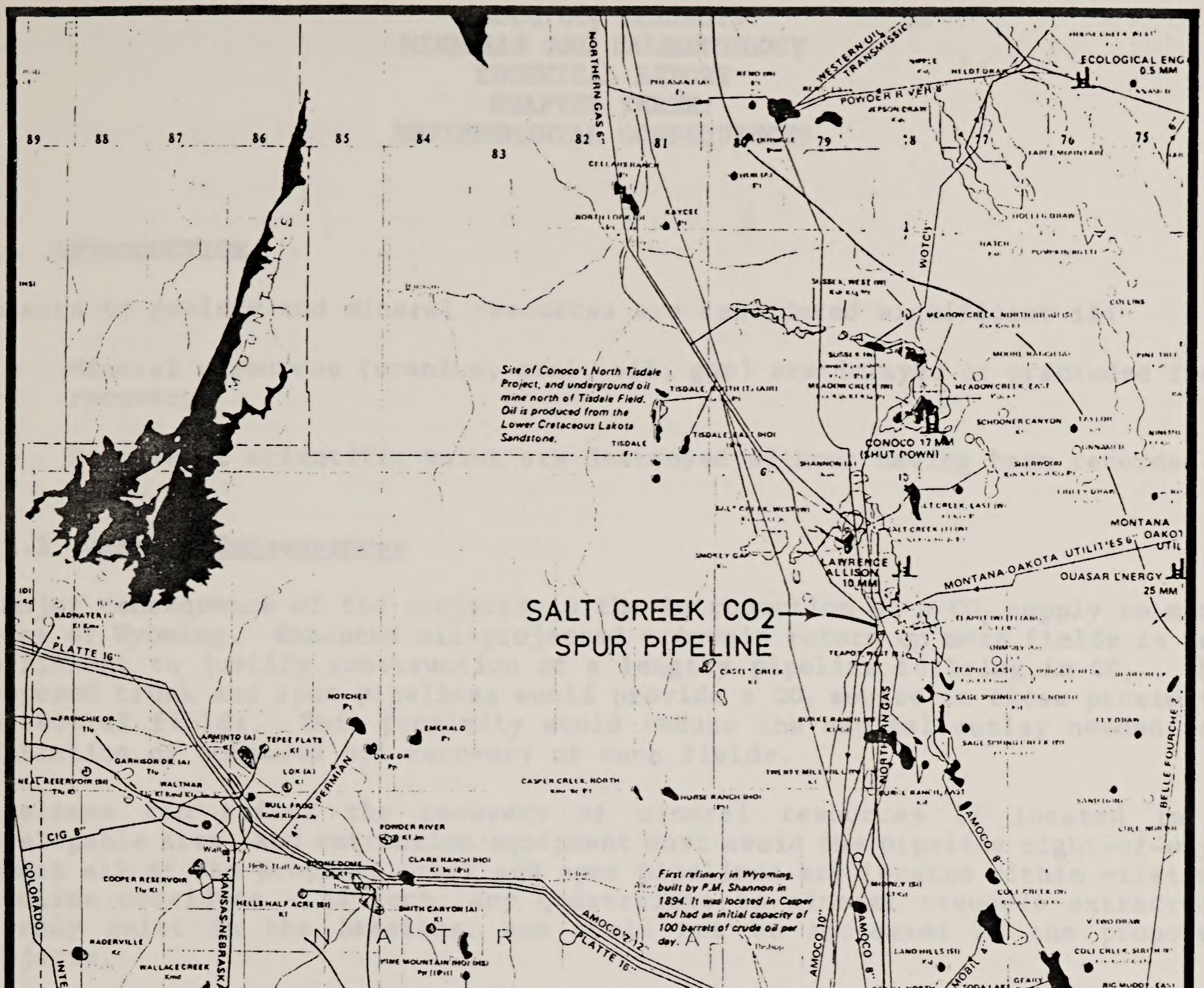


Figure 2—14. Oil & Gas Fields Near the Salt Creek CO_2 Project (Stephenson et al., 1984)

AMOCO CO_2 PROJECTS
MINERALS AND PALEONTOLOGY
TECHNICAL REPORT
CHAPTER THREE:
ENVIRONMENTAL CONSEQUENCES

3.1 INTRODUCTION

Impacts to geology and mineral resources are considered significant if:

- o Mineral resources (uranium, coal, oil, gas) are delayed or precluded from recovery;
- o Fossils of scientific value are destroyed without having been recorded.

3.1.1 <u>General Consequences</u>

A major consequence of the projects is the introduction of a CO_2 supply to many areas of Wyoming. Enhanced oil-projected economic return on most fields is not sufficient to justify construction of a lengthy pipeline to bring in CO_2. The proposed trunk and spur pipelines would provide a CO_2 source in close proximity to several fields. This proximity would reduce the capital outlay needed for initiation of enhanced oil recovery of such fields.

Pipelines can affect the recovery of mineral resources if located in a developable area, and extraction equipment must avoid the pipeline right-of-way. Almost all of the proposed trunk and spur pipelines are located within existing pipeline corridors. As such, any constraints to mineral resource extraction already exist in the baseline, and would not be increased by the proposed projects.

Construction activities that are capable of destroying paleontological resources, such as trenching, are also often responsible for the discovery of paleontological resources.

3.1.2 <u>Potential Impact Avoidance</u>

The paleontological sensitivity of the proposed rights-of-way has been mapped on 7.5 USGS quadrangles. Known paleontological sites are also mapped. These maps are on file at the BLM office in Casper.

The BLM has developed a standard stipulation for surface-disturbing actions in strata with a high potential for significant paleontological resources. Construction activities in these areas shall be monitored by a qualified paleontologist with an approved permit from the Wyoming State Office of the BLM (BLM, 1986c). The BLM shall be notified if any resources are discovered, and construction activities shall be stopped until the authorized officer gives notice to proceed (within five working days). During that time, the resource would be evaluated, and, if required, appropriate mitigation measures would be developed in consultation with the applicant (BLM, 1986b).

Mitigation in the form of paleontological inventory and recovery of the paleontological resource during pipeline construction would eliminate most of

the potential adverse impacts and may result in beneficial impacts if important paleontological resources are found and recorded as a result of the mitigation.

3.2 FONTENELLE CO_2 SUPPLY PROJECT

The proposed Fontenelle Gas Gathering System would traverse an area of high potential for oil and gas development. The project would not be in any areas presently being mined for coal, trona, uranium or oil shale.

The number of miles of geologic formations with low, moderate and high paleontological sensitivity that would be crossed by the proposed gas gathering pipelines is presented in Table 3-1. The project would cross approximately five miles of the Laney Member of the Green River Formation and approximately nine miles of the Bridger Formation. As discussed in Section 2.2, both of these formations have yielded significant fossil resources in the Kemmerer and Green River resource areas. East of Fontenelle Reservoir, however, the right-of-way borders the contact between the Green River Formation and an area of dune sand and loess, which has a low sensitivity rating.

As noted above in Section 3.1.2, pipeline trenching activities in all areas of high sensitivity for paleontological resources would be monitored.

3.3 ELK BASIN CO_2 SUPPLY PROJECT

Despite the proximity of the proposed Elk Basin CO_2 Trunk Pipeline to a number of mineral resources, the pipeline's placement within an existing right-of-way precludes it from impacting adjacent mineral recovery. Within the South Bighorns RMU (Platte River Resource Area), the pipeline would be adjacent to areas of intensive bentonite claims from approximately mileposts 145 to 155, but no other locatable minerals have been mapped in this area. Within RMU 14, the pipeline would run through an area with a high oil and gas potential (BLM, 1984b). While the pipeline would be in both the Big Horn and Wind River coal basins, it would not traverse any areas of known thick or abundant coal.

Approximately 60 percent of the proposed Elk Basin CO_2 Trunk Pipeline would cross geologic formations with a high paleontological sensitivity (Table 3-2), and would therefore be monitored. The proposed right-of-way would deviate from the existing corridors only where necessary to avoid cultural resources.

As discussed in Section 2.3, the proposed right-of-way segments between mileposts 50 and 76 and between mileposts 130 to 157 are of particular paleontological interest. Areas of known fossil resources in these areas have been mapped on a series of 7.5 minute topographic maps including the right-of-way. These maps are on file at the BLM office in Casper.

3.4 BEAVER CREEK CO_2 PROJECT

The proposed Beaver Creek CO_2 Trunk Pipeline would be in an area of moderate to high oil and gas potential. South of Sand Draw and to the west of Jeffrey City, the pipeline would cross a "mineralized area," where isolated pockets of rubies, sapphires and jade occur (Harris et al., 1985). However, as discussed in Section 2.4, these gems are not considered to be economically significant

Table 3-1. Fontenelle Gas Gathering System Paleontological Sensitivity by Milepost

	Low	High
		0 - 2.5
	2.5 - 4.0	
		4.0 - 15.0
		0w - 2.5w
	2.5w - 7.5w	
Total Miles	6.5	16

Table 3-2. Elk Basin CO2 Trunk Pipeline Paleontological Sensitivity by Milepost.

	Low	Moderate	High
			0 - 4
	4 - 9		9 - 12
		12 - 14	
	14 - 15		
		15 - 19	
	19 - 22		
			22 - 24
	24 - 30		
			30 - 40
	40 - 45		
			45 - 59
	59 - 62		
			62 - 71
	71 - 72		
			72 - 79
	79 - 87		87 - 95
		95 - 114	
			114 - 157
	157 - 159		
			159 - 171
		171 - 175	
	175 - 178		
Total Miles	37	29	112

mineral resources in this area. The placement of the proposed pipeline in the existing right-of-way precludes it from adversely affecting adjacent oil and gas recovery operations.

The White River, Wagon Bed and Wind River Formations, all with a high paleontological sensitivity rating, would be crossed by the proposed pipeline. The number of miles of high, moderate and low sensitivity formations that would be traversed by the pipeline are given in Table 3-3. The Miocene-age strata in this area have a moderate to high sensitvity rating. The areas traversed would be considered to have a rating of high sensitivity and would be monitored. This procedure follows the dictum of analysis of the worst-case-scenario.

3.5 LITTLE BUFFALO BASIN CO_2 PROJECT

The proposed Little Buffalo Basin CO_2 Spur Pipeline would not adversely affect the recovery of adjacent mineral resources. While the proposed pipeline would be constructed in the Bighorn Coal Basin, it would not be in an area of known thick or abundant coal.

There is a high probability that paleontological resources would be found along the proposed right-of-way, as over 80 percent of the pipeline would cross geologic formations with a high sensitivity (Table 3-4). As noted above in Section 3.1.2, pipeline trenching activities in all areas of high sensitivity shall be monitored. It should also be noted that although the first four miles of the ROW traverse gravel, pediment and fan deposits (rated low in sensitivity), the BLM has recorded fossil resources in the area (BLM, Worland District, File Data). The actual route of the proposed pipeline closely borders the contact between the Willwood Formation (high sensitivity) and gravel, pediment and fan Deposits (low sensitivity). Should this portion prove to be in a high sensitivity area when the route is field-checked, it shall be monitored.

3.6 SALT CREEK CO_2 PROJECT

The Salt Creek CO_2 Spur Pipeline would be constructed in an area of high potential for oil and gas occurrence, but would not cross any areas of coal or salable minerals (BLM, 1984a).

Cody shale is the only geologic formation that would be crossed by the proposed project. This formation has a moderate sensitivity for paleontological resources.

Table 3-3. Beaver Creek CO2 Trunk Pipeline Paleontological Sensitivity by Milepost.

	Low	Moderate	Mod-High	High
				0.0 - 13.0
			13.0 - 24.5	
				24.5 - 25.5
			25.5 - 37.5	
		37.5 - 39.0		
	39.0 - 42.5			
		42.5 - 44.0		
Total Miles	3.5	3.0	23.5	14.0

Table 3-4. Little Buffalo Basin CO2 Spur Pipeline Paleontological Sensitivity by Milepost.

	Low	Moderate	High
		0 - 4	
			4 - 33
	33 - 36		
Total Miles	3	4	29

AMOCO CO_2 PROJECTS
MINERALS AND PALEONTOLOGY
TECHNICAL REPORT
CHAPTER FOUR:
REFERENCES

Bartels, W. S. 1983. A Paleocene-Eocene reptile fauna from the Bighorn Basin, Wyoming. Herpetologica 39:359-374.

Becker, Clarence F. and John D. Alyea. 1964. Precipitation Probabilities in Wyoming. Agricultural Experiment Station, Bulletin 416. University of Wyoming, Laramie.

Becker, Clarence F. and John D. Alyea. 1964. Temperature Probabilities in Wyoming. Agricultural Experiment Station, Bulletin 415. University of Wyoming, Laramie.

Bown, T. M. 1970. Geology and mammalian paleontology of the Sand Creek facies, lower Willwood Formation, (lower Eocene), Washakie County, Wyoming. Wyoming Geological Survey Memoir 2:1-151.

Bown, T. M. 1983. Geology, paleontology and correlation of Eocene volcanoclastic rocks, southeast Abaroka Range, Hot Springs County, Wyoming. U.S. Geological Survey, Professional Paper 1201-A: 1-75.

Brodkord, P. 1970. An Eocene puffbird from Wyoming. Contributions to Geology, University of Wyoming. Winter, 1970:13-15.

Brown, G. W. 1983. The Chadron State Triceratops--Its capture, care and feeding. Proc. Nebraska Acad. Sci. Affil. Soc. 91:30. Abstract.

Bureau of Land Management. 1978. Proposed Domestic Livestock Grazing Management Program for the Sandy Area, Final EIS. Rock Springs, Wyoming.

Bureau of Land Management. 1982. Paleontology Technical Report; Public Service of New Mexico's New Mexico Generating Station EIS, Santa Fe, New Mexico.

Bureau of Land Management. 1984a. Platte River Resource Area DEIS. Casper, Wyoming.

Bureau of Land Management. 1984b. Platte River Resource Area FEIS. Casper, Wyoming.

Bureau of Land Management. 1985. Kemmerer Resource Area Resource Management Plan DEIS. Kemmerer, Wyoming.

Bureau of Land Management. 1986a. Draft Resource Management Plan/EIS for the Washakie Resource Area. Worland, Wyoming.

Bureau of Land Management. 1986b. Final Resource Management Plan/EIS for the Lander Resource Area. Lander, Wyoming.

Bureau of Land Management. 1986c. Kemmerer Resource Area Resource Management Plan FEIS, Record of Decision. Kemmerer, Wyoming.

Bureau of Land Management. 1988. Cody Resource Area Resource Management Plan DEIS. Preliminary draft. Cody, Wyoming.

Dunkle, D. H. 1971. Notes on an addition to fish fauna of the Mowry Shale (Cretaceous) of Wyoming. Kirtlandia 14:1-8.

Emry, R. J. and J. E. Storer. 1981. The hornless protoceratid Pseudoprotoceras (Tylopoda: Artiodactyla) in the early Oligocene of Saskatchewan and Wyoming. Journal of Vertebrate Paleontology, 1:101-110.

Estes, R. 1964. Fossil vertebrates from the Lance Formation, eastern Wyoming. University California Publications, Geological Sciences, 49:1-180.

Fox, R. C. 1976. An edentulous frog (Theatonius lancensis n. gen., n. sp.) from the upper Cretaceous Lance Formation of Wyoming. Canadian Journal Earth Sciences 13:1486-1490).

Gazin, C. L. 1976 Mammalian faunal zones of the Bridger middle Eocene. Smithsonian Misc. Collections 153:1-90.

Gingerich, P. D. 1983. New Adapisoridae, Pentacodontidae and Hyopsondontidae (Mammalia, Insectivora, and Condylarthra) from the late Paleocene of Wyoming and Colorado. Contributions to the Museum of Paleontology, University of Michigan 26:227-255.

Glass, Gary B. and D. L. Blackstone, Jr. 1987. Geology of Wyoming. The Geological Survey of Wyoming, Laramie.

Grande, L. 1984. Paleontology of the Green River Formation, with a review of the fish fauna. Geological Survey of Wyoming, Bull, 63:1-333.

Harris, Ray E., W. Dan Hausel and John E. Meyer, compilers. 1985. Metallic and Industrial Minerals Map of Wyoming. The Geological Survey of Wyoming, Laramie.

Hausel, W. Dan, Gary B. Glass, David R. Lageson, Alan J. Ver Ploeg and Rodney H. De Bruin, compilers. 1979. Wyoming Mines and Minerals. The Geological Survey of Wyoming, Laramie.

Hausel, W. Dan, Forrest K. Root, Richard W. Jones and Karl G. Albert. 1987. Guide to Some Rocks and Minerals of Wyoming. The Geological Survey of Wyoming, Laramie.

Horner, J. R. 1979. Upper Cretaceous dinosaurs from the Bearpaw Shale (marine) of south-central Montana with a checklist of upper Cretaceous dinosaur remains from marine sediments in North America. Journal of Paleontology 53:566-577.

Kristalka, L. 1983. Paleocene and Eocene marsupials of North America. Annals of the Carnegie Museum. 52: 229-263.

Kristalka, L. and R. Stucky. 1987. Report on Paleontological Survey in the Wind River Basin, WY, 1986-1987. Prepared in accordance with the Bureau of Land Management Antiquities Act Permit #044-WY-PA86. Report on file, Bureau of Land Management, Platte River Resource Area, Casper, Wyoming.

Bureau of Land Management. 1988. Cody Resource area resource management Plan DEIS. Preliminary draft. Cody, Wyoming.

Dunkle, D. H. 1967. Notes on an addition to fish fauna of the Mowry Shale (Cretaceous) of Wyoming. Kirtlandia 1:1-6.

Emry, R. J. and J. E. Storer. 1981. The hornless protoceratid *Pseudoprotoceras* (Tylopoda: Artiodactyla) in the early Oligocene of Saskatchewan and Wyoming. Journal of Vertebrate Paleontology, 1:101-110.

Estes, R. 1964. Fossil vertebrates from the Lance Formation, eastern Wyoming. University California Publications, Geological Sciences, 49:1-180.

Fox, R. C. 1976. An edentulous frog (*Theatonius lancensis* n. gen., n. sp.) from the upper Cretaceous Lance Formation of Wyoming. Canadian Journal Earth Sciences 13(1486-1490).

Gazin, C. L. 1976. Mammalian faunal zones of the Bridger middle Eocene. Smithsonian Misc. Collections 151:1-80.

Gingerich, P. D. 1983. New Adapisoricidae, Pentacodontidae and Hyopsodontidae (Mammalia, Insectivora, and Condylarthra) from the Late Paleocene of Wyoming and Colorado. Contributions to the Museum of Paleontology. University of Michigan 26:227-255.

Glass, Gary B. and D. L. Blackstone, Jr. 1987. Geology of Wyoming. The Geological Survey of Wyoming, Laramie.

Grande, L. 1980. Paleontology of the Green River Formation, with a review of the fish fauna. Geological Survey of Wyoming, Bull. 63:1-333.

Harris, Ray E., W. Dan Hausel and John E. Meyer, compilers. 1985. Metallic and Industrial Minerals Map of Wyoming. The Geological Survey of Wyoming, Laramie.

Hausel, W. Dan, Gary B. Glass, David R. Lageson, Alan J. Ver Ploeg and Rodney H. De Bruin, compilers. 1979. Wyoming Mines and Minerals. The Geological Survey of Wyoming, Laramie.

Hausel, W. Dan, Forrest K. Root, Richard W. Jones and Karl G. Albers. 1987. Guide to Gem Rocks and Minerals of Wyoming. The Geological Survey of Wyoming, Laramie.

Horner, J. R. 1979. Upper Cretaceous dinosaurs from the Bearpaw Shale (marine) of south-central Montana with a checklist of Upper Cretaceous dinosaur remains from marine sediments in North America. Journal of Paleontology 53:566-577.

Krishtalka, L. 1983. Paleocene and Eocene marsupials of North America. Annals of the Carnegie Museum. 52: 229-263.

Krishtalka, L. and R. Stucky. 1987. Report on Paleontological Surveys in the Wind River Basin, WY, 1986-1987. Prepared in accordance with the Bureau of Land Management Antiquities Act Permit [illegible]. Report on file, Bureau of Land Management, Platte River Resource Area, Casper, Wyoming.

Kristalka, L. and R. Stucky. 1983. Revision of the Wind River faunas, early Eocene of central Wyoming. Part 3. Marsupialia. Annals of the Carnegie Museum. 52:; 204-227.

Love, J. D. and A. C. Christiansen. 1985. Geologic Map of Wyoming. USGS.

Lundberg, J. G. and G. R. Case. 1970. A new catfish from the Eocene Green River Formation. Jour. Paleontology. 44: 451-457.

Moodie, R. L. 1910. An armored dinosaur from the Cretaceous of Wyoming. Knasas Univ. Sci. Bull. 5: 257-273.

Mourer-Chauvire, C. 1983. Minerva antiqua (Aves, Strigiformes), an owl mistaken for an edentate mammal. Amer. Mus. Novitates. 2773: 1-11.

Rigby, J. K. 1980. Swain Quarry of the Fort Union Formation, middle Paleocene (Torrejonian), Carbon County, Wyoming: Geologic setting and mammalian fauna. Evol. Monographs 3, 179 pp.

Savage, D. E. and D. E. Russel. 1983. Mammalian Paleofaunas of the World. Addison-Wesley Publishing Company, London. 432 p

Schoch, R. M. 1983. A new species of Isectolophus (Mammalia, Tapiroidea) from the middle Eocene of Wyoming. Postilla 188: 1-4.

Stephenson, T. R., A. J. VerPloeg and L. S. Chamberlain. 1984. Oil and Gas Map of Wyoming; 1:500,000. Geological Survey of Wyoming.

Stucky, R. and L. Krishtalka. 1982. Revision of the Wind River Faunas, Early Eocene of Central Wyoming. Part 1, Introduction and Multituberculata. Annals of the Carnegie Museum, Vol. 51, May 6, 1982.

Krishtalka, L. and R. Stucky. 1983. Revision of the Wind River faunas, early Eocene of central Wyoming. Part 3. Marsupialia. Annals of the Carnegie Museum. 52(10): 205-227.

Love, J. D. and A. C. Christiansen. 1985. Geologic map of Wyoming. USGS.

Lundberg, J. G. and G. R. Case. 1970. A new catfish from the Eocene Green River Formation. Jour. Paleontology. 44: 451-457.

Moodie, R. L. 1910. An armored dinosaur from the Cretaceous of Wyoming. Kansas Univ. Sci. Bull. 5: 257-273.

Mourer-Chauvire, C. 1983. Minerva antiqua (Aves, Strigiformes), an owl mistaken for an edentate mammal. Amer. Mus. Novitates. 2773: 1-11.

Rigby, J. K. 1980. Swain Quarry of the Fort Union Formation, middle Paleocene (Torrejonian), Carbon County, Wyoming: Geologic setting and mammalian fauna. Evol. Monographs 3. 179 pp.

Savage, D. E. and D. E. Russell. 1983. Mammalian Paleofaunas of the World. Addison-Wesley Publishing Company, London. 432 p.

Schoch, R. M. 1983. A new species of Lambdotherium (Mammalia, Perissodactyla) from the middle Eocene of Wyoming. Postilla 190: 1-4.

Stephenson, T. R., W. J. MacFarlane and L. G. Thornton. 1984. Oil and Gas Map of Wyoming, 1:500,000. Geological Survey of Wyoming.

Stucky, R. and L. Krishtalka. 1982. Revision of the Wind River Faunas, Early Eocene of Central Wyoming. Part 1. Introduction and Multituberculata. Annals of the Carnegie Museum. Vol. 51, May 6, 1982.