Wyoming State Geological Survey
Gary B. Glass, State Geologist

Evaluation of Coal Resources on the Wind River Indian Reservation, Wyoming

by Joseph Gersic and Eileen K. Peterson

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Prepared under the authority of Resolution No. 4767 of the Joint Business Council of the Shoshone and Arapahoe Tribes, Wind River Indian Reservation, Wyoming, dated June 10, 1981, and Interagency Agreement No. 24 (Amendment No. 1, Appendix G) between the Bureau of Indian Affairs and the Bureau of Mines.

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EVALUATION OF COAL RESOURCES ON THE WIND RIVER INDIAN RESERVATION, WYOMING

by

Joseph Gersic[1] and Eileen K. Peterson[2]

SUMMARY AND RECOMMENDATION

Four sites, suggested by the U.S. Geological Survey as having potential for coal mining operations on the Wind River Indian Reservation, were evaluated by the U.S. Bureau of Mines under an interagency agreement pertaining to mineral recovery studies on certain Indian lands. All sites were considered for development using either longwall underground or open-pit surface mining methods because these two methods are best suited to recovery of subbituminous western coals from both the technological and economic standpoints. In situ gasification and liquefaction methods were not considered in this report because they are still in the experimental stage, and commercial production is probably years, if not decades, away.

In general, the quality of the coal on the Wind River Reservation in Wyoming is similar to that of other subbituminous western coals, but the tendency of the coal to disintegrate rapidly to a brown powder upon exposure to air makes it difficult to market. Because the coal cannot be stockpiled and has to be shipped in closed conveyances, it does not compare favorably with other subbituminous western coals, particularly those available in the Powder River Basin of Wyoming.

From the technical standpoint, small open-pit mines could be developed at both sites in the Alkali Butte Coalfield and at the site in the Muddy Creek Coalfield. Because only small quantities of coal could be extracted from any of the sites, the coal probably would have to be marketed locally as fuel for domestic heating. All three sites are many miles from local distribution points where the coal would be sold for use in domestic heating, and the cost of transporting the coal by truck from mine to market would be extremely high or even prohibitive.

Technically, a longwall underground mine probably could be developed at the site in the Hudson Coalfield. Because the coal cannot be stockpiled or shipped to out-of-state markets by conventional methods and local demand would not be large enough to justify the capital investment, mine development probably would not be economically feasible. Another possible plan, which was considered and rejected, was the construction of a coal-fired, mine-mouth

[1]Physical Scientist.

[2]Mining Engineer.

Both authors are with the Intermountain Field Operations Center, Bureau of Mines, U.S. Department of the Interior, Denver, Colo.

powerplant, but the Wind River region already has ample electric power available for domestic and industrial applications for the foreseeable future.

Permits have been issued for a small coal mining operation in the Alkali Butte Coalfield a few miles east of the reservation. The mining operation would be similar to the open-pit mines suggested for both Alkali Butte sites, except that the coal reserves are 2 to 3 times larger than the reserves at either Alkali Butte site and transport distances to local markets would be 5 to 6 miles longer. If the mine is successful, it would indicate that the Alkali Butte sites have some potential; however, a successful mine probably would "corner" the local coal market, thereby eliminating the need for any other mines.

Although mines theoretically could be developed at any or all of the sites, the demand for coal probably is not great enough to justify their development in the foreseeable future. The only market for the coal is as fuel for domestic heating locally, and coal would have strong competition in this market from both natural gas and wood. Further mine feasibility investigations, including drilling, coring, and testing, are not recommended for any of the four sites until market demand increases.

INTRODUCTION

This Phase III report, prepared by the U.S. Bureau of Mines (BuMines), as part of an ongoing series for the U.S. Bureau of Indian Affairs (BIA), considers the potential for economic development of coal deposits on the Wind River Indian Reservation in Wyoming. In Fiscal Year (FY) 1982, it was proposed initially to conduct a detailed onsite resource availability study on three areas of the Wind River Reservation that the U.S. Geological Survey (USGS) determined to have potential for coal mining operations and to design a drilling program to be implemented in FY 1983 on the most favorable deposits. During the spring of 1982 a literature search was done on known coal deposits on or near the reservation. Field investigations were completed on the three areas in June and July of 1982. Drilling, coring, testing, and mine feasibility investigations originally were to have been conducted during FY 1983.

Previous Investigations

Numerous papers, reports, and theses, both published and unpublished, have been written about the geology and mineral resources of the Wind River region. Because this report deals with coal resources, only those studies related to coal resources on or near the Wind River Reservation will be discussed.

The first substantial reports on the coal in the Wind River region were published around the turn of the century. In 1893 Eldridge visited a mine near Hudson during his geological reconnaissance of northwest Wyoming. In his 1894 paper, Eldridge (5) describes the coal in the Muddy Creek Field,

[3]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Lander Field, and Upper Wind River region. Eldridge's paper also contains two analyses from the Lander Field and three analyses from the Upper Wind River region. In an 1895 report on Wyoming coals, Knight (11) describes briefly the known coal resources in Fremont County, including coal rank and production data. Woodruff (27) wrote a short paper in 1906 on the Lander Coalfield in which he discusses stratigraphy, structure, mine locations, underground workings, and coal analyses. In 1910 Woodruff and Winchester (28) published the first comprehensive study of the coalfields of the Wind River region. The report contains stratigraphical and structural data on the coal-bearing formations, including measured stratigraphic sections, coal sections, and geologic maps. Detailed descriptions are given of the Muddy Creek, Pilot Butte, Hudson, Alkali Butte, and Powder River Fields. Four different analyses were performed on 15 coal samples. Locations of mines are given, uses of the coal are discussed, and markets for the coal are considered.

During the late 1940's, early 1950's, and middle 1960's, five more reports were written that are useful. In an unpublished 1949 report, Travis (19) describes in detail four coal mining operations in Fremont County. The 1950 report on the Coal Resources of Wyoming by Berryhill, Brown, Brown, and Taylor (1) summarizes data on all the coalfields in the Wind River Basin, including reserves and production tonnages. In 1952 Thompson and White (18) published a report on their geologic investigations of the Alkali Butte, Big Sand Draw, and Beaver Creek Fields. Keefer and Troyer (10) in 1964 published a detailed report on the geology of the Shotgun Butte area, including a section on coal. Bolmer and Biggs (2) wrote a preliminary report on the mineral resources of the Wind River Indian Reservation in 1965.

The most recent reports on coal in the Wind River Basin are by Seeland and Brauch, 1975 (17); Glass and Roberts, 1978 (8); Glass, 1978 (6); Glass, 1980 (7); and Windolph, Hickling, and Warlow, 1982 (25). The first and last reports just mentioned are part of the same series as this report.

The combined Phase I report by Seeland and Brauch (17) compiles and summarizes available information on the geology and mineral and energy resources on the Wind River Indian Reservation. The economic development potential of the resources is evaluated. Sources for the Phase I report included published and unpublished data, and personal communications. No field work was done.

A Phase II report by Windolph, Hickling, and Warlow (25), classifies and quantifies the coal resources of the Wind River Indian Reservation. The report contains "* * * data on coal occurrences, thicknesses, stratigraphic and structural relationships of the coal-bearing strata, and composition, quality, and rank of the coal resources." The report also delineates sites that may have development potential for conventional mining methods or may have potential for in situ gasification and liquefaction.

For readers interested in a broader discussion of the region, the Wyoming Geological Association 30th Annual Field Conference Guidebook, 1978, Resources Of The Wind River Basin, (29) is recommended.

Acknowledgments

Some data used in this evaluation were supplied by John F. Windolph, Jr., and his associates, of the USGS in Reston, Va. A mineral resource study was authorized by the Joint Business Council of the Shoshone and Arapahoe tribes and was certified by Alfred Ward, Chairman of the Shoshone Business Council, and Joseph Oldman, Chairman of the Arapahoe Business Council. Personnel of the BIA Wind River Indian Agency at Ft. Washakie, Wyo., were very helpful, especially the Superintendent, Richard Whitesell, and two members of his staff, Richard Harbour and Camille Matt.

GEOGRAPHY

Although the Wind River Indian Reservation boundary encompasses about 2,292,000 acres in Fremont and Hot Springs Counties of west-central Wyoming, the Shoshone and Arapahoe Tribes only own about 1,748,000 acres (pl. 1 and fig. 1). The remaining 544,000 acres are divided as follows: (1) allotted about 100,000 acres; (2) fee patent, about 147,000 acres; (3) Riverton Reclamation Project and Boysen Reservoir Withdrawal Area, about 295,000 acres; and (4) other government land, about 2,000 acres. Acreages were determined by using an electronic digitizer on the Wind River Land Status Map prepared by the BIA, Branch of Real Property Management, Titles and Records Section; ownership on the Wind River Land Status Map was based on a Land Title Status Printout dated December 11, 1979. This report deals only with coal on tribally owned land.

Physiography

Most of the reservation lies in the western half of the Wind River Basin (fig. 2). The interior of the basin is a rolling plain dissected by generally broad valleys formed by ephemeral and perennial streams. Altitudes on the interior plain range from about 4,700 feet to about 6,000 feet. Toward the margins of the basin, the rolling plain gives way to buttes, cuestas, sharp-crested ridges, and occasional badlands.

The southwestern part of the reservation extends upward to more than 12,700 feet along the Continental Divide at the crest of the Wind River Mountains. The Absaroka Mountains border the reservation on the northwest, and the Owl Creek Mountains lie across the northern part of the reservation. The altitudes in these northern mountains range from about 6,000 feet to nearly 12,000 feet within the reservation. A small part of the reservation lies along the northern slopes and foothills of the Owl Creek Mountains in the Big Horn Basin.

The Wind River is the master stream on the reservation. From its headwaters in the Absaroka Mountains in the northwest end of the Wind River Basin, the Wind River flows southeastward across the reservation to its confluence with the Little Wind River near Riverton. Here, it turns northeastward towards Boysen Reservoir and the Owl Creek Mountains where it flows through the Wind River Canyon into the Big Horn Basin. The main tributaries of the Wind River are Bull Lake Creek, Little Wind River, Popo Agie River, Crow Creek, Five Mile Creek, and Muddy Creek.

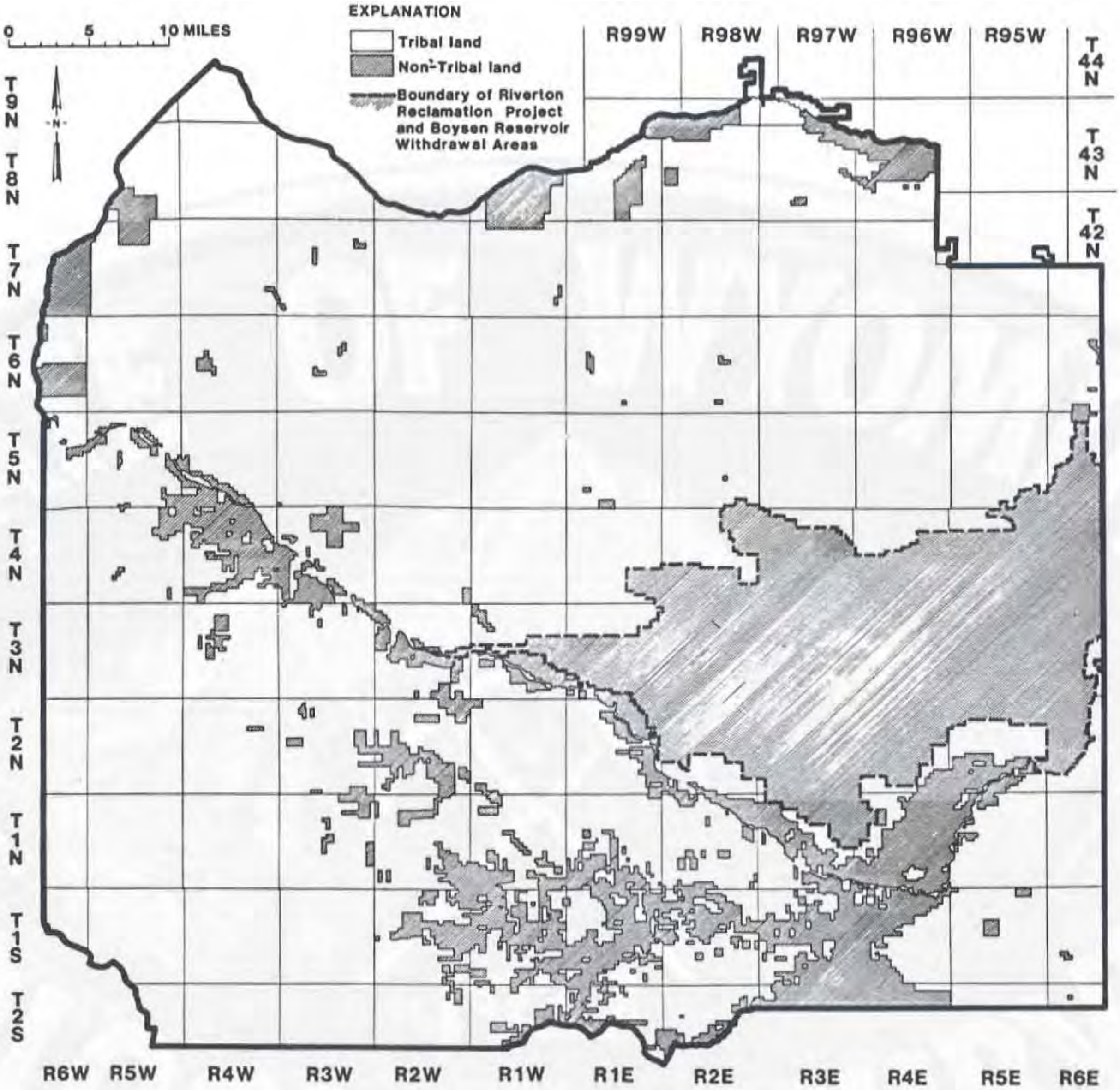

FIGURE 1.— Land status of the Wind River Indian Reservation, Wyoming. (Modified from Wind River Land Status Map—1979, Branch of Real Property Management, BIA Wind River Indian Agency, Ft. Washakie, Wyo., scale 1:125,000 approximately)

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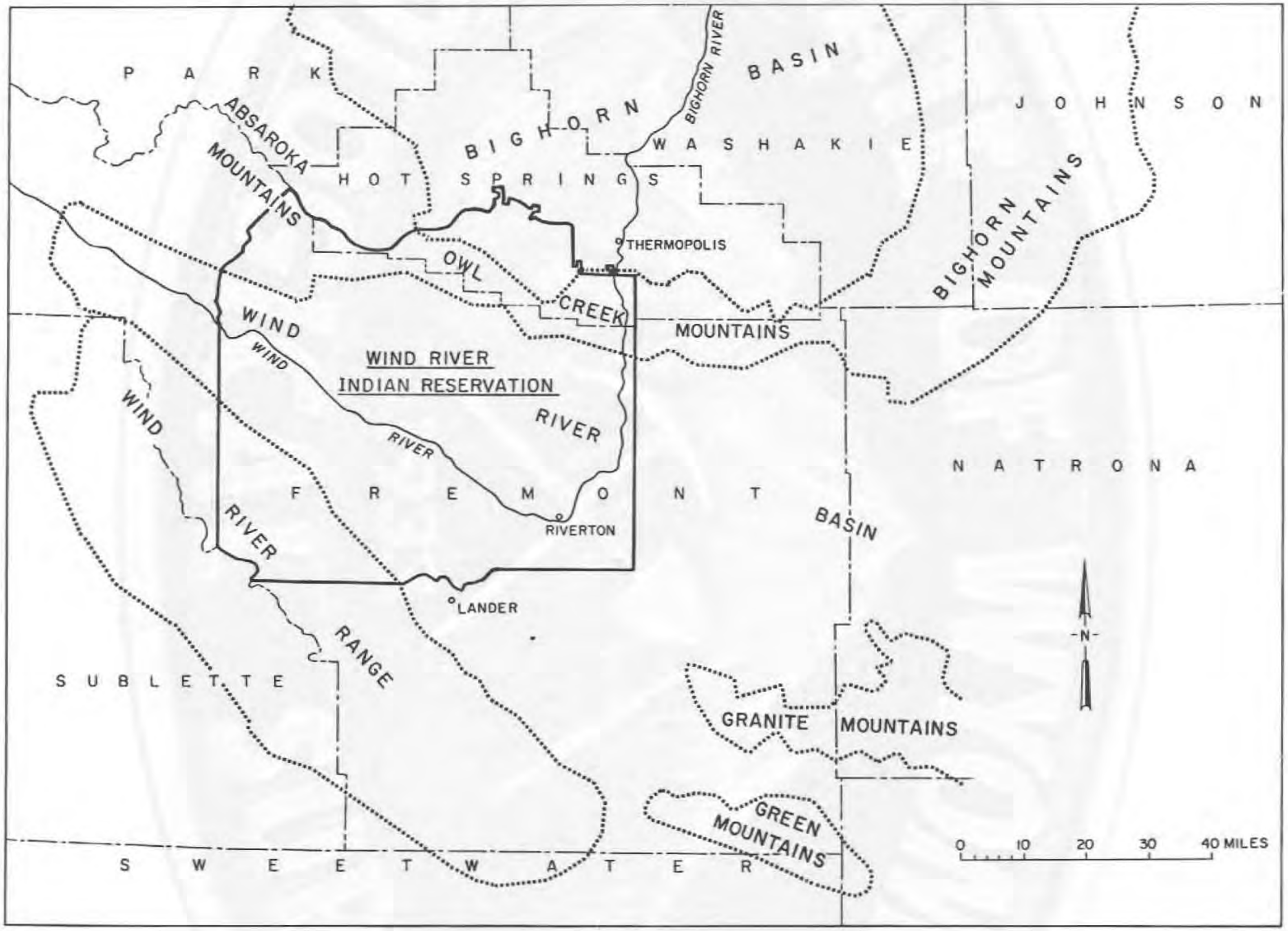

FIGURE 2.— Physiographic features of the Wind River Basin, Wyoming.

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The climate of the reservation is characterized by extremes (2). Temperatures on the plains range from -42° F to 102° F. There are about 127 frost-free days in an average year. Average annual precipitation ranges from less than 8 inches in the arid basin interior to more than 40 inches in the humid Wind River Mountains. Abundant sunshine and variable winds are characteristic of the lower altitudes.

The soils and vegetation on the reservation are diverse (2). On the arid plains mostly light-colored, alkaline soils ranging in texture from heavy clays to sandy loams, have developed. Brown and chestnut soils have developed on the foothills and mountains. Sagebrush, the dominant plant cover at lower altitudes, covers 45 percent of the reservation. Grass, found in the wetter intermediate areas, covers 15 percent of the reservation. The alpine forest of the higher altitudes covers 13 percent. Saltsage, weeds, and greasewood cover another 5 percent. Twenty-two percent of the reservation is relatively barren, such as badlands and rock outcrops that support little vegetation.

Demography

In 1980, the population of Fremont County was 38,992, and the population of Hot Springs County was 5,710 (22). More than half of the inhabitants of the region live in established communities. The four largest towns in the area are Riverton (pop. 9,588), Lander (pop. 7,867), Thermopolis (pop. 3,852), and Dubois (pop. 1,067) (22). Riverton is a trade and service center with a strong dependence upon developments in the energy industries. Lander, the county seat of Fremont County, is a regional medical center, and it also supplies goods and services for the surrounding agricultural areas. Thermopolis, the county seat of Hot Springs County, is primarily a resort and retirement community. The economy of Dubois is based on tourism, timber, and livestock. Numerous other towns and communities with a few hundred or fewer residents are present in the area.

Utilities

Electric power is available throughout most of the reservation, even in sparsely populated areas. A privately owned electric utility grid and local Rural Electric Association (REA) networks serve customers in the region. There are two electric powerplants on the reservation; both are Federally owned hydroelectric generating stations. The Pilot Butte Reservoir (1.6-MW) station is connected to the regional power grid by a 115-kV transmission line. The Boysen Reservoir (15.0-MW) station also supplies power to the regional grid through three 115-kV transmission lines. Two 230-kV electric transmission lines also cross the eastern half and southeastern corner of the reservation, respectively.

There are several petroleum and natural gas fields on and near the reservation. The supply of natural gas for local use is virtually unlimited (2). The natural gas consumed locally is used mainly for domestic heating, but the quantity consumed is so small that most of the natural gas is marketed elsewhere. Several pipelines carry petroleum and natural gas from the reservation to Casper and other refining and marketing centers.

According to McGreevy, Hodson, and Rucker (12), domestic water used in the region is mostly ground water. Riverton, Pavillion, Hudson, and Shoshoni are all supplied from municipally owned wells. Ft. Washakie and Ethete, however, get their domestic water from infiltration galleries in the bed of the Little Wind River. Residents in other communities and in rural areas generally depend on individually owned wells. In some of the remote, uninhabited parts of the reservation, potable water is scarce or unavailable.

Transportation

The Burlington Northern, Inc., railroad crosses eastern Wyoming along the North Platte River Valley to Casper thence westward to Bonneville which is just a few miles east of the reservation. Burlington tracks turn northward at Bonneville and pass through the northeastern corner of the reservation on the way to the Wind River Canyon and other places farther north.

The Chicago and North Western Railway Co. uses Burlington tracks from Orin Junction, about 60 miles east of Casper, to Bonneville. From Bonneville, North Western tracks go southwest through Shoshoni and across the reservation to Riverton. In the past, North Western tracks passed through Riverton and Hudson ending in Lander, but the tracks have been removed beyond Riverton.

Almost all the reservation is accessible by vehicle, although in the more remote and rugged portions a 4-wheel drive vehicle is necessary. Three Federal Highways and seven State Highways afford access to the more densely populated portions of the reservation. Federal Highway 287 enters the reservation just north of Lander and continues about 31 miles northwestward to a junction with Federal Highway 26. Federal Highway 26 enters the reservation just west of Shoshoni and follows the course of the Wind River southwest towards Riverton and then northwest towards Dubois. Federal Highway 20 passes through the northeastern corner of the reservation between Shoshoni and Thermopolis. The State Highways form a network of all-weather roads servicing the agricultural areas in the south-central and east-central portions of the reservation. Some secondary roads, a few paved and many graveled, are well maintained because they provide access to the petroleum and natural gas fields. The reservation is crisscrossed with hundreds of miles of "roads" created by seismic companies during their surveys for oil companies. Some roads extend into both the Owl Creek and Wind River Mountains, but they can be very rough and should not be attempted in any vehicle other than a pick-up or 4-wheel drive. The southwestern part of the reservation is a roadless wilderness area closed to all motorized vehicles.

The airport at Riverton has regularly scheduled airline service and Lander has an airport capable of servicing light aircraft. Pavillion and Thermopolis have landing fields, but no facilities.

GENERALIZED GEOLOGY

The Wind River Coal Basin is part of a large, structurally complex sedimentary basin. Margins of the basin are delineated by a group of complexly folded and faulted Precambrian, Paleozoic, and Mesozoic rocks exposed in the surrounding mountains and uplifts (pls. 2 and 3). The central part of the basin contains less disturbed rocks of Cenozoic age.

COAL RESOURCES

All agencies of the Department of the Interior use a "standardized" method of classification for resource/reserve studies covering all mineral resources including coal. Coal Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey, USGS Bulletin 1450-B, defines terms and suppies criteria to be used in classifying coal (23). Selected quotes that summarize the classification system follow:

"This system employs a concept by which coal beds are classified in terms of their degree of geologic identification and economic and technologic feasibility of recovery."

"Within this system the term 'coal resource' designates the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible. The 'coal reserve' is that part of the resource for which rank, quality, and quantity have been reasonably determined and which is deemed to be minable at a profit under existing market conditions."

"Estimates of the different classes of coal resources and reserves are arbitrarily based upon three criteria: (1) thickness, rank, and quality of the coal bed, (2) depth of the coal bed, and (3) the proximity of the coal resource data upon which the estimate was based."

"These criteria apply only to those coal bodies that are or will be economically extractable by underground, surface, and/or in situ methods."

Criteria may vary depending upon changing conditions without altering the basic definitions. Definitions and criteria follow:

"Identified Resources.--Specific bodies of coal whose location, rank, quality, and quantity are known from geologic evidence supported by engineering measurements."

"Reserve Base.--That portion of the Identified Coal Resource from which Reserves are calculated. Includes beds of bituminous coal and anthracite 28 inches (70 cm) or more thick and beds of subbituminous coal 60 inches (150 cm) or more thick that occur at depths to 1,000 feet (300 m)."

"Reserve.--That portion of the Identified Coal Resource that can be economically mined at the time of determination. The reserve is derived by applying a Recovery Factor to that component of the Identified Coal Resource designated as the Reserve Base."

"Recovery Factor.--The percentage of total tons of coal estimated to be recoverable from a given area in relation to the total tonnage estimated to be in the Reserve Base in the ground. On a national basis the estimated Recovery Factor for the total Reserve Base is 50 percent."

As can be seen from the definitions and criteria, the coal reserves in an area may be considerably less than the coal resources.

Coal reserves on the Wind River Indian Reservation are much smaller than the estimated coal resources. Windolph, Hickling, and Warlow (25) estimated total coal resources, that is, subbituminous or bituminous coal 2.5 feet thick or more at depths between 0 and 6,000 feet, as 8,492,583,000 short tons. The reserve base, which includes only coals 5 feet thick or more at depths to 1,000 feet, is estimated to be 87,911,000 short tons.

In order to compare the estimates of Windolph, Hickling, and Warlow with previous resource estimates, equivalent data were extracted from tables in the Phase II report (25) and tables in Coal Resources of Wyoming by Berryhill, Brown, Brown, and Taylor (1) (table 1).

TABLE 1. - Comparison of estimated coal resources on the Wind River Indian Reservation, Wyoming

Classification (Criteria)	Estimated coal resources (millions of short tons)	
	Berryhill	Windolph
Reserve Base (5 ft thick; demonstrated resources; 0 to 1,000 ft overburden)	17.25	87.91
Estimated Resources (2.5 ft thick; identified resources 0 to 3,000 ft overburden)	47.86	244.39

Source: Berryhill, H. L., Jr., D. M. Brown, A. Brown, and D. A. Taylor. Coal Resources of Wyoming. U.S. Geol. Survey Circular 81, 1950, 78 pp.
Windolph, J. F., Jr., N. L. Hickling, and R. C. Warlow. Coal Resource Assessment of the Wind River Indian Reservation, Fremont and Hot Springs Counties, Wyoming. U.S. Geol. Survey Field Mineral Studies of Indian Lands. Interagency Agreement No. 8. Unpublished. Available to BIA and Tribes. 1982, 215 pp.

Windolph, Hickling, and Warlow (25) increased the amount of coal considered to be reserve base by about 500 percent. The coal reserves computed from the reserve base, however, are supposed to be coal that is minable at a profit under existing market conditions. Market conditions change both rapidly and drastically, thereby altering the amount of coal that can be mined at a profit. Although relatively large amounts of coal (resources) exist on the reservation, at best, only small amounts of coal (reserves) could be mined commercially under present market conditions.

Coal Mining History

Earlier explorers of the Wind River region examined coalbeds along the Popo Agie River. In 1870 the first recorded coal development in the region was begun at an underground mine about 1 mile south of Hudson, Wyo. (28). The mine was worked periodically until the Wyoming Central Coal Co. accquired the property and opened a new mine. At least five other small mines opened in the Hudson Field in the late 1800's and early 1900's, but they were worked unsystematically and the coal was used locally. Until 1906, the only market for the coal was in the sparse settlements in the vicinity of the mines.

When the Wyoming & North Western Railroad was completed from Casper to Lander in 1906, the "golden age" for the Hudson Coalfield began as more distant commercial markets became accessible (28). Annual production in the field reached 95,000 tons by 1910. During the next 18 years, annual production for the Wind River Basin varied between about 95,000 and 290,495 tons. The maximum annual production of 290,495 tons occurred in 1920.

After 1927, annual production started its gradual, but steady, decline. In 1942 annual production dropped to 18,511 tons, 5,606 tons of which was shipped by rail or used for fuel by the railroad (19). This coal was the last shipped or used by the railroad. In 1950 annual production of 3,692 tons came from only five mines. In 1960 annual production was 1,534 tons from the last two mines operating in the basin (8). Production in the basin ceased after 1966 when the George Mine, an underground operation south of Hudson, closed. The only reported production since 1966 was 85 tons from the small, privately owned Muddy Creek Strip Mine, which is in the north-central part of the reservation.

According to Glass and Roberts (8), 99.8 percent of all the recorded production from the basin came from mines in the Hudson Coalfield. Most of the recorded coal production (97.7 percent) within the reservation also came from mines in the Hudson Coalfield; in fact, the Indian Mine by itself accounted for 83.4 percent of the cumulative total coal production.

As of January 1, 1981, reported coal production in Wyoming was more than 824 million tons and, by now, the cumulative total probably has passed one billion tons (13). The total recorded coal production from the Wind River Basin is 3,982,378 tons (8), and the reported production from coal mines within the Wind River Indian Reservation boundaries is only 353,234 tons (table 2). As can be seen from these figures, neither the amount of coal produced within the reservation nor the amount produced in the entire basin account for more than a miniscule part of the cumulative coal production of the State.

TABLE 2. - Cumulative coal production from mines inside the Wind River Indian Reservation boundary 1/

Mine name (Previous name)	Location	Dates of operation	Total production (tons)
Muddy Creek Coalfield			
Clifford	sec 34, T 6 N, R 2 E	Pre-1909	NR 2/
LeClair	sec 30, T 6 N, R 2 E	Pre-1908	NR
Muddy Creek Strip 3/	secs 17,20 T 6 N, R 1 E	1973	85
Muddy Creek 3/	sec 20, T 6 N, R 1 E	Pre-1909	NR
Arrowhead 3/ (Welton)	sec 20, T 6 N. R 1 E	1941-42, 1945-47, 1960	1,549
Shotgun	sec 20, T 6 N, R 1 E	Unknown	NR
Penton	sec 12, T 5 N, R 1 W	Unknown	NR
Williams	sec 12, T 5 N, R 1 W	Unknown	NR
Armstrong	sec 27, T 5 N, R 1 E	Unknown	NR
Barquin 3/	sec 29, T 5 N, R 1 E	1931-1951	6,000 4/
Unknown	sec 30, T 6 N, R 2 W	Unknown	? 5/
Unknown	sec 25, T 6 N, R 3 W	Unknown	?
Pilot Butte Coalfield			
Meade (Mead) 3/	sec 13, T 3 N, R 1 W	1929;1931; 1941-42	442
Kinnear 3/	sec 13, T 3 N, R 1 W	Early 1900's	NR
Unknown 3/	sec 24, T 3 N, R 1 W	Unknown	?
Hudson Coalfield			
Rogers (Wise, George & Rogers; Wise and Rogers; Wise)	sec 21, T 1 S, R 2 E	1942-1957	40,324
Valley (Sviler)	sec 2, T 1 S, R 2 E	1937-1940	1,384
Mitchell No. 2 (Mitchell)	sec 22, T 1 S, R 2 E	1925-1942	8,856
Indian (Hudson; Hudson No. 1)	sec 2, T 2 S, R 2 E	1909-11;1938	294,594
McKinley	sec 2, T 2 S, R 2 E	Unknown	NR
Hickey	sec 11, T 2 S, R 2 E	Unknown	NR
Alkali Butte Coalfield			
Shipton	sec 5, T 2 S, R 6 E	Early 1900's	NR
Unknown	sec 5, T 2 S, R 6 E	Unknown	?
Blue Holes Coalfield			
Unknown	sec 5, T 5 N, R 5 W	Unknown	?
Total Reported Production			353,234

1/ Adapted from Glass and Roberts, 1978; and Windolph, and others, 1982.
2/ NR - Never Reported.
3/ These mines are on privately owned lands.
4/ Data from Keefer and Troyer, 1964, USGS Bull. 1157, p. 59.
5/ Queried where it is not known if any coal was produced.

At present, no coal mines are operating in the Wind River Basin. In 1977, Dixie Natural Resources applied for permits for two mining operations in the Alkali Butte Field a few miles east of the reservation (3-4). The proposed Alkali Butte Mine was to have been a small strip mine affecting about 50 acres of land and the proposed Bell Mine was to have been a combination of a very small strip and a deep underground mine affecting about 9.5 acres. Neither mine has been developed. In 1982, the Alkali Butte Coal Co. applied for permits to operate a small strip mine 27 miles southeast of Riverton in the Alkali Butte Field (14). This proposed mine appears to be located in approximately the same areas proposed in the Dixie Natural Resources, Inc., permits. The proposed strip mine would use something termed a "Kentucky sidewall" mining method to extract about 6,000 tons a month for 7 years, or about 500,000 tons of coal during the life of the mine. The coal seam to be mined, the Signor bed, dips 27 degrees to the west. If the permit is granted and the principals are still inclined to pursue the mining venture, development is scheduled to start in the spring and intrastate sale of coal will begin in June 1983.

Coal Mining Methods

During informal discussions with John F. Windolph, Jr., in January and June of 1982, three areas were determined to have potential for coal mining operations. The areas selected were the only ones considered potentially to contain sites minable now by either longwall underground or open-pit mining methods. In situ gasification and liquefaction methods were not considered during site selection or in this report because in situ methods are still in the experimental stage and commercial production is probably many years, if not decades, away. The three areas are in the Alkali Butte (two sites), Hudson (one site), and Muddy Creek (one site) Coalfields.

In the past most of the coal produced on the reservation and in the basin was from deep underground mines using conventional room and pillar mining methods. The only exception is the 85 tons of coal produced from the Muddy Creek Strip Mine in 1973. A short discussion of modern underground and surface mining methods is included in this section to enable the reader to understand why only longwall underground or open-pit mining methods are considered in this report.

Basically the three different types of underground coal mines are the drift mine, the slope mine, and the shaft mine (16). A drift mine is generally the easiest and cheapest to open because the opening into the mine is made directly into the outcrop of a horizontal, or nearly horizontal, coalbed. A slope mine has an inclined opening that either follows a coalbed downdip from the outcrop or is driven through rock overlying a coalbed that does not crop out. A shaft mine has a vertical opening from the surface to the coalbed. Slope mines are being used on ever deeper coalbeds, but if the coalbed is deeply covered, the shaft mine is preferred because of modern automatic hoisting equipment.

Generally, production methods used in modern underground coal mines are termed conventional, continuous, longwall, or shortwall depending upon the type of equipment used (16). Conventional mining extracts the coal in a sequence of operations using special equipment for each step in the sequence.

Conventional mining requires more manpower than other mechanized systems, but it is advantageous where seams are highly irregular or where coalbeds must be mined selectively to eliminate partings or impuritites. The continuous mining system uses single machines, called continuous miners, to break the coal mechanically and load it for transport out of the mine. Continuous mining is done efficiently with fewer working places than required for conventional mining, thereby reducing both the need for ventilation and supervision. Longwall mining systems extract large blocks of coal outlined in the development process in a single, continuous operation. A plow or shearer cuts the coal from a face shielded by hydraulic yielding jacks that support the roof at the face as the coal is removed. Many of the jack units (chocks or shields) are self-advancing and, as the coal is removed from the face, they move forward allowing the overlying rocks to cave behind them. Shortwall mining combines continuous mining and longwall mining systems. Continuous miners are used to develop a mine, and then, longwall-type roof supports are used in conjunction with the continuous miners to extract the coal from the pillars. Modern conventional and continuous mining equipment works efficiently on moderate slopes, but when grades are more than 10 percent (about 6 degrees), operating problems increase rapidly, and when the grade reaches 20 percent (about 11 degrees), problems become prohibitive. Longwall mining may be more effective than conventional or continuous mining in pitching seams. In the past, mechanized longwall systems operated in seams pitching up to 14 percent (about 8 degrees) in the United States; however, at the Snowmass Coal Co. mine near Carbondale, Colo., a mechanized longwall system is being used on a coalbed pitching at 57.7 percent (30 degrees) (26). Reportedly, the Snowmass Mine is a technological triumph, but it may not be an economic success.

The advantages of longwall mining are: (1) lower labor and operating costs, (2) higher percentage of coalbed recovery, (3) potential for greater tonnage output, and (4) improved safety. The disadvantages of longwall mining are: (1) size of capital investment, (2) long payback period, (3) high breakeven point, and (4) required long term commitment necessitating a sustained demand for coal.

Surface mining in the United States generally can be categorized as area mining, contour mining including mountaintop removal, or open-pit mining. Area mining occurs where horizontal, or nearly horizontal, marketable coalbeds underlie a flat or gently rolling surface. The coal deposit is developed using conventional dragline or shovel methods to excavate a sequence of parallel pits that may extend several thousand feet in length. This method is referred to as single-cast or area mining. The mine progresses across the area by placing the overburden from each new pit into the previous pit after the coal has been removed. Contour mining and mountaintop removal generally occur in mountainous terrain such as found in many areas of Appalachia. The earthen overburden is removed from a coalbed cropping out on the side of a hill and pushed downhill from the pit, thus exposing the coal. The coal is then removed from the pit in trucks and a second pit is excavated by placing the overburden from the second pit into the first pit. Thus, a series of pits moves around the side of a mountain along a contour delineated by the coalbed. Mountaintop removal is simply a special case of contour mining where the coalbed is close enough to the top of a hill so that it is economically feasible to mine the coal by removing all the overburden. Open-pit mining is somewhat like quarrying and is used where the coal is too thick to be mined by the single-cast method using only large draglines or shovels. Scrapers, shovel and trucks, or conveyors are used to remove the overburden from the coal and to place it in the spoil area. The open pit consists of as many benches of overburden and coal as necessary to develop the thick coalbed. The method used to mine a specific coalbed actually may be a hybrid or combination of the three surface methods.

Two problems commonly occur where surface mining is used on steeply dipping beds, that is beds dipping at more than 8 degrees (15). If the pit runs perpendicular to the dip of the coalbed, part of the coal is removed along with the overburden. The other problem, in addition to coal loss, is the tendency of spoil to slide back into the pit before the coal can be removed. The recommended method for alleviating problems is stripping updip perpendicular to the outcrop of the coalbed instead of mining downdip parallel to the outcrop (15).

Coalfields

Glass and Roberts (8) define the Wind River Coal Basin as only that portion of the Wind River Basin underlain by Mesaverde or younger rocks, because the Mesaverde is considered the oldest "important" coal-bearing formation in the basin. The Wind River Coal Basin, as defined, covers about 2,500 square miles and is areally the fourth largest in Wyoming. Approximately the western one-third of the coal basin is in the Wind River Indian Reservation (fig. 3). Counterclockwise from the northwestern corner of the basin, Glass and Roberts (8) divide the coal basin into the following seven fields: Muddy Creek, Pilot Butte, Hudson (Lander), Beaver Creek, Big Sand Draw, Alkali Butte, and Arminto (Powder River).

The Phase II report (25) also divides the Wind River Coal Region into seven coalfields, but only five of the seven coalfields have the same names. Six of the coalfields defined in the Phase II report are all or at least partly in the Wind River Reservation; they are the Blue Holes, Crowheart Butte, Muddy Creek, Pilot Butte, Hudson, and Alkali Butte Fields (fig. 4). The Arminto Field, which is not in the reservation, is not discussed in the Phase II report.

The Alkali Butte, Hudson, and Muddy Creek Coalfields contain the sites determined by the USGS to have potential for coal mining operations. These fields will be discussed further. Anyone interested in more information about the other fields should read the papers by Woodruff and Winchester (28), Glass and Roberts (8), Windolph, Hickling, and Warlow (25).

Alkali Butte Coalfield

The Alkali Butte Coalfield is a relatively remote, unimportant field in the southern part of the Wind River Coal Basin. About one-fifth of the field is inside the Wind River Indian Reservation (fig. 4). This part of the field is at least 12 to 14 miles by air southeast of Riverton; by road it is 16 to 20 miles.

Coal-bearing formations crop out on the flanks and nose of the asymmetric Alkali Butte Anticline (18). Several coalbeds or coal zones are present in the Mesaverde and Lance Formations. Only the Mesaverde coalbeds are of any consequence. A lenticular Lance coalbed, 3 to 6 feet thick with shale and sandstone partings, crops out in T 1 S, R 6 E. The anticline plunges about 10 degrees northward. The beds on the westside of the anticline dip as steeply as 65 degrees, and on the east side, the beds dip from 15 to 30 degrees. The trace of the Emigrant Trail Thrust Fault follows the west flank of the anticline. Minor faults are present in the field and, in one place, a fault displaces a coalbed.

The "A" coalbed of the Maverick Spring Coal Zone, which is in the lower part of the Mesaverde Formation, does not crop out around the anticline (25). The "A" coalbed thins to zero before reaching the surface, but according to the Phase II report, it thickens rapidly in the subsurface and exceeds 10 feet in thickness a few miles north and west of Alkali Butte.

The three most prominent coalbeds that crop out around the butte are named the Signor, Beaver, and Shipton beds. Thompson and White (18) and Windolph, Hickling, and Warlow (25) agree that the lowermost bed is the Signor, the uppermost bed is the Shipton, and the Beaver and an unnamed coalbed lie between them. In their measured section 18 near the old Bell Mine, Windolph, Hickling, and Warlow (25) place the Beaver Coalbed about 214 feet above the Signor bed, the unnamed coalbed about 474 feet above the Signor, and the Shipton Coalbed about 554 feet above the Signor. Thompson and White in a composite stratigraphic section (18, fig. 4, p. 6) reverse the position of the Beaver and unnamed coalbed placing the unnamed coal about 230 feet above the Signor Coalbed and the Beaver Coalbed about 430 feet above the Signor. The two reports also show differences between the way the beds have been mapped in secs 4, 5, 8, and 9, T 2 S, R 6 E, in the southeastern corner of the reservation. Windolph, Hickling, and Warlow (25) also mapped another unnamed coalbed in the upper part of the Mesaverde Formation in secs 4 and 5, T 2 S, R 6 E, and secs 28, 29, 32, and 33, T 1 S, R 6 E. In this report, the interpretation by Windolph, Hickling, and Warlow is used for geology within the reservation.

The Signor is the thickest and most laterally persistent coalbed in the Alkali Butte Field. It can be traced for more than 10 miles, although it is covered for intervals up to a mile in length. The Signor is covered sporadically for more than half of its 1.75-mile length on the reservation. Along this interval the bed dips to the north and the west at angles ranging from 14 to 30 degrees. Where the Signor crops out in the reservation, it thins from 9 feet on the east side of the Alkali Butte Anticline, through 7.9 feet near the nose, to 3.5 feet on the west side of the anticline. The coalbed has been burned east of Alkali Butte and the clinkered bed may be traced eastward from the 9-foot-thick coal until it is covered by soil.

Windolph, Hickling, and Warlow (25) depict the Signor coal as extending northward for more than 12 miles into the basin at depths greater than 6,000 feet and as extending westward for about 20 miles at depths less than 6,000 feet. In this extended area, the coal ranges in thickness from less than 2.5 feet to over 10 feet. The thicker areas are north of Alkali Butte, on the Riverton Dome, and just east of Hudson. The total estimated resource for the Signor Coalbed on the reservation is 1,742,505,000 short tons.

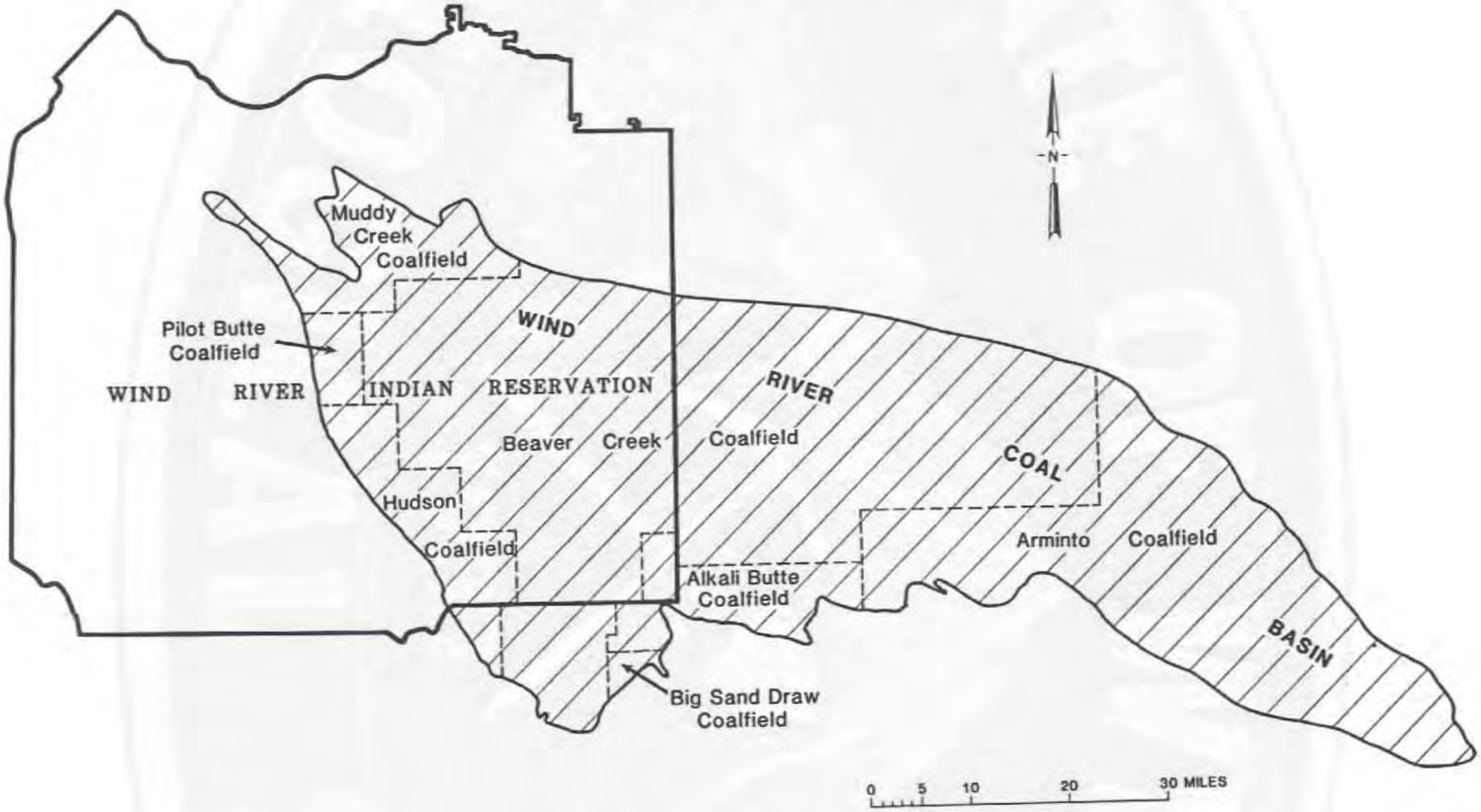

FIGURE 3.— Wind River Coal Basin and coalfields as defined by Glass and Roberts in 1978.

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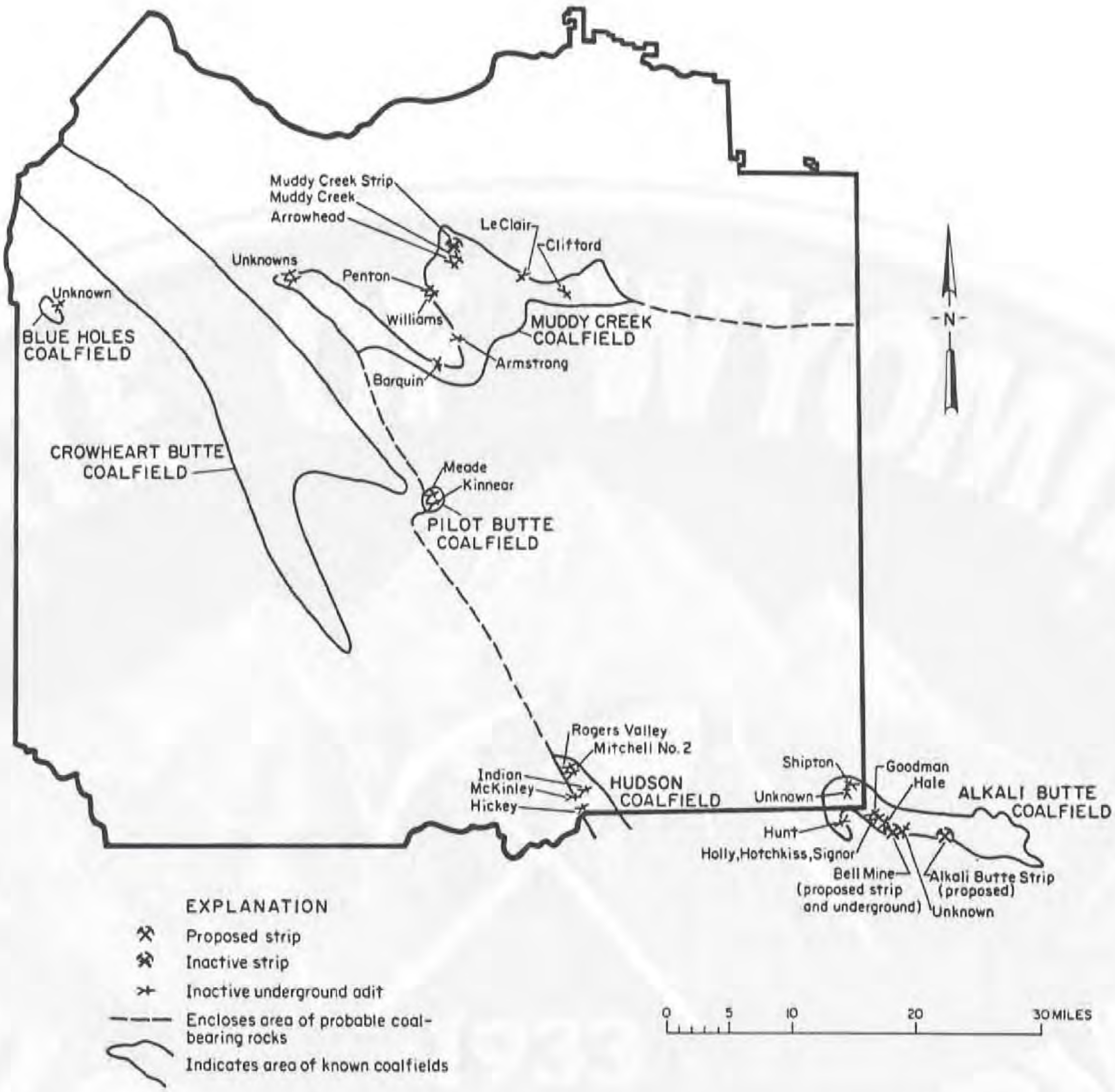

FIGURE 4.— Coalfields in or near the Wind River Indian Reservation as defined by Windolph, Hickling, and Warlow in 1982.

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The Beaver Coalbed crops out about 200 to 280 feet above the Signor Coalbed in the Alkali Butte area (25). The Beaver coal is thinner and less widespread than the Signor coal. On the reservation, the Beaver bed can be traced for more than a mile and probably is present under cover for another half mile. The bed dips to the north and west at angles ranging from 18 to 28 degrees. The coal appears to be clean and is 2.5 to 3 feet thick where exposed. The coal thickens to 10 feet in the subsurface near the Beaver Creek Oilfield south of the reservation. Windolph, Hickling, and Warlow (25) estimate the resources of the Beaver Coalbed as 886,131,000 short tons on the reservation.

The only place the Shipton Coalbed crops out is 170 to 360 feet above the Beaver Coalbed on the flanks of Alkali Butte (25). On the north side of Alkali Butte the coal is 5.5 feet thick including a 0.5-foot-thick, tuffaceous sandstone parting (18). About 500 feet farther west, the coal is about 3 feet thick with several partings and is of poor quality. Less than one-half mile farther west at the caved Shipton Mine, there is about 5 feet of impure coal. At the Shipton Mine the coalbed turns southwest towards an unnamed mine, where the coal supposedly thickens to 8.5 feet without partings (18). About 1 mile farther southwest outside the reservation, the coal thickens to 9.5 feet. The bed dips to the north and west at angles ranging from 18 to 35 degrees. North of Alkali Butte and north of Hudson, the Shipton Coalbed is 8 feet thick in the subsurface and at Riverton Dome, the coal thickens to 15 feet in the subsurface (25). Windolph, Hickling, and Warlow (25) estimate the resources of the Shipton Coalbed as 914,563,000 short tons on the reservation.

The Shipton Coalbed appears to be the only coalbed mined on the reservation in the Alkali Butte Field. The Shipton Mine had an essentially horizontal entry driven 45 feet into the coalbed (28). The adit is caved. The unnamed mine in the SE1/4 SW1/4 sec 5, T 2 S, R 6 E, has four partially caved adits driven into the coalbed. No production was recorded from either mine. Both of the mines are just west of a normal fault that strikes northeast and offsets the coalbed about 20 feet down to the southwest (25).

Nine coal mines have been worked in the Alkali Butte Coalfield. The total recorded production of 1,134 tons came from three mines working the Signor Coalbed south of the reservation. The three mines are the Hunt, Hotchkiss, and the Holly. In 1910 Woodruff and Winchester (28) stated that one of the main problems in the Alkali Butte Field was the absence of drinkable water. Later, water in the mine workings was considered a critical problem. So much water was encountered at 165 feet down dip in the main entry of the old Bell Mine that pumping costs were high (18).

Alkali Butte Sites

The two sites examined in the Alkali Butte Coalfield are in the SE1/4 sec 5, T 2 S, R 6 E, and in the NE1/4 sec 9 and NW1/4 sec 10, T 2 S, R 6 E. The sites were considered for both surface and underground mining operations. The first site is about 18.5 miles by road from Riverton and the second site is about 20 miles from the railhead at Riverton.

Near the first site, the Shipton Coalbed crops out and was mined at both the Shipton Mine and an unnamed mine about 1,100 feet southwest of the Shipton Mine (fig. 5). The two mines mark the opposing ends of the area studied. The Shipton Coalbed is covered on the hill between the two mines. A normal fault striking about N 30° E offsets the coalbed down about 20 feet to the west in the study area (25).

In 1909 the Shipton Mine consisted of a nearly horizontal entry 45 feet long ending in a zone of weathering (28), but the adit has long since collapsed. The mine is on the north side of a draw hereinafter informally called "Shipton Draw." The coalbed dips northward at 20 degrees near the caved adit. The coalbed in the Shipton Mine is about 6 feet of impure coal containing 0.7 foot of bone in the upper 1.3 feet (28). Carbonaceous shales and buff sandstones occur both above and below the coalbed.

At the unnamed mine, there are four caved adits driven into the Shipton Coalbed. The adits are spread out along the outcrop for a distance of about 300 feet on the northwest side of another draw, hereinafter informally called "Coal Mine Draw." The coalbed strikes N 10° E and dips west-northwest at 15 degrees. The coal is about 5 feet thick and contains thin tonsteins (shale bands derived from volcanic ash) and petrified wood which appears to have been charred before burial. Gray shale lies above and below the coalbed. A thin coal seam, 0.1- to 0.3-foot-thick, occurs about 4 feet below the thick coalbed and overlies about 4 feet of reddish-brown shale. A thick sequence of buff shales and sandstones overlies the 1.5-foot-thick gray shale just above the Shipton Coalbed.

Windolph, Hickling, and Warlow (25) placed a drillhole about 300 feet northwest of the unnamed mine on the relatively level area between Shipton and Coal Mine Draws (Appendix, p. 45). In this drillhole the top of the Shipton Coalbed is 96.6 feet below the surface and the base is less than 102.7 feet down. The 6-foot-thick coal is bright containing bone and pyrite bands. The contact with the overlying dark gray to grayish-brown shale is sharp. A 0.5-foot-thick tonstein immediately underlies the coal and the tonstein is underlain by grayish-brown carbonaceous shales.

Technically, a small open-pit mine could work the Shipton Coalbed in the area between the two old mines. The pit, however, would cover only about 20 acres. The total estimated tonnage from the open-pit at best would be: 1,770 (short tons/acre-foot) X 5.3 (average coal thickness in feet) X 20 (acres) = 187,620 short tons. Because the coalbed dips at angles ranging from 15 to 20 degrees, problems inherent to open pit mining on steeply pitching beds probably would occur. The special techniques discussed earlier in the paper, such as stripping and loading updip and placing the pit perpendicular instead of parallel to the outcrop, possibly would reduce the problems.

Longwall underground mining was rejected because of the steeply dipping beds, the possible presence of other faults in the subsurface, and the probability of excessive amounts of groundwater in deep workings. A stock well in the NE1/4 NW1/4 sec 25, T 34 N, T 95 W, about 2 miles southeast of the Shipton Mine (outside the reservation) is the closest source of data. The well is 403 feet deep and water occurs at a depth of 235 feet. The well is drilled in the Mesaverde Formation northeast of the Goodman Mine.

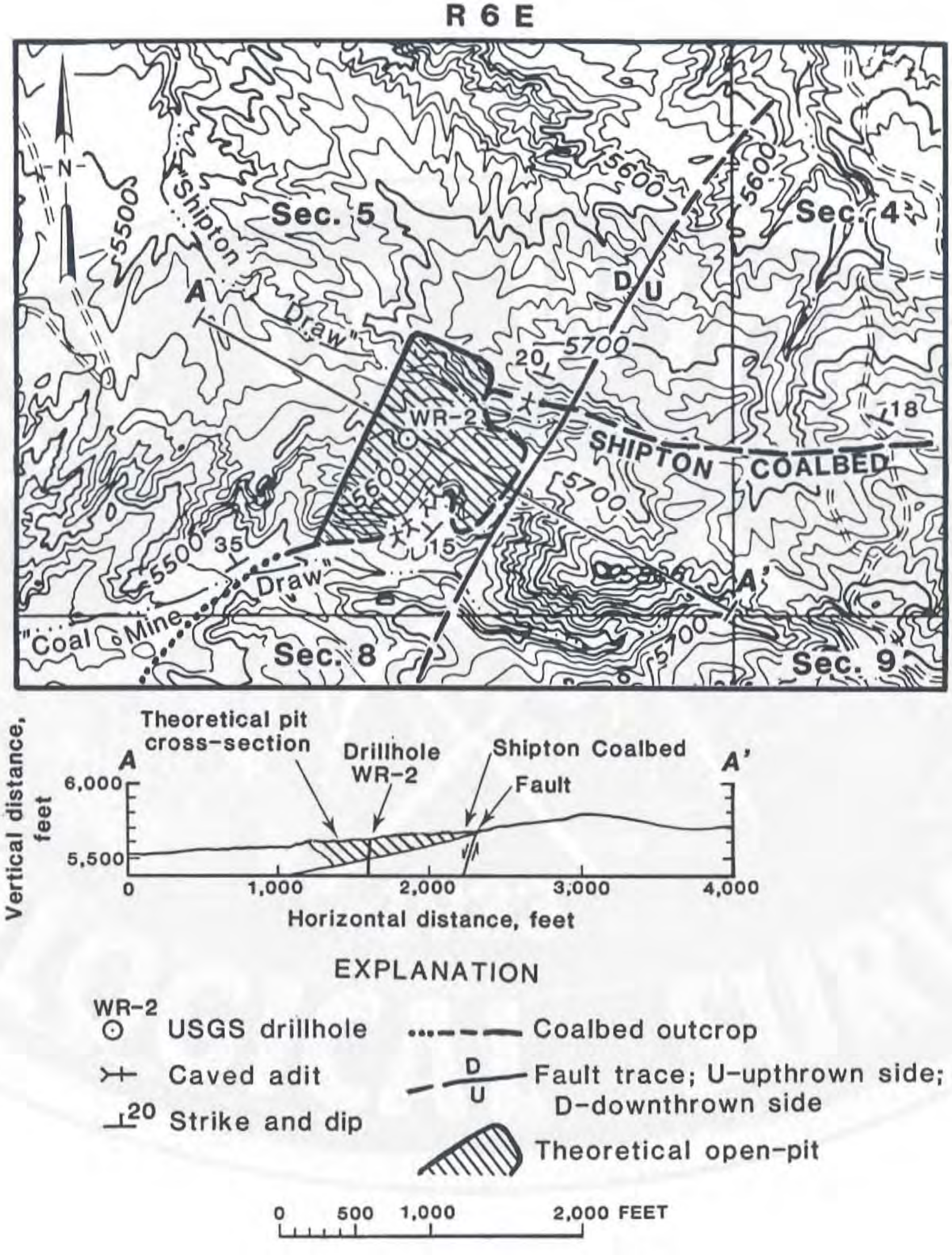

FIGURE 5.— Potential mine site 1 in Alkali Butte Coalfield.

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As mentioned previously, water is a twofold problem in the Alkali Butte Coalfield. Large amounts of dissolved solids and high percentages of sodium may make groundwater unsuitable for drinking or irrigation and only fair to poorly suitable for stock water (24). Whitcomb and Lowry (24) state that the sandstones of the Fort Union, Lance, Meeteetse, and Mesaverde Formations yield small quantities of water that generally are unsuitable for domestic use and may be marginal for stock.

The second site is east of Alkali Butte and both the Beaver and Signor Coalbeds underlie part of the area (fig. 6). The Signor Coalbed, however, is the bed that probably could be mined. The Signor Coalbed crops out west of the site and south of the site, but it is covered by soil and alluvium within the site. The site is a relatively flat area at the head of Alkali Creek and northeast of a gate in the reservation boundary.

Windolph, Hickling, and Warlow (25) drilled two holes within the site (Appendix, p. 33). The two holes were drilled northeast of the estimated position of the Signor Coalbed, if it were to crop out. The drillholes are 400 and 800 feet, respectively, northeast of the gate in the boundary fence.

In the drillhole closer to the gate, the top of the Upper Split of the Signor Coalbed is 157.1 feet deep and the bottom is 161.5 feet deep. The Upper Split consists of mostly bright coal (a constituent of banded coal which is jet black, pitchy in appearance, more compact than dull coal, and breaks with a conchoidal fracture), but it includes bone (a hard coallike substance high in noncombustible mineral matter), scattered resin, blebs of pyrite, and a 0.2-foot-thick ash parting 2 feet below the top (25). The Lower Split of the Signor Coalbed ocurs at depths between 195.4 and 203.9 feet. The coal is described as hard, clean, and bright with detrital sandstone lenses in the upper 3 inches, pyrite on cleat surfaces, scattered resin blebs, and gypsum crystals (25).

In the drillhole farther from the gate, the Beaver Coalbed occurs between the depths of 107.5 and 113.0 feet (26). From the top, the coalbed consists of 2 feet of dull to bright coal containing both pyrite on the cleats and resin blebs, about 1.4 feet of bentonitic, carbonaceous shales and 2.2 feet of dull to bright bony coal containing pyrite crystals and resin blebs. The Upper Split of the Signor Coalbed occurs between the depths of 373 and 378.5 feet. From the top, it consists of 0.5 foot of bright to dull, bony coal, 0.3 foot of carbonaceous shale, and 4.8 feet of bright to dull bony coal containing gypsum crystals on the cleats and a thin ash bed. The Lower Split of the Signor Coalbed occurs between the depths of 397.5 and 407.4 feet. From the top, it consists of 0.2 foot of sandstone lenses and bone, 8.7 feet of bright to dull coal containing gypsum crystals on cleats and pyrite crystals, 0.3 foot of carbonaceous shale, and 0.7 foot of bony coal containing pyrite crystals.

The Signor Coalbed west of the second site ranges in thickness from nearly zero to about 8 feet in a distance of less than 300 feet. The coalbed also appears to have burned leaving only clinker adjacent to the potential mine site. The sandstones that crop out adjacent to the site strike N 16° W and dip east-northeast at 26 degrees.

Technically, an open-pit could be used to mine the Signor Coalbed in this area. Even if the Beaver Coalbed and both splits of the Signor Coalbed were mined to depths of 150 feet the pit would cover about 20 acres, and the total estimated tonnage from the open pit would be:

(short tons/acre foot)(average coal thickness in feet)(acres) = short tons

Lower Split Signor Coalbed:	1,770 X 8.5 X 7.5 =	112,838 short tons
Upper Split Signor Coalbed:	1,770 X 4.6 X 7.5 =	61,065 short tons
Beaver Coalbed:	1,770 X 4.2 X 5.0 =	37,170 short tons
Total estimated tonnage	=	211,073 short tons

Problems would occur because of the steeply dipping beds, and special techniques would have to be used to overcome them.

Longwall underground mining was rejected because of the steeply dipping beds and the possibility of excessive amounts of groundwater in deep workings. Windolph, Hickling, and Warlow (25) did not mention any water in the two holes that were drilled within the site. Water is present at a depth of 235 feet in the stock well about 0.7 mile south of the second site.

Hudson Coalfield

In the past, the Hudson Coalfield, formerly called the Lander Coalfield, was the "important" coalfield in the Wind River Basin. Four-fifths of the coalfield is within the Wind River Indian Reservation (8). The Popo Agie River and its 3/4-mile-wide flood plain separate the northern four-fifths of the field from the southern fifth.

The town of Hudson sits on the flood plain astraddle the reservation boundary. On State Highway 789 Hudson is about 14 miles southwest of Riverton and about 10 miles northeast of Lander. The Chicago and North Western Railroad served both Hudson and Lander before the tracks were removed back to Riverton. Railroad spur tracks extended northward about 2 miles from Hudson to the Indian Mine of the Hudson Coal Co. and southward about 5 miles from Hudson to the Poposia No. 1 and No. 2 Mines of the Hudson Coal Co. The northern spur track was removed after 1915 and the southern spur track was removed in 1929 (19, 21).

Strata in the coalfield generally dip northeast at 10 to 20 degrees except in an area about 2 miles north of Hudson. There, rocks dip at angles up to 30 degrees and coal outcrops are deflected to the east because of the McTurk Syncline and McGowen Anticline. No faults have been found in the coalfield.

Massive sandstones in the Mesaverde Formation form a north-northwest trending ridge north of Hudson; the ridge takes the form of a cuesta having steep cliffs on the west side and a gentler, moderately rolling east slope. The coal-bearing Mesaverde strata crop out mainly on the steeper western side of the ridge, but coalbeds do crop out on the east slope. Tuffaceous and conglomeratic beds of the Indian Meadows Formation unconformably overlie the Mesaverde strata and cover most of the east side of the ridge.

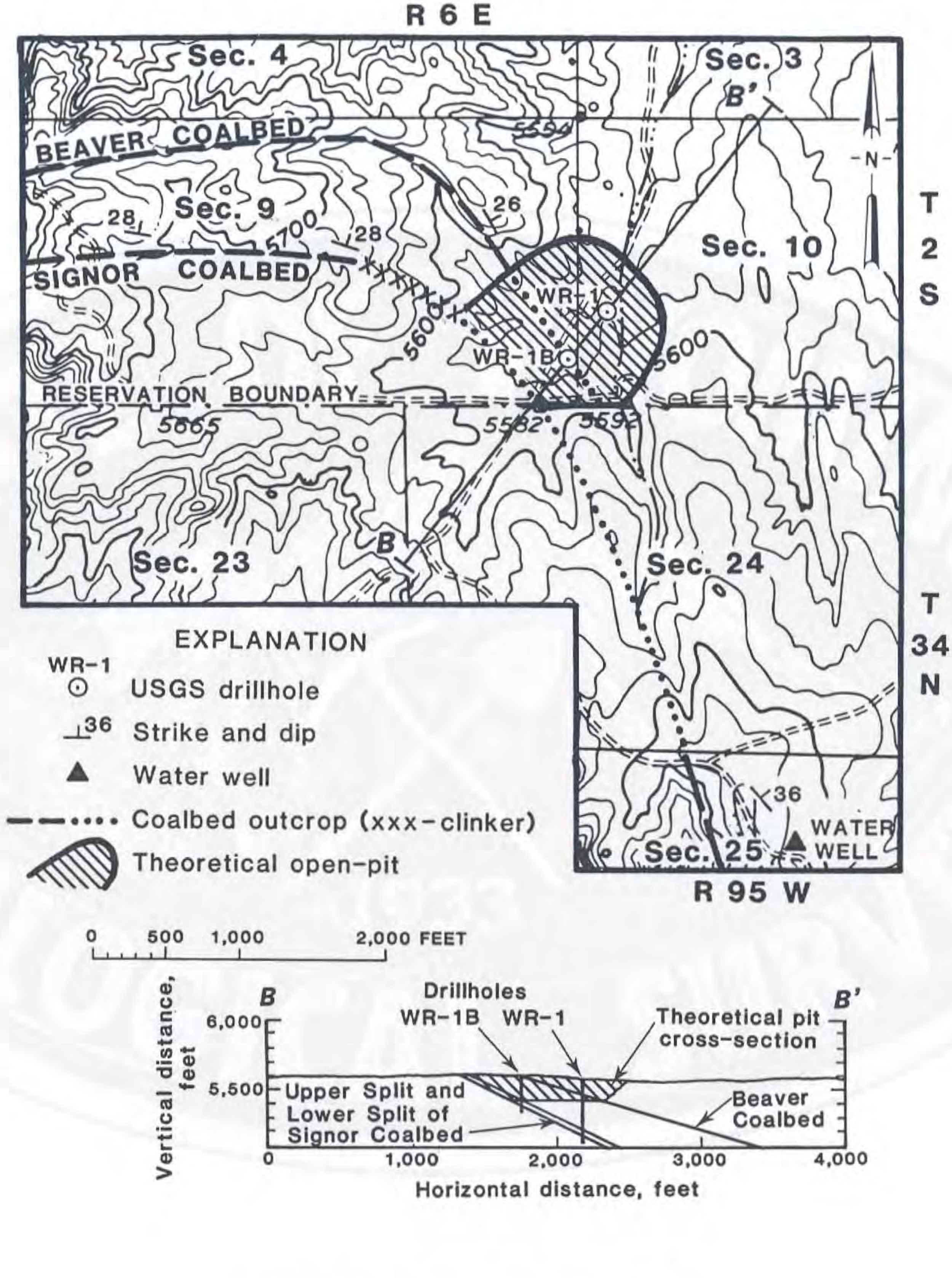

FIGURE 6.— Potential mine site 2 in Alkali Butte Coalfield.

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On the reservation, three Mesaverde coals that are 2.5 feet thick, or more, crop out sporadically over a distance of about 7 miles. South of the reservation the coal outcrops are exposed more, but all eventually are concealed under the overlapping conglomerates of the Indian Meadows Formation. On the reservation, the lower two coalbeds are the "A" Coalbed and the Upper Coalbed of the Maverick Spring Coal Zone; the uppermost coalbed is the Signor Coalbed (25).

The "A" Coalbed ranges in thickness between 2.5 and 3 feet for about 5.5 miles along the outcrop towards the northwest from a point about 2 miles northwest of Hudson. The 2.5-foot-thick coalbed also extends northeastward downdip into the basin to depths greater than 6,000 feet. At the Mitchell No. 2 Mine, 8,856 tons of coal was mined from the "A" Coalbed. In 1910 the Mitchell No. 2 Mine consisted of a 200-foot-long slope at 15 degrees with a 30-foot-long entry on the right near the bottom (25). Windolph, Hickling, and Warlow (25) estimate the coal resources of the "A" Coalbed in the Hudson Field on the reservation as 67,373,000 short tons.

The Upper Coalbed is 2.5 feet thick, or more, for about 2.5 miles along the outcrop and in the subsurface northwest of Hudson (25). The Upper Coalbed crops out about 60 feet above the "A" Coalbed. The coalbed ranges in thickness between 2.5 and 6.3 feet. The coalbed has been mined extensively south of the reservation where it is known as the Lander Coalbed. Several mines on the reservation also worked the Upper Coalbed, but no production was recorded. Windolph, Hickling, and Warlow (25) estimate the resources of the Upper Coalbed in the Hudson Field on the reservation as 28,420,000 short tons.

The Signor Coalbed crops out about 100 feet above the Maverick Spring Coal Zone. The coalbed is 2.5 feet thick, or more, for about 8 miles along the outcrop and in the subsurface north of Hudson (25). The coal is over 5 feet thick in the Indian Mine and in the subsurface east of the mine and northeast of Hudson. Recorded production of the Indian Mine is 294,594 tons (8). The McKinley Mine, which is just southwest of the Indian Mine, may have worked the Signor Coalbed, but no production from the mine was recorded. The estimated resources of the Signor Coalbed for the entire reservation are 1,742,505,000 short tons (25).

All of the 19 mines identified in the Hudson Coalfield were underground (8) and 99.8 percent (3,973,402 tons) of the coal produced in the Wind River Basin came from them. The Poposia (Poposia No. 1) and Hudson No. 2 (Poposia No. 2), the two largest mines in the field, are south of Hudson. The combined cumulative production of 3,325,682 tons from the two mines, 2,739,284 tons from the Poposia and 586,398 tons from the Hudson No. 2, accounts for 83.7 percent of the total production from the Hudson Coalfield and 83.5 percent of the total production from the Wind River Coal Basin. The Indian Mine, on the reservation north of Hudson, was the third most productive mine in the field having produced 294,594 tons. Less than 9 percent of the total coal produced from the Hudson Coalfield and the Wind River Basin, however, came from mines on the reservation.

The principal problems encountered in the Hudson Coalfield were caused by poor early transportation, by competition from wood in the local market, by increasing amounts of impurities in the coal with depth in some mines, and by rapid disintegration of the coal upon exposure to air. Woodruff and Winchester (28) also reported that one mine south of Hudson had enough water in the workings to require constant pumping. Gas also was present in this mine, but the quantity was small enough that it was not dangerous and did not require any special equipment.

Hudson Site

The Hudson site is north of the Indian Mine in the E1/2 sec 35, T 1 S, R 2 E (fig. 7). The site is about 2 to 3 miles northwest of Hudson and the railhead at Riverton is about 14 to 16 miles away. The Signor Coalbed, the only coalbed considered at this site, averages about 6.7 feet in thickness and dips to the north-northeast at angles ranging from 7 to 11 degrees. The site is on the north limb of the McGowen Anticline immediately north of the Indian Mine. Both surface and underground mining operations are considered.

The original workings at the Indian Mine apparently were on the south side of Mitchell Draw. The mine was on the south limb of the McGowen Anticline and the main entry extended downdip at an angle of 14 degrees into the McTurk Syncline. The workings consisted of several thousand feet of underground passages with as many as five back entries that extended at least one-fourth of a mile southwest of the main entry (28). Pishel measured two sections in the mine in 1911 (28). The first section was 7.7 feet thick containing 5.5 feet of coal and 2.2 feet of carbonaceous shale and bone partings. The second section was 10.5 feet thick containing 7.5 feet of coal and 3 feet of carbonaceous shale and bone partings. Five other sections measured in the mine in 1910 by H. M. Wolfin averaged 7.5 feet in thickness, including 6.9 feet of clean coal and 0.6 feet of bony or shaly coal (21). The Hudson Coal Co. reportedly closed the Indian Mine in 1911 "* * * because the bed splits and contains a greater percentage of impurities in the deeper workings than it does near the surface (28)."

The Indian Mine was worked again in 1938 (8). The mine workings described in Windolph, Hickling, and Warlow (25) may date from this period because they are partly open and appear to have been worked more recently than those south of Mitchell Draw. The workings are described as extending about 600 feet down a 10-degree slope and the Signor Coalbed was measured as about 7.2 feet thick.

Open pit mining was rejected for the Hudson site because of the nature of the strata overlying the Signor Coalbed. A chert-pebble-boulder conglomerate in the tuffaceous member of the Indian Meadows Formation unconformably overlies the coalbed. It is an extremely hard rock and would have to be removed by drilling and blasting if an open pit were established. The conglomerate is about 20 feet thick in a hole drilled by the USGS 200 feet north of the open adit at the Indian Mine (Appendix, p. 56), and the conglomerate generally thickens downdip (25). The drilling and blasting costs probably would be prohibitive.

Technically, a longwall underground mine probably could be developed at the site. Extensive drilling would have to be done to confirm the thickness, quality, and extent of the Signor Coalbed. The drilling would be difficult and expensive. Potential coal tonnage between the surface and

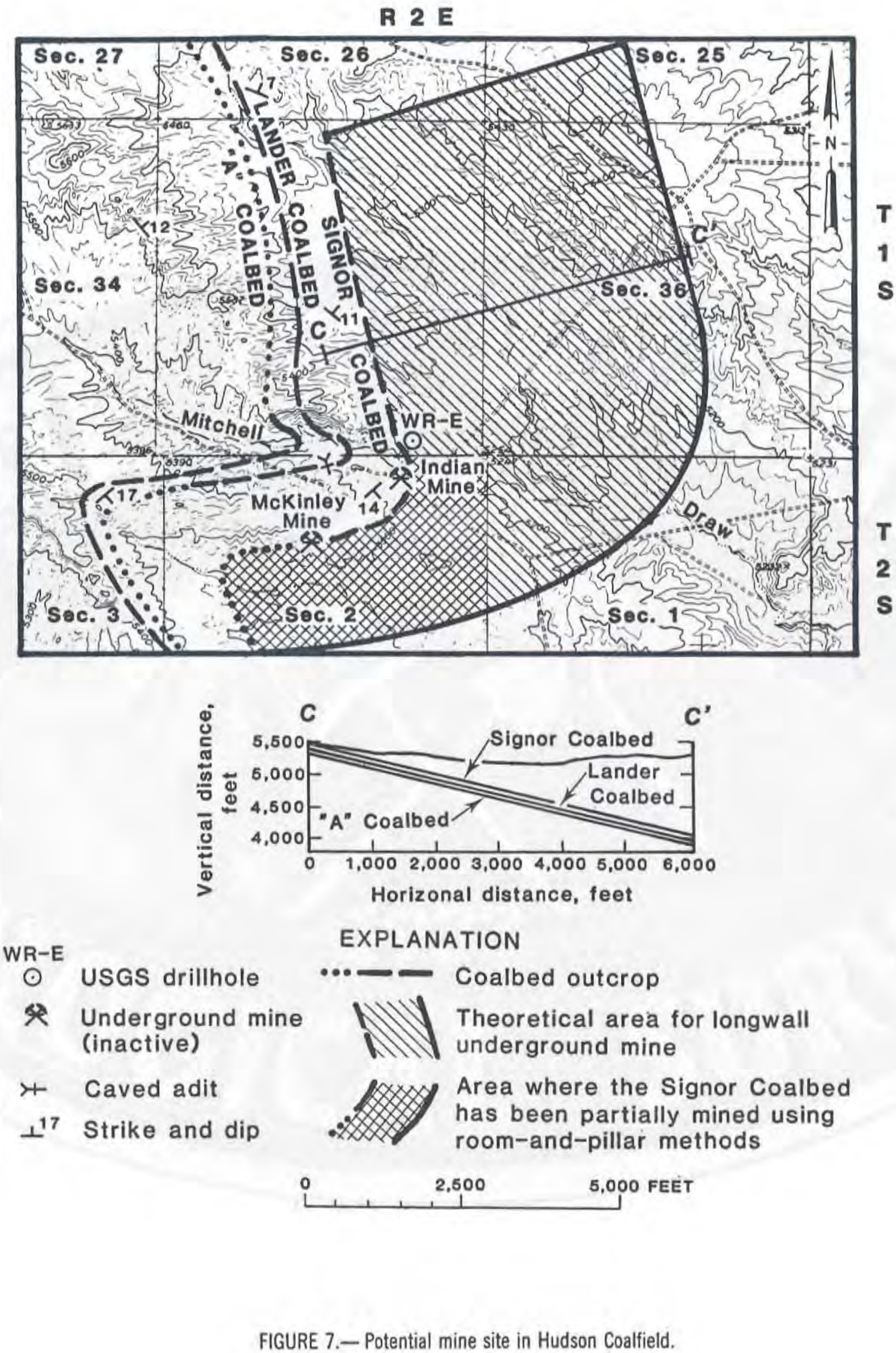

FIGURE 7.— Potential mine site in Hudson Coalfield.

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1,000 feet within the site is: 1,770 (short tons/acre-foot) X 6.8 (average coal thickness in feet) X 1,000 (acres) = 12,036,000 short tons. The inflow of groundwater could be a serious problem in deep workings. Gas (methane) probably would be present in the workings, but on the basis of past data, the gas should not be a serious problem.

Muddy Creek Coalfield

The Muddy Creek Coalfield is in the northwestern part of the Wind River Coal Basin and it is the most rugged and remote coalfield in the basin. Access to most of the coalfield is by a combination of paved highways, improved gravel roads, and unimproved jeep trails. The railhead at Riverton is more than 40 miles from the closer parts of the field and nearly 80 miles from the farther parts.

The Muddy Creek Coalfield is in one of the more structurally complex parts of the Wind River Basin. In this area the Mesaverde and Meeteetse, the two primary coal-bearing formations, have been folded into an en echelon series of northwest-trending, southeast-plunging anticlines and synclines. The folds are southwest asymmetric meaning that generally the dips are steeper on the southwest sides of the anticlines and the northeast flanks of the synclines. Dips on beds generally range from 20 to 25 degrees, but in some places, the beds are overturned. Dips recorded at known mines in the area vary from 19 to 60 degrees.

All the noteworthy Mesaverde coals in this field are part of the Maverick Spring Coal Zone that underlies about 1,200 square miles (25). The "A" Coalbed and the Upper Coalbed are the most persistent coals in the zone. Two lenticular coalbeds overlie the more widespread coals in small areas of the coalfield. The Welton seam is the only thick and persistent coalbed in the Meeteetse Formation that crops out on the reservation.

The "A" Coalbed crops out in eight areas in the coalfield. The individual areas will be described from the westernmost occurrence towards the easternmost.

The "A" Coalbed crops out on southwest limb of the Coal Draw Syncline. The average dip of the beds is about 30 degrees in this area and the coal is 2.5 to 4 feet thick. There are four caved adits here, but no production was recorded. Estimated coal resources for this area are 6,580,000 short tons (25).

The "A" Coalbed also crops out on the east limb of the Coal Creek Syncline. The beds are overturned in this area and dip northeast at 84 degrees. The coal is 2.5 to 8 feet thick and the total estimated resources in this deposit are 21,347,000 short tons (25).

Some thin deposits of the "A" Coalbed crop out on the overturned northeast limb of the Crow Draw Syncline. The beds dip northeast at 74 degrees and the 2.5 to 3 feet thick coal crops out for only a short distance. The estimated coal resources in this deposit are 1,387,000 short tons (25).

The "A" Coalbed is 2.5 to 4.8 feet thick and crops out south of Eagle Point (25). The Penton Mine, Williams Mine, and an unknown mine worked this bed in sec 12, T 5 N, R 1 W. The beds dip northeast at angles ranging from 24 to 48 degrees. There are 6,375,000 short tons of estimated resources in this deposit (25).

Another part of the "A" Coalbed crops out for about 3 miles around the northwest end of Shotgun Butte Syncline (25). The coalbed is 2.5 to 7.7 feet thick, including many partings locally. Dips of the beds on the east limb of the syncline range from 55 to 90 degrees, and in some places, the beds are overturned. Dips on the west limb of the syncline are between 20 and 30 degrees. Estimated resources are 7,846,00 short tons for this part of the "A" Coalbed (25).

The largest part of the "A" Coalbed in the Muddy Creek Field underlies the entire Shotgun Butte area, but it only crops out for short distances in two areas. The coalbed surfaces for about 2 miles on the northeast side of the deposit near Arapahoe Ranch. The beds dip at angles between 55 and 62 degrees in this area. At the LeClair Mine, about 100 tons of coal was removed from an irregular opening about 50 feet deep on the "A" bed which is 7.5 feet thick and dips southwest at 60 degrees (25). The "A" Coalbed also crops out for about 2 miles on the east flank of the Little Dome Anticline about 2 to 4 miles northeast of the Barquin Mine. The beds in this area dip towards the east at angles ranging from 42 to 54 degrees. The thickness of the coal ranges between 2.5 and 8 feet in this extensive part of the "A" bed and the estimated resources of this part are 192,335,000 short tons (25).

Two small outcrops of the "A" Coalbed occur east of Arapahoe Ranch about 3 and 6 miles, respectively. Several anticlines and synclines and numerous faults populate this structurally complex area. The coal crops out in parts of secs 27 and 34, T 6 N, R 2 E. The coalbed is 2.5 to 3 feet thick and dips southeast at angles around 25 degrees. Windolph, Hickling, and Warlow (25) estimated the coal resources as 412,000 short tons for this part. In sec 29, T 6 N, R 3 E, the 2.5- to 3.6-foot-thick "A" Coalbed crops out in overturned strata that dip about 50 degrees to the northeast. The estimated resources for this part of the "A" Coalbed are 329,000 short tons (25).

The Upper Coalbed crops out in three areas in the Muddy Creek Coalfield. The first area is in Coal Draw Syncline, the second area is east of Little Dome Anticline, and the third area is west of Jenkins Mountain.

A small deposit of the Upper Coal, which is 2.5 to 3.4 feet thick, crops out 45 feet above the "A" Coalbed on the overturned limb of Coal Draw Syncline. The beds dip northeast at 72 degrees in this area. Windolph, Hickling, and Warlow (25) estimated the resources as 736,000 short tons. A second, larger deposit is about 3 miles northwest of the small deposit and it also lies in Coal Draw Syncline. The Upper Coalbed is about 50 feet above the "A" Coalbed here, and it ranges in thickness from 2.5 to 8.7 feet. The beds on the northeast limb of the syncline are nearly vertical or are overturned. On the southwest limb, the beds dip northeast at angles ranging from 16 to 50 degrees. Estimated resources for this part of the Upper Coalbed are 26,748,000 short tons (25).

Windolph, Hickling, and Warlow (25) describe the part of the Upper Coalbed east of Little Dome Anticline as being 2.5 to 4.3 feet thick and as containing estimated resources of 1,768,000 short tons. The beds in this area dip to the east at angles ranging from 18 to 54 degrees.

West of Jenkins Mountain, the Upper Coalbed crops out for 9 miles, but the bed is folded and faulted. The coalbed dips normally in some areas, is overturned in others, and ranges in thickness between 2.5 and 4.9 feet. The Upper Coalbed is about 100 feet above the "A" Coalbed. The Clifford Mine worked the coalbed in sec 34, T 6 N, R 2 E, but no production was recorded from the mine. There are 43,545,000 short tons of estimated coal resources in this part of the Upper Coalbed (25).

An unnamed coalbed crops out about 320 feet above the "A" Coalbed in secs 7, 17, and 18, T 5 N, R 1 W, on the east limb of the Coal Draw Syncline. The coalbed is about 2.5 feet thick and dips northeast at about 72 degrees on the northeastern overturned limb of the syncline. Estimated resources are 5,805,000 short tons (25).

Another small lenticular bed, the Barquin Coalbed, crops out about 165 feet above the "A" Coalbed in sec 29, T 5 N, R 1 E. The Coal has been worked at the Barquin Mine, which is on 80 acres of private land. The recorded production between 1931 and 1946 was 4,932 tons. The mine reportedly was active until 1963, but no other production figures have been recorded. The beds dip south at 11 degrees in the vicinity of the Barquin Mine. Windolph, Hickling, and Warlow (25) did not make a separate estimate of the coal resources of the Barquin Coalbed.

In the Meeteetse Formation, only the Welton Coalbed is thick and persistent enough near the surface to be considered as potentially minable. The Welton Coalbed is about 800 feet above the base of the formation. The Welton crops out in three parts of the Muddy Creek Coalfield, but the outcrops are scarce because in many areas the bed has been eroded or it is unconformably covered by conglomerates of the Indian Meadows Formation (25).

The Welton Coalbed extends in the subsurface from one outcrop area west of Jenkins Mountain to another outcrop area about 2 miles east of the Barquin Mine. The bed is between 2.5 and 5 feet thick along the 6.5-mile-interval where it is exposed west of Jenkins Mountain. Along a 1.3-mile-long outcrop east of the Barquin Mine, the coal is 2.5 to 5.9 feet thick. The Armstrong Mine opened the coalbed near its thickest point, but there was no recorded production. The total estimated resources for this part of the Welton Coalbed are 466,383,000 short tons; however, much of the coal in this area is covered by as much as 6,000 feet, and in some places more than 6,000 feet, of overburden (25).

A smaller deposit of the Welton Coalbed crops out along Muddy Creek in an area called the Shotgun District by Woodruff and Winchester (28). The coalbed crops out for about 2 miles along the southwest limb of the Shotgun Butte Syncline about 3 miles east of Eagle Point. The thickness of the coal ranges from less than 1.2 feet at the surface to 18 feet in the subsurface. The maximum thickness measured along the outcrop is 17.4 feet with 1.3 feet of partings in the upper one-fourth of the bed. Windolph, Hickling, and Warlow (25) estimated the resources for this part of the Welton Coalbed at 52,434,000 short tons.

At least three mining operations have tried to extract and sell coal from this area. At the Muddy Creek Mine in NW1/4 sec 20, T 6 N, R 1 E, an opening ranging in width from 6 to 10 feet extended 75 feet down a 28 degree slope. There is no record of production from this mine, but Woodruff and Winchester (28) estimated that less than 150 tons of coal had been mined. The overall thickness of the bed was 14.6 feet including 10.5 feet of coal and 3.1 feet of bone. The Welton Mine, more recently known as the Arrowhead Mine, also worked the Welton Coalbed, but its exact location seems to be unclear. Glass and Roberts (8) place it in section 20 south of the Muddy Creek Mine, but Windolph, Hickling, and Warlow (25) show it as being in section 17 north of two other mines called the Muddy Creek and the Welton. The recorded production from the Arrowhead (Welton) Mine is 1,549 tons regardless of where it is located. The most recently operated mine in this area was the Muddy Creek Strip Mine. The only officially recorded production from the small open pit in NW1/4 sec 20, T 6 N, R 1 E, is 85 tons in 1973. The Welton Coalbed dips 19 degrees east in the pit and is at least 12 feet thick. The Muddy Creek Strip Mine property was foreclosed on by a bank in Riverton in 1982.

The best coal in this area is on private land in sections 17 and 20. The legal description of the private land follows:

Owner: Eula Harmon Hoff, and others
Section 17: NE1/4 SW1/4, SE1/4 NW1/4, W1/2 SE1/4 (160 acres)
Section 20: W1/2 NE1/4 (80 acres)

Owner: American National Bank of Riverton
Section 17: SE1/4 SW1/4 (40 acres)
Section 20: NE1/4 NW1/4 (40 acres)

The Muddy Creek Coalfield has the second largest recorded coal production in the Wind River Basin, second only to the Hudson Coalfield. The recorded coal production, however, is only 6,566 tons from three mines, at least two of which are on privately owned land. The Barquin Mine was the most productive with 4,932 tons and the Arrowhead was next with 1,549 tons. The Muddy Creek Strip, the only strip mine ever to operate in the Wind River Coal Basin, was last with 85 tons.

Principal problems encountered in producing coal from the Muddy Creek Coalfield are three-fold. As discussed previously, the coal tends to disintegrate into a brown powder upon prolonged exposure to air. Secondly, the strata in the area have been intensely deformed causing many of the coalbeds to dip at steep angles; in some areas the coalbeds are offset by faults. Thirdly, the ruggedness and remoteness of the coalfield cause transportation problems.

Muddy Creek Site

The Muddy Creek site is south of the Muddy Creek Strip Mine in the W1/2 sec 20, T 6 N, R 1 E (fig. 8). The site is about 55 miles from the railhead at Riverton by way of existing roads.

The only significant coalbed in the vicinity is the Welton. The Welton Coalbed crops out in the Meeteetse Formation for about 2 miles along the east side of a draw that is tributary to Muddy Creek. The coalbed ranges in thickness from less than 1.2 feet to 17.4 feet along the outcrop. The Welton Coalbed is about 12 feet thick, including bone in the upper 4 feet, in the pit of the Muddy Creek Strip Mine. The beds in the area generally dip eastward from 17 to 25 degrees. The central part of the Welton coal outcrop, a 1-mile-long interval that includes the thickest part of the coalbed, is on privately owned land.

An "inactive" mine, possibly the Arrowhead, worked the Welton Coalbed at the southernmost exposure of the bed in the study site. There are three closely spaced, partially caved adits at this locale. The coal is about 7 feet thick where it crops out and is overlain by a massive buff sandstone. The observed thickness is consistent with the 7.2 feet thickness given for the Welton Coalbed in the Arrowhead Mine by Glass and Roberts (8).

Windolph, Hickling, and Warlow (25) describe the Welton Coalbed as being about 14 feet thick in a hole drilled by the USGS 800 feet south-southeast of the three adits (Appendix, p. 52). In the drillhole, the coalbed occurs between the depths of 156.2 feet and 170.2 feet. The upper 3.4 feet of the coalbed consists of interbedded bright coal, bony coal, and carbonaceous shale containing fossil roots and pyrite crystals. The next 10.2 feet is bright coal containing a 1-foot-thick zone of bone and pyrite lenses and a 0.3-foot-thick bony zone. The basal 0.4 foot of the bed consists of interbedded bone and bright coal lenses.

Technically, a small open-pit mine could be opened on the Welton Coalbed south of the inactive Muddy Creek Strip Mine. Assuming an average dip of 24 degrees and a maximum mining depth of 150 feet, an open pit covering approximately 25 acres could be placed in the 3,500-foot-long interval between the private property and Muddy Creek. The estimated average thickness of clean, usable coal is 9 feet. The total estimated coal tonnage in the open pit would be: 1,770 (short tons/acre-feet) X 9 (average coal thickness in feet) X 25 (acres) = 398,250 short tons. Problems caused by open-pit mining on steeply dipping beds probably could be mitigated by using special techniques. Another potential problem would be flooding of the pit caused by heavy run-offs during the spring thaw or after thunderstorms.

Coal Quality and Rank

Coal quality "* * * refers to individual measurements such as heat value, fixed carbon, moisture, ash, sulfur, phosphorous, major, minor, and trace elements, coking properties, petrologic properties, and particular organic constituents (23)." Rank is "the classification of coals relative to other coals, according to their degree of metamorphism, or progressive alteration in the natural series from lignite to anthracite (23)." Coals of higher rank are classified according to fixed carbon on a dry basis; coals of lower rank are classified according to British thermal units (Btu) on a moist basis (20). Bituminous coal is high in carbonaceous matter and contains between 15 and 50 percent volatile matter (20). In specifications adopted jointly by the American Society for Testing Materials (D 388-38) and the American Standards Association (M 20.1-1938), subbituminous coals are those with calorific values in the range 8,300-13,000 Btu, calculated on a moist, mineral-matter-free basis (20).

Physical characteristics of the coals are similar throughout the basin. Coals in the Wind River Basin are black with a vitreous luster (28). Freshly mined coal when first exposed to air crumbles into irregularly shaped, black blocks. They are moderately hard and show subcubical jointing and conchoidal fracturing. When continuously exposed to air, the coal weathers rapidly and soon disintegrates into a fine, dark brown powder. Reportedly the coal ignites easily and burns with a short red flame. The coal does not tend to clinker, fuse, or coke. Amber-colored nodules of resin and small disks of pyrite along joint planes are the main accessory minerals in the coal.

Of 40 samples analyzed in the Phase II study (25), 29 are subbituminous A, B, or C rank. The other 11 coal samples are of high-volatile bituminous C rank. Authors of the Phase II report postulate that the higher rank of the 11 samples resulted from the intense deformation that occurred along the basin margins and not from the depth of burial. Table 3 lists data on coalbeds at the four potential mine sites.

Coal Uses

The primary use for the coal always has been as fuel for domestic heating. In the past, it was used as fuel under stationary boilers and in lime kilns where there was no forced draft (28). When it was used under forced draft, the coal disintegrated and partially burned coal was blown from the grates and out the stack. Economic losses resulted from lost heating value of the unburned coal.

Partially burned coal when blown from the stacks caused fires, particularly when used in locomotives. The Chicago & North Western Railway apparently experimented with using coal from the Hudson Field as fuel for its locomotives running between Lander and Casper; but the experiment was abandoned because too much coal was blown out the stacks.

Heating values (Btu/lb) of the coal are similar to other subbitiminous coal in the Rocky Mountain region (25). The coal is mostly in the low-sulfur category, and the sulfur is mainly in the pyritic form that is susceptible to removal by cleaning (25). The ash fusion temperatures are generally higher than those of other subbitiminous Rocky Mountain coal, and make the coal attractive for use under boilers (25). The single greatest disadvantage of the coal is the rapid disintegration upon exposure to air. If shipped by rail, closed cars have to be used to prevent the coal from blowing away. The coal cannot be held in storage for long periods; therefore, mining must be done whenever there is an immediate need for the coal. In the past, the coal used for domestic heating was mined during the winter, which made the mining more difficult and expensive.

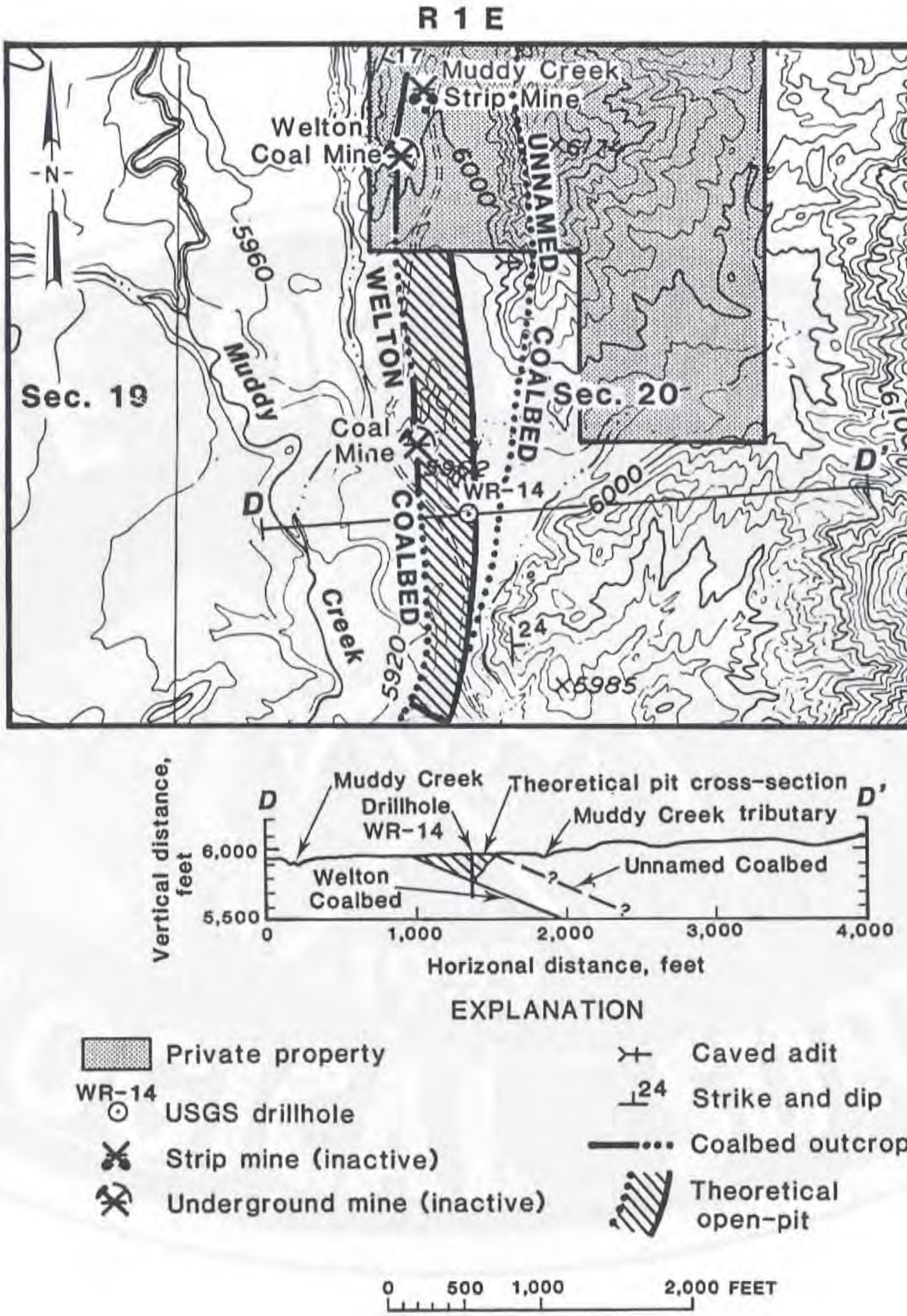

FIGURE 8.— Potential mine site in Muddy Creek Coalfield.

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TABLE 3. - Selected coal characteristics at four potential mine sites on the Wind River Indian Reservation, Wyoming

[Data is from analyses done on an as-received basis.]

Site	Coalbed name	Rank	Selected characteristics			Remarks
			Heat of combustion (Btu/lb)	Ash (percent)	Sulfur (percent)	
Alkali Butte 1	Shipton	Subbituminous B	8,510	11.3	1.7	about 2/3 of sulfur is pyritic
Alkali Butte 2	Upper Split Signor	Subbituminous B	9,140	8.5	0.7	most of sulfur is organic
	Lower Split Signor	Subbituminous B	9,490	6.4	1.0	about equal parts of organic and pyritic sulfur
Hudson	Signor	Subbituminous 1/	9,560	5.5	0.5	values are averages from Indian Mine
Muddy Creek	Welton	Subbituminous A	9,510	15.8	0.3	sulfur is mainly organic

Source: U.S. Bureau of Mines. Analyses of Wyoming Coals. BuMines Tech. Paper 484, 1931, 159 pp.
Windolph, J. F., Jr., N. L. Hickling, and R. C. Warlow. Coal Resource Assessment of the Wind River Indian Reservation, Fremont and Hot Springs Counties, Wyoming. U.S. Geol. Survey Field Mineral Studies of Indian Lands. Interagency Agreement No. 8. Unpublished. Available to BIA and Tribes, 1982, 215 pp.
1/ Coal was not classified as subbituminous A, B, or C in the BuMines Tech. Paper 484.

Coal Markets

An important factor in determining the "minability" of a coal deposit is whether a market exists. Coal may be extractable from a technological standpoint and yet be unminable because the coal cannot be sold at a profit. The depressed condition of the United States and World economy has resulted in less demand for coal. Forecasts for Wyoming coal production in the next 9 years were recently revised downward because of the decrease in market demand (9).

The quality of the coal on the reservation is similar to other subbituminous western coals, but the coal has some traits that seriously limit its marketability. The ash content of the coals indicate that they would be acceptable for common uses. Sulfur content above one percent reduces the marketability of the coal because of environmental considerations. Pyritic sulfur can be cleaned from the coal, but cleaning increases the production costs. The coal disintegrates rapidly to a brown powder upon exposure to air making it necessary to mine the coal as close as possible to the time it is used and to ship the coal in closed conveyances. Because the coal cannot be stockpiled or shipped easily, it does not compare favorably with other subbituminous western coals.

The coal in the Wind River Basin rarely would be competitive with Powder River Basin coal in markets outside of the Wind River Basin. For example, the Wyodak-Anderson Coalbed alone contains an estimated strippable reserve base of 19 billion tons. The coal is subbituminous, averages 70 feet in thickness, and can be followed in outcrop for more than 100 miles along the east side of the Powder River Basin (6).

Within the Wind River Basin, coal has stiff competition for the domestic heating market from natural gas and wood. The two Alkali Butte sites and the Muddy Creek site contain rather small quantities of coal which make the sites unattractive for anything but small scale operations selling coal locally for domestic heating. All three sites are several miles from the railhead in Riverton or from local distribution points where the coal would be sold for use in domestic heating. The cost of transporting the coal by truck from the sites to any market would be extremely high or even prohibitive.

The Hudson site probably has sufficient quantities of coal to justify putting in an expensive underground mine if only the coal could be stockpiled and shipped to out-of-state markets by conventional methods. Alone, the local market in domestic heating could not support a large longwall underground mine. Another possible market, which was considered and rejected, was a coal-fired, mine-mouth powerplant, but the Wind River Region already has ample electric power available for domestic and industrial applications for the foreseeable future.

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APPENDIX

Lithologic and drill core descriptions from selected USGS drillholes

[Copied from APPENDIX B in Coal Resource Assessment of the Wind River Indian Reservation in Fremont and Hot Springs Counties, Wyoming, by Windolph, Hickling, and Warlow (25)]

LITHOLOGIC AND GEOPHYSICAL LOG

DRILL HOLE NUMBER WR-1 LOCATION NE 1/4, SW 1/4 SEC. 10

T. 2S R. 6E QUAD Alkali butte

COUNTY Fremont STATE Wyoming TOTAL DEPTH 462'-0"

Cored; yes X no interval(s) 95'-0",115'-0";355'-0",386'-0";413'-0"

Drilling Medium: Air Yes Foam Yes Mud No

Bedding Attitude; Strike 120° Dip 20°NE Surface elevation 5562'

Interval (feet)	Lithology
	QUATERNARY Holocene
0-15	Soil and weathered rock
	Unconformity
	CRETACEOUS Mesaverde Formation
15-20	Sandstone, brown, fine- to medium-grained, fragments of iron stained siltstone
20-25	Sandstone, light-brown, very fine-grained, silty, very calcareous
25-30	Sandstone, light-brown, fine-grained, friable many very calcareous siltstone fragments
30-35	Sandstone, light-brown, very fine-grained, very silty
35-40	Sandstone, light- to medium-brown, very fine-grained, very calcareous, few friable fragments
40-45	Sandstone, light-gray to medium-brown, very fine-grained, few bentonitic gray shale fragments
45-50	Shale and sandstone; shale-medium-gray, bentonitic, calcareous with sandstone, light-gray to medium-brown, very fine-grained, silty, friable
50-55	Shale, medium-gray, calcareous sandstone, medium-brown, very fine- to fine-grained, light and dark mineral grains

Interval (feet)	Lithology
55-60	Shale, medium-gray, very calcareous, sandstone, light-gray to medium-brown, very fine-grained
60-65	Sandstone, light-gray to medium-brown, fine-grained, light and dark mineral grains
65-70	Sandstone, light-gray to light-brown, very fine-grained, silty, very calcareous, light and dark mineral grains
70-75	Sandstone, light-gray to medium-brown, fine-grained, friable, very calcareous, light and dark mineral grains
75-80	Sandstone, light-gray to medium-brown, fine-grained, friable, very calcareous, light and dark mineral grains
80-85	Sandstone and shale: Sandstone--light-brown, fine-grained, friable, light and dark mineral grains; shale--medium gray, calcareous
85-90	Sandstone and shale: Sandstone--light-gray to yellow-brown, fine-grained, very calcareous; with few reddish-brown fragments; shale--medium-gray
90-95	Sandstone, medium-gray, fine-grained, silty, very calcareous; shale, medium gray
95-100	Shale, medium-dark gray, very calcareous
100-105	Coal and shale: Coal--bright; shale--dark-grayish-brown
105-110	Coal, shale, and sandstone: Coal--bright; shale--carbonaceous medium-grayish brown; sandstone--dark-brown, fine-grained
110-115	Shale, medium gray, dark-grayish-brown to bentonitic, sandy, carbonaceous dark grayish brown (water table)
115-135	Shale, medium-gray, bentonitic, sandy
135-150	Sandstone and shale: Sandstone--light-gray, fine- to medium-grained, light and dark mineral grains; shale--medium-gray, bentonitic; few coal fragments
150-155	Shale and sandstone: Sandstone--medium-gray, bentonitic; sandstone--light-gray, fine- to medium-grained
155-215	Sandstone and shale: Sandstone--fine- to medium-grained, light and dark mineral grains; shale--medium-gray, bentonitic, few fragments of siltstone and coal

Interval (feet)	Lithology
215-220	Shale and sandstone: Shale-medium-gray, bentonitic; sandstone--light-gray, fine- to medium-grained
220-225	Sandstone, light-gray, fine- to medium-grained with bentonite and coal fragments
225-230	Shale, medium-gray, bentonitic, silty, carbonaceous
230-265	Sandstone, light- to medium-gray, very fine- to fine-grained, calcareous, dark and light mineral grains with few carbonaceous shale chips
265-270	Underclay, sandstone, and shale: Underclay-medium-gray, bentonitic; sandstone medium-gray, very fine- to fine-grained; shale--carbonaceous, light-brown with a few coal fragments
270-275	Shale, carbonaceous, light-grayish-brown
275-280	Shale and sandstone: Shale--carbonaceous, light-brown to medium-gray; sandstone--medium-gray, very fine- to fine-grained, calcareous, light and dark mineral grains
280-285	Sandstone, light- to medium-gray; very fine- to fine-grained, light and dark mineral grains
285-305	Sandstone, light- to medium-gray, very fine- to fine-grained, dark and light mineral grains, calcareous
305-310	Sandstone, light-gray to light-brown, very fine- to fine-grained; light brown, bentonitic
310-320	Sandstone, light-gray to light-brown, fine- to medium-grained, light and dark mineral grains, very calcareous, with iron stained siltstone fragments
320-325	Siltstone and sandstone: Siltstone-medium-gray to brown, iron stained, very calcareous; sandstone--medium-gray, fine-grained, light and dark mineral grains
325-350	Sandstone siltstone, and shale: Sandstone--light- to medium-gray, fine-grained, light and dark mineral grains, calcareous; siltstone--brown, very calcareous; shale--medium-gray, bentonitic
350-365	Sandstone, siltstone, and shale: Sandstone--light-brown to medium-gray, fine-grained, light and dark mineral grains; siltstone--brown, iron stained, calcareous; shale--medium-gray, bentonitic

Interval (feet)	Lithology
365-370	Coal and sandstone: Coal--bright; sandstone, light-gray and brown
370-375	Sandstone, light-gray to brown, fine-grained; coal abundant, few siltstone fragments
375-385	Sandstone and shale: Shale--light-gray and light-brown, fine-grained; shale—medium gray, bentonitic and abundant coal fragments
385-390	Siltstone, sandstone, and shale: Siltstone—medium-brown, sandstone--medium-gray, fine-grained; shale, medium-gray; coal abundant
390-410	Coal and sandstone: Coal--mostly bright; sandstone--medium-gray to medium-brown, fine-grained
410-415	Sandstone, light-gray to medium-brown, fine-grained; few coal fragments
415-420	Coal and sandstone: Coal--mostly bright; sandstone, medium-gray, fine-grained
420-425	Sandstone, light-gray to brown, fine-grained; few coal fragments
425-445	Sandstone, light-gray to brown, fine-grained, few coal and siltstone fragments
445-460	Poor circulation in hole - mostly fragments from upper section
460-462	Lost circulation; no sample

DRILL CORE WR-1

Thickness (Ft.-In.)	Lithology
	CRETACEOUS Mesaverde formation
Core starts at 95'-0"	
1-8 (96-8)	Sandstone, medium-light-gray, fine-grained, light and dark mineral grains, calcareous, with shale laminations
1-1 (97-9)	Sandstone, medium-gray, fine-grained, calcareous, burrows, light and dark mineral grains
1-5 (99-2)	Sandstone, medium-gray, fine-grained, light and dark mineral grains shale laminations, burrows
2-9 1/2 (101-11 1/2)	Sandstone, medium-light-gray, light and dark grains, fine-grained, shale laminations
0-9 (102-8 1/2)	Sandstone, medium-gray, fine-grained, light and dark mineral grains calcareous, burrows, shale laminations
0-8 1/2 (103-5)	Sandstone, fine- to medium-grained, light and dark mineral grains, calcareous, 1/4 inch coal lamination at base
1-10 (105-3)	Shale, medium-gray, with light-gray silty laminations; small microfault in middle, 1/8 in. displacement
1-8 (106-11)	Shale, medium-dark-gray, with light-gray silty laminations, burrows
0-7 1/4 (107-6 1/4)	Shale, dark-grayish brown, carbonaceous, coal laminations in basal 2 in.
	-Top Beaver Coal Bed-
1-11 (109-5 1/4)	Coal, dull to bright, pyrite crystals on cleats, resin blebs
0-6 (109-11 1/4)	Shale, dark-grayish-black, carbonaceous, with laminations, resin, blebs pyrite crystals
0-10 1/2 (110-9 3/4)	Shale, very carbonaceous, bentonitic, coal laminations
2-2 (112-11 3/4)	Coal, dull to bright, pyrite crystals, resin blebs, bony

Thickness (Ft.-In.)	Lithology
	-Base Beaver Coal Bed-
0-11 113-10-3/4)	Sandstone, light-brown, fine- to medium-grained, very carbonaceous,
1-0 114-10 3/4)	Sandstone, light-grayish-brown, slightly carbonaceous, few coal fragments
4-0 118-10 3/4)	Sandstone, medium-gray, fine- to medium-grained, light and dark mineral grains
Core starts at 355'-0"	
0-7 355-7)	Sandstone, medium-gray, fine- to medium-grained, light and dark mineral grains, soft
1-4 1/2 356-11 1/2)	Shale, medium-grayish-brown, carbonaceous
0-9 357-8 1/2)	Shale, dark-grayish-brown, carbonaceous
4-1 361-9 1/2)	Sandstone, medium-gray, fine-grained, light and dark mineral grains, carbonaceous laminations
2-3 1/2 (364-1)	Sandstone, medium-light-gray, very fine-grained, light and dark mineral grains, carbonaceous laminations, includes 1 in. thick bentonite
2-2 1/2 366-3 1/2)	Shale, dark-grayish-brown, carbonaceous, burrows, coal laminations, fossil trunk, resin blebs
2-4 368-7 1/2)	Sandstone, medium-gray, fine-grained, carbonaceous shale and coal laminations, irregular bedding
3-1/2 (371-8)	Sandstone, medium-gray, fine-grained, light and dark mineral grains, carbonaceous and coal laminations, friable
1-4 (373-0)	Shale, medium-gray, carbonaceous, silty, burrowed, irregular bedding, few coal fragments

Thickness (Ft.-In.)	Lithology
	Top Upper Split Signor Coal Bed
0-5 1/2 (373-5 1/2)	Coal, bright to dull, bony
0-3 (373-8 1/2)	Shale, grayish-brown, carbonaceous, coal lenses
4-9 (378-5 1/2)	Coal, bright to dull, upper 2 in. bony, gypsum crystals on cleats; ash bed 1/4 in. thick, coal is slightly bony below ash bed
	Base Upper Split Signor Coal Bed
2-1 1/2 (380-7)	Underclay, medium-gray, very carbonaceous, fossil roots and plants, resin blebs
3-1 1/2 (383-8 1/2)	Underclay and shale, medium-dark-gray to brown, burrows, fossil plant fragments, vitrain lenses, sandy, carbonaceous
0-7 1/2 (384-4)	Siltstone (underclay), carbonaceous, irregular bedding, coal laminations, and fossil plant fragments
0-2 1/2 (384-6 1/2)	Coal, impure, bony, vitrain bands
1-3 1/2 (385-10)	Shale, dark-brown, carbonaceous, with coal laminations, resin blebs
0-2 (386-0)	Shale, medium-gray, vitrain lenses
0-5 1/2 (386-5 1/2)	Shale, dark-gray to brown, carbonaceous, vitrain bands, resin blebs
0-3 (386-8 1/2)	Shale, carbonaceous, sandy, coal fragments, laminations
2-6 1/2 (389-3)	Shale and underclay: Shale--medium-gray to brown, carbonaceous, fossil roots and plant fragments, underclay--irregular bedding, sandy to silty, coal fragments and lenses, few bentonite zones, burrows

Thickness (Ft.-In.)	Lithology
8-3 (397-6)	Sandstone, medium-gray to medium-light-gray, fine-grained, light and dark mineral grains, carbonaceous with coal laminations, burrowed thin, irregular bedding, vitrain lenses, few sandstone lenses, fossil roots and plant impressions
	-Top Lower Split Signor Coal Bed-
6-2 (403-8)	Coal, bright to dull, upper 2 in. bony, few sandstone lenses at top, gypsum crystals on cleats, pyrite crystals, few fusain laminations
2-9 (406-5)	Coal, bright with few pyrite crystal zones
0-3 1/2 (406-8 1/2)	Shale (underclay), medium-gray to medium-dark-gray, carbonaceous
0-8 (407-4 1/2)	Coal, bright, basal 3 in. bony pyrite crystals
	-Base Lower Split Signor Coal Bed-
0-4 (407-8 1/2)	Shale, medium-gray to brown, vitrain coal lenses
0-1/2 (408-9)	Sandstone, medium-light-gray, very fine-grained
4-3 (413-0)	Core Loss

LITHOLOGIC AND GEOPHYSICAL LOG

DRILL HOLE NUMBER WR-1B LOCATION SE 1/4, SE 1/4 SEC. 9

T. 2S R. 6E QUAD Alkali Butte

COUNTY Fremont STATE Wyoming TOTAL DEPTH 209'3"

Cored; yes X no interval(s) 133'-0", 209"-3"

Drilling Medium: Air Yes Foam Yes Mud No

Bedding Attitude: Strike 120° Dip 20°NE Surface elevation 5576'

No chip samples described at this location (500 feet SW of WR-1)

Thickness (Ft.-In.)	Lithology
	CRETACEOUS Mesaverde Formation
Core starts at 133'-0"	
1-4 (134-4)	Shale, dark-gray to black, interbedded with coal, contains scattered resin blebs. Coal laminations, bright to dull canneloid coal fragments, thin-bedded, dark-gray to brown, fossil roots and plant impression
0-8 (135-0)	Shale, carbonaceous (underclay) dark-gray to brown, coal fragments, resin blebs, vitrain lenses, irregular bedding, fossil roots
2-1 1/4 (137-1 1/4)	Underclay, medium-gray, coal fragments and laminations, very bentonitic, silty, fossil roots
0-1 (137-2 1/4)	Shale, medium- to dark-grayish-brown, carbonaceous with coal fragments
0-1 (137-3 1/4)	Limestone, very light-brown to light-gray, very calcareous, very fine-grained, crystalline
0-4 1/2 (137-7 3/4)	Shale, medium-gray to dark-gray, bentonitic, few carbonaceous laminations
0-3 1/2	Shale, medium-dark-gray to brown, carbonaceous, sandy, calcareous fossil shell fragments, resin blebs
3-7 (141-3 1/4)	Sandstone, medium-gray to medium-light-gray, very fine-grained, light and dark mineral grains, carbonaceous laminations, thin-bedded, calcareous

Thickness (Ft.-In.)	Lithology
1-7 (142-10 1/4)	Sandstone, medium-gray, very fine-grained, thin carbonaceous laminations interbedded with shale, medium-gray, three limestone beds 1 in. ± thick, bentonitic
1-1 1/2 (143-11 3/4)	Shale, dark-grayish-brown, silty, carbonaceous, calcareous, fossil shell fragments
2-2 1/4 (146-2)	Sandstone, medium-light-gray, very fine-grained, silty, coal fragments and coal laminations, thin irregular bedding, scattered resin blebs
0-3 (146-5)	Shale, dark-grayish-brown, carbonaceous, coal fragments and laminations
0-3 1/4 (146-8 1/4)	Sandstone, medium-gray, fine-grained, dark and light mineral grains
0-3 1/2 (146-11 3/4)	Siltstone, light-gray
3-11 (150-1 3/4)	Sandstone, medium-gray, fine-grained, thin irregular bedding, abundant coal fragments
4-1 (154-2 3/4)	Sandstone, medium-light-gray, fine-grained, dark and light grains, silty, non-calcareous, thin irregular carbonaceous laminations
2-10 1/2 (157-1 1/4)	Sandstone, very fine-grained, carbonaceous laminations, burrows, thin irregular bedding, scattered coal fragments, pyrite grains, 1/4 in. thick pyrite lens at base
	Top Upper Split Signor Coal Bed
4-4 3/4 (161-6)	Coal, mostly bright, bony in upper 1/4 in., scattered resin, blebs pyrite, 1 in. thick bony coal 4 in. below top, 2 in. thick ash parting in zone with resin blebs 2 ft. below top. Coal slightly bony - canneloid.
	Base Upper Split Signor Coal Bed
0-5 (161-11)	Underclay, medium-light-gray in upper 3 in., medium-gray in base, fossil roots, resin blebs, includes coal, vitrain lens 1/8 in. thick 3 in. below top
3-8 (165-7)	Sandstone, light- to medium-gray, fine- to very fine-grained, includes coal and carbonaceous laminations and 7 in. thick shale zone, medium-gray, 1 ft. 6 in. below top, thin-bedded. Basal 2 ft. 2 in. very silty and shaly with 1 in. thick sandstone lens at base; fossil roots and plant impressions

Thickness (Ft.-In.)	Lithology
0-10 (166-5)	Limestone, light-grayish-brown, very hard, fossil plants
2-3 (168-8)	Underclay, medium-gray, abundant coal and carbonaceous laminations and lenses, silty, sandy
0-6 (169-2)	Coal, impure, thin vitrain bands, resin blebs, shaly, bony
3-3 (172-5)	Underclay, carbonaceous shale, light-brown to medium-dark-gray thin-bedded, fossil plants and roots, abundant vitrain lenses and carbonaceous laminations, basal 1 ft. 6 in. is hard and silty
10-10 1/2 (183-3 1/2)	Sandstone, medium-light-gray, very fine- to fine-grained, thin carbonaceous lenses, vitrain lenses
0-3 1/2 (183-7)	Coal, detrital, includes sand grains, resin blebs.
0-11 (184-6)	Sandstone, medium- to light-gray, fine-grained, dark and light mineral grains, carbonaceous, coal laminations
1-6 1/2 (186-1/2)	Sandstone, medium-light-gray, fine-grained, dark and light mineral grains, friable, slightly calcareous
9-4 1/2 (195-5)	Sandstone, medium-light-gray, fine- to medium-grained, light and dark mineral grains, massive, slightly calcareous, contains 6 ft. contorted shaly zone-4 ft. 4 in. below top. Basal 2 ft. contains carbonaceous shale and coal laminations
	Top Lower Split Signor Coal Bed
8-3 (203-8)	Coal, upper 3 in. detrital with sandstone lenses, very fine-grained, silty. Coal mostly bright, pyrite on cleat surfaces, scattered resin blebs, gypsum crystals, hard, clean
0-3 (203-11)	Coal, bright as above
0-3 (204-2)	Underclay, medium-gray, fossil roots, soft, slightly carbonaceous
0-7 1/2 (204-9 1/2)	Coal, bright, scattered resin blebs

Thickness (Ft.-In.)	Lithology
	Base Lower Split Signor Coal Bed
0-1 (204-10 1/2)	Shale, medium-gray to brown, carbonaceous, sandstone lens
0-8 (205-6 1/2)	Underclay, medium-gray, fossil roots, shale and sandstone laminations, thin-bedded
0-11 (206-5 1/2)	Sandstone and coal: Sandstone--medium-light-gray, fine-grained, with thin beds of siltstone, fossil root; coal--fine-grained fragments in lower part
0-5 1/2 (207-11)	Shale, medium-gray with interbeds of thin-bedded sandstone, very fine grained
0-2 (207-1)	Sandstone, medium-light-gray, very fine- to fine-grained, coal streaks
0-2 (207-3)	Shale, medium to dark-gray, thin-bedded
2'-0 (209'-3')	Core Loss

LITHOLOGIC AND GEOPHYSICAL LOG

DRILL HOLE NUMBER WR-2 LOCATION NW 1/4, SE 1/4 SEC. 5

T. 2S R. 6E QUAD Alkali Butte

COUNTY Fremont STATE Wyoming TOTAL DEPTH 602'-0"

Cored; yes X no interval(s) 90'-0" to 108'-0"; 175'-0", to 192'-0".

Drilling Medium: Air Yes Foam Yes Mud No

Bedding Attitude; Strike 30° Dip 15°NW Surface elevation 5610'

Thickness (Ft.-In.)	Lithology
	QUATERNARY Holocene
	Unconformity
0-5	Soil and weathered sandstone fragments, yellow to gray, calcareous
	CRETACEOUS Mesaverde Formtion
5-15	Sandstone and shale: sandstone--yellow-brown, fine-grained, very calcareous; shale--medium-gray, calcareous
15-25	Shale and sandstone: shale--medium-gray, very calcareous; sandstone--fine-grained, thin beded
25-30	Sandstone--yellow-brown, fine-grained, very calcareous; siltstone--iron-stained, very calcareous; shale--medium-gray
30-40	Shale and sandstone: shale--medium-gray, calcareous; sandstone--yellowish-brown, fine-grained, very calcareous
40-45	Shale, sandstone, and siltstone: shale--light- to medium-olive gray, calcareous; sandstone--light- to medium-gray, fine-grained; siltstone--grayish-red, calcareous
45-50	Shale and sandstone: shale--light- to medium-olive-gray; sandstone--yellow-gray, fine-grained, gypsum lenses
50-55	Shale and sandstone: shale--olive-gray, calcareous; sandstone--yellow-brown, fine-grained
55-60	Shale, medium-gray, calcareous, silty

Thickness (Ft.-In.)	Lithology
60-70	Siltstone, medium-gray, calcareious; shale—medium-gray
70-85	Shale and siltstone: shale--medium-gray, calcareous; siltstone--medium-gray
85-90	Shale and siltstone: shale--medium-gray, very calcareous; siltstone—light-gray; trace of coal
90-100	Shale and coal: shale--carbonaceous, medium- to dark-gray, calcareous; coal--bright
100-105	Shale, medium- to dark-gray, bentonitic
105-110	Sandstone, light- to medium-gray, very fine-grained, silty, friable
110-115	Shale and sandstone: shale--medium-gray, carbonaceous; sandstone--light- to dark-gray mineral grain, medium-grained
115-130	Sandstone, light-gray, fine- to medium-grained, friable
130-140	Sandstone, light- to medium-grayish-brown, very fine-grained, carbonaceous, friable, very calcareous
140-160	Sandstone and shale: sandstone—light- to medium-gray, fine- to medium-grained, pyrite crystals; shale--medium-gray, bentonitic
160-165	Shale and sandstone: shale--medium-gray, bentonitic; sandstone--medium-gray, fine-grained
165-170	Sandstone, shale and coal: sandstone--medium-gray, fine-grained; shale--medium-gray, bentonitic; coal--bright
170-180	Coal, shale and sandstone: Coal--bright; shale--medium-gray, bentonitic; sandstone--fine-grained
180-185	Coal and shale: coal--bright; shale--grayish-brown, bentonitic
185-195	Sandstone, shale and coal: sandstone--medium-gray, pyritic; shale--medium-gray, bentonitic; coal--bright
195-205	Coal, shale and sandstone: coal--bright; shale--medium-gray, bentonitic; sandstone--fine-grained, iron-stained, friable
205-230	Sandstone, shale and coal: sandstone—medium-gray, medium-grained, calcareous; shale--medium-gray, bentonitic; coal--bright
230-240	Sandstone and coal: sandstone—medium-gray, medium-grained; coal--bright

Thickness (Ft.-In.)	Lithology
240-245	Sandstone, tonstein, and coal: sandstone--medium-gray, calcareous, light and dark mineral grains, pyrite crystals; tonstein--bentonitic, light-grayish-pink; coal--bright
245-255	Sandstone and coal: sandstone--medium-gray, fine- to medium-grained, calcareous, pyritic; coal--bright
255-260	Sandstone, medium-gray, fine- to medium-grained, light and dark mineral grains, calcareous, few coal fragments
260-265	Sandstone and bentonite: sandstone--medium-gray, fine- to medium-grained, light and dark mineral grains, calcareous; bentonite--grayish-brown, sandy; coal fragments
265-285	Bentonite and sandstone: bentonite--grayish-brown; sandstone--medium-gray, fine- to medium-grained, light and dark mineral grains, calcareous; coal fragments, bright
285-305	Coal, sandstone, and bentonite: coal--bright; sandstone--medium-gray, fine- to medium-grained; bentonite--grayish-brown
305-310	Sandstone, medium-gray, fine- to medium-grained, light to dark mineral grains, calcareous; coal fragments, bright
310-315	Sandstone and bentonite: sandstone--medium-gray, fine- to medium-grained; bentonite--grayish-brown
315-330	Sandstone and bentonite: sandstone--medium-gray, fine- to medium-grained, calcareous, light and dark grains; bentonite--coal fragments, bright
330-340	Sandstone and bentonite: sandstone--medium-gray, fine- to medium-grained, calcareous, light and dark mineral grains; bentonite--grayish-brown
340-345	Bentonite and shale: bentonite--grayish-brown; shale--carbonaceous, grayish-brown
345-360	Bentonite and sandstone: bentonite--grayish-brown; sandstone--medium-gray, fine-grained; coal fragments, bright
360-365	Bentonite and sandstone: bentonite--(tonstein), reddish-brown; sandstone--medium-gray, fine-grained; coal fragments, bright
365-375	Bentonite and sandstone: bentonite--grayish-brown; sandstone--medium-gray, fine- to medium-grained, calcareous, light and dark mineral grains

Thickness (Ft.-In.)	Lithology
375-385	Bentonite, sandstone, and shale: bentonite--grayish-brown; sandstone--medium-gray, fine- to medium-grained, calcareous, light to dark mineral grains; shale--carbonaceous, grayish-brown
385-400	Coal, sandstone, and bentonite: coal--bright; sandstone--medium-gray, fine-grained; bentonite--grayish-brown
400-405	Bentonite and sandstone: bentonite--grayish-brown; sandstone--medium-gray, fine-grained, pyrite crystals; coal fragments, bright
405-420	Bentonite, sandstone, and shale: bentonite--grayish-brown; sandstone--medium-gray, fine-grained, pyrite; shale--carbonaceous, grayish-brown
420-430	Lost circulation: no sample
430-480	Sandstone, medium-gray, fine- to medium-grained, light and dark mineral grains, calcareous
480-500	Sandstone, light- to medium-gray, fine- to medium-grained, light and dark mineral grains, calcareous
500-540	Lost circulation; no samples
540-560	Sandstone, medium-gray, fine- to medium-grained, light and dark mineral grains, friable, calcareous
560-565	Coal, bright
565-570	Coal, bright
570-580	Sandstone, medium-gray, fine- to medium-grained, light and dark mineral grains, friable, calcareous
580-590	Lost circulation; no sample
590-602	Sandstone, medium-gray, fine- to medium-grained

DRILL CORE WR-2

Thickness (Ft.-In.)	Lithology
	CRETACEOUS Mesaverde formation
1st Core starts at 90'-0	
0-3 1/2 (90-3 1/2)	Limestone, gray, massive, lower half carbonaceous
3-4 1/2 (98-8)	Shale, medium-gray to grayish-brown, carbonaceous, sandy laminations, burrows, calcareous, ironstone nodules
0-4 3/4 (94-3/4)	Shale, medium-grayish-brown, carbonaceous, burrows, sandy laminations, calcareous
2-7 (96-7 3/4)	Shale, medium-dark-gray to grayish-brown, carbonaceous, sandy laminations, burrows, scattered resin blebs, ironstone nodules in lower 5 in.
	- Top Shipton Coal Bed -
6-0 1/4 (102-8)	Coal, bright, bony, pyrite bands, top contact with shale, sharp and irregular
	- Base Shipton Coal Bed -
0-6 (103-2)	Tonstein, (ash bed), light-pinkish-gray to grayish-brown, few ash fragments, and phenocrysts
0-7 (103-9)	Shale, dark-grayish-brown, carbonaceous
1-3 1/2 (105-1/2)	Shale, light-grayish-brown, carbonaceous, burrows, irregular bedding
1-0 (106-1/2)	Shale, medium-dark-gray to grayish-brown, carbonaceous
0-3-1/2 (106-4)	Shale, dark-grayish-brown, carbonaceous, coal laminations

Thickness (Ft.-In.)	Lithology
0-5 1/2 (106-9 1/2)	Coal, bright, bony, scattered resin blebs
0-7 (107-4 1/2)	Shale, dark-grayish-brown, carbonaceous, sandy laminations
0-7 1/2 (108-0)	Sandstone, medium-gray, silty laminations, burrows
2nd core begins at 175'-0	
0-10 (175-10)	Sandstone, medium-gray to light-gray, very fine- to fine-grained, light and dark mineral grains, very calcareous, very few coal laminations
3-4 1/2 (179-2 1/2)	Shale, medium-dark-gray to dark-grayish-brown, microfaults, fossil shell fragments in basal 1 in., carbonaceous, silty laminations, burrows, few coal laminations, very calcareous
0-7 1/4 (179-9 3/4)	Shale, medium-gray to dark-grayish-brown, sandy, carbonaceous, fossil shell fragments in upper 3 in., irregular bedding, very calcareous
1-6 1/2 (181-4 1/4)	Sandstone, very fine-grained, carbonaceous laminations, burrows, microfaults, scattered pyrite crystals and resin blebs, irregular bedding
1-8 (182-10 1/4)	Shale, medium-dark-gray to dark-gray, carbonaceous, burrows, sandy, pyrite crystals in basal 1 in., coal band 1/4 in. thick, and few coal laminations
	- Top Beaver Coal Bed -
2-11 3/4 (185-10)	Coal, bright, slightly bony, pyrite crystals in fusain zones
	- Base Beaver Coal Bed -
0-4 1/2 (186-2 1/2)	Underclay, very carbonaceous, coal fragments, resin blebs, 1/8 in. thick vitrain band at base
-	
0-10 1/2 (187-1)	Siltstone, medium-gray, microfaults, shale laminations, few burrows
1-3 1/4 (188-4 1/4)	Shale, medium-gray, few silt laminations

Thickness (Ft.-In.)	Lithology
1-7 1/2 (189-11 3/4)	Sandstone, medium-gray, very fine- to fine-grained, light and dark mineral grains, depositional slumping, shale and silt laminations, few coal and carbonaceous laminations
1-5 1/2 (191-1/4)	Sandstone, light-gray, very fine- to fine-grained, microfaults, few medium-gray shale laminations
0-3/4 192-0	Core Loss

LITHOLOGIC AND GEOPHYSICAL LOG

DRILL HOLE NUMBER WR-14 LOCATION NE 1/2 SW 1/4 SEC. 20

T. 6N R. 1 E QUAD Eagle Point

COUNTY Fremont STATE Wyoming TOTAL DEPTH 185' - 0"

Cored; yes X no ___ intervals(s) 154' 3" - 174' 2-1/2"

Drilling Medium: Air Yes Foam Yes Mud No

Bedding Attitude; Strike 358° Dip 18° E Surface elevation 5925'

Interval (feet)	Lithology
	CRETACEOUS Meeteetse Formation
0-25	Sandstone, light-yellowish-gray, very fine- to fine-grained, dark mineral grains
25-35	Sandstone, light-yellowish-gray, very fine- to fine-grained
35-45	Sandstone, light-yellowish-gray, very fine- to fine-grained, very calcareous
45-50	Sandstone, light-yellowish-gray, very fine- to fine-grained
50-55	Coal, sandstone, and shale: coal--bright; sandstone--light-yellowish-gray, very fine- to fine-grained; shale--carbonaceous
55-65	Shale, medium- to dark-gray, carbonaceous
65-85	Shale, medium-gray
85-90	Coal and shale: coal--bright; shale--medium-gray
90-100	Shale, medium-gray, carbonaceous
100-105	Shale, medium-gray
105-110	Coal and shale: coal--fragments, bright; shale--light-grayish-brown, carbonaceous
110-115	Shale and coal: shale--medium-gray; coal--bright
115-120	Shale, coal, and sandstone--medium-gray; coal--bright; sandstone--medium- to light-gray, fine-grained

Interval (feet)	Lithology
120-125	Coal and shale: coal--bright; shale--medium-gray
125-130	Shale and sandstone: shale--medium gray; sandstone--light-gray, very fine-grained
130-135	Sandstone, light-gray, very fine-grained
135-140	Sandstone and coal: sandstone--light-gray, very fine-grained; coal--bright
140-145	Lost circulation; no sample
145-150	Shale and sandstone: shale--medium-gray, sandstone--brown, fine-grained
150-165	Coal and shale: coal--bright; shale--medium-gray
165-167	Coal, bright
167-170	Shale, medium-gray; bright coal fragments
170-175	Shale and sandstone: shale--medium-gray; sandstone--light-gray, fine-grained, bright coal fragments
175-185	Shale, light-gray, silty

DRILL CORE WR-14

Thickness (Ft.-In.)	Lithology
	CRETACEOUS Meeteetse Formation
Core starts at 154'-3"	
1-9 (156-0)	Sandstone, medium-light-gray, sharp basal contact, cross-bedded, massive, light and dark mineral grains
0-2 (156-2)	Shale, medium-dark-gray to black, thin-bedded, with few coal fragments
	- Top Welton Coal Bed -
0-2 (156-4)	Coal, bony
0-6 (156-10)	Coal, bright, few fossil roots, pyrite crystals
0-4 (157-2)	Shale, dark-gray to black, very carbonaceous, fossil roots
0-6 (157-8)	Shale, medium-gray to light-gray, silty, basal 2 in. dark-gray, very carbonaceous, fossil roots
0-6 1/2 (158-2 1/2)	Coal, bright, pyrite crystals on fossil roots
0-6 (158-8 1/2)	Shale, black, slickensides, pyrite crystals on fossil roots, very carbonaceous, broken
0-3 (158-11 1/2)	Coal, bony, shaly, fossil roots
0-8 (159-7 1/2)	Shale, dark-gray, pyrite on fossil roots, carbonaceous
6-0 (165-7 1/2)	Coal, bright, 1 ft. bony zone and pyrite lenses 3 ft. 6 in. below top; pyrite crystals on cleats
4-2 (169-9 1/2)	Coal, bright, cleats, vertical fractures; 3 in. bony zone 6 in. below top, few fusain zones and 1 in. thick pyrite lenses

Thickness (Ft.-In.)	Lithology
0-4 (170-1 1/2)	Bone, few bright lenses, basal 1/2 in. bright coal
	- Base Welton Coal Bed -
0-9 (170-10 1/2)	Underclay, medium-dark-gray, few bright lenses, resin specks, fossil roots
3-4 (174-2 1/2)	Underclay, medium-gray, silty, disturbed bedding, fossil roots and coal fragments, microfaults

LITHOLOGIC GEOPHYSICAL LOG

DRILL HOLE NUMBER WR-E LOCATION SE 1/4 SE 1/4 SEC. 35

T. 1S R. 2E QUAD Hudson

COUNTY Fremont STATE Wyoming TOTAL DEPTH 445'

Cored: yes ___ no X interval(s) ___

Drilling Medium: Air Yes Foam Yes Mud No

Bedding Attitude; Strike 350° Dip 12°NE Surface elevation 5260'

Thickness (Ft.-In.)	Lithology
	<u>QUATERNARY</u> Pleistocene
0-5	Sand, light-yellowish-gray, very fine- to coarse-grained
5-10	Sand and clay: sand--light-yellowish-gray, very fine- to coarse-grained, quartz-chert pebbles; clay, light-to medium-gray
	Unconformity
	<u>EOCENE</u> Indian Meadows Formation
10-15	Shale and sandstone: shale--light-greenish-gray, silty; sandstone--light-gray, very fine- to coarse-grained, conglomeratic cobbles
15-20	Sandstone, medium-light-gray, very fine- to very coarse-grained, conglomeratic, arkosic, tuffaceous
20-25	Sandstone, light-yellowish-brown, very fine- to coarse-grained, arkosic
25-30	Sandstone, medium-light-gray to light-greenish-gray, very fine- to coarse-grained, arkosic, pebbles
30-35	Sandstone and shale: sandstone--medium-light-gray, very fine- to coarse-grained, arkosic; shale--light-greenish-gray to light-brown, carbonaceous
35-40	Sandstone, medium-light-gray to light-grayish-brown, very fine- to coarse-grained, arkosic

Thickness (Ft.-In.)	Lithology
40-45	Sandstone, medium-light-gray to light-greenish-brown, very fine- to coarse-grained, conglomeratic, arkosic, trace of chert, quartz
45-50	Sandstone, medium-light-gray to yellowish-brown to light-greenish-brown, very fine- to coarse-grained, conglomeratic, trace of chert, quartz
50-55	Sandstone, medium-light-gray, very fine- to coarse-grained, conglomeratic, arkosic, tuffaceous, hard chert cobbles
55-60	Sandstone, medium-light-gray, very fine- to coarse-grained, conglomertic, arkosic, tuffaceous, hard chert cobbles
60-65	Sandstone, medium-light-gray, very fine- to coarse-grained, conglomeratic, arkosic, tuffaceous, hard chert
	Unconformity
	CRETACEOUS Mesaverde Formation
65-70	Shale and sandstone: shale--light-brown, carbonaceous; sandstone--medium-gray, very fine-grained, bright coal fragments
70-75	Shale, light-grayish-brown, carbonaceous, silty, sandy, bright coal fragments
75-80	Coal and sandstone: coal--bright; shale--light-grayish-brown; sandstone--medium-light-gray, very fine-grained, silty
80-85	Shale and sandstone: shale--light-grayish-brown, carbonaceous fragments; sandstone--medium-light-gray, very fine-grained, silty, bright coal fragments
85-90	Sandstone and shale: sandstone--medium-light-gray, very fine-grained; shale--light-grayish-brown, carbonaceous, bright coal fragments
90-95	Sandstone, medium-light-gray, very fine-grained; bright coal fragments
95-100	Sandstone and shale: sandstone--medium-light-gray, very fine-grained; shale--light-grayish-brown to medium-gray, carbonaceous; bright coal fragments

Thickness (Ft.-In.)	Lithology
100-105	Sandstone, medium-light-gray, very fine-grained, silty
105-110	Sandstone, medium-light-gray to medium-gray, very fine-grained, silty
110-115	Sandstone, medium-light-gray to medium-gray, very silty
115-120	Sandstone, medium-light-gray to medium-gray, very silty
120-125	Sandstone, medium-light-gray to medium-gray, very silty
125-130	Sandstone, medium-light-gray to medium-gray, very silty, lower 1 ft. is calcareous
130-135	Sandstone, medium-light-gray to medium-gray, very fine-grained, very calcareous
135-140	Sandstone, medium-light-gray to medium-gray, very fine-grained, silty, calcareous
140-145	Sandstone and shale: sandstone--medium-gray, fine- to medium-grained; shale--medium-gray, silty,
145-150	Sandstone and shale: shale--medium-gray, very fine-grained, silty; shale--medium-gray, silty
150-155	Sandstone and shale: sandstone--medium-gray, very fine-grained, silty; shale--medium-gray to light-grayish-brown, carbonaceous, silty
160-165	Sandstone and shale: sandstone--medium-gray, very fine-grained, silty; shale--medium-gray, silty
165-170	Sandstone and shale: sandstone--medium-gray, very fine- to fine-grained, silty; shale--medium-gray, silty, carbonaceous fragments
170-175	Shale and sandstone: shale--medium-gray to medium-dark-gray, silty, carbonaceous fragments; sandstone--medium-gray, very fine- to fine-grained, silty, pyrite crystals
175-180	Shale and sandstone: shale--medium-gray to medium-dark-gray, silty; sandstone--medium-light-gray, very fine- to fine-grained, silty

Thickness (Ft.-In.)	Lithology
180-185	Sandstone and shale: sandstone--medium-light-gray, very fine- to fine-grained, silty; shale--medium-gray to medium-dark-gray, silty
185-190	Sandstone and shale: sandstone--medium-light-gray, very fine- to fine-grained, silty; shale--medium-gray, fossil plants
190-195	Sandstone, medium-light-gray to medium-gray, very fine-grained, silty
195-200	Shale and sandstone: shale--medium-gray, silty, bright impure coal, pyrite crystals; sandstone--medium-light-gray, very fine- to fine-grained
200-205	Sandstone, medium-light-gray, very fine- to fine-grained, shaly, few coal fragments
205-210	Sandstone, coal and shale: sandstone--medium-light-gray, very fine- to fine-grained; coal--bright, impure, shaly, pyrite crystals; shale--light-grayish-brown
210-215	Sandstone and shale: sandstone--medium-light-gray, very fine-grained, silty, carbonaceous laminations; shale--light-grayish-brown, carbonaceous, coaly
215-220	Sandstone and shale: sandstone--medium-light-gray, very fine-grained, silty; shale--medium-gray to medium-dark-gray, carbonaceous laminations, silty, coal fragments
220-225	Siltstone, medium-gray; shale--medium-gray, laminated, trace of coal
225-230	Coal, tonestein, shale, and sandstone: coal--bright, fossil plants; tonstein--light-brown; shale--medium-gray to light-grayish-brown; sandstone--medium-light-gray, very fine-grained, silty
230-235	Sandstone and coal: sandstone--medium-light-gray, very fine-grained, silty; coal--bright, pyrite crystals
235-240	Sandstone and coal: sandstone--medium-light-gray, very fine-grained, silty; coal--bright, pyrite crystals
240-245	Shale and sandstone: shale--light-grayish-brown, calcareous, fossil shell fragments, coal fragments; sandstone--medium-light-gray, very fine-grained, silty

Thickness (Ft.-In.)	Lithology
245-250	Sandstone, medium-light-gray, very fine-grained, silty, pyrite crystals; shale--medium-gray, very calcareous
250-255	Sandstone and shale: sandstone--medium-light-gray, very fine- to fine-grained, calcareous, fossil shell fragments, coal laminations; shale--medium-gray, coal fragments
255-260	Shale, medium-gray, carbonaceous fragments, very calcareous, silty, traces of coal
260-265	Sandstone and shale: sandstone--medium-gray, very fine-grained, silty, fossil shell fragments; shale--medium-gray, traces of coal
265-270	Sandstone and shale: sandstone--medium-gray to light-grayish-brown, carbonaceous, fossil shell fragments; shale--medium-gray, carbonaceous fragments
270-275	Sandstone and shale: sandstone--medium-gray to medium-dark-gray, carbonaceous fragments; shale--medium-gray, traces of coal
275-280	Sandstone, coal, and shale: sandstone--medium-light-gray, very fine-grained, silty; coal, bright, pyrite crystals; tonstein--light-brown; shale--carbonaceous, sandy; coal--bright fragments
280-285	Coal, tonestein, shale, and sandstone: coal--bright; tonstein--light-brown; shale--medium-gray to light-grayish-brown, carbonaceous; sandstone--medium-light-gray, very fine-grained
285-290	Coal, tonstein, shale, and sandstone: coal--bright, tonstein--light-brown; shale--medium-gray to light-grayish-brown, carbonaceous; sandstone--medium-light-gray, very fine-grained
290-295	Coal and shale: coal--bright; shale--light-grayish-brown, carbonaceous
295-300	Coal, and sandstone: coal--bright; sandstone--light-gray, fine- to medium-grained; pyrite crystals
300-305	Sandstone, light-gray to medium-light-gray, very fine- to fine-grained, dark mineral grains
305-310	Sandstone, light-gray to medium-light-gray, very fine- to fine-grained, dark mineral grains

Thickness (Ft.-In.)	Lithology
310-315	Sandstone, light-gray to medium-light-gray, very fine- to fine-grained, dark mineral grains
315-320	Sandstone, light-gray to medium-light-gray, very fine-grained, silty
320-325	Sandstone, light-gray to medium-light-gray, very fine- to fine-grained, silty, dark mineral grains
325-330	Sandstone, light-gray to medium-light-gray, well-sorted, dark mineral grains
330-335	Sandstone, medium-light-gray, fine-grained, silty, dark mineral grains
335-340	Sandstone, medium-light-gray, very fine-grained, silty, dark mineral grains, few medium-gray shale chips
340-345	Sandstone, medium-light-gray, very fine- to fine-grained, silty, dark mineral grains
345-350	Sandstone, light-gray to medium-light-gray, very fine- to fine-grained, silty, dark mineral grains,
350-355	Sandstone, light-gray to medium-light-gray, fine-grained, well-sorted, dark mineral grains
355-360	Sandstone, medium-gray, very fine-grained, silty, dark mineral grains
360-365	Sandstone, light-gray to medium-light-gray, very fine- to fine-grained, silty, dark mineral grains
365-370	Sandstone, medium-gray, very fine- to fine-grained, silty, dark mineral grains
375-380	Sandstone, medium-gray, very fine-grained, silty, dark mineral grains
380-385	Sandstone, medium-light-gray, very fine-grained, silty, shaly, dark mineral grains, pyrite crystals; bright coal fragments
385-390	Sandstone, medium-gray, very fine-grained, silty, shaly, dark mineral grains, trace of coal

Thickness (Ft.-In.)	Lithology
390-395	Sandstone and siltstone: sandstone—medium-light-gray to medium-gray, very fine-grained, pyrite crystals, dark mineral grains; siltstone--medium-gray, hard, sandy, shaly
395-400	Sandstone and siltstone: sandstone—medium-light-gray, very fine-grained, dark mineral grains; siltstone--medium-gray, hard
400-405	Sandstone, medium-light-gray to medium-gray, pyrite crystals; few shale chips, dark mineral grains
405-410	Sandstone and siltstone: sandstone—medium-light-gray, very fine- to fine-grained, very calcareous, dark and light mineral grains; siltstone—light-grayish-brown
410-415	Sandstone and shale: sandstone--medium-light-gray to medium-gray, very fine-grained, silty, dark mineral grains, very calcareous; shale--medium-gray, carbonaceous fragments
415-420	Sandstone and siltstone: sandstone—medium-light-gray to medium-gray, very fine-grained, silty, very calcareous; siltstone—medium-gray, shaley
420-425	Siltstone, medium-gray, shaly, very calcareous
425-430	Siltstone, medium-gray, very calcareous
430-435	Sandstone and siltstone: sandstone—medium-light-gray, very fine-grained, silty; siltstone--medium-gray, very calcareous
435-440	Sandstone, medium-light-gray to medium-gray, very fine-grained, silty, very calcareous, dark mineral grains
440-445	Sandstone, medium-light-gray to medium-gray, very fine-grained, silty, very calcareous, dark mineral grains

GPO 839-693

STATE OF WYOMING
1933
GEOLOGICAL SURVEY

WYOMING STATE
1933
GEOLOGICAL SURVEY

Geology -- Interpreting the past to provide for the future

Evaluation of Coal Resources on the Wind River Indian Reservation, Wyoming

R 59