Chapter SB

# A SUMMARY OF COAL IN THE FORT UNION FORMATION (TERTIARY), BIGHORN BASIN, WYOMING AND MONTANA

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## Contents



## Figures

# Figures—Continued





Click here or on this symbol
in the toolbar to return.

# INTRODUCTION

The Bighorn Basin of north-central Wyoming and south-central Montana (fig. SB-1) occupies an area of about 7,500 $mi^2$ (Keefer and others, 1998) in parts of Park, Hot Springs, Washakie, and Big Horn Counties, Wyoming, and in parts of Stillwater, Sweetgrass, and Carbon Counties, Montana (fig. SB-2). The basin is surrounded by mountainous uplifts including the Bighorn and Pryor Mountains to the east and northeast, respectively, the Owl Creek Mountains to the south, the Absaroka Range to the west, and the Beartooth Mountains to the northwest. Coal-bearing strata in the basin are present within Cretaceous rocks of the Cloverly, Frontier, Mesaverde, Meeteetse, and Lance Formations, and within Tertiary rocks of the Paleocene Fort Union Formation and the Eocene Willwood and Tatman Formations (fig. SB-3). Thicker coal beds and more extensive coal resources are primarily restricted to the Upper Cretaceous Mesaverde and Meeteetse Formations and the Paleocene Fort Union Formation (Glass and others, 1975). Based on the distribution of coal-bearing outcrops and the interpreted extent of these rocks in the subsurface, 11 coalfields have been designated within the Bighorn Basin: the Bridger, Stillwater, Silvertip (part), and the combined Red Lodge-Bearcreek coalfield (formerly the Red Lodge coalfield; Woodruff, 1909b) in Montana, and the Garland, Basin, Silvertip (contiguous with the Silvertip coalfield in Montana), Southeastern, Gebo, Grass Creek, Meeteetse, and Oregon Basin (Cody coalfield of Woodruff, 1909a) coalfields in Wyoming (Luhr and Jones, 1985) (fig. SB-4). Estimates of total in-place Bighorn Basin coal resources (bituminous and subbituminous rank coal) in both Upper Cretaceous and Paleocene strata in the basin are on the order of 1.8 billion short tons (R.W. Jones, written communication reported in Love, 1988). Berryhill and others (1950) estimated that 17.9 million tons of Upper Cretaceous bituminous coal resources are present to a depth of 3,000 ft in the Silvertip coalfield (Wyoming), and of this total, Glass and others (1975) suggest that only 4.1 million tons should be considered as a recoverable resource within constraints of overburden, coal thickness, and production and mining loss. Original estimates of subbituminous coal resources (Upper Cretaceous and Paleocene) in marginal areas of the Wyoming part of the Bighorn Basin are on the order of 564 million tons (Berryhill and others, 1950). However, Glass and others (1975) indicate that only 41.7 million tons of subbituminous-rank coal can be considered as a recoverable resource. In the Red Lodge-Bearcreek coalfield of Montana, Rawlins (1986) estimates that the remaining Paleocene coal reserves (subbituminous rank) in the Bearcreek district alone may exceed 700 million tons.

This report presents a brief summary of the geology, coal production history, and coal quality of Tertiary (Paleocene) coal deposits in the Fort Union Formation of the Bighorn Basin as part of the assessment of Tertiary coal resources in the Northern Rocky Mountains and Great Plains region (fig. SB-1). Within the framework of the National Coal Resources Assessment (NCRA) project of the U.S. Geological Survey, Fort Union coal in the Bighorn Basin is considered as “low priority” in terms of its viability as a significant production target in the near future. This low prioritization is not intended to preclude all possibility of future coal production within the basin. In fact, it should be noted that Fort Union coal in the Red Lodge-Bearcreek coalfield of Montana (Bearcreek district) is currently being assessed by private concerns as a possible fuel source for mine-site power generation, although this is in a very early stage of evaluation (James Gruber, U.S. Bureau of Land Management, oral communication, 1999). In the context of the NCRA project, however, the concept of “low priority” suggests a degree of skepticism with regard to any large-scale upswing or significant rejuvenation of coal mining in the area. In reference to Paleocene coal in the Bighorn Basin, this skepticism is supported by the restricted areal extent of thicker coal deposits (see, for example, Woodruff, 1909b; Rawlins, 1986; Roberts and Stanton, 1994), the lack of thick or persistent coal beds in Fort Union Formation outcrops throughout most of the basin (see, for example, Roberts, 1998), and the apparent lack of significant Fort Union coal in the subsurface (Johnson, 1998). Additionally, although Cretaceous coal resources were a large part of the historic coal production, particularly in the Wyoming part of the Bighorn Basin, Cretaceous coal is not addressed in detail in this report.

## COAL PRODUCTION HISTORY

A total of 53 million tons of Cretaceous and Paleocene coal is estimated to have been produced in the Bighorn Basin as of 1983 (Love, 1988). Coal mining in the basin began in the late 1800's, with larger, more commercial mines opening in the early 1900's (Glass and others, 1975). Between 1919 and 1929, coal production in the Wyoming part of the basin ranged from 450,000 to 550,000 tons per year, and then decreased to between 90,000 and 200,000 tons per year from 1930 to 1956 (Glass and others, 1975). A total of 12,271,664 tons is reported to have been produced in Wyoming, and about 90 percent of this production (11,032,114 short tons) came from 13 or more mines working Upper Cretaceous coal deposits (Mesaverde Formation ) in the Gebo coalfield (Glass and others, 1975). The remaining historic coal production accounting for the 1983 total (Love, 1988) came primarily from Montana, where as much as 30-40 million tons of coal is estimated to have been produced from the Fort Union Formation in the Bearcreek district of the Red Lodge-Bearcreek coalfield (Rawlins, 1986). Commercial mining in the Red Lodge-Bearcreek coalfield began around 1890, and annual production reached as much as 1,000,000 tons in the 1920's. Development of surface coal mines in Colstrip, Montana, during the 1920's, as well as the eventual conversion of locomotives to diesel fuel, greatly reduced the demand for Red Lodge-Bearcreek coal. Following a brief revival of coal production during World War II, most of the mines in the Red Lodge-Bearcreek area closed by the early 1950's (Rawlins, 1986).

The most recent coal production in the Bighorn basin took place in the Grass Creek coalfield in Wyoming (fig. SB-4), where some 300,500 tons of Fort Union coal was produced between 1989 and 1993; maximum coal production occurred in 1991 when 108,720 tons of coal was mined (Resource Data International, 1998). Operations there ceased by 1994 and currently, there are no active coal mines in the Bighorn Basin.

## COALFIELDS

The following coalfield summary of Fort Union Formation coal in the Bighorn Basin is compiled primarily from Glass and others (1975) and Glass (1981). In these previous studies the authors adopted nomenclature of Jepsen (1940) and refer to the Fort Union Formation as the Polecat Bench Formation. Additional references are cited where applicable. Measured sections for specific coalfields or areas adjacent to coalfields are modified from Woodruff (1909b) and Roberts (1998). An explanation of symbols used in the measured sections of Roberts (1998) is shown in figure SB-5. Carbonaceous shale as identified in these measured sections generally contains thin beds or, more typically, laminations of coal. No summaries are included for the Silvertip, Stillwater, and Bridger coalfields because pertinent data on Fort Union coal in these areas is lacking, and to a lesser degree, because Cretaceous coal was the primary production target. Figure SB-4 shows the locations of all the coalfields.

## GARLAND COALFIELD (WYOMING)

Although the apparent lenticular nature of Fort Union coal beds in this field restricted any significant production, five small mines (fig. SB-4) were opened on a basal Fort Union coal bed and at least two small prospects (locations unknown) may have been opened on a stratigraphically higher Fort Union coal bed. Mined coal-bed thickness ranged from 4.4 to 7 ft for the basal coal horizon and from 2.5 to 3.5 ft for the higher coal horizon. At least one small mine produced coal from the Cretaceous Mesaverde Formation. No production figures were recorded for this coalfield.

## BASIN COALFIELD (WYOMING)

Workable Fort Union coal beds are present in this coalfield, although their lateral extent is limited and the coal beds tend to grade rapidly to carbonaceous shale (see, for example, Washburne, 1909). A total of 17,542 tons of Paleocene coal was produced in three mines where the mined coal-bed thickness ranged from 3 to 8.7 ft and averaged 6.5 ft. A measured stratigraphic section (fig. SB-6) of about 2,300 ft of Fort Union Formation strata in the northern part of the Basin coalfield near Greybull (fig. SB-4; locality A) indicates an abundance of carbonaceous shale horizons. Carbonaceous shale and coal beds in the measured section are typically on the order of a few ft or less in thickness. In the southern part of the coalfield near Manderson (fig. SB-4), coaly carbonaceous shale horizons of as much as 14.7 ft in thickness have been observed in outcrop.

## SOUTHEASTERN COALFIELD (WYOMING)

The Southeastern coalfield encompasses a remote area of the Bighorn Basin, and thus, has played only a very minor role in coal production. There are no coal production figures from this field. Glass and others (1975) report that two small mines operated in Fort Union strata. However, Luhr and Jones (1985) indicate that one of these mines (Kimball Draw mine) was opened in Cretaceous strata of the undifferentiated Lance-Meeteetse Formations rather than in the Fort Union Formation. The coal mined from the Fort Union Formation was 3.5 ft thick. Elsewhere in the coalfield, Fort Union coal beds locally (albeit rarely) attain a thickness ranging from 5.6 to 10 ft in outcrops. Measured stratigraphic sections (fig. SB-7) of parts of the Fort Union Formation in the Honeycombs area and along U.S. Highway 16 about 12 miles east of Worland (fig. SB-4, localities B and C, respectively) show abundant carbonaceous shale and some coal beds. At the Honeycombs, coal beds are locally as much as 4 ft in thickness, although these coal beds typically include layers of bone (high ash) coal and carbonaceous shale. Carbonaceous shale beds are generally less than 3 ft thick. Placement of the contact separating the Paleocene Fort Union Formation from the underlying Upper Cretaceous Lance and Meeteetse Formations (undifferentiated) in the Honeycombs section is based on palynological analyses of Nichols (1998).

## GEBO COALFIELD (WYOMING)

Most of the historic coal production (90 percent) in the Wyoming part of the Bighorn Basin was from the Gebo coalfield. However, this production came entirely from mines working Upper Cretaceous coal in the Mesaverde Formation. Only one small mine in the Gebo coalfield (fig. SB-4) has been identified as working Fort Union coal. A measured stratigraphic section (fig. SB-8) representative of the Fort Union Formation in the Gebo area (fig. SB-4, locality D) shows an abundance of carbonaceous shale and less abundant coal beds. Similar to previously described areas, carbonaceous shale beds are generally a few ft or less in thickness, as are the coal beds. However, these coal and carbonaceous shale beds thicken and thin within short distances, and it is likely that the Fort Union coal mined in the Gebo field is laterally equivalent to carbonaceous shale and thin coal beds in the middle or upper part of the locality D measured section. The lowermost coal bed in the Fort Union section at locality D (fig. SB-8) actually consists of a 5-ft-thick interval of interbedded coal, bone coal and carbonaceous shale.

## MEETEETSE COALFIELD (WYOMING)

As much as 8,000 tons of coal was produced in the Meeteetse coalfield. One mine produced coal from a 4-ft-thick coal bed near the base of the Fort Union Formation. Additional coal prospects and mines in the coalfield worked Cretaceous coal in the Mesaverde Formation and to a lesser degree, coal in the Meeteetse Formation.

## OREGON BASIN COALFIELD (WYOMING)

The Oregon Basin coalfield was another minor player in terms of Bighorn Basin coal production. Total production for the field is estimated to have been less than 3,000 tons. The coalfield, which was formerly known as the Cody coalfield (Woodruff, 1909a), included 13 operating coal mines. Glass and others (1975) report that two mines produced coal from Fort Union Formation in the Oregon

Basin field. However, subsequent work by Luhr and Jones (1985) indicate that these mines opened in the Cretaceous Mesaverde Formation. In addition to coal production from the Mesaverde Formation, some coal production also came from the Cretaceous Meeteetse Formation.

## GRASS CREEK COALFIELD (WYOMING)

Mines in the Grass Creek coalfield produced the second largest amount of coal in the Wyoming part of the basin. As of 1975, some 67,337 tons of coal had been mined in this field, 66,422 tons of which came from a single underground mine that closed in 1973. Surface mining continued into the early 1990's until production finally ceased in the Grass Creek coalfield just prior to 1994. Although minor amounts of coal were produced from the Upper Cretaceous Mesaverde Formation, Paleocene coal production predominates in this area, and the overwhelming majority of coal production came from the Paleocene Fort Union Formation. Only the lower 1,030 ft or less of the Fort Union Formation is preserved in this coalfield (Hewett, 1926; Roberts and Stanton, 1994). Measured stratigraphic sections (fig. SB-9) of the Fort Union Formation near the Grass Creek strip mine and east of the mine on Ilo Ridge (fig. SB-4, localities E and F, respectively) indicate that coal and carbonaceous shale is present in two zones (lower and upper) in this area (Roberts and Bossiroy, 1995). The lateral extent of both coal zones is limited (fig. SB-10), and the lower coal zone is better developed in southeastern areas of the coalfield whereas the upper coal zone is best developed in the western part of the coalfield. The lower coal zone ranges from 45 to 130 ft thick, and includes coal beds as much as 3.5 ft thick. However, most coal and carbonaceous shale beds in this zone are 1.5 ft thick or less. The upper coal zone is between 425 ft and 655 ft above the basal bed of the Fort Union Formation (Hewett, 1926), and includes the 36.8-ft-thick Mayfield coal bed, which is the thickest reported coal bed in the Fort Union Formation anywhere in the Bighorn Basin. Figure SB-11 shows the varying terminology applied to coal beds in this part of the formation. The Mayfield coal bed was the primary target for production in this zone, and in the Grass Creek strip mine this coal bed is about 26 ft thick including 4.2 ft (cumulative thickness) of claystone partings (Roberts and others, 1994). The Rider 1 and 2 coal beds (figs. SB-9 and SB-11), which are restricted to the Grass Creek coal mine area, attain a maximum thickness of 9 ft and 19 ft, respectively. Prior to mining in the Grass Creek strip mine, Stewart (1975) estimated coal reserves in the Mayfield coal bed to be on the order of 15 million tons underlying an area of about 468 acres.

## RED LODGE-BEARCREEK COALFIELD (MONTANA)

The Red Lodge-Bearcreek coalfield (formerly the Red Lodge coalfield) encompasses about 32 $mi^2$ between the communities of Red Lodge and Bearcreek in south-central Montana (Woodruff, 1909b; fig. SB-4). More coal was produced from this area than from any other coalfield in the Bighorn Basin, and production totals were on the order of 30-40 million tons between 1870 and the middle 1960's (see, for example, Rawlins, 1986). The coalfield includes the Red Lodge and Bearcreek mining districts, which are geographically separated by a high topographic ridge. All coal production in this field came from Fort Union Formation coal. In this area, the Fort Union Formation consists of a lower, non-coal-bearing interval that is about 5,700 ft thick, a middle coal-bearing interval about 825 ft thick, and an upper, non-coal-bearing interval about 1,975 ft thick (Woodruff, 1909b). In the Red Lodge district, at least seven coal beds, originally designated as coal beds 1 through 7 (descending order), were identified in the coal-bearing interval of the Fort

Union (Woodruff, 1909b). Additional beds within the coal zone were later discovered, and subsequently designated as coal beds 1 1/2 and 4 1/2 (fig. SB-12). Note that coal bed 7 typically includes a zone of multiple thin coal beds. A similar, if not identical coal-bearing succession is present in the Bearcreek district (Woodruff, 1909b), although Rawlins (1986) designates eight “major” coal beds in this area of the field. The coal beds are as much as 11.5 ft thick, and may locally include numerous partings of carbonaceous shale. At least 16 underground mines operated in the Red Lodge-Bearcreek coalfield during its history of production (Luhr and Jones, 1985). In an evaluation of six coal beds, each greater than 4 ft thick in the Bearcreek district, Rawlins (1986) estimates that total Fort Union coal reserves in this area may exceed 700 million tons.

## COAL QUALITY

Quality analyses (heat-of-combustion, ash yield, moisture, and total sulfur content) for Fort Union coal in many parts of the basin are lacking, and analytical data typically emphasize major production targets such as the Mayfield coal bed and coal beds in the Red Lodge-Bearcreek coalfield. Glass and others (1975) report the following summary analyses (on an as-received basis) for Fort Union Formation coal in the Wyoming part of the Bighorn Basin, based on 12 samples (locations unknown): moisture ranging from 10.7 to 17.8 percent (arithmetic mean of 14.3 percent), ash yield ranging from 5.0 to 15.3 percent (arithmetic mean of 9.8 percent), total sulfur content ranging from 0.2 to 2.1 percent (arithmetic mean of 0.6 percent), and heat-of-combustion values ranging from 8,858 to 11,246 Btu/lb (arithmetic mean of 10,150 Btu/lb). The apparent rank of Fort Union Formation coal beds ranges from subbituminous to bituminous.

As-received analyses based on 10 face channel samples from highwall exposures of the Mayfield coal bed in the Grass Creek strip mine (Roberts and others, 1994) indicate moisture ranging from 6.6 to 14.2 percent (arithmetic mean of 9.8 percent), ash yield ranging from 6.9 to 26.5 percent (arithmetic mean of 13.8 percent), total sulfur content ranging from 0.27 to 0.72 percent (arithmetic mean of 0.36 percent), and heat-of-combustion values ranging from 9,023 to 11,003 Btu/lb (arithmetic mean of 10,124 Btu/lb). Based on six samples from this same coal bed, Glass and others (1975) report the following analyses (on an as-received basis): moisture ranging from 10.7 to 12.8 percent (arithmetic mean of 12.3 percent), ash yield ranging from 5.0 to 9.4 percent (arithmetic mean of 7.4 percent), total sulfur content ranging from 0.3 to 0.6 percent (arithmetic mean of 0.4 percent), and heat-of-combustion values ranging from 10,730 to 11,246 Btu/lb (arithmetic mean of 10,970 Btu/lb). The apparent rank of the Mayfield coal bed varies from subbituminous B to high volatile A bituminous (see, for example, Berryhill, 1950; Glass, 1991).

Analyses (on an as-received basis) from core samples of five coal beds in the Bearcreek district of the Red Lodge-Bearcreek coalfield indicate moisture of 10-11 percent, ash yield ranging from 10-12 percent, total sulfur content of 1.2-3.0 percent, and heat-of-combustion values ranging from 10,500-10,700 Btu/lb (Rawlins, 1986). The high sulfur values likely reflect the presence of pyrite which is concentrated at the top and base of the coal beds (Rawlins, 1986). In this same report, analytical results (on an as-received basis) based on a fresh channel sample from the Brophy mine indicate moisture of 11.04 percent, ash yield of 10.68 percent, total sulfur content of 1.33 percent, and a heat-of-combustion value of 10,539 Btu/lb (Rawlins, 1986).

## COAL-BED METHANE

Little information is published regarding the coal-bed methane potential of the Fort Union Formation in the Bighorn Basin. Indirectly, the presence of coal-bed gas associated with Fort Union coal is evidenced by the 1943 gas explosion (methane ?) in the Smith Mine in the Bearcreek mining district of Montana. Additionally, Nuccio and Finn (1998) suggest that thermal maturity parameters observed in Fort Union Formation strata allow for a “fair to good” potential for biogenic gas generation from coal and carbonaceous shale around the periphery of the basin and in the deep trough of the basin. Perhaps the single, most limiting factor reducing the potential for coal-bed methane resources in the Fort Union Formation is the apparent lack of thick, persistent coal in much of the basin. Stewart (1975) and Roberts and Stanton (1994) demonstrate that the Mayfield coal bed, which is the thickest Fort Union coal bed, and additional thick coal beds associated with this bed are restricted to the areas within a mile or so of the Grass Creek strip mine. The restricted areal extent of these thick coal deposits and their relatively shallow depth of occurrence (maximum of 200 ft of overburden; Stewart, 1975) greatly diminish the potential for significant coal-bed methane resources in this area. Additional stratigraphic studies of Roberts (1998) in other areas of the Wyoming part of the Bighorn Basin indicate that only relatively thin (less than 5 ft thick) coal and carbonaceous shale beds are predominant in most other Fort Union outcrops. This apparent lack of thick coal beds in Fort Union outcrops in most of the marginal areas of the southern Bighorn Basin (Wyoming) decreases the likelihood of coal-bed methane resource development in these areas as well.

Woodruff (1909b) identified an area underlain by “workable” coal in the Red Lodge-Bearcreek coalfield that incorporates about 32 $mi^2$. Within this area, cumulative coal thickness can reach in excess of 80 ft (Woodruff, 1909b). This, coupled with the indirect evidence of coal-bed gas, based on the 1943 mine explosion, make the Red Lodge-Bearcreek coalfield a potential area for coal-bed methane exploration. As of this writing, however, we could not locate any published information regarding coal-bed methane exploration or assessment in this area.

The potential for coal-bed methane associated with deep, subsurface coal in the basin seems low, based on studies of Johnson (1998). Using interpretations of resistivity, sonic, density, and gamma-ray logs from oil and gas tests, Johnson demonstrated that cumulative coal thickness in the Fort Union Formation in deeper parts of the basin rarely exceeds 10 ft. The thickest cumulative coal (26 ft) was found in a well penetrating the Fort Union Formation in the southern part of the Bearcreek mining district. Overall, however, the potential for coal-bed methane accumulations derived from deeper Fort Union coal seems hampered by the mere lack of laterally extensive, thick coal beds in the formation throughout most of the Bighorn Basin.

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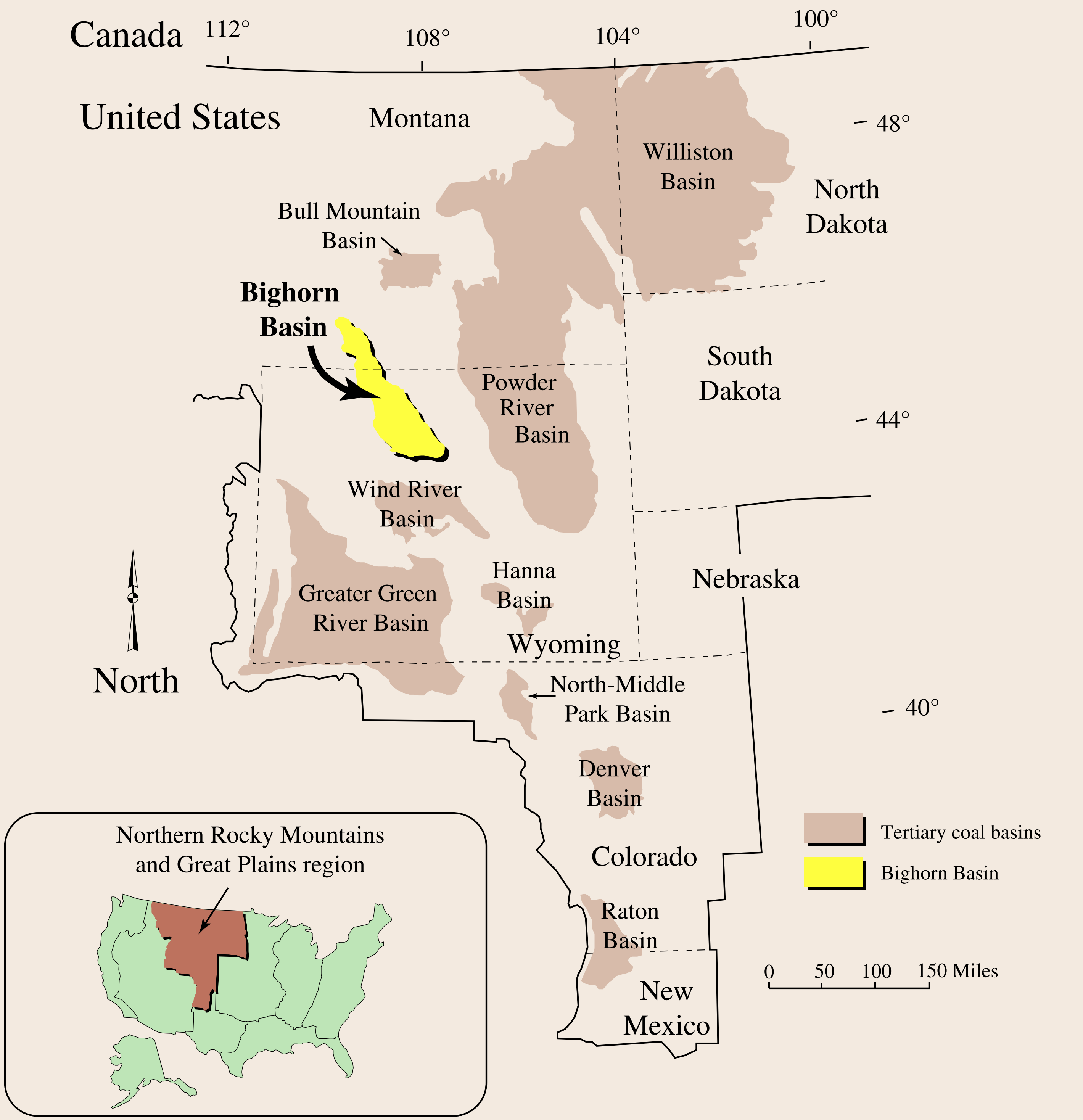


**Figure SB-1**. Index map showing the Bighorn Basin and associated Tertiary coal basins in the Northern Rocky Mountains and Great Plains region.

USGS
science for a changing world

1999 Resource assessment of selected Tertiary coal beds and
zones in the Northern RockyMountains and Great Plains region,
U.S. Geological Survey Professional Paper 1625-A

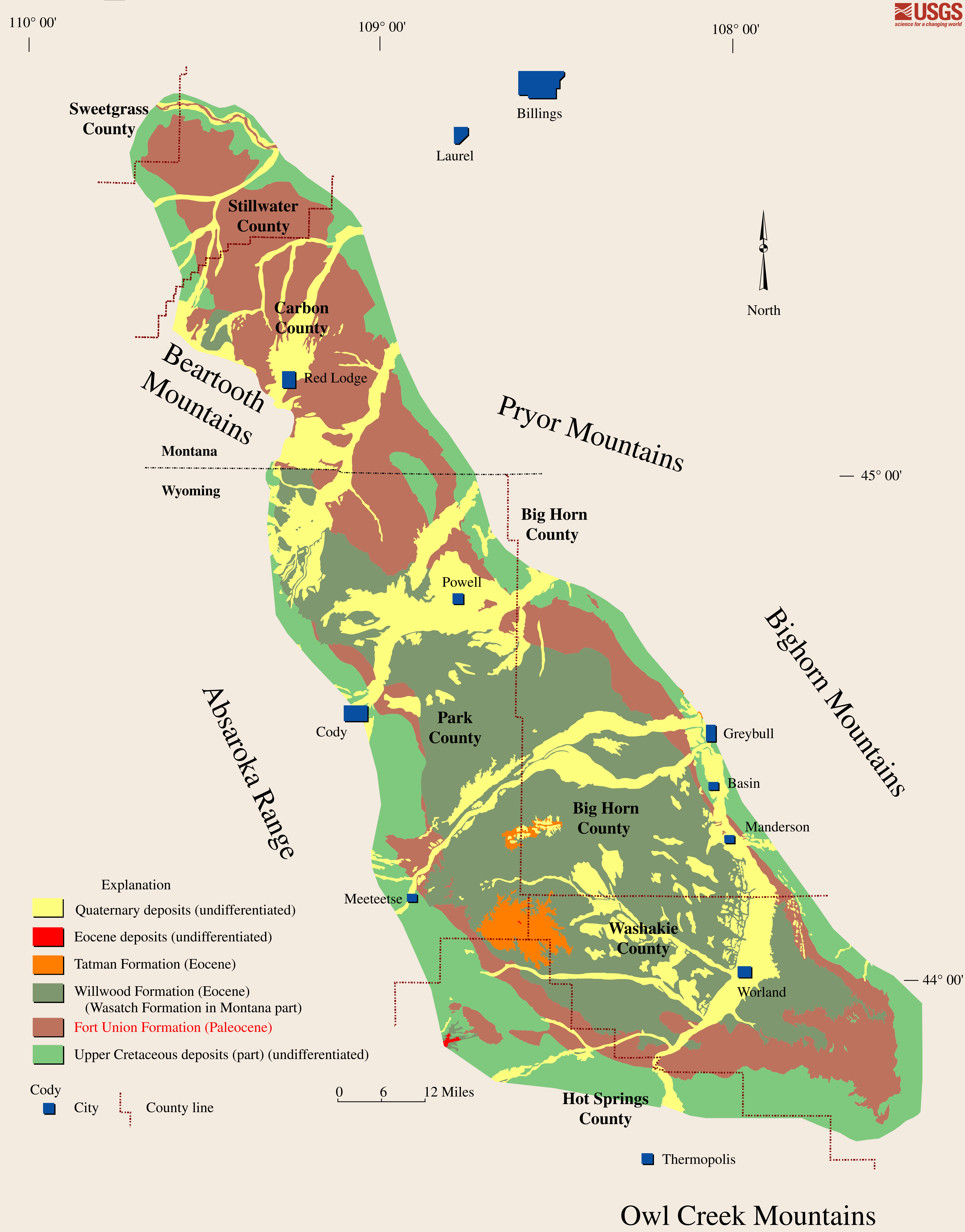


**Figure SB-2.** Map showing generalized Upper Cretaceous (part), Tertiary, and Quaternary geology, Bighorn Basin, Montana and Wyoming. Geology modified from Green and Drouillard (1994) and Raines and Johnson (1996).

## Bighorn Basin

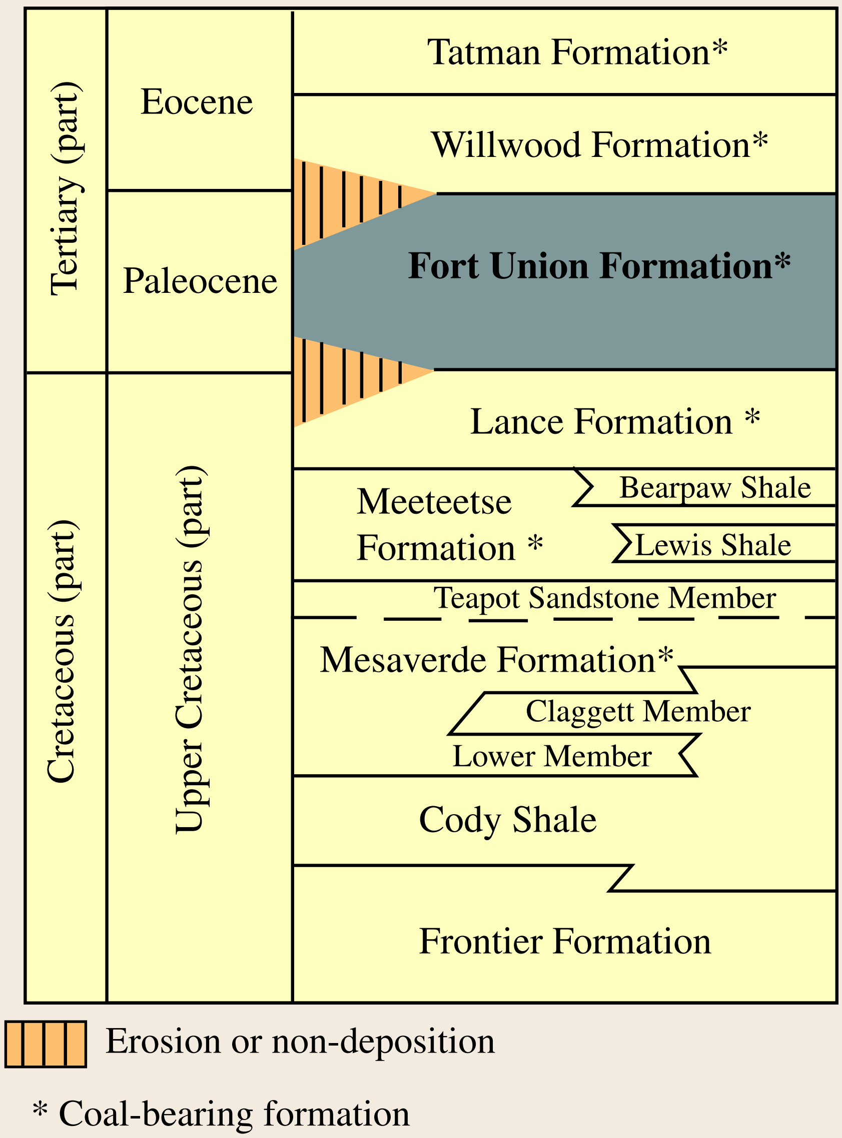


**Figure SB-3**. Stratigraphic column showing Upper Cretaceous (part) and Tertiary formations in the Bighorn Basin, Montana and Wyoming. Chart modified from Keefer and others (1998).

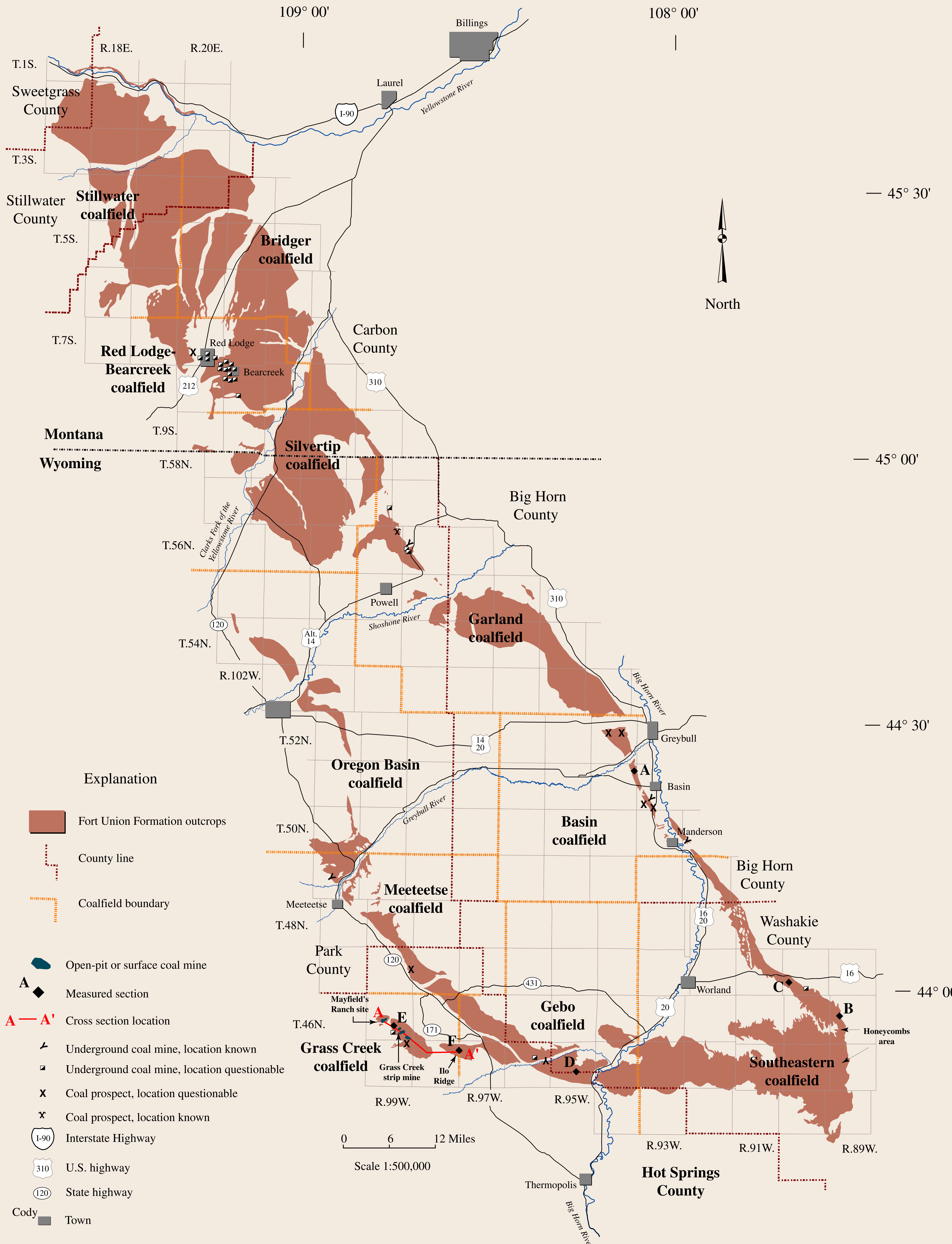


**Figure SB-4**. Map showing locations of coalfields, abandoned coal mines, and measured stratigraphic sections, Bighorn Basin, Montana and Wyoming. Abandoned mine locations and coalfield boundaries modified from Luhr and Jones (1985).

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in the toolbar to return.

## Explanation

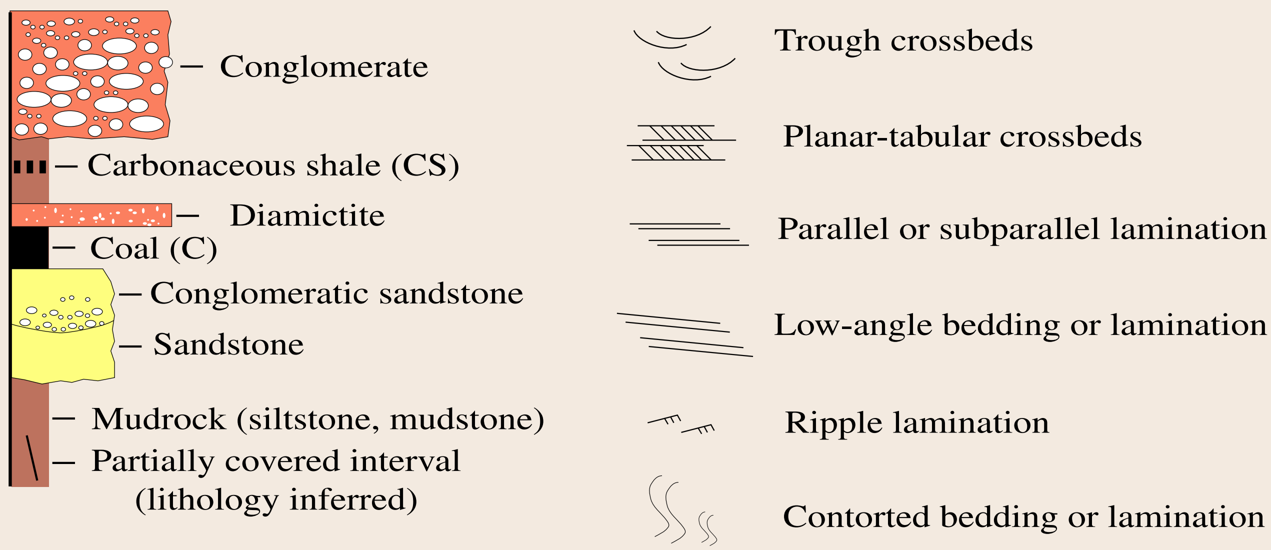


**Figure SB-5**. Lithologic and sedimentologic symbols used in measured stratigraphic sections of the Fort Union Formation shown in figures SB-6 through SB-9 in this report.

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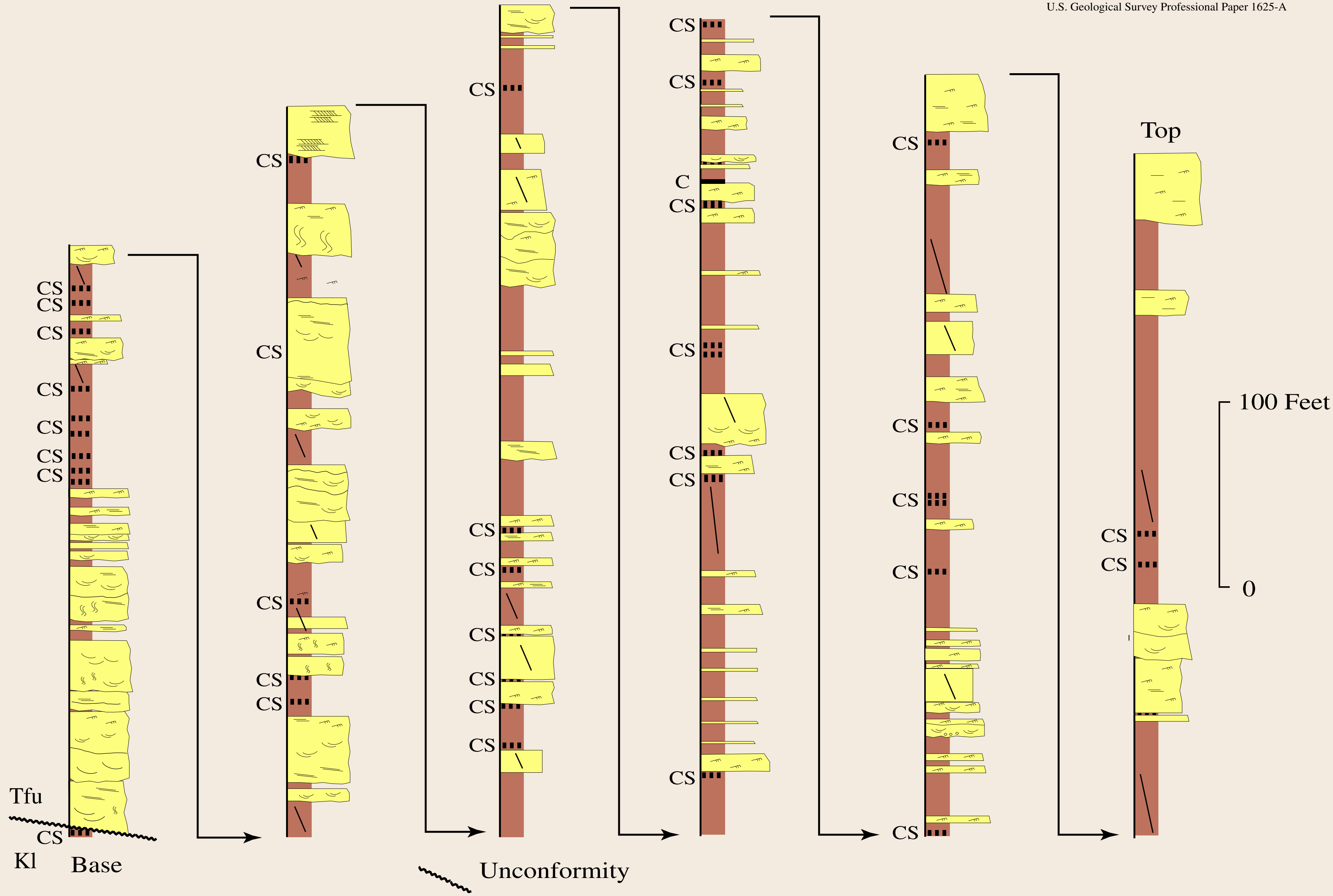


**Figure SB-6**. Measured stratigraphic section of the Fort Union Formation (part) at locality A in the Basin coalfield, Tps. 51 and 52 N., R. 94 W., eastern Bighorn Basin, Wyoming. Measured section location shown in figure SB-4 (this report). Explanation for lithologic symbols shown in figure SB-5 (this report). Tfu, Fort Union Formation (Tertiary); Kl, Lance Formation (Cretaceous). Modified from Roberts (1998).

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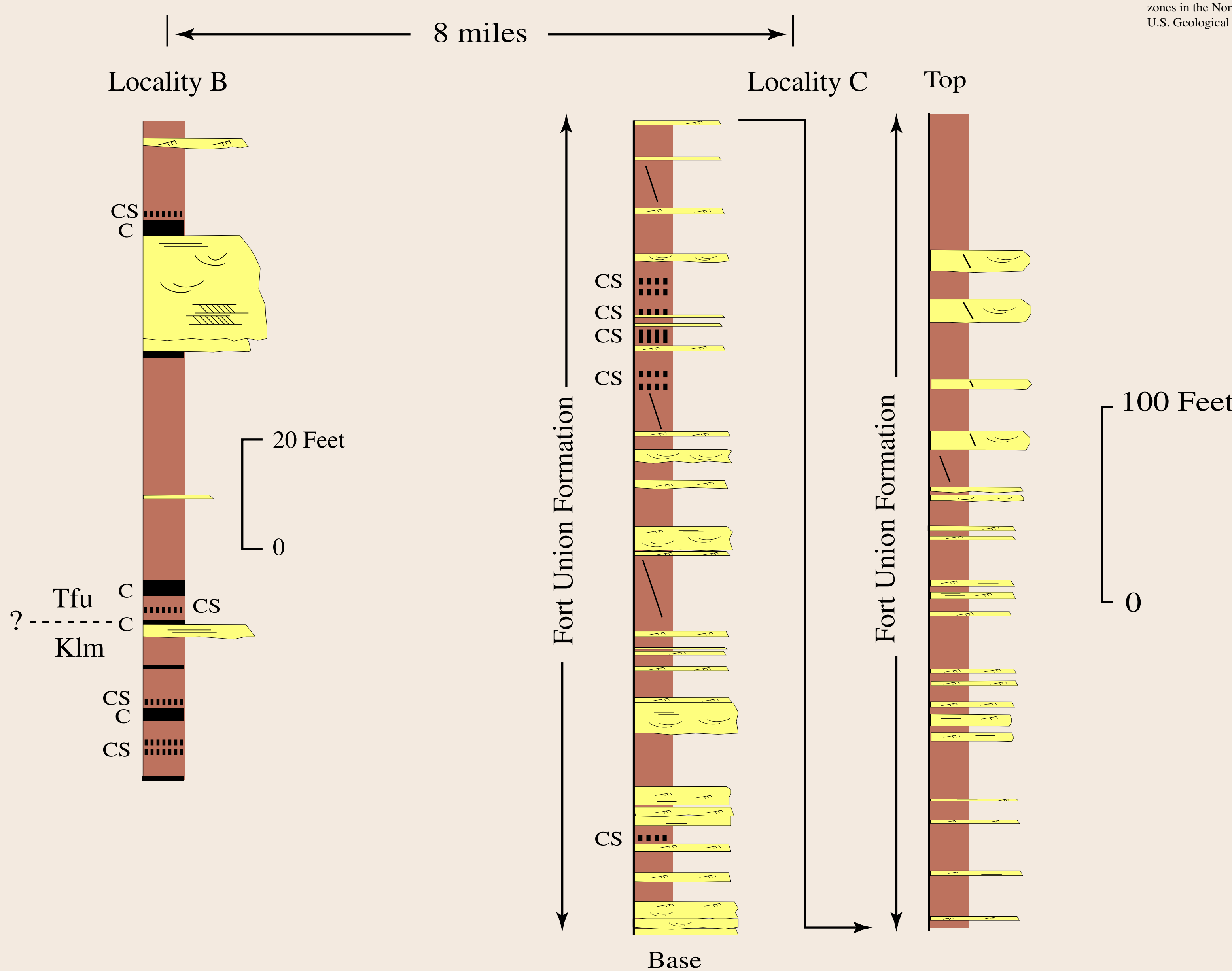


**Figure SB-7**. Measured stratigraphic sections of the Fort Union Formation (part) at localities B and C, Southeastern coalfield, Tps. 46 and 47 N., Rs. 89 through 91 W., southeastern Bighorn Basin, Wyoming. Measured section locations shown in figure SB-4 (this report). Explanation for lithologic symbols shown in figure SB-5 (this report). Tfu, Fort Union Formation (Tertiary); Klm, Lance and Meeteetse Formations, undifferentiated (Cretaceous). Modified from Roberts (1998).

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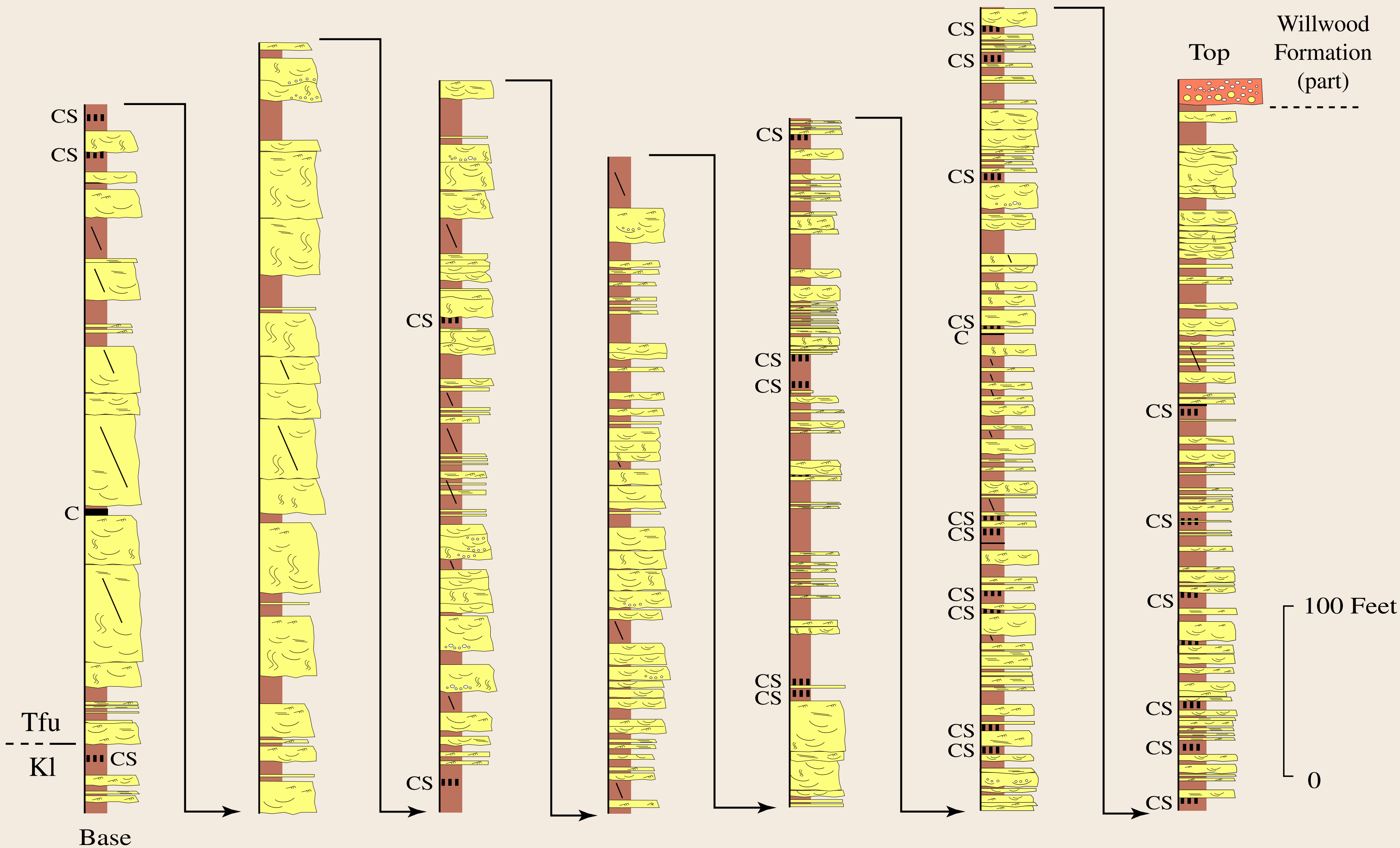


**Figure SB-8**. Measured stratigraphic section of the Fort Union Formation at locality D in the Gebo coalfield, T. 45 N., Rs. 95 and 96 W., south-central Bighorn Basin, Wyoming. Measured section location shown in figure SB-4 (this report). Explanation for lithologic symbols shown in figure SB-5 (this report). Tfu, Fort Union Formation (Tertiary); Kl, Lance Formation (Cretaceous). Modified from Roberts (1998).

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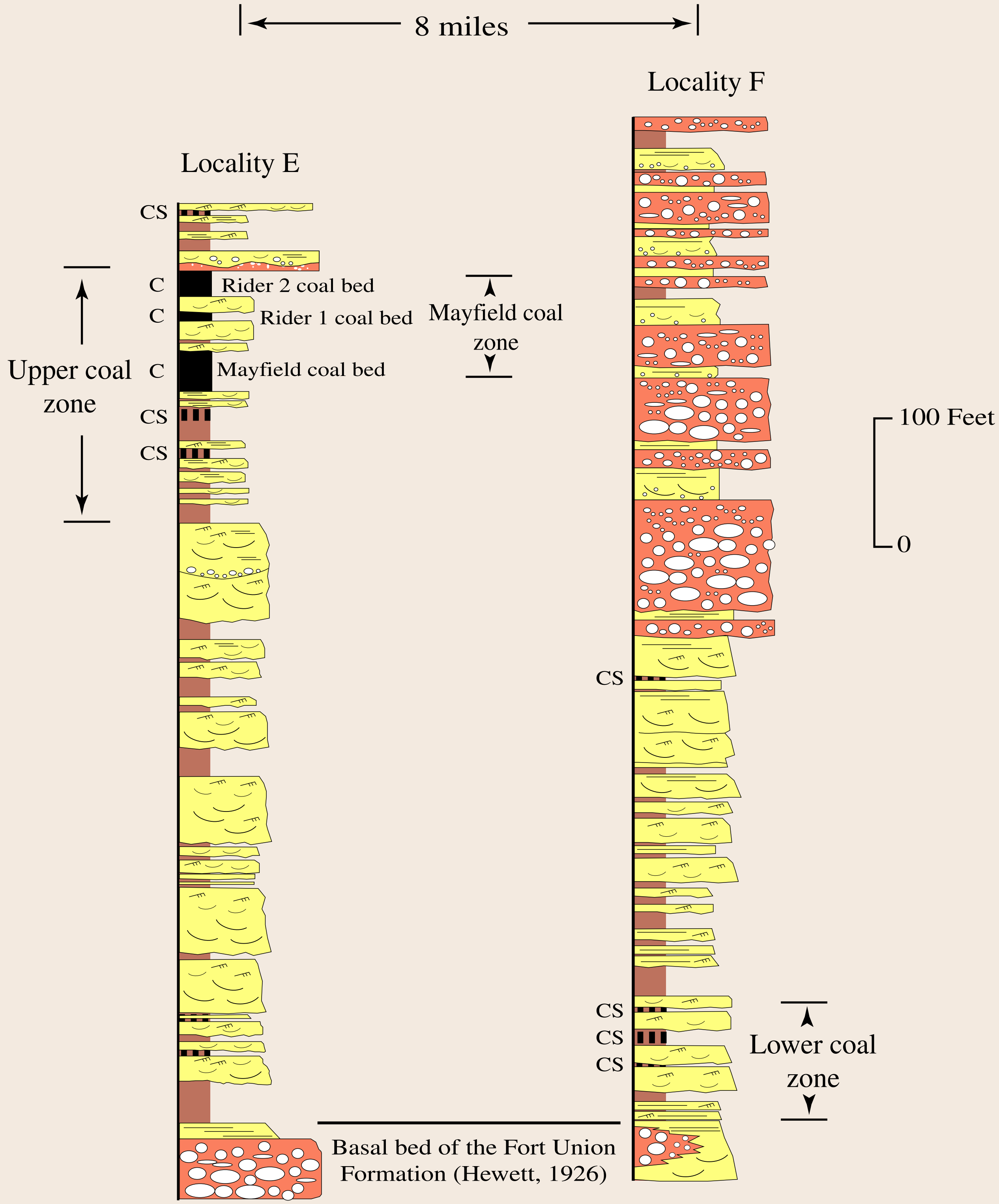


**Figure SB-9**. Measured stratigraphic sections of the Fort Union Formation (part) at localities E and F in the Grass Creek coalfield, Tps. 45 and 46 N., Rs. 97-99 W., southwestern Bighorn Basin, Wyoming. Measured section locations shown in figure SB-4 (this report). Explanation for lithologic symbols shown in figure SB-5 (this report). Modified from Roberts (1998).

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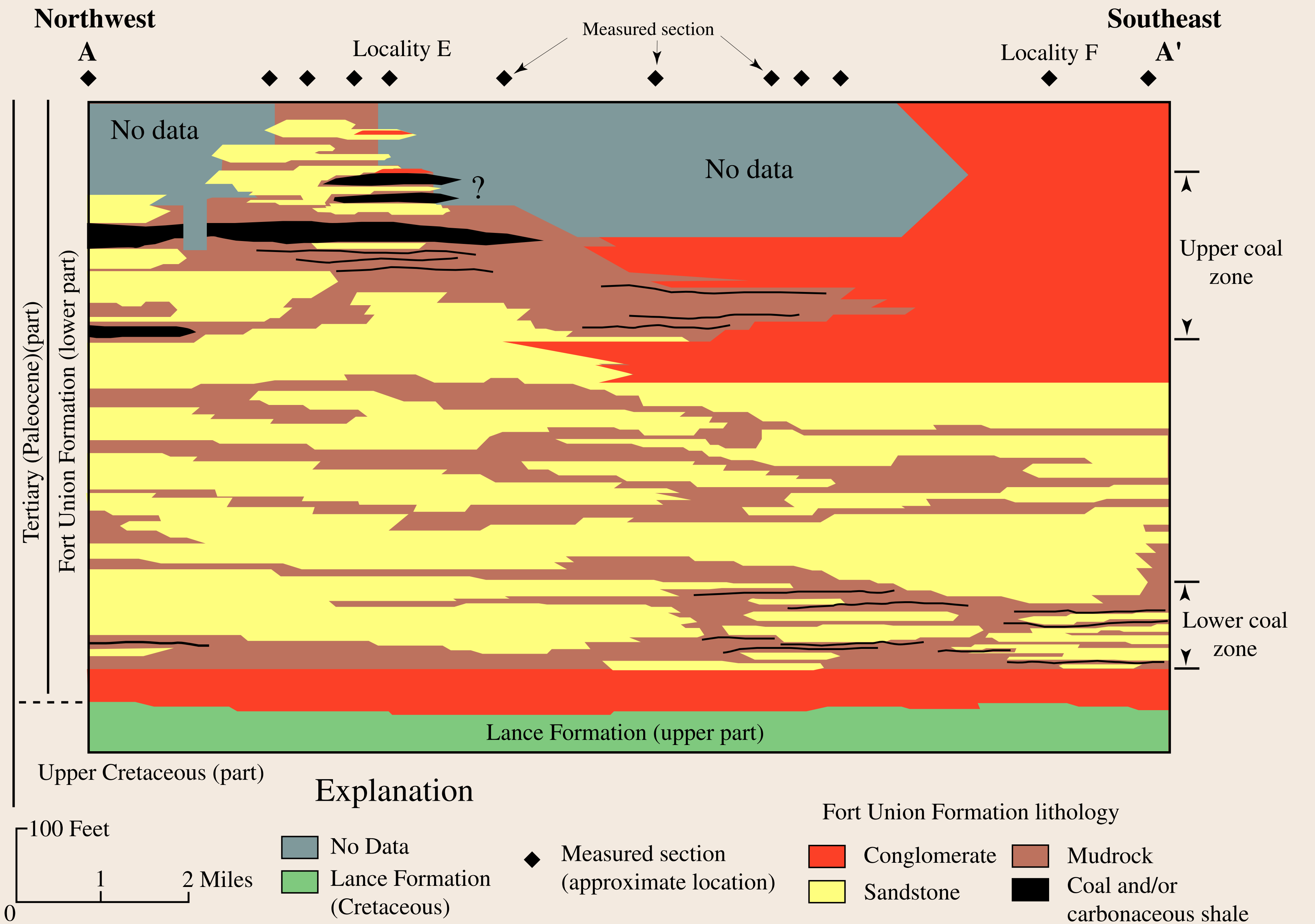


**Figure SB-10**. Schematic cross section A-A' showing the lateral variation in Fort Union Formation lithology and the stratigraphic position of coal zones in the Grass Creek coalfield, Tps. 45 and 46 N., Rs. 97-99 W., southwestern Bighorn Basin, Wyoming. Cross section location shown in figure SB-4 (this report). Modified from Roberts and Bossiroy (1995).

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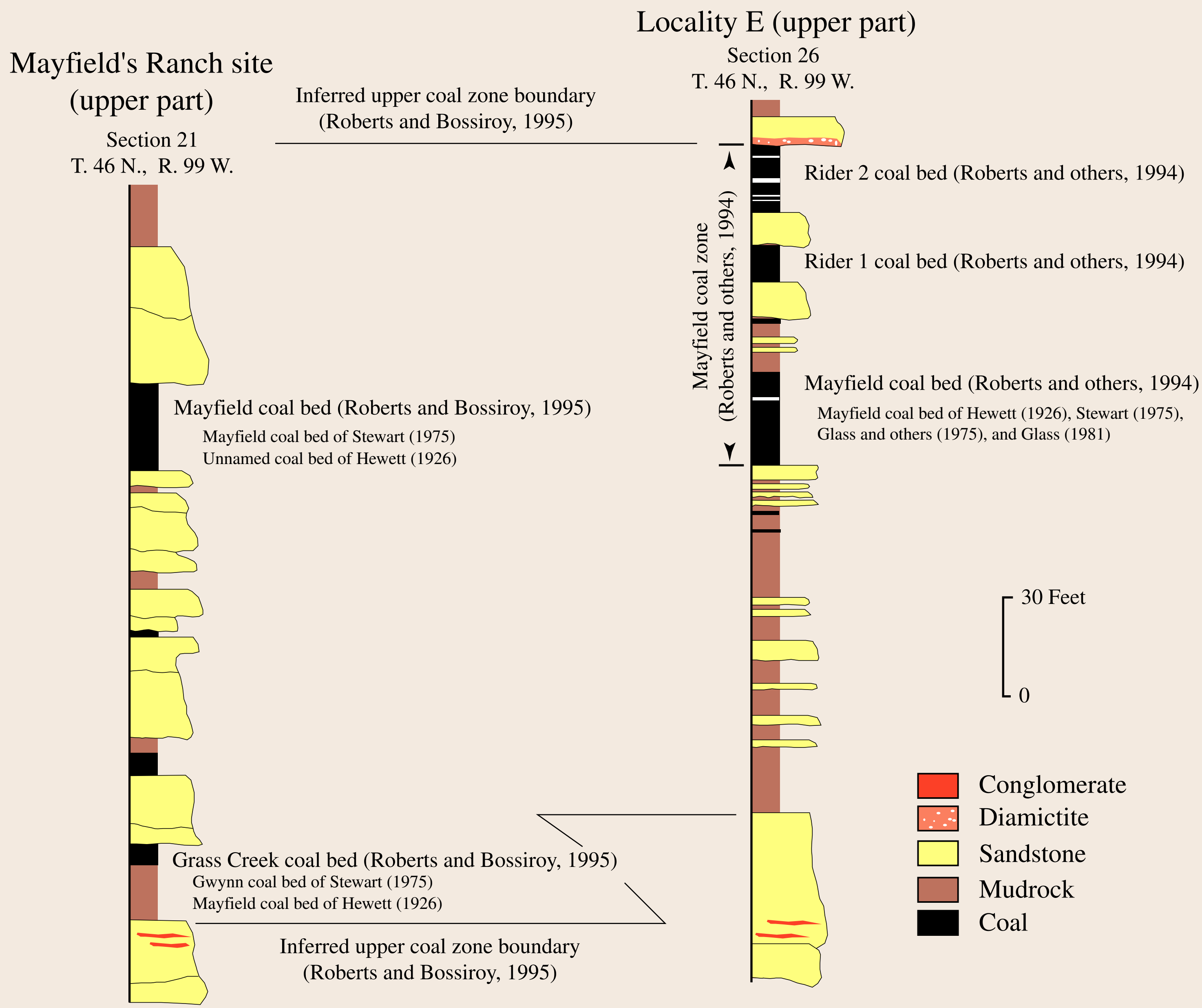


**Figure SB-11**. Diagram comparing stratigraphic terminology for coal beds in the upper coal zone of the Fort Union Formation, Grass Creek coalfield, southwestern Bighorn Basin, Wyoming. Location of measured sections shown in figure SB-4 (this report). Modified from Roberts and Bossiroy (1995).

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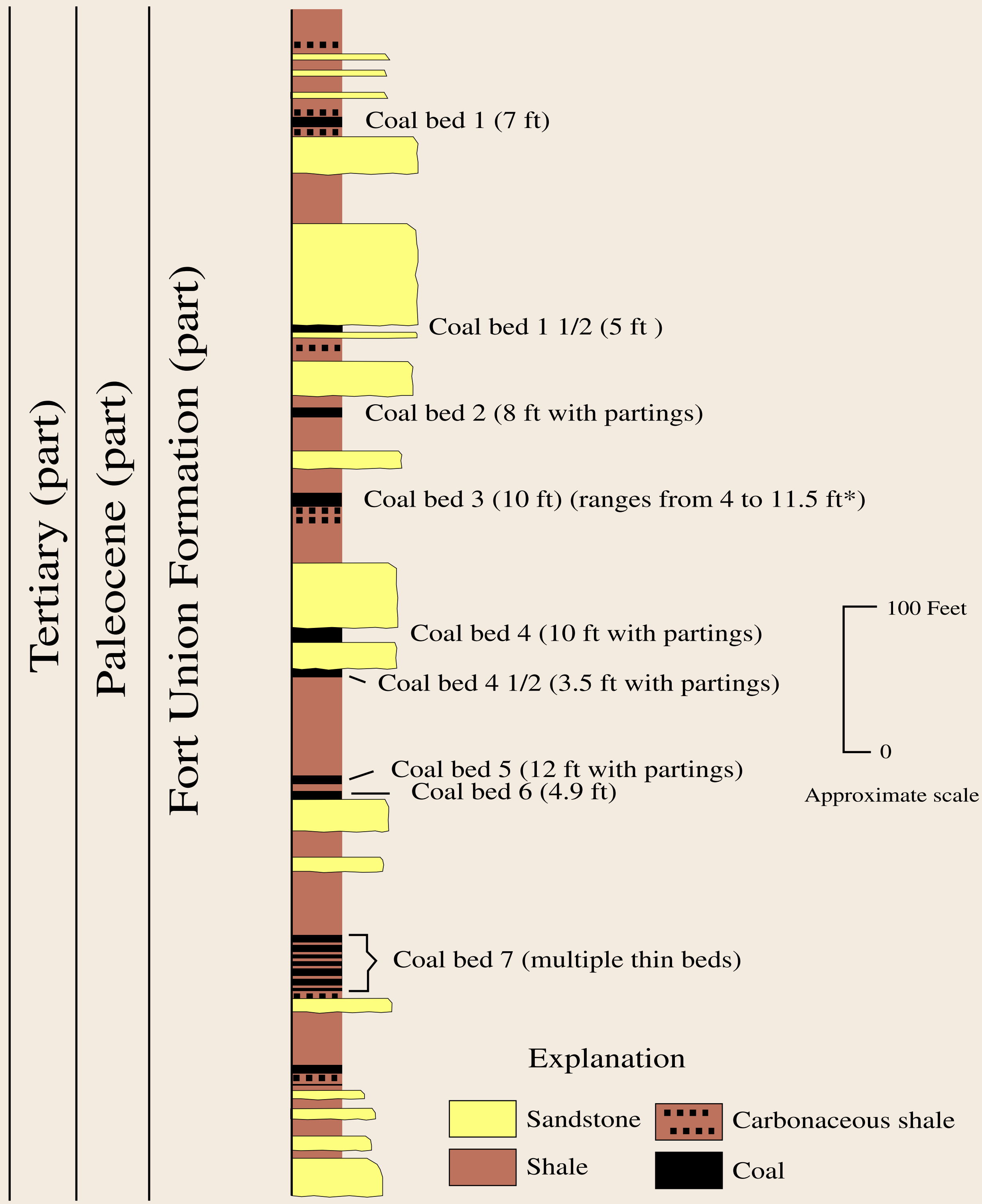


*Range of coal thickness from Rawlins (1986)

**Figure SB-12**. Generalized stratigraphic column showing Fort Union Formation coal beds in the area of Red Lodge, northern Bighorn Basin, Montana. Stratigraphy adapted from Woodruff (1909b) and Rawlins (1986).