Chapter PC

# COLSTRIP COALFIELD, POWDER RIVER BASIN, MONTANA: GEOLOGY, COAL QUALITY, AND COAL RESOURCES

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# INTRODUCTION

The Colstrip coalfield incorporates an area of some 395 square mi in parts of Big Horn, Rosebud, and Treasure Counties in south-central Montana (fig. PC-1). The coalfield is named for the town of Colstrip, which is adjacent to the Rosebud coal mine in the northeastern part of the field. Access through the coalfield area is limited to State Highways 315 and 384 and an associated network of improved and unimproved gravel roads. Numerous, relatively small perennial or intermittent streams transect the coalfield. Major drainages include Sarpy Creek and Rosebud Creek (fig. PC-1).

In the Colstrip coalfield, the Rosebud-Robinson coal zone has been designated as a priority coal assessment unit within the framework of the National Coal Resource Assessment (NCRA) project of the U.S. Geological Survey. The coal zone includes three primary coal beds (descending order): the Rosebud, McKay, and Robinson coal beds (fig. PC-2). The coalfield extent is defined by both geologic and geographic parameters. The western and northwestern boundary is delimited by the outcrop or burn line (clinker contact) of the Robinson coal bed, whereas the northern and eastern limits of the field are defined by the outcrop or burn line (clinker contact) of the Rosebud coal bed (fig. PC-1). Ideally, the Robinson coal bed, which is the stratigraphically lowest coal bed in the Rosebud-Robinson coal zone, would best delineate the maximum geologic extent of the coalfield as we define it. However, the absence of published geologic maps accurately depicting the continuity and position of the Robinson bed in the central and eastern parts of the coalfield necessitated our use of the stratigraphically higher Rosebud coal-bed horizon as the boundary for the coalfield in these areas. This horizon is well established in published maps of Matson and Blumer (1973) and Derkey (1986). The southern and southwestern boundaries of the coalfield are defined by the Northern Cheyenne and Crow Indian Reservation boundaries, respectively (fig. PC-1).

The Colstrip coalfield is mostly within the Lame Deer 30’ x 60’ quadrangle with some extension into the eastern part of the Hardin 30’ x 60’ quadrangle, and the field includes all or parts of nineteen 7.5’ quadrangles (fig. PC-3). The coalfield is roughly equivalent to the southern half of the Forsyth coalfield as defined by Dobbin (1929), and includes all of the Colstrip coal deposit of Matson and Blumer (1973). Federally owned coal is interspersed with privately owned coal sections throughout most of the coalfield (fig. PC-4).

Coal mining has been on-going in the Colstrip area since the early 1900’s (see, for example, Dobbin, 1929), and currently three surface (strip) mines, the Rosebud, Big Sky, and Absaloka (Sarpy Creek) coal mines, are producing coal in this area (fig. PC-1). Production is from the Rosebud coal bed in the Rosebud and Big Sky mines, although some historic production of the McKay bed also took place in the Big Sky mine. The Absaloka mine produces coal from the Robinson bed and the Rosebud-McKay coal bed, which comprises a single bed at this location. From 1989 through the early part of 1998, these three mines produced a combined 180+ million short tons of coal from the Rosebud-Robinson coal zone (Resource Data International, Inc., 1998); the majority of this total (about 60 percent) reflects production of the Rosebud coal bed in the Rosebud mine alone. Some of the produced coal from the Rosebud bed in the Rosebud mine feeds two 350 megawatt power plants adjacent to the town of Colstrip.

## GEOLOGIC OVERVIEW AND COAL STRATIGRAPHY

The Fort Union Formation (Paleocene) is the predominant bedrock unit in the area of Colstrip, and the uppermost member of this formation, the Tongue River Member, outcrops throughout the Colstrip coalfield (fig. PC-5). Older rocks in the underlying Lebo Member and the basal Tullock Member of the Fort Union Formation are exposed in areas just north and west of the coalfield, and deposits of the Hell Formation Creek (Upper Cretaceous) are present to the west of the Absaloka mine in T. 1 N., R. 36 E. In the coalfield, the thickness of the Tongue River Member reaches a maximum of some 1,686 ft (Dobbin, 1929), although in western areas of the coalfield near the Absaloka mine (Sarpy Creek area; fig. PC-1), only about 750 ft of the Tongue River Member is preserved. In this same area, the Lebo Member ranges from 75 to 125 ft in thickness, and the Tullock Member attains a thickness of about 300 ft (Tudor, 1975).

Rocks of the Tongue River Member are composed primarily of shale, sandy shale, sandstone and coal beds ranging in thickness from 3 to about 30 ft (Dobbin, 1929; Chadwick and others, 1975). The underlying Lebo Member is composed mainly of dark claystone and mudstone, and this member forms badlands in western parts of the coalfield; the base of the Lebo Member is defined by the Big Dirty coal bed (Dobbin, 1929). The Tullock Member, the lowermost member of the Fort Union Formation, consists predominantly of interbedded sandstone (calcareous), gray sandy shale, siltstone and carbonaceous shale.

In general, Fort Union Formation strata dip very gently (less than a few degrees) in easterly and southerly orientations from west to east across the coalfield, respectively. Locally, however, dips are steepened by high-angle normal faults that



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are present throughout much of the Colstrip area (fig. PC-5). The faults in western areas of the coalfield range from 0.5 to 3 mi in mapped length, with displacements of as much as 140 ft in some cases (Robinson and Van Gosen, 1986). In the central and eastern parts of the coalfield, faults exceeding 6 mi in mapped length are present (Derkey, 1986). In most cases, fault displacement is slight (Matson and Blumer, 1973), although displacement in excess of 100 ft, based on drill-hole information used in this study, is evident in central areas of the coalfield. Our depiction of fault locations and orientations in this study is based on Robinson and Van Gosen (1986), and Derkey (1986). Alternative interpretations can be found in Matson and Blumer (1973).

Clinker, formed from the natural burning of coal beds, is a prominent feature of the coalfield (fig. PC-5). In places where the Rosebud and McKay beds have merged to a single bed, clinker deposits may attain a thickness of as much as 120 ft (Tudor, 1975).

The major coal beds in the Colstrip coalfield are present within the Tongue River Member of the Fort Union Formation (fig. PC-2). Minor coal is present in the lowermost Tullock Member, and one coal bed (the Big Dirty bed) at the base of the Lebo Member is from 3 to 13 ft in thickness. The Rosebud-Robinson coal zone, the priority assessment unit in the coalfield, is in the lower part of the Tongue River Member. As mentioned previously, the coal zone comprises three main coal beds: the lowermost Robinson coal bed, the base of which constitutes the base of the coal zone, the overlying McKay bed, and the uppermost Rosebud coal bed, the top of which defines the top of the coal zone. These coal bed names are consistent with terminology of Dobbin (1929) and nomenclature adhered to in subsequent studies of Matson and Blumer (1973), Tudor (1975), Robinson and Van Gosen (1986) and

Derkey (1986). An additional coal bed, named the Stocker Creek coal bed (Dobbin, 1929; fig. PC-2), is present stratigraphically above the Robinson coal bed in areas just north of the coalfield boundary. Because we could not positively identify an equivalent coal bed to the Stocker Creek bed within the assessment area boundaries, we do not apply this terminology to the Rosebud-Robinson coal zone as defined in this report. In the Absaloka mine area, the Rosebud and McKay beds merge to form a single coal bed (Tudor, 1975; Robinson and Van Gosen, 1986). Each of these main coal beds split in certain areas of the coalfield; where the Robinson coal bed splits, the base of the lower split delimits the base of the coal zone. Where the Rosebud coal bed splits, the top of the upper split defines the top of the coal zone. Local thin and non-persistent coal beds are present within the zone in some parts of the coalfield, and the number of coal beds within the Rosebud-Robinson zone varies from one at points along the Robinson coal bed outcrop west of the Absaloka mine to as many as five in the SW 1/4 of T. 2 N., R. 39 E. The maximum thickness of the Rosebud-Robinson coal zone in the Colstrip coalfield is estimated to be about 365 ft.

Lines of cross section (fig. PC-6) depicting our coal-bed correlations in the coalfield are shown in figures PC-7 through PC-10. These cross sections are based on interpretations of geophysical logs and drill cuttings descriptions from coal exploration projects conducted by the U.S. Geological Survey, Amax Coal Company, Westmoreland Resources, Inc. (see, for example, Robinson and Van Gosen, 1986), and the Western Energy Company. Most of the cross sections traverse faulted areas, and an interpretation of fault displacement is shown where applicable. In some areas, where the distance between control points (drill holes) is significant, the estimated displacement along the faults is highly inferred. Fault location and offset orientation is based mainly on Robinson and Van Gosen (1986) and Derkey (1986), although some inferred faults are based on our observations of the stratigraphic offset of correlative coal beds between drill holes along the lines of section.

The Robinson coal bed is estimated to be about 150-225 ft above the base of the Tongue River Member (Dobbin, 1929). This coal bed ranges from 14-23 ft in thickness (Dobbin, 1929) with its greater thickness attained in the Absaloka mine area. In this same area, west of the mine, the coal bed splits into a generally thin upper bench (2-3 ft thick) and a thicker lower bench as much as 16 ft thick (Robinson and Van Gosen, 1986). The overlying McKay coal bed is estimated in this study to be only 40-50 ft above the Robinson coal bed in the central part of the coalfield (T. 1 N., R. 39 E.), and may be separated from the Robinson bed by as much as 120 ft of interburden where the Rosebud and McKay beds have merged near the Absaloka mine (T. 1 N., Rs. 37 and 38 E.) (Tudor, 1975). In the extreme southern and southeastern part of the coalfield, we suggest that the McKay coal bed is not present (fig. PC-8). Where not merged with the Rosebud bed, the McKay coal bed reaches a maximum thickness of about 17 ft in western areas of the coalfield (see, for example, Robinson and Van Gosen, 1986), and averages about 8 ft in thickness throughout much of the central and eastern part of the coalfield (Matson and Blumer, 1973). The Rosebud coal bed averages about 25 ft in thickness throughout much of the central coalfield area (Matson and Blumer, 1973), and reaches a maximum of about 29 ft within the Rosebud coal mine (Chadwick and others, 1975). Near the Absaloka mine (fig. PC-1), the Rosebud coal bed is as much as 19 ft thick where not merged with the McKay coal bed (Robinson and Van Gosen, 1986), whereas the merged Rosebud-McKay coal bed is locally as much as 35 ft thick (Tudor, 1975).

## COAL QUALITY

The apparent rank of coal in the Rosebud-Robinson coal zone ranges from subbituminous C to low-range subbituminous B (Robinson and Van Gosen, 1986). In western coalfield areas surrounding the Absaloka mine, as-received analyses of 57 samples from the Robinson coal bed indicate an average moisture of 25.31 percent, average ash yield of 7.88 percent, average total sulfur content of 0.79 percent, and a mean heat-of-combustion value of 8,665 Btu/lb. As-received analyses of 37 samples from the McKay coal bed indicate average values for moisture, ash yield, total sulfur content, and heat-of-combustion are 24.34 percent, 8.83 percent, 0.89 percent, and 8,642 Btu/lb, respectively. In 28 samples of the Rosebud coal bed in the Absaloka mine area, the average as-received values for moisture, ash yield, total sulfur content, and heat-of-combustion were 24.22 percent, 8.24 percent, 0.65 percent, and 8,767 Btu/lb, respectively (Robinson and Van Gosen, 1986). For comparison, the average values for ash yield, total sulfur content, and heat-of-combustion of coal shipped from the Absaloka mine between 1989 and the first quarter of 1998 are 8.9 percent, 0.6 percent, and 8,745 Btu/lb, respectively (Resource Data International, Inc., 1998).

Chemical analyses (on an as-received basis) based on 16 samples of the Rosebud coal bed from coal exploratory drill holes throughout the Colstrip coalfield indicate moisture ranging from 20.24 percent to 23.88 percent (arithmetic mean = 22.50 percent), ash yields ranging from 7.86 percent to 12.58 percent (arithmetic mean = 9.54 percent), total sulfur content ranging from 0.53 percent to 7.20 percent (arithmetic mean = 1.22 percent), and heat-of-combustion values ranging from 7,810 Btu/lb to 9,090 Btu/lb (arithmetic mean = 8,835 Btu/lb) (see, for example, Matson and Blumer, 1973). In a study of total sulfur content in the Rosebud and

McKay coal beds in the Rosebud mine area, Chadwick and others (1975) indicate that sulfur concentrations exceeding 1.2 percent are present in discreet areas within the coal mine, and these higher sulfur concentrations are typically associated with pyrite occurrences in the lower and upper 1 ft or so of the Rosebud and McKay coal beds. Although total sulfur content in the Rosebud coal bed can be quite high in areas of these pyritic concentrations, selective mining that excludes recovery of the higher sulfur uppermost and lowermost intervals of the Rosebud bed has mitigated the sulfur issue to a certain degree. This is perhaps reflected in the 0.67 percent average total sulfur content for produced coal from the Rosebud bed shipped between 1989 and the first quarter of 1998 (Resource Data International, Inc., 1998). Additionally, Rosebud coal bed product shipped from the Rosebud mine during this same time had an average ash yield of 8.4 percent, and an average heat-of-combustion of 8,637 Btu/lb. Coal shipped from the Big Sky mine (primarily the Rosebud bed) from 1989 to early 1998 had an average total sulfur content of 0.69 percent, average ash yield of 8.7 percent, and an average heat-of-combustion of 8,781 Btu/lb (Resource Data International, Inc., 1998).

## TOTAL, NET COAL THICKNESS (ISOPACH) MAP

The total, net coal isopach map (fig. PC-11) is an interpretation of total (cumulative), net coal thickness for coal beds within the Rosebud-Robinson coal zone in the Colstrip coalfield. At each drill-hole or outcrop data point, net coal thickness (excluding partings) is measured for each coal bed within the zone, and then these individual coal thicknesses are summed to derive a cumulative value of total net coal within the coal zone at that data point. These total coal thickness values for all data points are then contoured by a computer modeling program to develop maps showing lines of equal coal thickness. It is important to bear in mind, however, that the isopach map reflects the distribution of the cumulative (summed) coal thickness for all coal beds within the Rosebud-Robinson zone rather than the thickness of any individual coal bed except in areas stratigraphically below the McKay (or Rosebud-McKay) coal bed where thickness values reflect the thickness of the Robinson (or lower Robinson) coal bed alone.

About 300 drill-hole and outcrop data points were used to develop the total coal isopach map. Only the public data points are shown (fig. PC-11), and proprietary data from mine operators and the Cheyenne and Crow Tribes that were also used in the calculations are omitted. Based on all of these data, the total, net coal in the Rosebud-Robinson coal zone ranges in thickness from 2.6 ft (outcrop of the lower Robinson bed) to about 60 ft. Because of the paucity of data in central and southern parts of the coalfield (for example, T. 1 N., R. 39 E., and T. 1 S., Rs. 40 and 41 E.; fig. PC-11), we consider our interpretations ot total, net coal thickness to be somewhat speculative in these areas.

Because the isopach map for the Rosebud-Robinson coal zone is based on cumulative coal thickness values, the following factors, either individually or collectively, can account for variations in the total, net coal thickness as seen on the map: (1) thickening or thinning of individual coal beds within the zone, (2) reduction in the number of coal beds because of lateral pinchout, (3) reduction in the number of coal beds in stratigraphically lower horizons nearing the outcrop limits of the coal zone, and (4) reduction of the total coal in clinker areas where coal has been lost because of natural burning. Therefore, thickness variations exhibited by apparent "thinning or thickening" trends in the total coal isopach map actually reflect variations in the total coal accumulation influenced by some or all of the factors listed above.

Areas of thicker coal accumulation are shown by warmer (yellow) color shades, whereas minimal coal accumulation areas are highlighted by cool (blue) shades. Based on the total, net coal isopach map (fig. PC-11), thicker total coal accumulations are present in T. 1 N., Rs. 38 and 39 E., and in isolated areas west of the Absaloka mine in T. 1 N., Rs. 36 and 37 E. Total coal accumulation apparently decreases markedly in southern and southeastern areas of the coalfield, although data scarcity deems we tread lightly on this interpretation.

## OVERBURDEN THICKNESS (ISOPACH) MAP

The overburden isopach map (fig. PC-12) is an interpretation of the varying thickness of rock that overlies the base of the Rosebud-Robinson coal zone within the Colstrip coalfield, and for this reason, defines the maximum overburden for the coal zone. The overburden in this case also includes all coal beds and interburden in the Rosebud-Robinson coal zone. Based on drill-hole and outcrop data used in this study, the Rosebud-Robinson coal zone ranges in thickness from 3.6 ft where the coal zone comprises outcrops of the lower Robinson coal bed alone, to a maximum of about 365 ft where the entire coal zone is present. Consequently, the minimum overburden (that is, the thickness of rock overlying the top of the Rosebud-Robinson coal zone) can vary from the maximum overburden by as much as 365 ft. Use of maximum overburden criteria in this study follows analogous methodology used in coal resource studies in the Colorado Plateau region of Colorado and Utah (see, for example, Hettinger and others, 1996; Brownfield and others, 1998). These interpretations of overburden are derived by subtracting a computer-generated grid of values representing the bottom surface (elevation) of the Rosebud-Robinson coal zone (base of the Robinson or lower Robinson coal bed) from a Digital Elevation

Model (DEM) grid of topographic elevation, resulting in a calculated grid of thickness values that can be contoured.

Areas of thicker overburden (fig. PC-12) are represented by shades of green and yellow, while areas of less overburden are highlighted by shades of blue. Comparison of the total coal isopach map and the overburden thickness map indicates that areas of thickest cumulative coal in the Rosebud-Robinson coal zone are coincident (in part) with areas of maximum overburden thickness ranging from less than 100 ft to more than 1,000 ft.

## COAL RESOURCES

Coal resource estimates for the Rosebud-Robinson coal zone are reported in tables PC-1 through PC-3. In table PC-1, resources are tabulated by county, net coal thickness categories, and overburden categories. Table PC-2 includes a summary of coal resources reported by 7.5’ quadrangle, and table PC-3 includes a summary of coal resources reported by county and Federal surface and subsurface ownership criteria. It is important to note that these resource estimates are not comparable to ‘reserve’ estimates, and therefore, do not reflect in any way the amount of coal that can be economically produced at the present time.

The quantification of coal resources in the Colstrip coalfield follows a scheme of resource calculation reported in Wood and others (1983). The basic quantification formula is as follows: $R = A \times T \times C$,

where

$R$ is the coal resource estimate (in short tons)

$A$ is the area underlain by coal (in acres)

*T* is the cumulative (total) net coal thickness (in feet; excluding partings) based on isopach grids, and

*C* is a weight/unit volume (density) conversion factor (in short tons/acre-foot).

All resources are reported in millions of short tons and are reported in accordance with criteria established by Wood and others (1983). Coal tonnages were calculated for coal beds greater than 2.5 ft in thickness using an average density (*C*) for subbituminous coal of 1,770 short tons per acre-foot. Tonnage values are rounded to two significant figures and the tabulated totals may not equal the sum of the components because of independent rounding. Areas for which resource estimates are not reported include the Rosebud, Big Sky, and Absaloka coal mines, tribal lands (including parts of the Crow and Northern Cheyenne Indian Reservations), and areas underlying clinker of the Rosebud, McKay, and Rosebud-McKay coal beds.

Reported reliability categories (table PC-1) include measured, indicated, inferred, and hypothetical coal resources. Measured resources occur within a 0.25-mile radius of a data point, indicated resources within the area between 0.25 miles and 0.75 miles from a data point, and inferred resources are present within a radius from 0.75 miles to 3 miles surrounding a data point. Hypothetical resources are present in areas more than 3 miles beyond a data point (Wood and others, 1983).

Overburden categories (table PC-1) represent the thickness of overburden above the base of the Rosebud-Robinson coal zone. Therefore, the overburden in this case represents a maximum overburden estimate, and the overburden includes all coal beds and interburden in the Rosebud-Robinson coal zone as well as rocks overlying the coal zone.

Confidence limits and estimates of uncertainty for total coal resources in the Rosebud-Robinson coal zone are shown in table PC-4 and table PC-5, respectively. A confidence interval is a statistic designed to capture uncertainty associated with a point estimate. Confidence limits reported here are based on total, net coal thickness measurements from 160 drill-hole and outcrop locations. From these data, we computed 90-percent confidence intervals on the volume of coal in the Rosebud-Robinson coal zone in the measured, indicated, inferred, and hypothetical categories. In this case, volume refers to the calculated resource in millions of short tons (MST).

The confidence limits were derived through a complex series of steps. These steps included modeling coal thickness trends and removing the trends using a nonparametric regression algorithm called loess (with span = 0.75), and using residual thickness to compute a semivariogram and fitting the semivariogram to a spherical model. Parameter estimates were sill = 118.64 $ft^2$, nugget = 55.52 $ft^2$, and range = 2.63 miles. Standard deviations of coal thickness were obtained from the semivariogram model. Differences in point densities were compensated for by calculating sample size, called pseudo *n*, within each reliability category and calculating the variability of volume for each of the reliability categories. The volume of coal in the Rosebud-Robinson coal zone was then calculated at a 90-percent confidence interval with measurement error. A description of the methodology used is given in Schuenemeyer and Power (1998) and Ellis and others (1999).

The three main potential sources of error that might bias the confidence intervals are preferential sampling, measurement errors, and model fitting. The probabilistic interpretation of a confidence interval is based upon a random sample, which does not exist in this situation, because there is preferential sampling in those areas deemed to be minable. Measurement error can be caused by an error in recording the coal-bed thickness or in the definition of coverage areas. Modeling fitting variability and bias result from the choice of models and fitting procedures.

## SOURCES OF DATA

### DRILL-HOLE DATA

The following drilling reports contain much of the drill hole information used in this study, although additional point data was collated from the U.S. Geological Survey National Coal Resources Data System (NCRDS), unpublished field logs, and from a limited set of proprietary records.

U.S. Geological Survey and Montana Bureau of Mines and Geology, 1977, Geophysical logs for Dawson, McCone, Richland, and Rosebud Counties, Montana; Chapter F of Preliminary report of 1977 coal drilling in eastern Montana and northeastern Wyoming: U.S. Geological Survey Open File Report 77-721-F, 74 p.

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U.S. Bureau of Land Management, 1980, Surface and mineral management status map, Lame Deer 30' x 60' quadrangle, Montana, scale 1:100,000.

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State and County boundary data from U.S. Geological Survey National Mapping Division and based on 1990 TIGER files digitally compiled by the Water Resources Division of the U.S. Geological Survey.

Digital coverages of 1:100,000- and 1:24,000-scale quadrangle map index acquired from National Mapping Division, U.S. Geological Survey.

Public Land Survey System (PLSS) data from Montana Natural Resource Information System (NRIS), Montana State Library, scale 1:100,000.

Digital hydrologic coverage from U.S. Environmental Protection Agency, Reach File Version 3, scale 1:100,000.

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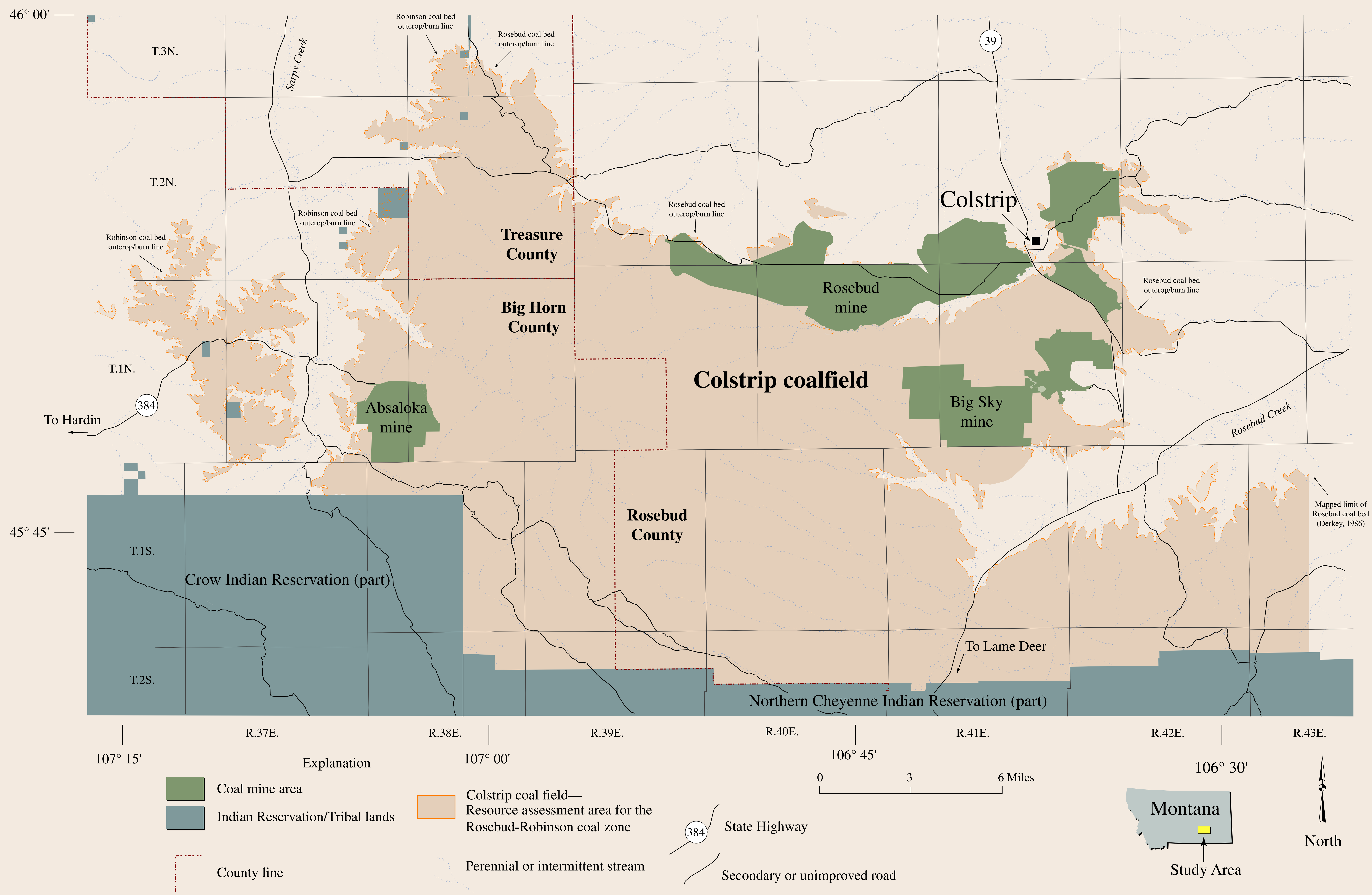


**Figure PC-1**. Index map showing the Colstrip coalfield and vicinity, south-central Montana.

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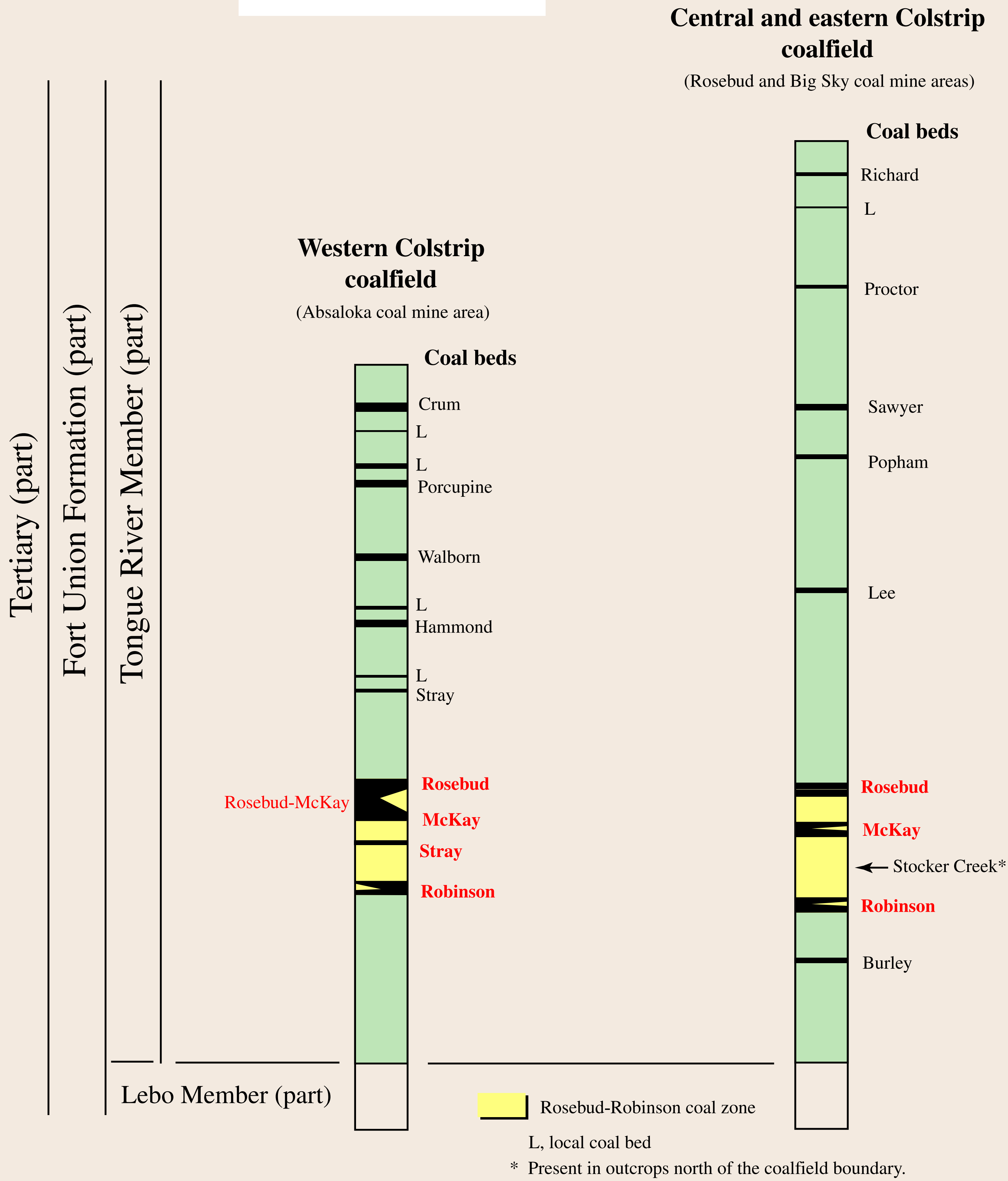


**Figure PC-2**. Stratigraphic columns showing generalized coal stratigraphy and coal-bed terminology in the Colstrip coalfield, south-central Montana. Coal bed names based on Robinson and Van Gosen (1985) and Dobbin (1929). Diagram not to scale.

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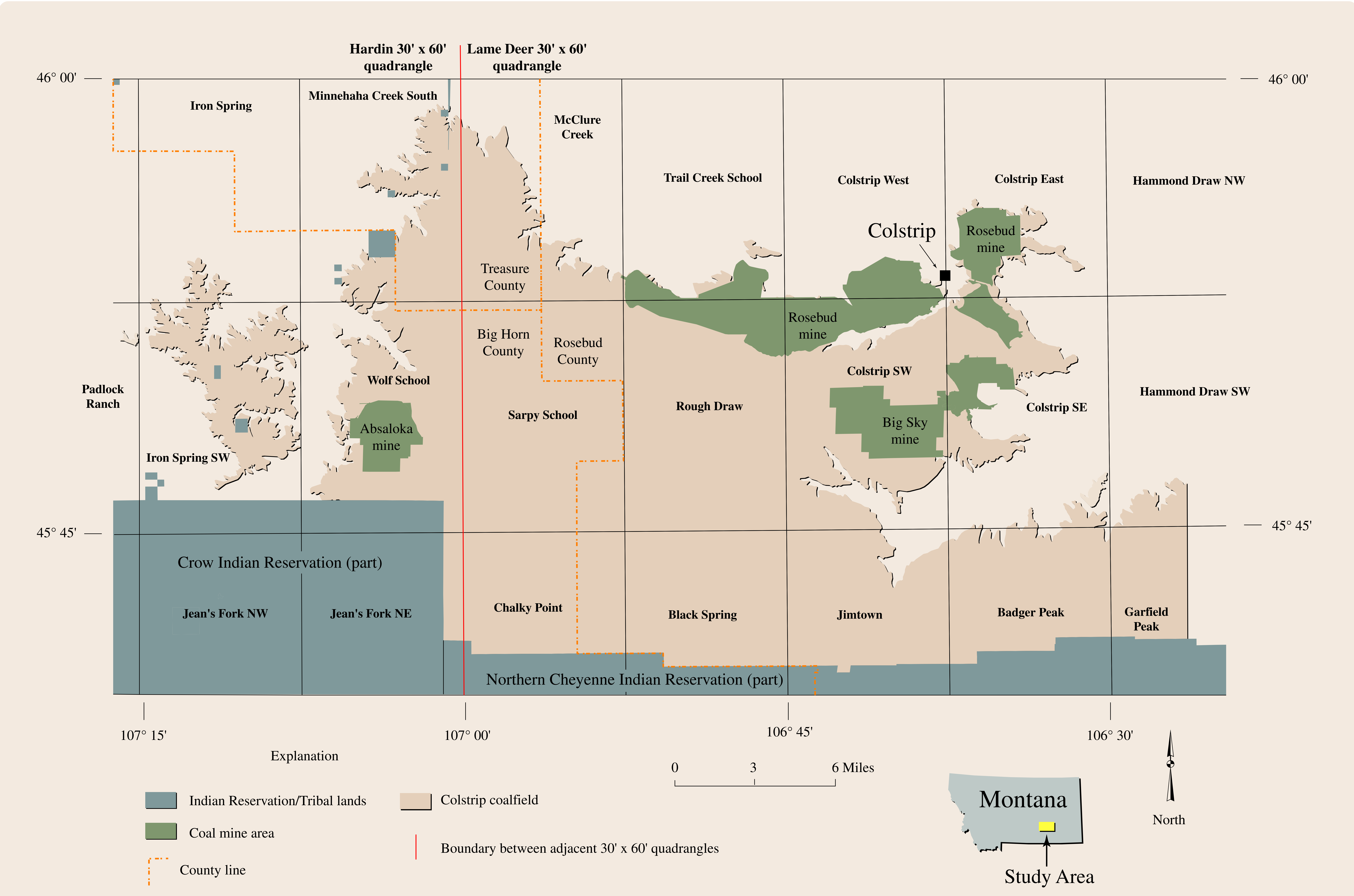


**Figure PC-3**. Index map showing 7.5' and 30' x 60' quadrangle maps in the Colstrip coalfield and vicinity, south-central Montana.

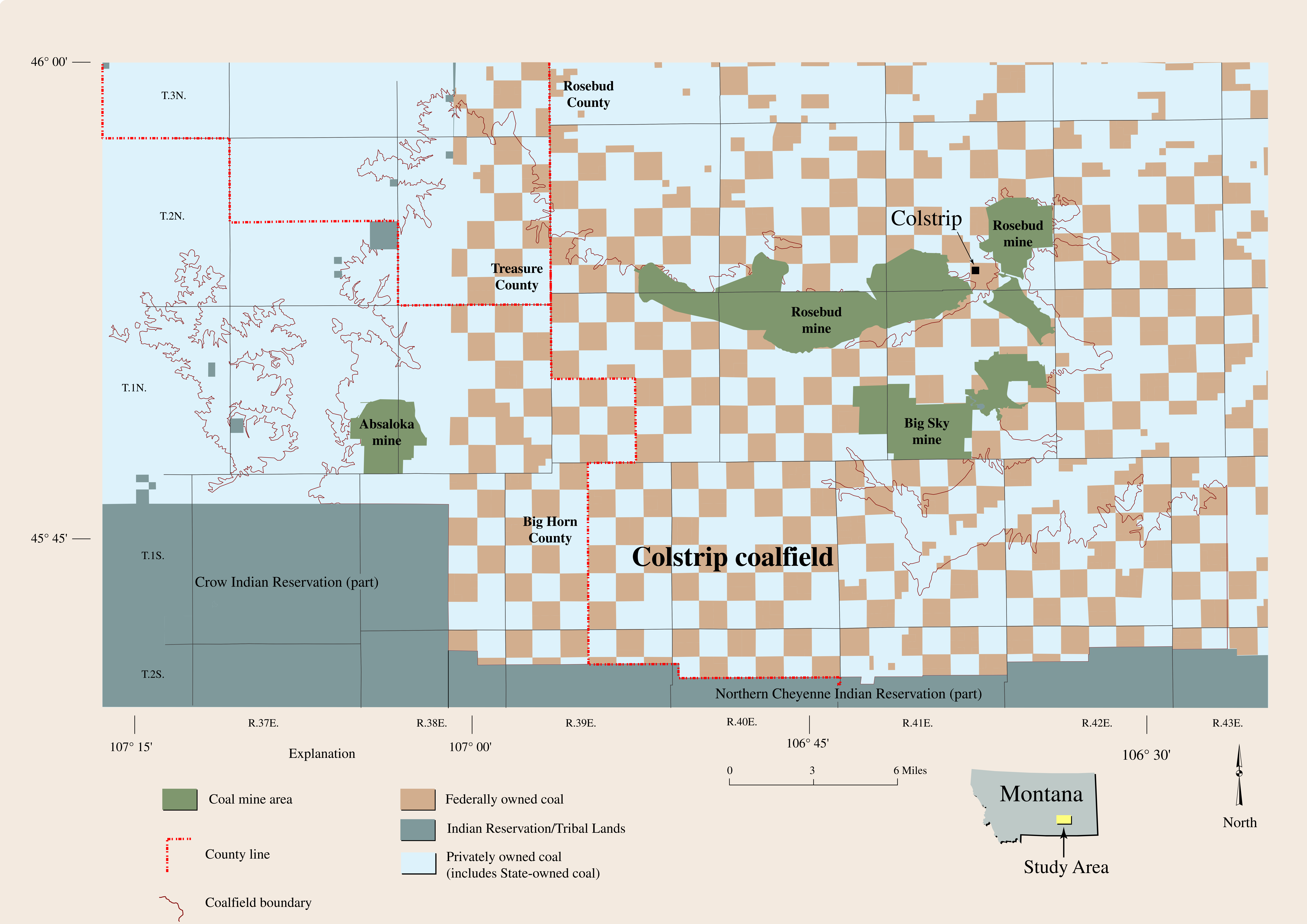


**Figure PC-4.** Map showing Federal coal ownership, Colstrip coalfield and vicinity, south-central Montana.

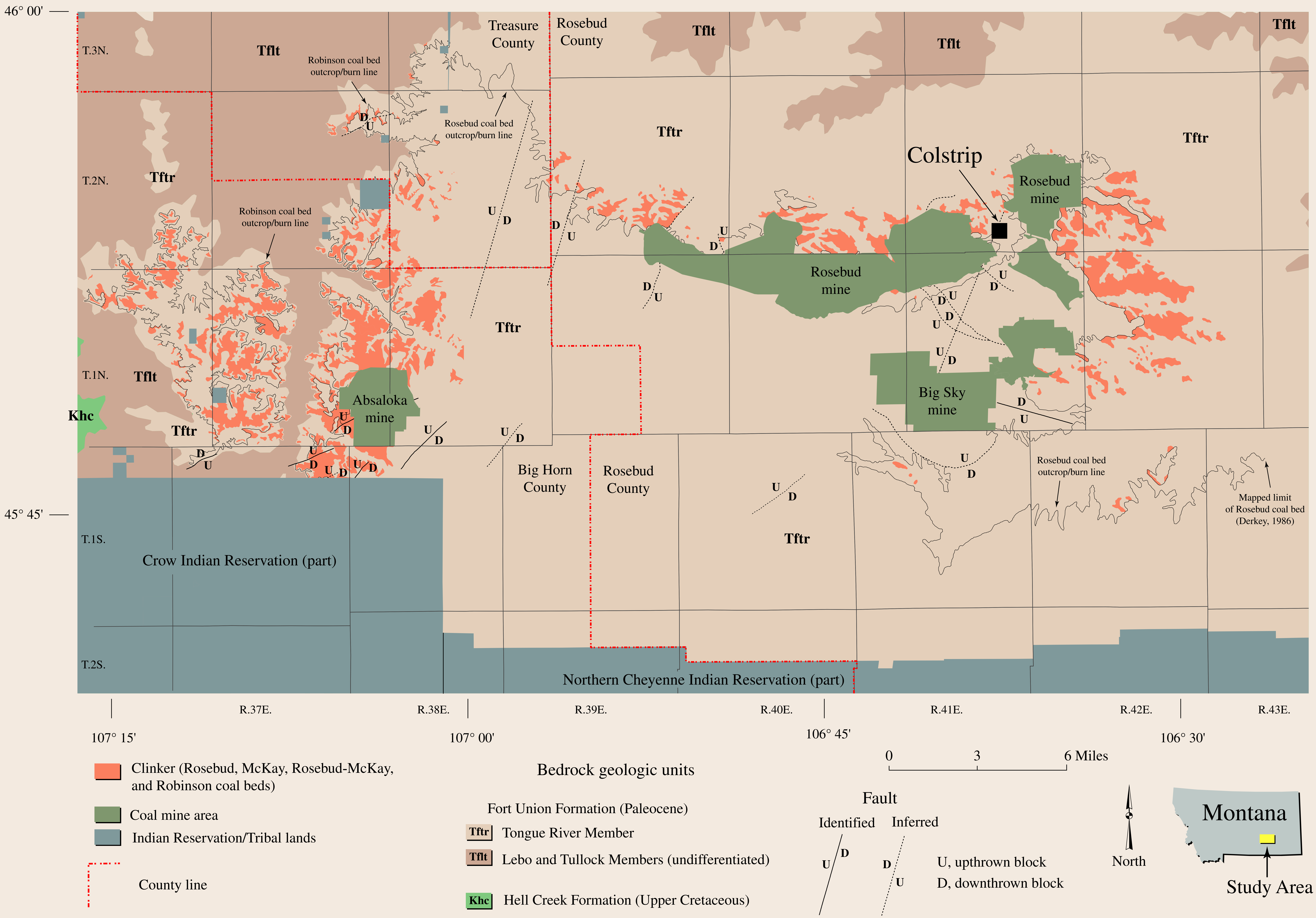


**Figure PC-5**. Generalized bedrock geologic map of the Colstrip coalfield area, south-central Montana.

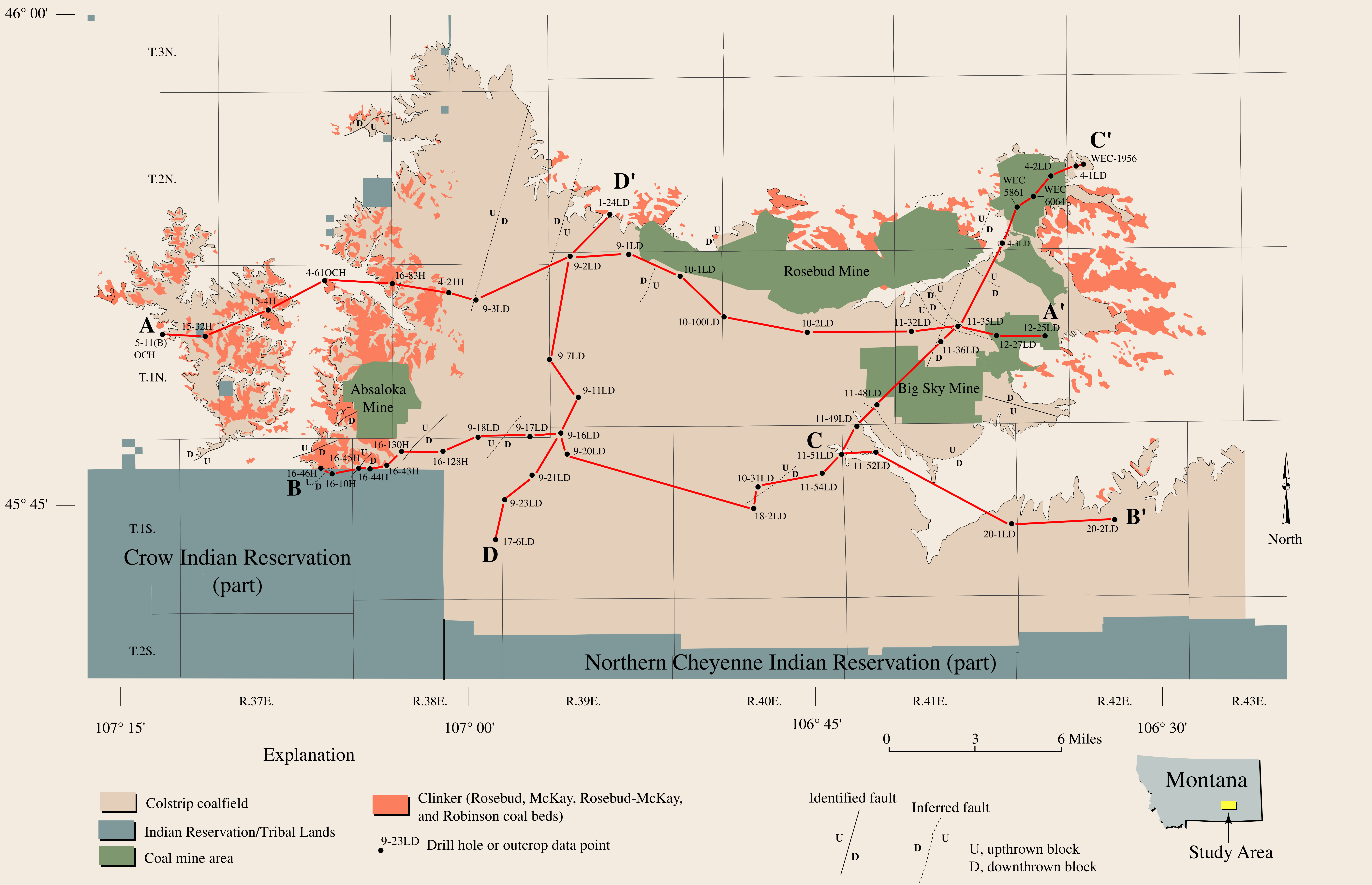


**Figure PC-6.** Index map showing cross section locations, Colstrip coalfield, south-central Montana.

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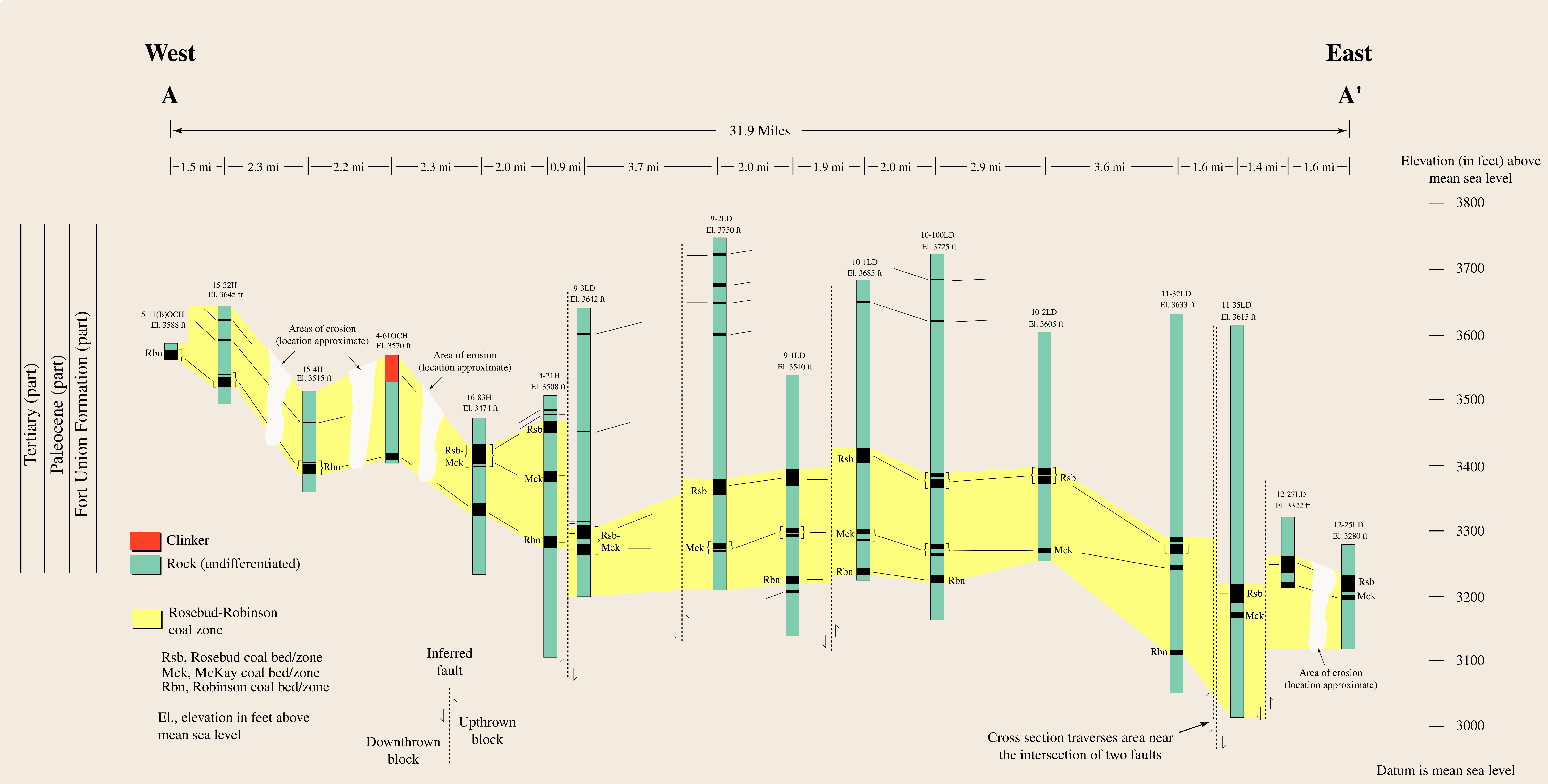


**Figure PC-7.** West-east cross section A-A', Colstrip coalfield, south-central Montana.

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in the toolbar to return.

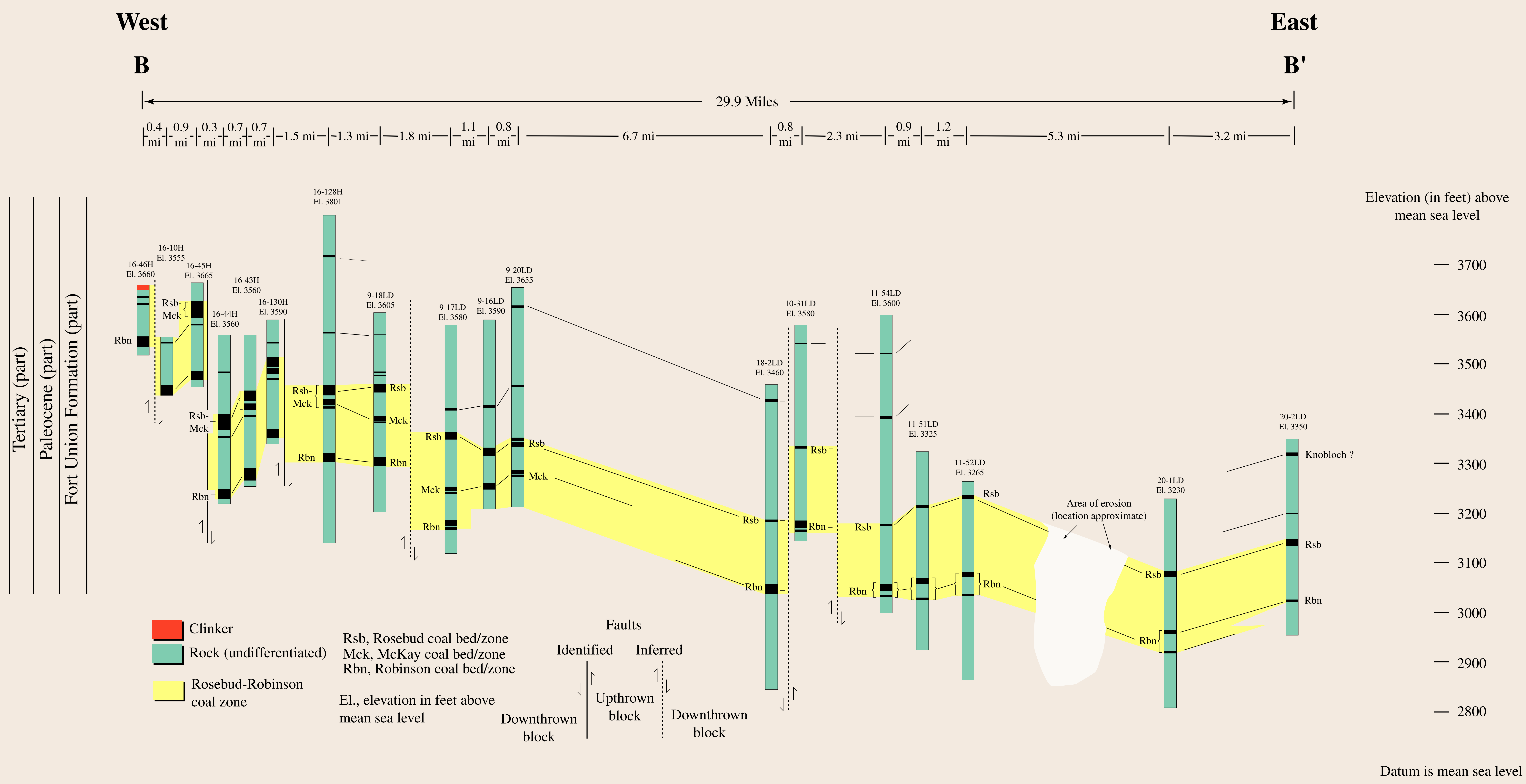


**Figure PC-8**. West-east cross section B-B', Colstrip coalfield, south-central Montana.

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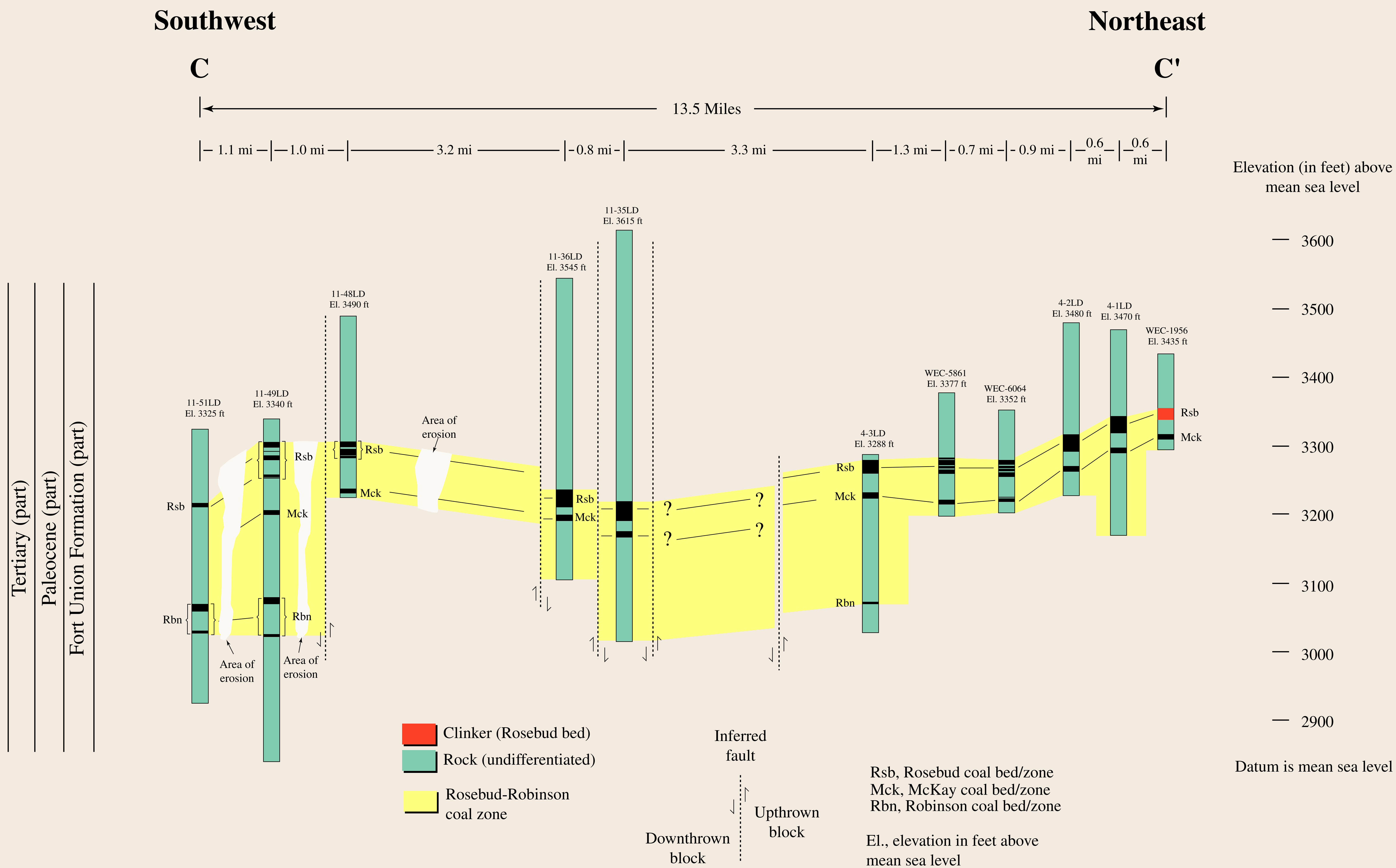


**Figure PC-9.** Southwest-northeast cross section C-C', Colstrip coalfield, south-central Montana.

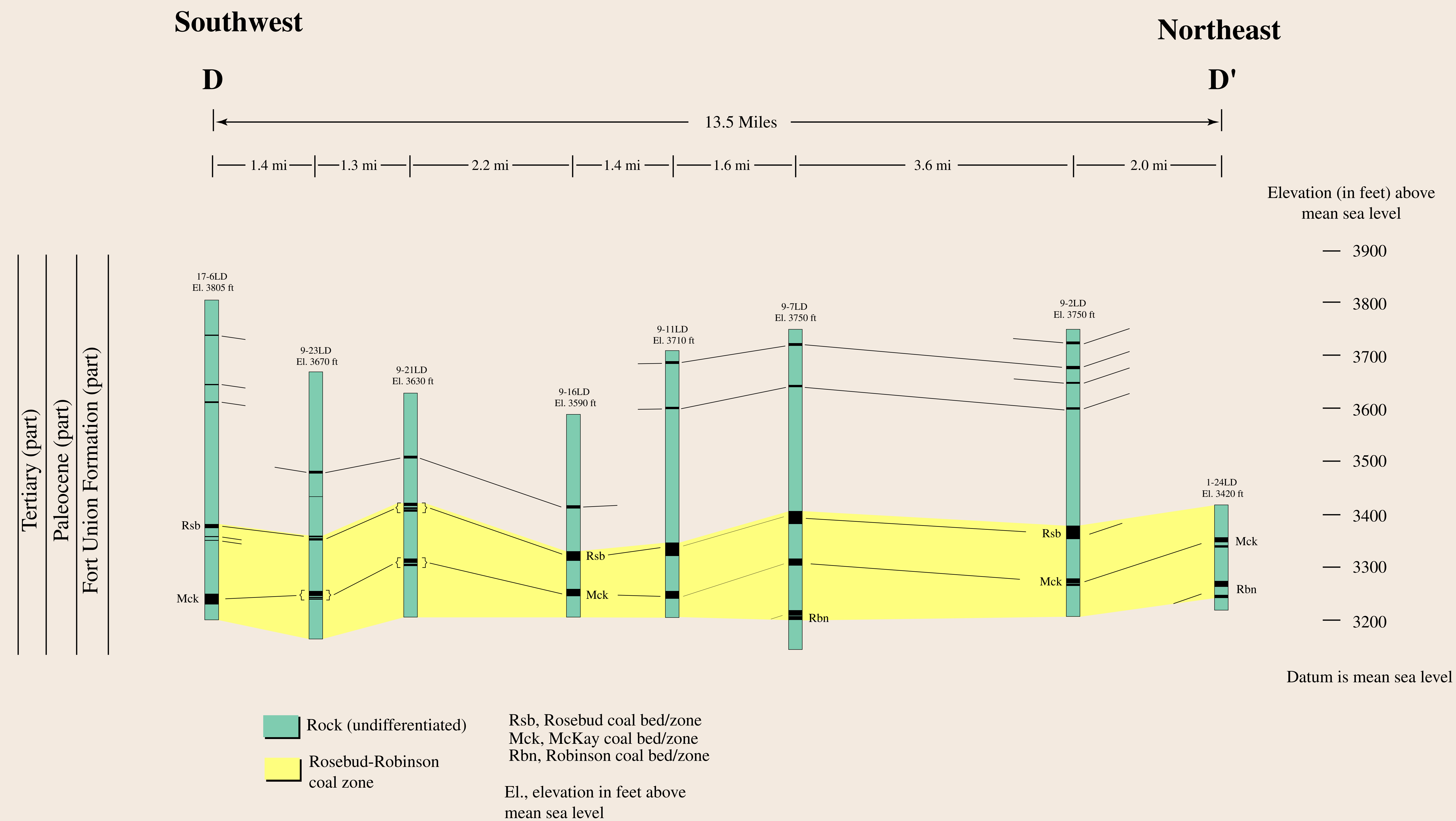


**Figure PC-10.** Southwest-northeast cross section D-D', Colstrip coalfield, south-central Montana.

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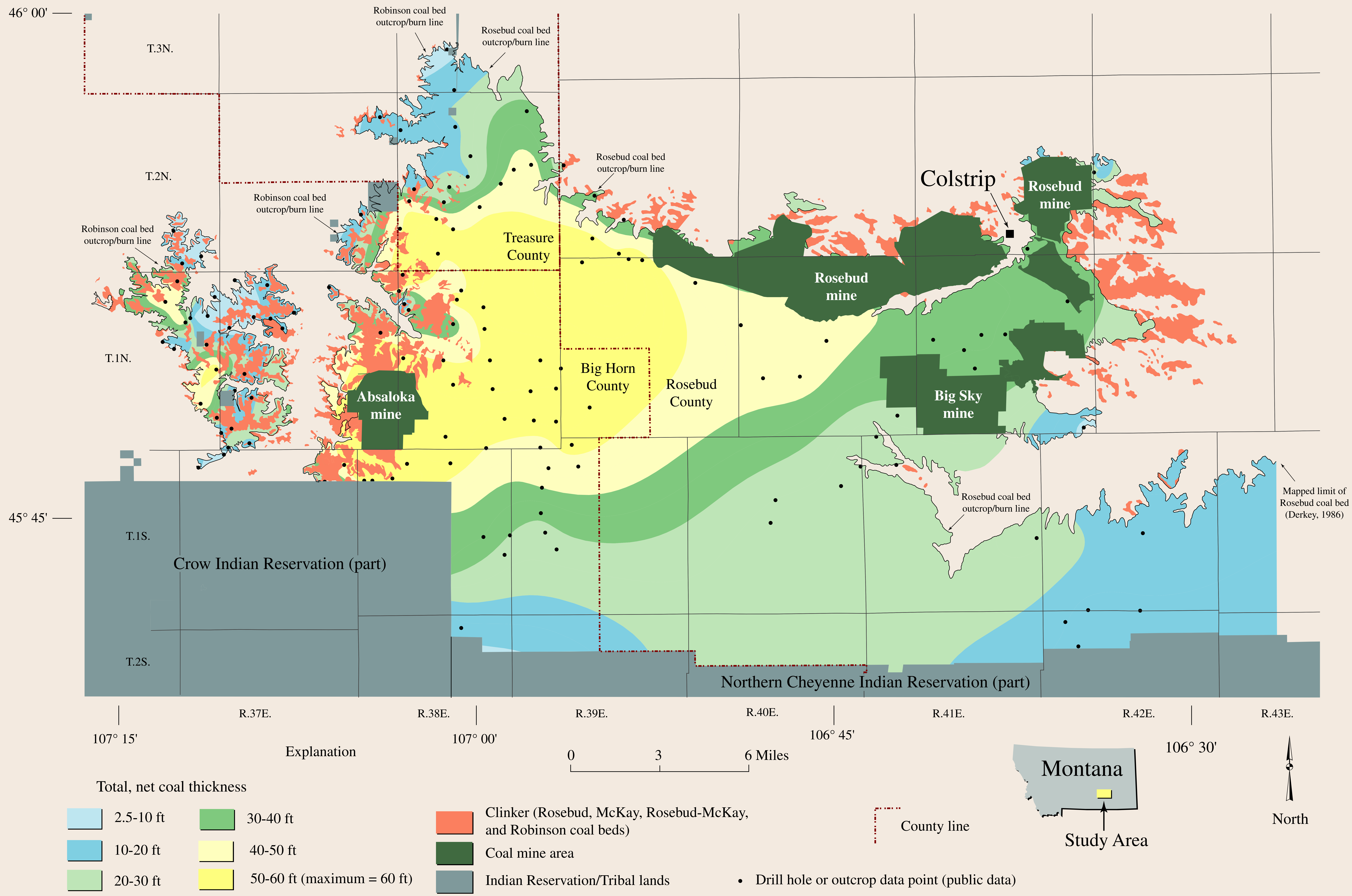


**Figure PC-11**. Total, net coal thickness (isopach) map of the Rosebud-Robinson coal zone, Colstrip coalfield, south-central Montana.

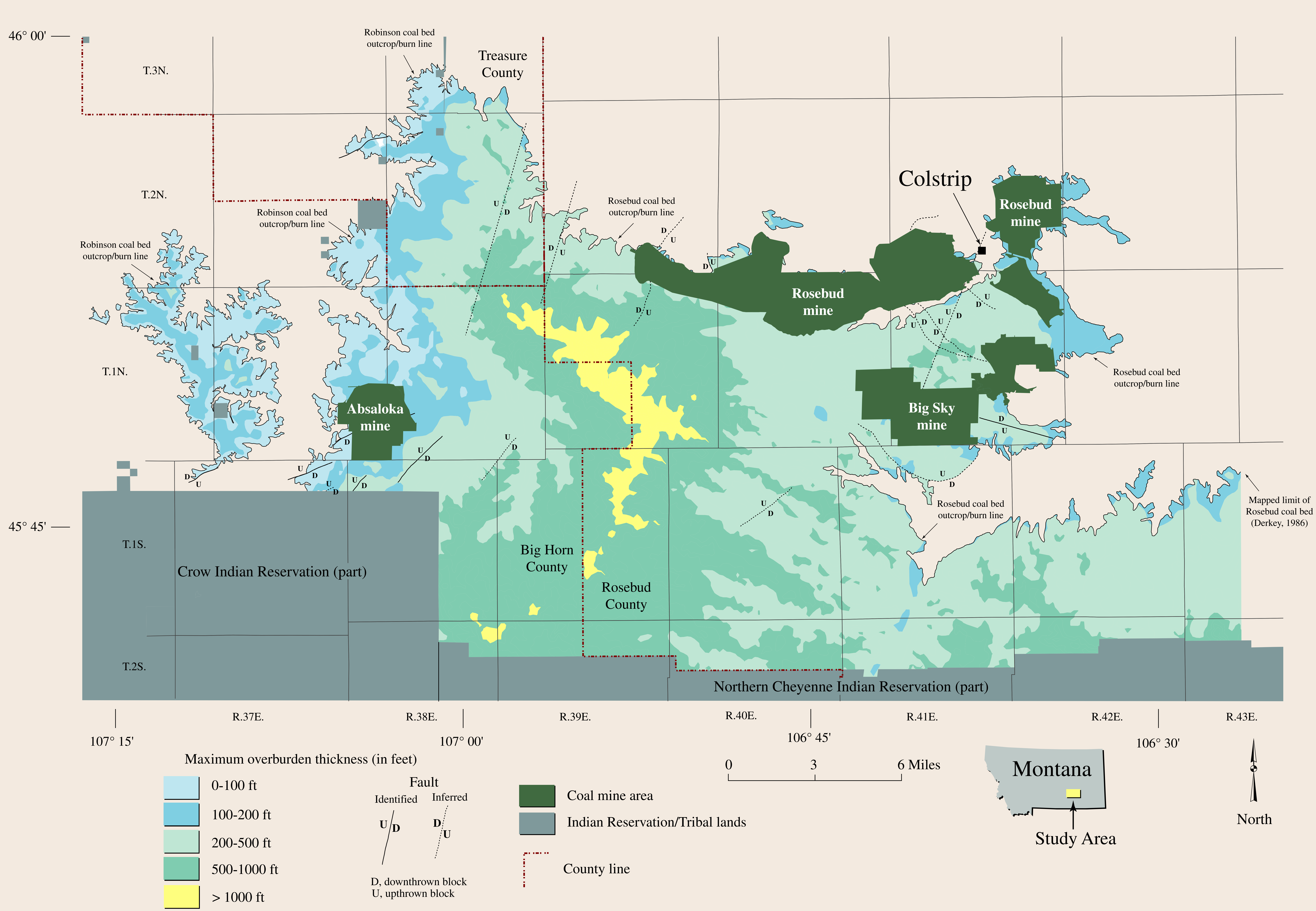


**Figure PC-12.** Map showing the estimated overburden thickness above the base of the Rosebud-Robinson coal zone, Colstrip coalfield, south-central Montana.

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**Table PC-1.** Total, net coal resources in the Rosebud-Robinson coal zone reported by county, maximum overburden, total, net coal thickness, and reliability categories. Resources do not include coal in tribal lands, areas underlying clinker, or coal mine areas. Zeros (0) indicate categories where no coal resources were calculated. Resources are reported in millions of short tons (MST) with two significant figures. Columns may not sum because of independent rounding

| County | Maximum overburden thickness | Total, net coal thickness | Reliability categories (distance from data point) | | | | Total (MST) |
|---|---|---|---|---|---|---|---|
| | | | Measured (<1/4 mi) | Indicated (1/4-3/4 mi) | Inferred (3/4-3 mi) | Hypothetical (>3 mi) | |
| BIG HORN | 0-100 ft | 2.5-5 ft | 1.3 | 2.9 | 0.023 | 0 | 4.1 |
| | | 5-10 ft | 14 | 36 | 6.9 | 0 | 57 |
| | | 10-20 ft | 11 | 110 | 91 | 0 | 210 |
| | | 20-40 ft | 13 | 150 | 100 | 0 | 260 |
| | 0-100 ft total | | 39 | 290 | 200 | 0 | 530 |
| | 100-200 ft | 2.5-5 ft | 0.093 | 0 | 0 | 0 | 0.093 |
| | | 5-10 ft | 4.4 | 5.7 | 0.32 | 0 | 10 |
| | | 10-20 ft | 9.9 | 39 | 5.3 | 0 | 54 |
| | | 20-40 ft | 70 | 310 | 92 | 0 | 470 |
| | 100-200 ft total | | 85 | 350 | 97 | 0 | 540 |
| | 200-500 ft | 5-10 ft | 0.68 | 0.34 | 0 | 0 | 1 |
| | | 10-20 ft | 21 | 61 | 4.5 | 0 | 87 |
| | | 20-40 ft | 250 | 890 | 110 | 0 | 1,300 |
| | 200-500 ft total | | 270 | 950 | 120 | 0 | 1,300 |
| | 500-1000 ft | 5-10 ft | 2.3 | 13 | 99 | 17 | 130 |
| | | 10-20 ft | 34 | 200 | 290 | 0 | 520 |
| | | 20-40 ft | 28 | 340 | 560 | 0 | 930 |
| | 500-1000 ft total | | 64 | 560 | 950 | 17 | 1,600 |
| | >1000 ft | 5-10 ft | 0 | 0 | 9.4 | 0 | 9.4 |
| | | 20-40 ft | 0 | 0 | 200 | 0 | 200 |
| | >1000 ft total | | 0 | 0 | 210 | 0 | 210 |
| BIG HORN total | | | 460 | 2,200 | 1,600 | 17 | 4,200 |

**Table PC-1.** Total, net coal resources, Rosebud-Robinson coal zone—continued

| County | Maximum overburden thickness | Total, net coal thickness | Reliability categories (distance from data point) Measured (<1/4 mi) | Indicated (1/4-3/4 mi) | Inferred (3/4-3 mi) | Hypothetical (>3 mi) | Total (MST) |
|---|---|---|---|---|---|---|---|
| ROSEBUD | 0-100 ft | 5-10 ft | 2.0 | 3.6 | 0.26 | 0 | 5.8 |
| | | 10-20 ft | 11 | 7.5 | 16 | 1.0 | 36 |
| | | 20-40 ft | 0.056 | 0.23 | 0 | 0 | 0.29 |
| | 0-100 ft total | | 13 | 11 | 16 | 1.0 | 42 |
| | 100-200 ft | 5-10 ft | 3.9 | 2.6 | 25 | 22 | 54 |
| | | 10-20 ft | 12 | 33 | 150 | 27 | 220 |
| | | 20-40 ft | 1.1 | 0.46 | 0 | 0 | 1.6 |
| | 100-200 ft total | | 17 | 36 | 180 | 49 | 280 |
| | 200-500 ft | 5-10 ft | 9.4 | 77 | 320 | 130 | 540 |
| | | 10-20 ft | 67 | 430 | 1,600 | 230 | 2,300 |
| | | 20-40 ft | 88 | 410 | 300 | 0 | 800 |
| | 200-500 ft total | | 160 | 920 | 2,200 | 360 | 3,600 |
| | 500-1000 ft | 5-10 ft | 6.2 | 30 | 79 | 42 | 160 |
| | | 10-20 ft | 22 | 78 | 950 | 310 | 1,400 |
| | | 20-40 ft | 16 | 190 | 980 | 35 | 1,200 |
| | 500-1000 ft total | | 44 | 300 | 2,000 | 380 | 2,700 |
| | >1000 ft | 10-20 ft | 0 | 0 | 39 | 5.8 | 45 |
| | | 20-40 ft | 0 | 0 | 410 | 7.7 | 420 |
| | >1000 ft total | | 0 | 0 | 450 | 14 | 460 |
| ROSEBUD Total | | | 240 | 1,300 | 4,800 | 810 | 7,100 |
| TREASURE | 0-100 ft | 5-10 ft | 2.0 | 30 | 19 | 0 | 51 |
| | | 10-20 ft | 0 | 5.1 | 1.2 | 0 | 6.4 |
| | | 20-40 ft | 2.7 | 15 | 1.7 | 0 | 19 |
| | 0-100 ft total | | 4.7 | 50 | 22 | 0 | 76 |

**Table PC-1.** Total, net coal resources, Rosebud-Robinson coal zone—continued

| County | Maximum overburden thickness | Total, net coal thickness | Reliability categories (distance from data point) | | | | Total (MST) |
|---|---|---|---|---|---|---|---|
| | | | Measured (<1/4 mi) | Indicated (1/4-3/4 mi) | Inferred (3/4-3 mi) | Hypothetical (>3 mi) | |
| TREASURE | 100-200 ft | 5-10 ft | 13 | 34 | 9.6 | 0 | 56 |
| | | 10-20 ft | 24 | 46 | 7.2 | 0 | 77 |
| | | 20-40 ft | 22 | 88 | 5.6 | 0 | 120 |
| | 100-200 ft total | | 58 | 170 | 22 | 0 | 250 |
| | 200-500 ft | 5-10 ft | 0.36 | 3.6 | 0 | 0 | 4.0 |
| | | 10-20 ft | 15 | 150 | 94 | 0 | 260 |
| | | 20-40 ft | 55 | 210 | 210 | 0 | 470 |
| | 200-500 ft total | | 70 | 370 | 300 | 0 | 740 |
| | 500-1000 ft | 10-20 ft | 0.26 | 3.2 | 9.4 | 0 | 13 |
| | | 20-40 ft | 0.81 | 7.2 | 210 | 0 | 210 |
| | 500-1000 ft total | | 1.10 | 10 | 220 | 0 | 230 |
| TREASURE total | | | 130 | 600 | 560 | 0 | 1,300 |
| Grand total (MST) | | | 830 | 4,000 | 6,900 | 830 | 13,000 |

**Table PC-2.** Total, net coal resources in the Rosebud-Robinson coal zone reported by 7.5-minute quadrangle. Coal resource totals do not include resources in tribal lands, areas underlying clinker, or in coal mine areas. Coal resources are reported in millions of short tons (MST) with two significant figures. Column may not sum due to independent rounding

| 7.5-minute Quadrangle | Total (MST) |
|---|---|
| BADGER PEAK | 520 |
| BLACK SPRING | 810 |
| CHALKY POINT | 730 |
| COLSTRIP EAST | 67 |
| COLSTRIP SE | 340 |
| COLSTRIP SW | 1,000 |
| COLSTRIP WEST | 6.8 |
| GARFIELD PEAK | 200 |
| HAMMOND DRAW SW | 51 |
| IRON SPRING | 8.0 |
| IRON SPRING SW | 320 |
| JEANS FORK NE | 92 |
| JIMTOWN | 690 |
| McCLURE CREEK | 980 |
| MINNEHAHA CREEK SOUTH | 540 |
| ROUGH DRAW | 2,100 |
| SARPY SCHOOL | 3,100 |
| TRAIL CREEK SCHOOL | 40 |
| WOLF SCHOOL | 1,100 |
| Grand total (MST) | 13,000 |

**Table PC-3.** Total, net coal resources in the Rosebud-Robinson coal zone reported by county and by Federal coal and surface ownership. Coal resource totals do not include resources in tribal lands, areas underlying clinker, or in coal mine areas. Coal resources are reported in millions of short tons (MST) with two significant figures. Column may not sum due to independent rounding

| County | Federal ownership | Total (MST) |
|---|---|---|
| BIG HORN | No Federal coal or surface ownership | 2,800 |
| | Federal coal, but no Federal surface ownership | 1,300 |
| | Federal coal and surface ownership | 97 |
| BIG HORN total | | 4,200 |
| ROSEBUD | No Federal coal or surface ownership | 4,000 |
| | Federal coal, but no Federal surface ownership | 3,000 |
| | Federal coal and surface ownership | 190 |
| ROSEBUD total | | 7,100 |
| TREASURE | No Federal coal or surface ownership | 910 |
| | Federal coal, but no Federal surface ownership | 370 |
| | Federal coal and surface ownership | 2.0 |
| TREASURE total | | 1,300 |
| Grand total (MST) | | 13,000 |

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**Table PC-4.** Computations of confidence intervals within reliability categories for estimated total coal resources in the Rosebud-Robinson coal zone in the Colstrip coalfield, Montana. Volume refers to the calculated resource in millions of short tons (MST). NA, not applicable

| Parameter | Reliability category | | | | Entire Area |
|---|---|---|---|---|---|
| | Measured | Indicated | Inferred | Hypothetical | |
| Area (in square meters) | 53,972,398 | 249,745,998 | 493,881,231 | 87,696,026 | 885,295,653 |
| Percent of area | 6 | 28 | 56 | 10 | 100 |
| Acres | 13,337 | 61,714 | 122,041 | 21,670 | 218,761 |
| SD (Standard deviation (in ft) from variogram model) | 9.216 | 11.122 | 13.049 | 13.197 | NA |
| Acre feet (Acres x SD) | 122,916 | 689,387 | 1,592,500 | 285,976 | NA |
| Volume standard deviation (MST) | 21 | 164 | 1,085 | 506 | 1,777 |
| Pseudo *n* (Minimum number of points in the area) | 106 | 55 | 7 | 1 | NA |

**Table PC-5.** Volume and estimates of uncertainty for estimated total coal resources in the Rosebud-Robinson coal zone, Colstrip coalfield, Montana, with measurement error. Resource calculations are in millions of short tons (MST) with four significant figures. Volume refers to the calculated resource in millions of short tons (MST).

| Parameter | Reliability category | | | | Entire area |
|---|---|---|---|---|---|
| | Measured | Indicated | Inferred | Hypothetical | |
| Estimated total coal resources (MST)) | 832 | 4,017 | 6,948 | 826 | 12,620 |
| Lower 90% confidence bound (MST) | 797 | 3,746 | 5,162 | 0 | 9,699 |
| Upper 90% confidence bound (MST) | 867 | 4,287 | 8,733 | 1,659 | 15,550 |