Chapter PH

SHERIDAN COALFIELD, POWDER RIVER BASIN: GEOLOGY, COAL QUALITY, AND COAL RESOURCES

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STRUCTURAL AND STRATIGRAPHIC SETTING

The Sheridan coalfield contains the Fort Union Formation (Paleocene) that includes, from bottom to top, the Tullock, Lebo, and Tongue River Members (fig. PH-1). These members are mainly distributed in the western part of the coalfield (see fig. PH-1; Barnum, 1974, 1975; Ebaugh, 1976; Kanizay, 1978; Law and others, 1979).

The Eocene Wasatch Formation, which conformably overlies the Fort Union Formation, is distributed in the easternmost part of the coalfield (see fig. PH-1; Culbertson, 1975; Culbertson and Mapel, 1976). Undifferentiated Fort Union Formation is in the southwestern part of the coalfield. The contact between these formations is not delineated in the subsurface because they have basically the same lithology and are difficult to correlate. However, the surface contact between the Wasatch and Fort Union Formations is placed at the top of the Roland coal bed, following Baker (1929). These rocks dip 1-3 degrees eastward.

The Sheridan coalfield boundary approximately follows the area defined by Taff (1909), who investigated the mining areas in the Fort Union Formation north and northwest of Sheridan, and mapped Wasatch coal east of Sheridan. In this study, the Sheridan coalfield (see fig. PH-1) is delineated by the surface contact line of the Lebo and Tongue River Members on the west, the surface contact line of the undifferentiated Fort Union and Tongue River Members on the south, the 106-degree, 45-minute longitude line on the east, and the Wyoming and Montana State line on the north.

The coal beds of the Wyodak-Anderson coal zone of the Tongue River Member of the Fort Union Formation are mined in the Sheridan coalfield and are locally named, from top to bottom, Dietz 2, Dietz 3, and Monarch (Canyon) coal beds (Law and others, 1979). These coal beds, including the Carney coal (more than 20 ft below the Monarch or Canyon coal), were extensively mined by underground methods (Taff, 1909; Dunrud and Osterwald, 1980).

These coal beds merge, split, or pinch out into mudstone, siltstone, and sandstone. These rocks are undifferentiated in the cross sections. The Fort Union rocks are displaced by numerous northeast-southwest-trending normal faults.

The coal beds are interbedded with carbonaceous shale, mudstone, siltstone, and sandstone as seen in the highwalls of the Big Horn coal mine (figs. PH-1 and PH-2). Here, the sandstone is fining-upward, shows an erosional base, and contains trough crossbeds that indicate a fluvial channel deposit (fig. PH-3). The sandstone is interbedded with, and laterally grades into, a tabular, rippled silty sandstone, which in turn is interbedded with mudstone and siltstone; these rocks are crevasse splay and floodplain deposits (fig. PH-4). The fluvial deposits are interbedded with the Dietz and Monarch (Canyon) coal beds (fig. PH-5) that accumulated in raised swamps and total as much as 54 ft in thickness.

The Wyodak-Anderson coal zone of the Tongue River Member is in the west-northwest part of the Sheridan coalfield near the city of Sheridan, Wyoming. Clinker, resulting from burned coal and related rocks of this zone, is well developed northwest of Sheridan (Kanizay, 1978).

The Anderson, Dietz, and Canyon (Monarch) coal beds of the Wyodak-Anderson coal zone were mined from 20 underground mines from 1894 to 1976 (Dunrud and

Osterwald, 1980). Surface subsidence pits and troughs mark locations of these abandoned underground mine workings.

These coal beds were strip mined in the Big Horn mine (see fig. PH-1) from 1962 to present. Annual mine production from 1989 to 1997 has declined from 106,000 to 43,000 short tons (Resource Data International, Inc., 1998).

DEPOSITIONAL SETTING

The stratigraphic variation, thickness, distribution, and shape of the Wyodak-Anderson coal zone (see cross sections; fig. PH-6) reflect its deposition in raised mires formed in meandering and anastomosed fluvial systems.

WYODAK-ANDERSON COAL ZONE—SHERIDAN COALFIELD

SHERIDAN COALFIELD STRUCTURAL CROSS SECTION A-A'

- The north-south oriented structural cross section A-A' (fig. PH-7) is more than 18 mi long. The Wyodak-Anderson coal zone, which is 300-ft thick, shows merging and splitting of as many as five coal beds. The coal beds dip south-southeast. This cross section was drawn using data from 19 drill holes, which are not labeled on the cross section.

- The coal beds of the Wyodak-Anderson coal zone are interbedded with, and split by, undifferentiated mudstone, siltstone, and sandstone (shown in green) that were deposited in floodplains, crevasse splays, and fluvial channels.

- The coal beds of the Wyodak-Anderson coal zone commonly pinch out into fluvial deposits.

- The coal beds of the Wyodak-Anderson coal zone tend to merge and pinch out in the central part of the cross section, pinch out to the south, and thicken to the north.

- The coal beds of the Wyodak-Anderson in the northern part of the cross section display a tabular geometry.

- The coal beds of the Wyodak-Anderson coal zone in the southern part of the cross section exhibit lenticular geometry.

- The lateral and vertical variations and geometry of the coal beds are controlled by the depositional environments of the coal and associated detrital sediments.

- Merging and splitting of the coal beds reflect absence or presence of fluvial channel deposits, respectively. Deposits of fluvial channels, such as sandstone, tend to split and expand the interval between coal beds due to compaction effects. During burial, sandstone is less compactible by overlying sediment than mudstone. Thus coal beds interbedded with mudstone tend to merge upon compaction by overlying sediments.

- Lateral migration and avulsion or shift of fluvial channels of meandering streams created “want areas” where the coal beds of the Wyodak-Anderson coal zone pinch out. Such areas are shown in the central part of the cross section.

- Local and regional subsidence, in combination with deposition in rain-fed raised mires that formed away from fluvial channels, controlled the accumulation of thick Wyodak-Anderson coal beds, and kept their ash content low.

- The undifferentiated Fort Union and Wasatch rocks above and Fort Union rocks below the Wyodak-Anderson coal zone are each more than 500 ft thick. The rocks include undifferentiated fluvial-channel, overbank, floodplain, and lacustrine deposits.

SHERIDAN COALFIELD STRUCTURAL CROSS SECTION B-B’

- The west-east oriented structural cross section B-B’ (fig. PH-8) is more than 18 mi long. The Wyodak-Anderson coal zone, as much as 250 ft thick, shows merging and splitting of as many as three coal beds that dip east. This cross section was drawn using data from 20 drill holes, which are not labeled on the cross section.

- Individual coal beds of the Wyodak-Anderson coal zone locally split, merge, and pinch out into undifferentiated mudstone, siltstone, and sandstone (shown in green) that were deposited in floodplains, crevasse splays, and fluvial channels.

- Splitting, merging, and pinching out of coal beds of the Wyodak-Anderson coal zone are common in the central and eastern parts of the cross section.

- Toward the west, the coal beds of the Wyodak-Anderson coal zone are laterally uniform and are interbedded with moderately thick, undifferentiated mudstone, siltstone, limestone, and sandstone (shown in green).

- The coal beds and the Wyodak-Anderson coal zone are uniformly thick from west to east. This indicates the absence of major fluvial-channel deposits that would disrupt and expand the interval.

- The lateral and vertical variations and geometry of the coal beds are controlled by the depositional environments of the coal and associated detrital sediments.

- The uniform distribution of the coal beds and coal zone suggests that precursor peat accumulated on interchannel raised mires, which probably occupied abandoned fluvial-channel and floodplain deposits.

- The undifferentiated Fort Union and Wasatch rocks above and Fort Union rocks below the Wyodak-Anderson coal zone are as much as 600 ft thick and more than 400 ft thick, respectively. The intervals are composed of undifferentiated fluvial-channel sandstone and overbank, floodplain, lacustrine mudstone, and siltstone.

SHERIDAN COALFIELD STRUCTURAL CROSS SECTION C-C'

- The west-east oriented structural cross section C-C' (fig. PH-9) is more than 15 mi long. The Wyodak-Anderson coal zone, as much as 250 ft thick, contains merging and splitting coal beds that dip eastward. This cross section was drawn using data from 13 drill holes, which are not labeled on the cross section.
- The coal beds merge in the central part of the cross section to form a bed about 50 ft thick.

- Toward the west and east, the coal beds of the Wyodak-Anderson coal zone are interbedded with and split by undifferentiated mudstone, siltstone, and sandstone (shown in green) that was deposited in floodplains and floodplain lakes, fluvial channels, and crevasse splays.

- The coal beds of the Wyodak-Anderson coal zone thin and pinch out toward the west, suggesting the extent of the raised mire in which the coal formed.

- The peat probably accumulated in an interchannel raised mire flanked by fluvial channels and/or crevasse splays. The thickening of detrital sediments associated with the split and pinched out coal beds may represent levee, overbank, or crevasse deposits that periodically intruded the adjoining mire.

- The undifferentiated Fort Union and Wasatch rocks above and Fort Union rocks below the Wyodak-Anderson coal zone are as much as 1,100 ft thick and more than 450 ft thick, respectively. The rocks consist of interbedded fluvial-channel sandstone, and overbank, floodplain, and lacustrine mudstone.

COAL QUALITY

Actively mined coal in the Sheridan coalfield, Powder River Basin, Wyoming is considered to be a "clean coal." Coal from the Sheridan coalfield is developed from one mine and utilized for electric power generation. The coal is a low-contaminant, compliant, subbituminous coal resource.

The Sheridan coalfield has one assessment unit, the Wyodak-Anderson coal zone. This coal zone has the following arithmetic mean values (on an as-received basis) for coal that is not presently being mined or under lease to be mined in the future: **moisture**–20.40%, **ash yield**–5.30%, **total sulfur**–0.70%, **calorific value**–9,540 (Btu/lb), **lb SO_2 per million Btu**–1.48, and **moist, mineral-matter-free Btu**–10,120. Arithmetic mean concentration (in parts per million and on whole-coal and remnant-moisture basis) of elements of environmental concern for the Wyodak-Anderson coal zone are: **antimony**–0.24, **arsenic**–3.2, **beryllium**–0.21, **cadmium**–0.09, **chromium**–3.6, **cobalt**–1.2, **lead**–1.8, **manganese**–21, **mercury**–0.08, **nickel**–4.8, **selenium**–0.45, and **uranium**–0.58. Table PH-1 is a summary of coal quality in this coalfield.

Summary data for the 18 variables mentioned in the previous paragraph were calculated for the Wyodak-Anderson coal zone. A common problem in statistical summaries of trace-element data arises when element values are below the limits of detection. This results in a censored distribution. To compute unbiased estimates of censored data for the elements in this table, we adopted the protocol of reducing all "less than" values by 50 percent to generate a real value for these data. Summary statistics of range (minimum and maximum value) and arithmetic means were generated using the modified data. Moisture values are reported on an as-received basis (American Society for Testing and Materials, 1994b, designation D3180-89). Because no equilibrium moisture values are available for this report, apparent ranks can not reliably be determined.

Between 1974 and 1994, the U.S. Geological Survey analyzed samples of coal for contents of major-, minor-, and trace-elements. Prior to performing the analyses, most of the coal samples were dried at room temperature and humidity for as much as 80 hours. However, some samples may have been dried only long enough to allow grinding (to less than 100 mesh). Moisture content in the samples is unknown, although moisture contents were probably similar to that which would remain after air-dry loss determination (American Society for Testing and Materials, 1994c, D3302-91). Since the actual moisture content of the samples analyzed between 1974 and 1994 is unknown, the elemental analysis of the samples cannot be converted to any other moisture basis. In addition, these analyses can only provide an approximation of load factors (such as, pounds of mercury per trillion Btu).

The locations of public data points used in the summary table are shown in figure PH-10. When more than one analysis was available per location, the analytical values were weight averaged on coal sample thickness. Figures PH-11 through PH-26, show values of the variables listed in the summary table for coal in the Wyodak-Anderson coal zone, except for calorific value and moisture content. For ash yield (fig. PH-11) and total sulfur content (fig. PH-12), the values are coded to low, medium, and high, following guidelines established in U.S. Geological Survey Circular 891 (Wood and others, 1983). For moist, mineral-matter-free Btu (apparent rank) (fig. PH-13), the apparent rank designations established by American Society for Testing and Materials, (1994a), designation D388-92a were utilized. For pounds of sulfur dioxide per million Btu ($lbSO_2$) (fig. PH-14), values are coded according to the U.S. Environmental Protection Agency's Phase I (low), Phase II (medium), and non-compliant (high) limits for sulfur emission from coal-fired power plants (U.S. Environmental Protection Agency, 1996).

No guidelines have been established for the elements of environmental concern (also referred to as "hazardous air pollutants" or "HAPs"). Analytical values for these elements (fig. PS-15 to PS-26) are color keyed based on the following parameters: (1) each element of environmental concern was ranked from the lowest to highest value for all data in the northern Rocky Mountains and Great Plains region; and (2) quartiles were established for each element. Low represents those values that are less than the .25 quartile (also known as the lower quartile or the 25th percentile). Medium represents those values that are within the .25 to .75 quartiles (two quartiles representing 50 percent of the values or between the 25th to 75th percentile). High represents those values that are in the upper .25 quartile (or greater than the 75th percentile).

COAL RESOURCES—WYODAK-ANDERSON COAL ZONE

RESOURCE ESTIMATES—AN OVERVIEW

- Coal resources are calculated using the specific gravity of the coal calculated from apparent coal rank, which is the weight of coal per unit volume, net coal thickness, and areal extent of the coal.

- Resource tables for the Wyodak-Anderson coal zone in the Sheridan coalfield include coal and overburden thickness categories from Wood and others (1983), which are based on apparent coal rank. Additional categories have been added to provide more detail in this area. Resources are also reported by Federal coal and surface ownership, and 7.5-minute quadrangle.

- Following USGS published guidelines (Wood and others, 1983); coal resource estimates are divided into measured, indicated, and inferred categories according to relative abundance and reliability of data.

- Where data are widely spaced, a hypothetical resource is extrapolated.

- Measured resources are tonnage estimates of coal in the coal zone within a radius of 0.25 mi of a control point where the net thickness of coal is measured.

- Indicated resources are tonnage estimates of coal that is within a radius of 0.25-0.75 mi of a control point where the net thickness of the coal is measured.

- Inferred resources are tonnage estimates of coal that is within a radius of 0.75-3 mi of a control point where the net thickness of the coal is measured.

- Hypothetical resources are tonnage estimates of coal that is beyond a radius of 3 mi of a control point where the net thickness of coal is measured.

- These resource categories assume a high to low degree of geologic certainty. A statistical method, which measures levels of uncertainty (confidence limits) for the Wyodak-Anderson resource estimates in the Sheridan coalfield, is also included in this study.

- Resource estimates are reported in millions of short tons with two significant figures.

WYODAK-ANDERSON COAL RESOURCES

The western extent (study limit) of the Wyodak-Anderson coal zone in the Sheridan coalfield is based on the Wyodak-Anderson outcrop or the Tertiary/Cretaceous contact from published maps by Baker (1929), Love and Christiansen (1985), and Green and Drouillard (1994). The western study limit was generalized in some areas to include small areas of coal outside of the main boundary. The eastern boundary was placed at the 106-degree, 45-minute longitude line; the southern boundary was delineated by the 44-degree, 45-minute latitude line; and the northern boundary was placed at the Montana/Wyoming state line. The total study area is 161,898 acres (65,518 hectares) in size.

Wyodak-Anderson coal resources in the Powder River Basin of Wyoming and Montana were calculated using several software packages and custom programs. Details of the methodology used are given in Ellis and others (1999, in press).

To calculate the Wyodak-Anderson coal resources in the Sheridan coalfield we compiled data in a StratiFact* (GRG Corporation, 1996) relational database. The coal beds in the Wyodak-Anderson coal zone, including the Anderson, Dietz, Canyon, and Monarch beds (see the explanation of coal bed nomenclature in chapter PS of this CD-ROM), were correlated in the database. We used a custom program to calculate the net coal thickness at each data point (drill hole or measured section) location.

The net coal thickness and overburden were gridded, and isopach maps were produced using EarthVision* (Dynamic Graphics, Inc., 1997) software. The grids were made using an isopach grid option (special handling of 0 values and terminated data) with a grid spacing of 200 x 200-meters.

The spatial parameters for querying the coal resources, for example 7.5-minute quadrangle map area (fig. PH-27, U.S. Geological Survey National Mapping Division unpublished data, undated), Federal coal and surface ownership (fig. PH-28, Biewick and others, 1998), net coal thickness (fig. PH-29), and overburden categories (fig. PH-30)) were created on individual layers as ARC/INFO* (ESRI, 1998a) polygon coverages. The coverages were unioned to make one polygon coverage with many attributes for each polygon. The polygons in the union coverage were edited in ARC/INFO* and ArcView* (ESRI, 1998b).

Coal resources were calculated using the EarthVision* (EV) volumetrics tool, which calculates tonnages in each polygon in the union coverage using the net coal thickness grid, the area of each polygon, and a conversion factor of 1,770 short tons per acre-ft for subbituminous rank coal (Wood and others, 1983). Data from the EV volumetrics report and the union coverage polygon attribute table were combined in Excel* (Microsoft, 1997) spreadsheet software. Data for polygons containing Wyodak-Anderson clinker (fig. PH-31) (Kanizay, 1978), Wyodak-Anderson mine or lease areas (fig. PH-31) (Dunrud and Osterwald, 1980), or areas of net coal less than 2.5 ft in thickness were deleted from the data set. Lease areas may include public and/or state leases in addition to Federal leases. Resource tables were created using data from the remaining polygons (tables PH-1 through PH-3). The final resource area (fig. PH-31) (area that met all coal resource criteria) was 149,662 acres (60,566 hectares) in area.

*Commercial software package.

CONFIDENCE LIMITS FOR WYODAK-ANDERSON COAL RESOURCES IN THE SHERIDAN COALFIELD

A confidence interval is a statistic designed to capture uncertainty associated with a point value estimate. In this study we computed 90-percent confidence intervals on the volume (total resource in millions of short tons) of coal in the Wyodak-Anderson coal zone in the measured, indicated, inferred, and hypothetical categories.

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 apply 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.

Confidence limits for coal resources of the Wyodak-Anderson coal zone in the Sheridan coalfield were calculated by J.H. Schuenemeyer and H.C. Power (University of Delaware). The data set that they used contained net coal measurements from 193 locations. This data set only included locations that contained Wyodak-Anderson coal (no 0 coal thickness values) and data that were representative of the entire coal zone (no terminated holes)).

The confidence limits were derived through a complex series of steps. These steps included modeling coal thickness trends and removing the coal thickness trends using a nonparametric regression algorithm called loess (with span=0.5). Spatial correlation, as determined from the semivariogram of residual thickness, was negligible. Standard deviation of coal thickness was computed from residual thickness. Differences in point densities were compensated for by calculating sample size, called a pseudo *n*, within each reliability category and calculating the variability of volume for each of the reliability categories. Volumes of Wyodak-Anderson coal were then calculated at a 90-percent confidence interval with measurement error. Some of the parameters used and results of the confidence interval calculations are shown in tables PH-5 and PH-6. A detailed description of the methodology used is given in Schuenemeyer and Power (in press), and in Ellis and others (1999; in press).

REFERENCES

American Society for Testing and Materials, 1994a, Annual book of ASTM Standards, Section 5, Petroleum products, lubricants and fossil fuels, vol. 05.05 Gaseous fuels; coal and coke; section D388-92a; Standard Classification of Coal by Rank: American Society for Testing and Materials, Philadelphia, Pennsylvania, p. 168-171.

1994b, Annual book of ASTM Standards, Section 5, Petroleum products, lubricants and fossil fuels, vol. 05.05 Gaseous fuels; coal and coke; section D3180-89; Standard Practice for Calculating Coal and Coke Analysis from As-Determined to Different Bases: American Society for Testing and Materials, Philadelphia, Pennsylvania, p. 318-320.

_____1994c, Annual book of ASTM Standards, Section 5, Petroleum products, lubricants and fossil fuels, vol. 05.05 Gaseous fuels; coal and coke; section D3302-91; Standard Test Method for Total Moisture in Coal: American Society for Testing and Materials, Philadelphia, Pennsylvania, p. 330-336.

Baker, A.A., 1929, The northward extension of the Sheridan coal field, Big Horn and Rosebud Counties, Montana: U.S. Geological Survey Bulletin 806-B, p. 15-67.

Barnum, B.E., 1974, Preliminary geologic map and coal resources of the Ranchester quadrangle, Sheridan County, Wyoming, and Big Horn County, Montana: U.S. Geological Survey Open-File Report 74-35, 4 p., 2 sheets.

_____1975, Geologic map and coal resources of the Ranchester quadrangle, Sheridan County, Wyoming, and Big Horn County, Montana: U.S. Geological Survey Coal Investigations Series Map C-75, scale 1:24,000.

Biewick, Laura R.H., Urbanowski, Shayne R., Cain, Sheila, and Neasloney, Larry, 1998, Land status and Federal mineral ownership in the Powder River Basin, Wyoming and Montana: a digital data set for geographic information systems: U.S. Geological Survey Open-File Report 98-108, coverage scale 1:100,000.

Bragg, L.J., Oman, J.K., Tewalt, S.J., Oman, C.L., Rega, N.H., Washington, P.M., and Finkleman, R.B, 1994, U.S. Geological Survey Coal Quality (Coalqual) Database: Version 1.3: U.S. Geological Survey Open-File Report 94-205, CD-ROM.

Culbertson, W.C., 1975, Preliminary geologic map and coal sections of the Wyarno quadrangle, Sheridan County, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-723, scale 1:24,000.

Culbertson, W.C., and Mapel, W.J., 1976, Coal in the Wasatch Formation, northwest part of the Powder River basin near Sheridan, Sheridan County, Wyoming: Wyoming Geological Association, 28th Annual Field Conference, p. 193-201.

Dunrud, C.R. and Osterwald, F.W., 1980, Effects of coal mine subsidence in the Sheridan, Wyoming area: U.S. Geological Survey Professional Paper 1164, p.7, figure 4.

Dynamic Graphics, Inc., 1997, EarthVision, v.4, 1015 Atlantic Ave., Alameda, CA 94501.

Ebaugh, W.F., 1976, Preliminary surficial and bedrock geologic map of the Big Horn quadrangle, Sheridan County, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-801, scale 1:24,000.

Ellis, M.S., Gunther, G.L., Flores, R.M., Ochs, A.M., Stricker, G.D., Roberts, S.B., Taber, T.T., Bader, L.R., and Schuenemeyer, J.H., 1999, Preliminary report on coal resources of the Wyodak-Anderson coal zone, Powder River Basin, Wyoming and Montana: U.S. Geological Survey Open-File Report 98-789A.

Ellis, M.S., Gunther, G.L., Flores, R.M., Stricker, G.D., and Ochs, A.M., in press, Preliminary report on methodolgy for calculating coal resources of the Wyodak-Anderson coal zone in the Powder River Basin, Wyoming and Montana: U.S. Geological Survey Open-File Report 98-789B.

ESRI-Environmental Systems Research Institute, Inc., 1998a, ARC/INFO, v. 7.1.1, 380 New York Street, Redlands, CA 92373, USA.

_____1998b, ArcView, v.3.0a, 380 New York Street, Redlands, CA 92373, USA.

Green G.N. and Drouillard, P.H., 1994, The digital geologic map of Wyoming in ARC/INFO format: U.S. Geological Survey Open-File Report 94-0425.

GRG Corporation, 1996, StratiFact, relational database software, v. 4.5: GRG Corporation, 4175 Harlan Street, Wheatridge, CO 80033-5150, USA.

Kanizay, S.P., 1978, Preliminary geologic map of the Sheridan area, northwestern Powder River Basin, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-1043, scale 1:50,000.

Law, B.E., Barnum, B.E., and Wollenzien, T.P., 1979, Coal bed correlations in the Tongue River Member of the Fort Union Formation, Monarch, Wyoming, and Decker Montana, areas: U.S. Geological Survey Miscellaneous Investigations Series Map I-1128.

Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.

Microsoft, 1997, Excel spreadsheet software, v. Office 97: Microsoft Corporation, 1 Microsoft Way, Redman, WA 98052.

Resource Data International, Inc., 1998, COALdat coal database: Resource Data International, Inc., 1320 Pearl St., Suite 300, Boulder, Colorado 80302.

Schuenemeyer, J. H. And Power H., in press, Uncertainty Estimation For Resource Assessment—An Application To Coal: Mathematical Geology.

Taff, J.A., 1909, The Sheridan coal field: U.S. Geological Survey Bulletin 341, p. 123-150.

U.S. Environmental Protection Agency, 1996, Standards of Performance for New Stationary Sources, 40CFR, Part 60.43, Standards for Sulfur Dioxide: Environmental Protection Agency, 27 p.

Wood, G.H., Jr., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

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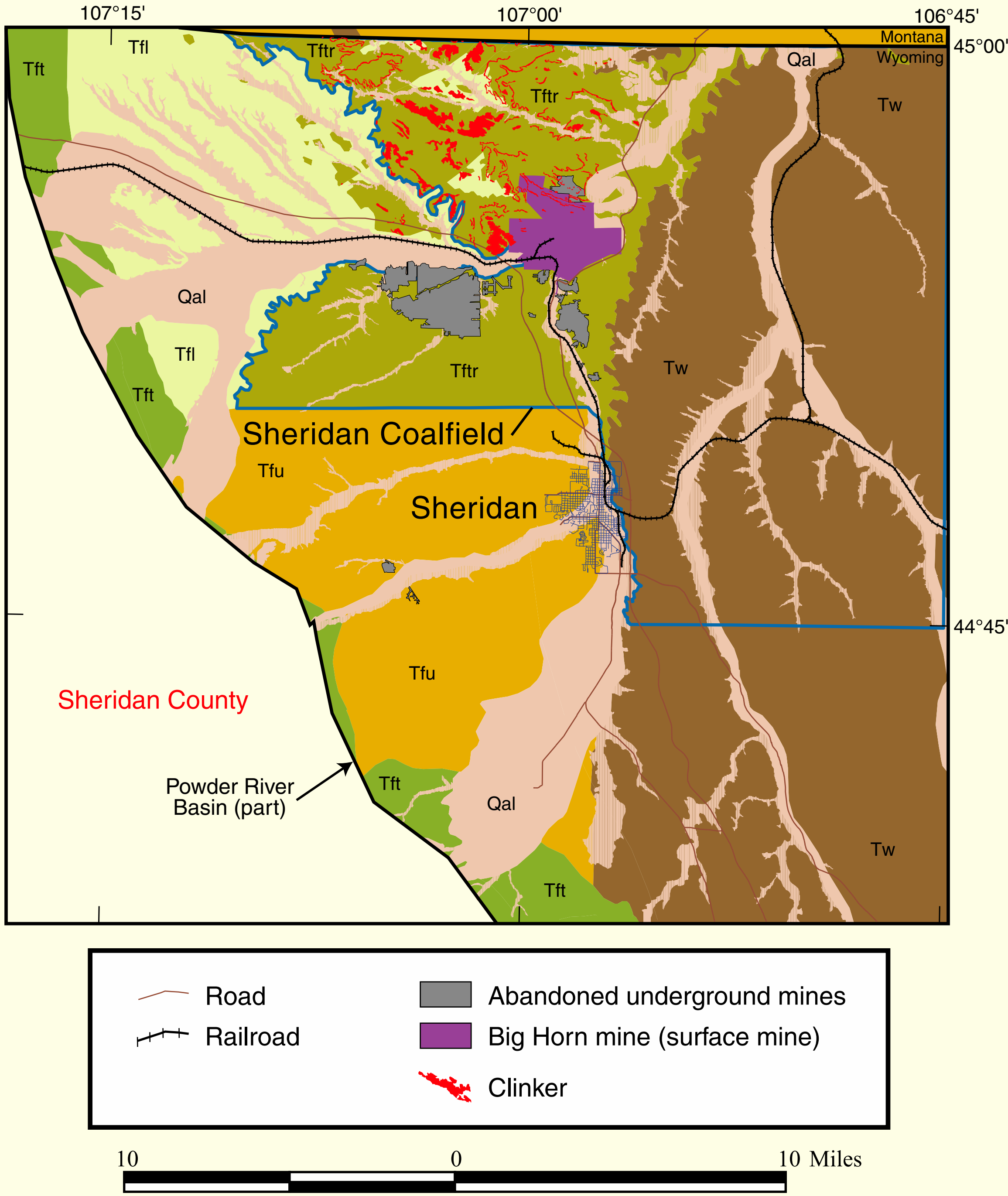
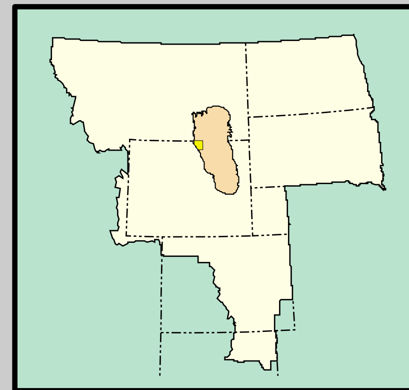


Figure PH-1. Geologic map of the Sheridan coalfield, Powder River Basin.



Explanation

Qal	Quaternary alluvium
Tw	Tertiary Wasatch Formation
Tftr	Tertiary Tongue River Member of the Fort Union Formation
Tfl	Tertiary Lebo Shale Member of the Fort Union Formation
Tft	TertiaryTullock Member of the Fort Union Formation
Tfu	Undifferentiated Fort Union Formation

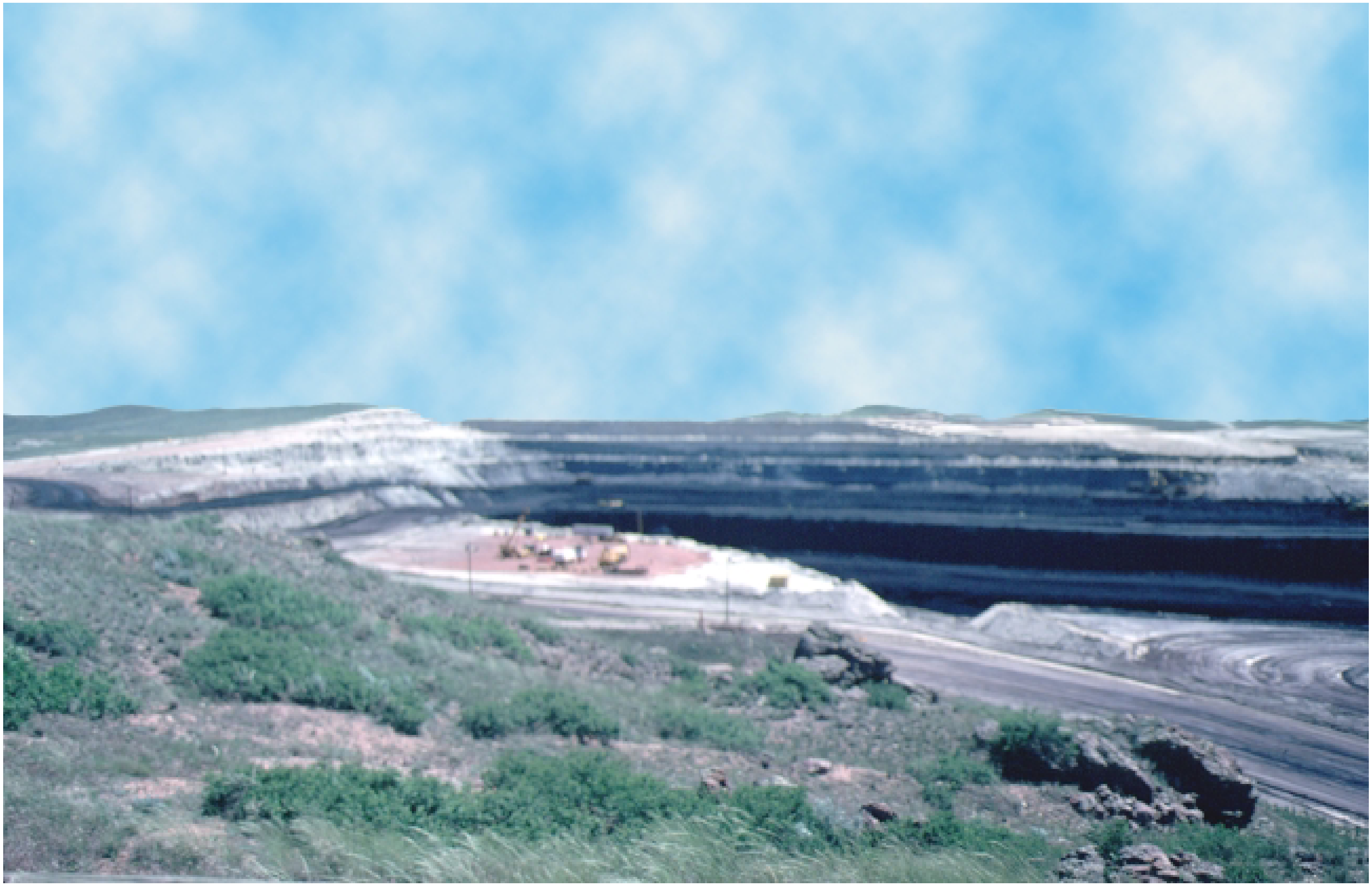


Figure PH-2. Coal beds of the Wyodak–Anderson coal zone and overlying carbonaceous shale, mudstone, siltstone, and sandstone in the highwall of the Big Horn mine. Photograph by R.M. Flores.

Figure PH-3. Fluvial channel sandstone above the Wyodak–Anderson coal zone in the highwall of the Big Horn mine. Photograph by R.M. Flores.

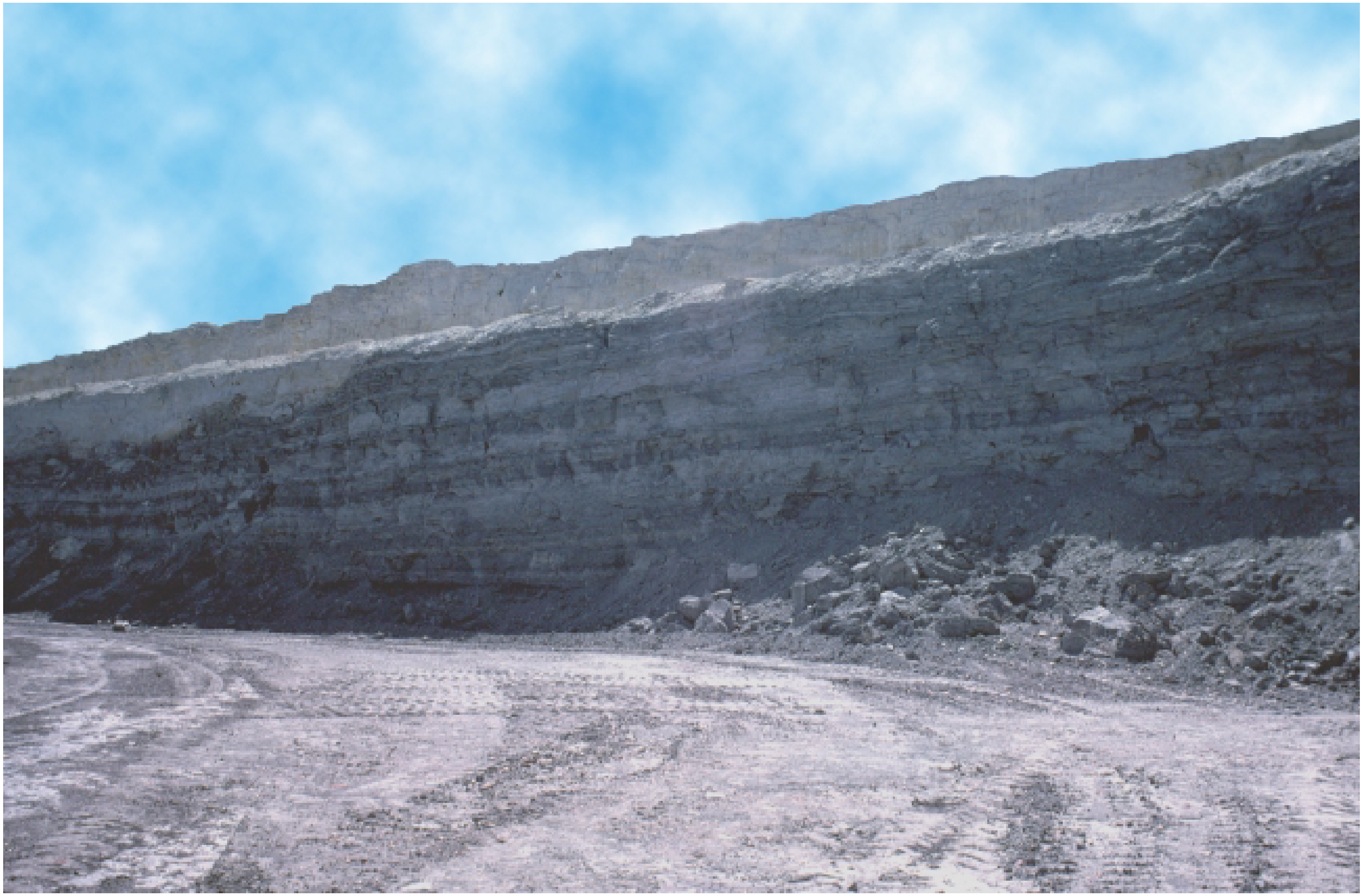


Figure PH-4. Interbedded mudstone, siltstone, and sandstone deposited in crevasse splay and floodplain environments in the highwall of the Big Horn mine. Photograph by R.M. Flores.

Figure PH-5. The Wyodak–Anderson coal zone consisting of the Dietz and Monarch coal beds in the highwall of the Big Horn mine. Photograph by R.M. Flores.

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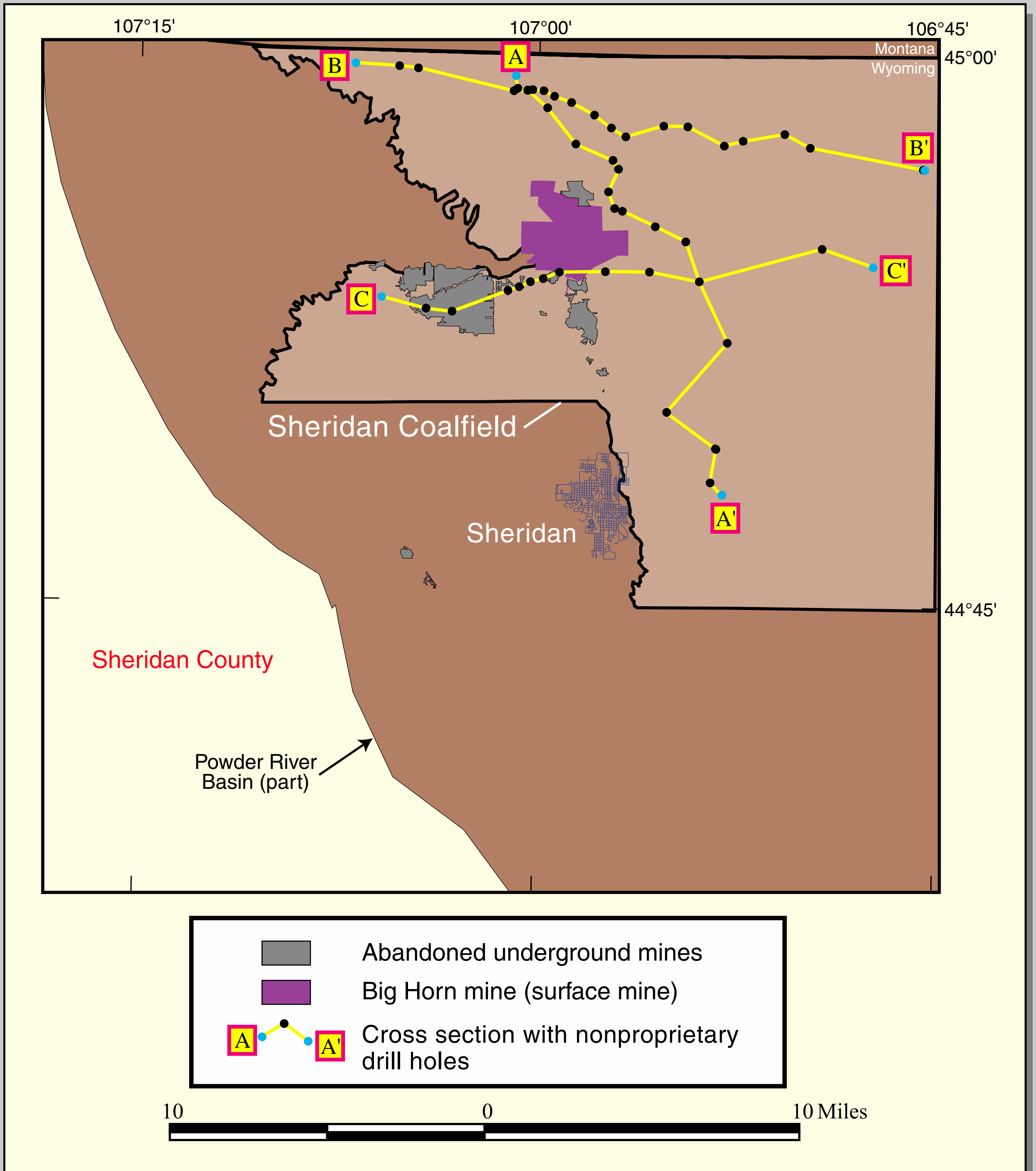
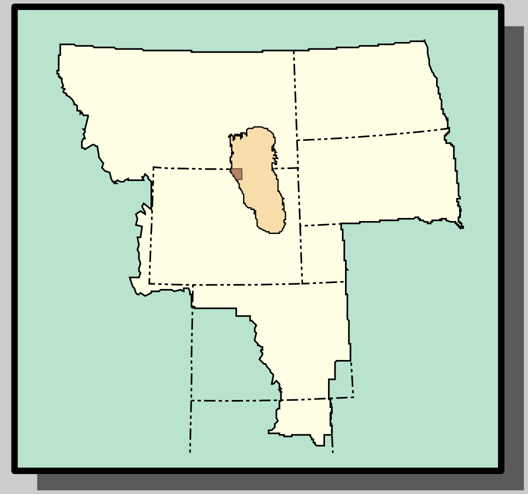


Figure PH-6. Index map showing locations of Sheridan coalfield cross sections and mines.



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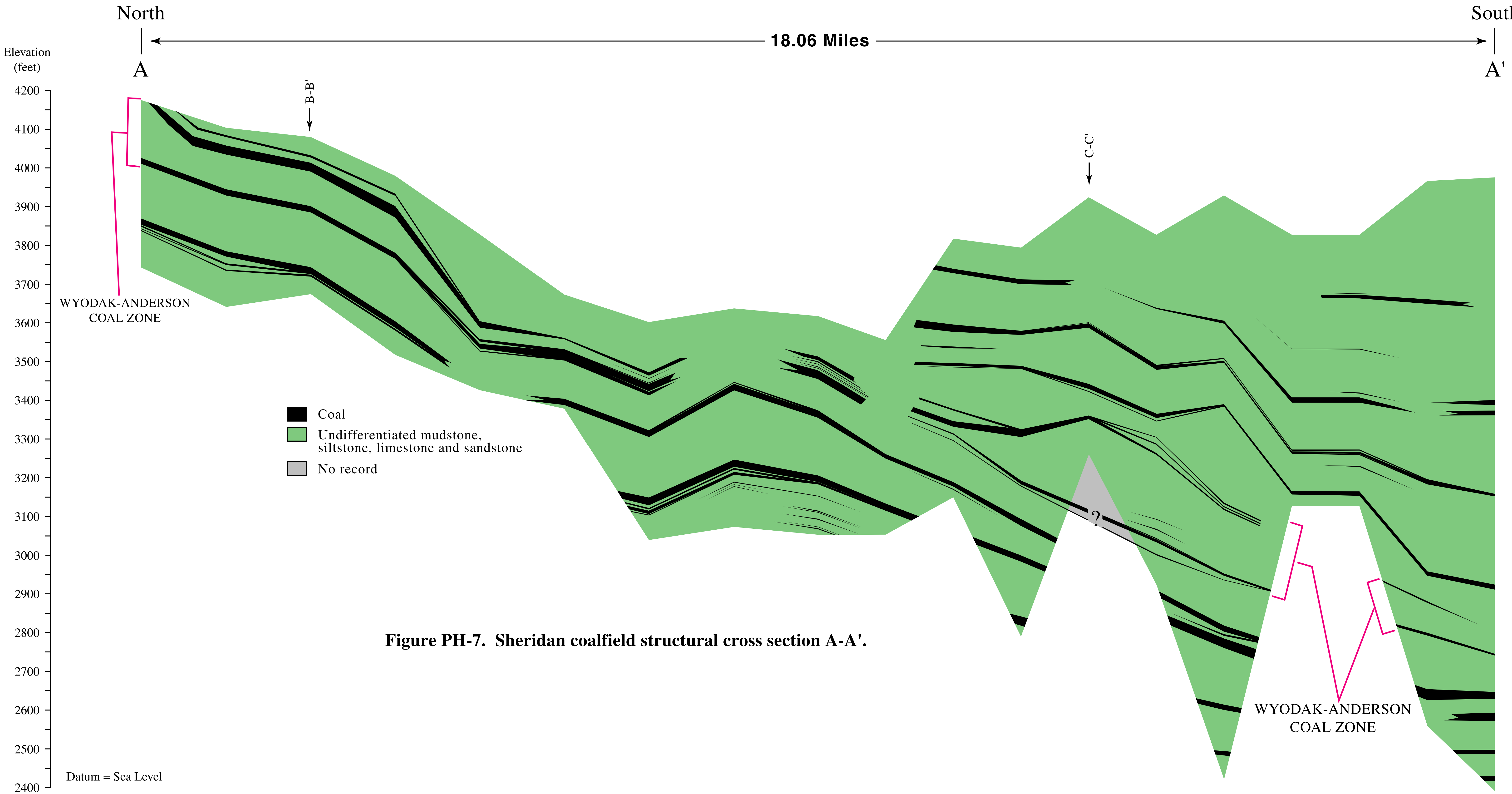

Figure PH-7. Sheridan coalfield structural cross section A-A'.

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in the toolbar to return.

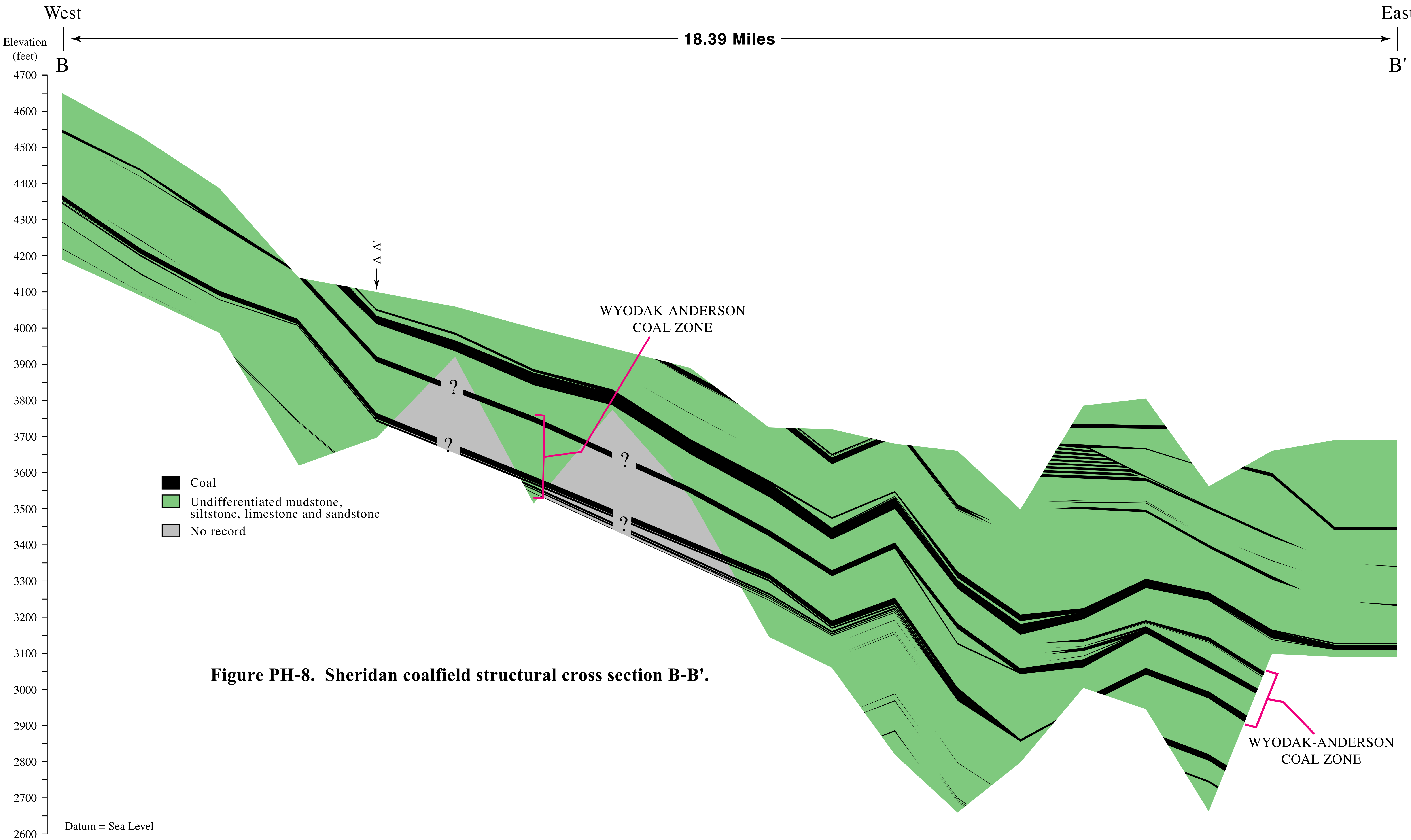

Figure PH-8. Sheridan coalfield structural cross section B-B'.

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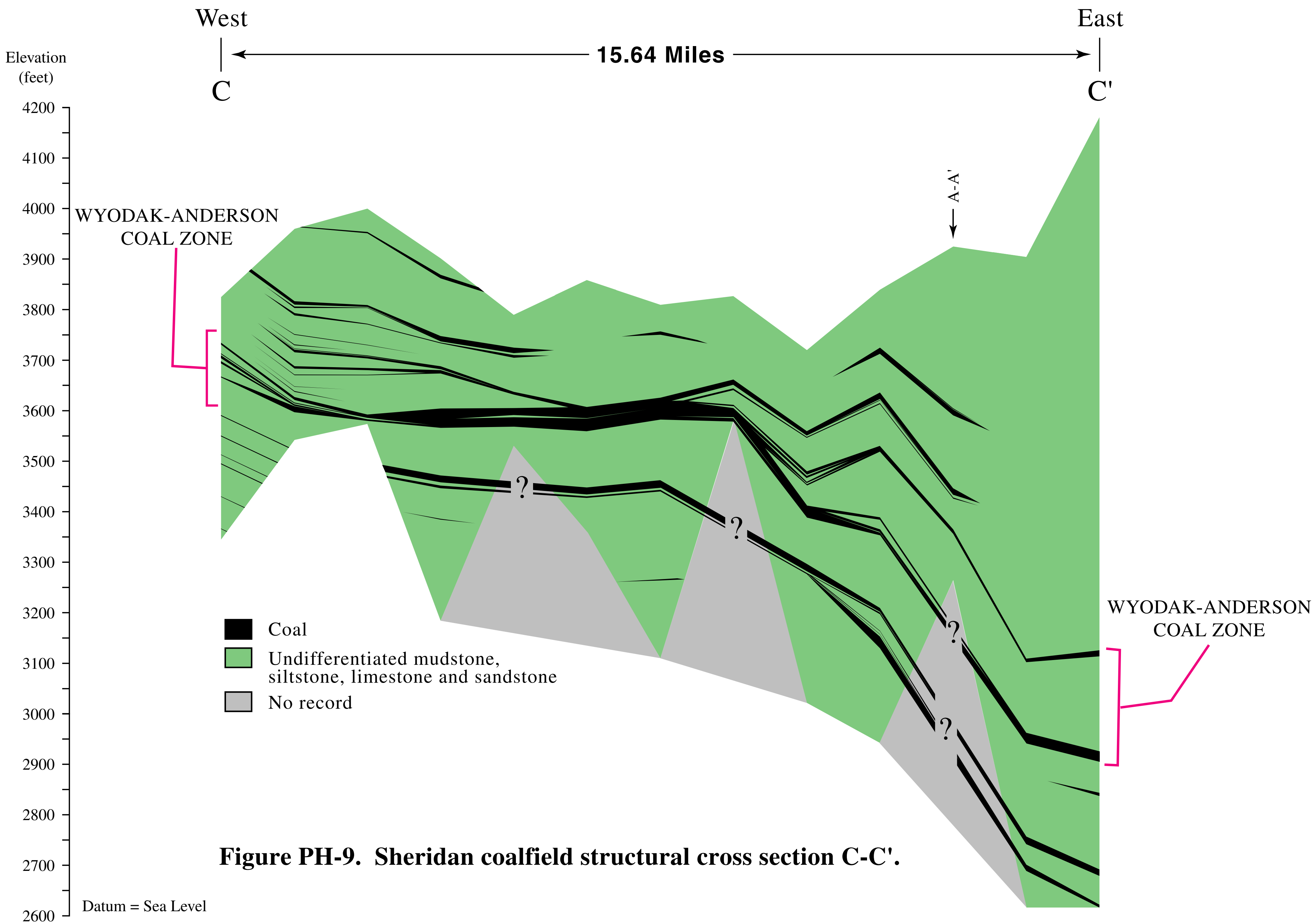

Figure PH-9. Sheridan coalfield structural cross section C-C'.

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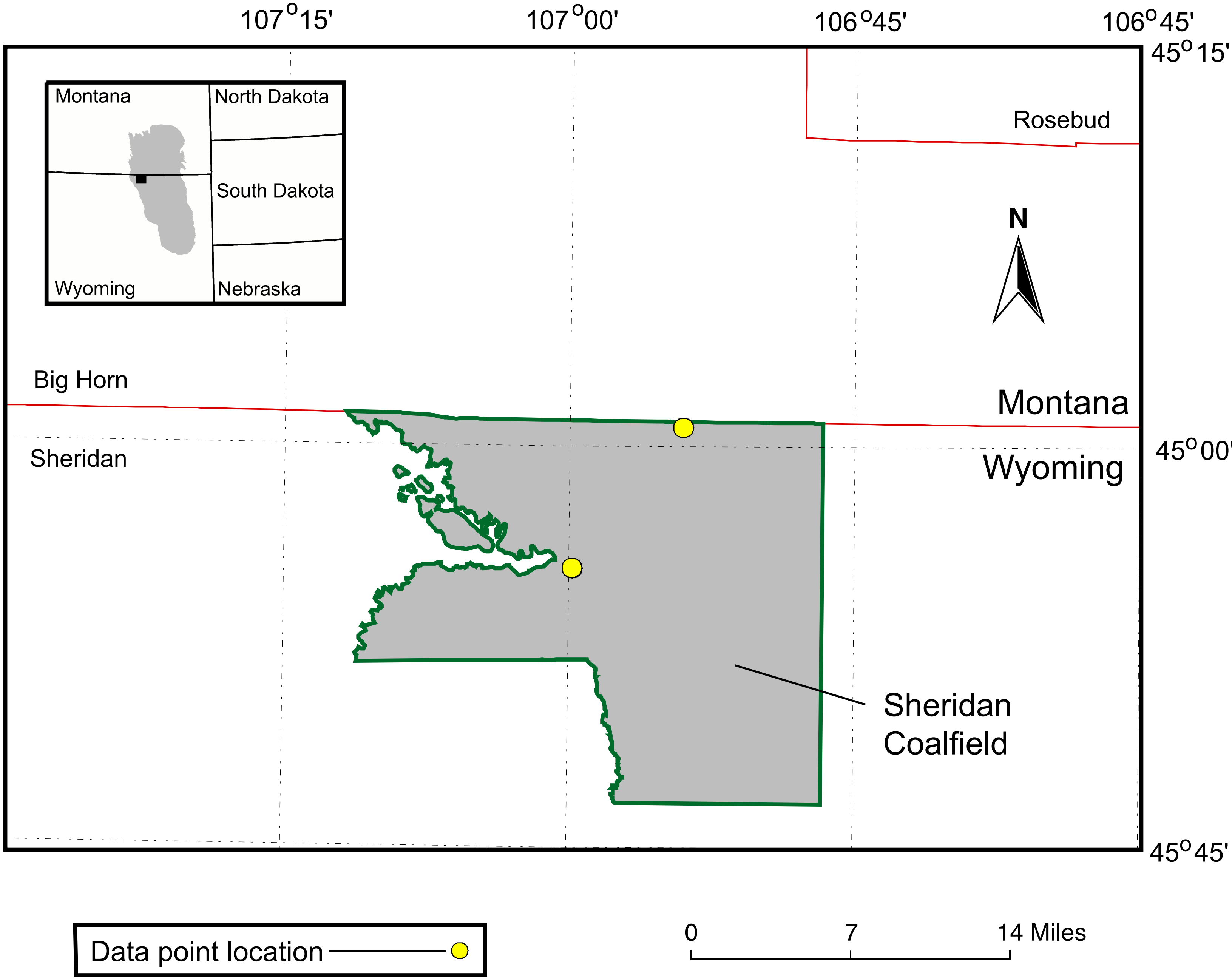

Figure PH-10. Index map showing coal quality data distribution in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

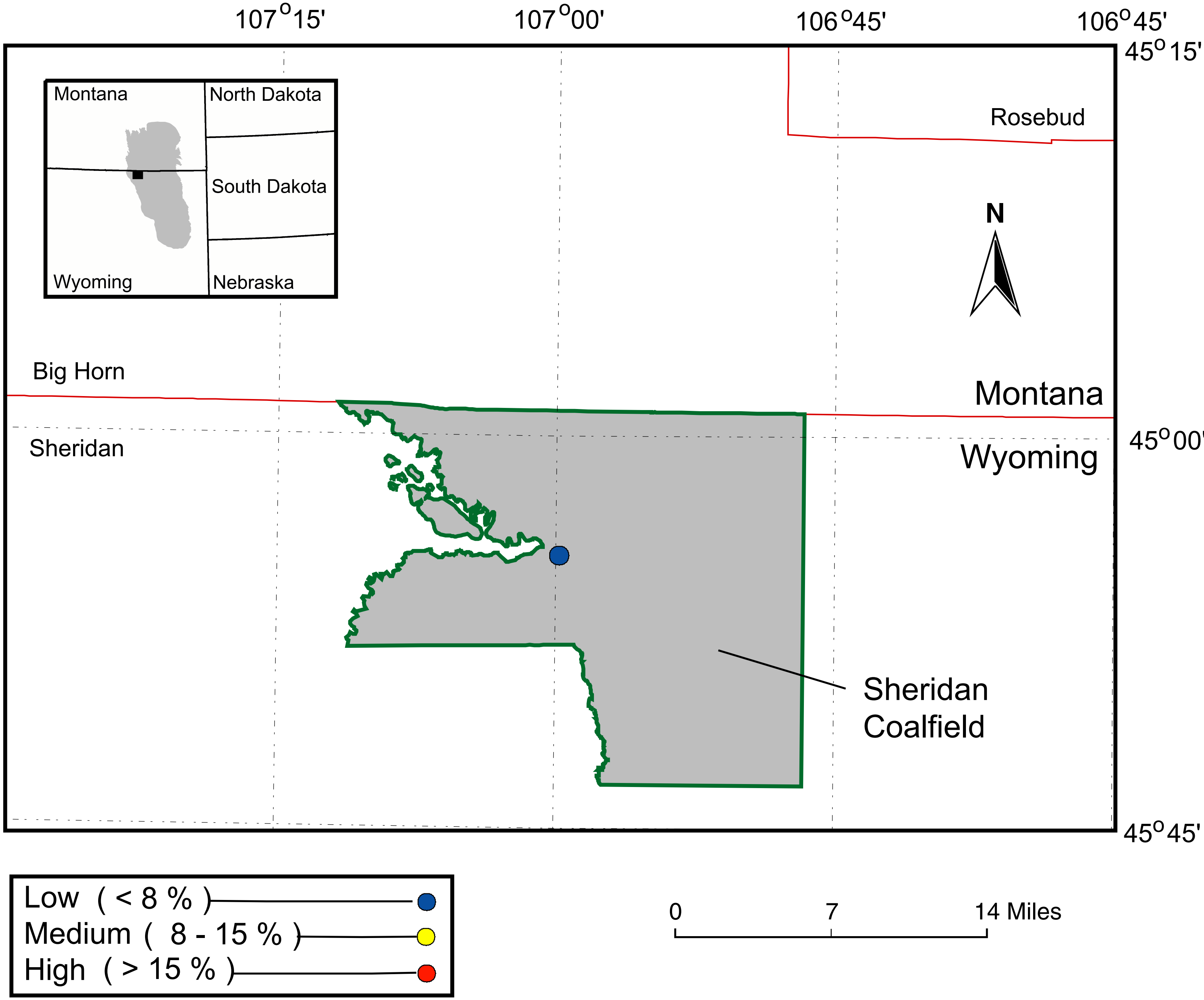

Figure PH-11. Ash yield in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

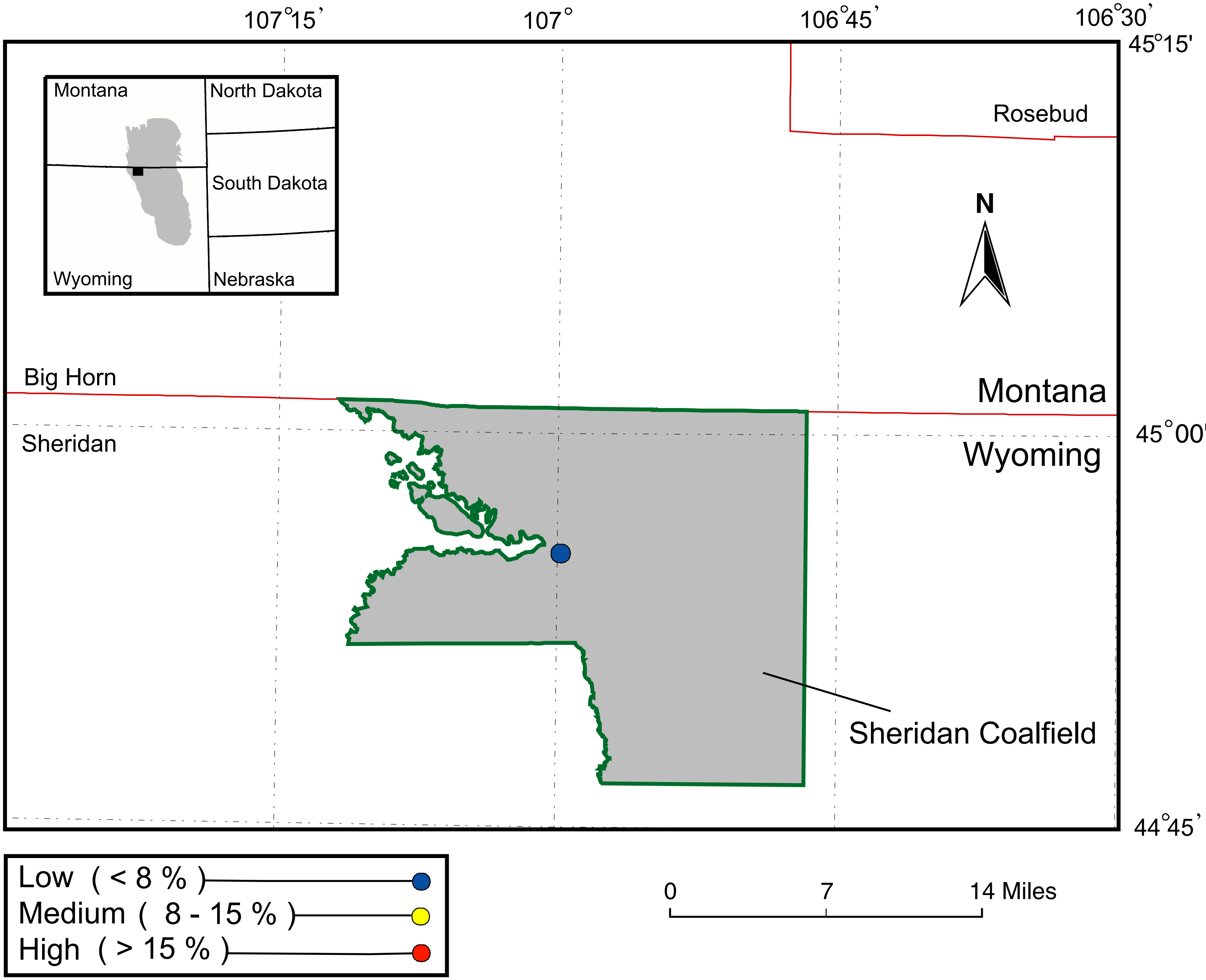

Figure PH-12. Sulfur content in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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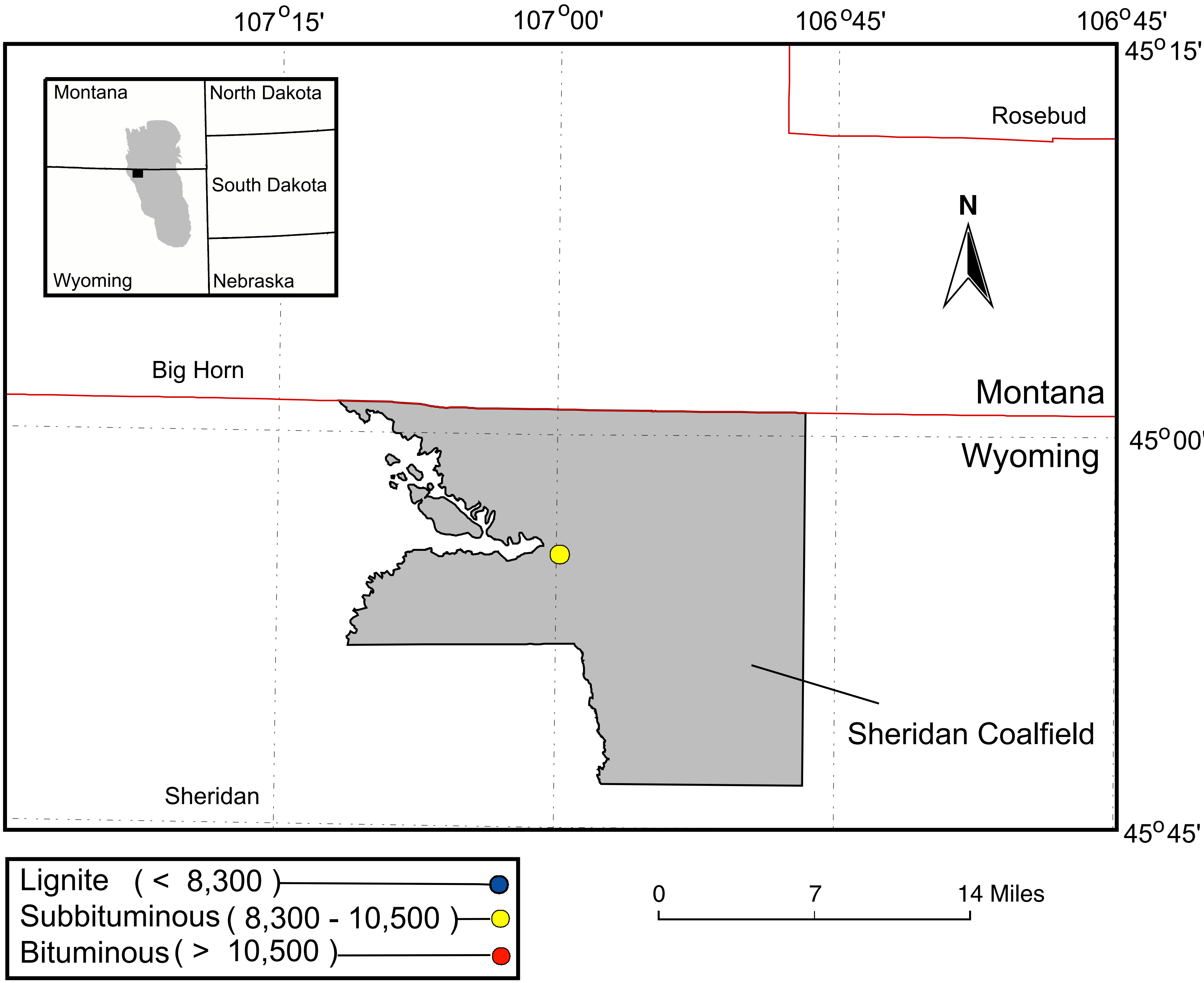

Figure PH-13. Moist, mineral-matter-free Btu/lb in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

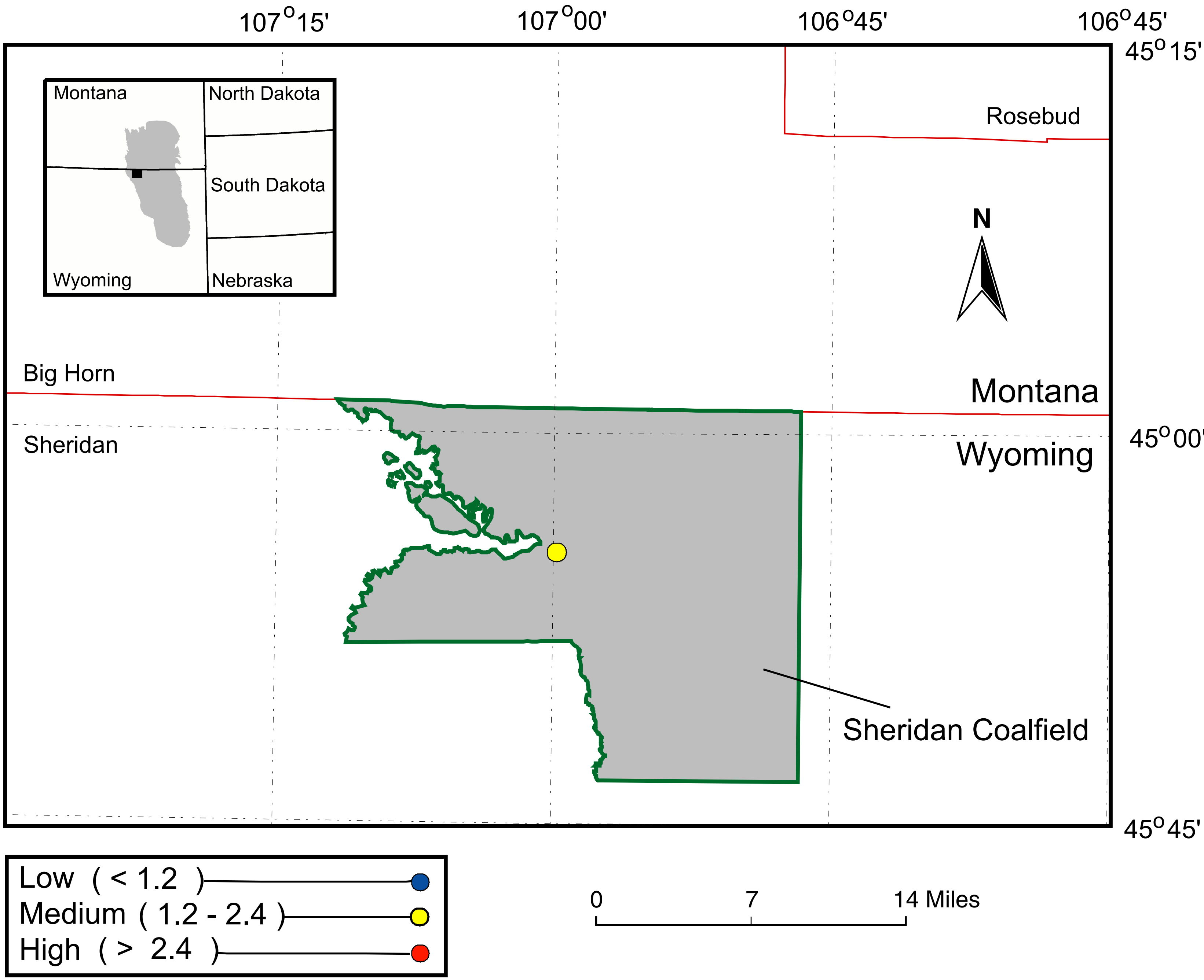

Figure PH-14. Pounds of sulfur dioxide per million btu in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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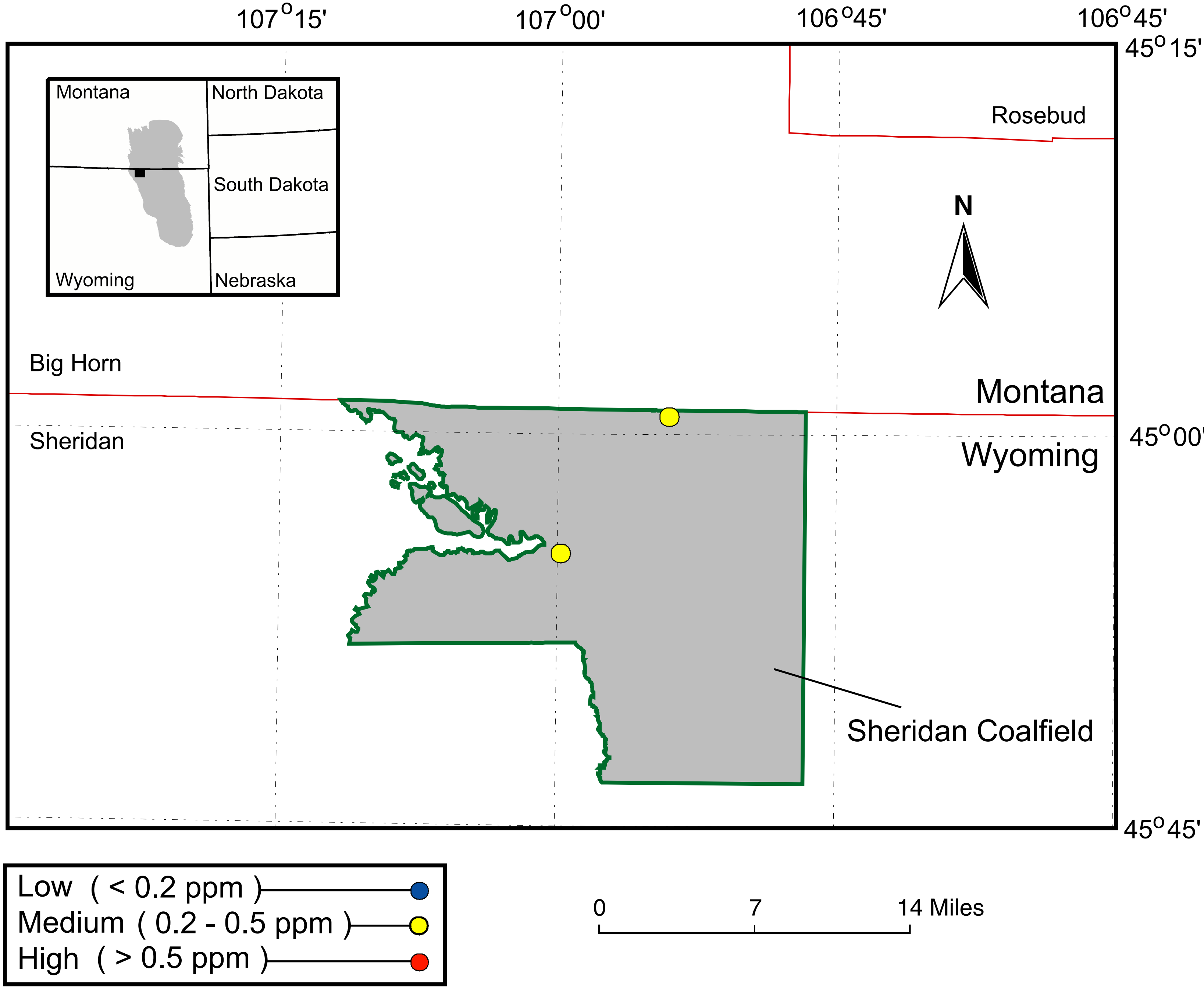

Figure PH-15. Antimony concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

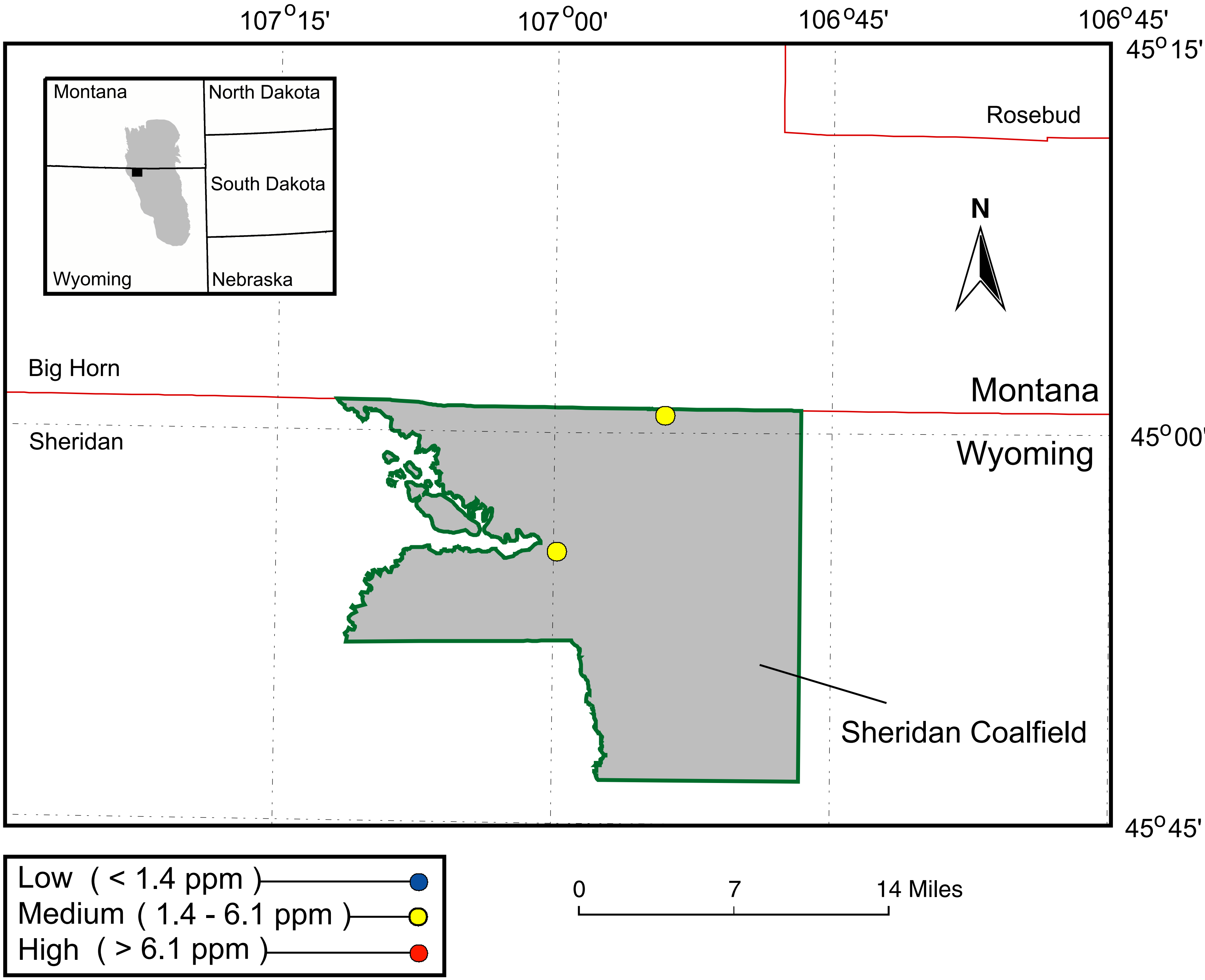

Figure PH-16. Arsenic concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

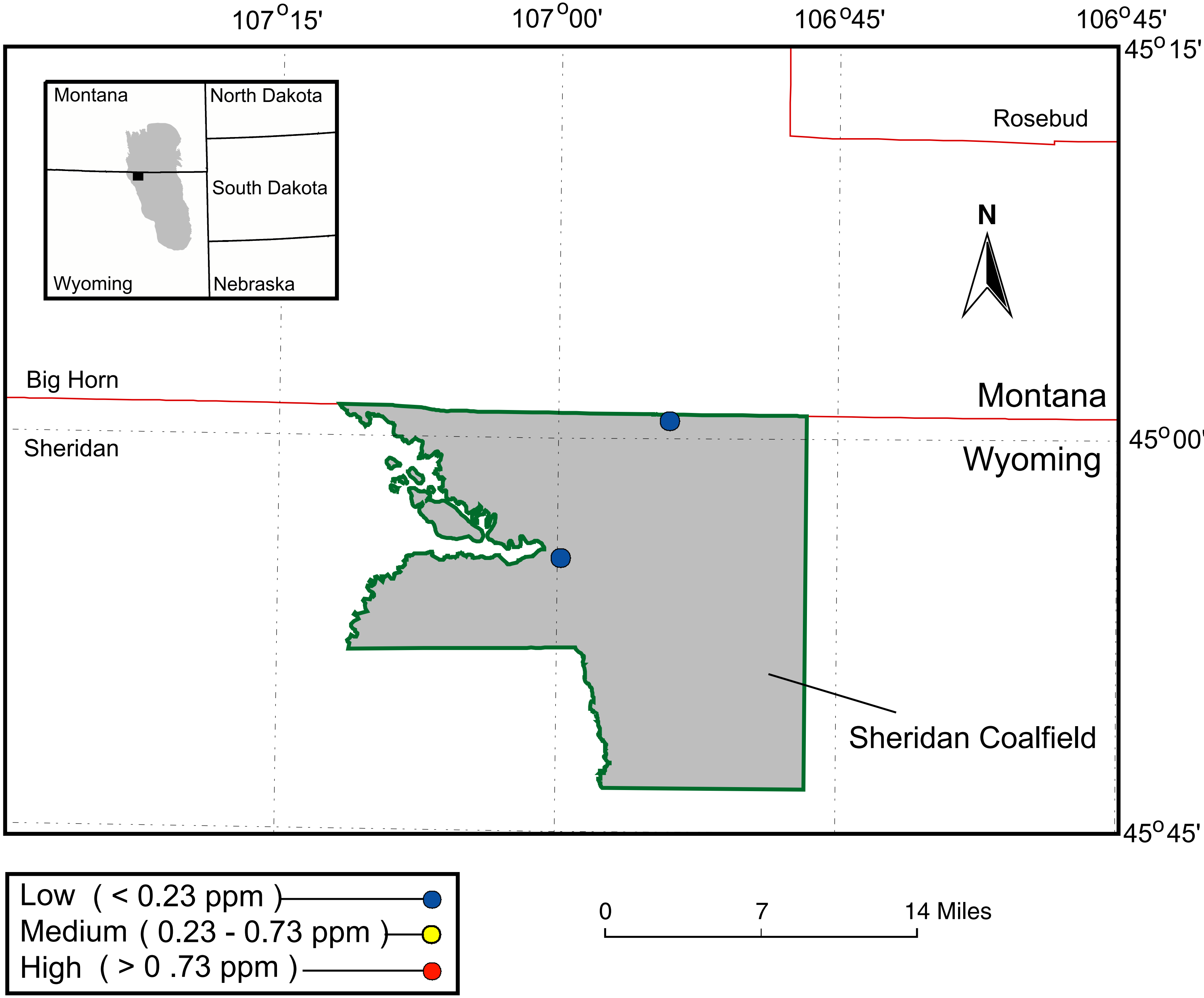

Figure PH-17. Beryllium concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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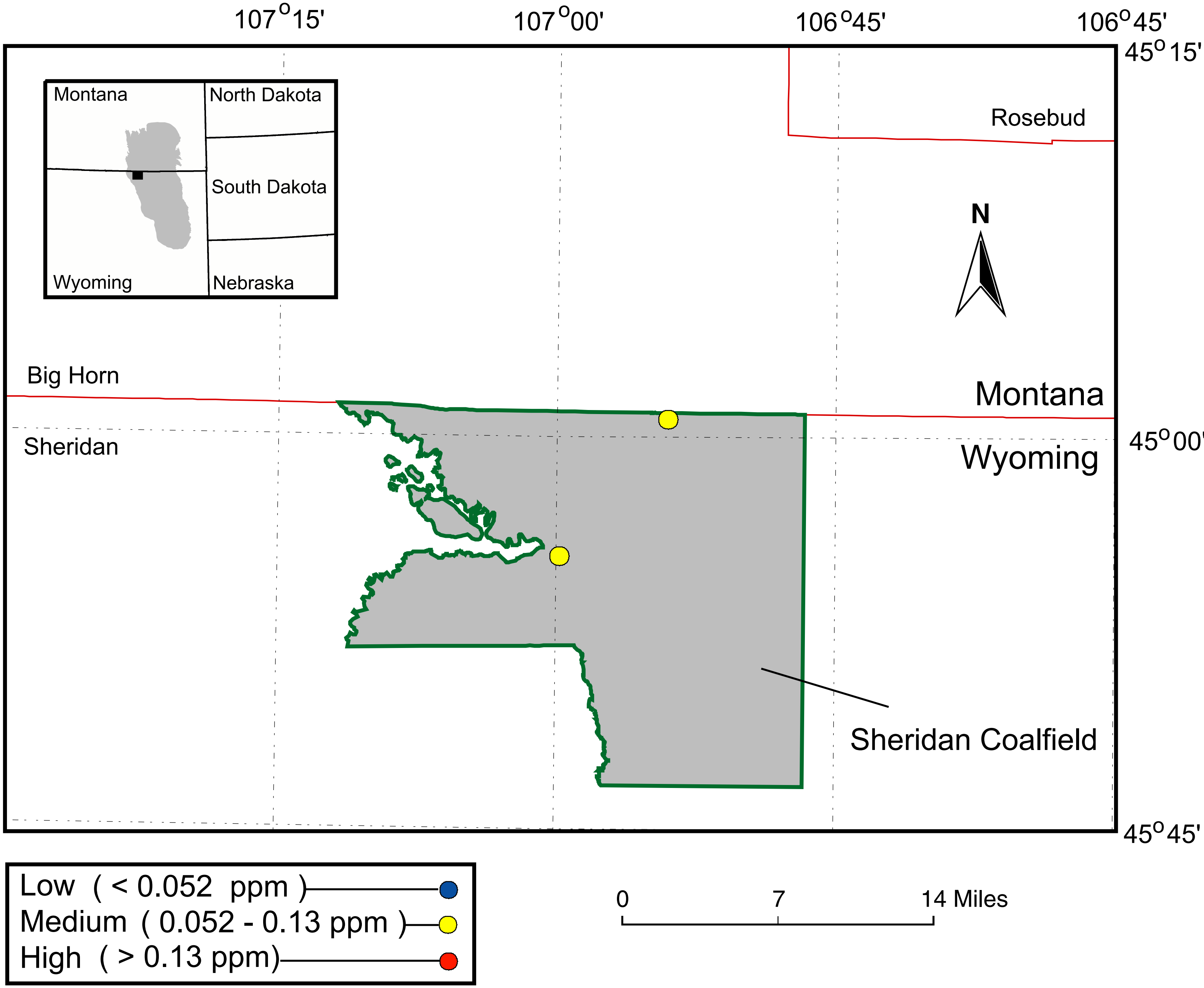

Figure PH-18. Cadmium concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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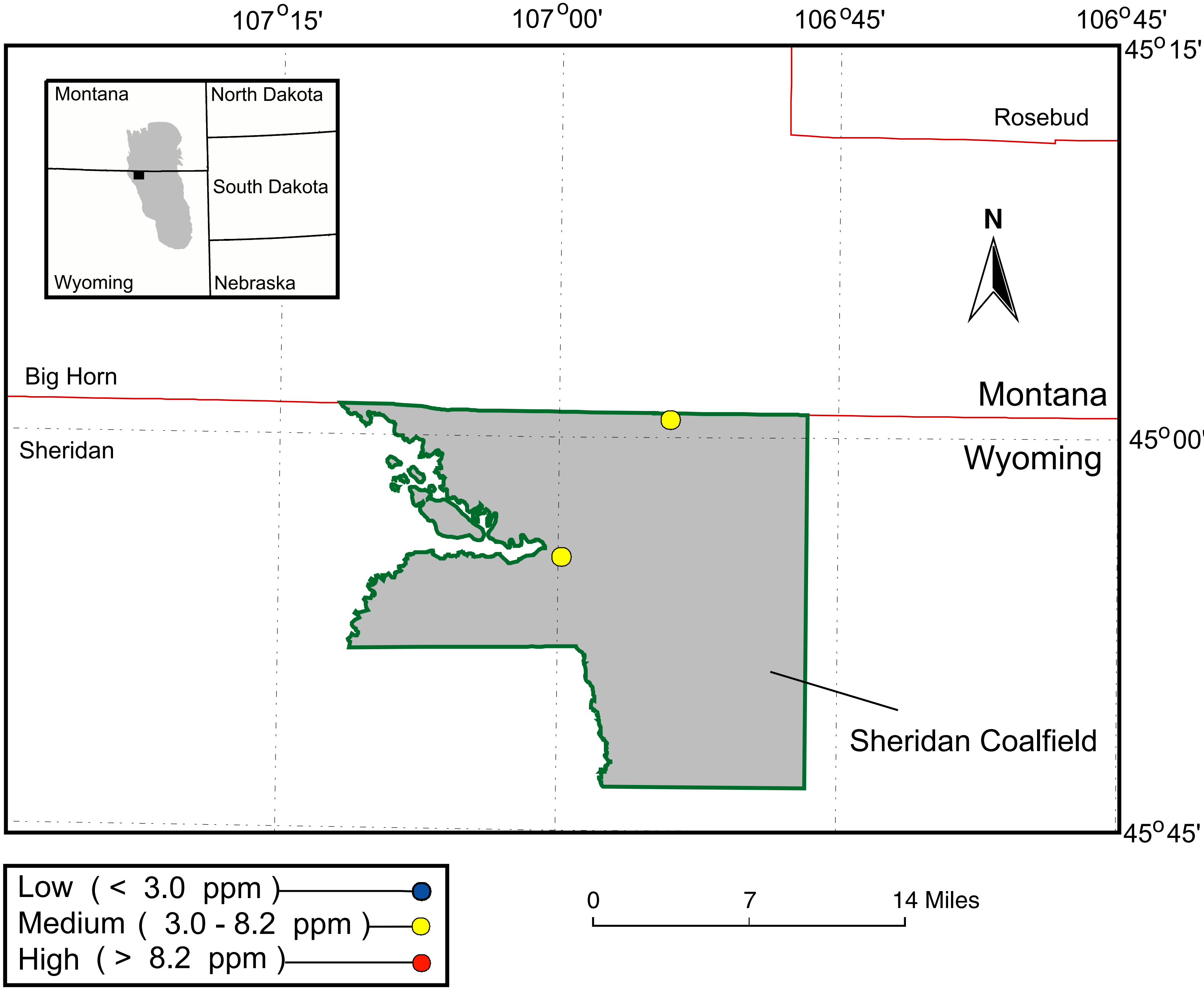

Figure PH-19. Chromium concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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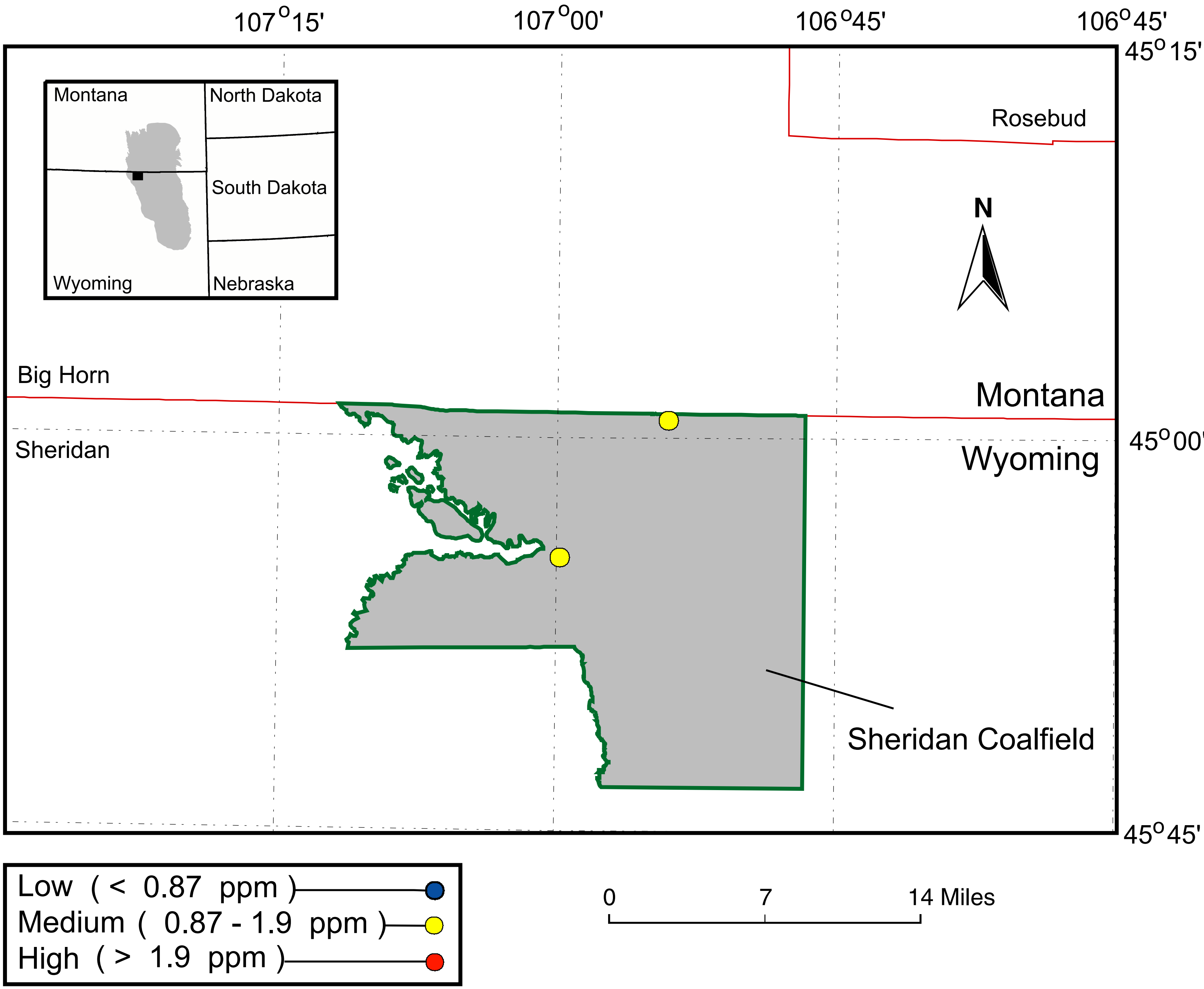

Figure PH-20. Cobalt concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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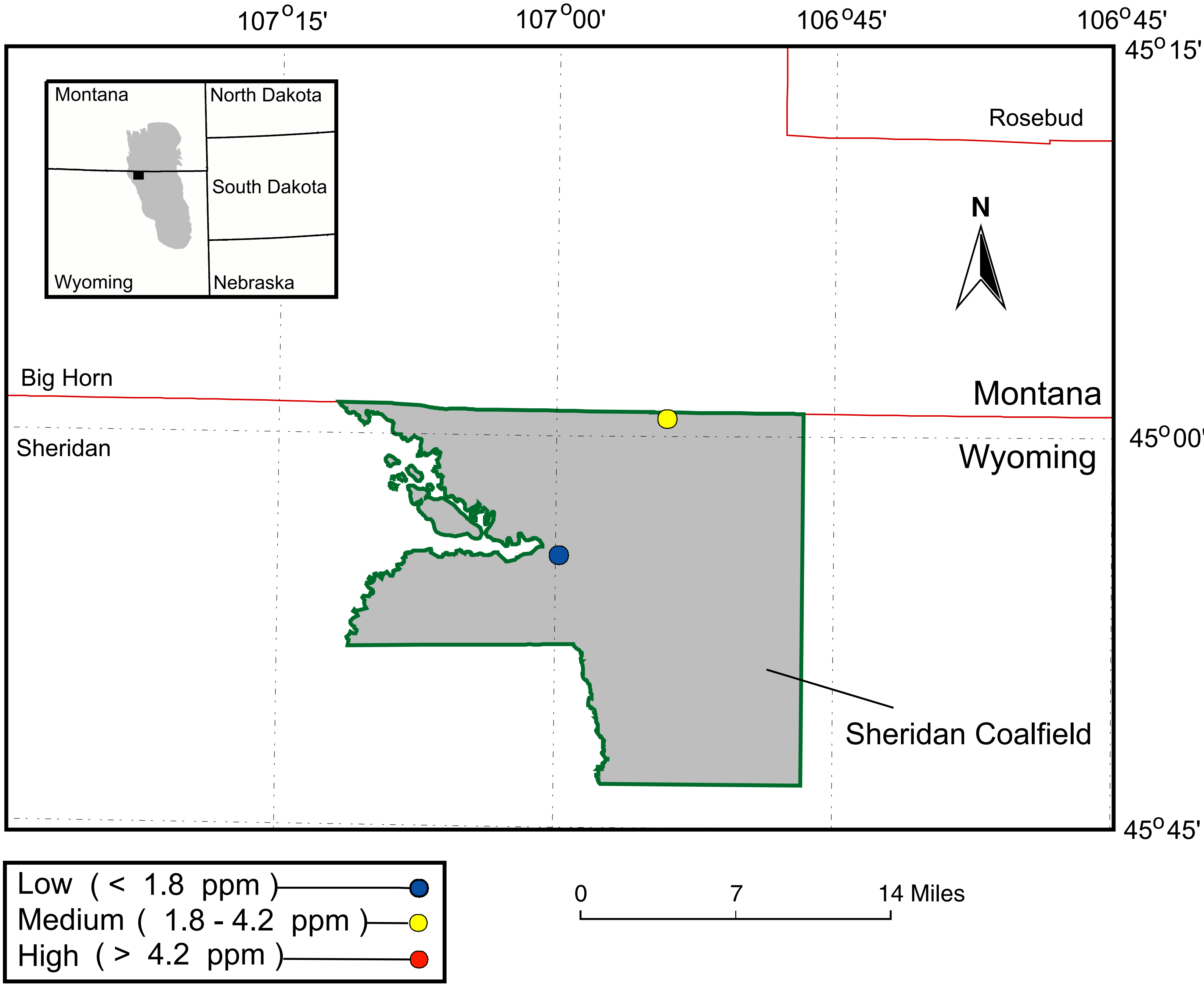

Figure PH-21. Lead concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

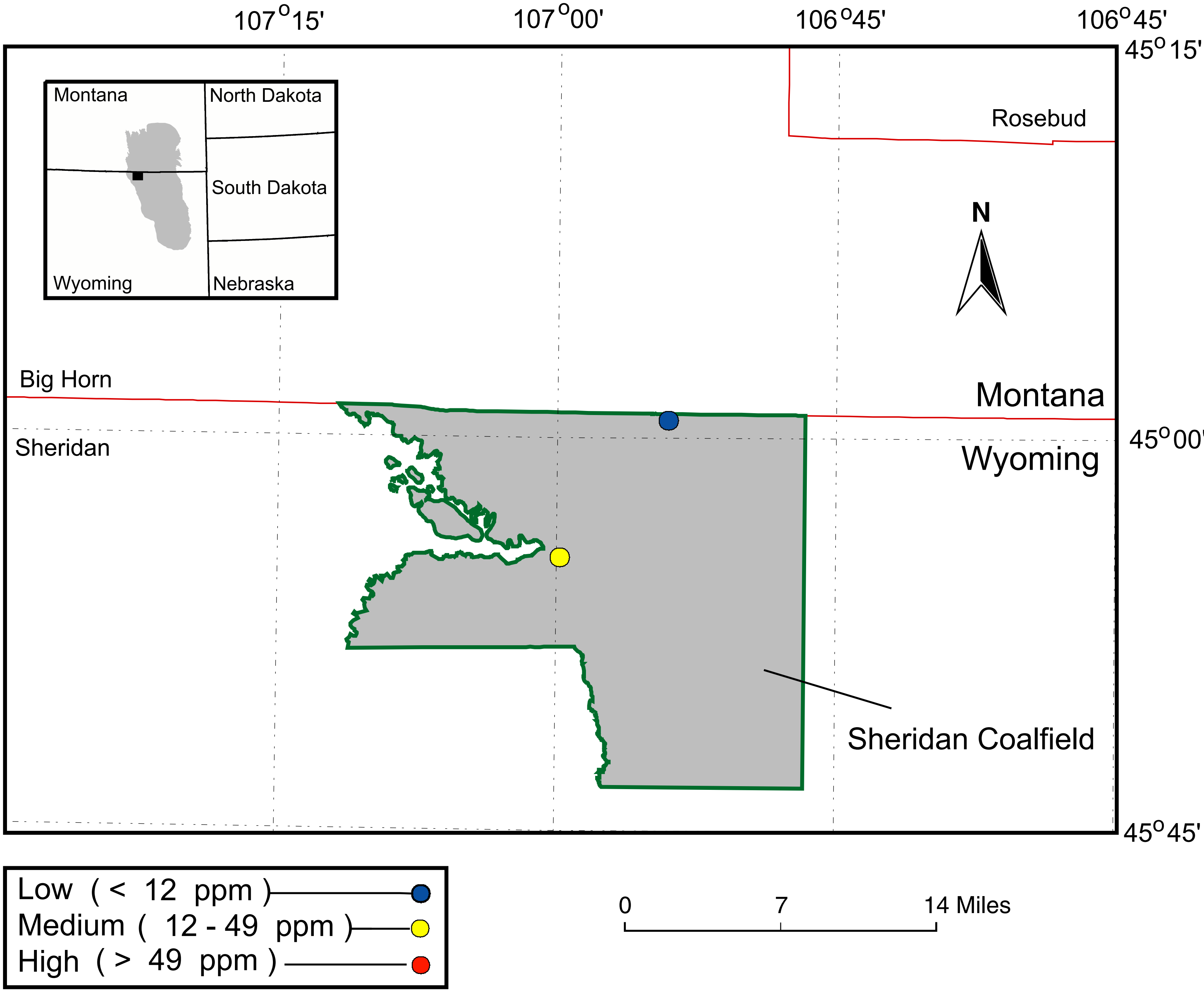

Figure PH-22. Manganese concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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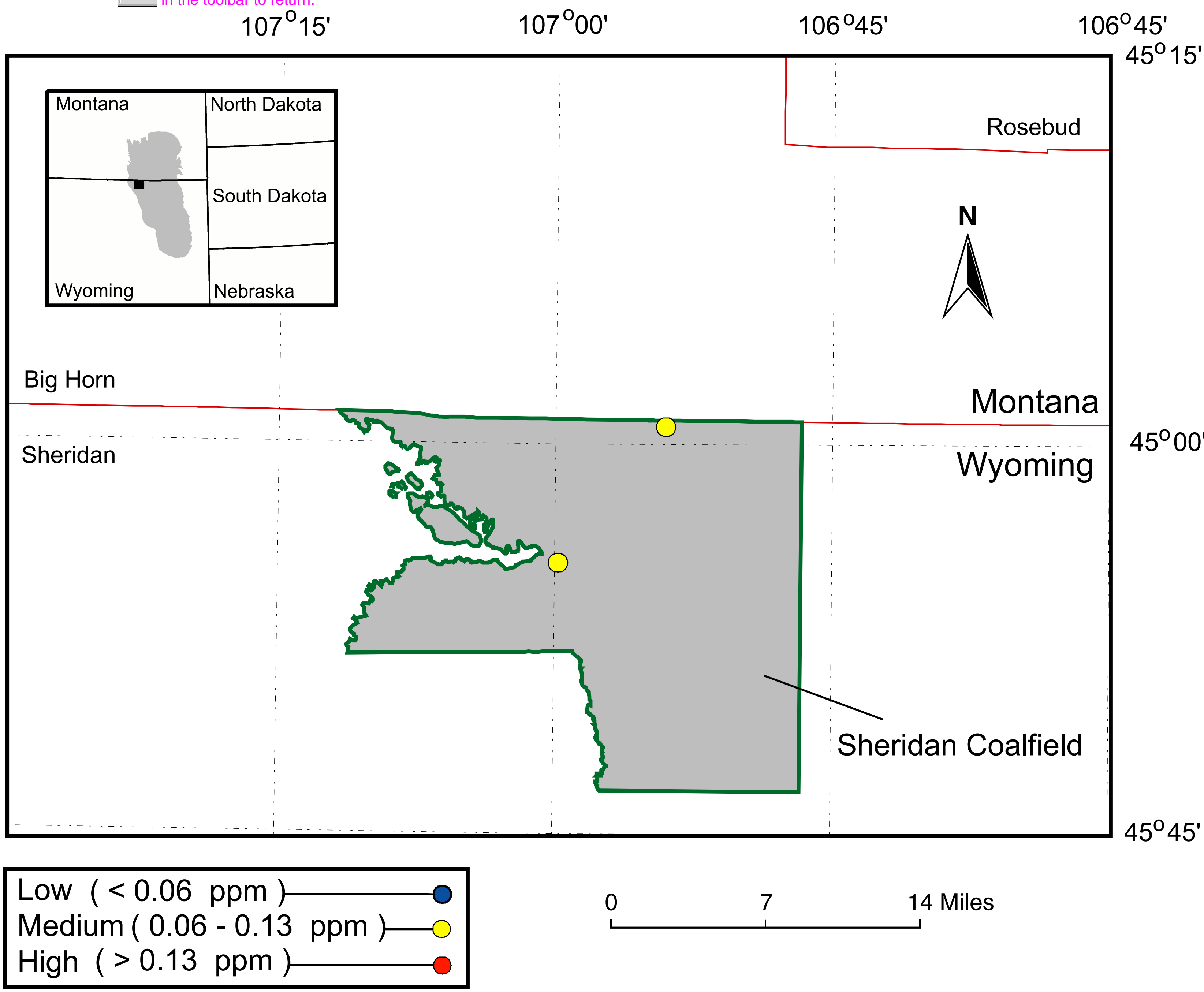

Figure PH-23. Mercury concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

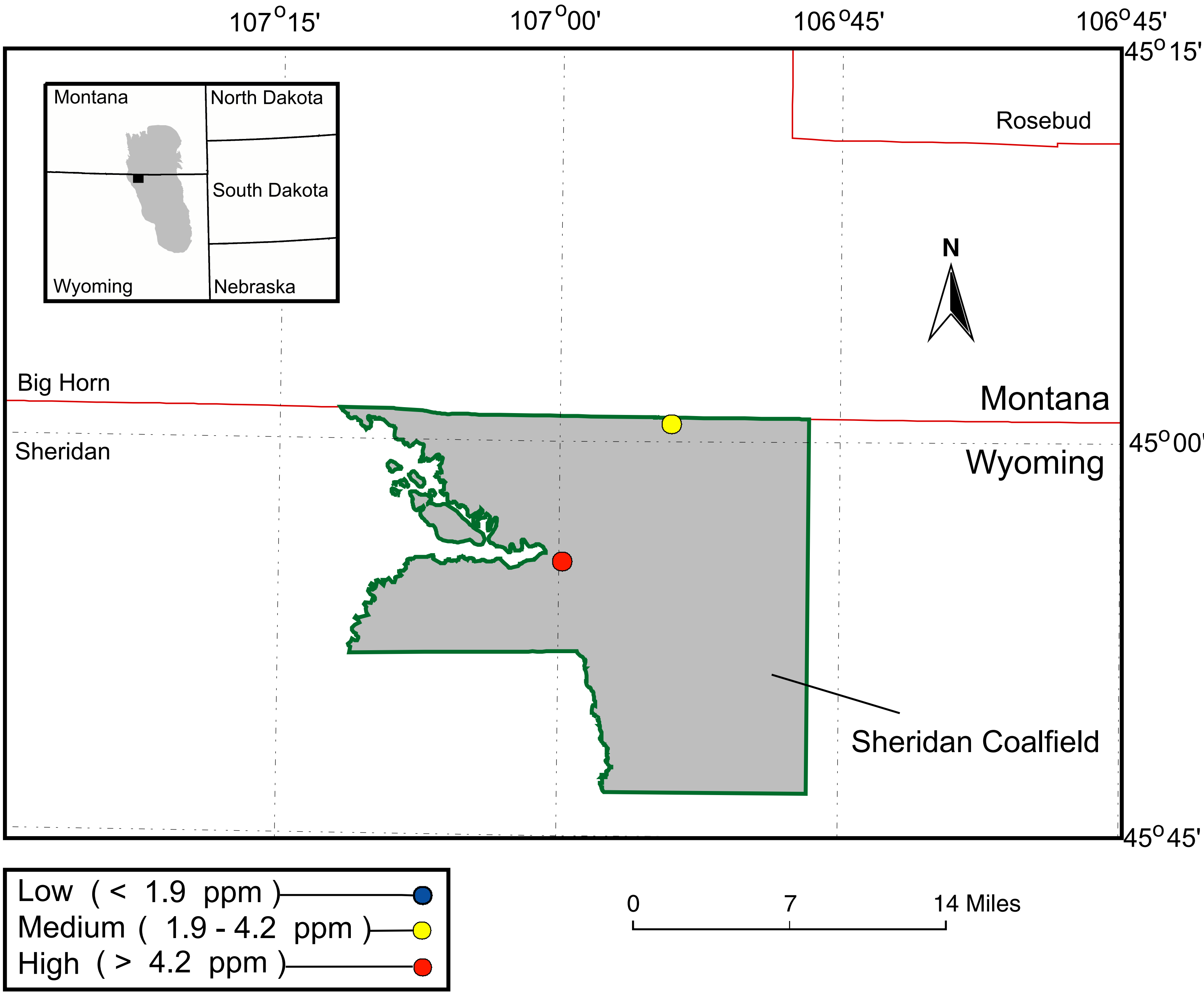

Figure PH-24. Nickel concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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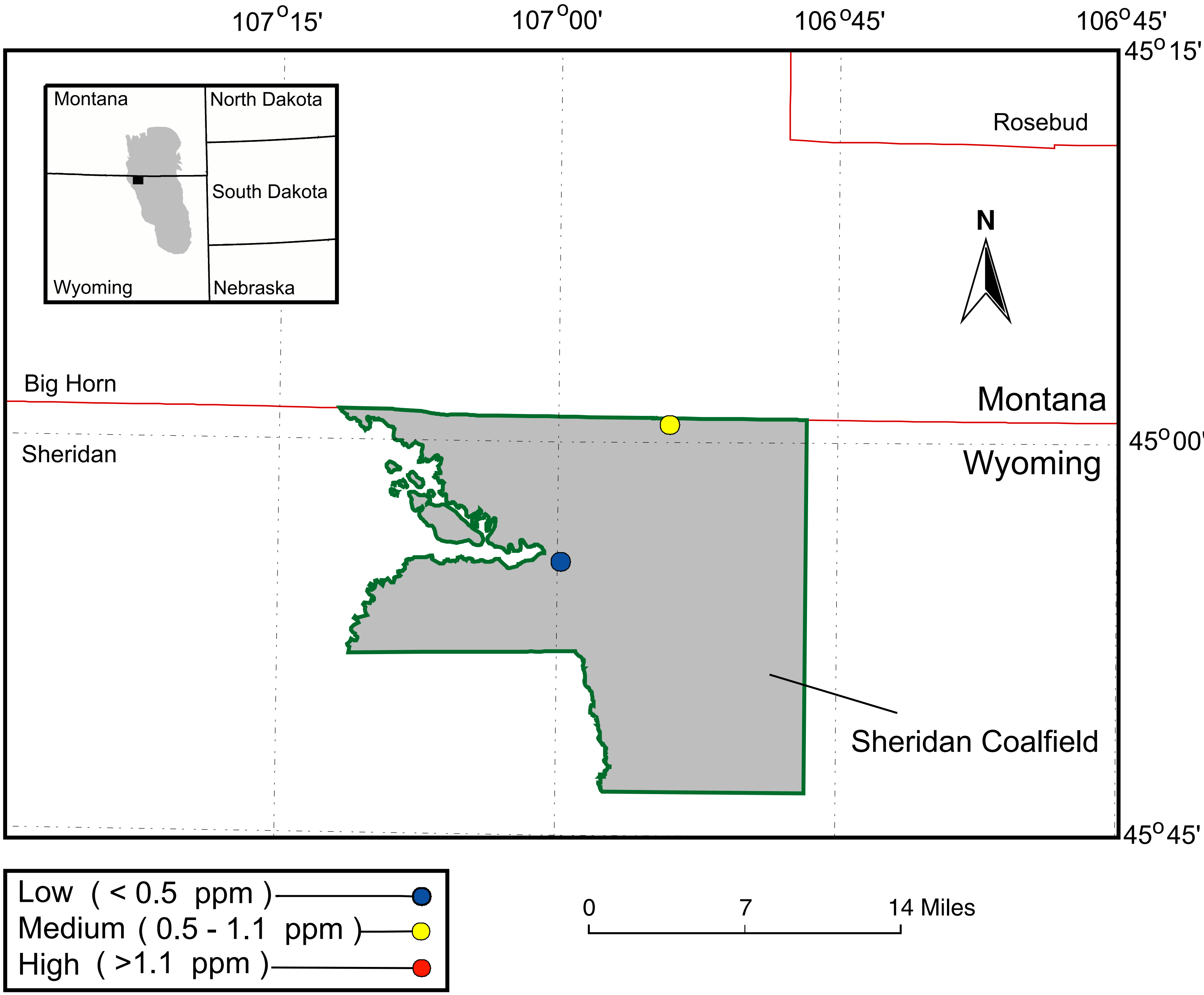

Figure PH-25. Selenium concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

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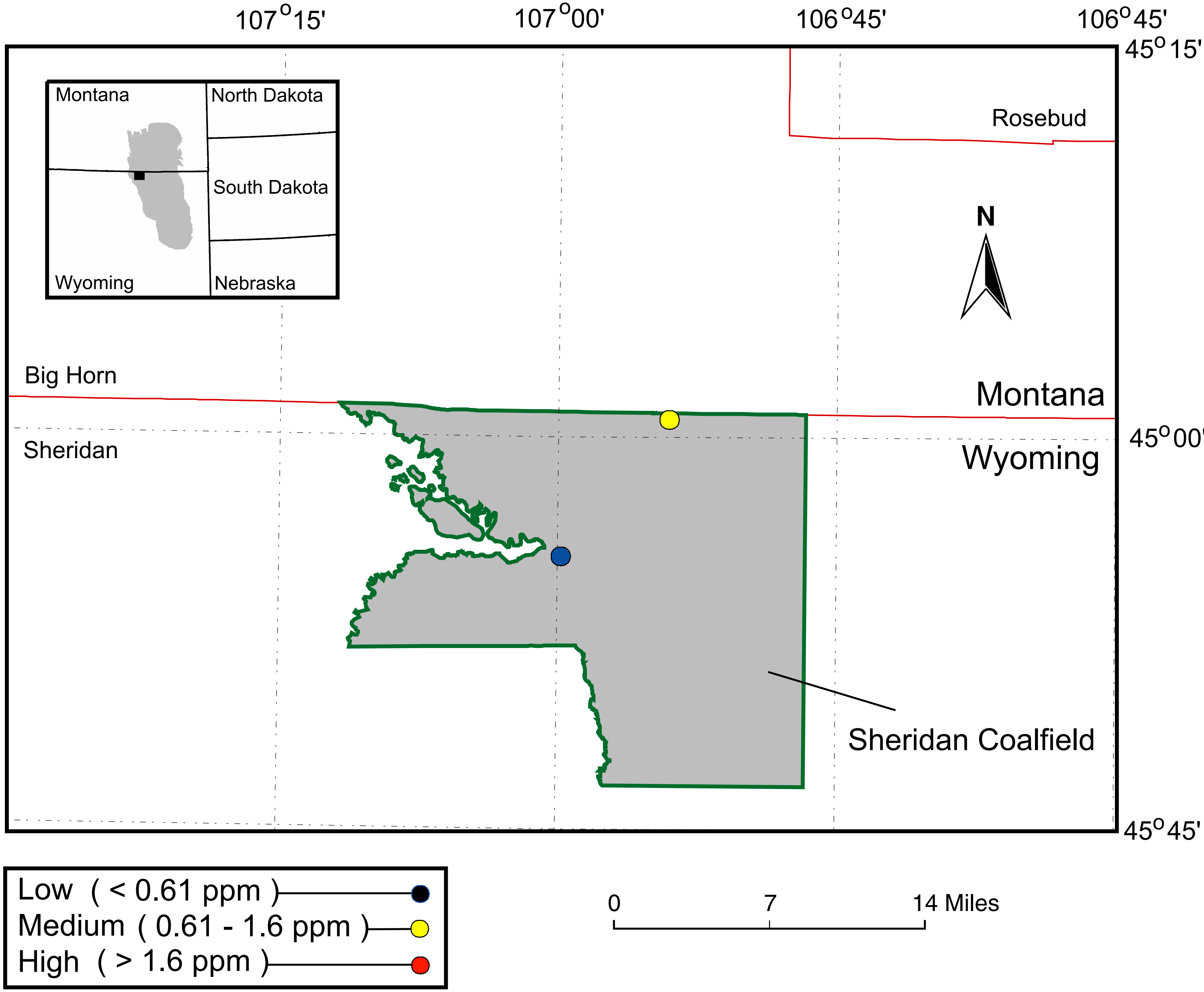

Figure PH-26. Uranium concentration in the Wyodak-Anderson coal zone, Sheridan coalfield, Powder River Basin, Wyoming.

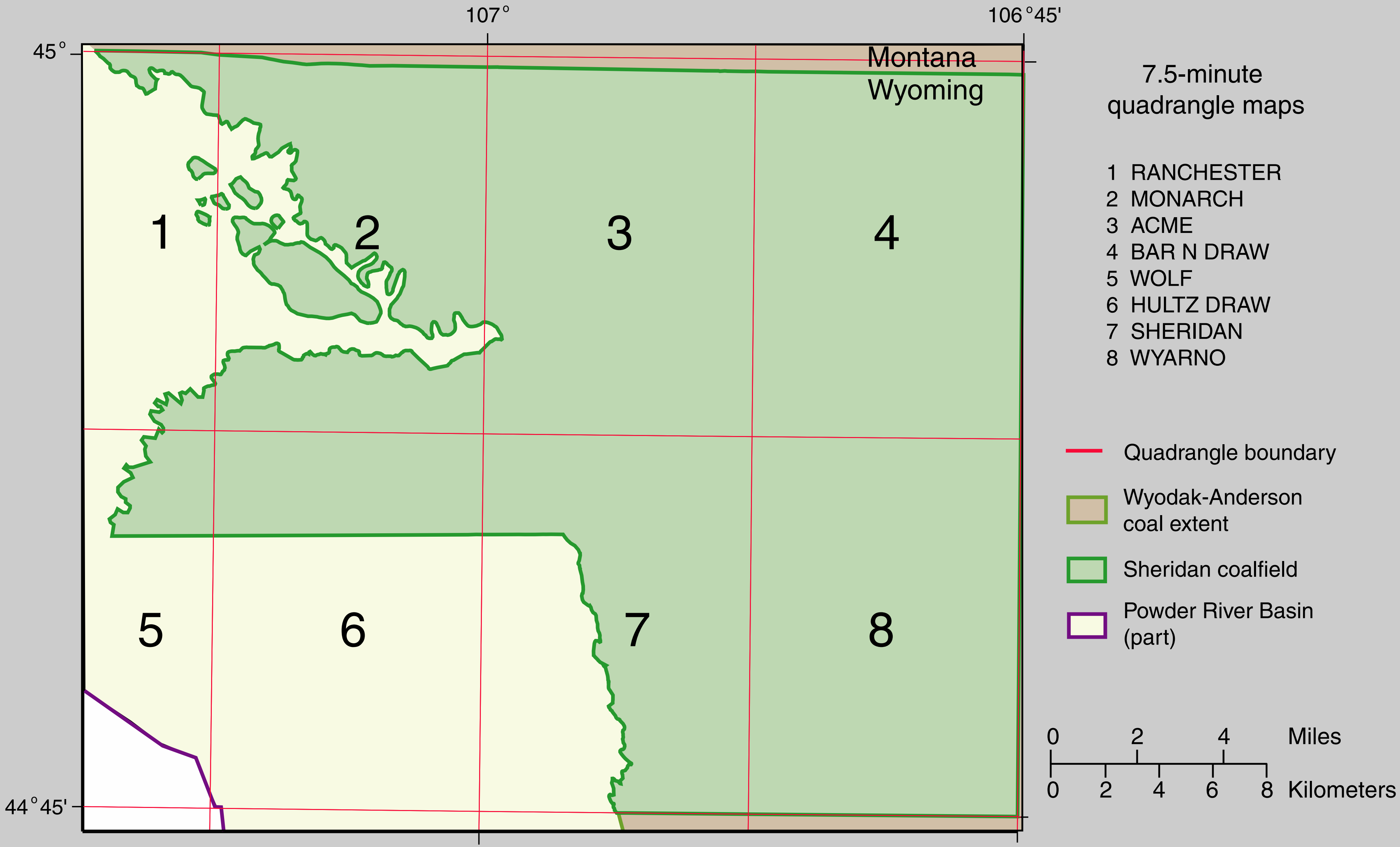

Figure PH-27. Location of 7.5-minute quadrangle maps in the Sheridan coalfield.

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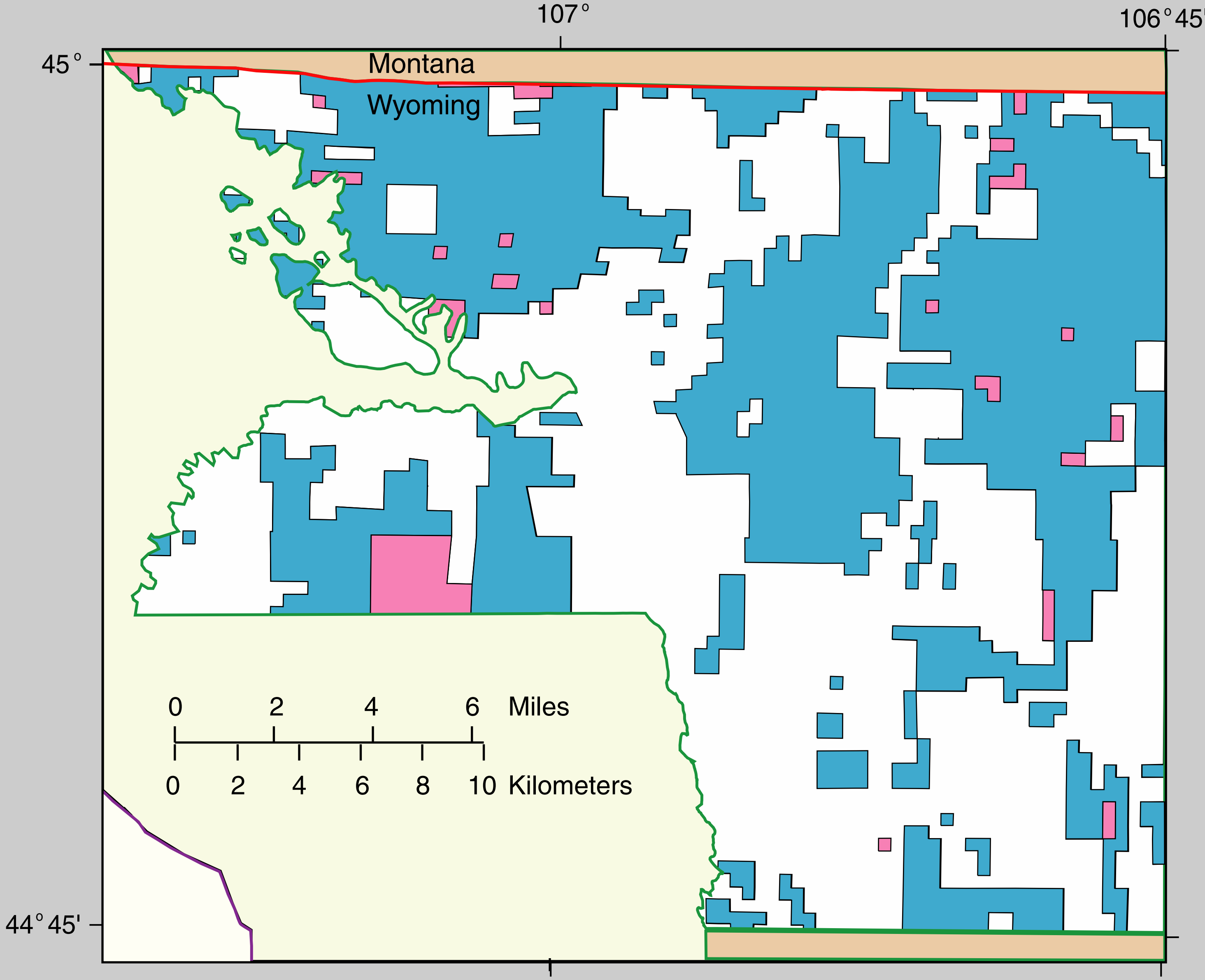
in the toolbar to return.



Federal Coal = Federal subsurface management of all minerals, coal only, or oil, gas, and coal

Federal Surface = Federal surface ownership

- Federal coal and surface
- Federal coal, but no Federal surface
- No Federal coal or surface
- Sheridan coalfield study limit
- Wyodak-Anderson coal extent (part)
- Powder River Basin (part)

Figure PH-28. Federal coal and Federal surface ownership in the Sheridan coalfield.

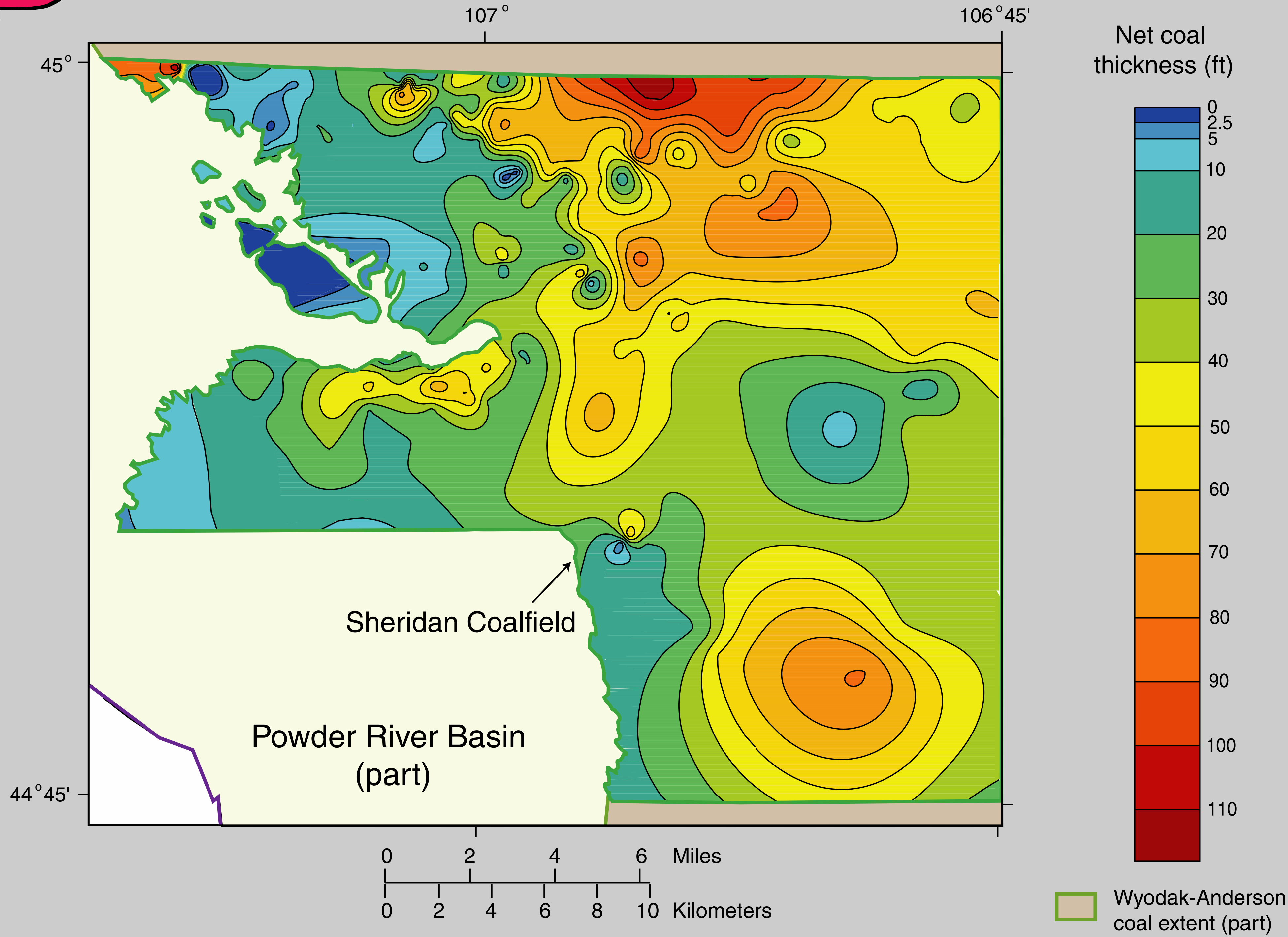


Figure PH-29. Wyodak-Anderson net coal isopach map in the Sheridan coalfield.

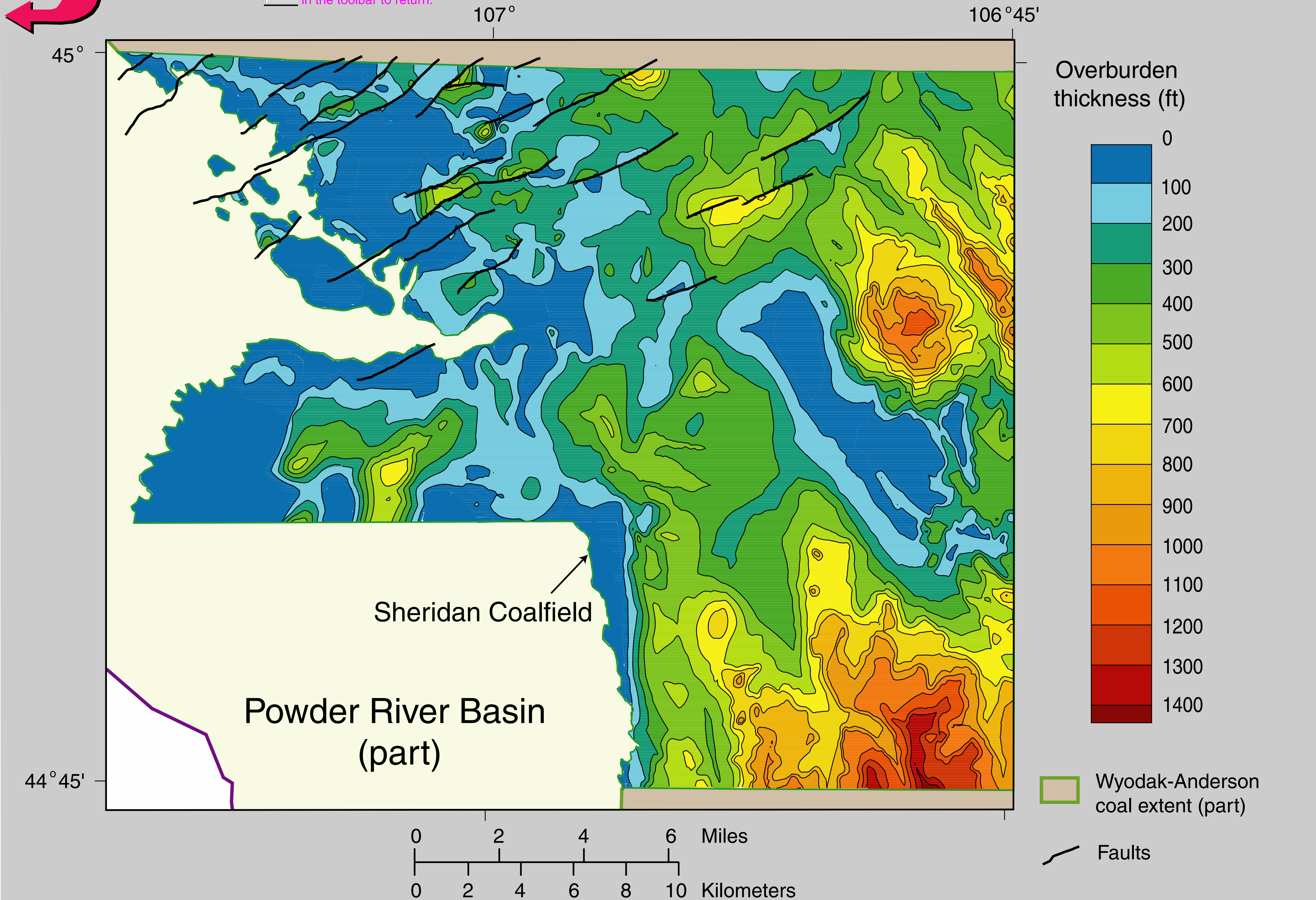


Figure PH-30. Wyodak-Anderson overburden isopach map in the Sheridan coalfield.

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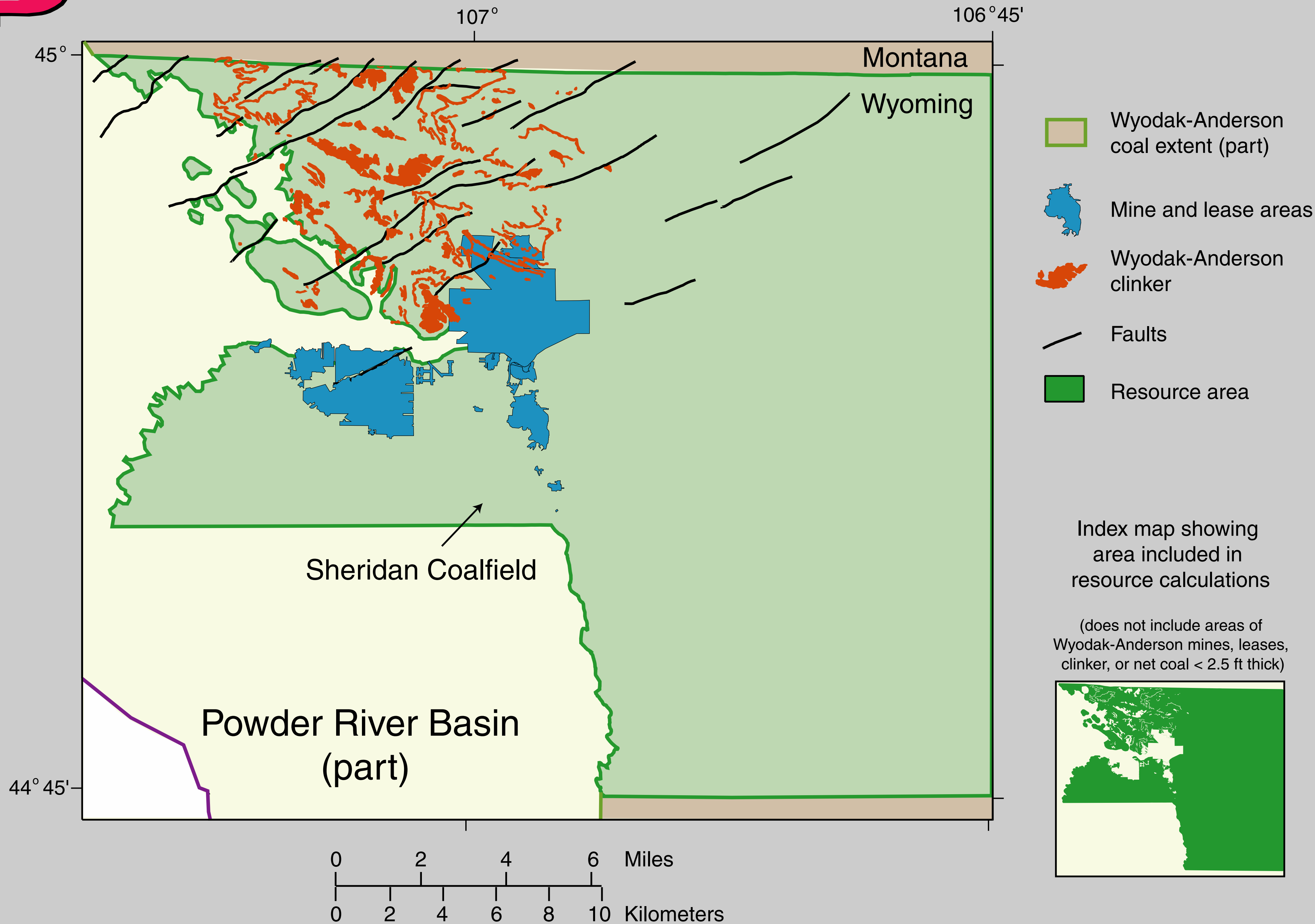

Figure PH-31. Wyodak-Anderson mine and lease areas, clinker, and resource area in the Sheridan coalfield.

Table PH-1. Summary data for Wyodak-Anderson coal zone in the Sheridan coalfield, Powder River Basin, Wyoming. Modified from unpublished U.S. Geological Survey coal quality database (USCHEM), February, 1992; Bragg and others (1994); and proprietary source(s)

Variable	Number of samples	Range Minimum	Range Maximum	Mean
Moisture [1]	1	20.40	20.40	20.40
Ash [1]	1	5.30	5.30	5.30
Total Sulfur [1]	1	0.70	0.70	0.70
Calorific Value [2]	1	9,540	9,540	9,540
lb SO_2 [3]	1	1.48	1.48	1.48
MMMFBtu [4]	1	10,120	10,120	10,120
Antimony [5]	2	0.23	0.25	0.24
Arsenic [5]	2	3.1	3.3	3.2
Beryllium [5]	2	0.20	0.23	0.21
Cadmium [5]	2	0.09	0.10	0.09
Chromium [5]	2	3.6	3.7	3.6
Cobalt [5]	2	1.1	1.2	1.2
Lead [5]	2	1.5	2.1	1.8
Manganese [5]	2	11	30	21
Mercury [5]	2	0.08	0.09	0.08
Nickel [5]	2	4.3	5.4	4.8
Selenium [5]	2	0.40	0.50	0.45
Uranium [5]	2	0.41	0.75	0.58

[1] Values are in percent and on an as-received basis.
[2] Value is in British thermal units (Btu).
[3] Value is in pounds per million Btu and on an as-received basis.
[4] Value is in British thermal units on a moist, mineral-matter-free basis.
[5] Values are in parts per million (ppm) on a whole-coal and as-received basis

Table PH-2. Wyodak-Anderson coal resources in the Sheridan coalfield, Sheridan County, Wyoming reported by overburden thickness (fig. PH-30), net coal thickness (fig. PH-29), and reliability categories. Resources are shown in millions of short tons (MST) and with two significant figures. Zeros (0) indicate that no coal resources were calculated within those categories. The table does not include resources in mine or lease areas, or areas containing Wyodak-Anderson clinker. Columns and rows will not sum due to independent rounding

Overburden thickness	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)	
0-100 ft	2.5-5 ft	0.16	7.6	39	0	47
	5-10 ft	5.4	33	140	7.7	190
	10-20 ft	17	120	220	5.1	360
	20-30 ft	7.2	83	56	0	150
	30-40 ft	11	36	3.6	0	51
	40-50 ft	29	34	0	0	63
	50-100 ft	38	20	34	0	92
0-100 ft total		110	330	490	13	940
100-200 ft	2.5-5 ft	0.20	5.0	1.6	0	6.8
	5-10 ft	4.4	40	41	0	85
	10-20 ft	17	85	120	7.5	230
	20-30 ft	38	190	84	0	310
	30-40 ft	55	100	3.0	0	160
	40-50 ft	79	76	2.1	0	160
	50-100 ft	100	170	12	0	280
100-200 ft total		290	660	260	7.5	1,200
200-300 ft	2.5-5 ft	0.11	2.5	0.57	0	3.1
	5-10 ft	3.3	14	6.4	0	24
	10-20 ft	29	68	78	8.9	180
	20-30 ft	56	160	130	0.75	350
	30-40 ft	34	140	56	0	230
	40-50 ft	15	120	9.8	0	150
	50-100 ft	150	640	53	0	840
	100-150 ft	0	9.6	0	0	9.6
200-300 ft total		280	1,200	330	9.6	1,800

Table PH-2. Wyodak-Anderson coal resources, Sheridan coalfield, Powder River Basin—continued

Overburden thickness	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)	
300-400 ft	2.5-5 ft	0.061	1.1	0	0	1.2
	5-10 ft	8.3	16	10	0	34
	10-20 ft	15	62	47	2.3	130
	20-30 ft	36	150	230	2.2	420
	30-40 ft	36	210	190	0.8	430
	40-50 ft	16	120	58	0	190
	50-100 ft	220	610	78	0	900
	100-150 ft	9.3	5.0	0	0	14
300-400 ft total		340	1,200	610	5.3	2,100
400-500 ft	2.5-5 ft	0.22	0.76	0	0	0.98
	5-10 ft	9.2	36	4.2	0	49
	10-20 ft	11	100	73	3.7	190
	20-30 ft	14	85	220	8.5	320
	30-40 ft	17	50	140	5.6	210
	40-50 ft	14	55	41	0	110
	50-100 ft	54	250	72	0	370
	100-150 ft	4.1	2.5	0	0	6.6
400-500 ft total		120	580	540	18	1,300
500-1,000 ft	2.5-5 ft	1.5	2.2	0	0	3.7
	5-10 ft	4.6	9.7	0	0	14
	10-20 ft	15	140	170	0.16	330
	20-30 ft	15	95	300	22	430
	30-40 ft	7.7	80	190	16	290
	40-50 ft	22	110	220	35	390
	50-100 ft	100	480	670	13	1,300
500-1,000 ft total		170	910	1,500	86	2,700

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Table PH-2. Wyodak-Anderson coal resources, Sheridan coalfield, Powder River Basin—continued

Overburden thickness	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)	
1,000-1,500 ft	20-30 ft	0	0	12	4.5	17
	30-40 ft	0	1.0	68	18	87
	40-50 ft	0	14	100	15	130
	50-100 ft	15	74	250	0	340
1,000-1,500 ft total		15	89	430	37	580
Grand total (MST)		1,300	4,900	4,200	180	11,000

Table PH-3. Wyodak-Anderson coal resources in the Sheridan coalfield, Sheridan County, Wyoming reported by Federal coal and Federal surface ownership (fig. PH-28) (Biewick and others, 1998). Coal resources are reported in millions of short tons (MST) with two significant figures. The table does not include resources in mine or lease areas, or areas containing Wyodak-Anderson clinker. Column will not sum due to independent rounding

Federal ownership	Total (MST)
No Federal coal or surface ownership	5,300
Federal coal, but no Federal surface ownership	5,200
Federal coal and Federal surface ownership	150
Grand total (MST)	11,000

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Table PH-4. Wyodak-Anderson coal resources in the Sheridan coalfield, Sheridan County, Wyoming reported by 7.5-minute quadrangle map area (fig. PH-27). Coal resources are reported in millions of short tons (MST) and with two significant figures. The table does not include resources in mine or lease areas, or areas containing Wyodak-Anderson clinker. Column will not sum due to independent rounding

7.5-minute quadrangle map	Total (MST)
ACME	2,700
BAR N DRAW	2,900
HULTZ DRAW	280
MONARCH	650
RANCHESTER	98
SHERIDAN	1,300
WOLF	42
WYARNO	2,700
Grand total (MST)	11,000

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Table PH-5. Data used for computation of confidence intervals within reliability categories for the Wyodak-Anderson coal zone in the Sheridan coalfield, Powder River Basin, Wyoming. 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)	68,915,982	264,330,666	258,679,514	13,736,407	605,662,568
Percent of area	11	44	43	2	100
Acres (area x 0.0002471)	17,030	65,318	63,921	3,394	149,662
SD (standard deviation (in ft) from residual thickness)	15.74	15.74	15.74	15.74	NA
Acre feet (acres x SD)	268,044	1,028,098	1,006,118	53,427	NA
Volume standard deviation (MST)	41	239	948	95	1,322
Pseudo *n*	136	58	4	1	NA

Table PH-6. Estimates of uncertainty (calculated with measurement error) for Wyodak-Anderson coal resources in the Sheridan coalfield, Powder River Basin, Wyoming. To show detail, resources are reported in millions of short tons (MST) with 4 significant figures

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Total calculated resource (MST))	1,333	4,904	4,221	176.0	10,640
Lower 90% confidence limit (MST)	1,266	4,510	2,662	21.00	8,459
Upper 90% confidence limit (MST)	1,400	5,298	5,780	332.0	12,810

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