Drill Hole Data for Coal Beds in the Powder River Basin, Montana and Wyoming
Drill Hole Data for Coal Beds in the Powder River Basin, Montana and Wyoming

By Jon E. Haacke and David C. Scott
Contents

Abstract..............................................................................................................................................1
Introduction and Objectives.................................................................................................................1
Study Methodology.............................................................................................................................3
  Data Collection..................................................................................................................................3
  Coal Bed Nomenclature and Correlations.......................................................................................3
Database.............................................................................................................................................4
  Location Fields (and Structure).......................................................................................................4
  Stratigraphy Fields (and Structure)..................................................................................................5
ARC Map...............................................................................................................................................5
  Downloadable Data and the Interactive Map....................................................................................5
The Data Package..................................................................................................................................7
Acknowledgments..................................................................................................................................7
References Cited...................................................................................................................................14

Figure

1. Map showing public domain drill hole locations for the Powder River Basin, Montana and Wyoming ...............................................................................................................................................2

Tables

1. List of the contents of the location table LITH_BY field showing the organization that made the lithology picks, and the number of drill holes entered.........................................................1
2. List of the contents of the stratigraphy table FORMATION and BED fields showing the 47 coal beds, in stratigraphic order from youngest to oldest, in the Powder River Basin of Montana and Wyoming, and the number of drill holes encountering each bed ..............................................................................................................................................6
3. List of the contents of the location table TYPE field showing the drill hole types and the number of drill holes of each type.........................................................................................................7
4. Federal and State publications and online sources with original drill hole logs in the Powder River Basin. The publication number is contained in the location table DAT_SOURCE field. The Comment column describes the drill hole number series and type of logs contained........................................................................................................................................8
5. List of the contents of the stratigraphy table PRIME_LITH and LITH_MOD fields and the number of occurrences of each combination...........................................................................12
Conversion Factors

Inch/Pound to SI

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>foot (ft)</td>
<td>0.3048</td>
<td>meter (m)</td>
</tr>
</tbody>
</table>

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NAVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD27).

Elevation, as used in this report, refers to distance above the vertical datum.
Drill Hole Data for Coal Beds in the Powder River Basin, Montana and Wyoming

By Jon E. Haacke and David C. Scott

Abstract

This report by the U.S. Geological Survey (USGS) of the Powder River Basin (PRB) of Montana and Wyoming is part of the U.S. Coal Resources and Reserves Assessment Project. Essential to that project was the creation of a comprehensive drill hole database that was used for coal bed correlation and for coal resource and reserve assessments in the PRB. This drill hole database was assembled using data from the USGS National Coal Resources Data System, several other Federal and State agencies, and selected mining companies. Additionally, USGS personnel manually entered lithologic picks into the database from geophysical logs of coalbed methane, oil, and gas wells. Of the 29,928 drill holes processed, records of 21,393 are in the public domain and are included in this report. The database contains location information, lithology, and coal bed names for each drill hole.

Introduction and Objectives

The PRB was previously assessed for coal resources and reserves by the USGS and other Federal and State agencies. These assessments generally involved studies that covered only limited geographic areas and (or) limited depths. The current U.S. Coal Resources and Reserves Assessment Project expanded the scope of past studies to include the entire PRB, all coal beds, and at all depths. For this purpose, the PRB was divided into four assessment areas to permit more timely publication of assessment results. These assessment areas (fig. 1) are (1) Gillette coal field (Luppens and others, 2008), (2) Northern Wyoming PRB (Scott and others, 2010), (3) Southwestern PRB (Osmonson and others, 2011), and (4) Montana PRB (Haacke and others, 2012).

As a foundation for the PRB assessment, the largest possible drill hole database was assembled. The core of the digital database came from the U.S. Geological Survey National Coal Resources Data System (NCRDS, http://energy.er.usgs.gov/products/databases/CoalQual/index.htm). Additional digital data were supplied by the Wyoming State Geological Survey (WSGS, http://www.wsgs.uwyo.edu/), the Montana Bureau of Mines and Geology (MBMG, http://www.mmbg.mtech.edu/), the Bureau of Land Management (BLM, http://www.blm.gov/wo/st/en.html), and a commercial database created by Goolsby, Finley, and Associates, LLC (Goolsby and others, 2001) that was released to public domain. Confidential drill hole data were loaned to the USGS by several mining companies operating in the PRB. A substantial amount of new data is now available from the recent development of coalbed methane (CBM) in Wyoming and Montana. Geophysical logs of an additional 13,358 CBM, oil, and gas wells were examined and the lithology picks entered in the database using the StratiFact® (GRG Corporation, 1998) drill hole database and graphics program (table 1).

The correlation of all coal beds was determined using the StratiFact program, with some 250,000 cross-sections viewed in order to place 47 coal beds into a single stratigraphic system. The interpretations from this greatly expanded database provided a more accurate view of the coal resources and reserves in the PRB. The resulting correlated database contained 29,928 drill holes, of which 21,393 are public domain (fig. 1). Each of the four assessment area reports, listed above, using the correlated drill hole dataset, contains discussions on geology, coal resources, and reserves tonnages. The purpose of this report is to make the drill hole data available to the public.

<table>
<thead>
<tr>
<th>Number of holes</th>
<th>Field contents</th>
<th>Full name</th>
</tr>
</thead>
<tbody>
<tr>
<td>697</td>
<td>GFA</td>
<td>Goolsby, Finley, and Associates, LLC</td>
</tr>
<tr>
<td>1,034</td>
<td>MBMG</td>
<td>The Montana Bureau of Mines and Geology</td>
</tr>
<tr>
<td>697</td>
<td>USBLM</td>
<td>The Bureau of Land Management</td>
</tr>
<tr>
<td>16,732</td>
<td>USGS</td>
<td>The U.S. Geological Survey</td>
</tr>
<tr>
<td>2,233</td>
<td>WSGS</td>
<td>The Wyoming State Geological Survey</td>
</tr>
</tbody>
</table>
Figure 1. Map showing public domain drill hole locations for the Powder River Basin, Montana and Wyoming. Locations are approximate.
Study Methodology

Two steps were used in producing the completed drill hole database (1) data collection and (2) coal bed correlation. The assessment process is discussed in detail in the four individual assessment reports.

Data Collection

The first phase in data collection began with a search of the USGS NCRDS database that contains coal drill hole and measured section data for the United States collected by the USGS and various State agencies. The NCRDS data that came from WSGS and MBMG were later augmented by additional digital data supplied by those State agencies. Coal companies having activity in the PRB were approached with requests for use of their data in the assessments and several supplied digital data upon conditions of anonymity and data confidentiality.

The next phase involved entering data from CBM, oil, and gas wells. In the mid-1990s, CBM drilling in the Wyoming portion of the PRB increased rapidly, and by 1999 thousands of CBM wells were being drilled. By the time that the PRB assessment project began in 2004 the large number of new publically available CBM wells as well as thousands of older oil and gas wells allowed a more comprehensive evaluation of geology and coal resources than had been possible in previous studies. TIFF images of drill hole geophysical logs, selected for data entry into StratiFact, were downloaded from the Wyoming Oil and Gas Conservation Commission (WOGCC) web site as were drill hole coordinates for all Wyoming wells.

In Montana, CBM, oil, and gas drilling is limited. CBM development has been restricted to an area south and east of the town of Decker (which is about 75 miles southeast of Billings). Additionally, oil and gas exploration and development in the Montana PRB has been much less extensive than in Wyoming. The result is a significant lack of publically available drill hole data in Montana as compared with Wyoming. Geophysical logs for Montana were purchased from MJ Systems (2009) and converted to TIFF format. Drill hole coordinates for all Montana wells were downloaded from the Montana Board of Oil and Gas (Montana Board of Oil and Gas, 2006).

The drill hole coordinates and elevations were derived from a variety of sources, accuracy of most of these data is unknown. A concentrated effort was made to check drill hole locations but, lacking access to much of the original data, locations of many drill hole could not be verified. The latitudes, longitudes and elevations of CBM, oil, and gas wells came from the respective oil and gas commissions of Montana and Wyoming, having been supplied by the operators of the wells. Both state commissions assume the coordinates and elevations to be in NAD 27 datum but it is not required. In addition, the state commissions only require that the well be in the permitted quarter-quarter of a section, so the coordinates may only be approximate. Overall, drill holes in this database are believed to have sufficiently accurate coordinates and elevations for regional coal correlations.

Other factors add to the variability in data consistency for entries in this database because (1) geophysical logs differ widely in type, quality, and resolution; (2) in a majority of CBM wells, only gamma ray logs were run and many of those were logged through drill pipe or casing; and (3) hundreds of wells were logged only to the top of the target coal. Oil and gas wells were logged primarily for detail in deep formations, and typically the upper (coal-bearing) intervals were either not logged or only gamma logged through the surface casing.

Lithology picks from geophysical logs were entered into the StratiFact program. The primary focus of the PRB assessment was to determine coal resources and reserves rather than to conduct a comprehensive geological study; therefore, no attempt was made to interpret non-coal lithologies and in cases where the lithology was not already described in detail, lithologies were coded as coal or rock. Partings within coal beds and interburden between coal beds were also coded as rock. An interval for which there was no geophysical logging, such as the shallower part of an oil or well or a CBM well that was not logged to the bottom of the well, was entered as “No Log.” However, if the methane-producing interval of the CBM well was available from production records, that interval was entered as “Coal, CBM Perf.” For some data supplied to the USGS, only coal picks were recorded and the non-reported intervals were entered as “Not Reported.” In some cases, those non-reported intervals possibly had coals that were not considered significant. Therefore the “No Log” and “Not Reported” intervals should be considered as null information rather than as not having any coal for correlation and modeling purposes. In all, lithologic data from 9,565 CBM wells and 3,091 oil and gas wells in Wyoming, and 290 CBM wells and 412 oil and gas wells in Montana were entered in the database.

Coal Bed Correlations and Nomenclature

The second step in producing the database was the correlation of coal beds. Historically, correlation of individually named coal beds and coal zones across the entire PRB has been difficult, because the beds commonly split, merge, and pinch out (Flores and others, 1999). Also, distances between individual drill holes were often widely spaced, increasing the uncertainty of coal bed correlations from one drill hole to the next. However, with this greatly expanded database, the distance between drill holes was reduced resulting in a higher density of subsurface data and increased correlation reliability.

Many different names for individual coal beds and coal zones in the PRB have been used during the past 30 years. A report by Kent and others (1980), who described the northern part of the Gillette coal field that falls within the Spotted Horse coal field of Olive (1957), established a coal bed nomenclature system that has become the standard for much of the PRB in Wyoming. Kent and others (1980) retained certain existing coal bed nomenclature and revised
other nomenclature by introducing new coal bed names. Molnia
and Pierce (1992) also described coal bed stratigraphy in the
central PRB in Wyoming and Montana; their nomenclature
followed the usage of Culbertson and others (1979), Law
and others (1979), Kent and others (1980), and Culbertson
and Saperstone (1987). Flores and others (1999) defined
a coal zone in the PRB known as the Wyodak-Anderson,
which includes many named coal beds in the upper part of
the Tongue River Member of the Fort Union Formation. Five
previously published regional cross sections were particularly
instrumental in setting the framework for coal bed correlations
in the PRB (1) McLellan and others (1990), (2) Pierce and
others (1990), (3) Hardie (1991), (4) McLellan (1991), and (5)
Molnia and Pierce (1992). Coal bed names used in this and
previous reports are discussed in the four individual assessment
reports mentioned earlier. The formation and bed names used
in this report and the number of holes that encountered each
coal bed are given in table 2.

The graphical interface of the StratiFact database was
a critical tool for managing the interpretation of the large
volume of information. On-screen cross sections were
selected, edited, and correlated. Both linear and circular cross
sections were constructed to correlate coal beds across the
PRB assessment area. Circular cross sections that verify
closure were especially valuable when coal beds either split
or thinned adjacent to sand channels. In this process, the
beginning and ending drill holes of the cross section are the
same, assuring correlation accuracy.

Guidelines were established regarding how to handle
situations in which two named beds merged into a single bed.
The general guideline used in these cases was that two named
beds were considered to have merged into a single named
bed when an intervening parting was less than 2.0 ft thick. The
following exceptions were made for modeling purposes:

- In individual holes, coal beds split by partings as
  much as 5.0 ft thick were considered to be merged if
  surrounding holes indicate the beds had merged into a
  single bed.

- In individual holes, coal beds with no partings or
  partings less than 2.0 ft thick were considered to be
  split into two beds if surrounding holes showed the
  coal has split into two beds.

- The upper bed’s name was used for the merged-bed
  name, except in the case of a rider bed that merged
  into the main bed; for example, where the Anderson
  bed merged with the Upper Anderson Rider bed, the
  resulting bed was considered the Anderson bed.

Database

The database consists of two tables, the location table and
the stratigraphy table. The data in the two tables are linked by
unique id numbers assigned to each drill hole. Each table is
supplied in two formats, containing identical data. The quote
and comma delimited format files have a “CSV” extension;
the dbase format files have a “DBF” extension.

The following section lists the fields in the database
tables. Each field name is described as a Character, Integer,
or Numeric field along with the size of the field. There is also
a brief description of the purpose of each field and for some
fields the specific contents of each field.

Location Fields (and Structure)

UNIQUE_ID (Integer)
Unique number assigned to each drill hole to relate data in
the location table to those in the stratigraphy table. Numbered
from 1 to the total number of drill holes in the database.

HOLE_ID (Character)
The drill hole identifier assigned by the company or agency
who drilled the well, except for CBM, oil, and gas wells where
the standard API number is used

LAT_NAD27 (Numeric, 5 decimals)
The Latitude coordinate, expressed in decimal degrees, in
NAD 27 datum

LONG_NAD27 (Numeric, 5 decimals)
The Longitude coordinate, expressed in decimal degrees, in
NAD 27 datum.

UTME_NAD27 (Numeric, 2 decimals)
Universal Transverse Mercator coordinates, expressed in
meters, zone 13, in NAD 27 datum. Values were converted
from the Latitude and Longitude coordinates using the Army
Corps of Engineers Corpscon 6 software.

UTMN_NAD27 (Numeric, 2 decimals)
Universal Transverse Mercator coordinates, expressed in
meters, zone 13, in NAD 27 datum. Values were converted
from the Latitude and Longitude coordinates using the Army
Corps of Engineers Corpscon 6 software.

ELEVATION (Numeric, 2 decimals)
Surface elevation of all drill holes, except for oil wells where
the elevation is taken at the kelly bushing.

DH_DEPTH (Numeric, 2 decimals)
The drilled depth of the drill hole.
TOWNSHIP (Character)
Township within the 6th Principal Meridian.

RANGE (Character)
Range within the 6th Principal Meridian.

SECTION (Numeric, 2 decimals)
The Section within a township and a range.

QTR_QTR (Character)
The Quarter, Quarter within a Section.

STATE (Character)
Contents are either Montana or Wyoming. There are 2,925 holes in Montana and 18,469 holes in Wyoming.

COUNTY (Character)
Contains the county name.

TYPE (Character)
Type of drill hole (table 3).

DAT_SOURCE (Character)
Data source with original drill hole information from which lithology picks were made. Much of the original drill hole data is publically available from publications and online sources. A detailed list of the sources with comments is in table 4.

LITH_BY (Character)
Name of the agency, organization, or company that made the lithology picks (table 1). Where available, the field also contains the name of the individual who made the picks.

COMPANY (Character)
For CBM, oil, and gas wells, this field contains the name of the company for which the well was drilled. For holes drilled for coal, this field either contains the name of the mining company or the government agency. There are 1,014 different entries in this field.

WELL_NAME (Character)
Contains the common well name for CBM, oil, and gas wells.

QUAD_MAP (Character)
Contains the name of the USGS 7.5 minute quadrangle map.

Stratigraphy Fields (and Structure)

HOLE_ID (Character)
The drill hole identifier assigned by the company or agency who drilled the well, except for CBM, oil, and gas wells where the standard API number is used.

TOP_DEPTH (Numeric, 2 decimals)
This is the depth, in feet, from the surface to the top of each lithologic unit.

BOT_DEPTH (Numeric, 2 decimals)
This is the depth, in feet, from the surface to the bottom of each lithologic unit.

PRIME_LITH and LITH_MOD (Character)
These two fields contain the primary lithology and lithology modifier for every stratigraphic record (table 5).

FORMATION (Character, 16) and BED (Character)
These two fields contain the correlated formation and coal bed names (table 2).

ARC Map

Supplemental to the database are GIS data created using Esri ArcGIS 9.3.1 (Esri, 2000) that can be used to show the drill hole database in map view along with other pertinent data layers. These layers include surface geology, coal assessment study area boundaries, townships and ranges, generalized surface ownership, topography, and various cultural features that are also included in basemap GIS services provided by Esri, Inc. (Esri, 2010).

Downloadable Data and the Interactive Map

The GIS is available for interactive analysis as a map document (both MXD and PMF formats) that can be downloaded from the USGS website at http://pubs.usgs.gov/ds/713/. Because of the ability to toggle layers on and off and analyze attributes, data analysis can be achieved effectively with the interactive map. The publishing process uses the ArcMap document (MXD) and creates a special file called a published map file (PMF). ArcGIS Publisher (Esri, 2008a, http://www.esri.com/software/arcgis/extensions/publisher/index.html) is the extension used to create the PMF from the MXD and packages the required data with the PMF file for easy distribution. PMFs can be viewed or printed using any ArcGIS (Esri, 2000, http://www.esri.com/software/arcgis/) desktop product, including ArcMap and the no-cost ArcReader (Esri, 2008b, http://www.esri.com/software/arcgis/arcreader/download.html) application. Users can download and install the ArcReader software...
Table 2. List of the contents of the stratigraphy table *FORMATION* and *BED* fields showing the 47 coal beds, in stratigraphic order from youngest to oldest, in the Powder River Basin of Montana and Wyoming, and the number of drill holes encountering each bed.

<table>
<thead>
<tr>
<th>Number of holes</th>
<th>Formation</th>
<th>Bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>186</td>
<td>Wasatch</td>
<td>Upper Healy</td>
</tr>
<tr>
<td>658</td>
<td>Wasatch</td>
<td>Healy/Lower Ulm</td>
</tr>
<tr>
<td>785</td>
<td>Wasatch</td>
<td>Murray</td>
</tr>
<tr>
<td>591</td>
<td>Wasatch</td>
<td>Ucross</td>
</tr>
<tr>
<td>1,989</td>
<td>Wasatch</td>
<td>Upper Felix</td>
</tr>
<tr>
<td>4,444</td>
<td>Wasatch</td>
<td>Felix</td>
</tr>
<tr>
<td>4,109</td>
<td>Wasatch</td>
<td>Lower Felix</td>
</tr>
<tr>
<td>5,710</td>
<td>Fort Union</td>
<td>Upper Roland Rider</td>
</tr>
<tr>
<td>1,619</td>
<td>Fort Union</td>
<td>Lower Roland Rider</td>
</tr>
<tr>
<td>9,987</td>
<td>Fort Union</td>
<td>Roland (Baker)</td>
</tr>
<tr>
<td>953</td>
<td>Fort Union</td>
<td>Roland (Taff)</td>
</tr>
<tr>
<td>326</td>
<td>Fort Union</td>
<td>Upper Smith</td>
</tr>
<tr>
<td>9,334</td>
<td>Fort Union</td>
<td>Smith</td>
</tr>
<tr>
<td>343</td>
<td>Fort Union</td>
<td>Upper Anderson Rider</td>
</tr>
<tr>
<td>480</td>
<td>Fort Union</td>
<td>Lower Anderson Rider</td>
</tr>
<tr>
<td>11,775</td>
<td>Fort Union</td>
<td>Anderson</td>
</tr>
<tr>
<td>883</td>
<td>Fort Union</td>
<td>Lower Anderson</td>
</tr>
<tr>
<td>672</td>
<td>Fort Union</td>
<td>Dietz 1</td>
</tr>
<tr>
<td>930</td>
<td>Fort Union</td>
<td>Dietz 2</td>
</tr>
<tr>
<td>4,816</td>
<td>Fort Union</td>
<td>Dietz 3</td>
</tr>
<tr>
<td>624</td>
<td>Fort Union</td>
<td>Dietz 4</td>
</tr>
<tr>
<td>726</td>
<td>Fort Union</td>
<td>Upper Canyon/Cox</td>
</tr>
<tr>
<td>9,354</td>
<td>Fort Union</td>
<td>Canyon</td>
</tr>
<tr>
<td>4,374</td>
<td>Fort Union</td>
<td>Lower Canyon</td>
</tr>
<tr>
<td>145</td>
<td>Fort Union</td>
<td>Upper Ferry</td>
</tr>
<tr>
<td>744</td>
<td>Fort Union</td>
<td>Ferry</td>
</tr>
<tr>
<td>4,460</td>
<td>Fort Union</td>
<td>Werner/Cook</td>
</tr>
<tr>
<td>328</td>
<td>Fort Union</td>
<td>Upper Otter</td>
</tr>
<tr>
<td>3,642</td>
<td>Fort Union</td>
<td>Otter</td>
</tr>
<tr>
<td>3,412</td>
<td>Fort Union</td>
<td>Gates/Wall</td>
</tr>
<tr>
<td>1,368</td>
<td>Fort Union</td>
<td>Pawnee</td>
</tr>
<tr>
<td>110</td>
<td>Fort Union</td>
<td>Brewster-Arnold</td>
</tr>
<tr>
<td>1,052</td>
<td>Fort Union</td>
<td>Odell</td>
</tr>
<tr>
<td>247</td>
<td>Fort Union</td>
<td>Cache</td>
</tr>
<tr>
<td>24</td>
<td>Fort Union</td>
<td>A Zone</td>
</tr>
<tr>
<td>44</td>
<td>Fort Union</td>
<td>Upper Rosebud/S1</td>
</tr>
<tr>
<td>2,206</td>
<td>Fort Union</td>
<td>Rosebud/Knobloch</td>
</tr>
<tr>
<td>86</td>
<td>Fort Union</td>
<td>Calvert</td>
</tr>
<tr>
<td>2,499</td>
<td>Fort Union</td>
<td>Mckay/Nance</td>
</tr>
<tr>
<td>63</td>
<td>Fort Union</td>
<td>Lower Mckay/S2</td>
</tr>
<tr>
<td>2,752</td>
<td>Fort Union</td>
<td>Flowers-Goodale/Danner</td>
</tr>
<tr>
<td>1</td>
<td>Fort Union</td>
<td>Upper Witham</td>
</tr>
<tr>
<td>1,491</td>
<td>Fort Union</td>
<td>Robinson/Witham</td>
</tr>
<tr>
<td>1,768</td>
<td>Fort Union</td>
<td>Roberts/Terret</td>
</tr>
<tr>
<td>50</td>
<td>Fort Union</td>
<td>Burley</td>
</tr>
<tr>
<td>91</td>
<td>Fort Union</td>
<td>Upper Stag</td>
</tr>
<tr>
<td>8</td>
<td>Fort Union</td>
<td>Lower Stag</td>
</tr>
</tbody>
</table>
from Esri. To access the MXD, users must have ArcGIS 9.3.1 or later software (Esri, 2000, http://www.esri.com/software/arcgis/eval-help/arcgis-931.html).

The ArcMap project is a compilation of both published and unpublished coal geology data. For the published data, the accompanying metadata have been retained as published. For the ArcGIS.com web services (formerly ArcGIS Online; Esri, 2010, http://www.esri.com/software/arcgis/arcgisonline/index.html), data descriptions, sources, and credits are stored as layer properties.

The Data Package

The report, whether downloaded from a USGS web site or from the CD consists of the text of this report (the pamphlet), the drill hole database, and the GIS data. The Data folder contains the drill hole database in CSV and DBF formats. The GIS folder contains the PRB_drill_holes.MXD and PRB_drill_holes.PMF files. All GIS data are stored in a geodatabase using the GCS_North_American_1983 coordinate system and reside in the ‘PRB_drill_holes.gdb’ folder within the GIS folder.

Acknowledgments

We would like to thank the staff of the Wyoming State Geological Survey, and Jay Gunderson of the Montana Bureau of Mines and Geology for supplying drill-hole data. The outstanding efforts of Laura R.H. Biewick and Lee M. Osmonson (U.S. Geological Survey) in creating the GIS map were extremely appreciated. Ronald H. Affolter, Scott A. Kinney, William R. Keefer, and Margaret S. Ellis, all of the U.S. Geological Survey, provided technical reviews of the manuscript which greatly improved this report.

<table>
<thead>
<tr>
<th>Number of holes</th>
<th>Field contents</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>12,553</td>
<td>CBM</td>
<td>Coalbed methane well</td>
</tr>
<tr>
<td>3,503</td>
<td>Coal test</td>
<td>Drilled for exploration and/or development of coal</td>
</tr>
<tr>
<td>5,003</td>
<td>Oil &amp; gas</td>
<td>Oil and gas well</td>
</tr>
<tr>
<td>334</td>
<td>Water well</td>
<td>Originally drilled as a water well</td>
</tr>
</tbody>
</table>
Table 4. Federal and State publications and online sources with original drill hole logs in the Powder River Basin. The publication number is contained in the location table DAT_SOURCE field. The Comment column describes the drill hole number series and type of logs contained.

<table>
<thead>
<tr>
<th>Source Publication</th>
<th>Comments</th>
</tr>
</thead>
</table>
Table 4. Federal and State publications and online sources with original drill hole logs in the Powder River Basin. The publication number is contained in the location table DAT_SOURCE field. The Comment column describes the drill hole number series and type of logs contained.—Continued

<table>
<thead>
<tr>
<th>Source Publication</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robinson, L.N. and Van Gosen, B.S., 1985, Maps and sections showing geology and coal resources of the northeastern part of the Crow Indian Reservation, Big Horn County, Montana: U.S. Geological Survey Miscellaneous Field Studies Map 1796, scale 1:24,000, 9 maps.</td>
<td>Contains numerous drill hole and measured section locations on maps with annotated coal intercepts. The published database contains 6 drill holes from this source publication.</td>
</tr>
</tbody>
</table>
### Table 4. Federal and State publications and online sources with original drill hole logs in the Powder River Basin. The publication number is contained in the location table DAT_SOURCE field. The Comment column describes the drill hole number series and type of logs contained.—Continued

<table>
<thead>
<tr>
<th>Source Publication</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robinson, L.N. and Van Gosen, B.S., 1986, Maps showing the coal geology of the Sarpy Creek area, Big Horn and Treasure Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map 1859, scale 1:24,000.</td>
<td>Coal picks and location maps for drill holes numbered 1 through 49. The published database contains 57 drill holes from this source publication.</td>
</tr>
</tbody>
</table>
Table 4. Federal and State publications and online sources with original drill hole logs in the Powder River Basin. The publication number is contained in the location table DAT_SOURCE field. The Comment column describes the drill hole number series and type of logs contained.—Continued

<table>
<thead>
<tr>
<th>Source Publication</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming Oil and Gas Conservation Commission <a href="http://wogcc.state.wy.us/">http://wogcc.state.wy.us/</a></td>
<td>Web site contains scanned logs of all Oil and Gas and Coalbed Methane wells in Wyoming along with location information for all wells. The published database contains 16,716 drill holes downloaded from this source.</td>
</tr>
</tbody>
</table>
Table 5. List of the contents of the stratigraphy table PRIME_LITH and LITH_MOD fields and the number of occurrences of each combination.

<table>
<thead>
<tr>
<th>Number of occurrences</th>
<th>Primary lithology</th>
<th>Lithology modifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Chert</td>
<td></td>
</tr>
<tr>
<td>10,972</td>
<td>Claystone</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Claystone</td>
<td>Bentonite</td>
</tr>
<tr>
<td>12</td>
<td>Claystone</td>
<td>Calcareous</td>
</tr>
<tr>
<td>116</td>
<td>Claystone</td>
<td>Carb/coaly</td>
</tr>
<tr>
<td>53</td>
<td>Claystone</td>
<td>Carb/silty</td>
</tr>
<tr>
<td>2,544</td>
<td>Claystone</td>
<td>Carbonaceous</td>
</tr>
<tr>
<td>189</td>
<td>Claystone</td>
<td>Coaly</td>
</tr>
<tr>
<td>50</td>
<td>Claystone</td>
<td>Root</td>
</tr>
<tr>
<td>1,442</td>
<td>Claystone</td>
<td>Sandy</td>
</tr>
<tr>
<td>15</td>
<td>Claystone</td>
<td>Shaley</td>
</tr>
<tr>
<td>475</td>
<td>Claystone</td>
<td>Silty</td>
</tr>
<tr>
<td>30</td>
<td>Claystone</td>
<td>Silty/carb</td>
</tr>
<tr>
<td>6</td>
<td>Claystone</td>
<td>Silty/sandy</td>
</tr>
<tr>
<td>122</td>
<td>Clinker</td>
<td></td>
</tr>
<tr>
<td>130,478</td>
<td>Coal</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Coal</td>
<td>Boney</td>
</tr>
<tr>
<td>792</td>
<td>Coal</td>
<td>Cbm perf</td>
</tr>
<tr>
<td>3</td>
<td>Coal</td>
<td>Clayey</td>
</tr>
<tr>
<td>19,890</td>
<td>Coal</td>
<td>High ash</td>
</tr>
<tr>
<td>187</td>
<td>Coal</td>
<td>Mod ash</td>
</tr>
<tr>
<td>607</td>
<td>Coal</td>
<td>Shaley</td>
</tr>
<tr>
<td>106</td>
<td>Conglomerate</td>
<td></td>
</tr>
<tr>
<td>153</td>
<td>Interbedded</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ironstone</td>
<td></td>
</tr>
<tr>
<td>253</td>
<td>Limestone</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Limestone</td>
<td>Shaley</td>
</tr>
<tr>
<td>4,229</td>
<td>Mudstone</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Mudstone</td>
<td>Bentonite</td>
</tr>
<tr>
<td>172</td>
<td>Mudstone</td>
<td>Carbonaceous</td>
</tr>
<tr>
<td>38</td>
<td>Mudstone</td>
<td>Coaly</td>
</tr>
<tr>
<td>157</td>
<td>Mudstone</td>
<td>Sandy</td>
</tr>
<tr>
<td>45</td>
<td>Mudstone</td>
<td>Silty</td>
</tr>
<tr>
<td>2</td>
<td>Mudstone</td>
<td>Silty/carb</td>
</tr>
<tr>
<td>6,469</td>
<td>No log</td>
<td></td>
</tr>
<tr>
<td>25,319</td>
<td>Not recorded</td>
<td></td>
</tr>
</tbody>
</table>
### Table 5.
List of the contents of the stratigraphy table PRIME_LITH and LITH_MOD fields and the number of occurrences of each combination.—Continued.

<table>
<thead>
<tr>
<th>Number of occurrences</th>
<th>Primary lithology</th>
<th>Lithology modifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Pyrite</td>
<td></td>
</tr>
<tr>
<td>118,649</td>
<td>Rock</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>13,126</td>
<td>Sandstone</td>
<td></td>
</tr>
<tr>
<td>340</td>
<td>Sandstone</td>
<td>Calcareous</td>
</tr>
<tr>
<td>272</td>
<td>Sandstone</td>
<td>Carbonaceous</td>
</tr>
<tr>
<td>239</td>
<td>Sandstone</td>
<td>Clayey</td>
</tr>
<tr>
<td>6</td>
<td>Sandstone</td>
<td>Coaly</td>
</tr>
<tr>
<td>2</td>
<td>Sandstone</td>
<td>Conglomeritic</td>
</tr>
<tr>
<td>2</td>
<td>Sandstone</td>
<td>Cross bedded</td>
</tr>
<tr>
<td>2</td>
<td>Sandstone</td>
<td>Fossiliferous</td>
</tr>
<tr>
<td>12</td>
<td>Sandstone</td>
<td>Muddy</td>
</tr>
<tr>
<td>72</td>
<td>Sandstone</td>
<td>Shaley</td>
</tr>
<tr>
<td>728</td>
<td>Sandstone</td>
<td>Silty</td>
</tr>
<tr>
<td>3,614</td>
<td>Shale</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shale</td>
<td>Bentonite</td>
</tr>
<tr>
<td>4</td>
<td>Shale</td>
<td>Calcareous</td>
</tr>
<tr>
<td>92</td>
<td>Shale</td>
<td>Carb/coaley</td>
</tr>
<tr>
<td>4</td>
<td>Shale</td>
<td>Carb/silty</td>
</tr>
<tr>
<td>2,837</td>
<td>Shale</td>
<td>Carbonaceous</td>
</tr>
<tr>
<td>87</td>
<td>Shale</td>
<td>Coaly</td>
</tr>
<tr>
<td>318</td>
<td>Shale</td>
<td>Sandy</td>
</tr>
<tr>
<td>5,276</td>
<td>Siltstone</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Siltstone</td>
<td>Burrowed</td>
</tr>
<tr>
<td>48</td>
<td>Siltstone</td>
<td>Calcareous</td>
</tr>
<tr>
<td>544</td>
<td>Siltstone</td>
<td>Carbonaceous</td>
</tr>
<tr>
<td>200</td>
<td>Siltstone</td>
<td>Clayey</td>
</tr>
<tr>
<td>15</td>
<td>Siltstone</td>
<td>Muddy</td>
</tr>
<tr>
<td>6</td>
<td>Siltstone</td>
<td>Root</td>
</tr>
<tr>
<td>406</td>
<td>Siltstone</td>
<td>Sandy</td>
</tr>
<tr>
<td>176</td>
<td>Siltstone</td>
<td>Shaley</td>
</tr>
<tr>
<td>121</td>
<td>Soil</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Surface gravel</td>
<td></td>
</tr>
<tr>
<td>282</td>
<td>Surface material</td>
<td></td>
</tr>
</tbody>
</table>
References Cited


Goolsby, Finley, and Associates, 2001, Drill hole database: Casper, Wyo., Goolsby. Finley, and Associates, LLC.


