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[3 sheets]

GEOLOGIC MAP AND COAL SECTIONS OF THE PEARL SCHOOL QUADRANGLE AND THE EASTERNMOST PART OF THE BAR V RANCH QUADRANGLE, BIG HORN COUNTY, MONTANA

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INTRODUCTION

The Pearl School and easternmost part of the Bar V Ranch quadrangles were mapped as part of the U.S. Geological Survey's program to classify and evaluate mineral lands in the public domain. Resources of economic interest within the map area are subbituminous coal, gravel, baked and fused rock, and potential occurrences of oil and gas at depth.

Previous geologic investigations include a reconnaissance of coal beds in the Tongue River Valley by Bass (1924), geologic mapping and coal investigations by Baker (1929), and a summary of some strippable coal resources in southeastern Montana by Matson and Blumer (1973). Additional drill-hole data and chemical analyses are available in U.S. Geological Survey open-file reports (U.S. Geological Survey and Montana Bureau of Mines and Geology, 1973, 1977a, 1977b, and 1978).

STRATIGRAPHY

The upper part of the Tongue River Member of the Fort Union Formation and the overlying lower part of the Wasatch Formation are exposed in the quadrangle. The Fort Union-Wasatch contact is placed at the top of the Roland coal bed of Baker (1929). Palynology studies by Tschudy (written commun., 1972, 1976) confirm a Paleocene age for exposed units of the Fort Union Formation and indicate a Paleocene and Eocene age for mapped units of the Wasatch Formation (see fossil chart).

The Wasatch and Fort Union Formations consist of lenticular and interbedded claystone, shale, siltstone, sandstone, thin coquina, carbonaceous shale, and paludal environments. Colors are mostly somber hues of light to dark gray, tan and brown. In contrast, colors are bright pink, red, and yellow where strata have been baked and fused by heat generated during the combustion of an underlying coal bed(s). Both formations are generally poorly resistant, with the exception of baked and fused rock and thin well-cemented sandstone, limestone, and coquina beds.

Other mapped units consist of undivided alluvial and colluvial deposits, minor terrace deposits, and landslide debris.

A detailed lithologic description of the major coal-bearing sequence is illustrated and described on the generalized columnar section.

FORT UNION FORMATION

The Fort Union Formation is divided into three members. In ascending stratigraphic order these are the Tullock, Lebo Shale, and Tongue River Members. The Tongue River Member is the major coal-bearing stratigraphic interval in this area and is the only member exposed (upper 500 ft) in the mapped area. The Tongue River is divided into three informal units: lower, middle, and upper. Discussion of the unexposed part of the Fort Union is based on lithologic interpretations and correlation of geophysical logs from oil-and-gas and coal test drill holes.

Tullock Member.--The Tullock Member is the lower member of the Fort Union. A cursory examination of geophysical logs from six oil-and-gas test drill holes indicates that the Tullock is lithologically similar to the Tongue River Member. Predominant lithologies are alternating beds of sandstone and shale. However, thick coal beds, characteristic of the Tongue River Member, are not present. The contact between the Tullock and the overlying Lebo Shale Member was picked on geophysical logs at the transition between the predominantly sandstone lithology of the Tullock and the predominantly shale lithology of the Lebo. This contact varies from sharp to gradational on geophysical logs.

Lebo Shale Member.--The Lebo Shale Member is the middle member of the Fort Union Formation and ranges in thickness from about 1,150 to 1,350 ft in the mapped area. Lithologic interpretations of available geophysical logs indicate that the predominant lithology is shale or claystone. Visual estimates of sand/shale ratios indicate a sand content of from 15 to 20 percent. One thin local coal(?) bed is present about 380-340 ft below the top of the member. The upper contact of the Lebo is at the abrupt change from predominantly shale lithology to the predominantly thick sandstone and coal-bearing sequence of the overlying Tongue River Member. A thin local coal bed is identified on some well logs about 35-45 ft below the Lebo-Tongue River contact. In the Ranchester quadrangle (about 6-7 mi southwest of the mapped area) Barnum (1975) placed the Lebo-Tongue River contact at the base of the Carney coal bed, which is about 600 ft stratigraphically higher than the lithologic contact in the mapped area. Subsurface correlations by Law and others (1975) indicate that the contact between the Lebo Shale and Tongue River Members "rises stratigraphically from the area around Birney, Mont., southwestward to Sheridan, Wyo."

Tongue River Member.--The Tongue River Member is the principal coal-bearing member of the Fort Union Formation. On the basis of gross lithologic differences, the Tongue River can be divided into three informal units: lower, middle, and upper.

The informal lower unit is defined by the base of the Tongue River Member and extends to the base of the Carney coal bed and ranges in thickness from about 500 to 630 ft. This unit is not exposed within the mapped area, but interpretations of geophysical logs indicate that the unit is predominantly sandstone with minor shale, and a few thin coal beds. The Wall coal bed is the only coal of regional extent present in this unit, and even it either is not present or is very thin on some well logs.

The informal middle unit extends from the base of the Carney coal bed to the base of the Smith coal bed and ranges in thickness from about 520 to 660 ft. This interval includes the following coal beds: Carney, Monarch, and Dietz (1,2,3). These coal beds are the thickest and most economically important in the mapped area. Lithologies separating coal beds are generally sandstone, with only minor shale. Exposures are usually covered by unmapped or mapped deposits of colluvial and alluvial debris or baked and fused rock where an underlying coal bed(s) has burned. About 50 ft of strata underlying the Smith coal bed are well exposed in various places in the mapped area. Interpretation of the geophysical log for Falcon and Seaboard Greer 1 (sec. 27, T. 9 S., R. 39 E.) indicates that interval between the Dietz 1 and Smith coal beds is mostly shale, with the interval changing to interbedded sandstone and shale about 50 ft below the Smith coal bed. Surface measured sections verify this lithologic interpretation of the geophysical log. In the southern part of the mapped area exposures of this interval are light gray and consist of interbedded shale and sandstone with scattered large clay-ironstone concretions and thin concretionary layers. In the northern part of the mapped area a thick yellowish-tan sandstone immediately underlies the Smith coal bed.

The informal upper unit includes strata from the Smith bed through the Roland of Baker bed, and ranges in thickness from about 160 to 200 ft. This unit is well exposed in the steep scarps forming valley walls along major stream drainages. Alternating light- and dark-colored lithologic beds impart a broadly banded appearance characteristic of this unit. Three stratigraphic zones or beds are continuous throughout the mapped area and serve as stratigraphic marker horizons. With rare exception, it is an association of beds rather than a specific bed that is distinctive enough to be used as a marker zone or bed.

From the stratigraphically lowest to the highest, these marker zones or beds are: the Smith coal bed, the Squirrel Creek coal zone, and the Roland coal bed of Baker.

The characteristics that distinguish the Smith coal bed marker are the light-gray strata or thick light-yellowish-tan sandstone underlying the Smith coal bed, the coal bed thickness (one or two benches as much as 19 ft thick), and the well-developed baked and fused rock deposits. In addition, fossil zones containing nonmarine pelecypods and gastropods are locally present about 20-30 ft above the Smith coal bed. These fossil zones are not as well developed nor laterally continuous as those above the Roland coal bed of Baker. Silicified stumps and logs are common throughout the interval between the Smith and the next highest stratigraphic marker, the Squirrel Creek coal zone, and then coal beds usually have indigenous silicified and ocherized logs and stumps.

The Squirrel Creek coal zone is overlain by a brownish-gray, fissile shale about 5-10 ft thick. This shale-and-coal zone is the most distinctive and recognizable marker zone in the mapped area. The brownish-gray shale is easily recognized as a dark band on aerial photographs. There are other similar shale beds in both the Tongue River Member of the Fort Union Formation and the Wasatch Formation, but they are generally thinner and are not associated with laterally continuous coal zones.

The Roland coal bed of Baker is the top of the Fort Union Formation and is the uppermost stratigraphic marker bed. Characteristics that define this coal bed are the thickness, 6-14 ft, and stratigraphic position, about 50-70 ft above the Squirrel Creek coal zone.

WASATCH FORMATION

The lithologies of the Wasatch Formation are very similar to those of the underlying Fort Union Formation. In contrast, however, Wasatch coal beds are generally thinner (usually less than 4 ft thick), but the total coal thickness, exclusive of partings, may be as much as 6 ft. A fossiliferous zone, as much as 30 ft thick, occurs about 30-80 ft above the Roland (of Baker) coal bed. This zone is characterized by thin coquina beds consisting of nonmarine, limestone-cemented, gastropod, pelecypod, and ostracode tests. Also included are scattered plant impressions. This zone has been used as a stratigraphic marker zone by Stone and Lupton (1908), Baker (1929), Olive (1959), and Law and Grazis (1972). On aerial photographs the formation has a banded appearance because of the thin dark carbonaceous (coal and shale) beds that contrast with interbedded light-colored shale and sandstone. Overall, the Wasatch is thinner bedded, less sandy, and more fossiliferous than the underlying Fort Union Formation.

STRUCTURE

The map area is near the structural axis of the northwest-trending asymmetrical Powder River Basin (Curry, 1971). Regional dip is southeast about 1-2°, but is modified by many small folds. Northeast-trending subparallel normal faults and monoclines are prominent structural features.

Four normal faults offsetting pre-Quaternary units are present in the Pearl School quadrangle. The First, Second, and Third faults are subparallel normal faults with a maximum displacement of about 30 ft and an average trend of N. 55°-60° E. Other characteristics common to these faults are: regular spacing (1.5 mi), reverse drag, southeast block downdropped, and, with decreasing displacement, lateral gradation to monoclinal flexures. A monocline in sec. 13, T. 9 S., R. 39 E., dips opposite to other fault-associated en echelon monoclines and may be a scissors flexure related to the Second fault. Reverse drag is well developed on downdropped blocks. This feature is illustrated on the structure-contour map between the First and Second faults and between the Second and Third faults. Reverse drag is usually associated with regional tensional stresses and characterized by decreasing fault surface dips with increasing depth (Hamblin, 1965). These circumstances are assumed to exist in the map area. In places, normal drag is present adjacent to fault traces. Normal drag is best developed on the upthrown blocks, and a maximum dip 72° southeast was measured in sec. 15, T. 9 S., R. 39 E. The North fault, near the north edge of the mapped area, is somewhat anomalous, trending N. 75°-80°E. Reverse drag is not evident, but normal drag is present adjacent to the fault trace. The southeast block is downdropped, as on the First, Second, and Third faults. There is no evidence indicating active faulting during coal deposition.

Morgando (1958) stated that fault displacement in Ash Creek and South Ash Creek oil fields, about 3 mi southwest of the map area, increased with depth. Faults have displacement of about 250 ft at the surface, which increases to about 600 ft at the Upper Cretaceous Shannon Sandstone Member of the Cody Shale. However, these faults differ from those in the Pearl School quadrangle in that the northwest block is downdropped and fault surfaces dip northwest (Morgando, 1958; B. E. Barnum, written commun., 1978).

There are two prominent monoclines of nontectonic origin on the northeast side of Squirrel Creek (sec. 4, T. 9 S., R. 39 E., and sec. 33, T. 8 S., R. 38 E.; and sec. 1, T. 9 S., R. 38 E., and sec. 36, T. 8 S., R. 38 E.). Structural axes parallel the valley, and dip is to the southwest. A coal bed 20-30 ft thick (Dietz 1) would crop out at about stream level, but is burned in both areas, and overlying strata have collapsed into the resultant void. Monoclinal axes probably approximate the burn limit.

No comprehensive regional, tectonic model has been published for this area. However, Stone (1971) projected the Nye-Bowler lineament through the Ash Creek area. Structural features in both the Pearl School and Ash Creek areas are at least superficially similar to those described by Wilson (1936) for the Nye-Bowler lineament in Montana. Stone (1971) showed the Nye-Bowler lineament as a basement fault having left-lateral offset. Wilson (1936) documented both left-lateral and vertical displacement for the Nye-Bowler lineament in Montana. Left-lateral movement along a buried basement fault could account for observed structures in both the Pearl School and Ash Creek areas. This inferred basement fault trends northwest at an oblique angle to mapped subparallel normal faults. Presumably, a trace of this inferred basement fault would be just south of the Pearl School quadrangle, dividing Ash Creek-type faults from Pearl School-Decker-type faults.

Law and Grazis (1972) suggested a common origin for faulting in the adjacent Decker quadrangle and the Tongue River lineation in the Bighorn Mountains, Wyo. (Hoppin and Jennings, 1971). The Tongue River lineation is poorly defined, but has a trend subparallel to faulting in both the Decker and Pearl School quadrangles. However, we believe left-lateral movement along a buried basement fault is a more likely concept for the described faults. Evidence to support this idea is: structural similarity to the Nye-Bowler lineament in Montana, subparallel normal faults, and the mirror-image relationship between faults of the Ash Creek and Pearl School areas.

ECONOMIC GEOLOGY

Coal

<u>Coal beds</u>.--Coal-bed nomenclature is that used in part by Baker (1929), Law and Grazis (1972), and Law, Barnum, and Wollenzien (1979). The Anderson bed of Matson and Blumer (1973) is herein referred to as Dietz 1, and their

Dietz 1 as Dietz 2,3. The Roland bed of Baker is designated RB, and the Roland bed of Taff is designated RT (Law and Grazis, 1972). Thinner local beds were named either for position above or below a formally named bed, or for geographic names or features in the map area.

Coal beds of economic quality are found only in the Tongue River Member of the Fort Union Formation. Several thinner coal zones were mapped for stratigraphic control, but are not included in this report.

Under the classification system of the American Society for Testing and Materials (1973, p. 54), samples of the Roland coal bed of Baker are lignite A (6,300-8,300 Btu/lb) and samples of the Dietz coal beds are subbituminous C (8,300-9,500 Btu/lb) and B (9,500-10,500 Btu/lb) (table 1). The heating value on an as-received basis ranges from 6,608 Btu/lb (Roland of Baker) to 9,850 Btu/lb (Dietz 1).

Subsurface coal beds.--Subsurface coal beds are the Wall, Carney, and Monarch beds. Although these coal beds are not exposed in the map area, they are significant coal resources. Information on the thickness and depth of these coal beds is shown on the coal sections (sheet 2).

Dietz beds.--The Dietz 1 and 2,3 coal beds have the most economic value in the map area, and are locally strippable.

The Dietz beds generally occur in two benches--an upper bench, Dietz 1, and a lower bench, Dietz 2,3. Where interburden is thin or absent, the Dietz beds are labeled Dietz 1,2,3. Where interburden is thick, they are labeled Dietz 1 and Dietz 2,3. Interburden ranges in thickness from 0 to 192 ft. Generally, this split is thin (0-5 ft) in the eastern half of the map, but thickens rapidly to the west. Available drill-hole data indicate a very regular split line trending north, bisecting the Pearl School quadrangle. Where combined, the Dietz 1, 2, and 3 beds range in total thickness from 59 to 87 ft (Matson and Blumer, 1973).

Strippable resources of Dietz coal beds underlie the east half and southern part of the mapped area. Strippable resources for the combined Dietz beds (Dietz 1,2,3) are herein defined as having less than 500 ft of overburden.

The most economically strippable coal resource area is between Spring Creek and the South Fork of Spring Creek in the northeastern corner of the map area. This area is bounded on the northwest by the North fault. Southeast of the fault, overburden is about 50-250 ft thick. The Dietz beds are combined, and coal thickness averages 80 ft, but reaches a maximum of 87 ft (Matson and Blumer, 1973). Northwest of the North fault, the Dietz beds are downdropped and overburden is a minimum of 140 ft thick. Also, the valley of Spring Creek narrows, decreasing the area underlain by strippable coal. Additional strippable resources may underlie the large area of baked and fused rock northeast of Spring Creek. However, drill hole US-7758 did not penetrate the baked and fused rock and so any possible resources are hypothetical.

Another high-potential strippable resource area is Squirrel Creek Valley, from the Second fault southeast to beyond the quadrangle boundary. The combined Dietz 1 and 2,3 beds are about 60-80 ft thick under less than 250 ft of overburden. Northwest of the Second fault, strippable areas are restricted to the narrow valley floor. Also, interburden separating the Dietz 1 and 2,3 benches thickens rapidly to the west, and only the Dietz 1 bed is near the surface.

The small unnamed valley southeast of Squirrel Creek (sec. 25, T. 9 S., R. 39 E.) would be a good stripping area, but the First fault bisects this valley. Overburden northwest of the First fault is at least 200 ft thick, whereas to the southeast, the combined Dietz 1 and 2,3 beds are downdropped and overburden is at least 350 ft thick.

Areas along Youngs and Tanner Creeks are probably underlain by strippable resources of the Dietz beds. However, these areas are small, complexly faulted, and partially burned.

Smith bed.--The Smith bed is about 7-19 ft thick in one or two benches. The most prominent and thickest split is in the southeastern part of the map area and is well illustrated in coal sections 209, 210, 213, and 214. In this same area, Baker (1929) identified the Smith bed as a new bed that he named the Powers bed. This miscorrelation resulted from his failure to recognize faulting in this area. Correlation of stratigraphic units across recognized faults indicates that the Powers bed does not exist as a separate coal bed.

The Smith bed underlies most mesas in the map area, cropping out just above valley floor margins. Although large economic resources of the Smith bed are present, there are no significant strippable resources.

Roland bed of Baker.--The Roland bed of Baker, or its associated baked and fused rock deposits, crops out along mesa margins. This bed is about 6-14 ft thick, with an average thickness of about 10 ft. Overburden is usually less than 250 ft on these broad mesas, and these areas are potentially strippable. The mesa between Squirrel Creek and the South Fork of Spring Creek is the largest area underlain by strippable RB coal. The mesa between Squirrel Creek and Tanner Creek is also underlain by significant coal resources, but the Second and Third faults have isolated strippable coal to small workable areas on fault blocks.

Coal quality.--Coal quality was determined from drill-core samples analyzed by the analytical laboratories of Montana Bureau of Mines and Geology (tables 1 and 2). Trace-element analyses of samples were made by the U.S. Geological Survey laboratories, Denver, Colo. (table 3).

Oil and gas

Ash Creek and Ash Creek South oil fields are about 3 mi southwest of the map area, and this proximity may indicate oil-and-gas potential.

Production in both fields is from the Shannon Sandstone Member of the Cody Shale, with oil accumulations trapped on the upthrown (southeastern) sides of normal faults (Morgando, 1958). A few deeper tests of Paleozoic formations were unproductive (Morgando, 1958).

Six oil-and-gas test holes have been drilled in the Pearl School quadrangle, three of which were on upthrown fault blocks. Examination of geophysical logs from these wells indicates northward thinning of the Shannon Sandstone Member and its absence in some wells. No shows were reported in any of these tests. The Muddy Sandstone, a prolific producer elsewhere in the Powder River Basin, is present at depth and, as suggested by Law and Grazis (1972), may be a possible production target.

Aggregate

Gravel resources within the mapped area are confined to small deposits on terraces and underlying the Tongue River flood plain.

Baked and fused rock is used locally as road metal. Large exploitable deposits near existing county roads occur in the northeast and southwest parts of the map area. Less accessible, but extensive, deposits occur along mesa margins where the Roland coal bed of Baker has burned.

REFERENCES

American Society for Testing and Materials, 1973, Standard specifications for classification of coals by rank, D388-66: Philadelphia, Pa., p. 54-58.

Baker, A. A., 1939, The northward extension of the Sheridan coal field, Big Horn and Rosebud Counties, Montana: U.S. Geological Survey Bulletin 806-B, pt. 2, p. 15-67.

Barnum, B. E., 1975, Geologic map and coal resources of the Ranchester quadrangle, Sheridan County, Wyoming, and Big Horn County, Montana: U.S. Geological Survey Coal Investigations Map C-75, scale 1:24,000.

Bass, N. W., 1924, Coal in Tongue River Valley, Montana--New coal fields about to be made accessible: Department of the Interior (U.S. Geological Survey) Memorandum for the Press 16748, 4 p., 2 plates.

Curry, W. H., 3d, 1971, Laramide structural history of the Powder River Basin, Wyoming, in Symposium on Wyoming Tectonics and their economic significance, Wyoming Geological Association Guidebook, 23d Annual Field Conference: p. 49-60.

Hamblin, W. K., 1965, Origin of "reverse drag" on the downthrown side of normal faults: Geological Society of America Bulletin, v. 76, no. 10, p. 1145-1164.

Hoppin, R. A., and Jennings, T. V., 1971, Cenozoic tectonic elements, Bighorn Mountain region, Wyoming and Montana, in Symposium on Wyoming tectonics and their economic significance, Wyoming Geological Association Guidebook, 23d Annual Field Conference: p. 39-47.

Law, B. E., Barnum, B. E., and Galyardt, G. L., 1975, Tectonic implications of the Fort Union Formation, northwestern Powder River Basin, Wyoming and Montana [abs.]: Geological Society of America Abstracts with Programs, v. 7, no. 7, p. 1164.

Law, B. E., Barnum, B. E., and Wollenzien, T. P., 1979, Coal bed correlations in the Tongue River Member of the Fort Union Formation: U.S. Geological Survey Miscellaneous Investigations Series I-1128 [1980].

Law, B. E., and Grazis, S. L., 1972, Preliminary geologic map and coal resources of the Decker quadrangle, Big Horn County, Montana: U.S. Geological Survey open-file report, scale 1:24,000, 3 sheets.

Matson, R. E., and Blumer, J. W., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bureau of Mines and Geology Bulletin 91, 135 p.

Morgando, F. P., 1958, Ash Creek and Ash Creek South fields, in Wyoming Geological Association Guidebook, 13th Annual Field Conference: p. 157-159.

Olive, W. W., 1957, The Spotted Horse coal field, Sheridan and Campbell Counties, Wyoming: U.S. Geological Survey Bulletin 1050, 84 p.

Stone, D. S., 1971, Tectonic sketch map of central Rocky Mountains, in Symposium on Wyoming tectonics and their economic significance, Wyoming Geological Association Guidebook, 23d Annual Field Conference: in pocket.

Stone, R. W., and Lupton, C. T., 1910, The Powder River coal field, Wyoming, adjacent to the Burlington Railroad: U.S. Geological Survey Bulletin 381, p. 115-136.

Taff, J. A., 1909, The Sheridan coal field, Wyoming: U.S. Geological Survey Bulletin 341-B, pt. 2, p. 123-150.

Tschudy, R. H., 1976, Pollen changes near the Fort Union-Wasatch boundary, Powder River Basin, in Wyoming Geological Association Guidebook, 28th Annual Field Conference: p. 73-81.

U.S. Geological Survey and Montana Bureau of Mines and Geology, 1973, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Sheridan and Campbell Counties, Wyoming, and Big Horn County, Montana: U.S. Geological Survey open-file report, 57 p.

U.S. Geological Survey and Montana Bureau of Mines and Geology, 1977a, Geophysical logs for Big Horn, Fallon, and Powder River Counties, Montana and northeastern Wyoming: U.S. Geological Survey Open-File Report 77-721-A, 77 p.

_____1977b, Geophysical logs for Big Horn County, Montana, chapter B of Preliminary report of 1977 coal drilling in eastern Montana and northeastern Wyoming: U.S. Geological Survey Open-File Report 77-721-B, 125 p.

_____1978, Geophysical logs for Campbell and Converse Counties, Wyoming, chapter E of Preliminary report of 1977 coal drilling in eastern Montana and northeastern Wyoming: U.S. Geological Survey Open-File Report 77-721-E, 202 p.

Wilson, C. W., Jr., 1936, Geology of Nye-Bowler lineament, Stillwater and Carbon Counties, Montana: American Association of Petroleum Geologists Bulletin, v. 20, no. 9, p. 1161-1188.