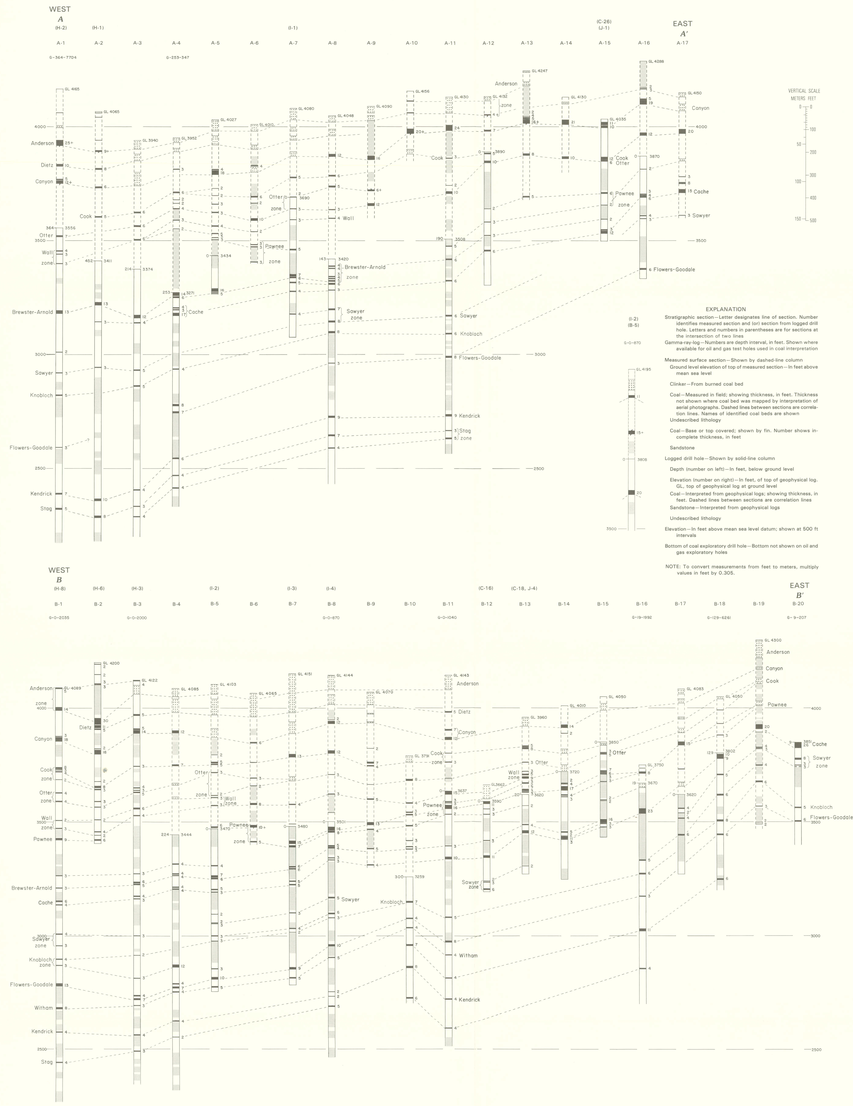

EXPLANATION

Stratigraphic section—Letter designates line of section. Number identifies measured section and (or) section from logged drill hole. Letters and numbers in parentheses are for sections at the intersection of two lines

Gamma-ray log—Numbers are depth interval, in feet. Shown where available for oil and gas test holes used in coal interpretation

Measured surface section—Shown by dashed-line column. Ground level elevation of top of measured section—In feet above mean sea level

Clinker—From burned coal bed

Coal—Measured in field; showing thickness, in feet. Thickness not shown where coal bed was mapped by interpretation of aerial photographs. Dashed lines between sections are correlation lines. Names of identified coal beds are shown

Undescribed lithology

Coal—Base or top covered; shown by fin. Number shows incomplete thickness, in feet

Sandstone

Logged drill hole—Shown by solid-line column

Depth (number on left)—In feet, below ground level

Elevation (number on right)—In feet, of top of geophysical log, GL, top of geophysical log at ground level

Coal—Interpreted from geophysical logs; showing thickness, in feet. Dashed lines between sections are correlation lines

Sandstone—Interpreted from geophysical logs

Undescribed lithology

Elevation—In feet above mean sea level datum; shown at 500 ft intervals

Bottom of coal exploratory drill hole—Bottom not shown on oil and gas exploratory holes

NOTE: To convert measurements from feet to meters, multiply values in feet by 0.305.

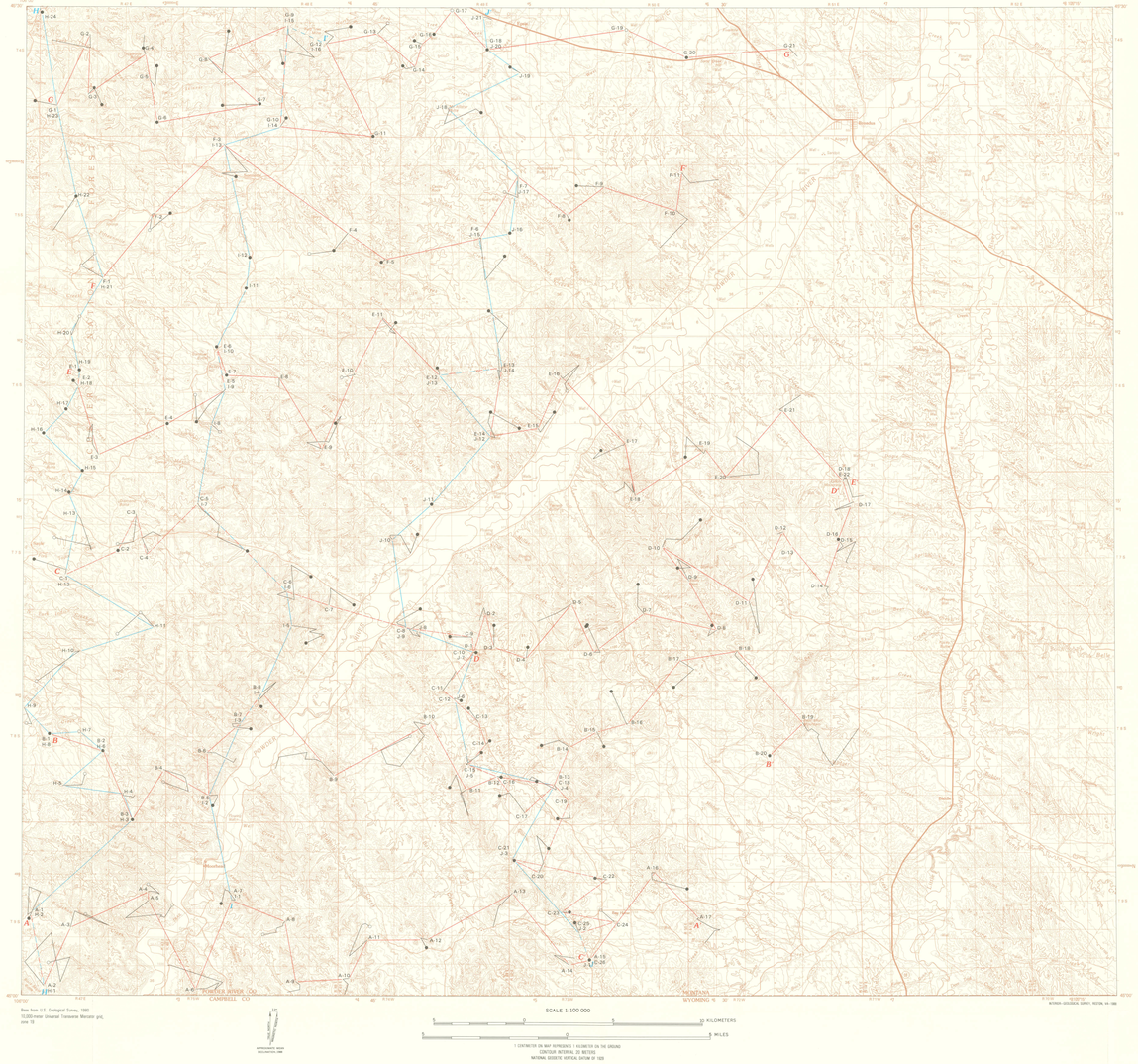

Figure 1.—Map showing stratigraphic-section localities and lines of sections *A–A′* through *J–J′*.

EXPLANATION

G–20 — **Location of stratigraphic section from log of drill hole**—Oil- and gas or coal exploratory hole. Solid circle, gamma-ray log available; open circle, no gamma-ray log available. Letter and number refer to stratigraphic section on line of section

G–17 — **Location of measured section**—Letter and number refer to stratigraphic section on line of section; letter and number are shown at top of section

B–8 — **Location of composite stratigraphic section**—Measured section combined with section interpreted from logs of one or more drill holes. Letter and number of composite section shown at top of section

Line of section—Line connects tops of stratigraphic sections

GEOLOGIC SETTING

The stratigraphic framework of the Paleocene Fort Union Formation coal beds in the western two-thirds of the Broadus 30′ × 60′ quadrangle is illustrated by a network of 156 stratigraphic sections on 10 cross sections (*A–A′* through *J–J′*, fig. 1). These upper Fort Union coal beds crop out on the northeastern flank of the Powder River Basin and generally dip less than 1/2° southwestward toward the basin axis, which lies about 25–30 miles west of the Broadus quadrangle (fig. 2). Coal beds in the study area (fig. 2) tend to merge northeastward and to split toward the southwest; the entire sequence of coal-bearing rocks thickens southwestward toward the basin axis (fig. 2). Maximum structural relief within the mapped area is about 700 ft; maximum topographic relief within the mapped area is 1,375 ft. Structural relief in the study area may be primarily the result of basin subsidence accompanying deposition of the coal-bearing rocks, and the rate of subsidence may have increased progressively from west to east during that time (Kent and others, 1980). Undoubtedly, some structural relief and contrasts in thickness of rock intervals between coal beds were caused by the differential compaction of sequences containing unequal proportions of shale. The coal beds were mapped by field investigations in 1981, 1982, and 1983, supplemented by study of aerial photographs and subsurface data.

Sediments making up the rocks of the Fort Union Formation in the Broadus area were deposited on the northeastern basin flank supplied mostly by debris shed by the Black Hills (Lewis and Hotchkiss, 1981, pls. 2, 3, 4). As the sediments were compacted, and large areas subsided to elevations below or near the water table, peat accumulated to great thicknesses in extensive swamps. Peat deposition ceased intermittently when the water table changed greatly or the swamp areas were flooded by sand and mud from rejuvenated uplift of the Black Hills, Cedar Creek anticline, Weldon-Brockton-Frost fault zone, and Northern Rocky Mountains. The peat beds were cut later by streams that deposited sand and mud as the drainage system of the basin changed repeatedly during Tertiary time.

SOURCES OF DATA

Stratigraphic sections shown along the lines indicated on figure 1 either were measured in the field or were prepared from geophysical logs of oil and gas exploration holes, and of shallow coal exploration holes; the sources of data are summarized in table 1. The logged drill holes used in this study were selected from about 300 holes drilled in the coal-bearing area. Preference was given to the use of log suites that included gamma-ray, electrical-resistivity, and formation-density logs. Gamma-ray logs were available for all U.S. Geological Survey coal exploratory holes except US–7964 and BCR 79–29.

GEOPHYSICAL-LOG RESPONSE TO COAL AND SANDSTONE

The coal beds within the Broadus quadrangle generally have very high resistivity, extremely low radioactivity, and a specific gravity of about 1.5. Relative measures of these properties on electrical-resistivity, gamma-ray, and formation-density logs generally provide positive identification of coal. Of these logs, resistivity is least useful in identifying coal. The resistivity of coal varies inversely with ash content and may be no higher than that of limestone or of fresh water-bearing sandstone.

Gamma-ray logs and formation-density logs, however, generally provide positive identification of coal. Gamma-ray response to coal enclosed by sandstone and shale, which are more radioactive, commonly is clearly and sharply defined; formation-density readings less than 1.5 g/cm³ indicate coal. Both the radioactivity and formation density of coal increase as impurities, or ash content, increase.

At many places within the Broadus quadrangle, thick fresh-water-bearing sandstones occur in the intervals between the coal beds. Subsurface occurrences of such sandstone are indicated on resistivity logs by discrete, sharply defined zones of relatively high resistivity. The stratigraphic sections in this report show sandstone beds 25 ft or more in thickness, as interpreted from geophysical logs, or as known from surface measurements.

COAL BED NOMENCLATURE

That part of the Broadus quadrangle that includes Tps. 4–6 S. (fig. 1) and lies northwest of the Powder River is in the Birney-Broadus coal field of Warren (1959). The coal-bearing part of the Broadus quadrangle that is southeast of the Powder River and Tps. 7–9 S. (fig. 1) that are northwest of the Powder River are in the Moorhead coal field of Bryson and Bass (1973). These coal fields and others in the Broadus area are shown on figure 2. Most coal beds in this report are named for the beds with which they correlate to the west, in the Birney 30′ × 60′ quadrangle (Culbertson, 1987). These names are shown in table 2.

REGIONAL COAL BED CORRELATIONS

During 1978 to 1981, the U.S. Geological Survey drilled a series of closely spaced coal exploratory holes across the Broadus 30′ × 60′ quadrangle. The geophysical logs and core records of these drill holes greatly facilitated the correlation of coal beds between the Ashland, Birney-Broadus, Moorhead, and Coalwood coal fields (fig. 2). Some previously named coal beds in the Broadus quadrangle are now recognized as not correlative with coal beds having the same name elsewhere in Montana and Wyoming.

The Terret coal bed was correlated from the subsurface in the Broadus 30′ × 60′ quadrangle to the surface in the Ashland coal field of western Powderville 30′ × 60′ quadrangle. It may be equivalent to the Kendrick coal bed.

The Flowers-Goodale coal bed of Broadus correlates with the Flowers-Goodale of Birney and with that of the surface Ashland coal field, Bass, 1932) in eastern Lame Deer and western Powderville 30′ × 60′ quadrangles. The Flowers-Goodale coal bed was mapped as the "Broadus" coal bed by Warren (1959) in secs. 4, 5, and 9, and the southwest corner of sec. 10, T. 4 S., R. 50 E. The bed referred to as "Broadus" in the subsurface of the Coalwood coal field and of the Leslie Creek 7 1/2-minute quadrangle (McLellan, 1981) is now considered to be the Flowers-Goodale. The underlying Witham coal bed converges with the Flowers-Goodale northward in Tps. 4 and 5 S (line of section *H–H′*).

The 73-ft-thick Knobloch coal bed in the northeastern part of the Birney 30′ × 60′ quadrangle is formed by the coalescing of several beds that are mapped on the surface to the west. As it extends in the subsurface eastward and northward toward the Broadus, Lame Deer, and Powderville 30′ × 60′ quadrangles, the Knobloch splits into three coal beds that were designated the Flowers-Goodale, Nance, and Knobloch in the easternmost part of the Birney 30′ × 60′ quadrangle (Culbertson, 1987).

The Knobloch coal bed of the Broadus 30′ × 60′ quadrangle correlates with the Knobloch of the eastern part of the Ashland coal field (Bass, 1932) and with the bed designated as the Nance coal bed in the easternmost part of the Birney 30′ × 60′ quadrangle (Culbertson, 1987).

The bed referred to as "Knobloch" in the subsurface of the southern Coalwood coal field and in the Leslie Creek 7 1/2′ quadrangle (Bryson, 1951; McLellan, 1981) is the lower bed of the Knobloch coal zone. This bed correlates with the bed mapped as Broadus in the Coalwood coal field and converges with the Sawyer and A beds to form the Broadus coal bed in the Birney-Broadus coal field (line of section *G–G′*).

The coal beds mapped as the lowest Sawyer and middle Sawyer by Warren (1959) in the Sonnette and Epsie NE 7 1/2-minute quadrangles converge westward and correlate with the coal bed designated as Knobloch in the easternmost part of the Birney 30′ × 60′ quadrangle. These beds converge northward in the Coalwood coal field, where they are known as the A bed and the Sawyer (Bryson, 1951; McLellan, 1981), and eastward, where they correlate with the Broadus coal bed mapped by Warren (1959) in the Sand Creek Hill area of the Epsie NE and Broadus 7 1/2-minute quadrangles (line of section *G–G′*). They also crop out in the eastern part of the Ashland coal field (Bass, 1932). Southward, the A bed traces into the Sawyer zone of coal beds (line of section *J–J′*). The Sawyer also correlates with the No. 12 coal bed of Bryson and Bass (1973) in the Ekalon Mountain area (line of section *E–E′*), and with their No. 11 and No. 12 coal beds in the Bear Skull Mountain and Wild Bill Creek 7 1/2-minute quadrangles (line of section *B–B′* and *D–D′*). The A bed converges with beds in the upper part of the Knobloch zone in some places (line of section *G–G′*).

The King coal bed, as Warren (1959) mapped it in the King Mountain area, is shown only as an unnamed coal bed and probably correlates with the highest Sawyer coal bed that Warren (1959) mapped in T. 4 S., R. 49 E., and possibly correlates with the Mackin-Walker and L1 coal beds of the Coalwood coal field (Bryson, 1951; McLellan, 1981). In the southern part (T. 4 S., R. 48 E., the unnamed coal bed converges with the Sawyer coal bed (line of section *F–F′*), but in T. 6 S., R. 49 E., it is separated from the Sawyer by a thick channel sandstone and is believed to correlate with the Cache coal bed (lines of section *E–E′* and *J–F′*).

The very extensive Cache coal bed underlies most of the coal-bearing area of the Broadus quadrangle and is thickest in the eastern part where it is as thick as 29 ft (line of section *D–D′*). Along a northeast-trending line about 6–10 mi northwest of the Powder River the Cache either pinches out or merges downward into an unnamed coal bed (lines of section *E–E′* and *J–F′*). It possibly may grade upward into the Odell coal bed in T. 5 S., Rs. 48 and 49 E. (line of section *F–F′*). In the eastern part of T. 8 S., R. 49 E., the coal bed mapped by Bryson and Bass (1973) as Cache is actually 50 ft above the Cache and correlates with the Odell or Brewster-Arnold.

The Odell coal bed is believed to correlate with the Stump coal bed in the Coalwood coal field (Bryson, 1951) or the Stump and L2 coal beds of the Leslie Creek 7 1/2-minute quadrangle (McLellan, 1981). Silicified tree stumps 3 ft or greater in diameter and in growth position are common on the outcrop of this bed in the northern part of the Broadus 30′ × 60′ quadrangle and are found locally elsewhere. The Odell is most extensive in the northern and western parts of the Broadus 30′ × 60′ quadrangle. In the central and southern parts it converges with the Brewster-Arnold coal bed, which lies above it to the west. In the southeastern part of the area, Tps. 8 and 9 S., Rs. 50 and 51 E., the Odell, Brewster-Arnold, and Cache converge to form the thickest Cache coal bed. In T. 7 S., R. 48 E., the Odell, Brewster-Arnold, and Pawnee converge (lines of section *C–C′* and *J–F′*).

The Pawnee coal bed of Warren (1959) was mapped along Pumpkin Creek in the northwestern part of the Broadus 30′ × 60′ quadrangle. The Pawnee correlates with the Poker Jim coal bed of Culbertson (1987) in the Birney 30′ × 60′ quadrangle, with the Dunning coal bed of Matson and Blumer (1973, pl. 34) in the Ashland coal field, and with the Kennedy coal beds of the Recluse 30′ × 60′ quadrangle, Wyoming (Kent and others, 1980). It is a thick coal bed beneath much of the central part of the quadrangle, but it splits to the southeast and is burned along most of its outcrop in the northern part of the area.

The Wall coal bed equals the Elk coal bed in the Ashland coal field (Matson and Blumer, 1973, pl. 34). In the Sonnette area (line of section *J–F′*) and in the southeast part of the Broadus Creek 7 1/2-minute quadrangle (line of section *A–A′*), lower coal beds of the Wall zone seem to correlate with upper coal beds of the Pawnee zone, and in the southwest corner of T. 9 S., R. 48 E., the Wall merges with the Pawnee.

The Otter coal bed was mapped as the lower Cook coal bed by Warren (1959) in the Sonnette area, as the Wall coal bed in Tps. 4–6 S., R. 47 E., but not mapped at all in the Cache Creek area where it is 85 ft below the Cook coal bed (line of section *E–E′*). It is equivalent to the lower Werner coal bed of the Recluse 30′ × 60′ quadrangle (Kent and others, 1980). The Otter and overlying Cook coal bed converge beneath most of Tps. 5–7 S., Rs. 47–48 E. The Cook coal bed generally correlates with the upper Werner coal bed of the Recluse 30′ × 60′ quadrangle, but in T. 58 N., R. 72 W., it correlates with the bed mapped as Canyon on the geologic map of the Recluse quadrangle (Kent and Berlage, 1980).

The Canyon coal bed is thick and extensive through western and southern parts of the Broadus 30′ × 60′ quadrangle where it continues southward into Wyoming, but it splits and thins to the northeast, it is burned along most of its outcrop. It may converge with the Dietz coal bed in T. 9 S., R. 49 E. In T. 58 N., R. 72 W., Wyoming, it correlates with the bed shown as lower Anderson on the geologic map of the Recluse 30′ × 60′ quadrangle (Kent and Berlage, 1980).

The Ferry, Canyon, and Dietz coal beds in the stratigraphic framework of the Broadus 30′ × 60′ quadrangle cannot be correlated with coal beds in Tps. 4–6 S., R. 48 E., shown on Warren's map (1959), because some of those coal beds were mislabeled.

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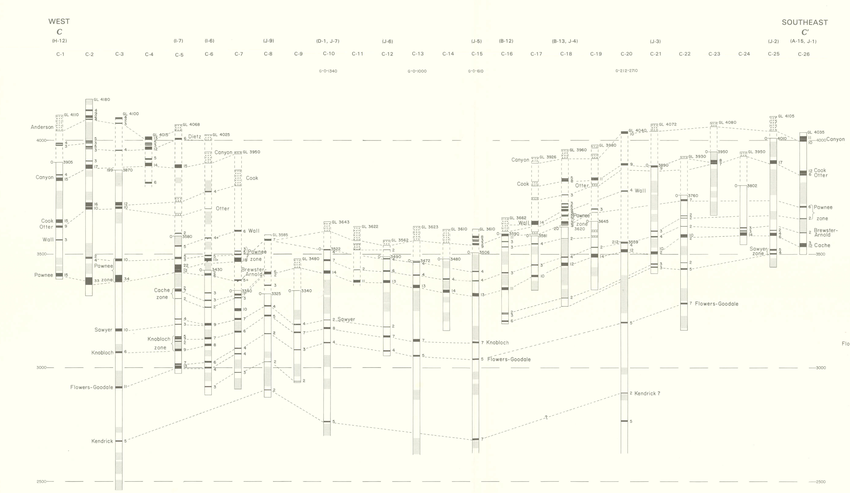

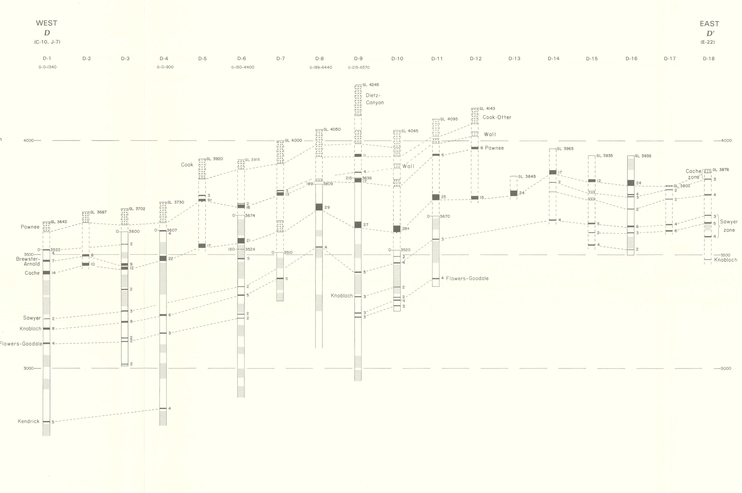

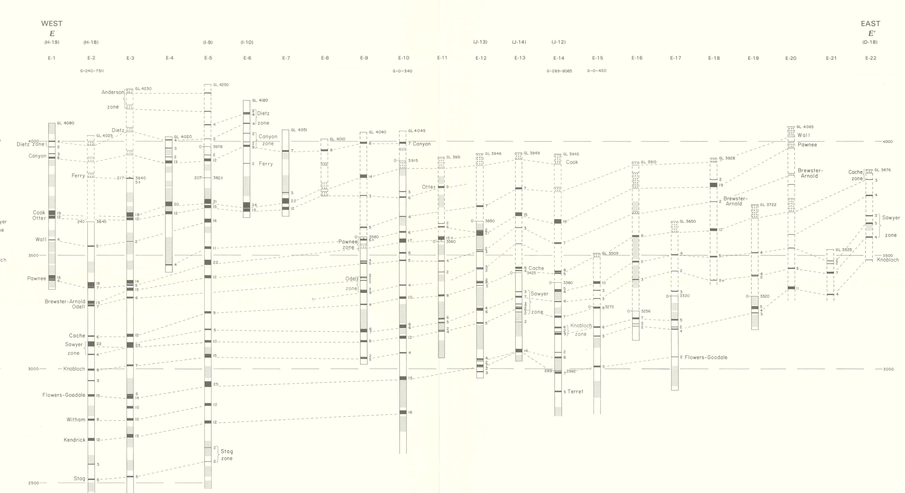

STRATIGRAPHIC FRAMEWORK OF THE PALEOCENE COAL BEDS IN THE BROADUS 30′ × 60′ QUADRANGLE, POWDER RIVER BASIN, MONTANA-WYOMING

By
Marguerite W. McLellan and Laura R. H. Biewick

1988

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