

# LOWER UPPER CRETACEOUS STRATA, BIGHORN BASIN, WYOMING AND MONTANA

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## INTRODUCTION

Sedimentary rocks of early Late Cretaceous age (Cenomanian through Coniacian) are included in the Frontier Formation and the lower part of the Cody Shale in the Bighorn Basin of northwestern Wyoming and south-central Montana. The Frontier consists mainly of shale, siltstone, and sandstone of marine and continental origin and probably ranges in thickness from about 400 to 800 feet (122 to 244 m). It lies conformably on the Lower Cretaceous Mowry Shale and is conformably overlain by the Upper Cretaceous Cody. Figure 1 depicts outcrops of the Frontier Formation on the flanks of the Bighorn Basin. The Cody Shale is composed dominantly of shale and siltstone of marine origin and ranges in thickness from about 1,700 to 3,600 feet (518 to 1,097 m) (Fox, 1954, p. 102). Locally, the lower part of the Cody intertongues with the upper part of the Frontier (Table 1).

The purpose of this report is to describe the lower Upper Cretaceous strata in the Bighorn Basin, emphasizing evidence of major unconformities and the temporal and spatial distribution of those unconformities. Data used in this investigation were obtained from 13 measured sections, about 50 fossil localities, and the electric logs from about 210 wells. Of the well logs examined, 20 are represented on the illustrations in this report. The locations of the wells and measured sections are shown on Figure 1 and described in Table 2.

Fossil mollusks collected from the rocks were compared with mollusks that comprise the revised sequence of Western Interior zone fossils (Merewether and Cobban, 1973) and the fossiliferous rocks were thereby related to the reference sequence of lower Upper Cretaceous formations in the northern Black Hills of Wyoming and Montana (Table 1). The collections of fossils, which are herein represented by numbers, include the species listed in Table 1 or other species of the same age.

Lower Upper Cretaceous rocks are a major source of petroleum in the Bighorn Basin. Prior to 1974, the Frontier Formation produced more than 70 million barrels of oil and 450 billion cubic feet of gas (Wyoming Oil and Gas Conserv. Comm., 1974?). Most of the production has been from anticlines, but the Frontier probably contains many unexplored stratigraphic traps (Weldon, 1972). The sandstone units in the formation that grade laterally into shale or are truncated by unconformities may contain additional reserves of oil and gas.

## LITHOLOGIC CHARACTER

Outcrops of the Frontier Formation on the flanks of the Bighorn Basin are composed of shale, siltstone, and

sandstone, and minor amounts of conglomerate, bentonite, and coal (Figs. 2, 3 and 4). The shale is chiefly dark gray to brownish gray, silty, and soft, but near Deep Lake (Section H, Fig. 1), Cody (Section I, Fig. 1), and Pitchfork (Section J, Fig. 1), on the western side of the basin, a small part of the shale is brownish black to grayish black and carbonaceous. Most of the siltstone is light gray to dark gray to light brownish gray, clayey or sandy and poorly cemented, except along the western margin of the basin where some of it is brownish black and carbonaceous. The Frontier includes a few thin beds of coal at the Deep Lake and Cody sections (Fig. 1). Bentonite beds in the formation are yellowish gray to light brownish gray or greenish gray and are poorly indurated. Sandstone units are light gray or medium gray to brownish gray, very fine grained and silty to coarse grained and conglomeratic, and friable to well cemented. The grain size increases from the base to the top of many units. Conglomeratic sandstone commonly occurs at the tops of sandstone sequences (Figs. 2, 3, and 4), but it also forms thick discrete units. Lenticular bodies of conglomeratic sandstone in the lower part of the Frontier crop out near Cody, Wyoming (Fig. 3). Most sandstone units are thin bedded and laterally discontinuous. Their sedimentary structures include well-defined horizontal beds, irregular horizontal beds, ripple marks, and crossbeds.

## THICKNESS

At the wells and sections depicted in this report, the Frontier Formation ranges in thickness from about 400 feet (122 m), in the north-central part of the Bighorn Basin, to about 800 feet (244 m) in the southeastern part of the basin. This variation is caused largely by the lenticularity of the sandy beds that define the top of the formation (Figs. 5-8). The uppermost sandstone or sandy siltstone can be located at most outcrops but may not be recognizable on electric logs; consequently, the formation thicknesses derived from surface and subsurface measurements in some areas may not be similar.

## FOSSILS

Invertebrate fossils of marine origin are common in the upper part of the Frontier and the lower part of the Cody, especially on the eastern side of the Bighorn Basin, but they are sparse in the lower part of the Frontier. They consist mainly of ammonites and pelecypods that indicate parts of the Cenomanian, Turonian, and Coniacian Stages of the Upper Cretaceous Series (Table 1). Many of the beds in the lower Upper Cretaceous sequence also contain trace fossils.

Fossils of Cenomanian, latest Turonian, and Coniacian age have been collected in the eastern and

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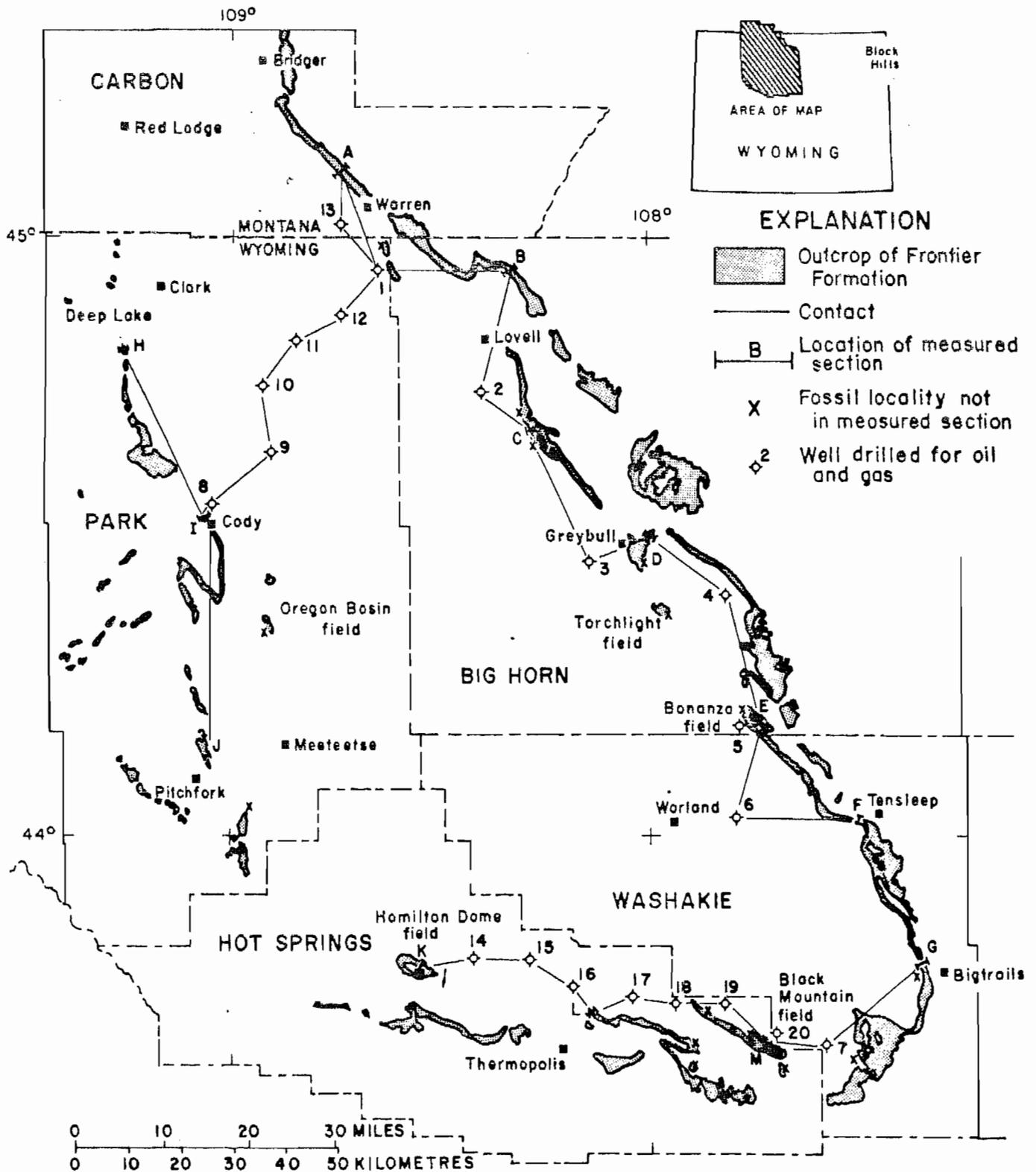


Figure 1 — Map of Bighorn Basin, Wyoming and Montana, showing outcrops of Frontier Formation, locations of measured sections, fossil localities not in measured sections, and selected wells drilled for oil and gas. From Love, Weitz, and Hose (1955) and Ross, Andrews, and Witkind (1955).

southeastern parts of the basin (Cobban and Reeside, 1952, p. 1957; Horn, 1963). They represent the following zones, in ascending order: *Plesiacanthoceras wyomingense*, *Dunveganoceras pondi*, *Dunveganoceras albertense*, *Inoceramus* cf. *I. incertus* and *Inoceramus erectus* (Table 1). On the eastern side of the basin, near Greybull, Wyoming, Fox (1954, p. 103-104) described foraminifera of probable late Cenomanian age (lower Greenhorn equivalent) from the basal 30 feet (9 m) of the Cody. These microfossils are the same age as the megafossils collected from the upper part of the Frontier and lower part of the Cody in the Greybull area (Cobban and Reeside, 1952, p. 1957). At the same locality, Fox (1954, p. 104-107) found foraminifera of middle Turonian age (lower to middle Carlile equivalent) from 30 to 94 feet (9 to 29 m) above the base of the Cody. The only middle Turonian megafossils currently recognized in the Bighorn Basin are from the Oregon Basin oil field-Cody area (Fig. 1).

On the western flank of the basin, between Clark and Thermopolis (Fig. 1), mollusks of middle Turonian and early Coniacian age have been found. These represent the zones, from oldest to youngest, of *Prionocyclus hyatti*,

*Inoceramus erectus*, and *Inoceramus deformis* (Table 1). At Cody (Fig. 1, Section I), on the west side of the basin, Eicher (1967, p. 172-174) reported foraminifera of late Cenomanian age from below the bentonite beds in the upper part of the Frontier. The foraminifera are probably about the same age as *Dunveganoceras pondi* or *Dunveganoceras albertense* (Table 1).

AGE AND CORRELATION

Based on the previously described fossil collections, the Frontier Formation in the Bighorn Basin is mainly Cenomanian in age and most of it correlates with the Belle Fourche Shale and the lower part of the Greenhorn Limestone in the northern Black Hills (Table 1). The Frontier conformably overlies the Mowry Shale of Albian age and contains, near the top, late Cenomanian fossils. The Peay Sandstone and Torchlight Sandstone Members of the Frontier Formation near Greybull (Fig. 5, Section D) (Pierce, 1948) are of early(?) and middle Cenomanian age, respectively. At Cody (Fig. 8, Section I) and in the Oregon Basin oil field (Fig. 1), on the west side of the basin, the Cenomanian strata are overlain by beds of middle

UPPER CRETACEOUS STAGES	WESTERN INTERIOR ZONE FOSSILS; NUMBERS REFER TO FOSSIL COLLECTIONS NOTED ON STRATIGRAPHIC SECTIONS	WESTERN FLANK OF BIGHORN BASIN, WYOMING	EASTERN FLANK OF BIGHORN BASIN, WYOMING AND MONTANA	NORTHERN BLACK HILLS, WYOMING AND MONTANA
SANTONIAN	24 <i>Clisocaphites saxitonianus</i> 23 <i>Scaphites depressus</i>	Cody Shale (part)	Cody Shale (part)	Niobrara Formation (part)
CONIACIAN	22 <i>Haploscapha grandis</i> 21 <i>Inoceramus deformis</i> 20 <i>Inoceramus erectus</i>	Unnamed member ?	Unnamed mbr	Sage Breaks Mbr
?	19 <i>Inoceramus waltersdorfensis</i> 18 <i>Inoceramus</i> cf. <i>I. incertus</i>	?	Unnamed mbr	Turner Sandy Mbr
TURONIAN	17 <i>Scaphites nigricollensis</i> 16 <i>Scaphites whitfieldi</i> 15 <i>Scaphites warreni</i> 14 <i>Prionocyclus macombi</i> 13 <i>Prionocyclus hyatti</i> 12 <i>Collignoniceras woollgari</i> 11 <i>Mammites nodosoides</i> 10 <i>Watinoceras coloradoense</i>	Frontier Formation Unnamed mbr	Frontier Formation Greenhorn Ls	Carlile Shale Pool Creek Sh Mbr Ls equivalent to Bridge Creek Ls Mbr
CENOMANIAN	9 <i>Sciponoceras gracile</i> 8 <i>Dunveganoceras albertense</i> 7 <i>Dunveganoceras pondi</i> 6 <i>Plesiacanthoceras wyomingense</i> 5 <i>Acanthoceras amphibolum</i> 4 <i>Acanthoceras alvaradoense</i> 3 <i>Acanthoceras muldoonense</i> 2 <i>Acanthoceras granerosense</i> 1 <i>Calycoceras gilberti</i>	Unnamed mbr	Unnamed mbr	Sh equivalent to Hartland Sh and Lincoln Ls Mbrs Belle Fourche Shale

Table 1. — Correlation of the Frontier Formation of the Bighorn Basin and Upper Cretaceous rocks of the Black Hills region, Wyoming and Montana.

TABLE 2 — Measured sections and selected wells in the Bighorn Basin, Wyoming and Montana

Section	Name	State	County	Sec.	Location		R.
					T.		
A	Warren	Mont.	Carbon	25		8 S.	24 E.
B	Crooked Creek	Wyo.	Big Horn	5		57 N.	95 W.
C	North Emblem	Wyo.	—do—	3 & 4		54 N.	95 W.
D	Greybull	Wyo.	—do—	2		52 N.	93 W.
E	Bonanza	Wyo.	—do—	25		49 N.	91 W.
F	Tensleep	Wyo.	Washakie	22 & 27		47 N.	89 W.
G	Bigtrails	Wyo.	—do—	13		44 N.	88 W.
H	Deep Lake	Wyo.	Park	21		56 N.	103 W.
I	Cody	Wyo.	—do—	31		53 N.	101 W.
J	Pitchfork	Wyo.	—do—	14		48 N.	102 W.
K	Hamilton Dome	Wyo.	Hot Springs	18		44 N.	97 W.
L	Thermopolis	Wyo.	—do—	9		43 N.	94 W.
M	Black Mountain	Wyo.	—do—	25 & 36		43 N.	91 W.

Well	Operator	Name	State	County	Location		R.
					Sec.	T.	
1	True Oil Co.	Whaley 14-2	Wyo.	Park	2	57 N.	98 W.
2	Empire Oil Co.	State 2	Wyo.	Big Horn	15	55 N.	96 W.
3	Trigood Oil Co.	Government 2	Wyo.	—do—	22	52 N.	94 W.
4	Columbian Fuel Corp.	U.S.A.-Saltbush 1	Wyo.	—do—	8	51 N.	91 W.
5	Carter Oil Co.	Hanover 1-X	Wyo.	Big Horn	34	49 N.	91 W.
6	Pan American Petroleum Corp.	Blanche-Hawks 1	Wyo.	Washakie	20	47 N.	91 W.
7	Hiawatha Oil and Gas Co.	Government 1-31	Wyo.	—do—	31	43 N.	89 W.
8	Husky Oil Co.	Stump 3	Wyo.	Park	20	53 N.	101 W.
9	—do—	1	Wyo.	—do—	21	54 N.	100 W.
10	Stanolind Corp.	1-6	Wyo.	—do—	8	55 N.	100 W.
11	Mobil Producing Co.	Bearcat Unit-Taggart F-21-13-P	Wyo.	—do—	13	56 N.	100 W.
12	Pan American Petroleum Corp.	A-3	Wyo.	—do—	31	57 N.	98 W.
13	Atlantic-Richfield Co.	Proebstel 1	Mont.	Carbon	25	9 S.	24 E.
14	Crystal Oil Co.	7-6	Wyo.	Hot Springs	7	44 N.	96 W.
15	Brinkerhoff Oil Co.	Coal Draw 1	Wyo.	—do—	8	44 N.	95 W.
16	Roden Oil Co.	Stump 1	Wyo.	—do—	30	44 N.	94 W.
17	True & Brown Cos.	Larson 1	Wyo.	—do—	32	44 N.	93 W.
18	E.L.K.	Government 1	Wyo.	—do—	6	43 N.	92 W.
19	Farmers Union Co.	Shad 1	Wyo.	—do—	6	43 N.	91 W.
20	Petro-Lewis and Brinkerhoff Cos.	Internat. Fed. 2-30	Wyo.	Washakie	30	43 N.	90 W.

Turonian age (early Carlile) which contain *Inoceramus howelli* (Table 1, Zone 13). At the same localities, the middle Turonian rocks are overlain by a lower Coniacian (lower Niobrara) sandstone unit of the uppermost Frontier which, in the Oregon Basin field, contains *Inoceramus erectus* (Table 1, zone 20). At Sections H, J, K, and L (Fig. 1), along the western and southern margins of the basin, the uppermost beds of the formation are also Coniacian (lower Niobrara) (Figs. 6 and 7).

At Sections E, F, G, and M, in the southeast part of the basin (Figs. 1 and 5), upper Cenomanian (lower Greenhorn) strata are overlain by beds of latest Turonian age. In the northeast part of the basin, near Warren, Montana, and Lovell, Wyoming (Fig. 5, Sections A, B, and C), upper Cenomanian rocks are overlain by beds that are probably of either latest Turonian or early Coniacian age.

Lower upper Turonian strata (Table 1, zone 16, upper Carlile) equivalent in age to the Wall Creek Sandstone Member of the Frontier, have not been identified in the area.

The uppermost part of the Frontier Formation varies in age locally because the upper contact is placed at the top of the highest conspicuous sandstone or sandy siltstone and these beds intertongue with the lower part of the Cody Shale. The top of the formation is of Cenomanian age at Sections C, D, and E (Figs. 1 and 5), at wells 3 and 4, and perhaps at wells 9 and 10 (Fig. 8). It is probably of latest Turonian age at sections F and M and at nearby wells (Fig. 5), and of Coniacian age at section A, near Warren, Montana, at outcrops along the western flank (Figs. 6 and 8) of the basin, and at sections K and L (Fig. 7) near Thermopolis, Wyoming.

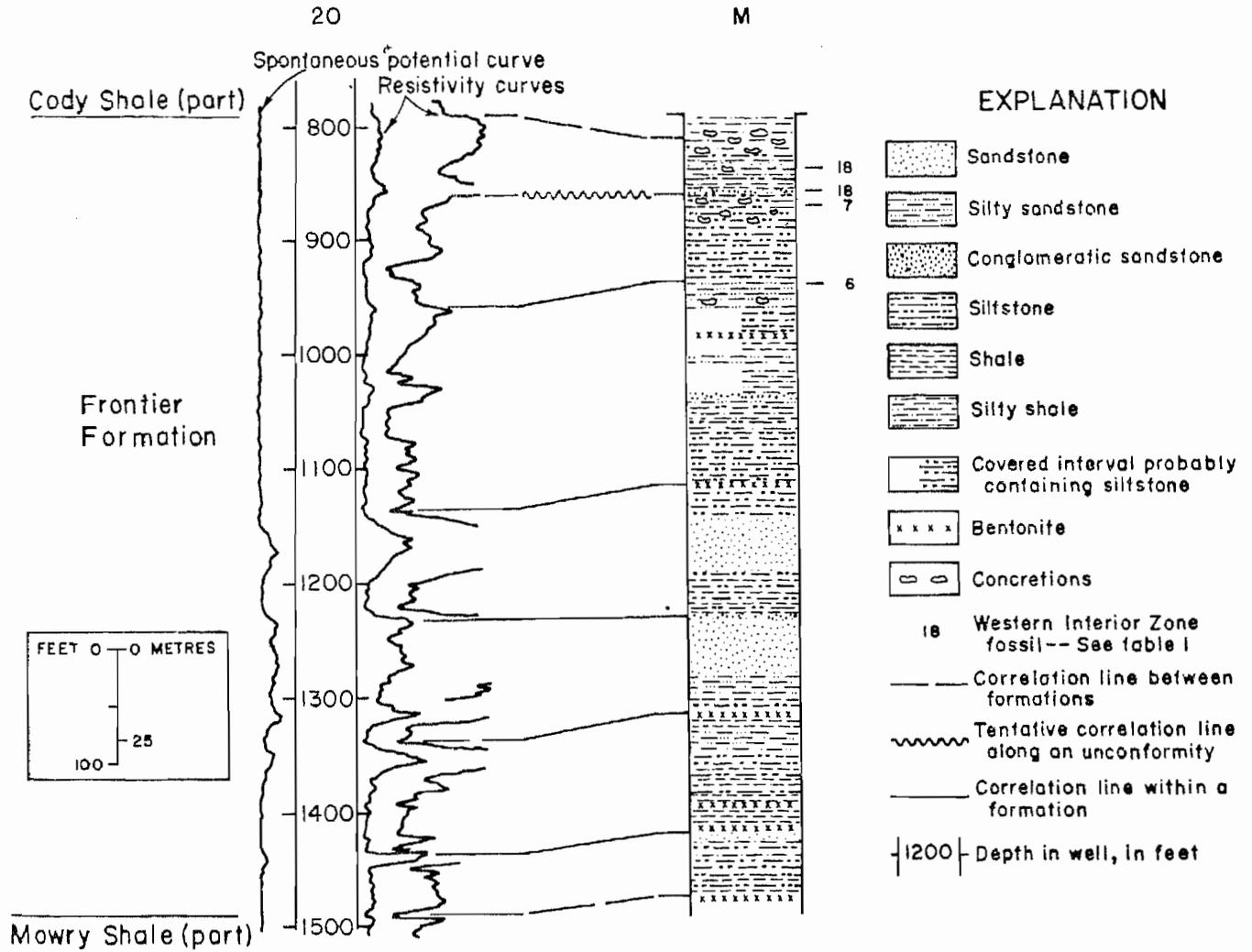


Figure 2. — Electric log and measured section of the Frontier Formation near the Black Mountain oil field, Hot Springs and Washakie Counties, Wyoming. See Figure 1 and Table 2 for locations.

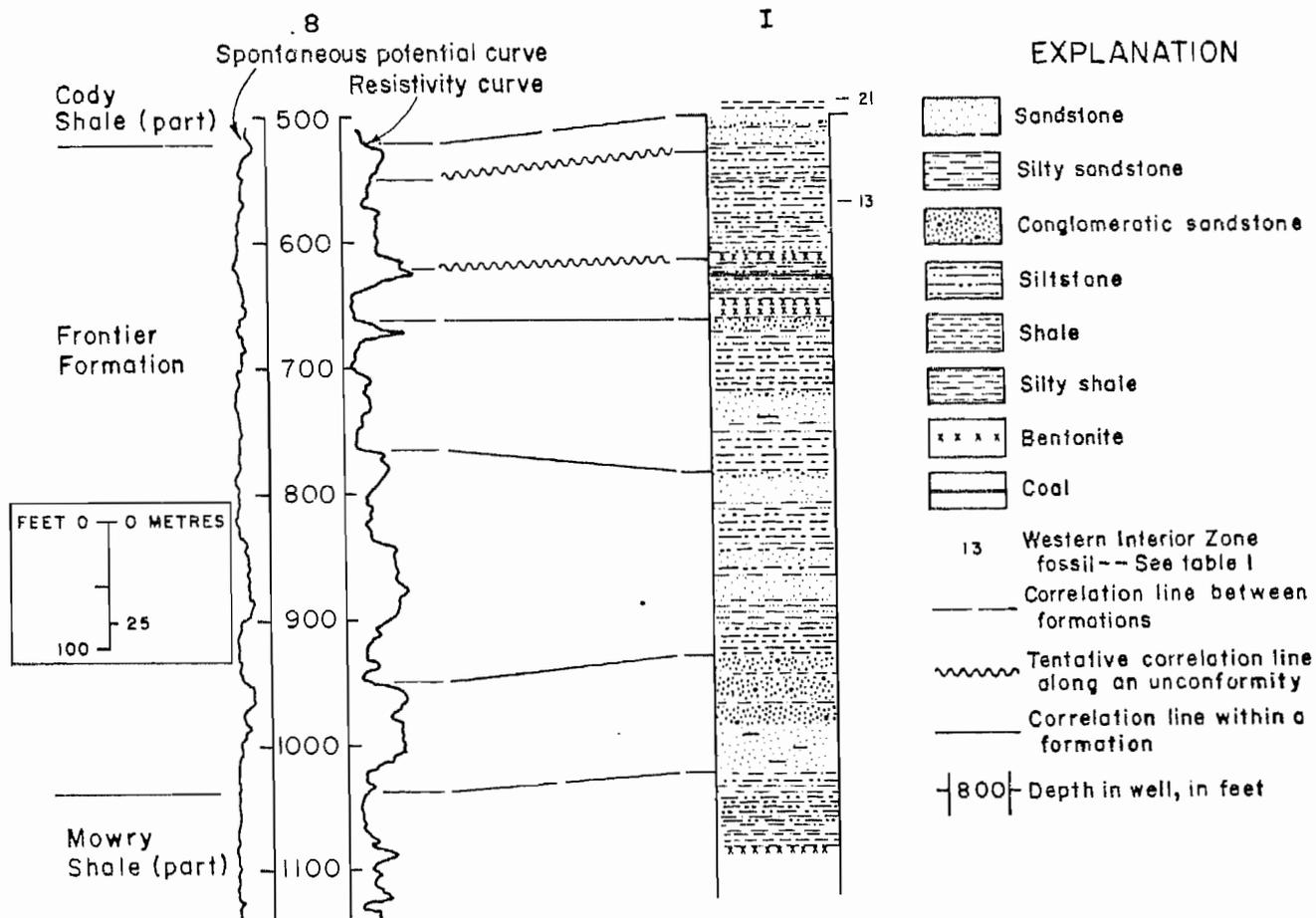


Figure 3. — Electric log and measured section of the Frontier Formation near Cody, Park County, Wyoming. See Figure 1 and Table 2 for locations.

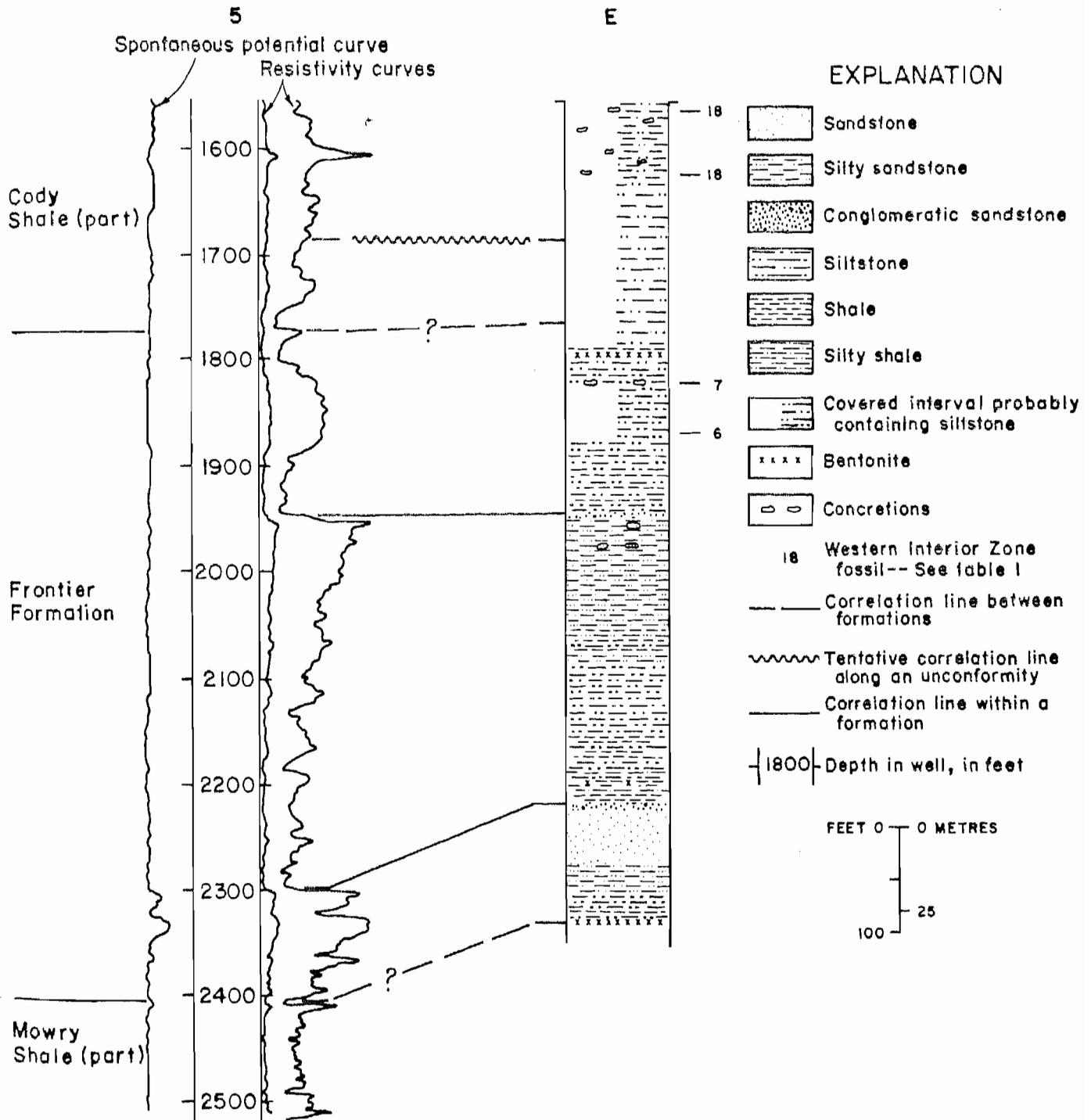


Figure 4. — Electric log and measured section of the Frontier Formation near the Bonanza oil field, Big Horn County, Wyoming. See Figure 1 and Table 2 for locations.

### UNCONFORMITIES

The disparity in age between superimposed stratigraphic units and the apparent truncation of units are evidence of unconformities within the lower Upper Cretaceous sequence of the Bighorn Basin. Two unconformities are recognized in the northwestern part of the basin near Cody, Wyoming (Fig. 1, Section I), and one has been confirmed in other parts of the basin. The truncation represented by the upper unconformity in the Cody area (Fig. 3) probably removed evidence of the earlier period of erosion in the remaining part of the region. At Section I (Figs. 1 and 3), the hiatus at the lower unconformity spans four or five fossil zones (Table 1) and represents strata at least 100 feet (30 m) thick in the northern Black Hills of northeastern Wyoming and southeastern Montana. The hiatus at the upper unconformity near Cody spans five or six fossil zones and represents about 250 feet (76 m) of strata in the Black Hills area. In the southeastern part of the Bighorn Basin (Fig. 1, Section M), where the two unconformities are united, the hiatus spans ten fossil zones and about 400 feet (122 m) of the Black Hills sequence.

In most of the Bighorn Basin, an unconformity truncates strata of late Cenomanian age, but near Hamilton Dome and Thermopolis in the southern part of the basin (Fig. 1, Sections K and L), it probably truncates beds as old as middle Cenomanian (Fig. 7). Between Hamilton Dome (Section K) and Black Mountain (Section M) and between Warren (Section A) and well 10, the unconformity appears to be slightly angular (Figs. 7 and 8). Along the east flank of the basin, it appears to be a disconformity (Fig. 5).

The Cenomanian rocks are unconformably overlain by strata of latest Turonian or Coniacian age in most of the basin; however, on the west side of the basin in the Oregon Basin field and at Cody (Section I), Cenomanian strata are unconformably overlain by middle Turonian beds (Table 1, zone 13). No evidence of uppermost Cenomanian and lower Turonian rocks has been reported in the Bighorn Basin and, with the possible exception of the Greybull area (Fox, 1954), no middle Turonian beds have been identified outside the Oregon Basin-Cody area. The strata of middle Turonian age are truncated by a second unconformity and are overlain by beds of early Coniacian age (Table 1, zone 20). The middle Turonian rocks apparently are a wedge of strata that is bounded by unconformities and restricted to the northwestern part of the basin (Figs. 6 and 8).

### GEOLOGIC HISTORY

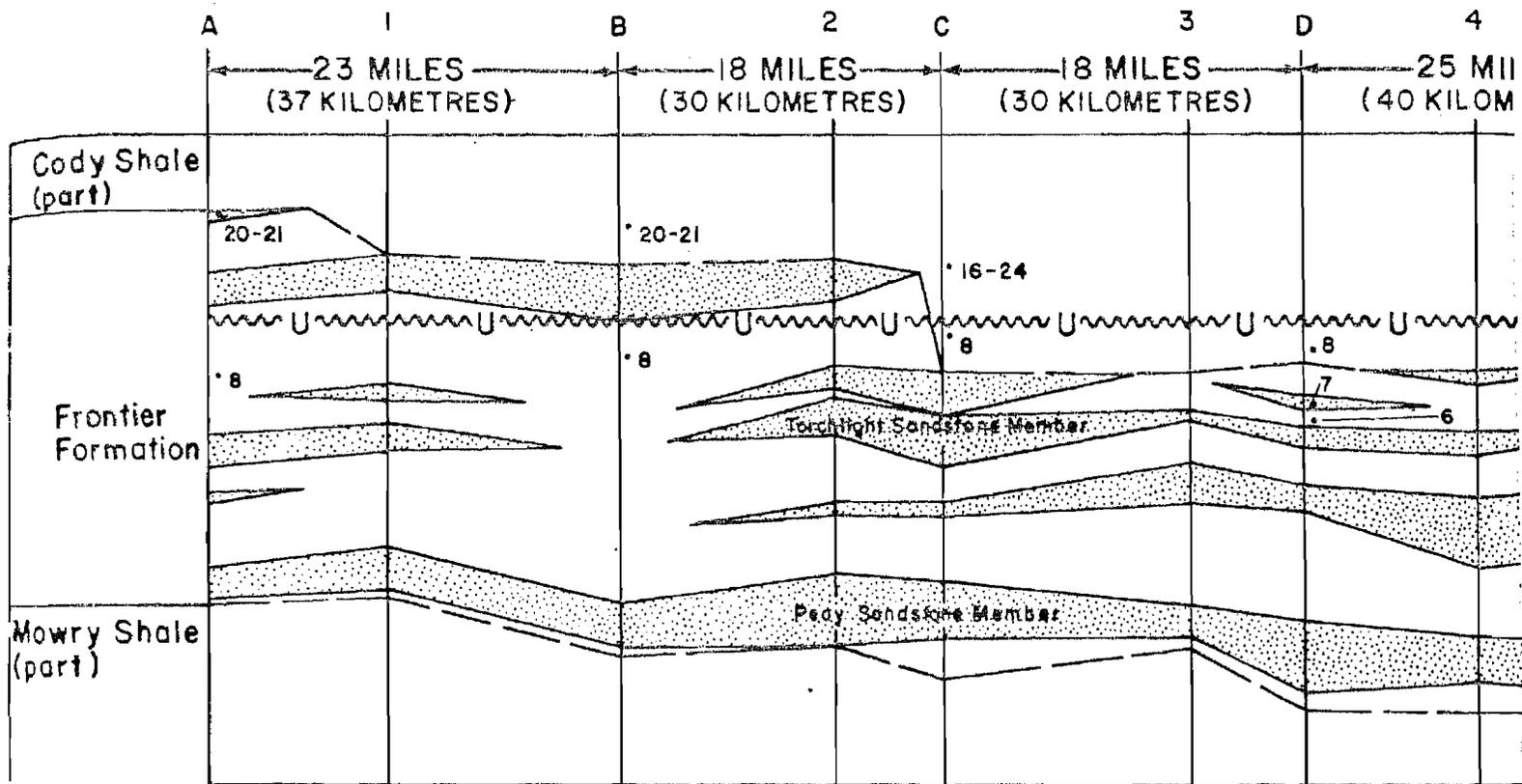
In the early Late Cretaceous, sediments were transported from tectonic highlands in Idaho, western Montana and western Wyoming and intermittently deposited in the region of the Bighorn Basin. During the Cenomanian, the Frontier Formation probably accumulated without interruption, largely in marine environments which varied from offshore to nearshore. Locally, near Cody and Deep Lake (Sections I and H), some of the Cenomanian beds were deposited in deltaic and alluvial plain environments.

The region was eroded during early Turonian time and was a site of marine deposition in middle Turonian time. Remnants of these Turonian rocks which probably accumulated in offshore and nearshore environments, are recognized in the Oregon Basin-Cody area and possibly in

the Greybull area. Part of the continental sequence that crops out at Section H may also be middle Turonian in age.

Middle Turonian deposition was followed by uplift and erosion during late Turonian time. The amount of truncation seems to be least in the northwestern part of the basin (Figs. 6 and 8), where middle Turonian rocks are preserved, and greatest in the southwestern part of the basin near Hamilton Dome (Fig. 7, Section K), where upper Cenomanian beds apparently are missing. The dip of the beds beneath this erosion surface (Figs. 7 and 8) is sparse evidence that the region was uplifted along a north-northwest-trending arch. In location and trend, the axis of the proposed arch corresponds approximately with the steeply dipping western flank of the basin.

The late Turonian uplift and erosion was succeeded by a major marine transgression and the deposition of strata of the uppermost Frontier and lowermost Cody during latest Turonian and Coniacian time. In general, these rocks grade from sandstone and shale in the upper part of the Frontier to shale in the overlying Cody. Most of the beds are of marine origin; however, near Cody and Pitchfork (Sections I and J), the basal part of the sequence probably was deposited on a deltaic plain. The rocks of latest Turonian and Coniacian age probably accumulated by onlap on a gently sloping erosion surface because the basal beds are older in the easternmost part of the basin (Sections E, F, G and M) and younger on the west side of the basin near the Oregon Basin oil field and Cody (Section I).



### EXPLANATION

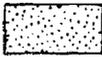
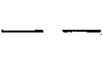
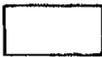
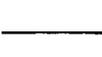
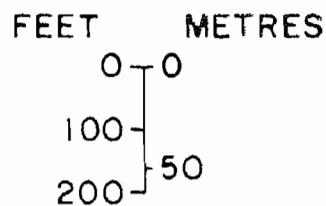
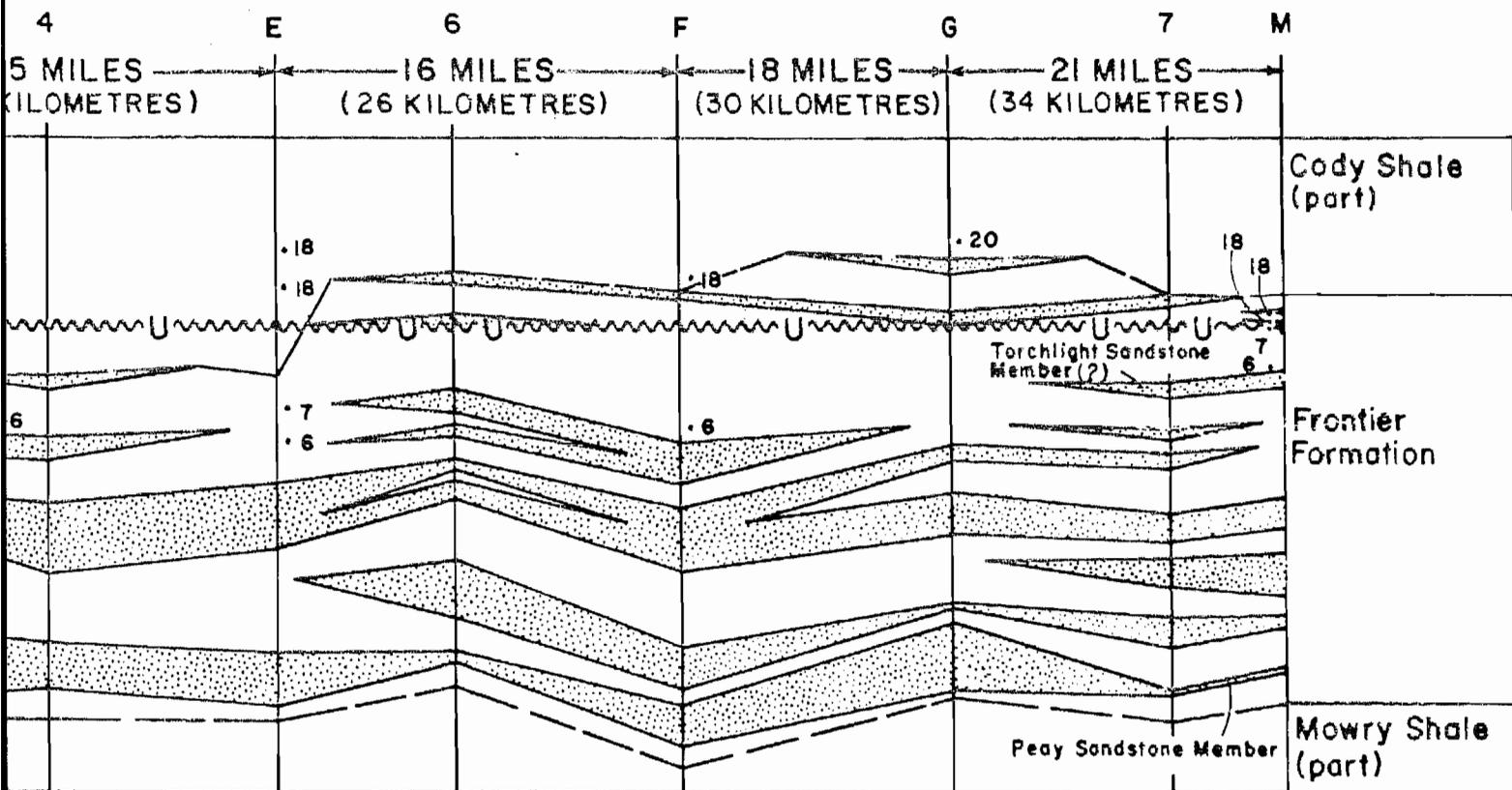
- |   |  |   |  |
|---|--|---|--|
|    | Sandstone of marine origin   |  | Formation boundary - approximately located |
|    | Siltstone and shale of marine origin                                   |  | Lithologic boundary                        |
|  8 | Fossil collection-number refers to molluscan sequence shown in table 1 |  | Unconformity                               |

Figure 5.--Stratigraphic diagram showing intertonguing relations and an unconformity flank of the Bighorn Basin. Location of sections A, B, C, and D are shown on the map.



formity in the Frontier Formation at outcrops and wells along the eastern of sections and wells shown on figure 1.

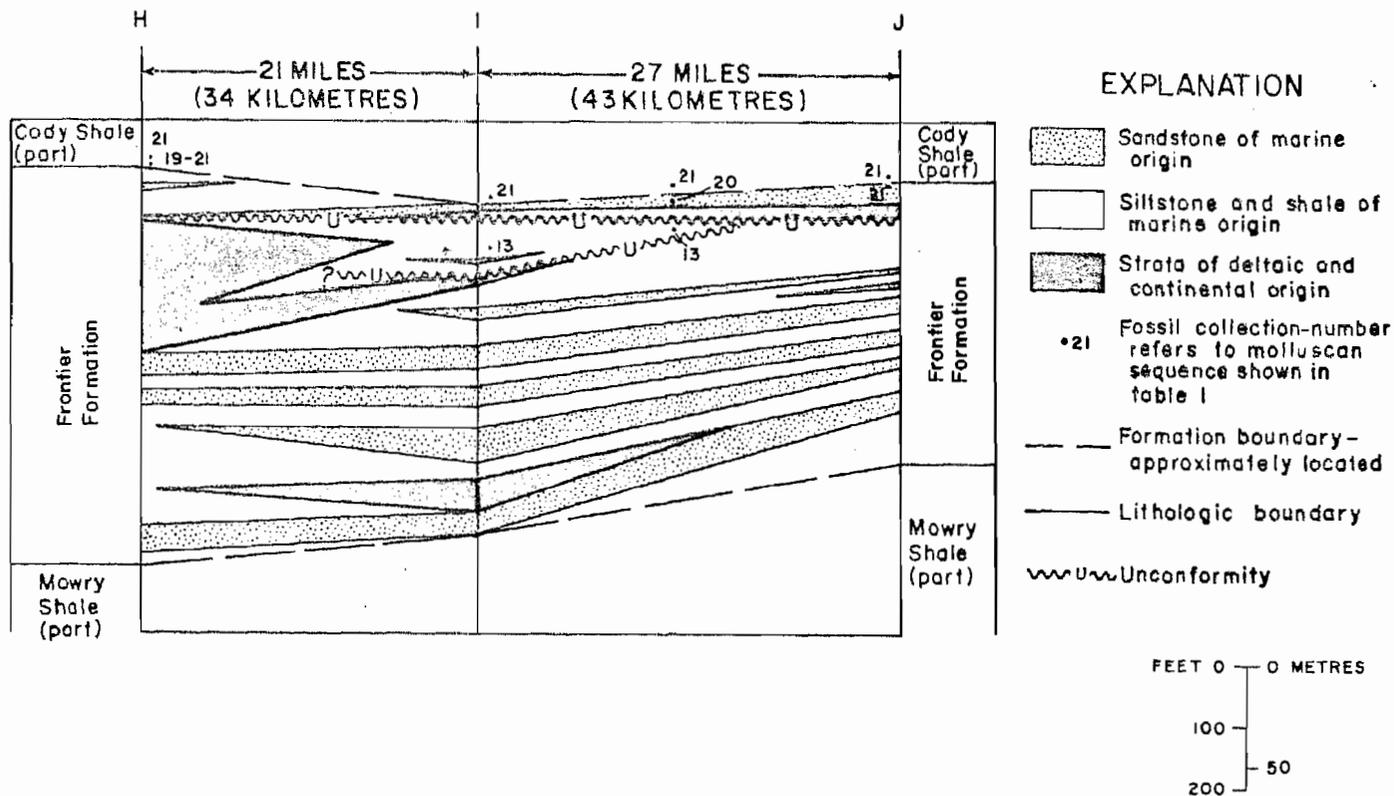


Figure 6. — Stratigraphic diagram showing intertonguing relations and unconformities in the Frontier Formation at outcrops along the western flank of the Bighorn Basin. Location of sections shown on Figure 1.

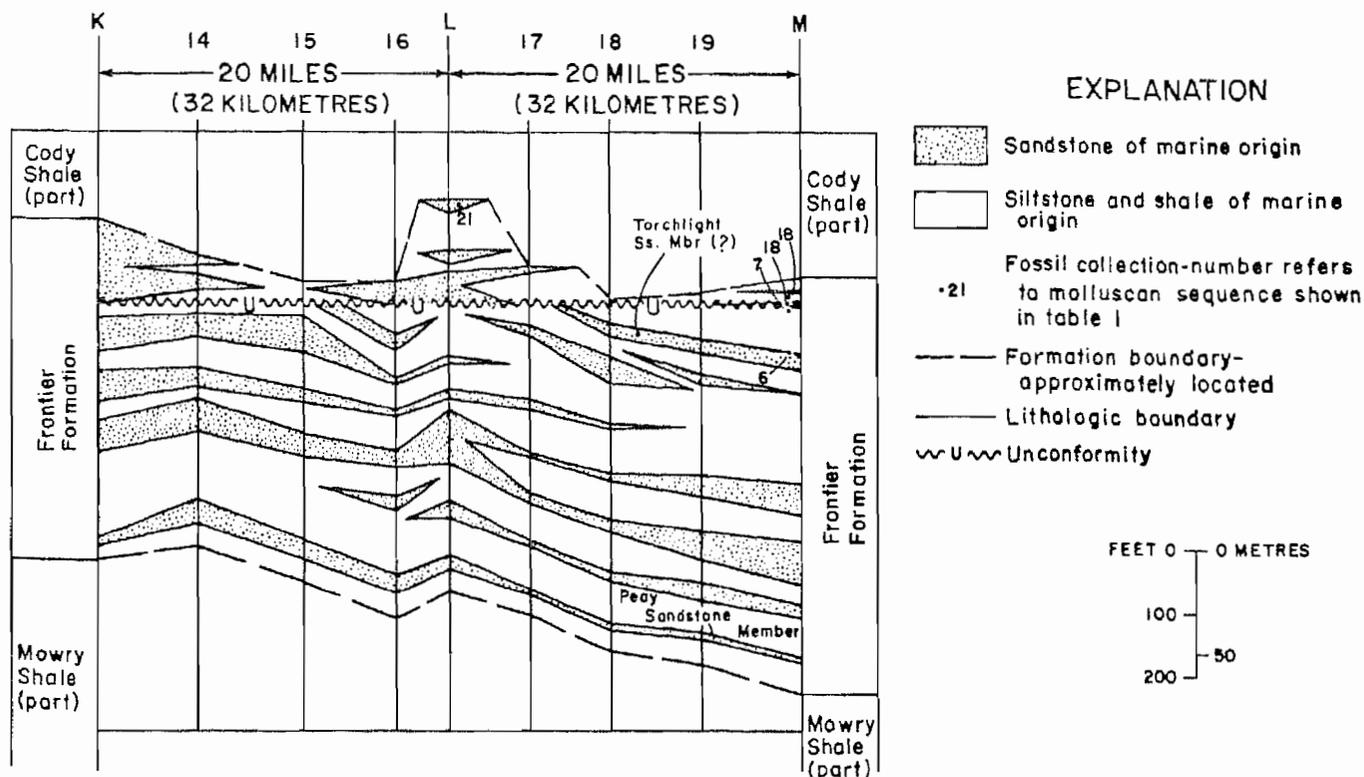


Figure 7. — Stratigraphic diagram showing intertonguing relations and an unconformity in the Frontier Formation at outcrops and wells along the southern flank of the Bighorn Basin.

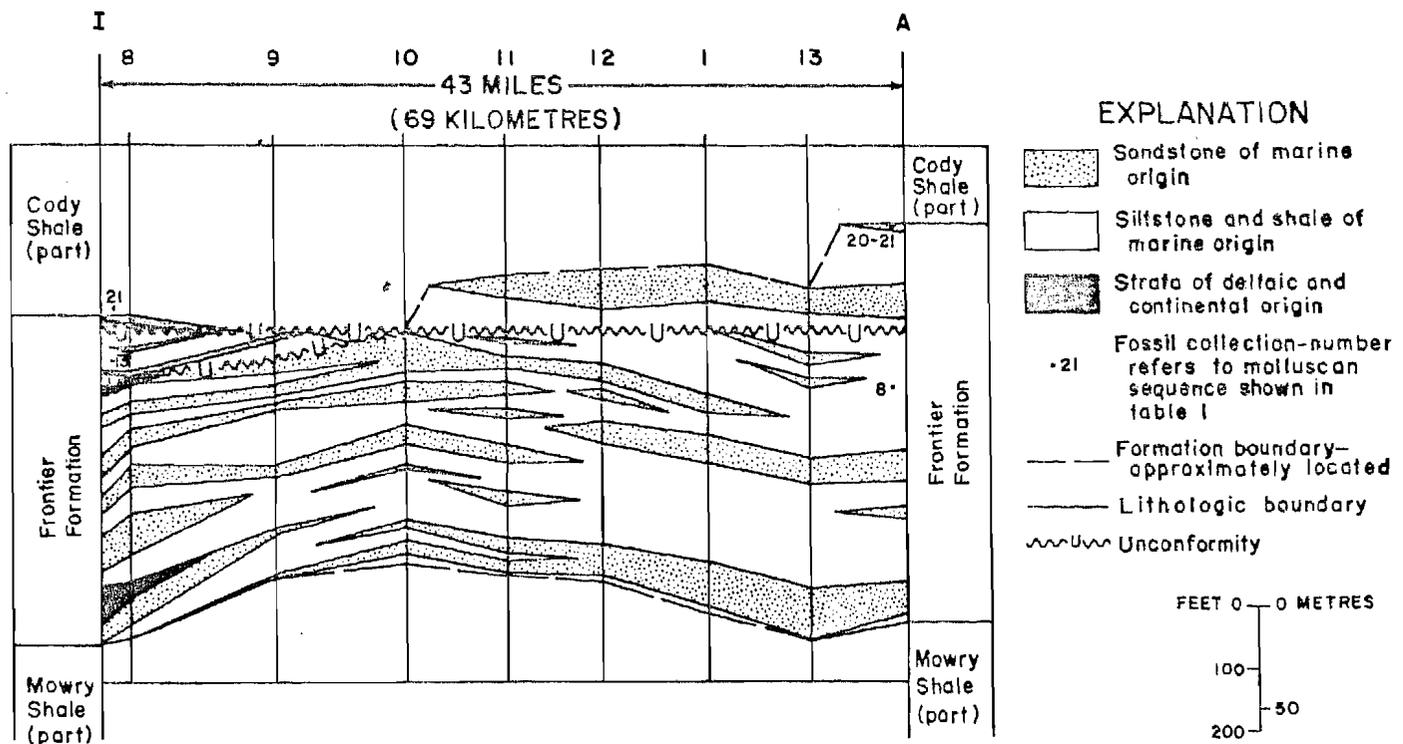


Figure 8. — Stratigraphic diagram showing intertonguing relations and unconformities in the Frontier Formation at outcrops and wells in the northern part of the Bighorn Basin.

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