Stratigraphy and Geologic History of the Montana Group and Equivalent Rocks, Montana, Wyoming, and North and South Dakota

By J. R. GILL *and* W. A. COBBAN

GEOLOGICAL SURVEY PROFESSIONAL PAPER 776

Stratigraphic, paleontologic, and radiometric data are combined to determine the paleogeography for a part of the upper Upper Cretaceous

---

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1973

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 73-600136

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 – Price 85 cents domestic postpaid or 60 cents GPO Bookstore
Stock Number 2401-00342

CONTENTS

ILLUSTRATIONS

TABLES

STRATIGRAPHY AND GEOLOGIC HISTORY OF THE MONTANA GROUP AND EQUIVALENT ROCKS, MONTANA, WYOMING, AND NORTH AND SOUTH DAKOTA

By J. R. GILL[1] and W. A. COBBAN

ABSTRACT

During Late Cretaceous time a broad north-trending epicontinental sea covered much of the western interior of North America and extended from the Gulf of Mexico to the Arctic Ocean. The sea was bounded on the west by a narrow, unstable, and constantly rising cordillera which extended from Central America to Alaska and which separated the sea from Pacific oceanic waters. The east margin of the sea was bounded by the low-lying stable platform of the central part of the United States.

Rocks of the type Montana Group in Montana and equivalent rocks in adjacent States, which consist of eastward-pointing wedges of shallow-water marine and nonmarine strata that enclose westward-pointing wedges of fine-grained marine strata, were deposited in and marginal to this sea. These rocks range in age from middle Santonian to early Maestrichtian and represent a time span of about 14 million years. Twenty-nine distinctive ammonite zones, each with a time span of about half a million years, characterize the marine strata.

Persistent beds of bentonite in the transgressive part of the Claggett and Bearpaw Shales of Montana and equivalent rocks elsewhere represent periods of explosive volcanism and perhaps concurrent subsidence along the west shore in the vicinity of the Elkhorn Mountains and the Deer Creek volcanic fields in Montana. Seaward retreat of strandlines, marked by deposition of the Telegraph Creek, Eagle, Judith River, and Fox Hills Formations in Montana and the Mesaverde Formation in Wyoming, may be attributed to uplift in near-coastal areas and to an increase in volcaniclastic rocks delivered to the sea.

Rates of transgression and regression determined for the Montana Group in central Montana reveal that the strandline movement was more rapid during times of transgression. The regression of the Telegraph Creek and Eagle strandlines averaged about 50 miles per million years compared with a rate of about 95 miles per million years for the advance of the strandline during Claggett time. The Judith River regression averaged about 60 miles per million years compared with movement of the strandline during the Bearpaw advance of about 70 miles per million years.

The final retreat of marine waters from Montana, marked by the Fox Hills regression, was about 35 miles per million years at first, but near the end of the regression it accelerated to a rate of about 500 miles per million years.

Rates of sedimentation range from less than 50 feet per million years in the eastern parts of North and South Dakota to at least 2,500 feet in western Wyoming. The low rates in the Dakotas correspond well with modern rates in the open ocean, and the rates in western Wyoming approach the rate of present coastal sedimentation.

[1]Deceased July 1972.

INTRODUCTION

This is a progress report on regional stratigraphic and paleontologic studies of the Upper Cretaceous Montana Group and equivalent rocks in the northern part of the western interior of the United States. It presents preliminary data on the positions of strandlines during a 14-m.y. (million year) span of the Late Cretaceous as well as our interpretations of the geologic history of this period.

We gratefully acknowledge the use of stratigraphic and paleontologic data collected by other members of the U.S. Geological Survey, notably those of H. A. Tourtelot, L. G. Schultz, E. A. Merewether, M. R. Reynolds, G. H. Horn, and the late A. D. Zapp and C. E. Erdmann. J. D. Obradovich, also of the U.S. Geological Survey, provided several potassium-argon age determinations on biotite collected from beds of bentonite in the Pierre and Claggett Shales.

GEOLOGIC SETTING

During much of Late Cretaceous time, the western interior of North America was the site of an epicontinental sea which extended from the Gulf of Mexico to the Arctic Ocean and which in places was as much as 1,000 miles wide (fig. 1). Along its entire length the sea was bounded on the west side by a narrow, unstable, and repeatedly rising north-trending cordilleran highland which separated the interior Cretaceous sea from Pacific waters. This cordilleran highland, flanked on the east by the Rocky Mountain geosyncline and on the west by the Pacific geosyncline, was the source of the clastics that ultimately filled the Cretaceous epicontinental sea. Gilluly (1963, p. 146) estimated that this source area occupied 160,000–200,000 square miles and that it contributed more than a million cubic miles

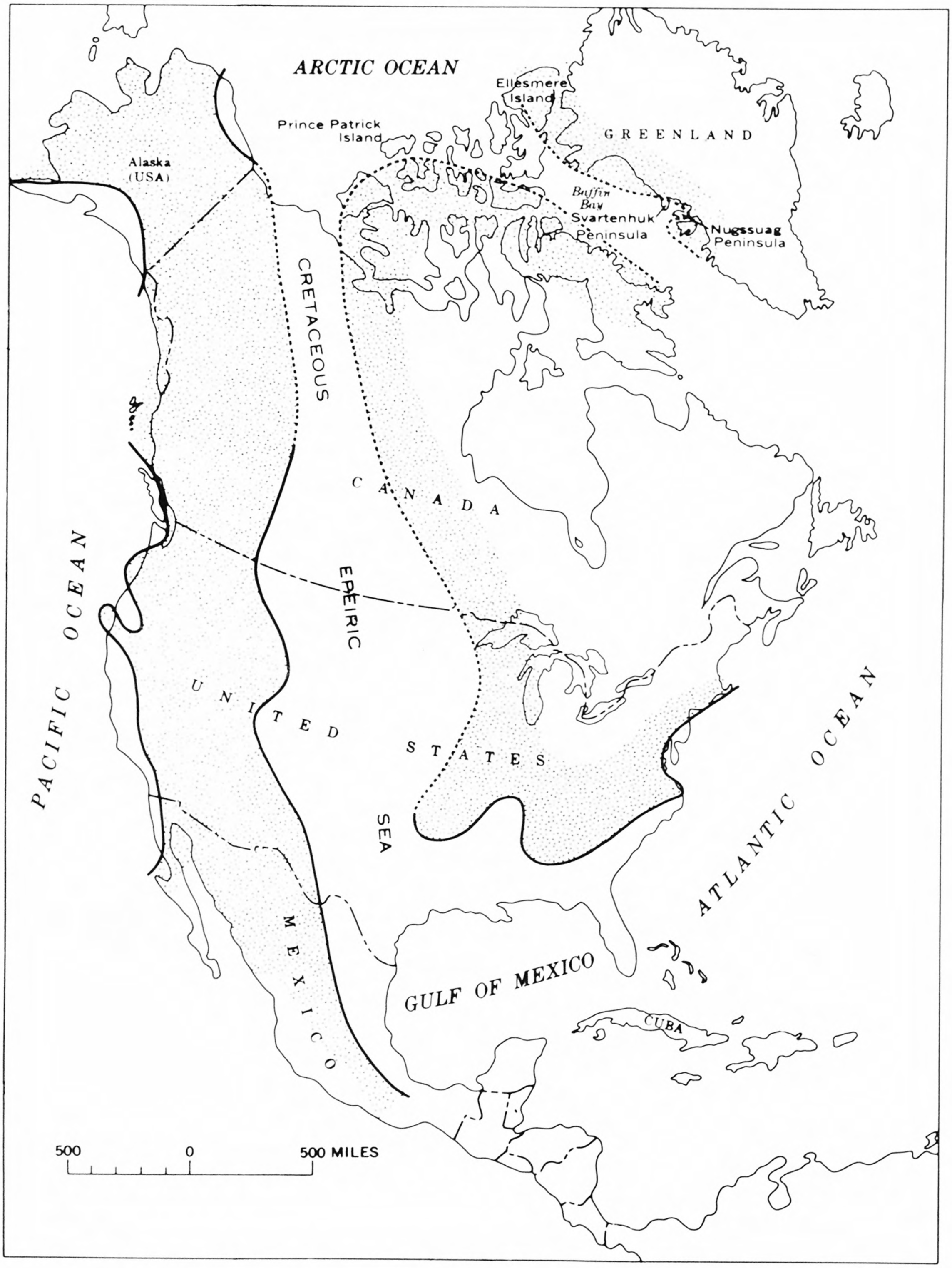


FIGURE 1.—Probable distribution of land and sea in North America during late Campanian time showing the geographic position of the seaway that divided the continent into eastern and western parts. Modified from Gill and Cobban (1966b, fig. 15).

of clastic sediment to the western interior sea. This volume of sediment would require erosion of the source area to a depth of about 5 miles which, according to Gilluly (1963, p. 147), is difficult to reconcile with known geology of the presumed source and thus suggests long-distance lateral transfer of material within the exposed source area.

The east margin of the interior sea was formed by the low-lying stable platform of the Eastern United States and Canada. The exact position of this shoreline is uncertain, but it was probably no farther west than the longitude of eastern Minnesota and Iowa. An arctic connection of this seaway with West Greenland seems certain; arguments for it were summarized recently by Birkelund (1965, p. 163–172) and Rosenkrantz (1970, p. 448–449).

Climatic conditions during the Late Cretaceous favored the development of a varied invertebrate and vertebrate fauna. Marine deposits are characterized by a distinctive molluscan fauna, perhaps most importantly the ammonites, some of which apparently immigrated from boreal and mediterranean realms and some of which were endemic. Cobban recognized 67 widespread and distinctive ammonite zones in the upper Albian to Maestrichtian rocks. In the present report we consider 31 of the younger ammonite zones, which range in age from late Santonian to early Maestrichtian. Potassium-argon dating of biotite from bentonites in the Bearpaw Shale and older rocks provides a basis for estimating that each ammonite range span is equivalent to about one-half million years (table 1; Gill and Cobban, 1966b, p. A35).

A biochronological time scale based on ammonite zonation and radiometric age determinations is, of course, only an approximation of the truth. Some workers question the reliability of radiometric age determinations and the attempts to calibrate the duration of fossil stages and zones. Jeletzky (1971, p. 6–10) summarized the problems inherent in such compilations and the reason he regards such attempts as unfounded and misleading. We agree with Jeletzky as to the difficulties involved in calibrating the duration of fossil zones. Variable rates of evolution are undoubtedly involved, and radiometric age determination may not be exact. We believe, however, that it is useful to attempt calibration of the duration of zones within a single biogeographic province in order to obtain an approximation of the magnitude of geologic events.

In 1966, Cobban (Gill and Cobban, 1966b, p. A35) attempted to establish the time relation of the type Montana Group to the standard stages of the Upper Cretaceous, to potassium-argon dates, and to the western interior ammonite sequence. At that time it was expected that the calibration of this time scale would need revision as new data became available. Recently J. D. Obradovich (written commun., 1968) provided several new age determinations on biotite from bentonites in the zones of *Didymoceras nebrascense* and *Baculites mclearni*. Two samples from the zone of *Didymoceras* yielded a date of 75.5±2 m.y. compared with our estimated age of 75 m.y. (table 1; Gill and Cobban, 1966, p. A35), and one from the *Baculites mclearni* level yielded a date of 79.5 m.y. compared with our estimated age of 79 m.y. These data may not validate the method of subdivision but neither do they contradict previous dates.

Most of the sediments deposited in the Montana and Wyoming parts of the Cretaceous sea were apparently derived from several distinct petrologic provinces along the western cordillera. The Montana part of the sea received a great flood of clastic and pyroclastic volcanic material from the Upper Cretaceous Elkhorn Mountains Volcanics along its western shore. Most of the Wyoming sediments came from crystalline and metamorphic terranes or from Paleozoic sedimentary beds in the western cordillera. Intermittent local tectonic activity, plutonism, and volcanism continually modified the configuration of the cordillera and the western shore as recorded in a great series of transgressive and regressive deposits.

AMMONITE SEQUENCE

Ammonites representing the genera *Desmoscaphites*, *Scaphites*, *Baculites*, *Didymoceras*, and *Exiteloceras* are useful in dividing the age span of the Montana Group into small increments of time (table 1). *Desmoscaphites*, which characterizes the oldest zones of the Montana Group, represents part of a lineage of scaphitid ammonites that has been traced back to late Cenomanian time (Cobban, 1951b, p. 6–11). The three forms of *Scaphites hippocrepis*, each characterizing a zone, are descendents of *S. leei* Reeside, a migrant into the western interior from the Gulf coastal region. The baculites, through the zone of *Baculites eliasi*, represent a single lineage of endemic forms. *Baculites baculus* is a migrant from the Gulf coastal region, and *B. grandis* and *B. clinolobatus* are descendents of that species. The heteromorphic ammonites, *Didymoceras* and *Exiteloceras*, are also migrants, presumably from the Gulf coast.

Desmoscaphites erdmanni Cobban.—This species (Cobban, 1951b, p. 38, pl. 21, figs. 10–23; 1955, p. 202,

TABLE 1.—*Time relation of the type Montana Group, central Montana, to the standard stages of the Upper Cretaceous, to potassium-argon dates, and to the western interior ammonite sequence*

[Modified from Gill and Cobban (1966b, p. A35)]

Upper Cretaceous stages and substages			Potassium-argon dates (Millions of years)	Estimated dates (Millions of years)	Western interior ammonite sequence[1]
Maestrichtian	Upper		63	63	
			64±2	64	
				65	
			66±2	66	
				67	
	Lower			68	*Discoscaphites nebrascensis*
					Discoscaphites roanensis
				69	*Sphenodiscus (Coahuilites)*
					Baculites clinolobatus 24
		Type Montana Group	70	70	*Baculites grandis* 23
?					*Baculites baculus* 22
Campanian	Upper			71	*Baculites eliasi* 21
					Baculites jenseni 20
				72	*Baculites reesidei* 19
					Baculites cuneatus 18
			75±2	73	*Baculites compressus* 17
					Didymoceras cheyennense 16
				74	*Exiteloceras jenneyi* 15
					Didymoceras stevensoni 14
			[2] 75.5±2	75	*Didymoceras nebrascense* 13
					Baculites scotti 12
				76	*Baculites gregoryensis* 11
					Baculites perplexus (late form)
				77	*Baculites gilberti* 10
					Baculites perplexus (early form)
				78	*Baculites* sp. (smooth)
					Baculites asperiformis 9
			[2] 79.5	79	*Baculites mclearni* 8
	Lower				*Baculites obtusus* 7
				80	*Baculites* sp. (weak flank ribs) 6
					Baculites sp. (smooth) 5
			81±2	81	*Scaphites hippocrepis* III
					Scaphites hippocrepis II 4
Santonian (part)	Upper			82	*Scaphites hippocrepis* I 3
					Desmoscaphites bassleri 2
				83	*Desmoscaphites erdmanni* 1

[1] Arabic numbers refer to strandlines shown in figures 13-14 and 16-20.

[2] Potassium-argon dates supplied by J. D. Obradovich (written commun., 1968).

pl. 1, figs. 4, 5) is a moderately stout tightly coiled scaphite that has a densely ribbed body chamber ornamented by about 10 long thin primary ribs and about three or four times as many shorter secondary ribs. Most primary ribs of the adult have a small conical tubercle at the margin of the venter. The juvenile whorls have four to six constrictions per whorl. Most of the characteristics of this species are illustrated in figures 2*A* and 2*B*.

Desmoscaphites bassleri Reeside.—This immediate descendent of *D. erdmanni* is more densely ribbed and has five or six secondary ribs separating the primary ribs on the body chamber. The species was originally described from the Mancos Shale of the San Juan Basin in New Mexico (Reeside, 1927, p. 16, pl. 21, figs. 17–21; pl. 22, figs. 8–12). Figure 2*C* is a composite drawing based on the holotype supplemented by specimens from the Telegraph Creek Formation near Hardin, Mont.

Scaphites hippocrepis (DeKay).—This species, originally described from the Merchantville Formation of Delaware (DeKay, 1827, p. 273, pl. 5, fig. 5), occurs in the western interior in the form of three chronological subspecies that have been assigned the Roman numerals I, II, and III (Cobban, 1969). The general features are shown in figures 2*D–F*). All forms are characterized by an interruption in the uniform spacing of the ventral ribs on the older part of the body chamber and by a row of small ventrolateral tubercles separated from a row of larger and sparser umbilical tubercles by a smooth or nearly smooth flank area. Of the three subspecies, *Scaphites hippocrepis* I has the fewest ribs, and its ventrolateral tubercles tend to be elongated (bullate). *Scaphites hippocrepis* II is more densely ribbed, and the ventrolateral tubercles are more circular. *Scaphites hippocrepis* III is still more densely ribbed, its ventrolateral tubercles may extend onto the phragmocone, and the area between the rows of ventrolateral and umbilical tubercles has a row of very weak nodelike ribs.

Baculites sp. (smooth).—Baculites that are dominantly smooth characterize the next zone above that of *Scaphites hippocrepis* III. The specimens attain a moderate size (as much as 2 in. or 5 cm in diameter) and have a low degree of taper and an ovate cross section (fig. 2*G*). The flanks of the adults are ordinarily smooth, and the venters may be smooth or weakly ribbed. Small juveniles may have noded flanks, but most are smooth. The lateral lobe of the suture is featured by a broad rectangular central area common to all baculitid sutures older than those from the zone of *B. gregoryensis*. The suture shown in figure 3*A*, which was drawn from a specimen of *B. gilberti*, could just as well be from a specimen of *B.* sp. (smooth).

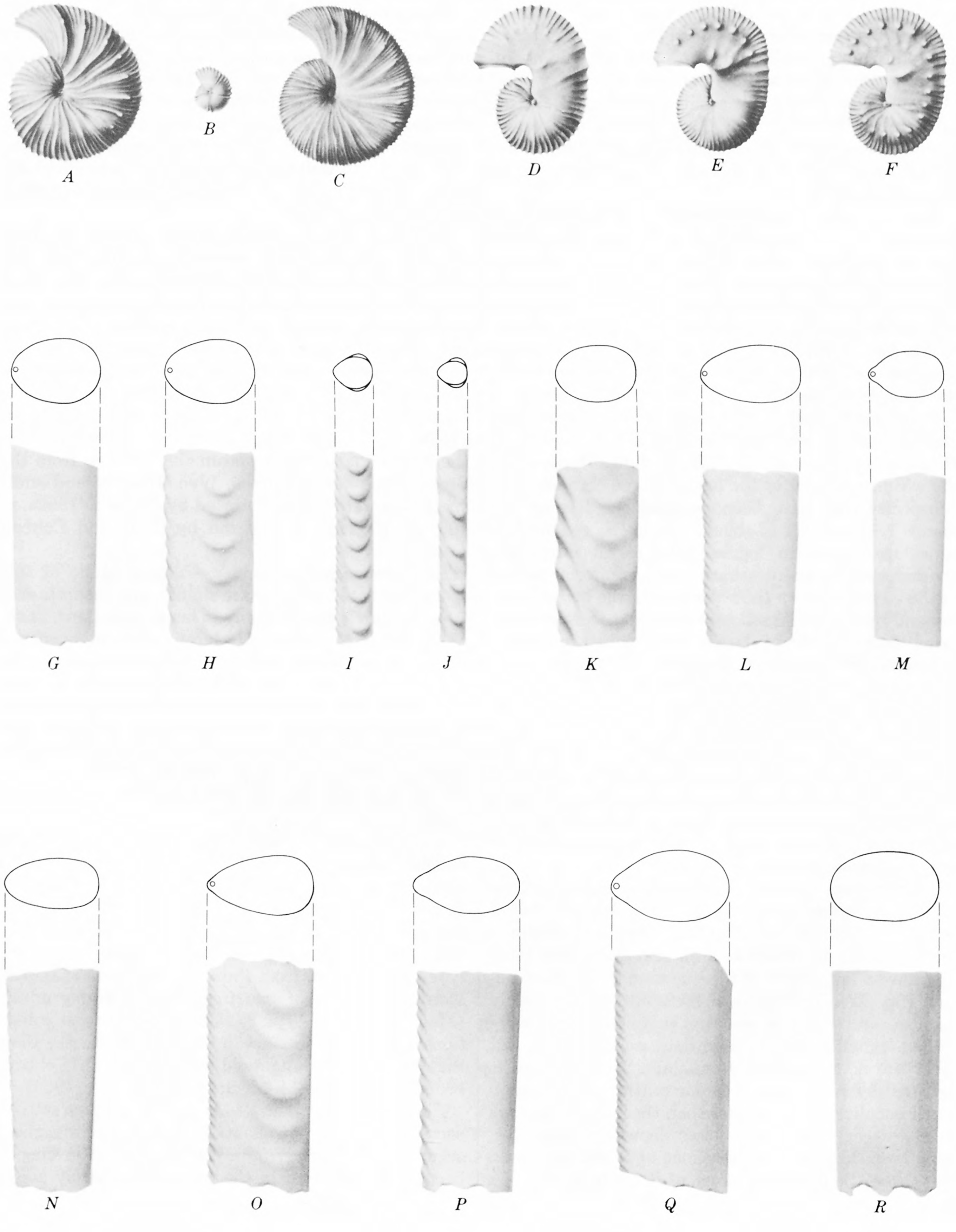
Baculites sp. (weak flank ribs).—The smooth baculites in the beds just above those containing *Scaphites hippocrepis* III apparently gave rise to a form characterized by flank ribs (fig. 2*H*). This ornamented form resembles its immediate ancestor in size—low degree of taper, ovate section, and suture pattern. Most specimens have very weak closely spaced arcuate flank ribs and smooth to well-ribbed venters. A few individuals have smooth flanks, and a few others have rather strongly ribbed flanks.

Baculites obtusus Meek.—This species is more strongly ribbed and is generally smaller than the slightly older weakly ribbed baculite (fig. 2*I*). Most specimens have conspicuous closely spaced arcuate nodelike ribs or blunt nodes on the flanks, and most have ribbed venters. The angle of taper is very low, and the cross section of the shell is ovate to trigonal. The suture is like that of the older baculitid species. *Baculites obtusus* was originally described by Meek (1876, p. 406, text figs. 57–60) from "Deer Creek on the North Platte," and presumably it came from the Steele Shale near Glenrock, Wyo. Juvenile and adult specimens were later illustrated by Cobban (1962a, p. 706, pl. 105, figs. 1–14) and by Scott and Cobban (1965).

Baculites mclearni Landes.—Young adults of this species and of *B. obtusus* are similar, and separation of these species is possible only in large collections. Juveniles of *B. mclearni* usually have more widely spaced flank ornamentation, and the adults commonly retain the flank ribs to greater diameters than in *B. obtusus*. The holotype, from the Pakowki Formation of Alberta, is part of a large adult (Landes, 1940, p. 165, pl. 7, figs. 1–3). Various growth stages have been illustrated by Cobban (1962a, p. 712, pl. 105, fig. 15; pl. 107, figs. 17–19, text figs. 1*g*, *h*) and by Scott and Cobban (1965).

Baculites asperiformis Meek.—Widely spaced strong nodelike ribs or arcuate flank nodes characterize this species (fig. 2*J*). It is closely related to *B. obtusus* and *B. mclearni* and resembles them in its moderately small size, very low degree of taper, ovate to triangular section, variable ribbing on the venter, and suture. The types, which came from the Claggett Shale of central Montana, consist of two fragments of young adults (Meek, 1876, p. 405, pl. 39, figs. 10a–d). Larger collections from other localities in the western interior show that the older adults tend to be smooth (Cobban, 1962a, pl. 106, figs. 14–16; Scott and Cobban, 1965).

Baculites sp. (smooth).—At some localities a smooth baculite is common in the rocks just above the highest occurrence of *B. asperiformis*. It resembles the smooth baculite found lower in the rocks immediately above


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R

those containing the latest form of *Scaphites hippocrepis*. The higher (younger) smooth baculite, which attains a greater size than any of the older species, was described and illustrated by Cobban (1962a, p. 714, pl. 108, figs. 1–4; text figs. 1i, j).

Baculites perplexus Cobban.—Strong ventral ribs and weak flank ribs characterize this species (fig. 2*K*), which attains a size as great as that of the slightly older smooth species. The angle of taper is very low, and the cross section of the shell in young adults is ovate and usually compressed a little. Large adults become smooth, and their cross sections become stout and elliptical. The suture (fig. 3*A*) is like that of the older species.

Baculites perplexus was described from the upper part of the Steele Shale near Glenrock, Wyo. (Cobban, 1962a, p. 714, pl. 107, figs. 1–16, text figs. 1a–c). The collection from which the types were selected consisted of more than 500 specimens, most of which had from 3.5 to 4 ventral ribs in a distance equal to the diameter of the shell. A more densely ribbed form from slightly younger rocks in Colorado was described as *B. gilberti* Cobban (1962a, p. 716, pl. 108, figs. 5–13, text figs. 1d–f). Most specimens in the type lot have five to seven ventral ribs for the shell diameter. Collections made later from rocks a little younger than those containing *B. gilberti* reveal that the baculites become more coarsely ribbed and revert to a form like *B. perplexus* with average rib counts of less than five for the shell diameter (Gill and Cobban, 1966b, p. A30). Accordingly, early and late forms of *B. perplexus* were recognized separated by *B. gilberti*, which could be considered a chronological subspecies of *B. perplexus*.

FIGURE 2.—Ammonites, one-half natural size, that serve as important index fossils. *A, B, Desmoscaphites erdmanni* Cobban based on the holotype and two partypes (USNM 106724, 106725c, 106725d). *C, D. bassleri* Reeside based on the holotype (USNM 73358) and specimens from the Telegraph Creek Formation near Hardin, Mont. *D. Scaphites hippocrepis* (DeKay) I based on a hypotype (USNM 160283). *E, S. hippocrepis* II based on a hypotype (USNM 160297). *F, S. hippocrepis* III based on a specimen from New Jersey (Acad. Nat. Sci. Philadelphia 19483). *G, Baculites* sp. (smooth) based on a specimen from the Shannon Sandstone Member of the Cody Shale of the Salt Creek oil field, Natrona County, Wyo. *H, Baculites* sp. (weak flank ribs) based on a specimen from the Gammon Ferruginous Member of the Pierre Shale of Butte County, S. Dak. *I, Baculites obtusus* Meek based on part of a hypotype (USNM 131011c). *J, Baculites asperiformis* Meek based on part of a hypotype (USNM 131015b). *K, Baculites perplexus* Cobban based on a paratype (USNM 108915e). *L, Baculites gregoryensis* Cobban based on a specimen from the Red Bird Silty Member of the Pierre Shale of Niobrara County, Wyo. *M, Baculites scotti* Cobban based on a specimen from the Pierre Shale near Oral, S. Dak. *N, Baculites compressus* Say based on a specimen from the Pierre Shale of Pennington County, S. Dak. *O, Baculites cuneatus* Cobban based on a paratype (USNM 108967a). *P, Baculites reesidei* Elias based on a specimen from the Pierre Shale of Campbell County, Wyo. *Q, Baculites jenseni* Cobban based on the holotype (USNM 131117). *R, Baculites eliasi* Cobban based on part of the holotype (USNM 108969).

Baculites gregoryensis Cobban.—The late form of *B. perplexus* gave rise to *B. gregoryensis* (fig. 2*L*) by an increase in the number of ventral ribs and by a subsequent reduction in the strength of the ribs, by an increase in the degree of taper, and by the disappearance of flank ribs on juveniles. A major change occurred in the suture—the lateral lobe became constricted just above its major lateral branches (figs. 3*B*, 4*B*). *Baculites gregoryensis* was originally described from the Gregory Member of the Pierre Shale of south-central South Dakota (Cobban, 1951a, p. 820, pl. 118, figs. 1–5, text figs. 8–13). Sketches of juvenile and adult growth stages were shown by Scott and Cobban (1965).

Baculites scotti Cobban.—Most specimens have smooth flanks and very weakly ribbed to almost smooth venters. The angle of taper is very low, and the cross section of the shell is ovate. Many individuals have a slight ventrolateral depression (fig. 2*M*). The suture is like that of *B. gregoryensis*. A variant that has broad ribs or arcuate swellings on the flank is usually found with the dominantly smooth form. The type specimens came from the Pierre Shale near Pueblo, Colo. (Cobban, 1958, p. 660, pl. 90, figs. 1–9, text figs. la–e, h).

Didymoceras nebrascense (Meek and Hayden).—The holotype is a small fragment which was described by Meek and Hayden in 1856 (p. 71) but which was not illustrated until 20 years later (Meek, 1876, pl. 22, figs. 1a–c). Several very well preserved specimens were described and illustrated later by Whitfield (1902) who called them *Heteroceras simplicostatum*. The diagnostic features of *D. nebrascense* have been summarized by Gill and Cobban (1966b, p. A31) as follows:

> *Didymoceras nebrascense* is an aberrant ammonite that has early whorls consisting of straight limbs connected by semicircular bends, later whorls in an open helicoid spire, and the final whorl bent at first away from the spire and then curved back toward it. There are closely spaced ribs and a row of small nodes on each side of the venter on the early straight limbs as well as on the later spiral part. Coarse ribs and strong nodes characterize the final recurved whorl.

Complete specimens of this loosely coiled ammonite have not been found, but a drawing showing how the complete shell may have looked is reproduced in figure 5*A*.

Didymoceras stevensoni (Whitfield).—This aberrant ammonite is more coarsely ribbed than *D. nebrascense*, and several of the larger whorls of the helicoid spire are either in contact or almost in contact with each other. The holotype came from the Pierre Shale

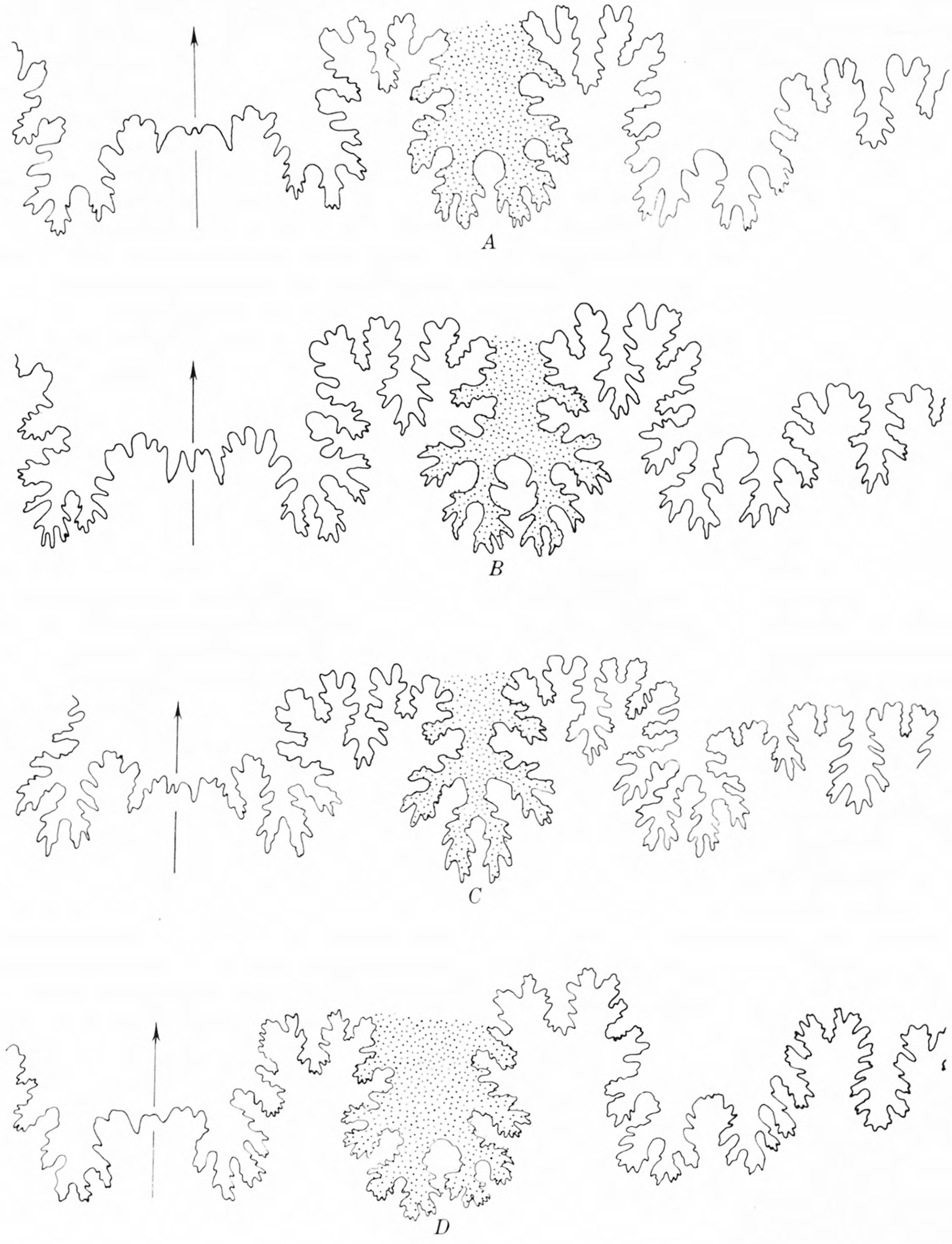


FIGURE 3.—Sutures of baculites from the Montana Group. The arrow marks the middle of the venter. The lateral lobe is stippled. *A, Baculites gilberti* Cobban, × 3, from the Mitten Black Shale Member of the Pierre Shale near Red Bird, Wyo. *B, B. gregoryensis* Cobban, × 3, from the Red Bird Silty Member of the Pierre Shale near Red Bird, Wyo. *C, B. reesidei* Elias, × 2, from the Pierre Shale of Campbell County, Wyo. *D, B. baculus* Meek and Hayden, × 2, from the upper part of the Pierre Shale near Red Bird, Wyo.

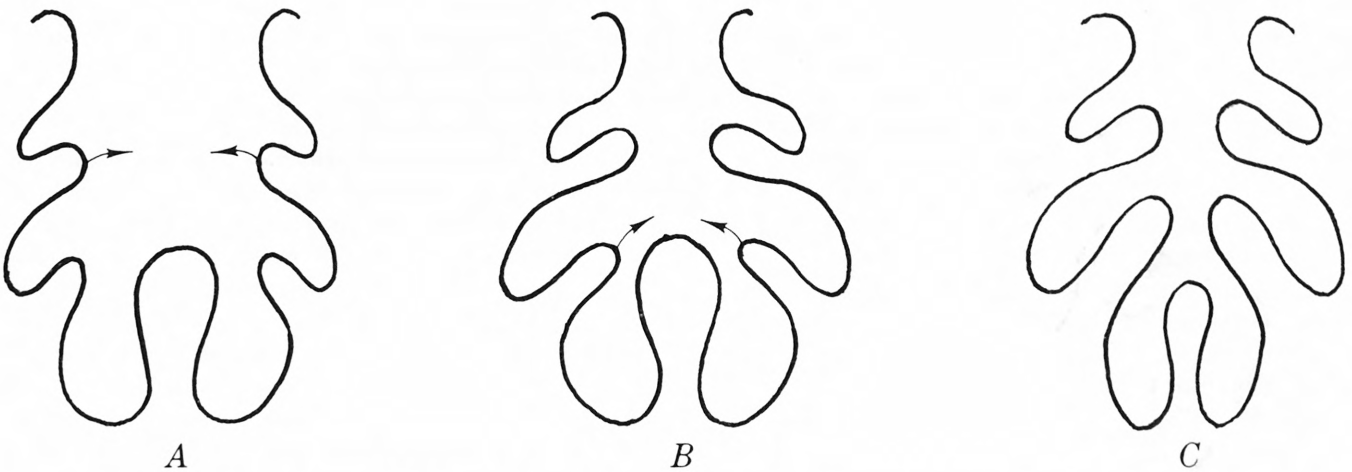


FIGURE 4.—Changes in the form of the lateral lobe of *Baculites* (no scale). Arrows point to direction of major shifts in the position of the saddles separating branches of the lobe. *A, Baculites perplexus; B, B. gregoryensis; C, B. eliasi.*

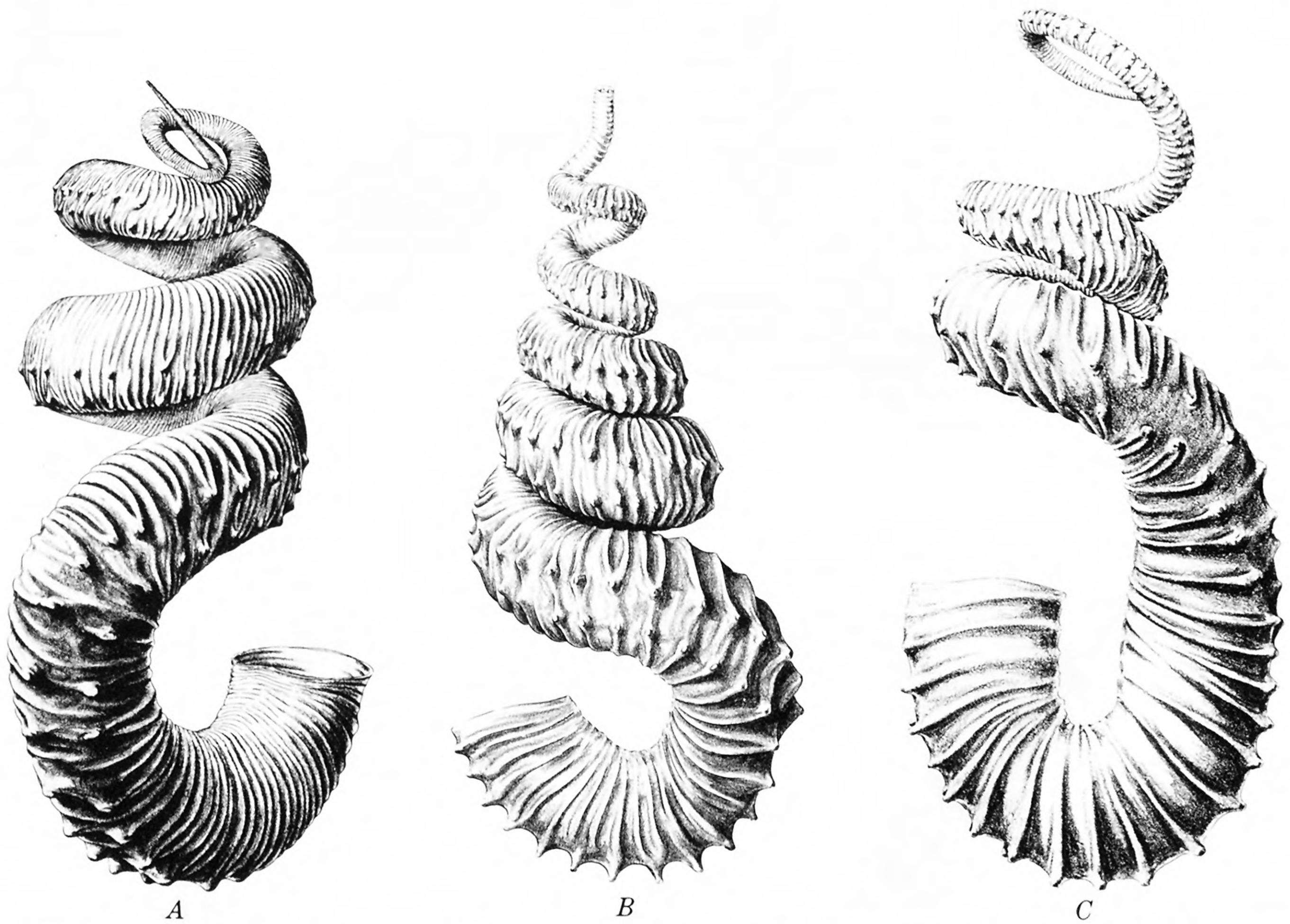


FIGURE 5.—Restorations. *A, Didymoceras nebrascense, B, D. stevensoni,* and *C, D. cheyennense,* all one-half natural size. From Scott and Cobban (1965) and Scott (1969, pl. 2).

near Newcastle, Wyo. (Whitfield, 1880), p. 447, pl. 14, figs. 5–8). A better specimen, from the Chadron area of Nebraska, was later illustrated by Whitfield (1901). A complete specimen has not been found, but a restoration of most of the shell has been published (Scott and Cobban, 1965) and is reproduced in figure 5*B*.

Exiteloceras jenneyi (Whitfield).—This aberrant ammonite has the juvenile whorls as straight limbs connected by semicircular bends and the adult portion as uniformly curved whorls loosely coiled in a plane. The species is well ribbed, with each rib terminating in a tubercle or spine at the margin of the venter. The holotype is from the Pierre Shale near Newcastle, Wyo. (Whitfield, 1880, p. 452, pl. 16, figs. 7–9). A complete specimen has not been found, but a restoration based on many specimens has been published (Scott and Cobban, 1965; Scott, 1969, pl. 2) and is reproduced in figure 6.

Didymoceras cheyennense (Meek and Hayden).—This ammonite resembles *D. nebrascense* in its loosely coiled spire and in its body chamber being curved back toward the spire, but is different in that its early whorls are more loosely coiled and its body chamber has a longer and straighter part. The holotype, a small fragment of a body chamber, came from the Pierre Shale at the mouth of the Cheyenne River in central South Dakota (Meek, 1876, p. 483, pl. 21, figs. 2a, b). A complete specimen has not been found, but a restoration of the nearly complete shell is shown in figure 5*C*.

Baculites compressus Say.—A slender ovate section, moderate angle of taper, and weakly ribbed to almost smooth venter characterize *B. compressus* (fig. 2*N*). The flanks are smooth on most specimens less than 2 inches (5 cm) in diameter; flanks of larger adults may or may not be ribbed. The suture is very distinct and is marked by lengthy branches of the lobes and saddles. The lateral saddle differs readily from that of *B. gregoryensis* and *B. scotti* in having the terminal branches constricted at their base like those shown in figures 3*C* and 4*C*. *Baculites compressus* was described long ago from specimens collected from the Pierre Shale of South Dakota (Say, 1820, p. 41).

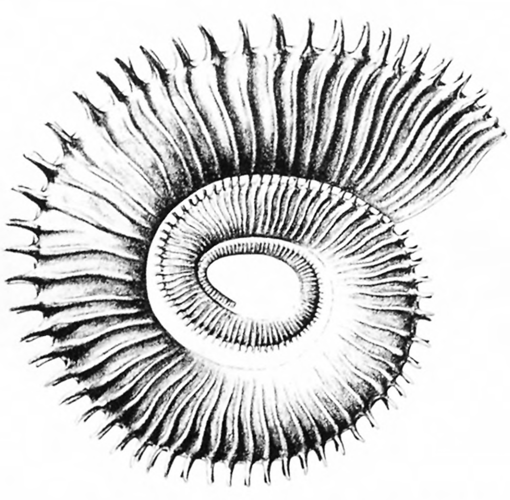


FIGURE 6.—Restoration of *Exiteloceras jenneyi* (Whitfield), one-half natural size. From Scott and Cobban (1965).

Baculites cuneatus Cobban.—A trigonal section, well-ribbed venter, and flank ribs on the adults distinguish *B. cuneatus* (fig. 2*O*). Juveniles are commonly curved and have a high angle of taper, whereas adults are straight and have a low angle of taper. The suture is like that of *B. compressus*. *Baculites cuneatus* is a large species attaining diameters as much as 3.5 inches (8.9 cm). The holotype came from the Bearpaw Shale near Hardin, Mont. (Cobban, 1962b, p. 127, pl. 25, figs. 1–8, text fig. 1b).

Baculites reesidei Elias.—A well-ribbed venter, slender section, and suture of the *compressus* type characterize *B. reesidei* (fig. 2*P*). Many adults have a ventrolateral depression reminiscent of that of *B. scotti*. Specimens less than 2 inches (5 cm) in diameter have smooth flanks, but some larger specimens have weakly ribbed flanks. The species attains a size comparable to that of *B. cuneatus*, and the suture is similar (fig. 3*C*). *Baculites reesidei* was originally described as *B. compressus* var. *reesidei* Elias (1933, p. 302, pl. 32, figs. 2a–c).

Baculites jenseni Cobban.—This species differs from its immediate ancestor, *B. reesidei*, chiefly in having a stouter cross section and a more finely ribbed venter (fig. 2*Q*). Many individuals have a ventrolateral depression, and all specimens seem to have smooth flanks. The suture is of the *compressus* type. The type specimens came from the Bearpaw Shale of east-central Montana (Cobban, 1962b, p. 129, pl. 26, figs. 1–12, text fig. 1a).

Baculites eliasi Cobban.—This species is easily identified by its stout elliptical section, low degree of taper, smooth flanks, smooth or very weakly ribbed venter, and suture of the *compressus* type (fig. 2*R*). It ordinarily does not exceed 2 inches (5 cm) in diameter. The types are from the upper part of the Bearpaw Shale of northeastern Montana (Cobban, 1958, p. 663, pl. 91, figs. 1–11, text figs. 1f, g, i, j).

Baculites baculus Meek and Hayden.—This species (fig. 7*A*), a migrant from the Gulf coastal area, is characterized by its large size, circular to broadly ovate section, broad arcuate flank ribs, and suture much like that of pre-*gregoryensis* baculites (fig. 3 *D*). The holotype, from the Fox Hills Sandstone near Glenrock, Wyo., was illustrated by Meek (1876, text figs. 51, 52).

Baculites grandis Hall and Meek.—A more ovate section and slightly larger size distinguish *B. grandis*

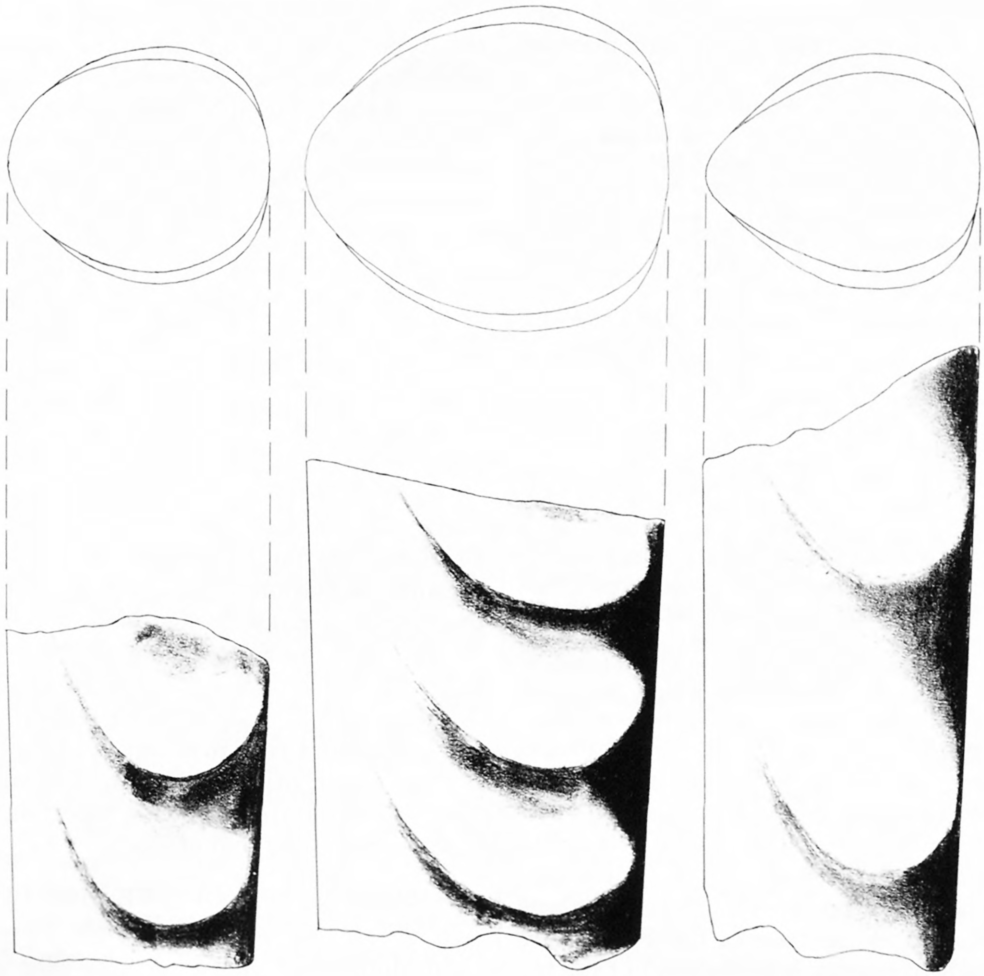


FIGURE 7.—Baculites, one-half natural size, that serve as major index fossils. *A, Baculites baculus* Meek and Hayden based on a specimen from the upper part of the Pierre Shale near Red Bird, Wyo. *B, Baculites grandis* Hall and Meek based on a cotype (Am. Mus. Nat. History 9545). *C, Baculites clinolobatus* Elias based on a specimen from the upper part of the Pierre Shale of Pennington County, S. Dak.

(fig. 7*B*) from its immediate ancestor *B. baculus*. Both species have similar sutures. *Baculites grandis* attains a diameter as much as 4 inches (10.2 cm). The types are from the upper part of the Pierre Shale of southwestern South Dakota (Hall and Meek, 1856, p. 402, pl. 6, fig. 10; pl. 7, figs. 1, 2; pl. 8, figs. 1, 2).

Baculites clinolobatus Elias.—This species, derived from *B. grandis*, has a slightly slender elliptical section in the juvenile and early adult stages and a trigonal section in the later adult stages (fig. 7*C*). It is not as large as *B. grandis*, and the venter is narrower. A dorsolateral depression is present on many young adults. Broad arcuate ribs, ordinarily widely spaced, are present on all adults. The suture is similar to that of *B. grandis* or *B. baculus*. *Baculites clinolobatus* was originally described from specimens collected from the uppermost part of the Pierre Shale of eastern Colorado (Elias, 1933, p. 310, pl. 30, figs. 1, 2; pl. 34, figs. 1, 2a, b).

HISTORICAL BACKGROUND OF THE MONTANA GROUP

The Montana Group was formally proposed by Eldridge (1889, p. 313) to provide a method of grouping of some upper Upper Cretaceous formations in the northern part of the western interior. His proposal was as follows: "The plan of grouping, suggested here, includes in the lower of the two more general divisions the formations of the Fort Benton and Niobrara; in the upper, the Fort Pierre and Fox Hills: for the former no better name can be found than that already in use—Colorado; for the latter the name—Montana—is now, for the first time proposed."

After a brief discussion of the then-existing nomenclature problems, Eldridge (1889, p. 321) summarized the merits of his proposal as follows:

1st, That of "Colorado": this is retained on account of its long established usage and the impossibility of finding a term more suitable to the demands made upon it by the principles upon which it is to be employed; it has, indeed, had a signification different from that now assigned it, but this is by no means universally accepted, and hence cannot be considered an obstacle to its employment when really found desirable from every other point of view.

2d, The term, "Montana": In the first place, as a name, it is of equal rank with those of the other general divisions of the Cretaceous as proposed in the present paper, that is, with the Dakota, the Colorado, and the Laramie, though of rather greater geographical value than the last; in the second place, it is an especially appropriate term from the facts, (a) that in the territory of Montana a large part of the surface area is occupied by one or the other of its sub divisions, between which, here, as elsewhere, it is impossible to draw a definite line of separation, either lithologically or paleontologically, and (b) that Montana contains a relatively greater proportion of the outcrops of this formation than any other region of the Northwest, with the possible exception of the British Northwest Territory; finally, there is the argument from its early discovery and study in this very area, an argument upon the principles of which, geological nomenclature has often, from the earliest times, been based.

Eldridge's suggestion has had wide adoption throughout the western interior. Although the unit was defined in a rock-stratigraphic sense, the distinctiveness of its included fauna was recognized. This fauna later led to the transformation of the Montana to a time-stratigraphic term. The lower boundary of the Montana Group was designated as the base of the Fort Pierre Group (Pierre Shale of current terminology) or the top of the Niobrara Formation, and the upper boundary as the top of the Fox Hills. As our understanding of the Montana Group has increased regionally, each boundary has been found to be time transgressive through the duration of nine ammonite zones or 4–5 m.y., and thus the use of Montanan as a time term has little precise meaning.

The boundaries for the Montana Group as originally defined (chalks below and dark shales above) are easily recognizable throughout North and South Dakota, Nebraska, Kansas, eastern Wyoming, Colorado, and New Mexico. In Montana, however, in the type area and the area in which the name has had widest application, the lithologic boundary between the Colorado and Montana Groups is difficult to determine. In place of the chalky beds of the Niobrara are the dark shales of the Colorado Shale, and in place of the dark shales of the Pierre are sandstone and nonmarine beds of the Telegraph Creek and Eagle Formations.

In this report we use Montana Group as a rock-stratigraphic unit and apply it with slight modification to only the rocks in central Montana designated by Stanton and Hatcher (1905, p. 63) and Cobban and Reeside (1952, chart 10b, col. 106) as the type formations of the type Montana Group. The formations are, in ascending order, as follows: Eagle (which originally included the Telegraph Creek), Claggett, Judith River, Bearpaw, and Fox Hills. Equivalent rock-stratigraphic units also included in the Montana Group are the Pierre Shale, Fox Hills Sandstone, Virgelle Sandstone, Gammon Shale, Parkman Sandstone, Two Medicine Formation, and Lennep and Horsethief Sandstones.

Overlying nonmarine Cretaceous rocks of the Hell Creek Formation were not included in the early descriptions of the Montana Group. We believe that, in view of the lithogenetic similarities of the Hell Creek to the underlying Cretaceous formations, the boundary of the Montana Group should be changed to include these rocks. The Miner Creek and St. Mary River Formations (fig. 9), however, are equivalents of the Hell Creek but are not included in the Montana Group.

Sandy beds transitional from the Colorado Shale into the overlying Eagle Sandstone were considered a part of the Eagle by Stanton and Hatcher (1905, p. 12). Some geologists, such as Lindvall (1956) and others, working in the Missouri River region have considered the Telegraph Creek to be a part of the Colorado Shale. It is, however, lithologically and faunally a part of the Montana Group and in this report is treated as the basal formation of that group.

STRATIGRAPHY OF THE MONTANA GROUP, MONTANA

In Montana, formations of the Montana Group consist of eastward-pointing wedges of regressive deposits of nonmarine and shallow-water marine strata (Telegraph Creek, Eagle, Parkman, Judith River, Two Medicine, and Fox Hills and its equivalents) that enclose westward-thinning wedges of fine-grained transgressive deposits of marine strata (Claggett and Bearpaw Shales). Section *A–A′*, constructed approximately perpendicular to depositional strike (figs. 8, 9) from Porcupine dome to the Dearborn River in Montana, demonstrates the change from the dominantly marine section of noncalcareous shale, sandstone, and calcareous shale on the east through all gradations of nearshore marine, lagoonal, and fluviatile sediments into the coarse volcanic sequence containing lava flows and welded tuffs on the west.

Marine rocks of the Montana Group in the northern third of the Crazy Mountains Basin (Bruno siding section, fig. 8) consist of shallow-water deposits of the Telegraph Creek Formation overlain by beach, barrier bar, and magnetite-rich placer deposits of the Virgelle Sandstone Member of the Eagle Sandstone. Lagoonal and fluviatile sediments of the unnamed member of the Eagle conformably overlie the Virgelle Sandstone

Member. The marine Claggett Shale and its sandy nearshore equivalents in the Two Medicine Formation overlie the Eagle. Elsewhere in Montana, the Claggett contains many persistent bentonite beds that represent a period of explosive volcanism in the Elkhorn Mountains region. These distinctive beds are represented here by bentonite, ash, and porcelanite in the upper part of the Eagle. Overlying the Claggett Shale is the Parkman Sandstone, a marine beach and barrier bar deposit that contains magnetite placers. It contains little volcanic detritus and appears identical to the Virgelle Sandstone Member of the Eagle.

The lower part of the Judith River Formation, like the upper part of the Eagle, contains thick brackish-water beds. The clastic volcanic component of the rocks increases greatly toward the western source areas. The upper part of the Judith River Formation contains many bentonite beds that extend eastward into the lower part of the Bearpaw Shale (Shawmut, Lavina, and Porcupine dome sections).

The Bearpaw Shale represents a widespread invasion of marine waters into western Montana and into the northern part of the Crazy Mountains Basin. Many bentonite beds in the lower part can be traced eastward into the middle part of the Bearpaw. Westward, the Bearpaw grades into shallow-water volcanic-rich marine sandstones of the Lennep and Horsethief Sandstones. These sandstones were deposited in an environment similar to that of the Virgelle Member and the Parkman, and they contain local beach placers rich in heavy minerals. The Lennep Sandstone is overlain by brackish-water and nonmarine beds of the Miner Creek or Hell Creek Formation, and the Horsethief Sandstone is overlain by the largely nonmarine St. Mary River Formation.

STRATIGRAPHY OF ROCKS EQUIVALENT TO THE MONTANA GROUP, WYOMING

The depositional history of the Wyoming part of the basin of sedimentation is similar in gross aspects to that of Montana. Cross section *B–B′*, approximately perpendicular to depositional strike from Cottonwood Creek in the southwestern part of the Bighorn Basin to Red Bird in the southeastern part of the Powder River Basin, shows the complex east-west facies changes from the great thickness of nonmarine rocks of the Mesaverde, Meeteetse, and Lance Formations on the west to the marine clay shales of the Pierre Shale on the east (fig. 10).

Rocks of Telegraph Creek and Eagle age (zone of *Desmoscaphites* through *Baculites* sp., smooth variety) are represented by shallow-water marine and fluviatile sediments of the lower part of the Mesaverde Formation in the western part of the Bighorn Basin and by the upper part of the Niobrara Formation and the lower part (including the Fishtooth sandstone, an informal term, Shannon and Sussex Sandstone Members) of the Cody Shale in the Powder River Basin.

Sediments of Claggett age (zone of *Baculites obtusus* through *B. asperiformis*) are represented by shallow-water marine and fluviatile beds that form the upper part of the Mesaverde Formation below the Teapot Sandstone Member in the western Bighorn Basin. The Ardmore and associated bentonite beds mark the base of rocks of Claggett age in the southeastern part of the Bighorn Basin and throughout the Powder River Basin.

Rocks of Judith River age (zone of *Baculites perplexus* through *Didymoceras cheyennense*) are represented by the thick sequence of shallow-water marine and brackish-water and fluviatile beds that form the upper part of the Mesaverde Formation of western areas (Nowater Creek section, fig. 10) and the Parkman Sandstone Member of the Mesaverde Formation of the western Powder River Basin. Rocks equivalent to the Judith River Formation have been removed by pre-Teapot erosion in the western part of the Bighorn Basin. The unnamed marine member of the Mesaverde represents an expansion of the sea not recorded in Montana but one that was widespread in Wyoming and to the south. The unnamed member contains at its top a shallow-water marine sandstone that is thought to represent the beginning of another regression. At that time in Montana, Judith River deposition came to a close and was followed by an expansion of the Bearpaw Sea.

While the sea was expanding in Montana, uplift and erosion were taking place throughout much of Wyoming. A considerable part of the record is missing in Wyoming, and the missing interval is represented by the unconformity at the base of the Teapot Sandstone Member (Gill and Cobban, 1966a). An angular unconformity is not obvious at the base of the Teapot in this area, but the unconformity is known to be present because the faunal zones in the upper part of the Pierre and the Lewis are parallel with the top of the Teapot, whereas those in the Cody Shale and in the lower part of the Pierre Shale lie at an angle to it. In the distance of 230 miles, from Red Bird to Cottonwood Creek, the Teapot cuts across possibly as many as 14 faunal zones.

After the deposition of the Teapot Sandstone Member, the sea again expanded, during which time the Meeteetse Formation and the lower part of the Lewis Shale were deposited. This expansion of the sea roughly coincides with culmination of the Bearpaw Sea in western Montana. Withdrawal of marine waters from Montana is marked by a thick regressive sandstone in the middle of the Lewis Shale in the Powder River Basin (within zone of *Baculites grandis*). Following this regression, the sea again expanded in eastern and

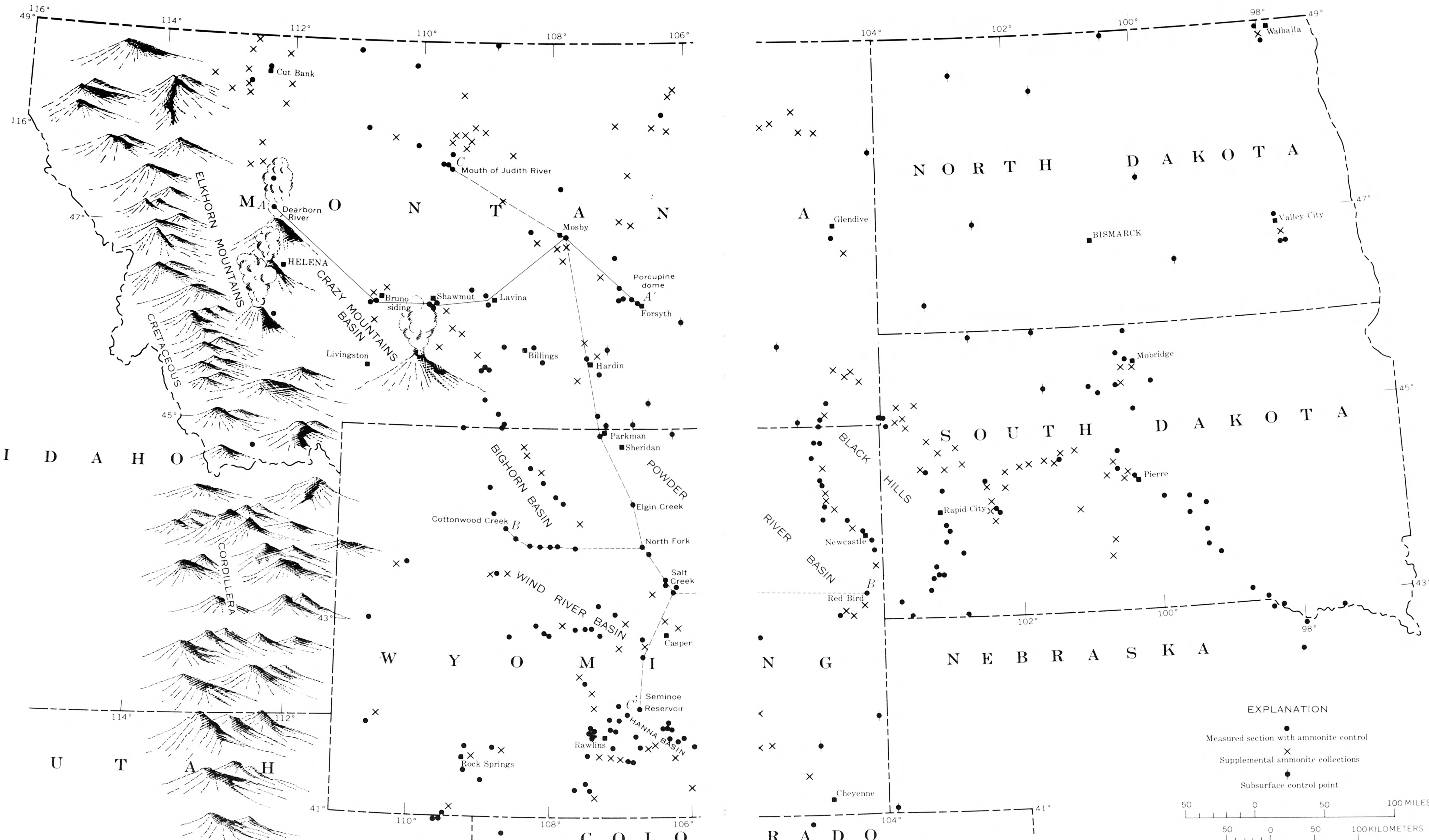


FIGURE 8.—Location of cross sections and principal control points used in constructing strandline maps, Wyoming, Montana, and North and South Dakota.

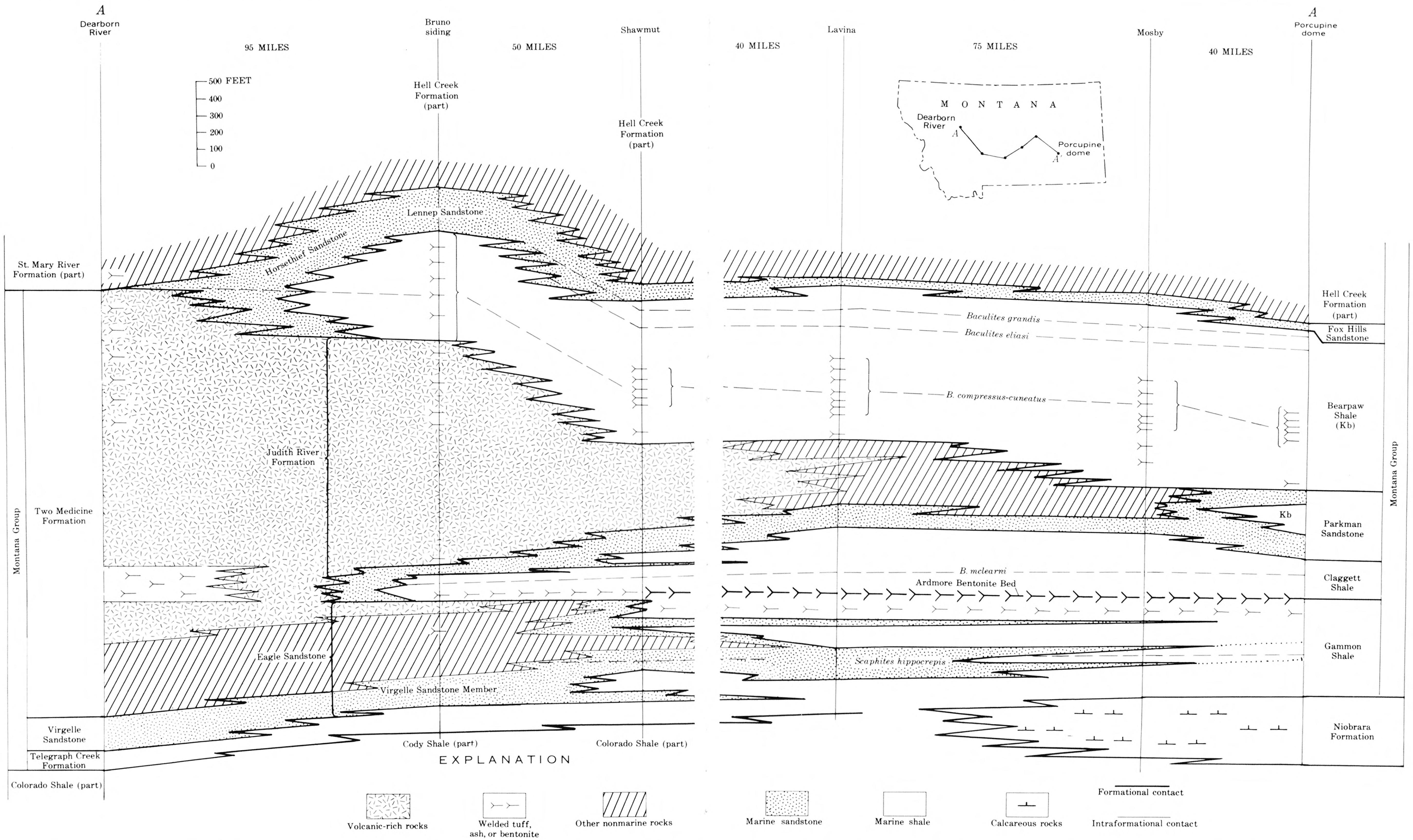


FIGURE 9.—Stratigraphic diagram A–A′ of rocks of the Montana Group between the Dearborn River and Pocupine dome, Montana. Approximate midpoint of selected ammonite zones shown by dashed lines. Vertical exaggeration × 210. Line of section shown in figure 8.

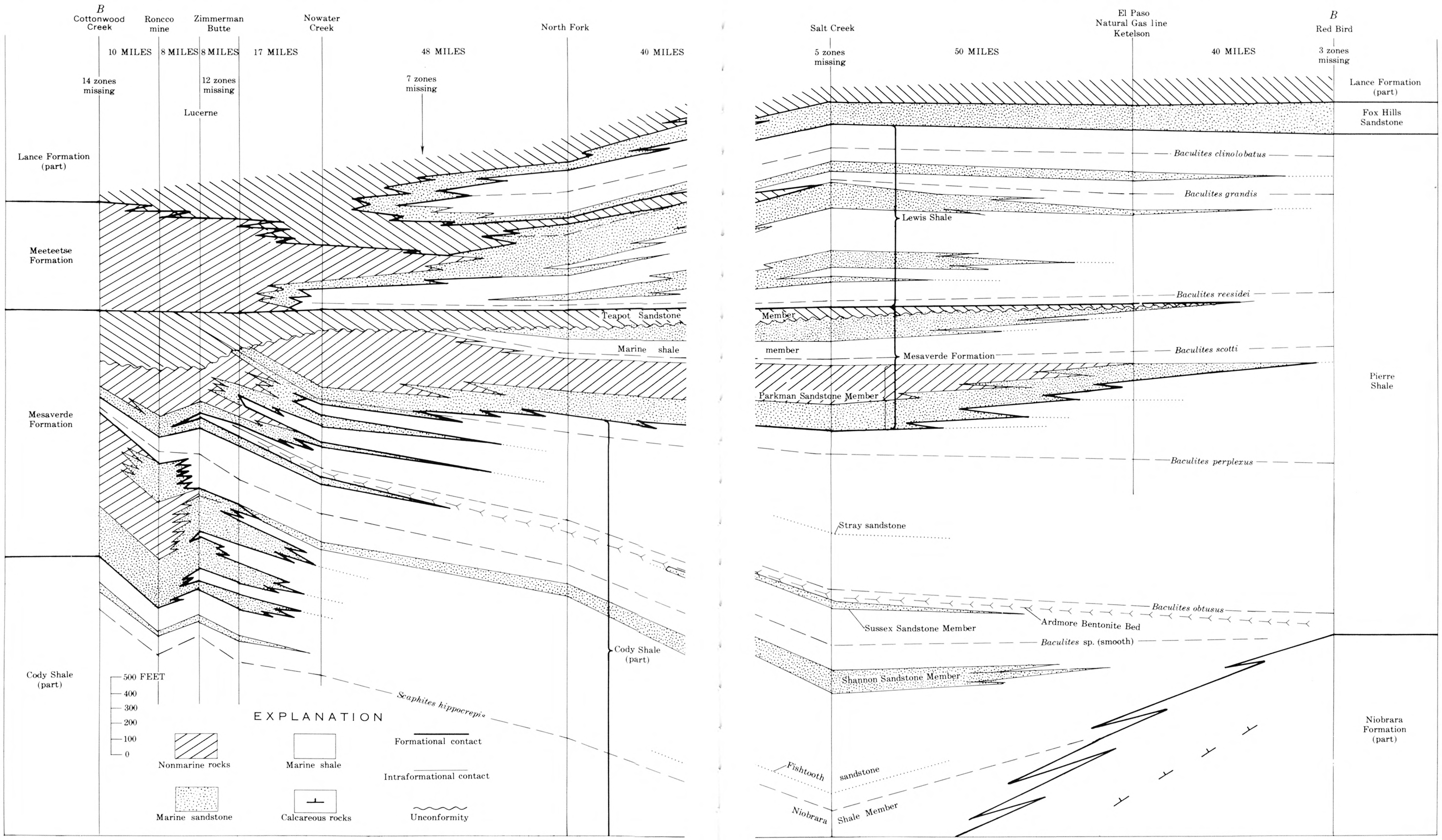


FIGURE 10.—Stratigraphic diagram *B–B′* of Cretaceous rocks of southwestern Bighorn Basin to southern Black Hills, Wyoming, showing the unconformity at base of the Teapot Sandstone Member of the Mesaverde Formation. Approximate midpoint of selected ammonite zones shown by dashed lines. Vertical exaggeration approximately × 40. From Gill and Cobban (1966a, p. B22—B23). Line of section shown in figure 8.

southern Wyoming depositing the upper part of the Lewis Shale (late in zone of *Baculites grandis* and *B. clinolobatus*). The final withdrawal of marine waters from Wyoming is marked by the deposition of the Fox Hills Sandstone.

CORRELATION OF ROCKS OF THE MONTANA GROUP

Section *C–C′* (fig. 11) extends from the mouth of the Judith River in central Montana south to Seminoe Reservoir in the Hanna Basin, south-central Wyoming. It documents the complex facies changes and different nomenclature usage. This line of section presents a view that is largely parallel to depositional strike and one that passes from an area of slow and uniform deposition (3,000 ft) into an area of rapid and erratic deposition (at least 9,000 ft for the same time interval). East-west sections *A–A′* (fig. 9) and *B–B′* (fig. 10) represent transects that are generally perpendicular to depositional strike and thus more clearly illustrate the intertonguing of transgressive and regressive deposits.

Correlation of rocks of the type Montana Group exposed along the Missouri River in Montana with correlative rocks exposed in the Powder River, Bighorn, and Hanna Basins of Wyoming is based on surface sections, ammonite collections, and subsurface studies. Ammonite zones and potassium-argon and estimated dates are shown on the right side of figure 12.

The type Telegraph Creek Formation and Eagle Sandstone are equivalent to the Fishtooth sandstone and the Shannon and Sussex Sandstone Members in the lower part of the Cody at some localities and to Steele Shale at other localities in the western Powder River Basin; they are equivalent to the upper part of the Niobrara Formation in the eastern part of the basin.

The Claggett Shale, with its distinctive bentonite beds, one of which is the Ardmore, is equivalent to the Ardmore Bentonite Bed and to the overlying part of Sharon Springs Member of the Pierre Shale in the southern Black Hills and to the thick bentonite and shale sequence that overlies the Sussex Sandstone Member of the Cody in the Salt Creek area. A potassium-argon date from this level in the Claggett Shale at the mouth of the Judith River in Montana gave an age of 79.5 m.y.

The Parkman Sandstone (zone of *Baculites asperiformis*), as now recognized in central Montana, is older than the type Parkman (zone of *Baculites perplexus*) and is equivalent to the upper part of the Cody Shale in the Salt Creek oil field. The type Judith River Formation is equivalent to the Parkman Sandstone Member and the unnamed marine shale member of the Mesaverde Formation in the western Powder River Basin and to the Allen Ridge Formation farther south.

The Bearpaw Shale is equivalent to an unknown amount of strata eroded from beneath the Teapot unconformity, to the Teapot Sandstone Member, and to the lower part of the Lewis Shale. The Fox Hills Sandstone of Montana is roughly equivalent to the mid-Lewis regressive sandstone at Salt Creek and to the Dad Sandstone Member of the Lewis in the Hanna Basin. The upper part of the Lewis Shale and the Fox Hills Sandstone in the Powder River Basin are represented by nonmarine strata of the Hell Creek Formation in Montana.

GEOLOGIC HISTORY OF THE MONTANA GROUP

The geologic history of the Late Cretaceous of the northern interior is recorded in the transgressive and regressive deposits of the Montana Group and equivalent rocks. About 150 stratigraphic sections and several hundred fossil collections (fig. 8) afford the basis for the construction of strandline maps (figs. 13–19). These maps are highly generalized in order to show our interpretation of the position of the strand for 24 selected ammonite zones.

TELEGRAPH CREEK–EAGLE REGRESSION

The Telegraph Creek–Eagle regression in Montana began during the range span of *Scaphites depressus*, about 85 m.y. (not shown). The Telegraph Creek Formation rises stratigraphically and transgresses time rapidly toward the east as shown in figure 13 by the strandlines of *Desmoscaphites erdmanni* (1), *D. bassleri* (2), *Scaphites hippocrepis* (3, 4), and an undescribed smooth species of *Baculites* (5). This overall regression was interrupted in late Eagle time by a sharp transgression accompanied by explosive volcanism during the range span of an undescribed baculite that has weak flank ribs (6). At that time the sea expanded westward for a short period and then retreated eastward. A pavement of black chert pebbles and granules marks this level throughout much of Montana and southern Canada. The Telegraph Creek–Eagle regression was caused by tectonism and volcanism in western Montana, which lasted about 5.5 m.y., while at least 3,000 feet of volcanic rocks constituting the lower part of the Elkhorn Mountains Volcanics was being deposited.

CLAGGETT TRANSGRESSION

The Telegraph Creek–Eagle regression in Montana ended about 79 m.y. ago at about the beginning of the zone of *Baculites obtusus* (7) (fig. 14). The Claggett transgression began with explosive volcanism and subsidence in coastal and near-coastal areas in western Montana. In a short time the sea expanded westward in western Montana, while in southern Montana and

Wyoming it retreated. The Claggett transgression culminated during the zone of *Baculites mclearni* (8); by late Claggett time (zone of *B. asperiformis*, 9) sedimentation outran subsidence, and the strand once again moved seaward, beginning the Judith River regression. The Claggett transgression lasted about 1.5 m.y., during which the strand moved westward as much as 140 miles—about 500 feet per thousand years.

Many thick and persistent bentonite beds occur in the lower part of the Claggett Shale (zone of *Baculites obtusus* and the lower part of *B. mclearni*). These beds appear to correlate with the middle unit of the Elkhorn Mountains Volcanics, which consists of 2,500 feet of welded tuff and ash-fall crystal tuff. About 500 cubic miles of bentonite is preserved in the Claggett Shale and its equivalents in Montana, Wyoming, and North and South Dakota (fig. 15). If the thickness of the deposits in Colorado, Nebraska, and southern Canada were known, more than twice that volume of bentonite probably would be indicated.

We postulate that the Claggett transgression began with explosive volcanism and subsidence in western Montana. This was followed by uplift near coastal areas and increased sediment delivery to the sea, which halted the advancing strand and finally brought about another regression.

JUDITH RIVER REGRESSION

The Judith River regression took place during the span of six ammonite zones as shown in figure 16—*Baculites perplexus* (10), used in a broad sense here and representing four zones, *B. gregoryensis* (11), and *B. scotti* (12)—and lasted about 3 m.y. During this time, the strand retreated eastward about 190 miles from its previous stand in central Montana during Claggett time at about 300 feet per thousand years. A similar movement seems to have taken place throughout much of Wyoming.

Much coarse volcanic detritus appears in the Judith River Formation in central Montana. Very little ash is apparent in the Judith River or in its fine-grained marine equivalents to the east. It seems that this was a period of uplift and volcanism in western Montana and of uplift and increased sediment delivery in other areas in the western cordillera.

BEARPAW REGRESSION

The Judith River regression was followed by another episode of explosive volcanism renewed sporadically through the range span of about six ammonite zones as shown in figure 17 (*Didymoceras nebrascense–Baculites cuneatus*, 13–18), or about 3 m.y. Thickness and distribution of bentonite beds in the Bearpaw Shale and equivalent rocks are not accurately known, but the volume is probably very much greater than that of the Claggett Shale. Continental ash beds and welded tuffs of this age are unknown at present in the western cordillera, but the probable source of the bentonite was the Elkhorn Mountains volcanic area.

The Bearpaw transgression was not as abrupt as the Claggett transgression, although the Bearpaw strandline moved farther west in Montana, 200 miles as compared with 140 for the Claggett. It seems that subsidence and explosive volcanism were episodic for a long time during which volcanic detritus continued to be delivered to the sea in considerable volume. Subsidence was greater than sediment accumulation, allowing marine waters to inundate the former coastal plain.

While the sea advanced into western Montana, it retreated across eastern Wyoming, clearly showing the importance of local crustal instability in effecting transgression or regression. Stratigraphic data show that while Montana was subsiding, central Wyoming was being uplifted and eroded (Gill and Cobban, 1966a; Reynolds, 1966; Zapp and Cobban, 1962).

FOX HILLS REGRESSION, INITIAL PHASE

Marine waters finally withdrew from Montana during the Fox Hills–Lennep regression (fig. 18). For clarity, this event is shown in figures 18 and 19. The retreat began during the zones of *Baculites cuneatus* and *B. compressus* (17–18). The close and parallel spacing of strandlines for *B. reesidei* (19), *B. jenseni* and *B. eliasi* (20–21), and *B. baculus* (22) indicates relatively slow and uniform withdrawal. In Wyoming, however, the sea, after a regression during *B. cuneatus* and *B. compressus* time, expanded rapidly until the time of *B. baculus*. The Deer Creek volcanic area, east of Livingston, Mont., appears to have influenced the strandlines at this time. The large eastward bulge of strandlines in northern Wyoming and southern Montana shows the beginning of what became an important paleogeographic feature in later Cretaceous time.

FOX HILLS REGRESSION, FINAL PHASE

The waning state of the Late Cretaceous sea in Montana is shown in figure 19 by the strandlines of *Baculites grandis* (23) and *B. clinolobatus* (24). These strandlines outline an elongate east-trending arcuate peninsularlike mass of dominantly nonmarine rocks that extends from northwestern Wyoming to eastern Montana and the western parts of North and South Dakota. This mass is interpreted as a deltaic complex, referred to here as the Sheridan delta, that separated Montana and Wyoming into distinct depositional provinces. The Sheridan delta was bounded on the north by the Mosby embayment, in which fine-grained rocks of the Bearpaw Shale accumulated, and on the

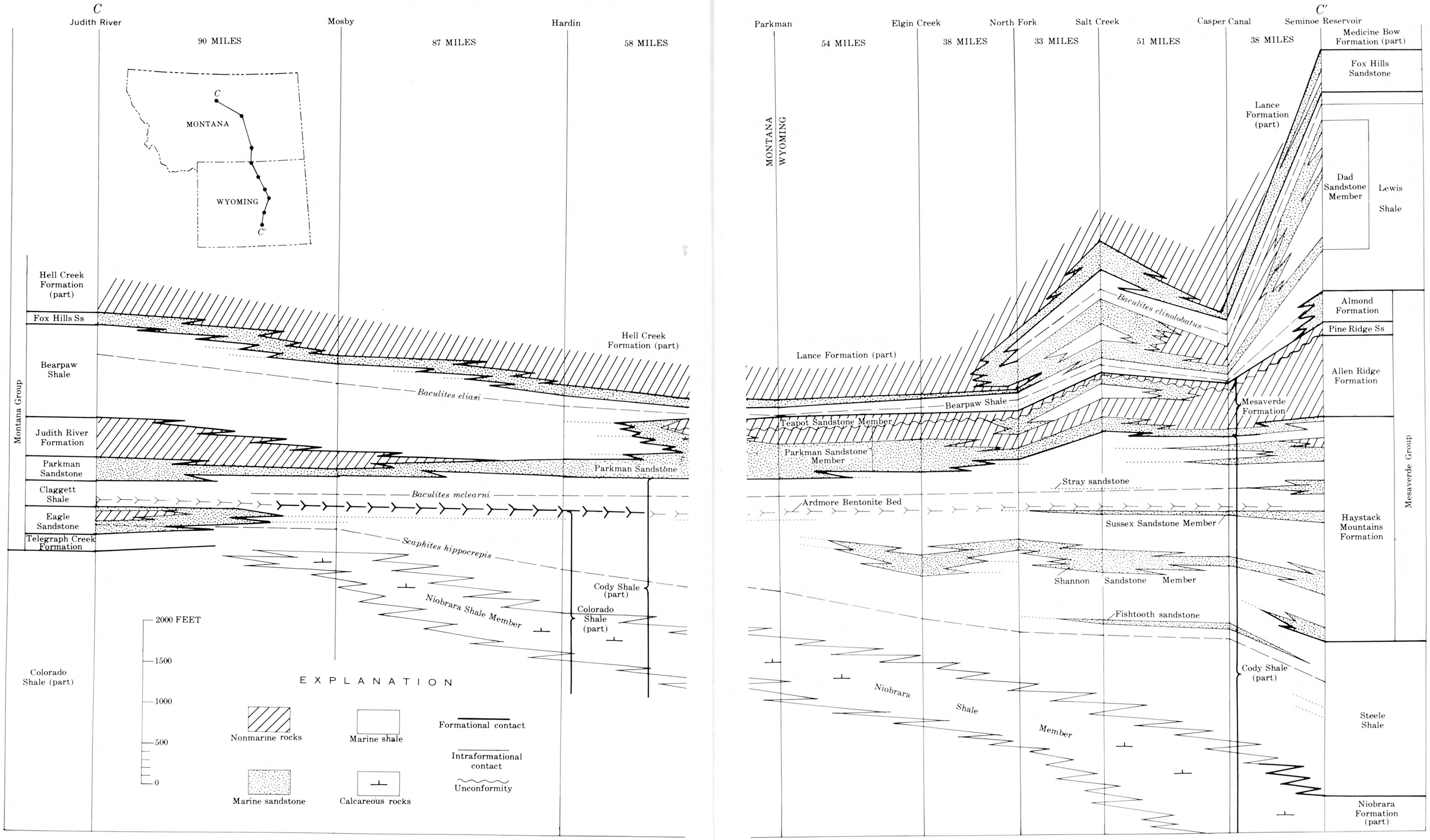


FIGURE 11.—Stratigraphic diagram *C–C′* from mouth of Judith River, Montana, to Seminoe Reservoir, south-central Wyoming, showing major lithologic and nomenclature change. Approximate midpoint of selected ammonite zones shown by heavy dashed lines. Vertical exaggeration approximately × 160. Line of section shown in figure 8.

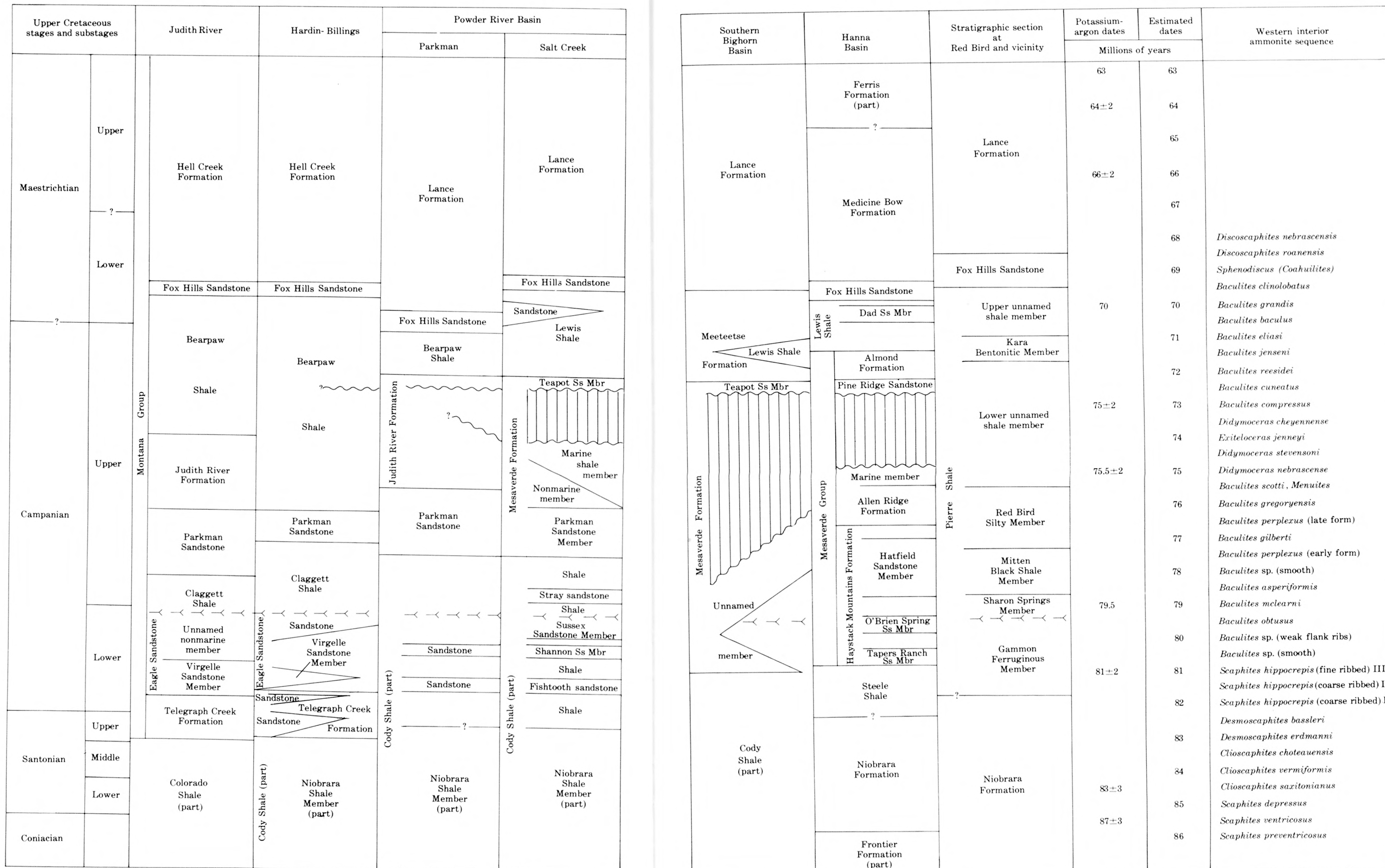


FIGURE 12.—Correlation of the Montana Group, Montana, with equivalent rocks in Wyoming.

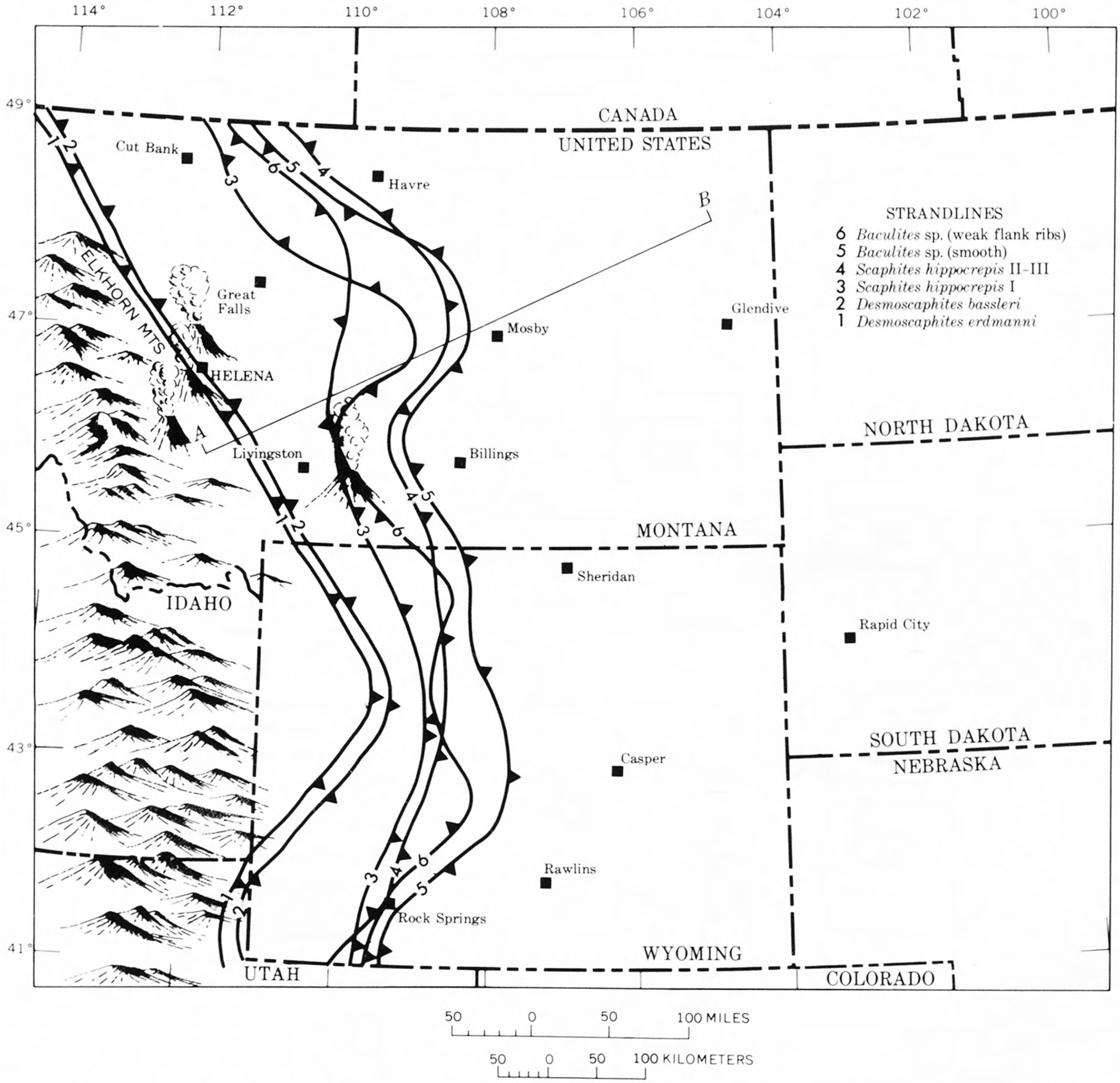


FIGURE 13.—Approximate position of strandlines during the Telegraph Creek–Eagle regression in Montana and Wyoming. Barbs show direction of strandline movement.

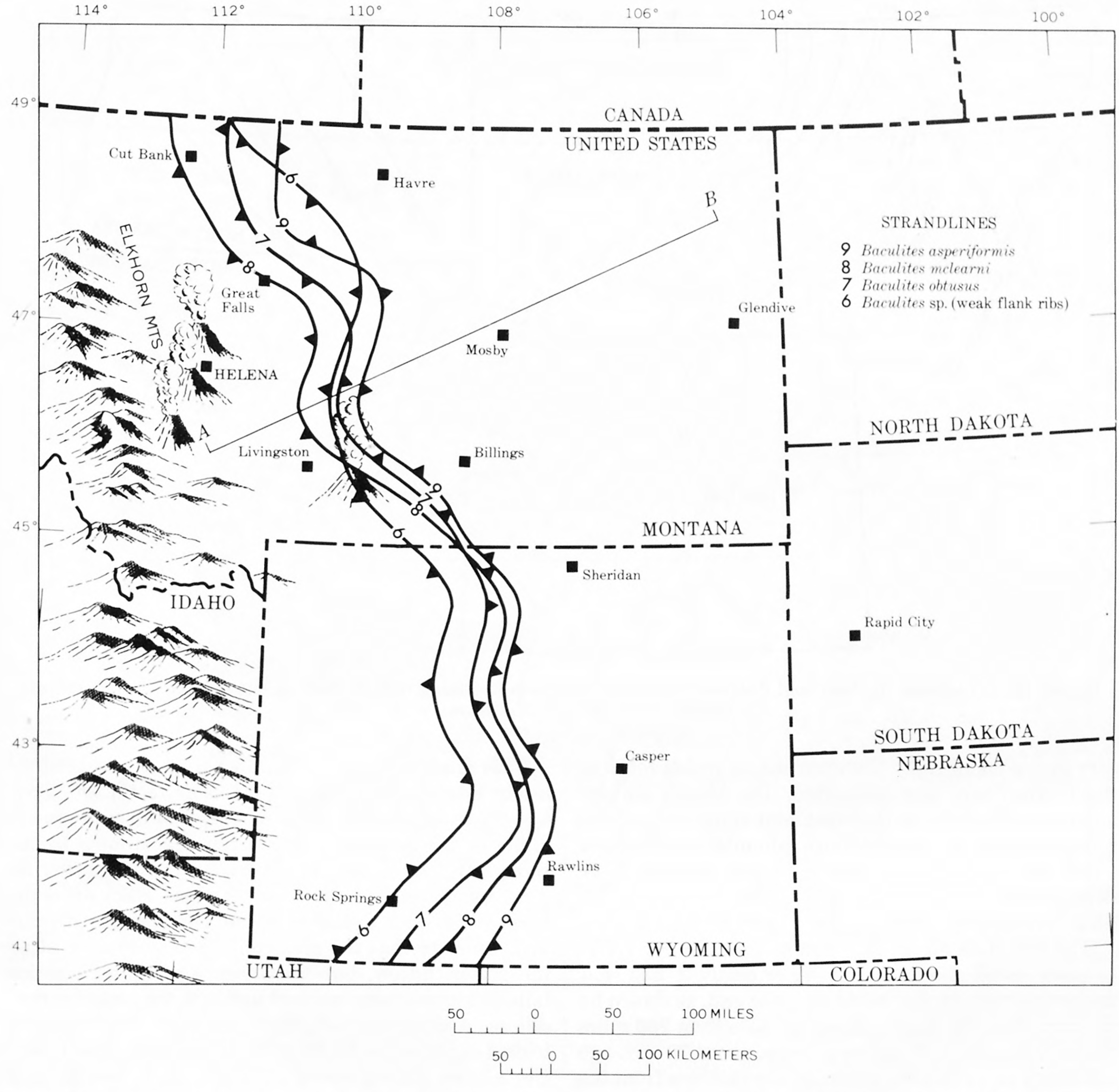


FIGURE 14.—Approximate position of strandlines during the Claggett transgression. Barbs show direction of strandline movement.

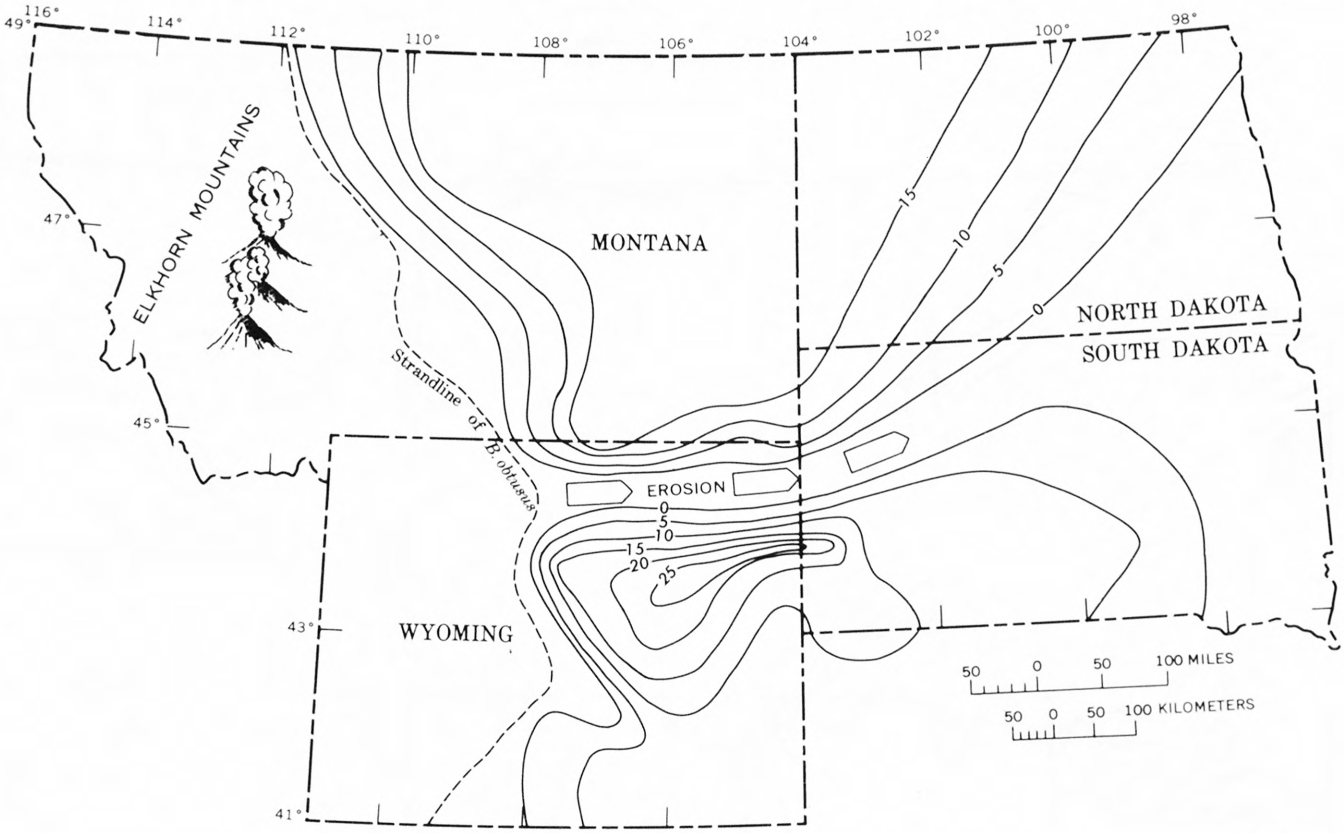


FIGURE 15.—Thickness (in feet) and distribution of bentonite beds deposited during the Claggett transgression. Zones of *Baculites obtusus* and *B. mclearni*.

east in the Dakotas by the open sea, in which rocks of the Pierre Shale were deposited. The Mosby embayment was flanked on the west and south by coastal ranges formed by the Elkhorn Mountains and Deer Creek volcanic centers. These ranges seem to have deflected sediment southward, concentrating it in the Sheridan delta.

The Fox Hills regression from Montana is estimated to have lasted about 2.5 m.y. Apparently it was slow and regular at first but rapid near the end, as shown by the fact that the strand retreated more than 250 miles during the zone of *Baculites grandis*, about 70 m.y. ago according to potassium-argon determinations from the biotite of a bentonite.

This final regression of the sea cannot now be definitely related to either volcanism or tectonism. Possibly it resulted from slow subsidence and subsequent filling of the Montana part of the depositional basin, though the thinness of the regressive nearshore marine sandstones seems to indicate otherwise. Thick accumulations of Upper Cretaceous and Tertiary continental beds indicate that the area continued to subside after the sea withdrew, but the absence of coarse clastics fails to suggest any marked uplift in the western cordillera. A eustatic lowering of sea level would seem a logical explanation for the withdrawal of the sea if Late Cretaceous transgressive and regressive events had been confined to the Montana part of the basin of depo-

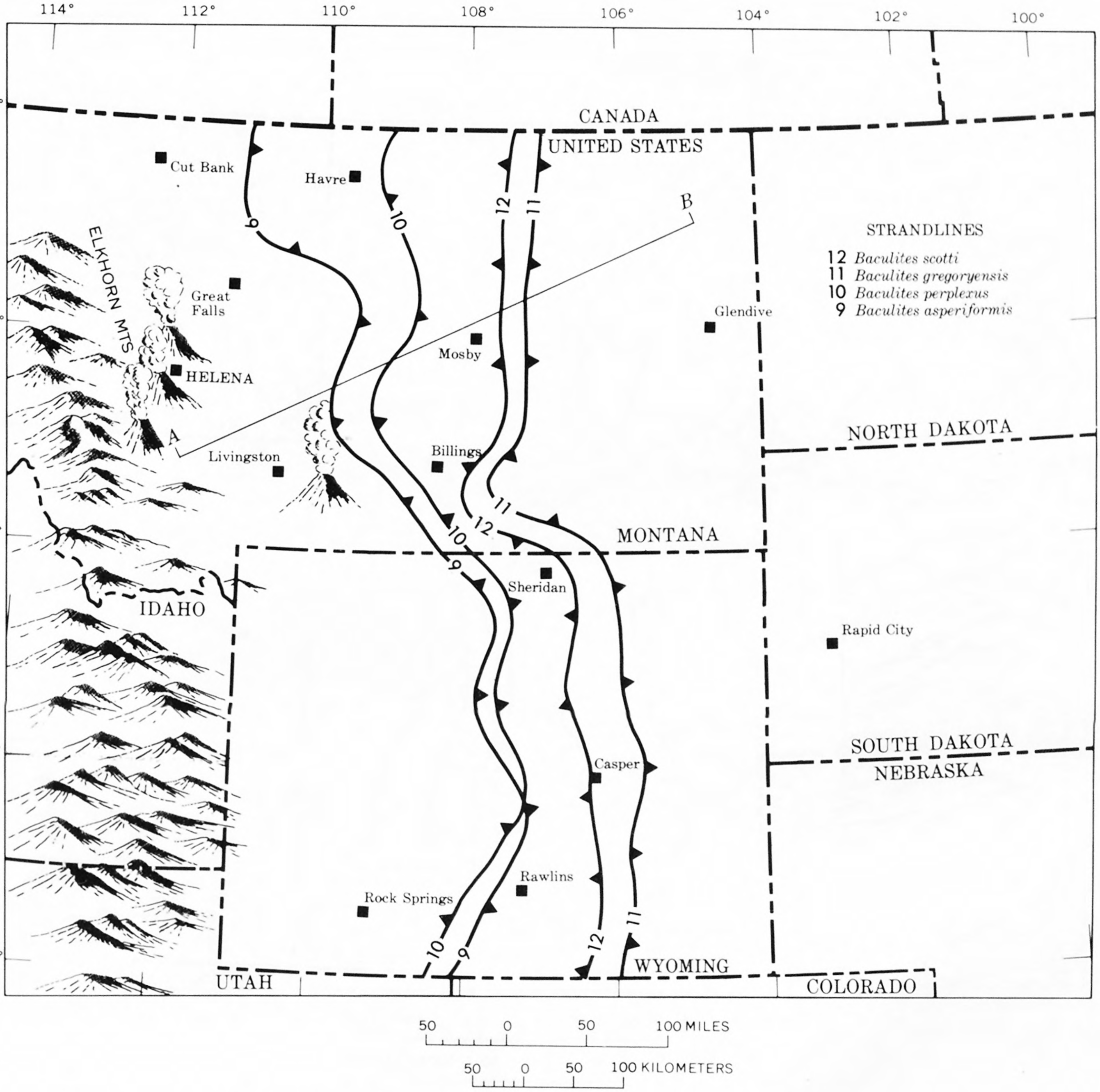


FIGURE 16.—Approximate position of strandlines during the Judith River regression. Barbs point in direction of strandline movement.

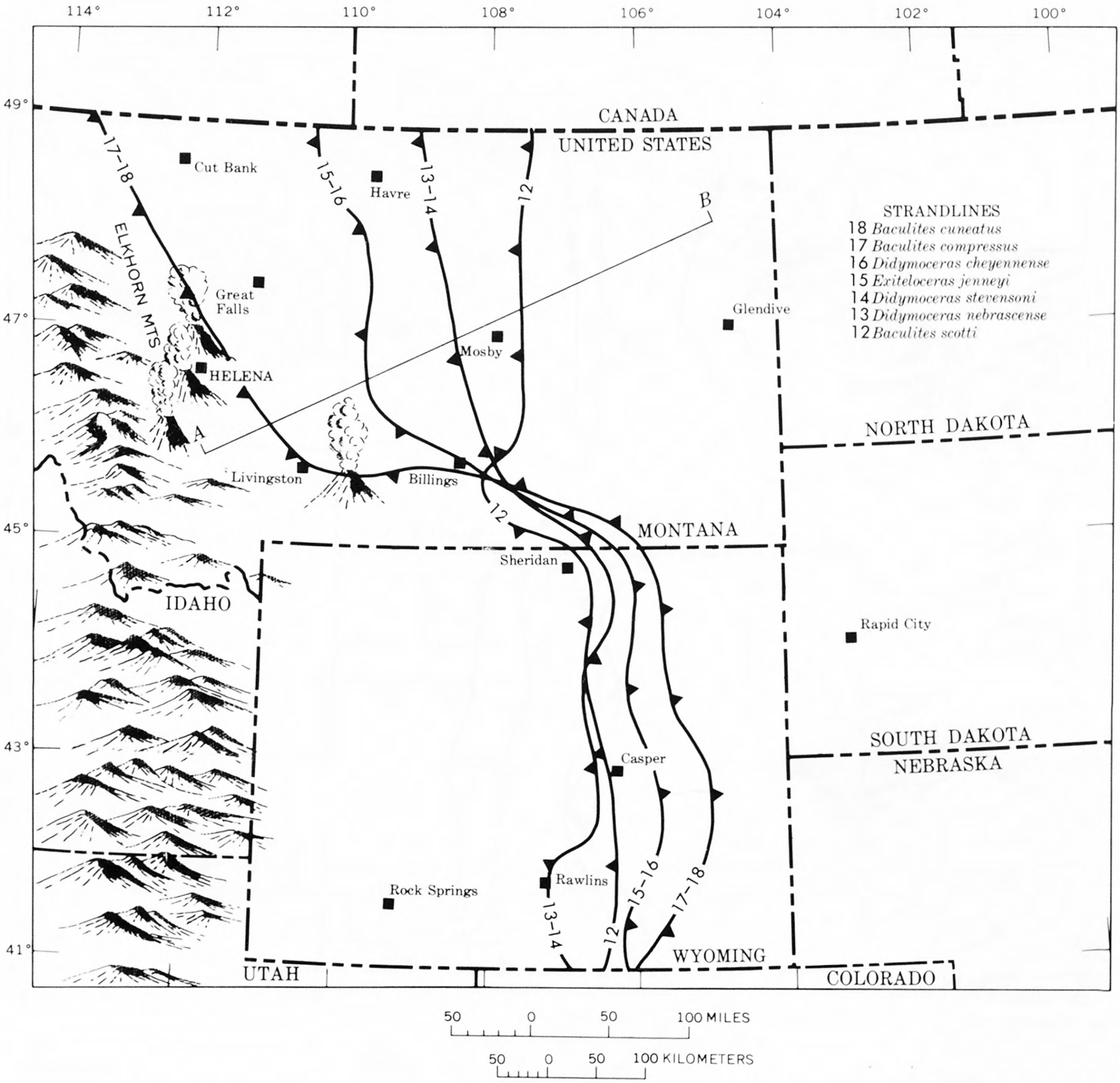


FIGURE 17.—Approximate position of strandlines during the Bearpaw transgression. Barbs point in direction of strandline movement.

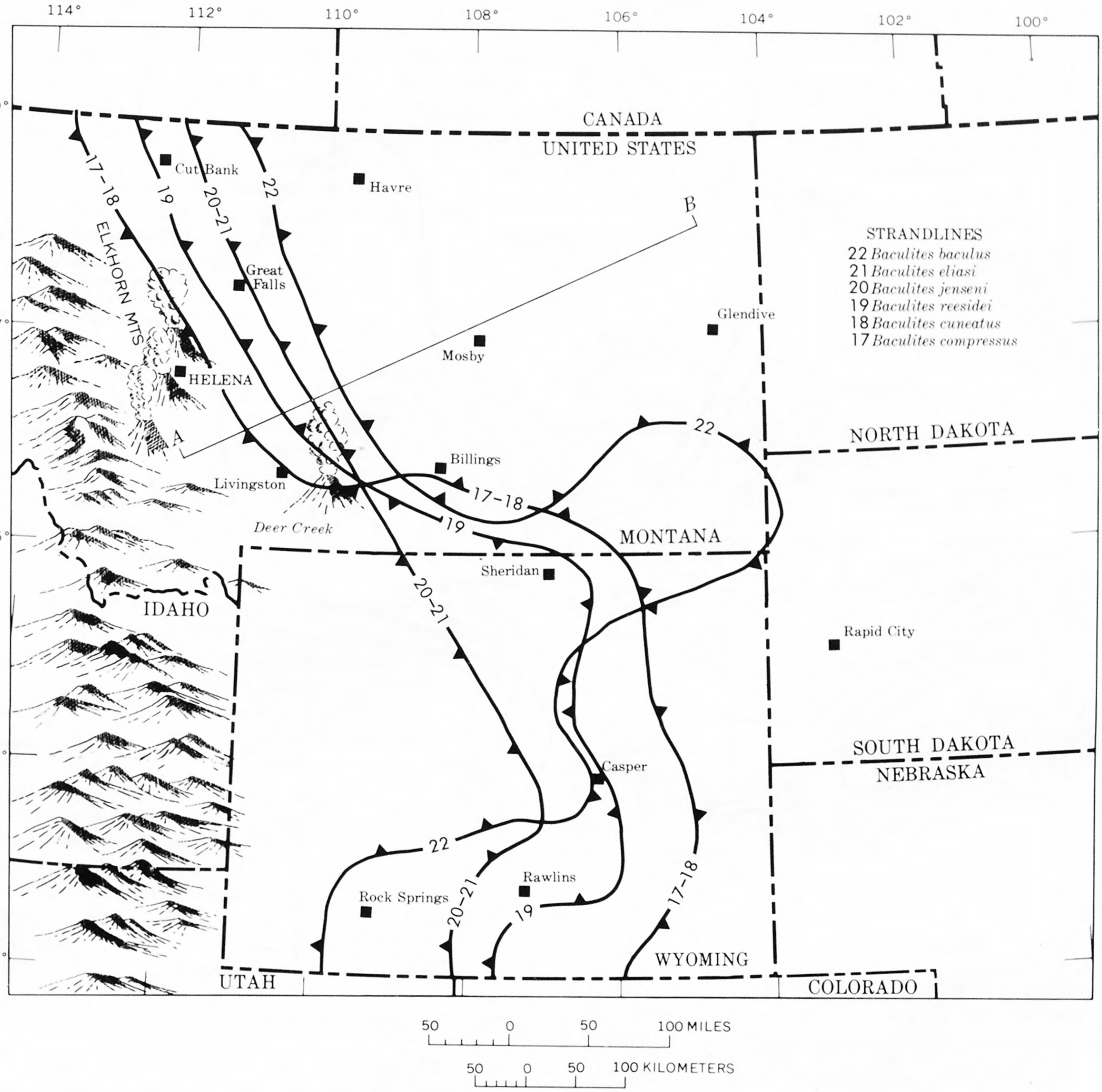


FIGURE 18.—Approximate position of strandlines during the initial phase of the Fox Hills regression. Barbs show direction of strandline movement.

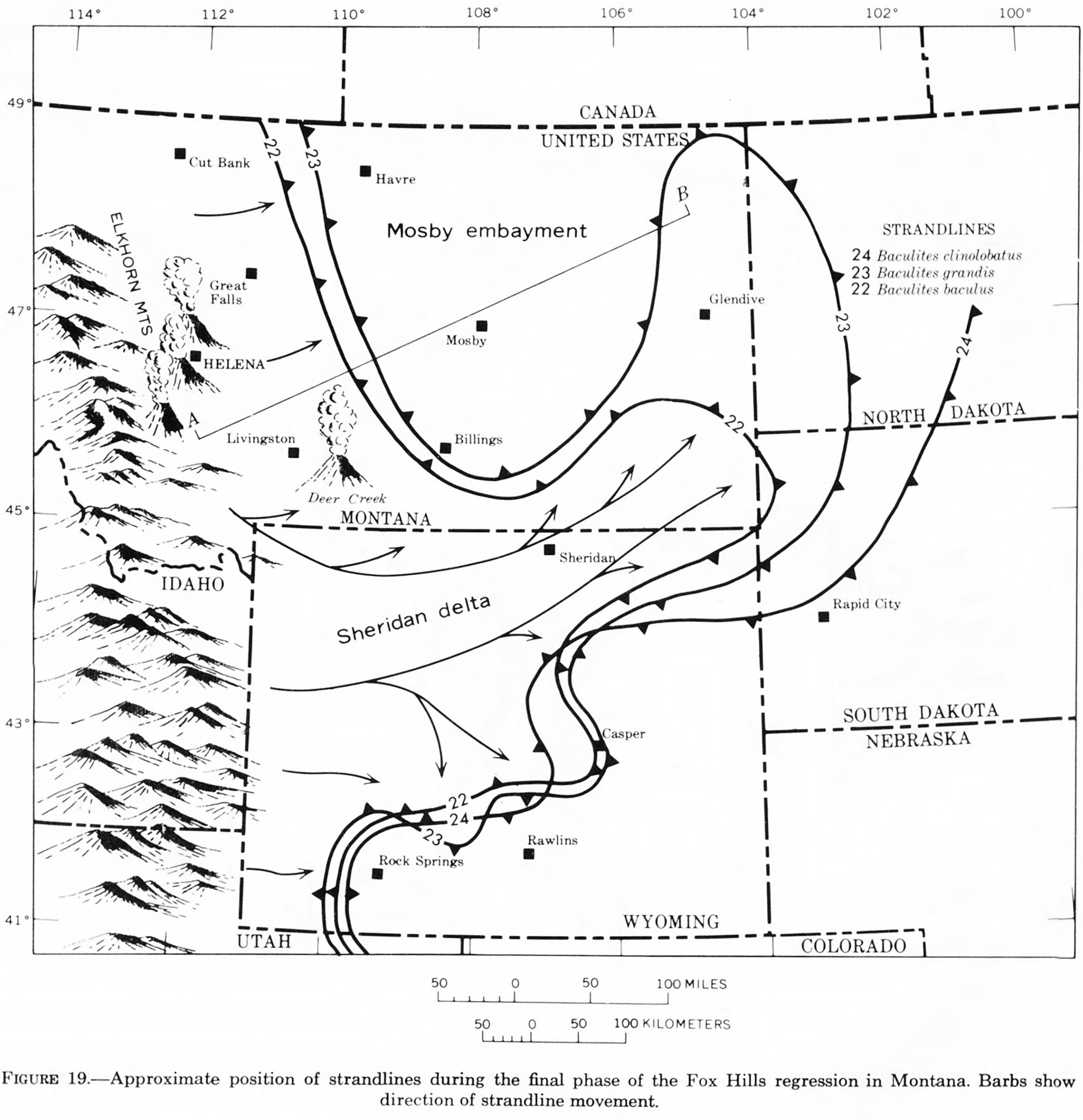


FIGURE 19.—Approximate position of strandlines during the final phase of the Fox Hills regression in Montana. Barbs show direction of strandline movement.

sition, but data from other areas of the western interior show that those events were not so confined.

Among possible causes for the final regression, the most attractive is a broad regional uplift in central Montana. The final stages of emplacement of the Boulder batholith in western Montana may have brought about such broad regional movements and influenced the marine withdrawal. Robinson, Klepper, and Obradovich (1968, p. 558) stated that the bulk of the Boulder batholith was emplaced in the interval of 78–72 m.y. ago. The 72-m.y. date is about the same as we estimate for the start of the Fox Hills regression. Data are not conclusive, but several recently determined potassium-argon dates for the Boulder batholith and for marine Cretaceous rocks in the area suggest that the regression of the Bearpaw Sea and the deposition of the Lennep, Horsethief, and Fox Hills Sandstones coincide with late stages of batholith emplacement (Robinson and others, 1968, p. 574, fig. 6).

Many geologists have considered eustatic rise and fall of sea level responsible for the formation and destruction of epicontinental seas. If sea level is nearly constant, local crustal instability becomes the main factor controlling the position and configuration of the basin of deposition; moreover, crustal instability, whether it affects the basin and adjacent land independently or concurrently, along with the rate of sediment supply, determines the distribution of transgressive and regressive deposits, and we think that was the situation here.

If transgression or regression were due to eustatic or epeirogenic movements, that movement in the same sense should be basinwide. But the strandlines of the late Santonian, Campanian, and Maestrichtian Stages in a 300,000-square-mile area in Montana, Wyoming, and North and South Dakota in the western interior basin clearly record independent movements in the various parts of the basin.

RATES OF TRANSGRESSION AND REGRESSION

Ammonite zonation, mapping of strandlines, and potassium-argon dating permit paleogeographic reconstructions and determination of rates of transgression, regression, and sedimentation. Cross section *A–B*, in figure 20, represents a highly generalized transect across part of the Montana basin of Late Cretaceous deposition.

Available data indicate that the Telegraph Creek–Eagle regression started about 85 m.y. ago and lasted about 5 m.y., during which the strand moved eastward about 240 miles. In the area of the section, the regression was about 180 miles in 2.5 m.y., a rate of about 70 miles per million years. The rate for the entire Telegraph Creek–Eagle regression was about 50 miles per million years.

The Claggett transgression, accompanied by explosive volcanism, was rapid and short. It lasted about 1.5 m.y., and the strand moved about 95 miles per million years.

The Judith River regression lasted about 3 m.y., with the strand retreating at about 60 miles per million years.

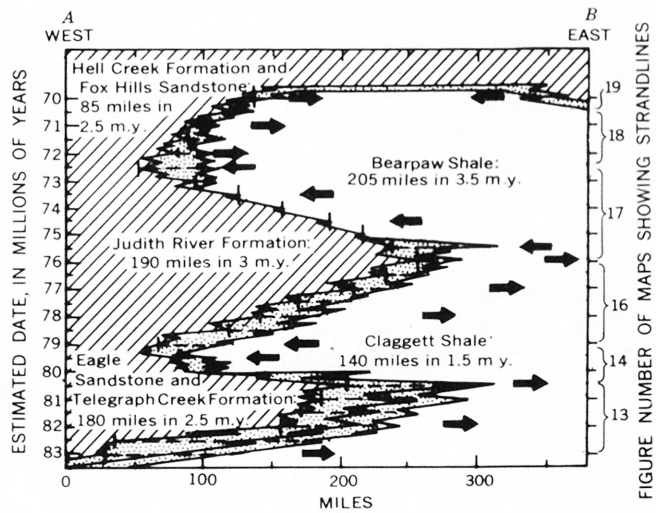


FIGURE 20.—Rates of transgression and regression, Montana Group, Montana. Nonmarine beds are to the left, shallow-water marine beds are stippled, and marine shale is to the right. Position of the strand for each ammonite zone is shown by vertical bar. Dashed lines represent the ammonite zones *Desmoscaphites erdmanni* through *Baculites grandis*. Line of section shown in figures 13, 14, and 16–19. Arrows show direction of strandline movement.

The Bearpaw transgression was slow and lasted about 3.5 m.y. It, like the Claggett, was accompanied by explosive volcanism. The strand advanced about 205 miles at a rate of about 70 miles per million years.

The Fox Hills regression was slow at first, averaging only about 35 miles per million years, but toward the end the strand moved more than 250 miles in less than half a million years. After the close of the marine deposition in Montana, the Cretaceous sea lingered for at least another 2 m.y. in South Dakota and adjacent regions. Shallow-water marine strata of early Paleocene age in the Dakotas show that the sea did not finally withdraw from the western interior until the early Tertiary.

RATES OF SEDIMENTATION

Rates of sediment accumulation and minimum rates of subsidence were estimated from the stratigraphic, paleontologic, and radiometric data available and are shown in figure 21. The method used in compiling figure 21 involves determining the number of ammonite zones and the maximum stratigraphic thickness at widely separated points. Adjustments were made, where possible, for known unconformities, such as the Teapot unconformity (Gill and Cobban, 1966a). Where the magnitude of the unconformity could not be evaluated accurately, rates were computed only for the sequence above and below the unconformity.

Figure 21 is based on the rates of deposition at more than 75 widely spaced localities. Subsurface data are used where reasonable correlations can be made with surface sections in which ammonite range spans are known. Thicknesses involved in the calculations range from a few hundred feet to 8,000 feet. Ammonite zones considered are as few as three and as many as 28. It must be emphasized that this map is but a rough estimate of rates of sedimentation and that the values shown by the contours may be sizably in error.

After the review of the literature, we believe that our estimates are probably minimum rates. A recent computation by Weimer (1970, p. 276–277) for the Niobrara Formation (Coniacian–early Campanian) gave rates from 2,000 feet per million years near source areas to 83.5 feet per million years in areas of dominantly biogenic accumulations. The latter figure corresponds well with determinations by Ericson, Ewing, and Wollin (1964) of rates in the deep Atlantic. Neither of Weimer's figures contradicts rates shown on our map (fig. 21).

The most comprehensive tabulation of depositional rates for Cretaceous rocks known to us is that of Kay (1955). His method was to determine the maximum thicknesses for a known period and then use the Holmes' (1947) time scale to calculate the rate in feet per million years. The rate of sedimentation during the Cretaceous for 10 various parts of the world, which were cited by Kay, are shown on table 2.

TABLE 2.—*Rate of sedimentation during the Cretaceous in various parts of the world*

[From Kay (1955), p. 674–675]

Locality	*Feet per million years*
Southern British Columbia	710
Maracaibo, Venezuela	480
Switzerland	380
Peru	320
California	765
Eastern Kyushu, Japan	1,600
Eastern Utah	1,000
Awaji Island, Japan	1,500
Coahuila, Mexico	410
Central California	600
Average (rounded)	775

Of all areas bordering the western shoreline of the Late Cretaceous sea, western Wyoming and adjacent parts of Utah and Colorado appear to have undergone the greatest amount of subsidence and sediment accumulation. Sedimentation rates in western Wyoming greatly exceed the maximum rates recorded by Kay (table 2 of present report)—2.500 versus 1,600 feet per million years. The average rate for Wyoming is about 620 feet per million years as compared with Kay's average of 775 feet.

Figure 21 shows extremely slow sedimentation in the eastern parts of North and South Dakota, an area far removed from the source of clastics. The lithology of rocks deposited in this area also reflects slow deposition in quiet water. The rocks consist of generally thin sequences of biogenic marlstone and chalk, siliceous shale, organic-rich shale containing phosphate nodules, abundant thin persistent beds of bentonite, and clay shale containing a large volume of manganese nodules. Sandy beds are scarce.

In the western parts of North and South Dakota, in eastern Montana, and in Wyoming, the rates of sedimentation increase gradually westward in the direction of a corresponding increase in thickness and a change in lithology. The distal edges of the eastward-pointing wedges of regressive sandstone bodies (Eagle, Judith River, and Mesaverde Formations) appear, reflecting the gradual approach to the western source. Rates of sedimentation increase slowly and uniformly across most of Montana. An exception is in southwestern Montana, where sedimentation rates were influenced by the coastal Elkhorn volcanic mountain range. In that area, in the vicinity of Helena, volcanism accounts for the high rates of deposition that are reflected by the eastern bulge in the contour lines (fig. 21). This bulge reflects the direction of dominant sediment transport from the volcanic pile to the sea.

Data are sparse for northwestern Montana, but sedimentation rates appear much lower here than for the southern part of the State. The Elkhorns and asso-

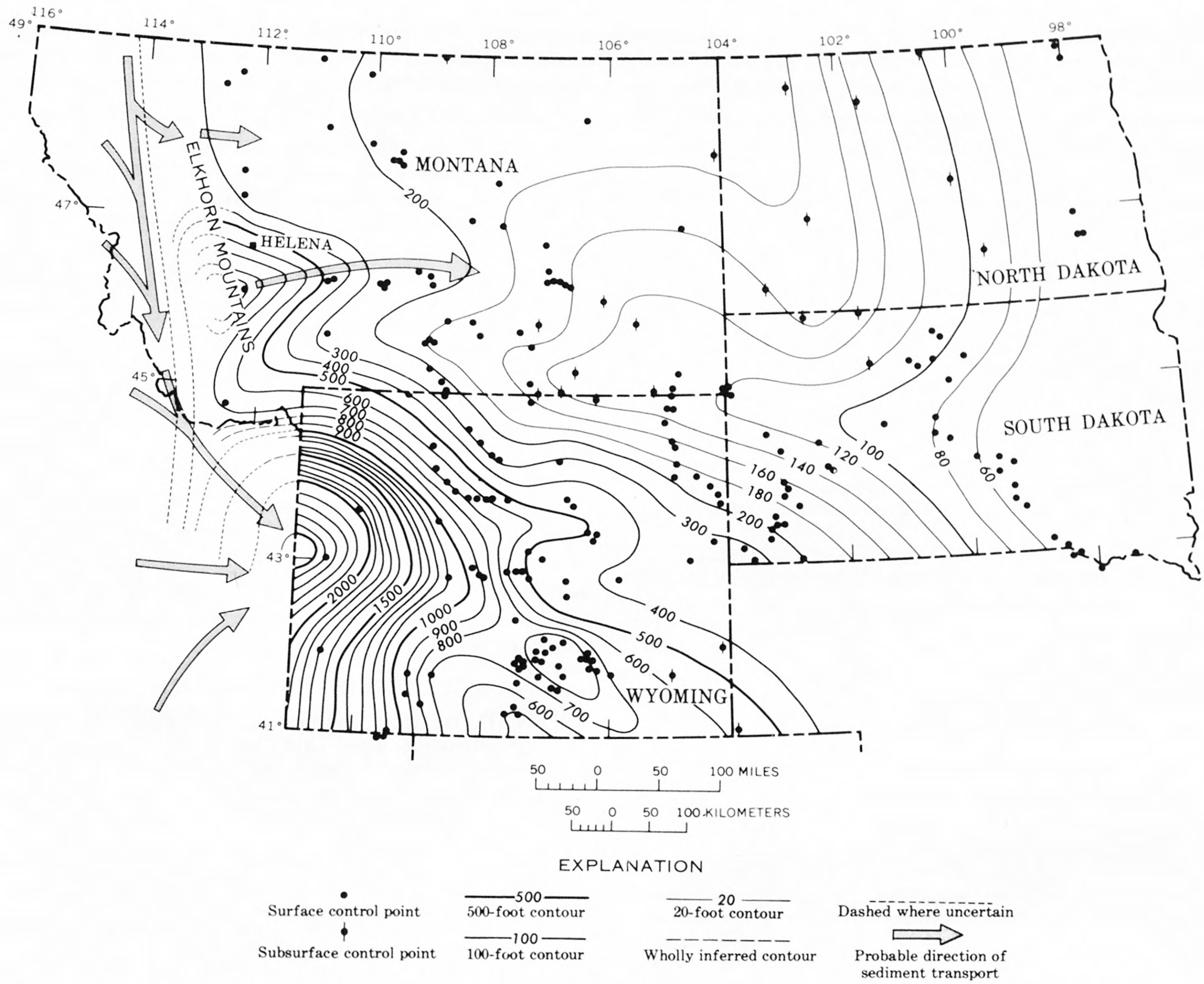


FIGURE 21.—Average rates of sedimentation in Montana, Wyoming, and North and South Dakota during the Late Cretaceous (late Santonian to early Maestrichtian), in feet per million years.

ciated near-coastal features appear to have interrupted the easterly sediment transport system, diverting it into a north-south system parallel to the axis of the then-existing fold belt. A similar suggestion was made by Gilluly (1963, p. 147) to account for the great volume of sediment in western and southern Wyoming.

Wilson (1970, p. 1861–1864), in a study of Upper Cretaceous synorogenic conglomerates in extreme southwestern Montana, showed a southeastward direction of sediment transport from Montana into Idaho and Wyoming.

Where nonmarine clastics or volcanic clastics are enclosed by datable marine strata, rates of deposition can be roughly estimated. In western Montana, volcanic-clastic rocks, derived from the Elkhorn Mountains, appear to have accumulated at a rate of about 340 feet per million years. Equivalent nonmarine rocks with minor volcanic components in nearby areas (Two Medicine and Judith River Formations) were deposited at a rate of about 160 feet per million years.

Marine shales, deposited during the Bearpaw transgression, appear to have accumulated at an average rate of 220 feet per million years compared with a rate of 665 feet per million years for equivalent rocks in Wyoming. This contrast in rates can be explained by variations in subsidence and (or) sediment delivery to the two areas. The lithology of the Bearpaw Shale in Montana clearly shows that in that region there was adequate space in the sea to accommodate a much greater volume of sediments than is present.

Wyoming, in contrast with Montana, was an area of rapid sedimentation and subsidence. The total volume of Upper Cretaceous deposits in this area as shown in figure 21 closely corresponds with that shown by Reeside (1944, map 2). The clastics delivered to this part of the sea came from the cordillera to the west. Gilluly (1963, p. 146–147) showed that it is unlikely that the cordillera directly to the west could have supplied the volume of sediments that is present. Of the several possible explanations that he suggests, we favor a stream pattern, generally parallel to the fold belt, by which much of the sediment was brought from areas to the north and south.

The rates of sedimentation in various broadly defined environments of deposition in the four-State area are shown in table 3. A comparison of these rates with rates of present sedimentation in other areas (table 4) shows a similarity only between the Cretaceous offshore areas and today's open-ocean basins.

TABLE 3.—*Average rates of sedimentation in selected environments during the Late Cretaceous in the western interior*

[In feet per million years. Compare with Kay's (1955) Cretaceous average of 775 (table 2)]

Environment	Wyoming	Montana	South Dakota	North Dakota	Alberta
Nonmarine:					
Sedimentary source	380	160	0	0	0
Volcanic source	0	340	0	0	0
Nearshore marine:					
During regression	600	240	0	0	0
During transgression	665	220	0	0	0
Offshore marine, open marine, and eastern shelf	0	0	<60	<60	0
Average (from fig. 21)	620	200	120	110	[1]150

[1]Folinsbee, Baadsgaard, and Lipson (1961, p. 357).

TABLE 4.—*Modern rates of sedimentation*

Environment	Rate (in ft per million yr)	Location	Reference
Deep ocean	83.5	Atlantic	Erickson, Ewing, and Wollin (1964, p. 731).
Do	115	Not given	Twenhofel (1939, p. 220).
Shoreline	3,000–5,000	Sapelo, Ga	Weimer (1970, p. 274).
Barrier island	4,000–6,000	Gulf Coast	Do.
Deltaic	20,000–40,000	Mississippi Delta	Do.
Do	18,000–41,000	Pedernales, Venezuela	Kidwell and Hunt (1958, p. 800).

The rates in the present-day shoreline environment (3,000–5,000 feet per million years) were approached only in western Wyoming. Rates in the barrier bar, delta, and prodelta environments are not duplicated by our method of calculation. These are environments of rapid deposition, and the effect upon them by the rapid lateral and vertical movement of the strand obscures their exact location on isopach and rate-of-sedimentation maps. Strandline maps, representing ½-million-year time spans, demonstrate the lateral and vertical migration of probable areas of deltaic sedimentation (figs. 13, 14, 16–19).

Strandline maps (figs. 18–19) of the first (Lewis Shale deposition in Wyoming) and second parts of the Fox Hills regression show lobate irregularities along the strand that we interpret as the probable sites of ancient deltas. The lobes on the strandlines for the time spans of *Baculites baculus*, *B. grandis*, and *B. clinolobatus* in southern Wyoming are in areas with high rates of deposition. In the vicinity of Rawlins, the Lewis Shale consists of marine prodelta sandstone, siltstone, and sandy shale, which we estimate accumulated at a rate in excess of 1,400 feet per million years. We believe that these high rates are the result of a rapidly subsiding part of the basin into which a delta system from the north (Red Desert delta of Asquith, 1970, p. 1209–1213) comingled with prodelta sediments from a northeast-trending delta rooted in northwestern Colorado (Weimer, 1961, p. 26, 1970, p. 289; Haun, 1961, p. 118–119).

The depositional setting of the Sheridan delta in northern Wyoming (fig. 19) is very different from the setting of the southern Wyoming deltas. The sediment transfer system that supported the Sheridan delta delivered its load into a part of the sea in which subsidence was less than sedimentation, accounting for the rapid eastward progradation of the strand. In that part of northern Wyoming the rate of sedimentation was less than 200 feet per million years, and the sediments spread laterally instead of building vertically as in southern Wyoming.

REFERENCES CITED

Asquith, D. O., 1970, Depositional topography and major marine environments, Late Cretaceous, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 54, no. 7, p. 1184–1224.

Birkelund, Tove, 1965, Ammonites from the Upper Cretaceous of West Greenland: Medd. Grönland, v. 179, no. 7, 192 p., 49 pls.

Cobban, W. A., 1951a, New species of *Baculites* from the Upper Cretaceous of Montana and South Dakota: Jour. Paleontology, v. 25, no. 6, p. 817–821, pl. 118.

———1951b, Scaphitoid cephalopods of the Colorado group: U.S. Geol. Survey Prof. Paper 239, 42 p., 21 pls. [1952].

———1955, Cretaceous rocks of northwestern Montana, *in* Billings Geol. Soc. Guidebook 6th Ann. Field Conf., Sweetgrass arch–Disturbed belt, Montana, 1955: p. 107–119.

———1958, Two new species of *Baculites* from the western interior region: Jour. Paleontology, v. 32, no. 4, p. 660–665, pls. 90, 91.

———1962a, Baculites from the lower part of the Pierre Shale and equivalent rocks in the Western Interior: Jour. Paleontology, v. 36, no. 4, p. 704–718, pls. 105–108.

———1962b, New baculites from the Bearpaw shale and equivalent rocks of the Western Interior: Jour. Paleontology, v. 36, no. 1, p. 126–135, pls. 25–28.

———1969, The Late Cretaceous ammonites *Scaphites leei* Reeside and *Scaphites hippocrepis* (DeKay) in the western interior of the United States: U.S. Geol. Survey Prof. Paper 619, 29 p., 5 pls.

Cobban, W. A., and Reeside, J. B., Jr., 1952, Correlation of the Cretaceous formations of the western interior of the United States: Geol. Soc. America Bull., v. 63, no. 10, p. 1011–1043, 1 pl.

DeKay, J. E., 1827, Report on several multilocular shells from the State of Delaware; with observations of a second specimen of the new fossil genus *Eurypterus:* Lyceum Nat. History New York Annals, v. 2, p. 273–279, pl. 5.

Eldridge, G. H., 1889, Some suggestions upon the methods of grouping the formations of the middle Cretaceous and the emloyment of an additional term in its nomenclature: Am. Jour. Sci., v. 38, p. 313–321.

Elias, M. K., 1933, Cephalopods of the Pierre formation of Wallace County, Kansas, and adjacent area: Kansas Univ. Sci. Bull., v. 21, no. 9, p. 289–363, pls. 28–42.

Ericson, D. B., Ewing, Maurice, and Wollin, Goesta, 1964, The Pleistocene epoch in deep-sea sediments: Science, v. 146, no. 3645, p. 723–732.

Folinsbee, R. E., Baadsgaard, Halfdan, and Lipson, J., 1961, Potassium-argon dates of Upper Cretaceous ash falls, Alberta, Canada, *in* Kulp, J. L., ed., Geochronology of rock systems: New York Acad. Sci. Annals, v. 91, art. 2, p. 352–363.

Gill, J. R., and Cobban, W. A., 1966a, Regional unconformity in Late Cretaceous, Wyoming, *in* Geological Survey research 1966: U.S. Geol. Survey Prof. Paper 550–B, p. B20–B27.

———1966b, The Red Bird section of the Upper Cretaceous Pierre Shale, in Wyoming, *with a section on* A new Echinoid from the Cretaceous Pierre Shale of eastern Wyoming, by P. M. Kier: U.S. Geol. Survey Prof. Paper 393–A, 73 p., 12 pls.

Gilluly, James, 1963, The tectonic evolution of the western United States—17th William Smith Lecture: Geol. Soc. London Quart. Jour., v. 119, no. 2, p. 133–174.

Hall, James, and Meek, F. B., 1856, Descriptions of new species of fossils from the Cretaceous formations of Nebraska, with observations upon *Baculites ovatus* and *B. compressus,* and the progressive development of the septa in *Baculites, Ammonites,* and *Scaphites:* Am. Acad. Arts and Sci. Mem., new ser., v. 5, p. 379–411, pls. 1–8.

Haun, J. D., 1961, Stratigraphy of post-Mesaverde Cretaceous rocks, Sand Wash basin and vicinity, Colorado and Wyoming, *in* Wyoming Geol. Assoc. Guidebook, 16th Ann. Field Conf., Green River, Washakie, Wind River, and Powder River Basins, 1961: p. 116–124.

Holmes, Arthur, 1947, The construction of a geological time scale: Geol. Soc. Glasgow Trans., v. 21, pt. 1, p. 117–152.

Jeletzky, J. A., 1971, Marine Cretaceous biotic provinces and paleogeography of western and Arctic Canada—Illustrated by a detailed study of ammonites: Canada Geol. Survey Paper 70–22, 92 p.

Kay, G. M., 1955, Sediments and subsidence through time, *in* Poldervaart, Arie, ed., Crust of the earth—a symposium: Geol. Soc. America Spec. Paper 62, p. 665–684.

Kidwell, A. L., and Hunt, J. M., 1958, Migration of oil in recent sediments of Pedernales, Venezuela, *in* Weeks, L. G., ed., Habitat of oil: Tulsa, Okla., Am. Assoc. Petroleum Geologists, p. 790–817.

Landes, R. W., 1940, Paleontology of the marine formations of the Montana group, *in* Geology of the southern Alberta plains: Canada Dept. Mines and Resources, Geol. Survey Mem. 221, p. 129–217, 8 pls.

Lindvall, R. M., 1956, Geology of the Kenilworth quadrangle, Montana: U.S. Geol. Survey Misc. Geol. Inv. Map I–129, 2 sheets.

Meek, F. B., 1876, A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U.S. Geol. Survey Terr. (Hayden) Rept. 9, 629 p., 45 pls.

Meek, F. B., and Hayden, F. V., 1856, Descriptions of new species of Gastropoda and Cephalopoda from the Cretaceous formations of Nebraska Territory: Acad. Nat. Sci. Philadelphia Proc., v. 8, p. 70–72.

Reeside, J. B., Jr., 1927, The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States: U.S. Geol. Survey Prof. Paper 151, 87 p., 45 pls.

———1944, Maps showing thickness and general character of the Cretaceous deposits in the Western Interior of the United States: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 10.

Reynolds, M. W., 1966, Stratigraphic relations of Upper Cretaceous rocks, Lamont-Bairoil area, south-central Wyoming, *in* Geological Survey research 1966: U.S. Geol. Survey Prof. Paper 550–B, p. B69–B76.

Robinson, G. D., Klepper, M. R., and Obradovich, J. D., 1968, Overlapping plutonism, volcanism, and tectonism in the Boulder batholith region, western Montana, *in* Coats, R. R., Hay, R. L., and Anderson, C. A., eds., Studies in volcanology—A memoir in honor of Howel Williams: Geol. Soc. America Mem. 116, p. 557–576.

Rosenkrantz, Alfred, 1970, Marine Upper Cretaceous and lowermost Tertiary deposits in West Greenland—Investigations before and since 1938: Dansk Geol. Foren. Medd., v. 19, no. 4, p. 406–453.

Say, Thomas, 1820, Observations on some species of zoophytes, shells, etc., principally fossil: Am. Jour. Sci., v. 2, p. 34–45.

Scott, G. R., 1969, General and engineering geology of the northern part of Pueblo, Colorado: U.S. Geol. Survey Bull. 1262, 131 p.

Scott, G. R., and Cobban, W. A., 1965, Geologic and biostratigraphic map of the Pierre Shale between Jarre Creek and Loveland, Colorado: U.S. Geol. Survey Misc. Geol. Inv. Map I–439.

Stanton, T. W., and Hatcher, J. B., 1905, Geology and paleontology of the Judith River beds: U.S. Geol. Survey Bull. 257, 128 p.

Twenhofel, W. H., 1939, Principles of sedimentation [1st ed.]: New York, McGraw-Hill Book Co., 610 p.

Weimer, R. J., 1961, Uppermost Cretaceous rocks in central and southern Wyoming, and northwest Colorado, *in* Wyoming Geol. Assoc. 16th Ann. Guidebook Field Conf., Green River, Washakie, Wind River, and Powder River Basins 1961: p. 17–28.

———1970, Rates of deltaic sedimentation and interbasin deformation, Upper Cretaceous of Rock Mountain region, *in* Morgan, J. P., ed., Deltaic sedimentation, modern and ancient: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 15, p. 270–292.

Whitfield, R. P., 1880, Paleontology of the Black Hills of Dakota, *in* Newton, Henry, and Jenney, W. P., Report on the geology and resources of the Black Hills of Dakota: U.S. Geog. and Geol. Survey Rocky Mtn. Region (Powell), p. 325–468, 16 pls.

———1901, Note on a very fine example of *Helicoceras stevensoni* preserving the outer chamber: Am. Mus. Nat. History Bull., v. 14, art. 16, p. 219, pls. 29, 30.

———1902, Observations on and emended description of *Heteroceras simplicostatum* Whitfield: Am. Mus. Nat. History Bull., v. 16, art. 5, p. 67–72, pls. 23–27.

Wilson, M. D., 1970, Upper Cretaceous–Paleocene synorogenic conglomerates of southwestern Montana: Am. Petroleum Geologists Bull., v. 54, no. 10, p. 1843–1867.

Zapp, A. D., and Cobban, W. A., 1962, Some Late Cretaceous strand lines in southern Wyoming, *in* Short papers in geology, hydrology, and topography: U. S. Geol. Survey Prof. Paper 450–D, p. D52–D55.

* U.S. GOVERNMENT PRINTING OFFICE: 1973—515–659/55