Contributions to Late Cretaceous Stratigraphy and Paleontology, Western Montana

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Contributions to Late Cretaceous Stratigraphy and Paleontology, Western Montana

A. Redefinition of Frontier Formation–Beaverhead Group Contact, Lima Peaks Area, Southwestern Montana and Southeastern Idaho

By T.S. DYMAN, J.C. HALEY, and W.J. PERRY, JR.

B. Biostratigraphic Correlation of Santonian and Campanian Formations in the Northwestern Part of Yellowstone National Park, and the Madison Range and Livingston Area of Southwestern Montana

By R.G. TYSDAL and D.J. NICHOLS

C. Occurrence and Significance of the Middle Turonian (Upper Cretaceous) Belemnite *Actinocamax* in Central Western Montana

By WILLIAM A. COBBAN

This volume is published as chapters A–C.
These chapters are not available separately

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Chapter A

Redefinition of Frontier Formation–Beaverhead Group Contact, Lima Peaks Area, Southwestern Montana and Southeastern Idaho

By T.S. DYMAN, J.C. HALEY, and W.J. PERRY, JR.

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CONTRIBUTIONS TO LATE CRETACEOUS STRATIGRAPHY
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CONVERSION FACTORS

Inch-pound units of measurement in this report may be converted to International System (SI) of metric units usng the following conversion factors:

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3048	meter(m)
mile (mi)	1.609	kilometer(km)
inch (in.)	2.54	centimeter(cm)

Redefinition of Frontier Formation–Beaverhead Group Contact, Lima Peaks Area, Southwestern Montana and Southeastern Idaho

By T.S. Dyman, J.C. Haley, *and* W.J. Perry, Jr.

Abstract

The Upper Cretaceous Frontier Formation and the overlying Upper Cretaceous lower part of the Beaverhead Group form a thick sequence of nonmarine, predominantly clastic sedimentary rocks south of Lima and Monida, Montana, north of the Continental Divide. The upper Frontier and lower Beaverhead have lithologies that are unique as well as common to both units, but the rocks are difficult to study because exposures are poor. Quartzite-clast conglomerates, lithic-rich sandstones with abundant limestone fragments, and limestone-pebble conglomeratic zones in the upper part of the Frontier Formation resemble those in the lower part of the Beaverhead Group. In the western part of the area, near Knob Mountain, an angular unconformity separates the two units and distinguishing them is easy. In the eastern part of the study area, near Humphrey, Idaho, the two units are conformable, and a mappable contact is difficult to identify.

Two distinct lithologies are present in the uppermost Frontier Formation but are absent in the overlying Beaverhead beds: (1) conglomerates and conglomeratic sandstones derived from Cretaceous and Jurassic formations, and (2) green to olive-green porcellanites and tuffaceous and porcellanitic sandstones. Upper Frontier limestone conglomerates containing clasts derived from Jurassic and Cretaceous formations occur below the sub-Beaverhead unconformity and are interbedded with typical upper Frontier mudstones and sandstones. Clasts contain gastropod fragments and oolites derived from the Middle Jurassic Rierdon Formation and the Lower Cretaceous Kootenai Formation. Green porcellanitic beds are interbedded with and are stratigraphically above conglomerates with Mesozoic-derived limestone clasts. These porcellanites form distinct and laterally continuous beds throughout the area.

Based on these new data, the Frontier-Beaverhead contact should be placed at the angular unconformity where it can be recognized. The contact separates two distinct lithologic associations interpreted as depositional cycles. Where the unconformity is absent, the contact should be placed at the top of the uppermost green porcellanitic unit of the upper Frontier Formation. The porcellanitic unit (1) is exposed everywhere in the Lima Peaks region where the upper Frontier occurs, (2) represents an excellent time marker, and (3) is near the top of the Frontier depositional cycle above several thousand feet of monotonous Frontier rocks that cannot be easily subdivided Intervening conglomerates with Mesozoic-derived limestone clasts and conglomeratic sandstones aid in identifying the approximate stratigraphic position of the porcellanite beds.

INTRODUCTION

Contact relationships between the Upper Cretaceous lower part of the Beaverhead Group and the underlying Upper Cretaceous Frontier Formation and older rocks in the Lima region of southwestern Montana and adjacent northeastern Idaho (fig. 1) have not been fully established. Difficulties in establishing the nature of the contact can be attributed to the following reasons: (1) the Frontier Formation is poorly exposed because its abundant mudstones and shales commonly form debris flow slopes; (2) both the Frontier Formation and lower part of the Beaverhead Group are characterized by profound facies changes across a distance of 15 miles (25.3 km) paralleling the Continental Divide between Red Conglomerate Peaks and Little Beaver Creek (fig. 2); and (3) the region was thrusted and folded during emplacement of the Idaho-Montana thrust belt. Frontier strata may be locally repeated by thrusting, and cross faults cut the Frontier-Beaverhead contact.

Facies relationships within the Beaverhead and Frontier, the nature of the Frontier-Beaverhead contact (is the contact conformable or unconformable?), and resultant implications for the tectonic history of this part of the Cordillera are the subjects of our ongoing research. Preliminary results suggest that the character of the sub-Beaverhead unconformity changes laterally from the back

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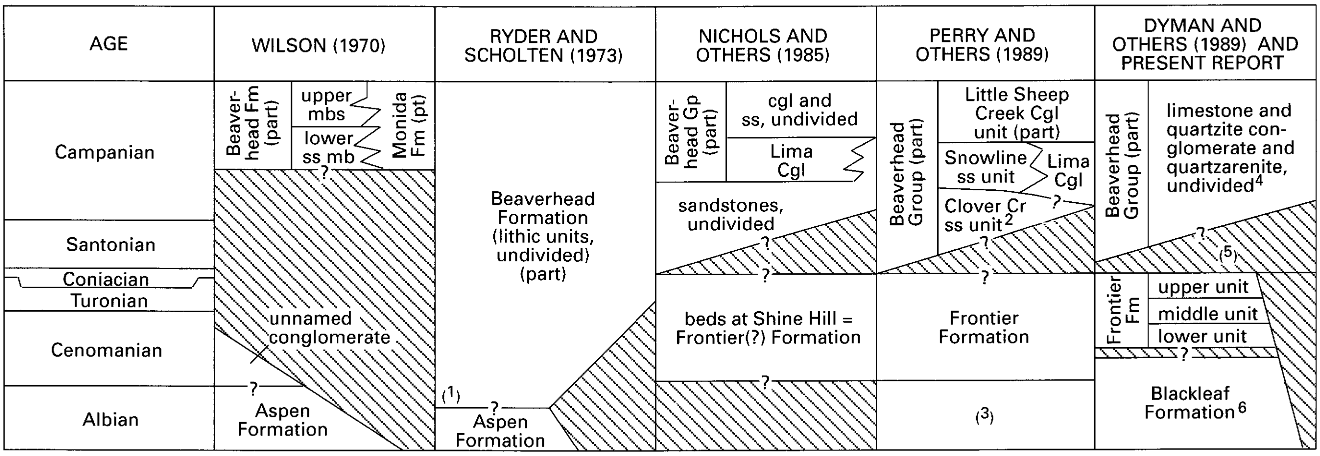

[1] Sawmill Creek beds of Ryder and Scholten (1973) with interbedded quarzite-clast conglomerates and lithologies typical of the Aspen Formation.

[2] Clover Creek sandstone unit of Perry and others (1989) is correlative with Monida sandstone unit of Ryder and Scholten (1973) and lower part of Monida Formation of Wilson (1970) and Monida Sandstone of Perry and others (1989).

[3] Perry and others (1989) did not address these beds in their report.

[4] Formal and informal Beaverhead units are not addressed in this report.

[5] The Frontier Formation and Beaverhead Group are disconformable over part of their outcrop areas south of Lima and Monida, Montana, but age relationships have not been fully established. The upper part of the Frontier Formation may be Cenomanian or Turonian in age. The sub-Beaverhead unconformity cuts out beds as old as early Mesozoic and late Paleozoic.

[6] Cobban and Kennedy (1989) indicated that the Mowry Shale (and equivalent beds including the upper part of the Blackleaf Formation) are all or part Cenomanian in age.

Figure 1. Stratigraphic chart of Lower and Upper Cretaceous (Albian to Campanian) rocks showing formal and informal geologic names used in this report.

of the Tendoy thrust sheet near Red Conglomerate Peaks eastward to south of Monida, Montana, where the contact is conformable or disconformable (fig. 2). If confirmed, such a relationship would suggest the presence of a "progressive syntectonic unconformity" (Riba, 1976) within the Upper Cretaceous sequence.

The purpose of this paper, therefore, is to briefly describe lateral and vertical facies variations within the uppermost Frontier and lowermost Beaverhead and to define a new Frontier-Beaverhead contact based on these new data. With recognition of the criteria defining the contact, the two formations can be more accurately mapped and dated, and facies will be better understood. Interpretation of the sedimentary-tectonic regime will be facilitated, which will aid understanding interrelationships of the thrust-belt and the Late Cretaceous foreland basin.

STRATIGRAPHIC NOMENCLATURE AND CONTACT RELATIONSHIPS

We experienced difficulties in understanding stratigraphic relationships regarding the Frontier-Beaverhead contact based on earlier published work, in part because of different nomenclature and in part because of the significant differences in where the contact was placed stratigraphically. Dillon (1947) was the first to discuss the contact relationships of Cretaceous rocks near the Continental Divide south of Lima. He described an angular unconformity between his Cenozoic rocks (rocks now assigned to the Beaverhead Group) and his underlying Mesaverde Formation (which contains rocks that are in part equivalent to the Frontier Formation).

In the Lima area, Lowell and Klepper (1953, p. 241) identified an unconformable contact between the Beaverhead and underlying strata; underlying strata were described as being as old as the Mississippian Madison Limestone and as young as strata equivalent to rocks of the Late Cretaceous Montana Group. This stratigraphic relationship of their Beaverhead Formation and Montana Group equivalents was identified in the western part of the area of this study (sec. 33, T. 15 S., R. 8 W., about 0.5 mi (0.8 km) north of Knob Mountain; fig. 2).

Scholten and others (1955) defined all post-Kootenai and pre-Beaverhead Cretaceous rocks in the Lima region as Aspen Formation, but stated that rocks of the Upper Cretaceous Mesaverde Formation could be exposed south of Lima and to the northeast in the Ruby River valley about 25 mi (40.2 km) northeast of Lima (see appendix for further details of use of the name Aspen Formation). A large part of their Aspen Formation is equivalent to rocks that we refer to as Frontier Formation. They stated that their Aspen Formation is overlain with profound angular unconformity by the Beaverhead Formation in the Lima region (Scholten and others, 1955, p. 368).

Ryder and Scholten (1973) discussed the basal Beaverhead contact in detail, but their basal Beaverhead is equivalent in part to rocks that we consider to be either

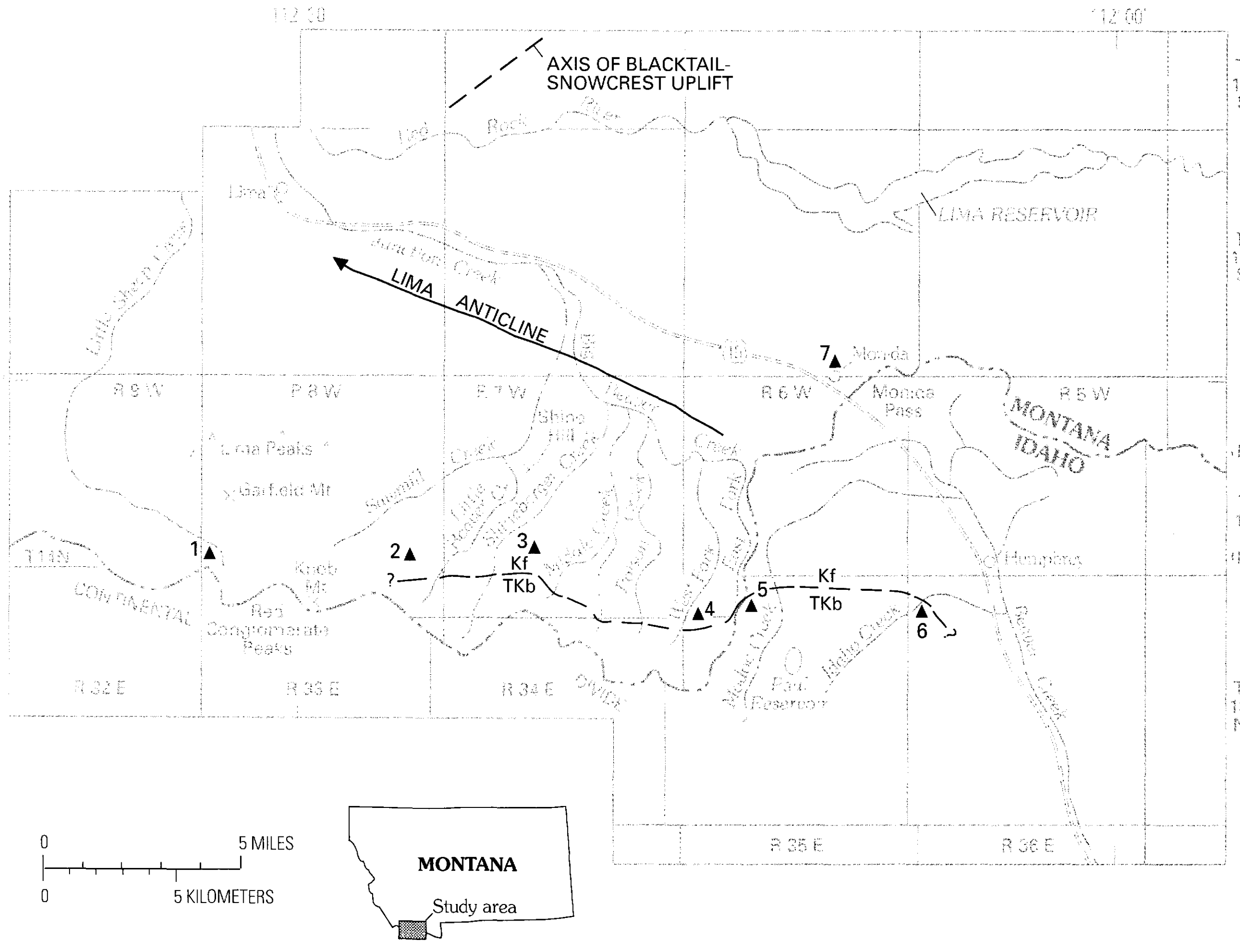

Figure 2. Index map of the study area in Montana and Idaho showing mountain ranges, streams, sample localities 1–7 (solid triangles with numbers), and Frontier Formation (Kff)–Beaverhead Group (TKb) contact. Contact dashed where covered or poorly exposed and queried where unknown. Arrow on anticline indicates direction of plunge.

Frontier Formation or the underlying Blackleaf Formation (fig. 1). They identified a profound angular unconformity between the Beaverhead and underlying rocks in the Red Conglomerate Peaks area and recognized that the unconformity diminished eastward through our study area. They suggested that the sequence may actually become conformable, and as evidence cited the following: (1) interbedding of Aspen Formation lithologic units (yellow shales and chert-bearing sandstones) with quartzite conglomerates along Sawmill Creek; and (2) the similarity in dips of the strata above and below their Aspen-Beaverhead contact along the Continental Divide south of Lima and Monida, Montana. On the west slope of Shine Hill (fig. 2), Ryder and Scholten (1973) designated conglomerate beds that are conformable with underlying and overlying strata as basal Beaverhead (see appendix for additional comments regarding the Shine Hill beds). Where no unconformity was observed, they placed the Aspen-Beaverhead contact at the "first appearance of conglomerates with Middle Proterozoic Belt Series (now Supergroup) quartzite clasts." Recent work has shown that Belt quartzite clasts also occur in conglomerates in the Blackleaf (Dyman and Nichols, 1988) and Frontier Formations (Dyman and others, 1989). Ryder and Scholten (1973) identified a minor(?) disconformity between their Aspen and Beaverhead Formations near Monida, where the Beaverhead lacks quartzite clast conglomerates. Ryder and Scholten's (1973) observations on changes in the sub-Beaverhead contact laid the groundwork for future studies. Wilson (1970) considered some of the conglomerates of Ryder and Scholten's (1973) Beaverhead Formation as part of his Aspen Formation, but his correlation chart (Wilson, 1970, p. 1850) clearly showed an unconformable relationship between the Aspen Formation (or unnamed conglomerate of Shine Hill) and the Beaverhead Formation. It should be noted, however, that Wilson worked primarily in an outcrop belt immediately north of our study area north of Interstate Highway 15 between Lima and Monida, Montana (fig. 1). The Beaverhead conglomerates in our study area are primarily limestone conglomerates of the Lima Conglomerate and equivalent distal sandstones.

Skipp and others (1976) mapped post-Kootenai–pre-Beaverhead strata as their Lower Cretaceous sandstone and claystone unit, which they considered equivalent to the

Aspen Formation. They identified a thrust contact placing Beaverhead over Aspen in the northern Edie Ranch 15-minute topographic quadrangle (area near Red Conglomerate Peaks along the Continental Divide, fig. 2). Haley (1986) believed that evidence supporting such an interpretation did not exist and considered the Aspen-Beaverhead contact (Aspen as used here is equal to our Frontier Formation) to be an angular unconformity as interpreted by earlier workers.

Perry and others (1983) discussed the Beaverhead and unnamed Upper Cretaceous rocks in their discussion of the petroleum potential of the region; they did not discuss contacts between the Beaverhead and underlying strata, which they grouped into one unit. Nichols and others (1985) and Dyman and Nichols (1988) stated that the "Shine Hill conglomerate beds," the basal Beaverhead of Ryder and Scholten (1973) are equivalent to the Frontier Formation and are in part Cenomanian in age based on a reinterpretation of Ryder and Scholten (1973) palynomorph assemblages. Perry and others (1989) also used the Frontier name for the youngest pre-Beaverhead sequence and recognized an angular unconformity separating the Frontier and Beaverhead rocks.

Dyman and others (1989) presented detailed lithologic and petrologic data for the Frontier and subdivided the formation into three lithologic units, from base to top: lower volcaniclastic, middle mudstone-shale, and upper clastic (fig. 1). They recognized the angular unconformity between the Frontier and the overlying Beaverhead between Shine Hill and the Continental Divide (localities 1 and 2, fig. 2) and suggested that the Frontier-Beaverhead contact should be placed at the unconformity where it could be easily identified. As a result of detailed mapping, they recognized that limestone conglomerates in the basal Beaverhead contained much larger clasts (clasts greater than 6 in. (15.3 cm) in diameter) than similar conglomerates in the uppermost Frontier (clasts less than 2 in. (2.4 cm) in diameter). They also recognized that interbedded sandstones in both units were somewhat different. Basal Beaverhead sandstones are quartz-rich (quartzarenites), whereas upper Frontier sandstones are chert-rich (salt-and-pepper sandstones). When an angular unconformity was not evident, the first appearance of either clast-supported limestone conglomerates or quartzarenites was established as the basal units of the Beaverhead. Our recent field investigations, however, indicate that upper Frontier limestone conglomerates are also clast-supported.

LITHOLOGIC RELATIONSHIPS

Facies of the uppermost Frontier and lowermost Beaverhead interval vary from one locality to another within the study area. These facies are discussed in the following paragraphs in order to better understand the criteria for redefining the formational contact.

The sub-Beaverhead unconformity is well pronounced about 4 mi (6.4 km) west of Knob Mountain near Little Sheep Creek (locality 1, fig. 2; N½ secs. 27 and 28, T. 15 S., R. 8 W., Gallagher Gulch 7.5-minute topographic quadrangle) where the Beaverhead Group rests unconformably on beds as old as the Triassic Thaynes Formation and as young as the Lower Cretaceous lower part of the Blackleaf Formation. To the northwest in the Tendoy Mountains, about 10 mi (16.1 km) northwest of Lima, the Beaverhead rests unconformably on older Mesozoic or Paleozoic strata.

Near Knob Mountain, lithologic units in the basal Beaverhead are dominated by limestone conglomerates, and an angular unconformity occurs between the Frontier and the Beaverhead. The Frontier-Beaverhead contact near Knob Mountain is best exposed at the north end of a north-trending ridge (locality 2, figs. 2, 3; NW¼, sec. 30, T. 15 S., R. 8 W., Lima Peaks 7.5-minute topographic quadrangle). At this locality about 200 ft (60.9 m) of interbedded olive-green mudstone and siltstone, salt-and-pepper sandstone, and quartzite conglomerate are exposed in a gully at the base of the ridge west of Little Beaver Creek. Limestone conglomerate of the basal Beaverhead Group is exposed at the top of the gully in angular discordance with the upper Frontier strata. Limestone conglomerates are overlain by, and interbedded with, quartzite-clast conglomerates and quartzarenites. No evidence of faulting could be recognized at the contact at this locality.

About 6 mi (9.6 km) east of Knob Mountain, near Shineberger Creek (locality 3, fig. 2; NE¼ sec. 29, T. 15 S., R. 7 W., Snowline 7.5-minute topographic quadrangle), the angular unconformity is still present and the base of the Beaverhead is marked by limestone conglomerates grading upward into interbedded limestone conglomerates and quartzarenites. About 0.5 mi (0.8 km) to the southwest of locality 3 (fig. 2; S½ sec. 29, T. 15 S., R. 7 W., Paul Reservoir 15-minute topographic quadrangle) quartzite-clast conglomerates occur above the contact in the lower Beaverhead, but they are interbedded with limestone conglomerates and quartzarenites. The quartzite-clast conglomerates contain about 70 percent white, red, and gray quartzite, 15 percent dark-gray chert, 15 percent green to gray silicic volcanic clasts, and rare conglomerate and bedded chert clasts.

About 12 mi (19.3 km) northeast of Knob Mountain, at Monida, Montana, along the northeast flank of the Lima anticline (fig. 2), the Frontier-Beaverhead contact may be a thrust fault. At Monida, salt-and-pepper plagioclase- and chert-bearing sandstones, olive-green to brown mudstones, and shales are abundant in the Frontier. Our recent mapping indicates that these beds are in angular discordance with tan, quartz-rich sandstones of the Monida sandstone unit of the basal Beaverhead Group, from which they are separated by a covered interval more than 200 ft (60.9 m) wide (locality 7, fig. 2). Conglomerates at Monida occur only as discontinuous pebble lenses.

At the eastern end of the study area, along Idaho Creek near Humphrey, Idaho, (locality 6, figs. 2, 3; W½, sec. 6, T. 13 N., R. 36 E., Paul Reservoir 15-minute topographic quadrangle) lithologic relationships differ from those to the west. Salt-and-pepper sandstones, mudstones, and shales of the Frontier are overlain conformably by quartzite- and limestone-clast conglomerates. Ryder and Scholten (1973) recognized quartzite-clast conglomerates here and placed them in their "Divide quartzite conglomerate unit." Quartzite-clast conglomerates are abundant in both the upper Frontier and lower Beaverhead, and individual beds at locality 6 are thicker than those at localities 2 and 3. At localities 4 and 5 (fig. 2), along the west and east forks of Big Beaver Creek, typical Frontier rocks are overlain with apparent conformity by a mixed suite of quartzite-clast conglomerates and quartzarenites. The angular unconformity seems to disappear between localities 3 and 4.

Quartzite-clast conglomerates in the upper part of the Frontier Formation resemble those in the lower part of the Beaverhead Group at localities 1–7. Lithic sandstones with abundant chert and limestone fragments and pebble-conglomeratic zones with abundant rounded to subangular limestone pebbles are present in both units. Near locality 2 (fig. 2), in the upper Frontier Formation, sandstones with interbedded conglomeratic zones contain limestone clasts as much as 3 in. (7.6 cm) in diameter. Our ongoing field studies suggest that these limestone clasts were derived from Jurassic and Cretaceous formations and are unlike clasts in the Beaverhead limestone conglomerates. Limestone conglomerates in the lower Beaverhead contain much larger limestone clasts (greater than 15 in. (38.1 cm) in diameter) than the upper Frontier (as much as 2 in. (5.1 cm)), and conglomerates in the Beaverhead are clast-supported. Near locality 2, where strata are well exposed, distinguishing the Frontier and Beaverhead is best accomplished by identifying the angular unconformity separating the two units.

DISTINCTIVE UPPER FRONTIER LITHOLOGIC UNITS

Field mapping of Frontier and Beaverhead strata and recognizing a Frontier-Beaverhead contact in the area of this study are difficult tasks at localities 4 through 6 because the Frontier and Beaverhead are conformable. Quartzarenites are not always present in the Beaverhead, and the upper Frontier is typically poorly exposed. Two distinct lithologic units occur in the uppermost Frontier Formation at each of the localities studied but are absent from overlying Beaverhead beds: (1) conglomerates and conglomeratic sandstones derived from Cretaceous and Jurassic formations, and (2) bright green to olive-green porcellanites and tuffaceous and porcellanitic sandstones. At localities 1 through 6, a distinctive limestone conglomerate and interbedded conglomeratic sandstone occurs in the uppermost Frontier Formation (figs. 1 and 3). The conglomerate is rich in limestone clasts derived from the Kootenai gastropod limestone (uppermost Kootenai Formation) and Jurassic Rierdon Formation. Clasts include bioclastic limestones rich in high- and low-spired gastropods typical of the uppermost Kootenai, micritic limestone clasts typical of the lower Kootenai, and oolitic limestone clasts typical of the Rierdon Formation. Paleozoic limestone clasts are rare or absent (Dyman and others, 1989). The conglomerate and conglomeratic zones vary from a few feet to more than 10 ft thick (a meter to more than 3 m) and may include one or more distinct beds. However, the unit is not present everywhere in the study area and laterally grades into olive-green to brown mudstone and siltstone beds most typical of the Frontier.

Dark-green to olive-green and gray porcellanite, porcellanitic mudstone, and green tuffaceous and porcellanitic sandstone beds form the second distinct lithologic unit in the upper Frontier. The interval consists of one or more porcellanitic beds generally less than, but as much as 10 ft (3.1 m) thick interbedded with tuffaceous sandstone or porcellanitic sandstone beds. Porcellanite is hard and dense, may have small (less than 0.3 in. (0.6 cm) in diameter) lithophysae, and is finely laminated. Some laminations show distinct color variations. Tuffaceous sandstone may be crossbedded and ripple-laminated, and is fine to coarse grained. Sandstone contains abundant volcanic rock fragments, chlorite, and biotite. Distinct porcellanite zones are thin to medium bedded and appear to thin and thicken laterally. Many of the tuffaceous beds appear to have been reworked in an aqueous environment. This porcellanitic zone is overlain, underlain, and interbedded with the distinct limestone conglomerate derived from Kootenai and Rierdon sources. The porcellanitic interval lies stratigraphically below the uppermost Frontier exposed at localities 2 and 3 and lies immediately below the thick quartzite-clast conglomerate zones at localities 4 through 6. Two distinct porcellanite beds are present at locality 6 (fig. 3).

DISCUSSION

Criteria used by Dyman and others (1989) to establish the Frontier-Beaverhead contact are inadequate at localities 4 through 6 (fig. 2). First, an angular unconformity cannot be identified at these localities. Second, limestone conglomerates are rare or absent in the basal Beaverhead. Upper Frontier limestone conglomerates with Jurassic and Cretaceous clasts lie below the unconformity at localities 2 and 3 and are only locally present because of their fluvial

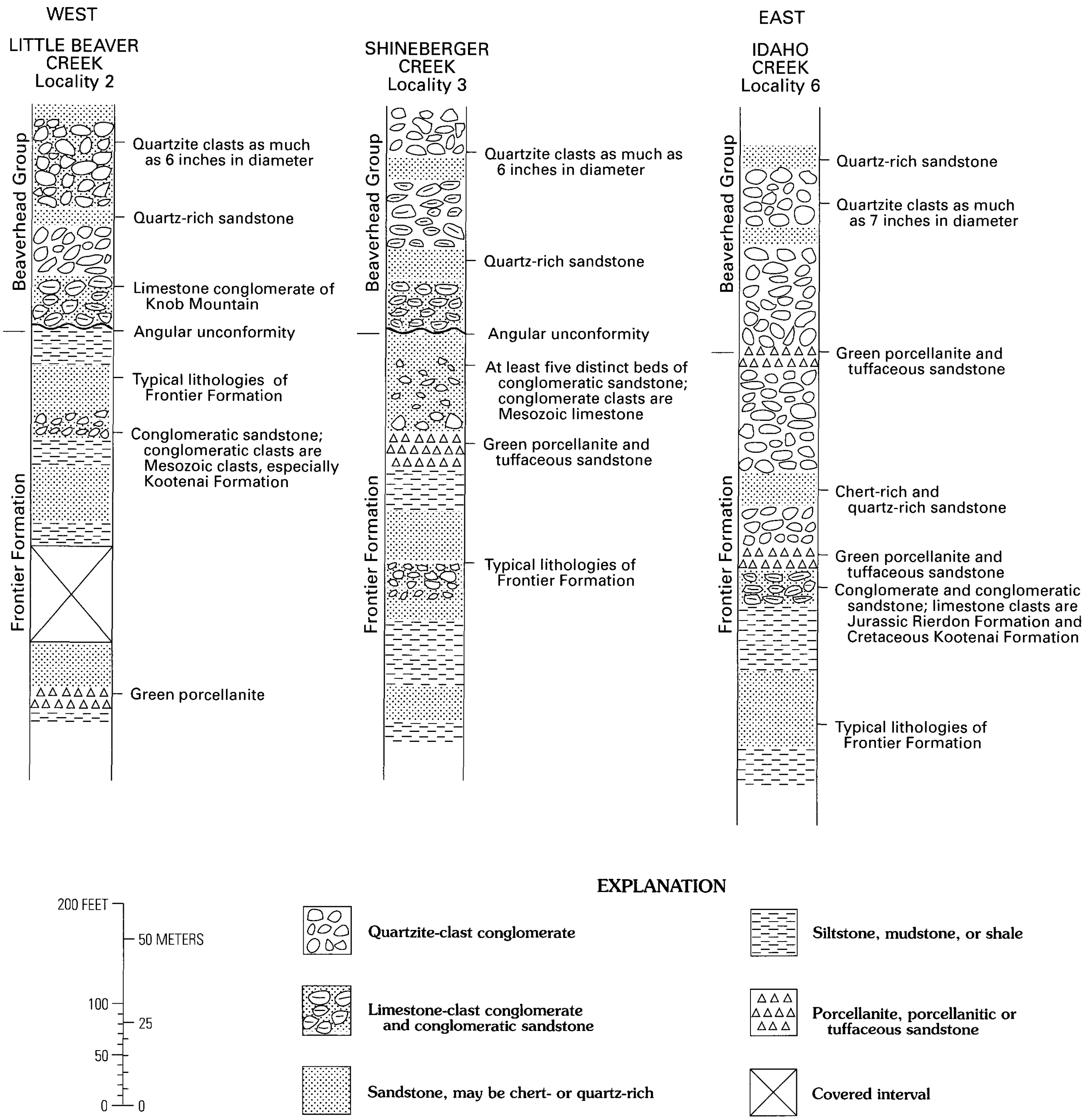

Figure 3. Generalized lithologic chart of upper part of Frontier Formation and lower part of Beaverhead Group showing major lithologic units exposed at or near the Frontier-Beaverhead contact at localities 2, 3, and 6 (fig. 2).

character. These beds are different from the basal Beaverhead limestone conglomerates at localities 2 and 3. Quartzite clast conglomerates with large clasts (greater than 6 in. (15.3 cm) in diameter) occur throughout the Frontier and Beaverhead. The informal lithologic units established by Dyman and others (1989) are large-scale units and can be generally recognized, but they are inadequate map units.

The green porcellanitic unit, however, is present at localities 1 through 6 (the stratigraphic position of Frontier beds at locality 7 cannot be adequately determined because of poor exposures) and is the best criteria for separating the Frontier and Beaverhead where no angular unconformity exists. The Frontier is absent at locality 1 and the angular unconformity is well exposed. The angular unconformity is well exposed at locality 2, and underlying and overlying rocks are typical for the two units. The green porcellanite zone, although poorly exposed, lies about 350 feet (106.7 m) below the unconformity at this locality, within typical upper Frontier beds. At locality 3, the angular unconformity is poorly exposed, but the green porcellanite zone lies about

150 ft (45.7 m) below it and is well exposed. At localities 4 through 6, where an angular unconformity cannot be recognized, the green porcellanitic zone is still well exposed and can be easily mapped (fig. 3).

Based on these new data, we recommend that the Frontier-Beaverhead contact be placed at the angular unconformity where it can be recognized. The contact separates two distinct lithologic associations interpreted as depositional cycles, in which each cycle contains several unique lithologic units and several lithologic units common to the other adjacent depositional cycle. Where the unconformity is absent, the contact should be placed at the top of the uppermost green porcellanitic unit of the upper Frontier Formation. The porcellanitic unit (1) is exposed everywhere in the Lima Peaks region where the upper Frontier occurs, (2) represents an excellent time marker, and (3) is near the top of the Frontier depositional cycle above several thousand feet of monotonous Frontier rocks that cannot be easily subdivided.

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APPENDIX

Aspen Formation:

The use of the term Aspen for mid-Cretaceous rocks near Lima, Montana persisted through the early 1980's although Skipp and Hait (1977) questioned use of the term. They based their concerns on the identification of the Vaughn Member of the Blackleaf Formation in two drill holes in the footwall of the Tendoy thrust. Perry and others (1983) similarly identified the Blackleaf at the same stratigraphic level in two wells flanking the Centennial Valley east of our study area. The Blackleaf Formation is Albian and Cenomanian in age and is, therefore, in part equivalent to the Aspen Formation. The thick sequence of post-Blackleaf pre-Beaverhead strata is younger in age and was identified as probably being a Frontier equivalent by Perry and others (1983). A later detailed study of the Blackleaf Formation by Dyman (1985) and stratigraphic studies by Dyman and Nichols (1988) and Tysdal and others (1989) clarified the Blackleaf-Frontier relationship and established the Frontier terminology.

Shine Hill Beds:

A significant source of confusion regarding the Frontier-Beaverhead contact deals with the outcrop belt of interbedded salt-and-pepper sandstones, mudstones and siltstones, quartzite-clast conglomerates, and porcellanites on the south flank of Shine Hill (SW¼NE¼, sec. 17, T. 15 S., R. 7 W., Snowline 7.5-minute topographic quadrangle; fig. 2). Scholten and others (1955), Ryder and Ames (1970), and Ryder and Scholten (1973) considered these beds to be basal Beaverhead outcropping beneath the Tendoy thrust. Ryder and Ames (1970) dated this sequence as Albian to Cenomanian based on palynomorph assemblages. This area was close to the Sawmill Creek locality of Ryder and Scholten (1973); they used the sequences of strata at this locality to support conformity between their Aspen and Beaverhead Formations. Wilson (1970) concluded that the quartzite-clast conglomerates were part of his Aspen rather than his Beaverhead Formation. Nichols and others (1985) also favored a pre-Beaverhead assignment for these strata but preferred to use the name Frontier Formation for them. Dyman and others (1989) illustrated that these rocks are probably part of the lower Frontier Formation.

Chapter B

Biostratigraphic Correlation of Santonian and Campanian Formations in the Northwestern Part of Yellowstone National Park, and the Madison Range and Livingston Area of Southwestern Montana

By R.G. TYSDAL and D.J. NICHOLS

U.S. GEOLOGICAL SURVEY BULLETIN 1962

CONTRIBUTIONS TO LATE CRETACEOUS STRATIGRAPHY
AND PALEONTOLOGY, WESTERN MONTANA

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CONVERSION FACTORS

Inch-pound units of measurement in this report may be converted to International System (SI) of metric units using the following conversion factors:

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
inch (in.)	2.54	centimeter (cm)

Biostratigraphic Correlation of Santonian and Campanian Formations in the Northwestern Part of Yellowstone National Park, and the Madison Range and Livingston Area of Southwestern Montana

By R.G. Tysdal *and* D.J. Nichols

Abstract

Biostratigraphic correlation of Santonian and Campanian formations in the Madison Range and the Livingston area of southwestern Montana and the northwestern part of Yellowstone National Park was accomplished largely with palynomorphs. Palynomorph-bearing sedimentary rocks from upper strata of the Everts Formation in the Madison Range were deposited during the latest Santonian to earliest Campanian. Palynological samples from several horizons within upper strata of the Everts Formation in Yellowstone National Park yielded assemblages that range from Coniacian through Santonian in age. Molluscan megafossils from strata beneath the Everts Formation in the Madison Range and from just north of the park indicate that the Everts in both areas probably is no older than middle Santonian. Palynomorphs from lower strata of the Landslide Creek Formation, which overlies the Everts in the park, are earliest Campanian in age.

In the vicinity of Livingston, Montana, palynomorphs from the lower part of the Cokedale Formation are of species that range from Coniacian through Santonian in age, but molluscan megafossils from beneath the Cokedale show that basal Cokedale strata are no older than middle Santonian. The middle part of the Cokedale yielded palynomorphs of middle to late Campanian age. Palynomorphs from the lower part of the Miner Creek Formation, which overlies the Cokedale, are of early Maastrichtian age and place an upper age limit on the Cokedale.

These biostratigraphic data indicate that the Cokedale Formation in the vicinity of Livingston, Montana, was deposited during the same general time span as the Livingston Formation in the Madison Range. The lower part of the Landslide Creek Formation in Yellowstone National Park is nearly the same age as basal strata of the Livingston Formation in the Madison Range and Cokedale strata near the town of Livingston; strata of the Landslide Creek must be time-equivalent to at least parts of these two formations.

INTRODUCTION

In the course of conducting geologic studies in the Madison Range of southwestern Montana in the early 1980's, the thick Upper Cretaceous sequence in the range was subdivided into formations by Tysdal and Simons (1985). The subdivision was accomplished through litho- and biostratigraphic correlation with formations present eastward in the vicinity of Livingston, Mont., and the northwestern part of Yellowstone National Park (fig. 1). As part of the biostratigraphic studies, new collections of plant microfossils (palynomorphs) were obtained from rocks in the park and are reported here for the first time. No new collections were obtained in the Livingston area, but we reevaluated collections of palynomorphs identified by E.B. Leopold and R.H. Tschudy in the 1960's. The fossils in these collections were reported in Roberts (1972) and were assigned provisional names at that time. We place our emphasis on updating identifications listed therein, in accordance with more current taxonomy and nomenclature, and on the biostratigraphic implications of certain species previously reported.

In this paper we establish the ages of the Everts Formation and the lower part of the Landslide Creek Formation in Yellowstone National Park, and we show their biostratigraphic correlation with formations in the Madison Range and in the vicinity of Livingston, Mont. (fig. 1). Age relationships of the various formations are shown in the correlation chart of figure 2. In the following sections, a general description is provided for each formation of concern and is followed by a review of the age assignment and refinement thereof.

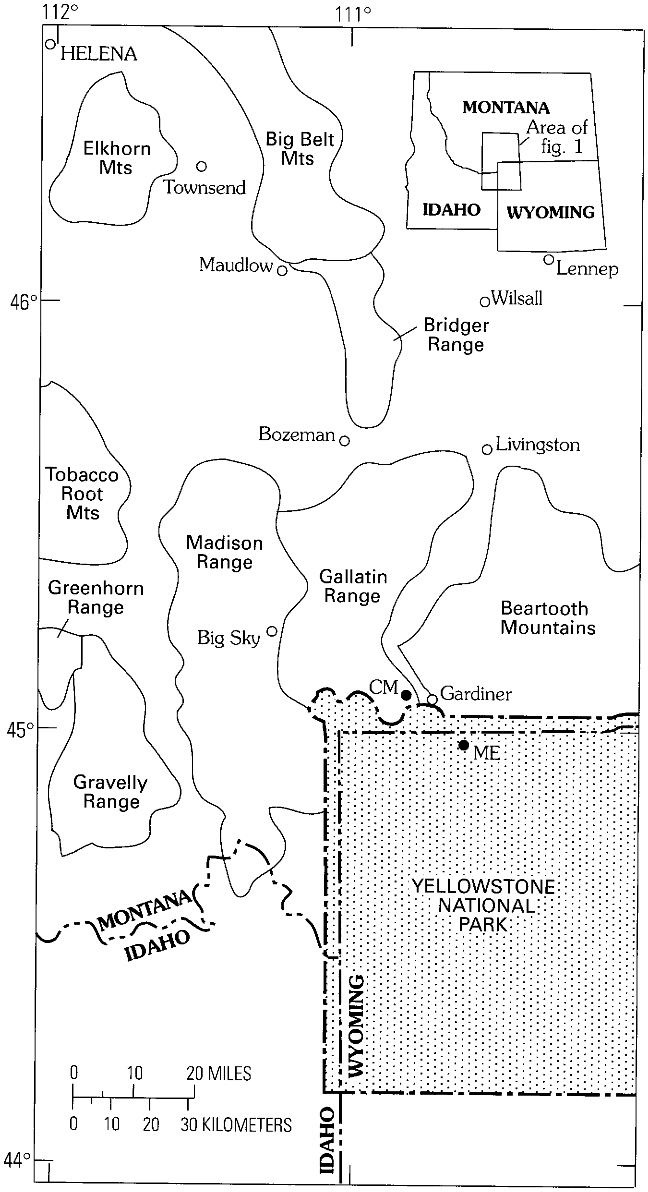


Figure 1. Index map of part of southwestern Montana showing mountain ranges, towns, and localities referenced in text. *CM*, Cinnabar Mountain; *ME*, Mount Everts.

Everts Formation

The Everts Formation was named by Fraser and others (1969) for rocks exposed on Mount Everts in the northwestern part of Yellowstone National Park. They described the formation as being about 1,250 ft (380 m) thick and consisting of interbedded light-colored lenticular sandstone and medium- to light-gray mudstone that is locally green, yellow, or brown, especially near the top. The formation contains altered volcanic ash. No type section was designated due to poor exposures and extreme local variability of the rocks of the formation.

In the Madison Range, the Everts Formation is about 1,400 ft (430 m) thick. It consists mainly of quartzose sandstone and interbedded siltstone, but the lower 200–300 ft (60–90 m) is thin-bedded mudstone, siltstone, shale, and minor sandstone and coal (Tysdal and Simons, 1985).

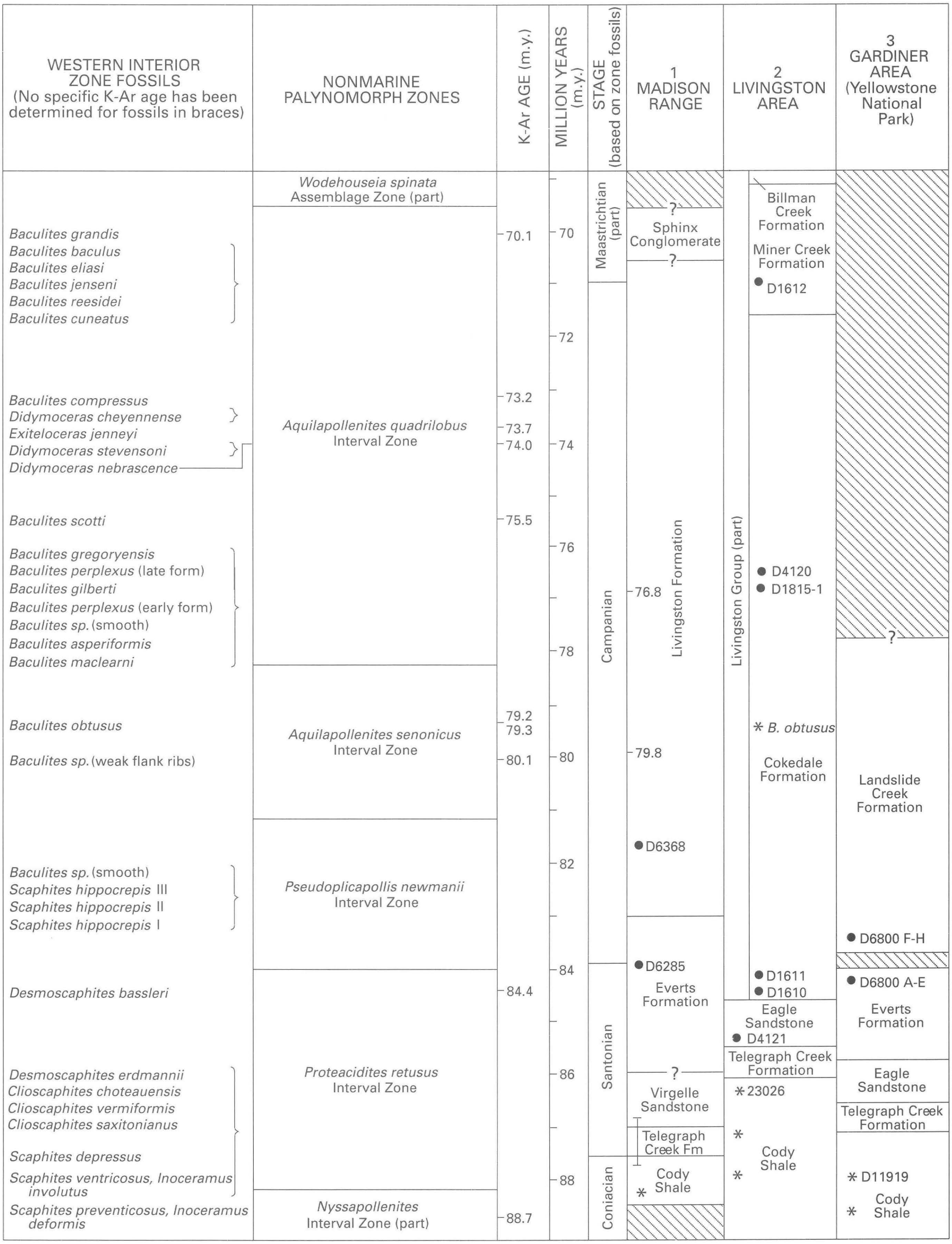
Age

The Everts Formation was considered to be mainly of Campanian age by Fraser and others (1969) on the basis of lithologic correlation with the Cokedale Formation near Livingston, Mont. These authors stated that the lowermost part could be late Santonian in age, however. The Everts is gradational with the underlying Eagle Sandstone and contains mollusks that are generically similar to those present in the Eagle, but the mollusks of the Everts Formation are not age-diagnostic. Fraser and others (1969) reported the following mollusks from near the base of the formation:

Ostrea sp.
Cymbophora sp., cf. *C. utahensis* Meek

Figure 2 (facing page). Correlation chart of Santonian and Campanian formations (and bounding units) in the Madison Range (col. 1), the Livingston, Mont., area (col. 2), and the northwestern part of Yellowstone National Park (col. 3). Boundaries of the Upper Cretaceous stages and Western Interior zone fossils are modified from Obradovich and Cobban (1975). There is no international agreement as to placement of the Campanian-Maastrichtian boundary; Obradovich and Cobban (1975) placed this boundary between the *Baculites cuneatus* and *B. reesidei* zone fossils. The Coniacian-Santonian boundary has been adjusted to include the *Scaphites depressus* faunal zone in uppermost part of the Coniacian, reflecting current usage (W.A. Cobban, written commun., 1989). Ages in K-Ar (potassium-argon) column are from Obradovich (1988), except that the 88.7 Ma of the *S. ventricosus* zone is from Obradovich and Cobban (1975), after recalculation for new ^{40}Ar decay constants (Steiger and Jäger, 1977). Ages in the K-Ar column correspond to specific, indicated zone fossils in the column headed "Western Interior Zone Fossils." Fossils within braces in the latter column are not tied to specific ages, and no age (or age range) is implied other than biostratigraphic position within the sequence and the age constraint afforded by zone fossils that have been dated. Individual zone fossils, or sequences of zone fossils, within braces could be slightly younger or older than indicated by position in the figure.

Column 1 is modified from Tysdal and others (1987). Column 2 is modified from Roberts (1972). Column 3 is from the present study. In column 1 (Madison Range), the two numbers are K-Ar ages on volcanic rocks. *Clioscaphites saxitoniatus* and *Scaphites depressus* occur together in both the Virgelle Sandstone and the Cody Shale of the Madison Range; hence, the two faunal zones overlap, and the two range zones are indicated by a single vertical bar. This overlap differs from findings in north-central Montana where *C. saxitoniatus* is wholly younger than *S. depressus* (W.A. Cobban, oral commun., 1984, in Tysdal and others, 1987). Solid circle, microfossil collection and locality number referenced in text; *, megafossil collection, with locality number shown only if locality referenced in text.


WESTERN INTERIOR ZONE FOSSILS (No specific K-Ar age has been determined for fossils in braces)
NONMARINE PALYNOMORPH ZONES
K-Ar AGE (m.y.)
MILLION YEARS (m.y.)
STAGE (based on zone fossils)
1 MADISON RANGE
2 LIVINGSTON AREA
3 GARDINER AREA (Yellowstone National Park)
Baculites grandis
Baculites baculus
Baculites eliasi
Baculites jenseni
Baculites reesidei
Baculites cuneatus
Baculites compressus
Didymoceras cheyennense
Exiteloceras jenneyi
Didymoceras stevensoni
Didymoceras nebrascence
Baculites scotti
Baculites gregoryensis
Baculites perplexus (late form)
Baculites gilberti
Baculites perplexus (early form)
Baculites sp. (smooth)
Baculites asperiformis
Baculites maclearni
Baculites obtusus
Baculites sp. (weak flank ribs)
Baculites sp. (smooth)
Scaphites hippocrepis III
Scaphites hippocrepis II
Scaphites hippocrepis I
Desmoscaphites bassleri
Desmoscaphites erdmannii
Clioscaphites choteauensis
Clioscaphites vermiformis
Clioscaphites saxitonianus
Scaphites depressus
Scaphites ventricosus, Inoceramus involutus
Scaphites preventicosus, Inoceramus deformis
Wodehouseia spinata Assemblage Zone (part)
Aquilapollenites quadrilobus Interval Zone
Aquilapollenites senonicus Interval Zone
Pseudoplicapollis newmanii Interval Zone
Proteacidites retusus Interval Zone
Nyssapollenites Interval Zone (part)
70.1
73.2
73.7
74.0
75.5
79.2
79.3
80.1
84.4
88.7
70
72
74
76
78
80
82
84
86
88
Maastrichtian (part)
Campanian
Santonian
Coniacian
Sphinx Conglomerate
Livingston Formation
76.8
79.8
D6368
D6285
Everts Formation
Virgelle Sandstone
Telegraph Creek Fm
Cody Shale
Livingston Group (part)
Billman Creek Formation
Miner Creek Formation
D1612
D4120
D1815-1
B. obtusus
Cokedale Formation
D1611
D1610
Eagle Sandstone
D4121
Telegraph Creek Formation
23026
Cody Shale
Landslide Creek Formation
D6800 F-H
D6800 A-E
Everts Formation
Eagle Sandstone
Telegraph Creek Formation
D11919
Cody Shale

We collected plant microfossils (palynomorphs) from several horizons in the upper 400 ft (120 m) of the Everts Formation in Yellowstone National Park, from the Mount Everts measured section 1 of Fraser and others (1969, p. 99–100). The collection (USGS paleobotany localities D6800–A, B, C, D, E) yielded the following fossils, some of which are shown in figure 3:

Araucariacites sp.
Cicatricosisporites sp.
Corollina sp.
Cupuliferoidaepollenites minutus (Brenner) Singh
Cyathidites minor Couper
Foraminisporis wonthaggiensis (Cookson and Dettmann) Dettmann
Gleicheniidites senonicus Ross
Hazaria sp. cf. *H. canadiana* Srivastava
Laevigatosporites sp.
Monocolpopollenites sp.
Pityosporites sp.
Proteacidites retusus Anderson
Quadripollis krempii Drugg
Taxodiaceaepollenites hiatus (Potonié) Kremp
Vitreisporites pallidus (Reissinger) Nilsson

The assemblage represents the *Proteacidites retusus* Interval Zone, which ranges from Coniacian through Santonian in age (fig. 2).

We obtained no fossils from basal strata of the Everts Formation in Yellowstone National Park and none have been reported in the literature. The age of the basal strata of the Everts can be no older than the late Coniacian marine mollusk *Inoceramus involutus* (Sowerby) collected from the lower part of the Cody Shale, which lies stratigraphically

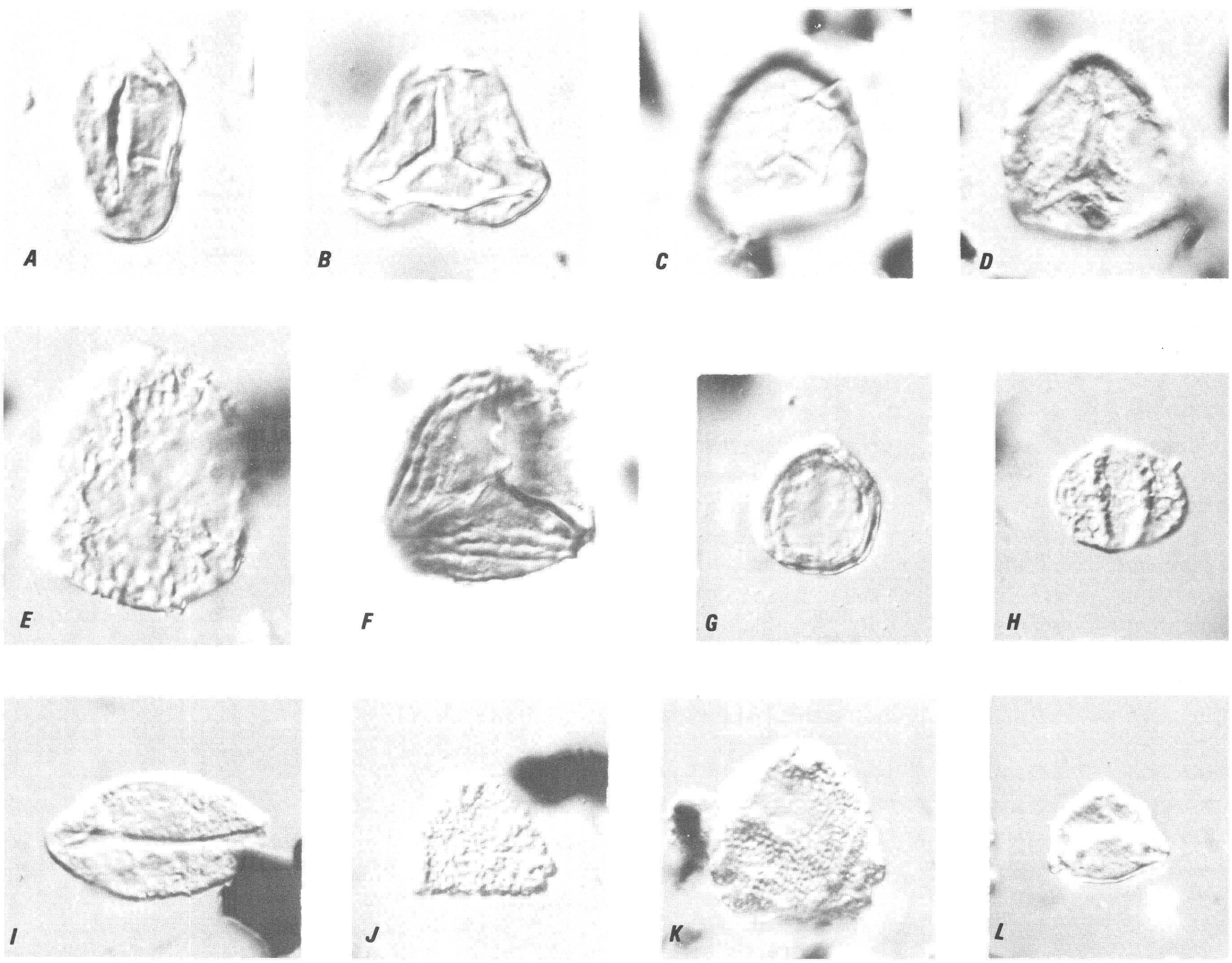


Figure 3. Stratigraphically significant pollen and spores from the Everts and Landslide Creek Formations in Yellowstone National Park. *A, Laevigatosporites* sp.; *B, Cyathidites minor* Couper; *C, Stereisporites* sp. 1; *D, Stereisporites* sp. 2; *E, Foraminisporites wonthaggiensis* (Cookson and Dettmann) Dettman; *F, Cicatricosisporites* sp.; *G, Corollina* sp.; *H, Vitreisporites pallidus* (Reissinger) Nilsson; *I, Monocolpopollenites* sp.; *J, Proteacidites retusus* Anderson; *K, Proteacidites* sp.; *L, Pseudoplicapollis newmanii* Nichols and Jacobson. Specimens *A, B, E, F, G, H, I,* and *J* are from the Everts Formation; *C, D, K,* and *L* are from the Landslide Creek Formation. All specimens enlarged ×1000.

below the Everts (fig. 2). The mollusk was collected about 12 mi (20 km) northwest of Mount Everts, near Cinnabar Mountain (*CM*, fig. 1; USGS Mesozoic locality D11919, fig. 2). We have placed the basal contact of the Everts in Yellowstone National Park in the middle Santonian. This placement allows time for deposition of the middle and upper parts of the Cody Shale, the Telegraph Creek Formation, and the Eagle Sandstone, which, according to Fraser and others (1969), total about 2,000 ft (600 m) thick.

In the Madison Range, a palynomorph assemblage from about 300 ft (90 m) below the top of the 1,400-ft-(425-m-) thick Everts yielded key forms of both the *Proteacidites retusus* and *Pseudoplicapollis newmanii* Interval Zones (USGS paleobotany collection D6285). The co-occurrence of these forms suggests that the upper strata of the Everts in the Madison Range were deposited during the latest Santonian to earliest Campanian (Tysdal and others, 1987).

Basal strata of the Everts Formation in the Madison Range have not been dated. They are no older than early Santonian, however, because the marine mollusk *Clioscaphites saxitonianus* (McLearn) of that age was collected from basal strata of the Virgelle Sandstone (Tysdal and others, 1987), which lies directly beneath the Everts. In figure 2, the base of the Everts is shown as middle Santonian, which allows a short amount of time for deposition of Virgelle rocks above its fossil-bearing basal strata.

Landslide Creek Formation

The Landslide Creek Formation was named by Fraser and others (1969) for outcrops along Landslide Creek in the northwestern part of Yellowstone National Park, 2 mi (3 km) west of Gardiner, Mont. (fig. 1). It unconformably overlies the Everts Formation and is unconformably overlain by Tertiary volcanic rocks. The Landslide Creek is a nonmarine unit that consists of interbedded dark-colored sandstone, local conglomerate, and varicolored mudstone and claystone. Volcanic debris, including bentonite, occurs throughout the formation. Fraser and others (1969) found the formation to be poorly exposed and subject to extensive landsliding. They measured several partial sections to determine the lithologic composition of the formation and its thickness, which they gave as between 1,300 and 2,300 ft (400–700 m); but they could not determine the thickness more accurately due to poor exposures. No type section was designated.

Age

The Landslide Creek Formation was assigned a Late Cretaceous age on the basis of scattered fragments of dinosaur bones and a palynomorph assemblage collected by J.D. Love (J.D. Love, written commun., 1961, in Fraser and others, 1969, p. 36). No fossil report is known to exist for the dinosaur bones, but we reexamined the original fossil report concerning the palynomorph assemblage (USGS unpub. laboratory report F–58–32D, sample No. L58–33–A). E.B. Leopold, who examined the collection and wrote the report, stated that the pollen and spores were rather undiagnostic and were of late Mesozoic age although probably not as young as Late Cretaceous.

Palynomorphs were collected by us from the lower 150 ft (45 m) of the Landslide Creek Formation in Yellowstone National Park, from the Mount Everts measured section 1 of Fraser and others (1969, p. 97–99). The collection (USGS paleobotany localities D6800–F, G, H) yielded the following fossils, some of which are shown in figure 3:

Camarozonosporites insignis Norris
Cicatricosisporites sp.
Cupuliferoidaepollenites minutus (Brenner) Singh
Cyathidites minor Couper
Foraminisporis wonthaggiensis (Cookson and Dettmann) Dettmann
Gleicheniidites senonicus Ross
Hazaria sp. cf. *H. canadiana* Srivastava
Laevigatosporites sp.
Proteacidites retusus Anderson
Pseudoplicapollis newmanii Nichols and Jacobson
Stereisporites sp.
tricolpate pollen, undifferentiated
trilete spores, undifferentiated

The assemblage represents the *Pseudoplicapollis newmanii* Interval Zone, which is indicative of the earliest Campanian (fig. 2).

Livingston Group and Livingston Formation

The name Livingston Formation was applied by Weed (1893) to a thick sequence of volcaniclastic strata in the vicinity of Livingston, Mont. (fig. 1) and was extended to the Madison Range by Peale (1896). Roberts (1963, 1972) redefined strata assigned to the Livingston near the town of Livingston, raised the unit to group status, and defined four new formations within the group. Formations of the Livingston Group, in ascending order, are as follows: Cokedale Formation, Miner Creek Formation, Billman Creek Formation, and Hoppers Formation. The Livingston has not been subdivided into formations in the Madison Range, however, and the name Livingston Formation is still used there. In this paper, we discuss the Livingston Formation in the Madison Range and the Cokedale Formation of the Livingston Group in the vicinity of the town of Livingston. A palynological assemblage from the basal part of the Miner Creek Formation also is discussed because it defines the upper age limit of the Cokedale Formation.

Livingston Formation

The Livingston Formation in the Madison Range is preserved in a 30-square-mile (78-square-kilometer) area about 10 mi (16 km) southwest of the town of Big Sky, Mont. (fig. 1). The formation comprises a sequence of volcanic and volcaniclastic rocks that ranges from about 1,800 to 2,800 ft (550–850 m) thick. It has been subdivided into three informal members (Beck, 1960; Hadley, 1980; Tysdal and others, 1987). The lower member is a composite unit of mudstone, siltstone, sandstone and conglomeratic sandstone, and minor tuff, basalt, and volcanic conglomerate; the middle member is composed of volcanic flows and flow breccia; and the upper member is composed of volcaniclastic sandstone and conglomeratic volcaniclastic sandstone (Tysdal and others, 1987). The formation is conformable with the underlying Everts Formation and, at least in some areas, with the overlying Sphinx Conglomerate (fig. 2).

Age

The lower member of the Livingston Formation in the Madison Range yielded palynomorphs of the earliest Campanian *Pseudoplicapollis newmanii* Interval Zone (USGS paleobotany collection D6368). Flows stratigraphically higher in the lower member yielded radiometric dates of 79.8±2.9 Ma and 76.8±2.5 Ma (shown in fig. 2, col. 1), which are early to middle Campanian and middle Campanian in age, respectively (Tysdal and others, 1987).

Cokedale Formation of Livingston Group

The Cokedale Formation is 1,550 ft (472 m) thick in the area of Livingston, Mont. (fig. 1), and consists of siltstone, sandstone, mudstone, water-laid tuff, bentonite, carbonaceous claystone, and, locally, coal. Roberts (1972) reported that the sedimentary strata were derived mainly from volcanic rocks of andesitic composition. The Cokedale is conformable with the underlying Eagle Sandstone and with the overlying Miner Creek Formation.

Age

The Cokedale Formation was assigned a Campanian age by Roberts (1972), who reported that it contains fossils of the *Baculites obtusus* faunal zone in its lower part. Roberts (1972, table 4) also published an extensive list of palynomorphs recovered from the lower and middle parts of the type section of the formation (USGS paleobotany localities D1610 and D1611 (lower part); D1815–1 and D4120 (middle part)).

Mollusks of the *Baculites obtusus* faunal zone were reported in a lower tuffaceous zone of the Livingston Group near Livingston (Roberts, 1972, p. C39). Several tuffaceous zones are present within the lower strata of the type section of the Cokedale Formation (of the Livingston Group), which is 1,550 ft (472 m) thick (measured section 16 of Roberts, 1972, p. C77–C84). We are uncertain which tuffaceous zone within the type section of the Cokedale is the lower tuffaceous zone of the Livingston, because Roberts (1972) did not identify it in his Cokedale measured section. Nevertheless, table 4 of Roberts (1972) showed that palynomorph collections D1851–1 and D4120 are from the middle part of the section (about 657 ft (200 m) and 670 ft (204 m), respectively, above the base of the section). Therefore, megafauna of the *B. obtusus* faunal zone must have been obtained from stratigraphically lower than these palynomorph collections.

Microfossils in the palynological collections just mentioned were identified by E.B. Leopold and R.H. Tschudy in the 1960's and were assigned provisional names (Roberts, 1972). We reevaluated palynomorph occurrence data of these collections. Emphasis was placed on updating identifications listed by Roberts (1972) in accordance with more current taxonomy and nomenclature, and on the biostratigraphic implications of certain species previously reported. The objective was to refine age determinations of the Cokedale Formation on the basis of palynology. Our results are summarized in the following paragraphs. Age determinations presented here are based on palynomorph biozones described by Nichols and others (1982).

Palynomorph assemblages identified by E.B. Leopold and R.H. Tschudy from localities D1610 and D1611 in the lower part of the Cokedale Formation include 20 species of spores and pollen. Among these, three species of the angiosperm pollen genus *Proteacidites* are biostratigraphically important. They indicate an age of Coniacian or Santonian (*Proteacidites retusus* Interval Zone, fig. 2). The genus *Proteacidites* also ranges throughout the Campanian and Maastrichtian, but the assemblages reported from the lower part of the Cokedale lack species that would indicate a post-Santonian age.

A maximum age for the Cokedale was determined from fossils in strata beneath the formation. The Eagle Sandstone lies directly beneath the Cokedale and yielded a palynological collection (USGS paleobotany locality D4121) from its middle strata (Roberts, 1972). The fossils, which were originally identified by R.H. Tschudy and which we reexamined for our study, are indicative of the *Proteacidites retusus* Interval Zone. This collection, as that from the basal part of the Cokedale, could be as old as Coniacian. The maximum age of the microfossils is determined by megafossils from downsection. About 120 ft (37 m) below the top of the upper member of the Cody Shale, the marine mollusk *Clioscaphites choteauensis* was reported (Richards, 1957; Roberts, 1972; USGS Mesozoic locality 23026), which is middle Santonian in age. Basal strata of the Cokedale, therefore, can be no older than middle Santonian.

We know of no published references to age-diagnostic microfossils or megafossils from between the base of the Cokedale and the upper member of the Cody (in the vicinity of Livingston) that would further restrict the lower age limit of the basal Cokedale. However, between the levels of the basal Cokedale plant microfossil collections and that of the megafossil from the upper member of the Cody lie about 1,000 ft (305 m) of strata (uppermost part of the Cody Shale, and all of the Telegraph Creek Formation and Eagle Sandstone). If these strata represent about the same amount of time as strata of the same formations in the Madison Range (fig. 2), then the basal strata of the Cokedale could be middle to late Santonian in age.

The middle part of the Cokedale Formation yielded 41 palynomorph species from localities D1815–1 and D4120 (Roberts, 1972). Among these species, only two are in common with the assemblages from the lower part of the formation, suggesting that the lower and middle parts of the Cokedale are of significantly different ages. The biostratigraphically significant species from the middle part are as follows: *Proteacidites* (four species differing from those in the lower assemblage); the angiosperm pollen species *Aquilapollenites trialatus* (= Aquila 4 var. of Roberts, 1972, table 4), *Fibulapollis scabratus* (= Aquila 29 of Roberts, 1972, table 4), and *Cranwellia* sp. (= Aquila 9 of Roberts, 1972, table 4); and the fern spore species *Balmeisporites kondinskayae* (= Charon-1 of Roberts, 1972, table 4) and *Kuylisporites scutatus* (= Hemi-4 of Roberts, 1972, table 4). This assemblage indicates a middle to late Campanian age (lower part of the *Aquilapollenites quadrilobus* Interval Zone).

The upper age limit of the Cokedale Formation was determined from fossils in the lower part of the Miner Creek Formation, which overlies the Cokedale. The palynomorph assemblage from locality D1612 (Roberts, 1972) in the lower part of the Miner Creek includes 46 species, of which only 7 are in common with those of the Cokedale Formation. Biostratigraphically important taxa from the Miner Creek are the angiosperm pollen species *Aquilapollenites delicatus* (= Aquila 6 of Roberts, 1972, table 4), *A. quadrilobus* (= Aquila 17 of Roberts, 1972, table 4), *A. turbidus* (= Aquila 2A of Roberts, 1972, table 4), *Manicorpus calvus* (= Aquila 5 of Roberts, 1972, table 4), *Kurtzipites circularis* (= C3-sm22 of Roberts, 1972, table 4), and *Proteacidites* sp. This assemblage suggests that the lower part of the Miner Creek Formation could be as young as early Maastrichtian (upper part of the *Aquilapollenites quadrilobus* Interval Zone). Uppermost strata of the Cokedale Formation, therefore, are considered to be of earliest Maastrichtian age, based on this polynomorph assemblage and on molluscan megafossils from the Miner Creek Formation that also place an upper age limit on the Cokedale, as discussed in the following paragraphs.

Age Relations Near the Cokedale–Miner Creek Contact

The Campanian-Maastrichtian boundary, as selected by Obradovich and Cobban (1975), is at the top of the *B. cuneatus* faunal zone and base of the *B. reesidei* faunal zone of the Cretaceous Western Interior zone fossils (fig 2). Roberts (1972, p. C39) stated that "an upper tuffaceous zone [of the Livingston] in the lower part of the Miner Creek Formation represents the *B. compressus* and *B. cuneatus* faunal zones ..." Roberts (1972, p. C48) also wrote that a megafauna of these zones, collected near Wilsall, Mont. (fig. 1), about 25 mi (40 km) north of the type section of the Miner Creek, is from marine sandstone that correlates with the Lennep Sandstone near Lennep, Mont. (fig. 1). In the type section of the Miner Creek, the lithic correlative of these marine sandstones is the nonmarine Sulphur Flats Sandstone Member, which constitutes the lower 323 ft (98 m) of the Miner Creek (Roberts, 1972). This lithic correlation suggests that the *B. compressus* and *B. cuneatus* megafaunal collection lies stratigraphically below the microfossils from USGS paleobotany locality D1612, which was obtained from 421 ft (128 m) above the base of the 1,350-ft- (411-m-) thick section, and is consistent with our conclusion that the polynomorph assemblage of collection D1612 is of early Maastrictian age.

On the basis of mapping in the area of Maudlow, Mont. (fig. 1), Skipp and McGrew (1977) reinterpreted Robert's (1972) correlation of the Sulphur Flats Sandstone Member of the Miner Creek Formation with the *B. compressus*- and *B. cuneatus*-bearing sandstone near Wilsall and the Lennep Sandstone near Lennep. Skipp and McGrew placed the Sulphur Flats Sandstone Member at about the level of the faunal zones of *Baculites* sp. (smooth) and *B. perplexus* (late form) (fig. 2). The entire Miner Creek Formation was considered to be Campanian, with the uppermost part time-equivalent to the Lennep Sandstone. We disagree with this reinterpretation and consider Robert's (1972) correlation of the Sulphur Flats Sandstone Member with the Lennep Sandstone to be more nearly correct, based on the following reasoning.

Tschudy (in Roberts, 1972, p. C48) originally interpreted the palynomorphs from USGS paleobotany locality D1612 (and a stratigraphically higher collection from locality D1613) in the Miner Creek Formation as containing species indicative of the upper one-fourth of the Campanian and the Maastrichtian. As described earlier, our reinterpretation of the palynomorphs assemblage in collection D1612 indicates an early Maastrichtian age, and the assemblage definitely is younger than the *B. compressus* and *B. cuneatus* faunal zones. The Campanian-Maastrichtian boundary is at the top of the *B. cuneatus* faunal zone and base of the *B. reesidei* faunal zone. The microfossil collections from paleobotany localities D1815–1 and D4120, near the middle of the Cokedale Formation, are middle to late Campanian in age. These data indicate (1) that at least the upper two-thirds of the Miner Creek Formation is early Maastrichtian or younger, and (2) that the age of the Sulphur Flats Sandstone Member is late Campanian to early Maastrichtian in age. The age of the Sulphur Flats Sandstone Member is considerably younger than that assigned by Skipp and McGrew (1977) on the basis of mapping, and is in agreement with the age assignment and lithostratigraphic correlation of Roberts (1972).

REGIONAL CORRELATION

The newly reported and reevaluated biostratigraphic data reported on here, and existing data from the Madison Range, indicate that the Livingston Formation in the Madison Range and the Cokedale Formation in the vicinity of Livingston, Mont., were deposited during the same general time span. The lower part of the Landslide Creek Formation, in the northwestern part of Yellowstone National Park, is nearly the same age as the basal parts of the Livingston and Cokedale Formations, and overlying strata of the Landslide Creek must be time-equivalent of at least part of these two formations.

The Livingston and Landslide Creek Formations are nonmarine and the Cokedale is largely nonmarine. All three formations contain abundant volcanic debris and fall within the span of time generally associated with deposition of the Elkhorn Mountains Volcanics (south of Helena, fig. 1) (Robinson and others, 1968; Tilling, 1974). This was a time of widespread volcanism in southwestern Montana, and the volcanic and volcaniclastic rocks had several local sources (Roberts, 1972). A local source may have existed for flows in the Livingston Formation in the Madison Range (Tysdal and others, 1987). Localized sources of volcanic rocks existed for time-equivalent rocks of the Cokedale in the Maudlow area (fig. 1) (Skipp and McGrew, 1977). Along the northeast flank of the Beartooth Mountains, volcanic rocks intertongue with the Eagle Sandstone (Rouse and others, 1937). The main phase of a stock that intruded these volcanics yielded rubidium-strontium dates of about 84 Ma (Meen and Eggler, 1987), which is about the Santonian-Campanian boundary and time-equivalent with some of the strata of the formations discussed in the present report.

CONCLUSIONS

1. The Everts Formation is middle to late Santonian in age, and may be as young as early Campanian in the Madison Range.

2. The lower part of the Landslide Creek Formation is early Campanian. The upper part of the formation has not been dated.

3. The Cokedale Formation in the Livingston area ranges from middle or late Santonian to late Campanian in age.

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Chapter C

Occurrence and Significance of the Middle Turonian (Upper Cretaceous) Belemnite *Actinocamax* in Central Western Montana

By WILLIAM A. COBBAN

U.S. GEOLOGICAL SURVEY BULLETIN 1962

CONTRIBUTIONS TO LATE CRETACEOUS STRATIGRAPHY
AND PALEONTOLOGY, WESTERN MONTANA

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CONVERSION FACTORS

Inch-pound units of measurement in this report may be converted to International System (SI) of metric units using the following conversion factors:

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometers (km)
inch (in.)	2.54	centimeter (cm)

Occurrence and Significance of the Middle Turonian (Upper Cretaceous) Belemnite *Actinocamax* in Central Western Montana

By William A. Cobban

Abstract

Two specimens of *Actinocamax* were recently found in the upper part of the Coberly Formation in Powell County, southeast of Drummond, Montana. Although badly weathered, the specimens are probably *A. manitobensis* (Whiteaves), a species known only from the ammonite zone of *Collignoniceras woollgari* of early middle Turonian age. The specimens were associated with *Rhynchostreon suborbiculatum* (Lamarck), an exogyrine bivalve known in the Western Interior only from rocks of middle Turonian age. The discovery of *Actinocamax* in the dominantly nonmarine Upper Cretaceous rocks of central western Montana is significant in precisely dating a marine transgression into this area.

INTRODUCTION

Age-diagnostic marine molluscan fossils were recently discovered in the Coberly Formation in central western Montana. According to Gwinn (1961), the Coberly consists of 570–650 ft (feet) (174–198 m (meter)) of "fossiliferous grey limestones and tan salt-and-pepper sandstones of early Late Cretaceous age lying between the Dunkleberg member of the Blackleaf formation below and the Jens formation above...High-spired snail shells and oyster fragments are found throughout the member."

While examining upper Coberly outcrops in 1987 in the Hoover Creek drainage 7.5 mi (mile) (12 km (kilometer)) southeast of Drummond (fig. 1), near the Powell-Granite County line, an exogyrine bivalve, *Rhynchostreon suborbiculatum* (Lamarck), was found by C.A. Wallace, R.G. Tysdal, T.S. Dyman, and the author (all U.S. Geological Survey), and S.M. Vuke-Foster and E.T. Ruppel (both Montana Bureau of Mines and Geology). This find is significant in that in the Western Interior of the United States *R. suborbiculatum* has been found only in marine rocks of middle Turonian age. Several specimens of this important guide fossil from the Carlile Shale of south-central Colorado were illustrated by Stanton (1893, pl. 5, fig. 6, pl. 6, figs. 1, 2, pl. 8, fig. 1). The middle Turonian of the Western Interior has the following ammonite zonation, from oldest to youngest; *Collignoniceras woollgari*, *Prionocyclus percarinatus*, and *P. hyatti*. *Rhynchostreon suborbiculatum* has been found in the zones of *C. woollgari* and *P. hyatti*, which gives the bivalve a range entirely through the middle Turonian.

In hopes of more closely dating the marine transgression represented by strata in the upper part of the Coberly Formation, the author, assisted by his son Robert, visited the Hoover Creek locality in 1989 in an attempt to find ammonites. We failed at this, but Robert discovered two badly weathered specimens of the belemnite *Actinocamax* associated with *Rhynchostreon suborbiculatum*. This is an important find inasmuch as *Actinocamax* is known in the middle Turonian of the Western Interior only from the zone of *Collignoniceras woollgari* (Cobban, 1983, p. 20), which suggests that the upper part of the Coberly is early middle Turonian.

LOCALITY OF *ACTINOCAMAX*

The two weathered specimens of *Actinocamax* (fig. 2) were found in brown-weathered, olive-gray, very fine grained, concretionary sandstone at USGS Mesozoic locality D12820 in the Hoover Creek valley about 7½ mi (12 km) southeast of Drummond near the center of the NE¼ sec. 17, T. 10 N., R. 11 W., Powell County. The specimens are from near the top of the Coberly Formation according to

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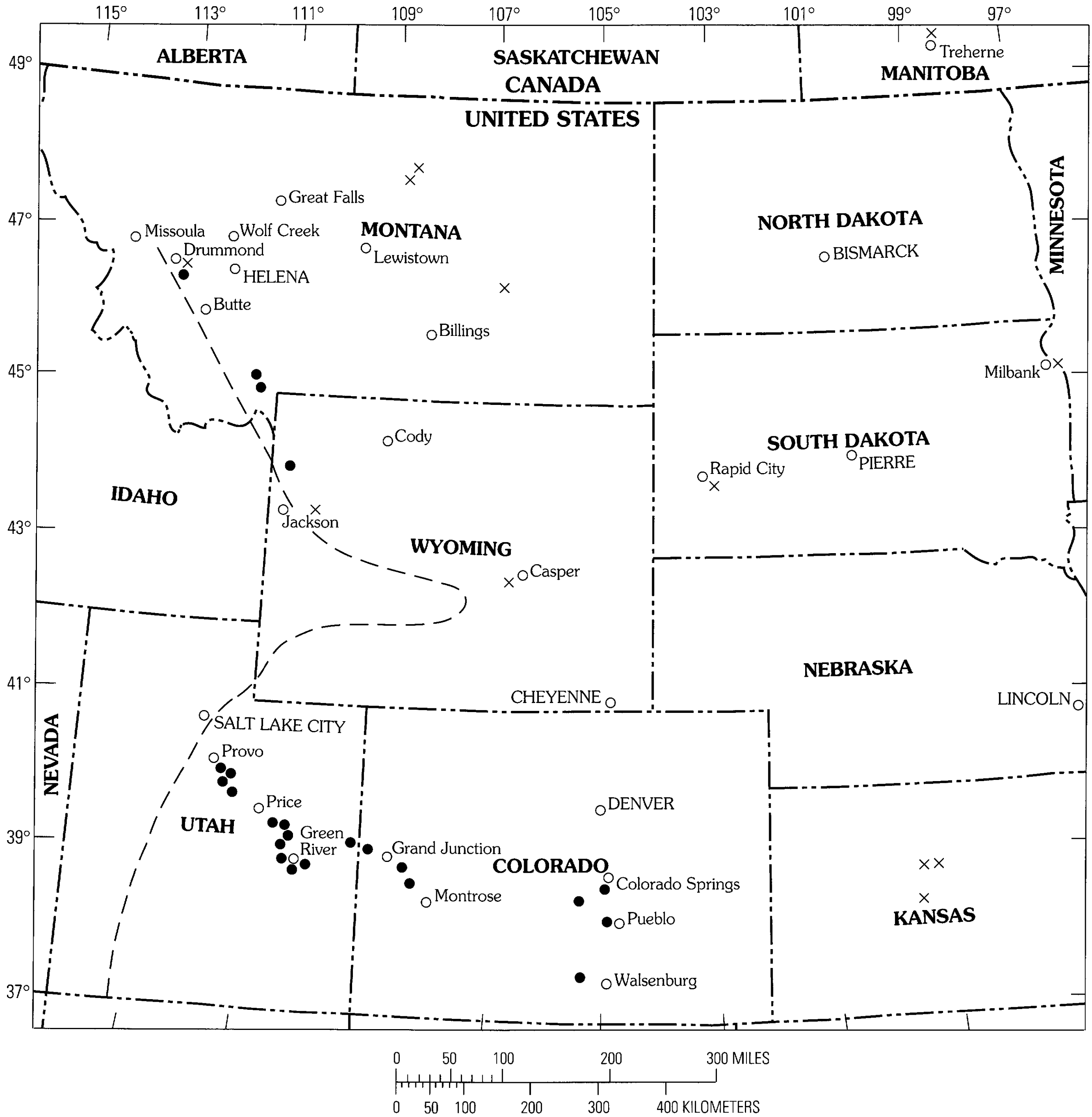

Figure 1. Map showing localities of middle Turonian *Actinocamax* (x) and *Rhynchostreon suborbiculatum* (solid circles) in Utah, Colorado, Kansas, Wyoming, South Dakota, Montana, and southern Manitoba. Dashed line is approximate position of western shoreline of the Western Interior seaway during early middle Turonian time (modified from Cobban and Hook, 1979, fig. 2). Not a palinspastic map.

Gwinn's 1961 map. Masses of *Rhynchostreon suborbiculatum* occur in places in the concretionary parts of the sandstone. This member of the oyster family was also found by S.M. Vuke-Foster in the upper sandstone part of the Coberly at USGS Mesozoic locality D12819 3.9 mi (6.3 km) farther southwest in the SW¼SW¼ sec. 31, T. 10 N., R. 11 W., Powell County.

COBERLY FORMATION

Gwinn (1961) named and briefly described the Coberly Formation on a map of the geology of the Drummond area. In that report Gwinn divided the Colorado Group into four formations, from oldest to youngest: Blackleaf Formation, Coberly Formation (new name), Jens

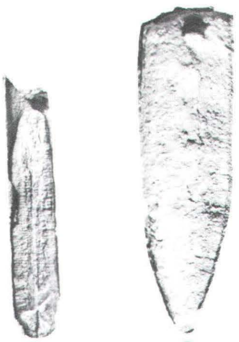

Figure 2. *Actinocamax* sp., from the upper part of the Coberly Formation at USGS Mesozoic locality D12820 in the NE¼sec. 17, T. 10 N., R. 11 W., Powell County, Montana. *A*, USNM 442110; *B*, USNM 442111. Natural size.

Formation (new name), and Carter Creek Formation (new name). Wallace and others (1986) pointed out that the Carter Creek was misnamed for Carten Creek, and that the unit should be the Carten Creek Formation.

In a later report, Gwinn (1965, p. 45–47) gave more details of the Coberly Formation and noted that it consisted of a "Basal gray mudstone-siltstone-olive sandstone facies," a "Medial limestone-oyster reef-associated terrigenous facies," and an upper "Sandstone facies." The dominantly calcareous middle unit with its brackish-water fossils is probably a bay or lagoon equivalent of the marine, calcareous Cone Member of the Marias River Shale farther northeast in the Wolf Creek area (Schmidt, 1978, p. 21, 22), which equates to the Bridge Creek Member of the Greenhorn Limestone of the Great Plains. A conspicuous unnamed white bentonitic bed observed by the present author in the calcareous middle part of the Coberly in the Hoover Creek area may be a westward equivalent of the 1-m-thick bed of bentonite recorded in northwestern and east-central Montana (Cobban, 1951, p. 2185, 2186; Cobban, 1956, p. 1002), and now known to cover much of the Western Interior (Elder, 1988, marker bed B). The bed probably persists northward into the Rocky Mountain Foothills of Alberta, where Stott (1963, p. 40) noted a widespread bed of bentonite near the base of the calcareous Vimy Member of the Blackstone Formation.

FOSSILS OF THE COBERLY FORMATION

Gwinn (1965, p. 45) observed only invertebrate burrows in the basal sandy unit of the Coberly Formation. The middle calcareous unit, however, contains abundant brackish-water fossils. Gwinn (1965, p. 45) described the unit a few miles southeast of Drummond as "mainly dark siltstone, mudstone and shale and beds of fetid black biomicritic limestone with thin-shelled gastropods and solitary pelecypods; in the dark mudstone-shale sequences are one- to four-feet thick oyster reefs (Ostrea soleniscus), from which radiate beds of coarse *Ostrea* debris and associated thick-shelled turritellid-like gastropods." The turritellid-like gastropods are *Gymnentome coalvillensis* (Meek), a species originally described from the Cretaceous rocks at Coalville, Utah (Meek, 1873, p. 502), and now known from localities as far south as Trans-Pecos Texas. The oysters are now assigned to *Crassostrea soleniscus* (Meek). Among other molluscan fossils from this part of the Coberly are the bivalve *Cyrena securis* Meek and the gastropod *Admetopsis subfusiformis* Meek, both of which were described from specimens from Coalville, Utah.

Gwinn (1965, p. 47) observed that the upper sandstone unit of the Coberly contained "external molds of large pelecypods at the type section." These molds are probably *Rhynchostreon suborbiculatum*, which occurs abundantly in the upper sandstone at the locality where *Actinocamax* was found about one-half mile north of the type section. The bivalve *Pleuriocardia* sp. was also found with *Actinocamax*, and *Crassostrea soleniscus*, *Cyrena securis*, and *Corbula* sp. were found several feet below.

ACTINOCAMAX CF. *A. MANITOBENSIS* (WHITEAVES)

The two weathered specimens represent parts of small and large individuals that are probably *Actinocamax manitobensis* (Whiteaves, 1889, p. 189, pl. 26, figs. 3, 3a, 3b). Both specimens are corroded down to their centers, as if they were split longitudinally (fig. 2*A*, *B*). The smaller guard, 34 mm (millimeter) in length with a diameter of 6.8 mm, is the alveolar end of a small, slender individual that closely resembles in size and shape the alveolar part of a small specimen of *A. manitobensis* illustrated by Jeletzky (1950, pl. 1, figs. 1a–c) from the Favel Formation near Treherne in southwestern Manitoba (fig. 1). The larger specimen is the apical part of a guard 40 mm in length with a diameter of 11.7 mm that closely resembles in size and shape the apical part of a large guard illustrated by Jeletzky (1950, pl. 1, figs. 4a–c). The two specimens from the Coberly Formation are kept at the National Museum of Natural History in Washington, D.C., where they have the catalogue numbers USNM 442110 and 442111.

DISTRIBUTION OF MIDDLE TURONIAN *ACTINOCAMAX* AND *RHYNCHOSTREON*

Actinocamax of middle Turonian age has been found in the zone of *Collignoniceras woollgari* in the Fairport Chalk Member of the Carlile Shale of central Kansas (Jeletzky, 1961, p. 507–515, pl. 72, figs. 1A–E, 2A–C, text figs. 1a, b, 2; Hattin, 1962, p. 54, 55, pl. 15, fig. C). Farther north, in western South Dakota, *Actinocamax manitobensis* was collected from the lower part of the Pool Creek Member of the Carlile Shale in association with *C. woollgari* near Rapid City at USGS Mesozoic locality 23067 in sec. 16, T. 1 S., R. 8 E., Pennington County (fig. 1). Fragments of *Actinocamax* have also been found with *C. woollgari* in northeastern South Dakota in Cretaceous limestone that rests directly on Precambrian granite (Cobban, 1983, p. 20, pl. 7, figs. 6, 7), and occasional specimens have been found in glacial drift farther southeast in northeastern Iowa and western Illinois (Cobban, 1983, p. 20, text fig. 5). A few specimens of *A. manitobensis*, associated with *C. woollgari*, are present in collections of the U.S. Geological Survey from the basal part of the Carlile Shale in east-central Montana (fig. 1). Jeletzky (1950, 1961) mentioned the occurrence of Turonian *Actinocamax* in Manitoba, Saskatchewan, Alberta, and British Columbia, and as far north as the lower Mackenzie Valley in the District of Mackenzie. *Actinocamax* is rare in Wyoming, where it is represented in the U.S. Geological Survey collections by one specimen from the Frontier Formation in the Jackson area and one specimen from the Frontier Formation near Casper (fig. 1). Both were found with *C. woollgari*.

Rhynchostreon suborbiculatum has a greater stratigraphic range, and a more limited geographic range, than the middle Turonian *Actinocamax*. Many localities of *Rhynchostreon* are along a sandy belt that parallels the western shoreline of the Western Interior Cretaceous seaway (fig. 1), but in Utah and Colorado, a belt of localities trends eastward to the Pueblo-Colorado Springs-Walsenburg area. The bivalve has been found with *Actinocamax* at only one locality in western Montana and at one locality in western Wyoming (fig. 1).

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