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GEOLOGICAL SURVEY PROFESSIONAL PAPER 684-A

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*By* G. A. IZETT, W. A. COBBAN, *and* J. R. GILL

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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*Stratigraphy, faunal zonation, and correlation of the Pierre Shale*

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# THE PIERRE SHALE NEAR KREMMLING, COLORADO, AND ITS CORRELATION TO THE EAST AND THE WEST

By G. A. Izett, W. A. Cobban, and J. R. Gill

## ABSTRACT

The Pierre Shale of early Campanian to early Maestrichtian age is well exposed near Kremmling, Grand County, Colo. It contains many levels of concretions that yield numerous fossil marine mollusks useful for regional correlation. Much of the Pierre was removed by erosion during Laramide deformation prior to the deposition of the Middle Park Formation of Late Cretaceous(?) and Paleocene age, and the maximum remaining thickness is about 5,000 feet. Regional correlation indicates that between 3,000 and 4,000 feet of the upper part of the Pierre was removed during Laramide time.

In the Kremmling area, the Pierre can be divided into three parts. A lower part, about 1,500 feet thick, consists chiefly of dark-gray to black nonsandy marine shale. The distinctive Sharon Springs Member, about 45 feet thick, is about 1,100 feet above the base of the lower part and contains at least eight bentonite beds. Ammonite zones in the lower part of the Pierre in ascending order include *Baculites* sp. (weak flank ribs), *B. obtusus*, *B. mclearni*, and *B. asperiformis*.

The middle sandy part of the Pierre, about 3.300 feet thick, consists of alternating sandy shale and several newly named sandstone members. In ascending stratigraphic order, the members and their thicknesses are as follows: The Kremmling Sandstone (new name), 20–70 feet thick; the Muddy Buttes Sandstone (new name), 5–30 feet thick; the Hygiene Sandstone, 50–120 feet thick; the Carter Sandstone (new name), 30–65 feet thick; and the Gunsight Pass (new name), 150–170 feet thick. The lower 400 feet of the middle sandy part of the Pierre consists of silty shale with a few interbedded sandstone beds. Of this 400 feet, the lower 200 feet is within the Range Zone of *B. asperiformis*, and the upper 200 feet is within the Range Zone of *B. perplexus*. The Kremmling Sandstone Member is about 400 feet and the Muddy Buttes Sandstone Member is about 600 feet above the base of the middle sandy part of the Pierre. Both members are within the Range Zone of *B. perplexus*. An unnamed silty shale member about 1,000 to 1,200 feet thick overlies the Muddy Buttes Sandstone Member; the lower 130 feet is in the Range Zone of *B. perplexus*, the middle 670 feet is in the Range Zone of *B. gregoryensis*, and the upper 200 feet is in the Range Zone of *B. scotti*. The Hygiene Sandstone Member is about 1,600 to 1,800 feet above the base of the middle sandy part of the Pierre and is in the Range Zone of *B. scotti*. About 370 feet of sandy shale separates the Hygiene from the overlying Carter Sandstone Member. The upper 200 feet is probably in the Range Zone of *Didymoceras nebrascense*. The Carter is possibly in the Range Zone of *Didymoceras stevensoni*. About 900 feet of sandy shale that contains several levels of fossiliferous concretions overlies the Carter and includes the Range Zones of *B. compressus*, *B. cuneatus*, *B. reesidei*, and *B. journal*. The Gunsight Pass Member is the upper 150–170 feet of the middle sandy part of the Pierre and consists of two standstone units separated by about 100 feet of silty shale. The member possibly is in the Range Zone of *B. eliasi* or *B. jenseni*.

The upper part of the Pierre remaining in the Kremmling area consists of about 200 feet of marine shale and lies within the Range Zone of *B. eliasi*.

The excellent fossil record in the Pierre near Kremmling permits correlation with the Pierre to the east near Boulder and with the Mesaverde Group to the west near Hamilton by way of Fish Creek. The lower shale part of the Pierre (1,500 ft thick) near Kremmling correlates with about the lower 1,000 feet of the shaly unit (1,650 ft thick) near Boulder. The middle sandy part (3,300 ft thick) of the Pierre near Kremmling correlates with about the upper 600 feet of the lower shale unit, the middle sandy unit (2,400 ft thick), and about the lower 100 feet of the upper shaly unit near Boulder. The upper shale part of the Pierre near Kremmling correlates with that part of the upper shaly unit from about 100 to 700 feet above the base near Boulder.

The lower shale unit of the Pierre near Kremmling correlates with the Mancos Shale from Fish Creek to near Hamilton; this correlation is with the units above the Niobrara Member and below a prominent zone of large sandstone concretions about 2,500 feet above the Niobrara that yield *B. asperiformis*. The middle sandy part of the Pierre correlates with about the upper 1,000 feet of the Mancos and the Iles and Williams Fork Formations. The Kremmling Sandstone Member probably correlates with the upper sandstone in the Mancos near Fish Creek, and the Muddy Buttes Sandstone Member is in the same stratigraphic position as the Loyd Sandstone Member of the Mancos Shale near Hamilton. The Hygiene correlates with an unnamed sandstone above the Tow Creek Sandstone Member of the Iles Formation, and the Carter is equivalent to nonmarine shale, sandstone, and coal beds in the upper part of the Iles. The Gunsight Pass Member probably correlates with the Twentymile Sandstone Member of the Williams Fork Formation. The upper shale in the Kremmling area correlates with the lowermost part of the Lewis Shale west of the Park Range.

## REGIONAL GEOLOGIC SETTING

The Pierre Shale, of Late Cretaceous age, in Middle Park near Kremmling, Grand County, Colo., contains many levels of concretions that yield numerous marine fossil mollusks useful for regional correlation. The formation is locally well exposed near Kremmling, and outcrops of the formation are the most complete of those in Middle, North, and South Parks known to the writers. The purpose of this paper is to briefly describe the Pierre Shale in the Kremmling area and to correlate the formation to the east near Boulder, Colo., and to the west near Hamilton, Colo., by way of Fish Creek (fig. 1).

The Pierre in Middle Park is separated from the Pierre of the Great Plains and from Cretaceous rocks of western Colorado by the uplifted Precambrian crystalline cores of the Front and Park Ranges. An understanding of the biostratigraphic relations of the Pierre in Middle Park is, therefore, especially important to reconstruct stratigraphic details of the regional east-west facies changes in Pierre age rocks. An eastern facies, which lies east of the Park Range and includes the Kremmling area, consists of interbedded marine shale and sandstone assigned to the Pierre Shale; on a regional scale it is characterized by western-pointing wedges of marine shale and eastern-pointing sandstone tongues. A western facies, which lies west of Kremmling and west of the Park Range, consists of interbedded units of marine and nonmarine shale, sandstone, and coal assigned to the Mancos Shale and to the Iles and Williams Fork Formations of the Mesaverde Group (fig. 1).

Rocks of the Pierre Shale represent accumulations of mud, silt, and sand deposited in the deeper parts of the Late Cretaceous epicontinental sea that covered much of the Western Interior region of North America. Much of the sediment delivered to this sea originated in a narrow unstable and constantly rising cordillera that bordered the sea on the west. Rocks deposited marginal to the source consist of eastward-pointing wedges of shallow-water marine and nonmarine strata (Iles and Williams Fork Formations of the Mesaverde Group in northwestern Colorado) enclosed in westward-pointing wedges of fine-grained marine strata which are tongues of the Pierre Shale but which have been designated the Mancos and Lewis Shales (fig. 2). Beyond the eastern limit of intertonguing with coaly rocks, the entire se-

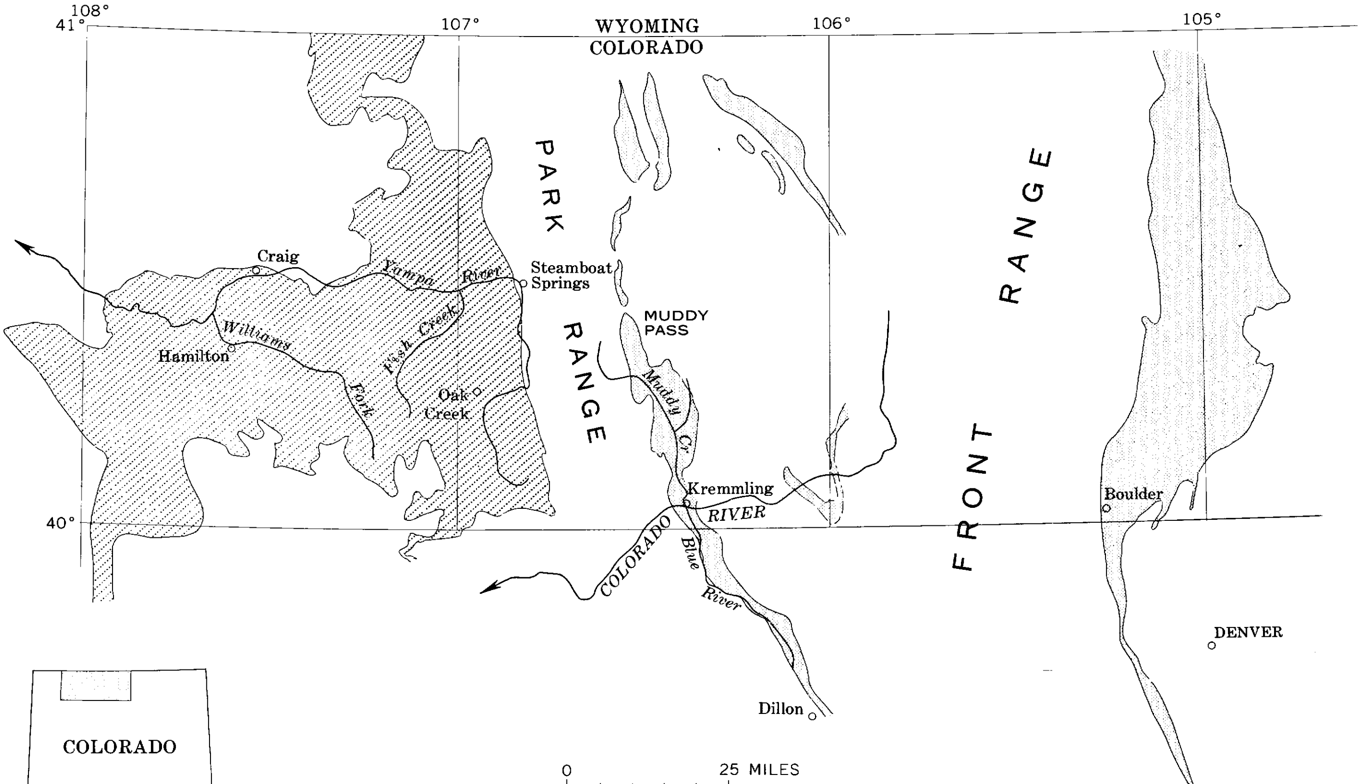


FIGURE 1.—Geologic sketch map of northern Colorado showing large outcrop areas of Cretaceous marine shale and sandstone of the Pierre Shale (shaded) and Cretaceous marine shale and sandstone and nonmarine mudstone, siltstone, and sandstone of the Mancos Shale and the Iles and Williams Fork Formations (diagonal ruling). Contacts modified from Burbank, Lovering, Goddard, and Eckel (1935), Hail (1968), Izett (1968), and Barclay (1968).

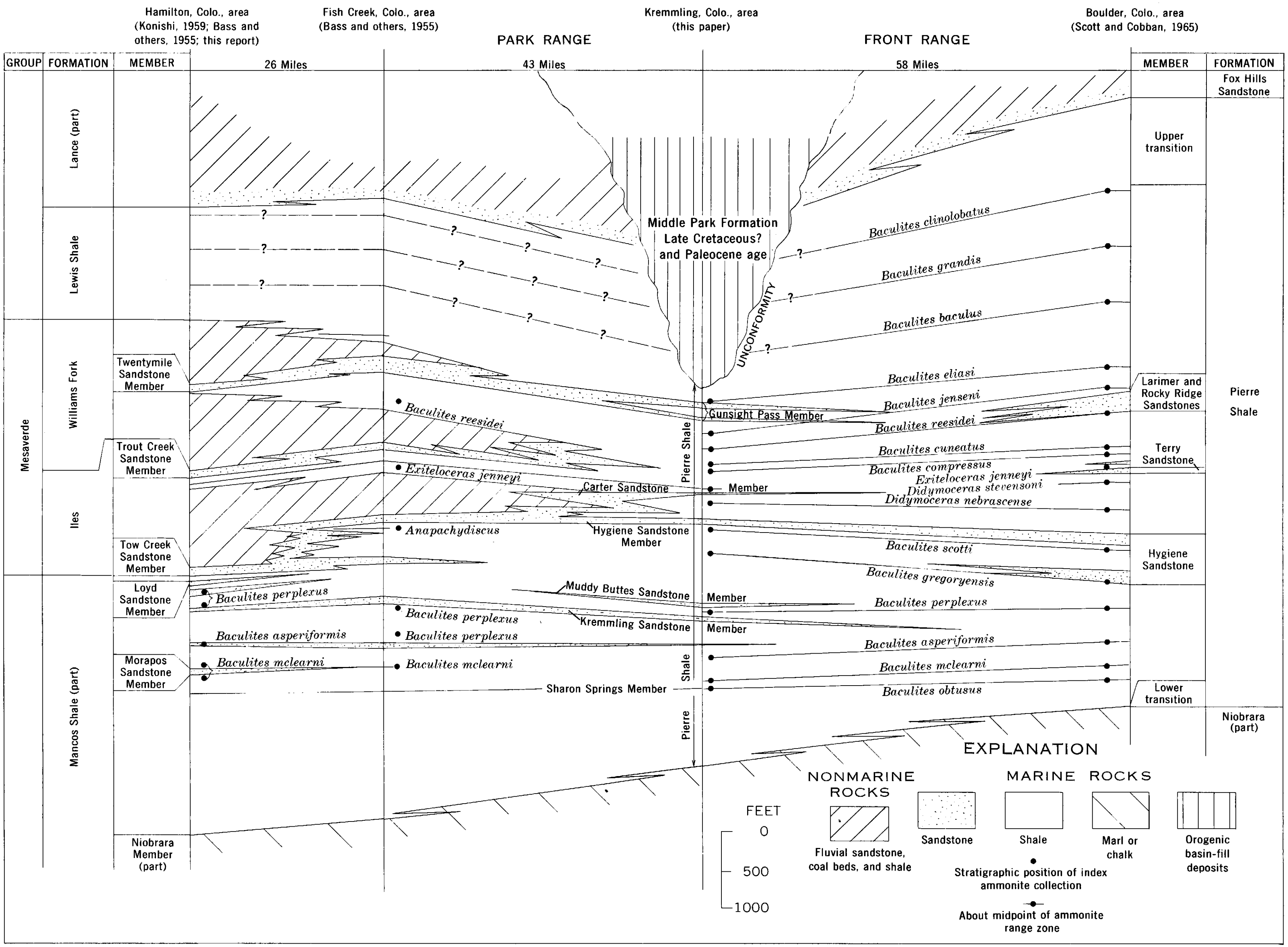


**FIGURE 2.—Correlation of selected Upper Cretaceous rocks from Hamilton to Boulder, Colo.**

quence of marine shale and interbedded sandstone is referred to the Pierre Shale.

The eastern margin of the sea was bounded by the low-lying stable platform of the central part of the United States. It seems that this area contributed little sediment to the sea, and all evidence of the position of the eastern shore has been removed by post-Cretaceous erosion. Stratigraphic studies of the Pierre Shale in the northern part of the Western Interior region (Gill and Cobban, 1965, 1966) indicate that the Pierre grades from marine shale in the central part of the seaway into shallow-water carbonate rocks in the eastern part of the seaway.

The Pierre Shale of figure 2 ranges in age from early Campanian to early Maestrichtian and represents a time span of about 12 million years. In 1952, Cobban and Reeside recognized six ammonite zones in the Pierre Shale and equivalent rocks, whereas in the same rocks in 1966, Cobban (Gill and Cobban, 1966, p. A35) recognized 28 ammonite zones, each occupying a time span of about one-half million years (table 1). A comparison of the thickness of beds that contain certain index ammonites for selected areas is shown in table 1. Because these ammonites and their associated molluscan fauna have a limited vertical stratigraphic range but a broad geographic range and occur in a variety of marine rocks, they are an indispensable aid for correlation in the Western Interior.

## PRESENT WORK

This paper is a result of current detailed mapping of the Kremmling 15-minute quadrangle, stratigraphic studies of the Pierre by Izett, and regional stratigraphic studies of Upper Cretaceous rocks in Montana, Wyoming, and Colorado by Gill and Cobban. A preliminary sketch map (fig. 3) that shows the distribution of the Pierre Shale in the Kremmling quadrangle includes the line of outcrop of several members and a zone of concretions of the formation.

## PREVIOUS WORK

The Pierre near Kremmling was first mapped and studied by Marvine (1874) of the Hayden Survey, who recognized the formation's equivalence to the marine Cretaceous Pierre of the Great Plains. More recently, the Pierre near Kremmling was studied as part of several theses, including those by Richards (1941), Miles (1961), Holt (1961), Howard (1961), and Barclay (1968). Griffitts (1949) made regional correlations of the Pierre of the Kremmling area with the Pierre east of the Front Range, Colo. In the late 1950's, Scott and Cobban (1959) collected fossils from the Pierre near Kremmling and made tentative correlations with sandstone beds in the Pierre east of the Front Range. Hail (1968) mapped the Pierre north of the Kremmling quadrangle, and Izett (1968) mapped the Pierre east of Kremmling near Hot Sulphur Springs, Colo.

## ACKNOWLEDGMENTS

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## PIERRE SHALE

The Pierre near Kremmling can be divided into several mappable marine sandstone members, newly named herein, separated by unnamed members of marine shale and silty and sandy shale. The newly named sandstone members of the Pierre are, in ascending order, the Kremmling, Muddy Buttes, Carter, and Gunsight Pass Members. The names Sharon Springs Member and Hygiene Sandstone Member of the Pierre are extended from the Great Plains into the Kremmling area. A columnar section of the Pierre in the Kremmling area (pl. 1) shows the general lithology and the position of selected fossil mollusk collections. Only a few of the many fossil mollusk collections made in the Kremmling area are shown on plate 1 to establish the succession of index ammonites. In addition to the index ammonites of Gill and Cobban (1966) shown on plate 1 other fossils associated with the ammonites from the Pierre are given in table 2. Not all the fossils shown on plate 1 were collected along the line of the measured sections; some stratigraphically important collections from elsewhere in the area were projected into the generalized columnar section where stratigraphic control was good.

The Pierre Shale, which is about 5,000 feet thick, can be divided for purposes of discussion into three parts. A lower part chiefly consists of dark-gray to black nonsandy marine shale about 1,500 feet thick. It is overlain by a middle part of interbedded marine silty shale and sandstone about 3,300 feet thick. An upper part, which originally could have been between 3,000 and 4,000 feet thick, has largely been removed by erosion, and only about 200 feet of dark-gray shale is preserved in the area. The top of the lower shale part of the Pierre occurs about 10–20 feet below fossil collection D5412 (pl. 1); the top of the middle sandy part is at the top of the Gunsight Pass Member and below collection D6575 (pl. 1).

At some places in Middle Park, part of the Pierre was removed by erosion during Late Cretaceous deformation prior to the deposition of the Middle Park Formation of Late Cretaceous (?) and Paleocene age, and only

TABLE 1.—*Comparison of the estimated thicknesses (in feet) of the range span of index ammonite zones in the Pierre Shale in the Kremmling area with other sections of the Pierre Shale exposed along the eastern Front Range in Colorado and the southern Black Hills in Wyoming.*

| Upper Cretaceous stages and substages | | Selected potassium-argon dates | Estimated dates | Western Interior ammonite sequence | Kremmling, Colo. | Boulder, Colo. (Scott and Cobban, 1965) | Pueblo, Colo. (Scott, 1969, p. 83, pl. 1) | Red Bird, Wyo. (Gill and Cobban, 1966, p. A28-A34) |
|---|---|---|---|---|---|---|---|---|
| Maestrichtian | upper | 63[1] | 63 | | Middle Park Formation (part) | Erosion? | | |
| | | 64 ± 2[1] | 64 | | | | | |
| | | | 65 | | | | | |
| | | 66 ± 2[1] | 66 | | | Laramie Formation | | Lance Formation |
| | | | 67 | | Erosion | | | |
| | lower | | 68 | *Discoscaphites nebrascensis* | | | | |
| | | | | *roanensis* | | | | |
| | | | 69 | *Sphenodiscus (Coahuilites)* | | Fox Hills | | Fox Hills Sandstone |
| | | | | | | 580± (Pierre Shale 8,020) | | |
| | | | | *Baculites clinolobatus* | | 855+ | | 175+ (Pierre Shale 3,100±) |
| | | 70[1] | 70 | *grandis* | | 740 | | 225 |
| | | | | *baculus* | | 770 | | 215 |
| Campanian | upper | | 71 | *eliasi* | 340+ (Pierre Shale (part) 4,900+) | 880 | | 240 |
| | | | | *jenseni* | 210 | 130 | | 65 |
| | | | 72 | *reesidei* | 260 | 500 | | 135 |
| | | | | *cuneatus* | 50 | 120 | | 5 (undated; possible unconformity) |
| | | 75 ± 2[1] | 73 | *compressus* | 115 | 75 | | |
| | | | | *Didymoceras cheyennense* | 115± | 135 | Top of exposure | |
| | | | 74 | *Exiteloceras jenneyi* | 110± | 70 | 50± (Pierre Shale (part) 1,615+) | 115 |
| | | | | *Didymoceras stevensoni* | 110 | 290 | 100+ | 30 |
| | | 75.5 ± 1[2,3] | 75 | *nebrascense* | 220 | 380 | 100 | 100 |
| | | | | *Baculites scotti* | 430 | 690 | 525 | 190 |
| | | | 76 | *gregoryensis* | 500 | 130 | 120 | 310 |
| | | | | *perplexus* (late form) | 705 | 590 | 200 | 125 } 900 |
| | | | 77 | *gilberti* | | | | 250 } 900 |
| | | | | *perplexus* (early form) | | | | 525 } 900 |
| | | | 78 | sp. (smooth) | 0 | 0 | 0 | 100 |
| | | | | *asperiformis* | 560 | 420 | 40 | 155 |
| | lower | 79.5 ± 2[2] | 79 | *mclearni* | 50 | 140 | 10? | 55 |
| | | | | *obtusus* | 180 | 265 | 40 | 90 |
| | | | 80 | sp. (weak flank ribs) | 510 | 235 (undated) | 290 | 30 (undated interval) |
| | | | | sp. (smooth) | 425± | | 140 | |
| | | 81 ± 2[1] | 81 | *Scaphites hippocrepis* III | Niobrara Formation (part) | Niobrara Formation (part) | Niobrara Formation (part) | Niobrara Formation (part) |
| | | | | *hippocrepis* II | | | | |
| | | | 82 | *hippocrepis* I | | | | |
| Santonian (part) | upper | | | *Desmoscaphites bassleri* | | | | |
| | | | 83 | *erdmanni* | | | | |

[1] Potassium-argon dates summarized by Gill and Cobban (1966, p. A35).
[2] J. D. Obradovich (written commun., 1968).
[3] Mean of age determinations on two separate bentonite samples.

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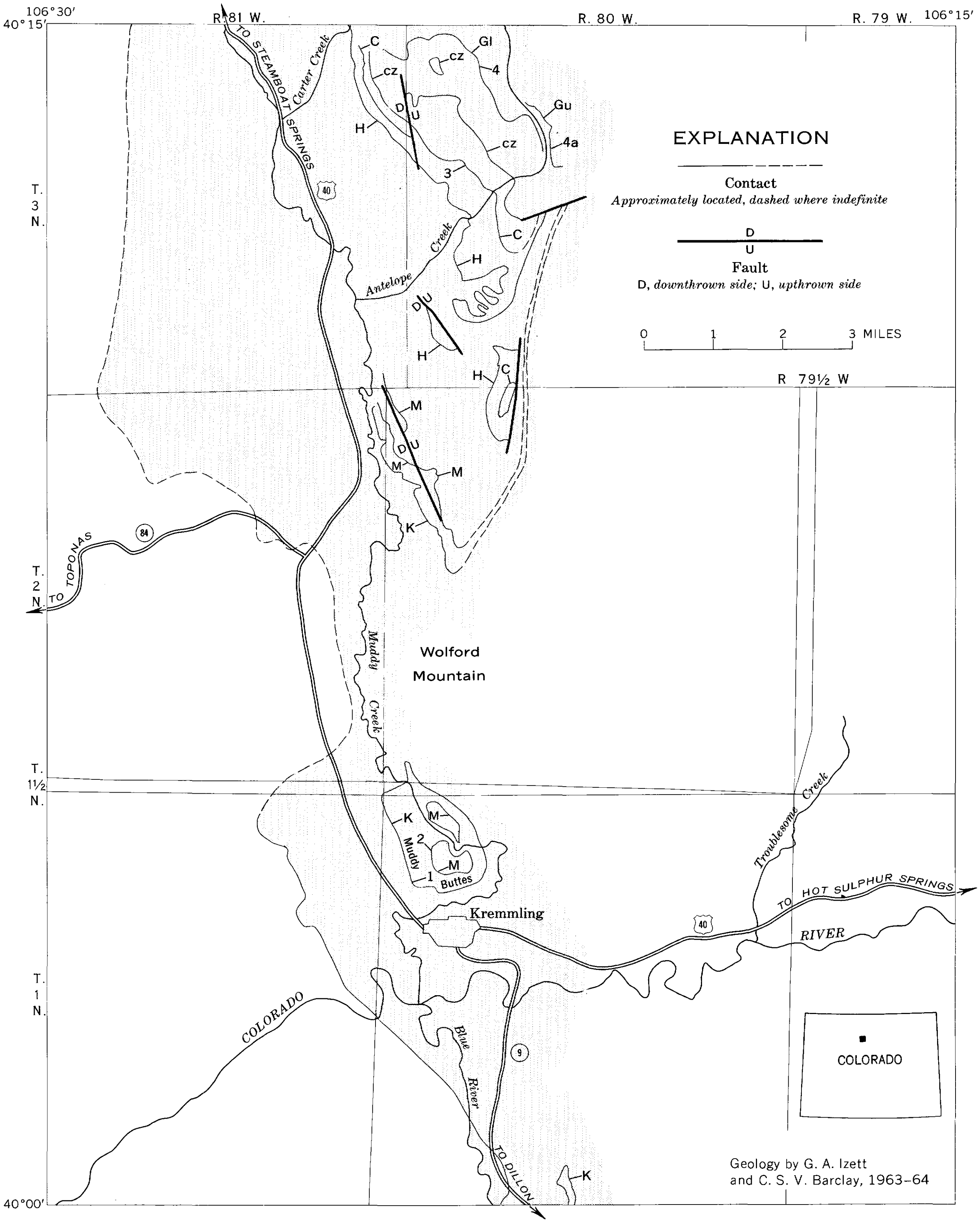


FIGURE 3.—Distribution of the Pierre Shale (shaded) including outcrop traces of several members and a zone of concretions of the formation, Kremmling 15-minute quadrangle, Grand County, Colo. Members and type localities (numbered) identified on facing page.

about the lower two-thirds of the Pierre remains. At other places in Middle Park, all the Pierre and older Mesozoic formations are truncated beneath the unconformity at the base of the Middle Park Formation. In Middle Park where the Pierre is preserved the middle sandy part of the formation is only slightly thicker than the equivalent part of the Pierre near Boulder, Colo., described by Scott and Cobban (1965). If thicknesses of the Pierre near Kremmling are comparable with thicknesses near Boulder, then about 3,000 feet of the upper part of the formation was eroded during latest Cretaceous time in Middle Park. Younger Cretaceous formations, the Fox Hills Sandstone and the Laramie Formation of the Great Plains, were probably present in Middle Park, but were removed during Laramide time.

### LOWER PART

The lower part of the Pierre Shale is intermittently well exposed in roadcuts along Colorado State Highway 9 south from Kremmling to near Dillon, Colo., and north of Kremmling along and generally west of U.S. Highway 40 to near Muddy Pass.

Near Kremmling, as elsewhere in Middle Park, the lower part of the Pierre is composed of about 1,500 feet of dark-gray to black fissile nonsandy marine shale. The unit is easily distinguished on electric logs as a generally uniform shale unit. It is generally clay shale that only rarely contains a few thin silty and sandy zones less than 2 feet thick. Several bentonite beds less than 3 inches thick crop out near the base of the unit, 350–400 feet above the base, and in the Sharon Springs Member.

At the base of the Pierre is a calcareous shale 10 feet or less thick that is transitional into the underlying Niobrara Formation. The contact between the transitional part of the Pierre and the Niobrara is well exposed at several places in the Kremmling area; one of the better exposures is in the SW¼ sec. 33, T. 1 N., R. 80 W., just east of State Highway 9. There, rocks assigned to the Niobrara are calcareous speckled platy shale that weathers tan, overlain by a few feet of dark-gray flaky calcareous shale assigned to the Pierre. Several yellowish-weathering thin bentonite beds less than 2 inches thick occur in the uppermost part of the Niobrara and the lower 50 feet of the Pierre.

TABLE 2.—*Fossils from the Pierre Shale*

| USGS Mesozoic locality | Location | Collector and year | Fossils |
|---|---|---|---|
| D5995 | NE¼NW¼ sec. 16, T. 3 N., R. 80 W. | G. A. Izett, 1967. | *Inoceramus* sp.<br>*Hoploscaphites* sp. |
| D6575 | SE¼SE¼ sec. 8, T. 3 N., R. 80 W. | G. A. Izett, 1968. | *Inoceramus typicus* (Whitfield).<br>*Pecten* (*Chlamys*) *nebrascensis* Meek and Hayden.<br>*Baculites eliasi* Cobban.<br>*Baculites* sp. (*baculus-grandis* group).<br>Fish scale. |
| D7047 | NE¼SW¼ sec. 8, T. 3 N., R. 80 W. | G. A. Izett, 1969. | *Lucina* sp.<br>*Pseudobaculites* sp. |
| D6565 | SE¼SE¼ sec. 12, T. 3 N., R. 81 W. | G. A. Izett, 1968. | *Baculites jenseni* Cobban. |
| D6564 | do | do | *Inoceramus* sp.<br>*Baculites* sp. |
| D5971 | SW¼SW¼ sec. 8, T. 3 N., R. 80 W. | G. A. Izett, 1967. | *Lingula* sp.<br>*Inoceramus* sp.<br>*Anisomyon centrale* Meek.<br>*Baculites* cf. *B. reesidei* Elias.<br>*Hoploscaphites nodosus* (Owen). |
| D6568 | NE¼NE¼ sec. 18, T. 3 N., R. 80 W. | G. A. Izett, 1968. | Pyriporoid bryozoan (on baculite).<br>*Inoceramus barabini* Meek.<br>*Anomia* sp.<br>*Astarte* sp.<br>*Thetis circularis* (Meek and Hayden).<br>*Geltena? gracilis* (Meek and Hayden).<br>*Drepanochilus* sp.<br>*Baculites reesidei* Elias.<br>*Hoploscaphites nodosus* (Owen). |
| D6563 | SE¼SE¼ sec. 12, T. 3 N., R. 81 W. | do | *Inoceramus* sp.<br>*Baculites reesidei* Elias.<br>*Hoploscaphites nodosus* (Owen).<br>*Placenticeras* sp. |
| D6569 | NE¼NE¼ sec. 18, T. 3 N., R. 80 W. | do | *Inoceramus* sp.<br>*Baculites reesidei* Elias.<br>*Hoploscaphites nodosus* (Owen). |
| D1284 | SW¼SW¼ sec. 7, T. 3 N., R. 80 W. | D. Arnold and W. A. Gillespie, 1956. | Bryozoan (on *Inoceramus*).<br>*Inoceramus* cf. *I. vanuxemi* Meek and Hayden.<br>*Ostrea inornata* Meek and Hayden.<br>*Baculites cuneatus* Cobban.<br>*Hoploscaphites nodosus* (Owen). |
| D1351 | NW¼SW¼ sec. 17, T. 3 N., R. 80 W. | G. R. Scott and W. A. Cobban, 1957. | *Inoceramus sagensis* Owen.<br>*Inoceramus vanuxemi* Meek and Hayden.<br>*Ostrea inornata* Meek and Hayden.<br>*Pecten* (*Camptonectes*) sp.<br>*Anomia* sp.<br>*Cymellabella* Conrad.<br>*Baculites compressus* Say.<br>*Anaklinoceras reflexum* Stephenson.<br>*Axonoceras compressum* Stephenson.<br>*Hoploscaphites nodosus* (Owen).<br>*Placenticeras meeki* Boehm. |

EXPLANATION OF FIGURE 3

Gu, Gunsight Pass Member, upper sandstone part (Zone of *Baculites eliasi*);
Gl, Gunsight Pass Member, lower sandstone part;
cz, concretion zone (Zones of *Baculites compressus* and *B. cuneatus*);
C, Carter Sandstone Member;
H, Hygiene Sandstone Member (Zone of *Baculites scotti*);
M, Muddy Buttes Sandstone Member (Zone of *Baculites perplexus*);
K, Kremmling Sandstone Member (Zone of *Baculites perplexus*);
1, Kremmling Sandstone Member;
2, Muddy Buttes Sandstone Member;
3, Carter Sandstone Member;
4, Gunsight Pass Member, lower sandstone and middle shale unit;
4a, Gunsight Pass Member, upper sandstone unit.

TABLE 2.—*Fossils from the Pierre Shale*—Continued

| USGS Mesozoic locality | Location | Collector and year | Fossils |
|---|---|---|---|
| D6556 | SE¼SE¼ sec. 12, T. 3 N., R. 81 W. | G. A. Izett, 1968. | *Inoceramus* sp.<br>*Ostrea* sp.<br>*Baculitescompressus* Say.<br>*Hoploscaphites nodosus* (Owen). |
| D6557 | SE¼SE¼ sec. 12, T. 3 N., R. 81 W. | do | *Inoceramus vanuxemi* Meek and Hayden.<br>*Hoploscaphites brevis* (Meek). |
| D5985 | Center SW¼ sec. 1, T. 3, N., R. 81 W. | G. A. Izett, 1967. | *Perrisonota* sp.<br>*Nucula* sp.<br>*Nuculana* sp.<br>*Inoceramus sublaevis* Hall and Meek.<br>*Pteria linguaeformis* (Evans and Shumard).<br>*Ostrea* sp.<br>*Pecten (Syncyclonema)* sp.<br>*Laternula* sp.<br>*Cuspidaria* sp.<br>*Cardium* sp.<br>*Dentalium pauperculum* Meek and Hayden.<br>*Baculites crickmayi* Williams.<br>*Hoploscaphites* sp.<br>*Didymoceras stevensoni* (Whitfield).<br>*Placenticeras* sp. |
| D5987 | NW¼NW¼ sec., 18, T. 3 N., R. 80 W. | G. A. Izett and W. A. Cobban, 1967. | Crinoid fragment.<br>*Perrisonata* sp.<br>*Nuculana* sp.<br>*Inoceramus sublaevis* Hall and Meek.<br>*Ostrea* sp.<br>*Cuspidaria* sp.<br>*Lucina* sp.<br>*Tenea circularis* (Meek and Hayden).<br>*Cymbophora* sp.<br>*Dentalium gracile* Hall and Meek.<br>*Drepanochilus obesus* Sohl (transitional form).[1]<br>*Ellipsoscapha subcylindrica* (Meek and Hayden).[1]<br>*Oligoptycha* sp.[1]<br>*Baculites crickmayi* Williams.<br>*Hoploscaphites* sp. |
| D6009 | SW¼NE¼ sec. 5, T. 2 N., R. 80 W. | do | *Inoceramus* aff. *I. turgidus* Anderson.<br>*Pteria linguaeformis* (Evans and Shumard).<br>*Didymoceras* sp. |
| D5904 | SW¼ sec. 29, T. 4 N., R. 80 W. | G. A. Izett, 1967. | Calcareous worm tube (attached to baculite).<br>*Oxytoma* sp.<br>*Cymella montanensis* (Henderson).<br>*Tellina* cf. *T. scitula* Meek and Hayden.<br>*Cymbophora formosa* (Meek and Hayden).<br>*Oligoptycha* sp.<br>*Eutrephoceras* sp.<br>*Baculites scotti Cobban.*<br>*Didymoceras* n. sp.<br>*Placenticeras* sp. |
| D5964 | NW¼ NW¼ sec. 12, T. 3 N., R. 81 W. | do | Calcareous worm tube.<br>*Dysnoetopora demissa* (White).<br>*Pteria linguaeformis* (Evans and Shumard).<br>*Oxytoma* cf. *O. nebrascana* (Evans and Shumard).<br>*Ostrea* sp.<br>*Pecten (Camptonectes)* sp.<br>*Crenella* sp.<br>*Baculites scotti* Cobban.<br>*Placenticeras* sp.<br>Crab fragments. |
| D5974 | NW¼NE¼ sec. 30, T. 3 N., R. 80 W. | do | Pyriporoid bryozoan (attached to baculite).<br>*Nuculana* sp.<br>*Inoceramus* sp.<br>*Baculites scotti* Cobban.<br>*Didymoceras* n. sp.<br>*Anapachydiscus complexus* (Meek and Hayden). |
| D5966 | NW¼SW¼ sec. 32, T. 3 N., R. 80 W. | do | Pyriporoid bryozoan (on inoceram).<br>*Inoceramus* sp.<br>*Pteria* cf. *P. linguaeformis* (Evans and Shumard).<br>*Baculites gregoryensis* Cobban.<br>*Didymoceras* sp.<br>*Menuites* n. sp. |
| D5990 | NE¼NE¼ sec. 11, T. 3 N., R. 81 W. | G. A. Izett and W. A. Cobban, 1967. | Pyriporoid bryozoan (attached to inoceram).<br>*Inoceramus* sp.<br>*Lucina* sp.<br>*Baculites gregoryensis* Cobban. |
| D6554 | NW¼NW¼ sec. 13, T. 3 N., R. 81 W. | G. A. Izett, 1968. | *Nuculana* sp. |
| D6007 | SE¼NE¼ sec. 6, T. 1 N., R. 80 W. | G. A. Izett, 1967. | *Inoceramus subcompressus* Meek and Hayden.<br>*Baculites perplexus* Cobban. |
| D6006 | NE¼NE¼ sec. 6, T. 1 N., R. 80 W. | W. A. Cobban, 1967. | Calcareous worm tubes (attached to baculite).<br>Pyriporoid bryozoan (attached to baculite).<br>*Cymbophora* sp.<br>*Baculites perplexus* Cobban.<br>*Hoploscaphites* n. sp. |
| D6005 | NW¼NE¼ sec. 6, T. 1 N., R. 80 W. | G. A. Izett and W. A. Cobban, 1967. | *Inoceramus subcompressus* Meek and Hayden.<br>*Baculites perplexus* Cobban. |
| D5996 | NE¼NE¼ sec. 1, T. 2 N., R. 81 W. | do | *Inoceramus subcompressus* Meek and Hayden.<br>*Baculites perplexus* Cobban. |
| D5997 | do | do | Pyriporoid bryozoan (attached to baculite).<br>*Inoceramus subcompressus* Meek and Hayden.<br>*Baculites perplexus* Cobban. |
| D5401 | NW¼NE¼ sec. 7, T. 1 N., R. 80 W. | G. A. Izett, 1966. | Pyriporoid bryozoan.<br>*Cymbophora?* sp.<br>*Baculites gilberti* Cobban. |
| D5893 | SE¼NE¼ sec. 18, T. 2 N., R. 80 W. | G. A. Izett, 1967. | *Inoceramus subcompressus* Meek and Hayden.<br>*Cymbophora* sp.<br>*Baculites perplexus* Cobban. |
| D6014 | NW¼SE¼ sec. 33, T. 1 N., R. 80 W. | do | *Baculites perplexus* Cobban. |
| D6546 | SW¼SE¼ sec. 33, T. 1 N., R. 80 W. | G. A. Izett, 1968. | *Baculites perplexus* Cobban. |
| D6550 | SE¼SE¼NW¼ sec. 7, T. 1 N., R. 80 W. | do | *Baculities perplexus* Cobban. |
| D6549 | do | do | *Inoceramus subcompressus* Meek and Hayden.<br>*Cymbophora* sp.<br>*Baculites perplexus* Cobban. |
| D5916 | SE¼SE¼ sec. 18, T. 2 N., R. 80 W. | G. A. Izett, 1967. | *Inoceramus subcompressus* Meek and Hayden.<br>*Baculites asperiformis* Meek. |
| D6548 | SE¼SE¼NW¼ sec. 7, T. 1 N., R. 80 W. | G. A. Izett, 1968. | *Inoceramus subcompressus* Meek and Hayden.<br>*Baculites asperiformis* or *B. perplexus.* |

See footnote at end of table.

TABLE 2.—*Fossils from the Pierre Shale*—Continued

| USGS Mesozoic locality | Location | Collector and year | Fossils |
|---|---|---|---|
| D5400 | do | G. A. Izett, 1966. | Pyriporoid bryozoan (on baculite).<br>*Inoceramus* sp.<br>*Cymbophora* sp.<br>*Baculites asperiformis* Meek.<br>*Hoploscaphites* sp. |
| D5409 | NE¼NE¼ sec. 1, T. 1 N., R. 81 W. | do | *Inoceramus* sp.<br>*Pteria linguaeformis* (Evans and Shumard).<br>*Cymbophora* sp.<br>*Baculites asperiformis* Meek.<br>*Hoploscaphites* sp. |
| D5412 | do | do | *Inoceramus* sp.<br>*Cymbophora* sp.<br>*Baculites* sp. (noded juveniles).<br>*Hoploscaphites* sp. |
| D6016 | W½SE¼ 33, T. 1 N., R. 80 W. | W. A. Cobban, 1967. | *Inoceramus subcompressus* Meek and Hayden.<br>*Baculites* sp. |
| D7042 | Center, sec. 18, T. 2 N., R. 80 W. | G. A. Izett and J. E. Peterson, 1969. | *Baculites asperiformis* Meek. |
| D6971 | NE¼SW¼ sec. 18, T. 2 N., R. 80 W. | G. A. Izett, 1969. | *Baculites asperiformis* Meek. |
| D7044 | SW¼SW¼ sec. 2, T. 2 N., R. 81 W. | G. A. Izett and J. E. Peterson, 1969. | *Baculites asperiformis* Meek. |
| D6980 | SW¼SW¼ sec. 2, T. 2 N., R. 81 W. | do | *Baculites mclearni* Landes. |
| D6970 | NE¼SW¼ sec. 18, T. 2 N., R. 80 W. | G. A. Izett, 1969. | *Inoceramus tausiensis* Aliev.<br>*Baculites obtusus* Landes. |
| D6011 | E½SW¼ sec. 33, T. 1 N., R. 80 W. | W. A. Cobban, 1967. | *Inoceramus* cf. *I. barabini* Morton.<br>*Baculites obtusus* Meek. |
| D6010 | do | G. A. Izett and W. A. Cobban, 1967. | *Inoceramus* sp.<br>*Ostrea* sp.<br>*Baculites* sp.<br>*Scaphites* n. sp. |
| D6543 | SE¼SW¼ sec. 33, T. 1 N., R. 80 W. | G. A. Izett, 1968. | *Baculites* sp. |
| D6586 | Center SW¼ sec. 33, T. 1 N., R. 80 W. | G. A. Izett, J. R. Gill, and W. A. Cobban, 1968. | *Cymbophora* sp.<br>*Baculites obtusus* Meek (early form).<br>Fish scales. |
| D6992 | SW¼SW¼ sec. 2, T. 2 N., R. 81 W. | G. A. Izett, 1969. | *Baculites* sp. |
| D7033 | NW¼SW¼ sec. 10, T. 3 N., R. 81 W. | G. A. Izett and J. E. Peterson, 1969. | *Baculites* sp. (weak flank ribs).<br>*Scaphites* n. sp. |

[1] Identified by N. F. Sohl, U.S. Geol. Survey, 1967.

Several distinctive types of concretions occur in the lower part of the Pierre. Some types of concretions are limited to the rocks of certain broad stratigraphic intervals and can be used to determine the approximate stratigraphic position of isolated shale outcrops in structurally complex areas. Thin platy reddish-brown-weathering ironstone layers and concretions generally less than 1 foot thick are found in much of the lower black shale part of the Pierre, but they are especially prominent below the Sharon Springs Member. Smooth medium-gray dense limestone concretions as much as 2 feet in diameter that weather yellowish gray occur chiefly in the Sharon Springs Member. Yellowish-gray-weathering septarian limestone concretions as much as 4 feet in diameter occur in the upper part of the Sharon Springs and in the overlying black shales (pl. 1; fig. 4).

Fossils are locally abundant in the lower part of the Pierre, especially in the Sharon Springs Member. Fossil fish vertebrae were found about 50 feet above the base of the Pierre, and fish scales are common in many of the thin platy ironstone concretions. Poorly preserved impressions in shale of a smooth baculite were found in the lower 200 feet of the Pierre. These may represent the Zone of *Baculites* sp. (smooth). (See Gill and Cobban, 1966, p. A35, for Western Interior ammonite sequence.) About 700 feet above the base of the Pierre, limestone concretions contain weakly ribbed baculites representing the Zone of *Baculites* sp. (weak flank ribs). Poorly preserved specimens of *Baculites obtusus* Meek (early form) occur in ironstone concretions about 130 feet below the base of the Sharon Springs, and well-preserved specimens of *Baculites obtusus* (late form) are found in limestone concretions in the Sharon Springs Member. The range of both forms of *B. obtusus* are shown together on plate 1. Crushed gypsiferous limonite specimens of *Baculites mclearni* Landes are restricted to a silty shale interval 5–10 feet thick above the top of the Sharon Springs Member. Limestone and ironstone concretions from 60 to about 500 feet above the Sharon Springs contain *Baculites asperiformis* Meek.

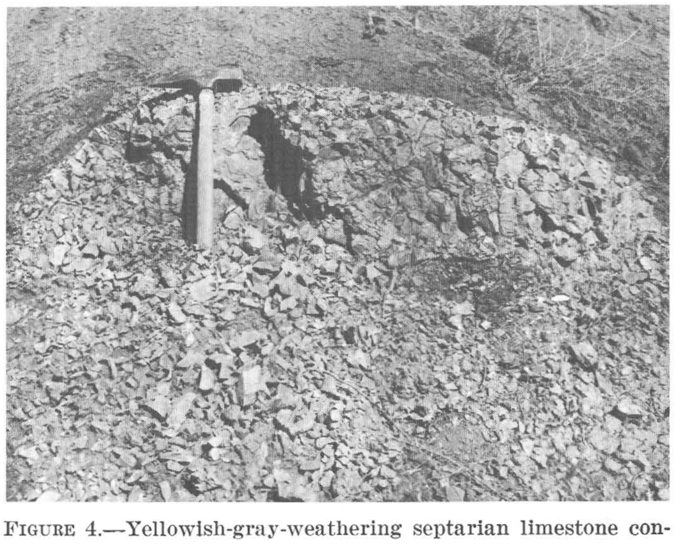

FIGURE 4.—Yellowish-gray-weathering septarian limestone concretion characteristic of the Sharon Springs Member of the Pierre Shale. Photograph taken in the SE¼SE¼ sec. 2, T. 2 N., R. 81 W., Grant County, Colo. Some specimens of *Baculites obtusus* occur in the septarian limestone concretions, but specimens of this species are also in smooth gray dense limestone concretions in the Sharon Springs.

## SHARON SPRINGS MEMBER

Extension of the name Sharon Springs Member of the Pierre Shale from the Great Plains into Middle Park is based on lithology, stratigraphic position, and fossil content. The member is generally about 45 feet thick and is well exposed at several places in the Kremmling area. Good exposures occur south of Kremmling in the S½ sec. 33 and the SW¼SW¼ sec. 21, T. 1 N., R. 80 W. North of Kremmling, good outcrops are along Muddy Creek in the NE¼SE¼ sec. 36, along Red Dirt Creek in the S½ sec. 2, T. 2 N., R. 81 W., and in a roadcut along U.S. 40 in the center NW¼ sec. 14, T. 3 N., R. 81 W. Other good outcrops are along Muddy Creek in the SW¼ sec. 18, T. 2 N., R. 80 W., and the NE¼NW¼ sec. 25, T. 3 N., R. 81 W.

The member is a distinctive buttress-weathering shale and bentonite-bearing unit that can be traced throughout much of the Kremmling area and elsewhere in the Western Interior region. It is useful in determining structure in a thick sage-covered shale sequence. The member crops out about 1,100 feet above the base of the Pierre in this area. The member is easily recognized and characterized by as many as eight thin bentonite beds in the lower part of the member and by a shale unit that is rich in organic material and more resistant and buttress weathering than the adjacent shale (fig. 5). The bentonite beds are easily traced along outcrops by their frothy surfaces and by scattered selenite and calcite crystals. The shale in the upper part of the member, informally called the buttress shale, characterizes the Sharon Springs in its type locality (Elias, 1931, p. 58–77) in western Kansas and in much of Wyoming and South Dakota. This shale unit contains much jaro-


FIGURE 5.—Buttress-weathering organic-rich black shale characteristic of the upper part of the Sharon Springs Member of the Pierre Shale in the SE¼SE¼ sec. 2, T. 2 N., R. 81 W., Grand County, Colo. Hammer shown for scale.

site-stained carbonaceous debris and fish remains and, at one locality, a log of a fossil conifer about 15 feet long. The base of the member was chosen at the lowest bentonite bed, and the top of the member is at the top of the buttress shale.

### MIDDLE PART

The middle part of the Pierre Shale is exposed best in the north-central part of the Kremmling quadrangle east of U.S. Highway 40. It is a diverse unit, about 3,300 feet thick, consisting of alternating marine silty shale and sandstone beds roughly equivalent to the Mesaverde Group of northwestern Colorado (fig. 2).

The lower 300 feet of the middle unit of the Pierre consists of slope-forming interbedded shaly siltstone and thin beds of ripple-marked very fine grained clayey sandstone. The sandstone beds are discontinuous and locally form small ledges. One of these calcareous sandstone beds, about 2 feet thick, contains many worm trails and occurs near the base of the middle unit.

The lower 300 feet of the middle unit contains discontinuous rusty siltstone concretions and layers and large yellowish-brown-weathering calcareous sandstone concretions that form an excellent marker zone about 25–75 feet above the base of the middle unit (fig. 6). These concretions are ellipsoidal and locally as much as 15 feet in diameter. They were traced through much of the Kremmling area and were identified in the upper part of the Mancos Shale along the Williams Fork River from Hamilton to Fish Creek.

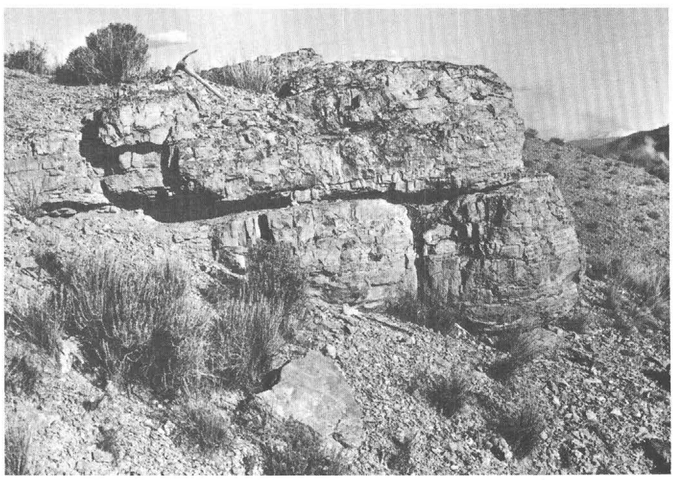

FIGURE 6.—Large yellowish-brown-weathering calcareous sandstone concretions about 350 feet below the top of the Kremmling Sandstone Member near the center of sec. 7, T. 1 N., R. 80 W., 0.5 mile northwest of Kremmling, Colo. Specimens of *Baculites asperiformis* that have widely spaced prominent flank nodes occur in the concretions, but are more common in yellowish-brown lenticular ferruginous siltstone concretions.

The lower 200 feet of the middle sandy part of the Pierre contains many concretions that contain abundant specimens of *Baculites asperiformis*. Other ammonites found in association with this baculite are *Hoploscaphites* sp. and small fragments of a heteromorphic ammonite. *Baculites perplexus* Cobban first occurs about 200 feet above the base of the middle part.

A discontinuous interval of dark-gray shale about 50 feet thick crops out 300 feet above the base of the middle part of the Pierre and below the Kremmling Sandstone Member. This shale unit contains several conspicuous reddish-brown limestone layers about 1 foot thick. These layers form small ledges that can be traced readily along outcrops, and they yield large well-preserved specimens of *Baculites perplexus* that show strongly ribbed venters. This zone with its numerous fossils can be traced intermittently north from Kremmling for at least 15 miles.

#### KREMMLING SANDSTONE MEMBER

Thin-bedded ledge- to cliff-forming sandstone beds that are about 1,900 feet above the base of the Pierre are here named the Kremmling Sandstone Member of the Pierre Shale. The member is well exposed at Muddy Buttes about half a mile north of Kremmling, and it can be mapped for many miles north and south of Kremmling. The type locality (fig. 7) is in the SE¼ NW¼ sec. 7, T. 1 N., R. 80 W., Grand County, Colo.; the member is named after the town of Kremmling, Grand County, Colo.

The thickness of the member ranges from 20 to 70 feet, the variation due to a gradational lower contact. The lower contact is placed between the laminated shaly siltstone of the Kremmling Sandstone Member and the underlying silty shale. The upper contact is placed at the highest sandstone bed overlain by shale.

The lower part of the member consists of shaly siltstone and sandstone, and the upper part is generally flaggy very fine grained sandstone. Ripple marks and worm trails and burrows are generally found along bedding planes.

The member is within the Range Zone of *Baculites perplexus*, and poorly preserved generally crushed specimens of *Baculites perplexus* were found at some outcrops.

#### UNNAMED SHALE MEMBER

Dark-gray slope-forming shale about 150–200 feet thick overlies the Kremmling Sandstone Member. Locally discontinuous sandstone beds less than 5 feet thick occur in the lowermost part of this unnamed shale member. This member is well exposed at Muddy Buttes in the NE¼ sec. 7, T. 1 N., R. 80 W., and along the east side of Muddy Creek in the E½ sec. 1, T. 2 N., R. 81 W. A zone of reddish-brown-weathering ledge-forming limestone layers generally occurs in the upper third of the unit below the Muddy Buttes Sandstone Member. The shale member is within the Range Zone of *Baculites perplexus* inasmuch as that species occurs in the overlying Muddy Buttes Sandstone Member. Many well-preserved baculites, many of which are inseparable from *Baculites gilberti* Cobban, weather from the limestone layers and litter the underlying slopes. In isolated exposures, these limestone layers resemble those in the shale below the Kremmling Sandstone Member, but they differ in that the average baculite from limestone layers below the Muddy Buttes is smaller and has more ventral ribs per shell diameter (*Baculites gilberti*) than the average baculite (*Baculites perplexus*) from below the Kremmling. Other ammonites from the unnamed shale unit are *Hoploscaphites* sp. and *Placenticeras* n. sp.

### MUDDY BUTTES SANDSTONE MEMBER

Thin-bedded ledge-forming sandstone beds about 150–200 feet above the Kremmling Sandstone Member are here named the Muddy Buttes Sandstone Member of the Pierre Shale. The type locality is in the NW¼ sec. 8 and the NE¼ sec. 7, T. 1 N., R. 80 W., at Muddy Buttes about 1 mile north of Kremmling, Grand County, Colo. (fig. 8). The member can be traced from near Kremmling for about 15 miles to the north and for several miles to the south.

The member ranges from 5 to 30 feet in thickness. The lower contact is gradational through several feet and is placed where silty shale grades upward into silty sandstone. The upper contact is generally sharp and is placed at the point where silty shale overlies sandstone.

The member is composed of very fine grained sandstone and shaly siltstone that weather yellowish brown. The sandstone is thin bedded to laminated, and bedding planes are covered by ripple marks and trails of unknown organisms. Along Muddy Creek, in the NW¼ sec. 1, T. 2 N., R. 81 W., the uppermost sandstone bed is overlain by a layer of glauconitic sandstone and associated ironstone.

The member is within the Range Zone of *Baculites perplexus*, as good collections of this fossil occur above and below the member (pl. 1). Fossils are sparse and not well preserved in the member, but a few specimens of *Baculites perplexus* were found.

### UNNAMED SHALE MEMBER

At least 1,000 feet and perhaps as much as 1,200 feet of shale overlies the Muddy Buttes Sandstone Member. A few good outcrops of this unit were seen in the NW¼ sec. 12, T. 3 N., R. 81 W., and in the SW¼ sec. 31, T. 3 N., R. 80 W., but for the most part, the member is exposed only in isolated outcrops.

The member is composed chiefly of gray hackly slope-forming silty shale that contains a few thin siltstone and sandstone beds in the lower 200 feet. Layers of gray silty limestone concretions less than 2 feet thick are scattered through the unit. The limestone concretion layers are unlike most others in the Pierre and characterize only rocks above the Muddy Buttes Member and below the Hygiene Sandstone Member. Smooth limestone concretions about 2 feet in diameter occur in the upper 300 feet of the unit.

The lower 130 feet of the member lies in the upper part of the Range Zone of *Baculites perplexus*, and a few collections of this fossil were found in limestone concretions and sandy shale above the Muddy Buttes Sandstone Member in the NE¼ sec. 6, T. 1 N., R. 80 W. Well-preserved ammonites are difficult to find in the middle part of this member, but enough were found to establish the presence of the Zone of *Baculites gregoryensis* Cobban. The baculites occur in silty limestone layers from about 500 to 800 feet above the base of the unit. Other ammonites found in this interval are *Didymoceras* sp. and *Menuites* n. sp. The interval from about 800 feet above the base to the top of the unit lies within the Range Zone of *Baculites scotti* Cobban (pl. 1). Several collections from limestone concretions in this shale interval yield *Baculites scotti*, *Didymoceras* n. sp., *Anapachydiscus complexus* (Hall and Meek), and *Menuites* n. sp.

### HYGIENE SANDSTONE MEMBER

Cliff-forming sandstone as much as 120 feet thick about 3,200 feet above the base of the Pierre is assigned to the Hygiene Sandstone Member of the Pierre. The name Hygiene is assigned to this thick sandstone near Kremmling because it occupies a stratigraphic position similar to the uppermost sandstone of the Hygiene of the type locality near Boulder and it also lies within the Range Zone of *Baculites scotti*. The Hygiene in the Boulder area is about 600–800 feet thick, and its base lies 2,400 feet above the base of the Pierre (Scott and Cobban, 1965).

The Hygiene in the Kremmling area generally forms a conspicuous cliff and is well exposed in the southwestern part of T. 3 N., R. 80 W., and in sec. 12, T. 3 N., R. 81 W. Typical outcrops of the member are shown in figure 9.

The thickness of the member is variable because of the gradational lower contact, but generally ranges from 50 to 120 feet. The lower contact is placed between silty sandy shale of the underlying shale unit and laminated to thin-bedded sandstone. The upper contact is

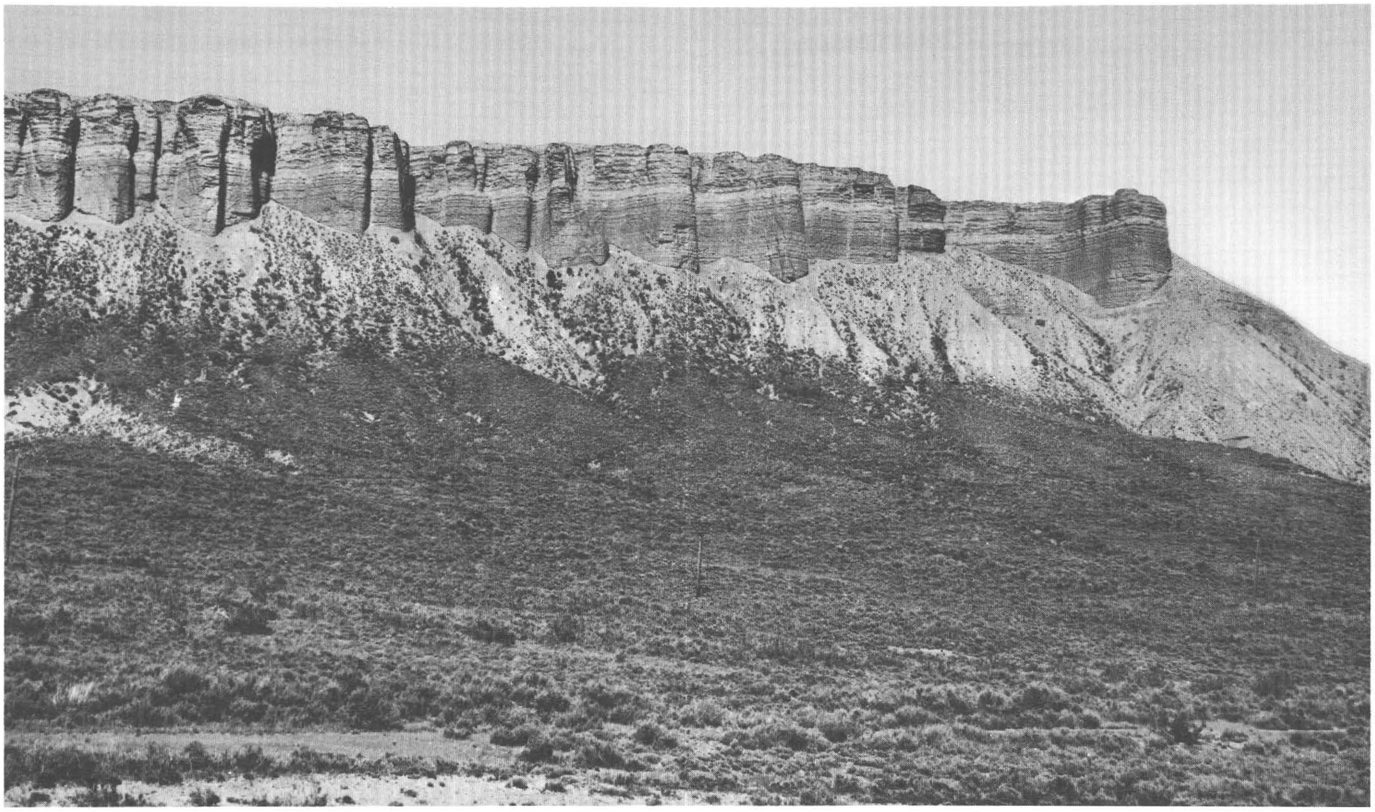

FIGURE 7.—Type locality of the Kremmling Sandstone Member of the Pierre Shale in the SE¼NW¼ sec. 7, T. 1 N., R. 80 W., 0.5 mile north of Kremmling, Grand County, Colo. Many adult specimens of *Baculites perplexus* occur in reddish-brown-weathering limestone layers in a shale unit 60–100 feet below the Kremmling Sandstone Member.


FIGURE 8.—Type locality of the Muddy Buttes Sandstone Member of the Pierre Shale in the NW¼ sec. 8 and the NE¼ sec. 7, T. 1 N., R. 80 W., about 1 mile north of Kremmling, Grand County, Colo. Well-preserved specimens of *Baculites perplexus*, some of which approach the specific characteristics of *Baculites gilberti*, are present in reddish-brown-weathering limestone layers from about 10 to 100 feet below the sandstone.

arbitrarily assigned to the topmost thin-bedded ledge-forming calcareous sandstone.

The lower part of the member consists of massive very fine grained sandstone that contains brown-weathering sandy limestone concretions as much as 8 feet in diameter. The upper part of the member is soft slope-forming thin-bedded sandstone.

The member lies within the Range Zone of *Baculites scotti*. Most of the fossils occur either in the large calcareous sandstone concretions or at the top of the massive sandstone.

Ammonites from the lower part of the Hygiene include *Baculites scotti*, *Anapachydiscus complexus*, *Didymoceras* n. sp., *Placenticeras* sp., and *Oxybeloceras* sp. Some of the same ammonites are found in the topmost bed of the Hygiene.

### UNNAMED MEMBER

About 370 feet of soft shaly siltstone, sandy shale, and sandstone overlies the Hygiene Sandstone Member. The member is poorly exposed and at most places forms sage-covered slopes. A few outcrops of the lower part of the unit were seen along Antelope Creek in the NE¼ sec. 19, T. 3 N., R. 80 W. Good outcrops of the upper 150 feet occur in the SE¼ sec. 5, T. 2 N., R. 80 W. Fragmentary fossil ammonites from the upper 100 feet of the member suggest that the rocks are in the Range Zone of *Didymoceras nebrascense* (Meek and Hayden).

### CARTER SANDSTONE MEMBER

A ridge-forming sandstone unit about 350 feet above the Hygiene Sandstone Member is here named the Carter Sandstone Member of the Pierre Shale. The member takes its name from Carter Creek in the northeastern part of T. 3 N., R. 81 W., in the Kremmling quadrangle, Grand County, Colo., and the type locality is a few miles south of Carter Creek in the NW¼NW¼ sec. 20 and the SW¼SW¼ sec. 17, T. 3 N., R. 80 W. (fig. 10).

The thickness of the member ranges from 30 to 65 feet and varies because of the gradational lower boundary. The lower contact is chosen at the horizon where sandstone of the Carter predominates over silty shale of the underlying unit. The upper contact is defined to be at the top of a layer of ellipsoidal calcareous sandstone concretions.

The sandstone is very fine grained and thick bedded to massive. Low-angle medium-scale cross-stratification is common in the member. Dark-brown-weathering calcareous sandstone concretions as much as 4 feet in diameter are in the uppermost beds of the member. Carbonaceous shale is present at the base near the center of sec. 12, T. 3 N., R. 81 W.

No fossils other than fragments of *Inoceramus* have as yet been found in the member, but it probably lies within the Range Zone of *Didymoceras stevensoni* (Whitfield) (pl. 1).

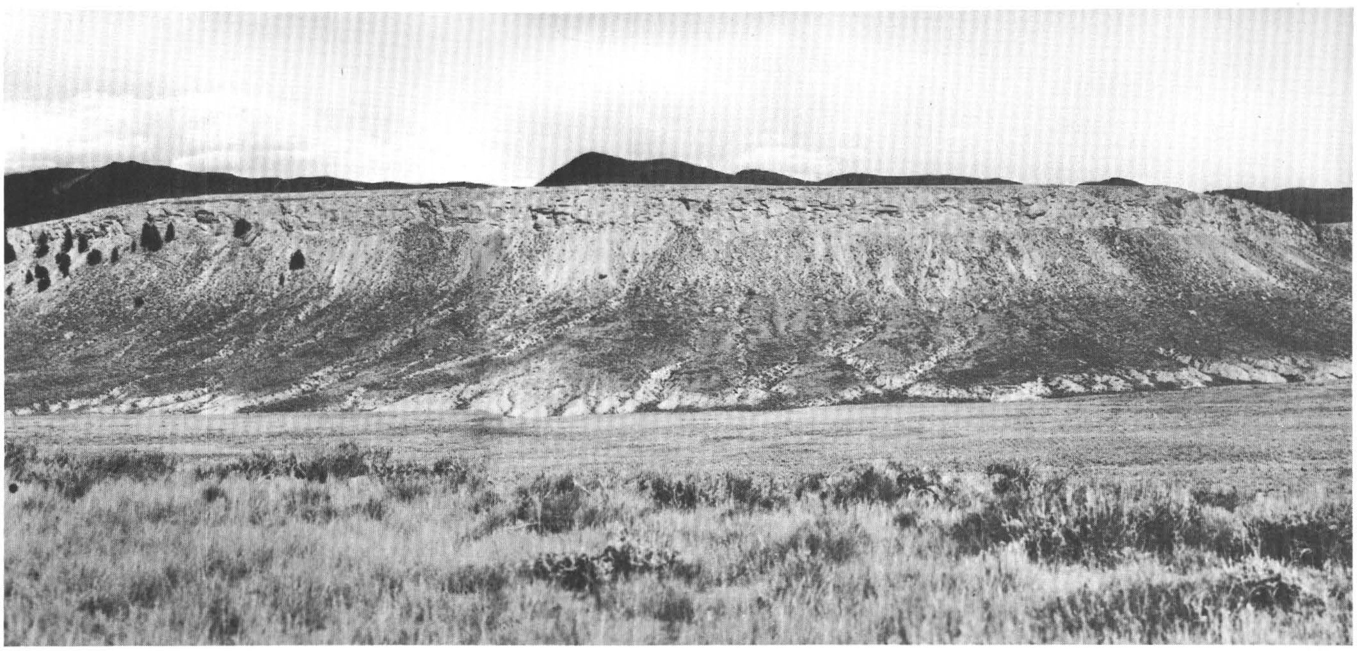

FIGURE 9.—The Hygiene Sandstone Member of the Pierre Shale in the SE¼ sec. 30 and the NE¼ sec. 31, T. 3 N., R. 80 W., about 9 miles north of Kremmling, Grand County, Colo. Specimens of *Baculites scotti* are in large brown-weathering calcareous sandstone concretions in the sandstone and in gray silty limestone concretions as much as 200 feet below the top of the sandstone.

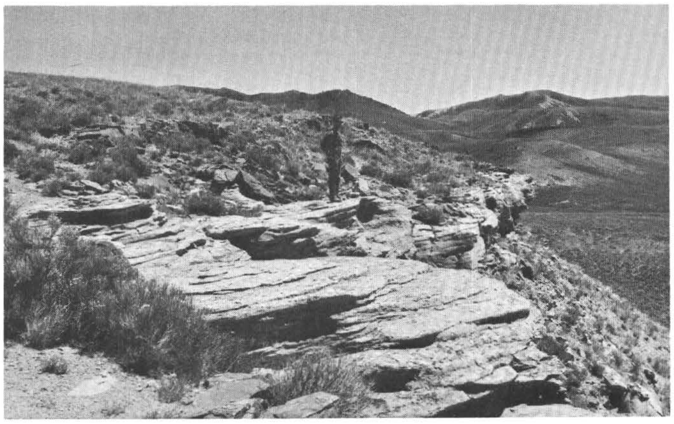

FIGURE 10.—Type locality of the Carter Sandstone Member of the Pierre Shale in the NW¼NW¼ sec. 20 and the SW¼SW¼ sec. 17, T. 3 N., R. 80 W., about 11 miles north of Kremmling, Grand County, Colo.

### UNNAMED SHALE MEMBER

About 900 feet of shale overlies the Carter Sandstone Member and is best exposed in the northwestern part of T. 3 N., R. 80 W., and in the northeastern corner of T. 3 N., R. 81 W.

The lower 30 feet of the member is soft silty and sandy shale that contains near its base smooth gray limestone concretions about 1 foot in diameter that locally yield specimens of *Baculites crickmayi* Williams and *Hoploscaphites* sp. Gray septarian limestone concretions in this interval are generally barren. At the top of this 30-foot shale interval of rocks is a distinctive marker bed of ledge-forming dark-green glauconitic sandstone about 3 feet thick capped by a thin reddish ironstone layer. Two glauconite zones are present in the E½ sec. 5, T. 2 N., R. 80 W. Phosphatic nodules are common in this sandstone. Concretions from this level contain the index ammonite *Didymoceras stevensoni* in addition to *Placenticeras* sp. and *Baculites* sp.

From 30 feet to about 350 feet above the top of the Carter Sandstone Member is a poorly exposed soft sandy and silty shale interval. Two bentonite beds occur about 50 feet above the top of the Carter. No ammonites other than poorly preserved *Baculites* have been found in this interval, probably owing to poor exposures and lack of concretions, but it probably lies partly in the Range Zones of *Exiteloceras jenneyi* (Whitfield) and *Didymoceras cheyennense* (Meek and Hayden).

A silty shale interval about 380 feet above the Carter is the most fossiliferous part of the Pierre in the Kremmling area. This level contains smooth limestone concretions in which are several kinds of ammonites including *Baculites compressus* Say, *Baculites* sp., *Hoploscaphites nodosus* (Owen), *Eutrephoceras* sp., *Axonoceras compressum* Stephenson, *Placenticeras meeki* Boehm, *Anaklinoceras reflexum* Stephenson, and *Solenoceras reesidei* Stephenson.

Limy sandstone concretions as much as 6 feet in diameter make an excellent marker zone about 420 feet above the top of the Carter. The lower limit of the Range Zone of *Baculites cuneatus* Cobban is at about this level in the SW¼ sec. 7, T. 3 N., R. 80 W. Large ellipsoidal concretions contain specimens 2 or 3 feet in diameter of *Placenticeras* in addition to many other marine fossils, including the index ammonite *Baculites cuneatus* and the ammonites *Hoploscaphites nodosus* and *Eutrephoceras* sp.

From 420 to 925 feet above the Carter Sandstone Member is silty and sandy slope-forming shale. Gray dense limestone concretions and silty limestone layers about 490 and 660 feet above the Carter contain the index ammonite *Baculites reesidei* Elias. Gray limestone concretions less than 2 feet in diameter about 780 feet above the Carter yield numerous well-preserved specimens of the index ammonite *Baculites jenseni* Cobban. Black shale about 40 feet thick that contains thin ironstone concretions and bentonite beds occurs about 800 feet above the top of the Carter Sandstone Member. The upper part of the unnamed shale unit consists of 80 feet of silty to sandy shale that is transitional to the overlying Gunsight Pass Member.

### GUNSIGHT PASS MEMBER

The Gunsight Pass Member of the Pierre Shale is here named for about 150–170 feet of sandstone and silty shale about 4,535 feet above the base of the Pierre. The member forms the topmost unit of the middle part of the Pierre. The member is named for Gunsight Pass in sec. 22, T. 3 N., R. 80 W., Grand County, Colo., and the type locality is in the northwestern part of T. 3 N., R. 80 W. The member can be divided into three parts. The lower part of the member is a 10- to 20-foot-thick very fine grained sandstone bed that is typically exposed in the SW¼NW¼ sec. 8, T. 3 N., R. 80 W. The base of this sandstone bed is chosen as the base of the Gunsight Pass Member. The contact is gradational through several feet and occurs where sandstone predominates over underlying silty shale. A zone of brown-weathering calcareous sandstone concretions about 3 feet in diameter is found in the unit. The middle part of the member, about 100 feet thick, is silty shale that contains gray calcareous siltstone concretions about 1 foot in diameter. The upper part is cliff-forming sandstone as much as 50 feet thick that is typically exposed in the SW¼NW¼ sec. 16, T. 3 N., R. 80 W. (fig. 11). The upper contact of the member with the overlying dark-gray shale is sharp.

The Gunsight Pass Member is in the Range Zone of either *Baculites jenseni* Cobban or *Baculites eliasi* Cobban. The only ammonite found in the member is *Pseudobaculites*, which occurs in the Range Zones of *B. jenseni* or *B. eliasi* elsewhere in the Western Interior.

### UPPER PART

The upper part of the Pierre remaining in the Kremmling area consists of about 200 feet of uniformly dark marine shale that contains numerous gray dense limestone concretions. Good exposures of the contact between the top of the Gunsight Pass Member and the upper part of the Pierre are shown in figure 11. The original thickness of this unit is unknown owing to latest Cretaceous deformation and erosion, but it likely was more than several thousand feet thick. The upper part of the Pierre is overlain with erosional unconformity by arkosic sandstone of the Middle Park Formation of Late Cretaceous(?) and Paleocene age.

The only ammonites found in the upper part are in phosphatic sandstone nodules as much as 6 inches long that contain poorly preserved fragments of *Baculites eliasi*, *Baculites* sp., and *Hoploscaphites* sp. These nodules lie on the top surface of the Gunsight Pass Member and in the lower 3 inches of the upper part.

## CORRELATION OF THE PIERRE SHALE TO THE EAST AND TO THE WEST

The Pierre Shale near Boulder, Colo., about 60 miles east of the Kremmling area, totals 8,020 feet in thickness in a section measured by G. R. Scott and R. F. Wilson (Scott and Cobban, 1965). It consists of a lower shale unit; a middle sandy unit containing the Hygiene, Terry, Rocky Ridge, and Larimer Sandstone Members; and an upper shaly unit. The upper shaly unit contains an unnamed sandstone member and at the top a thick sandy upper transition member that grades into the overlying Fox Hills Sandstone. The section is well dated by numerous collections of molluscan fossils.

The lower shale unit, about 1,600 feet thick, is calcareous in its basal 40 feet (lower transition member) and gradational into the underlying Niobrara Formation. Diagnostic fossils have not been found in the basal 320 feet of the lower shale unit, but the overlying 820 feet has mollusks indicating the Zones of *Baculites obtusus*, *B. mclearni*, and *B. asperiformis*. The upper part of the unit contains many levels of limestone and ironstone concretions with *B. perplexus*.

The middle sandy unit, about 2,300 feet thick, contains many fossiliferous concretions of sandstone and sandy, silty, or ferruginous limestone. *Baculites gre-*

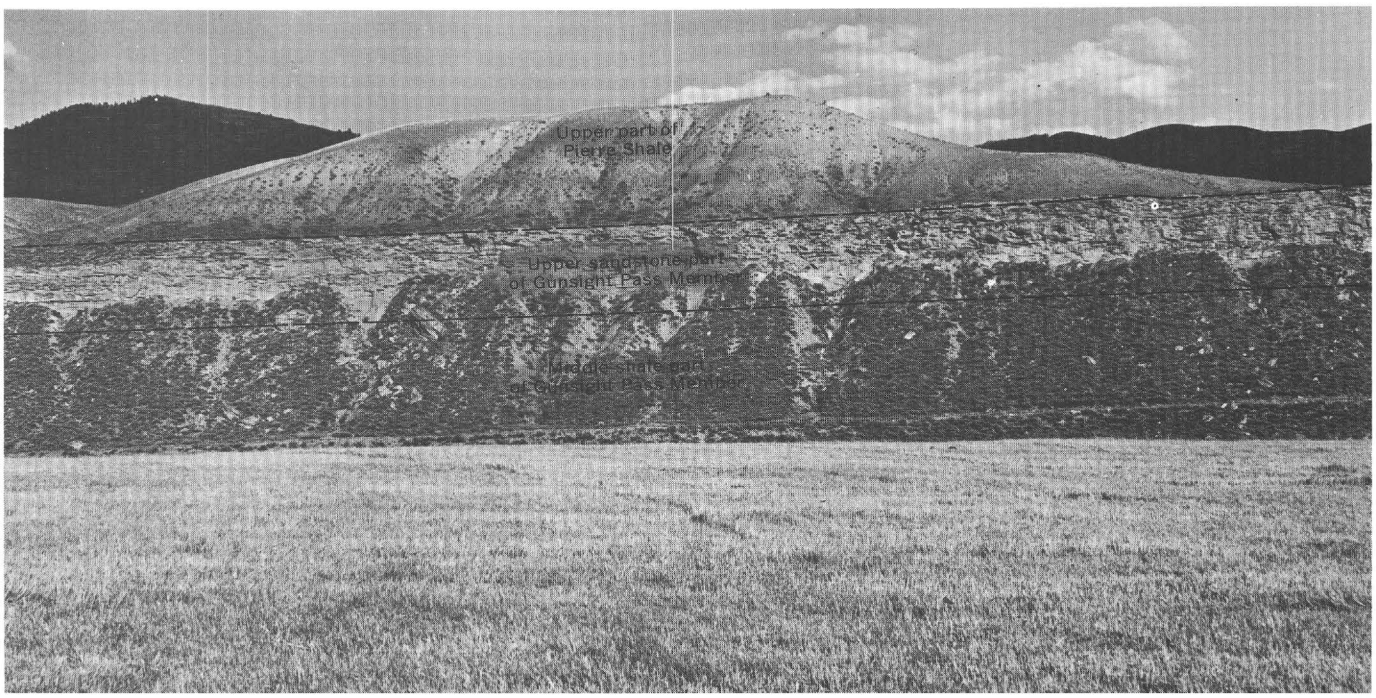


FIGURE 11.—Upper sandstone and middle shale parts of the Gunsight Pass Member of the Pierre Shale in the SW¼NW¼ sec. 16, T. 3 N., R. 80 W., about 11.5 miles north of Kremmling, Grand County, Colo. Specimens of *Baculites eliasi* are present in phosphatic nodules at the top of the sandstone.

*goryensis* occurs in the lower part of the Hygiene Sandstone Member, and *B. scotti* is found in the middle and upper parts. The shale separating the Hygiene and Terry Sandstone Members, about 800 feet thick, contains *B. scotti* in the lower 150 feet, *Didymoceras nebrascense* in the next 380 feet, and *D. stevensoni* in the rest. *Exiteloceras jenneyi* is found in the 60-foot Terry Sandstone Member and in the basal few feet of the overlying shale. The shale separating the Terry and Rocky Ridge Sandstone Members is about 750 feet thick and contains an unnamed sandstone bed in its lower part with *Didymoceras cheyennense* (Meek and Hayden) (not shown in fig. 2). The middle third of the shale contains ammonites indicative of the Zones of *Baculites compressus* and *B. cuneatus*. *Baculites reesidei* occurs in the upper third and in the Rocky Ridge and Larimer Sandstone Members.

The upper shaly unit of the Pierre is composed of two thick sequences, a lower sandy to nonsandy shale about 2,800 feet thick and an upper very sandy shale 1,170 feet thick (upper transition member) that contains beds of soft sandstone. Fossiliferous limestone and ironstone concretions are common in most of the upper shaly unit. *Baculites jenseni* occurs in the basal 100 feet, and *B. eliasi* occurs in the next 700 feet. An unnamed sandstone bed 1,010 feet above the base contains *Inoceramus typicus* (Whitfield) and scaphites of the *Hoploscaphites plenus* (Meek and Hayden) group suggestive of the Zone of *Baculites baculus* Meek and Hayden. *Baculites baculus* has been found with *I. typicus* as high as 1,750 feet above the base of the upper shaly unit. *Baculites grandis* Hall and Meek occurs higher in the unit, and *B. clinolobatus* still higher. The uppermost part of the unit (upper transition member) contains *B. clinolobatus* in the basal beds and ammonites of post-*clinolobatus* age in the rest.

The excellent fossil record in the Boulder area permits a ready correlation with the Pierre Shale in the Kremmling area up through the Zone of *B. eliasi* (fig. 2). Rocks as young as the Zone of *B. clinolobatus* were probably present at one time in the Kremmling area.

Rocks of Pierre age crop out in Fish Creek Canyon 40 miles west of the Kremmling section. Here the rocks are divided into Mancos Shale, Mesaverde Group, and Lewis Shale. The generalized section shown in figure 2 is based mainly on the graphic section of the uppermost part of the Mancos Shale and the overlying Mesaverde Group presented by Bass, Eby, and Campbell (1955, pl. 21, sec. 3). The thickness of the Lewis Shale is from the same authors, and the interval of rocks from the Loyd Sandstone Member of the Mancos Shale down to the Niobrara Member is from the electric log of the McCulloch Oil Corp.'s Skeeter No. 1 in the SW¼ SW¼ sec. 8, T. 5 N., R. 89 W., which is about midway between the Fish Creek and Hamilton sections.

Only the uppermost part of the Mancos Shale is exposed in Fish Creek Canyon. Bass, Eby, and Campbell's plotted section shows two sandstones about 550 feet apart of which the upper is 450–500 feet below the top of the Mancos. We found *Baculites perplexus* in limestone concretions in the shale separating the two sandstones. The upper sandstone resembles the Kremmling Sandstone Member, and the lower sandstone, which contains large yellowish-brown-weathering sandy concretions, is interpreted as the equivalent of the marker zone of similar concretions at Kremmling (fig. 6).

The third sandstone at Fish Creek is the Tow Creek Sandstone Member of the Iles Formation (Bass and others, 1955, pl. 21). It is fossiliferous, but none of the fossils collected are indices to a particular ammonite zone.

Nearly 400 feet of marine shale overlies the Tow Creek Sandstone Member. A robust normally coiled ammonite, *Anapachydiscus* sp., was found about 100 feet below the top. This genus is most common in the Zone of *B. scotti* in the Western Interior region.

Above the marine shale is a conspicuous cliff-forming sandstone containing *Inoceramus* aff. *I. pertenuis* Meek and Hayden. We believe that this sandstone is equivalent to the Hygiene Sandstone Member near Kremmling inasmuch as both sandstones physically resemble one another and each overlies marine shale containing *Anapachydiscus*.

Several hundred feet of coal-bearing nonmarine beds overlie the Hygiene equivalent. The nonmarine unit is overlain by a very poorly exposed marine shale grading up into the Trout Creek Sandstone Member at the top of the Iles Formation. Outcrops of this marine shale along the Oak Creek-Hamilton road about 9 miles southeast of Fish Creek in the S½ sec. 25, T. 4 N., R. 86 W., contain limestone concretions with *Exiteloceras jenneyi* (Whitfield). This ammonite has not been found in the Kremmling area as yet, but it may eventually be discovered low in the shale separating the Carter Sandstone Member from the Gunsight Pass Member.

Several hundred feet of coal-bearing rocks overlying the Trout Creek Sandstone Member forms the lower part of the Williams Fork Formation. These nonmarine rocks are overlain by a thick marine shale that grades up into the Twentymile Sandstone Member of the Williams Fork. Exposures of this marine shale are very poor on Fish Creek, but they are excellent in cuts along the Oak Creek-Hamilton road a few miles to the east *reesidei.* This ammonite occurs also near the middle of where the lower part of the unit contains *Baculites* the shale separating the Carter Sandstone Member from the Gunsight Pass Member in the Kremmling area. The Twentymile Sandstone Member is marine, but none of the fossils found can be assigned to a particular ammonite zone. However, a correlation with the Gunsight Pass Member seems logical (fig. 2).

The Lewis Shale, which overlies the Williams Fork Formation, is poorly exposed along Fish Creek, and no significant fossils were found. Collections of fossils from the Lewis Shale about 16 or 17 miles north of Fish Creek include "*Inoceramus*" *fibrosus* (Meek and Hayden), *Baculites clinolobatus*, and *Coahuilites*, which indicate an age at least as young as the Zone of *Baculites clinolobatus* Elias.

The Hamilton section (fig. 2) is based on graphic sections presented by Bass, Eby, and Campbell (1955, pl. 21, sec. 1) and Konishi (1959, pl. 1, sec. 1). In this area, the Iles and Williams Fork Formations are largely nonmarine. Five conspicuous sandstones are present in the upper part of the Mancos Shale. The lowest, Morapos Sandstone Member, lies in the Zone of *Baculites mclearni* (Dyni, 1966). The second sandstone, 350 feet higher, contains the same kind of large yellowish-brown-weathering calcareous sandstone concretions (fig. 6) with *B. asperiformis* as in the Fish Creek section. The third sandstone, about 350 feet higher, and a fourth sandstone, about 100–150 feet higher, lie in the older part of the Range Zone of *B. perplexus*. The next overlying sandstone, Loyd Sandstone Member, about 50–100 feet above the fourth, is highly fossiliferous (Dyni and Cullins, 1965, p. J5) and contains *B. gilberti*, which lies in the middle of the Range Zone of *B. perplexus*. Less than 100 feet of marine shale separates the Loyd Sandstone Member from the Tow Creek Sandstone Member at the base of the Iles Formation. Diagnostic fossils have not been found in this shale or in the Tow Creek Member.

Geologic reconnaissance in the fall of 1970 in the Yampa valley near Phippsburg and Oak Creek indicates that the Mancos Shale is roughly equivalent to that part of the Pierre Shale beneath the Hygiene Sandstone Member of the Kremmling area. The Sharon Springs Member of the Pierre is present as a distinctive unit in the Yampa valley and extends to the west as far as Rangely, Colo. Kucera (1959, p. 41–42) applied the names Devils Grave and Hunt Creek Sandstone Members of the Mancos Shale to sandstone units in the upper part of the Mancos in the Yampa valley. The lowermost sandstone, the Devils Grave, contains *Baculites asperiformis* and correlates approximately with the distinctive siltstone concretion layer (fig. 6) that crops out about 500 feet above the base of the Sharon Springs at Kremmling. The Hunt Creek Sandstone Member of the Mancos Shale of Kucera (1959, p. 41–42) consists of three beds of sandstone separated by thick beds of shale having an aggregate thickness of 265 feet (Kucera, 1959, p. 42, fig. 6). The upper sandstone of the Hunt Creek probably correlates with the Muddy Buttes Sandstone Member, and the lower sandstone of Hunt Creek probably correlates with the Kremmling Sandstone Member. The middle sandstone of the Hunt Creek is represented by shale in the Kremmling area. The Hunt Creek Sandstone Member of the Mancos Shale of Kucera (1959) and the Muddy Buttes and Kremmling Sandstone Members of the Pierre all lie within the range span of *Baculites perplexus*.

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