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By W. A. COBBAN, C. E. ERDMANN, R. W. LEMKE, *and* E. K. MAUGHAN

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A report of a formal subdivision and age assignments of a classic Cretaceous area

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By W. A. Cobban, C. E. Erdmann, R. W. Lemke, and E. K. Maughan

ABSTRACT

Rocks of Albian-Santonian age, cropping out on the Sweetgrass arch in north-central Montana, consist of the Blackleaf Formation, 186 to 253 m (610–830 ft) thick, and the overlying Marias River Shale, 280 to 363 m (920–1,190 ft) thick. In general, the Blackleaf thickens southward, and the Marias River thickens westward. Each formation has four named members.

The members of the Blackleaf Formation are, from oldest to youngest, Flood, Taft Hill, Vaughn, and Bootlegger. Quartz sandstone and very dark gray shale characterize the Flood Member, which rests disconformably on green and red mudstones of the nonmarine Lower Cretaceous Kootenai Formation.

The Flood Member is 42 m (138 ft) thick in its type section, where it consists of a basal ledge-forming thin-bedded flaggy sandstone, a medial slope-forming dark-gray shale, and an upper thick cliff-forming sandstone that contains huge sandstone concretions. Trace fossils, chiefly small tracks, trails, and burrows, are abundant in the flaggy beds and suggest a shallow-water near-shore marine environment for most of the member. On the east flank of the Sweetgrass arch, *Inoceramus comancheanus* Cragin, of late Albian age, was found in sandstone at the top of the member. This pelecypod is known from the Skull Creek Shale of the Black Hills area of South Dakota, the Kiowa Shale of Kansas, and the South Platte Formation of Colorado.

Glauconitic sandstone and medium-gray soft bentonitic silty shale characterize the Taft Hill Member, which is 74 m (242 ft) thick in its type section. The lower contact is gradational and the upper sharp and disconformable. The member is divisible into three units by a thick glauconitic sandstone separating a lower and an upper unit of silty bentonitic shale and thin glauconitic sandstone beds. Fossils, which are scarce in the member, include *Inoceramus bellvuensis* Reeside, of late Albian age.

The Vaughn Member, 26 m (86 ft) thick in its type section, is a nonmarine sequence of light-colored bentonitic clay, siltstone, and sandstone that rests sharply on the marine Taft Hill Member. In general, the Vaughn Member consists of a lower unit of pale-yellow friable arkosic sandstone and an upper unit of bentonitic clay and tuffaceous siltstone and minor amounts of bentonite and sandstone. Minute crystals of a red zeolite (clinoptilolite) are so abundant in the upper clayey unit as to impart a pinkish aspect to the outcrops. The Vaughn Member is usually poorly vegetated and erodes into badlands. Fossil logs are present in the lower sandstone unit, and a few fossil leaves and fragments of reptilian bones occur in the upper clayey unit.

The Bootlegger Member, a westward sandy equivalent of the Mowry Shale, totals 100 m (329 ft) in thickness in the type section and consists of thin beds of medium-gray very fine to fine-grained sandstone, gray siltstone, dark-gray shale, and bentonite. The sandstone, siltstone, and shale are usually interlaminated. At least 12 beds of bentonite are present in the type section; the two thickest beds (2–3 m) contain hard lenslike masses of zeolitic tuff. Thin beds of black-coated chert pebbles are present locally, and one, just below the top, contains pebbles as much as 5 cm in diameter in a matrix of coarse-grained salt-and-pepper sandstone that includes abundant fish bones. Many of the beds of sandstone, siltstone, and shale are hard, resulting in ledge-forming outcrops. Both contacts of the member are sharp. The Bootlegger thins westward largely by the lower part grading into nonmarine beds assigned to the Vaughn Member. Over much of the Sweetgrass arch, the Bootlegger Member is divisible into lower and upper hard sandy units separated by a medial unit of softer shale. Fish scales and bones are common in the upper sandy unit. *Neogastroplites,* an ammonite believed to be of latest Albian and earliest Cenomanian age, has also been found in the upper sandy unit.

The Marias River Shale consists of the Floweree, Cone, Ferdig, and Kevin Members. The Floweree Member unconformably overlies the Bootlegger Member and is 19.4 m (63.5 ft) thick at its type section. It consists chiefly of a sequence of dark-bluish-gray shale, lighter gray sandy shale, and thin beds of siltstone and sandstone. Thin layers of chert granules or small pebbles are present locally. Gray septarian limestone concretions occur on the east flank of the Sweetgrass arch. The Floweree Member is softer and darker than the underlying Bootlegger Member. Trace fossils, consisting of small tracks, trails, and burrows, are common on the sandstone and siltstone layers. These sandy beds have also yielded a few impressions of inoceramids and ammonites, including *Metoicoceras muelleri* Cobban and *M. mosbyense* Cobban, of late Cenomanian age. A slightly older late Cenomanian ammonite, *Calycoceras canitaurinum* (Haas), was found in one of the septarian limestone concretions. These fossils occur in the lower half of the Greenhorn Formation of the Black Hills area.

The Cone Member is a thin calcareous unit of latest Cenomanian and earliest Turonian age. A rather uniform thickness of 15–18 m (50–60 ft) is consistent over most of the Sweetgrass arch. Most of the member is dark-gray calcareous shale that weathers light bluish gray first and then yellowish white. The upper half of the member, and especially the uppermost part, contains thin beds of argillaceous or crystalline limestone that tend to form low ridges. Septarian limestone concretions occur at several horizons; the most conspicuous bed is just above the base and contains closely spaced concretions that weather pale lavender gray. Several beds of bentonite are present, and one, at the top of the lower third of the member, attains a thickness of nearly a metre. The contacts of the member are sharp and marked by an abrupt change from the limy shale of the Cone to the noncalcareous shale of the underlying Floweree and overlying Ferdig Members. A thin layer of limonitic siltstone at the base, containing shale pebbles, soft white siltstone nodules, and fish teeth and bones, probably marks a disconformity. Invertebrate fossils are abundant and reveal the zones of *Sciponoceras gracile* (Shumard)

and *Inoceramus labiatus* (Schlotheim) which are found in the upper part of the Greenhorn Formation of the Black Hills area.

The Ferdig Member, 68.6 m (224 ft) thick in its type section, is a sequence of gray noncalcareous shale containing thin hard sandy partings and gray- to yellow-weathering limestone concretions and dusky-red-weathering dolostone concretions. Three units make up the member—a lower dark-bluish-gray sandy shale containing gray- and yellow-weathering calcareous concretions, and an upper dark-bluish-gray shale containing gray-weathering calcareous concretions. Thin beds of bentonite are sparingly present. A very thin, but persistent, layer of conglomeratic sandstone in the upper part of the member contains polished granules and small pebbles of black, gray, brown, and green chert, as well as pebbles of quartz, quartzite, and argillite. The contact of the Ferdig with the underlying Cone Member is sharp and disconformable; it is marked by a thin layer of limonitic siltstone containing, in places, fish teeth, small pebbles of black chert, and larger gray and brown phosphatic pebbles. In well cuttings, the shale in the upper part of the Ferdig may show finely disseminated pyrite. The contact with the overlying Kevin Member is conformable. Molluscan fossils are common and reveal at least three zones. *Prionocyclus hyatti* (Stanton), of middle Turonian age, is found in the lower unit, characterized by dusky-red dolostone concretions. *Scaphites nigricollensis* Cobban, of middle late Turonian age, is present through much of the medial sandy unit. *Scaphites corvensis* Cobban, of slightly later Turonian age, occurs at the top of the sandy unit and in the overlying upper shale unit.

The Kevin Member, 188 m (617 ft) thick in its type section, is a dark-gray shale that contains some thin sandy parts, numerous thin layers of bentonite, and many beds of calcareous concretions that weather gray, yellow, or dusky red. The member is divisible into three units on the basis of abundance of bentonite beds and composition of concretions. Numerous beds of bentonite and gray- to yellow-weathering limestone concretions characterize the lowest unit, which is 53–55 m (175–180 ft) thick. The many thin layers of light-gray bentonite give the outcrop a distinctive banded appearance. The medial unit, about 60 m (200 ft) thick, contains numerous beds of orange- to dusky-red-weathering ferrocalcareous concretions and a few thin layers of bentonite and very fine grained sandstone. An important marker bed, the MacGowan Concretionary Bed, lies in the middle of this unit. The MacGowan Bed is a conglomeratic bed of concretionary dolostone that weathers light brown, orange brown, and dusky red, and contains polished granules and small pebbles of gray and black chert and larger pebbles of gray phosphatic siltstone. One or two thin layers of greenish-gray phosphatic pebbles are present in the medial unit in the interval 3–10 m above the MacGowan Bed. The upper unit of the Kevin Member consists of about 60 m (200 ft) of dark-gray shale that contains many beds of yellowish-gray-weathering limestone concretions and a few thin beds of bentonite and very fine grained shaly sandstone. The upper half of this unit is in part calcareous. The boundary between the Kevin Member and the overlying Telegraph Creek Formation is sharp but conformable; it is marked by a change from the dark-gray shale of the Kevin Member to the lighter gray shale and siltstone of the Telegraph Creek Formation, interlaminated with very fine grained sandstone. Molluscan fossils are abundant and varied in the Kevin Member. The lower unit, of early Coniacian age, contains a zone of *Inoceramus erectus* Meek below and a zone of *Inoceramus deformis* Meek above and is correlated with the Fort Hays Limestone Member of the Niobrara Formation of the central Great Plains. The middle unit, characterized by the red-weathering ferrocalcareous concretions, contains three faunal zones; from oldest to youngest, a zone of *Inoceramus (Volviceramus) involutus* Sowerby–*Scaphites ventricosus* Meek and Hayden of Coniacian age, a zone of *Inoceramus stantoni* Sokolow–*Scaphites depressus* Reeside of early Santonian age, and a zone of *Inoceramus cordiformis* Sowerby–*Clioscaphites vermiformis* (Meek and Hayden) of middle Santonian age. The upper unit contains the rest of the *C. vermiformis* zone and the younger Santonian zones of *C. choteauensis* Cobban and *Desmoscaphites erdmanni* Cobban.

INTRODUCTION

Rocks formerly assigned to the Colorado Shale (Fisher, 1909, p. 36) on the Sweetgrass arch of north-central Montana (fig. 1) are divided in this paper into an older Blackleaf Formation and a younger Marias River Shale, both formations of the Colorado Group. The Blackleaf Formation is assigned to the Lower Cretaceous and is subdivided into four members, from oldest to youngest: Flood Member, Taft Hill Member, Vaughn Member, and Bootlegger Member. The Marias River Shale, of Late Cretaceous age, is subdivided also into four units, from oldest to youngest: Floweree Member, Cone Member, Ferdig Member, and Kevin Member. Although these formations and members have been previously defined by the authors (Cobban and others, 1959), type sections, fossil lists, and the regional stratigraphy were not presented. The purpose of the present report is to complete this presentation.

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HISTORICAL SUMMARY

The earliest investigation of the rocks later assigned to the Colorado Group in Montana was undertaken in 1861 by Meek and Hayden, who gave the name "Fort Benton Group, Formation No. 2" to the "Dark gray laminated clays, sometimes alternating near the upper part with seams and layers of soft gray and light-colored limestone. *Inoceramus problematicus, I. tenuirostratus, I. latus?, I. fragilis, Ostrea congesta, Venilia Mortoni, Pholadomya papyracea, Ammonites Mullani, A. percarinatus, A. vespertinus, Scaphites warreni, S. larvaeformis, S. ventricosus, S. vermiformis, Nautilus elegans?* etc. Extensively developed near Fort Benton on the Upper Missouri" (Meek and Hayden, 1861, p. 419). Of these fossils, *Inoceramus tenuirostratus, Veniella mortoni* (as *Venilia Mortoni*), *Pholadomya papyracea, Scaphites ventricosus, Clioscaphites vermiformis* (as *Scaphites vermiformis*), and *Cymatoceras nebrascense* (as *Nautilus elegans?*) came from "Chippewa Point*** some twenty odd miles below

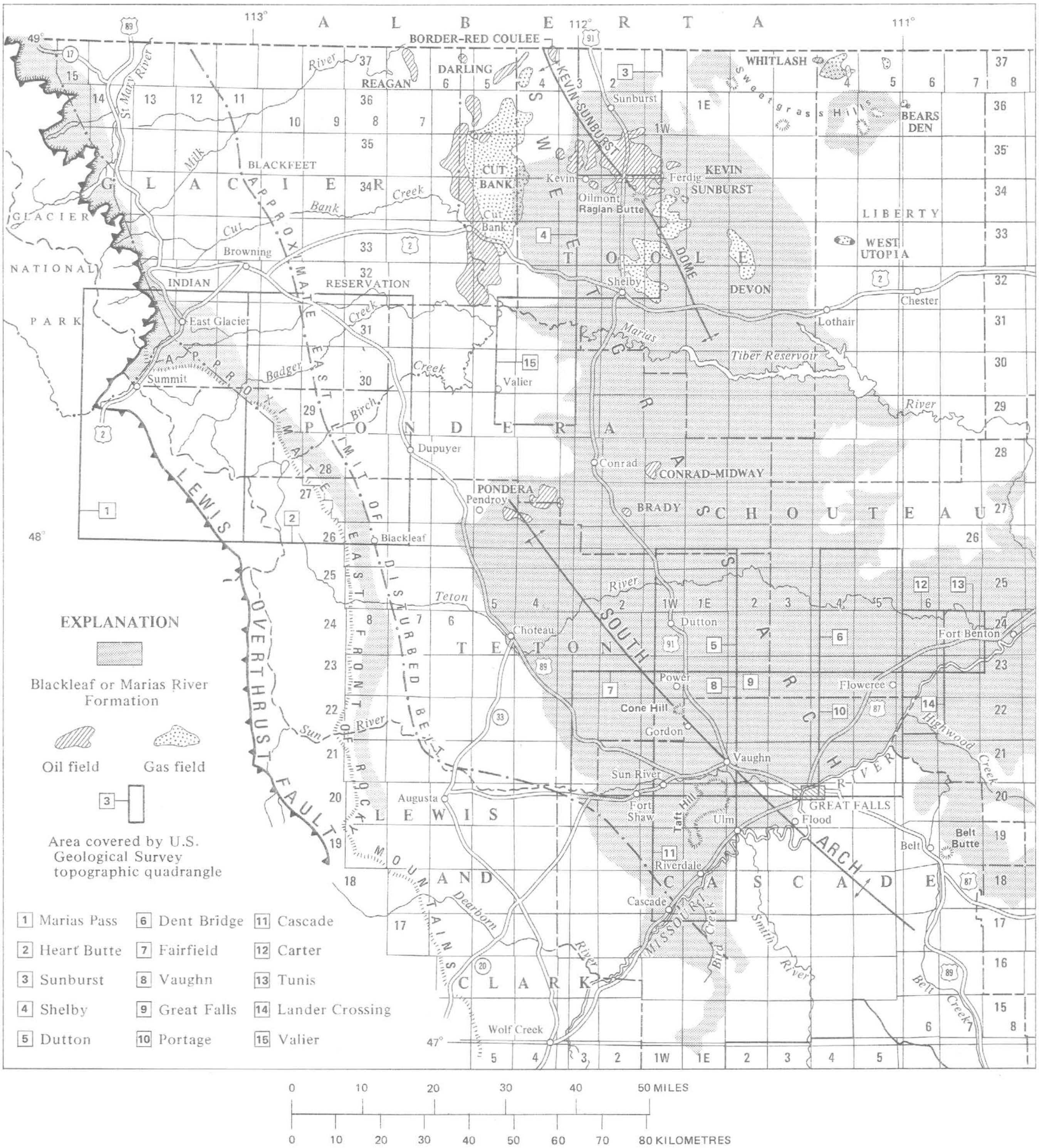


FIGURE 1.—Sweetgrass arch and surrounding area.

Fort Benton" (Meek and Hayden, 1862, p. 21–28. Those fossils are now known to be of Niobrara age. Meek and Hayden did not know that their chalky "Niobrara Division, Formation No. 3" underwent a facies change northwestward from its type locality at the mouth of the Niobrara River in Nebraska. Thus, inadvertently they included rocks of Niobrara age in the Benton Group which later was reduced to formation rank, the Benton Shale, and restricted to beds of Graneros, Greenhorn, and Carlile age.

Weed (1899, p. 2) applied the name Colorado Formation to the following highly generalized 565-m (1,850–ft) sequence on the southeastern part of the Sweetgrass arch, whose descriptive text has been taken from the columnar section sheet of the Fort Benton Folio:

Top

"Drab or lead-colored clay shale, carrying round or oval concretions of gray limestone.

Black shale with interbedded sandstones and a bed of tuff.

Red shale and sandstones in thin beds.

Lilac-colored sandstone, red clay, and thin limestone."

This formation rested on Weed's Dakota Formation, a sequence of "Red shale with limestone nodules capped by sandstone, and sandstone at the base." Overlying the Colorado Formation was a sandstone to which Weed gave the name Eagle Formation. The lower part of this unit probably includes the Telegraph Creek Formation, the basal formation of the Montana Group.

Willis (1902, p. 315, 326, 327), in describing the geology of what is now Glacier National Park, used the name Benton Shale for the uppermost or "lead-colored clay shale" member of Weed's Colorado Formation and the name Dakota Sandstone for the next-to-the-top unit. Willis listed several plant fossils from his Dakota Sandstone and a dozen marine molluscan genera from his Benton Shale.

The geology of the Great Falls coal field, south and southeast of Great Falls, was described by Fisher briefly in 1907 and in much more detail in 1909. He applied the term Colorado Shale to the upper two units (black and gray shales and interbedded sandstones) of Weed's Colorado Formation. The lower two units (red), as well as Weed's Dakota Formation, were assigned to the Kootenai Formation. The thickness of the strata referred to the Colorado Shale was therefore reduced to about 463 m (1,520 ft). Regarding the boundaries, Fisher (1909, p. 38) stated: "The Colorado shale rests with apparent conformity upon the underlying Kootenai, and is overlain conformably by the Eagle sandstone." Fisher (1907, p. 163; 1909, p. 37) gave a generalized section through the lower or sandy part of the Colorado Shale at Belt Butte.

Stanton (1913) extended the terms Colorado Shale and Eagle Sandstone into the Blackfeet Indian Reservation west of the crest of the Sweetgrass arch. In the following year, Stebinger (1914) used the name Virgelle in place of Eagle, inasmuch as the sandstone in the reservation represented only the lower or Virgelle Sandstone Member of the Eagle Sandstone. Stebinger (1914, p. 62) pointed out that the Virgelle Sandstone Member was massive in the upper part, whereas the lower half was "slabby*** becoming shaly toward the base." A little later, Stebinger (1916, p. 124; 1917, p. 285, 287, 289) applied the name Colorado Shale as far west as Glacier National Park, where the formation then included Willis' Dakota Sandstone and Benton Shale.

In the course of mapping the Disturbed belt along the Rocky Mountain front between Sun River and Birch Creek (southern boundary of Blackfeet Indian Reservation), Stebinger (1918, p. 154, 158–161) divided the Colorado Shale into a lower member, the Blackleaf Sandy Member, 183–213 m (600–700 ft) thick and an upper shale member 365 m (1,200 ft) thick. A generalized columnar section (Stebinger, 1918, p. 158) was given for the Blackleaf Sandy Member and basal part of the overlying shale member. The stratigraphic positions of five fossil collections were shown and the fossils listed (Stebinger, 1918, p. 160). Beginning about 24 m (80 ft) above the top of the Blackleaf, Stebinger recorded a "bituminous shale and maltha limestone" sequence, about 18 m (60 ft) thick, which contained abundant *Inoceramus labiatus* (Schlotheim). This unit had been noted earlier by Powers and Shimer (1914, p. 557), who noted "dark arenaceous shale" with abundant *Inoceramus labiatus* (Schlotheim) and *Lingula* sp. near the Sun River. Stebinger used the name Virgelle for the sandstone overlying the Colorado Shale and placed the boundary between the two formations "at the position where the amount of sandstone exceeds that of the shale in the transition beds."

Romine (1929, p. 786–788) brought Stebinger's name Blackleaf to the Sweetgrass arch. Collier (1929 [1930], p. 70–72) presented a generalized section of the member in the area a few miles north of Vaughn and listed 39 species of invertebrate fossils, identified by J. B. Reeside, Jr., from 17 localities on the Sweetgrass arch. The stratigraphic positions of the fossils were given in feet below the top of the Colorado Shale. Also, Dobbin and Erdmann (1930) used several sandstone units of the Blackleaf Sandy Member in structural mapping on the Sweetgrass arch.

Before 1939, the boundary between the Colorado Shale and the Virgelle Sandstone was placed either within the sandy transition beds (Stebinger, 1918, p. 164, 165) or at the top of the transition beds (Dobbin and Erdmann, 1930). Erdmann and Davis (1939) treated the transition beds as a separate formation designated "transition zone." Later (Erdmann and Schwabrow, 1941, p. 280–282; Blixt, 1941, p. 334, 335), the transition zone was considered as the lower member of the Eagle Sandstone. Erdmann (1948) applied the name Telegraph Creek(?) Formation to the transition beds. Later, Cobban (1950) was able to remove the query by listing fossils of Telegraph Creek age from the formation.

The upper part of the Colorado Shale on the Kevin-Sunburst dome was divided into two formations, Carlile and Niobrara, by Erdmann, Gist, Nordquist, and Beer (1947). A detailed columnar section of the Niobrara Formation was presented. The stratigraphic positions of key marker beds (lettered A through M) were indicated from near the top of the formation downward. Bed "F," near the middle of the Niobrara Formation, was described as a persistent and easily identified mud pellet conglomerate (later identified as conglomeratic phosphorite) that weathers orange buff and contains some chert pebbles. Bed "N," a thin hard layer of gray sandstone that contains gray and black chert pebbles, was used as the top of the Carlile Formation of Erdmann, Gist, Nordquist, and Beer (1947). In a later report by Erdmann (1949), on the Lothair area just southeast of the Kevin-Sunburst dome, the term Colorado Shale was used again.

Cobban (1951a) showed that the Colorado Shale on the Sweetgrass arch was divisible into many distinctive lithologic units that could be correlated by their fossil content and, in places, by their lithologic features with the formations and members of the Colorado Group of the Black Hills area of South Dakota. Most of the guide fossils were figured (Cobban, 1951b, 1955b). More recent refinements in correlation have been made possible by new fossil discoveries (Cobban and others, 1956, 1958).

Cobban, Erdmann, Lemke, and Maughan (1959), in recognition of a need for a more precise nomenclature in connection with geologic mapping on the Sweetgrass arch, divided the Colorado Group into an older Blackleaf Formation and a younger Marias River Shale. The Blackleaf Formation was assigned to the Early Cretaceous and divided into four members, from oldest to youngest: Flood Member, Taft Hill Glauconitic Member, Vaughn Bentonitic Member, and Bootlegger Member. The Marias River Shale was divided into four members, from oldest to youngest: Floweree Member, Cone Calcareous Member, Ferdig Shale Member, and Kevin Shale Member.

Aside from Stebinger's work (1918) in the Sun River–Birch Creek area, little had been published concerning the Colorado Shale in the Disturbed belt along the Rocky Mountains front until fairly recently. Some of the Cretaceous outcrops along the south side of Glacier National Park were identified by their fossil content and lithologic characteristics by Cobban (1956). Schmidt (1963, 1966), in his studies of the Dearborn River area, and Mudge (1965), in his studies of the Sun River area, applied the nomenclature of Cobban, Erdmann, Lemke, and Maughan (1959) except for dropping the adjectival part of the name for the Taft Hill and Vaughn Members. Fox and Groff (1966) and Fox (1966) also applied the nomenclature of Cobban, Erdmann, Lemke, and Maughan (1959) but dropped the adjectival parts of all member names. In order to be consistent, all adjectival terms are also eliminated in the present study. One other important work is that by Cannon (1966), who presented much information concerning the lithology, thickness, paleocurrent patterns, and genesis of the members of the Blackleaf Formation.

BLACKLEAF FORMATION

In defining his Blackleaf Sandy Member, Stebinger (1918, p. 158) stated:

> The lower 600 to 700 feet of the Colorado shale comprises an alternation of dark marine shales and gray sandstone in beds 20 to 75 feet thick, forming a unit clearly distinguishable from the remaining shaly portion of the Colorado. For convenience in reference and description it is here designated the Blackleaf sandy member, the name being taken from Blackleaf Creek, along which the beds are well developed.

The exposures on Blackleaf Creek are in the Disturbed belt along the Rocky Mountains front, about 6–11 km (4–7 mi) west of Blackleaf in western Teton County (Heart Butte quadrangle). With the exception of a small area near the south edge of his map, Stebinger included the Blackleaf with the Lower Cretaceous and Jurassic rocks as an undifferentiated cartographic unit.

Without referring to any specific locality, Stebinger (1918, p. 158, fig. 33) presented for his Blackleaf only a generalized columnar section in which the base of his member was "bluish-gray shale" and the top was "coarse gray sandstone." Reference to his geologic map (pl. xxiv), however, indicates that the locality probably is about 43 km (27 mi) northwest of Choteau, in sec. 18, T. 26 N., R. 8 W., and sec. 13, T. 26 N., R. 9 W., Teton County. Notation of several fossil collections on the column from various places in the Disturbed belt seems to imply that the column might be composite, but evidently these collections were inserted to show the horizons at which fossils were found. In addition to the Blackleaf, the columnar section shows two overlying units of shale, the lower about 24 m (80 ft) thick with a 0.15–m (6–in.) pebble bed about 9 m (30 ft) above the base, and the upper about 24 m (80 ft) thick, which consist of "bituminous shale" and "maltha limestone." Stebinger noted an abundance of the pelecypod *Inoceramus labiatus* (Schlotheim) in the bituminous unit. This unit, on the Sweetgrass arch, is the Cone Member of the Marias River Shale. In north-central Montana, the contact of this calcareous unit with the overlying noncalcareous shale is very sharp and is readily determined in well cuttings and on electric logs. This is the contact that is commonly used informally as the top of the Blackleaf by most of the petroleum geologists and scouts and to some extent formally in the literature (Collier, 1929, p. 70; Erdmann and Davis, 1939; Blixt, 1941, p. 337).

The Blackleaf Formation is recognized in the area between the Missouri River and the international boundary and between the Rocky Mountains front and about the longitude of Fort Benton. (See fig. 1.) To some extent, the name has been used in southern Alberta adjacent to the Montana boundary (Russell and Landes, 1940, p. 24, 25).

Throughout this area, the Blackleaf rests sharply on the Kootenai Formation of continental origin. At any one locality a disconformity is not apparent, but regional studies suggest a hiatus and that the Blackleaf was deposited on an uneven surface with a relief possibly amounting to about 30 m (100 ft). The basal metre of the Blackleaf has the appearance of having been reworked from the upper part of the Kootenai by the earliest transgression of the Lower Cretaceous sea. This initial advance may have been comparatively rapid, for there is no evidence that marine life had time to become established.

FLOOD MEMBER

NAME AND DEFINITION

The Flood Member, the lowest member of the Blackleaf Formation, is a transgressive-regressive marine unit that marks the earliest appearance of the Lower Cretaceous sea. The unit is the black-gray shale and quartz sandstone member of Cobban (1951a, p. 2175–2176).

The Flood was named formally by us (Cobban and others, 1959, p. 2787) for exposures along the bluffs on the west bank of the Missouri River valley in the vicinity of Flood, a siding on the Burlington Northern Railway in the NW¼ sec. 34, T. 20 N., R. 3 E., Cascade County, Mont., 8 km (5 mi) southwest of the City of Great Falls. The type section is about 8 km northwest of Flood on the south bank of Sun River in a shallow reentrant (fig. 2) in the bluffs in the NW cor. NE¼ sec. 7, T. 20 N., R. 3 E., about 7.2 km (4.5 mi) west of Great Falls (fig. 2*A*). Most of the measurements were made on the west wall of the reentrant, but the upper 6 m (20 ft) of the middle unit is better exposed across the reentrant to the southeast and was mostly measured there. For descriptive purposes, the type section was subdivided into three units (lower, middle, and upper).

Since the construction in 1959 of a stretch of U.S. Interstate Highway 15 between Great Falls and the village of Vaughn, two easily accessible and more or

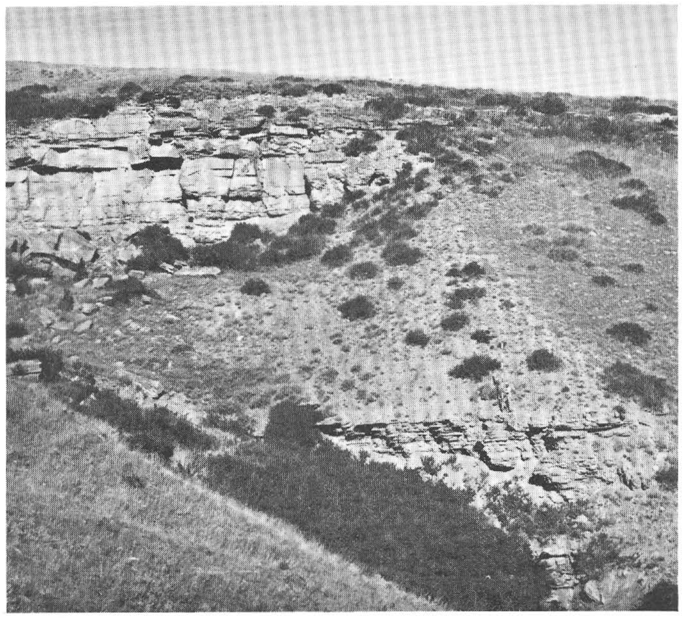


FIGURE 2.—Type section of the Flood Member in the NE¼ sec. 7, T. 20 N., R. 3 E., Cascade County, Mont. The threefold subdivision is well shown. Man, holding 4.3-m (14-ft) rod, is standing on top of lowest subdivision.

less completely exposed composite sections of the Flood Member have been studied and described from cuts and natural outcrops on the north side of the highway, each about 2.4 km (1.5 mi) north of the type section, between the vicinity of Emerson Junction and the Manchester Exit. One section, about 4.8 km (3 mi) west of Great Falls, in the SW¼SE¼ sec. 32, T. 21 N., R. 3 E., and hereafter referred to as the "reference section," exposes the Flood Member nearly continuously from top to bottom. The second section, about 6.4 km (4 mi) west of Great Falls in the center NW¼SE¼ sec. 31, T. 21 N., R. 3 E., exposes completely the upper 11.9 m (39 ft) of the Kootenai Formation, approximately the lower half of the Flood Member, and discontinuously exposes the remaining part of the member. The Flood Member is also completely exposed about 4 km (2.5 mi) southeast of the type section in a composite section along Gore Hill in the NE¼ sec. 21, T. 20 N., R. 3 E. These three sections supplement one another nicely and, together with the type section, reveal the character of the member in full.

THICKNESS

On the South arch of the Sweetgrass arch, the Flood Member ranges in thickness from 26 to 60 m (85 to 197 ft). At its type section the member is 42 m (138 ft) thick; it is 36.5 m (120 ft) thick in the reference section, 2.4 km (1.5 mi) northeast across Sun River valley. From this vicinity the member thins northeastward to

29.6 m (97 ft) along the Missouri River, 25.7 km (16 mi) northeast of Great Falls, and to 25.9 m (85 ft) on Belt Creek, 32 km (20 mi) east of Great Falls. Westward from the axis of the Sweetgrass arch, the Flood Member thickens as it approaches its source area. Fox (1966, p. 61–63) measured a total thickness of 60 m (197 ft) on the southwestern flank of the Sweetgrass arch. Along Sun River near the Rocky Mountain front, the member attains thicknesses of 45.7–167.6 m (150–550 ft) (Mudge, 1972, p. A6). Near Drummond, in T. 11 N., R. 12 W., Missoula County, about 169 km (105 mi) southwest of Great Falls, Gwinn (1961) reported thicknesses of 207–213 m (680–700 ft). Along the route of the Burlington Northern Railway 6.4 km (4 mi) southwest of East Glacier, the Flood Member is at least 68.6 m (225 ft) thick.

Well cuttings from the South arch indicate thicknesses of 15–46 m (50–150 ft), whereas cuttings from the northern part of the Sweetgrass arch reveal thicknesses of 15–30 m (50–100 ft). Reasons for these thickness variations, particularly local ones, are not well understood; they may be due to erosional relief on the underlying Kootenai Formation, or they may be due to channeling or scour between or within the units of the Flood Member.

OUTCROP DISTRIBUTION

On the Sweetgrass arch, the Flood Member crops out only across the southern part of the South arch. The thick sandstone at the top forms conspicuous bluffs along the Sun River from Great Falls westward for several kilometres, along the west side of the Missouri River valley between Great Falls and Flood, along both banks of the Missouri River valley between Flood and Ulm, and on both banks of the Smith River from Ulm southward for many kilometres. The member is exposed at many places in the southern and eastern parts of the Portage quadrangle northeast of Great Falls and in the Belt Creek valley 24–29 km (15–18 mi) east of Great Falls.

The Flood Member also is present in the Disturbed belt along the Rocky Mountain front, from Glacier National Park southeastward to Wolf Creek, where the thick sandstone at the top of the member forms prominent hogbacks wherever well exposed. Cobban (1956, p. 1001, 1002) has drawn attention to easily accessible outcrops along the U.S. Highway 2 and the Burlington Northern Railway south of the village of East Glacier, although recent highway construction has invalidated mileage details of his road log.

GENERAL DESCRIPTION

The strata of the Flood Member at the type section and in the vicinity can be separated into three individually distinctive lithologic units (fig. 2): (1) an inconspicuous lower unit of sandstone and siltstone, which constitutes about 16 percent of the total; (2) a middle unit of soft dark-gray somewhat carbonaceous shale, which is usually concealed in slopes and constitutes about 36 percent; and (3) an upper unit of cliff-making sandstone, which accounts for the remaining 48 percent.

The three lithologic units are herewith described in a general way. Further details are given in the type section and in other nearby sections.

Lower unit.—The boundary of the lower unit with the underlying Kootenai Formation appears to be disconformable. The upper part of the Kootenai in this area consists for the most part of beds of olive-gray siltstone, red to maroon mudstone, olive graywacke, and yellowish-gray sandstone of continental origin. The basal 1.5–2.4 m (5–8 ft) of the lower unit of the Flood Member has the appearance of having been reworked from this part of the Kootenai by the earliest transgression of the Lower Cretaceous sea. Thus, even at close distance, the boundary between the Kootenai Formation and the lower unit of the Flood Member may be indistinct, and the distinction between the lower unit and the Kootenai is not as simple as farther east, where the uppermost Kootenai strata are dusky red. Locally, the distinction between the Kootenai and the lower unit of the Flood is based on more uniform bedding and better development of fissility in the shale of the lower unit of the Flood and of better sorting in the sandstones, the prevalence of a grayish tone that increases in intensity upward from the boundary with continued mixing in of normal sediment from land, considerably less clastic mica in the sandstones, the absence of graywacke, and the appearance of thin laminae of reworked carbonaceous shale or coal in the siltstone. Moreover, the olive-gray beds here assigned to the Flood Member do not contain the freshwater "gastropod" limestone that is diagnostic of the upper part of the Kootenai Formation along the mountain front to the west.

The lower unit at the Flood type section and at other nearby exposures consists of about 6.7 m (22 ft) of shale, siltstone, and sandstone. Approximately the basal 1.5 m consists of soft olive-gray siltstone and fissile gray silty shale. This basal section commonly is overlain by a few feet of olive-gray siltstone with short irregular laminae of reworked carbonaceous debris and local thin films of coal. Layers of fine-grained quartz sandstone, less than 0.3 m thick, make resistant ledges in the siltstone. Approximately the upper 4.3 m (14 ft) of the unit at the type section consists mostly of a light-gray silty to fine-grained generally noncalcareous sandstone that forms a ragged cliffy outcrop. The sandstone, which occurs as uneven lenticular layers 1.3–51 cm (0.5–20 in.) thick, is separated by films of dark-gray shale or gray siltstone. In places it shows ripple marks and a "torrential" or planar type of crossbedding that dips southwest. Nearly every bedding plane between the sandstone and shale or siltstone exhibits casts of trace fossils (trail grooves?) and narrow elongate trains of sand that possibly were left as alimentary waste of marine worms (Mudge, 1972, fig. 31). Northeastward from the type section, the sandstone tends to thin and be replaced by shale. In the eastern part of the Portage quadrangle, only a few thin lenses of sandstone persist in this part of the Flood Member.

Middle unit.—This unit of the Flood Member consists mostly of medium-dark-gray shale about 15 m (50 ft) thick that rests rather sharply but conformably on the lower unit and probably represents the culmination of the first transgression of the Lower Cretaceous sea. The unit is largely concealed by colluvium and talus in the type section but is fairly well exposed in the reference section approximately 0.8 km (0.5 mi) north of Emerson Junction (west of Great Falls in the NE¼ sec. 5, T. 20 N., R. 3 E.) and in several exposures along Gore Hill, southeast of the type section (fig. 3). The basal 6 m (20 ft) of the unit includes several sandstone and siltstone beds up to about 0.6 m (2 ft) thick. Some siltstone beds contain abundant worm(?) castings or burrows. Sparingly present in lenticular sandstones representing some kind of channel fill are concretionary masses of compact olive-gray (brown-weathering) dolostone as well as a scattering of spherical concretions of marcasite. The shallow channels in which the concretions are found probably are of current origin and may have a general eastward trend. The middle 6 m (20 ft) of the unit consists chiefly of gray shale that is darker, more firm, and more fissile than most of the shale in the Blackleaf Formation. A 0.6-m (2-ft)-thick bed of grayish-black papery shale at the base of this middle part is so highly carbonaceous that its weathered surface resembles coal bloom. Approximately the upper 3 m (10 ft) of the unit consists chiefly of nodular sandstone with thin laminae and interbeds of dark-gray fissile shale, and it possibly represents the final stillstand of the first marine transgression. For want of an easily recognizable boundary, the top of the middle unit has been placed arbitrarily on a 13-cm-thick bed of gray silty limestone having cone-in-cone structure that overlies a 0.5-m (1.7-ft)-thick bed of calcareous siltstone containing small dark chert pebbles and granules.

Upper unit.—A conspicuous cliff-forming sandstone about 20 m (66 ft) thick at the type section constitutes the upper unit (fig. 2). Essentially the entire unit is exposed at the type section. More limited outcrops occur in bluffs along the Sun River valley to about 16 km (10 mi) west of Great Falls, where the west dip of the Sweetgrass arch carries it under the bed of the river in the SW¼ sec. 32, T. 21 N., R. 2 E. Closely related exposures occur in highway cuts west of Great Falls along the north valley wall of the Sun River, where in places the boundary between the Flood Member and the overlying Taft Hill Member is well revealed.

Approximately the lower 4.6 m (15 ft) of the unit at the type section consists of light-gray poorly sorted homogeneous siltstone and silty fine-grained sandstone that has a chunky or massive appearance and that weathers yellowish gray. Small amounts of fine carbonaceous material is locally intermixed. The sandstone is friable, noncalcareous, and erodes easily to slightly undercut the overstanding cliff. Thus, exposures are uncommon because of concealment by colluvium and talus. Small granules of dark chert are present in the basal bed. Trace fossils are common on the undersides of two persistent fine-grained sandstone beds that form narrow resistant ledges. This is the last appearance of these enigmatic forms in the Flood Member and probably results from the lack of fine mud that constituted their environment as the sea became shallower and there was greater depositional energy.

Approximately the middle 10.6 m (35 ft) of the unit is the principal cliff-making part of the Flood Member. It consists of a fairly homogeneous firm noncalcareous fine-grained sandstone with individual beds, 0.9–4 m (3–13 ft) thick, of slightly different hardness and texture. It is light gray to very light olive gray where fresh and various shades of grayish and yellowish orange where weathered. Sorting is moderate and suggests incomplete reworking of fluvial sand in an infralittoral (subbeach) environment. Subangular grains of clear quartz predominate, but some beds contain as much as 10 percent chert. Small spherical concretions of marcasite are accessory. Clay galls occur in some upper beds. Porosity is good. Trace fossils are absent, and no other fossils have been found in either the type section or nearby sections.

The upper part of the unit varies considerably in thickness and lithology within short distances of the type section and appears to rest on an erosion surface. Thicknesses range from 3 to 8 m (10 to 27 ft). At least five different lithologies are present. More or less in order of deposition, they are (1) intraformational conglomerate with lumps of ferruginous sandstone, (2) sandstone similar to that in the middle part of the unit (most abundant lithology but not present at every locality), (3) medium- to coarse-grained crossbedded sandstone, finely conglomeratic, with chert granules,

(4) dark-gray carbonaceous shale, in places with interbeds of olive cherty sandstone, and (5) huge concretions of hard, resistant, calcareous sandstone. Of these five lithologies, the huge brown-weathering sandstone concretions of group 5 constitute the most conspicuous element of this part of the unit. Two horizons of concretions are present, the stratigraphic interval between their respective tops ranging from 3.7 to 5.5 m (12 to 18 ft). The concretions in both horizons are similar in appearance. Generally, they occur as widely separated discrete masses, but, where abundant, they nearly coalesce into a continuous layer. They commonly range from simple tabular forms 2.7 by 2.7 by 0.3 m thick to huge paraelliptical masses 6.4 by 5.5 by 3 m thick (fig. 3). Some occupy channels. Internal structure generally is massive, but in places it is rudely concentric. Some of the crossbedded sandstone of group 3 alternates and interfingers with the marine sandstone of 2 in typical scour-and-fill arrangement. These sandstones may have been formed in a deltaic environment with distributary streams or in a barrier bar island environment. If these sandstones are upper deltaic deposits, it presupposes that the sea had all but disappeared either by infilling or by withdrawal toward the east, thus recording a regression of the Lower Cretaceous sea from the southern part of the Sweetgrass arch. The only fossils found in this part of the unit were bits of wood and a small fragment of a rib bone. The top of the unit, which is the Flood–Taft Hill boundary, is marked in places by a disconformity of small-time value where marine shale rest on thin cherty crossbedded sandstone.

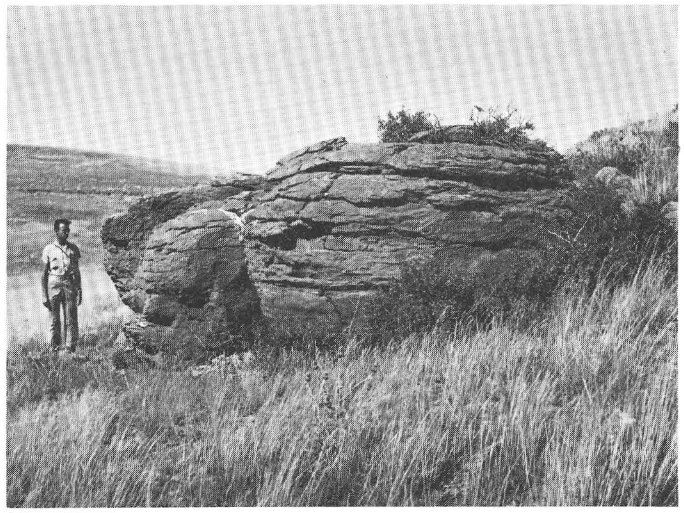


FIGURE 3.—Very large sandstone concretion in upper part of the upper unit of Flood Member in the N½ sec. 36, T. 21 N., R. 2 E., Cascade County, Mont.

CHARACTER OF FLOOD MEMBER IN THE NORTHERN SWEETGRASS ARCH AND DISTURBED BELT

A threefold division of the Flood Member suggestive of that shown by the outcrops in the vicinity of Great Falls can be noted in the subsurface in numerous tests for oil and gas along the crest of the Sweetgrass arch. For example, in the central part of the Kevin-Sunburst dome, T. 34 N., R. 1 W., 121–129 km (75–80 mi) north of Sun River, the Flood Member is about 30 m thick and consists of three units of sandstone separated by two shale units. In all probability they are paracontemporaneous homotaxial equivalents of some of the units of the type section, but direct correlation has not been established. Generally the lower sandstone, 3–7.6 m (10–25 ft) thick, is fine grained and tightly cemented. Commonly, however, it is so interbedded with shale that it is logged as sandy shale, and in consequence, only one or two massive sandstones are recognized. On the north flank of the dome, the shale content decreases and the grain size and porosity increase. There, the uppermost sandstone is commonly 1.5–9 m (5–30 ft) thick, fine to slightly coarse grained, and slightly to moderately porous. Water has been found in it at several localities, as in the Border–Red Coulee oil field, where the "1900-foot water sand" (Erdmann and Schwabrow, 1941, p. 318) appers to be a homologous equivalent of the upper unit of the Flood.

In the Disturbed belt west of the South arch, the basal sandstone of the Flood Member is thin and is partially replaced by shale. Farther northwest from Badger Creek, at least as far as the St. Mary River, a unit of freshwater shale and limestone lies between the massive varicolored mud rocks typical of the Kootenai Formation and the black fissile shale typical of the Flood Member (fig. 4). These freshwater beds are well exposed along the Burlington Northern Railway tracks, 6.4 km (4 mi) southwest of East Glacier in the west center of SE¼ sec. 35, T. 31 N., R. 13 W. (Cobban, 1956, p. 1001, 1002). Here the beds consist of the following sequence, numbered from oldest to youngest:

	M	Ft
Disconformity.		
4. Shale, olive-gray; some hard layers of siltstone at top	3.6	12.0
3. Limestone, sandy, fossiliferous; weathers brown	.8	2.7
USGS Mesozoic loc. D950: *Protelliptio douglassi* (Stanton) *Unio reesideanus* Yen *Unio farri* Stanton *Stantonogyra silberlingi* (Stanton)		
2. Shale, olive-gray	4.4	14.5
1. Limestone, gray, massive; weathers brown; crowded with small poorly preserved gastropods (*Reesidella montanaensis* Stanton?). See fig. 4	1.2	4.0

These olive-gray freshwater shales disappear eastward in the subsurface somewhere between the Disturbed belt and the Cut Bank oil and gas field on the west flank of the Kevin-Sunburst dome. Wells drilled

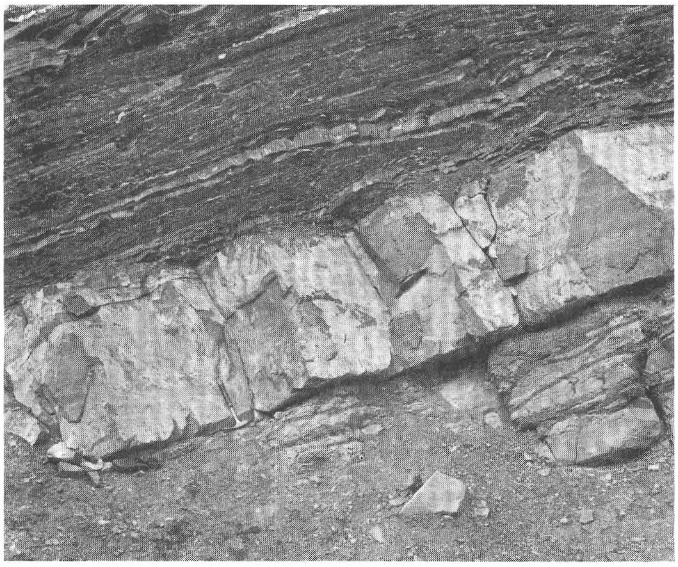


FIGURE 4.—Limestone bed largely formed of freshwater gastropods in upper part of Kootenai Formation in the SE¼ sec. 35, T. 31 N., R. 13 W., Glacier County, Mont. Hammerhead rests on top of green mudstone unit that underlies the gastropod limestone bed. Olive-gray shale containing hard layers of siltstone overlies the gastropod bed.

southwest of the Cut Bank field in the area between Birch Creek and the Pondera oil field generally show 3–6 m (10–20 ft) of black-gray slightly sandy shale that forms the base of the Flood Member and rests on massive varicolored mudstone of the Kootenai Formation.

The question arises whether the olive-gray shales should be assigned to the Kootenai Formation or to the Blackleaf Formation. The dark color and fissility of the shales favor a Blackleaf assignment, whereas the greenish cast of the shale and the typical Kootenai fauna suggest a Kootenai assignment. Perhaps the ultimate assignment will depend upon which is more useful to the fieldman, but in this paper they are assigned to the Kootenai Formation.

In the subsurface on the Sweetgrass arch, the lower contact of the Flood Member can be easily determined in well cuttings by the abrupt change downward from black-gray shale and light-gray flaggy quartzose sandstone to massive varicolored mudstone and lenticular fluviatile sandstone beds of the Kootenai Formation. The sandstones in the upper part of the Kootenai are generally some shade of greenish gray and consist of a great variety of colored grains in contrast to the predominance of colorless quartz grains in the sandstones of the Flood Member. The sharpness of the Kootenai-Blackleaf boundary is considered to indicate a disconformity although all exposed beds noted appear conformable. Erdmann and Schwabrow (1941, p. 284) also have described a conspicuous disconformity between the Kootenai and Blackleaf Formations in the Border–Red Coulee oil field on the north flank of the Kevin-Sunburst dome.

The upper boundary of the Flood Member cannot be determined in well cuttings as readily as that of the lower. It is marked by the change downward from gray soft bentonitic shale and greenish-gray glauconitic sandstone of the Taft Hill Member to the light-gray quartzose sandstone and black-gray shale of the Flood Member. The contact usually can be determined within a stratigraphic range of 3–4.5 m (10–15 ft).

AGE ASSIGNMENT AND CORRELATION

The upper part of the Flood Member is assigned a late Early Cretaceous age (late Albian). The lower part is undated.

On the east flank of the South arch, 9.6 km (6 mi) south of Floweree in the SE¼SW¼ sec. 19, T. 22 N., R. 6 E. (USGS Mesozoic locality D755), *Inoceramus comancheanus* Cragin and what may be an undescribed species of *Anomia* were found in the sandstone at the top of the Flood Member. *Inoceramus comancheanus,* a marine species of late Albian age, is characteristic of the Skull Creek Shale of the Black Hills, the Kiowa Shale of Kansas, and the South Platte Formation of the Front Range of Colorado.

The dark shale forming the greater part of the middle unit of the Flood Member in the type section may have formed in a marine environment, or it may have been deposited in a brackish-water lagoonal environment. Only trace fossils have been found in these shale beds. Some of these forms occur as casts of smooth sinuous comparatively elongate trail grooves(?) 3 mm wide and as much as 18 cm long on the underside of thin beds of sandstone parted by shale or siltstone. No evidence of hard parts or segmentation have been noted, and the forms are believed to have been made by some species of nematode worm moving over the surface of the mud. Burrows are present but very uncommon. The thin irregular sandstones in the upper part of the lower unit of the reference section are characterized by two or three other kinds of trace fossils, noticeably on top of the beds. A very abundant form consists of short unstriated sinuous trains of very fine sand 1–2 mm in diameter and as much as 3 cm long, which may have been left as alimentary waste by worms. Other trains, less common in occurrence, are 6–15 mm wide, as much as 4.5 cm long, and commonly are overlain by the smaller form. Nearly all of both types seem to have been broken. Even more rare is the form resembling *Ophiomorpha*, but which is fairly common in the outcrop just south of the Great Falls municipal airport. Insofar as known, no other member of the Blackleaf Formation contains such an abundance of trace fossils. The fragile nature of the remains, particularly in their original condition, obviously precluded much water movement or reworking and suggests that they originated at or just below wavebase in an infralittoral or upper neritic environment and that their parent organisms probably followed that environment regardless of how ephemeral it may have been. Thus, although of little worth for age determination by paleontologic methods, they are valuable intrinsic objects for local recognition of the Flood Member.

The brown-weathering ripple-marked quartzose sandstone forming the basal part of the Flood Member resembles the sandstone (First Cat Creek sand, an economic term) found at the base of the Colorado Shale in central Montana as well as some of the sandstone beds of the Fall River Formation of the Black Hills. The characteristic black-gray shale middle unit of the Flood Member resembles closely the 76 m (250 ft) of black-gray shale that immediately overlies the basal quartzose sandstone of the Colorado Shale of central Montana. It is also the type of shale that is characteristic of the very dark Skull Creek Shale of the Black Hills. The presence of late Albian fossils in the Skull Creek Shale is further evidence for correlating the basal part of the Flood Member with the Fall River Formation and with at least part of the Skull Creek Shale.

DESCRIPTIVE SECTIONS OF THE FLOOD MEMBER

The type section and the reference section for the Flood Member of the Blackleaf Formation described below are based primarily upon field descriptions. Only a few representative specimens have been examined under a binocular microscope, tested for solubility, or analytically screened for grain size or sorting; none has been analyzed petrographically or mineralogically. Further study along these lines, however, should prove very interesting and worthwhile.

In order to make the two described sections strictly comparable and fully complementary, the same subdivisions have been made for each section. Color descriptions follow the Rock-Color Chart of the National Research Council (Goddard and others, 1948). Cross-references within the bed descriptions and to the text also have been used where identification of individual beds seems important.

Type section of Flood Member

[Measured thicknesses by R. W. Lemke and C. E. Erdmann, May 15, 16, 1963, on the bluffs along the south side of Sun River valley, 7.2 km (4.5 mi) west of Great Falls, in the SW¼NW¼NE¼ sec. 7, T. 20 N., R. 3 E., Cascade County (Great Falls quadrangle) (fig. 5)]

	M	*Ft*
Pleistocene glacial lakebed silt.		
Blackleaf Formation:		
Taft Hill Member, basal part:		
33. Bentonite	0.2	0.5
32. Shale, medium-gray, soft, slumped	.6	2.1

Type section of Flood Member—Continued

	M	*Ft*
Blackleaf Formation—Continued		
Disconformity.		
Flood Member:		
Upper unit:		
31. Shale, gray; interbedded with 2–4-cm layers of cherty ripple-marked medium-light-gray sandstone that weathers to olive gray	.9	2.9
30. Sandstone, light-yellowish-gray, silty, fine-grained, thinly and irregularly bedded; weathers to light brownish orange; slight carbonaceous wisps along parting planes (current bedding). This is the horizon containing concretions which are not present on northwest side of draw but are present on southeast side of draw and abundant on north side of Sun River valley in NW¼NE¼NE¼ sec. 5, T. 20 N., R. 3 E.	3.2	10.4

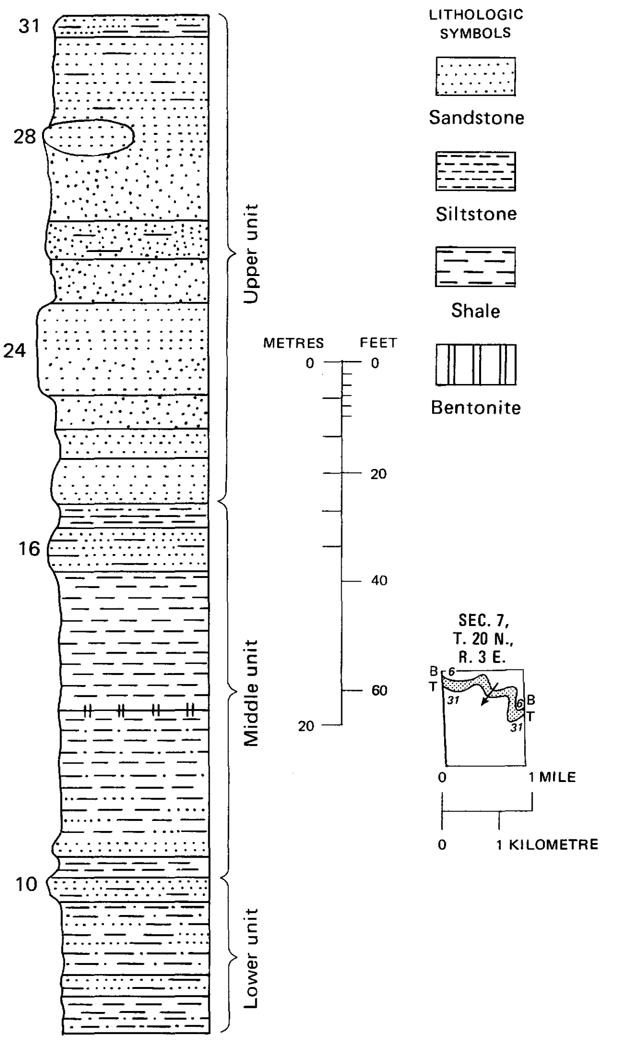


FIGURE 5.—Type section of the Flood Member of the Blackleaf Formation and map showing line of measured section, sec. 7, T. 20 N., R. 3 E. Numbers on the left side of the column are key beds in the measured section. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of Flood Member—Continued

Blackleaf Formation—Continued

Flood Member—Continued

Upper unit—Continued	*M*	*Ft*
29. Sandstone, medium-light-gray salt-and-pepper appearing, generally massive; weathers yellow gray stained with limonite; consists mostly of well-rounded to subrounded quartz and slightly less (3:2) chert and a few brown grains in a matrix of secondary calcite	.3	1.1
28. Sandstone, concretionary, calcareous, medium-light-gray (*N* 6); weathers dark yellowish brown (10*YR* 4/3) to moderate brown. Probably nearly equal parts of secondary calcite cementing fine channel sand containing a small amount of ferruginous material. Concretion about 12 m (40 ft) long with maximum thickness at southeast end. Top flat, thinly bedded, flush with surface of underlying bed; lower part massive, definitely truncating bedding of underlying sandstone. Unit thins to featheredge	1.4	4.5
27. Sandstone, grayish-yellow, fine-grained, very friable; bedding indistinct; thickness varies	3.0	10.0
26. Sandstone, grayish-yellow, medium-grained, well-sorted; some chert; crossbedded, with dip of foreset beds to the southwest. Generally massive except for about five distinct parting planes. Looks like a near-beach deposit	1.6	5.1
25. Sandstone, grayish-yellow, fine-grained, indistinctly bedded, friable, slightly calcareous	1.9	6.2
24. Sandstone, grayish-yellow, fine- to medium-grained, massive; weathers to grayish orange yellow; mostly quartz. Top surface has a thin film of medium-gray clay. Forms a prominent ledge overhanging beds below	3.8	12.6
23. Sandstone, light-yellowish-gray, indistinctly bedded, fairly friable and erodible. Upper 36 cm weathers yellowish orange (10*YR* 6/6) and is thinner bedded than part below	1.4	4.7
22. Sandstone, light-olive-gray; fine-grained, hard to soft; weathers pale yellowish brown to yellowish gray. Some flute casts and abundant casts of trace fossils	.7	2.3
21. Sandstone, light-gray, fine-grained, silty, poorly sorted; some finely macerated carbonaceous debris; nodular or chunky appearance. Trace fossils on some bedding surfaces. Basal part shaly siltstone	.9	3.2
20. Sandstone, light-gray, silty, poorly sorted; a few rounded granules of dark chert; nodular or chunky. Contains occasional discrete masses of concretionary marcasite as large as 6 by 10 cm. Supports a low rounded bench	1.4	4.6
Thickness of upper unit	20.1	66.0

Disconformity.

Type section of Flood Member—Continued

Blackleaf Formation—Continued

Flood Member—Continued

Middle unit:	*M*	*Ft*
19. Limestone, medium-dark-gray, silty; weathers light gray to pale yellowish gray; concretionary, with cone-in-cone structure	.1	.4
18. Siltstone, medium-gray; highly calcareous, grading upward into sandy calcareous siltstone containing a few granules of polished dark chert	.5	1.6
17. Shale, dark-gray (*N* 3), very fissile	.5	1.5
16. Sandstone, medium-gray, medium- to coarse-grained; thin nodular layers separated by laminae of dark-gray shale. Poorly exposed	1.8	6.0
15. Slope concealed by colluvium and talus. Probably soft dark-gray fissile shale	6.3	20.7
14. Shale, grayish-black, carbonaceous, soft, fissile, papery	.6	2.0
13. Shale, medium-dark-gray, poorly exposed	4.6	15.0
12. Sandstone, yellowish-gray, medium-grained; upper surface ripple marked, ferruginous, weathers medium brown. Lower 2 cm silty, containing small fragments of mineral charcoal (fusain) and trace fossils. A local asymmetric channel sand trending approximately east; maximum width about 12 m (40 ft) with thickest section on north side	.6	2.0
11. Shale, dark-gray, silty, fissile	.6	2.0
Thickness middle unit	15.3	50.2
Lower unit:		
10. Sandstone, light-gray, fine- to medium-grained, slightly ferruginous; in wavy layers 12–23 cm thick, alternating with somewhat thinner beds of siltstone. More indurated and better sorted than lower part of unit. Crossbedding, dipping southwest. Uppermost layer, 15 cm thick, of hard medium-gray sandstone conspicuously overhangs beds below. Forms a ragged cliffy slope	1.0	3.7
9. Siltstone, shaly, yellowish-gray, moderately friable; weathers grayish orange; contains three or four thin more resistant beds of fine-grained quartz sandstone with a little clastic mica. Trace fossils. Forms a ragged cliffy slope	3.1	10.0
8. Sandstone, light-olive-gray, quartzose; interbedded with about equal amounts of shaly siltstone with laminae marked by films of carbonaceous matter; trace fossils sparsely present, poorly preserved. Beds parted by short 1-cm-thick lentils of medium-dark-gray shaly siltstone which appear to represent mud-filled troughs of ripple marks. Depositional environment probably marine tidal flat	1.0	3.2
7. Slope, concealed by colluvium	1.0	3.2
6. Siltstone, yellowish-gray (5*Y* 7/2), poorly fissile; rests on light-olive-gray silty shale (5*Y* 6/1)	.6	2.0
Thickness of lower unit	6.7	22.1
Total measured thickness of Flood Member	42.1	138.3

Type section of Flood Member—Continued

	M	Ft
Disconformity.		
Kootenai Formation, upper part:		
5. Sandstone, arkosic, light-gray; fine- to medium-grained, friable, slightly to moderately calcerous; weathers light tan	.5	1.6
4. Shale, sandy, light-olive-green, only slightly fissile	.2	.7
3. Sandstone, grayish-brown, very fine grained, vertically jointed, calcareous, well-indurated	.2	.8
2. Shale, sandy, maroon, only slightly fissile	.2	.7
1. Shale, sandy, light-olive-green, slightly fissile	.5	1.7
Total measured thickness of part of Kootenai Formation	1.7	5.5

Reference section of Flood Member

[Measured by C. E. Erdmann, Oct. 4–10, 1965, on south-pointing spur on north valley wall of Sun River, about 5.6 km (3.5 mi) northwest of the city of Great Falls, 0.5 km (0.3 mi) northeast of Emerson Junction of Burlington Northern Railroad spur track of Chicago, Milwaukee, and St. Paul Railway. Base of section is in the NW¼NE¼NE¼ sec. 5, T. 20 N., R. 3 E.; top of section is in the SW¼SW¼SE¼ sec. 32, T. 21 N., R. 3 E.]

	M	Ft
Pleistocene deposits (very thin).		
Blackleaf Formation:		
Taft Hill Member, basal part:		
64. Shale, dark-gray, fissile, poorly exposed	0.6+	2.0+
63. Sandstone, medium-coarse, cherty, calcareous. Surface weathers dark brown	.3	1.0
62. Shale, very dark gray, very fissile	1.7	5.5
Flood Member:		
Upper unit:		
61. Sandstone, concretionary, fine-grained, calcareous, moderately gray. Concretions (large) are epigenetic and occupy scour channels in underlying sandstone	1.7	5.6
60. Sandstone, light-yellowish-gray, fine-grained, calcareous. Irregular wavy bedding 3–6 cm thick, parted by thin 6-mm laminae of medium-gray shale	3.3	10.7
59. Sandstone; similar to bed 56 below. Poorly sorted. Fine horizontal laminae. No cross-lamination	.2	.5
58. Sandstone, grayish-orange, fine-grained, calcareous. Similar to upper part of bed 53	1.3	4.3
57. Sandstone, light-yellowish-gray, fine- to coarse-grained, poorly sorted, cherty, tuffaceous, cross-laminated; thin planar layers dip 20° S.–20° W. Makes ledge	.4	1.4
56. Sandstone, grayish-orange, fine-grained. Similar to upper part of bed 53 below	.6	2.0
55. Sandstone, light-yellowish-gray, medium-grained, massive, hard. Makes ledge with small overhang	.4	1.2
54. Sandstone, light-yellowish-gray, fine-grained, calcareous; weathers grayish orange. Irregular wavy layers 3–6 cm thick parted by thin (0.5 cm) laminae of medium-gray shale	2.0	6.7
53. Sandstone, as immediately above, but fresh, light-yellowish-gray, unweathered. Makes top of excavated slope	2.6	8.5
52. Sandstone, olive-gray, medium-grained, poorly sorted, soft; contains irregular		

Reference section of Flood Member—Continued

	M	Ft
Blackleaf Formation—Continued		
Flood Member—Continued		
Upper unit—Continued		
52. Sandstone, etc.—Continued masses and partings of soft medium-gray shale	.5	1.5
51. Sandstone, light-gray, fine-grained, hard, massive. Trace fossils on both base and top	.1	.3
50. Sandstone, light-gray, fine-grained; thin (3-cm) partings of medium-gray fissile shale at 15-cm intervals	1.0	3.3
49. Siltstone, olive, soft, clayey	.1	.4
48. Sandstone, light-gray, fine-grained, faintly calcareous; traces of carbonaceous debris; in small lenticular to nodular masses 3–7 cm long, commonly enclosed by thin (1 cm) rinds of sandy gray clay. Bedding indistinct; resistant, ledge making. Upper 0.5 m weathers grayish orange	1.7	5.5
47. Shale, medium-gray (east side of spur)	.8	2.5
46. Sandstone, olive, soft, massive; irregular inclusions of shale	.6	2.0
45. Sandstone, light-yellowish-gray, poorly sorted, fine- to medium-grained, hard, faintly calcareous; a sprinkle of fine to coarse grains of rounded polished black chert, flakes of carbonaceous material, and clay galls; in small lenticular and nodular masses 2–8 cm long and 2–10 cm thick, some of which are encased or wrapped by rinds of light-medium-gray clay. Bedding very indistinct. Makes broken rubbly ledge. Lower 3–6 cm weathered dark yellowish orange (possible diastem)	.6	1.9
Total thickness of upper unit	17.9	58.3
Middle unit:		
44. Siltstone, olive-gray, sandy; in layers about 15 cm thick interbedded with medium-dark-gray shale and olive shale. Surface weathers into tough structureless mudstone	2.4	8.0
43. Shale, medium-dark-gray; thin lentils of olive sandstone	1.2	4.0
42. Shale, olive, fissile	.3	1.0
41. Sandstone, light-olive-gray, poorly sorted, fine- to coarse-grained, subangular, noncalcareous, soft, friable; surface weathers dark yellowish orange with small internal splotches of dusky yellow and light olive brown, phasing into the external color; some rounded granules of gray chert; all in a matrix of light-gray clay which also marks indistinct laminae	.1	.4
40. Shale, dark-gray, fissile (as below)	.5	1.7
39. Sandstone, olive-gray, fine-grained; thin slabby layers. Base slightly wavy (undulating), marked by 1 cm of dark-yellow ochre	.3	.9
38. Shale, black, very fissile (papery). Very thin layer of light-gray fine-grained finely laminated sandstone 0.8 m above base of bed	1.4	4.5

Reference section of Flood Member—Continued

	M	*Ft*
Blackleaf Formation—Continued		
Flood Member—Continued		
Middle unit—Continued		
37. Sandstone, olive-gray, fine-grained, finely laminated; weathers brown. Base exhibits casts of worm trails and a burrow. Top marked by 1 cm of dark-yellowish-orange siltstone whose surface shows trace fossils	.1	.4
36. Shale, dark-gray, fissile; laminae very thin, almost papery, soft	1.4	4.5
35. Siltstone, light-olive-gray	.1	.2
34. Sandstone, light-olive-gray to medium-light-gray, fine-grained, poorly sorted, massive, poorly stratified; weathers light yellowish brown to dark yellowish orange. Organically reworked; numerous galls and small irregular masses of dark-gray clay shale may represent burrow fillings from overlying bed. Oval siltstone casts of flattened tubes (worm burrows?)	.7	2.4
33. Shale, dark-gray, soft, fissile. Thickens to 1.7 m on west side of spur	.8	2.8
32. Siltstone, light-olive-gray; encloses a 12-cm pale-yellowish-brown bed in middle. Thin layers of shaly sandstone at base and top. Unit thickens to 0.9 m on west side of spur	.5	1.6
31. Shale, light-olive-gray. Similar to bed 29, below	1.8	5.8
30. Siltstone, pale-yellowish-brown (10*YR* 6/2)	.1	.4
29. Shale, light-olive-gray (5*Y* 6/1), poorly fissile, soft	.3	1.0
28. Siltstone, light-olive-gray; in beds 12–15 cm thick parted by 1-cm laminae of fine-grained olive sandstone. Numerous trace fossils (worm castings or trails?) on each upper surface. Thin layer of siltstone in middle weathers reddish brown. Layer of reddish-weathering marcasite(?) nodules at top, 3–6 cm thick	.5	1.6
27. Siltstone, light-olive-gray. Contains thin 3–6-cm-thick sandstone layers; those in middle show ripple-marked upper surfaces with relief of 2 cm. Numerous trace fossils	.4	1.3
26. Dolostone. Hard compact masses about 60 cm in diameter. Usually considerably shattered. Fresh surfaces medium gray, but weather to moderate brown (5*YR* 4/4) in rinds as much as 2 cm thick. Some fractures are dusted with small calcite crystals	.1	.4
25. Siltstone, light-medium-gray, soft, clayey	.2	.6
Total thickness of middle unit	13.2	43.4
Diastem(?)		
Lower unit:		
24. Sandstone, light-yellowish-brown, fine-grained; in layers 9–15 cm thick parted by laminae of medium-gray siltstone. Trace fossils (casts of worm trails?) on upper surfaces. Rock breaks into flat slabby hand-sized pieces 1–2 cm thick	1.2	3.8

Reference section of Flood Member—Continued

	M	*Ft*
Blackleaf Formation—Continued		
Flood Member—Continued		
Lower unit—Continued		
23. Siltstone, light-olive-gray, sandy, soft	.2	.6
22. Sandstone, light-yellowish-gray, fine-grained; in layers 9–15 cm thick, interbedded with light-olive sandy siltstone. Upper surfaces show trace fossils	.4	1.2
21. Siltstone, light-olive-gray; 15-cm layer of light-olive-gray fine-grained massive sandstone in middle which is overlain by a 6-cm layer of medium-dark-gray siltstone. Trace fossils on upper surface of the sandstone	.5	1.7
20. Sandstone, light-yellowish-gray, fine-grained; small flakes of carbonaceous debris, faintly calcareous; in even 6–12-cm finely laminated layers separated by thin (6 mm) laminae of light-gray siltstone with worm castings. Hard, resistant. Makes subdued ledge with slightly undulating top	.7	2.2
19. Sandstone, light-yellowish-gray, very fine grained; in 6–12-cm layers interbedded with layers of light-olive-gray siltstone of about same thickness. Bedding marked by very thin laminae (films) of gray clay. Trace fossils (casts of worm trails?) present but fragmentary	.4	1.4
18. Sandstone, light-olive, very fine grained, silty	.3	.9
17. Siltstone (or very fine grained sandstone), light-olive-gray, massive, nonfissile, tough	.3	1.0
16. Sandstone (or siltstone), light-yellowish-brown to moderate-yellowish-brown (10*YR* 5/4), fine-grained. Makes weak massive ledge. Contact with underlying bed gradational	.6	1.8
15. Claystone, bentonitic, silty; predominantly medium dark gray but olive at base and top. Breaks with subconchoidal fracture; becomes flaky upon weathering	1.4	4.5
Thickness of lower unit	6.0	19.0
Total thickness of Flood Member	36.8	120.7
Erosional disconformity.		
Kootenai Formation, upper part:		
14. Siltstone, light-olive-gray (5*Y* 6/1), thinly laminated; chippy where sandy	0.4	1.3
13. Mudstone, medium-dark-gray, sandy, poorly fissile, hard, tough; some slight mottling by light olive green	.2	.8
12. Siltstone, light-yellowish-gray, soft, clayey	.1	.5
11. Sandstone, light-yellowish-gray, medium-grained, noncalcareous, firm, massive; makes subdued ledge	.5	1.6
10. Claystone; light-greenish-gray when damp; weathers light yellowish gray	.1	.3
9. Claystone, soft; predominantly dusky red with some mottling (blebs) of dusky yellow green (5*GY* 5/2)	1.9	6.2
8. Siltstone; dull medium olive gray mottled pale		

Reference section of the Flood Member—Continued

Kootenai Formation, upper part—Continued	*M*	*Ft*
8. Siltstone, etc.—Continued olive gray by small rounded masses of fine sandstone. In flat layers 9–15 cm thick containing fine carbonaceous debris. Slakes down into thin flakes. Some manganese stain with a dull-purplish cast	.8	2.6
7. Sandstone, fine- to medium-grained; cemented by calcareous clay; medium gray with greenish cast; some joint faces weather moderate brown. Unit is a lenticular body about 12 m wide. Bedding in lower 30 cm is thin and indistinct; upper part more resistant, with hard 6–9-cm-thick massive layers that weather into large rounded blocks. Upper surface cut by sand-filled joint cracks 5 cm wide that strike N. 60° E. Occurrence suggests a lenticular depression fill trending N. 40° W. but not a running-water or channel sand because of the absence of planar cross-lamination. Other sand bodies occur nearby at same horizon	1.5	5.0
6. Mudstone, brownish-red. A wedge thinning rapidly to the northeast into a basin of overlying sand mass and seems to come up on other side. Local absence may result from scour in channel or it may have been squeezed out by load effect. Top gradational upward	.2	.8
5. Siltstone, sandy, light-olive-gray. Lower part clayey with nodular weathering. Upper 2.5 cm thinly laminated. Base cut into underlying bed	.5	1.5
4. Mudstone, clayey; alternate layers of brownish red and light olive gray but locally is all brownish red; crossbedded	.8	2.5
3. Mudstone, grayish-red (10*R* 4/2); similar to bed 1. Thin (6 cm) layer of greenish-gray siltstone 21 cm above base. Nodular weathering very well developed above green layer and indicates stratification. Nodules are oval in cross section and may be 3.6 cm long and 1.5 cm thick	.7	2.3
2. Siltstone, light-olive-gray, clayey, firm, compact, massive; joint faces smooth, but interior of bed has nodular structure. Thickness fairly uniform	.4	.14
1. Mudstone, grayish-red (10*R* 4/2), silty, finely micaceous, firm, massive, compact. Base concealed	1.2+	4.0+
Total measured thickness of part of Kootenai Formation	9.3+	27.4+

TAFT HILL MEMBER

NAME AND DEFINITION

The Taft Hill Member overlies the Flood Member and underlies the Vaughn Member. The Taft Hill Member consists chiefly of medium-gray soft bentonitic clayey to silty shale and fine-grained greenish-gray glauconitic sandstone; the unit is the glauconitic sandstone member of Cobban (1951a, p. 2177–2179). The member represents shelf deposits of the neritic zone of the first major transgression of the Lower Cretaceous sea. Cobban, Erdmann, Lemke, and Maughan (1959, p. 2790) named the member for exposures along the east and north slopes of Taft Hill, a prominent dissected bench extending from 2.4 to 9.6 km (1.5–6 mi) south of the village of Vaughn (Vaughn and Cascade quadrangles). The type section is a composite of measurements from four localities south of the Sun River between the east face of Taft Hill and a point 8 km (5 mi) farther east, the top being near the N¼ cor. sec. 12, T. 20 N., R. 1 E. (Vaughn quadrangle), and the base at Newman Spring, in the center of sec. 9, T. 20 N., R. 2 E. (Great Falls quadrangle). In general the beds in the lower half are so soft and poorly indurated that 10–20 percent of the total thickness of the type section is concealed. However, exposures made in 1960 and 1961 north of the Sun River during construction and rerouting of U.S. Interstate Highway 15 between Great Falls and Vaughn junction permitted study of excellent sections of the lower part of the member and of the underlying Flood Member. Descriptions and measurements from these localities, which are 5.6–8 km (3.5–5 mi) north and northeast of the type section of the Taft Hill Member, are described in this report as a composite reference section. Thus only about 1 m of the lower 40 m (132 ft) of the member in the Great Falls area has not been described from surface exposures and this interval was penetrated during 1960 by the U.S. Corps of Engineers in core hole I–10 (310x), NW¼NW¼ sec. 19, T. 21 N., R. 2 E., near Vaughn junction.

THICKNESS

The Taft Hill Member is 74 m (242 ft) thick in its type section south of the Sun River and is 76 m (249 ft) thick north of the Sun River in the area of the reference section. It has a comparatively uniform thickness over the central and eastern part of the Sweetgrass arch, with the thickness in the Great Falls area being about average. On the east flank of the South arch, Cobban measured 81 m (266 ft) in outcrop in sec. 17, T. 22 N., R. 6 E. (Lander Crossing quadrangle), and 74 m (242 ft) between the depths of 718.7 and 792.5 m (2,358 and 2,600 ft) in the Texas Company–Kiemele well 1 in the SE¼NW¼NE¼ sec. 26, T. 31 N., R. 13 E., Hill County. This line represents the east limit of the area in which the name may properly be applied. Farther east in the Bearpaw Mountains, Kerr and others (1957) reported 30–46 m (100–150 ft) of glauconitic beds in the Newcastle Sandstone equivalent in the Colorado Shale. Cuttings from a few tests for oil and gas along the crest of the South arch and high up on its west flank reveal thicknesses of 61–82 m (200–270 ft) for the Taft Hill. In the Pondera oil field (T. 27 N., R. 4 W.), there is a good sample thickness of 73 m (240 ft). In several old wells in the central and eastern part of

Kevin-Sunburst dome (Tps. 32–34 N., Rs. 1 E.–1 W.), where in one well the member was cored, thicknesses range from 70 to 72 m (230 to 235 ft). In the West Kevin district (T. 35 N., R. 3 W.), however, the member has thinned to 68.6 m (225 ft), and in one well in the Border–Red Coulee field (T. 37 N., R. 4 W.) to 61 m (200 ft). Apparently the thinning to the west and north results from replacement by nonmarine sediments (discussed in description of the Vaughn Member). In tests drilled along the southwest margin of the Sweetgrass arch, the Taft Hill Member thins to 55 m (180 ft) or slightly less. Farther west, in the Sun River Canyon area, Mudge (1972, p. *A*58–*A*60) noted that the Taft Hill Member thickened westwardly from 68 to 183 m (225–600 ft). In more recent investigations, Gwinn (1961) applied the name Taft Hill Member of the Blackleaf Formation to 273–305 m (900–1,000 ft) of strata in the noncontiguous Drummond area (T. 11 N., R. 12 W., Granite County), about 80 km (50 mi) southwest of Great Falls, where he described the lower 91 m (300 ft) as "crossbedded marine sandstones." However, Gwinn did not mention the presence of glauconite (the definitive mineral at the type section), and although his basal unit well may be the time equivalent of some part of the type Taft Hill Member, further study is required before the name can be definitely applied in the Drummond area.

OUTCROP DISTRIBUTION

Outcrops of the Taft Hill Member on the Sweetgrass arch are most extensive on the southern part of the South arch. Some of the best exposures, including parts of the type and reference sections, are near Vaughn, where they have been mapped by Maughan (1961). West from Vaughn the member crops out upstream along the south bank of the Sun River for 8 km (5 mi) before the regional west dip of the South arch carries it below the valley floor. South of Vaughn the upper part of the member is exposed extensively along the east side of Taft Hill from the north edge of sec. 35, T. 21 N., R. 1 E., in the Vaughn quadrangle, south at least to a point 6.4 km (4 mi) west of Ulm in sec. 3, T. 19 N., R. 1 E., in the Cascade quadrangle. Locally, the lower part is exposed in ravines or along roadcuts for 3.2–4.8 km (2–3 mi) east of Taft Hill. Northwest from Vaughn the member crops out fairly continuously up Muddy Creek for about 6.4 km (4 mi). Eastward it is exposed across the southern part of the Great Falls quadrangle, and northeastward through the Portage quadrangle to the Missouri River where outcrops extend into the Lander Crossing quadrangle and swing south along the west flank of the Highwood Mountains. Exposures also have been observed in the Sweetgrass Hills where the member is distinguished by a 6–15-m (20–50-ft) glauconite-bearing sandstone that probably is equivalent to the Second Whitlash sand of economic usage at Whitlash dome (Bartram and Erdmann, 1935, p. 274).

Along the Rocky Mountains front west of the South arch, a nonglauconitic marine time-equivalent of the Taft Hill Member crops out in the Disturbed belt. It is well exposed along the western edge of the tier of townships from T. 20 N., R. 8 W., north through T. 25 N., R. 8 W., and, thence, northwest to Birch Creek in T. 28 N., R. 10 W. Farther to the northwest, along the southeast boundary of Glacier National Park, those strata undergo a facies change by interfingering with and finally complete replacement by the nonmarine bentonitic Vaughn Member.

Glauconitic sedimentation, probably in an environment paralleling its occurrence in the Taft Hill Member, also may have operated more or less contemporaneously with the deposition of the Spinney Hill Member of the Joli Fou Formation in west-central Saskatchewan (Edwards, 1960), and the Bluesky Formation at the base of the Fort St. John Group in the Peace River country of northern Alberta. Equivalents of both the Joli Fou and the Bluesky Formations occur at the base of the Colorado Group as that group is used in that report area. Indirect correlation with the Taft Hill is suggested by the relationship of the Joli Fou Formation to the Skull Creek Shale in the southern part of the Williston basin (Edwards, 1960, p. 150). A much more direct correlation may be the development of glauconite in sandstone that rests directly on the Kootenai Formation in the Northern Pump-Emil Guertzgen well 1, SW¼NW¼NE¼. sec. 2, T. 31 N., R. 19 E., Bowes field, Blaine County, north of the Bearpaw Mountains. In the absence of the Flood Member which has wedged out farther west, the occurrence of Taft Hill lithology on Kootenai is directly analogous to the Spinney Hill sand–Mannville Formation relationship in Saskatchewan.

GENERAL DESCRIPTION

As noted previously, the boundary of the Taft Hill Member with the underlying Flood Member is essentially transitional and has been placed arbitrarily at the first appearance of marine rocks following the final episode of deltaic or barrier-island deposition marking the close of the Flood Member. The contact with the overlying Vaughn Member appears to be a disconformity marking a change from a marine to a continental environment.

Dark-gray soft bentonitic shale and greenish-gray glauconitic sandstone characterize the Taft Hill Member. The shale constitutes about 35 percent of the member in the type section and in the reference section, glauconitic sandstone about 25 percent, and nonglauconitic sandstone, siltsone, and thin concretionary limestone beds about 40 percent of the member. The sandstone beds generally crop out as low rounded ledges, whereas the shale beds form medium-gray poorly vegetated spongy slopes. Some of the concretionary limestone beds exhibit cone-in-cone structure and weather brown.

On the basis of lithology, the member can be subdivided into three units. The lower unit consists chiefly of bentonitic shale, the middle unit of glauconitic sandstone, and the upper unit of mostly quartzose sandstone, siltstone, and bentonitic shale. The following detailed descriptions of these units are based upon descriptions of lithologies in the type and reference sections and in other exposures in the vicinity. (See descriptions and graphic sections that follow later.)

Lower unit.—The lower unit is approximately 22 m (72 ft) thick at the type section. Shale, medium-dark-gray and poorly to moderately fissile, is the predominant lithology. Siltstone and glauconitic sandstone constitute most of the remainder. A few thin beds of bentonite account for the rest. A bentonite bed 0.6 m (2 ft) thick and about 0.3 m above the base of the unit in the type section makes an easily recognizable marker for differentiating the Taft Hill Formation from the underlying Flood Member because of the absence of bentonite beds in the underlying member. The bentonite bed is overlain by approximately 7 m (23 ft) of dark-gray fissile shale which closely resembles the shale of the middle unit of the Flood Member. Overlying the shale is a 0.6-m (2-ft)-thick glauconitic sandstone, which, locally, is the first appearance of glauconite in the Taft Hill Member. Above the glauconitic sandstone is about 6 m (20 ft) of soft dark-gray to medium-light-gray shale and siltstone. The upper approximate 7.6 m (25 ft) of the unit consists of a series of glauconitic sandstones and interbedded thin bentonites. The glauconitic sandstones are similar to those of the overlying middle unit, but they are more poorly indurated and, except for the lowest 1.5-m (5-ft)-thick sandstone, are rarely exposed. Knowledge of this part of the unit is obtained from the composite reference section.

Middle unit.—This unit is approximately 9 m (30 ft) thick at the type and reference sections. Because of the predominant lithology, it has commonly been referred to as "the glauconitic sandstone." Beds immediately underlying the middle unit are not exposed in the type section or in other natural outcrops in the area. However, the basal part of the unit and about a 7.6-m (25-ft) section of the underlying beds of the middle unit are exposed in a highway cut about 0.6 km to the east (NE¼SE¼ sec. 19, T. 21 N., R. 2 E.), and about 0.3 m of shale is exposed overlying the unit in a highway cut at Vaughn junction (approximate center of sec. 19, T. 21 N., R. 2 W.). In the absence of a more continuous sequence of beds, the middle unit in the type section and in other places has been positioned into the reference section of the member by aerial projection, taking into account the local dip of the beds. In the type section, the middle unit has been described as one bed (bed 14). In the reference section, this unit has been subdivided into a number of beds, more or less transitional with each other. Parts of the unit crop out in a number of places from Vaughn eastward across the southern parts of the Vaughn and Great Falls quadrangles. Farther east the glauconitic sandstone thins or grades laterally into shale, as indicated by its absence along the Missouri River in the eastern part of the Portage quadrangle. Southwest of the type section, the unit appears to thicken, 15 m (50 ft) of very glauconitic sandstone being penetrated at depths of 104–119 m (340–390 ft) in a well 4.8 km (3 mi) to the south in the NW¼SE¼ sec. 12, T. 20 N., R. 1 E. Also, glauconitic sandstone as thick as or thicker than in the well crops out farther south in the SW¼ sec. 17, T. 17 N., R. 1 E., but the strata are much disturbed and an accurate measurement has not been made.

The glauconitic sandstone is mostly olive green (10*Y* 5/2 to 10*Y* 5/4), fine to medium grained, and in layers (beds) commonly 15–60 cm (0.5–2 ft) thick. A few thin clay-ironstone concretionary masses having cone-in-cone structure constitute about the only variations in an otherwise essentially homogeneous unit. The upper part of the sandstone generally is thicker bedded and coarser grained than the lower part. The upper part also commonly exhibits a planar ("torrential") type of cross lamination, which is indicative of a shallow current entering quiet water of greater depth. Bedding surfaces in places show worm(?) castings or borings on ripple marks. Chunks of petrified wood, 8–10 cm long, were found near the top of the sandstone unit at one locality (NW¼NW¼ sec. 26, T. 21 N., R. 2 E., just east of Vaughn. The lower part of the sandstone unit is argillaceous and generally more friable.

Samples from the middle and upper parts of the sandstone from the type section 2.4 km (1.5 mi) south of Vaughn and from an exposure at the junction of U.S. Highways 89 and 91 about 0.4 km east of Vaughn were studied for mineral composition by W. T. Pecora (Cobban, 1951a, p. 2177–2178). He reported that the samples consisted of approximately 30 percent clear quartz, 25 percent murky chert, 10 percent glauconite, 5 percent fresh feldspar, and 30 percent coarse calcite (cementing material). The quartz and chert grains are well rounded and well sorted. Pecora stated that the glauconite was an impure type formed "in a marine environment by replacement of material that was originally ferromagnesian, such as hornblende."

Upper unit.—In the type section the upper unit is approximately 43 m (140 ft) thick. The entire unit is exposed at the type section, except approximately the basal 1.2 m, which probably is bentonitic shale. The thickness of the covered 1.2 m interval between the upper unit and the middle unit was estimated by areal projection between the two localities, taking into account the local dip.

The upper unit consists predominantly of bentonitic shale and bentonitic siltstone, which, together with three beds or bentonite beds, form a generally gray poorly vegetated spongy slope (fig. 6). A bed of brown-weathering calcareous concretions, characterized by cone-in-cone structure, is present 3.7 m (12 ft) above the base. Beds of sandstone are present here and there but are thickest and most numerous near the top. They are chiefly light olive gray, fine grained, and somewhat glauconitic and bentonitic. About 3 m below the top of the unit in the type section is a 1.1-m-thick bed of fine-grained sandstone that persists as a ledge former across the Vaughn and Great Falls quadrangles and into the Portage quadrangle, where it thickens to 2.4 m. On the east face of Taft Hill, a thin bed of coarse-grained sandstone lies about 0.9 m below this ledge maker. Locally, south of the county road near the center of the north line of sec. 18, T. 20 N., R. 2 E., this coarse bed is represented by conglomerate that consists of pebbles as much as 5 cm in diameter of gray, green, and reddish quartzite and black-coated gray, black, and brown chert. In the type section, this bed (bed 31) is fine to coarse grained, thin bedded to massive, and has undetermined green grains. It contains a few poorly preserved molds of freshwater unios and gastropods and fragments of large bones, probably dinosaurian. Possibly the bed represents a littoral deposit into which the freshwater elements were washed. Deposition in either shallow marine water or brackish water is indicated for the 3.1 m (10.2 ft) of sandstone (bed 34) at the top of the member by the presence of the brachiopod *Lingula subspatulata* Hall and Meek.

AGE ASSIGNMENT AND CORRELATION

Fossils are scarce in the Taft Hill Member in its type section west of Great Falls. A small marine fauna with

FIGURE 6.—Upper bentonitic part of upper unit Taft Hill Member on the north face of Taft Hill in the S½SE¼ sec. 1, T. 20 N., R. 1 E., Cascade County, Mont. Sandstone, forming ledges on upper part of slope on right side of photograph, is basal unit of Vaughn Member.

Early Cretaceous (late Albian) affinities was collected from near the base of the member between Great Falls and Vaughn. The specimens that are lowest stratigraphically (USGS Mesozoic loc. D3920, D4319, and D4320) were collected approximately 4.2 m (14 ft) above the base of the Taft Hill Member. This horizon has yielded the following fauna:

Anomia n. sp.
Inoceramus bellvuensis Reeside
Phelopteria sp.
A worm burrow

Two other collections made by Cobban (1951a, p. 2179) in the N½ sec. 27, T. 21 N., R. 2 E., and in the S½ sec. 10, T. 20 N., R. 2 E., from a horizon approximately 3 m stratigraphically higher, include the following:

Discinoid brachiopod
Inoceramus cf. *I. caddottensis* McLearn
Inoceramus sp.
Phelopteria cf. *P. salinaensis* (White)
Anchura cf. *A. quitmanensis* Stanton
Fragment of a smooth compressed ammonite

This same zone crops out below the equivalent of the middle unit, the glauconitic sandstone, in a very limited area in the SE. cor. SE¼SW¼ sec. 17, T. 17 N., R. 1 E. Collections by C. E. Erdmann and K. S. Soward contained the following fauna:

USGS Mesozoic loc. D2931 (upper bed):
Lingula cf. *L. subspatulata* Hall and Meek
Ostrea anomioides Meek
Ostrea larimerensis Reeside
Trigonia sp.
Cardium kansasense Meek
Callistina? *belviderensis* (Cragin)?
Cyrena? *dakotensis* Meek?

USGS Mesozoic loc. D2930 (lower bed):
Lingula cf. *L. subspatulata* Hall and Meek
Phelopteria sp.
Anomia sp.
Trigonia sp.
Anchura sp.

The middle unit (glauconitic sandstone) of the Taft Hill Member appears not to contain any fossil mollusks; at least none have been found. But a broken isuroid shark tooth, generically and specifically indeterminate, and a small (10 by 12 by 27 mm) striated coprolite were collected from near the base of the unit at Vaughn junction. The explanation for the absence of a marine molluscan fauna in this unit and other glauconitic facies of the Taft Hill is believed to be related to the chemical character of the water in which they were laid down. The sea at that time probably was brackish, with a low concentration of calcium carbonate and a seasonally variable pH value centering around 7.5. Hence, sufficient $CaCO_3$ may never have accumulated for marine animals to make shells, or, if they did, subsequent lower concentrations or increases in acidity (lower pH values) might have caused the carbonate to go back into solution.

Fossils consisting of the long-ranging pelecypod genera *Nucula, Nuculana,* and *Lucina* were found in the upper part of the member in soft silty gray shale exposed in a streambank 3.2 km (2 mi) north of Vaughn in the NW¼SW¼NW¼ sec. 7, T. 21 N., R. 2 E. (USGS Mesozoic loc. D529). Also, as noted previously, the brachiopod *Lingula subspatulata* Hall and Meek has been reported from the uppermost bed of the type section.

The best dating for the lower part of the Taft Hill Member has been from collections made by M. R. Mudge at the Rocky Mountains front, on Sun River, about 92 km (57 mi) west of Vaughn. There, Mudge (1972, p. A62–A63) collected *Inoceramus comancheanus* Cragin and other marine pelecypods and gastropods of late Albian age from many levels. Both *I. comancheanus* Cragin and *I. bellvuensis* Reeside also have been reported by Stelck (1958, p. 3) from the Joli Fou Shale in northern Alberta, but, unfortunately, their position with respect to the Spinney Hill Member, which may not have been present there, is not stated. In the United States, these fossils indicate a correlation with at least part of the Skull Creek Shale of the Black Hills region and the Kiowa Shale of Kansas. Evidently they indicate a normal shallow-water marine environment. The strata containing *I. comancheanus* Cragin on Sun River have not been correlated with the type section, so the stratigraphic relationship of the fossiliferous beds to the middle unit, the glauconitic sandstone, is not known in Montana either. There is some reason to believe, however, that they may be equivalent to the lower part of the member, or even somewhat older, since it is possible to show that some of the upper part of the Taft Hill may be early late Albian in age.

Cobban (1951a, p. 2177) originally considered the beds herein assigned to the middle unit of the Taft Hill Member as "the probable equivalent of the Newcastle sandstone" of the Black Hills, inasmuch as both units overlay black shale of Skull Creek age (late Albian). Mudge's recent discovery of late Albian fossils in the Taft Hill equivalent west of Vaughn suggested the possibility that the member as a whole represents an inner sublittoral facies of the upper part of the Skull Creek Shale. The Cyprian Sandstone Member at the middle of the Thermopolis Shale in the Little Rocky Mountains of north-central Montana also has been suggested as a Newcastle Sandstone equivalent by Knechtel (1959, p. 740). When referred to the base of the Colorado Group (top of Kootenai Formation), the base of the Cyprian Sandstone Member, which is about 7.6 m (25 ft) thick, occupies approximately the same stratigraphic level as the thin littoral conglomerate (bed 31, type section), 5.1 m (16.6 ft) below the top of the Taft Hill Member. Although no direct correlation has been established between these two units, this correspondence of horizon is roughly suggestive of equivalence. There also is noticeable similarity in the appearance of their chert pebbles. The sandstones at the top of the Taft Hill, therefore, may likewise be equivalent to the Newcastle Sandstone.

Knechtel (1959, p. 740) also pointed out that the Cyprian Sandstone Member "is considered to be equivalent to the Viking Sandstone of southern Alberta and Saskatchewan, Canada." The Viking Sandstone overlies the Joli Fou Formation in eastern Alberta and west-central Saskatchewan, and the probable correlation of the glauconitic Spinney Hill Member of the Joli Fou with the middle (glauconitic sandstone) and lower units of the Taft Hill has been suggested. According to Stelck (1958, p. 3), the "Viking sandstone belongs to the base of the upper Albian substage near the top of the Lower Cretaceous," but in his correlation chart (1958, fig. 1, p. 4) it has been placed somewhat higher, with the Joli Fou Formation at the base of the upper Albian, overlapping slightly into the upper part of the middle substage of the Albian.

DESCRIPTIVE SECTIONS OF TAFT HILL MEMBER

The following descriptions of type and reference sections of the Taft Hill Member of the Blackleaf Formation are based primarily upon field descriptions. Only a few representative specimens have been studied petrographically and mineralogically. In order to make the two described sections as comparable and complementary as possible, each section has been subdivided into three units. Cross-reference within the bed descriptions and to the text have been used where identification of individual beds seems important.

Type section of Taft Hill Member

[Composite section from measurements by R. W. Lemke and E. K. Maughan at four localities south and southeast of Vaughn in the Great Falls and Vaughn quadrangles. Units 2–6 were measured in the center of sec. 9, T. 20 N., R. 2 E.; units 7–13 in SE¼ sec. 2, T. 20 N., R. 2 E.; unit 14 on south bank of Sun River in the SW¼ sec. 25, T. 21 N., R. 1 E.; and units 15–35 in the SW¼SE¼ sec. 1, T. 20 N., R. 1 E. (fig. 7)]

Blackleaf Formation:
  Vaughn Member (entire member exposed at this locality but only basal bed described here):
    35. Sandstone, light-gray to buff, poorly consolidated, friable to platy. Lower third is calcareous and contains carbonized plant fragments; rest of unit is noncalcareous, slightly bentonitic near base, and weathers yellowish orange. Platy beds are fine to

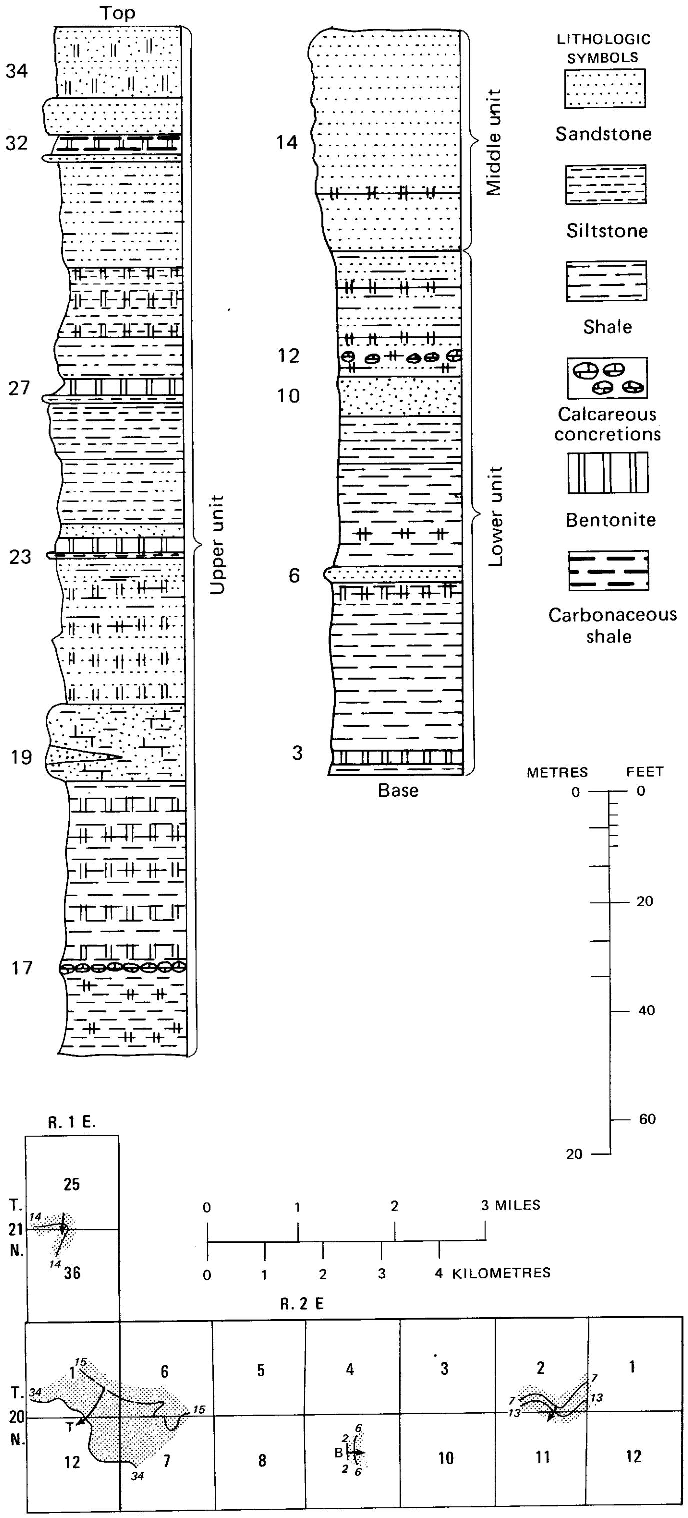


FIGURE 7.—Type section of the Taft Hill Member of the Blackleaf Formation and map showing line of measured section, secs. 2 and 9, T. 20 N., R. 2 E., sec. 1, T. 20 N., R. 1 E., and sec. 25, T. 21 N., R. 1 E. Numbers on the left side of the column are key beds in the measured section. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of Taft Hill Member—Continued

	M	Ft
Blackleaf Formation—Continued		
Vaughn Member—Continued		
35. Sandstone, etc.—Continued medium grained, calcareous, and locally crossbedded; these thicken northward into massive crossbedded sandstone. Top of bed forms a flat conspicuous bench 30–60 m (100–200 ft) wide	6.2	20.3
Taft Hill Member:		
Upper unit:		
34. Sand, light-olive-gray, glauconitic, fine-grained, slightly bentonitic; weathers light yellowish gray; contains carbonaceous fragments and locally numerous small brachiopod (*Lingula*) shells. At top and 2 m from base are lenses of platy light-olive-gray (5*Y* 6/1) to greenish-gray (5*GY* 6/1) glauconitic sandstone that weather purplish gray	3.1	10.2
33. Sandstone, light-gray, fine-grained, thin-bedded, well-jointed; weathers light bluish gray; top of bed forms a ledge	1.1	3.6
32. Sand, slightly bentonitic; contains thin lenses of black carbonaceous material	.9	2.8
31. Sandstone, pale-olive (10*Y* 6/2); fine- to coarse-grained, calcareous, finely stratified to massive, well jointed (N. 72° W.); weathers dark greenish gray. Composed largely of poorly sorted well-rounded to subrounded grains of clear and smoky quartz, dark chert, and undetermined green grains, as well as some black chert pebbles and abundant fish teeth and bones	0.2	0.6
30. Claystone, chiefly very light gray and buff, silty to sandy, fine-grained, slightly bentonitic; contains thin siltstone layers near top. A few brown-weathering calcareous concretions that have cone-in-cone structure are 2 m above base	4.6	15.1
29. Siltstone, olive-brown, bentonitic, soft. Weathered surface is spongy and medium gray mottled with yellow. At base are a few calcareous concretions that have cone-in-cone structure	2.9	9.6
28. Shale, light-olive-gray, silty, indistinctly fissile, slightly calcareous; outcrop weathers to conspicuous grayish white (fig. 6) and can be traced for many kilometres. Locally contains hard thin siltstone layers and ovoid to round calcareous siltstone or argillaceous limestone concretions about 1 m in diameter; these concretions, light greenish buff on fresh fracture, weather to rounded nodules that are grayish buff mottled with dark brown	1.7	5.7
27. Bentonite, greenish-yellow, impure; forms a light-gray spongy bench	.7	2.2
26. Siltstone, light-gray, glauconitic, moderately well bedded; weathers light bluish gray; consists chiefly of subangular frosted quartz grains with some hornblende and glauconite. Contains carbonaceous fragments along bedding surfaces. Few very		

Type section of Taft Hill Member—Continued

	M	Ft
Blackleaf Formation—Continued		
Taft Hill Member—Continued		
Upper unit—Continued		
26. Siltstone, etc.—Continued small crystals of red clinoptilolite in fractures at top of unit. Here and there are brown-weathering concretions that have cone-in-cone structure	.3	.9
25. Shale, dark-gray; fissile, slightly bentonitic; becomes lighter gray and silty upward. At base is a discontinuous bed of brown-weathering limestone that has cone-in-cone structure	1.5	5.0
24. Shale, nearly black, bentonitic, partly fissile; weathers to a gray spongy slope. Includes a lenticular brownish-weathering bed of light-greenish-gray medium-grained slightly friable calcareous sandstone that contains a few grains of glauconite, hornblende, and mica	4.1	13.5
23. Bentonite, greenish-yellow, nearly pure; forms spongy bench. Scattered irregularly shaped gray siltstone concretions containing carbonaceous fragments. Forms a distinct spongy bench	.7	2.3
22. Siltstone, dark-gray; weathers bluish gray	.2	.6
21. Sandstone, fine-grained, bentonitic, soft; interbedded with dark-gray bentonitic shale and in upper 1 m iron-stained bluish-gray-weathering siltstone	3.4	11.1
20. Sandstone, olive-buff, fine-grained, distinctly laminated, calcareous, bentonitic, soft; weathers to spongy surface marked by dark-gray bands, some of which are stained orange	2.9	9.5
19. Sandstone, light-gray, mostly silty and friable, massive, moderately calcareous; contains brown-weathering concretionary lenses of fine- to medium-grained gray calcareous sandstone through most of upper two-thirds of bed. Top of unit is lenticular bed as much as 24 cm thick of dark-gray argillaceous limestone that weathers brown and has indistinct cone-in-cone structure	3.0	9.8
18. Shale, bentonitic; weathers to light-gray spongy surface. Lower part is dark gray except for basal 0.6 m, which is nearly all yellowish-green bentonite; limestone concretions occur 1.8 m and 3.7 m (6 ft and 12 ft) above base. Upper part is distinctly fissile and silty and weathers to a gray spongy surface; a thin bentonite bed is 5.5 m (18 ft) above base	7.9	25.8
17. Cone-in-cone concretions, medium-dark-gray, calcareous; weather brown; some as large as 1 m in diameter	.2	.6
16. Shale, bentonitic; weathers to a light-gray spongy surface	2.4	8.0
15. Covered	1.2	4.0
Middle unit:		
14. Sandstone, olive-green (10*Y* 5/2–10*Y* 5/4), fine- to medium-grained, platy and friable		

Type section of Taft Hill Formation—Continued

	M	Ft
Blackleaf Formation—Continued		
Taft Hill Member—Continued		
Middle unit—Continued		
14. Sandstone, etc.—Continued to massive and well-cemented, locally crossbedded; mostly quartz with abundant glauconite, chert, and calcite; silty to shaly near base. Unit weathers to rough irregular surfaces. An impure greenish-yellow bentonite layer 18 cm thick lies 2.4 m (8 ft) above base. Some very thin lenses of black-weathering siderite occur about 0.5 m below top	9.1	30.0
Lower unit:		
13. Covered	4.3	14.0+
12. Concretions, dark-brown, highly fractured; argillaceous and ferruginous limestone about 10 cm thick and 30–60 cm in diameter, showing prismatic structure	.2	.5
11. Covered	.9	3.0
10. Sandstone, olive-green, medium-grained, glauconitic, friable, noncalcareous	1.5	5.0
9. Siltstone, bluish-gray, friable	0.6	2.0
8. Siltstone, gray, clayey, partly fissile; a few bentonite beds 3–6 cm thick	1.4	4.5
7. Shale, black, fissile; a few bentonite beds 3–6 cm thick	4.4	14.5
6. Sandstone, dusky-yellow (5*Y* 6/4), medium-grained, well-sorted, porous, friable, indistinctly laminated, slightly glauconitic	.6	2.0
5. Shale, grayish-yellow, sandy, bentonitic, poorly exposed	.9	3.0
4. Shale, black, distinctly fissile; includes a few beds of bentonite about 3 cm thick	6.1	20.0
3. Bentonite, greenish-yellow	.6	2.0
2. Shale, black, fissile	.3	1.0
Total Taft Hill Member (rounded)	74	242
Flood Member (top):		
1. Sandstone, light-gray, poorly exposed; weathers tan	3.7+	12.0+

Composite reference section for approximately the lower half of the Taft Hill Member

[Measured by C. E. Erdmann, Oct. 1962 and May 1967, along U.S. Interstate 15 northwest of Great Falls between the S½ sec. 36, T. 21 N., R. 2 E., and Vaughn junction (sec. 19, T. 21 N., R. 2 E.), Cascade County, Mont. Beds 78–82 were measured along Manchester exit road between secs. 26 and 25, T. 21 N., R. 2 E.; beds 77–53 were measured in the center of sec. 19, T. 21 N., R. 2 E.; beds 52–35 were measured in the NE¼SE¼ sec. 19, T. 21 N., R. 2 E.; beds 34–19 were measured in the NE cor. NW¼SW¼ sec. 26, T. 21 N., R. 2 E.; and beds 18–1 were measured in the NE¼NW¼ sec. 36, T. 21 N., R. 2 E.]

	M	Ft
Pleistocene:		
Pre-Wisconsin. Terrace gravels along the Sun River consisting chiefly of argillite and quartzite from the Belt Supergroup; lime coated, loosely consolidated in a sandy matrix	2.1	7.0
Unconformity.		
Blackleaf Formation:		
Taft Hill Member:		
Upper unit:		
82. Siltstone, soft; weathers rusty	.6	2.0
81. Bentonite, light-gray, soft, weathered	.1	.3
80. Siltstone, medium-light-gray; weathers rusty	3.1	10.0

Composite reference section for approximately the lower half of the Taft Hill Member—Continued

	M	Ft
Blackleaf Formation—Continued		
Taft Hill Member—Continued		
Upper unit—Continued		
79. Bentonite, light-yellowish-gray	.1	.3
78. Siltstone, medium-light-gray, soft, fissile; contains a few thin limonitic laminae. Base darker (*N* 3), with 0.6-cm-thick laminae of light-olive-gray shale at intervals of about 3 cm	2.7	9.0
Diastem(?)		
Middle unit (the glauconitic sandstone):		
77. Sandstone, olive-gray, fine-grained; thin 0.6-cm horizontal wavy layers. Top irregular with local relief of 50 cm	.2	.5
76. Sandstone, light-olive-gray, fine-grained. Top irregular and marked by a thin film of dark-gray sandy clay (graded bedding?). Below this upper 15 cm there is exhibited planar ("torrential")-type cross-lamination with true dip 20° S. to 11° E. Bedding in lower 10 cm essentially horizontal. Homogeneous (nonlaminated) layers are here and there calcareous	.2	.8
75. Sandstone, light-olive-gray, fine-grained. Upper half cross-laminated with 2-cm-thick beds dipping 20° S. to 15° W. (component dip?); lower part massive, with thin horizontal laminae	.3	1.0
74. Sandstone, light-olive-gray, thin, soft, friable	.1	.3
73. Sandstone, light-olive-gray, fine-grained, firm; consists of moderately resistant 5- to 15-cm-thick layers. 15-cm-thick bed, in middle, has 0.6-cm-thick laminae in planar-type cross-lamination dipping 15° S	.6	2.1
72. Sandstone, light-olive-gray, fine-grained. Top marked by horizontal laminae of dark-gray silty shale. Lower 15 cm has 0.6-cm-thick sandstone laminae in planar-type cross-lamination dipping 15° S	.2	.8
71. Sandstone, light-olive-gray, fine-grained; weathers dusky yellowish brown to dark yellowish brown in scabby ferruginous crusts 0.3–0.6 cm thick. Locally persistent	.1	.3
70. Sandstone, light-olive-gray, fine-grained; in 5-cm-thick noncalcareous layers. Softer than underlying bed	.6	2.0
69. Sandstone, light-olive-gray, fine-grained, calcareous, hard, resistant; makes a thin ledge on freshly cut slope. Base irregular. Locally persistent	.2	.7
68. Sandstone, light-olive-gray, fine-grained; in thin 1- to 5-cm soft friable layers. Top locally undercut	.4	1.3
67. Shale, light-olive-gray (5*Y* 5/2), soft, finely laminated, fissile; weathers dusky yellowish olive to dark yellowish orange	.1	.2
66. Sandstone, olive-gray, medium-grained, thinly laminated, soft, glauconitic	.1	.4
65. Clay ironstone, compact aphanitic to sandy,		

Composite reference section for approximately the lower half of the Taft Hill Member—Continued

Blackleaf Formation—Continued

Taft Hill Member—Continued

Middle unit, etc.—Continued

	M	*Ft*
65. Clay ironstone, etc.—Continued hard, brittle; more or less completely weathered through with dark-yellowish-orange concentric structures; surface commonly brownish black with manganese oxide stain and fine-textured botryoidal forms; contains short thin lentils of loosely consolidated glauconitic sand that weathers out to leave small flat elliptical cavities. A broken isuroid shark tooth and a small (10 by 12 by 27 mm) striated coprolite have been found on surface of bed. Locally persistent	.1	.2
64. Sandstone, light-olive-gray, fine- to medium-grained; in soft friable horizontal 5-cm-thick layers	.7	2.2
63. Sandstone; as above, as 5-cm-thick layers with laminae of detrital glauconite. Casts of trace fossils on bedding surfaces. Top marked by thin film of olive-gray (5*Y* 4/1) fissile shale; 15-cm-thick upper bed exhibits planar cross-lamination dipping 10°–12° S. 10° W. Makes an indistinct ledge	.6	2.0
62. Sandstone, light-olive-gray, fine-grained, glauconitic; softer and more friable than underlying bed; bedding indistinct	1.0	3.2
61. Sandstone, light-olive-gray, fine-grained, glauconitic. Upper half soft; lower half firm, calcareous	.2	.5
60. Sandstone, as immediately above; contains epigenetic banded crusts 0.6–1 cm thick of very dusky red clay ironstone in lentils 10 cm long and 3 cm thick, which are especially well developed in lower part	0.2	0.5
59. Sandstone, light-olive-gray, fine-grained, glauconitic; more thinly bedded than above. Entire sequence makes indistinct ledge	.2	.5
58. Cone-in-cone calcite, light- to medium-gray; occurs as radiating fibers in asymmetric brushlike aggregates 3–8 cm long replacing yellowish-gray bentonite, some of which remains intergrown at point (base) of cones. Contains 0.6-cm-thick crusts of very fine fibrous yellow-brown calcite with silty luster	.1	.3
57. Cone-in-cone calcite; weathers dark yellowish orange. More massive than overlying bed, into which it grades	.2	.6
56. Sandstone, light-olive-gray, hard, massive, calcareous; grades upward into fine-grained bentonitic sandstone that weathers dark yellow orange. Entire sequence very distinct, locally persistent, making a valuable marker bed	.2	.7
55. Sandstone, light-olive-gray, glauconitic, fine-grained; in 3- to 20-cm-thick layers separated by softer more finely laminated partings. Slightly irregular bedding surfaces are marked by thin laminae of detrital glauconite which show trace fossils (worm trails?) and other markings	.8	2.7
54. Siltstone, olive-gray, soft; transitional into bed above	.1	.2
53. Bentonite, light-yellowish-gray (5*Y* 8/1), tuffaceous, firm, compact; weathers light yellowish orange. Breaks with flat subconchoidal fracture. Thickens and thins	.1	.2
52. Sandstone, olive-gray, glauconitic. Lower part is shaly and thinly laminated with medium-dark-gray shaly partings weathering light olive gray	.3	1.0
51. Sandstone, olive-gray, glauconitic. Top makes weak ledge. Lower part is thinly laminated, with partings of soft medium-dark-gray fissile shale that weathers light olive gray	.2	.8
50. Sandstone, light-olive-gray, fine- to medium-grained, glauconitic; upper part makes protruding ledge	.4	1.3
49. Sandstone, olive-gray, fine-grained, silty, soft	.2	.8
48. Sandstone. Upper 30 cm is light olive gray, fine grained, less silty, noncalcareous, but firm and resistant, and forms lowest ledge marker of middle unit. Lower 18 cm is softer, weathers into rounded form by spalling corners off joint blocks. This is the basal bed of the glauconitic sandstone. Can actually be seen to wedge out to the east with base stepping upward	.5	1.6
Measured thickness of middle unit	8.9	29.2
Lower unit:		
47. Sandstone, light-olive-gray, glauconitic, fine-grained, silty, soft, friable. Stratification marked here and there by thin rusty-weathering bentonitic(?) laminae	2.2	7.3
46. Bentonite; upper part is clayey, light olive gray (5*Y* 5/2), and weathers dark yellowish orange. Lower part is more bentonitic, is light yellowish gray, soft, and weathers dark yellowish orange	.1	.3
45. Sandstone, light-olive-gray (5*Y* 5/2), glauconitic, fine-grained, silty, soft, friable. Traces of thin laminae of olive-gray shale	1.5	4.8
44. Sandstone, olive-gray, clayey	.7	2.2
43. Bentonite, soft, silty; weathers grayish orange	.2	.5
42. Sandstone, olive-gray, clayey; weathers downward into thin scales. Contains two or three thin (0.6 cm) bentonite beds	1.1	3.5
41. Bentonite, light-olive-gray, soft, clayey. Base sharp and distinct; top gradational	.1	.2
40. Sandstone, pale-olive-gray; 5-cm (2-in.)-thick layer of soft dark-olive-gray clayey silt at base	.2	.7
39. Bentonite, dark-yellowish-orange, completely weathered, soft, flakey. Base sharp; top gradational	.1	.2

Composite reference section for approximately the lower half of the Taft Hill Member—Continued

Blackleaf Formation—Continued

Taft Hill Member—Continued

Lower unit—Continued

	M	*Ft*
38. Sandstone, pale-olive-gray, glauconitic	.3	.9
37. Bentonite, light-yellowish-gray to grayish-orange, soft, fissile. Base sharp; top gradational	.1	.2
36. Sandstone, pale-olive-gray, glauconitic, fine-grained, silty, soft, friable, poorly consolidated. Very homogeneous; indistinct bedding marked by thin laminae of bentonite	0.9	3.0
35. Interval concealed	1.1	3.5
34. Bentonite, very light yellowish to greenish-olive-gray, soft, weathers dark yellowish orange; clayey, with waxy luster. Top gradational	.1	.3
33. Siltstone, medium-dark-gray, soft, fissile. Weathered surface shows numerous thin translucent sheets and films of secondary selenite	.8	2.5
32. Sandstone, olive-gray to moderate-olive-brown, fine- to medium-grained, cherty, glauconitic, soft, noncalcareous; matrix of dusky-yellow silt; contains thin flattened galls of medium-dark-gray siltstone as much as 3 cm across. Top marked locally by a thin layer of very fragile light-brown *Inoceramus* prisms. Estimated percentage composition of sand fraction: subangular quartz, 60, with yellowish-gray dust from matrix; chert, dark gray to black, subangular to subround, unpolished, 25; glauconite (first appearance in Taft Hill Member), dusky yellowish green, smooth ovoidal or lobate grains and compound spherical masses ranging in diameter from 0.5 to 1.3 mm, loosely embedded in the sandstone but not in the clay galls; nondetrital, authigenic (diagenetic), but with a few irregular intergranular masses as much as 2 cm across; accessory muscovite, rare	.3	1.0
31. Siltstone (mudstone), medium-dark-gray; contains scattered concretions of light-yellowish-gray calcite with cone-in-cone structure; weathers brownish gray to dusky red, in very complex intergrowths with mudstone. Individual masses as much as 1 m long and spaced variably at intervals of 3–15 m. Lower surface of concretions is irregular, cutting across bedding. Where cone-in-cone structure has not developed, base of unit may contain flat oval masses 5 by 20 cm of massive olive-gray calcareous siltstone that contain fragments of *Inoceramus*	.2	.5
30. Siltstone, medium-dark-gray	.2	.5
29. Bentonite, light-gray, soft, clayey; in local lenses, some of which show a thin basal layer of very light gray vitric tuff	.1	.2
28. Siltstone, medium-dark-gray; locally shows thin olive laminae in upper 30 cm. Middle and lower part characterized at vertical		

Composite reference section for approximately the lower half of the Taft Hill Member—Continued

Blackleaf Formation—Continued

Taft Hill Formation—Continued

Lower Unit—Continued

	M	*Ft*
28. Siltstone, etc.—Continued intervals of 9–15 cm by many short lentils of finely laminated fine-grained light-olive-gray sandstone	1.1	3.7
27. Bentonite, light-yellowish-gray; weathers rusty at base and top	.1	.2
26. Siltstone, medium-dark-gray; contains short thin lentils of intraformational microconglomerate in a matrix of light-medium-gray fine-grained calcareous sandstone that weathers light olive gray. A more or less persistent layer 3–6 cm thick containing fragments of *Inoceramus* occurs in middle of unit. A very thin olive-brown fine- to medium-grained poorly sorted sandstone layer at base contains fragments of very dark gray carbonaceous mudstone and impressions and fragments of *Inoceramus*	.7	2.3
25. Siltstone, medium-dark-gray, soft, flaky; some laminae weathering olive gray	.9	3.0
24. Vitric crystal tuff, very light gray to light-yellowish-gray, partially devitrified, firm, compact, porous; cutting easily, but slightly more resistant than enclosing siltstone; weathering or stained dark yellowish orange at some localities. Very fine grained, breaking with subconchoidal fracture; largest crystal fragments range from about 0.007 to 0.155 mm	.1	.2
23. Siltstone, medium-dark-gray; some laminae weather light olive gray; very thin light-gray layer of bentonite near base	.3	1.1
22. Sandstone, light-gray, fine-grained, cherty; calcareous cement; soft and friable where weathered. Occurs in thin (3 cm) short lentils. Locally, a thin (3 cm) rusty-weathering bentonite at base	.2	.6
21. Siltstone, medium-dark-gray, soft, fissile; a few rusty laminae	.4	1.2
20. Bentonite, light-gray (grayish-white), soft, clayey; weathers dark yellowish orange; base locally irregular	.4	1.2
19. Shale, medium-dark-gray, fissile	1.1	3.6
18. Sandstone, medium-gray, fine-grained, clayey, calcareous. Contains a few thin granules of polished brownish-gray chert as much as 3 mm in diameter, and claystone pellets 3 by 6 cm and 1 cm thick. Flute casts on base; bedding irregular; top irregular, with ripple marks in places in a thin film of brown ferruginous sandstone with wavelength of 6 cm and amplitude of 1 cm. Worm tubes filled with gray clay	.1	.3
17. Shale, medium-dark-gray; weathers rusty brown along sandy laminae	.2	.6
16. Sandstone, light-gray, fine-grained, noncalcareous. In short lentils	.2	.7
15. Shale, dark-gray, poorly exposed	.3	1.0
14. Shale and sandstone; in thin layers. Sand-		

Composite reference section for approximately the lower half of the Taft Hill Member—Continued

Blackleaf Formation—Continued
Taft Hill Formation—Continued
Lower unit—Continued

	M	*Ft*
14. Shale and siltstone, etc.—Continued stone is light medium gray and fine grained; shale is medium dark gray	.1	.3
13. Sandstone, conglomeratic, medium-light-gray, calcareous, hard; firm and compact when fresh; weathers light yellowish brown in places. In finely laminated lenses of variable thickness and width separated by thinner irregular partings of soft olive clay. Sand facies or matrix fine to medium grained, subangular, and with salt-and-pepper appearance. Conglomeratic facies characterized by usually small (2 mm or less) rounded granules and pebbles of brownish and dark-gray chert; also characterized by subrounded granules as much as 5 mm in size of very light gray yellowish-gray to white aphanitic tuff. Percentages vary, but chert and tuff combined may make about 40 percent, and when about equal give the rock a very distinctive appearance. Fish scales and vertebrate bones are rare as accessories	.1	.4
12. Sandstone, light-gray, calcareous, hard, firm; makes a weak ledge	.2	.6
11. Sandstone, olive to light-yellowish-gray, fine grained, soft; weathers rusty brown in places. Occurs in thin (0.5–1 cm) lentils separated by thin partings of dark-gray clay	.2	.8
10. Shale, medium-dark-gray, clayey, soft, plastic. Less fissile than that just below	.4	1.4
9. Shale, medium-dark-gray, fissile, papery; thin layer of fine-grained sandstone at top	.3	1.1
8. Clay, dark-gray, soft. Contains thin laminae of fine-grained rusty sandstone	.2	.6
7. Sandstone, fine- to medium-grained. In small lentils or pods	.1	.2
6. Clay, sandy, but soft and plastic; olive-gray when moist. Contains here and there brown-weathering concretions of calcareous olive mudstone 60 cm in diameter and 13 cm thick, with a layer of cone-in-cone structure on top	.1	.4
Intramember erosional disconformity.		
5. Sandstone, medium-gray, calcareous, hard; weathers brownish gray; makes ledge; fine to medium grained, with a sprinkling of small granules of dark chert cemented by authigenic crystals of calcite. Top slightly irregular; rusty brown	.5	1.7
Thickness of partial section of Taft Hill Member (rounded)	31	101

Erosional disconformity.

Flood Member:

	M	*Ft*
4. Sandstone, yellowish-gray, medium-grained, subangular, weakly cemented, friable; good porosity and permeability; predominantly clear glassy quartz whose crystal faces glisten brightly, with about 5 percent yellowish-gray weathered feldspar and 5 percent dark minerals (chert)	1.1	3.4
3. Sandstone, yellowish-gray, fine- to medium-grained (as above). Largely concealed by rubble	4.9	16.0
2. Sandstone, yellowish-gray; as above, with a few small spherical concretions of orange-brown limonitic sandstone. Top makes resistant ledge	2.6	8.5
1. Sandstone, medium-gray, fine-grained; in short lentils or nodules separated by thin partings of medium-gray siltstone and shale	0.6+	2.0+
Thickness of partial section of Flood Member (rounded)	9.0	30.0

VAUGHN MEMBER

NAME AND DEFINITION

Strata of the Vaughn Member of the Blackleaf Formation were formerly referred to as the "red speck zone" (Erdmann and Schwabrow, 1941, p. 284; Blixt, 1941, p. 337) and the "nonmarine member" (Cobban, 1951a, p. 2180). Later, in subdividing the Colorado Group, the strata were called the Vaughn Bentonitic Member of the Blackleaf Formation by us (Cobban and others, 1959, p. 2790) with the intent of including rocks of nonmarine origin between the Taft Hill Glauconitic Member below and the Bootlegger Member above. As first measured by us (Cobban and others, 1959) and illustrated by Maughan (1961), the type section of the member included transitional beds at the base that are only locally present. These strata are now believed to be of marine origin and have been assigned to the Taft Hill Member in this paper. The Vaughn Member by definition is exclusively continental in origin.

The Vaughn Member is named from excellent exposures north and south of Vaughn, 19 km (12 mi) west of Great Falls. The type section crops out along the east bank of an unnamed intermittent wash in the N½NE¼ sec. 6, T. 21 N., R. 2 E., and on a southwest-pointing spur in the SE¼SW¼SE¼ sec. 31, T. 22 N., R. 2 E. (Vaughn quadrangle) (fig. 8). This locality is somewhat inaccessible in that it cannot be seen or quickly reached from any main road. The easiest approach to it is over an unsurfaced road from the north and down an abrupt escarpment between secs. 31 and 32, T. 22 N., R. 2 E., to the NE. cor. sec. 6, T. 21 N., R. 2 E.; from there it is about a 0.8-km (0.5 mi) walk to the west. For greater accessibility, a composite reference section of the member designated in this report has been measured and described in detail 4 km (2.5 mi) to the

FIGURE 8.—Type section of the Vaughn Member about along the center line of the NE¼ sec. 6, T. 21 N., R. 2 E., Cascade County, Mont. The sandstone cropping out in the upper middle part of the photograph below the light-gray bentonitic unit bare of vegetation marks the base of the member. R. W. Lemke is standing on a limestone bed 8.5 m (28 ft) below the top of the Taft Hill Member.

southwest, along U.S. Highway 91 (Interstate 15), in the NE¼ sec. 11 and SE¼ sec. 2, T. 21 N., R. 1 E.

THICKNESS

In its type section the Vaughn Member has a thickness of approximately 26 m (86 ft). As first defined (Cobban and others, 1959, p. 2790), the thickness given was 29.6 m (97 ft), but this thickness included underlying probable marine strata now assigned to the Taft Hill Member. The thickness in the composite reference section, about 4 km southwest, is 26 m (86 ft). In an outcrop 17.7 km (11 mi) east (escarpment north of Blackhorse Lake Flat east of the Bootlegger Trail, 11.2 km or 7 mi north of the city of Great Falls), the thickness has decreased to 15.9 m (52 ft). The member continues to thin to the southeast toward Belt Butte, where its thickness is only 7.9 m (26 ft) in sec. 30, T. 19 N., R. 7 E. The increase in thickness to the west, however, is more rapid. Schmidt (1963) assigned 114 m (375 ft) of strata to the member in the Wolf Creek area; south of the town of East Glacier, Vaughn lithology seems to have completely replaced the Taft Hill Member and the Bootlegger Member.

Although not commonly recognized in old cable-tool drillers' logs, some part of the Vaughn usually can be identified microscopically in formation samples, and it serves as a general marker for the middle part of the Blackleaf Formation. No part of it, however, provides a satisfactory datum for regional structural mapping. Thicknesses in the subsurface on the Sweetgrass arch seem not to be so systematic in their range as those in outcrops. A number of factors, singly or in combination, probably contribute to this condition: (1) The internal character of the boundaries changes from place to place in consequence of the variable continental lithology; (2) the top may be affected by a slight erosional disconformity, with some variation in the overlying units; and (3) local absence of the diagnostic mineral clinoptilolite. Apparently some anomalous thicknesses result from disaggregation and "washing out" of montmorillonite from the claystone. For these reasons the top of the member is not a good datum plane for regional structural mapping.

The Vaughn is 45 m (150 ft) thick in the Brady oil field, 69 m (227 ft) thick near the west edge of the Pondera oil field, 22 m (74 ft) thick at the top of the Kevin-Sunburst dome (sec. 15, T. 34 N., R. 1 W.), 37 m (120 ft) thick on the west side of the Cut Bank oil and gas field (sec. 13, T. 35 N., R. 6 W.), and 160 m (525 ft) thick in the Chicago Petroleum Corporation's Mabel Armstrong Well 1 Allotted 168 in sec. 35, T. 36 N., R. 8 W. The member thins eastward from the Kevin-Sunburst dome and has not been recognized east of the Sweetgrass Hills.

OUTCROP DISTRIBUTION

On the Sweetgrass arch the Vaughn Member crops out only on the southern part of the South arch. Beginning with the outcrops along the Missouri River in the northeastern part of the Portage quadrangle, the belt of outcrop extends southwestward across that quadrangle to the Blackhorse Lake Flat area, 8–13 km (5–8 mi) north of the city of Great Falls. From Blackhorse Lake Flat, the belt of outcrop trends slightly north of west and crosses the Great Falls quadrangle just below its middle. The outcrop continues west into the Vaughn quadrangle and up Muddy Creek to a point in the SE¼ sec. 32, T. 22 N., R. 1 E., where it dips below the valley floor. Along the Sun River the member is exposed from a point 1.6 km (1 mi) west of Vaughn on up the valley for 9.6 km (6 mi) to the southern part of sec. 36, T. 21 N., R. 1 W., where the top disappears below the river. South of Vaughn the member is very well exposed along the east side of Taft Hill and southward through the Cascade quadrangle. The outcrop crosses the Missouri River at Riverdale and continues south up Bird Creek valley for 16 or 17 km.

West of the South arch the Vaughn Member is exposed at many localities in the Disturbed belt from 3.2 km (2 mi) northeast of Wolf Creek in sec. 31, T. 15 N., R. 3 W., northwest to the southeast boundary of Glacier National Park, where the Vaughn has completely replaced the Bootlegger Member.

GENERAL DESCRIPTION

Light-colored bentonitic clay, siltstone, and sandstone largely compose this member. Most of the rocks are soft and readily erode into poorly vegetated badlands that are conspicuous in the Cascade, Vaughn, Great Falls, and Portage quadrangles (Cobban, 1955a, fig. 2).

In the type section northeast of Vaughn (fig. 8), the basal unit of the member consists of 4.6 m (15 ft) of pale-greenish-yellow medium-grained very friable arkosic sandstone. At a locality 13 km (8 mi) to the south, along a road ascending Taft Hill, in the SE¼SW¼ sec. 7, T. 20 N., R. 2 E., the base of this sandstone bed is coarse grained, contains some gray shale pebbles, and is channeled into the underlying fine-grained glauconitic sandstone of the Taft Hill Member. This basal sandstone bed of the Vaughn Member persists across the South arch eastward at least as far as the Missouri River, in the Lander Crossing quadrangle. The bed has been mapped by Dobbin and Erdmann (1930) as "sandstone A." A freshwater origin is probable for this bed. Fossil wood can be found on almost any outcrop, and locally, large logs are present. In a few places in the eastern part of the Portage quadrangle, beds of lignitic shale are at the top of the sandstone.

The rest of the Vaughn Member consists dominantly of clayey beds that are light to dark gray, greenish gray, grayish green to olive green, greenish yellow, pink, or chocolate brown and generally are very bentonitic. The clayey beds are interbedded with thinner lenticular units of gray to green bentonitic siltstone and sandstone that are commonly tuffaceous and, in places, are orthoquartzites. Some of the beds of clay, siltstone, and sandstone contain small crystals of orange-red clinoptilolite (determined by L. G. Schultz, U.S. Geol. Survey). Locally, as in the small badland area traversed by U.S. Highway 91, about 5.6–6.4 km (3.5–4 mi) northwest of Vaughn, this zeolite is so abundant that it imparts a pinkish color to the outcrops. Bentonitic clay containing clinoptilolite forms the uppermost 8.5 m of the type section. About 6 km to the west, along Muddy Creek, black carbonaceous shale, which has been prospected for coal, forms the top of the member (fig. 9; also Cobban, 1955a, text fig. 2).

The Vaughn Member is easily recognized in cuttings from wells drilled for oil and gas on the Sweetgrass arch. The clays are largely light to medium shades of gray or green, and the sandstones are generally light gray to white. The rocks are very bentonitic, and most contain small crystals of the orange-red zeolite. The sandstones are fine to medium grained, massive, soft, and clayey. They are composed mainly of subangular grains of clear quartz and white, gray, black, brown, yellow, green, and pink grains of quartz, chert, and other minerals, including some mica. Abundant white clay serves as a cement. Most wells reveal whitish fine- to medium-grained sandstone 1.6–10.7 m (5–35 ft) thick at or near the base of the member. Wells drilled low on the west flank of the Sweetgrass arch, where the Vaughn Member is 61–91 m (200–300 ft) thick, may show as many as four beds of white sandstone 4.6 m (15 ft) or more thick. Black carbonaceous shale has been penetrated at the top of the member in some wells in the Pondera and Kevin-Sunburst oil fields.

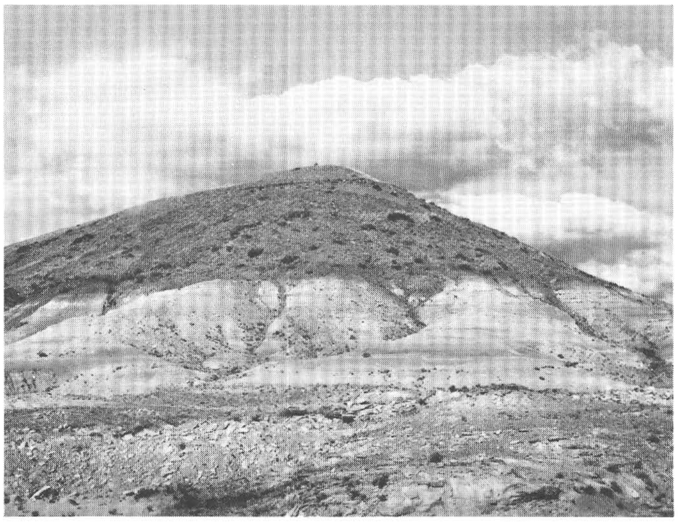


FIGURE 9.—Upper part of Vaughn Member (light-gray bentonitic beds bare of vegetation) capped by layer of lignitic shale (black band) and overlain by lower part of Bootlegger Member 6.5 km (4 mi) northwest of Vaughn in the NE¼ sec. 4, T. 21 N., R. 1 E., Cascade County, Mont.

The top of the Vaughn Member is readily determined in well cuttings by the abrupt change downward from dark-gray more or less sandy shale to light-colored clay or, more rarely, white bentonitic sandstone or black lignitic shale. The lower contact is not so easily placed. A unit, 6 m to more than 11 m thick, of medium- to dark-medium-gray soft silty shale commonly lies between the lowest whitish bentonitic sandstone typical of the Vaughn Member and the uppermost greenish glauconitic sandstone typical of the Taft Hill Member. Interbedded with this silty shale are thin beds of light- to medium-gray very fine to fine-grained shaly sandstone and siltstone that are slightly glauconitic. Locally, these beds contain tiny specks of the orange-red zeolite in addition to the glauconite. These beds are considered to represent intertonguing of the Vaughn and Taft Hill facies and are here assigned to the Taft Hill Member.

AGE ASSIGNMENT AND CORRELATION

The fossil record from the Vaughn Member consists of leaves, logs, and, rarely, fragments of reptile bones. The fossil plants, all from the vicinity of Vaughn, have been identified by R. W. Brown (Cobban, 1951a, p. 2180) as *Pinus* sp., *Araucarioxylon* sp., *Anemia fremonti* Knowlton, *Nelumbites* sp., *Dryandroides*? sp., and *Tempskya knowltoni* Seward. Zeller and Read (1956) regarded the genus *Tempskya* as a possible guide to rocks of Albian (late Early Cretaceous) age. Other evidence which suggests a possible late Albian age is the position of the Vaughn Member below the Bootlegger Member. The Bootlegger Member is an equivalent of part or all of the Mowry Shale of other areas. The Mowry Shale contains *Neogastroplites*, *Inoceramus* cf. *I. anglicus* Woods, and other mollusks that are considered as being probably of very late Albian age (Reeside and Cobban, 1960, p. 28–30). A recent addition to the fossil flora from the Vaughn Member is *Tempskya grandis* Read and Brown.

Formerly the Vaughn Member was thought to be equivalent to the lower part of the Mowry Shale (Cobban, 1951a, p. 2180), but in light of the discovery by Mudge (1972, p. A62) of Skull Creek fossils in the Taft Hill equivalent, a correlation of the Vaughn Member with the Newcastle Sandstone of the Black Hills seems more logical.

DESCRIPTIVE SECTIONS OF THE VAUGHN MEMBER

The following type section and reference section are based chiefly upon field descriptions. Only a small amount of mineralogical work, mainly related to identification of the minerals clinoptilolite and chamosite, has been done. The type section was originally measured by R. W. Lemke and E. K. Maughan in 1956, with minor revisions by R. W. Lemke and A. F. Bateman in 1973. The reference section was measured by C. E. Erdmann in 1968 and 1969. The lithology in both sections is similar, but the stratigraphic units have been subdivided considerably more by Erdmann in the reference section. Also, similar strata in the two sections are not always described in exactly the same way, and therefore correlation of beds between the two sections is not always possible. In addition, the reference section, unlike the type section, is subdivided into three units (upper, middle, and lower), based upon the inferred environmental conditions that existed during deposition of the units. In spite of these inconsistencies,we believe that description of both sections herein is desirable.

Type section of Vaughn Member

[Measured by R. W. Lemke and E. K. Maughan, 5.6–6.1 km (3.5–2.8 mi) north-northeast of Vaughn in the NW¼NE¼ sec. 6, T. 21 N., R. 2 E., and SW¼SE¼ sec. 31, T. 22 N., R. 2 E., Cascade County (Vaughn quadrangle) (fig. 10)]

	M	*Ft*
Blackleaf Formation:		
Bootlegger Member (basal beds):		
21. Sandstone, gray, fine-grained, moderately friable; weathers mottled bluish gray and orange brown; shaly at base, becoming more sandy toward top; upper 18 cm is greenish gray (5*GY* 6/1) that weathers pale olive (10*Y* 6/2), is platy, and contains *Lingula* sp	2.1	6.8
Vaughn Member:		
20. Shale, distinctly fissile, grayish-black, nonbentonitic, noncalcareous; carbonaceous, particularly in basal part. Forms a grassy slope, in contrast to nonvegetated beds below	3.3	10.9
19. Concretions, dark-brown, noncalcareous, fer-		

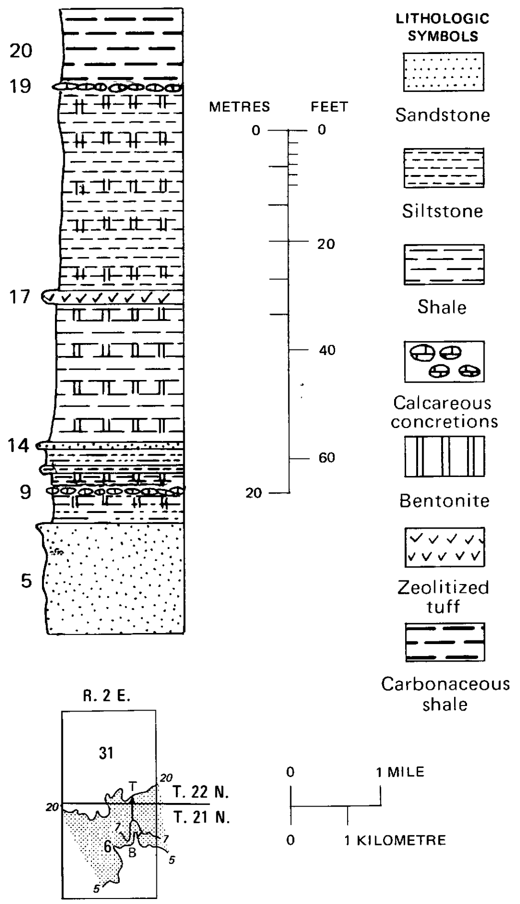


FIGURE 10.—Type section of the Vaughn Member of the Blackleaf Formation and map showing line of measured section, sec. 6, T. 21 N., R. 2 E., and sec. 31, T. 22 N., R. 2 E. Numbers on the left side of the column are key beds in the measured section. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of Vaughn Member—Continued

Blackleaf Formation—Continued

Vaughn Member—Continued

	M	*Ft*
19. Concretions, etc.—Continued ruginous; weather to a very dark metallic brown to bluish black	.1	.2
18. Clay, bentonitic; contains red specks of clinoptilolite. Divisible into several subunits that form distinct benches (mostly with spongy surfaces) separated by low scarps; subunits range in color from light greenish gray through dark gray to chocolate brown. Includes 18 cm of dark-gray siltstone and 1.6 m of alternating beds of hard tuffaceous siltstone and light-gray bentonitic clay. Forms nonvegetated slope	8.4	27.8
17. Siltstone, medium-light-gray (*N* 6), very hard and dense, tuffaceous, lenticular; weathers very light gray (*N* 8); has very fine uneven laminae; contains red clinoptilolite grains and small nodules of light-green clay. Local-		

Type section of the Vaughn Member—Continued

Blackleaf Formation—Continued

Vaughn Member—Continued

	M	*Ft*
17. Siltstone, etc.—Continued ly, upper 15 cm has a distinct red appearance, owing to abundance of finely disseminated clinoptilolite	.5	1.5
16. Clay, bentonitic, noncalcareous; contains red grains of clinoptilolite. Divisible into several subunits that form distinct benches (mostly with spongy surfaces), separated by low scarps. Subunits are light greenish gray to dark gray (a few are greenish gray to olive green). Includes two beds of dark-gray hard and dense tuffaceous siltstone 30 cm or less thick and also a few beds of papery shale near top. Forms nonvegetated slopes	4.9	16.2
15. Clay, bentonitic, slightly silty, moderately greenish yellow (10*Y* 7/2) to grayish-green; mottled with markings of medium-gray (*N* 5) clay that may be of organic origin or fillings in small desiccation cracks	1.0	3.2
14. Sandstone, light-gray, fine-grained, dense, noncalcareous; weathers salmon pink; breaks along indistinct joints into rectangular blocks about 30 cm long and 15 cm wide	.2	.8
13. Siltstone, light-gray, locally clayey	.6	2.0
12. Siltstone, medium-olive-gray (5*Y* 5/1), tuffaceous(?), dense, and very hard; weathers yellowish gray with some light-brown-stained surfaces; many sharply angular quartz grains, some light-green grains, and a few black grains and small black plant fragments. Breaks into very small, sharply angular pieces	.3	1.0
11. Clay, light-gray, silty, slightly bentonitic	.6	2.0
10. Sandstone, gray, fine-grained, resistant, slightly calcareous; breaks into irregular blocks owing to indistinct jointing. Abundant fossil wood at base	.2	.5
9. Claystone concretions, dark-brown, tabular (as much as 0.6 m in diameter), slightly ferruginous, very resistant, noncalcareous; weather to very dark metallic brown to metallic bluish black; some plant fragments	.1	.4
8. Clay, greenish-gray and buff, bentonitic, noncalcareous	1.3	4.4
7. Ironstone concretions, dark-brown, tabular, slightly calcareous; weather bluish and brownish black with a slight metallic luster	.1	.2
6. Sandstone, light-yellowish-gray, fine- to medium-grained, hard, dense, noncalcareous; weathers medium to dark brown; well-developed parallel joints about 7.5 cm apart cause sandstone to break into blocks 30–46 cm long. Abundant rushlike plant remains	.1	.3
5. Sandstone, pale-greenish-yellow (10*Y* 8/2), medium-grained, very friable, thinly bedded to massive, somewhat crossbedded, arkosic, porous, slightly calcareous; consists chiefly of subangular to subrounded quartz grains, abundant feldspar, and some dark grains (in-		

Type section of the Vaughn Member—Continued

	M	Ft
Blackleaf Formation—Continued		
Vaughn Member—Continued		
15. Sandstone, etc.—Continued cludes chert, magnetite, and biotite); light-colored petrified wood in logs as much as 1.8 m long. Locally, 1.8–2.7 m (6–9 ft) above base is a finer grained more resistant sandstone that is grayish brown, massive, and highly calcareous. Scattered ironstone concretions	4.6	15.0
Total Vaughn Member	26.3	86.4
Taft Hill Member (part of upper unit):		
4. Siltstone, light- to dark-gray, shaly to sandy, thinly bedded, noncalcareous to highly calcareous; weathers light yellowish gray (cut by fracture fillings that weather yellow orange); includes, near the top, sandstone lenses several feet long and as much as 0.5 m thick that are medium gray, fine grained, calcareous, dense, and weather orange brown. Local lenticular sandstone near base. Upper boundary gradational	3.2	10.4
3. Clay, gray to greenish-gray, shaly to silty, bentonitic; weathers light gray with crackly surface; scattered nodular fine-grained concretions and local platy sandstone as much as 0.8 m (2.5 ft) thick in upper part. Lower 1.2 m is more bentonitic and contains a few red clinoptilolite grains	5.4	17.7
2. Limestone, yellowish-gray (5*Y* 8/1), coarsely crystalline, layered; weathers brown; poorly developed cone-in-cone structure; breaks into small irregularly shaped brown fragments	.1	.3
1. Siltstone, light-olive-gray (5*Y* 5/2) to dark-greenish-gray (5*GY* 4/1), dense, hard, probably glauconitic, slightly calcareous to noncalcareous; contains *Lingula* sp. and macerated fossil plants. A clayey carbonaceous shale 15 cm thick divides the siltstone into two subunits. Unit cut by well-developed parallel joints that strike N. 71° W	.9	3.0
Total measured thickness of part of Taft Hill Member (upper unit)	9.6	31.4

Reference section of Vaughn Member

[Measured by C. E. Erdmann, June 25–Oct. 3, 1968, and Dec. 17–21, 1969. Base of section starts in north center NE¼NW¼NE¼ sec. 11, T. 21 N., R. 1 E., just below surface of U.S. Highway 91 (Interstate 15). Measurements extend along northeast side of highway to summit of small conical hill in NE. cor. SW¼SW¼SE¼ sec. 2, T. 21 N., R. 1 E.; thence northeast to southwest face of escarpment. Top of measurement in center NE¼SW¼SE¼ sec. 2, Vaughn quadrangle, Cascade County, Mont.]

	M	Ft
Blackleaf Formation:		
Bootlegger Member (basal part):		
28. Sandstone, greenish-gray (5*GY* 6/1), fine grained, compact, thin slabby layered, calcareous, hard, resistant; weathers olive brown; contains trace fossils	0.3	1.0
27. Shale, medium-dark-gray, clayey, poorly fissile. Rusty laminae at intervals of about 3 cm in lower 1.5 m. Weathers into cracked clay slope	4.3	14.0

Reference section of Vaughn Member—Continued

	M	Ft
Blackleaf Formation (basal part)—Continued		
Disconformity; erosional relief slight, about 1 m in this vicinity.		
Vaughn Member:		
Upper unit (lake or swamp environment):		
26. Sandstone, yellowish-gray, thin and platy layered, fine- to medium-grained, locally crossbedded. Surface of upper bed may show irregularities resembling oscillation ripple marks: wave length, 1.0 ft; amplitude, 0.1; strike, S. 55° E. Contains small carbonized logs. Usually makes a massive unit that supports resistant bench. Upper surface also may be marked by inclusion of small irregular reworked lumps of light-bluish-gray (5*B* 7/1) siltstone containing broken laminae and thin pods of medium- to coarse-grained yellowish-gray, cherty sandstone, and angular fragments of brownish-gray carbonaceous shale	1.8	6.0
25. Sandstone, yellowish-gray; in thin (5–10 cm) layers separated by somewhat greater thicknesses (15–30 cm) of soft yellowish-gray clayey siltstone	2.6	8.4
24. Shale, brownish-gray, silty, carbonaceous, soft, flaky	.2	.5
23. Clay, olive-gray, silty, slightly carbonaceous. Weathered surface cracks or checks; unvegetated	.6	2.0
Measured thickness of upper unit	5.2	16.9
Middle unit (pyroclastic clays, water laid):		
22. Mudstone, medium-gray; weathers light gray; contains numerous small dark granules of chamosite. Matrix firm, moderately resistant, weathering out of slope. Base irregular	.3	1.0
21. Claystone, very dark gray, nearly black; has small undetermined light-gray specks	.6	1.9
20. Claystone; weathers pinkish gray, as in unit 18	.1	3.6
19. Tuff, vesicular, water laid (as in unit 17). Pale olive gray, with vesicles occupied by orange-pink clinoptilolite. Compact; tough	.2	.5
18. Claystone; weathers pinkish gray (5*YR* 8/1)	3.0	9.7
17. Tuff, vesicular, silty, light-greenish-olive-gray; weathers very light pinkish gray. In thin layers. Vesicles 0.2–0.6 mm in diameter and filled with clay. Some layers are hard, silicified, and float from them is characterized by a grayish-red (10*R* 4/2) to dark-reddish-brown (10*R* 3/4) clinoptilolite patina, giving the pieces the appearance of a reconstituted igneous rock	.7	2.2
16. Claystone, greenish-olive-gray. Probably largely montmorillonite	1.1	3.7
15. Claystone, pink; contains clinoptilolite	.2	.7
14. Claystone, light-olive-gray	.9	3.1
13. Claystone, light-olive-gray to pinkish; contains small grains of clinoptilolite. Weathers into soft spongy unvegetated surface layer with expanded "popcorn" texture, which flows downslope when wet. Thin siltstone layer at top	2.4	8.0

Reference section of Vaughn Member—Continued

Blackleaf Formation—Continued

Vaughn Member—Continued

Middle unit, etc.—Continued	*M*	*Ft*
12. Tuff and siltstone, medium-gray and greenish-gray. Tuff has vesicles occupied by light-olive-green clay	.1	.3
11. Sandstone; in rounded, flattened, oval balls. Hard, light gray, fine grained, clayey, with a few galls of greenish clay. Top of bed slightly undulating	.5	1.5
10. Mudstone (claystone), light-yellowish-gray. Surface cracked, tough. Makes unvegetated slope	1.7	5.5
Measured thickness of middle unit	11.8	41.7
Lower unit (fluviatile):		
9. Sandstone, light-gray, fine- to medium-grained. Upper 15 cm contains small pellets of light-gray clay. Thinly laminated by slightly more resistant brownish-gray crusts that may be a variety of parting lamination	.4	1.3
8. Sandstone, very light yellowish gray (5*Y* 9/1); predominantly fine to medium angular to subangular quartz with some chalky feldspar, with about 6 or 8 percent dark grains, of which biotite in flakes as much as 0.1 mm wide are most abundant, with chert next, in a tight cement of very light gray (white) clay. Becomes light greenish gray (5*GY* 8/1) upon weathering through color change of cement, and friable upon its loss. In thin (1–24 cm) massive layers, some of which show low-angle east-dipping cross-lamination. Hard and tough when fresh, forming a low resistant ledge	2.5	8.3
7. Sandstone, clayey; light-gray; orange mottling; soft	1.4	4.5
6. Sandstone, light-gray, fine- to medium-grained; in thin alternating layers with softer clayey sandstone. Poorly exposed	2.7	9.0
5. Sandstone, light- to medium-gray, fine- to medium-grained; in massive 10- to 15-cm layers, but strongly crossbedded where thinner; lower 30 cm hard, brown, and ferruginous in places. Base irregular. Contains thin lentils of conglomeratic sandstone noticeably characterized by rounded lumps of soft grayish-yellow (5*Y* 8/4) clay ranging in size from 0.5-cm pellets to irregular fragments 7–10 cm long and 2 cm or more thick. Flattened clay galls are abundant on bedding surfaces. In addition, the matrix of coarse, cherty, subangular, light-olive-gray sand with clay cement exhibits sharp angular 1-cm pieces of firm compact yellowish-gray to pale-olive siltstone; subround pebbles of dark-gray chert 3–12 mm in diameter; and clear glassy quartz in subround grains 2 mm in diameter that break with conchoidal fracture. This facies in particular, which is uncommon, makes the basal conglomerate of the Vaughn Member	1.2	4.0

Reference section of Vaughn Member—Continued

Blackleaf Formation—Continued

Vaughn Member—Continued

Lower unit (fluviatile)—Continued	*M*	*Ft*
Measured thickness of lower unit	8.2	27.1
Total measured thickness of Vaughn Member (rounded)	25.0	86.0
Disconformity; slight erosional relief.		
Taft Hill Member (part of upper unit):		
4. Sandstone, medium-yellow-orange, soft, friable, fine-grained; weathers moderate brown	.5	1.7
3. Sandstone, medium-grained; light olive at top	.2	.7
2. Sandstone, clayey (mudstone), soft; surface cracks. Poorly exposed	3.4	11.2
1. Clay ironstone; in fragmented chippy mounds that have diameters of 0.5–1 m at intervals of 3 m or more, on thin gray-green sandstone. Ironstone surface overlain by thin light-brown recrystallized calcite. Base concealed by alluvium	.2	.5
Measured thickness of part of Taft Hill Member (upper unit)	4.1	13.6

BOOTLEGGER MEMBER

NAME AND DEFINITION

The Bootlegger Member is the "upper member of sandy shale and sandstone of marine origin" that was correlated with the upper part of the Mowry Shale by Cobban (1951a, p. 2180). The member was named by us (Cobban and others, 1959, p. 2791) from the exposures along the east-trending escarpment that is crossed by the Bootlegger Trail 11–13 km (7–8 mi) north of Great Falls near the common corner of Tps. 21 and 22 N., R. 3 E., and Tps. 21 and 22 N., R. 4 E., Cascade County (Great Falls quadrangle). Inasmuch as the member is not completely exposed at any one locality, the section presented here as the type is composite from measurements at several places along the escarpment westward for more than 24 km (15 mi) from the crossing of the Bootlegger Trail. Although parts of the section are not well exposed, the total thickness can be measured in roadcuts along U.S. Highway 91 (Interstate 15) and vicinity northwest of Vaughn in secs. 34 and 35, T. 22 N., R. 1 W. Thin beds of medium-gray sandstone, gray siltstone, dark-gray shale, and yellowish bentonite, compose most of the Bootlegger Member. Much of the sandstone, siltstone, and shale is interlaminated.

THICKNESS

The composite type section is 100 m (329 ft) thick. However, the overall thickness of the member in sec. 3, T. 21 N., R. 2 E., and sec. 34, T. 22 N., R. 2 E., is 84 m (275 ft). This difference in thickness appears to result chiefly from thinning of bed 3 and also above bed 30 of the type section as it is traced westward. Along Muddy Creek, in sec. 4, T. 21 N., R. 1 E., and sec. 33, T. 22 N., R. 1 E., the Bootlegger is 72.5 m (238 ft) thick. Farther northeast in sec. 4, T. 22 N., R. 6 E., and in sec. 16, T. 23 N., R. 6 E., Lemke and Maughan measured a total thickness of 87.2 m (286 ft). In the subsurface Cobban (1951a, p. 2180) noted that the member "thins westward from 320 feet on the east flank of the Sweetgrass arch to 60 feet on the west flank. This westward thinning is due to gradual facies change of the lower part into non-marine sediments."

OUTCROP DISTRIBUTION

On the South arch the Bootlegger Member forms a conspicuous escarpment that extends from Gordon on Muddy Creek near the center of the Vaughn quadrangle eastward across the middle of the Great Falls quadrangle to Blackhorse Lake Flat. From there the escarpment strikes northeastward across most of the Portage quadrangle but is obscured by overlying glacial deposits. The member crops out here and there northeastward at least as far as the Missouri River in the Lander Crossing and Carter quadrangles. In the Vaughn quadrangle the Bootlegger is exposed from the vicinity of Vaughn northwestward 17 km (10.5 mi) up Muddy Creek to the center of sec. 2, T. 22 N., R. 1 W., where it disappears below the valley floor. West of Vaughn the Bootlegger crops out along the Sun River valley as far as 2.4 km (1.5 mi) beyond the town of Sun River. South of Vaughn the basal part of the member caps Taft Hill in the Vaughn and Cascade quadrangles.

Outcrops of the Bootlegger Member are restricted to the central part of the Kevin-Sunburst dome in sec. 5, T. 33 N., R. 1 W. (Shelby quadrangle) where the upper 3.5–4.5 m crops out, and the very top also was exposed during the excavation of the stock watering pond in the NW¼NE¼ sec. 32, T. 34 N., R. 1 W. These exposures bear very close resemblance in texture and composition to typical Bootlegger where it is crossed by U.S. Highway 91 about 9.5 km north of Vaughn.

Outcrops of Bootlegger lithology are not known in the Disturbed belt, owing to its probable replacement by the Vaughn Member.

GENERAL DESCRIPTION

On Taft Hill south of Vaughn a 10-m-thick fine-grained massive bed of sandstone forms a light-brown cliff at the base of the Bootlegger Member. This sandstone, mapped by Dobbin and Erdmann (1930) as "sandstone B," is equivalent to the 17 m (56 ft) of sandy beds that form the basal part of the Bootlegger Member in its type section. There the basal part of the member consists of 8.2 m (27 ft) of light-gray fine- to medium-grained thin-bedded sandstone overlain by 4 m of shaly siltstone and in turn by a fine- to medium-grained sandstone unit of two 0.3-m-thick beds of hard ledge-forming sandstone separated by 1.4 m of softer shaly sandstone. The lower of these 0.3 m ledges weathers dark brown and contains *Lingula*, a brachiopod genus found in both brackish-water and normal marine water. Lemke and Maughan traced these two ledges of sandstone from Muddy Creek, in the center of the Vaughn quadrangle, eastward across the Great Falls and Portage quadrangles and into the Lander Crossing quadrangle where the two beds of sandstone dip below the Missouri River at the mouth of Black Coulee. They found that the interval separating the two sandstone ledges varied from 1.5 to 4.5 m. In the Portage quadrangle the lower ledge is the more conspicuous of the two, whereas the upper ledge is generally the more prominent in the western half of the Great Falls and Vaughn quadrangles. The sandy to shaly interval underlying these hard sandstone ledges and overlying the Vaughn Member thins westward from the type section into the Vaughn quadrangle. About 4 km northwest of Vaughn, the lower sandstone ledge lies a metre or so above the Vaughn Member.

In the type section the upper of the two ledges of sandstone is overlain by 6.4 m (21 ft) of dark-gray shale that contains a layer of bentonite 25 cm (10 in.) thick. Above this shale is 4.4 m (14.3 ft) of sandy siltstone characterized by irregular vertical and diagonal fractures. A thin brown-weathering bed of hard medium-grained sandstone forms a small ledge on top of the siltstone. Above the sandstone is 1.7 m (5.4 ft) more of shaly siltstone. This siltstone and sandstone sequence thins eastward and is very shaly where it dips under the Missouri River below the mouth of Black Coulee in the northwestern part of the Lander Crossing quadrangle. Locally, particularly along the escarpment north of Blackhorse Lake Flat in the Great Falls quadrangle, and at a few other places in the Portage and Vaughn quadrangles, the siltstone and sandstone sequence is well indurated and forms well-defined benches.

The silty unit in the type section of the Bootlegger Member is overlain by 10.8 m (35.3 ft) of very dark gray shale that contains a bed of bentonite 0.7 m (2.2 ft) thick in the basal part. Above this shale is a unit about 12 m (40 ft) thick (beds 17–21 of type section) of thinly bedded sandstone and siltstone with a local bed of black-coated chert pebbles near the middle. This sandy unit is believed to be the equivalent of the sandstone along Highwood Creek (Reeves, 1929, p. 162, bed 24). Another shaly unit about 9.5 m (31 ft) thick overlies these sandy beds and contains a 2-

m-thick bed of greenish-yellow bentonite near its base that forms a conspicuous light-colored poorly vegetated band for many miles westward along the escarpment from the type section. The 12-m (39-ft) thickness of beds above this shaly unit is largely concealed but includes two thin conglomeratic beds with black-coated chert pebbles as much as 5 cm in diameter. The next 7.6 m (25 ft) consists of poorly exposed beds of dark shale and thick layers of bentonite including one 3 m (10 ft) thick. The 3-m-thick bentonite contains, especially in its upper part, lenselike masses of zeolitic tuff and forms a conspicuous white band along the escarpment westward for more than 24 km. It is probably the westward extension of the Arrow Creek Member of the Colorado Shale of central Montana (Reeside and Cobban, 1960, p. 8, pl. 1). A black chert sandstone bed as much as 0.9 m thick just below the base of the bentonite bed forms the upland surface over several square miles west and northwest of the type section. The rest of the Bootlegger Member, about 21 m (70 ft), is mostly interbedded and interlaminated sandstone, siltstone, and sandy shale that contain abundant fish scales. Several layers of bentonite are present, and one that is about 15 cm thick lies at the top. Just beneath this uppermost layer of bentonite is a brown medium- to coarse-grained massive bed of hard sandstone about 30 cm (1 ft) thick crowded with fish bones and scales and, here and there, black-coated chert pebbles as much as 5 cm in diameter. This conspicuous bed of coarse sandstone is present from the western part of the Great Falls quadrangle westward across most of the Vaughn quadrangle. It can be seen readily along U.S. Highway 91 about 9.6 km (6 mi) northwest of the intersection near Vaughn with U.S. Highway 89 and forms the upland surface for some distance to the north and northeast.

The upper and lower contacts of the Bootlegger Member are sharp. Along Muddy Creek in the Vaughn quadrangle, gray shaly fine-grained sandstone at the base rests abruptly on black carbonaceous shale that forms the top of the Vaughn Member (fig. 9; Cobban, 1955a, text fig. 2). At other localities gray shaly sandstone or darker sandy shale forming the basal bed of the Bootlegger rests sharply on light-gray clay or white crossbedded sandstone at the top of the Vaughn (fig. 8). The boundary between the Vaughn and Bootlegger Members can be seen clearly in a cut on U.S. Highway 91 about 4.8 km (3 mi) northwest of Vaughn, south of the center of sec. 2, T. 21 N., R. 1 E. The upper boundary is determined easily in most places by a 15-cm-thick layer of bentonite that rests on the hard bed of coarse-grained to pebbly sandstone which contains abundant brown fish bones. The overlying Floweree Member of the Marias River Shale contains no bentonite and only rarely fish scales or bones. That contact can be seen on the north, west, and south sides of the hill that bears the Cone triangulation station in sec. 13, T. 22 N., R. 1 W., about 4.8 km west of U.S. Highway 91 in the Vaughn quadrangle.

Wells drilled for oil and gas on the Sweetgrass arch reveal a threefold division for the Bootlegger Member at many localities on both the South arch and Kevin-Sunburst dome. In general the basal unit is sandy, the medial unit is soft shale, and the upper unit is sandy, hard, and contains fish scales.

The basal subsurface unit, about 30 m (100 ft) thick, is chiefly gray fine-grained thin-bedded sandstone interbedded with darker sandy shale. Small black carbonaceous flakes are common. Glauconite is sparingly present, and pyrite occurs in a few places. One or two thin layers of black chert granules or small pebbles are present in some wells; one such layer commonly marks the top of this unit.

The medial subsurface unit is dominantly dark-gray soft shale with a few thin beds of fine-grained sandstone and bentonite. Glauconite and pyrite are present but sparse. Granules and small pebbles of black chert occur locally. The thickness of this soft shaly unit averages about 15 m.

The upper subsurface unit, 18 m to more than 30 m thick, is characterized by thin beds of hard medium-gray sandstone and siltstone interlaminated and interbedded with darker gray silty shale. Fish scales are abundant. Several beds of bentonite are present. Almost all well cuttings show a few centimetres of very coarse sandstone or conglomerate at the top of this unit. The sandstone consists mostly of poorly sorted clear grains of quartz showing secondary crystal faces, subrounded to rounded colorless frosted quartz grains, and lesser amounts of subangular gray and black chert. Pebbles are chiefly gray chert that has a black patina. Brown fish bones are generally present. Locally the sandstone is somewhat an orthoquartzite. Small amounts of pyrite occur in the sandstone in some of the well cuttings.

The boundaries of the Bootlegger Member can be determined as readily in the subsurface as on the outcrop. The coarse more or less conglomeratic sandstone layer at the top is an excellent key bed. Where it is absent, the top can be placed at the abrupt change from the dark-gray shale of the Floweree Member to the lighter gray fish-scale-bearing interlaminated and interbedded sandstone, siltstone, and silty shale of the Bootlegger. The lower contact is equally as sharp. It marks the change from dark-gray silty or sandy shale of the Bootlegger to light-colored clay, white bentonitic sandstone, or black carbonaceous shale at the top of the Vaughn Member.

AGE ASSIGNMENT AND CORRELATION

The Bootlegger Member contains the common Mowry fish scales described by Cockerell (1919) as *Holcolepis transversus, Leucichthyops vagans,* and *Erythrinolepis mowriensis.* The ammonite genus *Neogastroplites* has been found in the member on Belt Butte 29 km (18 mi) southeast of Great Falls and at several localities on the Sweetgrass arch north, northwest, and west of Great Falls. This ammonite seems to range in age from latest Albian to early Cenomanian.

The Bootlegger Member is correlated with the Mowry Shale of central Montana and the Black Hills region. Both units contain *Neogastroplites* and abundant fish scales. However, the Bootlegger Member is much less siliceous than the Mowry Shale, lacks the silvery-white weathering, and is very much sandier. It can be interpreted as a near-shore facies of the Mowry Shale. Exposures of the upper part of the Bootlegger Member near Carter Ferry (Carter quadrangle) suggest a gradation to typical Mowry Shale aspect. Here these beds are more siliceous and in part weather grayish white.

TYPE SECTION OF THE BOOTLEGGER MEMBER

The following type section is based almost entirely upon field descriptions. Only a limited amount of petrographic and mineralogic work was done. This was confined mostly to the identification of zeolitic tuff in some of the bentonite beds, which previously had been referred to as porcellanite. Because no great thickness of section is exposed at any one place, the type section is a composite section extending over a distance of approximately 32 km (20 mi). Therefore, the member at no one locality has the thickness or exactly the lithology described in the type section.

Type section of the Bootlegger Member

[Measured by R. W. Lemke and E. K. Maughan, along escarpment that is crossed by the Bootlegger Trail 9.6 km (6 mi) north of Great Falls, Cascade County, Great Falls quadrangle, and near Cone triangulation station, Teton County, Vaughn quadrangle: Units 1–10, SW¼ sec. 31, T. 22 N., R. 4 E.; units 11–30, SE¼ sec. 36, T. 22 N., R. 3 E.; units 31–38, SE¼ sec. 35, T. 22 N., R. 2 E.; units 39–52, NE¼ sec. 33, T. 22 N., R. 2 E.; units 53–54, SE¼ sec. 29, T. 22 N., R. 2 E.; units 54–55, SE¼ sec. 13, T. 22 N., R. 1 W. (fig. 11)]

	M	*Ft*
Marias River Shale:		
Floweree Member (part of basal unit):		
56. Siltstone, dark-gray, sandy to shaly, thinly bedded, somewhat platy; weathers to bluish gray with yellow-brown mottling	1.5	5.0
Blackleaf Formation:		
Bootlegger Member:		
55. Bentonite, grayish-yellow; impure with small selenite crystals	.2	.6
54. Sandstone, yellowish-brown to brown (weathered), medium- to coarse-grained, resistant, blocky; contains abundant fish bones and scales. Locally contains numerous black-		

Type section of the Bootlegger Member—Continued

	M	*Ft*
Blackleaf Formation—Continued		
Bootlegger Formation—Continued		
54. Sandstone, etc.—Continued coated gray chert pebbles as much as 5 cm long. Forms upland surface over many square kilometres to the north	.3	1.0
53. Covered	3.4	11.0
52. Sandstone, light-gray, fine-grained, platy; weathers grayish tan; upper 0.9 m is calcareous. Contains fish scales	2.7	9.0
51. Covered	3.2	10.5
50. Bentonite, yellowish-brown	.2	.5
49. Siltstone, dark-gray, sandy, platy; alternates with silty brownish-gray platy sandstone. Contains fish scales	2.1	7.0
48. Covered	1.5	5.0
47. Bentonite, yellowish-white	.3	1.0
46. Siltstone, dark-gray, sandy, thin-bedded, platy; contains fish scales	1.4	4.5
45. Covered	1.7	5.5
44. Siltstone, dark-gray, sandy, thin-bedded, platy; contains fish scales	.2	.5
43. Bentonite; greenish-yellow and pure in lower part; grades upward into light-gray silty impure bentonite	.9	3.0
42. Siltstone, dark-gray, sandy, thin-bedded, platy; contains fish scales	.6	2.0
41. Shale, gray to tan, sandy	.5	1.8
40. Bentonite, greenish-yellow	.1	.4
39. Siltstone, dark-gray, sandy, thin-bedded, platy; alternates with fine-grained medium-gray sandstone that weathers bluish gray. Contains fish scales	.6	2.0
38. Siltstone, dark-gray, sandy; alternates with silty shale. Thin layer of impure bentonite about midway in unit	1.5	5.0
37. Bentonite, greenish-yellow	1.1	3.5
36. Siltstone, dark-gray; weathers yellowish orange on flat surfaces; shaly	1.1	3.6
35. Bentonite, greenish-yellow	.3	.9
34. Shale, brown, silty	.3	1.0
33. Shale, silty, moderately fissile; nearly black except for yellow powder along bedding planes	1.5	4.9
32. Bentonite; yellowish green at base grading upward into gray silty impure bentonite at top. About midway in interval are lenslike masses, commonly 1–3 m long and 0.3–0.6 m thick, of white thin and irregularly bedded zeolitic tuff that breaks into angular to rounded splintery pieces. Bentonite is iron stained and impure in upper 1.2 m	3.0	10.0
31. Shale, dark-gray to black, silty, distinctly fissile	.5	1.5
30. Sandstone, light-gray, fine- to coarse-grained, resistant, blocky, noncalcareous; mostly quartz with a few black chert grains; fairly numerous gray-blue flat claystone nodules as much as 10 cm long. Contains fish scales. Locally conglomeratic with very numerous black-coated chert pebbles 3–50 mm long. Unit locally as much as 0.9 m thick	.2	.6
29. Covered. A bentonite bed indicated at base of interval	6.9	22.5

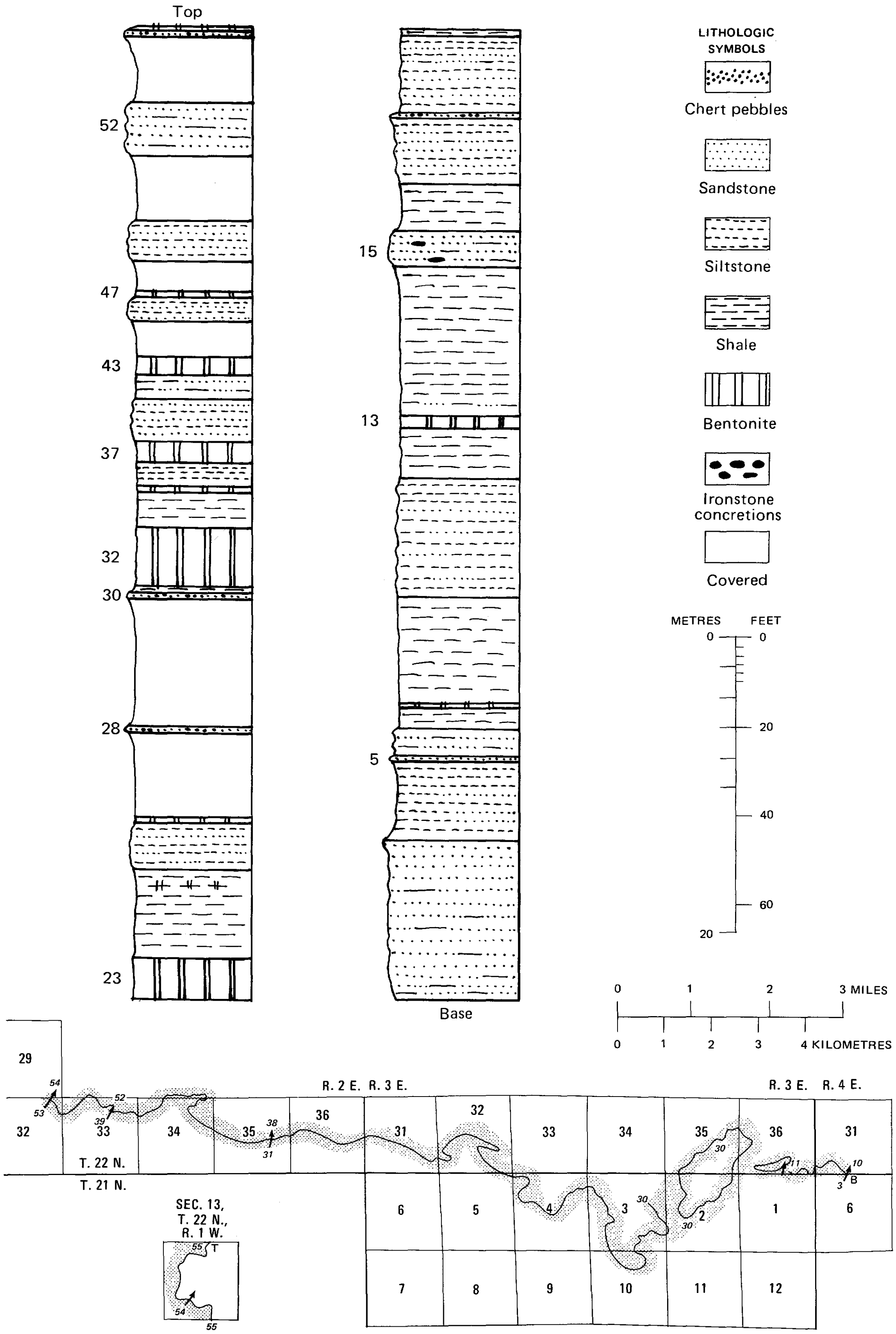


FIGURE 11.—Type section of the Bootlegger Member of the Blackleaf Formation and map showing line of measured section, sec. 31, T. 22 N., R. 4 E., sec. 36, T. 22 N., R. 3 E., secs. 29, 33, and 35, T. 22 N., R. 2 E., and sec. 13, T. 22 N., R. 1 W. Numbers on the left side of the column are key beds in the measured section. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of the Bootlegger Member—Continued

Blackleaf Formation—Continued

Bootlegger Member—Continued	*M*	*Ft*
28. Sandstone, gray, blocky, resistant, calcareous; weathers dark gray. Conglomeratic with very numerous black-coated gray chert pebbles mostly about 3 mm long. Contains fish scales	.4	1.3
27. Covered	4.4	14.5
26. Bentonite; greenish yellow at base grading upward into bentonitic black clay	.3	.9
25. Siltstone, gray, shaly, sandy, noncalcareous; weathers to irregular ledge	2.4	7.7
24. Shale, nearly black, distinctly fissile. Bentonitic near top	4.6	15.0
23. Bentonite; dark yellowish green in lower part grading upward into grayish-green silty impure bentonite at top. Contains tuffaceous lenses similar to unit 32	2.0	6.5
22. Clay, dark-gray, bentonitic	.3	1.0
21. Siltstone, thinly bedded; alternates with fine-grained sandstone and grades upward into dark-gray fissile shale; weathers to irregular ledge	1.6	5.3
20. Sandstone, light-gray, blocky, resistant, thin-bedded, noncalcareous	.2	.8
19. Poorly exposed. Float indicates sandstone and siltstone beds	2.4	8.0
18. Sandstone, light-gray, lenticular, resistant, thin-bedded, noncalcareous; weathers yellowish tan. Upper part breaks into rectangular blocks on surface. Locally contains abundant black-coated chert pebbles	.3	1.0
17. Siltstone, dark-gray, sandy, thin-bedded; alternates with medium-gray sandstone. Forms irregular ledge	3.4	11.0
16. Shale, silty, noncalcareous	2.4	7.9
15. Sandstone, silty, irregularly bedded, noncalcareous. Contains scattered flat dark-brown calcareous ironstone concretions about 30 cm in diameter	1.8	5.8
14. Shale, very dark gray, distinctly fissile, noncalcareous. Ferruginous sandstone layer about 24 cm above base. Poorly exposed	7.5	24.7
13. Bentonite; yellowish green in lower half grading upward into olive-green bentonitic shaly clay. Scattered brown ovoid-shaped ironstone concretions at top as much as 50 cm in diameter	.7	2.2
12. Shale, dark-gray, silty, noncalcareous	2.6	8.4
11. Siltstone, light- to medium-gray, shaly, friable, noncalcareous; orange-brown stained films	1.7	5.4
10. Sandstone, medium-gray, medium-grained, resistant; weathers medium brown	.2	.7
9. Siltstone, bluish-gray, sandy, friable, irregularly (vertical) fractured, noncalcareous; stained orange-yellow in places. Lenses of fine-grained sandstone throughout interval; a 15-cm-thick thin-bedded sandstone layer at base. Upper half is covered east of Bootlegger Trail but is well exposed west of road where it is a thin-bedded friable noncalcareous light-gray sandstone containing thin films of carbonaceous material that weathers mottled gray and orange brown	4.4	14.3
8. Shale, dark-gray, distinctly fissile, noncalcareous; yellow and orange-yellow films along parting planes. Bentonite bed, 25 cm thick, 1.2 m above base	6.3	20.8
7. Sandstone, light-gray; fine- to medium-grained, resistant, noncalcareous; weathers light gray with orange-brown stains along vertical fractures; contains small wormlike trails	.3	1.0
6. Sandstone, silty to shaly, irregularly fractured, noncalcareous; grades upward into silty shale	1.4	4.5
5. Sandstone, dark-gray, medium-grained, resistant, lenticular, calcareous, fossiliferous (*Lingula* sp.). Upper half weathers very dark brown and forms fairly continuous outcrops. Lower part is finely bedded, locally crossbedded, and weathers grayish tan	.3	1.0
4. Siltstone, shaly, noncalcareous; grades laterally into sandstone beds alternating with shaly siltstone; irregularly fractured and friable and forms gentle slopes; weathered surface is mottled bluish gray and orange brown	4.1	13.5
3. Sandstone, light-gray, fine- to medium-grained, thinly bedded (mostly less than 10 cm thick), noncalcareous; some thin films of dark-gray carbonaceous material; weathers mottled bluish gray and orange brown. Well-developed vertical joint pattern striking N. 70° W. Upper 30 cm is more resistant than remainder and forms a conspicuous ledge with well-developed ripple marks. Lower part includes some thin beds of sandy to silty shale and is rarely exposed	8.2	27.0
Total Bootlegger Member (rounded)	100.0	329.0
Vaughn Member (uppermost):		
2. Shale, bentonitic, distinctly fissile, noncalcareous; medium gray at base to dark gray at top	2.9	9.4
1. Shale, nearly black, bentonitic; contains red clinoptilolite grains; distinctly fissile at top and noncalcareous	4.0	13.2
Total Vaughn Member (measured)	6.9	22.6

MARIAS RIVER SHALE

The name Marias River Shale was given by us (Cobban and others, 1959, p. 2793) to the 275–365 m (900–1,200 ft) of dark-gray Upper Cretaceous shale that lies between the Blackleaf and Telegraph Creek Formations on the Sweetgrass arch and westward into the Rocky Mountains front. The name is from the excellent exposures along the Marias River, which crosses the Sweetgrass arch between the South arch and the Kevin-Sunburst dome. Here most of the formation is exposed in a synclinal area, known as the Marias River saddle (Dobbin and Erdmann, 1955), along the boundary between Toole and Pondera Counties. The Marias River Shale includes all but the uppermost sandy transitional beds of Stebinger's (1918, p. 161) "shale above the Blackleaf sandy member" in the Birch Creek–Sun River area where he noted that "The remainder of the Colorado shale above the Blackleaf member forms the principal body of shale in this area and by its thickness alone is readily differentiated from the other shale units present." The Marias River Shale also more or less includes Willis' (1902, p. 315, 326, 327) Benton Shale in the Glacier National Park area and the upper or "lead-colored clay shale" part of Weed's (1899) Colorado Formation.

We (Cobban and others, 1959, p. 2793) divided the Marias River Shale into four members, which are from oldest to youngest, Floweree, Cone, Ferdig, and Kevin. The type sections of the Floweree and Cone Members are on the South arch, whereas those of the Ferdig and Kevin Members are on the Kevin-Sunburst dome. In terms of the standard stages of the Upper Cretaceous the Floweree Member is late Cenomanian, the Cone is late Cenomanian and early Turonian, the Ferdig is middle and late Turonian, and the Kevin is Coniacian and early Santonian.

The Marias River Shale occupies the surface over much of the Sweetgrass arch. It crops out also around the Sweetgrass Hills and in the Disturbed belt. In general the formation thickens from east to west. East of the Kevin-Sunburst dome the thickness is about 283 m (930 ft) in the West Utopia oil and gas field and as little as 277 m (910 ft) in wells drilled 16–19 km (10–12 mi) east of this field. Northward from the West Utopia field, the formation thickens to 293 m (960 ft) in the Sweetgrass Hills. The full thickness of the Marias River Shale is not known along much of the crest of the Sweetgrass arch inasmuch as the upper part of the formation has been eroded. Wells drilled in and about the Cut Bank oil and gas field, west of the Kevin-Sunburst dome, show a rather uniform northwest thickening from 311 m (1,020 ft) in the southern part of the Cut Bank field to 363 m (1,190 ft) on the Chalk Butte nose 16 km (10 mi) northwest of this field. A westward thickening is shown by wells drilled on the northwest flank of the South arch where the formation is 311–332 m (1,020–1,090 ft) thick.

FLOWEREE MEMBER

NAME AND DEFINITION

The Floweree Member was named for exposures about 3.2 km (2 mi) northeast of Floweree along Black Coulee in secs. 16 and 17, T. 23 N., R. 6 E., Chouteau County (Carter quadrangle). It is chiefly dark-gray shale and medium-gray shaly siltstone. The member was correlated earlier by Cobban (1951a, p. 2174) with the Belle Fourche Shale of the Black Hills and that part of the Colorado Shale of central Montana that lies between the Mowry Shale Member and the Mosby Sandstone Member.

THICKNESS

The Floweree Member varies greatly in thickness. A total thickness of 19.4 m (63.5 ft) was measured by Lemke and Maughan at the type section. In the Vaughn quadrangle to the west and in the northern part of the Cascade quadrangle, most measured sections reveal thicknesses of 6–14 m (20–45 ft). At the Cone triangulation station (type section for the Cone Member) in sec. 13, T. 22 N., R. 1 W., the member is 10.7 m (35 ft) thick. In sec. 6, T. 21 N., R. 1 E., 9.7 km (6 mi) northwest of Vaughn, Maughan (1961) noted the member to be only 3 m (10 ft) thick.

In the subsurface, the greatest thicknesses known are in the Bears Den district of the Sweetgrass Hills where as much as 45.7 m (150 ft) has been recorded (Cobban, 1951a, p. 2183). Thicknesses revealed by wells on the Kevin-Sunburst dome are commonly 23–30 m (75–100 ft). On the South arch thicknesses greater than 15 m (50 ft) are rare. In the Pendroy area west of the Pondera oil field, the member thins to as little as 4 m.

The member crops out at many places along the Rocky Mountains front. The thickness is 11.6 m (38 ft) at the southeast edge of Glacier National Park (Cobban, 1956, p. 1003) and is about 9 m in the Sun River Canyon area (Mudge, 1972, p. A66) 97 km (60 mi) west of Great Falls.

OUTCROP DISTRIBUTION

The Floweree Member is exposed on the southern part of the South arch, on the crest of the Kevin-Sunburst dome, in the Sweetgrass Hills, and along the Rocky Mountains front.

The largest outcrop area is on the South arch. From the Missouri River below Carter Ferry in the southeastern corner of the Carter quadrangle, the belt of outcrop (largely concealed by glacial deposits) extends west and slightly southwest to the Benton Lake area in the northeast part of the Great Falls quadrangle. From there it trends west across the Great Falls and Vaughn quadrangles to Muddy Creek where the top of the Floweree Member dips below the stream level 3.2 km southeast of Power near the center of sec. 2, T. 22 N., R. 1 W. Southeastward from that point the outcrop follows along the west side of the valley of Muddy Creek and crosses the divide separating the Muddy Creek drainage from the Sun River drainage in sec. 8, T. 21 N., R. 1 E. From there the outcrop extends up Sun River valley almost to Fort Shaw. South of the Sun River valley the member forms a narrow south-trending outcrop in the eastern part of the northwest quarter of the Cascade quadrangle.

On the Kevin-Sunburst dome the Floweree Member crops out around the apex of the dome, making a "ring" possibly as much as 2.4 km in width, that in large part is obscured by glacial deposits. The principal area of exposure is in secs. 28, 29, 30, and 31, T. 34 N., R. 1 W., in the Shelby quadrangle where measurements have revealed the lower 9 m. The total thickness in this area probably is of the order of 24.4 m (80 ft).

West of the Sweetgrass arch the Floweree Member is exposed near the Missouri River 3.2 km northeast of Wolf Creek in sec. 31, T. 15 N., R. 3 W., and from the Sun River in the SW. cor. T. 22 N., R. 8 W., north to T. 26 N., R. 8 W., and from there northwest to the southeast boundary of Glacier National Park.

GENERAL DESCRIPTION

Dark-bluish-gray shale, lighter colored sandy shale, and thin beds of sandstone and siltstone (fig. 12) characterize the member. Both contacts are sharp; the lower is marked by an abrupt change from the dark-gray shale of the Floweree to either a bentonite bed or coarse fish-bone-bearing sandstone at the top of the Bootlegger Member, and the upper boundary is marked by an equally abrupt change from noncalcareous shale to the limy shale of the Cone Member.

In the type section, 3.2 km northeast of Floweree on the east flank of the South arch, the basal part of the Floweree Member consists of 1.5 m of dark-gray shale that grades upward into 4.3 m (14 ft) of gray shaly siltstone. Part of the siltstone is characterized by odd ellipsoidal partings that give a nodularlike appearance to the beds. These ovoid-shaped masses weather bluish gray with orange-yellow rinds. A crude shaly structure is present although the overall appearance is massive. Numerous inclined fractures filled with yellowish-brown siltstone cross the beds. A 2.1-m-thick bed of dark-bluish-gray shale overlies the siltstone unit. It contains large sandy calcareous concretions that weather light yellowish brown. A fine- to medium-grained layer of sandstone, less than 0.3 m thick, rests on the shale. Above the thin bed of sandstone is 4 m of shaly siltstone cut by diagonal fractures. Distantly

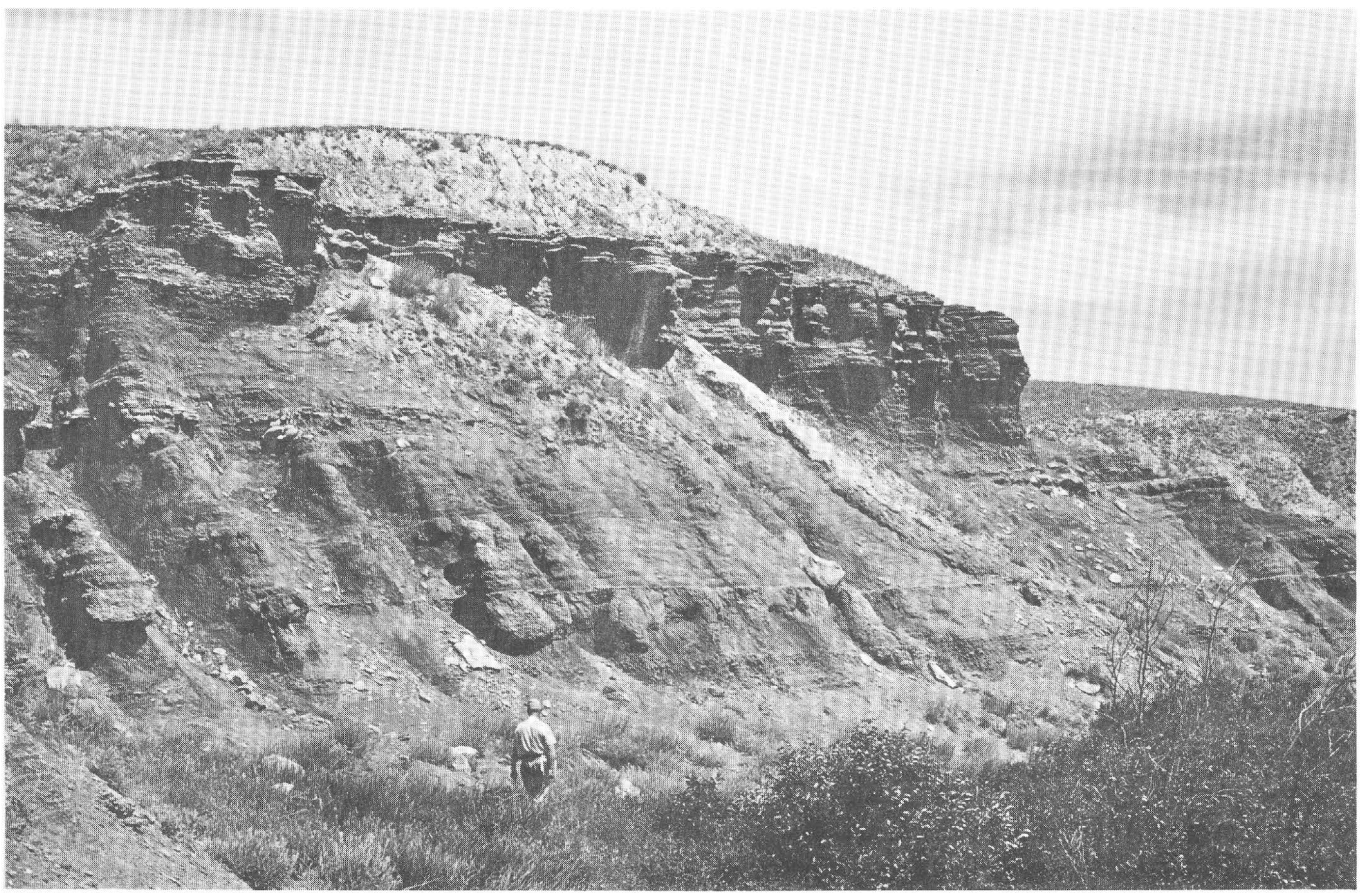


FIGURE 12.—Floweree Member of the Marias River Shale at its type section in Black Coulee in the SE¼SW¼NE¼ sec. 17, T. 23 N., R. 6 E., Chouteau County, Mont.

spaced gray sandy calcareous septarian concretions are present near the top of this siltstone unit. Another thin layer of yellowish-brown-weathering sandstone overlies the shaly siltstone. Above it is nearly 1.2 m of siltstone that contains numerous gray septarian limestone concretions. Dark-gray shale forms the upper approximate 6 m.

The calcareous concretions noted in the type section are absent on the west flank of the South arch but are well exposed in secs. 28 and 29, T. 34 N., R. 1 W., on the Kevin-Sunburst dome, where at least nine beds of concretionary limestone are present.

Local layers of chert granules and small pebbles are present on the crest and west flank of the South arch as well as on the east flank at the type section of the member. Well cuttings show the presence of chert granules and pebbles locally at other places on the Sweetgrass arch. None of these beds are conspicuous, and all seem to be an inch or less in thickness.

AGE ASSIGNMENT AND CORRELATION

The sandstone and siltstone layers in the Floweree Member contain numerous worm(?) burrows or castings and a few well-preserved worm(?) tracks. About 3.2 km southwest of Power in the NW¼NW¼SW¼ sec. 2, T. 22 N., R. 1 W., thin hard sandy layers in the upper half of the member contain the following marine fossils (USGS Mesozoic loc. D535):

Inoceramus aff. *I. mesabiensis* Bergquist
Metoicoceras muelleri Cobban
Metoicoceras mosbyense Cobban

These fossils occur in the Mosby Sandstone Member of central Montana. The Mosby, which contains the ammonite *Dunveganoceras albertense* (Warren) of late Cenomanian age, is correlated by its fossil content with the middle part of the Greenhorn Formation of the Black Hills.

At the type section of the Floweree Member, a still older ammonite has been found in the bed of calcareous septarian concretions 7.6 m (25 ft) below the top of the member. This ammonite, *Calycoceras*? *canitaurinum* (Haas), originally described as *Mantelliceras canitaurinum* (Haas, 1949, p. 9–14, pls. 1–4, text figs. 1–4) from the lower part of the Cody Shale of Wyoming, occurs in the basal limestone bed of the Greenhorn Formation in the Black Hills area (Cobban, 1951a, p. 2184).

Fossils other than worm(?) burrows or castings have not been found in the lower half of the Floweree Member. Possibly this half is equivalent to some part of the Belle Fourche Shale of the Black Hills. However, inasmuch as the Belle Fourche Shale attains thicknesses of more than 150 m (500 ft) and contains several Cenomanian ammonite zones, the probability that this thin undated part of the Floweree Member represents much of Belle Fourche time seems unlikely.

TYPE SECTION OF THE FLOWEREE MEMBER

The following type section is based entirely upon field descriptions. Measurements were made along a 1.2-km (0.8-mi) segment of Black Coulee along the valley wall. Distinguishable beds, mostly concretionary beds, were traced laterally. Where not exposed, the beds were projected upstream taking into account the local dip. The thickness of the section is believed to be accurate to within half a metre.

Type section of the Floweree Member

[Section measured by R. W. Lemke and E. K. Maughan on the north side of Black Coulee about 3.2 km (2 mi) northeast of Floweree, Chouteau County (Carter quadrangle). Base of section starts above creek bed of Black Coulee along a north-south section-line fence in SE¼SE¼NE¼ sec. 17, T. 23 N., R. 6 E. Top of section is in NW¼SE¼NW¼ sec. 17, T. 23 N., R. 6 E. (fig. 13)]

	M	*Ft*
Marias River Shale:		
Cone Member (basal bed; most of member exposed upslope):		
12. Limestone, concretionary, argillaceous; weathers light grayish lavender; commonly 15–30 cm thick, 0.5–1 m in diameter, and spaced 1 to several metres apart; septarian with veins of yellow calcite; enclosed by fissile medium-brownish-gray calcareous shale	0.3	1.0
Floweree Member:		
11. Shale, very dark gray, distinctly fissile, non-		

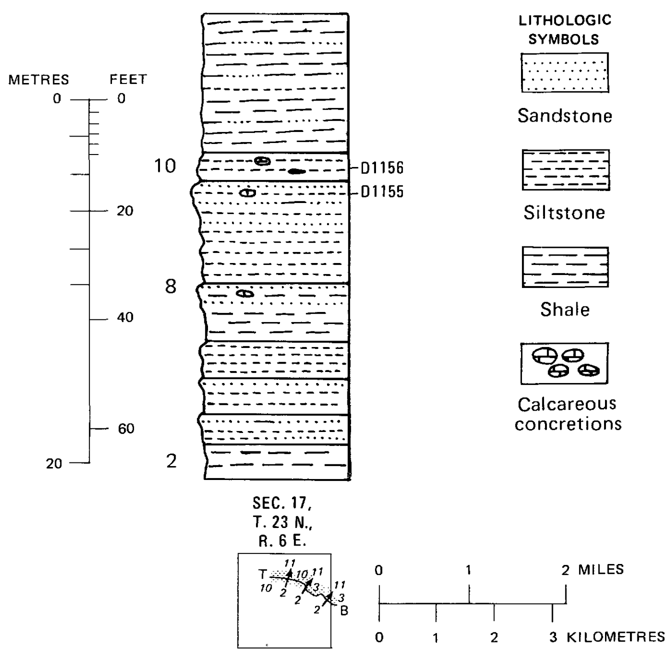


FIGURE 13.—Type section of the Floweree Member of the Marias River Shale and map showing line of measured section, sec. 17, T. 23 N., R. 6 E. Numbers on the left side of the column are key beds in the measured section; numbers on the right side are USGS Mesozoic collections. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of the Floweree Member—Continued

Marias River Shale—Continued

Floweree Member—Continued

	M	Ft
11. Shale, etc.—Continued calcareous; some yellow powder along bedding planes. A few beds of sandy siltstone less than 2 cm thick. A few lenses consisting of chert granules and small pebbles. Poorly exposed and forms gentle slope. *Inoceramus* sp	5.7	18.8
10. Siltstone, medium-bluish-gray, shaly to sandy; contains scattered light-gray argillaceous limestone concretions 15 cm thick and 30–60 cm in diameter which are septarian with veins of yellow to brown calcite. Near base some orange-brown ironstone that weathers to orange-brown chips. Rarely a fossil	1.2	3.8
USGS Mesozoic loc. D1156: *Inoceramus* sp. *Anomia*? sp. *Pecten* (*Syncyclonema*) sp. *Callista*? sp.		
9. Sandstone, gray, noncalcareous, thin-bedded, resistant, locally platy; weathers to yellowish-buff or orange-brown ledge; contains some worm(?) tracks. Top surface ripple marked	.2	.6
8. Siltstone.Upper one-third is sandy and weathers light bluish gray with orange-yellow films along fracture surfaces. Lower two-thirds, which is shalier and less resistant than upper part, contains yellow powder along bedding planes and is cut by diagonal fractures with veinlike fillings. A fine-grained sandstone about 6 cm thick divides the two parts. Near top are a few gray calcareous septarian concretions that yielded a single specimen of *Calycoceras*? *canitaurinum* (Haas). USGS Mesozoic loc. D1155.	4.0	13.0
7. Sandstone, fine- to medium-grained, somewhat platy, lenticular; weathers grayish buff; forms small ledge	.2	.8
6. Shale, dark-bluish-gray, moderately fissile; upper part softer and more papery than lower part and interbedded with thin layers of siltstone. Unit cut by diagonal fractures that have been filled with yellow and brown calcite. Calcareous sandstone concretions as much as 1.5 m in diameter occur 0.6 m below top and weather buff yellow to buff brown	2.1	7.0
5. Siltstone, shaly; cut by diagonal fractures that have been filled with brown sandy siltstone	1.5	4.8
4. Siltstone, somewhat shaly; consists of ovoid masses 5–10 cm long that are grayish blue with rinds of orange yellow. Cut by diagonal fractures filled with yellowish-brown sandy siltstone. Top 2 cm is brown sandstone that contains very small black chert pebbles	1.4	4.5
3. Siltstone, light-gray, sandy, thin-bedded; interbedded with dark-gray silty shale	1.5	4.8
2. Shale, dark-gray, noncalcareous; upper part papery, with yellow powder along bedding planes and interbedded with shaly siltstone.		

Type section of the Floweree Member—Continued

Marias River Shale—Continued

Floweree Member—Continued

	M	Ft
2. Shale, etc.—Continued Grades into overlying unit	1.7	5.4
Total Floweree Member (rounded)	20.0	64.0
Blackleaf Formation:		
Bootlegger Member (top):		
1. Bentonite; weathers yellowish orange; impure near top	.6	1.9

CONE MEMBER

NAME AND DEFINITION

The Cone Member is the so-called Greenhorn Limestone of the Sweetgrass arch. It is the calcareous shale and chalk marl member of Cobban (1951a, p. 2186), the resistant shale member of Dobbin and Erdmann (1930), the black lime of drillers (Erdmann and Schwabrow, 1941, p. 283), and equivalent probably to part of the rocks mapped around the Highwood Mountains east of Great Falls by Reeves (1929, p. 162, pl. 44) as the Mosby Sandstone Member of the Colorado Shale. The unit was given the formal name Cone Calcareous Member of the Marias River Shale by us (Cobban and others, 1959, p. 2794) for the excellent exposures on the slopes of the conspicuous hill on which the Cone triangulation station is situated, 6 km (3.7 mi) south of Power near the center of sec. 13, T. 22 N., R. 1 W., Teton County (Vaughn quadrangle). The term calcareous is dropped from the formal name. The type section was measured on the south slope of the hill. Very calcareous dark-gray shale largely composes the member.

THICKNESS

A rather uniform thickness of about 15–18 m (50–60 ft) is maintained by the Cone Member over much of the Sweetgrass arch. The thickness is 16.5 m (54 ft) at the type section. Stebinger (1918, p. 162) gave 15.2 m (50 ft) as an average for this member west of the Sweetgrass arch in the Birch Creek–Sun River area. Along the southeast boundary of Glacier National Park, the thickness appears to be of this order although a complete section has not been measured by us. In the subsurface the member thickens eastward from about 15–18 m (50–60 ft) on the Kevin-Sunburst dome to as much as 24 m (80 ft) in wells drilled near the Sweetgrass Hills. Westward from the Sweetgrass arch, the Cone thickens to about 30 m in the Sun River Canyon area (Mudge, 1972, p. A66).

OUTCROP DISTRIBUTION

The Cone Member is well exposed at many localities on the South arch. From the type section on Cone hill this member is exposed northwest up Muddy Creek 5.6

km (3.5 mi) nearly to the center of sec. 34, T. 23 N., R. 1 W.; there it dips below the stream level. Eastward from Muddy Creek the member forms a belt 3–6 km wide across the north-central part of the Vaughn and Great Falls quadrangles and the northern part of the Portage quadrangle to Floweree. From the type section on Cone hill the member crops out southward along the west side of Muddy Creek valley to the Muddy Creek–Sun River divide in sec. 7, T. 21 N., R. 1 E. West from there the outcrop follows the Sun River valley about to Fort Shaw, where the Cone dips below the stream level. South of the Sun River valley the member is poorly exposed. The line of outcrop seems to trend south more or less along the eastern edge of the west third of the Cascade quadrangle. The outcrops continue southward from this quadrangle and follow Willow Creek in T. 17 N., R. 1 E.

On the Kevin-Sunburst dome the member is poorly exposed at several places near the crest of the structure. Some of the best exposures are on Raglan Butte in N½ sec. 13, T. 34 N., R. 2 W., 6 km (4 mi) southwest of Ferdig. Here the beds are much disturbed owing to glacial action. Perry (1928, p. 5) considered these rocks as an equivalent of the Mowry Shale. The same beds crop out just south of the NE. cor. sec. 13, T. 34 N., R. 3 W.

The member crops out at many localities in the Disturbed belt. Powers and Shimer (1914, p. 557) recorded it as "dark arenaceous shale" and noted the abundance of *Inoceramus labiatus* [*Mytiloides*]. Stebinger (1918, p. 158, 161–164) described the member as "bituminous shale and maltha limestone" and observed its occurrence at several places in the Birch Creek–Sun River area. Cobban (1956, p. 1002–1004) has drawn attention to many outcrops along the southeast boundary of Glacier National Park.

GENERAL DESCRIPTION

The limy character of the Cone Member readily distinguishes it from the other members of the Marias River Shale. Calcareous shale is the chief constituent. Other constituents include argillaceous limestone, crystalline limestone, limestone concretions, bentonite, and noncalcareous shale.

The boundaries of the member are extraordinarily sharp. Both are marked by an abrupt change from the limy shale of the Cone to the noncalcareous shale of the underlying Floweree Member and of the overlying Ferdig Member.

A thin layer, commonly less than 2 or 3 cm, of soft rusty limonitic silt or siltstone marks the base in many places. It consists of a mixture of silt, limonite, and crystals of selenite, with here and there gray shale pebbles, fish teeth and bones, and soft white silty nodules. This contact layer is well exposed in the vicinity of the hill capped by the Cone triangulation station in sec. 13, T. 22 N., R. 1 W., and along the county road about 4.3 km (3 mi) south-southwest of Power in the NW¼NW¼SW¼ sec. 11, T. 22 N., R. 1 W. (Vaughn quadrangle).

Overlying the thin limonitic basal layer is a bed of limy shale less than 60 cm thick that contains closely spaced limestone concretions. Most of the concretions are 30–40 cm thick and a metre or more in diameter. They are dark gray on fresh fracture but weather to a pale lavender gray. The fresh and weathered surfaces show numerous minute white specks. Most concretions are septarian, with calcite veins that show as many as three orders of crystallization. The outer wall of the veins consists of a thin layer of small brown calcite crystals. The inner and greater part of most veins consists of larger crystals of translucent white or yellowish-white calcite. Some of the thicker veins have larger crystals of barite deposited on top of the light-colored calcite crystals. The barite is mostly translucent and pale bluish gray to pale lavender gray, but a few clear colorless crystals are present. These septarian concretions are remarkably widespread and apparently extend all the way from Glacier National Park (Cobban, 1956, p. 1003) southeastward at least as far as Mosby 270 km (167 mi) southeast of Great Falls (Cobban, 1951a, p. 2186).

The calcareous shale, which composes most of the Cone Member, is very dark gray where fresh and contains abundant minute white specks. Goodman (1951) believed these specks were coccoliths and rhabdospheres.

Crystalline limestone beds are present only in the upper part of the member. These limestones are thin, shaly, silty, and irregularly bedded. They are medium gray where fresh and brownish gray where weathered. Part of the limestones is composed of pelagic Foraminifera and tiny calcareous prisms from macerated *Mytiloides* shells. Small oysters and fragments of *Mytiloides* are abundant. The limestones are hard and crop out as a series of small ledges in contrast to the slope formed by the shales of the lower part of the member (fig. 14). These ledge-forming beds around the Highwood Mountains were mistaken for the calcareous Mosby Sandstone Member by Reeves (1929, p. 162, pl. 44).

Limestones in the middle of the member are argillaceous and shaly and softer than those higher in the member. They are very dark gray but weather light blue and then orange brown. Minute white specks, pelagic Foraminifera, and *Mytiloides mytiloides* (Mantell) are numerous.

Seven bentonite beds are present in the type section.

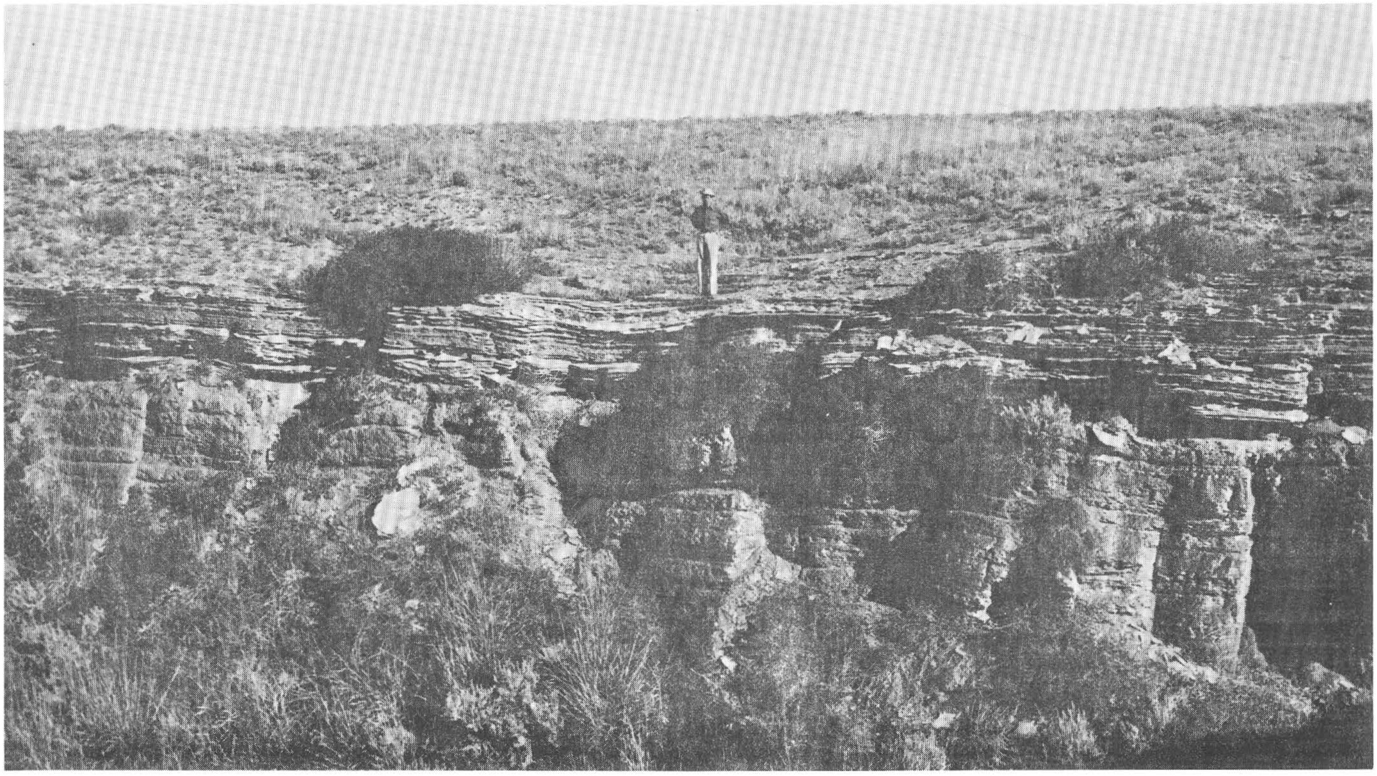


FIGURE 14.—Upper part of Cone Member of Marias River Shale at its type section in the SE¼ sec. 13, T. 22 N., R. 1 W., Teton County, Mont.

The lowest and thickest is a 0.9-m white low-swelling bed 4.3 m (14 ft) above the base. This bed is very widely distributed and extends from Glacier National Park southeastward at least as far as Mosby, a distance of 434 km (270 mi) (Cobban, 1956, p. 1002). Over this great distance the bed seems to maintain a thickness of between 0.9 and 1.5 m.

The Cone Member is readily determined in well cuttings by the change downward from dark-gray fissile noncalcareous shale to massive black-gray or very dark gray calcareous shale containing minute white specks, and the fragments of gray limestone with numerous inoceramid prisms. The 0.9-m-thick bed of bentonite in the lower part of the member is easily recognized in cuttings. On electric logs the top of the Cone Member is represented by the well-known "Greenhorn kick."

The bluish-weathering argillaceous limestone and shale (unit 5) immediately overlying the 0.9-m-thick bed of bentonite contains numerous *Mytiloides mytiloides* (Mantell) of early Turonian age. In the central Great Plains, *M. mytiloides* is abundant in the Bridge Creek Limestone Member of the Greenhorn Limestone.

The soft calcareous shale (unit 11) higher in the type section of the Cone Member contains the ammonite *Watinoceras reesidei* Warren which is known also from the Disturbed belt (Cobban, 1956, p. 1003, 1004).

Bed 14, 7–11 feet below the top of the member, contains *Mytiloides labiatus*. The overlying 2.1 m of the member contains fragments of *Mytiloides* which appear to be *M. labiatus*. On the Kevin-Sunburst dome the ammonite *Collignoniceras woollgari* (Mantell) has been found 1.8 m below the top of a dark-gray slightly calcareous white-speckled shale (Cobban and others, 1956). This unit does not occur in the type section of the Cone Member and may represent strata that elsewhere are in the hiatus at the top of this member. *Collignoniceras woollgari* is a middle Turonian ammonite that is a guide to rocks that are equivalent in age to the Fairport Chalky Shale Member of the Carlile Shale of the central Great Plains.

AGE ASSIGNMENT AND CORRELATION

The Cone Member contains numerous marine fossils. At the type section limestone concretions at the base of the member (bed 2) and at the top of the shale (bed 3) that immediately underlies the 0.9 m bentonite bed contain *Sciponoceras gracile* (Shumard). This ammonite is a guide to the latest zone of the Cenomanian Stage of the Late Cretaceous. In the central Great Plains, *S. gracile* is confined to the basal beds of the

Bridge Creek Limestone Member of the Greenhorn Limestone.

In the bentonite are tuffaceous siltstone concretions, not found at the type section, that commonly are fossiliferous. A collection (USGS Mesozoic loc. 25029) from these concretions in the NW¼SW¼SW¼ sec. 28, T. 21 N., R. 1 W., has been identified by J. B. Reeside, Jr., as follows:

Inoceramus sp.
Phelopteria gastrodes (Meek)
Nymphalucina aff. *N. subundata* (Hall and Meek)
Drepanochilus ruida (White)
Sciponoceras gracile (Schumard)
Watinoceras aff. *W. coloradoense* (Henderson)

Type section of the Cone Member

[Measured by W. A. Cobban on the south side of the hill on which is the Cone triangulation station 6.3 km (3.9 mi) south of Power in the SE¼ sec. 13, T. 22 N., R. 1 W., Teton County (Vaughn quadrangle) (fig. 15)]

	M	Ft
Marias River Shale:		
Ferdig Member (lower part):		
23. Bentonite; lower part rusty brown; upper part gray; impure, nonswelling	0.5	1.5
22. Shale, black-gray, fissile, noncalcareous; tends to resist weathering; contains a few thin layers of yellowish- and bluish-weathering hard siltstone or very fine grained sandstone with worm(?) tracks on the bedding surfaces. Basal 2–3 cm limonitic and silty	8.1	26.6
Total part of Ferdig Member measured	8.6	28.1
Disconformity		
Cone Member:		
21. Limestone, dark-gray, shaly; weathers bluish gray and tan; contains minute white specks	0.1	0.3
20. Bentonite, gray, somewhat limonitic, impure	.2	.7
19. Limestone, dark-gray, shaly; weathers bluish gray and tan; forms small ledge; contains fish bones and scales, some fragments of *Mytiloides*, and abundant pelagic Foraminifera	.2	.5
18. Shale, dark-gray, calcareous. Few very thin bluish-weathering limestone layers. A 2-cm-thick layer of bentonite 18 cm above base	.4	1.3
17. Bentonite, limonitic, shaly, impure	.1	.3
16. Shale, limy, hard; weathers bluish	.1	.4
15. Shale, calcareous; contains many very thin limestone layers that weather brownish gray and contain pelagic Foraminifera, worm(?) burrows or castings, and fragments of *Mytiloides* and *Ostrea* sp.	1.1	3.7
14. Limestone; dark medium gray on fresh fracture, buff gray on weathering; in thin layers as much as 2 cm thick separated by gray limy shale; forms ledges. Contains abundant pelagic Foraminifera, small oysters, and fragments of *Mytiloides labiatus* (Schlotheim). USGS Mesozoic loc. D559	1.2	4.0
13. Shale, gray, limy, soft. Some thin layers as much as 1 cm thick of medium-gray argillaceous limestone that contain fragments of		

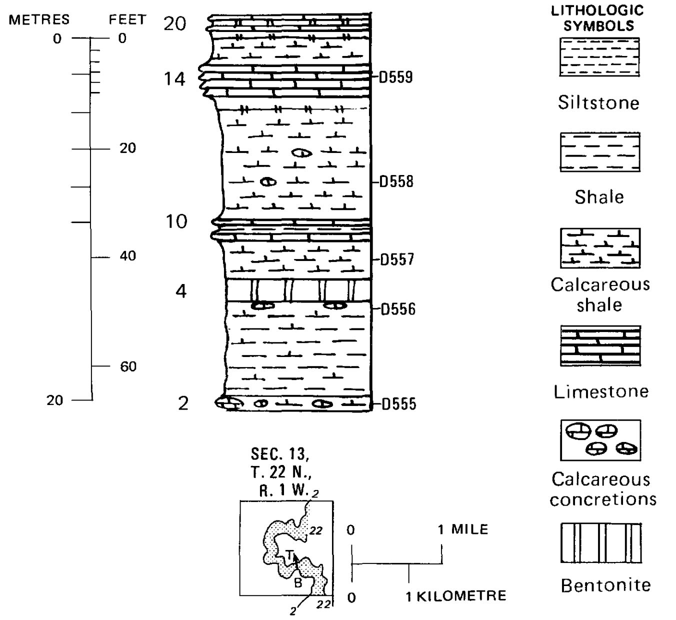


FIGURE 15.—Type section of the Cone Member of the Marias River Shale and map showing line of measured section, sec. 13, T. 22 N., R. 1 W. Numbers on the left side of the column are key beds in the measured section; numbers on the right side are USGS Mesozoic collections. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of the Cone Member—Continued

	M	Ft
Marias River Shale—Continued		
Cone Member—Continued		
13. Shale, etc.—Continued *Mytiloides* and numerous pelagic Foraminifera	.6	2.0
12. Bentonite, dusky-yellow, limonitic, impure	.1	.3
11. Shale, dark-gray, very calcareous, soft, papery; weathers medium gray. Contains at least two beds of very hard and distantly spaced limestone concretions that are dark gray on fresh fracture but light bluish gray where weathered. The concretions range in size from 2 cm thick and 5 cm in diameter to 5 cm thick and 30 cm in diameter. Each is enclosed by a softer limonitic rind 1–3 cm thick. The concretions and the shale of the unit contain minute white specks and the following fossils	4.8	15.7
USGS Mesozoic loc. D558:		
Mytiloides mytiloides (Mantell) s.l.		
Watinoceras reesidei Warren		
Scaphites delicatulus Warren		
10. Limestone; weathers bluish; shaly; forms ledge; contains fish scales, small oysters, and fragments of *Mytiloides mytiloides* (Mantell) s. l.	.1	.4
9. Shale, medium-gray, calcareous, soft	.3	1.0
8. Limestone, argillaceous, somewhat shaly; weathers gray; forms ledge. Abundant fragments of small oysters and *Mytiloides mytiloides* (Mantell) s. l.	.1	.3
7. Shale, soft, calcareous; weathers light buff gray	.2	.7
6. Bentonite, dusky-yellow, nonswelling	.2	.7

Type section of the Cone Member—Continued

	M	Ft
Marias River Shale—Continued		
Cone Member—Continued		
5. Shale, dark-gray; weathers light blue; very limy, in part an argillaceous shaly limestone; contains abundant minute white specks and pelagic Foraminifera. A 2-cm bentonite layer 43 cm from top. Basal 46 cm and uppermost 61 cm moderately hard and form low bluish-gray ledges. Unit crowded with *Mytiloides mytiloides* (Mantell) s. l. USGS Mesozoic loc. D557	1.4	4.5
4. Bentonite, white, low-swelling	.9	3.0
3. Shale, dark-gray, soft, papery, slightly calcareous to noncalcareous. At very top are small light-gray-weathering limestone concretions 2–5 cm thick and 8–10 cm in diameter that contain poorly preserved and crushed fossils	3.7	12.2
USGS Mesozoic loc. D556: *Inoceramus* sp. *Nymphalucina* sp. *Sciponoceras gracile* (Shumard)		
2. Shale, medium-brownish-gray, soft, papery, calcareous; basal 2–3 cm is limonitic and contains soft white silty nodules. Contains closely spaced lavender-gray-weathering septarian limestone concretions commonly 0.4 m thick and 1 m in diameter and smaller and harder light-gray weathering nonseptarian concretions. The veins in the septarian concretions are made up of a thin outer wall of brown finely crystalline calcite and a thick inner part of coarsely crystalline white calcite; a few veins have still more coarsely crystalline colorless to pale-bluish-gray barite deposited on the white calcite. Fossils are rare and poorly preserved	.5	1.8
USGS Mesozoic loc. D555: *Inoceramus* sp. *Sciponoceras gracile* (Shumard) *Ichthyodectes* sp. (scales)		
Total Cone Member (rounded)	16.0	54.0
Floweree Member (uppermost bed):		
1. Shale, dark-bluish-gray, fissile, noncalcareous; few thin lenses of gray siltstone and fine-grained sandstone	1.1	3.5

FERDIG MEMBER

NAME AND DEFINITION

The name Ferdig Shale Member of the Marias River Shale was given by us (Cobban and others, 1959, p. 2794) to a unit of gray firm noncalcareous shale that contains numerous thin hard sandy partings and concretions of gray- and yellow-weathering limestone and red-weathering ferruginous dolostone. The term shale is removed from the formal name. This member overlies the limy Cone Member and underlies the softer and less sandy Kevin Member. The Ferdig Member comprises the beds described by Cobban (1951a, p. 2191, 2192) as the equivalent of the Carlile Shale of the Black Hills. The name is taken from the post office of Ferdig in sec. 31, T. 35 N., R. 1 W., Toole County, about 9.7 km (6 mi) north of the summit of the Kevin-Sunburst dome (Sunburst quadrangle). The type section is composite from exposures 5–8 km (3–5 mi) northwest of Ferdig as well as from outcrops 13 km (8 mi) southeast of Ferdig.

THICKNESS

The Ferdig Member is 68.6 m (224 ft) thick in its type section in T. 35 N., R. 2 W., on the Kevin-Sunburst dome. Wells drilled on both the east and west flanks of this dome also show thicknesses of this order. The member is about 70 m (230 ft) thick as far east as the West Utopia oil and gas field 41.8 km (26 mi) east of the top of the Kevin-Sunburst dome. On the South arch the Ferdig Member thickens northwestward from 31 m (101 ft) at its outcrop, 4.8 km (3 mi) north of the town of Sun River, to about 63 m (205 ft) in wells drilled in the Pondera oil and gas field and 67–73 m (220–240 ft) in wildcat wells drilled in the Pendroy–Birch Creek area.

OUTCROP DISTRIBUTION

The Ferdig Member makes a wide concentric "ring" around the outcrops of the Bootlegger, Floweree, and Cone Members on the Kevin-Sunburst dome and greatly strengthens the areal geologic expression of the dome. In places this belt has a width of 11 km (7 mi), emphasizing the difficulty of obtaining an accurate section.

The best exposure, from the top (unit 50 of the type section) down to unit 15, is on the west-facing escarpment extending through secs. 1, 12, and 13, T. 35 N., R. 2 W., where, because of the north dip, approximately 80 percent of the member can be seen in excellent detail free of glacial cover. Another extensive exposure of the middle part, from unit 36 down to unit 15, is in low west-facing slopes along the east bank of the north fork of Antelope Coulee from near the SW cor. sec. 19, T. 33 N., R. 1 E., northward through secs. 18, 7, and 6; thence westward into sec. 1, T. 33 N., R. 1 W.; and north again into sec. 36, T. 34 N., R. 1 W. Units below unit 15 are exposed in places as along the south and west sides of sec. 36, where the type section was completed.

The Ferdig Member also is exposed in the Sweetgrass Hills. South of Kevin-Sunburst dome an inlier of the upper part of the Ferdig Member occurs where the Marias River has trenched into the Marias River saddle, the west end of the exposure being where U.S. Highway 91 crosses the river.

On the South arch the Ferdig Member crops out from

Fort Benton on the Missouri River westward across the southern part of the Tunis, Carter, and Dent Bridge quadrangles. The outcrop pattern swings south a little and crosses the northern part of the Great Falls quadrangle in the high country north of Lake Creek. The outcrop continues westward across the northern part of the Vaughn quadrangle and into the northeastern corner of the Fairfield quadrangle. From there it extends southeast along the west side of Muddy Creek valley to the Sun River–Muddy Creek divide in sec. 7, T. 21 N., R. 1 E., and west up the Sun River 2–3 km (1–2 mi) west of Fort Shaw. From the Sun River valley the outcrops extend south through the western part of the Cascade quadrangle.

In the Disturbed belt the Ferdig Member crops out 3.2 km (2 mi) northeast of Wolf Creek in the NW¼ sec. 31, T. 15 N., R. 3 W., and near the Rocky Mountains front from T. 20 N., R. 8 W., north through T. 28 N., R. 8 W., and northwest to the eastern boundary of Glacier National Park.

GENERAL DESCRIPTION

On the Sweetgrass arch the Ferdig Member consists of a lower dark-bluish-gray shale unit that contains hard red-weathering concretions of ferruginous dolostone, a medial gray sandy shale that contains gray- and yellow-weathering calcareous concretions, and an upper dark-bluish-gray shale unit with small gray calcareous concretions.

The lower unit, about 15 m (50 ft) thick, beds 1–15 in the type section, is a rather firm dark-bluish-gray shale that contains a few very thin sandy partings and numerous beds of reddish-weathering concretions or thin layers of ferruginous dolostone and limestone. These concretions or layers are dark gray to dark olive gray on fresh fracture and very fine grained and hard. They weather from rusty brown to grayish red and very dusky red. They are so abundant on the outcrops near the crest of the Kevin-Sunburst dome that a reddish color is imparted to the hillsides. The concretions may be readily seen on the hill east of U.S. Highway 91 about 0.6 km (0.4 mi) south of Four Corners in the NW¼ sec. 3, T. 34 N., R. 2 W., and along the Kevin-Oilmont road (Shelby quadrangle). On the South arch the concretions can be seen along both sides of the valley followed by U.S. Highway 89 and the Chicago, Milwaukee, St. Paul and Pacific Railway northwest of the town of Sun River (Vaughn quadrangle). They may be seen also near U.S. Highway 2 along the southeast boundary of Glacier National Park (Cobban, 1956, p. 1002, mileages 7.8, 8.4; p. 1004, mileage 10.5). In the Glacier National Park area a bed of black, gray, and greenish chert pebbles occurs in the ironstone unit (Cobban, 1956, p. 1004).

Bentonite is sparingly present in the lower unit. A gray to brownish bed 15–46 cm thick occurs 8.2 m (27 ft) above the base of the unit on the outcrops in the Sun River–Power area on the South arch; this bed is present also on the Kevin-Sunburst dome.

The medial part, about 46 m (150 ft) thick in the type section (beds 16–42), is a resistant bluish-gray-weathering shale that contains some thin layers of sandstone and tends to form smoothly rounded poorly vegetated slopes. Much of the surface is flecked by small thin flakes of rusty iron-stained shale that appears to result from the oxidation of laminae of pyritic shale or bentonite. These chips make about 25 percent of the surface litter for a total of about 15 m of the medial unit and provide a very useful widespread gross characteristic for the recognition of this part of the Ferdig. The sandstone, very fine grained and relatively resistant, is present chiefly as individual wavy layers or lentils an inch or less in thickness, though in places in assemblages of a few feet, that are light gray (*N*6) to light olive gray (5*Y*6/1) on fresh fracture and brownish where weathered. Upper bedding surfaces are commonly ripple marked and may show well-preserved tracks, trails, impressions, and burrows that appear to have been made by small crustaceans, annelids, and ammonites. The lowest of these sandstones is the thin layer in bed 18, which seems to represent the north wedge-edge of the bed capping the hill at triangulation station Cone. Other distinctive features of the middle part of the Ferdig Member are various concretionary lithologies that occur in no other part of the Marias River Shale, such as the layered concentric septarian limestone masses in bed 20, and also the replacement of bentonite by selenite in the upper part of bed 39.

On the Kevin-Sunburst dome a thin but very persistent layer of conglomeratic sandstone marks the top of the medial unit of the Ferdig Member. This layer (unit 42 of the type section and bed N of Erdmann and others, 1947) consists of light-gray to light-olive-gray very fine to fine-grained sandstone that contains polished granules and small pebbles of black chert and some pebbles of white, gray, brown, and green chert, quartz, quartzite, and argillite. This pebbly layer, 0.3–5 cm thick, is irregularly bedded and commonly contains trails and burrows of small organisms and here and there a coprolite or an impression of a scaphite. Locally the bed is represented by light-olive-gray-weathering sandy calcareous concretions that contain a sprinkling of pebbles on their upper surfaces. In the type section this pebbly bed lies 60.7 m (199 ft) above the base of the member and 8.2 m (27 ft) below the top. This bed readily can be seen west of the Kevin-Sunburst road 5–6 km (3.2–3.8 mi) north-northeast of Kevin in the W½ sec. 13, T. 35 N., R. 3 W.

(Sunburst quadrangle). It possibly is equivalent to the conglomerate unit in the Bighorn (Cardium) Formation of southwestern Alberta. The Bighorn Formation has been recognized in wells in the Pincher Creek gas field 26 km (16 mi) north of the international boundary in sec. 24, T. 3 N., R. 29 W., 4th Meridian (Douglas, 1952, cross-section A–C); it has not been identified, however, farther east in structurally higher areas on the north extension of the Sweetgrass arch (Spratt, 1931, fig. 3).

In the Disturbed belt, about 3.2 km (2 mi) east-northeast of Wolf Creek in the NW¼ sec. 31, T. 15 N., R. 3 W., a 6-m-thick ridge-forming bed of brownish-gray sandstone lies at the top of sandy beds that seem to be correlative with the medial unit of the Ferdig Member of areas farther east. The sandstone is fine grained, thin bedded, and ripple marked. It is capped by a thin layer of coarser sandstone that contains gray and green smooth argillite pebbles derived from the Belt Supergroup of Precambrian age, gray and black chert, and a few pebbles of light- to medium-gray dolomite with crinoid columnals of possible derivation from the Madison Limestone of Mississippian age. Most pebbles are 1–2 cm in diameter, but some are as much as 5 cm. The small pelecypod *Cardium pauperculum* Meek is abundant in the uppermost beds. This fossil, together with the lithologic character and thickness of the beds, suggests correlation with the Bighorn (Cardium) Formation of the Crowsnest River area of southwestern Alberta (Webb and Hertlein, 1934, fig. 2, p. 1394–1396). The eastward thinning of the Bighorn is well recognized in southern Alberta (Scruggs, 1956, p. 25–29). It is evident that eastward thinning also prevails in Montana in beds at this horizon. The mechanism of the thinning is believed to be onlap of the strata onto the rising Sweetgrass arch; further reference is made to it in the discussion on the upper unit of the member.

Thin pebbly layers characterize the medial unit at several other localities. Wells drilled in an area about 40 km (25 mi) long, extending from the Brady oil field northeast to the Marias River, consistently penetrate a pebbly bed 30 m (100 ft) above the base of the Ferdig Member. On the north side of Sun River 2.4 km (1.5 mi) north of Fort Shaw, a 3–5-cm-thick pebbly layer is 24 m (78 ft) above the base of the member.

The sandy medial unit of the Ferdig is well exposed along U.S. Highway 91 from 1.5 to 3 km (1–2 mi) northeast of Power (Vaughn quadrangle) and from the same highway 13 km (8 mi) north of Shelby north-northwestward for 3.2 km in secs. 4 and 9, T. 33 N., R. 2 W. (Shelby quadrangle).

The upper unit, 8.2–10.7 m (27–35 ft) thick on the north flank of the Kevin-Sunburst dome, is chiefly dark-gray shale that contains a few thin beds of gray concretionary limestone. The top consists of a persistent layer of concretionary limestone 10–25 cm (4–10 in.) thick that is olive gray where fresh and grayish yellow to yellow brown where weathered. It has a conspicuous hackly fracture. This bed was mapped by Erdmann, Gist, Nordquist and Beer (1947) and designated bed M. The most accessible place to see the upper unit of the Ferdig is just west of the Kevin-Sunburst road in the north center of sec. 13, T. 35 N., R. 3 W. Here, about 3 m below the top, fossils of late Carlile age (late Turonian) were collected. Not far away, in the south center of sec. 12, fossils of very early Niobrara age (early Coniacian) were collected 5.2 m (17 ft) above the top of the Ferdig. There appears to have been continuous deposition from upper Ferdig into lower Kevin. Comparison of the type section of the Ferdig Member with a section measured by Lemke and Maughan in the center of the N½ sec. 15, T. 21 N., R. 1 W., indicates that much of the middle unit of the Ferdig is absent at this locality on the South arch.

The contact of the Ferdig Member with the Cone Member is very sharp. The lower boundary of the Ferdig could not be determined in the type section owing to poor exposures of the basal beds. On the basis of correlation with sections on the South arch, only a few feet of beds may be concealed. However, the base of the Ferdig on the Kevin-Sunburst dome can be seen on the south bank of a coulee in the SW. cor. NE¼SW¼ sec. 5, T. 32 N., R. 1 E., where it is overlain by a few feet of beds not observed at the Cone type section. This is believed to result from the disconformity between the Cone and Ferdig Members.

On the South arch the base of the Ferdig Member is commonly marked by a thin layer of soft limonitic siltstone 2–3 cm thick which may locally contain fish teeth, small pebbles of black chert, and larger gray and brown phosphatic pebbles. The basal bed with fish teeth and pebbles can be seen along the county road 8.5 km (5.3 mi) southeast of Cascade in the SE¼NE¼ sec. 20, T. 17 N., R. 1 E. On the Kevin-Sunburst dome the boundary with the Kevin Member is drawn at the top of the persistent concretionary bed M of Erdmann, Gist, Nordquist, and Beer (1947). On the South arch this contact is not so easily determined and is placed at the change upward from nonbentonitic dark-gray shale to medium-olive-brown shale with numerous beds of bentonite.

In well cuttings the shale forming the upper part of the Ferdig Member is slightly harder and darker than that of the Kevin Member and may contain pyrite. In addition the upper part of the Ferdig lacks bentonite whereas the lower part of the Kevin contains several beds.

AGE ASSIGNMENT AND CORRELATION

Three faunal zones and possibly a fourth are known from the Ferdig Member. The unquestioned zones are, from oldest to youngest, *Prionocyclus hyatti, Scaphites nigricollensis,* and *Scaphites corvensis* (Cobban and Reeside, 1952, correlation chart). The questionable zone is that of *Collignoniceras woollgari,* which is based on the impression of a single juvenile ammonite that seems assignable to *C. woollgari* (Mantell) var. *regulare* Haas. This impression is in a piece of ferruginous siltstone from near the base (bed 2) of the type section of the Ferdig Member. Because of the great variation within ammonite species, additional material is needed before the zone of *C. woollgari* can be stated definitely as present in the basal Ferdig beds.

The zone of *Prionocyclus hyatti* can be demonstrated for at least the upper part of the lower or dolostone-bearing part of the Ferdig Member. Poorly preserved juveniles of this ammonite have been found in dolostone at many localities on the South arch and Kevin-Sunburst dome. *Scaphites carlilensis* Morrow, a guide fossil for this zone, was collected from bed 12 of the type section. *Scaphites carlilensis* and *Prionocyclus hyatti* are restricted to late Turonian rocks equivalent to the Blue Hill Shale Member of the Carlile Shale of Kansas.

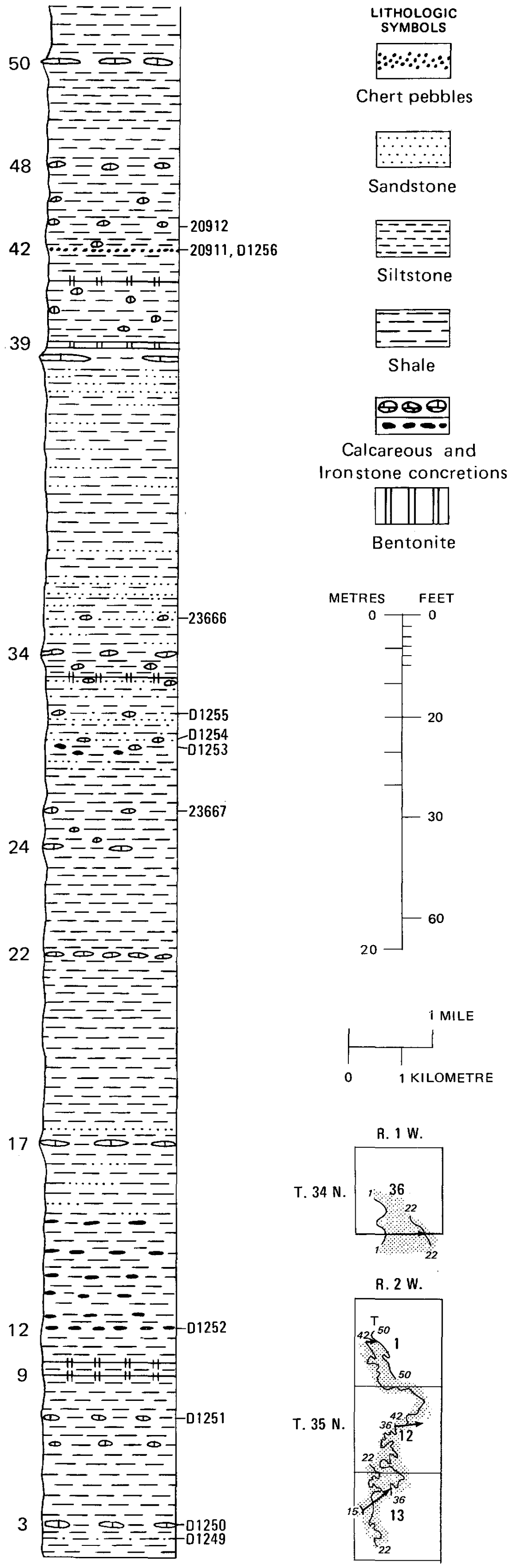
The late Turonian ammonite *Scaphites nigricollensis* is the next youngest species known from the Sweetgrass arch. In the type section of the Ferdig Member, *S. nigricollensis* has been found in the middle part (beds 26–36) of the medial unit associated with *Baculites yokoyamai* Tokunaga and Shimizu. Over much of the western interior region between the Black Hills of South Dakota and the San Juan Basin of northwestern New Mexico, three zones of ammonites (*Scaphites warreni, Scaphites ferronensis,* and *Prionocyclus wyomingensis wyomingensis*) lie between the zones of *Prionocyclus hyatti* and *Scaphites nigricollensis*. Fossils indicative of these three zones have not been found on the Sweetgrass arch, and the time span of these zones is probably represented by a hiatus. The middle unit of the Ferdig is correlated with the upper part of the Turner Sandy Member of the Carlile Shale of the Black Hills. Equivalent rocks seem to be absent in Kansas.

The top bed of the middle unit of the Ferdig Member (bed 42 of the type section) and the overlying upper unit of the Ferdig lie in the latest Turonian zone of *Scaphites corvensis*. This part of the Ferdig correlates with the Sage Breaks Member of the Carlile Shale of the Black Hills.

Type section of the Ferdig Member

[Measured by C. E. Erdmann beginning 7.4 km (4.6 mi) north-northwest of Ferdig in the NE¼SW¼ sec. 1, T. 35 N., R. 2 W., Toole County (Sunburst quadrangle). The section extends south through sec. 12 into the SW¼NW¼ sec. 13, T. 35 N., R. 2 W., and terminates in sec. 36, T. 34 N., R. 1 W. (fig. 16). The original field measurements were in feet and inches]

	M	*Ft*
Marias River Shale:		
Kevin Member (basal bed):		
51. Shale, olive-gray, flaky, noncalcareous	2.5	8.3
Ferdig Member:		
50. Limestone, olive-gray, concretionary, hard, aphanitic; weathers grayish yellow to moderate yellowish brown; surface rough, hackly, with epigenetic prismatic structure; a continuous resistant layer making structural benches. Bed M of Erdmann and others (1947)	.2	.5
49. Shale, gray, fissile	4.6	15.0
48. Limestone, dark-gray, concretionary; shattered noncontinuous discoid masses 30–40 cm in diameter	.1	.2
47. Shale, gray, fissile, as above	1.2	4.0
46. Shale, dark-gray, fissile; contains small discoid septarian concretions of dark-gray limestone weathering light olive gray	.7	2.3
45. Shale, dark-gray; as above, but without concretions	.6	2.0
44. Limestone, dark-gray, concretionary, septarian, much shattered; weathers light yellowish gray. Makes small mounds with diameter of 0.8 m at infrequent intervals, but horizon is locally persistent. Fossiliferous	.1	.3
USGS Mesozoic loc. 20912:		
Inoceramus sp.		
"Martesia" sp.		
Scaphites sp.		
43. Shale, dark-gray; a few thin concretions of gray limestone about 20 cm above base of bed. Slope heavily littered with small thin brown chips	.8	2.7
42. Sandstone, light-gray to gray, very fine- to fine-grained; upper surface sprinkled with rounded, polished granules of black chert and accessory gray chert, quartz, and argillite with thin black patina. Bed N of Erdmann, Gist, Nordquist, and Beer (1947)	.1	.2
USGS Mesozoic locs. 20911 and D1256		
Inoceramus sp.		
Scaphites corvensis Cobban		
S. corvensis var. *bighornensis* Cobban		
Prionocyclus sp.		
41. Shale, brownish-olive-gray, noncalcareous, soft, flaky; a few thin ochreous yellow and brown laminae. A 1-cm-thick bed of rusty bentonite at base	1.6	5.2
40. Shale, dark-gray, soft, fissile; scattered flat, oval (20 by 40 by 5 cm) septarian concretions of gray limestone	2.7	8.8
39. Bentonite, gray, soft, sandy textured; weathers light yellowish gray and moderate yellow to dark yellowish orange; in places replaced by caramel-brown-weathering prismatic calcite,		



Type section of the Ferdig Member—Continued

Marias River Shale—Continued

Ferdig Member—Continued

	M	Ft
39. Bentonite, etc.—Continued with development of incipient cone-in-cone and gnarly structure, and further local epigenetic development of selenite rosettes in upper part. Bed is lenticular, breaking up into discrete concretionary masses, but is persistent	.3	1.0
38. Shale, gray, flaky; contains at base gray limestone concretions 1 by 2.5 by 0.3 m at intervals of 15–30 m	.6	2.0
37. Shale, dark-gray; contains thin stringers and laminae of fine-grained gray sandstone and ferruginous siltstone	10.5	34.3
36. Shale, dark-gray, fissile; 0.3–0.6-cm-thick layers of yellowish-gray siltstone and gray fine-grained sandstone at intervals of 15 cm or less. Scattered discoid septarian concretions of gray fossiliferous concretionary limestone at base	1.1	3.6
USGS Mesozoic loc. 23666: *Baculites* sp. *Scaphites nigricollensis* Cobban *S. nigricollensis* var. *meeki* Cobban		
35. Shale, dark-gray, fissile; in beds 20–25 cm thick parted by thin 0.5-cm-thick laminae of fine-grained gray sandstone	1.5	5.0
34. Shale, dark-gray; contains yellowish-gray-weathering septarian limestone concretions 10–50 cm in diameter and 5–20 cm in thickness	.9	2.9
33. Shale, dark-gray	.6	2.0
32. Shale, brownish-olive-gray; contains thin layers of ferruginous siltstone and a 2-cm-thick layer of bentonite near top	1.7	5.7
31. Shale, brownish-olive-gray; middle part contains small concretions of fossiliferous gray limestone	.2	.8
USGS Mesozoic loc. D1255: *Inoceramus* sp. *Scaphites nigricollensis* Cobban *S. pisinnus* Cobban		
30. Shale, brownish-olive-gray, silty, soft, noncalcareous; contains a few very thin layers of light-gray fine-grained sandstone and thin layers of rusty-brown ferruginous siltstone. A few concretions of fossiliferous limestone at base	.6	2.1
USGS Mesozoic loc. D1254: *Inoceramus* cf. *I. fragilis* Hall and Meek		

FIGURE 16.—Type section of the Ferdig Member of the Marias River Shale and map showing line of measured section, sec. 36, T. 34 N., R. 1 W., and secs. 1, 12, and 13, T. 35 N., R. 2 W. Numbers on the left side of the column are key beds in the measured section; numbers on the right side are USGS Mesozoic collections. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

Type section of the Ferdig Member—Continued

	M	Ft
Marias River Shale—Continued		
Ferdig Member—Continued		
30. Shale, etc.—Continued		
Baculites cf. *B. besairiei* Collignon		
Scaphites nigricollensis Cobban		
29. Shale, brownish-olive-gray; contains scattered small oval limestone concretions at top and a thin rusty-brown siltstone layer in middle	.5	1.6
28. Limestone, dark-gray; weathers light gray; Concretionary, discrete oval septarian forms 15 by 20 to 20 by 25 cm with partitions of light-brown calcite. In places rests on a very thin sandstone. Fossiliferous	.1	.2
USGS Mesozoic loc. D1253:		
Inoceramus sp.		
Scaphites nigricollensis Cobban		
27. Shale, brownish-olive-gray; contains rusty-brown-weathering very thin resistant layers of ferruginous siltstone	2.7	8.7
26. Limestone, dark-gray, concretionary; masses of shattered angular fragments which weather orange, brown, and dusky red and whose centers commonly remain gray. Locally developed	.2	.5
USGS Mesozoic loc. 23667:		
Baculites cf. *B. besairiei* Collignon		
Scaphites nigricollensis Cobban		
S. nigricollensis var. *meeki* Cobban		
25. Shale, dark-gray; weathers bluish; contains a few small (diameter 15–20 cm) oval septarian concretions of gray limestone	1.6	5.1
24. Limestone, dark-gray, concretionary, ferruginous; weathers predominantly maroon (dark reddish brown, 10*R* 3/4, to very dusky red, 10*R* 2/2) with minor crusts of moderate yellowish brown (10*YR* 5/4) to dark yellowish orange (10*YR* 6/6) concentric about the maroon. Centers commonly light-yellowish-gray septarian limestone. Discrete masses as much as 1 m in diameter making low mounds on 3–4 m centers	.1	.4
23. Shale, medium-dark-gray (N5), moderately fissile, noncalcareous; poorly exposed in slope	4.9	16.0
22. Limestone, dark-gray, concretionary, clayey; weathers tan to dark yellowish orange (10*YR* 6/6). Continuous resistant layer with prismatic structure at top, locally slabby, making ledges, benches, or dip slopes. Small flat concretions of dark-gray ferruginous aphanitic limestone weathering orange brown rest on top with irregular spacing and make low chippy mounds	.2	.5
21. Siltstone, dark-olive-gray, poorly fissile, noncalcareous, finely micaceous. Surface littered with small rusty fragments	3.4	11.0
20. Siltstone, dark-olive-gray; as unit 21. Scattered throughout at irregular vertical and horizontal intervals are very finely crystalline light-olive-gray septarian limestone concretions weathering yellowish gray and having a thickness of 0.3 m and a diameter of 1 m	1.8	6.0
19. Limestone, olive-gray (5*Y* 4/1), concretionary, aphanitic; weathers grayish yellow, with minor mottling by moderate to dark reddish brown. Locally persistent	.2	.8
18. Shale, dark-gray, noncalcareous, poorly exposed. Contains a 3-cm-thick fine-grained platy sandstone layer 0.5 m above base	3.1	10.2
17. Limestone, dark-gray, ferruginous, concretionary; weathers rusty brown with minor dusky red (maroon); flat, panlike masses 1–1.5 m in diameter. Lower 10 cm stratified; rest concretionary with prismatic structure; discrete forms on about 15-m centers	.2	.5
16. Shale, dark-gray, moderately fissile, noncalcareous; weathers into thin flakes; contains a few thin (0.5 cm) layers of gray soft fine-grained sandstone	3.7	12.0
15. Dolostone, dark-gray, concretionary, ankeritic(?), very hard, aphanitic; weathers brown to dark brown; small noncontinuous much-shattered oval masses. Cores of massive maroon-weathering dolostone are enclosed in thin chippy dolostone weathering moderate brown	.1	.2
14. Shale, dark-gray, moderately fissile, noncalcereous	1.2	3.8
13. Shale, dark-gray, noncalcareous, poorly fissile. Contains dusky-red-weathering concretions of hard dolostone at top and at 0.5, 1.3, and 2.3 m above base	3.3	10.7
12. Dolostone, olive-gray (5*Y* 4/1); weathers moderate brown to very dusky red (maroon); concretionary, syngenetic, in discrete but nearly coalescent oval forms as much as 40 by 55 cm in diameter supporting a small bench	.1	.3
USGS Mesozoic loc. D1252:		
Scaphites carlilensis Morrow		
11. Shale, medium-dark-gray, flaky, noncalcareous	1.5	5.0
10. Shale, medium-dark-gray, noncalcareous; a thin bentonite in middle and at top	.6	2.1
9. Bentonite, yellowish-gray (5*Y* 8/1); weathers dark yellowish orange	.1	.3
8. Shale, medium-dark-gray, noncalcareous	1.8	6.0
7. Limestone, concretionary, dark-olive-gray; ferruginous; weathers moderate brown; breaks down into chippy fragments in inconspicuous mounds 0.3 by 1 m; fossiliferous	.1	.3
USGS Mesozoic loc. D1251:		
Inoceramus cf. *I. fragilis* Hall and Meek		
Scaphites sp.		
6. Shale, medium-dark-gray, noncalcareous	1.1	3.5
5. Limestone, brownish-black; weathers dark yellowish brown and dusky red; concretionary; sandy texture. *Inoceramus* sp.	.1	.2
4. Shale, medium-dark-gray, flaky, noncalcareous	3.6	11.7
3. Limestone, olive-gray; weathers yellowish gray; weathers rusty where locally ferrugi-		

Type section of the Ferdig Member—Continued

	M	Ft
Marias River Shale—Continued		
Ferdig Member—Continued		
3. Limestone, etc.—Continued nous; concretionary; flat, discrete oval forms 0.5–0.6 m in diameter, with radial and concentric structure developed by septae of white and light-brown calcite. Sparingly fossiliferous in softer silty brecciated outer crust. Widely spaced; usually much shattered, making inconspicuous chunky mounds	.1	.3
USGS Mesozoic loc. D1250: *Inoceramus fragilis* Hall and Meek; *Collignoniceras* sp.; *Ichthyodectes* sp. (scales)		
2. Shale, medium-brownish-olive-gray, fissile, noncalcareous. A thin yellowish-orange-weathering ferruginous fossiliferous siltstone layer at base	.6	2.1
USGS Mesozoic loc. D1249: *Collignoniceras* cf. *C. woollgari* (Mantell) var. *regulare* Haas		
1. Shale, medium-brownish-olive-gray, noncalcareous, papery	.9	3.0
Total measured Ferdig Member (rounded)	69.0	224.0
Base concealed by alluvium		

KEVIN MEMBER

NAME AND DEFINITION

The Kevin (pronounced Kee-vin) Member of the Marias River Shale was named by us (Cobban and others, 1959, p. 2797) for the very good exposures a few kilometres north and northwest of the town of Kevin on the northwest side of the Kevin-Sunburst dome. The type section was measured in the N½ T. 35 N., R. 3 W. (fig. 20), the same township in which Kevin is located. The member consists of dark-gray marine shale that contains some thin sandy partings, numerous thin layers of bentonite, and many beds of calcareous concretions weathering gray, yellow, or red; the term shale is removed from the formal name. This is the member of the Colorado Shale described by Cobban (1951a, p. 2193–2195) as equivalent to the Niobrara Formation of the Black Hills.

THICKNESS

In its type section on the northwest side of the Kevin-Sunburst dome the Kevin Member is about 189 m (620 ft) thick. It thickens westward to 213 m (700 ft) in the Cut Bank oil and gas field. Eastward from the type section, the thickness changes very little. It is 177 m (580 ft) thick in the West Utopia oil and gas field in T. 33 N., R. 4 E., and 171 m (560 ft) thick in the Bears Den oil field in T. 36 N., R. 6 E. On the South arch the Kevin thickens westward from 203 m (665 ft) a few kilometres north of the Pondera oil field to 232 m (760 ft) in wells drilled at the eastern edge of the Disturbed belt.

OUTCROP DISTRIBUTION

The Kevin Member has the greatest outcrop area of any of the members of the Marias River Shale. It forms the bedrock on the crest of the Sweetgrass arch beginning at a point 24 km (15 mi) north of Great Falls and extending northwest and north beyond Shelby. On the flanks of the Sweetgrass arch the Kevin crops out from Cascade northward to about one kilometre (within a mile) of the international boundary and southeast from there to Fort Benton. The member is exposed also around the flanks of the Sweetgrass Hills. In the Disturbed belt the Kevin crops out in a narrow northwest-trending belt about 16 km (10 mi) long north and east of Wolf Creek and a much larger area bordering the Rocky Mountain front from Sun River to the international line.

GENERAL DESCRIPTION

The Kevin Member can be subdivided into three units on the basis of the abundance of bentonite and the type of concretions. The lowest unit is correlated with the Fort Hays Limestone Member of the Niobrara Formation of the central Great Plains, and the middle and upper units are correlated with the lower and middle parts of the Smoky Hill Chalk Member of the Niobrara Formation of the central Great Plains.

The lowest unit, 53–55 m (175–180 ft) thick, is characterized by many beds of bentonite, calcareous concretions, and concretionary limestone. It includes beds between I and M of Erdmann, Gist, Nordquist, and Beer (1947). Most of the concretions in the unit are composed of oval masses of limestone that are dark gray on fresh fracture and medium light gray to yellowish gray where weathered. They range in size from 5–30 cm (2–12 in.) in thickness and 10–50 cm (4–20 in.) in diameter. Many are highly fossiliferous. Along the Marias River 8 km (5 mi) south of Shelby, brown-weathering ferruginous concretions, not present in the type section, occur in the lower part of the unit. In the upper part of the unit beds of hard gray aphanitic limestone consist of concretionary lenses 15–75 cm (6–30 in.) thick and 1–3 m long. Some of the limestone is septarian with veins of brown or white calcite. Gnarly cone-in-cone structure characterizes a few of the beds. Two conspicuous beds of limestone mapped by Erdmann, Gist, Nordquist, and Beer (1947) were designated beds J and K. Sandstone beds, a very minor constituent in the unit, are thin, very fine grained, and shaly, and they weather brown. Some have borings and trails made by small marine organisms. Bentonite is abundant; 20 layers 2–35 cm (1–14 in.) thick are present in this unit in the type section. Yellowish-brown-weathering prismatic calcite associated with two of the beds of bentonite were mapped by Erdmann, Gist, Nordquist, and Beer (1947) and designated beds I and L. The many layers of light-gray bentonite impart a banded appearance to the outcrops; this feature can be seen in figure 17.

This lowest unit of the Kevin Member can be seen readily along the county road 3.2 km (2 mi) north of Fort Shaw (Fairfield quadrangle), along U.S. Highway 91 about 6.4 km north-northeast of Power in the SW. cor. sec. 6 and NW. cor. sec. 7, T. 23 N., R. 1 E. (Dutton quadrangle), along the north bank of the Marias River where it is crossed by U.S. Highway 91 about 8 km (5 mi) south of Shelby, just out of Shelby on Highway 91 in SW¼SW¼ sec. 21, T. 32 N., R. 2 W., and at the type section of the Kevin Member 4.8 km (3 mi) north-northwest of Kevin. Cobban (1956, p. 1004) has drawn attention to outcrops along the southeast side of Glacier National Park.

Above the bentonitic unit with its gray limestone concretions and concretionary limestone is a unit of shale about 61 m (200 ft) thick that is characterized by numerous beds of reddish-weathering ferruginous concretions and concretionary limestone and dolostone. It includes the rocks from bed I to about midway between beds D and E of Erdmann, Gist, Nordquist, and Beer (1947; beds 58–143 of type section). The beds and concretions of limestone, commonly with gnarly cone-in-cone structure at the top, are dark gray to olive gray where fresh and yellowish gray to yellowish brown where weathered. The dolostone is ferruginous and occurs as concretions or concretionary layers which weather reddish brown to very dusky red. The beds of limestone commonly are 30 cm thick whereas the beds of dolostone rarely exceed 10 cm in thickness. Very thin layers of gray to olive-gray sandstone occur here and there. The sandstone is very fine grained, weathers brownish, and in places contains borings and trails of small marine organisms. A few thin layers of bentonite are present.

An important marker bed, bed F of Erdmann, Gist, Nordquist, and Beer (1947), lies near the middle of the red concretion unit. This bed was first noted in geologic literature by Clark (1923, p. 267) as "the yellow lime chert conglomerate." It is a conglomeratic bed of dolostone and limestone that weathers light brown, orange brown, and very dusky red. It contains polished rounded granules and small pebbles of gray and black chert as much as 2 cm in diameter and larger pebbles of light-olive-gray, medium-olive-gray, and medium-gray phosphatic siltstone as much as 5 cm in diameter. The phosphatic pebbles are much more numerous than the chert pebbles. A few dark phosphatic pebbles were

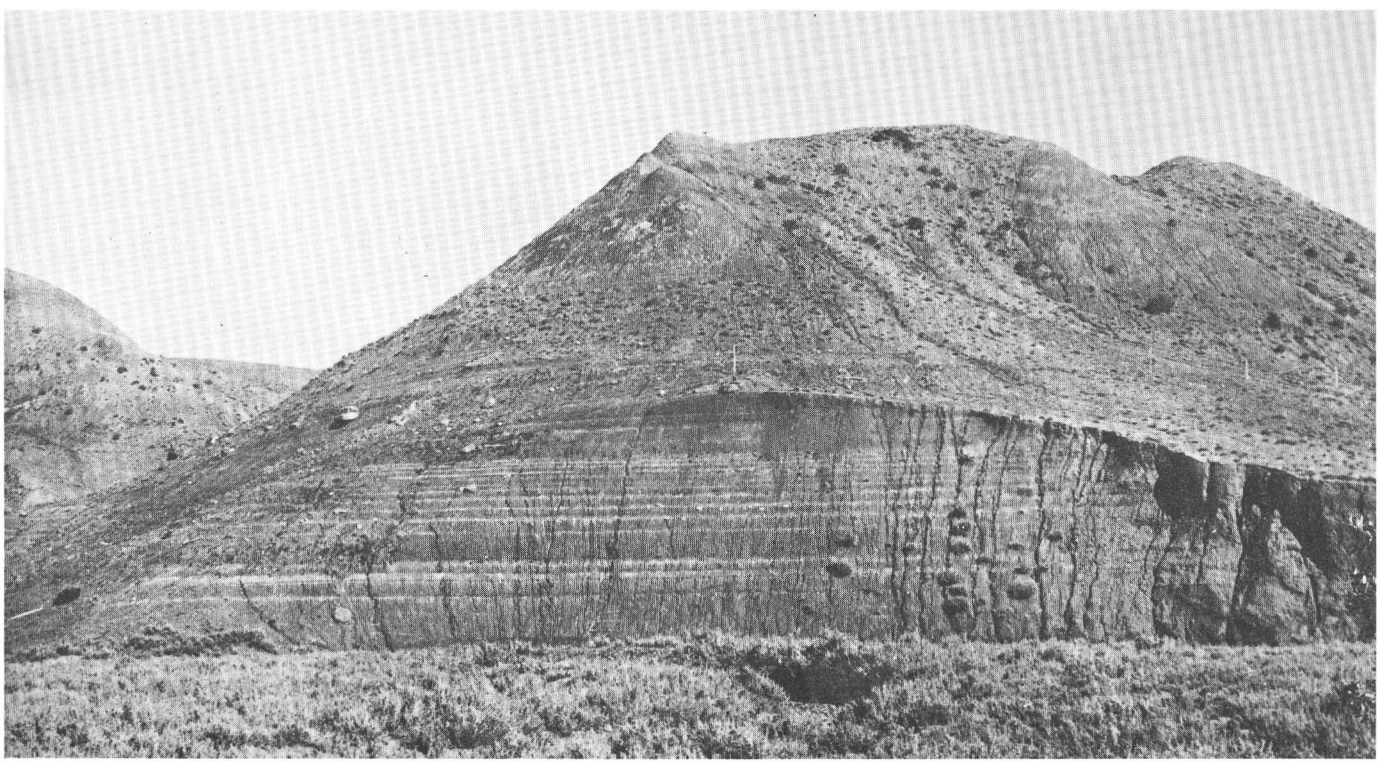


FIGURE 17.—Numerous thin beds of white bentonite in the lower part of the Kevin Member of the Marias River Shale in the SW¼ SW¼ sec. 18, T. 31 N., R. 2 W., Toole County, Mont.

originally small pelecypods or parts of ammonites. Koskinen (1951) has described this bed in further detail. The structure of many hundreds of square miles of the Kevin-Sunburst dome was mapped by means of this thin but distinctive pebbly bed. Reconnaissance shows that the bed is present from the Rocky Mountains front eastward across the Sweetgrass arch to the Bearpaw Mountains and southward from there at least as far as Shawmut in south-central Montana. Because of its widespread extent and ease of recognition, the bed was named by us (Cobban and others, 1959, p. 2795) the MacGowan Concretionary Bed for exposures on the MacGowan lease in the SE¼SW¼NE¼ sec. 4, T. 35 N., R. 3 W., about 8.5 km (5.3 mi) north-northwest of Kevin in the Kevin-Sunburst oil and gas field (Sunburst quadrangle). Bed 100 (p. 58) which was measured at this locality, is the type section. Here the bed is 0.5 m thick and lies in the middle of the Kevin Member (96 m or 314 ft below the top). The interval from the MacGowan Concretionary Bed to the top of the Kevin Member may show much variation, as in the SE¼NE¼ sec. 31, T. 30 N., R. 3 E., where it is only about 67 m (220 ft) thick, the decrease probably being due to a hiatus and absence of up to 24 m (80 ft) of strata in the upper part of the *Clioscaphites choteauensis* zone, and perhaps another small hiatus in the *Scaphites depressus* zone. One or two inconspicuous layers of phosphatic pebbles in places lie a short distance above the MacGowan Concretionary Bed. Three metres above the MacGowan Bed at its type locality is a 2-cm-thick bed of rounded to subrounded phosphatic siltstone and sandstone pebbles. These pebbles are greenish gray (5*GY*6/1) to olive gray (5*Y*4/1) with darker crusts, and some have a close irregular light-gray reticulation. They range in size from 0.6–4 cm. On the south bank of the Marias River near the center of the S½ sec. 17, T. 31 N., R. 3 W. (Valier quadrangle) two layers of phosphatic pebbles are present above the MacGowan Concretionary Bed. The lower pebbles, 5.8 m (19 ft) above the MacGowan Bed, consist of light-olive-gray glauconitic siltstone with an outer dark-greenish-gray surface (5*GY*4/1) crossed by irregular lighter greenish-gray (5*G*6/1 to 5*GY*6/1) lines. These pebbles attain diameters up to 2.5 cm. The upper pebbles, 10.4 m (34 ft) above the MacGowan Bed, are smaller, darker, and lack the greenish cast of the lower bed. They are dark gray (N3) with irregular light-olive-gray (5*Y*6/1) lines on the outer surface. Glauconitic, phosphatic pebbles similar to those of the lower bed occur on the southeast flank of the South arch 10.8 km (6.7 mi) northeast of Carter in the SE¼SE¼ sec. 16, T. 24 N., R. 7 E. (Tunis quadrangle).

The medial unit of the Kevin Member can be seen readily a few kilometres northwest of Kevin at many places in the NW¼ T. 35 N., R. 3 W., and T. 36 N., R. 3 W. (Erdmann and others, 1947). On the South arch the unit is well exposed 0.8–3.2 km (0.5–2.0 mi) north of U.S. Highway 87 from 2.4–11.3 km (1.5–7.0 mi) northeast of Carter (Carter and Tunis quadrangles). In the Disturbed belt easily accessible outcrops of these beds are along the Burlington Northern Railway tracks from the bridge over Two Medicine Creek (1.6 km or 1 mi northeast of East Glacier) northeastward for 6.4 km (4 mi) (Marias Pass quadrangle).

Overlying the medial red concretion unit of the Kevin Member is about 61 m (200 ft) of dark-gray shale that contains many beds of yellowish-gray-weathering concretionary limestone and a few thin layers of shaly sandstone and bentonite. The upper half or more of the shale is calcareous and, in places, sandy. Limestone occurs as concretionary lenses 2–60 cm (1–24 in.) thick and as much as 2.7 m (9 ft) in diameter. The limestone is dark gray to olive gray where fresh and yellowish gray to yellowish orange where weathered. Some of the beds of limestone are sandy and finely laminated. A few have cone-in-cone structure. Sandstone is represented by thin more or less shaly very fine-grained beds that weather yellowish gray. A few thin beds of bentonite are present. Thin layers of light-gray calcite occur in abundance associated with one of the beds of bentonite (bed A of Erdmann and others, 1947; bed 178 of type section) about 9 m (30 ft) below the top of the Kevin Member.

The boundary between the Kevin Member of the Marias River Shale and the overlying Telegraph Creek Formation (basal unit of the Montana Group) is very sharp on the west flank of the Kevin-Sunburst dome and can be recognized on the basis of both color and lithology (fig. 18). The highest bed (top of unit 187) is a thin persistent bentonite that commonly is obscured by colluvium, at which places it may be traced by reference to the resistant chips of light-gray translucent calcite from bed A (unit 178). The upper bentonite is underlain by about 1.2 m of dark-olive-gray shale that contains the "first white specks," which are a widely recognized subsurface marker for this horizon. Southward in Marias River valley, the color contrast in the basal part of the Telegraph Creek Formation disappears together with the shaly calcareous sandstone (units 180, 183, and 184), but the upper bentonite and bed A persist.

The best outcrops of the upper unit of the Kevin Member are north and northwest of Kevin, in Tps. 35 and 36 N., R. 3 W., and along the Marias River southwest of Shelby, in the northern part of the Valier quadrangle.

FIGURE 18.—Upper part of Kevin Member of Marias River Shale (dark) overlain by lighter gray sandy Telegraph Creek Formation and that, in turn, by the cliff-forming Virgelle Sandstone in the N½NE¼NW¼ sec. 24, T. 35 N., R. 4 W., Toole County, Mont.

AGE ASSIGNMENT AND CORRELATION

Most of the guide fossils from the Kevin Member have been listed by Cobban (1951a, p. 2194, 2195). They show that the member is of Coniacian and Santonian age and correlated with most of the Niobrara Formation of the central Great Plains.

The lower unit—characterized by many layers of bentonite, numerous beds of gray concretionary limestone, and the brown-weathering ferruginous concretions in the Marias River valley—contains two faunas. The lower part of the unit with the ferruginous concretions contains a pelecypod close to if not identical to *Inoceramus erectus* Meek and the ammonites *Scaphites preventricosus* Cobban, *S. preventricosus* var. *artilobus* Cobban, *S. mariasensis* Cobban, and *S. mariasensis* var. *gracillistriatus* Cobban. The rest of the unit contains *Inoceramus deformis* Meek, *Veniella goniophora* Meek, *Baculites mariasensis* Cobban, *B. sweetgrassensis* Cobban, *Scaphites preventricosus, S. preventricosus* var. *sweetgrassensis* Cobban, *S. impendicostatus* Cobban, *Pteroscaphites auriculatus* (Cobban), and *Actinocamax* n. sp. The entire unit is correlated with the Fort Hays Limestone Member of the Niobrara Formation on the basis of the presence of *Inoceramus deformis* in this limestone.

The middle unit, marked by the red ferruginous concretionary limestone and dolostone and by the phosphatic pebble beds, contains three faunal zones. The lowest embraces the rocks below the MacGowan Concretionary Bed. Guide fossils to this zone include the pelecypod *Inoceramus (Volviceramus) involutus* Sowerby (=*Inoceramus umbonatus* Meek and Hayden) and the ammonites *Scaphites ventricosus* Meek and Hayden and *Scaphites tetonensis* Cobban. The middle zone, which includes the MacGowan Bed and the overlying shales with the phosphatic pebble layers, contains *Inoceramus stantoni* Sokolow, *Scaphites depressus* Reeside, and *Scaphites binneyi* Reeside. The upper zone contains *Inoceramus (Cordiceramus) cordiformis* Sowerby, *Clioscaphites vermiformis* (Meek and Hayden), and *C. montanensis* Cobban. All three zones indicate correlation with the lower part of the Smoky Hill Chalk Member of the Niobrara Formation. Cobban, Erdmann, Alto, and Clark (1958, p. 658) have pointed out that rocks containing the *Scaphites depressus* fauna on the Kevin-Sunburst dome are not known to exceed a thickness of 16.8 m (55 ft), whereas in the Bighorn Basin of Wyoming the *Scaphites depres-*

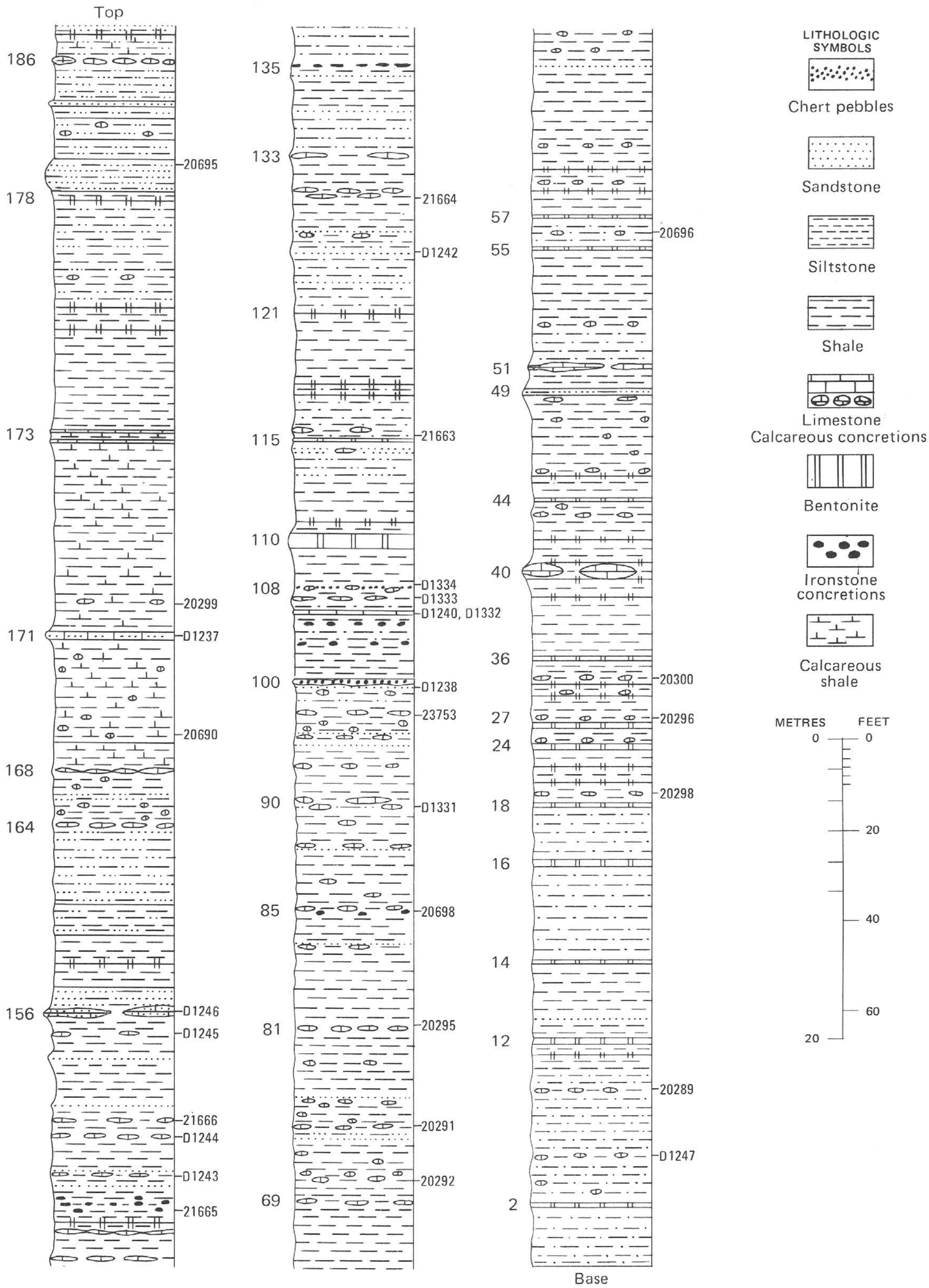


FIGURE 19.—Type section of the Kevin Member of the Marias River Shale and map showing line of measured section, secs. 3, 4, 12, 15, and 17, T. 35 N., R. 3 W. Numbers on the left side of the column are key beds in the measured section; numbers on the right side are USGS Mesozoic collections. On the map, the arrow points upward stratigraphically; B, base, and T, top of member.

sus fauna ranges through as much as 183 m (600 ft) of the Cody Shale. The thinness of the rocks representing this fauna on the Kevin-Sunburst dome together with the presence of as many as three beds of phosphatic pebbles suggest breaks in deposition or at least very slow deposition.

The upper unit of the Kevin Member contains the rest of the *Clioscaphites vermiformis* zone and two younger zones, a lower marked by *Clioscaphites choteauensis* Cobban and an upper characterized by the ammonites *Baculites thomi* Reeside, *Scaphites leei* Reeside, *Clioscaphites novimexicanus* (Reeside), and *Desmoscaphites erdmanni* Cobban. These zones, formerly believed to represent the youngest part of Niobrara time, are probably of middle Smoky Hill age, inasmuch as the upper part of the Smoky Hill Chalk Member is now believed to be of early Campanian age and to include rocks equivalent in age to the Telegraph Creek and Eagle Formations (Jeletzky, 1955). The upper zone also contains *Inoceramus* (*Sphenoceramus*) *lundbreckensis* McLearn (1929, p. 77, pl. 15, fig. 4; pl. 16, fig. 2). This species may be the same as *I. patootensiformis* Seitz (1965, p. 107, pls. 20–25).

Type section of the Kevin Member

[Measured by C. E. Erdmann at the following localities in T. 35 N., R. 3 W., Toole County, Sunburst quadrangle. Many other measurements also have been made but the strata are best exposed at these localities. The original field measurements were in feet and inches (fig. 19)]

Units (beds of Erdmann and others, 1947)	*Locality*
1 (base)–12 (L)	NE¼SW¼ sec. 12.
12 (L)–40 (K)	North-center sec. 15.
40 (K)–51 (J)	SE¼SW¼ sec. 3.
51 (J)–57 (I)	NE¼SW¼sec. 3.
57 (I)–81 (G)	NW¼SW¼sec. 3.
81 (G)–100 (F)	NW¼SW¼ sec. 3 to SE¼SE¼NE¼ sec. 4 (type section MacGowan Concretionary Bed).

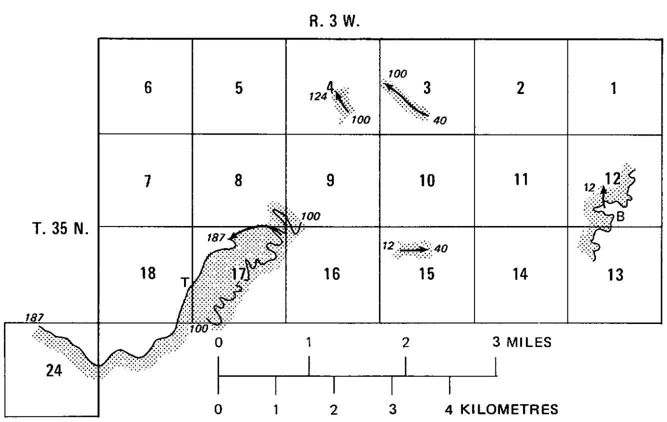


FIGURE 19.—Continued.

Type section of the Kevin Member—Continued

Units (beds of Erdmann and others, 1947)	*Locality*
100 (F)–124	NE¼SE¼sec. 4 (locality *Scaphites depressus* zone).
124–156 (D)	NE¼NE¼sec. 17.
156 (D)–187 (top)	NW¼NE¼sec. 17.

	M	*Ft*
Telegraph Creek Formation (basal part):		
189. Sandstone, buff (10*YR* 6/4), fine-grained	0.3+	1+
188. Shale, pale-yellowish-brown (10*YR* 6/2). Thinly laminated with fine sand	.4	1.2
Marias River Shale:		
Kevin Member:		
187. Shale, dark-olive-gray, fissile; some silt or very fine sand. A 3-cm-thick ferruginous bentonite bed at top. Horizon of "first white specks"	1.2	4.1
186. Limestone, concretionary, olive-gray; weathers yellowish gray; discrete oval masses as much as 1 m in diameter in a nearly continuous bed. Contains *Baculites* sp., *Ostrea* sp., and fragments of fossil bones	.3	1.0
185. Shale, dark-gray, sandy, fissile	1.8	6.0
184. Sandstone, gray, fine-grained; in thinly laminated crossbedded layers with thin partings of soft sandy shale. Makes a massive comparatively resistant ledge	.3	1.0
183. Shale, dark-gray, sandy, thinly laminated; contains a few thin layers of dark-gray fine-grained sandstone. Transitional into overlying unit	.6	2.0
182. Shale, dark-gray, sandy, thinly laminated; contains scattered limestone concretions	1.1	3.8
181. Shale, dark-gray, papery; more sandy toward top	.9	3.0
180. Sandstone, gray, soft, fine-grained, thinly laminated, crossbedded; in thin 1–5-cm-thick layers interlayed with minor amounts of gray sandy shale	1.6	5.2
USGS Mesozoic loc. 20695, 60 cm below top of bed: *Ostrea* sp. *Baculites* n. sp. aff. *B. haresi* Reeside *Baculites thomi* Reeside		
179. Shale, dark-gray, fissile	.5	1.8
178. Bentonite and calcite, light-gray; weathers yellowish gray. Bed A of Erdmann, Gist, Nordquist, and Beer (1947)	.1	.2
177. Shale, gray, flaky; thin sandy layers and laminae. A layer of thin discrete limestone concretions occurs 1.5 m above base	5.3	17.5
176. Shale, dark-gray, fissile. A 6-cm-thick bentonite bed at base and a very thin bed at top	1.2	4.0
175. Shale, gray, soft, flaky. A 3-cm-thick gray sandy thinly laminated limestone bed at base	5.2	17.1
174. Shale, gray, firm, calcareous, fissile	.5	1.5
173. Limestone, gray, sandy. Makes a thin resistant ledge	.1	.3
172. Shale, gray, firm, calcareous, flaky	9.6	31.5

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

	M	*Ft*
172. Shale, etc.—Continued		
USGS Mesozoic loc. 20299, 1.5 m above the base of this unit:		
Inoceramus lundbreckensis McLearn		
Pseudoperna congesta (Conrad)		
Clioscaphites novimexicanus Reeside		
Desmoscaphites erdmanni Cobban		
171. Limestone, gray, sandy. Makes thin resistant ledge. Thickness variable. Bed B of Erdmann, Gist, Nordquist, and Beer (1947)	.5	1.5
USGS Mesozoic loc. D1237:		
Inoceramus lundbreckensis McLearn		
Pseudoperna congesta (Conrad)		
Baculites thomi Reeside		
170. Shale, gray, calcareous; contains small nodular concretions and a few thin (1 cm) layers of gray sandy limestone	5.5	18.0
USGS Mesozoic loc. 20690, 2.4 m above base of this unit:		
Pseudomelania n. sp. aff. *P. hendricksoni* Henderson		
169. Shale, gray, calcareous, nonfissile	1.4	4.5
168. Limestone, gray, sandy, concretionary. Locally makes a thin ledge. Bed C of Erdmann, Gist, Nordquist, and Beer (1947)	.1	.3
167. Shale, gray; small nodular concretions of gray limestone	1.2	4.0
166. Shale, sandy; thin layers of sandstone	.3	1.0
165. Shale, gray; numerous small (5–30 cm in diameter) thin nodules of gray limestone	1.5	5.0
164. Limestone, gray; concretions 1 m in diameter	.2	.7
163. Shale; thin layers of sandstone as much as 3 cm thick	1.1	3.7
162. Shale, gray, sandy	2.1	7.0
161. Shale, gray, sandy; thin layers of fine-grained gray sandstone	1.4	4.5
160. Shale, gray, nonfissile; weathers into granular fragments	1.5	5.0
159. Bentonite, rusty-brown, weathered	.1	.2
158. Shale, gray, nonfissile; weathers into small granular fragments	1.2	4.0
157. Sandstone, gray, fine-grained; 1-cm-thick beds interbedded with thin layers of sandy shale	.8	2.7
156. Limestone, gray, concretionary, sandy, finely laminated; weathers yellowish gray to medium yellowish orange. Individual masses as much as 3.5 by 2 m in plan, making an almost continuous resistant layer, with interstices occupied by gray shale. Bed can be followed easily and makes a good marker. Fossiliferous. Bed D of Erdmann, Gist, Nordquist, and Beer (1947)	.6	2.0
USGS Mesozoic loc. D1246:		
Baculites asper Morton		
B. codyensis Reeside		
Clioscaphites vermiformis (Meek and Hayden)		
155. Shale, gray, soft, poorly exposed	.7	2.3
154. Limestone, dark-gray; weathers yellowish gray; concretionary; thin tabular masses,		

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

	M	*Ft*
154. Limestone, etc.—Continued		
widely spaced. In a few places very fossiliferous	.1	.2
USGS Mesozoic loc. D1245:		
Pseudoperna congesta (Conrad)		
Baculites asper Morton		
B. codyensis Reeside		
Clioscaphites montanensis Cobban		
C. vermiformis (Meek and Hayden)		
153. Shale, gray, soft. At base a 6-cm-thick bed of gray fine-grained soft sandstone	1.3	4.2
152. Claystone, gray, nonfissile	2.6	8.5
151. Sandstone, gray, fine-grained, thinly laminated, and crossbedded	.1	.5
150. Shale, gray, flaky, noncalcareous	.5	1.7
149. Limestone, gray, concretionary, very fine grained; weathers yellowish gray; flat oval masses 1 m in diameter, much shattered. Locally one is larger, weathers yellowish orange, and exhibits cone-in-cone structure. Widely separated. Fossiliferous	.1	.4
USGS Mesozoic loc. 21666:		
Inoceramus sp.		
Baculites codyensis Reeside		
Clioscaphites montanensis Cobban		
C. vermiformis (Meek and Hayden)		
148. Shale, gray, flaky	.6	2.0
147. Limestone, dark-gray, concretionary; weathers yellowish gray; upper surfaces rounded; aphanitic, hard, breaks with conchoidal fracture; locally makes continuous layer with minor development of cone-in-cone structure. Fossiliferous	.2	.6
USGS Mesozoic loc. D1244:		
Membranipora sp.		
Inoceramus n. sp.		
Pseudoperna congesta (Conrad)		
Baculites codyensis Reeside		
Clioscaphites montanensis Cobban		
C. vermiformis (Meek and Hayden)		
146. Shale, gray, flaky, noncalcareous. At base is a thin medium-olive-gray fine-grained finely laminated sandstone bed containing a few baculites	1.5	5.1
145. Limestone, concretionary; in thin, discrete masses densely packed with *Baculites codyensis,* replaced by white crystalline calcite	.1	.2
USGS Mesozoic loc. D1243:		
Baculites codyensis Reeside		
Clioscaphites montanensis Cobban		
144. Shale, medium-dark-gray; contains a very thin finely laminated layer of sandstone in middle and a few small dolostone concretions in lower 15 cm	1.5	4.8
143. Dolostone, olive-gray, concretionary, hard, aphanitic, fairly continuous; weathers brown to very dusky red. Top of middle unit of member	.1	.3
142. Shale, brownish-olive-gray, soft, flaky	.4	1.3
141. Dolostone, olive-gray, concretionary; weath-		

Type section of the Kevin Member—Continued

	M	*Ft*
Marias River Shale—Continued		
Kevin Member—Continued		
141. Dolostone, etc.—Continued ers brown to dusky red; small, infrequent oval masses; very fossiliferous	.1	.2
USGS Mesozoic loc. 21665: *Nuculana* sp. *Inoceramus* sp. *Baculites asper* Morton *B. codyensis* Reeside *Clioscaphites montanensis* Cobban *C. vermiformis* (Meek and Hayden)		
140. Shale, brownish-olive-gray, soft, flaky; contains a 3-cm-thick layer of bentonite	1.0	3.2
139. Limestone, dark-gray (*N*3), aphanitic, hard; weathers yellowish gray (5*Y* 7/2). Contains abundant baculites and a few fragments of scaphites	.1	.2
138. Shale, olive-gray, flaky	1.2	4.0
137. Limestone, gray, concretionary, ferruginous; weathers yellowish gray	.1	.3
136. Siltstone, brownish-olive-gray, noncalcareous; weathers down into sharp granular fragments and chips	2.4	7.8
135. Dolostone, olive-gray, concretionary, aphanitic, hard; weathers reddish brown and dusky red. Contains lentils of gray septarian limestone with dark-brown calcite septae. A persistent layer, making a small bench. Bed E of Erdmann, Gist, Nordquist, and Beer (1947)	.1	.4
134. Shale, brownish-olive-gray, flaky, noncalcareous; some thin sandy partings	4.6	15.2
133. Limestone, brownish-olive-gray, concretionary; weathers light yellowish gray. Shattered oval masses 1–2 m in diameter spaced at intervals of 3–6 m. Very fine grained at base, becoming prismatic toward top with some gnarly cone-in-cone structure. A fairly persistent bed	.4	1.2
132. Shale, olive-gray, flaky, noncalcareous	1.7	5.7
131. Limestone, gray, concretionary, ferruginous: weathers brown to light yellowish brown. Discrete tabular masses about 1 m in diameter	.1	.3
130. Shale, dark-gray, fissile	.3	1.1
129. Limestone, olive-gray, dolomitic, concretionary, aphanitic; weathers reddish brown and very dusky red. Tabular masses 1 m or more in diameter	.1	.3
USGS Mesozoic loc. 21664: *Inoceramus* sp. *Baculites* sp. *Clioscaphites* sp.		
128. Shale, dark-gray, flaky, noncalcareous; becomes light olive gray toward top	1.5	5.0
127. Shale, gray	.2	.5
126. Limestone, gray, sandy; weathers yellowish brown. Coquina type; many shell fragments	.1	.2
125. Shale, dark-gray; interlaminated with thin brownish-gray siltstone	.4	1.3
124. Sandstone, medium-olive-gray, fine-grained, hard, brittle, noncalcareous, very finely laminated; weathers medium yellowish brown	.1	.2
USGS Mesozoic loc. D1242: *Inoceramus* cf. *I. cordiformis* Sowerby *Baculites codyensis* Reeside *Clioscaphites*? sp.		
123. Shale, medium-dark-gray, silty, noncalcareous. A thin fine-grained sandstone bed at base	1.6	5.2
122. Shale, brownish-olive-gray	1.5	5.0
121. Bentonite, light-gray	.1	.3
120. Shale, brownish-olive-gray; as unit 119	3.3	11.0
119. Shale, brownish-olive-gray. At top and base are bentonite beds about 7 cm thick	.5	1.8
118. Shale, brownish-olive-gray (between 5*YR* 4/1 and 5*Y* 4/1), noncalcareous, poorly fissile	1.9	6.3
117. Limestone, light-olive-gray, concretionary, sandy textured, finely and evenly laminated; weathers yellowish brown. Oval masses 1–2 m in diameter, much jointed and shattered; spaced at intervals of 10 m or more and may not be present in local sections	.3	.9
USGS Mesozoic loc. 21663: *Inoceramus* sp. scaphite undet.		
116. Shale, brownish-olive-gray, silty, soft, noncalcareous, flaky	.4	1.2
115. Bentonite, grayish-orange (10*YR* 7/4), granular textured, finely and smoothly laminated; considerable biotite. Rests on 10 cm of hard finely crystalline concretionary limestone that weathers grayish to yellowish orange, but which may be locally absent	.2	.7
114. Shale, gray, flaky, noncalcareous	.3	1.0
113. Sandstone, medium-gray, calcareous; firm, relatively resistant, making a thin ledge. Very fine grained; with wavy lamination developed by short thin lentils of dark-gray noncalcareous sandstone. Locally grades laterally into circular masses of gray concretionary limestone 1 by 2.7 m	.2	.5
112. Shale, dark-brownish-olive gray; a few thin layers of fine-grained platy sandstone in upper 1.2 m. Lower 2.1 m is dark gray (*N*3) soft, fissile, noncalcareous	3.3	11.0
111. Shale, medium- to dark-gray, flaky, noncalcareous. A 6-cm-thick bed of bentonite at top	.5	2.0
110. Calcite and bentonite; grayish-orange, soft, friable; medium- to coarse-grained concretionary calcite and gray very micaceous bentonite	.8	2.5
109. Shale, olive-gray (5*Y* 4/1), soft, flaky, noncalcareous, poorly exposed	2.0	6.5
108. Phosphatic pebble bed. A concentration of smooth rounded concretions of phosphatic siltstone and sandstone, making a thin armored pavement-type surface over very limited areas, with here and there low mounds		

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

M Ft

108. Phosphatic pebble bed—Continued that contain small oval limestone concretions. The pebbles are greenish gray (5*GY* 6/1) to olive gray (5*Y* 4/1), with darker crusts, and some have a close, irregular light-gray reticulation. Size range: 5–40 mm, with mean 12–20 mm. All are rounded or subrounded and a few spindle shaped; many are broken, apparently along desiccation cracks. Here and there a small scaphite among the pebbles. Accessory limestone concretions are of two types, both similar to facies of the MacGowan Concretionary Bed: (1) moderate yellowish-brown limestone in nodules 15 by 10 by 5 cm, weathering dark yellowish orange, and containing pellets of light-gray phosphatic siltstone; (2) a single discoid mass of ferruginous limestone 25 by 20 by 5 cm, weathering very dusky red (10*R* 2/2) with small embedded pebbles as above. Fossiliferous ---------- .1 .2

USGS Mesozoic coll. D1334:
Inoceramus sp.
Scaphites sp.

107. Shale, olive-gray (5*Y* 4/1), soft, flaky, noncalcareous ---------- .5 1.5

106. Limestone, moderate-brown to grayish-red, concretionary, ferruginous; upper surface very dusky red. Thin hard resistant layer .1 .2

USGS Mesozoic loc. D1333:
Inoceramus stantoni Sokolow
Scaphites depressus Reeside var. *stantoni* Reeside
Baculites asper Morton
Baculites codyensis Reeside

105. Shale, olive-gray, silty, soft, flaky. At base was found a large fossil bone, probably a rib, nearly 2 ft long ---------- .6 2.0

104. Limestone, olive-gray, concretionary, aphanitic; weathers moderate brown; uniform persistent layer ---------- .1 .2

USGS Mesozoic loc. D1240 and D1332:
Inoceramus sp.
Baculites asper Morton
Baculites codyensis Reeside
Scaphites depressus Reeside

103. Shale, medium-gray, noncalcareous, silty; contains near top dusky-red-weathering dolostone concretions ---------- .8 2.6

102. Dolostone, dark-greenish-gray to olive-gray, concretionary, aphanitic; weathers very dusky red (maroon); in small hard discrete nodules as large as 8 by 15 cm. Sparingly fossiliferous ---------- .1 .3

101. Shale, olive-gray (5*YR* 4/1), noncalcareous, soft, poorly fissile. Thickness variable ---- 2.4 8.0

100. MacGowan Concretionary Bed. Bed F of Erdmann, Gist, Nordquist, and Beer (1947). Type section.

100c. Dolostone, brownish-gray (5*YR* 4/1), ferruginous, hard; weathers dark reddish

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

M Ft

100c. Dolostone, etc.—Continued brown (10*R* 3/4) to very dusky red (10*R* 2/2); aphanitic, breaking with subconchoidal fracture. Matrix contains a few small pellets (possibly reworked) of light-gray phosphatic siltstone. Bed caps underlying limestone concretions and fills interstices between them ---------- .1 .2

100b. Limestone, brownish-olive-gray (between 5*YR* 4/1 and 5*Y* 4/1); weathers to light orange brown (between 10*YR* 6/6 and 5*YR* 5/6) and shades of moderate brown (5*YR* 4/4 and 5*YR* 3/4) with mottling or splotches of moderate (10*R* 4/6) to dark reddish brown (10*R* 3/4); concretionary, conglomeratic; matrix aphanatic. A few concretions remain predominantly gray, weathering dull yellowish brown. Individual forms are flat-based round-topped fractured oval masses, noticeably septarian, that vary in diameter from 30 to 50 cm and are packed so closely as to form a continuous layer. Conglomeratic facies consist of erratic concretions and patches of irregularly shaped smoothly rounded pellets of yellowish-gray (5*Y* 8/1) to light-olive-gray (5*Y* 6/1) phosphatic mudstone as long as 2 cm, although usually smaller; cover as much as 10 percent or more of the outer surfaces of the concretions as crusts and are embedded more sparingly in the matrix. These pellets, with sharp color contrast to the weathered surface, plus an accessory sprinkling of 1 percent or less of smoothly rounded well-polished pebbles of black to olive-gray chert as much as 2 cm in diameter, but usually much finer, are the principal diagnostic features of the bed. Entire unit makes a thin resistent ledge capping spurs or dip slopes, whose surfaces are partially covered with a thin litter of angular fragments ---------- .1 .5

100a. Shale, dark-gray, noncalcareous, poorly fissile. At base a thin concretionary light-brown- to moderate-reddish-brown-weathering bed of limestone. Base of MacGowan Bed ---------- .2 .9

99. Shale, dark-olive-gray; a few thin laminae of fine-grained chippy sandstone in middle and at top ---------- .3 1.0

USGS Mesozoic loc. D1238:
Inoceramus sp.

98. Shale, olive-gray (5*Y* 4/1); small thin widely spaced septarian concretions of gray limestone ---------- .4 1.3

97. Shale, gray, sandy, poorly exposed -------- .6 2.1

96. Limestone, gray, concretionary; in thin flat discoid masses 30 cm in diameter that weather yellowish gray; dark-greenish-olive-gray hard aphanitic dolostone, with accessory marcasite and weathering dusky

Type section of the Kevin Member—Continued

	M	Ft
Marias River Shale—Continued		
Kevin Member—Continued		
96. Limestone, etc.—Continued red and yellowish orange	.1	.3
USGS Mesozoic loc. 23753: *Inoceramus (Volviceramus) involutus* Sowerby; *Pseudoperna congesta* (Conrad); *Baculites* sp.		
95. Shale, gray; occasional discrete oval concretions of dark-gray limestone, 30 by 15 cm, that weather yellowish gray. At base a thin light-olive-gray fine-grained soft finely laminated sandstone bed	.9	3.1
94. Limestone, olive-gray, concretionary, aphanitic; weathers yellowish gray; in discrete oval masses 30 cm in diameter. Septarian veins of dark calcite. Breaks into angular fragments	.2	.5
93. Shale, gray; contains a very thin gray fine-grained soft thinly laminated layer of sandstone	1.3	4.3
92. Limestone, dark-gray, concretionary; weathers lighter gray; small (diameter 30 cm) oval septarian forms	.2	.5
91. Shale, gray, silty, soft, noncalcareous	1.7	5.5
90. Limestone, gray, concretionary, finely granular (sandy); weathers yellowish orange and dark yellowish orange to yellowish brown. Lower 15 cm may exhibit rude cone-in-cone and prismatic structures. Thickness 0.3–0.5 m, diameter 1–3 by 4.5 m. Persistent, but occurring at large horizontal distances	.5	1.5
89. Shale, gray; as below	.3	1.0
88. Limestone, dull-red, concretionary, sandy; makes persistent layer locally	.1	.3
USGS Mesozoic loc. D1331: *Scaphites ventricosus* Meek and Hayden		
87. Shale, gray, soft, gypsiferous (radiating fibrous selenite crystals). Contains a few sandy ferruginous limestone concretions	2.2	7.4
86. Shale, dark-gray, soft, clayey; carries an occasional concretion of ferruginous limestone in lower 1.5 m. A very thin fine-grained sandstone bed at top	2.9	9.6
85. Limestone, gray; weathers buff to yellowish gray; concretionary; in fairly large isolated conspicuous masses making a small bench; flat and slabby at base, discrete oval forms at top; cone-in-cone structure in places	.1	.2
84. Limestone, dark-gray; ferruginous, aphanitic; weathers very dusky red. Fossiliferous	.1	.2
USGS Mesozoic loc. 20698: *Inoceramus (Volviceramus) involutus* Sowerby; *Inoceramus (Volviceramus) undabundus* Meek and Hayden		
83. Shale, gray, soft, clayey; contains a thin gray-weathering limestone bed at base overlain by a thin fine-grained sandstone bed. *Actinocamax* sp.	1.9	6.2
82. Shale, gray, soft; makes slope; poorly exposed	3.7	12.3
81. Limestone, dark-gray, concretionary, ferruginous, hard, aphanitic, persistent; weathers very dusky red and dark yellowish orange. Bed G of Erdmann, Gist, Nordquist, and Beer (1947)	.1	.3
USGS Mesozoic loc. 20295: *Inoceramus* sp.; *Baculites* sp.; *Scaphites ventricosus* Meek and Hayden		
80. Shale, gray, clayey, gypsiferous; contains scattered thin sandstone and small oval limestone concretions near middle and a thin gray fine-grained chippy sandstone bed at base	3.4	11.1
79. Shale, gray, soft, flaky	.2	.5
78. Limestone, dark-gray; concretionary, ferruginous; weathers very dusky red; oval to platy shapes; fairly continuous	.1	.2
77. Shale, gray, clayey; scattered concretions of ferruginous limestone	1.1	3.8
76. Limestone, dark-gray, concretionary, ferruginous, aphanitic; weathers very dusky red and brown; in large flat forms about 1 m in diameter	.1	.2
USGS Mesozoic loc. 20291: *Inoceramus (Volviceramus) undabundus* Meek and Hayden; *Baculites asper* Morton; *Scaphites ventricosus* Meek and Hayden; *Actinocamax* sp.		
75. Shale, gray, sandy, soft, flaky; contains a gray fine-grained thinly laminated sandstone layer at base	.6	2.0
74. Shale, dark-gray, clayey; contains a few small nodular concretions of ferruginous limestone weathering very dusky red	1.8	6.0
73. Limestone, dark-gray, concretionary, ferruginous; weathers very dusky red	.1	.3
72. Shale, dark-gray	.3	1.0
71. Limestone, dark-gray, concretionary, hard, aphanitic, brittle; weathers very dusky red; discrete masses commonly 30–50 cm long, and smaller nodules. Fossiliferous. One concretion contained a weathered bone nearly 1 m long and 15 cm in diameter	.1	.3
USGS Mesozoic loc. 20292: *Inoceramus (Volviceramus) involutus* Sowerby; *I. (Volviceramus) undabundus* Meek and Hayden; *Spondylus* sp.; *Baculites asper* Morton; *Scaphites ventricosus* Meek and Hayden		
70. Shale, gray, soft, clayey	1.1	3.5
69. Limestone, gray, concretionary; weathers yel-		

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

	M	Ft
69. Limestone, etc.—Continued lowish gray; in discrete masses with poorly developed cone-in-cone structure; resting on thin gray sandy bentonite. Makes a persistent marker. Bed H of Erdmann, Gist, Nordquist, and Beer (1947)	.1	.3
68. Shale, dark-gray, soft, clayey; checked surface stained by white efflorescent salt	3.3	11.0
67. Shale, dark-gray, soft, clayey; contains a few small oval concretions of limestone and thin 1–3-cm-thick gray chippy sandstones at intervals of 50–60 cm	2.1	7.0
66. Shale, dark-gray, soft, clayey (bentonitic); checked surface stained by white efflorescent salt	3.9	13.0
65. Limestone, dark-gray, concretionary; oval septarian masses about 30 cm long spaced at intervals of 3 m	.1	.3
64. Shale, dark-gray, soft, poorly fissile	1.1	3.8
63. Bentonite, gray, gritty; weathers tan	.1	.3
62. Shale, gray, soft, poorly exposed	.4	1.3
61. Limestone, gray, concretionary, aphanitic; oval septarian masses about 30 cm long with much brown and white crystalline calcite spaced at intervals of 1–6 m	.2	.5
60. Shale, gray, soft, poorly exposed	.5	1.5
59. Bentonite, gray, sandy	.1	.3
58. Shale, soft, poorly exposed	1.2	4.0
57. Calcite, light-yellowish-gray, sandy, prismatic (fibrous); weathers tan to caramel brown; poorly developed cone-in-cone structure. Probably a calcareous replacement of a layer of bentonite; fairly resistant, makes a bench and caps small outliers. Bed I of Erdmann, Gist, Nordquist, and Beer (1947). Top of lower unit	.1	.5
56. Siltstone, gray, noncalcareous, firm; brittle, with a harsh feel; contains fossiliferous oval concretions of gray aphanitic limestone 10–15 cm thick and 30–50 cm long in middle part	1.7	5.5
USGS Mesozoic loc. 20696: *Inoceramus* aff. *I. corpulentus* McLearn; *Ostrea* n. sp.		
55. Bentonite, gray	.1	.5
54. Shale, gray	3.6	12.0
53. Limestone, concretionary, gray; small rough oval masses	.1	.2
52. Siltstone, gray, firm; harsh feel; weathers into granular fragments	1.8	6.0
51. Limestone, gray, concretionary, aphanitic; weathers brownish; sandy at top, with some gnarly cone-in-cone structure; in rounded flat-topped much-fractured masses with septae of brown calcite; commonly 1 m in diameter but as much as 3 by 4 m. Makes ledge in main slope. Bed J of Erdmann, Gist, Nordquist, and Beer (1947)	.3	1.0
50. Shale, gray	.8	2.5
49. Sandstone, gray, fine-grained, thinly laminated; weathers brownish; some shale part-		

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

	M	Ft
49. Sandstone, etc.—Continued ings; bedding surfaces show worm (?) trails and related markings	.4	1.3
48. Limestone, gray, concretionary, aphanitic; small flat oval forms. Contains *Scaphites* sp. and *Inoceramus* sp.	.1	.2
47. Shale, gray, soft, flaky; contains a few oval concretions of gray limestone with fragments of *Scaphites* sp.	3.8	12.5
46. Limestone, gray, concretionary, aphanitic; small discrete masses at 6-m intervals. Contains *Inoceramus* sp. and *Ostrea* sp.	.1	.3
45. Shale, gray, soft; poorly exposed on slope. A 3-cm-thick layer of bentonite at top	1.2	4.1
44. Bentonite, gray, sandy, weathered; at top a thin layer of caramel-brown secondary fibrous calcite; makes slight ledge	.2	.5
43. Shale, gray, soft; a few hand-sized concretions of gray limestone; makes slope	.6	2.0
42. Limestone, dark-gray, concretionary; weathers light yellowish gray; in small 30–50-cm-thick much-fractured oval masses with septae of brown calcite; fossiliferous. Makes a rather distinct bench	.2	.6
41. Shale, gray, soft; poorly exposed on slope; contains 6-cm-thick layers of bentonite at base and middle	2.5	8.4
40. Limestone, gray, concretionary, aphanitic, gnarly; weathers rusty brown; veined with more or less white crystalline calcite; hard, resistant; massive discrete forms 0.5–3.0 m in diameter spaced on 3–5-m centers making small mounds. A conspicuous marker bed. Bed K of Erdmann, Gist, Nordquist, and Beer (1947)	.7	2.5
39. Bentonite, sandy; weathered rusty	.1	.3
38. Shale, dark-gray, soft, clayey; contains a 3-cm-thick layer of bentonite at base	.8	2.6
37. Shale, dark-gray, soft, clayey	3.2	10.5
36. Bentonite, sandy; weathers rusty	.1	.5
35. Shale, gray, soft, clayey; makes slope	.9	3.0
34. Limestone, gray, concretionary, fossiliferous; in oval discrete forms as much as 50 cm long	.1	.5
USGS Mesozoic loc. 20300: *Scaphites* sp.; *Actinocamax* sp.		
33. Bentonite, gray, sandy; weathers rusty	.1	.3
32. Shale, gray, soft, clayey	.3	1.0
31. Limestone, concretionary, gray	.1	.5
30. Bentonite, gray, sandy; weathers rusty	.1	.5
29. Shale, brownish-gray, clayey, bentonitic	1.1	3.8
28. Limestone, gray, concretionary, aphanitic, hard, smooth; weathers yellowish gray; in discrete oval forms 30 cm in diameter	.2	.5
USGS Mesozoic loc. 20296: *Inoceramus* sp.; *Ostrea* sp.; *Baculites mariasensis* Cobban; *Scaphites preventricosus* Cobban; *Actinocamax* sp.		
27. Bentonite, gray, sandy; weathers rusty	.4	1.2
26. Shale, gray, flaky; top is silicified	.5	1.5

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

	M	*Ft*
25. Limestone, gray, concretionary, aphanitic; small (diameter 30 cm) smooth discrete oval masses	.2	.5
24. Bentonite, gray	.4	1.2
23. Shale, dark-gray, soft, flaky. A very thin layer of bentonite in middle	1.4	4.9
22. Bentonite, light-gray	.2	.5
21. Shale, dark-gray, soft, flaky	.6	2.0
20. Limestone, dark-gray, concretionary; weathers yellowish gray; smooth oval discrete forms	.1	.5
USGS Mesozoic loc. 20298: *Inoceramus deformis* Meek; *Pseudoperna congesta* (Conrad); *Ostrea* n. sp.; *Pholadomya papyracea* Meek and Hayden; *Veniella goniophora* Meek; *Drepanochilus*? sp.; *Baculites mariasensis* Cobban; *B. sweetgrassensis* Cobban; *Scaphites preventricosus* Cobban		
19. Shale, dark-gray, soft, flaky	.5	1.5
18. Bentonite, rusty-brown, weathered; stain of white efflorescent salt above bed	.1	.5
17. Siltstone, dark-gray, soft; makes slope	2.7	9.0
16. Bentonite, gray, sandy; weathers tan; upper part of bed littered with caramel-color secondary prismatic calcite that has some cone-in-cone structure	.3	1.0
15. Siltstone, dark-gray, soft; weathers into gumbo with stains of white efflorescent salt. Poorly exposed in slope	4.6	15.0
14. Bentonite, light-brownish-gray, sandy	.2	.5
13. Shale, dark-olive-gray, soft, flaky, noncalcareous; contains a very thin rusty-brown fine-grained finely laminated sandstone bed near base	4.0	13.1
12. Bentonite, yellowish-gray; contains much light-brownish-gray (5*YR* 4/1) prismatic calcite that has a tendency toward cone-in-cone structure and weathers moderate yellowish brown (caramel). A few small flat-topped oval-shaped concretions of dark-brownish-gray aphanitic limestone. Bed L of Erdmann, Gist, Nordquist, and Beer (1947)	.3	1.0
11. Shale, dark-olive-gray, soft, noncalcareous	.4	1.3
10. Shale, brownish-gray, clayey, bentonitic. A 6-cm-thick pale-yellowish-brown micaceous bentonite bed at base	.1	.6
9. Shale, dark-gray, soft, poorly fissile, noncalcareous	1.0	3.3
8. Siltstone, dark-gray, soft; weathers brownish	.4	1.3
7. Limestone, dark-gray, aphanitic, concretionary, hard, fetid-smelling, fossiliferous; weathers light yellowish gray; in discrete oval types (30 cm in diameter) in places septariate with veins of white and brown crystalline calcite; spaced at intervals of about 3 m	.1	.4
USGS Mesozoic loc. 20289:		

Type section of the Kevin Member—Continued

Marias River Shale—Continued

Kevin Member—Continued

	M	*Ft*
7. Limestone, etc.—Continued		
Anomia cf. *A. subquadrata* Stanton; *Inoceramus* sp.; *Scaphites preventricosus* Cobban; *S. preventricosus* var. *sweetgrassensis* Cobban		
6. Siltstone, dark-gray, poorly fissile, soft, noncalcareous; weathers into small granular particles; some thin rusty laminae	2.9	9.5
5. Limestone, dark-gray, concretionary; weathers medium olive gray to light yellowish gray; almost a continuous bed of small (diameter 30 cm) closely packed discrete septarian masses that have rough upper surfaces and partitions of white calcite	.2	.5
USGS Mesozoic loc. D1247: *Inoceramus* sp.; *Oxytoma* sp.; *Tessarolax hitzii* White		
4. Siltstone, medium-dark-gray, noncalcareous; contains small (10-cm-thick) nodules of gray clayey limestone	.5	1.5
3. Siltstone, medium-dark-gray, noncalcareous. Surface littered with thin rusty-brown chips of clay ironstone. Unit also contains small 1-cm-thick irregularly shaped nodules or concretions of soft moderate-yellow silt, weathering dusky yellow, that have the same shapes and appearance as kernels of buttered popcorn	1.6	5.3
2. Bentonite, yellowish-gray (5*Y* 8/1), sandy, highly weathered	.2	.5
1. Siltstone, dark-gray, noncalcareous, poorly fissile. Base of Kevin Member	2.9	9.6
Total Kevin Member (rounded)	188.0	617.0

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