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CORRELATION CHART OF LOWER AND UPPER CRETACEOUS BLACKLEAF FORMATION, EASTERN PIONEER MOUNTAINS, SOUTHWESTERN MONTANA, TO DRUMMOND, CENTRAL-WESTERN MONTANA

By

T.S. Dyman, R.G. Tysdal, C.A. Wallace, and S.E. Lewis

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ABSTRACT

The Lower and lower Upper Cretaceous Blackleaf Formation in the eastern Pioneer Mountains of southwestern Montana and in the Drummond area and Flint Creek Range in central-western Montana was deposited at or near the western margin of the Western Interior seaway as marine and nonmarine facies of the Cordilleran foreland basin. The five measured sections presented here are of Blackleaf strata that were transported eastward during emplacement of Late Cretaceous to early Tertiary thrust sheets.

The upper Albian to Cenomanian Blackleaf Formation is underlain by the Aptian and Albian(?) Kootenai Formation. In the eastern Pioneer Mountains, overlying strata are assigned to the Frontier Formation and are, at least in part, time equivalent to the Cenomanian and Turonian Frontier Formation near Lima, Mont., and to the east and southeast in the Madison Range and ranges of western Wyoming. In the area of Drummond, Mont., overlying strata belong to the Cenomanian and Turonian Coberly Formation.

Strata of the Blackleaf Formation in the eastern Pioneer Mountains are subdivided into the sandstone- and shale-rich Flood Member and the overlying dominantly siliciclastic and volcaniclastic Vaughn Member. Near Drummond, the Blackleaf Formation is subdivided into the Flood, Taft Hill, and Vaughn Members, but because of difficulties in distinguishing Flood sandstone from Taft Hill sandstone, both members have been combined into a unit called "sandstones undivided."

The Flood Member consists of a mixed clastic sequence of greenish-gray quartz- and lithic-rich sandstone, mudstone, siltstone, and dark-gray shale. It ranges in thickness from 785 ft (239 m) at the Jerry Creek section, to 1,185 ft (361 m) at the Rock Creek section. The lowermost part of the Flood is not exposed at the Drummond section and its precise thickness cannot be determined, although it is at least 66 ft (20 m) thick at this locality. The Flood Member is at least 230 ft (70 m) thick near Avon, Mont., about 20 mi east of the Drummond section.

An undivided sandstone unit in the Flint Creek Range is marine and it is composed of thin, flat to rippled beds of tan to gray lithic- and quartz-rich sandstone that contains interbeds of mudstone, siltstone, and shale. The undivided sandstone unit is at least 570 ft (158 m) thick at Barnes Creek about 8 mi (13 km) south of Drummond. The mutual contact of the undivided sandstone unit and the overlying Vaughn is poorly exposed in the study area but is marked by a significant decrease in sandstone and dark-gray shale and an increase in olive mudstone and siltstone.

The Vaughn Member contains abundant porcellanitic mudstone, siltstone, lithic sandstone, and subordinate conglomerate. It varies in thickness from 1,950 ft (594 m) at the Rock Creek section to 2,880 ft (877 m) at the Drummond section. The upper Vaughn contact is not exposed at the Jerry Creek section and the lower Vaughn contact is not exposed at the Dickey Peak section but is locally exposed in the Dickey Peak area.

In the eastern Pioneer Mountains, the upper contact of the Vaughn is placed at the top of a porcellanite bed that is associated with limestone and calcareous dark-gray shale. The porcellanite bed consistently and directly overlies the highest maroon mudstone-siltstone bed of the upper Vaughn. The Frontier Formation above this contact in the eastern Pioneer Mountains contains brown to gray lithic-rich sandstone, brown to dark-gray siltstone and mudstone, and quartzite- and chert-rich conglomerate. In the Drummond area, maroon beds and porcellanite of the upper Vaughn form a sharp contact with overlying siltstone, salt-and-pepper sandstone, and fossiliferous limestone of the Coberly Formation.

INTRODUCTION

The Lower and lower Upper Cretaceous Blackleaf Formation was deposited along the western margin of the foreland basin that bordered the Cordilleran thrust belt (fig. 1). Rocks of the Blackleaf Formation are no longer at their original depositional sites because of eastward thrusting during Late Cretaceous and early Tertiary time (Gwinn, 1965; Wallace and others, 1990; Dyman and Tysdal, 1990). These nonmarine and marine rocks record sedimentation in response to marine transgressions and regressions, source area tectonism, and volcanism. Although different names have been applied to these thick and lithically diverse strata, the rocks have not been systematically described or integrated with the regional stratigraphic framework.

In this report we describe and correlate five measured sections of Blackleaf strata along a north-south line from (1) the eastern Pioneer Mountains northward to (2) the Mt. Fleecer area in an unnamed mountain range south of Anaconda, Mont. (two measured sections), (3) the Flint Creek Range, and (4) the Drummond, Mont. area (fig. 1). This report extends descriptions provided by two previous reports on the Blackleaf and equivalent strata from the Madison Range westward to the Lima Peaks area (Tysdal and others, 1989a), and from the Lima Peaks area northward to the eastern Pioneer Mountains (Dyman and Tysdal, 1990). We acknowledge the thorough and thoughtful reviews of this manuscript by W.A. Cobban, U.S. Geological Survey, and S.V. Foster and K.W. Porter, Montana Bureau of Mines and Geology.

MEASURED SECTIONS

Five measured sections and their stratigraphic correlations are presented here using the SRG (Stratigraphic Report Graphic). The SRG is a stratigraphic applications computer

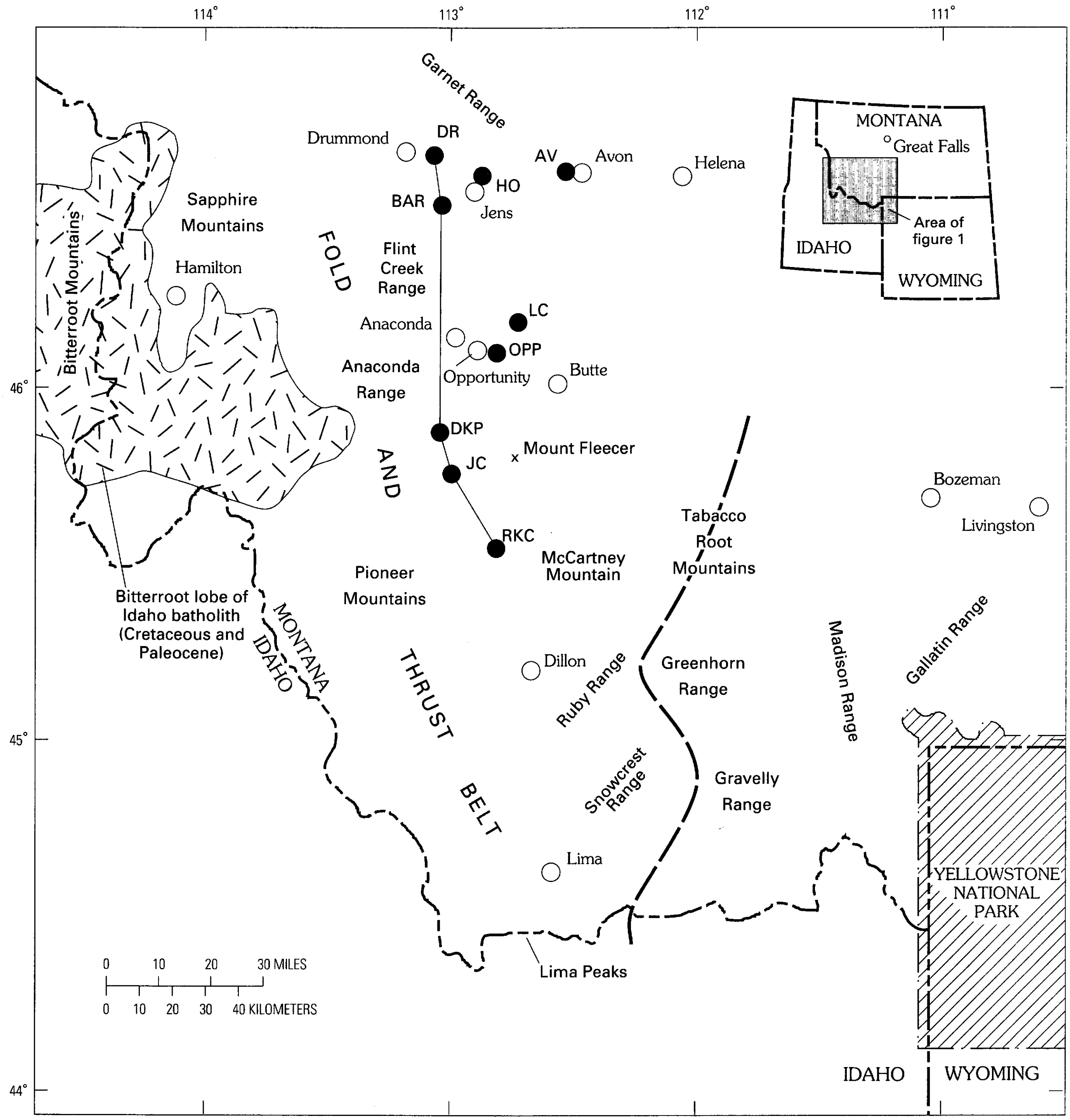

Figure 1. Index map of southwestern Montana showing locations of measured sections, outcrop localities, and other features. Abbreviations for outcrop sections and localities are as follows: AV, Avon; BAR, Barnes Creek; DKP, Dickie Peak; DR, Drummond; HO, Hoover Creek; JC, Jerry Creek; LC, Lost Creek; OPP, Opportunity; RKC, Rock Creek. Line of cross section indicated with line joining measured sections. Dashed line indicates change in nomenclature between Blackleaf Formation to the west and Thermopolis Shale and Mowry Shale to the east (Tysdal and others, 1989a, b).

program developed by the U.S. Geological Survey and Petroleum Information Corporation of Denver, Colo. It records sedimentologic, paleontologic, lithologic, paleoecologic, and nomenclatorial data for outcrop sections and cores, and displays these data in graphic form using a scale-variant format (Petroleum Information Corporation, 1984). The SRG is proprietary to Petroleum Information Corporation, but it is available by contract to the U.S. Geological Survey.

The southernmost measured section, at Rock Creek in the eastern Pioneer Mountains, was originally published by Dyman and Tysdal (1990). It is presented here because it establishes stratigraphic continuity from the eastern Pioneer Mountains northward to the Drummond area. The lower part of the Drummond section was described by Gwinn (1960), and it is supplemented here by additional data from Tysdal, Dyman, and L.E. Davis. The Jerry Creek section was previously published by Noel (1956) and was remeasured by Dyman, Tysdal, and Lewis. The Dickie Peak section was measured by Lewis, Tysdal, and Dyman. The Barnes Creek section, newly described by Tysdal, Dyman, and Wallace, is included to establish regional facies relations in the lower Blackleaf Flood-Taft Hill interval from the northern Flint Creek Range to the Drummond area.

The Rock Creek section is about 20 mi (66 km) south of the Jerry Creek section. The Dickie Peak section is only about 6 mi (10 km) north of the Jerry Creek section, but the Drummond section, the northernmost of the five sections, is 45 mi (75 km) north of the Dickie Peak section and 8 mi (13 km) north of the Barnes Creek section. Other partial Blackleaf sections are exposed in part of the Anaconda Range in the Mt. Haggin area, in the southern part of the Flint Creek Range north of Lost Creek, and near Mt. Fleecer in an unnamed mountain range east of Anaconda, Mont., but they were not measured because of complex structural relationships or intense metamorphism from local intrusions. Information for these sections is included in the following discussion, and their locations are given in the Appendix.

The Rock Creek and Drummond sections are generally well exposed. The lowermost and uppermost parts of the Blackleaf Formation are not exposed at the Drummond section; the section was supplemented by data for the lower Blackleaf from near Avon and Jens, Mont. (Appendix). The Jerry Creek and Dickie Peak sections are poorly exposed. The lower part of the Blackleaf Formation is not exposed at the Dickie Peak section and the upper part of the formation is not exposed at the Jerry Creek section. The Barnes Creek section contains a well-preserved Flood-Taft Hill interval; the Vaughn Member is poorly exposed along Barnes Creek and was not measured. Strata at the Rock Creek section were thermally altered by the Pioneer batholith.

STRATIGRAPHY

Lower and lower Upper Cretaceous strata exposed between the eastern Pioneer Mountains and Drummond are assigned to the Aptian and Albian(?) Kootenai Formation and the Albian and lower Cenomanian Blackleaf Formation (fig. 2). Strata that overlie the Blackleaf Formation in the eastern Pioneer Mountains have recently been included in the Cenomanian and Turonian Frontier Formation by Tysdal and others (1994). Dyman and Tysdal (1990) previously had left these rocks unnamed and undivided pending further study. Dyman and Nichols (1988), Dyman and others (1989), and Tysdal and others (1990) assigned overlying Upper Cretaceous strata south of Lima, Mont., to the Frontier Formation. Rocks of similar lithology and age in the Madison Range were also assigned to the Frontier Formation by Tysdal and others (1990). Age-equivalent strata at Drummond are assigned to the Cenomanian and Turonian Coberly Formation following Gwinn (1965) and Wallace and others (1986; 1990).

Several different names have been used previously for strata that are here assigned to either the Blackleaf and Coberly Formations or were left unnamed, but no consistent pattern of nomenclature had been established in earlier reports, in part because of the great distance between outcrops, the great thickness of strata, and local lithologic and facies changes.

The Blackleaf Formation of the Lima Peaks area was correlated with rocks in the Madison Range by Tysdal and others (1989a). These rocks were deposited in a foreland basin and shelf, respectively. In the measured sections of the Madison, Greenhorn, and Gravelly Ranges, Tysdal and others (1989a) assigned lithic equivalents of the Blackleaf to the Thermopolis Shale, Muddy Sandstone, and Mowry Shale. Dyman and Tysdal (1990) correlated Blackleaf strata of the Lima Peaks area with strata northward in the eastern Pioneer Mountains, and they demonstrated that facies change markedly and Blackleaf strata thicken significantly in the eastern Pioneer Mountains.

Stratigraphic relations and regional correlations in the Blackleaf Formation and overlying Cretaceous rocks are illustrated in figure 2. Figure 3 illustrates relative thicknesses of Blackleaf measured sections presented on each half of the chart. Stratigraphic relations in this report are described from south to north. All megafossils reported by us were identified by W.A. Cobban, U.S. Geological Survey.

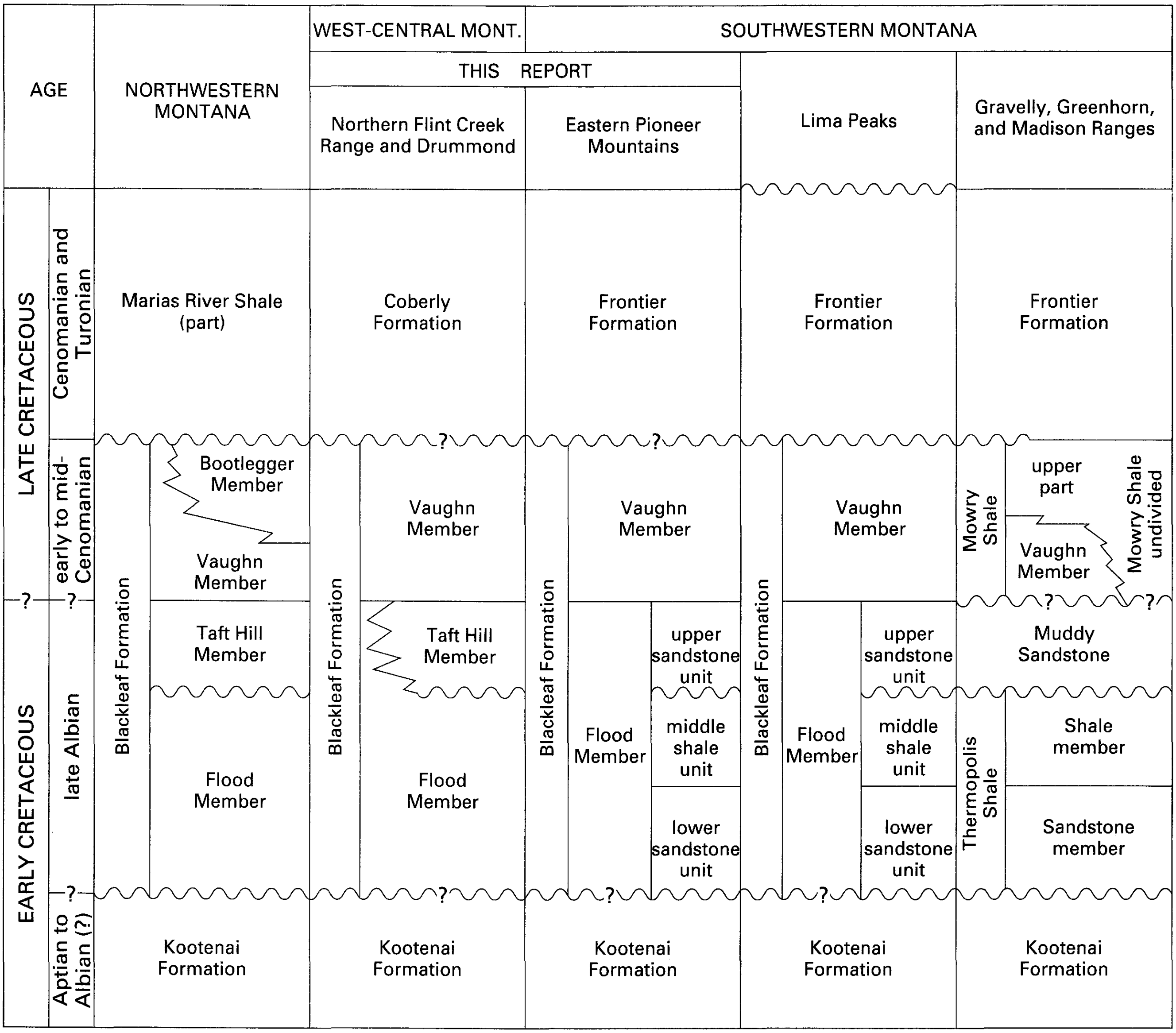

Figure 2. Correlation chart of Lower and Upper Cretaceous rocks in western Montana. Wavy line designates unconformity; only unconformities bounding formations shown. Recent work by Cobban and Kennedy (1989, p. 9) concludes that the upper part of the Mowry Shale may be early Cenomanian in age.

PREVIOUS STUDIES

Earlier studies of Lower and Upper Cretaceous rocks in the region were primarily mapping projects in which different formal and informal stratigraphic names were used, based in part on the level of detail in mapping. Post-Kootenai strata generally remained undivided. Post-Kootenai rocks in the Mt. Fleecer area north of the Pioneer Mountains and in the Flint Creek Range were assigned to the "Colorado formation" by McGill (1956, 1957), Fraser and Waldrop (1972), and Hastings and Harrold (1988); to the "Colorado shale" by Moore (1956) and Wanek and Barclay (1966); to the Colorado Group by Ruppel and others (1983), Brandon (1984), Pearson and Zen (1985), and Peterson (1985); to the Blackleaf Formation by Bierwagen (1964), Schwartz (1972, 1983), and Schmidt and others (1994); to the Blackleaf Formation and overlying undifferentiated Upper Cretaceous rocks by Lewis (1989); to the Flood, Taft Hill, and Dunkleberg Formations of the Colorado Group by Krause (1960); and to the Blackleaf and Coberly Formations by Gwinn (1960, 1961, 1965) and A.B. French and C.A. Wallace (unpub. data., 1990) for rocks in the Drummond area.

The name Blackleaf was first used for rocks near Drummond by Gwinn (1960, 1961, 1965), who subdivided the Blackleaf into the Flood, Taft Hill, and Dunkleberg Members, and traced the Flood and Taft Hill Members south into the eastern Pioneer Mountains and McCartney Mountain area. Schwartz (1972, 1983) described Blackleaf at localities in the eastern Pioneer Mountains and Drummond areas, and subdivided the formation into four informal lithic units (units A through D), but he did not publish his measured sections.

Tysdal and others (1989a) subdivided the Blackleaf into formal members in southern Beaverhead and Madison Counties south and southeast of the area of this study. Dyman and Nichols (1988), Dyman and others (1988), Tysdal and others (1989a, b), and Dyman and Tysdal (1990) discussed Cretaceous nomenclature in the Lima Peaks area and eastward in the Madison, Gravelly, Snowcrest, and Greenhorn Ranges and in the eastern Pioneer Mountains.

The name Frontier Formation was used by Dyman and Nichols (1988) and Dyman and others (1988) for beds that directly overlie the Blackleaf Formation in the southern part of the eastern Pioneer Mountains south of the area of this study. Their Blackleaf-Frontier contact was determined by an overall compositional change in the rocks, including an abrupt increase in the abundance of sandstone beds. Age-diagnostic palynomorphs and megafossils were not found in these strata, however, and correlation of rocks that overlie the Blackleaf at these localities was based on lithic similarities with the Frontier Formation throughout the region.

T.S. Dyman and R.G. Tysdal (unpub. field data, 1992) measured post-Blackleaf stratigraphic sections along the eastern flank of the Pioneer Mountains and correlated these rocks with the Frontier Formation south of Lima Peaks and in the Snowcrest and Gravelly Ranges to the east. In the area north of the eastern Pioneer Mountains and south of Drummond, strata above the Blackleaf Formation are lithically similar to Frontier rocks to the south and east, and are referred to as the Frontier in this report. Rocks overlying the Blackleaf Formation in the Drummond area were called the Coberly Formation by Gwinn (1960, 1961, 1965), Schwartz (1968, 1972), and Wallace and others (1986, 1990). These rocks are in part lithically similar to the Frontier Formation, but contain marine limestone, are thinner than equivalent rocks to the south, and probably were derived from a local source (Wallace and others, 1990).

KOOTENAI FORMATION

The Kootenai Formation is described briefly in this report because it underlies all of our measured sections, and contact relations with the overlying Blackleaf Formation require description of the upper part of the Kootenai. The uppermost part of the Kootenai in our study area contains gastropod-rich carbonate strata, informally called the "gastropod limestone," which marks the top of the formation throughout most of southwestern Montana and is used as a marker unit in this report. In the eastern Pioneer Mountains, local discontinuous beds of nongastropod-bearing limestone lie directly above the gastropod limestone and are interbedded with rocks typical of the lower Blackleaf to which they are assigned (Dyman and Nichols, 1988; Tysdal and others, 1989a, Dyman and Tysdal, 1990). C.A. Wallace (unpub. data, 1989) has placed similar post-gastropod limestone beds within the uppermost part of the Kootenai Formation in the Flint Creek Mountains and in the area near Drummond (fig. 1). Throughout the area of this study, strata directly above the gastropod limestone contain laterally discontinuous interbeds of dark-gray shale, sandstone, and mudstone. Kootenai-Blackleaf contact relationships change from place to place. McGill (1957, 1958) considered the interval transitional in the northwestern part of the Flint Creek Range. Gwinn (1965) placed the top of his Kootenai Formation at the base of a conglomerate bed directly above the gastropod limestone. This conglomerate bed forms a sharp contact between the two units but is seldom found in his map area. Wallace and others (1986) placed transitional beds of calcareous sandstone, siltstone, and shale, which overlie the gastropod limestone, within the upper part of the Kootenai Formation.

The Kootenai is considered Aptian in age by most workers (Suttner, 1969; James, 1977; Vuke, 1984; Schwartz, 1972, 1983). The upper part of the Kootenai lies within the lower Albian based on palynomorph biostratigraphy of lithically equivalent rocks in southern Alberta by (Burden, 1984). A palynomorph assemblage, including the species *Appendicisporites jansonii,* was collected from the "gastropod limestone" in the uppermost part of the Kootenai Formation in the Lima Peaks area south of our study area. *Appendicisporites jansonii* ranges from Berriasian to late Albian (Dyman and Nichols, 1988; Dyman and others, 1988). Palynomorphs were not recovered from samples of the uppermost Kootenai at the base of the five measured sections in the study area.

BLACKLEAF FORMATION

Cobban and others (1959, 1976) named four members of the Blackleaf Formation in northwestern Montana (from bottom to top): Flood, Taft Hill, Vaughn, and Bootlegger (fig. 2). Gwinn (1960, 1961, 1965) subdivided the Blackleaf into the Flood, Taft Hill, and Dunkleberg Members near Drummond, Mont. Wallace and others (1986) and Schmidt and others (in press), following extensive mapping in the vicinity of Drummond, did not use the name Dunkleberg because the rocks are similar to those of the type Vaughn, a regionally used name that predates Dunkleberg.

The name Flood was used in the eastern Pioneer Mountains by Schwartz (1972, 1983), Dyman and others (1988), and Dyman and Tysdal (1990). Dyman and Nichols (1988) used informal names for lithic units of the Blackleaf Formation. Lewis (1989) described and mapped similar strata in the eastern part of the Dickie Peak 7.5-minute quadrangle, a few miles northwest of the Jerry Creek measured section (fig. 1); she divided lower Blackleaf strata into six informal map units (Kbl_1–Kbl_6) equivalent to the Flood Member and overlying Vaughn Member. We use the name Flood in the

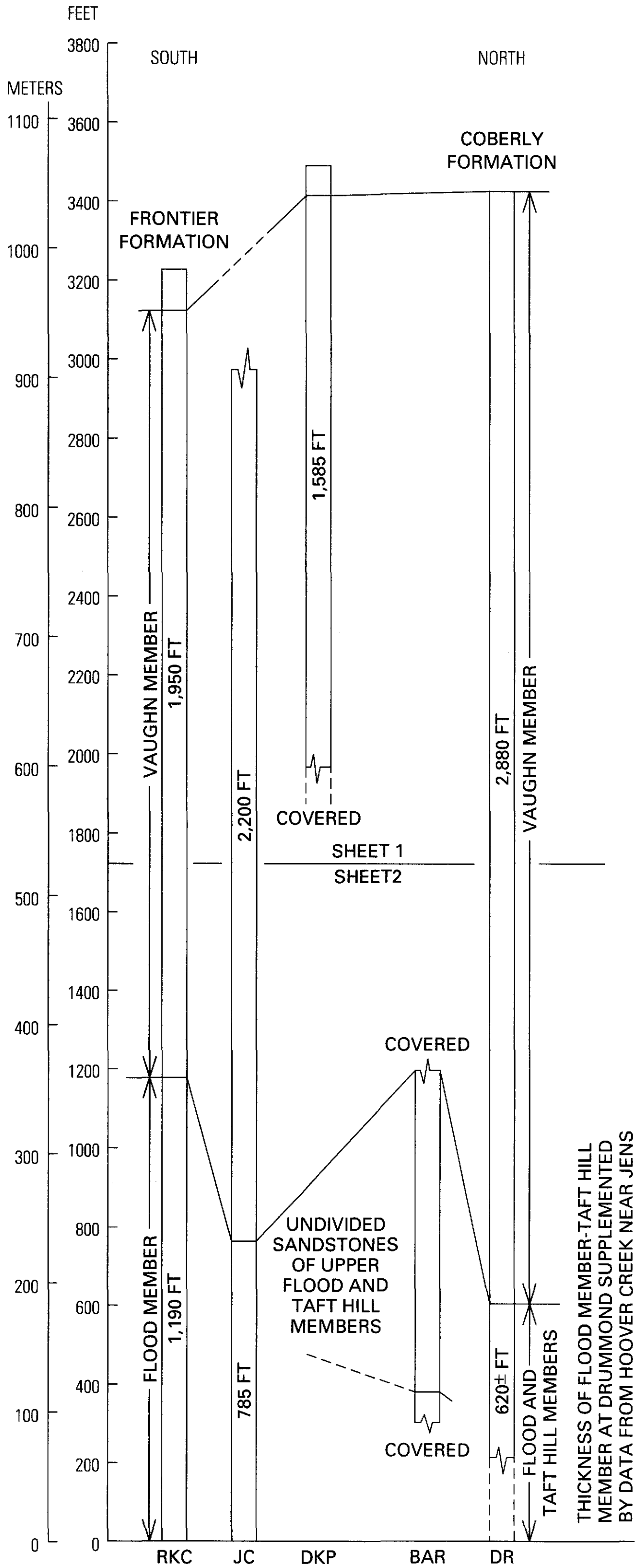

Figure 3 (facing column). Diagram showing (1) relative thicknesses of Blackleaf Formation measured sections of this study and (2) parts of each measured section presented on each sheet. RKC, Rock Creek; JC, Jerry Creek; DKP, Dickie Peak; BAR, Barnes Creek; DR, Drummond.

eastern Pioneer Mountains northward to Drummond, but recognize that rocks of this member in the area of this study differ from those southward at Lima Peaks and at the type section at Flood Siding near Great Falls in Cascade County, Mont. (fig. 1). Use of the term Taft Hill Member by Gwinn (1960, 1961, 1965) in the northern Flint Creek Range is appropriate, but we introduce an informal term "undivided sandstones" where Taft Hill rock types cannot be easily distinguished from rocks of the upper Flood. We correlate these undivided sandstones with the upper part of the Flood in the eastern Pioneer Mountains. In the Drummond area, undivided sandstones resembling the Taft Hill Member are restricted to the lower part of the Taft Hill (as recognized by Gwinn, 1960, 1961, 1965) which is composed of interbedded tan-weathering lithic sandstone and dark-gray shale.Overlying beds of lithic sandstone, siltstone, and mudstone that were originally included within the Taft Hill by Gwinn were assigned to the lower Vaughn by Wallace and others (1986). We agree with this assignment and place these beds in the lower part of the Vaughn Member in the Drummond area and northern Flint Creek Range because of the change in lithology. Sandstone of the overlying Vaughn is coarser-grained than sandstone of the Taft Hill (and our undivided sandstones), and the Vaughn contains interbeds of conglomerate. Taft Hill beds contain abundant marine and brackish-water bivalves, whereas the Vaughn contains no marine fossils. The Vaughn contains less dark-gray shale and more siltstone than the Taft Hill.

We follow our previous work (Tysdal and others, 1989a; and Dyman and Tysdal, 1990) and use the name Vaughn for the upper member of the Blackleaf in the eastern Pioneer Mountains, the Mt. Fleecer area, the Flint Creek Range, and the Drummond area. We recognize Schwartz's (1972, 1983) intervals of the Blackleaf Formation (designated by him as intervals A through D), although the upper part of his interval D in the eastern Pioneer Mountains includes strata that we assign to the Frontier Formation.

General correlation of the Blackleaf Formation in southwestern Montana with the formation near Drummond and on Blackleaf Creek northwest of Great Falls was established previously (Gwinn, 1960, 1961, 1965; Schwartz, 1972, 1983; Mudge, 1972; Cobban and others, 1976; James, 1977; Perry and others, 1983; Perry, 1986; Dyman and Nichols, 1988), but detailed correlation of members through the use of published measured sections had not been undertaken previously. We do not identify interbedded fine-grained sandstone and bentonitic shale typical of the Taft Hill Member of Cobban and others (1976) near Great Falls in the eastern Pioneer Mountains.

In the study area, the Blackleaf Formation ranges from a minimum thickness of 3,135 ft (956 m) at the Rock Creek section in the eastern Pioneer Mountains to a maximum of 3,450 ft (1,052 m) at the Drummond section (fig. 3). The

Blackleaf is at least 2,985 ft (910 m) thick at the Jerry Creek section, but the upper part of the Vaughn Member is not exposed and was not measured.

Flood and Taft Hill Members of the Blackleaf Formation

The Flood Member of the Blackleaf Formation in the eastern Pioneer Mountains is composed of three informal lithologic units that Dyman and Nichols (1988) designated as lower sandstone, middle shale, and upper sandstone (Fig. 2). These units show extensive lithologic and thickness variations, reflect several different depositional environments, and can be used for stratigraphic correlation throughout the region. The units form the basis for our discussion of the Flood Member.

The Flood Member ranges in thickness from a minimum of 785 ft (239 m) at the Jerry Creek section to 1,185 ft (361 m) at the Rock Creek section. The total thickness of the Flood could not be determined at the Barnes Creek and Drummond measured sections because the base of the Flood was not exposed, and because of difficulties in differentiating between the upper sandstone unit of the Flood and the overlying Taft Hill Member (see discussion below).

Lower sandstone unit of the Flood Member

The lower sandstone unit forms the base of the Flood Member at each of the three southernmost measured sections in the study area and consists of gray to green and red calcareous mudstone and siltstone and fine- to medium-grained quartz- and chert-rich sandstone. Minor micritic and nodular limestone, limestone conglomerate, and dark-gray shale form thin and lenticular interbeds. The unit contains mudstone zones that have abundant limestone nodules. At the Rock Creek measured section in the eastern Pioneer Mountains, sandstone is lithic-rich and contains abundant limestone detritus; it is quartz-rich at the Jerry Creek measured section and at the Avon locality (Appendix). The lower sandstone unit may be present at Drummond but it is not exposed at the measured section. It is present along Hoover Creek near Jens, Mont., about 8 mi (13 km) east of the Drummond section (fig. 1; Appendix) where it is only 50 ft (15 m) thick and only partly exposed. The sequence above the gastropod limestone and below the black fissile shale of the middle shale unit of the Flood Member is 100–150 ft (30–45 m) thick (estimated) along Highway 10A west of Drummond. The Kootenai-Blackleaf contact lies in the lower part of this sequence.

The lower sandstone unit is about 250 ft (76 m) thick at the Rock Creek section and about 170 ft (52 m) at the Jerry Creek section. Gwinn (1965) described 60–90 ft (18–27 m) of quartz-rich sandstone east of Garrison, Mont., that we infer to be equivalent to the lower sandstone unit of the Flood Member. The lower sandstone unit was not identified by us in the southern Flint Creek Range at the Lost Creek locality north of Anaconda (Appendix), but it is present about 2 mi east of Opportunity, Mont., in unnamed drainages of Homestead and Perdee Creeks. The rocks are metamorphosed to hornfels. The lower sandstone unit is the lithic equivalent of the lower sandstone member of Thermopolis Shale in the Gravelly, Greenhorn, and Madison Ranges of southwestern Montana and the Fall River Sandstone in east-central Montana.

Middle shale unit of the Flood Member

The middle shale unit of the Flood Member is gradational with the lower sandstone unit and contains abundant shale and subordinate mudstone, siltstone, and fine-grained quartz-rich sandstone. At the Drummond and Jerry Creek measured sections, dark-gray fissile shale is the dominant lithology, whereas at the Rock Creek measured section, nodular mudstone is interbedded with shale. The upper part of the unit near Drummond contains 10–50 ft (3–15 m) of interbedded shale and olive-green siltstone that grades downward into more typical dark-gray shale. Thin beds of ripple-marked, fine-grained sandstone and siltstone accompany shale and mudstone at each of the measured sections.

Trails and burrows are abundant on some bedding surfaces at each of the localities, but fossils are rare. We collected *Brachiodontes* sp., a non age-diagnostic bivalve found in brackish-water environments (W.A. Cobban, written commun., 1988), from the middle shale unit at Frying Pan Gulch, about 8 mi south of the Rock Creek measured section.

Although the shale unit is metamorphosed to a hornfels at the Opportunity locality (Appendix), it resembles the black shale beds at the measured sections. The middle shale unit varies in thickness from 340 ft (104 m) at Jerry Creek to about 350 ft (107 m) at Rock Creek. It is only partially exposed at the Barnes Creek and Drummond sections (minimum thickness is 66 ft (20 m) at Drummond section) but is at least 200 ft (61 m) thick at the Avon locality (Appendix). Gwinn (1960, 1961, 1965) recognized from 450 to 500 ft (137 to 152 m) of equivalent rocks in the middle part of the Flood in the Drummond area.

The middle shale unit is equivalent to the upper shale member of the Thermopolis Shale to the southeast in the Gravelly, Greenhorn, and Madison Ranges and in areas farther east in east-central Montana. It is equivalent to the Thermopolis Shale as used in Wyoming.

Upper sandstone unit of the Flood Member

In this section we describe the upper sandstone unit of the Flood Member for all of the study area except near Drummond, where stratigraphic and sedimentologic complications exist. We discuss the upper sandstone unit of the Drummond area in the section entitled "undivided sandstones."

In the eastern Pioneer Mountains, the upper sandstone unit of the Flood contains quartz- and chert-rich sandstone and subordinate mudstone, siltstone, shale, and rare conglomerate. The contact of the upper sandstone unit with the underlying middle shale unit may be sharp or gradational. Dark-gray fissile shale of the middle Flood is often overlain by less fissile brownish-gray silty shale and interbedded siltstone and sandstone of the lower part of the upper sandstone unit of the Flood or Taft Hill. Porter and others (1993) identified a regional unconformity within or at the base of the upper sandstone unit of the Flood in southwestern Montana and in equivalent rocks in east-central Montana.

The upper sandstone unit forms distinctive ridges at outcrop localities in the eastern Pioneer Mountains, and the top of the unit is marked by a topographic break. At the Jerry Creek measured section, the unit is poorly exposed and it is composed of thin to medium beds of quartz- and chert-rich sandstone in an upward-coarsening and thickening sequence.

Few identifiable megafossils were found in the upper sandstone unit of the Flood Member. A single specimen of *Anomia* (identified by W.A. Cobban, *in* Meyers, 1952) was found at the base of the upper sandstone unit of the Flood Member in the eastern Pioneer Mountains about 6 mi (10 km) south of the Rock Creek measured section.

The upper sandstone unit of the Flood is about 600 ft (183 m) thick at Rock Creek and only about 260 ft (79 m) at Jerry Creek. It is the lithic equivalent of the Muddy Sandstone to the southeast in the Gravelly, Greenhorn, and Madison Ranges, and of the unnamed sandy member of the Thermopolis Shale in east-central Montana (Porter and others, 1993).

Undivided sandstones of the Flood and Taft Hill Members

We use "undivided sandstones" on the chart for both the upper sandstone unit of the Flood and the Taft Hill in the Drummond area to accommodate existing nomenclature and mapping and to avoid confusing the two sandstones (upper Flood and Taft Hill) within the framework of existing definitions. Our reasoning is explained in the following paragraphs.

Criteria used to distinguish the Taft Hill from the Flood Member were set forth by Cobban and others (1976), and the criteria emphasized the use of volcanic detritus and depositional environments. At its type section near Great Falls, the Taft Hill is marine and contains abundant bentonitic shale, greenish-gray glauconitic sandstone, siltstone, and concretionary limestone, whereas the upper part of the Flood is nonmarine and contains chert- and quartz-rich sandstone, siltstone, and carbonaceous shale.

Westernmost outcrops of the upper sandstone unit of the Flood Member and the Taft Hill Member of the Blackleaf Formation in Sun River Canyon west of Great Falls (Mudge, 1972) can be readily distinguished and subdivided using criteria established by Cobban and others (1976). In the Drummond area, however, equivalent rocks were deposited farther west than those at both Great Falls and Sun River Canyon. These rocks represent a westernmost facies now only preserved in the Drummond area (including the Drummond and Barnes Creek measured sections and exposures along Hoover Creek; Appendix). Strict application of the criteria for differentiating upper Flood from Taft Hill rocks (Cobban and others, 1976) in the Drummond area is difficult because rocks at Drummond (1) were deposited in environments different from those at Great Falls, (2) are slightly older than those at Great Falls, and (3) lack the significant volcanic component of those at Great Falls. At Drummond, the Taft Hill may predate much of the regional volcanism observed in the Taft Hill at Great Falls.

Wallace and others (1986) were able to distinguish two sandstone units (upper Flood and Taft Hill) within their map area at Drummond, but because of local variations in depositional environments, differentiating one sandstone unit from another was difficult. For instance, our measured section at Barnes Creek contains a mixed fresh-water(?), brackish-water, and marine fauna throughout the interval; therefore, it might best be assigned to the Taft Hill Member. However, using physical properties of the sequence, Wallace and others (1986) believed the lowermost sandstone beds at Barnes Creek might best be assigned to the upper part of the Flood Member.

At Drummond, Wallace and others (1986) mapped the lower part of the sequence as Flood and the upper part as Taft Hill. On the basis of physical criteria, this seems appropriate even though no marine fossils were collected from the upper part. At Hoover Creek, we found no marine fossils, but the physical character of the sequence suggests that the unit is mostly marine, the lower part of which is lower shoreface and the upper part is upper shoreface.

Gwinn (1960) identified the Taft Hill Member as far south as McCartney Mountain and the eastern Pioneer Mountains but we do not. Sandstone beds in the eastern Pioneer Mountains are placed in the upper Flood because they are medium to coarse grained, are interbedded predominantly with mudstone and siltstone rather than shaly siltstone and silty shale, and they are predominantly nonmarine. Our stratigraphic analysis supports the conclusions of Gwinn (1960, 1961, 1965) and of Wallace and others (1990) who assigned these sandstone and shale beds to the Taft Hill Member in the northern Flint Creek Range and Drummond area. The northward thickening of the upper Flood interval appears to be accompanied by a change to a more marine environment, which is likely to be responsible for the facies differences between Taft Hill and Flood. Sandstone of the upper Flood in the eastern Pioneer Mountains south of the study area is generally medium to coarse grained and fluvial in origin (Flores and others, 1990; Porter and others, 1993). If the "Drummond facies" were more regionally widespread, application of a unique name would be appropriate, but the restricted areal preservation leads us to use the informal general name "sandstones undivided" for both the upper sandstone unit of the Flood and the Taft Hill Members together.

UNDIVIDED SANDSTONE AT DRUMMOND

In the Drummond area, the undivided sandstone is underlain by olive-green to gray-green silty shale. Sandstone is generally medium to coarse grained and may contain large-scale cross beds. At the Drummond measured section, two sandstone beds are present and are separated by mudstone and siltstone beds similar to those found at the base of the Flood Member. Based on physical criteria, Wallace and others (1986) mapped the lower part as Flood and the upper part as Taft Hill. The upper contact of the undivided sandstone at the Drummond measured section is different from the contact established by Gwinn (1960, 1961, 1965). Gwinn included olive-green mudstone and maroon siltstone and mudstone above tan-weathering fine-grained platy sandstone of the Taft Hill within his Taft Hill Member, but these overlying sandstone beds are included within the lower part of the Vaughn Member (Wallace and others, 1986).

UNDIVIDED SANDSTONE AT BARNES CREEK

Undivided sandstone at the Barnes Creek section in the northern Flint Creek Range consists of tan-weathering fine-grained sandstone and interbedded dark-gray shale, siltstone, and mudstone. Sandstone is flat and thin bedded and platy or rippled and crossbedded. Low-angle trough and hummocky crossbeds are common. Alternating beds of sandstone and shale range from a few feet to tens of feet thick in the sequence. Siltstone becomes shaley upward within the sequence. Shale is generally calcareous and silty and is less fissile and lighter gray than shale in the underlying middle shale unit of the Flood Member. Sandstone decreases in abundance upward and is replaced by siltstone and mudstone at the base of the lower Vaughn.

A fossil collection from the undivided sandstone at Barnes Creek indicated a mixed marine, and (or) brackish- and fresh-water(?) assemblage including *Ostrea* sp, *Pleuribema*? sp., and *Murraia*? sp. (W.A. Cobban, written commun., 1992).

Facies changes relating the upper sandstone unit of the Flood Member from the Jerry Creek measured section to the undivided sandstone at the Barnes Creek measured section are not fully understood. Although metamorphosed, beds overlying the middle Flood shale unit at the Opportunity locality (Appendix) more closely resemble upper Flood sandstone beds at the Rock Creek measured section than beds of the undivided sandstone at the Barnes Creek measured section.

The undivided sandstone is 380 ft (116 m) thick at Drummond and 570 ft (15 m) thick at the Barnes Creek section. It is the lithic equivalent of both the upper sandstone unit of the Flood Member and the Taft Hill Member of Cobban and others (1976) near Great Falls and of Mudge (1972) at Sun River Canyon.

VAUGHN MEMBER OF THE BLACKLEAF FORMATION

The name Vaughn Member was applied by Tysdal and others (1989a, b) to nonmarine strata overlying the Flood Member in southwestern Montana south of the study area. They presented measured sections in the Madison, Greenhorn, and Snowcrest Ranges, and in the Lima Peaks area. Dyman and Tysdal (1990) applied the name to equivalent strata in the eastern Pioneer Mountains. In this report we correlate the Vaughn and extend the upper contact described by Dyman and Tysdal (1990) northward to the Drummond area. Strata above the upper contact in the eastern Pioneer Mountains are best exposed in the vicinity of the Rock Creek measured section. At Rock Creek, strata overlying the Vaughn include brown-weathering siltstone, sandstone, and gray mudstone. Strata above the Vaughn in the Drummond area represent a sandstone-limestone facies of the marine Coberly Formation (Gwinn 1960, 1961, 1965; Wallace and others, 1986).

The Vaughn Member contains abundant volcanic detritus. Rock types include mudstone, tuff, porcellanitic tuff, porcellanitic mudstone, siltstone, volcaniclastic sandstone, chert- and quartzite-pebble conglomerate, and limestone. Mudstone and siltstone are the dominant rock types and are generally olive green to gray and commonly calcareous. Some mudstone beds, particularly in the lower and middle Vaughn at Rock Creek, exhibit porcellanitic textures, but are nonvolcanic in origin and resulted from thermal alteration associated with the Pioneer batholith. Lithophysae as much as 0.1 in. (0.03 cm) in diameter occur in tuffaceous and porcellanitic beds at all of the measured sections. Brown siltstone is abundant in the middle and upper Vaughn in the eastern Pioneer Mountains, at the Lost Creek locality in the southern Flint Creek Range (Appendix), and at the Dickie Peak measured section.

Conglomerate is present locally in the basal parts of several sandstone units throughout the Vaughn. Wallace and others (1986) recognized a distinctive zone of conglomerate near the middle of the Vaughn in the northern Flint Creek Range and in the Drummond area. Mudge (1972) described pebble- and cobble-conglomerate beds in the lower and middle part of the Vaughn in the Sun River Canyon area west of Great Falls, Mont. Schmidt (1978) identified similar conglomerate beds in the Vaughn in the Wolf Creek area about 30 mi (50 km) north of Helena, Mont. South of Drummond and south of the northern Flint Creek Range, conglomerate is more widely distributed within the Vaughn. Conglomerate is primarily composed of white to gray and pink quartzite and dark-gray chert. At least one conglomerate unit at the Rock Creek section contains limestone clasts. Conglomerate zones are lenticular and some are several tens of meters or more in width. Conglomerate beds may be abundant or absent near the top of the Vaughn in the eastern Pioneer Mountains south of the Rock Creek section (Dyman and Nichols, 1988; Dyman and Tysdal, 1990). Metaconglomerate is abundant in at least one horizon at the Beal Mine locality and at several horizons within the Vaughn at the Opportunity locality (fig. 1; Appendix).

The Vaughn Member ranges in thickness from a minimum of 1,950 ft (594 m) at the Rock Creek measured section to 2,880 ft (878 m) at the Drummond measured section. The member is 2,200 ft (671 m) thick at the Jerry Creek section and 1,585 ft (483 m) thick at the Dickie Peak section (fig. 3) but these are minimum thicknesses. The thickness increase northward from Rock Creek to the Drummond measured section (fig. 3) is accompanied by an increase in sandstone and conglomerate. Such lateral thickness changes are typical for continental deposition during active tectonism.

In the eastern Pioneer Mountains, the base of the Vaughn is at the base of a brown nonvolcanic mudstone-siltstone unit directly above gray and brownish-gray sandstone of the upper sandstone unit of the Flood Member. Mudstone and siltstone contain rare quartzite- and chert-clast conglomerate and quartz- and chert-rich sandstone. The lower Vaughn mudstone-siltstone interval varies in thickness from section to section, but it is overlain everywhere by porcellanitic mudstone and siltstone of the middle and upper Vaughn.

The upper contact of the Vaughn Member is easily traced northward from the eastern Pioneer Mountains to Drummond. In the eastern Pioneer Mountains, the upper contact is unconformable and represents a change in lithology from porcellanite-rich rocks below the contact in the upper Vaughn to porcellanite-poor rocks above the contact in the Frontier Formation. Conglomerate and sandstone occur in the porcellanite-bearing Vaughn sequence as well as higher in the section. The abundant volcanic and volcaniclastic components, particularly porcellanite, combined with conglomerate, sandstone, and siltstone, provide a unifying characteristic in the upper part of the Vaughn throughout the region. This characteristic led Tysdal and others (1989b) to use the name Vaughn in southwestern Montana. Porcellanitic rocks are abundant in the Vaughn Member throughout the area of the measured sections, but porcellanitic mudstone is rare in the overlying Frontier Formation in the eastern Pioneer Mountains, northward to the southern part of the Flint Creek Range, in the Coberly Formation in the northern Flint Creek Range, and near Drummond. At the Rock Creek measured section and at the Opportunity locality, the uppermost significant porcellanite (minimum thickness 10 ft; 3 m) is overlain by a sequence of brown siltstone and interbedded "salt-and-pepper" sandstone. The brown siltstone interval is present at the Lost Creek locality, but "salt-and-pepper" sandstone is rare. Metamorphosed rocks of the middle and upper Vaughn are preserved in several well-exposed outcrop belts at the Beal Mine locality (Appendix). Although metamorphosed to hornfels, porcellanite has retained its fine laminations and is easily recognizable. No post-Vaughn strata were recognized at the Beal Mine locality.

We chose the top of the Vaughn Member in the study area based on the volcanic/volcaniclastic criterion that is readily mappable. The contact criteria were set forth in Dyman and Tysdal (1990) and are repeated below.

An association of distinctive rock types is present in the uppermost part of the Vaughn Member. The association consists of maroon mudstone and siltstone, gray fresh-water limestone or locally very calcareous mudstone and siltstone, dark-gray shale, and bright-green porcellanite. The top of the member was chosen as the top of a porcellanite that consistently and directly overlies the highest maroon mudstone. This porcellanite unit is interbedded with micritic limestone beds. We have found the maroon beds and associated limestone, dark-gray shale, and porcellanite to extend for more than 105 mi (175 km), from about 20 mi (33 km) south of the Rock Creek measured section in the eastern Pioneer Mountains (Frying Pan Gulch measured section of Dyman and Tysdal, 1990; fig. 3) to Drummond (fig. 1). The contact is covered at the Drummond section, but it is well exposed at the Hoover Creek locality near Jens, Mont. (Appendix), where the uppermost bed of bright-green porcellanite is interbedded with sandstone and limestone typical of the lower part of the overlying Coberly Formation (see discussion below). Gwinn (1960, 1961, 1965) and Wallace and others (1986) recognized the base of the Coberly by distinctive rock types including brown calcareous salt-and-pepper sandstone and interbedded fossiliferous limestone.

Maroon siltstone and mudstone beds of the upper Vaughn are commonly calcareous, contain small (less than 0.5 in. (1.3 cm) in diameter) calcareous nodules, and are mottled gray green from bioturbation. Maroon and green banding locally cuts across bedding planes. The interval that contains maroon beds in the uppermost part of the member ranges in thickness from less than 20 ft (6 m) south of the Rock Creek measured section to more than 600 ft (183 m) at the Rock Creek and Drummond measured sections. It is as low as 500 ft (152 m) below the top of the Vaughn at the Rock Creek measured section, where eight individual maroon beds were identified, but only the uppermost maroon beds are associated with limestone and bright-green porcellanite. The maroon color may be related to paleosols in the upper Vaughn (Porter and others, 1993) and its association with nonmarine limestone, dark-gray shale, and bright-green porcellanite makes it useful as a stratigraphic marker.

Porcellanite near the top of the Vaughn is commonly bright green or very light gray, whereas porcellanite in the lower Vaughn is light green, gray, pink, or white. The zone of bright-green porcellanite in the uppermost Vaughn reaches a maximum thickness of more than 50 ft (15 m) at the Rock Creek section. The limestone beds at the top of the Vaughn Member in the eastern Pioneer Mountains are light to dark gray, silty, nodular, and concretionary. In the northern Flint Creek Range and at Drummond, limestone beds of the overlying Coberly Formation contain diagnostic marine megafossils that are not in Vaughn limestone.

Our Vaughn Member includes the upper part of Meyers' (1952) map unit Ku_2 and all of map unit Ku_3 (eastern Pioneer Mountains), although contact relations with these units are difficult to interpret from his discussion. Zen (1988) included strata that we refer to as Vaughn Member as his upper part of the Colorado Group (Kcu) in the eastern Pioneer Mountains. He also mapped individual conglomerate beds (Kcc) within his upper member. Based on geologic mapping, we infer that some strata of Zen's upper member are actually part of a younger and poorly understood depositional sequence. Zen's (1988) upper member, which is lithically and stratigraphically different from the Vaughn, is part of the Frontier Formation (R.G. Tysdal, T.S. Dyman, and S.E. Lewis, unpub. data, 1988).

No age-diagnostic fossils were found in the Vaughn Member in the study area. The freshwater clam *Plesielliptio* sp. and gastropod fragments (identifications by W.A. Cobban, written commun., 1983) were collected from a limestone bed in the uppermost part of the Vaughn at the Apex measured section about 20 mi south of the Rock Creek measured section (Dyman and Nichols, 1988; fig. 3). Several specimens of the seed fern *Tempskya* were found at measured sections in the eastern Pioneer Mountains; it is common in both Albian and Cenomanian strata in the Rocky Mountain region (Read and Ash, 1961). Cobban and Kennedy (1989) identified ammonites from the lower part of the equivalent Mowry Shale in Montana and Wyoming as early Cenomanian in age. Because the Vaughn Member is considered a nonmarine equivalent of the Mowry, it is also considered early Late Cretaceous in age.

Zartman and others (in press) used Pb-U age spectra on zircons from distinctive green porcellanite beds in the upper part of the Vaughn Member in order to determine the age of these strata. Ages ranged from (1) 95.8–97.2 Ma (early Cenomanian) for samples taken about 600 ft (182 m) below the top of the Vaughn in the eastern Pioneer Mountains and at Drummond to (2) 93–96 Ma (early middle Cenomanian) for samples taken at the top of the Vaughn in the eastern Pioneer Mountains. Stage assignments are based on recent revisions of the Cretaceous time scale by Obradovich (1993).

The Vaughn Member in the study area is correlative with the Vaughn Member at Lima Peaks and Mowry Shale to the east in the Gravelly, Greenhorn, and Madison Ranges (Tysdal and others, 1989b).

FRONTIER AND COBERLY FORMATIONS

Strata directly overlying the Blackleaf Formation differ markedly between Drummond in west-central Montana and the eastern Pioneer Mountains in southwestern Montana. At the Rock Creek section, strata directly overlying the uppermost porcellanitic mudstone of the Vaughn include chert-rich sandstone, conglomeratic sandstone, conglomerate, olive-green and dark-gray mudstone, dark-gray to brown siltstone, and limestone. Conglomerate clasts include quartzite and dark-gray chert; conglomerate forms discontinuous bodies encased in mudstone. Mudstone and siltstone form about 80 percent of the sequence. Conglomerate in the lower part of this post-Vaughn sequence forms beds more than 120 ft (37 m) thick as part of a total Vaughn measured section of 2,400 ft (732 m) where the upper part of the measured section terminates along the axis of a syncline. Frontier strata in the eastern Pioneer Mountains are coarser grained than typical Frontier strata to the east and southeast in Wyoming; however, the abundance of chert- and lithic-rich (salt-and-pepper) sandstone and interbedded siltstone, mudstone, and shale is typical of the Frontier in the region.

At the Lost Creek locality, several hundred feet of strata overlying the Vaughn are dominated by brown siltstone although these rocks are poorly exposed and the exact thickness of the sequence could not be determined. At the Dickie Peak section, the post-Vaughn sequence is poorly exposed but dark-gray shale and siltstone are abundant. These rocks are more similar to the Frontier than they are to the Coberly. No age information, from either fossils or radiometric methods, that may aid interpretation of lateral changes in facies have been obtained for these continental rocks in the Frontier in the eastern Pioneer Mountains.

In the Drummond area, rocks overlying the Vaughn are assigned to the Coberly Formation (Gwinn, 1960, 1961, 1965; Wallace and others, 1986; Wallace and others, 1990). The basal Coberly consists of interbeds of gray to brown mudstone, siltstone, sandstone, and rare limestone referred to as the "basal gray mudstone-siltstone-olive-sandstone facies" of Gwinn (1965). These rocks are generally thin bedded and variably calcareous. At least one thin, green porcellanite bed was identified within this interval at the Hoover Creek locality near Jens (fig. 1) at the type section of the Coberly Formation (Gwinn, 1965; T.S. Dyman and S.E. Lewis, unpub. data, 1991). This green porcellanite is above the uppermost green porcellanite that is associated with maroon siltstone of the uppermost Vaughn. Sandstone within the basal Coberly is strongly calcareous and chert- and quartz-rich. The Vaughn-Coberly contact is covered at the Drummond section but is well exposed and sharp at Hoover Creek (Appendix). No datable fossils have been recovered from the lower part of the Coberly (W.A. Cobban, oral commun., 1991), although an early middle Turonian age was determined for the upper part of the formation at Drummond on the basis of molluscan fauna (Cobban, 1991).

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APPENDIX

DRUMMOND MEASURED SECTION

Center of sec. 32, T. 11 N., R. 12 W., southeast to NE 1/4 sec. 5 and sec. 4, T. 10 N., R. 12 W. Section runs along north side of I–90 from sawmill on east side of Drummond east to Helmsville Road and further east about 1/4 mi. Drummond 15-minute quadrangle, Granite County, Mont. Originally measured by Gwinn (1960). Remeasured by Tysdal, Dyman, Lewis, and L.E. Davis, 1989 and 1990.

ROCK CREEK MEASURED SECTION

Secs. 26, 27, 28, T. 3 S., R. 10 W., Vipond Park 15-minute quadrangle, Beaverhead County, Mont. Along north side of Rock Creek along valley wall and protruding ridges. Measured by Tysdal and Dyman, 1987 and 1988.

DICKIE PEAK MEASURED SECTION

From an unsurveyed part of T. 2 N., R. 10 W., at the north end of ridge trending north from Hill 8,455 to Hill 8,554 (on Continental Divide) only a few hundred ft east of the west boundary of T. 10 W., Dickie Peak 7.5-minute quadrangle, Silver Bow County, Mont. Measured by Lewis, Dyman, and Tysdal, 1990 and 1991.

JERRY CREEK MEASURED SECTION

Unsurveyed part of T. 1 N., R. 10 W., along Spruce Creek from about 1/8 mi north of its intersection with Jerry Creek near Hill 6,276 north to hill 6,935, Silver Bow County, Mont., Wise River 7.5-minute quadrangle. Originally measured by Noel (1956). Remeasured by Tysdal and Dyman, 1987 and 1988.

BARNES CREEK MEASURED SECTION

NE 1/4 sec. 8, T. 9 N., R. 12 W., along unnamed tributary to Barnes Creek, about 8 mi south of Drummond, Granite County, Mont. Drummond 15-minute quadrangle. Measured by Dyman and Tysdal, 1992.

HOOVER CREEK LOCALITY

Center sec. 9, T. 9 N., R. 11 W., along west side of road and Hoover Creek, 2 mi north of I–90 at Jens exit. Garrison 15-minute quadrangle, Powell County, Montana. Exposures of Flood member of Blackleaf Formation on Saddle Mountain syncline. Vaughn Member exposed discontinuously south and west of this locality.

AVON LOCALITY

SE 1/4 sec. 31, T. 10 N., R. 9 W., along east side of U.S. Highway 12, about 4 mi west of Avon. Avon 15-minute quadrangle, Powell County, Mont. Roadcuts of upper Kootenai Formation and Flood Member of Blackleaf Formation.

BEAL MINE LOCALITY

Unsurveyed part of T. 2 N., R. 10 W., about 1 mi southwest of Beals Hill in Siberia Mining District, Dickie Peak 7.5-minute quadrangle, Silver Bow County, Mont. Sequence of Vaughn Member altered to metaconglomerate, hornfels, and quartzite.

OPPORTUNITY LOCALITY

Secs. 1 and 12, T. 4 N., R. 10 W., and secs. 6 and 7, T. 4 N., R. 9 W., along Homestead and Perdee Creeks and unnamed drainages, Deer Lodge and Silver Bow Counties, Mont. Opportunity and Warm Springs 7.5-minute quadrangles.

LOST CREEK LOCALITY

Secs. 11 and 14, T. 5 N., R. 11 W. Area between Antelope and Lost Creeks centered near Hills 7,215 and 6,931. Anaconda 15-minute quadrangle, Deerlodge County, Montana. Discontinuously exposed section of upper part of Vaughn Member and overlying unnamed rocks.

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