UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Measured Stratigraphic Sections of Lower Cretaceous Blackleaf Formation and Lower Upper Cretaceous Frontier Formation (Lower Part) in Beaverhead and Madison Counties, Montana

by

T. S. Dyman[1]

Open-File Report 85-431

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1985

[1]U.S. Geological Survey
P.O. Box 25046, MS 971
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

MEASURED STRATIGRAPHIC SECTIONS OF LOWER CRETACEOUS BLACKLEAF FORMATION AND LOWER UPPER CRETACEOUS FRONTIER FORMATION (LOWER PART) IN BEAVERHEAD AND MADISON COUNTIES, MONTANA

by

T. S. Dyman

INTRODUCTION

The Lower and lower Upper Cretaceous sequence in Beaverhead and Madison Counties, Montana, lie within and near the southwest Montana fold and thrust belt near the western depositional edge of the foreland basin (Kauffman, 1977). Eleven stratigraphic sections of the Aptian-Albian Kootenai Formation (uppermost part), the Albian Blackleaf Formation, and the Cenomanian Frontier Formation (lower part) were measured as part of a larger study to understand the regional stratigraphy, the sedimentology, and the petrography of the Cretaceous sequence in the region. A detailed analysis of this sequence may aid in (1) reconstructing the complex structural history of the fold-and-thrust belt and the depositional history of the foreland basin, and (2) evaluating the overall petroleum potential of the region.

Cretaceous rocks in the region (fig. 1) lie along the east flank of the Pioneer Mountains north of Dillon (measured sections 1 and 2); along the south flank of McCartney Mountain (measured sections 3 and 4); south of Dillon along Grasshopper Creek (measured section 5); along the north flank of the Blacktail Range south of Dillon (measured section 6); along the southeast flank of the Snowcrest Range (measured sections 7 and 11); and in the Gravelly Range (measured sections 8, 9, and 10) (Ross, Andrews, and Witkind, 1955; Schwartz,

1972; Mann, 1954; Hadley, 1980). An additional composite section south of Lima, Montana, was described in an earlier open-file report (Dyman, Niblack, and Platt, 1984).

The strata described here overlie older Mesozoic and Paleozoic sedimentary rocks and underlie the Upper Cretaceous Beaverhead Group (fig. 2). The Kootenai, Blackleaf, and Frontier Formations have been encountered in the neaby subsurface by drilling (Perry and others, 1983).

Because of faulting, slumping, and extensive covered intervals, secondary traverses were measured to verify interval thicknesses. Sections were measured using a Brunton compass and tape.

The following 6 preliminary lithofacies units were established for the sections:

(1) Frontier Formation--lower clastic lithofacies

(2) Blackleaf Formation--upper volcaniclastic lithofacies

(3) Blackleaf Formation--upper clastic lithofacies

(4) Blackleaf Formation--lower mudstone shale lithofacies

(5) Blackleaf Formation--lower transitional clastic lithofacies

(6) Kootenai Formation--upper carbonate lithofacies.

Palynomorphs were identified by D. J. Nichols, U.S. Geological Survey; mollusks were identified by W. A. Cobban, U.S. Geological Survey; and floral remains were identified by C. J. Smiley, University of Idaho, Moscow.

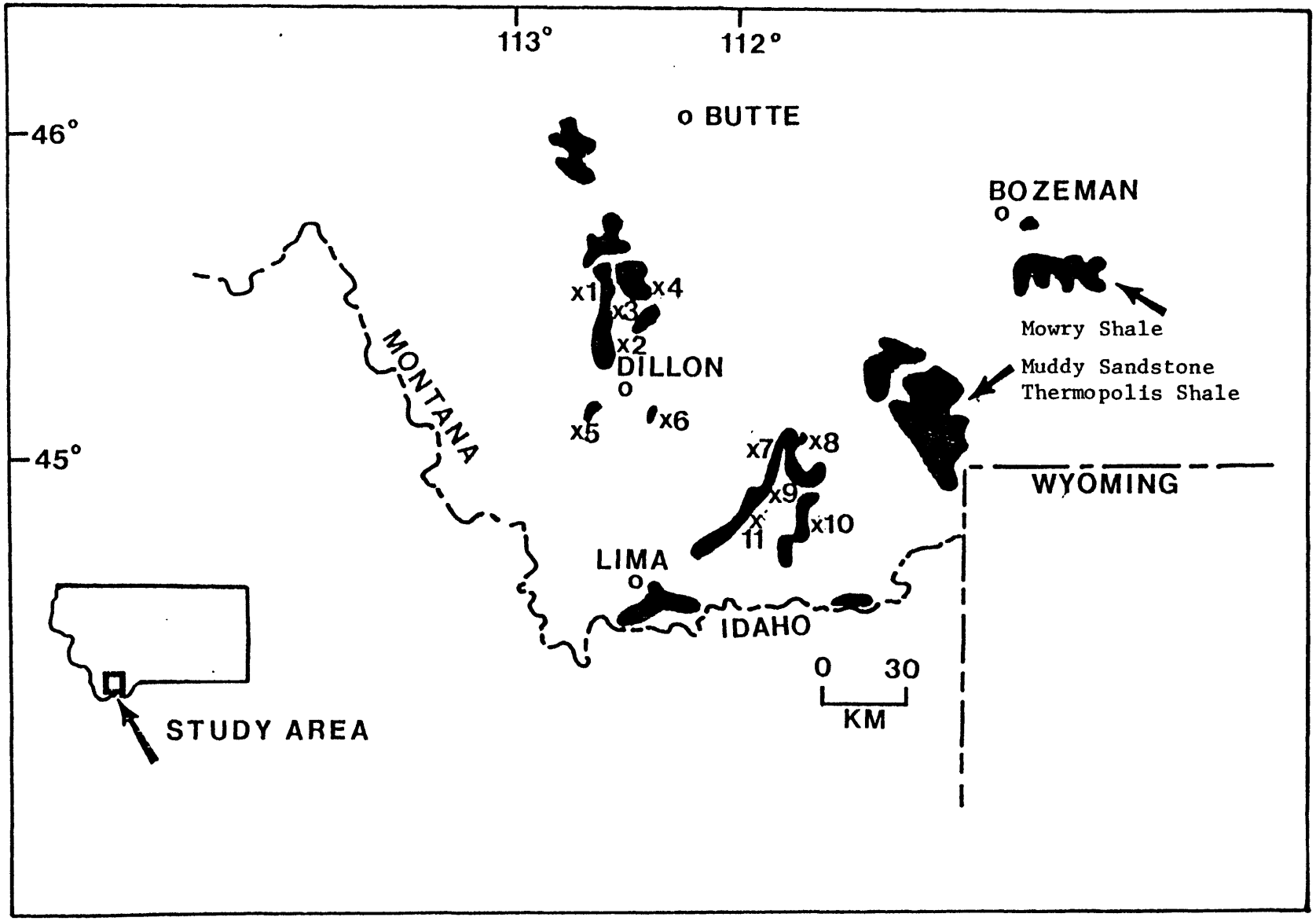

Figure 1.--Numbered outcrops of Blackleaf Formation, southwest Montana. Shaded areas represent known outcrop extent of Blackleaf Formation and its equivalents.

Figure 2.--Generalized geologic column, southwest Montana. Thickness values represent averages for region.

Maximum thickness ft. (m)	Age	Formation/ group (Gp)
5000 (1524)	Cenozoic	Undifferentiated
13000 (3962)	Upper Cretaceous	Beaverhead Gp. Frontier
2000 (610)	Lower Cretaceous	Blackleaf Kootenai
400 (133)	Jurassic	Morrison Swift Rierdon
1200 (360)	Triassic	Thaynes Woodside Dinwoody
800 (244)	Permian	Phosphoria
(2900) 884	Pennsylvanian	Quadrant Amsden
3500 (1007)	Mississippian	Big Snowy Gp. Mission Canyon Lodgepole
900 (274)	Devonian	Three Forks Jefferson
1000 (305)	Ordovician	Kinnikinic
1000 (305)	Cambrian	Pilgrim Park Meagher Wolsey Flathead

MEASURED SECTION 1 (Apex)

Frontier, Blackleaf, and Kootenai Formations along Barbour Gulch, eastern Pioneer Mountains, Beaverhead County, Montana:

[SE1/2 sec. 7, S1/2 sec. 6, T. 5S., R. 8 W., Twin Adams Mountain quadrangle; measured by T. S. Dyman and J. E. Platt, June-July, 1983]

Undifferentiated Frontier Formation:

unit		meters thickness	meters cumulative thickness
146.	Sandstone, dark-yellowish-orange to grayish-orange (10YR7/4); medium- to coarse-grained; angular-to-rounded grains; limonite stain; very calcareous; thick-bedded, with well developed trough cross-stratification; unit forms 3 fining-upward sequences with erosive bases.....	5.8	1027.3
145.	Mudstone and siltstone, olive-gray (5R4/1); weathers to light-olive-gray (5Y6/1); nodular, with limestone nodules up to 5 cm in diameter; very calcareous; weakly fissile; poorly exposed unit.....	6.5	1020.8
144.	Covered interval.....	10.0	1010.8
143.	Siltstone, light-olive-gray (5Y6/1); weathers to greenish-gray (5GY6/1); moderately calcareous; very thin-bedded.....	2.3	1008.5
142.	Sandstone, light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); fine-grained; rounded- to-subrounded grains; quartzose; thin-bedded; laterally discontinuous unit.....	0.9	1007.6
141.	Covered interval.....	5.3	1002.3
140.	Sandstone, yellowish-gray (5Y7/2); weathers to medium-gray (N5); medium-grained; weakly calcareous; rounded- to-subrounded grains; laterally discontinuous channel-like body with erosive base.....	0.8	1001.5
139.	Covered interval.....	3.7	997.8
138.	Sandstone, light-olive-gray (5Y5/2); fine-grained; rounded-to-angular grains; micaceous; limonite stain; wood fragments and finely disseminated coal; conglomeratic at base with green mudstone clasts up to 0.5 cm in diameter; laterally discontinuous unit...	1.0	996.8

Undifferentiated Frontier Formation contiuned:

unit		meters thickness	meters cumulative thickness
137.	Sandstone, pale-yellowish-brown (10YR6/2); weathers to brownish-gray (5YR4/1); fine- to medium-grained; rounded- to-subangular grains; and interbedded mudstone, light-olive-gray (5Y5/2); weathers to olive-gray (5Y4/1); sandstone, one thick bed (0.3 m), laterally continuous for 40 m along strike; unit limonite stained and moderately calcareous.....	11.5	985.3
136.	Covered interval.....	9.8	975.5
135.	Limestone, medium-bluish-gray (5B5/1); weathers to light-gray (N7); very fine-grained; poorly exposed unit.....	4.2	971.3
134.	Siltstone and mudstone, pale-yellowish-brown (10YR6/2); weathers to brownish-gray (5YR4/1); and locally contains rare fine-grained sandstone as discontinuous lenses; moderately calcareous.....	3.0	968.3
133.	Sandstone, pale-yellowish-brown (10YR6/2); fine-grained; rounded- to subangular grains; moderately calcareous; fines upward to overlying siltstones and mudstones.....	1.5	966.8
132.	Covered interval.....	4.5	962.3
131.	Sandstone, pale-yellowish-brown (10YR6/2); weathers to dark-yellowish-brown (10YR4/2); fine- to medium-grained; rounded-to-subangular grains; with thin interbedded mudstones; very calcareous; limonite stained; sandstones as discontinuous channel-like bodies grading upward from trough cross-stratification at base to ripple lamination at top; sandstone beds average 1 to 2 m thick.....	21.5	940.8
130.	Mudstone, gray-green (10GY5/2); weathers to greenish-gray (5GY6/1); moderately fissile; and sandstone, pale-yellowish-brown (10YR6/2); weathers to brownish-gray (5YR4/1); sandstone very fine-grained and thin-bedded; sandstone occurs as thin (less than 0.5 m) discontinuous channel-like bodies; poorly exposed.....	27.3	913.5
129.	Sandstone, light-olive-gray (5YR4/1); fine-grained; rounded-to-subangular grains; weakly calcareous; finely disseminated coal; and pale-yellowish-brown mudstone, moderately fissile and weakly calcareous; sandstone in channel-like bodies grading upward to mudstone.....	17.2	896.3

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
128.	Sandstone and mudstone, medium-gray (N5) to brownish-gray (5YR4/1); weathers to moderate-yellowish-brown (10YR5/4); sandstone predominatly medium-grained; very thin-bedded; cherty; limonite stained; sandstone occurs as 4 distinct channel-like bodies; rare dark-gray mudstone clasts near base of sandstone bodies; sandstone grades upward to mudstone.....	17.2	879.1
127.	Siltstone and sandstone, light-bluish-gray (5B7/1) to light-olive-gray (5YR4/1) to medium-gray (N5); siltstone moderately calcareous and ripple laminated; subordinate medium-grained sandstone; thin-bedded; finely disseminated coal fragments; quartzose.....	27.0	852.1
126.	Covered interval.....	21.5	830.6
125.	Sandstone and conglomerate, moderate-brown (5YR3/4) to olive-gray (5Y4/1); weathers to medium-gray (N5); medium- to coarse-grained; thick-bedded; angular-to-subangular grains; cherty; conglomerate as thin basal lag; trough cross-stratified with troughs up to 0.3 m thick.....	4.5	826.1
124.	Sandstone and mudstone, light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); sandstone very fine-grained; rounded-to-subangular grains; thin-bedded; very calcareous; sandstone as 3 distinct beds with erosive(?) bases; mudstone bioturbated and weakly fissile.....	4.0	822.1
123.	Sandstone and conglomerate, dark-yellowish-brown (10YR4/2) to very-pale-orange (10YR8/2); weathers from yellowish-gray (5Y8/1) to brownish-gray (5YR4/1); medium-grained; thin-bedded; very calcareous; conglomerate clasts are limestone and mudstone up to 0.5 cm in diameter; comglomerate as lag deposit at base of unit.....	12.6	809.5
122.	Sandstone, light-olive-gray (5Y6/1); weathers to moderate-yellow-brown (10YR5/4); very fine-grained; subrounded-to-angular grains; thin-bedded; finely disseminated coal; limonite stain; calcareous; scour marks and mudcracks on lower surface.....	2.4	807.1

Undifferentiated Frontier Formation continued:

unit		meters thickness	meters cumulative thickness
121.	Mudstone, siltstone and sandstone, dusky-yellow-green (5GY5/2) to pale-green (10G6/2); weathers to moderate-yellowish-brown (10YR5/4); sandstone very fine-grained; thin-bedded; weakly calcareous; sandstone and siltstone ripple laminated; mudstone moderately fissile; all lithologies appear gradational; poorly exposed....	44.6	762.5
120.	Siltstone and mudstone, light-gray (N7); weathers to medium-light-gray (N6); very calcareous siltstone unit with erosive base; fining upward to mudstone.....	3.6	758.9
119.	Sandstone, light-gray (N7); weathers to medium-light-gray (N6); very fine-grained; well-rounded grains; quartzose; strongly bioturbated with escape burrows; discontinuous with erosive base.....	2.4	756.5
118.	Mudstone, dusky red (5R3/4) to light-olive-gray (5Y5/2); weathers from olive-gray (5Y3/2) to grayish-red (5R4/2); moderately bioturbated with escape burrows; rare disseminated organic matter; weakly-to-moderately calcareous.....	6.4	750.1
117.	Sandstone and conglomerate, greenish-gray (5GY6/1); weathers to brownish-gray (5YR4/1); sandstone fine-grained; thin-bedded; mudstone clasts up to 1 cm in diameter in conglomerate; discontinuous channel-like unit with erosive base.....	0.5	749.6
116.	Siltstone, greenish-gray (5GY6/1); weathers to brownish-gray (5YR4/1); strongly bioturbated.....	0.5	749.1
115.	Covered interval.....	5.0	744.1
114.	Mudstone, dusky-red (5R3/4) to greenish-gray (5G6/1); weathers from medium-bluish-gray (5B5/1) to brownish-gray (5YR4/1); moderately calcareous; strongly bioturbated.....	6.5	737.6
113.	Siltstone and sandstone, greenish-gray (5GY6/1); weathers to olive-gray (5Y4/1); sandstone very fine-grained; rounded-to-subrounded grains; very calcareous; unit strongly bioturbated with escape burrows; lower part nodular with limestone nodules up to 2.0 cm diameter..	10.1	727.5
112.	Limestone, greenish-gray (5GY6/1); weathers to olive-gray (5Y4/1); medium-to-thick bedded; fossiliferous, with broken unidentified fragments; strongly bioturbated with escape burrows.....	1.0	726.5

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
111.	Sandstone, medium-bluish-gray (5B5/1); weathers to brownish-gray (5YR4/1); fine-grained; rounded-to-subrounded; very calcareous; nodular with limestone nodules up to 0.3 m diameter; erosive base; continuous for 30 m along strike.....	1.0	725.5
110.	Sandstone and conglomerate, medium-bluish-gray (5B5/1); weathers to brownish-gray (5YR4/1); sandstone medium-grained; rounded-to-subangular; moderately-to-weakly calcareous; medium-bedded with trough cross-stratification; unit composed of 2 erosively based fining upward sequences.....	16.0	709.5
109.	Sandstone and mudstone, light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); sandstone fine-grained; medium-bedded; weakly calcareous; mudstone fissile with rare carbonaceous matter, bentonitic(?); sandstone as discontinuous channel-like bodies forming the bases of fining-upward sequences.....	31.6	677.9
108.	Sandstone and conglomerate, dusky-yellow (5Y6/4); weathers to light-olive-gray (5Y5/2); sandstone coarse-grained; medium- to thick-bedded; very calcareous; lithic-rich and micaceous; conglomerate clasts predominantly chert, with clasts up to 2.0 cm in diameter; limonite stain; unit forms continuous ledge for 30 m along strike; erosive base with slight upward fining.....	1.9	676.0
107.	Siltstone and mudstone, light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); very-to-weakly calcareous; weakly-to-strongly fissile; tool marks; poorly developed ripple lamination in siltstone; unit strongly bioturbated with well-developed burrows; wood fragments on bedding planes; single impression of bivalve *Tellina* sp. identified by W. A. Cobban; siltstones more common near base of unit.....	19.1	656.9
106.	Sandstone, greenish-gray (5G6/1); weathers to light-olive-gray (5Y6/1); very fine-grained; rounded-to-subrounded grains; very calcareous; finely-developed horizontal laminations; gradational contact with overlying unit 107.....	1.5	655.4

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
105.	Mudstone, light-olive-gray(5Y6/1); weathers to olive-gray (5Y4/1); weakly calcareous; weakly-to-strongly fissile; bioturbated; finely disseminated organic matter.....	5.4	650.0
104.	Sandstone, moderate-yellowish-brown (10YR4/2); weathers to dark-yellowish-brown (10YR4/2); medium- to coarse-grained; angular-to-subrounded grains; very thickly bedded, with beds up to 0.5 m thick; cherty; strong limonite stain; unit with erosive base; fines upward and gradational with overlying mudstone unit; unit forms resistant ridge.....	4.8	645.2
103.	Sandstone and mudstone, moderate-yellow-brown (10YR5/4) to greenish-gray (5G6/1); weathers from dark-yellowish-brown (10YR4/2) to dark- greenish-gray (5GY4/1); fine- to very fine-grained; rounded-to-subangular grains; weakly calcareous; thin-bedded; mudstone in thin (less than 0.3 m thick) interbeds; strongly bioturbated; sandstones in discontinuous beds with erosive bases; poorly exposed unit.....	9.2	636.0
102.	Sandstone and conglomerate, greenish-black (5GY2/1) to grayish-black (N2); weathers from dusky-yellowish-brown (10YR2/2) to moderate-yellow-brown (10YR5/4); sandstone fine- to coarse-grained, but predominantly coarse-grained; angular-to-subrounded grains; micaceous; conglomerate forms basal lag; conglomerate clasts of dark-gray chert and porcellanite; unit forms discontinuous channel-like body and fines upward.....	2.5	633.5
101.	Sandstone, dusky-yellowish-green (10GY3/2) to light-olive-gray (5Y6/1); weathers from greenish-gray (5GY6/1) to pale-yellowish-brown (10YR6/2); fine-grained; rounded-to-subrounded grains; rare disseminated limonite grains; quartzitic; massive.....	8.5	625.0
100.	Mudstone and shale, dark-gray (N3) to dark-greenish-gray (5GY4/1); weathers to medium-light-gray (N6); hard; porcellanitic(?); weakly-to-strongly fissile....	3.3	621.7

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
99.	Sandstone and conglomerate, light-gray (N7) to medium-gray (N5); weathers from medium-gray (N5) to pale-yellowish-brown (10YR6/2); sandstone fine- to coarse-grained; rounded-to-subangular grains; quartzitic; conglomerate clasts up to 1.0 cm in diameter; clasts predominantly dark-gray chert and porcellanite; clasts oriented parallel to bedding and imbricated; unit medium-bedded with rare trough cross-stratification; trough sets up to 0.2 m thick; erosive base; fines upward and is continuous for 100 m along strike.....	7.4	614.3
Total thickness of undifferentiated Frontier Formation.....		418.8	

Blackleaf Formation upper volcaniclastic lithofacies:

98.	Mudstone and siltstone, medium-gray (N5); weathers to light-gray (N7); predominantly mudstone, with thin, discontinuous siltstone beds; mudstone porcellanitic and hard; lithophysae (Ross and Smith, 1961) up to 0.5 cm in diameter.....	14.3	600.0
97.	Sandstone and conglomerate, dark-gray (N3) to light-olive-gray (5Y6/1); weathers to moderate-yellow-brown (10YR5/4); fine- to medium-grained; subrounded-to-angular grains; conglomerate clasts dark-gray siltstone and porcellanite; clasts up to 2 cm in diameter; sandstone quartzitic and hard; unit conglomeratic and massive at base grading upward to fine-grained rippled sandstone near top; unit has with erosive base and is laterally discontinuous.....	2.8	597.2
96.	Porcellanitic mudstone and siltstone, light-olive-gray (5Y6/1) to olive-gray (5Y4/1); weathers to pinkish-gray (5YR8/1); very hard and dense, breaking into sharp angular fragments; small porcellanitic clasts up to 2 mm in diameter appears to be floating in porcellanitic matrix; ovular lithophysae abundant; single, thin discontinuous siltstone bed near middle of unit.....	13.2	584.0
95.	Covererd interval, presumed to be porcellanitic mudstone.....	20.5	563.5

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
94.	Porcellanitic mudstone and siltstone, light-olive-gray (5Y6/1) to olive-gray (5Y4/1); weathers to pinkish-gray (5YR8/1); very hard and dense, breaking into sharp angular fragments; small porcellanitic clasts up to 2 mm in diameter appear to be floating in porcellanitic matrix; ovular lithophysae abundant; single, thin discontinuous siltstone bed near middle of unit.....	4.0	559.5
93.	Sandstone and conglomerate, light-olive-gray (5Y6/1) to olive-gray (5Y4/1); weathers to medium-light-gray (N6); sandstone fine- to coarse-grained; rounded-to-angular grains; conglomerate clasts predominantly chert and porcellanite up to 1.5 cm in diameter; conglomerate in basal lag of laterally discontinuous unit; erosive base; unit gradational with overlying mudstone.....	2.5	557.0
92.	Porcellanitic mudstone, light-greenish-gray (5G8/1); weathers to light-greenish-gray (5GY8/1); very hard and dense, breaking into sharp angular fragments; predominantly structureless, but rare faint parallel laminations.....	5.7	551.3
91.	Sandstone, greenish-gray (5GY6/1); weathers to light-olive-gray (5Y6/1); fine-to medium-grained, predominantly fine-grained; angular-to-subangular grains; finely disseminated opaque(?) minerals; fine parallel laminations; hard and dense, highly fractured unit; forms erosive(?) base and discontinuous along strike.....	0.9	550.4
90.	Porcellanitic mudstone, light-greenish-gray (5G8/1); weathers to light-greenish-gray (5GY8/1); very hard and dense, breaking into sharp angular fragments; predominantly structureless, but rare faint parallel laminations.....	4.1	546.3
89.	Sandstone, light-bluish-gray (5B7/1) to dark-greenish-gray (5GY4/1); weathers from light-olive-gray (5Y6/1) to olive-gray (5Y4/1); very fine-grained; very hard and dense; moderately calcareous; unit structureless.....	0.3	546.0

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
88.	Mudstone and sandstone, very light-gray (N8) to medium-dark-gray (N4); weathers to light-brownish-gray (5YR6/1); sandstone very fine-grained; rounded-to-subrounded grains; quartzitic; ripple lamination; mudstone weakly fissile; hard and dense; sandstone as 2 thin discontinuous beds less than 0.3 m thick....	29.0	517.0
87.	Sandstone and mudstone, light-olive-gray (5Y5/2); weathers to moderate-olive-brown (5Y4/4); sandstone medium- to coarse-grained; subrounded-to-angular grains; feldspathic; micaceous; mudstone as thin (less than 0.3 m thick) bed separating 2 sandstone beds; sandstone beds with erosive bases and continuous along strike.....	2.9	514.1
86.	Porcellanitic mudstone, greenish-gray (5GY6/1); weathers to light-olive-gray (5Y5/2); very hard and dense; in part finely laminated; unit highly fractured.....	16.4	497.7
85.	Siltstone and mudstone, medium- bluish-gray (5B5/1); weathers to brownish-gray (5YR4/1); fine parallel laminations; hard and dense; predominantly siltstone, with thin (less than 0.2 m thick) porcellanitic mudstone bed near center of unit.....	3.7	494.0
84.	Porcellanitic mudstone and sandstone, light-greenish-gray (5G8/1) to light-bluish-gray (5B7/1); weathers to greenish-gray (5GY6/1); mudstone hard and dense; flow structures(?) and contorted bedding; sandstone very fine-grained; rounded-to-subangular grains; weakly calcareous; pyrite cubes up to 0.3 cm in diameter; ripple lamination; sandstone as 2 thin (less than 0.5 m thick) discontinuous beds within mudstone; ovular lithophysae up to 0.2 cm in diameter common.....	16.0	478.0
83.	Mudstone, sandstone, and conglomerate, greenish-gray (5GY6/1); weathers to olive-gray (5Y4/1); sand and conglomerate subordinate to and "floating" in mudstone matrix; conglomerate grains porcellanitic; hard and dense, breaking into sharp angular fragments; unit fines upward into overlying mudstone.....	1.8	476.2
82.	Porcellanitic mudstone, greenish-gray (5G6/1); weathers to olive-gray (5Y4/1); very hard and dense; in part finely laminated; pyrite cubes up to 0.3 cm present; poorly exposed.....	6.7	469.5

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	cumulative thickness
81.	Sandstone, greenish-gray (5GY6/1) to light-olive-gray (5Y6/1); weathers to brownish-gray (5YR4/1); fine- to medium-grained; subrounded-to-angular grains; cherty; finely disseminated carbonaceous matter and coal; pyrite cubes up to 0.2 cm in diameter; small scale quartz-filled fractures; unit coarsens upward and gradational with overlying mudstone unit.....	3.5	466.0
80.	Mudstone, light-olive-gray (5Y6/1) to dusky-yellow-green (5GY5/2); weathers to olive-gray (5Y4/1); poorly exposed.....	6.2	459.8
79.	Covered interval, presumed to be mudstone.....	4.1	455.7
78.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to medium-bluish-gray (5B5/1); medium-grained; mildly calcareous; quartzose; thin- to medium-bedded; erosive base presumed to be gradational with mudstone above.....	1.6	454.1
77.	Mudstone, dusky-red (5R3/4) to dark-greenish-gray (5GY4/1); weathers from olive-gray (5Y4/1) to grayish-red (10R4/2); mildly calcareous; bentonitic; massive to moderately fissile; poorly exposed.....	10.1	444.0
76.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to medium-bluish-gray (5B5/1); medium- to coarse-grained; angular-to-subrounded grains; weakly calcareous; micaceous; thin- to thick-bedded; forms discontiuous channel-like body with erosive base.....	1.7	442.3
75.	Porcellanitic mudstone and siltstone, grayish-green (10GY5/2); weathers to light-greenish-gray (5G8/1); weakly- to-moderately calcareous; mudstone hard and dense, breaking into sharp angular fragments; finely developed horizontal laminations; predominantly mudstone with 1 thin siltstone bed (less than 0.3 m thick) near base of unit.....	12.6	429.7
74.	Sandstone and conglomerate, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to light-olive-gray (5Y6/1); sandstone fine- to medium-grained; subangular-to-subrounded grains; weakly calcareous; quartzose; conglomerate clasts up to 3 cm in diameter; clasts predominantly greenish-gray (5G6/1); porcellanitic mudstone; clasts in part imbricated; conglomerate restricted to lower part of unit; unit		

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
	forms laterally restricted channel-like body with erosive base; fines upward and gradational with overlying mudstone unit.....	2.4	427.3
73.	Mudstone, grayish-green (10GY5/1); weathers to light-greenish-gray (5B8/1); weakly calcareous; weakly fissile.....	5.3	422.0
72.	Sandstone and conglomerate, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to olive-gray (5Y4/1); sandstone fine- to coarse-grained; rounded-to-angular grains; moderately calcareous; conglomerate clasts up to 1.5 cm in diameter; clasts predominantly light-greenish-gray (5GY8/1) porcellanitic mudstone; conglomerate restricted to lower part of unit; unit forms laterally restricted channel-like body with erosive base; fines upward and gradational with overlying mudstone unit; unit cut by numerous calcite-filled fractures.....	2.4	419.6
71.	Porcellanitic mudstone and siltstone, greenish-gray (5GY6/1); weathers to olive-gray (5Y4/1); weakly calcareous; rare finely disseminated carbonaceous matter and coal(?); predominantly mudstone with 1 thin (less than 0.5 m thick) siltstone unit near top; rare porcellanitic ripup clasts within mudstone and siltstone; entire unit hard and dense.....	17.2	402.4
70.	Sandstone, mudstone, and conglomerate, greenish-gray (5GY6/1); weathers to greenish-gray (5G6/1); sandstone fine- to medium-grained, predominantly medium-grained; angular-to-subrounded grains; weakly calcareous; fine parallel laminations; conglomerate restricted to lower part of unit; clasts predominantly light-olive-gray (5Y6/1) and less than 1.0 cm in diameter; unit fines upward to mudstone in top 2.5 m; unit laterally restricted with erosive base.....	6.4	396.0
69.	Porcellanitic mudstone, siltstone, and sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers from pale-yellowish-brown (10YR6/2) to greenish-gray (5GY6/1); sandstone very fine- to medium-grained; predominantly rounded-to-subangular grains; weakly calcareous; cherty; 3 thin fining upward sequences each with erosive bases; mudstone predominant; hard and dense, breaking into sharp angular fragments; in part finely laminated; sandstone beds each less than 0.3 m thick and massive.....	25.5	370.5

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	cumulative thickness
68.	Mudstone, and siltstone, gray-yellow-green (5GY7/2) to dusky-yellow-green (5GY5/2); weathers from greenish-gray (5GY6/1) to greenish-gray (5G6/1); predominantly mudstone with thin, subordinate siltstone beds less than 0.3 m thick; weakly calcareous; entire unit hard and dense; appears massive.....	24.0	346.5
67.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to light-olive-gray (5Y6/1); very fine-grained; rounded- to-subrounded; quartzitic; hard and dense; rare disseminated carbonaceous(?) matter; in part, finely developed horizontal laminations.....	4.5	342.0
66.	Porcellanitic mudstone and sandstone, grayish-olive (10Y4/2); weathers to light-olive-gray (5Y5/2); predominantly porcellanitic mudstone with 1 thin (less than 0.3 m thick) discontinuous sandstone bed near middle of unit; mudstone micaceous; finely disseminated carbonaceous matter; in part finely laminated; sandstone medium-grained; angular-to-subrounded grains; micaceous weakly calcareous; red-orange heulandite(?) stain; sandstone massive with erosive base.....	21.7	320.3
65.	Sandstone and conglomerate, light-bluish-gray (5B7/1); weathers to light-olive-gray (5Y6/1); sandstone fine- to coarse-grained; subrounded-to-subangular grains; quartzitic; moderately calcareous; conglomerate clasts up to 0.4 m diameter; clasts predominantly well-rounded dark-gray mudstone; clasts parallel to bedding; conglomerate as basal lag; unit very discontinous (less than 10 m lateral extent); low angle trough cross-stratification with sets up to 0.5 m thick; unit fines upward and gradational with overlying mudstone.....	2.8	317.5
64.	Mudstone, light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); in part porcellanitic; finely developed carbonaceous matter and coal(?); limonite stain along fracture surfaces; bioturbated.....	5.5	312.0
63.	Sandstone and siltstone, greenish-gray (5GY6/1) to pale-yellow-brown (10YR6/2); weathers from olive-gray (5Y4/1) to grayish-orange (19YR7/4); well-developed alternate color bands; sandstone fine- to medium-grained; moderately calcareous; micaceous; cherty; mudstone with finely disseminated carbonaceous		

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
	matter; hard and dense; in part porcellanitic; unit fines up and gradational with overlying mudstone.....	2.6	309.4
62.	Mudstone, greenish-gray (5G6/1); in part porcellanitic; hard and dense, breaks into sharp angular fragments; porcellanitic beds predominantly structureless; in part fissile with finely disseminated carbonaceous matter.....	19.9	289.5
61.	Siltstone and mudstone, dusky-yellow (5Y6/4) to light-olive-gray (5Y5/2); weathers from light-olive-gray (5Y6/1) to olive-gray (5Y4/1); 3 fining upward cycles each approximately 7 m thick; siltstone bioturbated and ripple laminated; limonite stain; pyrite cubes common, up to 0.2 cm in diameter; entire unit highly fractured.....	17.7	271.8
Total	thickness Blackleaf Formation upper volcaniclastic lithofacies.....	342.5	

Blackleaf Formation upper clastic lithofacies:

60.	Conglomerate and sandstone, light-greenish-gray (5GY8/1) to dark-yellowish-brown (19YR4/2); weathers to light-brown (5YR5/6); sandstone medium- to coarse-grained; angular-to-rounded grains; weakly calcareous; micaceous; limonite stain; conglomerate clasts up to 3.0 cm in diameter; clasts all medium- to dark-gray mudstone; mudstone clasts porcellanitic and laminated to structureless; laterally discontinuous unit with erosive base.....	1.6	270.2
59.	Conglomerate and sandstone, light-olive-gray (5Y6/1) to light-brownish-gray (5YR6/1); weathers to brownish-gray (5YR4/1); conglomerate as laterally discontinous channel-like body (continuous for 50 m along strike) with erosive base; laterally grades into medium- to coarse-grained sandstone; sandstone with rounded- to subangular grains; weakly- to-moderately calcareous; limonite stain; cherty; conglomerate clasts up to 5.0 cm in diameter; clasts rounded- to well-rounded; clasts predominantly dark-gray chert and light-gray quartzite; strongly fractured with calcite fracture fillings.....	2.2	268.0

Blackleaf Formation upper clastic lithofacies continued:

unit		meters thickness	cumulative thickness
58.	Mudstone, yellow-gray (5Y7/1); weathers to light-brownish-gray (5YR6/1); moderately fissile; disseminated carbonaceous matter; weakly calcareous...	9.7	258.3
57.	Mudstone, medium-dark-gray (N4); moderately fissile; abundant wood fragments and disseminated carbonaceous matter; limonite and hematite stain.....	1.0	257.3
56.	Sandstone, light-olive-gray (5Y5/2); weathers to 5YR4/4; fine- to medium-grained; rounded- to subangular grains; micaceous; strong limonite stain; bioturbated(?); thick-bedded; grain-size fines upward within unit; unit continuous for more than 100 m along strike.....	9.7	247.6
55.	Mudstone, yellow-gray (5Y7/1); weathers to light-brownish-gray (5YR6/1); weakly calcareous; limonite and hematite stain; strongly bioturbated; rootlets(?).....	7.6	240.0
54.	Sandstone and conglomerate, yellow-gray (5Y7/1); weathers to light-brownish-gray (5YR6/1); sandstone fine-grained; rounded- to subangular-grains; quartzose; calcite fracture fillings; conglomerate above scour surface in upper part of unit; clasts of gray mudstone and chert up to 0.3 cm in diameter; abundant wood fragments in upper part of unit; in part bioturbated; thick-bedded.....	3.3	236.7
53.	Mudstone, yellow-gray (5Y7/1); weathers to light-brownish-gray (5YR6/1); limonite and hematite stain; bioturbated; poorly exposed.....	14.3	222.4
52.	Sandstone, light-olive-gray (5Y6/1) to pale-yellowish-brown (10YR6/2); weathers from light-brown (5YR6/4) to moderate-yellowish-brown (10YR5/4); fine-grained; rounded- to-subangular grains; cherty; limonite stain; quartzose; thick-bedded; in part bioturbated.....	6.9	215.5
51.	Siltstone, moderate-yellowish-brown (10YR5/4); weathers to moderate-brown (5YR4/4); strong limonite stain; finely laminated.....	1.0	214.5

Blackleaf Formation upper clastic lithofacies continued:

unit		meters thickness	cumulative thickness
50.	Sandstone and conglomerate, medium-light-gray (N6) to pale-blue (5PB7/2); weathers to pale-yellowish-brown (19YR6/2); sandstone medium- to coarse-grained; well rounded-to-subangular grains; moderately calcareous; quartzose; cherty; limonite stain; conglomerate clasts up to 4 cm in diameter; clasts predominantly light-gray mudstone; conglomerate forms basal lag of fining upward unit; unit continuous for more than 100 m along strike.....	10.5	204.0
49.	Sandstone, pale-yellowish-brown (19YR6/2) to light-brownish-gray (5YR6/1); weathers from brownish-gray (5YR4/1) to olive-gray (5Y4/1); medium- to coarse-grained; rounded-to-subangular grains; cherty; quartzitic; limonite stain; very calcareous; rare flat mudstone pebbles at base and middle of unit; unit actually composed of 2 sandstone beds separated by erosion surface; poorly-developed moderately dipping trough cross-stratification; forms distinct ridge.....	14.0	190.0
48.	Sandstone and mudstone, medium-gray (N5) to light-brownish-gray (5YR6/1); weathers from light-brown (5YR6/4) to light-brownish-gray(5YR6/1); sandstone predominant; fine-grained; rounded- to-subangular grains; weakly calcareous; quartzose; thin-bedded; interbedded mudstone moderately fissile; strongly calcareous; in part finely laminated; in part strongly bioturbated with well developed horizontal burrows; wood fragments and carbonaceous matter abundant along bedding planes; very small (less than 2 mm in diameter) calcareous(?) nodules; slickensides and calcite fracture fillings within entire unit.....	10.5	179.5
47.	Sandstone, grayish-red-purple (5RP4/2) to light-brownish-gray (5YR6/1); weathers from light-olive-gray (5Y6/1) to medium-gray (N5); fine-grained; rounded- to-subangular grains; moderately-to-very calcareous; quartzose; cherty; poorly developed trough cross-stratification; in part fine horizontal laminations; generally thin- to medium-bedded; very thin interbedded shales (less than 1 cm thick).....	13.9	165.6
Total	thickness Blackleaf Formation upper clastic lithofacies.....	106.2	

Blackleaf Formation lower mudstone-shale lithofacies:

unit		meters thickness	meters cumulative thickness
46.	Mudstone, siltstone, and shale, medium-dark-gray (N4) to dark-gray (N3); weathers from dark-gray (N3) to brownish-gray (5YR4/1); weakly calcareous; limonite stain; calcareous nodular zones, with nodules up to 1.0 cm in diameter; in part fine horizontal laminations; in part strongly bioturbated with well-developed burrows and trails; carbonaceous matter and coal(?).....	5.6	160.0
45.	Siltstone, medium-dark-gray (N4) to dark-gray (N3); weathers from dark-gray (N3) to olive-gray (5Y4/1); very thin-bedded; fissile; hard and dense; moderately calcareous; disseminated carbonaceous matter; bioturbated.....	2.6	157.4
44.	Mudstone, medium-dark-gray (N4); weathers to brownish-gray (5YR4/1); weakly calcareous; limonite stain; weakly fissile; bioturbated.....	0.7	156.7
43.	Sandstone, pale-blue (5PB7/2) to medium-light-gray (N6); weathers from light-olive-gray (5Y6/1) to greenish-gray (5GY6/1); fine-grained; rounded-to-subangular grains; cherty; weakly calcareous; limonite stain; quartzose; parallel laminations; beds up to 10 cm thick; calcite fracture fillings.....	2.7	154.0
42.	Siltstone, medium-gray (N5); weathers to light-brownish-gray (5YR6/1); moderately calcareous; strong hematite stain; in part finely laminated; in part strongly bioturbated with well-developed burrows; rootlets(?); fluid escape structures(?); abundant carbonaceous matter and coal.....	4.5	149.5
41.	Mudstone and siltstone, medium-gray (N5) to medium-dark-gray (N4); weathers from brownish-gray (5YR4/1) to medium-dark gray (N5); very calcareous; limonite stain; strongly bioturbated with well-developed vertical and horizontal burrows; abundant carbonaceous matter and coal; fluid escape structures.....	7.3	142.2
40.	Covered interval, presumed to be mudstone.....	2.0	140.2

Blackleaf Formation lower mudstone-shale lithofacies continued:

unit		meters thickness	cumulative thickness
39.	Siltstone and mudstone, dark-gray (N3) to medium-dark-gray (N4); weathers to brownish-gray (5YR4/1); very calcareous; bioturbated; horizontal and ripple lamination; hard and dense.....	1.8	138.4
Total	thickness Blackleaf Formation lower mudstone-shale lithofacies.....	27.2	

Blackleaf Formation lower transitional clastic lithofacies:

38.	Conglomerate and sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers to medium-gray (N5); sandstone predominantly coarse-grained; poorly sorted, with rounded- to-angular grains; very calcareous; cherty; conglomerate clasts up to 2.5 cm in diameter; clasts entirely micritic limestone; clasts rounded; unit composed of 1 massive channel-like bed laterally continuous for 10 m along strike; laterally grades into calcareous siltstone.....	1.2	137.2
37.	Limestone, medium-gray (N5) to medium-light-gray (N6); weathers to medium-bluish-gray (5B5/1); micritic; silty; very thin-bedded.....	1.5	135.7
36.	Sandstone, pale-yellowish-brown (10YR6/2) to medium-bluish-gray (5B5/1); weathers from light-olive-gray (5Y6/1) to moderate-brown (5YR4/4); fine- to medium-grained; rounded-to-subangular grains; very calcareous; cherty; quartzose; thin-bedded; low angle trough cross-stratification; laterally discontinuous unit with erosive base; fines upward within unit.....	2.9	132.8
35.	Mudstone and siltstone, medium-bluish-gray; weathers to yellowish-gray (5Y8/1); mudstone predominant; mudstone finely laminated in part; bioturbated; siltstone as 1 thin (less than 0.5 m thick bed) bed near middle of unit; siltstone with well-developed ripple lamination; entire unit very calcareous and nodular.....	2.9	129.9
34.	Limestone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers from moderate-yellowish-brown (10YR5/4) to olive-gray (5YR6/1); very nodular, with nodules up to 10 cm in diameter; limonite and hematite stain; calcite filled fractures; in part conglomeratic(?); uneven, erosional(?) lower contact; laterally grades into olive-green mudstone.....	1.8	128.1

Blackleaf Formation lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
33.	Sandstone and siltstone, light-olive-gray (5Y6/1) to greenish-gray (5G6/1); weathers from moderate-yellowish-brown (10YR5/4) to olive-gray (5Y4/1); sandstone fine- to very fine-grained; rounded- to subangular grains; quartzose; in part fine horizontal laminations; very thin-bedded; weakly calcareous at base to non-calcareous at top of unit; fines upward within unit; erosive base.....	3.3	124.8
32.	Sandstone, medium-light-gray (N6) to greenish-gray (5G6/1); weathers from yellowish-gray (5Y8/1) to brownish-gray (5YR4/1); predominantly fine-grained; rounded-to-subangular grains; quartzose; cherty; very calcareous; well-developed limonite grain coatings; very thin-bedded; well-developed horizontal laminations; center 1 m of unit darker in color, bioturbated, and disseminated carbonaceous matter; in part conglomeratic; clasts predominantly gray mudstone and limestone(?); calcite filled fractures; unit grades laterally into covered interval; at least 3 separate erosion surfaces within unit separating sandstone beds.....	14.6	110.2
31.	Covered interval.....	4.2	106.0
30.	Sandstone, light-gray (N7) to medium-light-gray (N6); weathers to pale-yellow-brown (10YR6/2); fine- to very fine-grained; rounded-to-subangular grains; very calcareous; quartzose; cherty; rare limonite grain coatings; bioturbated in part; carbonaceous matter; finely developed ripple lamination; unit fines upward; poorly exposed.....	2.5	103.5
29.	Siltstone, greenish-black (5G2/1); weathers from light-olive-gray (5Y5/2) to olive-gray (5Y3/2); weakly calcareous; well-developed limonite stain; disseminated carbonaceous matter; strongly bioturbated; fissile.....	0.5	103.0
28.	Siltstone, medium-light-gray (N6) weathers to light-gray (N7); very calcareous; abundant carbonaceous matter and wood fragments up to 2.0 cm in diameter; strongly bioturbated; in part conglomeratic with small (less than 0.5 cm diameter) limestone(?) clasts; massive; very poorly sorted unit.....	0.6	102.4

Blackleaf Formation lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
27.	Sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers from pale-yellow-brown (10YR6/2), to light-olive-gray (5Y6/1); very fine-grained; quartzose; very calcareous; limonite stain; disseminated carbonaceous matter and coal; nodular, with limestone(?) nodules up to 2.0 cm in diameter; strongly bioturbated; in part well-developed ripple lamination; unit laterally grades into covered interval.....	2.9	99.5
26.	Sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers to gray-orange (10YR7/4); very fine-grained; rounded-to-subangular grains; very calcareous; cherty; finely-developed horizontal laminations; calcite-filled fractures.....	0.8	98.7
25.	Limestone, medium-light-gray (N6) to yellowish-gray (5Y8/1); weathers to pinkish-gray (5Y8/1); very nodular, with nodules up to 10 cm in diameter; limestone micritic; hard and dense; laterally grades into covered interval.....	1.7	97.0
24.	Sandstone, medium-light-gray (N6) to medium-gray (N5); weathers to yellow-gray (5Y7/2); very fine-grained; rounded-to-subangular grains; very calcareous; cherty; quartzose; hematite stain; calcite-filled fractures; 1 massive bed gradational with overlying limestone unit.....	1.5	95.5
23.	Limestone and sandstone, medium-light-gray (N6); weathers to pinkish-gray (5YR8/1); alternating beds of micritic limestone and very calcareous very fine-grained sandstone; sandstone rounded-to-subangular grains; cherty; quartzose; limestone strongly bioturbated and nodular.....	5.5	90.0
22.	Siltstone and sandstone, light-gray (N7) to medium-gray (N5); weathers to light-olive-gray (5Y6/1); siltstone predominant and strongly bioturbated; well-developed vertical burrows and trails; sandstone very fine-grained; quartzose; cherty; poorly developed ripple lamination; sandstone beds with erosive(?) bases and laterally discontinuous; sandstone laterally and vertically grades into siltstone.....	6.8	83.2

Blackleaf Formation lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
21.	Mudstone, medium-gray (N5) to medium-dark-gray (N4); weathers to light-olive-gray (5Y5/2); weakly calcareous; strongly bioturbated with well-developed trails and burrows.....	2.1	81.1
20.	Mudstone and siltstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to yellow-gray (5Y7/2); very calcareous; strongly bioturbated; nodular, with calcareous-rich nodules up to 1.0 cm in diameter; thin-bedded and gradational with overlying mudstone unit.....	1.7	79.4
19.	Limestone, light-bluish-gray (5B7/1); weathers to medium-bluish-gray (5YR6/1); very nodular with nodules up to 8.0 cm in diameter; sharp lower base; grades laterally into sandstone described in unit below.....	1.0	78.4
18.	Sandstone, light-olive-gray (5Y5/2); weathers to medium-olive-gray (5Y4/4); fine- to very fine-grained; quartzose; hard and dense; ripple lamination; erosive(?) base.....	1.8	76.6
17.	Sandstone and mudstone, medium-gray (N5); weathers to pale-yellow-brown (10YR6/2); sandstone predominant; fine- to very fine-grained; rounded-to-subangular grains; very calcareous; cherty; quartzose; sandstone as thin, discontinuous channel-like bodies grading upward to structureless mudstone; thin-bedded; strongly fractured.....	14.6	62.0
16.	Mudstone and sandstone, medium-gray (N5) to medium-light-gray (N6); weathers to pale-yellow-brown (10YR6/2); mudstone weakly bioturbated; sandstone very fine-grained; very calcareous; cherty; very thin-bedded; sandstone as thin, discontinuous channel-like bodies as unit above, but mudstone predominant.....	7.4	54.6

Blackleaf Formation lower transitional clastic lithofacies continued:

unit		meters thickness	cumulative thickness
15.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to moderate-yellowish-brown (10YR5/4); fine-grained; rounded- to subangular grains; very calcareous; cherty; finely developed horizontal laminations in upper part; well-developed trough cross-stratification in lower part; erosive base; forms resistant ridge.....	2.9	51.7
Total	Blackleaf Formation lower transitional clastic lithofacies.....	86.7	
Total	thickness Blackleaf Formation.....	562.6	

Kootenai Formation upper carbonate lithofacies (gastropod limestone):

14.	Limestone and mudstone, medium-light-gray (N6) to medium-gray (N5); weathers to moderate-brown (5YR4/4); coarsely crystalline; abundant broken gastropods; thin "flaggy" bedding; very silty; mudstone very calcareous; strongly fissile; limestone predominant with thin mudstone interbeds....	5.7	46.0
13.	Sandstone, medium-light-gray (N6); weathers to moderate-brown (5YR4/4); fine-grained rounded-to-subangular grains; very calcareous; cherty, quartzose; thin-bedded with finely developed horizontal laminations; laterally discontinuous unit with sharp lower contact.....	0.9	45.1
12.	Limestone and mudstone, medium-dark-gray (N4); weathers to medium-gray (N5); limestone very dense, predominantly crystalline; variably fossiliferous with abundant gastropod fragments restricted to distinct beds; disseminated carbonaceous matter; bioturbated; subordinate mudstone moderately fissile and very calcareous; limestone silty; entire unit with mottled weathering surfaces.....	8.6	36.5
11.	Sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to moderate-brown (5YR3/4); very fine-grained; very calcareous; cherty(?); quartzitic; thin-bedded; laterally discontinuous with erosive base.....	0.9	35.6

Kootenai Formation upper carbonate lithofacies (gastropod limestone) cont.:

unit		meters thickness	meters cumulative thickness
10.	Limestone, dark-gray (N3); weathers to medium-dark-gray (N4); coarsely crystalline; abundant gastropods; thin-bedded; calcite filled fractures; strongly fractured with slickensides.....	2.4	33.2
09.	Siltstone and mudstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers to dark-yellow-brown (10YR4/1); siltstone with finely-developed horizontal and ripple lamination; mudstone fissile; well-developed hematite stain along bedding planes; entire unit very calcareous; 2 distinct thin siltstone beds (less than 0.5 m thick) interbedded with thicker mudstone beds.....	2.0	31.2
08.	Siltstone and mudstone, medium-light-gray (N6) to light-olive-gray (5YR4/2); siltstone with finely developed horizontal and ripple lamination; mudstone fissile; well-developed hematite stain along bedding planes; entire unit very calcareous; 2 distinct siltstone beds (less than 0.5 m thick) interbedded with thicker mudstone beds.....	5.1	26.1
07.	Limestone, medium-gray (N5) to medium-dark-gray (N4); weathers to olive-gray (5Y4/1); coarsely crystalline; abundant gastropods and ostracods(?); silty; disseminated carbonaceous matter; undulatory bedding surfaces; thin-bedded.....	0.6	25.5
06.	Siltstone and mudstone, medium-dark-gray (N4); weathers to yellowish-gray (5Y8/1); interbedded siltstone and mudstone; moderately to very calcareous; limonite stain; thin-bedded; mudstone fissile; disseminated carbonaceous matter and wood; slickensides; calcite-filled fractures.....	3.4	22.1
05.	Sandstone, medium-light-gray (N6) to medium-dark-gray (N4); weathers from pale-yellow-brown (10YR6/2) to moderate-yellow-brown (10YR5/4); fine-grained; rounded-to-angular grains; very calcareous; very cherty; quartzose; hard and dense; finely developed horizontal laminations with distinct grain zonation (banding); thickly-bedded to massive(?); laterally continuous for 20 m along strike; erosive base.....	2.1	20.0

Kootenai Formation upper carbonate lithofacies (gastropod limestone) cont.:

unit		meters thickness	meters cumulative thickness
04.	Sandstone and mudstone, light-bluish-gray (5B7/1); weathers to light-brownish-gray (5YR6/1); fine-to-medium-grained; rounded-to-subangular grains; very calcareous; cherty; quartzose; medium-bedded; sandstone grades upward to mudstone; mudstone fissile; bioturbated.....	3.8	16.2
03.	Limestone, medium-dark-gray (N4) to dark-gray (N3); weathers to medium-gray (N5); coarsely crystalline; abundant gastropods; gastropods up to 1.0 cm in length; medium-bedded; mottled weathering surfaces; unit continuous for 50 m along strike.....	1.9	14.3
02.	Mudstone and siltstone, light-gray (N7) to light-olive-gray (5Y6/1); weathers from light-gray (N7) to yellow-gray (5Y8/1); very calcareous; mudstone predominant; fissile; bioturbated in part; siltstones as 2 thin discontinuous beds near base and middle of unit; siltstones mud-cracked; wavey bedding; finely disseminated carbonaceous matter.....	10.5	3.8
01.	Limestone, medium-dark-gray (N4); weathers to medium-gray (N5); coarsely crystalline; fossiliferous; abundant gastropods; thin- to medium-bedded; mottled weathering surfaces; unit continuous for more than 50 m along strike.....	3.8	0.0
Partial thickness Kootenai Formation upper carbonate lithofacies.....		51.7	

MEASURED SECTION 2 (Frying Pan Gulch)

Frontier, Blackleaf, and Kootenai Formations, exposed along Frying Pan Gulch, western Pioneer Range, Beaverhead County, Montana:

[Sec. 30, T. 6 S., R. 9 W., Bond quadrangle; measurued by T. S. Dyman and R. Niblack, July-August, 1983]

Frontier Formation lower clastic lithofacies:

unit		meters thickness	meters cumulative thickness
53.	Sandstone, yellowish-gray (5Y8/1) to light-olive-gray (5Y6/1); weathers to light-olive-gray (5Y6/1); medium-grained; rounded-to-subangular grains; quartzose; feldspathic; disseminted carbonaceous matter and coal; limonite stain; weakly(?) cemented and highly weathered exposure; appears massive with sharp, erosive(?) base.....	3.7	745.5
52.	Mudstone and siltstone, pale-green (10G6/2) to grayish-yellow-green (5GY7/2); very weakly calcareous; poorly fissile; mudstone predominant; finely disseminated carbonaceous matter; rare limonite stain; some thin beds with well-developed hematite nodules up to 3 cm in diameter; nodules hard and dense.....	34.5	711.0
51.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to brownish-gray (5YR4/1); medium- to coarse-grained, predominantly coarse-grained; rounded-to-angular grains; cherty; very calcareous; well-developed hematite stain along fractures and bedding planes; unit massive to trough cross-bedded; medium scale trough cross-stratification; unit fines upward and gradational with overlying mudstone.....	4.2	706.8
50.	Mudstone, porcellanitic, greenish-gray (5G6/1); micaceous; hard and dense; poorly exposed.....	10.2	696.6
49.	Sandstone, pale-yellowish-brown (10YR6/2) to light-olive-gray (5Y6/1); weathers to pale-yellowish-brown (10YR6/2); medium- to coarse-grained; rounded- to-angular grains; very calcareous; limonite stain along fracture surfaces; medium- to large-scale trough cross-stratification; unit continuous laterally for 50 m where it grades into mudstone; erosive lower contact.....	1.1	695.5

Frontier Formation, lower clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
48.	Mudstone and shale, medium-gray (N5) to medium-dark-gray (N4); moderately fissile; weakly calcareous; disseminated carbonaceous matter.....	3.4	692.1
47.	Mudstone and siltstone, pale-green (10G6/2) to grayish-yellow-green (5GY7/2); mudstone predominant; very weakly calcareous; limonite stain; in part, hard and dense; poorly exposed.....	7.6	684.5
46.	Siltstone and mudstone, light-olive-gray (5Y6/1) to light-bluish-gray (5B7/1); weathers from light-bluish-gray (5B7/1) to moderate-yellowish-brown (10YR5/4); mudstone and siltstone in subequal amounts; mudstone very weakly calcareous; porcellanitic in part; siltstone as discontinuous beds; siltstone with finely disseminated carbonaceous matter and wood fragments; strongly bioturbated.....	7.0	677.5
45.	Covered interval, presumed to be porcellanitic mudstone.....	9.4	668.1
44.	Sandstone and conglomerate, medium-gray (N5) to pale-blue (5PB7/2); weathers to pale-yellowish-brown (19YR6/2): sandstone fine- to medium-grained; rounded-to-angular grains; quartzose; cherty; very calcareous; limonite stain; conglomerate subordinate as basal lag; clasts predominantly dark-gray chert, porcellanitic mudstone, and quartzite; unit with well-developed erosive base; abundant large-scale trough cross-stratification; unit composed of several internal fining upward sequences; unit continuous for 150 m along strike and laterally grades into more conglomerate-rich beds.....	4.6	663.5
43.	Covered interval, presumed to be porcellanitic mudstone.....	7.5	656.0
42.	Conglomerate and sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to brownish-gray (5YR4/1); conglomerate predominate with clasts up to 10 cm in diameter; abundant clasts include dark-gray porcellanitic mudstone, light-gray quartzite, and color-variant chert; rare clasts include conglomerate, sandstone, and siltstone; clasts strongly imbricated; sandstone medium- to coarse-grained; rounded-to-subangular grains; quartzose; cherty; sandstone both as continuous beds and discontinuous "drapes" above conglomerate units;		

Frontier Formation, upper clastic lithofaceis continued:

unit		meters thickness	cumulative thickness
	sandstone poorly sorted; well-developed trough cross-stratification; entire unit channel-like with well-developed erosive base; base with well-defined flute or tool marks (gutter marks?); unit strongly fractured; continuous for 100 m along strike; laterally grades into coarse-grained sandstone.....	5.9	650.1
41.	Covered interval.....	29.9	620.2
40.	Siltstone and mudstone, light-olive-gray (5Y6/1); very calcareous; limonite-stain; weakly- to-moderately fissile; bioturbated; finely dissemintated carbonaceous matter; poorly exposed.....	5.4	614.8
39.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to olive-gray (5Y4/1); medium- to coarse-grained; very calcareous; cherty; limonite stain; rounded-to-angular grains; hematite nodules; unit massive(?), with sharp lower contact; unit laterally grades into covered interval.....	1.6	613.2
38.	Covered interval, presumed to be mudstone and siltstone.....	16.0	597.2
37.	Mudstone, porcellanitic and sandstone, greenish-gray (5G6/1); sandstone as 2 dicontinuous channel-like bodies; sandstone fine-grained; abundant ovular lithophysae up to 0.4 cm in diameter; poorly exposed.....	14.1	583.1
36.	Sandstone, medium-dark-gray (N4) to dark-gray (N3); weathers from yellowish-gray (5Y8/1) to dark-yellowish-orange (10YR6/6); fine-grained; micaceous; finely disseminated coal; bioturbated; unit laterally discontinuous.....	0.7	582.4
35.	Porcellanitic mudstone, medium-gray (N5) to greenish-gray (5G6/1); hard and dense; ovular lithophysae up to 0.3 cm in diameter; poorly exposed.....	8.9	573.5
34.	Sandstone and conglomerate, pale-yellowish-brown (10YR6/2) to moderate-yellow-brown (10YR5/4); weathers to dusky-yellowish-brown (10YR2/2); sandstone predominantly coarse-grained; rounded-to-subangular grains; quartzose; cherty; limonite stained; conglomerate subordinate with clasts restricted to basal portions of distinct sandstone beds within unit; clasts predominantly chert, siltstone and		

Frontier Formation, upper clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
	dark-gray porcelanitic(?) mudstone; individual beds massive to trough cross-stratified; unit channel-like in shape with erosive base and limited lateral extent (30 m); unit forms very distinct ridge.....	5.3	568.2
33.	Porcellanitic mudstone, very-light-gray (N8); weathers to light-olive-gray (5Y6/1); bentonitic; ovular lithophysae up to 0.2 cm in diameter; very thinly-bedded; in part hard and dense; lower half poorly exposed.....	28.1	540.1
32.	Porcellanitic mudstone, greenish-gray (5GY6/1) to light-greenish-gray (5GY8/1); weathers yellowish-gray (5Y8/1); very small (less than 1 mm) limonitic nodules; bentonitic; finely diseminated carbonaceous matter; thin-bedded; in part finely laminated; hard and dense, breaking into angular fragments; in part poorly exposed.....	9.3	530.8
31.	Conglomerate and sandstone, moderate-yellow-brown (10YR5/4) to medium-gray (N5); weathers to brownish-gray (5YR4/1); predominantly conglomerate with clasts up to 0.3 m in diameter; clasts strongly imbricated; clasts predominantly dark-gray chert, dark-gray to tan quartzite; and color-variant mudstone; sandstone moderately calcareous; unit composed of several stacked conglomerate-rich beds; slight fining-upward within unit; well-defined erosional base with "gutter marks"; unit laterally grades into sandstone-rich unit.....	5.2	525.6
Total thickness Frontier Formation measured.....		223.6	

Blackleaf Formation, upper volcaniclastic lithofacies:

30.	Porcelanitic mudstone, greenish-gray (5GY6/1); very thin-bedded; poorly exposed.....	20.3	505.3
29.	Sandstone, greenish-gray (5G6/1) to medium-bluish-gray (5B5/1); weathers from olive-gray (5Y4/1) to dark-yellowish-brown (10YR4/2); medium- to-coarse-grained; rounded-to-subangular grains; very calcareous; quartzose; cherty; limonite stain; very thin (less than 1 mm thick) shale partings; ripple laminated in part; unit laterally discontinuous; poorly exposed.....	1.5	503.8

Blackleaf Formation, upper volcaniclastic lithofacies continued:

unit		meters thickness	cumulative thickness
28.	Covered interval, presumed to be mostly mudstone.....	238.3	265.5
27.	Sandstone and conglomerate light-bluish-gray (5B7/1); weather to brownish-gray (5YR4/1); sandstone medium- to coarse-grained; rounded-to-subrounded grains; very weakly calcareous; quartzose; cherty; thin-bedded; conglomerate subordinate; clasts predominantly chert and dark-gray mudstone; clasts weakly imbricated; unit laterally discontinuous (less than 100 m) with erosive(?) base.....	2.3	263.2
26.	Mudstone, greenish-gray (5GY6/1); in part porcellanitic; very poorly exposed.....	93.7	169.5
Total	thickness Blackleaf Formation, upper volcaniclastic lithofacies.....	356.1	

Blackleaf Formation, upper clastic lithofacies:

25.	Sandstone, moderate-yellowish-brown (10YR5/4) to dark-yellowish-brown (10YR4/2); weathers to moderate-brown (5YR3/4); coarse- to very coarse-grained; rounded-to-subangular grains; very calcareous; quartzose; cherty; well-developed limonite grain coatings and nodules; thick-bedded to massive, with very thin (less than 1 mm thick) shale partings; in part conglomeratic, with clasts up to 4 mm in diameter; clasts predominantly dark-gray chert and porcellanitic mudstone; slight coarsening upward within unit; unit continuous.....	7.0	162.5
24.	Sandstone, very-pale-orange (10YR8/2); weathers to moderate-yellowish-brown (10YR5/4); fine-grained; rounded-to-subrounded grains; quartzose; weakly calcareous; hematite and limonite stain; rare medium-scale trough cross-stratification; nodular with well-developed hematite-rich nodules up to 4 cm in diameter; several distinct sandstone beds with sharp lower erosive bases; unit more massive near top.....	10.6	151.9
23.	Mudstone, dusky-red (5R3/4); one thin interbed.....	0.3	151.6

Blackleaf Formation, upper clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
22.	Sandstone, grayish-orange-pink (10R8/2) to light-gray (N7); weathers from brownish-gray (5YR4/1) to moderate-yellowish-brown (10YR8/2); fine-grained; rounded- to-subrounded grains; weakly calcareous; hematite and limonite stained; strongly bioturbated in part; ripple lamination; at least 2 small-scale fining upward sequences; erosive base.....	10.4	141.2
21.	Covered interval.....	8.6	132.6
Total	thickness Blackleaf Formation upper clastic lithofacies.....	36.9	

Blackleaf Formation, lower mudstone-shale lithofacies:

20.	Siltstone and mudstone, medium-gray (N5); interbedded calcareous siltstones and mudstones; unit poorly exposed.....	13.1	119.5
19.	Covered interval, presumed to be mudstone.....	9.8	109.7
18.	Shale and mudstone, medium-gray (N5); weathers from medium-gray (N5) to yellowish-gray (5Y8/1); strongly bioturbated with abundant trails and burrows; moderately fissile; rare, finely disseminated organic matter; in part poorly exposed.....	19.6	90.1
17.	Covered interval, presumed to be mudstone and shale...	6.1	84.0
Total	thickness Blackleaf Formation, lower mudstone-shale lithofacies.....	48.6	

Blackleaf Formation, lower transitional clastic lithofacies:

16.	Sandstone, pale-yellowish-brown (10YR6/2); weathers to brownish-gray (5YR4/1); medium-grained; rounded-to-subrounded grains; very calcareous; limonite stain; strongly cross-bedded, with medium- to small-scale trough cross-stratification; unit continuous for 100 m along strike; erosive base.....	6.7	77.3
15.	Covered interval.....	7.7	69.6
14.	Sandstone and siltstone, light-bluish-gray (5B7/1); weathers to light-brownish-gray (5YR6/1); sandstone fine-grained; very calcareous; thin discontinuous sandstone beds (less than 0.2 m thick) within siltstones; entire unit ripple laminated and bioturbated; poorly exposed.....	4.2	65.4

Blackleaf Formation, lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
13.	Covered interval, presumed to be mudstone or siltstone.....	5.8	59.6
12.	Sandstone, light-olive-gray (5Y6/1); weathers to pale-yellowish-brown (10YR6/2); medium-grained; rounded-to-subrounded grains; very calcareous; cherty; medium- to thick-bedded; laterally continuous.....	1.8	57.8
11.	Sandstone and conglomerate, medium-gray (N5); conglomerate clasts from medium-gray (N5) to moderate-yellow-brown (10YR5/4); weathers to light-gray with irregular patches of yellow-gray (5Y8/1); rounded-to-angular grains; conglomerate predominant with clasts up to 1 cm in diameter; clasts predominantly micritic limestone, siltstone, and mudstone; channel-like unit with erosive base; continuous for 10 m along strike; poorly exposed; gradational with overlying unit.....	0.5	57.3
10.	Sandstone and siltstone, with subordinate mudstone; yellowish-gray (5Y8/1) to light-olive-gray (5Y6/1); weathers to brownish-gray (5YR4/1); fine- to very fine-grained sandstone; rounded-to-subrounded grains; very calcareous; sandstone and siltstone in subequal amounts as discontinous(?) beds; thin, calcareous mudstone interbeds; poorly exposed.....	6.8	50.5
09.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers from moderate-yellowish-brown (10YR5/4) to dark-yellowish-brown (10YR4/2); medium-grained; rounded-to-subangular grains; very calcareous; very cherty; quartzose; calcite fracture fillings; limonite stain; low angle, medium-scale trough cross-stratification; several distinct sandstone beds; entire unit with sharp erosive base; forms well-defined ridge.....	8.0	42.5
08.	Siltstone and mudstone, pale-red (5R6/2) to pale-olive (10Y6/2); weathers to grayish-orange (10YR7/4); color variant siltstone and mudstone; very nodular with calcite-rich nodules up to 4 cm in diameter; poorly exposed.....	11.2	31.3

Blackleaf Formation, lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
07.	Conglomerate and sandstone, medium-gray (N5) to yellowish-gray (5Y8/1); weathers to light-gray (N7); very poorly sorted; rounded-to-angular grains; clasts predominantly micritic limestone up to 2 cm in diameter; no distinct imbrication or clast alignment; laterally discontinuous with sharp, erosive base; gradational with overlying unit.....	1.9	29.4
06.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers from olive-gray (5Y4/1) to light-olive-gray (5Y6/1); fine- to very fine-grained; rounded-to-subrounded grains; very calcareous; cherty; limonite stain; carbonaceous matter and coal; thin-bedded; ripple laminated(?) in part; laterally discontinuous.....	0.4	29.0
05.	Mudstone and siltstone, medium-bluish-gray (5B5/1) to pale-yellowish-brown (10YR6/2); moderately- to very-calcareous; thin interbeds of mudstone and siltstone; in part nodular; poorly exposed.....	8.8	20.2
04.	Sandstone, medium-light-gray (N6) to light-bluish-gray (5B7/1); fine-grained; rounded-to-subangular grains; very calcareous; cherty, quartzose; very thin-bedded; ripple laminated in part; sharp lower contact; laterally discontinuous.....	0.8	19.4
03.	Mudstone and siltstone, pale-yellowish-brown (10YR6/2); in part nodular; calcareous; in part poorly exposed.....	15.4	4.0
Total	thickness Blackleaf Formation, lower transitional clastic lithofacies.....	80.0	
Total	thickness Blackleaf Formation.....	521.6	

Kootenai Formation, upper carbonate lithofacies:

02.	Limestone, medium-gray (N5) to medium-bluish-gray (5B5/1); weathers from light-gray (N7) to yellowish-gray (5Y8/1); micritic; very silty; thin-bedded; calcite fracture-fillings.....	1.9	2.1
01.	Limestone, medium-gray (N5); weathers to medium-bluish-gray (5B5/1); coarsely crystalline; abundant gastropods.....	2.1	0.0

MEASURED SECTION 3 (McCartney Mountain I)

Blackleaf and Kootenai Formations along Creasey and Buhrer Gulches, McCartney Mountain area, Madison County, Montana:

[E $\frac{1}{2}$ secs. 21, 28 and S. $\frac{1}{2}$ sec. 16, T. 4 S., R. 8 W., Block Mountain Quadrangle; measured by T. S. Dyman, M. Gamache and R. Niblack, August 1983].

Blackleaf Formation, upper volcaniclastic lithofacies:

unit		meters thickness	meters cumulative thickness
36.	Conglomerate and sandstone, light-olive-gray (5Y6/1) to medium-bluish-gray (5B5/1); weathers to medium-gray (N5); conglomerate with subordinate sandstone; conglomerate clasts rounded-to-subrounded; clasts predominantly dark-gray to white chert, quartzite and porcellanitic mudstone; clasts up to 4.0 cm in diameter; in part poorly imbricated; sandstone very coarse; rounded-to-subangular grains; very weakly calcareous; channel-like massive bed 25 m in diameter and 3 m maximum thickness; sharp lower contact; unit laterally grades into sandstone and porcellanitic mudstone.....	3.0	230.2
35.	Coverd interval, presumed to be porcellanitic mudstone.....	5.0	225.2
34.	Porcellanitic mudstone, dark-gray (N3); hard and dense; poorly exposed.....	10.5	214.7
33.	Covered interval; presumed to be mudstone.....	8.5	206.2
32.	Siltstone and mudstone, medium-gray (N5); weakly fissile; siltstone predominant as discontinuous beds; lower part nodular, with limestone nodules up to 4 cm in diameter; poorly exposed.....	8.8	197.4
Total	minimum thickness, Blackleaf Formation, upper volcaniclastic lithofacies.....	35.8	

Blackleaf Formation, upper clastic lithofacies:

31.	Sandstone, medium-bluish-gray (5B5/1) to medium-dark-gray (N4); weathers to light-olive-gray (5Y6/1); medium-grained; rounded-to-subangular grains; very calcareous; cherty; rare limonite stain; hard and dense; well-developed trough cross-stratification; parting lineation along bedding planes.....	5.3	192.1

Blackleaf Formation, upper clastic lithofacies continued:

unit		meters thickness	cumulative thickness
30.	Sandstone, medium-gray (N5), to pale-yellowish-brown (10YR6/2); weathers to brownish-gray (5YR4/1); predominantly coarse-grained; rounded-to-subangular grains; weakly- to- moderately calcareous; well-developed limonite grain coatings (orange speck); unit massive; sharp lower contact.....	4.9	187.2
29.	Sandstone light-brownish-gray (5YR6/1) to medium-light-gray (N6); weathers to brownish-gray (5YR4/1); fine- to very fine-grained; rounded-to-subrounded grains; cherty; quartzose; very calcareous; well-developed ripple and parallel laminations; in part bioturbated; rare finely disseminated wood and coal fragments; at least 2 distinct beds separated by sharp contact; flute marks along lower bedding planes.....	0.4	186.8
28.	Sandstone and conglomerate, medium-gray (N5) to dark-gray (N3); weathers to light-olive-gray (5Y6/1); sandstone predominant; coarse-grained; rounded-to-angular grains; very calcareous; cherty; conglomerate clasts restricted to distinct beds; clasts up to 1.5 cm in diameter; clasts predominantly dark-gray shale and mudstone; sharp lower and upper contact.....	1.2	185.6
Total	thickness Blackleaf Formation, upper clastic lithofacies	11.8	

Blackleaf Formation, lower mudstone-shale lithofacies:

27.	Shale in part silty, medium-gray (N5), weathers from light-gray (N7) to yellowish-gray 5Y8/1); strongly fissile; abundant carbonaceous matter; in part bioturbated; Sample MM33-1; one palynomorph species identified by D. J. Nichols: *Vitreisporites pallidus*.....	0.5	185.1
26.	Shale and siltstone, medium-gray (N5); weathers to brownish-gray (5YR4/1); shale predominant; weakly-to-strongly fissile; abundant carbonaceous matter; very calcareous; siltstone subordinate; siltstone as discontinuous lens-like bodies less than 0.5 m thick; ripple laminated, with climbing ripple lamination; bioturbated in part; well-developed horizontal and vertical burrows up to 0.5 cm in diameter; limonite and hematite coatings along fractures and bedding planes; rootlets; well-developed liesegang banding in silty beds.....	24.9	160.2

Blackleaf Formation, lower mudstone-shale lithofacies continued:

unit		meters thickness	meters cumulative thickness
25.	Shale, medium-gray (N5); weathers to medium-light-gray (N6); strongly fissile; abundant carbonaceous matter; burrowed and bioturbated in part.....	11.7	148.5
24.	Sandstone, medium-dark-gray (N4) to brownish-gray (5YR4/1); weathers to medium-dark-gray (N4); predominantly medium-grained; rounded-to-subangular grains; cherty; abundant wood and carbonaceous matter; well-developed burrowing and bioturbation; ripple-laminated in part; hematite as cement and along bedding planes and fractures; medium- to thick-bedded.....	3.1	145.4
23.	Shale, medium-dark-gray (N4); weathers from yellowish-gray (5Y8/1) to medium-gray (N5); moderately to strongly fissile; wood and carbonaceous matter abundant; in part bioturbated.....	6.8	138.6
22.	Sandstone and shale, medium-gray (N5) to brownish-gray (5YR4/1); weathers from olive-gray (5Y4/1) to yellowish-gray (5Y8/1); sandstone predominant; fine- to very fine-grained; rounded-to-subrounded grains; abundant carbonaceous matter and wood; variably calcareous; rootlets; in part ripple-laminated; abundant horizontal burrows and trails on bedding planes; subordinate shale weakly-to-strongly fissile; sandstone in part trough cross-bedded; discontinuous channel-like bodies with sharp lower contacts.....	8.8	129.8
21.	Sandstone and siltstone, pale-yellowish-brown (10YR6/2) to dark-yellowish-brown (10YR4/2); weathers from pale-yellowish-brown (10YR6/2) to dark-yellowish-orange (10YR6/6); fine- to very fine-grained; rounded-to-subrounded grains; weakly calcareous; quartzose; well-developed burrowing; in part bioturbated; limonite stain along fractures and bedding planes; fines upward within unit; in part rippled; laterally continuous unit.....	7.5	122.3
20.	Mudstone and siltstone, medium-gray (N5) to light-olive-gray (5Y6/1); mudstone and siltstone in subequal amount; weakly calcareous; very weakly fissile; micaceous; carbonaceous matter; poorly exposed.....	1.6	120.7

Blackleaf Formation, lower transitional clastic lithofacies continued:

unit		meters thickness	cumulative thickness
19.	Limestone conglomerate, medium-light-gray (N6) to grayish-orange (10YR7/4); poorly sorted; rounded-to-angular grains; very calcareous; conglomerate clasts up to 0.3 cm in diameter; clasts 90 percent micritic limestone; no distinct imbrication or clast orientation; well-developed limonite stain; two laterally discontinuous channel-like bodies traced within 200 m along strike; channels encased within fine-grained units.....	1.1	119.6
18.	Mudstone and siltstone, medium-gray (N5); moderately to very calcareous; in part nodular, with limestone nodules up to 7 cm in diameter; poorly exposed.....	7.4	112.2
17.	Shale and mudstone, medium-gray (N5); weathers to light-olive-gray (5Y6/1); weakly-to-strongly calcareous; weakly fissile; carbonaceous matter.....	0.5	111.7
16.	Covered interval, presumed to be shale or mudstone....	5.9	105.8
Total thickness Blackleaf Formation, lower mudstone shale lithofacies.....		79.8	

Blackleaf Formation lower transitional clastic lithofacies:

15.	Sandstone and mudstone, medium-gray (N5) to brownish-gray (5YR4/1); weathers to moderate-yellowish-brown (10YR5/4); sandstone predominant, fine- to medium-grained; moderately calcareous; cherty; limonite and hematite stain; subordinate mudstone as single thin bed (less than 0.5 m) near middle of unit; slight fining up within unit; very thin-bedded; well-developed parting lineation; laterally continuous unit.....	4.0	101.8
14.	Covered interval.....	3.4	98.4
13.	Sandstone, and siltstone, medium-gray (N5) to pale-yellowish-brown (10YR6/2); weathers to brownish-gray (5YR4/1); predominantly medium-grained; rounded-to-subangular grains; very calcareous; cherty; quartzose; limonite as stain and grain coating (orange-speck); rare conglomerate clasts as basal lag; at least 3 distinct sandstone bodies with sharp lower contacts; fining upward within unit; two thin (less than 0.5 m thick) siltstone beds, one near the base and one near the top of unit; well-developed moderately dipping trough cross-stratification; unit laterally continous along strike.....	12.8	85.6

Blackleaf Formation, lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
12.	Mudstone and sandstone, medium-gray (N5) to olive-gray (5Y4/1); interbedded mudstone and subordinate sandstone; sandstone as discontinous channel-like bodies; sandstone fine- to very fine-grained; moderately calcareous; poorly exposed.....	24.8	60.8
11.	Sandstone, medium-gray (N5) to olive-gray (5Y4/1); weathers to olive-gray (5Y4/1); fine- to very fine-grained; rounded-to-subrounded grains; very calcareous; cherty; quartzose; limonite grain coatings; fine parallel laminations near base and ripple lamination near top; unit as discontinuous channel-like body.....	1.5	59.3
10.	Shale and mudstone, medium-gray (N5); weakly fissile; in part bioturbated; poorly exposed.....	8.8	50.5
09.	Sandstone, medium-gray (N5) to olive-gray (5Y4/1); fine- to very fine-grained; rounded-to-subrounded grains; cherty; quartzose; weakly-to-moderately calcareous; ripple laminated in part; massive near base; unit with sharp lower contact; continuous along strike.....	1.3	49.2
08.	Mudstone and siltstone, light-bluish-gray (5B7/1); weathers from yellowish-gray (5Y8/1) to light-bluish-gray (5B7/1); mudstone and siltstone in subequal amount; weakly-to-very calcareous; nodular with limestone nodules up to 5 cm in diameter.....	8.2	41.0
07.	Sandstone, light-olive-gray (5Y6/1); weathers to pale-yellowish-brown (10YR6/2); very fine-grained; quartzose; rare limonite stain; very calcareous; bioturbated in part; massive in lower part and rippled(?) near top; grades upward into overlying siltstone unit.....	1.7	39.3
06.	Siltstone and mudstone, light-bluish-gray (5B7/1); interbedded siltstone and mudstone in subequal amount; very calcareous; poorly fissile; poorly exposed.....	5.3	34.0
05.	Sandstone, light-bluish-gray (5B7/1) to light-olive-gray (5Y6/1); weathers to light-olive-gray (5Y6/1); fine- to very fine-grained; rounded- to-subrounded grains; quartzose; disseminated carbonaceous matter and coal(?); strongly bioturbated; in part ripple laminated; unit discontinuous along strike; sharp lower contact.....	4.5	29.5

Blackleaf Formation;, lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
04.	Limestone conglomerate(?) and limestone, medium-light-gray (N6); weathers from light-gray (N7) to yellowish-gray (5Y8/1); micritic limestone matrix with micritic limestone clasts and wood fragments; clasts less than 0.3 cm in diameter; clasts angular-to-rounded; in part micritic limestone; finely ripple-laminated; thin- to thick-bedded.....	3.4	26.1
03.	Sandstone, medium-bluish-gray (5B5/1); weathers to brownish-gray (5YR4/1); fine- to medium-grained; very calcareous; strongly bioturbated; limonite and hematite stained; thin-bedded to massive; unit overlain by 6 m thick basalt(?) sill; slickensided....	4.2	21.9
02.	Covered interval, assumed to be mudstone.....	14.9	7.0
Total	thickness Blackleaf Formation, lower transitional clastic lithofacies.....	98.8	
Total	minimum thickness Blackleaf Formation.....	226.2	

Kootenai Formation, upper carbonate lithofacies:

01.	Limestone, medium-gray (N5); weathers to medium-bluish-gray (5B5/1); weathers to medium-bluish-gray (5B5/1); coarsely crystalline; abundant gastropods and rare bivalves; fossil concentrations greatest along distinct horizons; thin-bedded.....	7.0	0.0

MEASURED SECTION 4 (McCartney Mountain II)

Blackleaf and Kootenai Formations near Sandy Hollow along the Big Hole River south of Block Mountain, Madison County, Montana:

[NE 1/4 sec. 35, T. 4 S., R. 8 W., Block Mountain Quadrangle; measured by T. S. Dyman and M. Gamache, August, 1984]

Blackleaf Formation upper clastic lithofacies:

unit		meters thickness	meters cumulative thickness
24.	Sandstone, and siltstone, light-olive-gray (5Y6/1); fine- to medium-grained, rounded-to-subrounded grains; very calcareous; limonite stain; hematite stain along fracture surfaces; thin, interbedded siltstone beds; poorly developed ripple lamination; small-scale erosive(?) surfaces.....	3.2	59.4
23.	Sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); fine- to very fine-grained; rounded-to-subrounded grains; moderately calcareous; limonite stain; thin-bedded; in part horizontal laminations; low angle trough cross-stratification in part; flutes along lower bedding surfaces; parting lineation; sharp lower contacts; at least 3 distinct sandstone beds....	3.1	56.3
22.	Sandstone and shale, light-olive-gray (5Y6/1); fine-grained; rounded-to-subangular grains; moderately calcareous; limonite stain; well-developed trough cross-stratification; parting lineation; sharp lower contact with flute casts.....	1.6	54.7
Total	minimum thickness, Blackleaf Formation, upper clastic lithofacies.....	7.9	

Blackleaf Formation, lower mudstone-shale lithofacies:

21.	Siltstone and shale, light-olive-gray (5Y6/1) to medium-gray (N5); weathers to medium-gray (N5); interbedded siltstone and shale; shale moderately fissile; weakly-to-moderately calcareous; hematite stain.....	1.4	53.3
20.	Conglomerate, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to pale-yellow-brown (10YR6/2); clasts less than 0.5 cm in diameter and predominantly less than 0.3 cm in diameter; clast composition 90 percent dark-gray micritic limestone, 10 percent dark-gray calcareous mudstone; clasts angular-to-subangular; channel-like unit continuous for 15 m along strike.....	1.5	51.8

Blackleaf Formation lower mudstone-shale lithofacies continued:

unit		meters thickness	meters cumulative thickness
19.	Siltstone and mudstone, medium-dark-gray (N4) to olive-gray (5Y4/1); weathers to light-olive-gray (5Y6/1); thin interbedded rippled siltstone and massive mudstone; moderately calcareous siltstone and weakly calcareous mudstone.....	1.6	50.2
18.	Shale, dark-gray (N3); weathers to medium-dark-gray (N4); moderately calcareous; strongly fissile; disseminated carbonaceous matter.....	0.3	49.9
17.	Mudstone and siltstone, brownish-gray (5YR4/1) to olive-gray (5Y4/1); thin, interbedded mudstsone and siltstone; mudstone predominant; siltstone beds up to 5 cm thick and discontinuous.....	0.5	49.4
16.	Sandstone, medium-light-gray (N6); very fine-grained; rounded-to-subangular grains; moderately calcareous; limonite stain; poorly developed low angle trough cross-stratification; unit with sharp lower contact; laterally discontinuous.....	0.2	49.2
15.	Shale, medium-dark-gray (N4); moderately fissile; carbonaceous matter; in part hard and dense.....	1.7	47.5
14.	Sandstone and mudstone medium-light-gray (N6); weathers to medium-gray (N5); thin, discontinuous sandstone beds surrounded by mudstone; sandstone fine- to very fine-grained; ripple and climbing-ripple lamination; beds in part contorted; poorly developed loads within sandstone beds; sandstone beds up to 1.0 m thick.....	4.6	42.9
13.	Sandstone and siltstone, medium-light-gray (N6); weathers to light-olive-gray (5Y6/1); fine- to medium-grained; rounded-to-subangular grains; very calcareous; quartzose; moderately dipping trough cross-stratification; beds thin and fine upward within unit; sharp lower contact; unit continuous along strike.....	1.4	41.5
12.	Mudstone and sandstone, medium-dark-gray (N4) to olive-gray (5Y4/1); weathers to light-olive-gray (5Y6/1); predominantly mudstone, with thin, discontinuous sandstone beds; sandstone very fine-grained; moderately calcareous; limonite stain; trails and burrows along bedding planes; sandstone thin-bedded and rippled.....	6.1	35.4

Blackleaf Formation lower mudstone-shale lithofacies continued:

unit		meters thickness	meters cumulative thickness
11.	Mudstone and shale, medium-dark-gray (N4); weakly-to-moderately fissile; disseminated carbonaceous matter; moderately calcareous.....	0.3	35.1
Total	thickness, Blackleaf Formation lower mudstone-shale lithofacies.....	19.6	

Blackleaf Formation, lower transitional clastic lithofacies:

10.	Sandstone, medium-gray (N5); weathers to light-olive-gray (5Y6/1); medium-grained; very calcareous; quartzose; limonite stain; thick-bedded; sharp lower contact with load casts; unit continuous along strike.....	3.3	31.8
09.	Shale and siltstone dark-gray (N3) to medium-dark-gray (N4); moderately fissile; disseminated carbonaceous matter and coal; single, thin interbedded siltstone.....	1.0	30.8
08.	Mudstone and sandstone, brownish-gray (5Y4/1) to medium-gray (N5); weathers to medium-gray (N5); sandstone fine-grained; rounded-to-subrounded grains; moderately calcareous; cherty; quartzose; massive near base to ripple laminated near top; mudstone interbeds; hematite stained; strongly fractured.....	3.3	27.5
07.	Shale, and sandstone dark-gray (N3); weathers to medium-gray (N5); predominantly strongly fissile shale with single thin (less than 0.2 m) fine-grained sandstone bed; sandstone quartzose; rounded-to-subrounded grains; hematite-filled fractures; entire unit strongly calcareous.....	1.5	26.0
06.	Shale and mudstone, dark-gray (N3) to olive-gray (5Y4/1); weathers to brownish-gray (5YR4/1); weakly-to-strongly fissile; very calcareous; nodular, with small (less than 1 cm in diameter) iron-rich nodules..	3.1	22.9
05.	Mudstone, moderate-red (5R4/6); weathers to pale-red (10R6/2); strongly calcareous; nodular; poorly exposed.....	0.2	22.7

Blackleaf Formation lower mudstone-shale lithofacies continued:

unit		meters thickness	meters cumulative thickness
04.	Covered interval, assumed to be mudstone.....	1.5	21.2
03.	Mudstone and siltstone, grayish-olive-green (5GY3/2) to medium-gray (N5); predominantly mudstone with very thin siltstone interbeds; nodular, with abundant limestone nodules averaging 2-3 cm in diameter; moderately calcareous; poorly exposed.....	3.0	18.2
02.	Covered interval.....	16.7	1.5
Total	thickness Blackleaf Formation, lower transitional clastic lithofacies.....	33.6	
Total	minimum thickness Blackleaf Formation.....	61.1	

Kootenai Formation, upper carbonate lithofacies:

01.	Limestone, medium-dark-gray (N4); weathers to medium-gray (N5); coarsely crystalline, fossiliferous limestone; abundant gastropods; thin- to very thin-bedded; unit laterally continuous.....	1.5	0.0

MEASURED SECTION 5 (Grasshopper Creek)

Blackleaf and Kootenai Formations along the south side of Grasshopper Creek, south of Dillon, Beaverhead County, Montana:

[SE 1/4 sec. 26, T. 8 S., R. 10 W., Daleys Quadrangle; measured by T. S. Dyman and J. E. Platt, June, 1983]

Blackleaf Formation, lower transitional clastic lithofacies:

unit		meters thickness	meters cumulative thickness
08.	Sandstone, pinkish-gray (5YR8/1) to light-gray (N7); weathers to light-gray (N7); fine-to medium-grained; rounded-to-angular grains; very calcareous; quartzose; limonite as grain coatings and fracture fillings; thick-bedded with beds up to 1.0 m thick; very weathered outcrop; forms dip slope along east side of unnamed gulley; overlain unconformably by Upper Cretaceous Beaverhead Group.....	4.2	33.0
07.	Mudstone and siltstone, light-olive-gray (5Y6/1) to pale-reddish-brown (10R5/4); strongly color-variant beds; very calcareous; in part nodular; poorly exposed.....	3.5	29.5
06.	Sandstone, light-gray (N7); weathers to grayish-orange (10YR7/4); very fine-grained; rounded-to-subrounded grains; quartzose; very calcareous; bioturbated in part; ripple laminated; laterally discontinous with sharp lower contact.....	0.3	29.2
05.	Mudstone, grayish-olive-green (5GY3/2); weakly fissile; poorly exposed.....	2.7	26.5
04.	Sandstone, light-gray (N7) weathers to grayish-orange (10YR7/4); very fine-grained; rounded-to-subrounded grains; quartzose; very calcareous; thin-bedded; bioturbated in part; flute(?) and groove casts on lower bedding surfaces; weathers to rounded masses.....	0.5	26.0

Blackleaf Formation, lower transitional clastic lithofacies continued:

unit		meters thickness	cumulative thickness
03.	Mudstone and siltstone, grayish-olive-green (5GY3/2) to pale-reddish-brown (10R5/4); color variant beds; moderately calcareous; poorly exposed.....	7.3	18.7
02.	Covered interval, presumed to be mudstone.....	10.7	8.0
Total minimum thickness, Blackleaf Foramtion.....		29.2	

Kootenai Formation, upper carbonate lithofacies:

01.	Limestone, pale-yellowish-brown (10YR6/2); weathers from pale-yellowish-brown (10YR6/2) to light-gray (N7); coarsely crystalline fossiliferous limestone; abundant gastropods and bivalves; mottled weathering surfaces; thin- to medium-bedded; forms resistant ridge.....	8.0	0.0

MEASURED SECTION 6 (Blacktail Gulch)

Blackleaf and Kootenai Formations immediately northwest of the Crampton Ranch, northern Blacktail Range, Beaverhead County, Montana:

[NE 1/4 sec. 15, T. 9 S., R. 9 W., Gallagher Mountain Quadrangle; measured by T. S. Dyman and M. Gamache, August, 1984]

Blackleaf Formation, lower transitional clastic lithofacies:

unit		meters thickness	meters cumulative thickness
05.	Siltstone and mudstone, pale-yellowish-brown (10YR6/2); poorly fissile; moderately calcareous; nodular with rare limestone nodules up to 5 cm in diameter; poorly exposed.....	4.1	10.4
04.	Sandstone, medium-gray (N5); weathers to medium-light-gray (N6); fine- to very fine-grained; cherty; quartzose; very calcareous; thin-bedded; well-developed parting lineation; abundant low angle trough cross-stratification; unit continuous along strike.....	1.8	8.6
03.	Sandstone, medium-gray (N5); weathers to medium-light-gray (N6); very fine-grained; cherty; quartzose; very calcareous; very thin-bedded; well-developed symmetric ripples; unit continuous along strike.....	2.0	6.6
02.	Sandstone and shale, medium-dark-gray (N4); weathers to medium-gray (N5); sandstone predominant; fine- to very fine-grained; rounded-to-subangular grains; cherty; quartzose; very calcareous; thin flaggy beds; thin shale interbeds; poorly exposed.....	3.2	3.4
Total	minimum thickness Blackleaf Formation.....	11.1	

Kootenai Formation upper carbonate lithofacies;

01.	Limestone, medium-gray (N5); weathers to light-gray (N7); coarsely crystalline fossiliferous limestone; abundant gastropods; medium-bedded; forms resistant ridge.....	3.4	0.0

MEASURED SECTION 7 (Ruby River)

Frontier, Blackleaf, and Kootenai Formations, exposed along the north side of Ruby River Road, northern Snowcrest Range, Madison County, Montana:

[SE 1/4 sec. 18, T. 9 S., R. 3 W., Home Park Ranch quadrangle; measured by T. S. Dyman and R. Niblack, June-July, 1983]

Frontier Formation undifferentiated:

unit		meters thickness	meters cumulative thickness
53.	Sandstone, light-gray (N7) to medium-light-gray (N6); weathers to moderate-yellowish-orange (10YR6/6); medium- to coarse-grained; rounded-to-subangular grains; weakly calcareous; cherty; quartzose; well-developed limonite stain; rare rootlets and carbonaceous matter; calcite fracture filling; medium-bedded in part; small-scale trough cross-stratification; unit continous for 20 m along strike.....	1.6	212.6
52.	Mudstone and siltstone, light-gray (N7); weathers to yellowish-gray (5Y8/1); weakly calcareous; weakly fissile; poorly exposed.....	3.4	209.2
51.	Sandstone, yellowish-gray (5Y8/1); weathers to medium-light-gray (N6); medium-grained; rounded-to-subangular grains; cherty; quartzose; weakly calcareous; calcite filled fractures; small-scale moderately dipping trough cross-stratification; unit with sharp lower (erosive?) contact; fining upward within unit and gradational with overlying mudstone...	0.8	208.4
50.	Covered interval, presumed to be mudstone.....	2.0	206.4
49.	Sandstone and siltstone, greenish-gray (5G6/1) to medium-bluish-gray (5B5/1); weathers to greenish-gray (5GY6/1); fine-grained; subrounded-to-subangular grains; cherty; micaceous; calcite filled fractures; thin-bedded; platy; slickensides; unit with sharp lower contact; fining upward within unit and gradational with overlying mudstone(?).....	3.5	202.9

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
48.	Sandstone and siltstone, dark-gray (N3); weathers to light-olive-gray (5Y6/1); fine- to coarse-grained; subrounded-to-angular grains; very calcareous; cherty; disseminted carbonaceous matter; coal(?); wood fragments; strongly fractured, with calcite filled fractures; slickensides; gradational with underlying unit.....	5.4	199.4
47.	Limestone, medium-gray (N5); weathers from yellowish-gray (5Y8/1) to light-olive-gray (5Y6/1); finely crystalline (micritic); silty; thin-bedded; calcite filled fractures; slickensides.....	0.6	198.8
46.	Sandstone, light-gray (N7) to medium-light-gray (N6); weathers to yellowish-gray (5Y7/2); very fine-grained; rounded(?) -to-subangular grains; very calcareous; cherty; finely disseminated carbonaceous matter; medium- to thickly-bedded; pervasive fracturing; slickensides; slight upward fining within unit; erosive.....	4.2	194.6
45.	Siltstone and mudstone, grayish-olive-green (5GY3/2) to medium-gray (N5); weathers from light-gray (N7) to greenish-gray (5GY6/1); green muds near base to gray muds near top of unit; weakly to very calcareous; thin siltstone bed (less than 0.5 m thick) near base; very calcareous; in part strongly bioturbated; fractured with calcite-filled fractures; poorly exposed.....	5.2	189.4
44.	Sandstone, light-olive-gray (5Y6/1); weathers to pale-yellowish-brown (10YR6/2); fine- to very fine-grained; very calcareous; limonite stain; finely disseminated carbonaceous matter; thin-bedded; rippled(?); strongly bioturbated; poorly exposed unit.....	2.2	187.2
43.	Sandstone, light-gray (N7) to greenish-gray (5GY6/1); weathers to yellowish-gray (5Y8/1); fine- to medium-grained; subrounded-to-angular grains; weakly to very calcareous; cherty; limonite stain; hematite nodules and grain coatings; medium- to thick-bedded; moderately dipping trough cross-stratification; in part ripple laminated; strongly fractured and slickensided; erosive base; unit forms resistant ridge.....	2.2	185.0

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
42.	Covered interval.....	2.2	182.8
41.	Sandstone, light-olive-gray (5Y5/2) to medium-gray (N5); weathers from pale-yellowish-brown (10YR6/2) to light-gray (N7); medium-grained; subrounded-to-angular grains; moderately calcareous; cherty; limonite stain; medium-bedded; calcite filled fractures; slickensides; discontinous unit with erosive base.....	0.6	182.2
40.	Sandstone and conglomerate, medium-dark-gray (N4); weathers to greenish-black (5GY2/1); sandstone medium- to coarse-grained; well rounded-to-subangular grains; cherty; limonite stain; weakly calcareous; thick-bedded; conglomerate clasts up to 0.5 cm in diameter; clasts predominantly medium-gray siltstone and mudstone; conglomerate confined to base of unit; unit fines upward; erosive base; slickensides.....	0.5	181.7
39.	Sandstone, light-olive-gray (5Y6/1); weathers from yellowish-gray (5Y8/1) to pale-yellowish-brown (10YR6/2); fine-grained; subrounded-to-subangular grains; strongly calcareous; limonite stain; cherty; disseminated carbonaceous matter and wood fragments; strongly bioturbated; medium-bedded; sharp lower contact.....	1.4	180.3
38.	Siltstone and mudstone, medium-light-gray (N6); weathers to light-olive-gray (5Y6/1); very calcareous; finely disseminated organic matter; well-developed ripple lamination; 2 thin discontinuous siltstone beds separated by mudstone.....	2.2	178.1
37.	Sandstone and conglomerate, medium-gray (N5) to medium-bluish-gray (5B5/1); weathers from medium-light-gray (N6) to yellowish-gray (5Y8/1); medium-grained; rounded-to-subangular grains; very calcareous; cherty; rare limonite stain; rare conglomerate clasts up to 0.3 cm in diameter; clasts of dark-gray mudstone and siltstone(?); calcite filled fractures abundant; wood fragments (up to 1 cm in length) and carbonaceous matter common; flute marks on sole surfaces; thick-bedded with beds up to 0.4 m thick; unit with erosive base; fining upward within unit and gradational(?) contact with overlying mudstones.....	1.5	176.6

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
36.	Limestone and siltstone, medium-gray (N5); weathers from light-gray (N7) to pinkish-gray (5YR8/1); limestone finely crystalline and structureless; siltstone very calcareous; finely disseminated carbonaceous matter; micaceous; finely developed parallel laminations.....	1.3	175.3
35.	Sandstone, siltstone, and mudstone, greenish-gray (5GY6/1) to light-olive-gray (5Y6/1); weathers from pale-brown (5YR5/2) to light-gray (N7); sandstone as 3 thin (less than 1 m thick) discontinuous channel-like nodules; sandstone fine-grained; subrounded-to-subangular grains; weakly calcareous; cherty; sandstone fines upward to siltstone.....	4.8	170.5
34.	Siltstone and mudstone, moderate-yellow-brown (10YR5/4) to medium-light-gray (N6); weakly to very calcareous; micaceous; limonite stain; very fossilferous; abundant carbonaceous matter and wood; wood fragments up to 4 cm in length; abundant bivalves; entire unit weakly to strongly fissile; *Pleuriocaradia pauperculum* (Meek) identified by W. A. Cobban, (sample RR-50).....	1.1	169.4
33.	Mudstone and siltstone, pale-brown (5YR5/2) to light-olive-gray (5Y6/1); very calcareous; abundant finely disseminated carbonaceous matter; limonite stain; strongly fissile in part; bioturbated; concretionary with rare calcareous concretions up to 1.5 cm in diameter; poorly exposed; sample RR46-1; palynomorphs identified by D. J. Nichols include: *Arecipites* sp. *Cupuliferoidaepollenites* sp. *Cyathidites* minor *Eucommiidites* minor *Nyssapollenites albertensis* *Pitysporites* spp. *Rugubivesiculites* sp. *Vitreisporites pallidus*.....	6.2	163.2
32.	Sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers to brownish-gray (5YR4/1); fine- to very fine-grained; subrounded-to-angular grains; very calcareous; cherty; micaceous; limonite stain; well-developed ripple lamination; laterally continuous along strike.....	3.7	159.5

Undifferentiated Frontier Formation continued:

unit		meters thickness	meters cumulative thickness
31.	Mudstone, medium-gray (N5); calcareous; fissile; poorly exposed.....	0.6	158.9
30.	Sandstone, pale-yellowish-brown (10YR6/2) to light-olive-gray (5Y5/2); weathers from yellowish-gray (5Y7/1) to dusky-yellow (5Y6/4); fine- to medium-grained; subrounded-to-angular grains; moderately calcareous; micaceous, with abundant biotite; fossiliferous, with abundant unidentified bivalves and disseminated carbonaceous matter; thin-bedded; unit with sharp lower contact.....	4.8	154.1
29.	Mudstone, light-olive-gray (5Y5/2) to light-olive-gray (5Y6/1); weakly to non calcareous at base to very calcareous near top of unit; finely disseminated carbonaceous matter; more bioturbated near base of unit; fissile in part.....	4.5	149.6
28.	Sandstone, light-brownish-gray (5YR6/1) to brownish-gray (5YR4/1); weathers to dark-yellowish-brown (10YR4/2); fine- to medium grained; rounded-to-subangular grains; very calcareous; cherty; micaceous; 1 thin discontinuous bed; grades upward into overlying mudstone.....	0.5	149.1
27.	Covered interval, presumed to be mudstone.....	2.3	146.8
Total	minimum thickness undifferentiated Frontier Formation.....	69.3	

Blackleaf Formation upper volcaniclastic lithofacies:

26.	Mudstone and siltstone, light-olive-gray (5Y5/2); weakly calcareous; limonite stain; in part porcellanitic(?); poorly exposed.....	1.0	145.8
25.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers from light-olive-gray (5Y6/1) to olive-gray (5Y4/1); fine- to very fine grained; rounded- to-subangular grains; moderately calcareous; quartzose; cherty; hard and dense, breaking into sharp angular fragments; thin-bedded; sharp(?) lower contact.....	0.8	145.0
24.	Mudstone, light-olive-gray (5Y5/2); weakly calcareous; limonite stain; porcellanitic.....	1.1	143.9

Blackleaf Formation upper volcanclastic lithofacies continued:

unit		meters thickness	cumulative thickness
23.	Siltstone and mudstone, light-bluish-gray (5B7/1); weathers to medium-bluish-gray (5B5/1); finely disseminated carbonaceous matter; limonite stain; weakly calcareous; hard and dense; in part porcellanitic; several thin fining upward sequences within unit; siltstone predominant; very thin-bedded..	12.1	131.8
22.	Covered interval, presumed to be mudstone.....	2.9	128.9
21.	Sandstone and conglomerate, light-bluish-gray (5B7/1); weathers to light-olive-gray (5Y6/1); fine- to very fine-grained; subrounded-to-subangular grains; weakly calcareous, with calcareousness confined to fracture fillings; quartzose; micaceous; abundant coal and disseminated carbonaceous matter; conglomerate clasts rare; clasts predominately dark-gray mudstone; thin-bedded; hard and dense; unit highly fractured.....	1.8	127.1
20.	Mudstone and siltstone, medium-bluish-gray (5B5/1) to medium-dark-gray (N4); weathers to light-olive-gray (5Y6/1); mudstone predominant; hard and dense; weakly calcareous; fissile; in part porcellanitic; siltstone as very thin discontinuous beds; siltstone ripple laminated in part; bioturbated; in part poorly exposed.....	18.8	108.3
19.	Sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to light-olive-gray (5Y6/1); fine-grained; rounded-to-subangular grains; moderately calcareous; cherty; quartzose; unit trough cross-stratified in lower part; unit fines upward and gradational with overlying mudstone; erosive base.....	0.6	107.7
18.	Mudstone and siltstone, greenish-gray (5GY6/1) to dark-greenish-gray (5GY4/1); weathers from yellowish-gray (5Y8/1) to light-greenish-gray (5G8/1); calcareous only along fractured surfaces; finely disseminated carbonaceous matter; limonite stain on weathered surfaces; mudstone predominant; weakly-to-moderately fissile; siltstone as thin laterally discontinuous beds discontinuous beds; entire unit highly fractured; slickensides well developed.....	4.9	102.8

Blackleaf Formation upper volcaniclastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
17.	Sandstone, medium-dark-gray (N3) to dark-gray (N2); weathers from light-olive-gray (5Y5/2) to grayish-brown (5YR3/2); fine-grained; rounded-to-subangular grains; quartzose; cherty; very hematitic in lower part; micaceous; ripple lamination throughout but poorly developed; unit burrowed; rare flute marks; unit continuous along strike; sharp lower contact.....	4.3	98.5
16.	Mudstone, bentonitic, porcellanitic, moderate-orange-pink (10R7/4) to light-gray (N7) to greenish-black (5GY2/1); unit strongly color variant with alternating light and dark bentonitic and porcellanitic beds; unit highly fractured and slickensided; hard and dense, breaking into sharp angular fragments; dark-gray beds more porcellanitic and mineralized; limonite concretions(?) and well-developed calcite fracture fillings; ovular lithophysae(?) up to 0.2 cm in diameter.....	5.0	93.5
15.	Coverd interval, presumed to be porcellanitic mudstone.....	2.4	91.1
14.	Mudstone, porcellanitic, light-olive-gray (5Y6/1) to dark-gray (N3); weathers from medium-gray (N5) to olive-gray (5Y4/1); unit highly fractured and slickensided; hard and dense, breaking into sharp angular fragments; well-developed calcite fracture fillings; ovular lithophysae up to 0.2 cm in diameter.....	1.8	89.3
13.	Sandstone, moderate-reddish-orange (10R6/6); fine- to very fine-grained; rounded-to-subangular; quartzose; cherty; hematite stained; one thin bed; strongly fractured; unit discontinuous.....	0.3	89.0
12.	Mudstone and sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to medium-gray (N5); sandstone fine- to medium-grained, predominantly medium-grained; rounded-to-subangular grains; quartzose; cherty; moderately calcareous; well-developed limonite stain as grain coatings; mudstone porcellanitic; hard and dense; mudstone predominant with thin-bedded discontinuous sandstone beds with sharp lower contacts.....	7.0	82.0

Blackleaf Formation upper volcaniclstic lithofacies continued:

unit		meters thickness	cumulative thickness
11.	Mudstone and shale, medium-gray (N5) to dark-gray (N3); weathers to olive-gray (5Y4/1); moderately to strongly fissile; limonite and hematite stain; calcareousness only along fracture surfaces; abundant dissementated carbonaceous matter and coal; fractured; well-developed slickensides.....	9.8	72.2
10.	Mudstone and siltstone, pale-olive (10Y6/2) to medium-gray (N5); weathers from olive-gray (5Y4/1) to dusky-yellow (5Y6/4); weakly-to-moderately fissile; mudstone predominant with thin discontinuous silty interbeds; disseminated carbonaceous matter; limonite stain; color variant, with gray beds containing finely disseminated carbonaceous matter; top one-half of unit predominantly gray in color sample RR17-1; palynomorph species identified by D. J. Nichols include: *Cicatricosisporites* *Costatoperforosporites* *Cupuliferoidaepollenites* *Cyathidites* *Gleicheniidites* *Laevigatosporites* *Lycopodiumsporites* *Pityosporites* *Taxodiaceaepollenites* *Vitreisporites*.....	6.1	66.1
Total thickness Blackleaf Formation upper volcaniclastic lithofacies.....		80.7	

Blackleaf Formation upper clastic lithofacies:

09.	Sandstone, olive-gray (5Y4/1) to light-olive-gray (5Y6/1); weathers to brownish-gray (5YR4/1); fine- to coarse-grained, predominantly medium-grained; rounded-to-angular grains; quartzose; cherty; very calcareous; thin (less than 3 mm thick) shale partings; bioturbated in part; at least 2 distinct sandstone beds separated by sharp (erosive ?) contacts; sands coarsen upward within unit; bedding surfaces strongly hematite stained; moderately- to-steeply dipping trough cross-stratification; generally medium- to thick-bedded.....	4.3	61.8
Total thickness Blackleaf Formation upper clastic lithofacies.....		4.3	

Blackleaf Formation lower mudstone-shale lithofacies:

unit		meters thickness	meters cumulative thickness
08.	Shale, medium-gray (N5) to medium-dark-gray (N4); weathers from medium-light-gray (N6) to yellowish-gray (5Y8/1); moderately calcareous; strongly fissile; wood fragments and disseminated carbonaceous matter; rare unidentified bivalve fragments; concretionary with calcareous concretions up to 5 cm in diameter.....	15.0	46.8
07.	Sandstone, medium-gray (N5) to medium-dark-gray (N4); fine-grained; moderately calcareous; one thin discontinuous bed; poorly exposed.....	0.2	46.6
06.	Shale, medium-gray (N5) to medium-dark-gray (N4); weathers from medium-light-gray (N6) to pale-yellowish-brown (10YR6/2); limonite stain; finely disseminated carbonaceous matter and coal(?); strongly fissile.....	17.1	29.5
Total	thickness Blackleaf Formation lower mudstone-shale lithofacies.....	32.3	

Blackleaf Formation lower transitional clastic lithofacies:

05.	Sandstone, pale-yellowish-brown (10YR6/2) to medium-light-gray (N6); weathers from brownish-gray (5YR4/1) to moderate-brown (5YR3/4); fine- to medium-grained; rounded-to-subangular grains; micaceous; well-developed limonite stain; quartzose; strongly bioturbated; poorly defined bedding in lower part, but rippled near top of unit; parting lineation near base; unit fractured.....	2.0	27.5
04.	Shale, medium-gray (N5) to medium-dark-gray (N4); weathers from medium-light-gray (N6) to yellowish-gray (5Y8/1); strongly fissile; rare, finely disseminated organic matter; limonite stain.....	0.3	27.2
03.	Sandstone and mudstone, light-olive-gray (5Y5/2) to olive-gray (5Y4/1); weathers to light-olive-gray (5Y6/1); interbedded sandstone and mudstone; sandstone fine-grained; rounded-to-subangular grains; quartzose; micaceous; abundant coal fragments, and burrows and trails on bedding planes; thin-bedded; mudstone strongly fissile.....	3.4	23.8

Blackleaf Formation lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
02.	Mudstone and shale, yellowish-gray (5Y7/2) to light-olive-gray (5Y5/2); weathers to yellowish-gray (5Y7/2); moderately-to-strongly fissile; very calcareous; finely disseminated carbonaceous matter; limonite stain; rare unidentified bivalves; in part poorly exposed.....	10.6	13.2
Total	thickness Blackleaf Formation lower transitional clastic lithofacies.....	16.3	
Total	thickness Blackleaf Formation.....	202.9	

Kootenai Formation upper carbonate lithofacies (gastropod limestone):

01.	Limestone, medium-gray (N5) to medium-light-gray (N6); weathers to medium-bluish-gray (5B5/1); coarsely crystalline gastropod-rich limestone; silty; bedding surfaces undulatory.....	13.2	0.0

MEASURED SECTION 8 (Warm Springs Creek)

Blackleaf and Kootenai Formations, exposed west of Warm Springs Creek, Greenhorn Range, Madison County, Montana:

[E $\frac{1}{2}$ sec. 15 and NE $\frac{1}{4}$ sec. 22, T. 9 S., R. 3 W., Varney Quadrangle, measured by T. S. Dyman and R. Niblack, July-August, 1983]

Blackleaf Formation, upper volcaniclastic lithofacies:

unit		meters thickness	meters cumulative thickness
31.	Mudstone and siltstone, medium-gray (N6); weathers from medium-light-gray (N7) to pale-red (10R6/2); porcellanitic in part; finely disseminated coal and carbonaceous matter; heulandite(?); hard and dense....	4.3	165.1
30.	Mudstone, pale-red (10R6/2) to olive-gray (5Y4/1) to medium-gray (N5); strongly color-variant with distinct green, red, and gray interbeds; porcellanitic and bentonitic in part; poorly exposed.....	5.8	159.3
29.	Mudstone, medium-dark-gray (N4); in part porcellanitic; massive.....	2.1	157.2
28.	Porcellanitic mudstone, light-olive-gray (5Y6/1) to dusky-yellow-green (5GY5/2); in part bentonitic; poorly exposed.....	1.1	156.1
27.	Porcellanitic mudstone, medium-gray (N5) to dark-gray (N3); weathers to medium-gray (N5); alternating color-variant beds; hard and dense; structureless in part, but distinct finely laminated beds; finely disseminated carbonaceous matter; unidentified fossil wood fragements.....	2.1	154.0
26.	Porcellanitic mudstone and siltstone, medium-gray (N5) to greenish-gray (5GY6/1); weathers to grayish-yellow-green (5GY7/2); thin subordinate siltstone beds form resistant ledges; in part hard and dense; rootlets; in part finely laminated; burrows(?); poorly exposed.....	17.2	136.8
25.	Mudstone, yellowish-gray (5Y7/2); strongly bioturbated and structureless; finely disseminated carbonaceous matter; rootlets; limonite stain; strongly fractured.....	11.2	125.6
24.	Sandstone, light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); thin, discontinuous sandstone bed; very fine-grained; finely laminated; strongly fractured.....	1.4	124.2

Blackleaf Formation, upper volcaniclastic lithofacies continued:

unit		meters thickness	cumulative thickness
23.	Mudstone, yellowish-gray (5Y7/2); strongly bioturbated and structureless; finely disseminated carbonaceous matter; rootlets; limonite stain; strongly fractured.....	8.2	116.0
22.	Covered interval, assumed to be mudstone.....	1.9	114.1
21.	Sandstone and mudstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers from olive-gray (5Y4/1) to light-olive-gray (5Y6/1); fine-grained; rounded-to-subangular grains; very calcareous; bioturbated; finely disseminated carbonaceous matter; two thin (less than 0.5 m thick) sandstone beds separated by dark-gray mudstone; sandstone with sharp lower contact and continuous along strike.....	3.6	110.5
20.	Sandstone, light-olive-gray (5Y6/1); weathers to medium-light-gray (N6); fine- to medium-grained; rounded-to-subangular grains; moderately-to-very calcareous; carbonaceous matter and wood; cherty; quartzose; limonite stain; bioturbated in part; thin- to medium-bedded; two distinct sandstone beds; laterally continuous with sharp lower contacts.....	2.1	108.4
19.	Mudstone and shale, medium-gray (N5); weathers to medium-light-gray (N6); moderately-to-poorly fissile; carbonaceous matter; poorly exposed.....	0.8	107.6
Total	minimum thickness Blackleaf Formation, upper volcaniclastic lithofacies.....	61.8	

Blackleaf Formation, upper clastic lithofacies:

unit		meters thickness	meters cumulative thickness
18.	Sandstone, medium-gray (N5); weathers from medium-light-gray (N6) to light-olive-gray (5Y6/1); fine- to medium-grained; rounded-to-subangular grains; cherty; quartzose; weakly-to-moderately calcareous; limonite stain; very finely laminated with grain orientation and mineral zonation near top; moderately dipping trough cross-stratification near base; very thin shale interbeds; sharp lower contact; unit continuous along strike.....	5.1	101.5
17.	Sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); fine- to medium-grained; rounded-to-subangular grains; cherty; quartzose; very calcareous; rare limonite stain; finely disseminated carbonaceous matter along bedding planes; finely laminated near top; moderately-to-steeply dipping trough cross-stratification near base; thin shale interbeds; sharp lower contact; unit continuous along strike; forms resistant ridge.....	7.3	94.2
16.	Sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to olive-gray (5Y4/1); fine- to medium-grained; rounded-to-subangular grains; very calcareous; finely disseminated carbonaceous matter; abundant bivalves and bivalve fragments; a single specimen was identified by W. A. Cobban: *Ostrea anomioides* Meek; thin, flaggy beds; unit forms base of large ridge; unit continuous along strike; sharp, lower contact....	3.4	90.8
Total	thickness Blackleaf Formation, upper clastic lithofacies.....	15.8	

Blackleaf Formation, lower mudstone-shale lithofacies:

15.	Covered interval, forms talus slope from overlying sandstone units.....	10.8	80.0
14.	Covered interval, presumed to be mudstone and shale...	9.9	70.1
13.	Shale and mudstone, olive-gray (5Y4/1); weathers to light-olive-gray (5Y6/1); limonite stain; carbonaceous matter; strongly fissile; poorly exposed.....	5.1	65.0

Blackleaf Formation, lower mudstone-shale lithofacies continued:

unit		meters thickness	meters cumulative thickness
12.	Covered interval, presumed to be mudstone or shale....	9.8	55.2
11.	Shale, medium-dark-gray (N4) to olive-gray (5Y4/1); limonite stain; disseminated carbonaceous matter; moderately fissile; poorly exposed.....	3.7	51.5
10.	Covered interval, presumed to be mudstone or shale....	21.4	30.1
09.	Shale, olive-gray (5Y4/1); weathers to light-olive-gray (5Y6/1); finely disseminated carbonaceous matter along bedding planes; in part micaceous; limonite stain; strongly fissile.....	8.6	21.5
08.	Covered interval, presumed to be mudstone or siltstone.....	4.0	17.5
Total thickness, Blackleaf Formation, lower mudstone-shale lithofacies.....		73.3	

Blackleaf Formation, lower transitional clastic lithofacies:

07.	Sandstone, medium-bluish-gray (5B5/1) to medium-gray (N5); weathers to brownish-gray (5YR4/1); fine-grained; rounded-to-subangular grains; quartzose; strongly bioturbated; carbonaceous matter; rippled in part; thin, flaggy beds; discontinuous unit with sharp lower contact.....	0.5	17.0
06.	Covered interval, presumed to be mudstone or siltstone.....	2.8	14.2
05.	Sandstone, yellowish-gray (5Y8/1) to light-gray (N7); weathers to brownish-gray (5YR4/1); fine- to very fine grained; rounded-to-subrounded grains; quartzose; limonitic along fractures and bedding planes; burrowed and bioturbated; thin-bedded; well-developed slickensides; laterally continuous unit.....	1.2	13.0
04.	Covered interval, presumed to be mudstone or siltstone.....	4.1	8.9
03.	Sandstone, pale-yellowish-brown (10YR6/2) to yellowish-gray (5Y8/1); weathers from brownish-gray (5Y4/1) to pale-red (10R6/2); fine-grained; rounded-to-subrounded grains; very quartzose; micaceous; limonite stain; weakly calcareous; bioturbated in part; thin-bedded; laterally continuous unit; sharp lower contact; slickensides.....	1.2	7.7

Blackleaf Formation, lower transitional clastic lithofacies continued:

unit		meters thickness	meters cumulative thickness
02.	Covered interval, presumed to be siltstone and mudstone.....	4.7	3.0
Total	thickness Blackleaf Foramtion, lower transitional clastic lithofacies.....	14.5	
Total	minimum thickness Blackleaf Formation.....	165.4	

Kootenai Formation, upper carbonate lithofacies;

01.	Limestone, medium-light-gray (N6); coarsely crystalline bioclastic limestone; abundant gastropod and bivalve(?) fragments; ostrocods(?); thin, flaggy beds; laterally persistent unit; highly fractured.....	3.0	0.0

MEASURED SECTION 9 (Cottonwood Iron Creek)

Blackleaf Formation along north side Cottonwood Iron Creek, Gravelly Range, Madison County, Montanta:

[N 1/2 sec. 25, T. 10 S., R. 3 W., Monument Ridge Quadrangle, measured by T. S. Dyman, August, 1984]

Blackleaf Formation upper clastic lithofacies:

unit		meters thickness	meters cumulative thickness
03.	Sandstone, light-olive-gray (5Y6/1) to medium-light-gray (N6); weathers to brownish-gray (5YR4/1); medium- to-coarse-grained; rounded-to-subangular grains; very weakly calcareous; cherty; quartzose; poorly-developed trough cross-stratification; at least 3 sandstone beds separated by sharp contacts; forms top of distinctive ridge.....	17.2	11.7
02.	Sandstone and conglomerate, medium-dark-gray (N4); weathers to medium-light-gray (N6); sandstone and conglomerate at base of unit and sandstone near top; conglomerate as gravel lag near base; sandstone, medium- to coarse-grained; very cherty; quartzose; rounded-to-subangular grains; conglomerate clasts up to 10 cm diameter; clasts predominantly dark-gray chert and tan quartzite; no pebble orientation or imbrication; in part trough cross-stratified; gravel lag discontinuous; but other similar beds along strike; well-preserved wood and wood impressions.....	5.2	6.5
01.	Sandstone, medium-light-gray (N6); weathers to brownish-gray (5YR4/1); medium- to coarse grained; rounded-to-subangular grains; very cherty; quartzose; well-developed trough cross-stratification; lower contact hidden by covered interval.....	6.5	0.0
Total	thickness Blackleaf Formation upper clastic lithofacies.....	28.9	

MEASURED SECTION 10 (Monument Hill)

Blackleaf and Kootenai Formations along southwest flank of Monument Hill, Gravelly Range, Madison County, Montana:

[unsurveyed area about 1/2 mile west of Gravelly Range Road in unnamed gulch, Monument Ridge 15′ Quadrangle; measured by T. S. Dyman, August, 1983]

Blackleaf Formation, upper volcaniclastic lithofacies:

unit		meters thickness	meters cumulative thickness
16.	Sandstone and conglomerate, yellowish-gray (5Y7/2); fine- to coarse-grained; poorly sorted; very thin shale interbeds; finely disseminated coal and wood fragments parallel to bedding planes; limonite stain; bentonitic(?); very thinly-bedded; well-developed slickensides; poorly exposed.....	2.0	82.0
15.	Mudstone and siltstone, medium-dark-gray (N4); weathers to light-bluish-gray (5B7/1); porcellanitic; hematite stain along fractures and bedding planes; fine parallel laminations; rare carbonaceous matter; hard and dense; discontinuously exposed.....	2.0	80.0
14.	Covered interval, assumed to be mudstone.....	10.2	69.8
Total	minimum thickness Blackleaf Foramtion, upper volcaniclastic lithofacies.....	14.2	

Blackleaf Formation, upper clastic lithofacies:

13.	Sandstone, medium-gray (N5); medium-grained; rounded-to-subangular grains; weakly-to-moderately calcareous; cherty; quartzose; wood and carbonaceous matter abundant; very thin (less than 1 cm thick) shale partings; well-developed low angle trough cross-stratification; thin- to thick-bedded; sharp lower contact.....	4.0	65.8
12.	Sandstone, medium-gray (N5); weathers to olive-gray (5Y4/1); medium-grained; rounded-to-subangular grains; cherty; quartzose; at least one very fossilferous bed with many broken specimens of thick-shelled unidentified brackish water(?) bivalves (W. A. Cobban, written communication); very calcareous; well-developed shale partings in part; poorly developed trough cross-stratification; erosive lower contact.....	6.1	59.7

Blackleaf Formation, upper clastic lithofacies continued:

unit		meters thickness	cumulative thickness
11.	Shale, dark-gray (N3); strongly fissile with rare hard, hematite concretions; weakly-to-strongly calcareous; carbonaceous matter and wood fragments....	1.6	58.1
10.	Sandstone, medium-gray (N5) to medium-light-gray (N6); fine- to very fine-grained; rounded-to-well rounded grains; very calcareous; cherty; quartzose; very thin-bedded; fine parallel laminations in part; unit thins laterally.....	0.5	57.6
Total	thickness Blackleaf Formation upper clastic lithofacies.....	12.2	

Blackleaf Formation lower mudstone-shale lithofacies:

09.	Siltstone and mudstone, medium-gray (N5); thin-bedded siltstone beds with subordinate mudstone; siltstone as discontinuous, ripple-laminated beds; mudstone with carbonaceous matter; unit strongly-to weakly calcareous; single, large (7 cm in diamter) *Inoceramus comancheanus* cast near base of unit (identified by W. A. Cobban); poorly exposed in gully bottom and margins.....	6.3	51.3
08.	Covered interval, presumed to be mudstone and shale...	9.7	41.6
07.	Shale, dark-gray (N4); weakly-to-strongly fissile shale beds with rare thin siltstone beds; hematite stain along fracture surfaces; moderately-to-weakly calcareous; siltstone beds in part ripple laminated; bioturbated; discontinuously exposed along gully bottom.....	11.6	30.0
06.	Sandstone, medium-gray (N5) to medium-dark-gray (N4); weathers to medium-gray (N5); fine- to very fine-grained; rounded-to-well rounded grains; weakly-to-moderately calcareous; cherty; carbonaceous matter and wood fragments abundant; strongly bioturbated; limonite stain along bedding planes; rootlets near top of unit; rare poorly exposed sole marks along base; sharp lower contact.....	0.7	29.3

Blackleaf Formation, lower mudstone-shale lithofacies continued:

unit		meters thickness	cumulative thickness
05.	Shale and mudstone, olive-gray (5Y4/1) to medium-gray (N5); weathers to dark-yellowish-brown (10YR4/2); moderately-to-poorly fissile; finely disseminated carbonaceous matter and coal(?); limonite stain along bedding planes; lower part concretionary with common hematite concretions up to 5 cm in diameter; exposed along slopes and in gully; sample MH8-1; palynomorph species identified by D. J. Nichols include: *Appendicisporites*, *Cicatricosisporites*, *Corollina*, *Cupuliferoidaepollenites*, *Gleicheniidites*, *Taxodiaceaepollenites*, *Pityosporites*, *Vitreisporites*.....	6.8	22.5
04.	Shale and siltstone; dark-yellow-brown (10YR4/2); weakly- to-moderately fissile; limonite stain; finely disseminated carbonaceous matter; in part concretionary with hard, hematite-rich concretions up to 5 cm in diameter; discontinuously exposed along margins of gully.....	7.3	15.2
Total	thickness Blackleaf Formation lower mudstone-shale lithofacies.....	42.4	

Blackleaf Formation, lower transitional clastic lithofacies:

03.	Sandstone, very-pale-orange (10YR8/2) to moderate-yellowish-brown (10YR5/4); weathers to dark-yellowish-brown (10YR4/2); fine- to very fine grained; rounded grains; very quartzose; hematite and limonite stain; rare clay and siltstone clasts up to 0.5 cm in diameter; massive in lower part but thin-bedded with parallel laminations near top; rare moderately dipping trough cross-stratification in lower part; unit continuous along strike, but poorly exposed.....	5.0	10.2
02.	Mudstone and siltstone, moderate-brown (5YR4/4) to light-gray (N7); moderately-to-very calcareous; nodular with limestone nodules up to 3 cm in diameter; in part, hematite stained; poorly exposed...	8.1	2.1
Total	thickness Blackleaf Foramtion, lower transitional clastic lithofacies.....	13.1	
Total	minimum thickness, Blackleaf Foramtion.....	81.9	

Kootenai Formation, upper carbonate lithofacies:

unit		meters thickness	meters cumulative thickness
01.	Limestone, light-gray (N7) to yellowish-gray (5Y8/1); weathers to light-gray (N7); coarsely crystalline bioclastic limestone with abundant gastropod fragments and rare bivalves; thin- to thick-bedded.....	2.1	0.0

MEASURED SECTION 11 (Antone Peak)

Frontier, Blackleaf, and Kootenai Formations north of Antone Guard station northwest of Deer and Rough Creeks near Antone Pass, Snowcrest Range, Beaverhead County, Montana:

[NW 1/4 sec. 22, sec. 15, SW 1/4 sec. 11, T. 12 S., R. 5 W., Antone Peak Quadrangle; measured by T. S. Dyman and R. E. Lambert, August, 1982]

Frontier Formation, undifferentiated:

unit		meters thickness	meters cumulative thickness
13.	Sandstone and limestone, medium-light-gray (N6); weathers to light-olive-gray (5Y6/1); medium- to coarse-grained predominant sandstone; rounded-to-angular grains; sandstone cherty and lithic-rich; bioturbated in part; sandstone in part conglomeratic; conglomerate clasts predominantly dark-gray mudstone up to 0.5 cm in diameter; conglomerate confined to base of unit; interbedded subordinate limestone beds; limestone micritic and in part concretionary; sandstone rippled near top of unit; unit composed of at least 2 sandstone beds separated by erosive(?) contacts; unit fines upward.....	8.3	474.0
12.	Mudstone and shale, medium-dark-gray (N4); weathers to medium-gray (N5); weakly-to-moderately calcareous; weakly-to-moderately fissile; carbonaceous matter and coal(?); sample RC-4-1; palynomorph genera identified by D. J. Nichols include: *Araucariacites* *Callialasporites* *Cicatricosisporites* *Corollina* *Costatoperforosporites* *Cupuliferoidaepollenites* *Cyathidites* *Foveosporites* *Gleicheniidites* *Laevigatosporites* *Pityosporites* *Rugubivesiculites* *Taxodiaceaepollenites* *Vitreisporites*.....	1.9	472.1
11.	Siltstone, yellowish-gray (5Y8/1) to light-olive-gray (5Y6/1); finely laminated; in part, bioturbated(?).....	2.6	469.5

Undifferentiated Frontier Formation continued:

unit		meters thickness	cumulative thickness
10.	Sandstone, medium-light-gray (N6); weathers to light-olive-gray (5Y6/1); medium-grained; rounded- to-angular grains; quartzose; cherty; lithic-rich; very calcareous; wood and carbonaceous matter; dicot leaf base identified by C. J. Smiley: *Vitis* sp. Other unidentified dicot leaf prints; thin- to medium-bedded; moderately dipping trough cross-stratification in lower part; grains fine upward within unit; sharp lower contact and laterally continuous unit.....	4.4	465.1
09.	Covered interval, presumed to be mudstone.....	4.9	460.2
08.	Sandstone, light-brownish-gray (5YR6/1); weathers to brownish-gray (5YR4/1); medium-grained; rounded-to-angular grains; very calcareous; cherty; lithic-rich; ripple lamination; laterally continuous unit.....	1.7	458.5
Total	minimum thickness Frontier Formation.....	23.8	

Blackleaf Formation, upper volcaniclastic lithofacies:

07.	Covered interval. Thickness verified by alternate traverses laterally along strike; forms characteristic swale on Antone Pass. Porcellanite in float; presumed to represent upper volcaniclastic lithofacies.....	378.5	80.0
Total	presumed thickness, Blackleaf Formation upper volcaniclastic lithofacies.....	378.5	

Blackleaf Formation, upper clastic lithofacies:

06.	Sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to brownish-gray (5YR4/1); medium-grained; rounded-to-subangular grains; cherty; quartzose; weakly calcareous; limonite stain; coal and carbonaceous matter abundant, parallel to bedding planes; flat, clay chip conglomerate near base of unit; very poorly exposed in upper part; laterally persistant ridge former; several distinct sandstone beds within unit.....	14.4	65.6

Blackleaf Formation, upper clastic lithofacies continued:

unit		meters thickness	cumulative thickness
05.	Sandstone, light-olive-gray (5Y6/1); weathers to light-brownish-gray (5YR6/1); fine- to medium-grained; rounded-to-subangular grains; cherty; very calcareous; limonite stain; thick-bedded; trough cross-stratified near base; structureless and strongly bioturbated near top of unit; unidentified brakish water bivalve fragments near base (W. A. Cobban written communication); laterally continuous ridge forming unit.....	13.6	52.0
Total	thickness, Blackleaf Formation, upper clastic lithofacies.....	28.0	

Blackleaf Formation, lower mudstone-shale lithofacie:

04.	Covered interval, presumed to be mudstone or shale....	32.5	19.5
Total	presumed thickness, Blackleaf Formation lower mudstone-shale lithofacies.....	32.5	

Blackleaf Formation, lower transitional clastic lithofacies:

03.	Sandstone, light-olive-gray (5Y6/10 to medium-gray (N5); weathers from brownish-gray (5YR4/1) to light-brownish-gray (5YR6/1); fine- to medium-grained; rounded-to-subrounded grains; limonite stain; bioturbated; weakly calcareous; finely disseminated carbonaceous matter and coal; unidentified bivalve and gastropod fragments; massive to thickly-bedded; resistant ridge former; laterally continuous unit.....	2.1	17.4
02.	Mudstone and siltstone, pale-red (10R6/2) to medium-gray (N5); poorly fissile; weakly-to-strongly calcareous; limestone concretions in part abundant; very poorly exposed.....	16.4	1.0
Total	thickness Blackleaf Formation, lower transitional clastic lithofacies.....	18.5	
Total	thickness Blackleaf Formation.....	457.5	

Kootenai Formation, upper carbonate lithofacies:

01.	Limestone, moderate-yellow-brown (10YR5/4) to light-gray (N7); weathers to medium-gray (N5); coarsely crystalline bioclastic limestone; abundant gastropod fragments; medium-bedded.....	1.0	0.0

REFERENCES

Dyman, T. S., Niblack, R., and Platt, J. E., 1984, Measured stratigraphic section of Lower Cretaceous Blackleaf Formation and lower Upper Cretaceous Frontier Formation (lower part) near Lima, Montana: U.S. Geological Survey Open-File Report 84-838, 25 p.

Hadley, J. B., 1980, Geology of the Varney and Cameron Quadrangles, Madison County, Montana: U.S. Geological Survey Bulletin 1459, 108 p.

Kauffman, E. G., 1977, Geological and biological overview: Western Interior Cretaceous Basin: Mountain Geologist, v. 14, p. 75-99.

Mann, J. A., 1954, Geology of part of the Gravelly Range, Montana: The Yellowstone - Bighorn Association Research Contribution 190, 92 p.

Perry, W. J., Wardlaw, B. R., Maughan, E. K., and Bostick, N., 1983, Structure, burial history, and petroleum potential of frontal thrust belt and adjacent foreland, southwest Montana: American Association of Petroleum Geologists Bulletin, v. 67, no. 5, p. 725-743.

Ross, C. P., Andrews, D. A., and Witkind, I. J., 1955, Geologic map of Montana, Washington, D.C.: U.S. Geological Survey, scale 1:250,000.

Ross, C. S., and Smith, R. L., 1961, Ash flow tuffs: their origin, geologic relations and identification: U.S. Geological Survey Professional Paper 366, 81 p.

Schwartz, R. K., 1972, Stratigraphic and petrographic analysis of the Lower Cretaceous Blackleaf Formation, southwestern Montana: Unpublished Ph.D. Thesis, Indiana University.