

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MEASURED STRATIGRAPHIC SECTION OF LOWER CRETACEOUS
BLACKLEAF FORMATION AND LOWER UPPER CRETACEOUS
FRONTIER FORMATION (LOWER PART) NEAR LIMA,
IN SOUTHWESTERN MONTANA

By

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

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INTRODUCTION

The Lower and lower Upper Cretaceous sequence near Lima, Montana lies within the southwest Montana fold-and-thrust belt near the western depositional edge of the foreland basin (Kauffman, 1977). A composite stratigraphic section of the Albian Blackleaf Formation and the Cenomanian Frontier Formation (lower part) was measured as part of a larger study to understand the regional stratigraphy, sedimentology, and 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.

A stratigraphic section near Lima Peaks was measured in August, 1982 and July, 1983 by the authors in sections 13, 14, and 18, T. 15 S., R. 8 W., Lima Peaks Quadrangle, Beaverhead County, Montana, approximately 10 km south of the town of Lima (fig. 1). Because of poor exposures, the section was measured in 3 segments within 1.5 km along the strike of the beds.

Cretaceous rocks of the Lima Peaks section lie along the southwestern flank of Lima Peaks in a narrow, south-dipping approximately 8-km-wide outcrop belt (Scholton and others, 1955). The Lima Peaks section conformably overlies older Mesozoic and Paleozoic sedimentary rocks exposed down dip in a wide outcrop belt extending northward to Lima Peaks. The strata described here underlie the Upper Cretaceous Beaverhead Group to the south and west. The Blackleaf and Frontier Formations have been encountered in the nearby subsurface by drilling (Perry and others, 1983).

Because of faulting and slumping in the area, secondary traverses were measured to verify interval thicknesses. The section was measured using a Brunton compass and tape.

The following 5 preliminary lithofacies units were established for the section:

- (1) Frontier Formation--lower clastic lithofacies
- (2) Blackleaf Formation--upper volcanoclastic lithofacies
- (3) Blackleaf Formation--upper clastic lithofacies
- (4) Blackleaf Formation--lower transitional clastic lithofacies
- (5) 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.

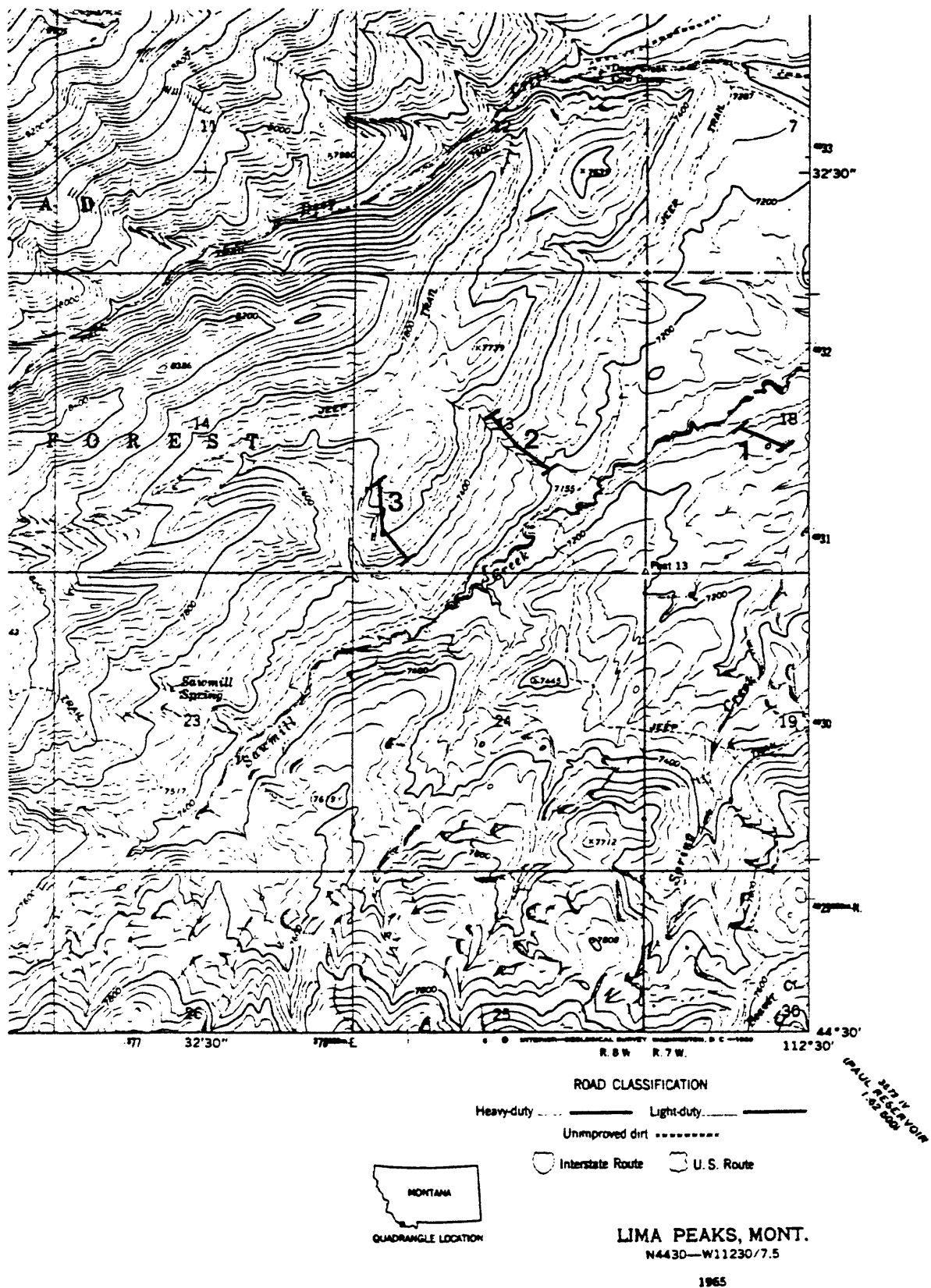


Figure 1. Locations of composite section

MEASURED SECTION

Partial section 1--Frontier Formation (units 115-122): exposures along north and south side of small ridge (fig. 1).

Frontier Formation, lower clastic lithofacies:

<u>unit</u>	<u>meters</u> <u>thickness</u>	<u>cumulative</u> <u>thickness</u>
122. Sandstone, light-olive-gray (5Y6/1); fine- to medium-grained, predominantly fine-grained; very calcareous and micaceous through out; very thin-bedded with well-developed horizontal laminations and shale partings; unit appears continuous for 20 m along strike and grades upward into covered interval.....	1.5	604.0
121. Covered interval.....	14.0	590.0
120. Sandstone and mudstone, medium-bluish-gray (5B5/1); weathers to light-olive-gray (5Y6/1); sandstone very fine-grained with rounded-to-subangular grains; weakly calcareous; very thin-bedded; mudstone, strongly calcareous, nodular, bentonitic (?).	2.0	588.0
119. Interbedded mudstone and siltstone, medium-dark-gray (N4); weathers to medium-gray (N5); mudstone fissile; very calcareous; nodular, with limestone nodules up to 30 cm in diameter; finely disseminated carbonaceous matter and coal.....	0.8	587.2
118. Sandstone, dark-yellowish-orange (10YR6/6) to grayish-orange (10YR7/4); weathers to grayish-orange (10YR7/4); fine- to coarse-grained, but predominately medium-grained; subangular-to-rounded grains; cherty; thin-bedded, with minor interbedded mudstone and siltstone; erosional contact at base(?).	1.2	586.0
117. Mostly covered, mudstone and siltstone.....	3.0	583.0
116. Sandstone, dark-yellowish-orange (10YR6/6) to grayish-orange (10YR7/4); fine- to coarse-grained, poorly sorted, with some beds coarser than others; limonite stain; micaceous; finely disseminated organic matter; thin- to thick-bedded.....	3.0	580.0
115. Sandstone, medium-bluish-gray (5B5/1) to medium-gray (N5); weathers to medium-light-gray (N6); fine- to very-fine-grained; subangular-to-rounded grains; micaceous; very calcareous; very thin-bedded with horizontal laminations; gradational with unit 116.....	2.7	577.3

Partial section 2--Frontier Formation and Blackleaf Formation (units 34-114):
flanks of small tributary to Sawmill Creek (fig. 1).

Frontier Formation lower clastic lithofacies continued:

114.	Covered interval.....	53.3	524.00
113.	Siltstone and mudstone, brownish-black (5YR2/1) to olive-gray (5Y4/1); weathers to brownish-gray (5YR4/1); mudstone near base, grading upward to carbonaceous siltstone near top of unit; weakly calcareous; well-preserved leaf imprints, and some wood fragments; moderately fissile; strongly fractured with limonite fracture fillings; dicot leaf fragments identified by C. J. Smiley include: <i>Aralia veatchii</i> Knowlton (?) <i>Populites</i> sp. (?) <i>Vitis</i> sp.....	7.0	517.0
112.	Sandstone, olive-gray (5R4/1); weathers to light-olive-gray (5Y6/1); subrounded-to-subangular grains; fine- to medium-grained, predominantly medium-grained; finely disseminated carbonaceous matter; laterally discontinuous unit with erosional base.....	1.8	515.2
111.	Mudstone and siltstone, light-olive-gray (5Y6/1) to olive-gray (5Y4/1); weathers to yellowish-gray (5Y8/1); predominantly nodular mudstone and siltstone at base, grading to moderately calcareous mudstone at top; well-developed rootlets and disseminated carbonaceous matter; rare disseminated sand-sized grains.....	3.2	512.0
110.	Sandstone, medium-bluish-gray (5B5/1) to greenish-gray (5G6/1); weathers from light-olive-gray (5Y6/1) to light-bluish-gray (5B7/1); medium- to coarse-grained, predominantly coarse; subrounded-to-subangular grains; cherty; micaceous; with limonite and hematite (?) stain; finely disseminated carbonaceous matter; sandstone becomes more friable upward in unit; sandstone appears massive, has an erosive base, and continues laterally along strike for 100 m.....	3.5	508.5

Frontier Formation lower clastic lithofacies continued:

109.	Sandstone and siltstone, medium-light-gray (N6); weathers to brownish-gray (5YR4/1); fine- to medium-grained sandstone near base, grades upward to siltstone near top; rounded-to-subangular grains; cherty and micaceous; very calcareous; well-developed trough cross-stratification throughout; poorly exposed, but erosive contact at base; laterally continuous.....	2.3	506.2
108.	Mudstone and siltstone, brownish-gray (5YR4/1); weathers to light-olive-gray (5Y6/1); carbonaceous-rich mudstone with subordinate siltstone; very fissile with leaf and wood impressions along bedding planes; U.S. Geological Survey paleobotany sample 6586F; species identified by D. J. Nichols include: <i>Appendicisporites</i> sp. <i>Cicatricosisporites</i> spp. <i>Culpuliferoidaepollenites</i> spp. <i>Cyathidites</i> Minor <i>Densoisporites</i> sp. <i>Foveotrilletes</i> sp. <i>Laevigatosporites</i> sp. <i>Microreticulatisporites</i> sp. <i>Podocarpidites</i> sp. <i>Pseudoschizaea</i> sp. <i>Rouseisporites reticulatus</i> <i>Rugubivesiculites</i> sp. <i>Taxodiaceapollenites hiatus</i> <i>Vitreisporites pallidus</i> <i>cf. Iosettes</i> sp. reticulate tricolpate sp. psilate tricolporate sp.....	0.8	505.4
107.	Sandstone and conglomerate, olive-gray (5Y4/1) to light-gray (N7); weathers to light-olive-gray (5Y6/1); rounded-to-subangular grains, predominantly subrounded; fine- to medium-grained; micaceous and cherty; conglomeratic at base only, with clasts up to 0.3 cm in diameter; clasts predominantly well-rounded mudstone; very calcareous at base to non calcareous at top; thin- to medium-bedded; outcrop poorly exposed with slickensides and numerous small-scale faults throughout.....	6.4	499.0
106.	Mostly covered, inferred to be gray mudstone.....	4.0	495.0

Frontier Formation lower clastic lithofacies continued:

105.	Sandstone, light-gray (N7); weathers to light-olive-gray (5Y6/1); fine- to very-fine grained; rounded-to-angular grains, predominantly subrounded-to-subangular; micaceous; finely disseminated carbonaceous matter; thin-bedded, laterally discontinuous; erosive base.....	0.6	494.4
104.	Sandstone and siltstone, light-gray (N7); weathers to light-brownish-gray (5YR6/1); fine- to very-fine grained; rounded-to-angular grains; micaceous, weakly calcareous, finely disseminated carbonaceous matter; sandstone grades upward to siltstone near top of unit; well-developed trough cross-stratification in lower part; laterally discontinuous; erosive base.....	2.4	492.0
103.	Sandstone and siltstone with subordinate mudstone, medium-light-gray (N6); weathers from light-brownish-gray (5Y6/1) to yellowish-gray (5Y8/1); sandstone very fine-grained; subangular-to-rounded grains; weakly calcareous; finely disseminated carbonaceous matter; sandstone grades upward to siltstone and mudstone; very thin-bedded; sandstone laterally discontinuous.....	1.7	490.3
102.	Shale, olive-black (5Y2/1); weathers to olive-gray (5Y4/1); moderately calcareous; well-preserved leaf and wood impressions; very fissile.....	1.3	489.0
101.	Mudstone and siltstone, dark-greenish-gray (5GY4/1); weathers from light-olive-gray (5Y6/1) to greenish-gray (5GY6/1); moderately-to-weakly calcareous; rare silt-sized chert fragments; hematite stain; bentonitic; mudstone grades upward to siltstone; weathers to form characteristic "popcorn texture".....	3.7	485.3
100.	Sandstone and conglomerate, medium-light-gray (N6) to grayish-green (5GY6/1); weathers from light-olive-gray (5Y6/1) to light-brownish-gray (5Y6/1); fine- to coarse-grained; subrounded-to-subangular grains; weakly-to-moderately calcareous; disseminated carbonaceous matter and coal; conglomerate in discontinuous lenses at base; rich in green to black mudstone and siltstone clasts with clay matrix; beds are massive		

Frontier Formation lower clastic lithofacies continued:

and form laterally discontinuous sandstone channels with erosive bases; sandstone fines upward within unit.....	1.7	483.6
Total Thickness Frontier Formation Measured.....	120.4	

Blackleaf Formation upper volcanoclastic lithofacies:

99. Mudstone, gray-green (10GY5/2); weathers to greenish-gray (5GY6/1); hard, slightly fissile; very weakly calcareous.....	5.6	478.0
98. Sandstone, medium-light-gray (N6); weathers to light-gray (N7); and interbedded mudstone, gray-green (10GY5/2); weathers to greenish-gray (5GY6/1); sandstone as 5 very thin (less than 5 cm thick discontinuous beds; fine- to medium-grained; subrounded-to-angular grains; cherty; micaceous; mudstone hard; weakly calcareous.....	2.8	475.2
97. Sandstone, light-gray (N7); weathers from light-olive-gray (5GY6/1) to light-gray (N7); fine- to medium-grained; subrounded-to-angular grains; limonite stain; very thin-bedded, with well-developed grain alignment parallel to bedding; laterally discontinuous channel-like unit with erosive base.....	2.6	472.6
96. Mudstone, gray-green (10GY5/2); weathers to greenish-gray (5GY6/1); hard, slightly fissile; fissile; weathers to characteristic "popcorn texture".....	2.6	470.0
95. Sandstone and mudstone; sandstone pale-reddish-brown (10R5/4); weathers to grayish-red (10R4/1); subrounded-to-angular grains; fine- to medium-grained; calcareous fracture fillings; hematite (?) stain; sandstone occurs as 3 thin-bedded, discontinuous units each approximately 0.4 m thick; sandstone units separated by gray-green mudstone units similar to unit 96 above; bone fragments from upper sandstone unit (468.8 m).....	4.8	465.2
94. Mudstone, gray-green (10GY5/2); weathers to greenish-gray (5GY6/1); hard, slightly fissile; weakly calcareous; bentonitic with well-developed "popcorn texture".....	15.2	450.0

Blackleaf Formation upper volcanioclastic lithofacies continued:

93.	Sandstone, pale-red (5R6/2); fine- to medium-grained; angular-to-subrounded grains; cherty, micaceous; rare hematite (?); thin-bedded; laterally discontinuous.....	0.6	449.4
92.	Sandstone and mudstone; sandstone greenish-gray (5GY6/1); weathers to gray-green (10GY5/2); predominantly coarse-grained; angular-to-subangular grains; lithic-rich with dark mudstone grains; cherty; weakly calcareous; sandstone grades upward to porcellanitic mudstone, greenish-gray (5GY6/1); mudstone hard; entire unit highly fractured.....	2.1	447.3
91.	Sandstone and conglomerate, medium-light-gray (N6) to greenish-gray (5GY6/1); fine- to coarse-grained poorly sorted sandstone; conglomerate clasts up to 5 mm in maximum diameter; subrounded-to-angular grains; sandstone lithic-rich; cherty; micaceous; conglomerate clasts predominantly green and gray, mudstone and porcellanite; laterally discontinuous channel-like body with conglomerate and sandstone at base grading upward to sandstone at top.....	0.5	446.8
90.	Mudstone and sandstone, light-gray (N7) to light-olive-gray (5Y6/1); predominantly mudstone with 4 thin (less than 5 cm thick) discontinuous sandstone units; mudstone bentonitic (?); sandstone fine- to medium-grained; subangular-to-angular grains; cherty; weakly calcareous; sandstone horizontally laminated; highly fractured with calcite fracture fillings.....	1.0	445.8
89.	Sandstone and siltstone, light-gray (N7) to light-brownish-gray (5YR6/1); weathers to light-olive-gray (5Y6/1); very fine-grained; subrounded-to-angular grains; tuffaceous with hematite (?) stain; cherty; very weakly calcareous; massive; laterally continuous.....	3.1	442.7
88.	Mudstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to greenish-gray (5GY6/1); weakly calcareous; slightly fissile; highly fractured.....	1.5	441.2

Blackleaf Formation upper volcaniclastic lithofacies continued:

87. Shale, dark-gray (N3) to black (N1); weathers to medium-dark-gray (N4); rich in carbonaceous matter; wood fragments; weakly calcareous; rare hematite stain; U.S. Geological Survey paleobotany sample D6586C; species identified by D. J. Nichols include:
- Cicatricosisporites* sp
Cyathidites minor
Gleicheniidites sp
Laenigatasporites sp
Pityosporites sp..... 2.2 439.0
86. Mudstone and siltstone, moderate-reddish-brown (10R4/6); weathers to moderate-reddish-orange (10R6/6); predominantly mudstone with thin (less than 5 cm) discontinuous siltstone bands; one thin (1.0 cm) porcellanite bed near top of unit; porcellanite is conglomeratic with green-to-gray porcellanitic mudstone clasts up to 0.5 cm in diameter; entire unit weakly-to-moderately calcareous; unit continuous along strike for more than 100 m..... 3.7 435.3
85. Bentonitic mudstone, gray-brown (5YR3/2) to light-olive-gray (5GY8/1); weathers from pale-yellow-brown (10YR6/2) to light-greenish-gray (5GY8/1); weakly calcareous; hematite (?) common; weakly developed fissility..... 3.5 431.83
84. Mudstone, brownish-gray (5YR4/1) to olive-gray (5Y4/1); weathers to medium-gray (N5); porcellanitic; weakly calcareous; finely disseminated hematite stain; breaks into very indurated, sharp-edged blocky fragments; highly fractured unit..... 7.2 424.6
83. Sandstone and conglomerate, medium-gray (N5) weathers to greenish-gray (5GY6/1); predominantly fine- to medium-grained sandstone with up to 30 percent coarse sandstone and conglomerate; sandstone, angular-to-subrounded grains; conglomerate clasts entirely sedimentary in origin with porcellanitic mudstone and siltstone predominating; unit weakly-to-moderately calcareous; discontinuous channel-like body; poorly exposed..... 0.4 424.2

Blackleaf Formation upper volcaniclastic lithofacies continued:

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|---|-----|-------|
| 82. Mudstone and siltstone, greenish-gray (5GY6/1);
porcellanitic; cherty; weakly calcareous;
finely laminated; hematite stain, especially
along fractured zones..... | 0.7 | 423.5 |
| 81. Sandstone, olive-gray (5Y4/1) to brownish-gray
(5YR4/1); weathers from grayish-red (10R4/1)
to light-olive-gray (5Y6/1); medium-grained;
well sorted; subrounded-to-angular grains;
cherty; moderately calcareous; nodular, with
calcareous nodules (limestone ?) up to 15 cm
in diameter; rare, finely disseminated hematite
(?); beds thin (less than 5 cm thick);
sandstone very friable; sandstone grades
upward to unit 82; poorly exposed..... | 1.0 | 422.5 |
| 80. Sandstone and siltstone, medium-light-gray (N6)
with thin discontinuous light-brownish-gray
(5YR6/1) bands; weathers to light-gray (N7);
predominantly medium-grained sandstone at base
grading upward to siltstone at top of unit;
subrounded-to-angular grains; weakly calcareous;
rare disseminated hematite (?); medium-to-large
scale trough cross-stratification with sharp
upper contacts and some mudstone drapes; some
mudstone conglomerates above reactivation
surfaces; mudstone clasts calcareous and up to
2 cm in diameter; sandstone unit forms resistant
ledge for 10 m along strike; passes laterally
into covered interval..... | 2.2 | 420.3 |
| 79. Sandstone and mudstone, moderate-gray (N5) to
dark-greenish-gray (5GY4/1); weathers to
greenish-gray (5GY6/1); fine- to very fine-
grained; subangular-to-subrounded grains;
micaceous; weakly calcareous; rare finely
disseminated heulandite (?); nodular, with
hard siliceous nodules up to 20 cm in diameter;
sandstone massive at base, grading upward to
mudstone at top of unit; unit continuous for
at least 50 m along strike; small faults with
less than 1 m displacement and well-developed
slickensides..... | 2.1 | 418.2 |

Blackleaf Formation upper volcanoclastic lithofacies continued:

- | | | | |
|-----|--|-----|-------|
| 78. | Sandstone, moderate-gray (N5) to dark-greenish-gray (5GY4/1); weathers to light-gray (N7); medium-grained; angular-to-subangular grains; cherty; moderately calcareous; finely-developed horizontal laminations; abundant calcite-filled fractures; separated from overlying unit by poorly exposed 10 cm thick mudstone unit; laterally discontinuous with erosive base..... | 1.1 | 417.1 |
| 77. | Siltstone, grayish-olive-green (5GY3/2); weathers to grayish-yellow-green (5GY7/2); subrounded-to-subangular grains; finely disseminated hematite; very thin-bedded (less than 5 cm thick); weathers to distinctive, irregular fragments; unit cut by numerous small faults and calcite-filled fractures; unit appears continuous for at least 60 m along strike..... | 0.3 | 416.8 |
| 76. | Mudstone and sandstone, light-bluish-gray (5B7/1) to medium-bluish-gray (5B5/1); weathers to greenish-gray (5G6/1); predominantly mudstone with several very thin (less than 5 cm thick) discontinuous sandstone beds; sandstone fine-grained; subangular-to-angular grains; mudstone nodular, with hard, rounded hematite-rich nodules up to 3 cm in diameter; finely disseminated carbonaceous matter; entire unit weakly calcareous; unit cut by numerous small faults and calcite-filled fractures; continuous for at least 60 m along strike..... | 7.3 | 409.5 |
| 75. | Sandstone, medium-light-gray (N6); weathers to light-gray (N7); fine- to medium-grained; subrounded-to-angular grains; cherty; micaceous; moderately calcareous; very strongly fractured with calcite-filled fractures; laterally discontinuous; erosive base; poorly exposed..... | 0.7 | 407.8 |
| 74. | Porcellanitic mudstone, grayish-olive (10Y4/2); weathers to light-olive-gray (5Y5/2); hard; weakly calcareous; 5 cm thick calcareous nodular zone at base of unit..... | 0.8 | 407.0 |

Blackleaf Formation upper volcaniclastic lithofacies continued:

73.	Sandstone, pale-reddish-brown (10R5/4) to light-bluish-gray (5B7/1); weathers from grayish-red (10R4/2) to pale-red (5R6/2); exposed as discontinuous masses of red and gray with sharp color contacts; fine- to very fine-grained; subangular-to-angular grains; cherty; slightly-to-moderately calcareous; weathers into rounded masses; abundant fractures and slickensides; unit actually 3 sandstone beds separated by erosive(?) contacts.....	0.9	406.1
72.	Porcellanitic mudstone, medium-bluish-gray (5B5/1); weathers from medium-bluish-gray (5B5/1) to light-bluish-gray (5B7/1); weakly calcareous; rare finely disseminated hematite.....	0.6	405.5
71.	Sandstone, pale-reddish-brown (10R5/4); weathers to pale-red (5R6/2); fine-to-medium grained, predominantly fine-grained; subangular-to-angular grains; cherty; moderately calcareous; limonite grain coatings; beds less than 5 cm thick; sharp, irregular (erosive ?) lower contact with underlying mudstone; discontinuous, channel-like unit; highly fractured.....	1.2	404.3
70.	Porcellanitic mudstone, dusky-yellow-green (5GY5/2); weathers to gray-green (10GY5/2); rare hematite stain along fractures; numerous small faults, fractures and slickensides; hard, dense; breaks into sharp angular masses; unit continuous for 40 m along strike.....	6.4	397.9
69.	Tuffaceous sandstone, moderate-red-orange (10R6/6); weathers to pale-red-brown (10R5/4); fine- to very fine-grained, predominantly very fine-grained; subrounded-to-angular grains; cherty; micaceous; very weakly calcareous; rare disseminated carbonaceous matter; 10 cm thick nodular zone at base with very calcareous nodules; well-developed horizontal laminations above nodular zone; highly fractured; sharp lower contact; unit continuous for at least 20 m along strike.....	0.7	397.2

Blackleaf Formation upper volcanoclastic lithofacies continued:

68.	Mudstone and siltstone, mudstone medium-bluish-gray (5B5/1); weathers to light-bluish-gray (5B7/1); hematite and limonite stain; thin, discontinuous red siltstone bed (less than 2 cm thick) within mudstone; siltstone hematite stained; weakly calcareous; mudstone continuous for at least 20 m along strike.....	0.2	397.0
67.	Shale, dark-gray (N3); weathers to medium-dark-gray (N4); irregular masses of green and red stain; rich in carbonaceous matter with well-preserved wood textures; weakly-to-strongly calcareous; micaceous; very thin discontinuous (less than 2 cm thick) siltstone stringers; rare calcareous nodules; moderately fissile.....	2.3	394.7
66.	Sandstone, medium-light-gray (N6); weathers to light-gray (N7); predominantly coarse-grained; subrounded-to-angular grains; lithic-rich with sedimentary lithic grains dominant; hematite as grain coatings and irregular masses; moderately calcareous; discontinuous, massive channel-like body with sharp lower contact; gradational with overlying dark-gray shale unit 67.....	0.9	393.8
65.	Porcellanitic mudstone, brownish-gray (5YR4/1) to light-olive-gray (5Y5/2); weathers from dusky-yellow (5Y6/4) to light-brownish-gray (5YR6/1); weakly calcareous; micaceous; hematite stain; sharp, blocky fracture; central portion of unit forms resistant ledge.....	1.0	392.8
64.	Sandstone (tuffaceous?), pale-red (5R6/2); weathers to moderate-orange-pink (10R7/4); fine- to very fine-grained; subangular; micaceous; cherty; hematite stain; rare disseminated carbonaceous matter; sharp lower contact; grades upward into overlying mudstone unit 65.....	1.1	391.7
63.	Porcellanitic mudstone, olive-gray (5Y4/1); weathers to greenish-gray (5GY6/1); hard, dense mudstone with blocky fracture; silt-sized hematite grains common; non calcareous lower part, and moderately calcareous upper more nodular part.....	1.0	390.7

Blackleaf Formation upper volcaniclastic lithofacies continued:

62.	Bentonitic mudstone, light-olive-gray (5Y6/1); weathers to grayish-yellow (5Y8/1); very friable, weathers to distinctive "popcorn texture"; faint laminations developed on fresh surfaces; poorly exposed, but appears gradational with overlying unit 63.....	3.7	387.0
61.	Porcellanitic mudstone, gray-black (N1); weathers to dark-gray (N3); very hard and dense, breaking into sharp angular fragments; common irregular masses of hematite (?); ledge former; gradational with over lying unit 62.....	1.5	385.5
60.	Sandstone and siltstone, medium-light-gray (N6) to light-olive-gray (5Y5/6); weathers from brownish-gray (5YR4/1) to light-olive-brown (5Y5/6); fine- to medium-grained sandstone at base of unit to siltstone near top; rounded-to-subangular grains; cherty; micaceous; moderately calcareous; much carbonaceous matter with some woody texture preserved; thinly-bedded with fine light-to-dark mineralogically-controlled laminations; unit strongly fractured; entire unit grades upward into overlying mudstone, unit 61.....	3.3	382.2
59.	Mudstone and siltstone, medium-dark-gray (N4) to light-olive-gray (5Y5/2); weathers from yellow-gray (5Y8/1) to light-greenish-gray (5GY8/1); predominantly mudstone with one 20 cm thick siltstone bed near base; mudstone highly fractured with cone-in-cone structure; siltstone micaceous; one small (1 mm diameter) unidentified tooth (?) found near base of siltstone bed; unit weathers as rounded masses.....	5.0	377.2
58.	Sandstone, moderate-gray (N5); weathers to light-olive-gray (5Y6/1); predominantly fine-grained; rounded-to-angular grains; micaceous; moderately calcareous; rare limonite stain; well-developed ripple lamination; very thin (less than 1.0 mm thick) clay interlaminae; in part poorly exposed.....	0.4	376.8
57.	Siltstone, medium-dark-gray (N4); weathers to medium-gray (N5); rounded-to-subrounded grains; moderately calcareous; rare carbonaceous matter; hematite and limonite stain; massive bed with poorly exposed lower contact.....	12.1	375.5

Blackleaf Formation upper volcanioclastic lithofacies continued:

56.	Covered interval, presumed to be mudstone.....	12.1	363.4
55.	Mudstone, dark-red-brown (10R3/4); weathers to pale-red (5R6/2); moderately calcareous; weakly fissile; irregular, discontinuous red and green bands; grades upward into covered interval.....	4.5	358.9
54.	Sandstone, medium-gray (N5); weathers to grayish-red (10R4/2); fine- to very fine-grained; rounded-to-subangular grains; cherty; very calcareous; coal and carbonaceous matter abundant along bedding surfaces; unit composed of 4 distinct thin beds; weathers to rounded, bulbous masses; strongly fractured.....	0.3	358.6
53.	Shale, dark-gray (N3) to medium-gray (N5); strongly-to-moderately calcareous; abundant carbonaceous matter and coal fragments; red-orange detrital hematite grains; strongly fissile; U.S. Geological Survey paleobotany sample D6586B; one species identified by D. J. Nichols: <i>Laeigatosporites</i> sp.....	0.3	358.3
52.	Mudstone, grayish-green (10GY5/2); weathers to pale-green (10G6/2); weakly-to-moderately calcareous; finely disseminated micaceous matter and coal; in part very nodular, with interbedded green shale or mudstone partings that lack nodular appearance; very calcareous, with well developed calcite rosettes in basal 5 cm; grades upward into overlying shale unit 53.....	1.2	357.1
51.	Mudstone, dark-red-brown (10R3/4); weathers to pale-red (5R6/2); moderately calcareous; strongly color variant with thin discontinuous red, gray, and green bands; abundant hematite stain; weakly fissile; finely disseminated carbonaceous matter and coal; forms slump blocks and debris-flow slopes near traverse.....	3.9	353.2
50.	Covered interval, mudstone in slump blocks and debris-flow slopes.....	14.7	338.5
49.	Mudstone, dusky-yellow-green (5GY5/2); weathers to greenish-gray (5GY6/1) with yellow-orange stain along fracture surfaces; abundant limonite; weakly fissile.....	4.2	334.3

Blackleaf Formation upper volcanioclastic lithofacies continued:

48.	Sandstone, medium-dark-gray (N4) to medium-gray (N5); weathers to moderate-brown (5YR3/4); fine-grained; subrounded-to-angular grains; cherty; moderately calcareous; abundant carbonaceous matter, especially along thin zones parallel to bedding planes; rare limonite stain; single, massive discontinuous bed with erosive lower base.....	1.5	332.8
47.	Covered interval.....	22.6	310.2
46.	Mudstone, medium-gray (N5); weathers to medium-light-gray (N6); very calcareous; fissile; interbedded with one thin (less than 0.5 m) discontinuous sandstone bed similar to unit 48 above.....	6.7	303.5
45.	Sandstone, light-olive-brown (5Y5/6) to yellowish-gray (5Y7/2); weathers from yellowish-gray (5Y8/1) to light-olive-gray (5Y6/1); medium-grained; rounded-to-angular grains; up to 5 percent disseminated carbonaceous matter and coal; very calcareous; cherty; one massive discontinuous channel-like bed; poorly exposed outcrop, unit grades upward into overlying mudstone.....	3.5	299.3
44.	Sandstone and mudstone, medium-gray (N5); weathers to light-olive-gray (5Y6/1); fine-to medium-grained; rounded-to-subangular grains, with quartz predominantly rounded; carbonaceous matter and coal fragments present along bedding planes; moderately calcareous; thin, flaggy beds in part with well-developed ripple lamination; sandstone discontinuous and grades upward to mudstone.....	1.2	298.6
43.	Siltstone and mudstone, medium-dark-gray (N4); weathers to light-gray (N7); weakly-to-moderately calcareous; rich in carbonaceous matter with distinct woody texture; one small (3 mm in diameter) unidentified bivalve fragment; hematite stain; fissile.....	0.7	296.7
42.	Mudstone, dark-greenish-gray (5GY4/1); weathers to greenish-gray (5GY6/1); red carbonaceous (?) matter; moderately fissile.....	1.9	295.5

Blackleaf Formation upper volcaniclastic lithofacies continued:

41. Mudstone and siltstone, dark-red-brown (10R3/4); weathers to gray-red (10R4/2); predominantly mudstone with thin, discontinuous siltstone lenses; carbonaceous matter disseminated throughout unit; pervasive hematite stain; very weakly calcareous.....	1.2	295.5
40. Sandstone, light-olive-gray (5Y6/1); fine-grained; rounded-to-subangular grains; cherty, micaceous; moderately calcareous; hematite stain; carbonaceous matter disseminated throughout unit but concentrated mostly along bedding planes; unit very bioturbated; moderately developed ripple lamination; discontinuous channel-like unit; poorly exposed.....	3.1	292.4
39. Covered interval; presumed to be predominantly mudstones.....	<u>79.8</u>	212.6
Total thickness of Blackleaf Formation upper volcaniclastic lithofacies.....	271.0	

Blackleaf Formation, upper clastic lithofacies:

38. Sandstone, light-gray (N7) to medium-light-gray (N6); weathers to light-olive-gray (5Y6/1); fine- to medium-grained; rounded-to-subangular grains; very cherty; very calcareous; abundant disseminated carbonaceous matter; rare hematite-rich nodules up to 5 mm in diameter; ripple laminated; sandstone more quartzitic and chert-rich than those above; very poorly exposed.....	5.5	207.1
37. Covered interval; abundant sandstone float similar to unit 38 above.....	48.7	158.4
36. Sandstone, olive-gray (5Y4/1) to light-olive-gray (5Y5/2); weathers to dusky-yellow (5Y6/4); fine- to coarse-grained, predominantly fine-grained especially near top of unit; rounded-to-subangular grains; weakly-to-moderately calcareous; cherty; distinctive limonite grain coatings (orange speck); abundant disseminated carbonaceous matter and coal; strongly bioturbated with abundant unidentified		

Blackleaf Formation upper clastic lithofacies continued:

trace fossils along bedding planes; well-developed ripple lamination in upper part of unit, with ripple crest wavelengths averaging 4 cm; lower part massive; shale partings; less than 2 mm thick.....	3.4	155.0
35. Sandstone, greenish-gray (5GY6/1) to light-bluish-gray (5B7/1); weathers from yellowish-gray (5Y8/1) to moderate-reddish-brown (10R4/6); fine- to very fine-grained; rounded-to-subangular grains; cherty; strongly to moderately calcareous; abundant limonite as detrital grains and grain coatings (orange speck); abundant wood impressions and carbonaceous debris, especially along bedding planes; largest wood impression greater than 4 cm in length; broken shell fragments of unidentified bivalves and low-spired gastropods disseminated throughout unit but abundant along discrete horizons; bivalves possibly marine (W. A. Cobban, oral commun.); well-developed current-ripple lamination (wave length averages 5 cm, wave height averages 2 cm); mudcracks (?), groove casts, and load casts on lower bedding surfaces; several small-scale (5-10 cm thick) fining-upward sequences.....	6.1	148.9
34. Sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers from medium-olive-brown (5Y4/4) to medium-bluish-gray (5B7/1); fine-to-coarse grained, predominantly coarse near base of unit, fine near top; rounded-to-subangular grains; cherty; weakly-to-strongly calcareous; abundant limonite stain; abundant carbonaceous matter; large-scale trough cross-stratification near base, grading upward to ripple-lamination; strongly fractured with hematite and limonite fracture fillings; small scale erosion surfaces (?); unit poorly exposed, especially in lower part but continuous along strike for 1.0 km.....	5.8	143.1
Total Thickness Blackleaf Formation upper clastic lithofacies.....	69.5	

Partial section 3--Blackleaf Formation (units 1-33):

Section continuous to the southwest approximately 750 m along strike in an unnamed tributary to Sawmill Creek.

Blackleaf Formation, lower transitional clastic lithofacies:

33.	Covered interval.....	6.2	136.9
32.	Limestone, grayish-red-purple (5RP4/2); weathers from pale-red-purple (5RP6/2) to pale-yellow-brown (10YR6/2); very nodular, with micritic (?) nodules up to 10 cm in diameter; nodules hematite-stained and color variant; nodules weather as rounded masses; interbedded with moderate-reddish-brown (10R6/6) calcareous mudstone.....	1.1	135.8
31.	Covered interval, presumed to be gray-green mudstone.....	8.0	127.8
30.	Sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers from pale-yellow-brown (10YR6/2) to gray-orange-pink (5YR7/2); fine- to medium-grained; rounded-to-subangular grains; cherty; quartz-rich; weakly-to-moderately calcareous; rare limonite grain coatings; large-scale, trough (?) cross-stratification near base, grading upward to horizontal lamination near top; continuous unit with erosive (?) base; poorly exposed.....	3.6	124.2
29.	Sandstone and conglomerate, medium-gray (N5) to moderate-yellow-brown (10YR5/4); weathers to light-gray (N7) with irregular masses of yellow-gray (5Y8/1); very poorly sorted; rounded-to-angular grains; sandstone contains 50 percent matrix; cherty; moderately calcareous; conglomerate clasts up to 3 cm in diameter; limestone clasts (60 percent), siltstone and claystone clasts (30 percent), sandstone clasts (10 percent); limestone clasts with abundant gastropod fragments; limonite stain; no distinct imbrication but crude clast alignment; strongly fractured with calcite vein fillings; laterally discontinuous with sharp, erosive base; laterally grades into pale-red (10R6/2) fine-grained calcareous sandstone.....	3.0	121.2
28.	Siltstone and sandstone, grayish-red (10R4/2) to brownish-gray (5YR6/1); weathers from pale-red (10R6/2) to pale-yellow-brown (10YR6/2); coarse silt and very fine-grained sandstone; subrounded-to-subangular (?) grains; weakly-to-moderately calcareous; cherty; rare limonite grain coatings; very thin beds (less than 3.0 cm thick).....	3.9	117.3

Blackleaf Formation lower transitional clastic lithofacies continued:

27.	Sandstone and conglomerate, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers to light-olive gray (5Y6/1); predominantly fine- to very fine-grained sandstone with intraclasts up to 3 cm in diameter; rounded-to-subangular grains; very calcareous; cherty; quartz-rich; unit massive and continuous for 30 m along strike; sharp lower contact; several small-scale faults with well-developed slickensides.....	1.1	116.2
26.	Sandstone, pale-red (5R6/2) to gray-red (5YR4/2); weathers to pale-red (5R6/2); very fine-grained; subrounded-to-subangular grains; nodular, with small (up to 2.0 cm in diameter) hematite-stained limestone nodules; sandstone strongly calcareous; cherty; strongly hematite stained; appears as a single massive, continuous bed; fractured; friable.....	2.6	113.6
25.	Mudstone and siltstone, red and gray, poorly exposed.....	1.4	112.2
24.	Sandstone, green-gray (5GY6/1); weathers from gray-orange-pink (5YR7/2) to green-gray (5GY6/1); fine- to very fine-grained; rounded-to-subangular grains; nodular, with hematite stained calcareous nodules up to 1.0 cm in diameter; nodules increasing in abundance upward in unit; thick-bedded with thin, less than 1-cm-thick mudstone interbeds; unit continuous for 10 m along strike.....	0.4	111.8
23.	Conglomerate and sandstone, medium-light-gray (N6) to light-olive-gray (5Y6/1); weathers from light-olive-gray (5Y6/1) to greenish-gray (5Y6/1); sandstone coarse-grained; rounded-to-subrounded grains; conglomerate clasts composed of fine- to medium-grained sandstone (70 percent), limestone (30 percent); very calcareous; discontinuous channel-like unit 4 m in diameter; massive with no observable clast orientation; laterally grades into overlying sandstone unit 24; poorly exposed.....	0.6	111.2
22.	Mudstone and siltstone, nodular (?); red; very poorly exposed.....	0.3	110.9

Blackleaf Formation lower transitional clastic lithofacies continued:

21.	Siltstone and sandstone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers to light-olive-gray (5Y6/1); coarse silt to very fine-grained sandstone; rounded-to-subrounded grains; moderately calcareous; quartz-rich; small-scale trough cross-stratification; unit continuous for 20 m along strike.....	2.6	108.3
20.	Sandstone and mudstone, medium-light-gray (N6); weathers to moderate-yellow-brown (10YR5/4); very fine-grained; rounded-to-subangular grains; cherty; quartz-rich; very calcareous; two thick-bedded discontinuous sandstone beds separated by red-to-gray mudstone; mudstone very calcareous and nodular; poorly exposed.....	3.8	104.5
19.	Mudstone, siltstone and sandstone, light-olive-gray (5Y6/1); weathers to yellow-gray (5Y7/2); very fine-grained sandstone at base of unit, grading upward to mudstone near top; sandstone grains rounded-to-subangular; strongly calcareous; cherty; well-developed horizontal lamination; thick-bedded at base with decreasing bed thickness upward; poorly exposed unit.....	4.2	100.3
18.	Mudstone and sandstone, dusky-red (5R3/4) to very dusky-red-purple (5RP2/2); weathers to dusky-red (5R3/4); very calcareous; nodular, with calcareous nodules up to 4.0 cm in diameter; stained with hematite; one thin, discontinuous channel-like sandstone interbed (78.0-78.3 m), medium-light-gray (N6); weathers to light-olive gray (5Y6/1); sandstone very fine-grained; rounded-to-subangular grains; very calcareous; rare disseminated carbonaceous matter.....	17.7	82.6
17.	Sandstone, light-olive-gray (5Y6/1) to light-gray (N7); weathers from yellow-gray (5Y8/1) to light-olive-gray (5Y6/1); fine-to-medium grained; rounded-to-subangular grains; cherty; very calcareous; limonite stain; beds average 0.3 m thick; unit continuous as small ridge for 50 m along strike.....	2.1	80.5
16.	Mudstone, dusky-red (5R3/4); very calcareous; nodular, with small (less than 2 cm) calcareous nodules; hematite stain; poorly exposed.....	1.6	78.9

Blackleaf Formation lower transitional clastic lithofacies continued:

15. Sandstone and siltstone, medium-light-gray (N6) to light-olive gray (5Y6/1); weathers from yellow-gray (5Y8/1) to light-green-gray (5GY8/1); interbedded sandstone and siltstone; sandstone very fine-grained; rounded grains; quartz-rich; very calcareous; very thin (less than 1.0 cm) interbedded shale partings; rare disseminated carbonaceous matter; thick-bedded with beds up to 50 cm thick; strongly bioturbated with well-developed vertical burrows; unit contains at least 3 sharp internal erosion surfaces, separating discontinuous sandstone beds; entire unit continuous for at least 30 m along strike.....	3.3	75.6
14. Mudstone, moderate-yellow-brown (10R4/2), with bands and irregular masses (less than 2 mm in diameter) of greenish-gray (5GY6/1); weathers from grayish-orange (10YR7/4) to very-pale-orange (10YR8/2); rare disseminated carbonaceous matter; limonite stain.....	0.3	75.3
13. Sandstone and conglomerate, light-olive-gray (5Y5/2) to medium-gray (N5); weathers from yellow-gray (5Y7/2) to pale-olive (10Y6/2); fine- to very fine-grained; rounded-to-subangular grains; large mudstone clasts (ripups?), gray-green (5GY6/1) to grayish-red (5R4/2) up to 1.5 cm in diameter; clasts restricted to discrete vertical zones; traces of carbonaceous matter; discontinuous massive channel-like 0.3 m thick; slight upward fining within unit.....	0.3	75.0
12. Mudstone, moderate-brown (5YR3/4) with thin grayish-green bands (10GY5/2); weathers from pale-yellow-brown (10YR6/2) to grayish-orange (10YR7/4); very calcareous; very thin-bedded; poorly exposed.....	2.9	72.1
11. Mudstone, dark-yellow-brown (10YR4/2) to medium-dark-gray (N4); weathers to pale-yellow-brown (19YR6/2); very calcareous; nodular, with calcareous nodules up to 4.0 cm in diameter; very thin-bedded, may be continuous, but grades into covered interval; poorly exposed.....	6.7	65.4
10. Covered interval.....	<u>6.5</u>	58.9
Total thickness of Blackleaf Formation lower transitional clastic lithofacies.....	84.2	

Blackleaf Formation lower transitional clastic lithofacies continued:

Total thickness of Blackleaf Formation..... 437.8

Kootenai Formation, upper carbonate unit (gastropod limestone):

09. Limestone, pale-yellow-brown (10YR6/2) to medium-light-gray (N6); weathers to yellowish-gray (5Y8/1); very fossiliferous with abundant high-spined gastropods; disseminated carbonaceous matter; limestone coarsely crystalline..... 4.6 54.3
08. Limestone, medium-dark-gray (N4) to olive-gray (5Y6/1); weathers from pale-orange (10YR8/2); to yellowish-gray (5Y7/2); very dense, predominantly micritic; variably fossiliferous, with abundant gastropods limited to distinct beds in lower part of unit; gastropods up to 1 cm in length; rare disseminated carbonaceous matter; beds 3-10 cm thick; bedding surfaces undulatory; weathered surfaces deeply solution pitted; unit forms continuous ridge for 30 m along strike..... 5.7 48.6
07. Sandstone, medium-dark-gray (N4) to light-olive-gray (5Y6/1); weathers from medium-gray (N5) to yellowish-gray (5Y8/1); fine- to medium-grained, dominantly medium-grained; rounded-to-subangular grains; very calcareous; very thin-bedded (less than 5 cm)..... 1.7 46.9
06. Siltstone and mudstone, olive-gray (5Y4/1) to medium-dark-gray (N4); weathers from light-olive-gray (5Y6/1) to yellowish-gray (5Y8/1); moderately calcareous; limonite stain; strongly fissile; calcite fracture-fillings; U.S. Geological Survey paleobotany sample D6586A; species identified by D. J. Nichols include:
- Appendicisporites jansonii*
Cicatricosisporites spp.
Concavissimisporites variverrucatus
Cyathidites minor
Pityosporites sp..... 3.3 43.6

Kootenai Formation upper carbonate lithofacies continued:

05.	Limestone, light-gray (N7) to light-olive-gray (5Y6/1); weathers from light-gray (N7) to yellowish-gray (5Y8/1); abundant gastropods, ostrocods (?); abundant plant fragments; very silty; massive bedding; forms ridge.....	0.5	43.1
04.	Covered interval, presumed to be red-to-gray mudstone and siltstone.....	14.4	28.7
03.	Limestone, medium-gray (N5) to light-olive-gray (5Y6/1); weathers from pale-yellow-brown (10YR6/2) to yellowish-gray (5Y8/1); very silty; alternating thin-beds (less than 2 cm) of micritic limestone and coarsely crystalline gastropod-rich limestone; abundant carbonaceous matter; mottled surfaces; highly fractured.....	4.2	24.5
02.	Limestone, medium-gray (N5) to medium-olive-gray (5Y4/1); weathers from light-gray (N7) to medium-light-gray (N6); coarsely-crystalline gastropod-rich limestone; gastropods high-spired, up to 3 cm in length; medium- to thick-bedded; weathered surfaces mottled and solution pitted; highly fractured.....	2.0	22.5
01.	Limestone, medium-gray (N5) to medium-light-gray (N6); weathers to medium-bluish-gray (5B5/1); coarsely crystalline; abundant gastropods, rare bivalves; fossil concentrations greatest along distinct horizons; gastropods up to 1.5 cm in length; beds vary from 4 to 10 cm in thickness; numerous fractures and small faults; unit poorly exposed in lower part and grades into covered interval.....	9.4	0.0
Total thickness of Kootenai Formation, upper carbonate lithofacies measured.....		45.8	

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