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MEASURED SECTIONS AND CORRELATIONS OF MID-CRETACEOUS ROCKS NEAR THE LOMBARD THRUST OF THE HELENA SALIENT IN SOUTHWESTERN MONTANA

by

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INTRODUCTION

Two surface sections that generally characterize mid-Cretaceous strata in the central to southern part of the Helena salient of the Montana thrust belt (Figs. 1 and 2) are presented here. We have not published detailed descriptions of the lithic units of these sections, and the stratigraphic correlations are tentative. The sections are presented in this preliminary form because they may aid interpretations of seismic and borehole data of petroleum exploration companies active in the salient.

MEASURED SECTIONS

The western measured section, near Indian Creek, is on the hanging wall of the Lombard thrust, whereas the Sixteenmile Creek--County Line composite measured section is in the footwall to the east (Figs. 1 and 2). The two measured sections, which begin at the top of the Kootenai Formation, include the Lower Cretaceous Thermopolis Shale, and Upper Cretaceous Mowry Shale, Frontier Formation, and Cody Shale. The Thermopolis Shale through Frontier Formation were measured by us at both localities. The Cody Shale at Sixteenmile Creek is from descriptive information of Skipp and Peterson (1965). The Cody at Indian Creek is from a measured section of Tysdal and is part of a sequence that Klepper and others (1957) named the Slim Sam Formation. The strata illustrated here were correlated with the Cody by Tysdal (unpublished data).

The Thermopolis through Mowry section at Indian Creek was measured by Tysdal and Dyman along an unnamed tributary of Indian Creek in SW1/4 sec. 29 and SE1/4 sec. 30, T. 7 N., R. 1 W., in the Elkhorn Mountains. This location is about one mile north of the Indian Creek road where the units were originally measured by Klepper and others (1957). Exposures vary from good to poor. The Frontier Formation was measured along the north side of Indian Creek by Tysdal, Dyman, and Porter (Figure 1).

In the eastern section, the Thermopolis through lower Mowry interval was measured by Porter and Dyman along the boundary between Meagher and Gallatin Counties, 1/4 mile east of the Maudlow-Ringling county road (County Line measured section). These same rocks are poorly exposed along Sixteenmile Creek. The Frontier Formation is best exposed along the north side of Sixteenmile Creek (Figure 1; Sixteenmile Creek measured section) where it was measured by Porter, Dyman, and Thompson. The Frontier Formation is very poorly exposed at the County Line section.

STRATIGRAPHY AND CORRELATION

The stratigraphic names and correlations presented here are preliminary, but are based on previous work by Tysdal and others (1989a; b), Dyman and others (1994), Porter and others (1993), and Dyman and others (1995) for equivalent rocks in southwestern Montana, and on unpublished data of Tysdal in the Indian Creek area. The southwest Montana studies generally recognized a western, predominantly nonmarine succession of mid-Cretaceous rocks that includes the Blackleaf and Frontier Formations, and an eastern, predominantly marine succession that includes the Thermopolis Shale, Mowry Shale, Frontier Formation, and Cody Shale.

For a detailed discussion of equivalent rocks north of the Lewis and Clark line, in the vicinity of Great Falls, refer to Cobban and others (1976), who recognized four members of the Blackleaf Formation in the Great Falls area: in ascending order, the Flood, Taft Hill, Vaughn, and Bootlegger Members. The Thermopolis Shale of this report is equivalent to the Flood Member of the Blackleaf Formation in southwest Montana and the Flood and Taft Hill Members of the Blackleaf in the Great Falls area. We use the Vaughn name for the nonmarine member of both the Blackleaf Formation and Mowry Shale in southwestern Montana (Tysdal and others, 1989b). The Mowry Shale at Indian Creek is entirely nonmarine; hence, the name Vaughn Member is applied to the entire formation. The marine Bootlegger Member of the Blackleaf Formation near Great Falls may be in part equivalent to the lower part of the Frontier Formation in the area of this study. In the Indian Creek area, the Cody Shale is the lithic equivalent of the uppermost member of the Marias River Shale, described in the Great Falls area by Cobban and others (1976); lithic equivalents of the other three members of the Marias River Shale are absent from the area.

The datum for the cross section in Figure 2 is the base of the Cody Shale, which is within the upper mid-Coniacian *Scaphites ventricosus* biozone. *S. ventricosus* was identified at both localities in the lower part of the Cody and forms a regionally recognized time horizon (Cobban and others, 1994). A regional stratigraphic perspective for these rocks is contained in Dyman and others (1995). Megafaunal identifications were made by W.A. Cobban (U.S. Geological Survey). Chronostratigraphically significant fossils are presented on the measured sections in Figure 2.

Indian Creek Measured Section

The Cody Shale is about 425 ft thick where measured along Indian Creek and consists of interbedded dark-gray mudstone (silty and/or sandy claystone), siltstone, and sandstone. The mudstone and siltstone are the most abundant rock types. The sandstone is medium to light gray, fine grained, and generally forms beds three to four ft thick, but one interval is 20 ft thick. Burrowing was observed locally within all of the lithologies.

The Frontier Formation, well exposed along Indian Creek, is comprised of light-gray sandstone and lesser interbeds of siltstone. The sandstone is a medium- to coarse-grained, quartz-feldspar-chert "salt-and-pepper" lithology in intervals (amalgamated beds) that range up to 50 ft thick. Lower parts of some thick beds contain rounded pebbles of dark-gray chert. Interbedded strata, mainly siltstone, comprise less than a fourth of the formation.

The nonmarine Vaughn Member of the Mowry Shale is exposed best along an unnamed drainage (SE 1/4 sec. 30 and SW 1/4 sec. 29, T. 7 N., R. 1 W.), 0.5 to one mile east of Indian Creek. The formation is comprised mainly of nonmarine olive-green siltstone and mudstone, some fine-grained sandstone, and minor porcellanite (siliceous mudstone).

The Thermopolis Shale is a marine unit that consists of three parts. The upper part is composed of light-gray, fine- to medium-grained, "salt-and-pepper" quartz-, feldspar-, and chert-rich sandstone that is slightly calcareous. This unit, about 150 ft thick along the Indian Creek road, is the stratigraphic equivalent of the Muddy Sandstone; however, we have made no decision to use that name in the Elkhorn Mountains area. The middle part is comprised of medium-gray, fissile, micaceous, clayey shale, and a few thin interbeds of siltstone. This unit is about 160 ft thick near Indian Creek but only 125 ft thick where measured about one mile to the east. The lower part of the Thermopolis, about 50 ft thick along Indian Creek, is comprised of quartz-rich fine- to coarse-grained sandstone that

contains abundant oscillatory ripples and thin interbeds of siltstone; horizontal trace fossils are abundant.

Sixteenmile Creek--County Line Measured Section

The Cody Shale at Sixteenmile Creek was not measured by us. Its thickness and lithology are from a map description of Skipp and Peterson (1965) and is included here only for comparison with our measured section at Indian Creek. Skipp and Peterson (1965) described the Cody as shale and mudstone with minor interbedded sandstone and siltstone. It is approximately 1,200 ft thick along Sixteenmile Creek and is well exposed along the north boundary of sec. 12 and south boundary of sec. 1, T. 4 N., R. 5 E. Sandstones are fine grained, quartzose, glauconitic, calcareous, clayey, and fossiliferous; they form well-developed ledges and are easily identified in the predominantly mudstone-shale sequence.

The Frontier Formation is best exposed along the north side of Sixteenmile Creek along the north boundary of sec. 7 and south boundary of sec. 6, T. 4 N., R. 6 E. We measured 570 feet of interbedded sandstone, siltstone, mudstone, and limestone at this locality. Sandstones constitute 50 percent or more of the Frontier Formation and are rich in chert, quartz, and lithic fragments. They are generally medium gray to greenish gray, medium to coarse grained, and may contain conglomeratic horizons of chert and quartzite pebbles up to one inch in diameter; sandstones form composite beds 30 ft or more thick. Mudstones and siltstones are generally brownish gray to dark gray, bioturbated, calcareous, and contain root structures. Coquina beds in the upper part of the Frontier include limestones composed of clams. Bentonites occur throughout the Frontier at Sixteenmile Creek

The Vaughn Member of the Mowry Shale is best exposed along the north side of Sixteenmile Creek just east of the Frontier outcrop belt along the north boundary of sec. 7 and south boundary of sec. 6, T. 4 N., R. 6 E. It is 150 ft thick there and comprised of pastel-colored bentonitic mudstone, bentonite, siltstone, and sandstone. The Vaughn is a nonmarine unit that contains root structures and rippled siltstones comprising overbank deposits associated with fluvial channels. Sandstones are fine to coarse grained and greenish gray to medium gray. They form about 25 percent of the Vaughn Member, are often clay rich, and contain abundant lithic fragments. The lower part of Skipp and Peterson's (1965) unit Kcm (middle unit of Colorado Shale) is equivalent to the Vaughn Member.

The lower part of the Mowry Shale and the Thermopolis Shale are best exposed at the County Line section about 1/4 mile east of the Maudlow-Ringling county road along the Gallatin-Meagher County line in center sec. 16, T. 5 N., R. 7 E. The lower part of the Mowry, about 100 ft thick, is a fine grained marine unit comprised of porcellanite, bentonitic mudstone, sandstone, and siltstone. Distinct white to light-green porcellanite beds are abundant in the lower Mowry.

The Thermopolis at the County Line section is about 325 ft thick and is lithically similar to the Thermopolis at Indian Creek; it is also subdivided into three parts. The upper part is comprised of greenish-gray, fine- to medium-grained, lithic-rich sandstone that is variably calcareous. Sandstones are thin bedded, rippled and crossbedded, glauconitic, and bioturbated. Sandstones fine upward and are interbedded with thin bentonitic mudstone beds that increase in abundance upward in the unit. The unit, about 110 ft thick, is the lithic equivalent of the upper sandstone unit of the Flood Member of the Blackleaf Formation in southwest Montana and the Taft Hill Member of the Blackleaf near Great Falls. The middle part of the Thermopolis is comprised of dark-gray fissile, micaceous shale, and a

few thin interbeds of rippled siltstone. Both shales and siltstones contain abundant horizontal trace fossils. Iron-rich concretionary horizons are abundant in the lower to middle part. This unit is about 130 ft thick at the County Line section. Sandstones dominate the lower part of the Thermopolis Shale and are tan to medium gray, fine to medium grained, quartz rich, and contain abundant oscillatory ripples, and thin interbeds of siltstone. Horizontal trace fossils are abundant. This lower part, although poorly exposed, is about 70 ft thick at the County Line section.

BIBLIOGRAPHY

Cobban, W.A., Erdmann, R.W., Lemke, R.W., and Maughn, E.K., 1976, Type sections and stratigraphy of the Blackleaf and Maria River Formations (Cretaceous) of the Sweetgrass arch, Montana: U.S. Geological Survey Professional Paper 974, 66 p.

Cobban, W.A., Merewether, E.A., Fouch, T.D., and Obradovich, J.D., 1994, Some Cretaceous shorelines in the Western Interior of the United States: *in* Caputo, M.V., Peterson, J.A., and Franczyk, eds., Mesozoic systems of the Rocky Mountain region, U.S.A.: Rocky Mountain Section SEPM (Society for Sedimentary Geology), p. 393-414.

Dyman, T.S., Porter, K.W., Tysdal, R.G., Cobban, W.A., Fox, J.E., Hammond, R.H., Nichols, D.J., Perry, W.J., Jr., Rice, D.D., Setterholm. D.R., Shurr, G.W., Haley, J.C., Anderson, S.B., and Campen, E.B., 1995, West-east stratigraphic transect of Cretaceous rocks- southwestern Montana to southwestern Minnesota: U.S. Geological Survey Miscellaneous Investigations Map 2474-A, 27 p.

Dyman, T.S., Tysdal, R.G., Wallace, C.A., and Lewis, S.E., 1994, Correlation of Lower and Upper Cretaceous Blackleaf Formation, eastern Pioneer Mountains, southwestern Montana, to Drummond, central-western Montana: U.S. Geological Survey Miscellaneous Field Studies Map I-2478.

Klepper, M.R., Weeks, R.A., and Ruppel, E.T., 1957, Geology of the southern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U.S. Geological Survey Professional Paper 292, 82 p.

Porter, K.W., Dyman, T.S., and Tysdal, R.G., 1993, Sequence boundaries and other surfaces in Lower and lower Upper Cretaceous rocks of central and southwest Montana-- a preliminary report, *in* Hunter, L.D., and Ames, V.E., eds., Energy and Mineral Resources of Central Montana: Montana Geological Society 1993 Field Conference Guidebook, p. 45-60.

Skipp, B. and Peterson, A.D., 1965, Geologic map of the Maudlow quadrangle southwestern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-452, scale 1:24,000.

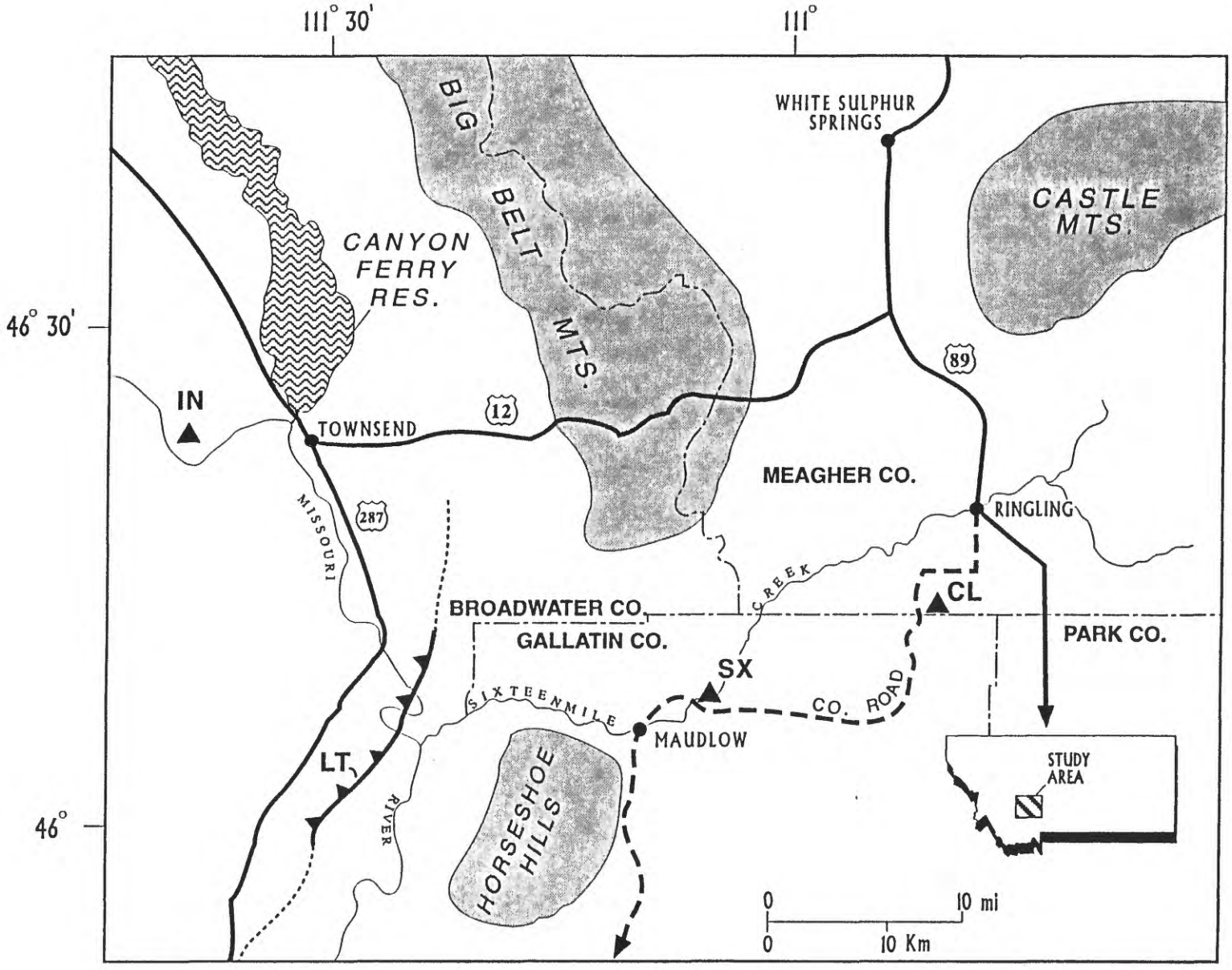
Tysdal, R.G., Dyman, T.S., and Nichols, D.J., 1989a, Correlation of lower Cretaceous rocks, Madison Range to Lima Peaks area, southwestern Montana: U.S. Geological Survey Miscellaneous Field Studies Map I-2067.

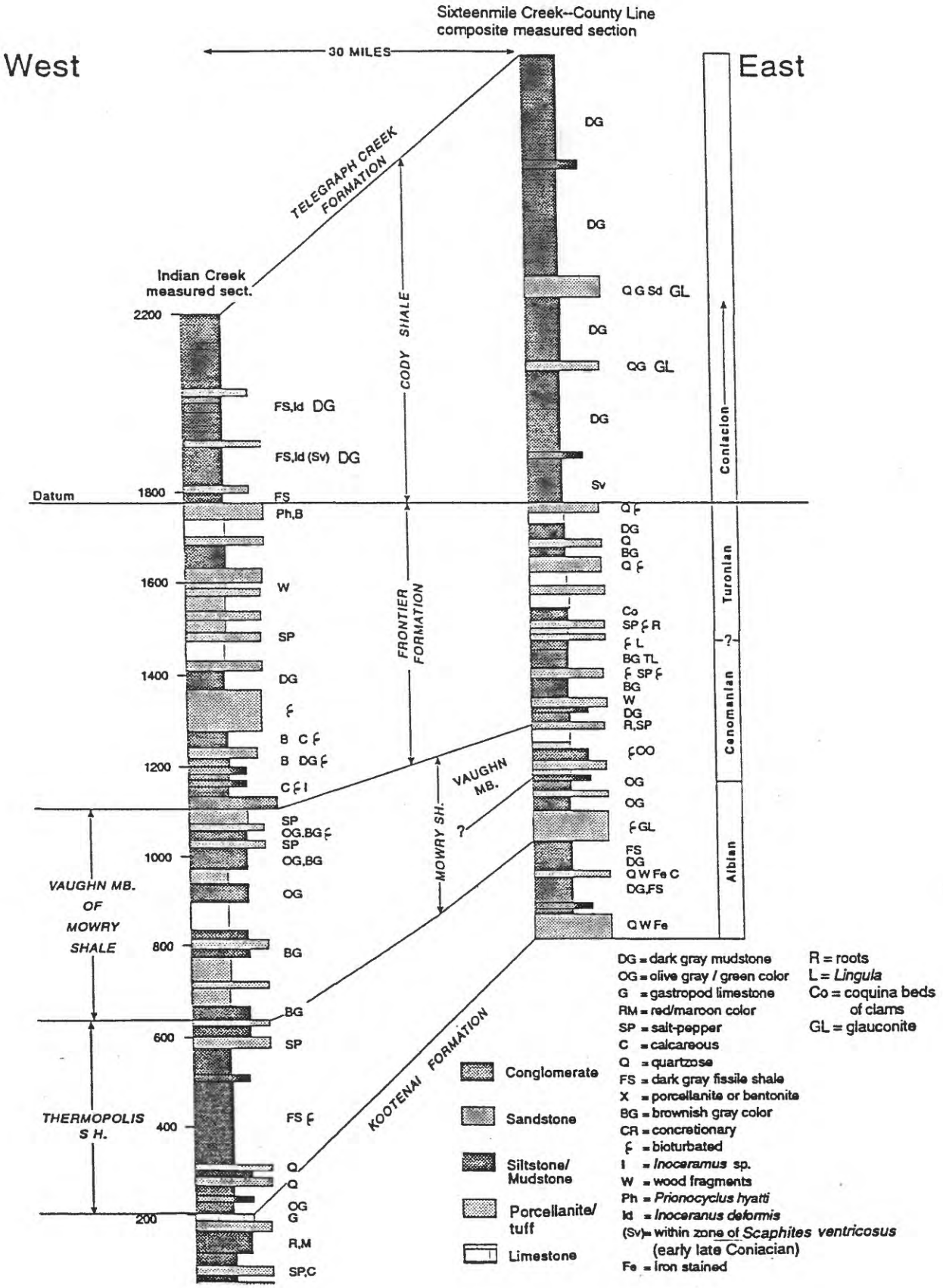
Tysdal, R.G., Dyman, T.S., and Nichols, D.J., 1989b, Lower Cretaceous bentonitic strata in southwestern Montana assigned to Vaughn Member of Mowry Shale (east) and of Blackleaf Formation (west): Mountain Geologist, v. 26, no. 2, p. 53-61.

FIGURE CAPTIONS

Figure 1. Location map of the area of study in southwestern Montana showing mountain ranges, rivers, highways, and key features refered to in the text of this report. Locations of measured sections are as follows: SX, Sixteenmile Creek; IN, Indian Creek; CL, County Line. LT indicates Lombard thrust fault.

Figure 2. Stratigraphic correlation chart of the Indian Creek and Sixteenmile Creek--County Line measured sections. Datum is middle Coniacian *Scaphites ventricosus* biozone of Cobban and others (1994). Refer also to Cobban and others (1994) for age ranges of biozones identified on this chart. Chronostratigraphically significant fossils are identified on the chart. Some beds are too thin to show at the graphic scale of this chart.


111° 30'
111°
46° 30'
46°
BIG BELT MTS.
CANYON FERRY RES.
WHITE SULPHUR SPRINGS
CASTLE MTS.
IN
TOWNSEND
12
89
MEAGHER CO.
RINGLING
287
MISSOURI
BROADWATER CO.
GALLATIN CO.
PARK CO.
CL
SX
SIXTEENMILE CREEK
CO. ROAD
MAUDLOW
LT
RIVER
HORSESHOE HILLS
STUDY AREA
0 10 mi
0 10 Km


Sixteenmile Creek--County Line
composite measured section
West
30 MILES
East
TELEGRAPH CREEK FORMATION
CODY SHALE
FRONTIER FORMATION
MOWRY SH.
VAUGHN MB.
VAUGHN MB. OF MOWRY SHALE
THERMOPOLIS SH.
KOOTENAI FORMATION
Indian Creek measured sect.
Datum
2200
1800
1600
1400
1200
1000
800
600
400
200
Coniacian
Turonian
Cenomanian
Albian
DG
QGSd GL
QG GL
Sv
FS,Id DG
FS,Id (Sv) DG
FS
Ph,B
W
SP
B C f
B DG f
C f I
OG,BG f
OG,BG
BG
FS f
Q
OG
G
R,M
SP,C
Q f
BG
Co
SP f R
f L
BG TL
f SP f
R,SP
f CO
f GL
FS
Q W Fe C
DG,FS
Q W Fe
Conglomerate
Sandstone
Siltstone/ Mudstone
Porcellanite/ tuff
Limestone
DG = dark gray mudstone
OG = olive gray / green color
G = gastropod limestone
RM = red/maroon color
SP = salt-pepper
C = calcareous
Q = quartzose
FS = dark gray fissile shale
X = porcellanite or bentonite
BG = brownish gray color
CR = concretionary
f = bioturbated
I = Inoceramus sp.
W = wood fragments
Ph = Prionocyclus hyatti
Id = Inoceranus deformis
(Sv) = within zone of Scaphites ventricosus (early late Coniacian)
Fe = iron stained
R = roots
L = Lingula
Co = coquina beds of clams
GL = glauconite