Field Trip # 1
Marine Cretaceous Reservoirs in Central and Northern Montana: Road Log for Day 1

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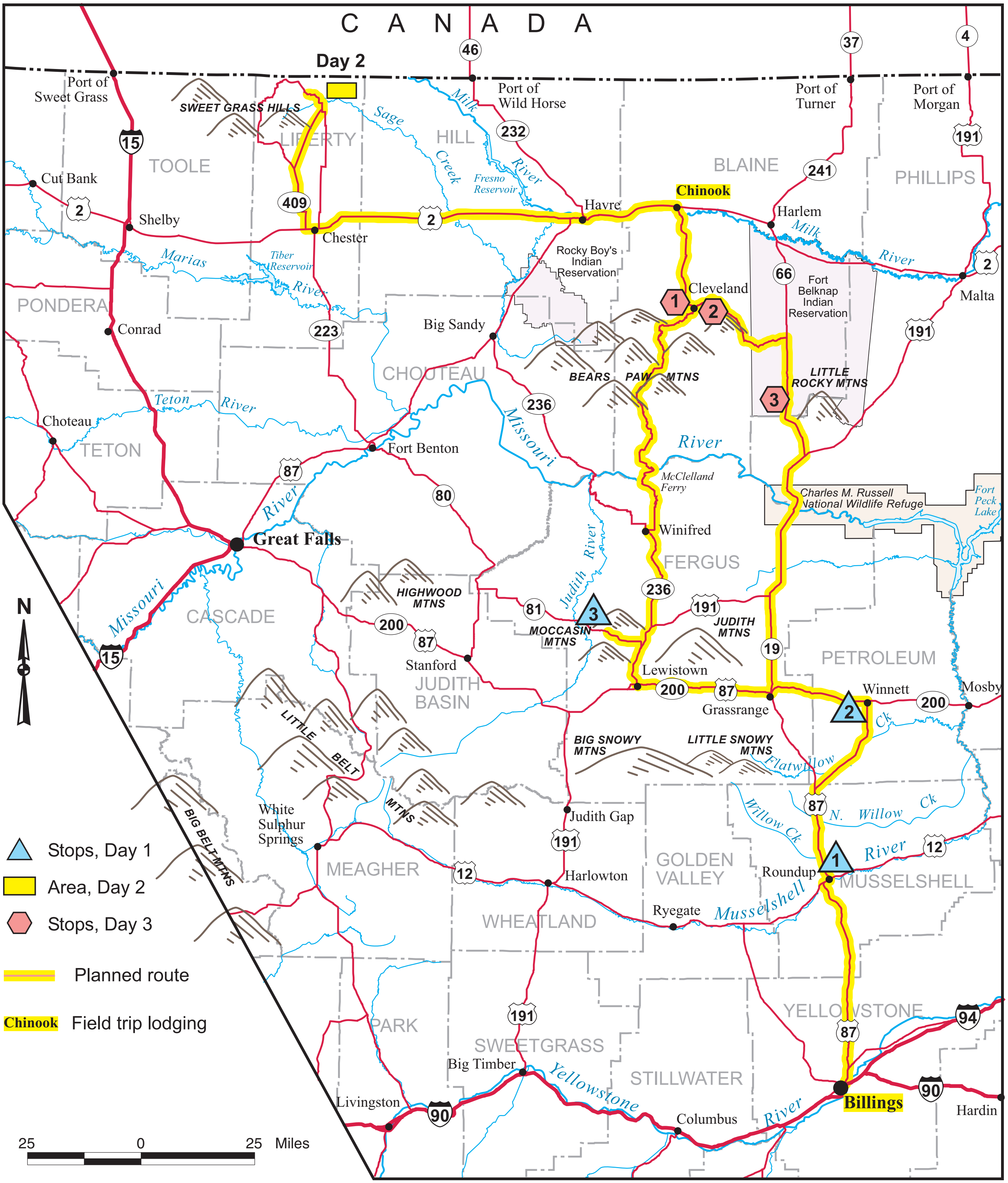

Figure 1. Location map for area of central Montana showing field trip route and field stops for three-day trip.

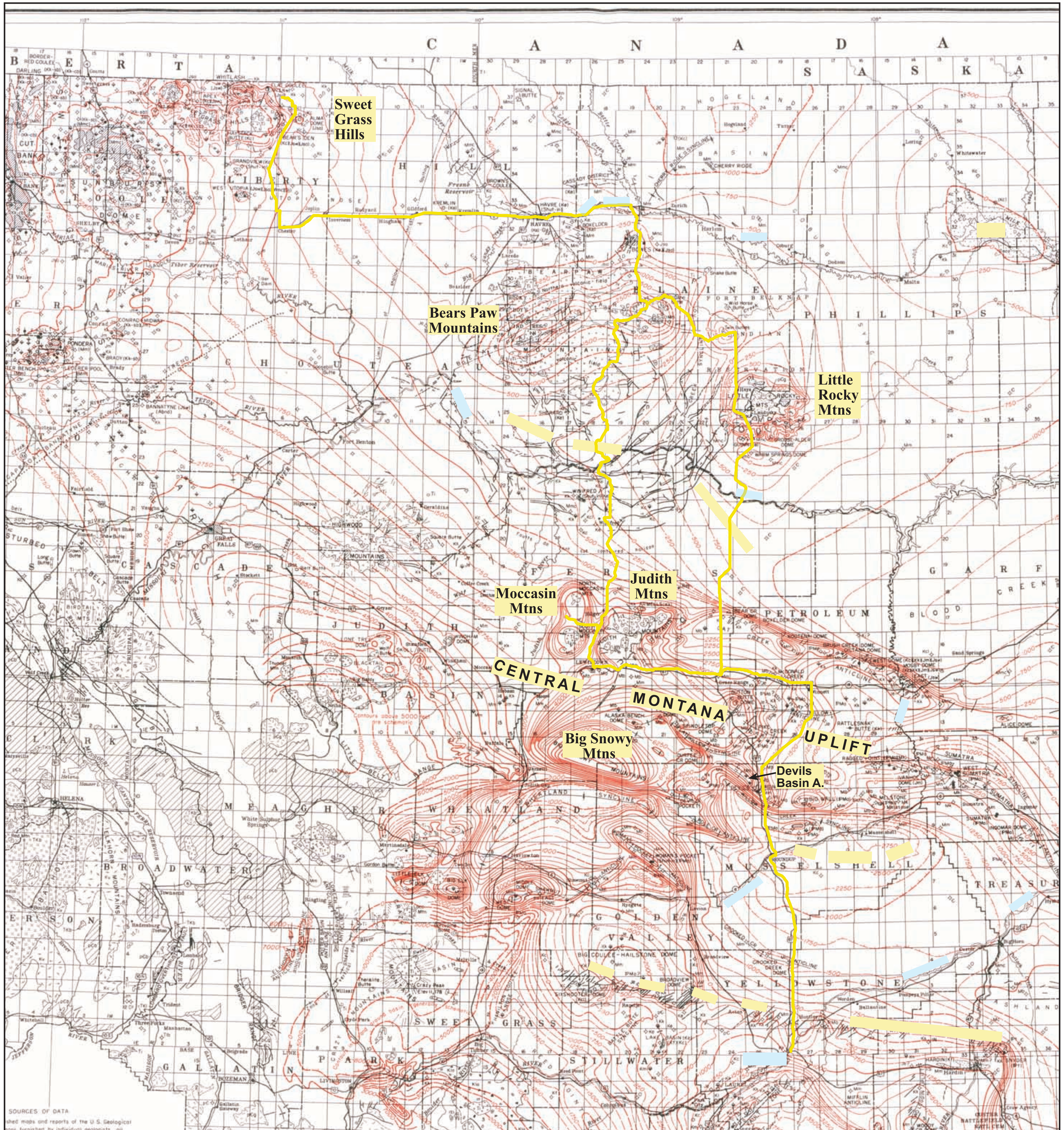

Figure 2. Portion of *Structure Contour Map of the Montana Plains* showing geologic structures of central Montana (reduced from original scale), and route traveled during field trip.

Field trip route

Modified from: Dobbin, C.E., Erdmann, C.E., 1955, Structure contour map of the Montana Plains: United States Geological Survey Oil and Gas Map 178B, 1:1,000,000.

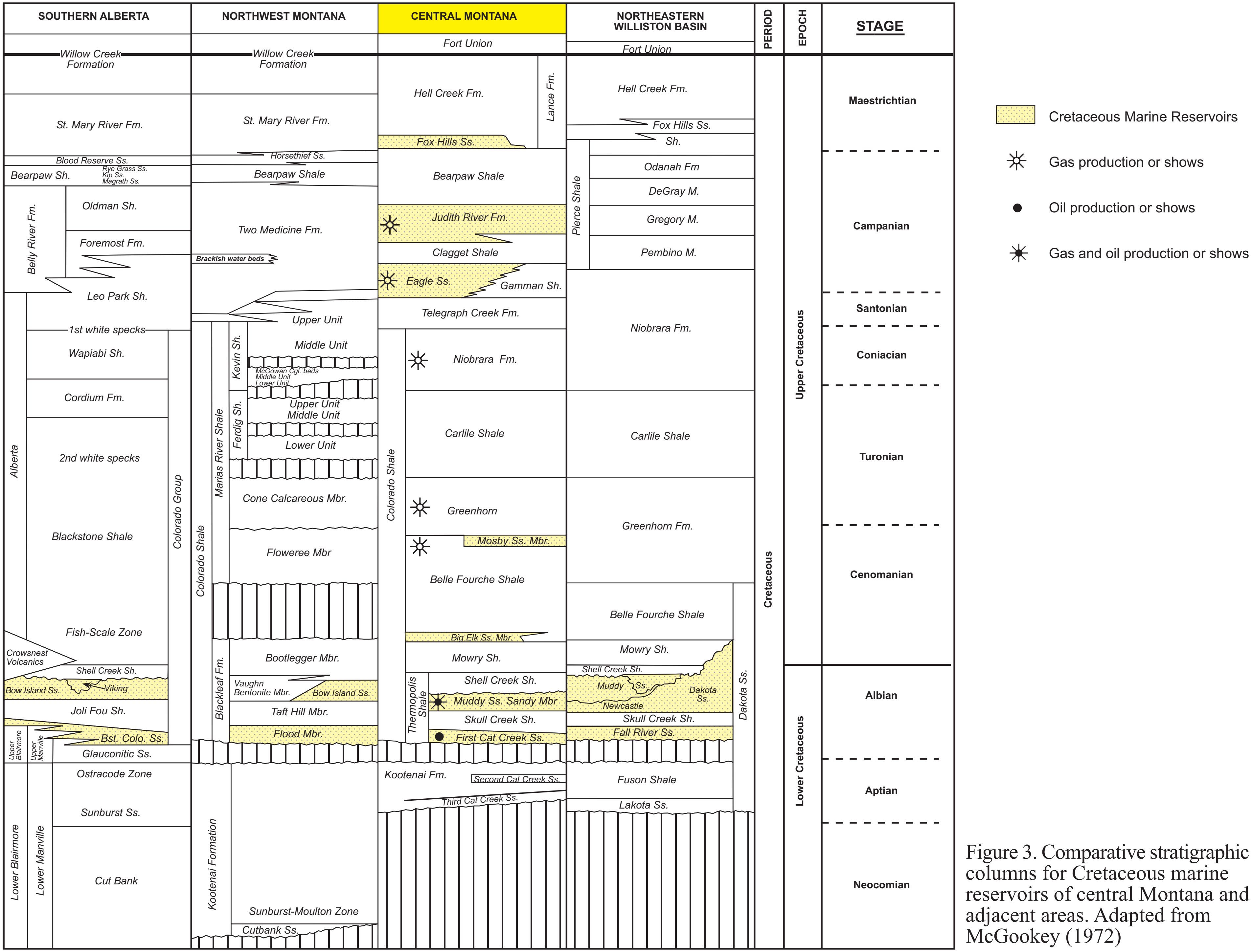

Figure 3. Comparative stratigraphic columns for Cretaceous marine reservoirs of central Montana and adjacent areas. Adapted from McGookey (1972)

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ROAD LOG FOR DAY 1:
Billings to Chinook via Roundup, Winnett, Lewistown, Winifred, and Cleveland

INTRODUCTION

The following road log is in five separate legs over a travel distance of 317 miles, and covers Day 1 of the three-day field trip. It begins in Billings, MT and covers the traverse north across the Bull Mountains Basin onto the Central Montana Uplift, then west to Lewistown, north to Winifred, north across the Missouri River into the Bears Paw Mountains to Cleveland, and north to Chinook on the Montana Highline. Exposed strata will be principally Tertiary and Upper Cretaceous in age; Lower Cretaceous, Upper Jurassic, and Paleozoic strata will dominate the section in the Lewistown area.

Figure 1 shows the route traveled in this road log for Day 1 and also for the other two days of the field trip. Figure 2, modified from Dobbin and Erdmann (1955) shows the structural features of central Montana. Figure 3 provides comparative stratigraphic columns for the region.

Road logs for Days 2 and 3 of this Field Trip are provided in Montana Bureau of Mines and Geology Special Publication 113 (Porter, 1998), provided separately.

LEG 1: Billings to Roundup, a distance of 45.2 mi (72.3 km). Traverses rocks of Upper Cretaceous and Tertiary age across the Lake Basin Fault Zone and the Bull Mountains Basin. One rolling stop, south of Klein.

LEG 2: Roundup to Winnett, a distance of 55.5 mi (88.8 km). Traverses the north flank of the Bull Mountains Basin, then onto the Central Montana Uplift across Tertiary and Cretaceous beds exposed in the Devils Basin Anticline and northward. STOPS 1 and 2.

LEG 3: Winnett to Lewistown, a distance of 52.4 mi (83.8 km). Approximately parallels northwest-southeast trend of Central Montana Uplift, crossing Upper and Lower Cretaceous strata exposed in northwest-striking, low rolling folds subparallel to the uplift. Jurassic and Paleozoic beds exposed in domes in Lewistown area. No field stops. Lunch stop in Lewistown.

LEG 4: Lewistown to junction of State Highway 81, plus a round-trip loop on Hwy. 81, a distance of 51 mi (81.6 km). Traverses Upper Cretaceous beds and extensive gravel deposits exposed on flanks of Judith and South and North Moccasin Mountains. STOP 3.

LEG 5: State Highway 81 junction north to Winifred and Chinook, a distance of 113 mi (180.8 km) via McClelland Ferry and Cleveland. Traverses Upper Cretaceous rocks in gravity-slide folds and faults south of Bears Paw Mountains. In mountains, Tertiary volcanic rocks flank a Cretaceous sediment-filled graben. Alternate route in wet weather is Winifred to Big Sandy via County Road 236 across Missouri River at Judith Landing (PN) Bridge, then north to Havre, east to Chinook. No field stops, either route.

LEG I: BILLINGS TO ROUNDUP

(45.2 mi/72.3 km; one rolling stop) via Highway 87

Log begins at intersection of 1st Avenue North and U.S. Highway 87, on the east side of Billings. During the cross-town drive from the motel area to the starting point, the Eagle Sandstone is seen forming the "rimrock" to the north and east, dipping 4° to 6° east. It is transitionally underlain by silty mudstone, siltstone, and shaly sandstone of the Upper Cretaceous Telegraph Creek Formation, forming the lower cliff faces. To the north, lower stratigraphic section is largely obscured by extensive terraces. To the south, however, the highly dissected dark shales down to the valley floor are Upper Cretaceous units earlier assigned to the Colorado Shale, now assigned to the Mowry Shale and Belle Fourche Shale west of Blue Creek (at Blue Creek Road Exit off I-90), and to the Carlile Shale and Niobrara Formation east of Blue Creek (Lopez, 2000). Repeat of section by faulting is common in these shales (D. Lopez, pers. comm.).

Mileage
Cum. Inc.

0.0 **START. TURN NORTH ON U.S. HIGHWAY 87 toward Roundup.** Traveling on Upper Cretaceous Claggett Shale; no exposures.
0.4

0.4 Crossing Five Mile Creek. Start gentle uphill grade toward outcrops of Judith River Formation ahead at 1:00**,** gently northeast-dipping into Bull Mountains Basin.
0.9

1.3 Judith River beds exposed intermittently both sides of highway next 5 miles.
2.5

3.7 South-dipping Judith River beds in low road cut on right reflect displacement along one of the many NE-trending en echelon faults of the Huntley-Lake Basin fault zone (Lopez, 2000). This NW-SE-trending zone is over 100 miles long, up to 10 miles wide, and parallels other structural features of central Montana such as the Nye-Bowler fault zone and Cat Creek Anticline. These NW-trending features, and associated NE-trending en echelon faults, are thought to be related to left-lateral displacement along major basement faults at depth. Bull Mountains ahead on skyline occupy center of Bull Mountains syncline.
0.8

4.5 Hill crest. Judith River beds form low ridge at 3:00**.** Valley ahead is developed on Bearpaw Shale with overlying Fox Hills Sandstone (probable) and Hell Creek Formation forming buttes, knobs and ridges both sides of road (surface mapping of Fox Hills to east by E.M. Wilde (pers. comm.), suggests Fox Hills is present in this area). Gentle north dip continues to reflect south flank of Bull Mountains Basin
2.6

6.9 Shepherd-Acton crossroad. Traveling on Bearpaw Shale. Timbered ridge in middle distance at 9:00 composed of Fox Hills (probable) and Hell Creek beds. Bull Mountains ahead on skyline at 12:30 are Tertiary Fort Union Formation
2.4

10.3 Mailbox Road crossroad.
0.5

10.8 Lowermost Hell Creek beds form low NE-dipping ridge at 11.00. Beds are probably underlain by Fox Hills (Lennep) Sandstone that is soft and slope-forming above the Bearpaw Shale. Bull Mountains lie across skyline ahead; they are named for the stocky scrub Bull Pine that grows on these slopes.
0.9

11.7 Crossing Crooked Creek drainage.
1.6

13.3 Fox Hills(?) and Hell Creek both sides of road. Upper Hell Creek and Tullock, lowest member of Fort Union Formation, underlie knobby topography over next 10 miles with intermittent exposures.
2.7

15.9 Passing under power line.
0.9

16.8 South-dipping sandstones in low cut on right reflect south flank of Crooked Creek Anticline.
0.2
17.4 (Mile Post 22) Crest of hill. Approximate crest of Crooked Creek Anticline. Begin crossing deep ravine cut in NE-dipping Hell Creek and Tullock Member beds on north limb of anticline, south flank of Bull Mountains Basin.
1.0
18.4 Crest of hill. North-dipping Tullock beds both sides road. Begin descent into broad valley developed in Lebo Shale, middle member of Fort Union Formation. Bull Mountains ahead in basin center composed of coal-bearing Tongue River, upper member of Fort Union.

Coal mining has been an important part of Montana's economic base over the past hundred years. Underground and strip mines have provided coal to fuel the railroads, heat local farms and ranches, and generate electricity. Abandoned underground mines are now being evaluated as sites for storage of water. Such subsurface reservoirs could provide off-stream storage that would not inundate agricultural land and would lose less water to evaporation than surface reservoirs (Wheaton, 1992, 1993).
1.6
20.0 Entering Musselshell County. **Mileages from here on are less accurate.**
1.4
21.4 Crossing high spot; road on Tongue River. Lebo Shale valley ahead; Tongue River beds form cliff face ahead.
3.5
24.9 Buildings of old 30 Mile Ranch**,** both sides of road. Entering Bull Mountains. Evidence of earlier fires apparent on hill sides.
0.4
25.3 Small coal seams visible in road cuts next 15 miles**.**
3.7
29.0 Intersection of Coal Road on right; summit of Bull Mountains in approximate middle of Tongue River Member. Excellent exposures including thin coals both sides of road. Sub-bituminous coal from seams up to 15 ft (4.6 m) or more thick in Tongue River Member of Fort Union Formation began to be produced in 1906 to supply the Pacific coast extension of the Chicago, Milwaukee, and St. Paul Railway. The underground mining from twenty or more seams continued into the 1950s, and is presently being reactivated.
1.0

Figure 4. *Coal bed in middle part of Tongue River Member of Tertiary Fort Union Formation along U.S. Highway 87 in Bull Mountains south of Roundup (photo by K. Porter).*

30.0 Paved road on right, and signs for Divide Coal Mining Company and Blue Flame Coal Mining. This road also goes to Meridian Minerals Company site (3.2 miles east). Road is old road to Delphia.
5.4
35.4 [mileage may be incorrect] Power substation on right.
5.8
41.2 **SLOW DRIVING SPEED**: **HISTORY OF COAL MINING IN AREA.** Note red clinker beds in recessed area on right, resulting from the natural burning of exposed coal beds, producing the red rock called “clinker”. Site is old Klein mine, opened in 1907 as the Milwaukee Road (Chicago, Milwaukee, St. Paul & Pacific RR) built into the valley. On west side highway, directly across from red surface of coal bum, note cliff house constructed by miners in Tongue River sandstone ledge behind buildings on west. **CONTINUE NORTH.**
0.2
41.4 Entering old coal mining town of Klein. Note excellent exposures of channel sandstones in Tongue River Member.
0.9
42.3 Cemetery for United Mine Workers of America on right.
0.3
42.6 Cemeteries on both sides of road.
0.6
43.2 Site of old town of Roundup marked by restored log building on knoll on left. Established here before the turn of the century, the town moved across the Musselshell River when the railroad was built through the valley in 1906.

0.2

43.4 Crossing Musselshell River, named by Lewis and Clark in 1805**,** following the Indian name that refers to the then abundant fresh-water mussels along the river.

0.4

43.8 Crossing over old railroad bed of the Milwaukee Road, and entering intersection of U.S. Hwy. 12 left to Harlowton. **TURN RIGHT, STAYING ON U.S. HIGHWAY 87**. Outcrops of Tongue River on left at turn.

1.1

44.9 Entering Roundup.

0.3

45.2 Steeply dipping Tongue River beds on left (north) reflect SE flank of Pole Creek Anticline plunging into Bull Mountains Basin. **STAY ON U.S. HIGHWAY 87, TURNING NORTH THROUGH TOWN. END LEG 1.**

LEG 2: ROUNDUP TO WINNETT

(55.5 mi; 88.8 km; two stops)
via U.S. Highway 87 and County Road 244

0.0 **START ON U.S. HIGHWAY 87 AT NORTH END OF TOWN WHERE ROAD BENDS LEFT AND RIGHT-HAND LANE ENDS.**

Traveling on sandstones and shales of Tullock, lower member of Tertiary Fort Union Formation, and passing down section into Cretaceous Lance Formation. Regional low-angle dip to south reflects north flank of Bull Mountains syncline and south flank of Devils Basin Anticline.

0.3

0.3 Crossing onto Cretaceous Lance Formation exposed on axis of small anticline. No exposures visible from highway.

0.3

0.6 Begin uphill grade in long curve. Outcrops ahead and on right are Tullock Member with Lance swale between.

0.9

1.5 Crest of hill in Tullock Member. Airport road on right. Next several miles traveling on Tullock with Lance in grassy, rolling swales. Lance underlies Willow Creek Valley.

4.7

6.2 Mile Post 7. High point on highway, overlooking Willow Creek Valley. Big Snowy Mountains anticlinorium at 10:30 o'clock; Little Snowy Mountains at 11:00. To far west at 9:00, Crazy Mountains may be visible. Highway is on Tullock Member; a cap of olive brown Lebo shale, middle member of Fort Union Formation seen in road cut on right. Highway proceeds down into valley, straightens to north, and passes onto Lance Formation.

3.7

9.9 Big Wall Road on right heads east toward Big Wall oil field ten miles east on Big Wall Dome. Center of dome is floored by Upper Cretaceous Niobrara and Telegraph Creek Formations (Porter and Wilde, 1999). Production is from Pennsylvanian-Upper Mississippian Tyler Formation.

0.3

10.2 Highway crests on broad gravel bench; old buildings on right.

0.7

10.9 Little Snowy Mountains Road on left. Highway begins descent into deeply eroded Devils Basin Anticline. Traveling down section through steep, south-dipping Upper Cretaceous beds forming the south flank of the Devils Basin Anticline

0.1

11.0 **PULL OVER ON RIGHT SHOULDER. PARK SAFELY -** BLIND TRAFFIC ON HILL. WALK SHORT DISTANCE AHEAD TO OVERVIEW AND STOP 1

11.1 **STOP 1: OVERVIEW OF DEVILS BASIN ANTICLINE.**

Stratigraphic setting

We are standing on thin gravels overlying Tertiary Fort Union Formation; all beds on this south limb of anticline dip steeply to south. Immediately under gravels is the Tongue River Member (upper member), with sandstone exposed about 300 yards away to left (west). Yellow-brown Lebo (middle member) mudstones exposed behind fence on left and forming swale on right (east). South-dipping rusty-brown sandstone ridge ahead on right, with solitary tree and striking into curve of highway is Tullock (lower member). Broad flat on right with almost no outcrops is underlain successively by Upper Cretaceous Lance sandstone and mudstone, Bearpaw Shale, Judith River sandstone and mudstone, and Claggett Shale, passing downward into the basin to the prominent timbered, white sandstone of the Eagle. The Eagle can be visually traced around the basin and defines the southeast plunge of the Devils Basin Anticline. It passes in front of our view to the north. The Eagle will be examined at STOP 3, 65 miles to the northwest. Basinward from the Eagle are the unexposed Upper Cretaceous Carlile and Greenhorm Formations. Still farther across the basin floor, and stratigraphically lower, the prominent low cuesta is the Belle Fourche Shale capped by the Mosby Sandstone Member, subject of STOP 2, 40 miles to north. Stratigraphically below the Mosby in this view, the Upper Cretaceous Mowry Formation and Lower Cretaceous Thermopolis Shale are exposed. At the northwest end of the anticline, the Lower Cretaceous Kootenai Formation is exposed beneath thin gravels and forms the rollover on the structure. This center of the anticline has been targeted for exploration several times in the past.

Exploration history of Devils Basin Anticline. This discussion will be led by Duncan McBane, Exploration Geologist, Billings, MT.

REBOARD VEHICLES AND PROCEED SLOWLY DOWN HILL INTO BASIN.

0.2

11.3 Yellow weathering sandstone with darker caps both sides of highway are Lance Formation. Includes beds behind the red barn on left and this side of corrals on right. Note that Lance includes a light gray-white sandstone in this area. Beyond corrals on right, sage covered flat is underlain by Bearpaw Shale. On other side of sage flat see very poor, low sandstone patches of Judith River Formation where incised by small drainage. Between these Judith River beds and prominent timbered, white Eagle Sandstone ridge is a narrow, grassy flat underlain by Claggett Shale.

0.5

11.8 Passing red barn on left; Lance Formation all around.

0.8

12.6 Crossing strike of Eagle Sandstone. Low scarps in basin at 1:00 are Upper Cretaceous Belle Fourche Shale. Lumpy, “popcorn” weathering gray bentonite is consistent marker in lower part of formation. Behind bentonite exposures, approximately half-mile distance, see low resistant scarp of Mosby Sandstone Member at top Belle Fourche Shale.

0.8

13.4 Crossing strike of south-dipping Mosby Sandstone. Note concretion mounds in shale stratigraphically below (north side of) thin sandstone beds; these are characteristic of transition of Belle Fourche shales into Mosby sandstone.

Highway continues down section into basin and crosses North Willow Creek in Mowry Formation at approximate position of axial trace of Devils Basin Anticline. Highway continues on northeast-dipping Mowry and begins to climb up long tongue of bench; silvery gray, blocky mudstone exposed both sides of road.

1.7

15.1 Mile Post 16.

1.0

16.1 Mile Post 17. At 3:00, Moby Sandstone forms low scarp above basin floor. Eagle Sandstone forms timbered white ridge in far distance. Between are Greenhorn, Carlile, Niobrara, and Telegraph Creek Formations.

1.0

17.1 At 9:00, rollover on the Devils Basin Anticline occurs within the Lower Cretaceous Fall River and Kootenai Formations, not well exposed. Lone wooden structure approximately on crest of anticline.

0.3

17.4 Last Mowry exposures, now dipping northeast, strike under highway on right as we begin traveling on thin gravel cap.

2.5

19.9 Junction with Montana Highway 244 on right, within the active Winnett Junction oil field. **TURN ONTO HIGHWAY 244 TOWARD WINNETT**. Principal producing horizon in field is Pennsylvanian-Mississippian Tyler Formation. Traveling on gravel surface.

1.6

21.5 Entering Petroleum County.

1.4

22.9 Dropping off gravel bench into Flatwillow Creek Valley and onto marine shales of the Niobrara and Carlile Formations. Eagle Sandstone forms promontory on skyline at 1:00 – 3:00.

1.8

24.7 Conical feature and low ridge on right upheld by resistant concretions in (?)Carlile Shale.

0.9

25.6 Crossing Flatwillow Creek.

1.0

26.6 Crossing from alluvium of creek onto alluvial terrace. Eagle forms prominent rims to north and east.

3.2

29.8. Mile Post 10. Community of Flatwillow at 3:00.

1.8

31.6 Dropping off bench, crossing onto Niobrara Formation (no exposures in view)

0.1

31.7 Mile Post 12. Crossing east-flowing Pike Creek. Pike Creek Road to left. Continue on Highway 244, traveling on Niobrara and Quaternary alluvium.

4.9

36.6 Dropping off bench. Shales of Niobrara on right.
1.1
37.7 Mile Post 18. Elk Creek Road curves off to left, still in Niobrara, but no exposures.
1.1
38.8 Niobrara exposures both sides of highway at crest.
1.4
40.2 Grain bins on right.
0.8
41.0 Dropping into McDonald Creek drainage. Town of Winnett ahead; Eagle Sandstone rims on skyline.
0.5
41.5 **TURN LEFT ONTO GRAVEL ROAD TO STOP 2** – about 6.2 miles. Note extensive white salt deposits developed on poorly vegetated surface both sides of road. Such salt deposits are common throughout central Montana where Cretaceous marine shales form the surface.

Traveling slowly down section across Niobrara then Carlile Formations; almost no exposures. In about 2.3 miles, note gray, rubbly concretions in upper Niobrara on right side of road; at about 4.4 miles see good lower Carlile, both sides of road through bend and up low grade – bare, blue-gray patches, many with small red ironstone concretions.

At about 4.9 miles, crossing onto Greenhorn Formation through swale. At about 5.4, TURN RIGHT ONTO TRACK. Go 0.8 miles and park in small grassy flat above cliff face of Mosby Sandstone. **WE ARE MOSTLY ON STATE LAND; SOME PRIVATE LAND - PERMISSION IS REQUIRED.**

53.9 STOP 2: MOSBY SANDSTONE

The Upper Cretaceous Mosby Sandstone was named for outcrops near the community of Mosby, MT, just west of the Musselshell River in westernmost Garfield County on the Cat Creek Anticline – about 20 miles east from here. Cobban (1953) described this outcrop as approximately 34 ft of marine sandstone and noncalcareous shale in two small coarsening-upward cycles overlying dark shales of the Belle Fourche Shale. Regionally, uppermost beds of the Mosby are five to seven ft of well laminated, noncalcareous dark-gray shale. Overlying beds, now assigned to the basal Greenhorn Formation, typically are a calcareous shale containing a basal horizon of light gray septarian concretions and a rusty weathering bentonite. The lighter-gray calcareous shale of the Greenhorn Formation often weathers to a cream color.

***Figure 5**. STOP 2. Outcrop of Mosby Sandstone, looking south (photo by K. Porter).*

Rice (1984) discussed the regional stratigraphic setting for the Mosby across central Montana, postulating a northern source for the sand and a shallow marine shelf depositional environment. Although Rice (1976) first considered the Mosby a basal member of the overlying Greenhorn Formation, he later established it as the upper part of the Belle Fourche Shale (Rice, 1984), based on the gradational, coarsening-upward sedimentology observed on outcrop and in well logs (Fig. 3). The Mosby is equated with the Philips Sandstone of the subsurface by Rice (1976). Contact with the overlying Greenhorn is generally believed to be unconformable. Fossil collections within the Mosby interval are latest Cenomanian, and equated to the middle part of the Greenhorn of the Black Hills region and to the upper part of the Dunvegan Formation of Alberta and British Columbia (Cobban, 1953).

The Mosby Sandstone is found on outcrop as far southwest as the Devils Basin Anticline (STOP 1), but pinches out to the west somewhere beneath the gravel deposits west of the anticline and is gone in the Durfee Creek Dome area on the east flank of the Little Snowy Mountains (Porter and Wilde, 1999) (Figs. 1, 2).

Several concretion horizons within the upper Belle Fourche shale and Mosby Sandstone have widespread continuity across central Montana, even when the sandstone has pinched out; they are guides to stratigraphic position. We will see these horizons again on the north flank of the Bears Paw Mountains on Day 3. These zones are: (1) A thin zone of smooth, ovoid orange-weathering calcareous concretions, commonly highly fractured and forming a rubbly weathered surface occurs about 20 ft below the base of the Mosby; (2) Stratigraphically above, a zone of light-gray, dense, calcareous, commonly highly fractured concretions; this zone thickens where the lower sandstone cycle is poorly developed and commonly replaces the sandstone; (3) A horizon of light-gray, calcareous concretions with coarsely crystalline calcite veins commonly lies at the Mosby-Greenhorn contact.

Figure 5 is a view of the Mosby outcrop at STOP 2. Figure 6 (at end of Road Log) provides a composite outcrop section of the Mosby Sandstone in central Montana; most of the features shown are observed at STOP 2.

RETURN TO HIGHWAY 244. TURN LEFT (NORTH) TO WINNETT. Traveling alternately on Quaternary alluvium and Niobrara shale.

1.6

55.5 Entering Winnett.

Green water tank south of Winnett sits on bluff capped with Eagle Sandstone; lower slopes are Telegraph Creek Formation. Winnett is county seat of Petroleum County. Current county population is about 500, about 200 of whom live in Winnett. During the oil boom on the Cat Creek anticline in the early 1920s, Petroleum County population was as high as 3,400; in 1925, there were 14 post offices and 29 school districts. At that time, Winnett was the nearest rail terminal to the oil field. Petroleum County was established in 1920, out of the eastern part of Fergus County (Petroleum County Public Library).

Travel through town and exit to north at Junction of State Highway 200. **END LEG 2.**

Figure 7. *View of McDonald Creek valley, looking south over town of Winnett (in trees) with rim rocks of Eagle Sandstone above (photo by K. Porter).*

LEG 3: WINNETT TO LEWISTOWN

(52.4 mi/83.8 km; Lunch Stop en route)
Via State Highway 200

0.0 **START AT JUNCTION OF COUNTY ROAD 244 AND STATE HIGHWAY 200. TURN WEST (LEFT) TOWARD LEWISTOWN.** Road follows north side of east-flowing McDonald Creek, crossing several shallow folds across the broad, very gently south-dipping south flank of the Cat Creek Anticline. Starting out, road passes obliquely across east-plunging nose and north limb of McDonald Creek anticline (Porter and Wilde, 1993); rolling topography to north underlain progressively westward by largely unexposed Eagle, Telegraph Creek , and Niobrara Formations.

2.1

2.1 Gravel road to south. Ahead to south at 10:00 is east-sloping grassy surface underlain by Mosby Sandstone Member of Belle Fourche Shale, as it plunges underground around nose of anticline; trees are on underlying Belle Fourche shales. Road is on Niobrara Formation, not exposed.

1.3

3.4 Crossing approximate position of Niobrara-Carlile Shale contact.

0.9

4.3 Crossing approximate position of Carlile-Greenhorn Formation contact.

0.2

4.5 Gravel road on left (south).

02

4.7 Crossing approximate contact of Greenhorn-Belle Fourche Shale. Note dipslope of Mowry Shale on skyline to south at 9:00 on east plunge of McDonald Creek anticline.

0.8

5.5 Crossing approximate contact of Belle Fourche-Mowry. Mowry forms low hills off to north (right). To south at 10:00, trees are on unnamed sandy member of underlying Thermopolis Shale.

0.8

6.3 Low ridge of sandy Mowry Shale on north side of road, striking NW.

0.5

6.8 Crossing approximate position of Mowry-Thermopolis Shale contact. Mowry strikes north out of view. Low hills to north of road underlain by Thermopolis; road is on Thermopolis rest of distance to Grassrange.

0.6

7.4 Crossing approximate position of axis of McDonald Creek Anticline. Road now on south limb in Skull Creek, lowest member of Thermopolis. Trees on south side McDonald Creek are on unnamed sandy member of Thermopolis. Bare ridge behind is Mowry Shale capped with Quaternary gravel deposits.

The Thermopolis Shale, generally poorly exposed throughout central Montana, is 550 to 600 ft thick. It contains (1) the lower Skull Creek Shale Member, about 200 ft of very fissile, black shale with numerous thin sandstone beds in the lower part (the "Dakota silt"); (2) a middle unnamed sandy member containing 300 ft of dark gray, fissile to blocky marine shale with one or more thin intervals of fine-grained, locally pebbly sandstone commonly forming low scarps; and (3) the upper Shell Creek Shale Member, approximately 100 ft of medium gray, fissile shale (Porter and Wilde, 1993).

The unnamed sandy member commonly supports trees across otherwise untimbered grassland. Everywhere throughout central Montana at least one of the thin sandstones bears coarse sand and black chert pebbles (Fig. 8). **This horizon is thought to be the marine equivalent of the lowstand event that caused subaerial exposure and valley cutting on the margins of the Cretaceous Seaway – the late Albian lowstand sea level event that is widely recorded throughout the Western Interior of the U.S. and Canada. In central Montana, a residual body of water apparently remained as the sea withdrew; conditions remained marine. We will see this interval in the Little Rockies, the Bears Paw Mountains, and the Sweet Grass Hills.**

Figure 8. *Coarse-grained sandstone and black chert pebbles in unnamed sandy member of Thermopolis Shale (photo by K. Porter).*

Overlying the Thermopolis Shale, the Mowry Shale (Fish Scales Zone) is a distinct interval of highly siliceous, light silvery blue-gray weathering, well laminated siltstone and mudstone (Fig. 9). In west-central Montana the lower Mowry is a fine-grained sandstone, commonly forming a prominent ridge that is a reliable mapping horizon.

4.2

11.6 Blakeslee Road and old townsite of Teigen on right (north); one wooden building remains. Small butte to south composed of Mowry; a small NE-trending dike intrudes its SW side. Low hills to north capped with Mowry, typically visible as bare patches of light silvery-gray shale.

0.8

12.4 Entering Fergus County. Teigen Ranch buildings on left. Road on Thermopolis Shale. North-dipping Mowry forms low hills to north on flank of small unnamed syncline.

2.0

14.4 Thermopolis shales exposed to south in cut bank of McDonald Creek. Road crosses back over approximate axis of McDonald Creek anticline; north-dipping beds of Mowry Shale to north of road.

1.2

15.6 Crossing bridge over small creek; Mowry forms topography both sides of road.

0.2

15.8 Gravel road to north across Mowry dipslope.

2.4

Figure 9. *Mowry Shale showing typical well laminated siltstone with silvery blue weathered surfaces (photo by K. Porter).*

18.2 Crossing McDonald Creek. Judith Mountains ahead on skyline at 12.00 to 2:00 0'clock.
1.0
19.2 Bare hills on south are Thermopolis capped by Mowry; contact is at slight recession in slope.
1.2
20.4 Black shales of lower Thermopolis (Skull Creek) in road cuts on left. Trees in mid-ground at 2:00 are on unnamed sandy member of Thermopolis Shale. Entering broad floodplain of confluence of North and South forks of McDonald Creek.
1.9
22.3 Junction of U.S. Highway 87 from south and State Highway 19 from north. Town of Grassrange is one-half mile south. **CONTINUE WEST TOWARD LEWISTOWN ON HIGHWAY 200 AND U.S. 87,** following North Fork of McDonald Creek. Thermopolis forms both sides of valley; trees developed on unnamed sandy member.
0.5
22.8 Crossing South Fork of McDonald Creek and continuing west along south side of North Fork.
4.3
26.5 High bare ridge to north is Mowry. To south, trees are on dipslope of Thermopolis Shale above Fall River (First Cat Creek) Sandstone that becomes more visible westward.
3.3
29.8 Crossing North Fork of McDonald Creek and entering valley of Alkali Creek. Thermopolis shales to north; Fall River (First Cat Creek) dipslope to south.
0.7
30.5 Gravel road on right.
3.3
33.8 Small road cuts on south (left) expose thin, flaggy sandstone beds of upper Fall River Sandstone. Road near Fall River-Thermopolis contact.
1.4
34.4 Burnett Road on right. Mowry forms high bare ridge on north skyline. Mid-ground trees on sandy member of Thermopolis. Judith Mountains form distant skyline at 1:00-2:00 o'clock.
2.7
37.1 Roadside Historical Marker on right Mile Marker 98 on left:
"Fort Maginnis ... was built about 8 miles north of here in 1880 .... The soldiers were to protect the cattle from being mistaken for buffalo by hungry Indians, to encourage settlement of the Judith Basin west of here and to patrol the Carroll Road to keep supplies rolling between Carroll (near the mouth of the Musselshell River) and Helena. By 1890 the post was no longer needed, … and the fort was abandoned..." The DHS Ranch, a large Judith Basin open-range stock growing operation during the 1880's was located on Ford Creek about one mile from Ft. Maginnis.
0.8
37.9 Road swings down hill across Fall River (First Cat Creek) Sandstone. Butte ahead capped by Fall River above red beds of Lower Cretaceous Kootenai Formation.
1.1
39.0 Road north to Giltedge on right. Piper Cutoff Road on left goes south to Mercer Dome. Spotty sandstone outcrops both sides of road are Fall River Formation capping Kootenai. Contact between these two formations often forms slight notch across covered slopes.
0.6
39.6 Sandstone of Kootenai Formation in road cuts on right.
1.2
40.8 Divide Road (east end) on left heads southwest, following North Fork of McDonald Creek. Road rejoins highway several miles ahead. A massive Quaternary travertine caps timbered ridge to south, deposited across Kootenai Formation.
0.6
41.2 Timbered outcrops next to highway for next 0.4 mile are basal Kootenai Sandstone of Lower Cretaceous age, dipping gently southeast. At west end of timber, Kootenai overlies carbonaceous shales, coaly sandstone, and thin coal beds where surface diggings are still visible. These carbonaceous beds, traditionally assigned to the

uppermost Morrison Formation of Jurassic age, are now known to be Early Cretaceous in age (unpublished palynological data, Donald W. Engelhardt, University of South Carolina). The Lewistown coal district has been inactive for many years. It is described by Silverman and Harris (1967).

0.7

41.9 Jurassic Swift Formation (upper Ellis Group) sandstones crop out on right, starting just past ranch buildings set back on right. Highway continues west, traveling on Swift Formation and nearly parallel to strike across south flank of Skaggs Dome lying mostly to the north.

1.4

43.3 Road crossing Swift Sandstone.

0.3

43.6 Swift Sandstone forms low ridge above road on left, dipping south. Basal Kootenai sandstone forms timbered ridge ahead on right. Highway passes up section into Morrison Formation across north flank of Lewistown Bench Dome and follows Morrison-Kootenai contact to southwest around dome.

0.6

44.2 Divide Road (west end) on left as highway begins long curve to left around Lewistown Bench Dome.

1.0

45.2 Pond in grassy swale to left of highway lies about at Morrison-Swift contact within the dome. Rierdon and Piper Formations, middle and lower parts of the Ellis Group, respectively, are present but poorly exposed. Dense timber behind is underlain by Mississippian Heath Formation. Mississippian Otter Formation, not in view, forms center of dome. On right, open timber is underlain by Kootenai Formation.

1.4

46.6 Crossing SE-dipping Fall River, and passing down onto timbered sandstone and red beds of Kootenai. Fall River caps grassy benches to south and north for rest of distance into Lewistown.

3.6

50.2 Historical marker on right describes Lewistown history.

1.2

51.4 Entering Lewistown.

1.0

52.4 **Intersection with First Avenue. TURN RIGHT FOLLOWING SIGNS FOR U.S. 191 NORTH. END LEG 3.**

LEG 4: LEWISTOWN TO JUNCTION WITH STATE HIGHWAY 81

(51 mi/81.6 km; STOP 3)

Via U.S. Highway 191 and State Highway 81.

0.0 **START AT NORTH TURN ON U.S. Highway 191 NORTH, NORTH SIDE OF LEWISTOWN.** Traveling on alluvium of Spring Creek deposited on Lower Cretaceous Thermopolis Shale.

0.3

0.3 Crossing west-flowing Spring Creek.

1.2

1.5 Crossing Railroad tracks. Low, grassy hills underlain by Lower Cretaceous Thermopolis Formation.

0.5

2.0 Highway makes long curve uphill to right. Good overview of Spring Creek Valley.

0.4

2.4 Hanover Road on left. **Continue straight,** traveling on Upper Cretaceous Mowry Shale. Hanover Dome five miles to west is an up-thrown fault block exposing Mississippian Heath Formation in its center. South Moccasin Mountains ahead at 10:00-12:00 o'clock; North Moccasin Mountains coming into view in 12:00 o'clock distance.

0.2

2.6 Mile Post 3.

0.8

3.4 Outcrop of Mowry Formation sandstone in small gully left side of highway.

0.4

3.8 Top of bench. Judith Mountains on skyline at right. South and North Moccasin Mountains ahead on left.

0.7

4.5 Denton Cutoff Road on left. **Continue straight**. Traveling on Upper Cretaceous marine shales assigned to the Telegraph Creek and underlying Marias River Formation.

<u>A note about stratigraphic nomenclature</u>: Across Montana, Lower and Upper Cretaceous rocks, dominantly of marine origin, are traceable on outcrop over many miles from the Black Hills Uplift on the southeast westward to the Rocky Mountain Front. They record the depositional settings and events in the Western Interior Seaway, including shifts of shoreline, variations in sediment source and type, and the influence of both eustacy and tectonism. From one standpoint, the deposits of this interior seaway are remarkably homogeneous; from another, there is considerable variability. As stratigraphic studies progressed over seven decades or more, nomenclature has proliferated.

Of principal importance to the present field trip is the integration of "eastern" terminology from the Black Hills region with "western" terminology of the Great Falls region for the section above the Kootenai Formation and below the Telegraph Creek-Eagle Sandstone – the interval commonly termed the "Colorado Shale". In its statewide mapping program, the Montana Bureau of Mines and Geology has place this nomenclature shift along a roughly north-northeast to south-southwest line passing through the western Judith Mountains in central Montana (Figs. 1, 2). East of this line we employ the Black Hills terminology; west of the line, the Blackleaf and Marias River Formations contain the section, following the work of Cobban and others (1976). Figure 3 shows comparative stratigraphic columns for central Montana and the adjacent region.

1.2

5.7 Lower Carter Pond access road on right.

0.6

6.3 Central Montana Memorial Gardens and Upper Carter Pond access road on right.

0.3

6.9 Climbing onto higher bench in shales of Marias River Formation exposed in small patches on slope at left.

2.1

9.0 Junction with State Highway 81 on left. **TURN LEFT onto Highway 81** toward Denton. Still traveling on Marias River Formation shales. Bench on north skyline underlain by Upper Cretaceous Eagle Sandstone with gentle north dip.

0.3

9.3 Crossing Warm Spring Creek, west-flowing.

0.5

9.8 Passing sign for "Carroll Trail 1873-75". Upon return from Stop 3 we will turn here.

0.3

10.1 Road bends sharply to west (left). Yellow-tan outcrops of Eagle sandstone ahead in slope. Large white blocks strewn across grassy slope of North Moccasin Mountain are travertine moving down slope from large travertine deposits forming the top of the mountain.

2.9

12.0 On left are poor exposures of Upper Cretaceous Mowry and underlying Thermopolis Formations.

0.2

12.2 Crossing Warm Spring Creek.

2.0

14.2 Phillips Cattle Company on right. Traveling on gravels that are extensive across slopes of the Moccasin Mountains and other uplifts of central Montana.

0.8

15.0 In curve of highway, looking across to SW slope of North Moccasin Mountain see large landslide containing large blocks of brown shale of Upper Cretaceous Claggett Shale, and abundant blocks of white travertine.

0.4

15.4 Minute Man Missile facility on left. Highway passes down through tight curves.

0.7

16.1 Undisturbed Claggett Shale forms slope west of landslide.

2.0

18.1 Meadow Creek Road on right.

0.4

18.5 Plum Creek Road on right (gravel) **- TURN IN**. Ahead at 11:00 o'clock is STOP 3, the high timbered scarp of Eagle Sandstone below broad bench. West flank of North Moccasin Mountain on right.

1.8

20.3 72 Bench Road on left (gravel) – **TURN IN**.

0.8

21.1 **TURN INTO DRIVEWAY ON LEFT** (Hartman) and go about 1 mile to house. **STOP 3.** Park along edge of gravel drive area. **WE ARE GUESTS HERE; PERMISSION IS REQUIRED**.

Figure 10*. STOP 3. View of Eagle Sandstone, looking northwest. Light-colored rocks at slope base are Virgelle Member (photo by K. Porter).*

Walk approximately one-half mile west to best access and most complete exposures (Fig. 10). Figure 11 (at back of Road Log) provides a measured section of the Eagle Sandstone at this locality, from Rice and Shurr (1983).

REBOARD AND RETURN TO STATE HIGHWAY 81. TURN LEFT (EAST) BACK TO U.S. HIGHWAY 191 – watch for "Carroll Trail" sign on left for short cutoff across to Highway 191.

51.0 (Approximate). **U.S. Highway 191. END LEG 4.**

***Figure 12**. Southwestern area of Bears Paw Mountains. View from Bowery Peak, looking northward (photo by Michael Stickney).*

LEG 5: JUNCTION OF STATE HIGHWAY 81 AND U.S. HIGHWAY 191 NORTH TO WINIFRED, CLEVELAND, CHINOOK

(113 mi/180.8 km; short stop at river crossing)
Via U.S. Highway 191, County Road 236, and Missouri River crossing at McClelland Ferry

ALTERNATE ROUTE IN WET WEATHER: from Winifred, continue on County Road 236 to Big Sandy, then north to Havre and east to Chinook. No road log provided.

0.0 **START ON U.S. HIGHWAY 191 AT JUNCTION WITH STATE HIGHWAY 81, HEADING NORTH. Maiden Creek Road turns off to east (right).** Traveling on marine shales of Upper Cretaceous Telegraph Creek and underlying Marias River Formation; no exposures.
0.7

0.7 Climbing to top of bench underlain by gently north-dipping Eagle Sandstone. Spotty outcrops in grassy slope beneath a thick gravel cap.
3.6

4.3 Entering Hilger. Traveling on Claggett Shale.
0.1

4.4 **TURN LEFT ON COUNTY ROAD 236 TO WINIFRED** – 23 miles.
0.6

5.0 (Upper Cretaceous) in road cut on right. Note typical soft brown color and characteristic smooth, ovoid, orange-weathering concretions.
4.0

9.0 Judith River beds (Upper Cretaceous) form bluffs to right.

Rest of travel to Winifred is on Judith River Formation. Views to the east show occasional timbered ridges of Judith River beds faulted and/or folded upward against surrounding, flat-lying Bearpaw Shale underlying the broad sage flats. These structures were studied and explained in a regional context by Reeves (1924) who applied a model of gravity sliding to the large, in-tact, flat blocks of Upper Cretaceous sedimentary rocks south of the Bears Paw Mountains.

In the definitive geologic map publication of the Bears Paw Mountains, B. Carter Hearn, Jr. (1976) discusses the tectonic framework for this uplift and the associated large-scale gravity sliding. The arch is a composite anticlinal uplift in the center of the mountains that contains abundant intrusions and sedimentary rocks of Cretaceous, Jurassic, and Mississippian age. Drill-hole data indicate that the plainsward slope of deeper horizons continues beneath the volcanic fields, so that the Bears Paw Mountains uplift is considerably broader than the central arch. Deep drill-hole data also suggest that Precambrian crystalline basement is uplifted as much as 5,000 ft above its regional level 7,000 ft beneath the plains (Hearn, Jr., 1976).

In the **Winifred area**, south of the uplift, broad areas of Bearpaw Shale are crossed by numerous subparallel ridges of more resistant Judith River beds. Farther north, along the Missouri River, we will observe deeper erosion exposing stratigraphically lower Claggett Shale and Eagle Sandstone involved in the same structural geometries.

Structure of Area South of Bears Paw Mountains

(Following text adapted from Hearn, Jr., 1976). This broad region both north and south of the Missouri River is dominated by relatively shallow faults that apparently originated from the gravity-slide movement of very large fold- and fault-bounded blocks off the Bears Paw Mountains (Reeves, 1924, 1946; Hearn, Jr., 1976). Strata involved in gravity-slide displacement have formed steep-sided asymmetric anticlinal folds that commonly are broken by steep compressional faults. Many of these faults subsequently underwent back-sliding of the hanging wall under tension. Gravity-slide-faults and folds encircle the Bears Paw Mountain uplift at distances as much as 30 or more miles away from the mountain front. Surface and subsurface data (Hearn, Jr., 1976) indicate that thick shale in the Upper Cretaceous sedimentary section, particularly within the Carlile Formation, is the principal interval within which the bedrock failure has occurred; older strata appear essentially unfaulted.

According to Hearn (1976), the timing of this gravity sliding apparently was closely associated with the late early Eocene and middle Eocene uplift of the Bearpaw Arch and with the synchronous widespread deposition of very thick volcanic flows and pyroclastics (as much as 6,000 ft thick - Hearn, Jr., 1976; Marvin and others, 1980). The greatly overweighted sedimentary layers failed, causing large blocks of strata and volcanics to be transported down-slope onto the surrounding plains. These detached blocks left graben structures along the margins of the central Bearpaw Arch into which the volcanic fields collapsed and have been preserved, while volcanic rocks on slabs carried onto the plains have been eroded away. A variety of intrusive rocks, also emplaced during this middle Eocene time, have been preserved in the central arch graben area and on the arch flanks as well as in the adjacent plains. Both the intrusive and volcanic rocks of the Bears Paw region are associated with the middle Eocene phase of intrusion and volcanism in the Central Montana Alkalic Province.

Erosion in post-middle Eocene time removed the distal portions of the volcanic fields, stripped away formations of early Eocene, Paleocene, and Late Cretaceous age in the plains, and produced pediment and terrace deposits of Miocene to Pleistocene age. In Pleistocene time a continental ice sheet advanced from the northwest and covered the western, northern, and eastern sides of the Bears Paw Mountains with glacial deposits.

14.0

23.0 **(approximate). ENTERING WINIFRED. FOLLOW BUREAU OF LAND MANAGEMENT SIGNS FOR GRAVEL ROAD TO McCLELLAND FERRY.** If the weather is wet we will, instead, stay on County Road 236 to Big Sandy.

From Winifred we travel 12 miles north to the Missouri River, still traveling on Judith River Formation and Bearpaw Shale. Approaching the river, the Judith River begins to develop the spectacular badlands topography that dominates the Missouri Breaks in this area. Overall, the formation is composed of a thick marine shoreface sandstone at its base overlain by a thick sequence of variegated pink, green, tan, and light-gray mudstones interbedded with brown lenticular sandstones, black coals, and brown carbonaceous shales, with local concentrations of rusty ironstone concretions. The entire section is bentonitic and there are many clean bentonite beds. The Judith River Formation has been studied in detail by Raymond Rogers (1993) who has applied a sequence stratigraphic framework to the regional relationships observed in the Missouri Breaks.

A moderate to steep gravel road on Claggett Shale descends onto the river bottom. The ferry will take two vehicles at a time. **On the north side of the river the road makes a short, steep ascent off the river bottom on an ungraveled track** for a little over a mile, traversing complexly faulted Judith River and Bearpaw Shale beds up onto Ragland Bench. From there, the road becomes more graveled and continues to traverses Judith River and Bearpaw northward into the heart of the Bears Paw Mountains, emerging on their north flank at Cleveland. From the north side of the river the travel time to Cleveland is about 1 and ¾ hours in good weather.

TRAVEL NORTH ON PAVED ROAD 22 MILES TO CHINOOK AND CHINOOK MOTOR INN. This 22-mile distance will be traveled again and described on Day 3.

113.0 (approximate) **ENTERING CHINOOK. END LEG 5.**

317 TOTAL MILES, DAY ONE.

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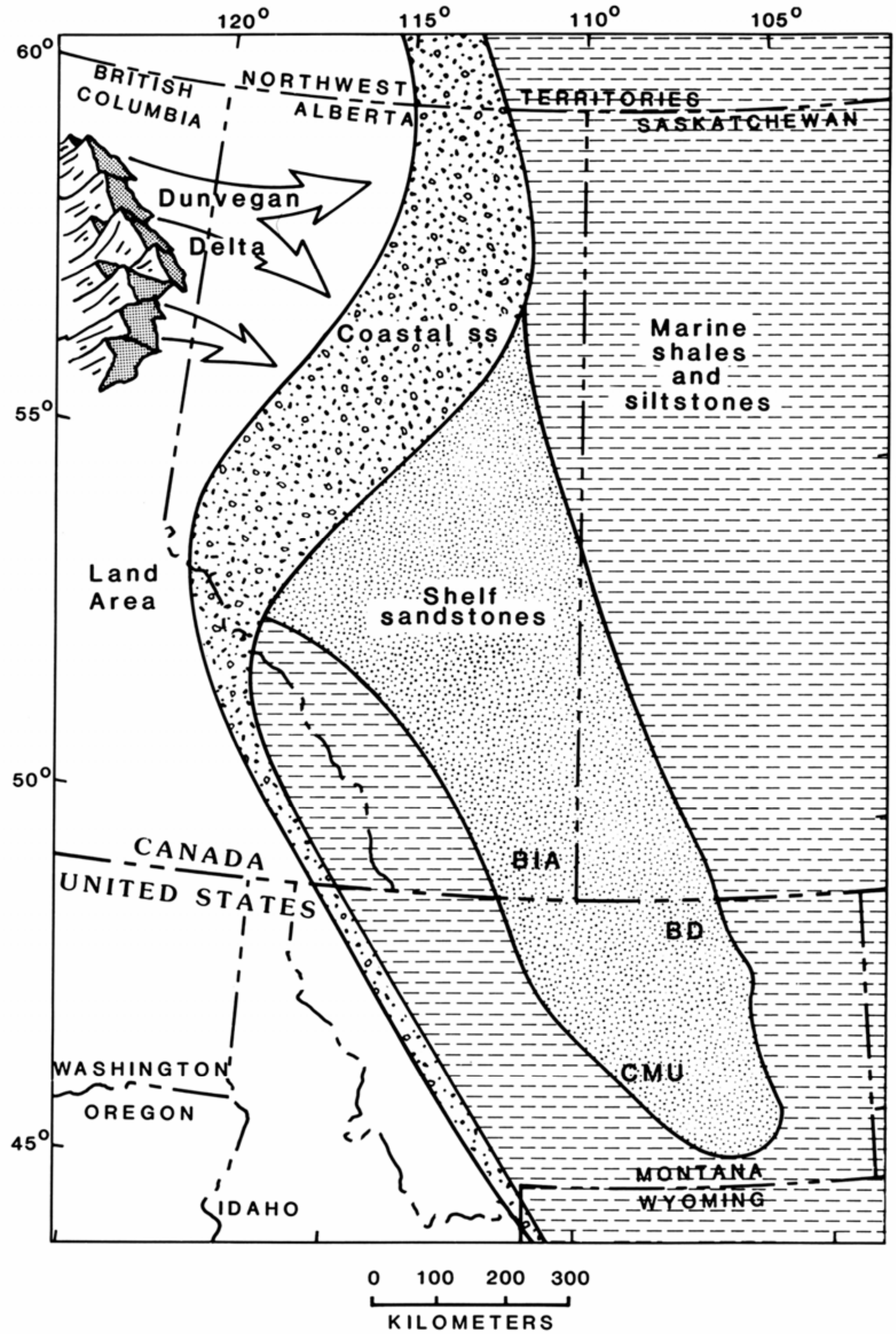

Fig. 3.—Paleogeographic map of northwestern United States and southwestern Canada during deposition of Mosby Sandstone Member. Dunvegan delta area is modified from Williams and Burk (1964). BIA, Bow Island Arch;

BD, Bowdoin Dome; CMU, Central Montana Uplift

Figure 6A. Paleogeographic setting and depositional limit of Mosby Sandstone in central Montana and Canada (Rice, 1984).

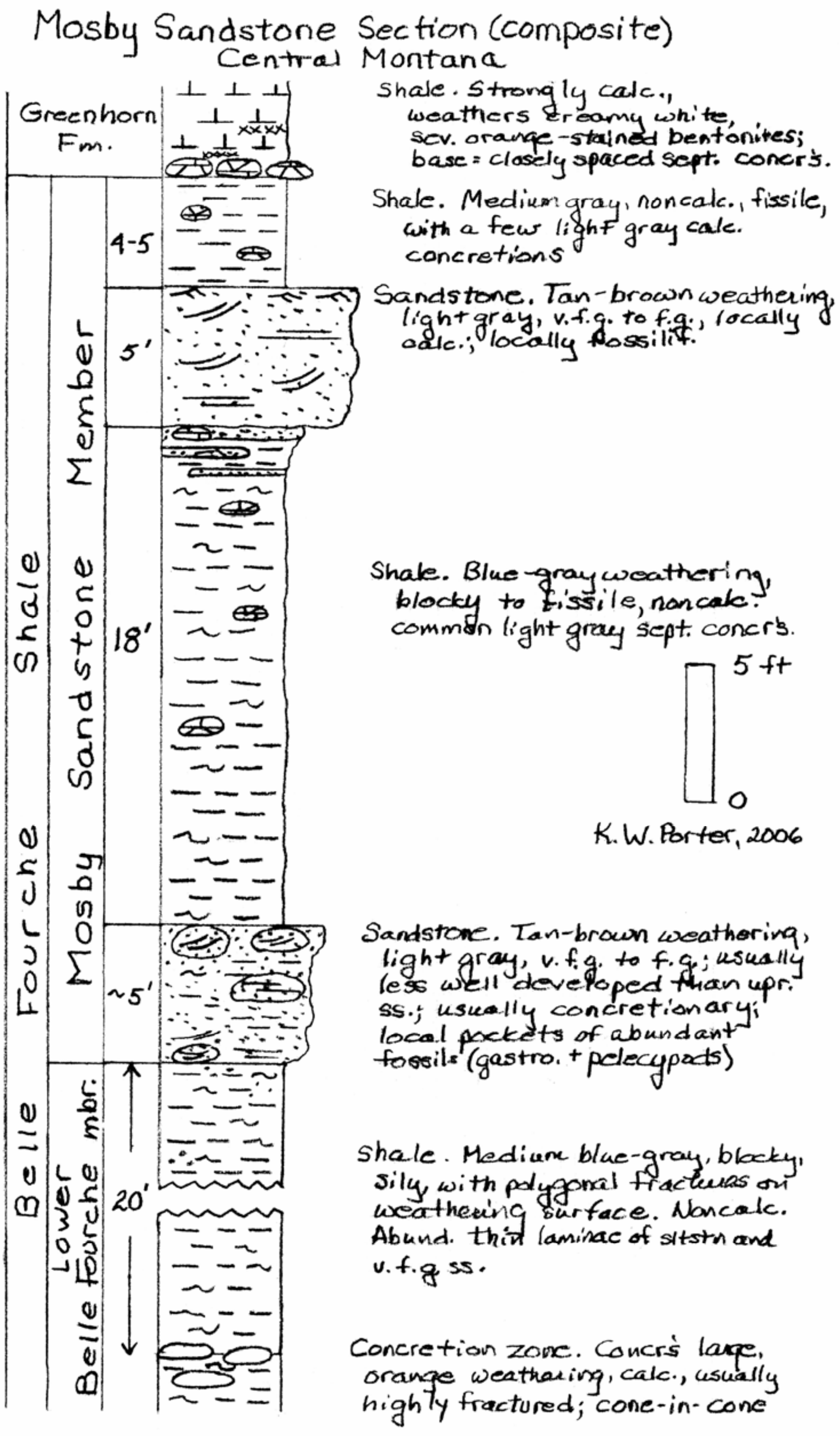

Figure 6B – Composite measured section of Mosby Sandstone, central Montana.

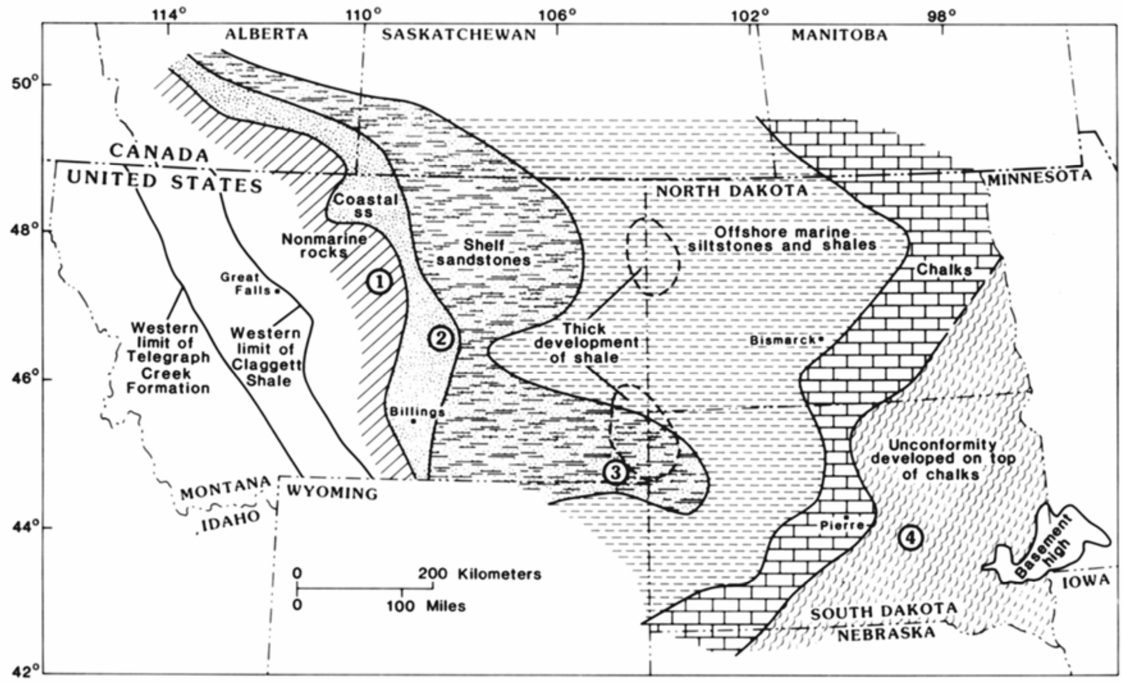

Figure 3. Facies map for Eagle Sandstone and equivalent rocks. Numbers refer to general location of study areas: (1) Bearpaw Mountains, (2) Central Montana uplift, (3) northern Black Hills, and (4) eastern South Dakota.

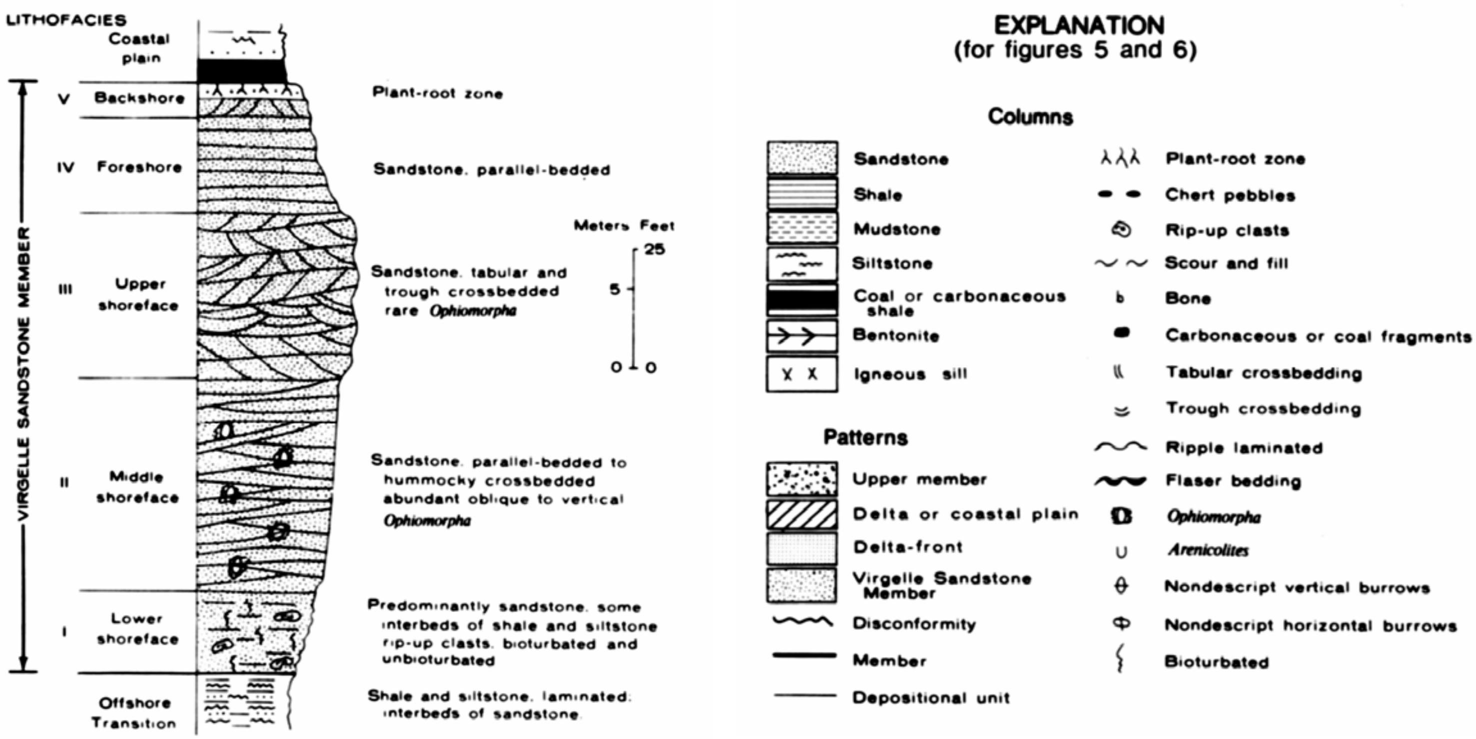

Figure 6. Typical Virgelle sequence of the Bearpaw Mountains.

Figure 11A. Eagle Sandstone, central Montana. Figures from Rice and Shurr (1983).

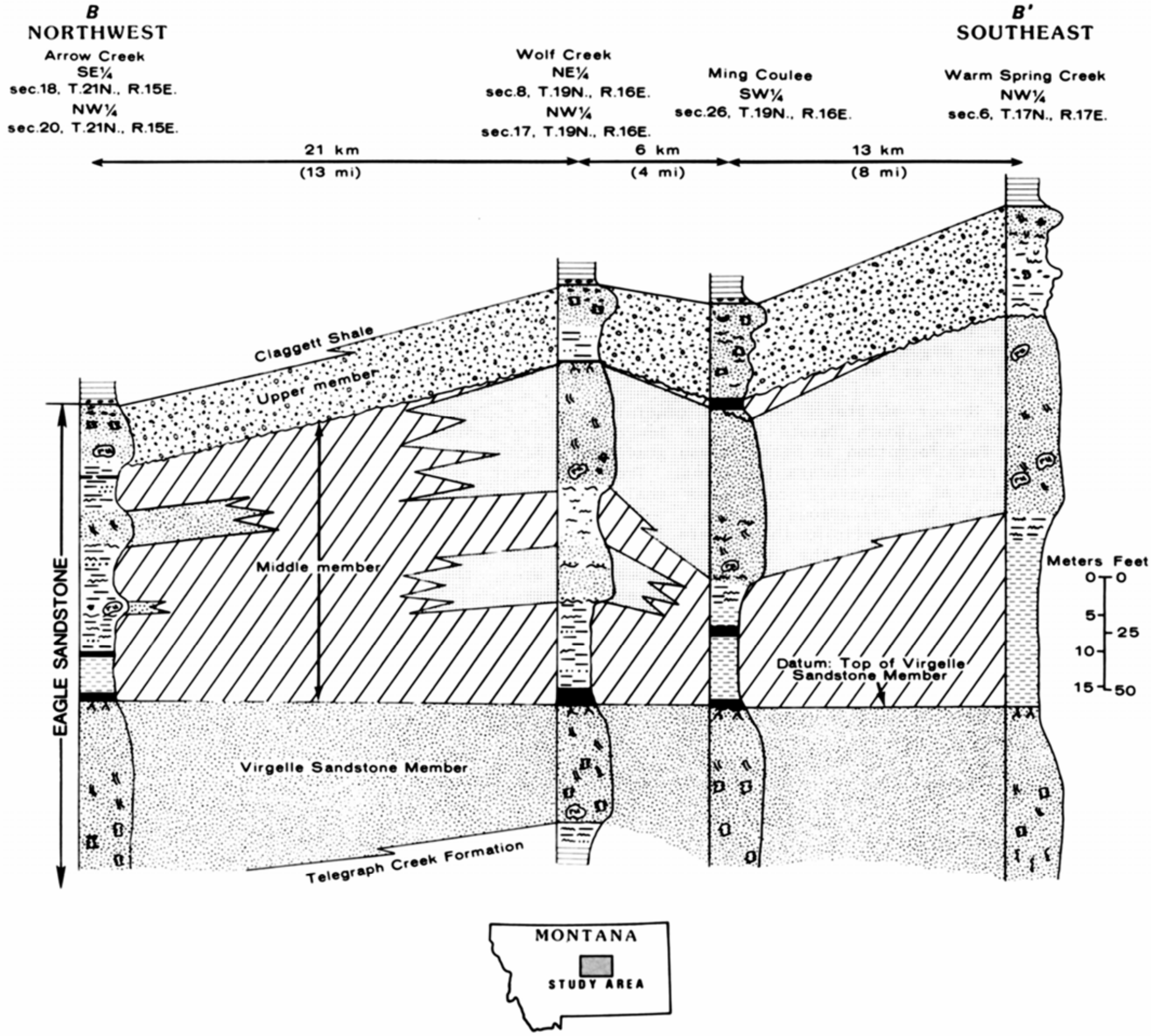

Figure 5. Section *B–B'* of the Eagle Sandstone, Bearpaw Mountains, north-central Montana.

Figure 11B. STOP 3 is the measured section at Warm Spring Creek. From Rice and Shurr (1983). Note: all these sections are from south of the Missouri River.