GEOLOGY AND PETROLEUM POTENTIAL
CENTRAL MONTANA PROVINCE

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INTRODUCTION

The central Montana province, as defined for oil and gas appraisal, incorporates Golden Valley, Musselshell, Treasure, Wheatland, and Yellowstone Counties, Rosebud County north of the Montana base line, and several townships in southeasternmost Meagher County; a total area of approximately 32,375 square kilometers (12,500 square miles). This report summarizes the geology relative to oil and gas production in the province. Oil has been produced primarily from the Tyler Formation of Early Pennsylvanian age, and additional discoveries from this formation is the principal hydrocarbon exploration play considered in this study. Paleozoic rocks older than Pennsylvanian have been only sparsely tested. The carbonate rocks in the older Paleozoic formations, especially the Mississsissippian Madison Limestone, may have potential for hydrocarbon discoveries. A minor amount of oil is produced from Mesozoic rocks in central Montana. Gas is produced primarily from Cretaceous rocks at a few places in the province; gas produced from the Pennsylvanian strata is negligible. Numerous studies provide information relative to the geology and its application to petroleum exploration in the central Montana province, and many publications that are not cited in the text are included in the selected bibliography of this report.

REGIONAL GEOLOGY

The central Montana province (fig. 1) lies athwart the central Montana trough (Peterson and Smith, 1986, fig. 2) and it is adjacent to the eastward extension of the Lewis and Clark lane into south-central Montana from the western part of the State (Maughan and Perry, 1986). Major structural features in the region are outlined in figure 2 and on plate 1. The uplifts and basins in central Montana are structural elements of a probable aulacogen related to either the east-southeast trending Lewis and Clark lane, or to the northeast-trending Greenhorn lineament (fig. 2). The central Montana trough has been the center of structural development that has included subsidence or uplift during several epeirogenic episodes in the Phanerozoic Eon . Structurally more stable parts of the western North American cratonic shelf, the Alberta shelf on the north and the Wyoming shelf on the south, lie adjacent to the trough. Subsidence is indicated by several lower Paleozoic stratigraphic units that are somewhat thicker along the central Montana trough than on adjacent parts of the shelf. Tectonic inversion of the central Montana trough is indicated by uplift during the Devonian Period along this same trend. Subsidence also occurred during the Carboniferous (Maughan, 1984), and uplift reoccurred during the Late Cretaceous and early Tertiary Laramide orogeny. Differential uplift within the Lewis and Clark lane and adjacent areas during the Laramide orogeny of Late Cretaceous and early Tertiary time commonly was along rejuvenated faults, but opposite the sense of late Paleozoic movements (Cooper, 1956). Major Laramide structures in the central Montana province and adjacent areas are chiefly basins and domes that are evident on the structure contour map of the Montana plains (Dobbin and Erdmann, 1955) and by the structural configuration of the top of the Madison Group (Feltis, 1981; 1984a,b,c; 1985a,b; and summarized on plate 1)..

STRATIGRAPHY

Paleozoic and Mesozoic rocks, important to the consideration of hydrocarbon accumulations, and younger rocks are named and locally correlated for central Montana in figure 3, and a generalized stratigraphic column is shown in figure 4. A brief summary of the nomenclature in the Big Snowy Mountains and regional relations of the stratigraphic units is given by Lindsey (1980), and the geology of the Crazy Mountains basin is the subject of

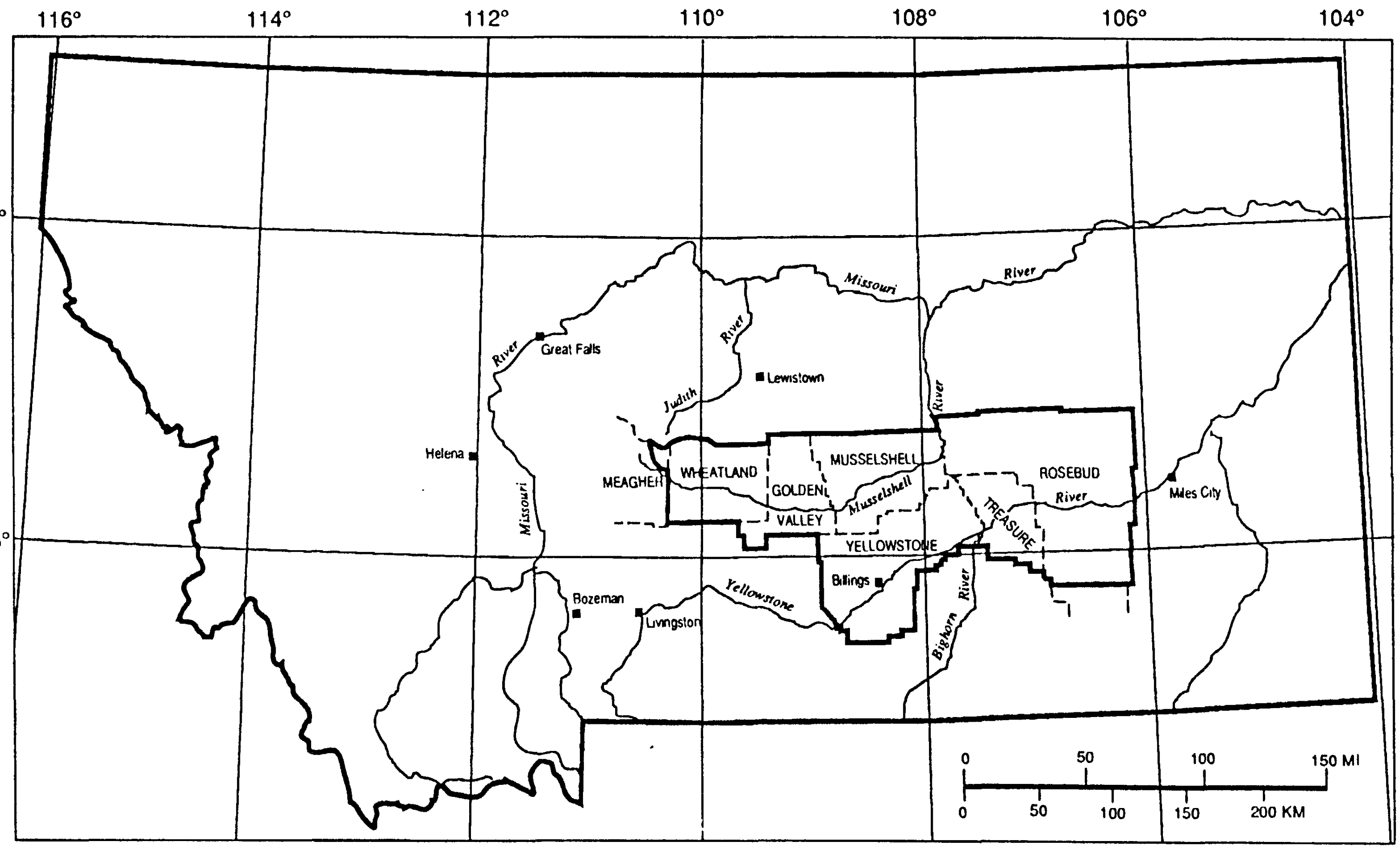


Figure 1.- Outline of central Montana province (heavy line) and counties included.

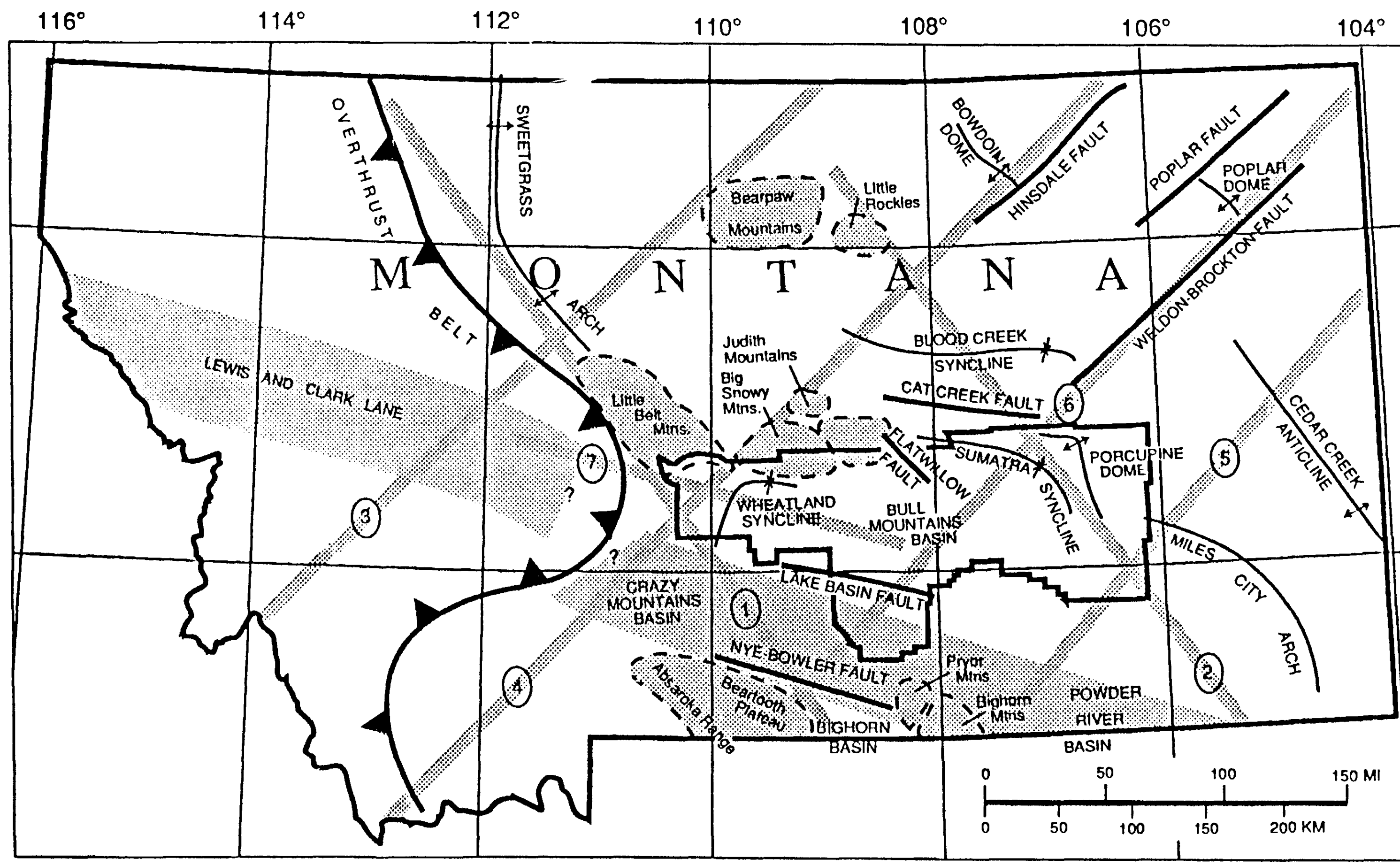


Figure 2- Principal structural features in central Montana and adjacent areas. Dotted line outlines the central Montana province. Major lineaments (from Maughan and Perry, 1986): 1,Bridger: 2, Chadron; 3, Great Falls, 4, Greenhorn; 5, Greybull; 6, Snake River-Yellowstone; 7, Wheatland; 8, Musselshell.

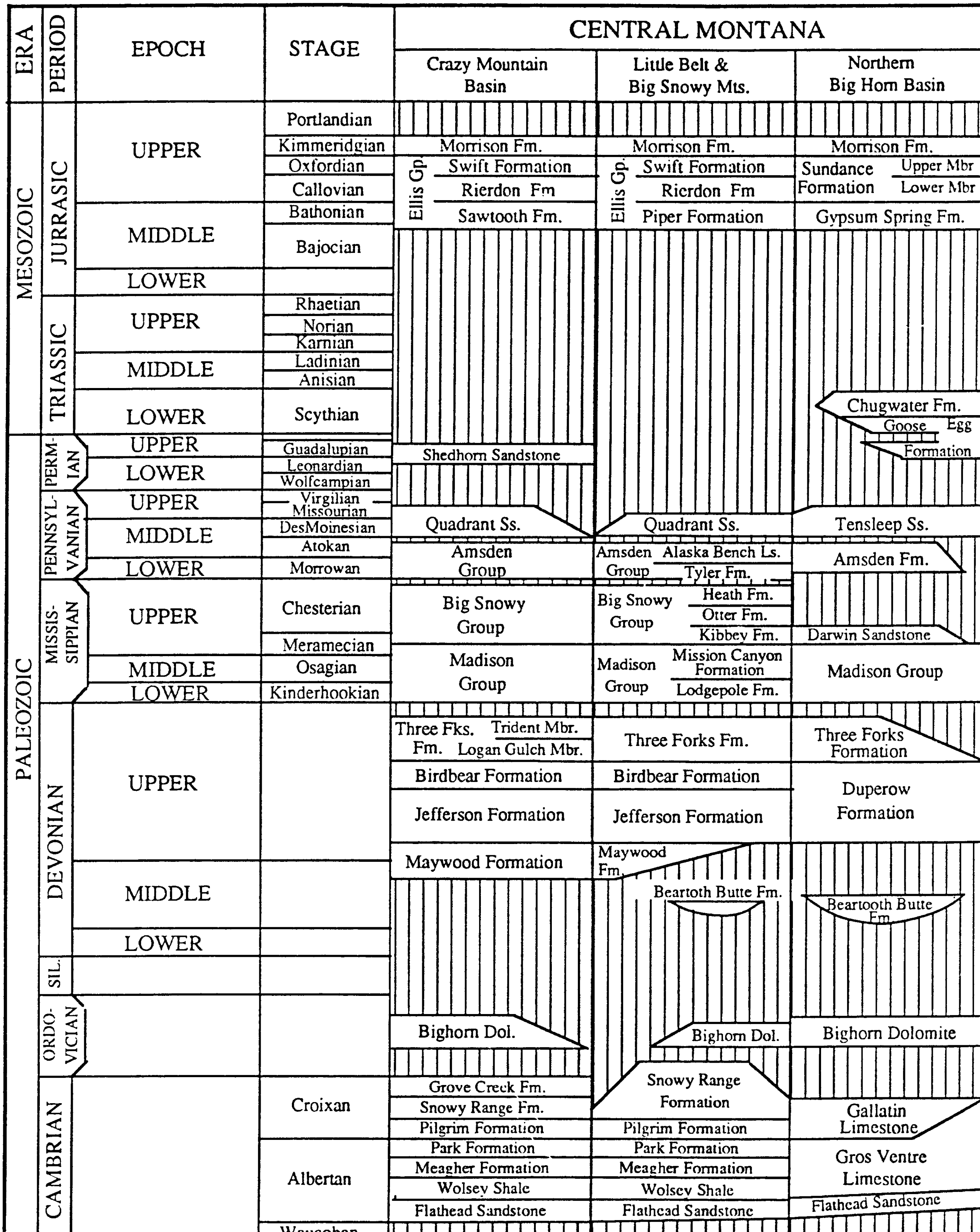
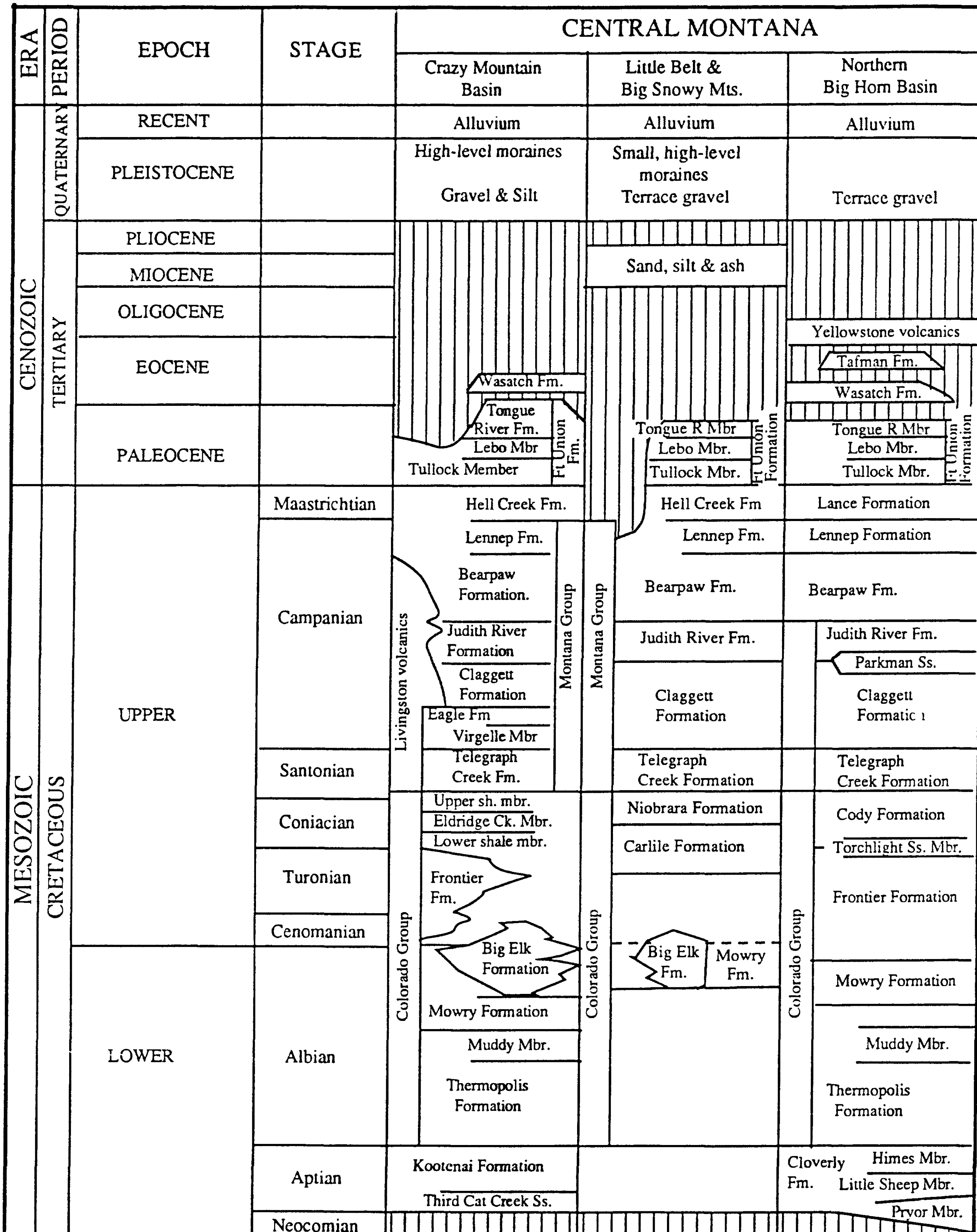


Figure 3.—Stratigraphic nomenclature in central Montana (modified from Balster, 1971; Ballard and others, 1983; Lindsey, 1980).



Figur‹ 3 (continued).

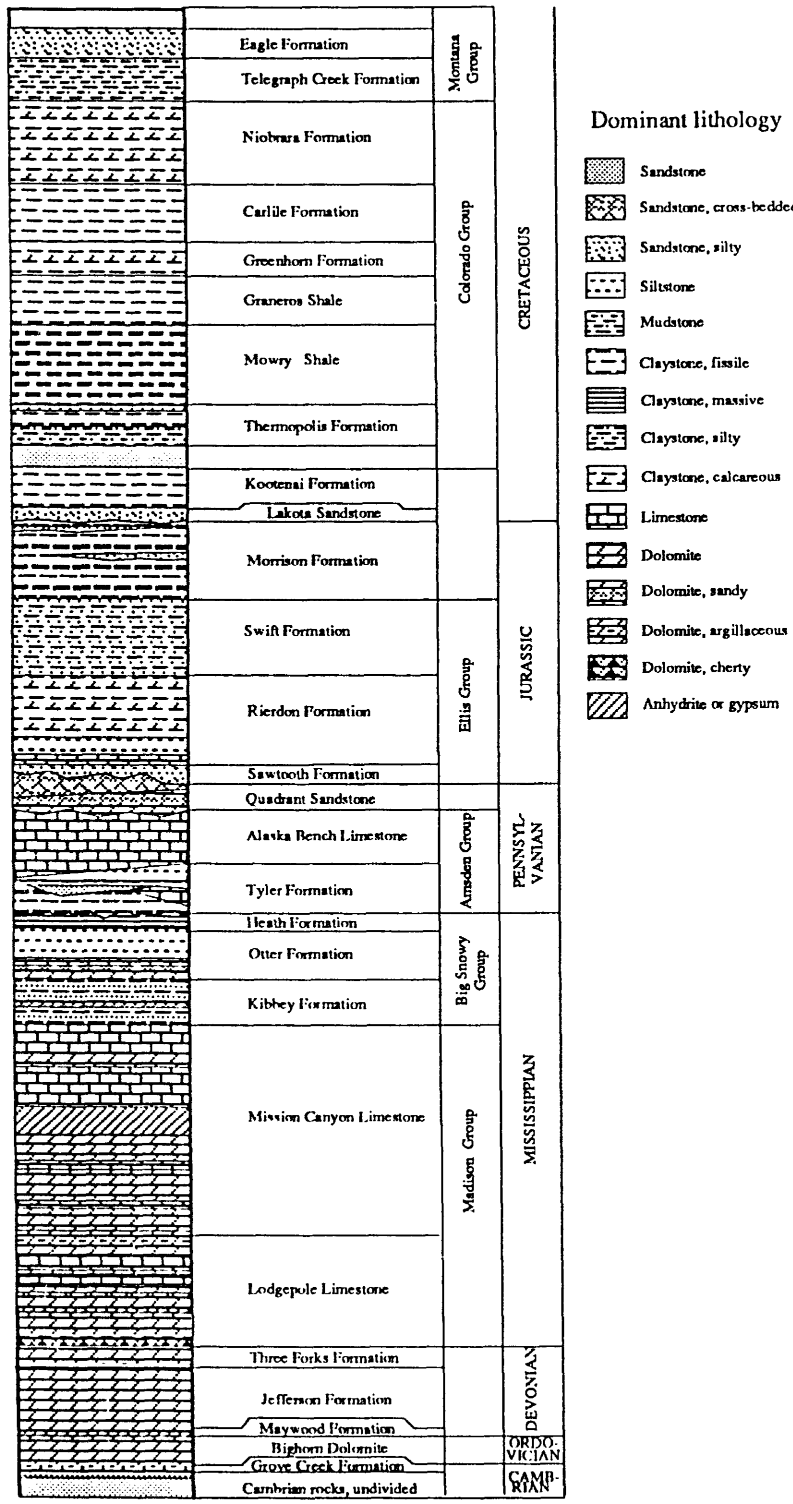


Figure 4.- Generalized stratigraphic column for central Montana adapted from several sources and using mostly eastern Montana names (Black Hills and Williston basin) for Cretaceous rocks.

geological guidebooks (Graves, 1957; Lynn and others, 1972). The stratigraphy and nomenclature in the subsurface in the eastern part of the province is commonly described in relation to the geological units of the Williston basin and of the Black Hills.

Lower Paleozoic rocks in central Montana are parts of broad, onlapping sequences of sandstone, mudstone, and limestone deposits. The Cambrian sediments were regionally deposited in an onlapping sequence onto the shelf from the west, the Ordovician sediments seem to have lapped onto the shelf from the south, and the Lower Devonian strata are part of an onlapping sequence from the northwest (D.L. Macke, personal commun., 1989). Details of the character of the lower Paleozoic rocks in central Montana are known primarily from the exposures on the flanks of the mountain ranges south of the province and secondarily from lithologic logs of borehole cuttings and cores. The lithologic data for the lower Paleozoic rocks within the province are quite sparse; only 66 holes have penetrated below the top of the Mississippian Madison Group, and of these only two boreholes have been drilled through the lower Paleozoic beds into Precambrian rocks.

A thick shelf carbonate sequence was deposited during slow, Mississippian epeirogenic subsidence focused along an axis coinciding approximately with the central Montana trough (Peterson and Smith, 1986). Late Mississippian to Early Pennsylvanian was a time of increased tectonic disturbance compared to earlier in the Mississippian, and the deposition of the Mississippian, dominantly carbonate rock, sequence was terminated with the abrupt, new development of the Big Snowy trough bounded on the southwest by the Lewis and Clark lane. Lower Pennsylvanian fluvial-deltaic and paralic sediments filled the Big Snowy trough, which was bounded on the south-southwest primarily by the Musselshell lineament that lies parallel with the Lewis and Clark lane (fig. 2). Deposition of these largely terrigenous clastic sediments was succeeded across the region by Middle Pennsylvanian intertidally deposited mudstone and shallow-water, epeiric marine limestone when lowlands adjacent to the trough were submerged by transgression of the Pennsylvanian sea. Subsequently, intertidal and supertidal sandy dolomite muds that were succeeded by coastal dune sediments were deposited above the marine beds as part of a widespread erg that engulfed the epeiric sea (Maughan, 1984). During Permian through Middle Jurassic time the region was elevated to a stable lowland, the Milk River uplift (figs. 11 and 12), where some of the older Paleozoic strata, notably the Pennsylvanian rocks to the north of the central Montana province were removed by erosion. The region slowly subsided episodically during Mesozoic time. Mesozoic sediments were deposited in the Western Interior seaway as marine waters transgressed and shallowly covered the region in Late Jurassic and again during the Cretaceous Period. About 5,000 to 6,000 feet of Mesozoic sediments accumulated in central Montana.

Cambrian.— Strata of Cambrian age are succinctly described in the Crazy Mountain basin (Hanson, 1957) where they comprise, in ascending order, the Flathead Sandstone, Wolsey Shale, Meagher Limestone, Park Shale, Pilgrim Limestone, and the Red Lion Formation. The Cambrian rocks are also described in the vicinity of the Big Snowy Mountains and identified with a somewhat different nomenclature by Lindsey (1980) who adapted nomenclature from south-central Montana into the northwestern part of the central Montana province. Cambrian rocks in the northern Big Horn Mountains are described by Richards (1955) and by Shaw (1954). Thickness of Cambrian rocks in the central Montana province in relation to Cambrian rocks of the entire State are shown by isopachs in figure 5.

Ordovician.— The Bighorn Dolomite comprises rocks of Late Ordovician age in the western part of the province. The Bighorn does not occur in the Little Belt and in the Big Snowy Mountains, but the formation thickens southeastward from a 0-edge in the subsurface immediately south of these mountainous uplifts. The thickness of the Bighorn in exposures along the front of the Beartooth Plateau is at least about 30 m (100 ft), and in the Pryor and Big Horn Mountains it is about 120 m (400 ft) (Richards, 1955, p. 13; Richards and Nieschmidt, 1957). A thin sandstone or sandy dolomite unit locally in the base of the Bighorn probably is equivalent to the Lander Sandstone Member (Richards and Nieschmidt, 1957). The Ordovician rocks (fig 6) are as much as 180 m (600 ft) thick in the eastern part of the province (Foster, 1972) where Williston basin nomenclature is generally used. In the east the Winnipeg Formation at the base of the Ordovician sequence comprises about 30 m (100 ft) of sandstone and carbonaceous mudstone that may comprise strata equivalent to the Lander. Above the Winnipeg are about 120 m (400 ft) of dolomite assigned to the Red River Formation, which is

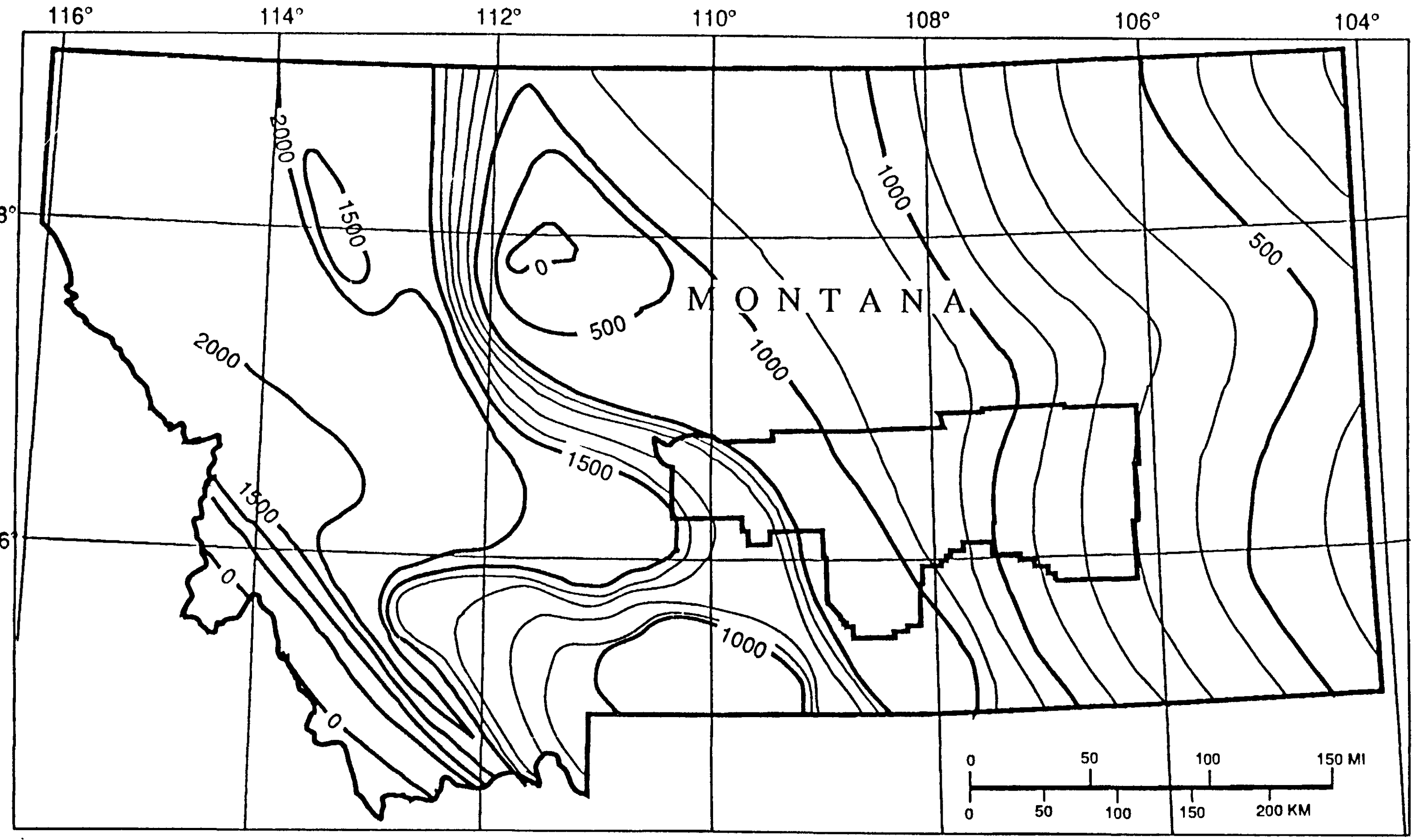


Figure 5.- Thickness of Cambrian rocks in Montana (Lochman-Balk, 1972). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

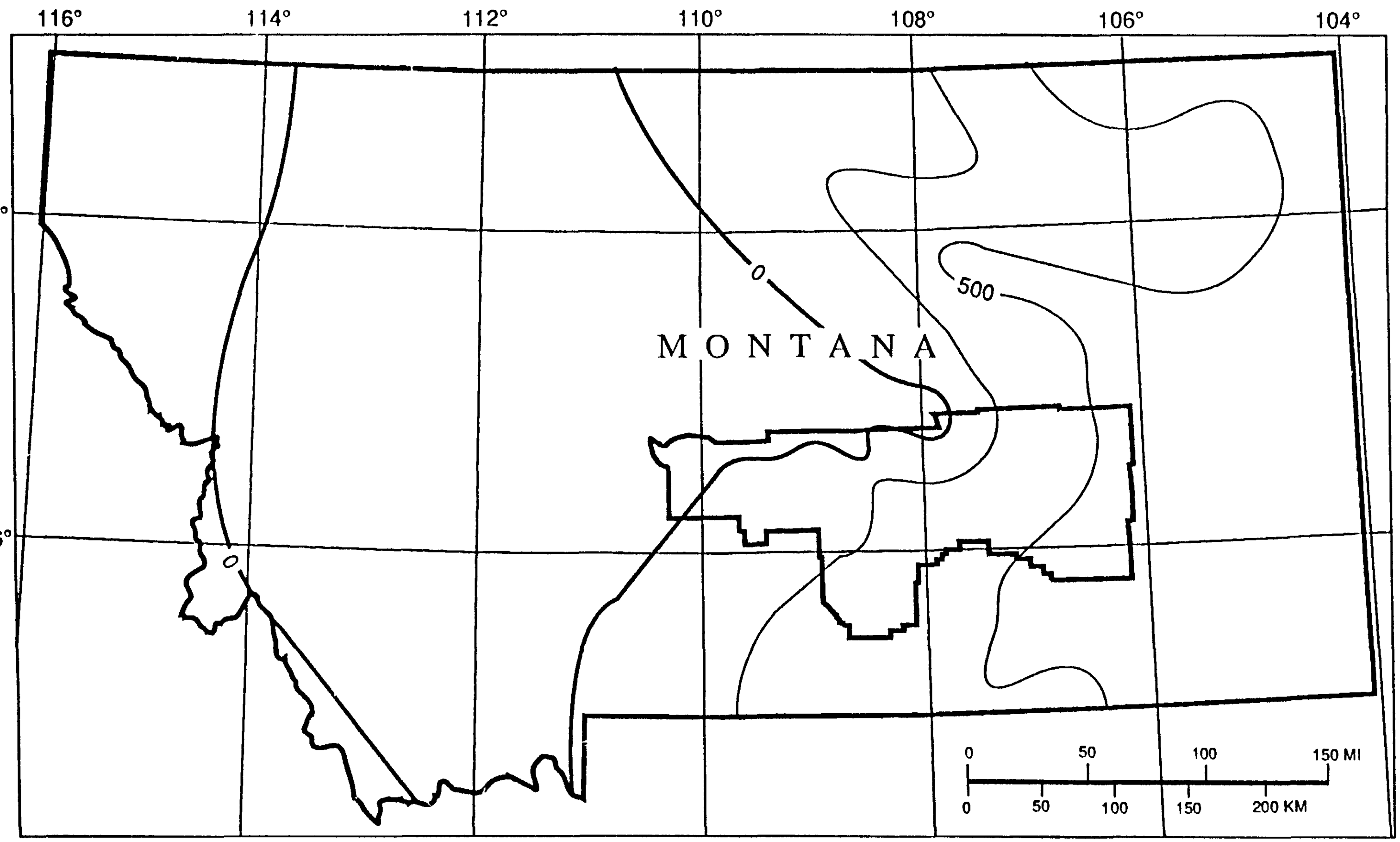


Figure 6.- Thickness of Ordovician rocks in Montana (Foster, 1972, p.79). Heavy line is outline of central Montana province. Isopach interval, 250 ft.

equivalent to the Bighorn. The Red River is overlain by about 35 m (120 ft) of argillaceous limestone and dolomite assigned to the Stony Mountain Formation, which is erosionally truncated to the west and there are no equivalent strata in the western part of the province.

Devonian.— Only Upper Devonian strata occur in central Montana, except for local remnants of the Lower Devonian Beartooth Butte Formation that occurs as channel-fill and karst-fill deposits in the region. The Maywood Formation, Jefferson Formation, and the Three Forks Formation comprise the bulk of the Upper Devonian strata in the central and western part of the province. Equivalent strata in the eastern part of the province are identified by names extended from the Williston basin (Sandberg and Mapel, 1967; Peterson, 1984, plate 5) and they comprise the Souris River Formation, the Duperow Formation, and the Birdbear Formation. The Sappington Member of the Three Forks Formation to the west, the Cottonwood Canyon Member of the Lodgepole Limestone in the Madison Group to the south, and the Bakken Formation to the north and east are equivalent rocks generally considered to be of Late Devonian and of Early Mississippian age (Sandberg and Mapel, 1967; Baars, 1972, p.99). Because the Bakken, Sappington, and Cottonwood Canyon unconformably overlie the Upper Devonian strata and represent the initial sediments of the overlying sequence of dominantly carbonate Mississippian strata, and because a partial Devonian age is questionable (Macke, in press), they are discussed below with the Mississippian sequence. Thickness of the Devonian sequence is shown by isopachs in figure 7.

Regionally, Middle Devonian and older Paleozoic rocks were partially eroded or entirely removed from several local highlands that had been elevated within and adjacent to the central Montana trough prior to the Late Devonian deposition (Peterson and Smith, 1986). Distribution of the Upper Devonian strata and their facies relationships indicate syntectonic deposition in central Montana. Consequently, the stratigraphic relationships are complex and are known only in a general way because of the paucity of both surface exposures and of borehole penetration into these strata.

Maywood, Jefferson, and Three Forks were deposited primarily by multiple transgressive and regressive marine cycles followed by an erosional interval. The lithologies of the Upper Devonian strata, in general, reflect their deposition as an intertonguing shallow marine sequence of dominantly siliciclastic sediments of terrigenous origin that grade laterally and upward into dominantly carbonate rocks and then grade back into dominantly siliciclastic sediments in the upper part of the sequence. Carbonaceous mudstone beds are common in the dominantly carbonate rocks of the Three Forks Formation.

Reservoir character of the Upper Devonian rocks is not well known. Because most of these strata include significant fine-grained siliciclastic components and dolomitic and anhydritic cements in large part, it may be assumed that porosity and permeability generally are low. The siliciclastic components are important lithologic elements proximal to the source terrains that were mostly in or near the western part of the province. Although sand is moderately abundant in some parts of the Upper Devonian sequence, finer grained clastics are more common, especially eastward in the province where these terrigenous clastic components decrease in grain size away from the sediment source terrains. Reservoir quality may be good where carbonate rocks predominate, but drill hole information from these rocks is very limited and an adequate assessment can only be generalized. Much of the carbonate component in the Devonian strata is primary or early diagenetically formed dolomite, which also suggests unfavorable reservoir fabric for these rocks. Possible secondary porosity in some carbonate rocks may result from weathering and alteration where there has been subaerial exposure during Late Devonian tectonic activity, and especially along the erosional unconformity beneath the Mississippian rocks.

Mississippian.— The Sappington Member of the Three Forks Formation to the west, the Cottonwood Canyon Member of the Madison Limestone to the south, and the Bakken Formation to the north and east, which are thin and not shown on the nomenclature chart (fig. 3), converge in the vicinity of the central Montana province. These strata are the initial mostly siliciclastic and organic carbon-rich deposits of the Early Mississippian marine transgression that are transitional into the thick shelf carbonate sediments of the Lodgepole Limestone in the Madison Group. The character of these rocks reflects the influx of terrigenous clastic sediments into a shallow intracratonic marine or possibly paralic basin during the initial stages of this transgression. A prolific biota in the shallow, marine to brackish water

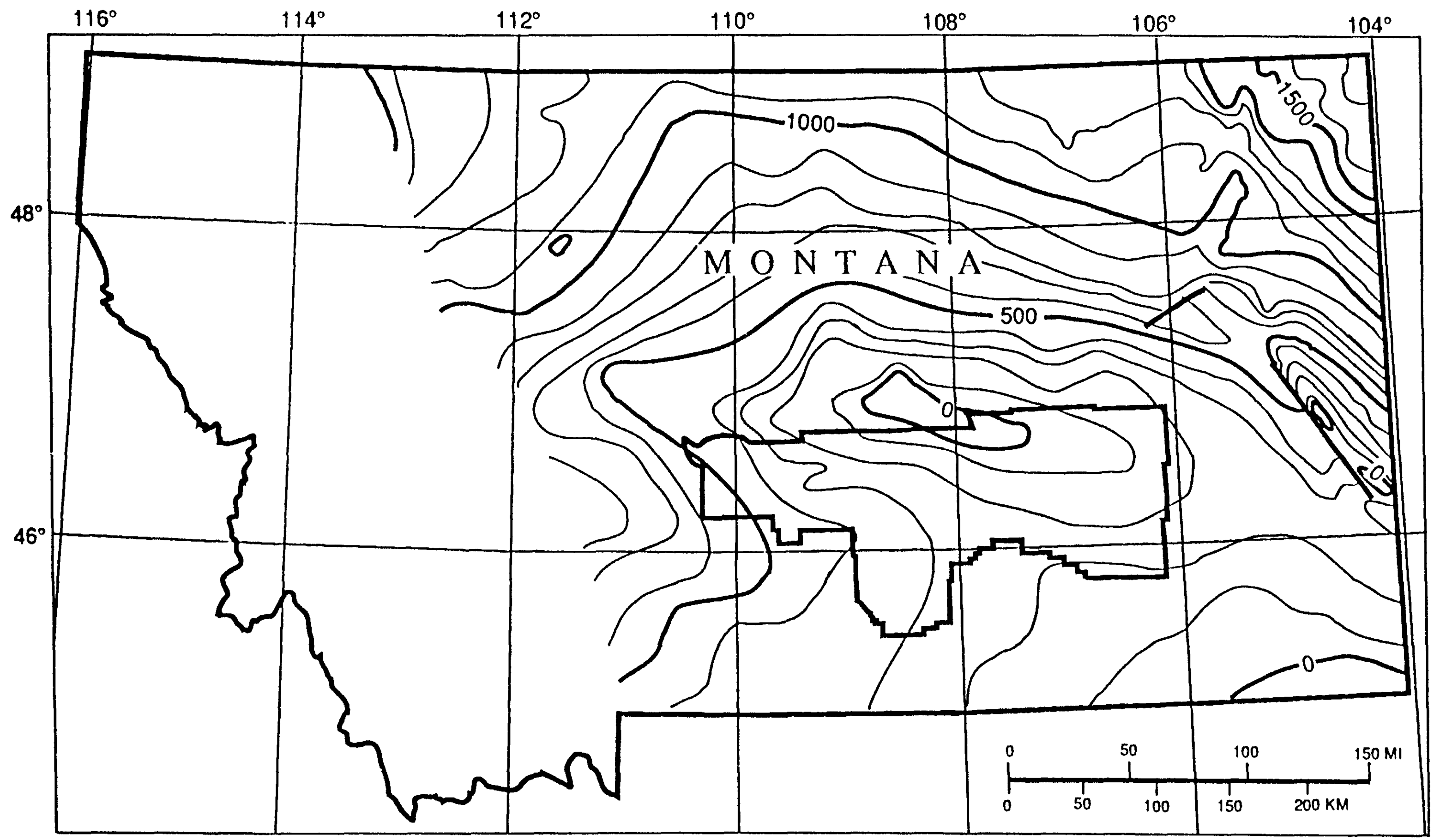


Figure 7.- Thickness of Upper Devonian rocks in Montana (Baars, 1972, p.94). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

sea contributed an abundance of organic matter and developed sapropels regionally in an euxinic depositional environment. These sapropelic mudstone beds intertongue into terrigenous clastic sediments that were distributed basinward from regional lowlands terrains and local uplifts that had been elevated by Late Devonian (Antler?) tectonism. Within the central Montana province the Bakken thins and grades from north to south across the province into the dominantly carbonate and siliciclastic rocks of the Cottonwood Canyon Member of the Lodgepole Limestone. Thickness of the Bakken and Cottonwood Canyon is shown in figure 8.

The Madison Group is divided into the underlying Lodgepole Limestone and the overlying Mission Canyon Limestone. Gypsum or anhydrite beds within the Mission Canyon are tongues of the thick evaporite deposits in the Charles Formation in the Williston basin. Uppermost Mississippian rocks comprise the Big Snowy Group composed of the Kibbey Formation, the Otter Formation, and the Heath Formation. Isopach lines in figure 9 show the thickness of the Mississippian rocks in the central Montana province and other parts of central and eastern Montana.

The Madison Group is almost entirely carbonate rock deposited upon the western North American continental shelf during a marine transgression and regression in Kinderhookian through early Meramecian time (Rose, 1976). The Big Snowy Group represents a similar sequence deposited during the middle Meramecian marine regression and the succeeding late Meramecian and Chesterian marine transgression (Vail and others, 1977). However, in contrast to the paralic sediments at the base of the Bakken-Madison sequence, the Kibbey Formation was deposited as a sabkha facies during the Meramecian marine regression. The carbonate shelf sediments of the Big Snowy sequence, the Lombard Limestone, which are cognate to the Madison carbonate rocks, were deposited farther to the west near the North American shelf margin during Chesterian marine transgression and regression. The Otter and the Heath Formations, which consist mostly of terrigenous sediments, were deposited by infilling of the epeiric sea in central Montana in a backreef, probable lagoonal to swamp environment during the Chesterian transgression.

The Kibbey Formation is mostly red mudstone and sandstone, but includes limestone, dolomite, and gypsum in a regionally extensive, although thin unit near the middle of the formation. Thin gypsum beds also occur locally in strata transitional between the underlying Mission Canyon Formation and the Kibbey. Sandstone, mostly in the upper part of the Kibbey, is generally poorly sorted, ranging from clay-size particles to coarse-grained sand, and it is commonly subarkosic with chert, feldspar, and ferromagnesian clasts. Deposition occurred regionally in a sabkha environment upon the carbonate rock platform of the Madison Limestone.

The Otter Formation comprises thin beds of argillaceous limestone and interbedded calcareous mudstone and claystone, and generally has an abundant marine fauna with many bryozoans and brachiopods. The Otter is characterized principally by its greenish color.

The Heath Formation is composed of thin beds of carbonaceous claystone and mudstone and dense, argillaceous and carbonaceous limestone and dolomite. A gypsum bed and some gypsiferous strata occur in exposures in the Little Snowy Mountains. Many of the carbonate rock and some of the mudstone strata are fossiliferous. Some fossil coquinas occur. The fauna includes mostly brachiopods, pelecypods, and gastropods and indicate deposition in a lagoon that ranged from brackish water through normal marine and into hypersaline. Deposition of the Heath is indicated to have occurred during a period of tectonic stability in central Montana. Deposition seems to have been terminated by tectonism and the variability in the thickness of this formation owing to differential erosion in the vicinity of the Big Snowy and the Little Snowy Mountains is shown in plate 2. Similar differences in thickness exist where the Heath occurs in subsurface elsewhere in the province.

Pennsylvanian.— The Amsden Group and the Devils Pocket Formation comprise the Pennsylvanian rocks in the Big Snowy trough (fig. 10) in central Montana (Maughan and Roberts, 1967). The Amsden is divided into the underlying dominantly fluvially deposited rocks of the Tyler Formation and into the overlying dominantly marine rocks of the Alaska Bench Limestone. The Tyler is unconformable above Upper Mississippian formations of the Big Snowy Group, and the Alaska Bench is unconformable beneath the Devils Pocket Formation. The Devils Pocket is erosionally bevelled beneath Jurassic rocks.

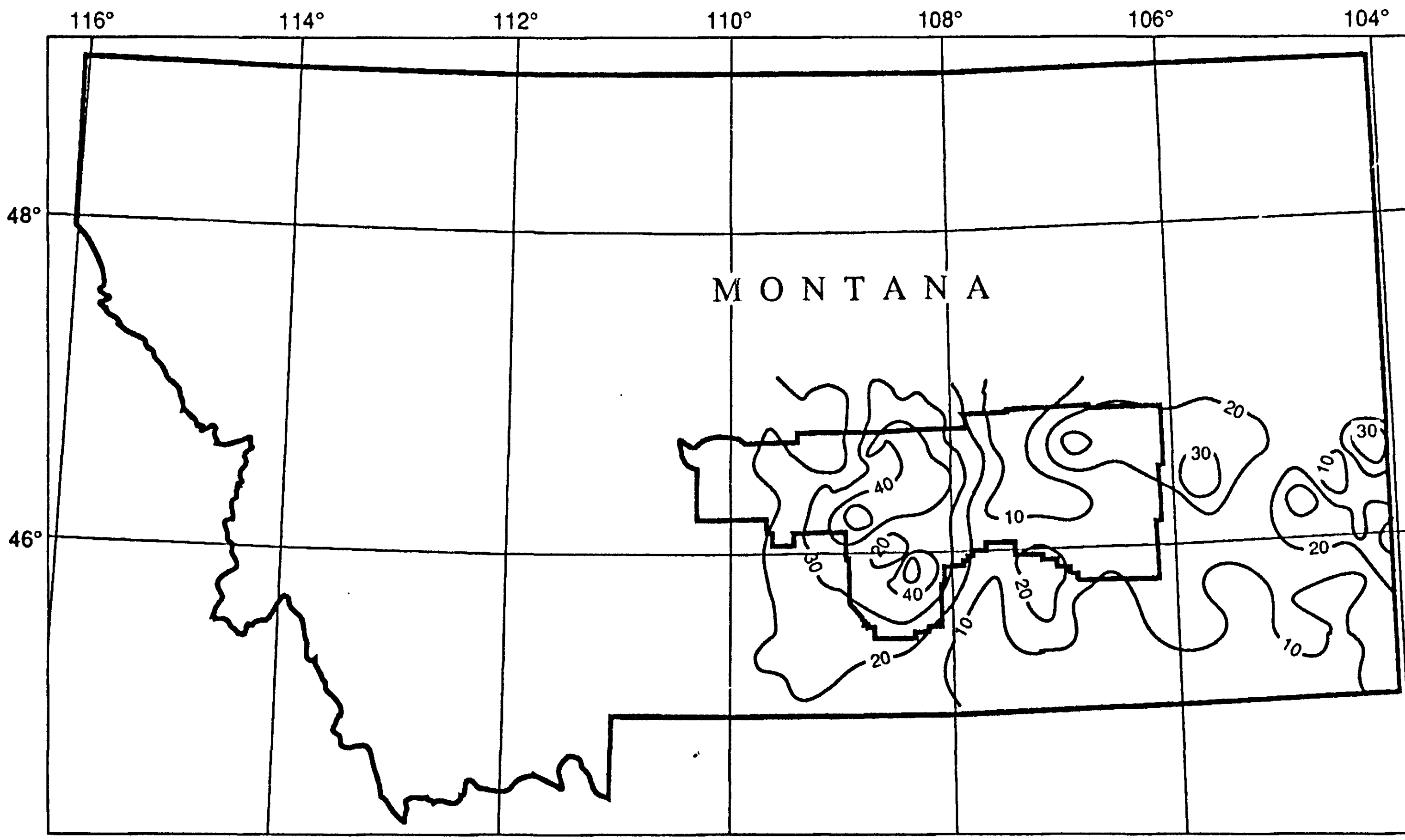


Figure 8.—Isopach map of Bakken Formation and Cottonwood Canyon Member of Lodgepole Limestone in southeastern Montana (written commun. D.A. Macke, 1989). Heavy line is outline of central Montana province. Isopach interval, 10 ft.

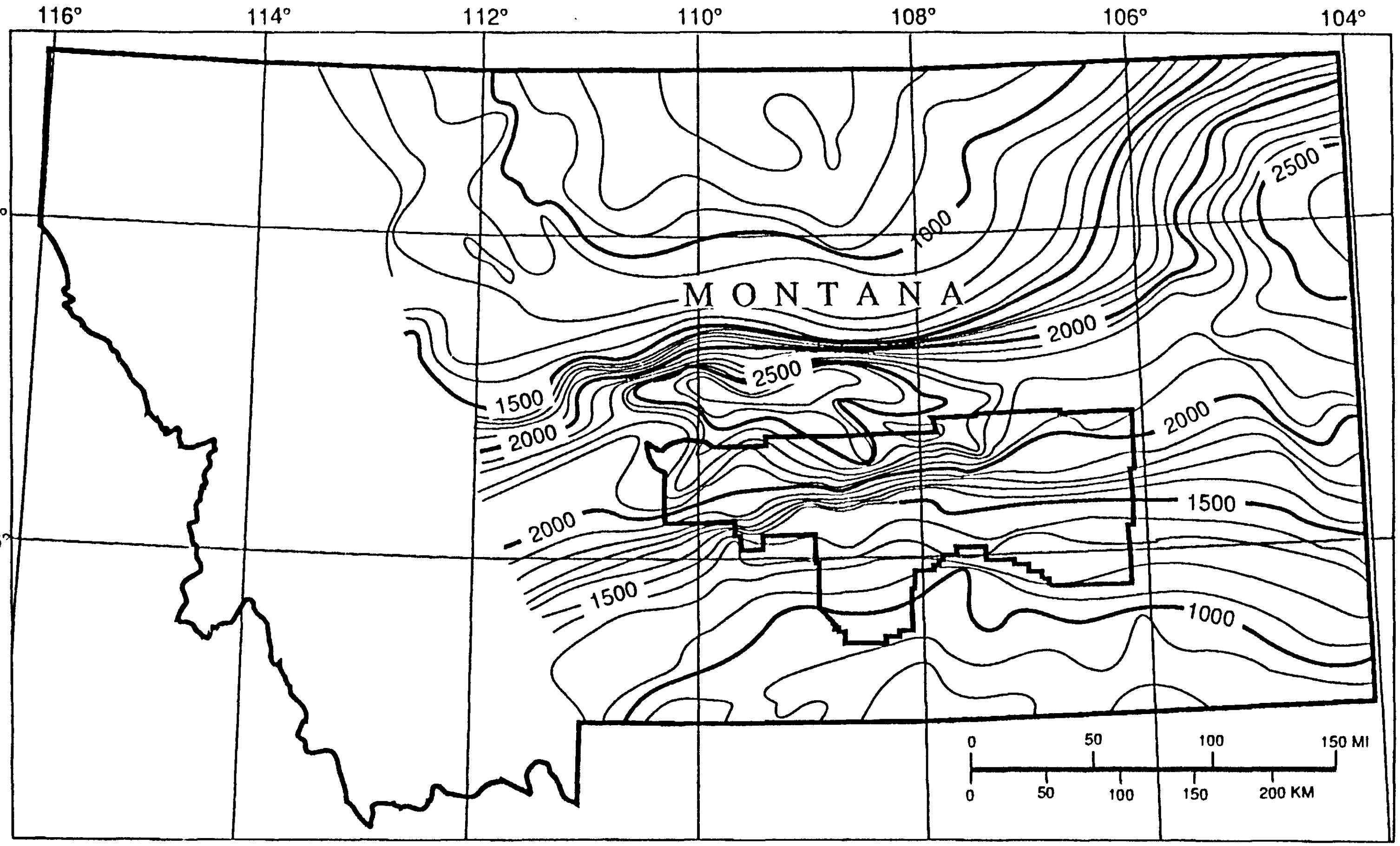


Figure 9.—Thickness of Mississippian rocks in Montana (Craig and others, 1972). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

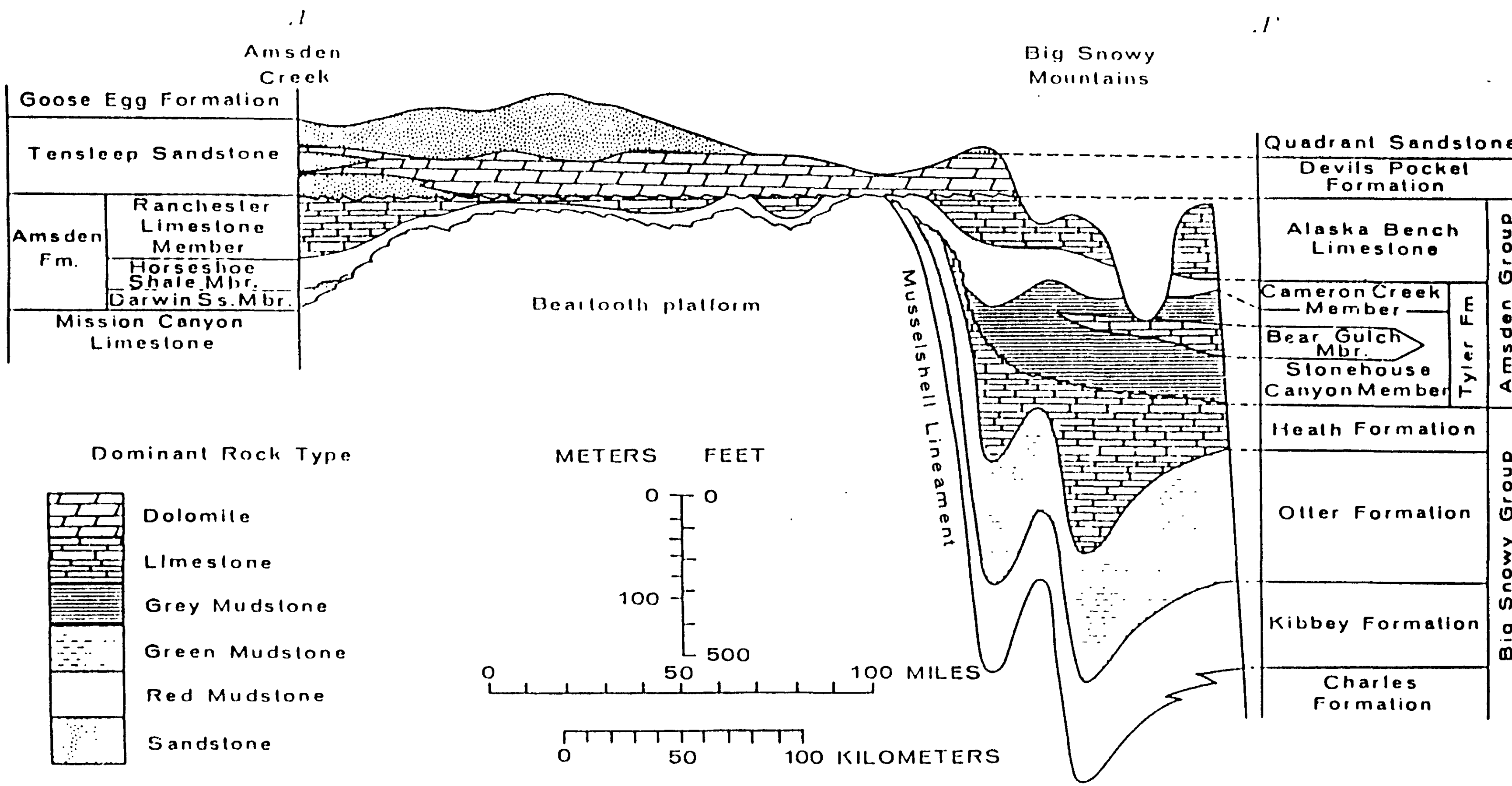


Figure 10- Cross section of Big Snowy Group (Mississippian) and Amsden Group (Pennsylvanian) from northern Bighorn Mountains (A) to central Montana (A'). (Adapted from Maughan and Roberts, 1967, and Maughan, 1984).

South of the Musselshell lineament, which marked the southern boundary of the Big Snowy trough, the Amsden Formation was deposited on the elevated terrain of the Wyoming shelf. These shelf deposits unconformably overlie Mississippian rocks and consist of redbeds of the Horseshoe Member overlain by thin-bedded limestone of the Ranchester Member of the Amsden. The Darwin Sandstone, which grades laterally into the Kibby Formation and is equivalent to the lower part of the Big Snowy Group (Maughan and Roberts, 1967; Maughan, 1979), is excluded as a member of the Amsden Formation in this report because it is of probable Late Meramecian age and because it unconformably underlies the Horseshoe Member with significant hiatus that represents all or most of the Chesterian Stage. The Amsden Formation (with the exception of the Darwin Sandstone Member) on the Beartooth platform (fig. 2, 10) to the south of the trough incorporates redbeds equivalent to the upper part of the Tyler and limestone equivalent to the Alaska Bench (Maughan and Roberts, 1967). The Amsden is unconformably overlain by the Tensleep Sandstone, and the Tensleep is unconformable beneath Jurassic rocks in the northern part of the Beartooth platform and beneath Permian rocks in the southernmost part of the province. The lower part of the Tensleep includes a lower member of thin-bedded sandy dolomite, greenish-grey mudstone, and sandstone that is equivalent to the Devils Pocket Formation (Maughan, 1979, p. U32) and an upper member of dominantly eolianitic sandstone beds that is thicker to the south. The facies and stratigraphic relations of the Devils Pocket and the Tensleep are similar to stratigraphic relations in southwestern Montana where the Devils Pocket intertongues and is included as a lower member below eolianites in the Quadrant Sandstone (Saperstone, 1986; Maughan, 1979, fig. 12).

Thickness of the Pennsylvanian rocks in the region is shown in figure 11. The thickness of the Amsden Group and Amsden Formation varies considerably because the Tyler Formation and equivalents are thickened where these dominantly siliciclastic sediments accumulated in structural sags, and the Alaska Bench and equivalent carbonate rock strata, conversely, are thinned where they have been erosionally bevelled across post-depositional structural ridges prior to deposition of the younger, Middle Pennsylvanian strata in the Devils Pocket.

The Tyler Formation comprises strata that are transitional from fluvial channel sediments and floodplain deposits in the lower part, through deltaic facies, lagoonal, shoreface and delta-front sands into intertidally deposited muds in the upper part (Maughan, 1984). The fluvial and deltaic rocks of the Tyler comprise the lower part of the Stonehouse Canyon Member; the lagoonal facies, composed of a tongue of platy limestone, comprises the Bear Gulch Member; and siliciclastic sediments deposited in intertidal and shallow littoral marine environments comprise the upper part of the Stonehouse Canyon and the overlying Cameron Creek Member. Details of the character of the sandstone deposits in the Tyler Formation are described by Stanton and Silverman (1989). The generalized relationship of these strata to underlying Mississippian rocks and overlying Pennsylvanian strata are shown in figure 10.

Deposition of the Tyler Formation occurred during marine transgression into the tectonically formed Big Snowy trough. Initially during the Early Pennsylvanian, the source terrains for the terrigenous sediments deposited in the Tyler were distant cratonic hinterlands, notably the transcontinental arch, and nearby low-lying uplands adjacent to the trough. Some of the siliciclastic material in the Tyler was derived from the Beartooth platform and transported northward into the trough. The influx of these sediments decreased, however, when the trough was fully inundated by the sea and adjacent shelf source terrains were submerged. When the provenances of the terrigenous sediments became more distant, the prograding fluvial and deltaic sedimentation gave way to shore, paralic lake, lagoonal, and littoral depositional environments. The mostly carbon-rich, argillaceous limestone of the Bear Gulch Member of the Tyler Formation occurs chiefly in the northern part of the province and seems to represent prodelta sediments. Terra rosa on the Madison carbonate rock terrain, which had been subaerially exposed on the Wyoming shelf during the Early Pennsylvanian, was incorporated into the intertidally reworked redbeds of the Horseshoe. The redbeds of the Cameron Creek Member of the Tyler were deposited where the terra rosa residuals were swept into the shallow marine embayment along the Big Snowy trough. The Alaska Bench and the Ranchester Member were subsequently deposited in a shallow, epeiric sea when most of the western North American continental shelf had been engulfed by the marine transgression and all but distant source terrains for terrigenous sediments had been submerged.

Amsden sedimentation ended with regional mid-Pennsylvanian epeiric tectonism that differentially elevated and depressed the terrains across the Wyoming shelf and in the Big Snowy trough. Thickness of the of the Alaska Bench and Ranchester varies throughout the region owing to differences between preservation of the sediments in depressed areas and their erosion from uplifted areas. The Amsden limestone beds, and in some places the entire Amsden , are locally absent because of planation that had occurred prior to the deposition of overlying Devils Pocket.

The mid-Pennsylvanian tectonism initiated southward progression of a large erg that comprises the Quadrant Formation. This erg is believed to have originated by the erosion of sandstone bodies elevated in the Cordilleran mobile belt to the northwest (Maughan, 1975). The Devils Pocket Formation, previously considered to be a part of the Amsden sequence (Maughan and Roberts, 1967), lies above a regional unconformity above the Amsden, and is correlated southward into the lower, dolomitic member of the Tensleep Sandstone in the western part of the Powder River Basin, the Big Horn Basin, and elsewhere in south-central Montana and in northwestern Wyoming (Maughan, *in* Lageson and others, 1979). Similar sandy and dolomitic strata form the lower part of the Quadrant Sandstone in southwestern (Saperstone, 1986; Saperstone and Ethridge, 1984).

The Devils Pocket Member comprises thin, planar beds of varying proportions of mixed dolomite and sand that was deposited subtidally and intertidally when sand was blown across the region into the shallow, epeiric sea. Thin beds of green mudstone, which are probable interdune or paralic lake or playa deposits, are interbedded with the sandy dolomite and dolomitic sandstone strata. The thin-bedded dolostone in the Devils Pocket superficially resemble the thin-bedded limestone in the Alaska Bench, which has led to its previous identification as part of the Amsden in central Montana and in northwestern Wyoming. Similar strata to the dolomitic beds in the Devils Pocket occur in equivalent rocks of the middle member of the Minnelusa Formation in the Williston basin to the east and in the eastern part of the Powder River Basin to the southeast.

The Devils Pocket is increasingly sandy upward and it grades into thick, cross-bedded eolianite beds that comprise the upper member of the Tensleep and of the Quadrant. Southeast progression of the erg brought increasingly large amounts of sand into the central Montana region and across much of the Wyoming shelf to the south. The epeiric sea and the characteristic dolomitic strata deposited in it was replaced by a vast field of eolian dunes that comprise the upper member of the Tensleep Sandstone and of the Quadrant Sandstone. Similar dune deposits probably formed across all of the central Montana province, but they are absent in the northwestern part of the province where the Pennsylvanian rocks have been erosionally bevelled from the Milk River uplift (Maughan, 1975). Exposures of the Quadrant on the south flank of the Big Snowy Mountains consist of only the lower part of this sequence with minor eolianite beds in the Devils Pocket Member. Dunes diminish eastward in the province. Dolomitic beds occupy an increasingly higher stratigraphic position in the Middle Pennsylvanian sequence distal to the area of deposition of the massive dune sands in the main body of the erg (Maughan, 1975) and the equivalent strata to the east are included in the middle member of the Minnelusa Formation.

The sandstone beds in the Tyler Formation, and the eolianites in the Quadrant Sandstone have locally open fabric and are good reservoir rocks. The dolomitic beds of the Devils Pocket also may have good reservoir porosity and permeability locally as evidenced by hydrocarbon production from these strata on the Cat Creek anticline in Petroleum County (pl. 2) where they underlie Jurassic rocks. The dolomitic beds were subjected to subaerial weathering and the porosity enhanced along this structure during some of the long hiatus prior to their burial beneath Upper Jurassic sediments. Some tectonic fracturing associated with the development of the Cat Creek structure may have enhanced the reservoir capability, also. Similar weather solution and fracture porosity of dolomite may occur on structures elsewhere, especially along the Cat Creek lineament, where it extends east-southeast from Cat Creek into the Porcupine dome in the northeastern part of the central Montana province.

Permian and Triassic.— Redbeds and evaporite deposits that include dolomite and gypsum or anhydrite of Permian and Triassic age extend only insignificantly into the southernmost part of the central Montana province (figs. 12 and 13) and are not described in this report. The province was elevated as part of the Milk River uplift in Early Permian time and may have been covered, at least partially, by later Permian and Triassic sediments that lapped onto the

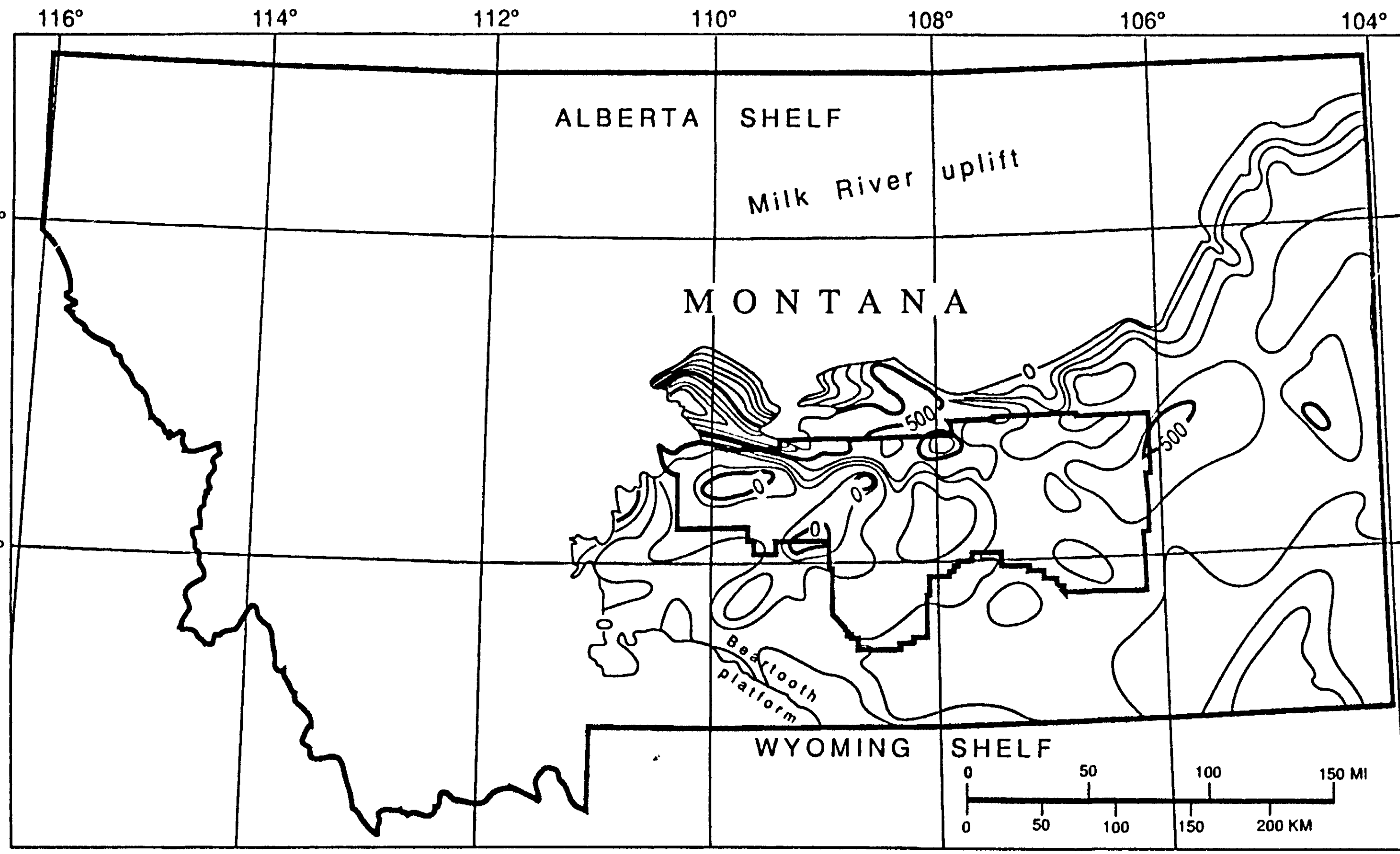


Figure 11.- Thickness of Pennsylvanian rocks in Montana (Maughan, 1975). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

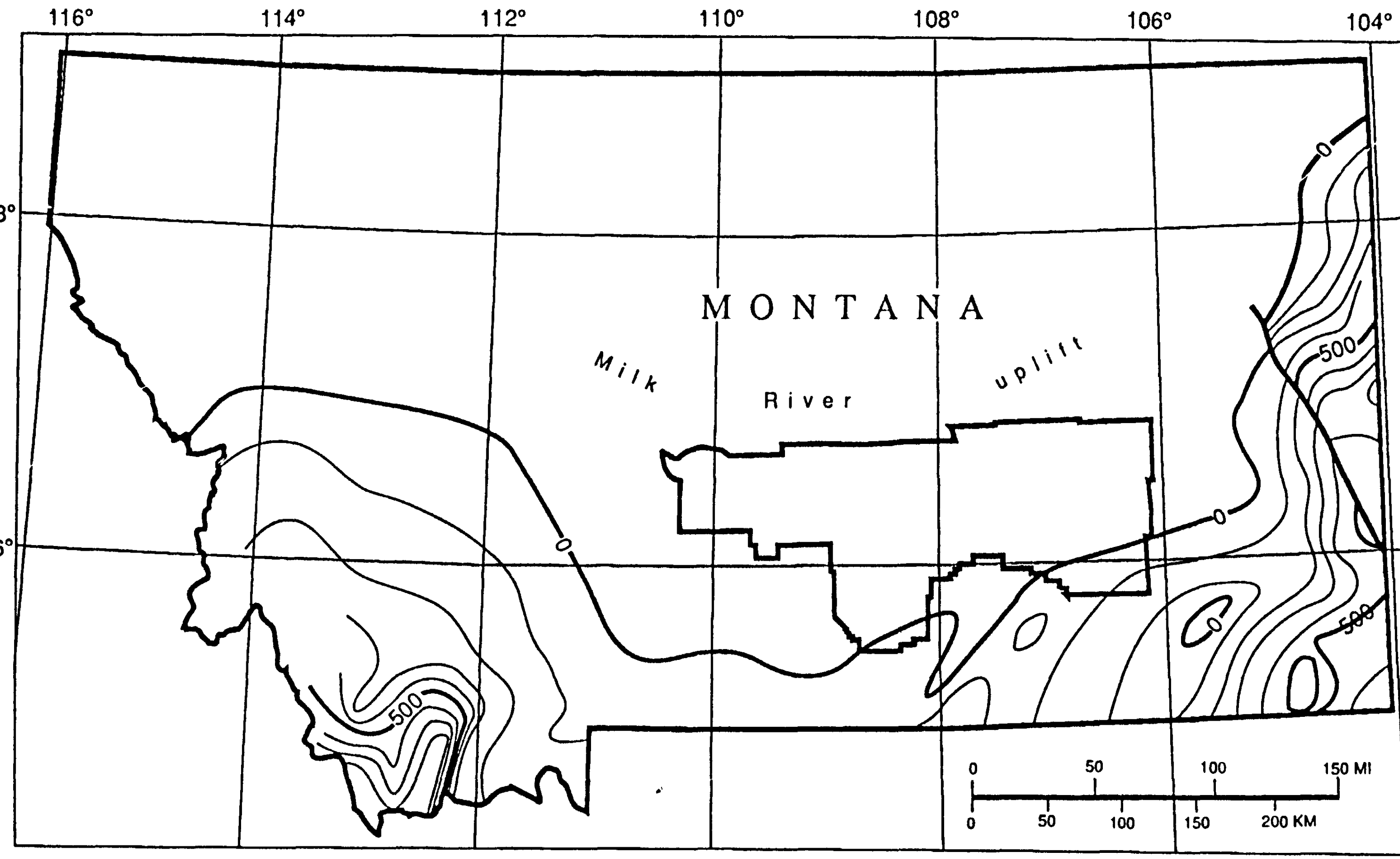


Figure 12.- Thickness of Permian rocks in Montana (Maughan, 1967). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

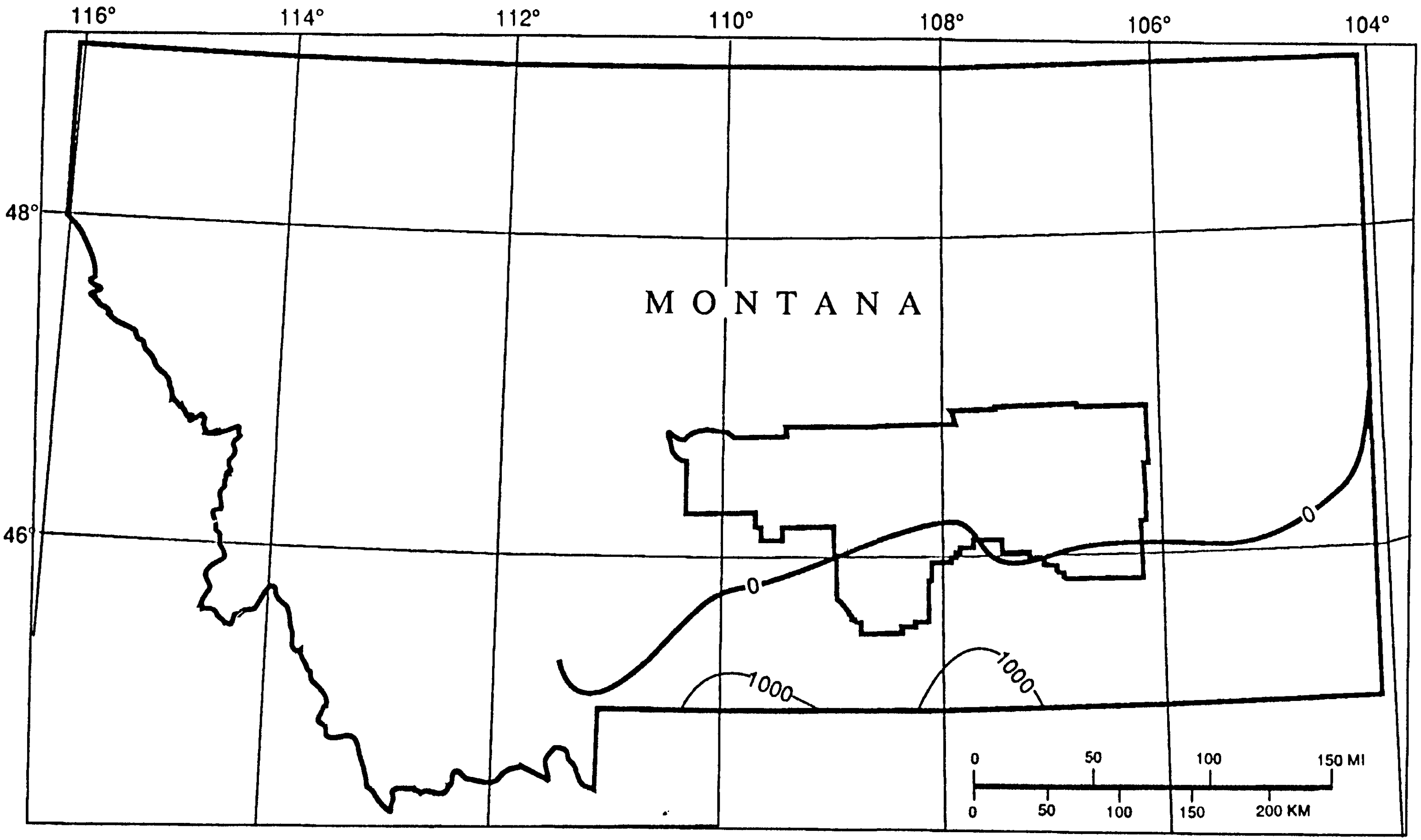


Figure 13.- Thickness of Triassic rocks in Montana (McKee and others, 1959, pl. 5, modified by Maughan from unpublished data). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

uplift. However, regional erosion that had bevelled the Pennsylvanian and Mississippian strata on the Milk River uplift prior to the deposition of Middle and Upper Jurassic strata also removed any of these strata that may have been deposited in central Montana.

Jurassic.— The Sawtooth Sandstone, the Rierdon Formation, and the Swift Sandstone are marine rocks that comprise the Ellis Group of Middle and Upper Jurassic age in western and west-central Montana. Red mudstone, siltstone, sandstone, and gypsum beneath these marine Jurassic rocks, the Saude Formation of Zieglar (1955), lies unconformably upon northward bevelled strata of the underlying Permian and Triassic Spearfish Formation in southeastern Montana. These strata thin westward toward central Montana where they pinch out in the vicinity of the northeastern corner of the province. The Saude probably is of Jurassic age, although these strata have commonly been identified as part of the Spearfish Formation (Goldsmith, 1959, p. 4). The Saude thickens eastward in the Williston basin where it overlies successively older strata farther east and north and seems to represent continental and marginal marine sediments deposited along the coastal plain in advance of the Jurassic marine transgression. Marine Jurassic rocks in the Williston basin comprise the Nesson, Piper, Rierdon, and Swift Formations. Nonmarine sediments of the Upper Jurassic Morrison Formation lie above the marine Jurassic sequence throughout the region. Thickness of the Jurassic rocks is shown in figure 14.

The Ellis Group lies unconformably upon older rocks ranging from Mississippian immediately north of the north boundary of the central Montana province to Permian and possibly Triassic in the southernmost sectors of the province. Westward in the province the Ellis Group laps onto the eastern flank of the Belt island (Cobban, 1945), a lowland that lay farther west in central Montana (fig. 14). The Sawtooth and the Rierdon thin depositionally and were erosionally bevelled on the flanks of Belt island (Imlay and others, 1948) and locally where they overlie lesser structurally positive features. The Swift Sandstone uncertainly may have been deposited across the higher reaches of Belt island. The group is overlain by the nonmarine Morrison Formation of Late Jurassic age.

The Jurassic rocks were deposited during several regional marine transgressive-regressive events and sedimentation was influenced by local subsidence and uplift of the western continental shelf. In general, the provenance of siliciclastic sediments was elevated terrains farther west in the Cordilleran orogenic belt. Belt island was also a source of terrigenous sediments, especially during regressive marine phases. The terrigenous sediments were transported eastward from the western elevated terrains into the epeiric Sundance sea in eastern Montana where evaporite and carbonate sediments are dominant. Sand and mud from western sources intertongue in central Montana with the allochemical sediments and mud deposits that dominate in the east.

The Nesson and the Piper Formations are composed of onlapping redbeds and evaporites that were deposited marginally to the shore during the early incursion of the Sundance sea. Several widespread, thin limestone beds suggest sea level oscillations and times of marine water deposition during Middle Jurassic time (Peterson, 1972). Sea level oscillations are indicated also in the central Montana province where sandstone typical of the Sawtooth intertongue with limestone and related rocks of the Piper facies where the strata thin and lap onto the flank of Belt island.

The Rierdon Formation consists chiefly of limestone and green and greenish grey mudstone. Some medium and dark grey mudstone occurs within the Rierdon, especially in the eastern part of the province. Deposition occurred during regional expansion and deepening of the Sundance sea and sand from the western source terrains was mostly trapped in nearshore areas to the west of the central Montana province. The Rierdon depositionally thins westward on the flanks of Belt island in the western part of the central Montana province, and it was erosionally removed from the crest of this lowland in the northwesternmost parts of the province prior to deposition of the overlying Swift Sandstone. Rejuvenation of the Belt island uplift, which probably was periodic, is indicated by thinning of the Rierdon and the subsequently formed erosional surface. In the eastern part of the province the contact of the Rierdon into the Swift is transitional (Peterson, 1957; 1972).

The Swift Sandstone was deposited in the margins of the epeiric sea, and it too tongues eastward into shallow-water marine carbonate and evaporite deposits. However, sand from the western provenance in the Cordilleran belt dominated the sedimentation farther to the east than it did in the earlier Sundance sea, and the generation and influx of carbonate

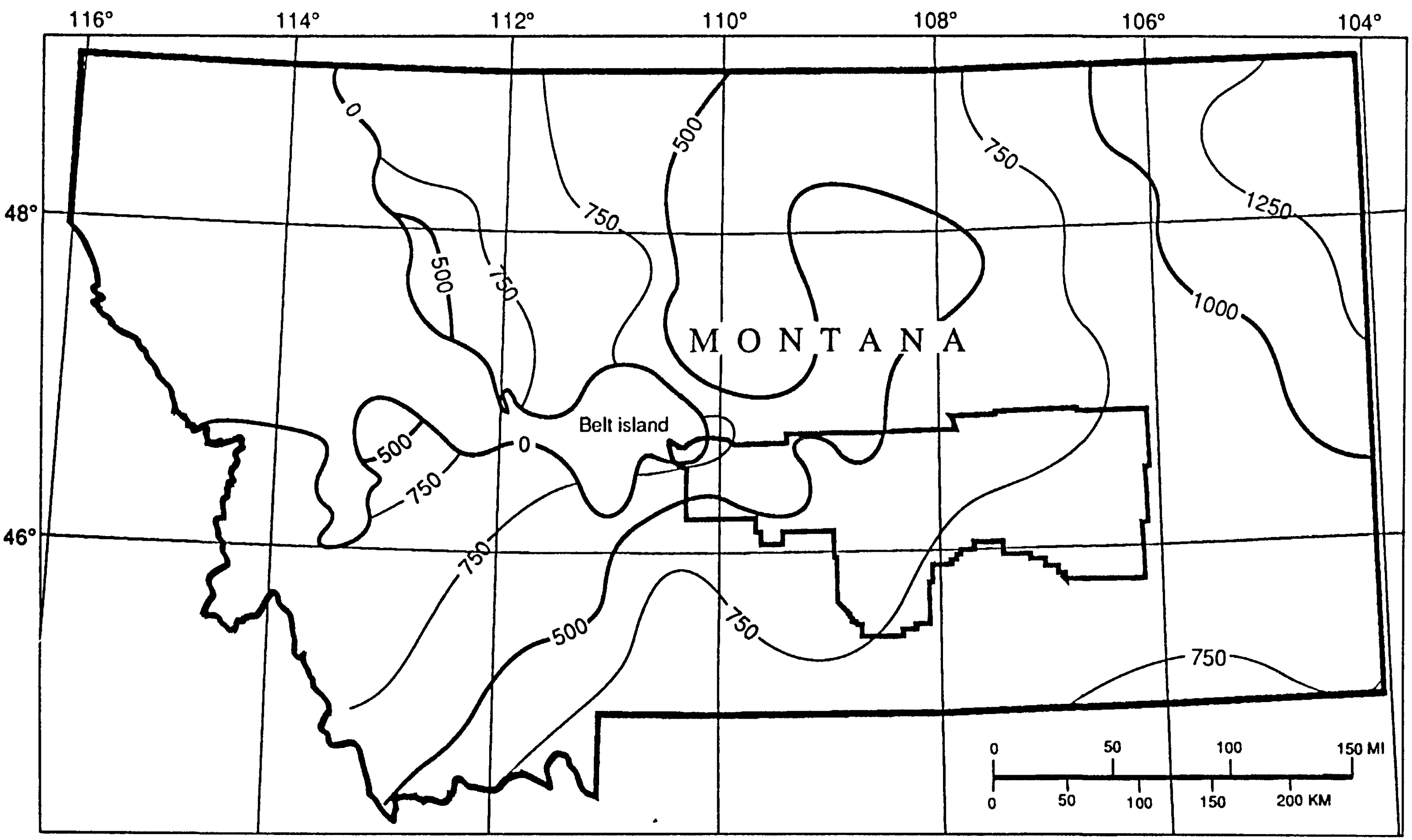


Figure 14.- Thickness of Jurassic rocks in Montana (Peterson, 1972, p.180). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

sediments declined. Deposition seems primarily to have been during marine regression and the sediments filled the shallow epicontinental basin to displace the Sundance sea.

The uppermost Jurassic Morrison Formation forms a blanket of varied lacustrine, deltaic, coastal plain, and fluvial rocks. Lithologically the rocks mostly comprise varicolored mudstone with lesser amounts of sandstone, carbonate rocks, and locally some slightly carbonaceous mudstone and possibly some coal.

Cretaceous.— Cretaceous rocks comprise a comparatively thin continental redbeds sequence overlain by a very thick sequence of mostly marine, carbonaceous mudstone strata, and an uppermost sequence of marginal marine to continental fluvial and deltaic rocks. The entire sequence includes several interbedded sandstone units within these mostly shaly beds.

The Lower Cretaceous Kootenai Formation comprises dominantly lacustrine, fluvial, and deltaic redbed deposits. Sandstone in the lower part of the Kootenai in this area is the 3d Cat Creek sand of drillers and oil explorationists. Regionally, the lowermost Cretaceous sandstone is time-transgressive from older to younger from the north to south. Consequently, the stratigraphic equivalent of the 3d Cat Creek sand on the Sweetgrass arch to the northwest is the Cutbank sand, whereas to the south it is fluvially deposited pebble conglomerate and pebbly sandstone that comprises the Pryor Conglomerate Member of the Cloverly Formation. To the east and southeast equivalent strata are in the Lakota Formation of the Inyan Kara Group.

The 2nd Cat Creek sand of informal usage occurs within the Kootenai Formation, and its regional relationships are unknown.

Coal beds in the Kootenai Formation have been exploited in the Lewistown coal field along the north flank of the Little Snowy Mountains and adjacent areas (Calvert, 1909). In the central Montana province some coal probably occurs in these strata in the subsurface south of these mountains.

The regional relationships of the Kootenai and stratigraphically equivalent rocks suggest that they are a lower Cretaceous continental fluvial complex that includes mostly lacustrine beds west of the central Montana province, lacustrine delta front sands to the north, delta distributary and interfluvial swamp sediments in central Montana, and mostly upper delta and braided stream deposits to the south. The source terrain for the detritus that comprises these rocks was most likely the broad, northern flank of the transcontinental arch to the southeast and uplifts or domes in the Sevier orogenic belt that formed to the southwest prior to Late Cretaceous thrusting (Heller and Paola, 1989). This terrigenous clastic wedge thins and is geologically younger from north to south in Montana. Sedimentation of the detritus prograded onto the coastal plain adjacent to the southward transgression of the Cretaceous sea along the cratonic foreland trough. The wedge thins farther southward and southeastward where inundation by this epicontinental sea encroached the transcontinental arch. The source terrain on the arch was increasingly engulfed by marine water and the sediment supply was diminished during part of the Early Cretaceous. Uplifts in the Sevier orogenic belt were likely the provenance of much of the gravelly sediments in strata equivalent to the Kootenai. However, most sand and coarser detritus from the west would have been trapped in the extensive freshwater lakes that occupied the foreland basin in southwestern Montana that lay immediately east of the uplifted terrains (DeCelles, 1986); but pebbles in the Cloverly Formation probably originated in uplifts to the southwest (McGookey and others, 1972).

Marine Cretaceous rocks above the continental Kootenai Formation are identified in figure 3. Regional thicknesses of all but the youngest Cretaceous rocks are shown in figures 15 and 16. The Thermopolis Formation is the lowest formation in the marine sequence. The contact of the Thermopolis with the underlying Kootenai Formation is conformable and gradational at some places, but at many places there is an abrupt lithologic change and a probable minor hiatus where the contact is along a ravinement surface. The Thermopolis Formation is dominantly dark grey mudstone and claystone; but a sandstone member, commonly referred to as the rusty beds, occurs at the base. The basal rusty bed member is equivalent to the Fall River Sandstone to the east and southeast, but locally in the province this member is informally identified as the 1st Cat Creek sand.

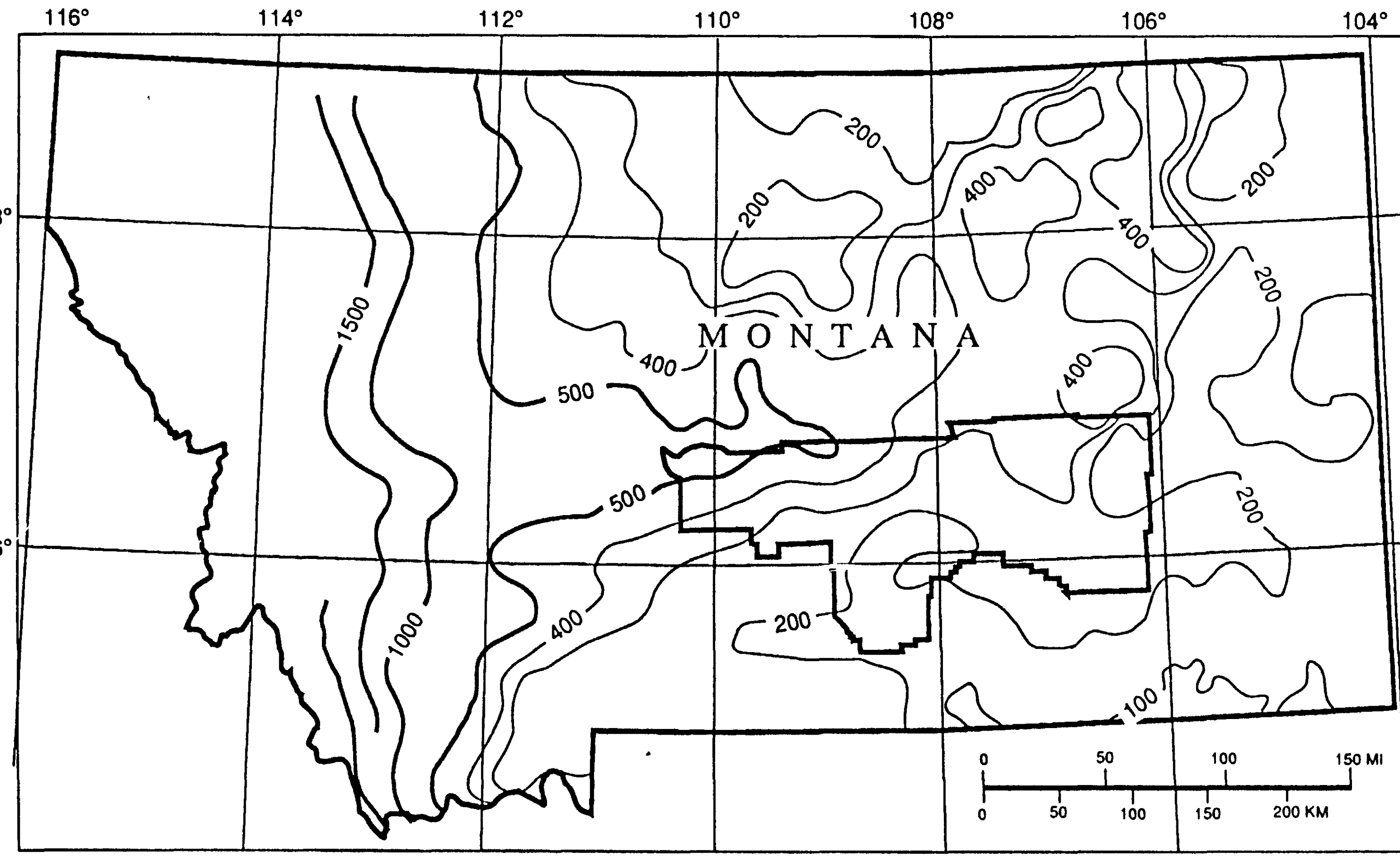


Figure 15.- Thickness of lower sequence of Cretaceous rocks in Montana (McGookey and others, 1972, p.197). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

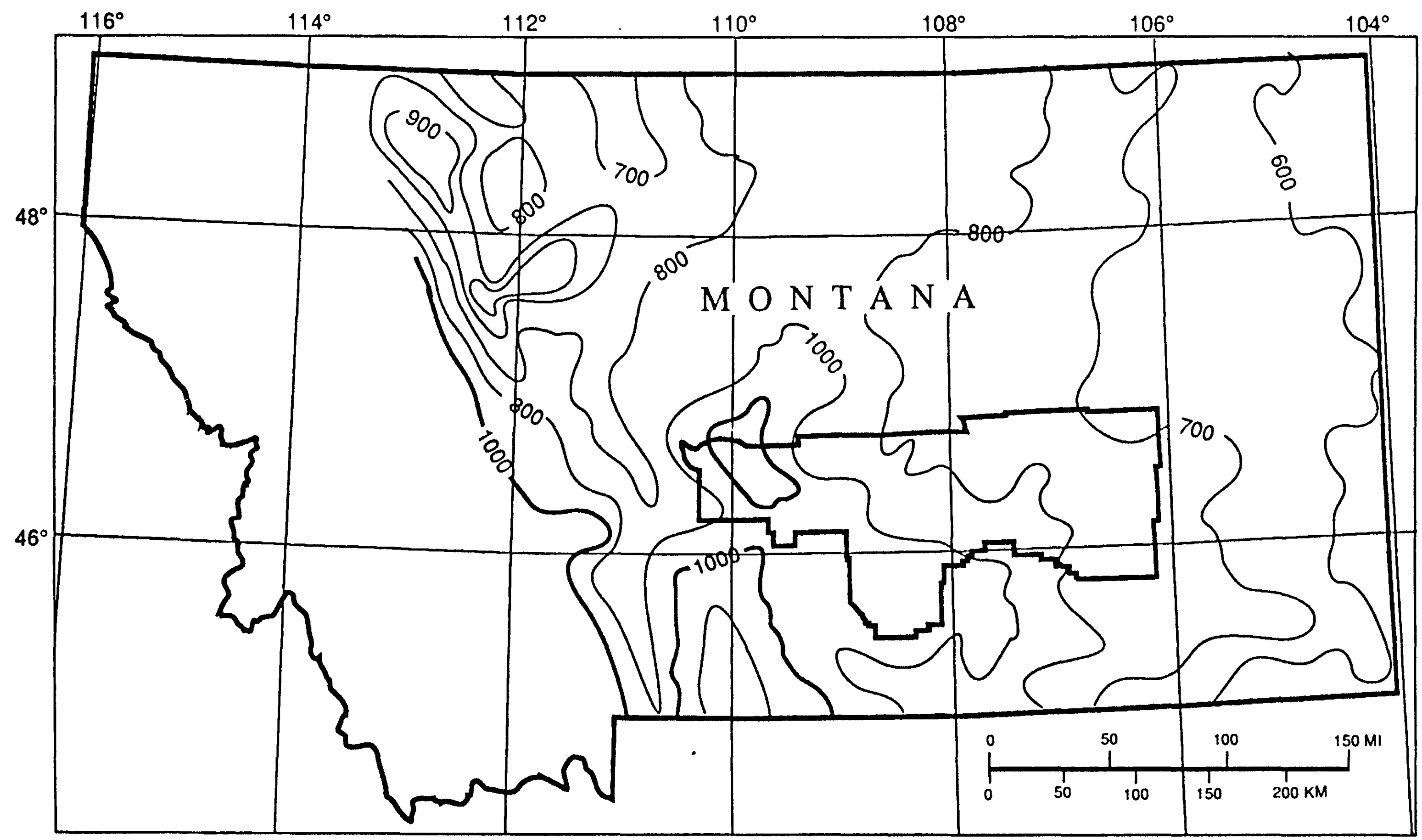


Figure 16.- Thickness of middle sequence of Cretaceous rocks in Montana (McGookey and others, 1972, p.199). Heavy line is outline of central Montana province. Isopach interval, 100 ft.

Most of the marine Cretaceous rocks above the Thermopolis are composed of grey, carbonaceous mudstone and claystone in several formations, and the sequence includes a few relatively thin sandstone units (fig. 3). The upper part of the Cretaceous sequence and the overlying Tertiary sequence are not discussed in this report.

STRUCTURE

Structures in the central Montana region comprise many faults, domes, and basins (pl. 1) adjacent to the probable east-southeast extension of the Lewis and Clark lane (Maughan and Perry, 1986). The lane is a possible ancient rift into the margin of the craton that projects from the Cordilleran miogeosyncline through western Montana into the continental interior, and is shown in figure 2 with a probable offset between the parallochthonous terrains in the western overthrust belt and the autochthonous terrain in central and eastern Montana owing to easterly transport by the thrusts. Many structures in this region and within the province seem to be associated with lineaments that cross the central Montana province along west-northwest trends that are approximately parallel with the Lewis and Clark lane. Some structures seem to be related to other lineaments of regional extent that are oriented along northwesterly and along northeasterly trends (fig. 2). Most of the principal structures in the province coincide with major lineaments. The Nye-Bowler lineament south of the province (Nye-Bowler fault on fig. 2) is shown here at the southern edge of the Lewis and Clark lane, and the Lake basin fault zone along the approximate northern edge of the lane. The Musselshell lineament and the Cat Creek lineament, which are parallel with the Nye-Bowler lineament and the Lake basin fault zone, have been the principal loci of tectonic movements within the province. Major lineaments, such as the Greenhorn lineament and the Snake River-Yellowstone lineament, cross the province along northeasterly trends; and others, such as the Horn and the probable extension of the Chadron lineament, cross along a conjugate northwesterly trend (fig. 2). These northeast-southwest and northwest-southeast trending lineaments also have been the loci for many of the structures in central Montana.

Episodes of vertical faulting and reverse movements related to compressional and extensional events along the lineaments and the Lewis and Clark lane are indicated by thickness patterns and facies trends in the Phanerozoic rocks. The central Montana trough formed adjacent to the lane during the late Precambrian and early Paleozoic wherein sediments were deposited somewhat thicker than on the adjacent continental shelves in Alberta and Wyoming (Peterson, 1981; 1985). Pronounced structures have formed at later times throughout the Phanerozoic, and especially during several episodic epeirogenic intervals that occurred principally during Middle to Late Devonian, Early Pennsylvanian to Early Permian, and Late Cretaceous to early Tertiary time.

Central Montana was differentially elevated during Middle and possibly during Late Devonian time and the older Paleozoic rocks were eroded entirely from the more elevated areas. The Devonian structures, although poorly known, seem to indicate north-south compressional tectonics, the Pennsylvanian structures seem to indicate north-south extensional tectonics, and the principal Late Cretaceous and early Tertiary structures indicate return to north-south compression. Most faults reflect vertical movement, but the numerous en echelon faults of the Lake Basin fault zone suggests some shear component to the structures in the Cretaceous rocks along that lineament.

EXPLORATION SUMMARY

Petroleum exploration in Montana has been summarized by Fanshawe (1985), and he briefly has described the structural reversals in central Montana that have led to some of the negative exploration results in this province. The first oil production in central Montana occurred in 1919 from the Heath Formation in the Devil's Basin field in 1919. Subsequent field discoveries through 1986 are listed in Table 1; and the drilling record in Table 2 shows the number of wells and the footage drilled in the recent years, 1980-1987.

Total hydrocarbon production in the Central Montana province during 1987 according to the Montana Oil and Gas Conservation Division (Annual Review for the Year 1987 Relating to Oil and Gas, v. 31) was 1,615,316 bbl of oil and 450,917 mcf of gas. Initial discovery of oil in the province was in the Heath Formation in 1919 (Table 1) and total cumulative production of crude oil through 1987 has been 99,869,176 bbl,(Table 3). About 18,908,333 bbl of the total production have been from the Devils Pocket Formation (reported as Amsden), about 79,154,456 bbl have been from the Tyler, about 145,555 have been from the Heath Formation, and 1,316,552 have been from the Cretaceous rocks (Table 4).

Total cumulative production of natural gas through 1987 (Table 5) has been 9,412,243 mcf.of which 1,556,266 mcf were from Pennsylvanian Tyler and Devils Pocket, and 7.849,841 mcf were from the Jurassic Morrison and the Cretaceous Lakota and Dakota Formations. The source of the gas in an additional 6,136 mcf is not specified. Crude oil production in Central Montana through 1987 represents about 8.3% of the cumulative production for the the entire State.

Petroleum reservoirs in the Tyler Formation in central Montana are in an area of complex facies relationships that involve interstratification of nearshore littoral sands, marine to brackish-bay carbonate and terrigeneous mud deposits, and probable chenier and fluvial to estuarine sands. The sandstone reservoirs in the Stonehouse Canyon Member of the Tyler Formation in Musselshell and Rosebud Counties (pl. 2) are lenticular, elongate, and sinuous. Most of the sands are part of a shore sequence of fluviatile channel sands deposited in tributaries that coursed from an upland to the south and merged through estuaries into a beach complex that includes the probable chenier plain and offshore sand bars (Maughan, 1984). Other reservoir sand bodies seem to be fluvial sediments deposited during westward progradation of delta distributary sands during oscillatory transgression of the Pennsylvanian sea eastward into the estuary of the Tyler river. Geophysical studies, especially seismic reflections, have successfully located some of the larger sandstone bodies in the Tyler (A.W.Butler,III, oral commun., 1988), and.high resolution seismic stratigraphy and detailed sedimentological studies are recommended for further exploration (Stanton and Silverman, 1989, p. 47).

SOURCE ROCKS

The Bakken has been recognized as an important petroleum source rock that is distributed throughout much of northern and eastern Montana. Carbonaceous beds within the Cottonwood Canyon (Sandberg, 1963) evidence the similar depositional environment as that of the Bakken, and these rocks are a probable oil generating horizon at this stratigraphic level within most of the central Montana province. Figure 9 illustrates the thickness and extent of the Bakken and Cottonwood Canyon in central Montana and adjacent areas, but there are no published data that establish the degree of the oil generation capability of these rocks in this area.

The hydrocarbons in the Pennsylvanian Tyler Formation have been derived principally from the organic carbon-rich beds of the underlying Mississippian Heath Formation. Carbonaceous mudstone beds in the Tyler Formation are probable source rocks of petroleum. Much of the carbonaceous matter in the mudstone beds is from terrestrial plants, however, and these beds are lower in their hydrocarbon generation capability in comparison to the underlying Heath Formation. The limestone beds that comprise the Bear Gulch Member, however, display a strong petroliferous odor indicative of petroleum catagenesis.

The Mesozoic rocks in most of the region have been too shallowly buried for effective thermal maturation of organic matter to hydrocarbons.

The Paleozoic rocks have been within the thermal range of the oil generation window since Middle to Late Cretaceous time, except in a few places. An exception, for example, is the carbonaceous mudstone in the Heath Formation on the north flank of the Little Snowy Mountains that comprises locally immature oil shale beds (Dirkey, 1983). This immaturity contrasts with the Heath about 50 km (30 mi) to the southeast where it has been thermally matured and is the source of the oil in the Tyler Formation (Kranzler, 1966).

In the Williston basin in eastern Montana and North Dakota, the Winnipeg and Red River Formations are important hydrocarbon source rocks, but the carbonaceous beds in these formations thin and presumably are less organically rich to the west so that minor source potential may occur only in the eastern part of the central Montana province.

PLAY DESCRIPTIONS

Tyler Play.— The Tyler exploration play described in this report lies almost entirely in the northern part of the province where this formation is greater than 30 m (100 ft) thick (pl. 2). The play extends beyond the bounds of the central Montana province to the limit of preservation of the Lower Pennsylvanian rocks in adjacent provinces to the north in Judith Basin, Fergus, Petroleum, and Garfield Counties, and to the west in Park and Meagher Counties. The Pennsylvanian Tyler Formation in central Montana has been one of the most oil productive targets in Montana; however, discoveries have been sporadic and with a relatively low ratio of success (Stanton and Silverman, 1989, p. 29). The Tyler play requires defining the distribution of the Heath source rocks, their degree of thermal maturation and locating the limits of the channel and sheet sands in the Stonehouse Canyon Member within the Big Snowy trough. High resolution seismic stratigraphy and detailed sedimentological analyses are important elements for successful exploration (Stanton and Silverman, 1989, p. 47-48). Large, sparsely drilled regions in the province are not as likely exploration targets as the already productive regions owing to shallow burial and the consequent inadequate ambient temperatures for thermal maturation of the organic carbon-rich shales in the Heath.in most of these areas.

The source beds of the oil in the Tyler are the organic carbon-rich mudstone and limestone of the Heath Formation, the upper unit of the Big Snowy Group, although some oil likely has been derived from the carbonaceous mudstone beds that are indigenous to the Tyler.

The Tyler play is confined to the part of the central Montana province where the Tyler Formation is greater than 30 m (100 ft) thick as shown on plate 2. The general area of Tyler production and the oil producing fields are also shown on plate 2, and details of the distribution and the character of the reservoir sands are provided by Stanton and Silverman (1989).

Mississippian Carbonates Play.— Petroleum reservoirs are likely in the Madison, but none have been discovered in central Montana owing chiefly to the paucity of exploration into these and older strata in this area. Favorable reservoirs probably exist in some of the algal and oolitic grainstone facies and in the bioclastic and crinoidal facies that are shown to be common in the Madison Group in central Montana (Peterson, 1984, pls. 4, 5, 12, 14, 16, and 18). Waulsortian mounds have been described in Madison rocks in northern Park County in the Bridger Range, about 50 km (30 mi) west of the province boundary (Stone, 1972). Conceivably, similar mounds, which could be hydrocarbon reservoirs, may occur within the central Montana province. The Mississippian carbonates exploration play covers the entire province and extends into adjacent provinces with the exception in the northwest of areas that are on the flanks of the Little Belt, Big Snowy, and the Little Snowy Mountains.

Carbonaceous claystone and mudstone beds in the Bakken, Cottonwood Canyon, and some of the lower strata in the Lodgepole Limestone are petroleum source rocks in other parts of the region (Meissner, 1978) and probably have generated petroleum in or near the central Montana province. Distribution and thickness of these source rocks are shown in a general way in figure 9. Hydrocarbons that originated in these underlying strata and, possibly, in the overlying Heath Formation could be reservoired in the Madison.

Cretaceous Play.— The potential for oil generation from carbonaceous shale beds in stratigraphically higher Cretaceous rocks in the central Montana province is not very favorable because of shallower burial in most of the provinces. Gas and some oil have been discovered in Cretaceous rocks in a few fields that exhibit local structural and thermal anomalies.

Lower Paleozoic Play.— Paleozoic formations older than the Mississippian in the central Montana province have been only sparsely tested and without success other than for minor shows of oil. However, oil is produced from these rocks elsewhere in the region, especially eastward in the Williston basin where most of the oil in that province is recovered from the lower Paleozoic rocks. Many of the favorable factors that have led to the generation and pooling of oil elsewhere, are likely to exist in the central Montana province. Petroleum source rocks, except for organic carbon-rich strata in Upper Devonian and Lower Mississippian rocks and in younger strata may be inadequate. Hydrocarbon source rocks in older Paleozoic rocks in the Williston basin, such as those in the Stony Mountain and in the Winnipeg Formations, may extend westward onto the eastern flank of Porcupine dome; but most or all of the organic carbon-rich beds in the lower Paleozoic strata either are thin or have been eroded from most of the central Montana province.

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Table 1. Oil fields in central Montana, producing formation and year of discovery. Data from Montana Oil and Gas Conservation Division Annual Review Relating to Oil and Gas for each of the years cited.

FIELDS IN CHRONOLOGICAL SEQUENCE			FIELDS IN ALPHABETICAL SEQUENCE		
Field	Producing Formation	Discovery Year	Field	Producing Formation	Discovery Year
Devil's Basin	Heath	1919	Ace High	Tyler	1986
Devil's Pocket	Heath	1920	Big Gully	Tyler	1976
Mosser	Kootenai	1936	Big Gully North	Tyler	1977
Gage	Devils Pocket	1944	Big Wall	Devils Pocket & Tyler	1953-1948
Big Wall	Devils Pocket & Tyler	1948	Big Wall North	Tyler (Stensvad)	
Melstone	Tyler	1948	Breed Creek	Tyler	1976
Sumatra	Tyler	1949	Crooked Creek	Dakota	1985
Wolf Springs	Devils Pocket	1955	Delphia	Devils Pocket	1957
Ivanhoe	Devils Pocket & Tyler	1956	Devil's Basin	Heath	1919
Ragged Point	Tyler	1956	Devil's Pocket	Heath	1920
Delphia	Devils Pocket	1957	Gage	Devils Pocket	1944
Stensvad	Tyler	1958	Gage Southwest		
Hibbard	Devils Pocket	1960	Grebe		
Keg Coulee	Tyler	1960	Gumbo Ridge	Tyler	1975
Keg Coulee North	Tyler	1964	Hawk Creek		
Mason Lake	Lakota	1964	Hiawatha	Tyler	1967
Kelley	Tyler	1966	Hibbard	Devils Pocket	1960
Weed Creek	Devils Pocket	1966	High Five	Tyler	1976
Hiawatha	Tyler	1967	Howard Coulee	Tyler	1974
Little Wall Creek	Tyler	1970	Injun Creek	Tyler	1981
Willow Creek North	Tyler	1970	Ivanhoe	Devils Pocket & Tyler	1956
Jim Coulee	Tyler	1971	Jim Coulee	Tyler	1971
Jim Coulee North	Tyler	1972	Jim Coulee North	Tyler	1972
Winnett Junction	Tyler	1973	Keg Coulee	Tyler	1960
Howard Coulee	Tyler	1974	Keg Coulee North	Tyler	1964
Rosebud	Tyler	1974	Kelley	Tyler	1966
Sheepherder	Tyler	1974	Kincheloe Ranch West	Tyler	1979
Wagon Box	Tyler	1974	Laurel	Dakota	
Gumbo Ridge	Tyler	1975	Little Wall Creek	Tyler	1970
Rattler Butte	Tyler	1975	Mason Lake	Lakota	1964
Big Gully	Tyler	1976	Mason Lake North	Devils Pocket	
Breed Creek	Tyler	1976	Melstone	Tyler	1948
High Five	Tyler	1976	Mosser	Kootenai	1936
Big Gully North	Tyler	1977	Mud Creek	Devils Pocket	
Kincheloe Ranch West	Tyler	1979	Musselshell	Tyler	1981
Tippy Buttes	Tyler	1980	Ragged Point	Tyler	1956
Injun Creek	Tyler	1981	Rattler Butte	Tyler	1975
Musselshell	Tyler	1981	Rosebud	Tyler	1974
wildcat, Golden Valley Co.		1984	Sheepherder	Tyler	1974
wildcat, Rosebud Co.		1984	Stensvad	Tyler	1958
Wolf Springs South	Devils Pocket	1984	Sumatra	Tyler	1949
Crooked Creek	Dakota	1985	Tippy Buttes	Tyler	1980
Ace High	Tyler	1986	Wagon Box	Tyler	1974
Big Wall North	Tyler (Stensvad)		Weed Creek	Devils Pocket	1966
Gage Southwest			Willow Creek North	Tyler	1970
Grebe			Winnett Junction	Tyler	1973
Hawk Creek			Wolf Springs	Devils Pocket	1955
Laurel	Dakota		Wolf Springs South	Devils Pocket	1984
Mason Lake North	Devils Pocket		Yellowstone		
Mud Creek	Devils Pocket		wildcat, Golden Valley Co.		1984
wildcat, Musselshell Co.			wildcat, Musselshell Co.		
Yellowstone			wildcat, Rosebud Co.		1984

Table 2 Drilling record showing number of wells and footage, 1980-1987. Data from Annual review for the years cited relating to oil and gas, Montana Oil and Gas Conservation Division.

COUNTY	1980 Wells Drilled	1980 Footage	1981 Wells Drilled	1981 Footage	1982 Wells Drilled	1982 Footage	1983 Wells Drilled	1983 Footage
GOLDEN VALLEY	4	9,478	8	27,293	3	23,530	2	8,239
MUSSELSHELL	53	204,896	42	180,880	37	151,432	20	91,302
ROSEBUD	24	120,320	27	142,986	66	640,859	24	125,719
TREASURE	2	5,040	2	12,140				
WHEATLAND					3	10,825		
YELLOWSTONE	33	70,998	7	31,461	10	45,913	3	3,090
PROVINCE TOTALS	116	410,732	86	394,760	119	872,559	49	228,350

COUNTY	1984 Wells Drilled	1984 Footage	1985 Wells Drilled	1985 Footage	1986 Wells Drilled	1986 Footage	1987 Wells Drilled	1987 Footage
GOLDEN VALLEY	1	2,547	2	4,707				
MUSSELSHELL	19	66,870	25	109,347	11	40,398	15	62,163
ROSEBUD	19	103,838	15	33,729	12	66,219	11	49,330
TREASURE	3	18,792	2	13,428				
WHEATLAND	4	22,054						
YELLOWSTONE	13	54,806	10	51,638	11	31,194	11	31,922
PROVINCE TOTALS	59	268,907	54	212,849	34	137,811	37	143,415
							TOTAL WELLS, 1980-1987	554
							TOTAL FOOTAGE, 1980-1987	2,669,383

Table 3 Crude oil production in barrels (bbls.) from 1976 and prior years through 1987. Data from Montana Oil and Gas Conservation Division Annual Review Relating to Oil and Gas for each of the years cited.

Field	Producing Formation	Discovery Year	79 Cumulative	1980 Production	80 Cumulative	1981 Production	81 Cumulative
Ace High	Tyler	1986					
Big Gully	Tyler	1976	77,982	4,593	82,575	3,074	85,649
Big Gully North	Tyler	1977	9,840	2,915	12,755	3,045	15,800
Big Wall	Devils Pocket & Tyler	1953-1948	6,904,462	104,447	7,008,909	83,716	7,092,625
Big Wall North	Tyler (Stensvad)		6,373	575	6,948	270	7,218
Breed Creek	Tyler	1976	348,166	110,532	458,698	83,469	542,167
Crooked Creek	Dakota	1985					
Delphia	Devils Pocket	1957	300,971	2,123	303,094	1,449	304,543
Devil's Basin	Heath	1919	58,879	3,583	63,462	23,910	87,372
Devil's Pocket	Heath	1920					
Gage	Devils Pocket	1944	562,333	1,988	564,321	24,174	588,495
Gage Southwest			16,289	0	16,289	0	16,289
Grebe							
Gumbo Ridge	Tyler	1975	315,108	34,667	349,775	45,259	395,034
Hawk Creek			6,577	0	6577	1,167	7,744
Hiawatha	Tyler	1967	1,318,267	30,672	1,348,894	30,953	1,379,847
Hibbard	Devils Pocket	1960	171,872	3,152	175,024	5,509	180,533
High Five	Tyler	1976	881,812	196,401	1,078,213	165,602	1,243,815
Howard Coulee	Tyler	1974	95,302	4,002	99,304	3,935	103,239
Injun Creek	Tyler	1981	23,038		23038	7,696	30,734
Ivanhoe	Devils Pocket & Tyler	1956	4,408,596	13,779	4,422,375	14,917	4,437,292
Jim Coulee	Tyler	1971	3,316,624	143,639	3,460,263	126,502	3,586,765
Jim Coulee North	Tyler	1972			0	4,590	4,590
Keg Coulee	Tyler	1960	4,807,930	64,366	872,296	55,162	927,458
Keg Coulee North	Tyler	1964	338,043	19,080	357,123	16,841	373,964
Kelley	Tyler	1966	866,733	13,359	880,092	16,150	896,242
Kincheloe Ranch West	Tyler	1979			0	89,761	89,761
Laurel	Dakota		434	391	825	192	1,017
Little Wall Creek	Tyler	1970	1,727,048	213,932	1,940,980	217,657	2,158,637
Mason Lake	Lakota	1964	364,358	139,967	504,325	82,767	587,092
Mason Lake North	Devils Pocket		8,244	1,803	10,047	1,882	11,929
Melstone	Tyler	1948	2,096,513	152,349	2,248,862	220,797	2,469,659
Mosser	Kootenai	1936	286,139	5,893	292,032	7,570	299,602
Musselshell	Tyler	1981	14,938	0	14938	2,351	17,289
Ragged Point	Tyler	1956	3,097,429	52,696	3,150,125	45,410	3,195,535
Rattler Butte	Tyler	1975	100,146	16,632	116,778	85,503	202,281
Rosebud	Tyler	1974	333,696	17,734	351,430	16,938	368,368
Sheepherder	Tyler	1974	56,709	2,771	59,480	2,723	62,203
Stensvad	Tyler	1958	10,013,993	6,662	10,020,655	15,482	10,036,137
Sumatra	Tyler	1949	37,075,059	1,042,058	38,117,117	874,533	38,991,650
Tippy Buttes	Tyler	1980	4,820	7,025	11,845	31,806	43,651
Wagon Box	Tyler	1974	20,080	944	21,024	1,015	22,039
Weed Creek	Devils Pocket	1966	576,671	4,724	581,395	3,992	585,387
Willow Creek North	Tyler	1970	262,148	9,146	271,294	10,112	281,406
Winnett Junction	Tyler	1973	423,118	77,678	500,796	70,416	571,212
Wolf Springs	Devils Pocket	1955	4,551,528	15,420	4,566,948	14,279	4,581,227
Wolf Springs South	Devils Pocket	1984					
Yellowstone			39,405	0	39,405		39,405
wildcat, Golden Valley Co.		1984					
wildcat, Musselshell Co.			925	0	925	0	925
wildcat, Rosebud Co.		1984					
			85,888,598	2,521,698	84,411,251	2,512,576	86,923,827

Table.3 (cont.)— Crude oil production in barrels (bbls.) from 1976 and prior years through 1987.

Field	1982 Production	83 Cumulative	1983 Production	83 Cumulative	1984 Production	84 Cumulative
Ace High						
Big Gully	3,837	89,486	2,941	92,427	252	92,679
Big Gully North	977	16,777	1,886	18,663	253	18,916
Big Wall	72,729	7,165,354	68,146	7,233,500	65,150	7,298,650
Big Wall North	0	7,218	0	7,218	0	7,218
Breed Creek	57,077	599,244	92,354	691,598	127,924	819,522
Crooked Creek						0
Delphia	3,588	308,131	3,784	311,915	2,721	314,636
Devil's Basin	11,158	98,530	1,251	99,781	1,204	100,985
Devil's Pocket						0
Gage	10,922	599,417	8,033	607,450	6,199	613,649
Gage Southwest	0	16,289	0	16,289	0	16,289
Grebe		0		0	795	795
Gumbo Ridge	54,076	449,110	47,684	496,794	34,899	531,693
Hawk Creek	860	8,604		8,604	627	9,231
Hiawatha	26,520	1,406,367	24,684	1,431,051	22,701	1,453,752
Hibbard	21,618	202,151	6,913	209,064	4,409	213,473
High Five	150,853	1,394,668	160,034	1,554,702	162,843	1,717,545
Howard Coulee	6,039	109,278	5,784	115,062	3,447	118,509
Injun Creek	37,862	68,596	24,793	93,389	11,808	105,197
Ivanhoe	9,654	4,446,946	18,593	4,465,539	1,234	4,466,773
Jim Coulee	114,714	3,701,479	108,435	3,809,914	84,053	3,893,967
Jim Coulee North	8,279	12,869	9,022	21,891	7,868	29,759
Keg Coulee	52,827	980,285	90,897	1,071,182	104,613	1,175,795
Keg Coulee North	19,231	393,245	15,729	408,974	10,785	419,759
Kelley	10,098	906,340	9,793	916,133	23,915	940,048
Kincheloe Ranch West	70,468	160,229	67,055	227,284	66,358	293,642
Laurel	0	1,017	0	1,017	0	1,017
Little Wall Creek	300,475	2,459,112	236,237	2,695,349	170,429	2,865,778
Mason Lake	72,739	659,831	77,386	737,217	11,569	748,786
Mason Lake North	1,757	13,686	1,596	15,282	1,335	16,617
Melstone	193,758	2,663,417	157,683	2,821,100	19,794	2,840,894
Mosser	8,531	308,133	8,167	316,300	10,707	327,007
Musselshell		17,289	1,309	18,598	442	19,040
Ragged Point	38,379	3,233,914	71,032	3,304,946	138,770	3,443,716
Rattler Butte	256,995	459,276	158,793	618,069	98,692	716,761
Rosebud	14,084	382,452	12,934	395,386	12,364	407,750
Sheepherder	2,387	64,590	2,013	66,603	1,767	68,370
Stensvad	15,355	10,051,492	8,697	10,060,189	9,438	10,069,627
Sumatra	690,390	39,682,040	701,356	40,383,396	611,458	40,994,854
Tippy Buttes	16,032	59,683	24,931	84,614	19,090	103,704
Wagon Box	797	22,836	3,614	26,450	3,962	30,412
Weed Creek	3,655	589,042	5,097	594,139	266	594,405
Willow Creek North	10,208	291,614	7,833	299,447	6,322	305,769
Winnett Junction	54,360	625,572	44,607	670,179	51,457	721,636
Wolf Springs	12,940	4,594,167	12,715	4,606,882	11,117	4,617,999
Wolf Springs South				0	95,501	95,501
Yellowstone	0	39,405	0	39,405	0	39,405
wildcat, Golden Valley Co.				0	7,774	7,774
wildcat, Musselshell Co.	0	925	0	925	0	925
wildcat, Rosebud Co.				0	220	220
	2,436,279	89,360,106	2,303,811	91,663,917	2,026,532	93,690,449

Table.3 (cont.)— Crude oil production in barrels (bbls.) from 1976 and prior years through 1987.

Field	1985 Production	85 Cumulative	1986 Production	86 Cumulative	1987 Production	87 Cumulative
Ace High		0	3,686	3,686	0	3,686
Big Gully	4,691	97,370	834	98,204	760	98,964
Big Gully North	4,977	23,893	59	23,952	0	23,952
Big Wall	66,187	7,364,837	83,484	7,448,321	70,575	7,518,896
Big Wall North	0	7,218	0	7,218	0	7,218
Breed Creek	106,627	926,149	89,404	1,015,553	77,050	1,092,603
Crooked Creek	8,494	8,494	11,320	19,814	3,315	23,129
Delphia	3,152	317,788	2,782	320,570	3,060	323,630
Devil's Basin	1,867	102,852	1,451	104,303	3,975	108,278
Devil's Pocket	21,641	21,641	7,770	29,411	7,866	37,277
Gage	7,911	621,560	5,227	626,787	6,192	632,979
Gage Southwest	0	16,289	0	16,289	0	16,289
Grebe	0	795	0	795	0	795
Gumbo Ridge	27,554	559,247	15,086	574,333	4,848	579,181
Hawk Creek	507	9,738	104	9,842	506	10,348
Hiawatha	19,047	1,472,799	19,798	1,492,597	23,099	1,515,696
Hibbard	2,387	215,860	44	215,904	0	215,904
High Five	146,400	1,863,945	133,706	1,997,651	105,562	2,103,213
Howard Coulee	3,206	121,715	1,603	123,318	1,260	124,578
Injun Creek	5,495	110,692	2,863	113,555	3,832	117,387
Ivanhoe	21,222	4,487,995	6,395	4,494,390	2,138	4,496,528
Jim Coulee	81,643	3,975,610	67,142	4,042,752	66,109	4,108,861
Jim Coulee North	0	29,759	3,760	33,519	2,885	36,404
Keg Coulee	115,299	1,291,094	103,255	1,394,349	71,111	1,465,460
Keg Coulee North	8,003	427,762	7,684	435,446	1,703	437,149
Kelley	16,339	956,387	12,406	968,793	9,183	977,976
Kincheloe Ranch West	139,306	432,948	45,289	478,237	34,313	512,550
Laurel	0	1,017	0	1,017	0	1,017
Little Wall Creek	157,894	3,023,672	288,049	3,311,721	204,200	3,515,921
Mason Lake	151,461	900,247	24,206	924,453	9,788	934,241
Mason Lake North	0	16,617		16,617	0	16,617
Melstone	307,169	3,148,063	95,934	3,243,997	111,253	3,355,250
Mosser	10,028	337,035	11,262	348,297	9,868	358,165
Musselshell	6,386	25,426	2,129	27,555	2,763	30,318
Ragged Point	142,037	3,585,753	101,574	3,687,327	90,623	3,777,950
Rattler Butte	52,279	769,040	43,553	812,593	31,054	843,647
Rosebud	11,563	419,313	10,097	429,410	9,661	439,071
Sheepherder	3,392	71,762	2,465	74,227	1,777	76,004
Stensvad	8,722	10,078,349	10,526	10,088,875	20,205	10,109,080
Sumatra	525,122	41,519,976	505,154	42,025,130	461,075	42,486,205
Tippy Buttes	9,349	113,053	4,324	117,377	2,753	120,130
Wagon Box	1,841	32,253	126	32,379	0	32,379
Weed Creek	3,693	598,098	1,659	599,757	1,697	601,454
Willow Creek North	2,873	308,642	2,514	311,156	11,819	322,975
Winnett Junction	48,084	769,720	39,250	808,970	31,678	840,648
Wolf Springs	9,881	4,627,880	10,901	4,638,781	19,591	4,658,372
Wolf Springs South	252,283	347,784	0	347,784	96,169	443,953
Yellowstone	0	39,405	0	39,405	0	39,405
wildcat, Golden Valley Co.	0	7,774	0	7,774	0	7,774
wildcat, Musselshell Co.	0	925	268,524	269,449	0	269,449
wildcat, Rosebud Co.	0	220	0	220	0	220
	2,516,012	96,206,461	2,047,399	98,253,860	1,615,316	99,869,176

Table 4. Natural gas production, central Montana. Values in thousand cubic feet (mcf). Data from Annual review for the years cited relating to oil and gas, Montana Oil and Gas Conservation Division.

Gas Field	Producing Formation	1977 Production	1978 Production	1979 Production	1980 Production	1981 Production	1982 Production	1983 Production
Big Coulee (non associat	Dakota	1,397,243	1,388,246	1,235,579	857,667	765,405	485,522	551,143
High Five	Lakota & Morrison							5,932
Breed Creek	Devils Pocket							
Delphia	Devils Pocket							250
Gumbo Ridge	Devils Pocket							2,206
Hiawatha	Devils Pocket & Tylor							1,362
Jim Coulee	Tyler							7,951
Jim Coulee North	Tyler							540
Keg Coulee	Tyler							1,790
Kelley	Tyler							1,305
Kincheloe Ranch West	Tyler							20,017
Little Wall Creek	Tyler							38,945
Little Wall Creek South	Tyler							
Mason Lake	Tyler							27,566
Mason Lake North	Tyler							80
Melstone	Tyler							24,644
Ragged Point	Tyler							
Rattler Butte	Tyler							48,881
Rosebud	Tyler							1,619
Stensvad	Tyler							5,129
Sumatra	Tyler							8,915
Tippy Buttes	Tyler	266,213	112,314	28,687				7,029
Weed Creek	Tyler							523
Wolf Springs	Tyler							21,887
wildcat Yellowstone Co.	Not designated							6,136
	Total annual productio	1,663,456	1,500,560	1,264,266	857,667	765,405	485,522	781,630

Gas Field	1984 Production	1985 Production	1986 Production	1987 Production	Total Gas through 1987 Field	mcf		mcf
Big Coulee (non associat	326,969	543,159	33,507	228,106	Big Coulee (non associated	7,812,546	Total Createous	
High Five	10,384	6,861	6,437	7,681	High Five	37,295	and Jurassic	7,849,841
Breed Creek	1,203		1,181	1,522	Breed Creek	3,906		
Delphia					Delphia	250		
Gumbo Ridge	1,458	1,147	727	385	Gumbo Ridge	5,923		
Hiawatha	1,443	1,726	1,808	2,105	Hiawatha	8,444		
Jim Coulee	6,091	5,998	5,087	5,108	Jim Coulee	30,235		
Jim Coulee North	472	367	300	229	Jim Coulee North	1,908		
Keg Coulee	370	89	91	90	Keg Coulee	2,430		
Kelley	3,014	2,210	1,570	1,096	Kelley	9,195		
Kincheloe Ranch West	18,448	17,276	12,590	9,521	Kincheloe Ranch West	77,852		
Little Wall Creek	42,879	19,906	16,851	18,805	Little Wall Creek	137,466		
Little Wall Creek South	6,583	40,023	134,785	17,672	Little Wall Creek South	199,063		
Mason Lake	3,248	4,607			Mason Lake	35,421		
Mason Lake North					Mason Lake North	80		
Melstone	62,753	69,981	11,356	17,829	Melstone	186,563		
Ragged Point				1,071	Ragged Point	1,071		
Rattler Butte	21,266	860	2,106	618	Rattler Butte	73,711		
Rosebud	1,549	1,384	1,246	1,011	Rosebud	6,809		
Stensvad					Stensvad	5,129		
Sumatra	9,329	8,199	107,435	127,386	Sumatra	259,264		
Tippy Buttes	5,427	2,639	1,219	777	Tippy Buttes	424,305		
Weed Creek	496	688	729	752	Weed Creek	3,188		
Wolf Springs	18,622	17,185	17,486	9,073	Wolf Springs	84,053	Total Pennsylvanian	1,556,266
wildcat Yellowstone Co.					wildcat Yellowstone Co.	6,136	Not designated	6,136
	542,004	744,305	356,511	450,917	Total for central Montana	9,412,243		

Table 5. Barrels of crude oil produced, reported by stratigraphic units and by fields in central Montana. Data from Montana Oil and Gas Conservation Division Annual Review Relating to Oil and Gas for each of the years cited.

PRODUCING FORMATION	FIELD	DISCOVERY YEAR	PRODUCTION THROUGH 1987	FORMATION TOTAL
Dakota	Crooked Creek	1985	23,129	
	Laurel		1,017	24,146
Kootenai	Mosser	1936	358,165	358,165
Lakota	Mason Lake	1964	934,241	934,241
Devils Pocket	Delphia	1957	323,630	
	Gage	1944	632,979	
	Hibbard	1960	215,904	
	Mason Lake North		16,617	
	Weed Creek	1966	601,454	
	Wolf Springs	1955	4,658,372	
	Wolf Springs South	1984	443,953	
	Big Wall	1953-1948	7,518,896	
	Ivanhoe	1956	4,496,528	18,908,333
Tyler	Willow Creek North	1970	322,975	
	Winnett Junction	1973	840,648	
	Ace High	1986	3,686	
	Big Gully	1976	98,964	
	Big Gully North	1977	23,952	
	Big Wall North		7,218	
	Breed Creek	1976	1,092,603	
	Gumbo Ridge	1975	579,181	
	Hiawatha	1967	1,515,696	
	High Five	1976	2,103,213	
	Howard Coulee	1974	124,578	
	Injun Creek	1981	117,387	
	Jim Coulee	1971	4,108,861	
	Jim Coulee North	1972	36,404	
	Keg Coulee	1960	1,465,460	
	Keg Coulee North	1964	437,149	
	Kelley	1966	977,976	
	Kincheloe Ranch West	1979	512,550	
	Little Wall Creek	1970	3,515,921	
	Melstone	1948	3,355,250	
	Musselshell	1981	30,318	
	Ragged Point	1956	3,777,950	
	Rattler Butte	1975	843,647	
	Rosebud	1974	439,071	
	Sheepherder	1974	76,004	
	Stensvad	1958	10,109,080	
	Sumatra	1949	42,486,205	
	Tippy Buttes	1980	120,130	
	Wagon Box	1974	32,379	79,154,456
Heath	Devil's Basin	1919	108,278	
	Devil's Pocket	1920	37,277	145,555
Unknown	Gage Southwest		16,289	
	Grebe		795	
	Hawk Creek		10,348	
	Yellowstone		39,405	
	wildcat, Golden Valley Co.	1984	7,774	
	wildcat, Musselshell Co.		269,449	
	wildcat, Rosebud Co.	1984	220	344,280