GENERAL HISTORY

The Rocky Boys Indian Reservation was created in 1916 when the U.S. Congress set aside 56,035 acres from the abandoned Fort Assiniboine Military Reservation. The reservation was created for Chief Rocky Boys (a miss-translation of Stone Child from Chippewa to English) band of Chippewa Indians and other homeless Indians in Montana. Additional acreage was added to the reservation in 1935, 1939, and 1947. In recent years, several additional small purchases have been made.

All reservation land is tribally owned. None has ever been allotted. The Tribe makes free-use assignments of as much as 160 acres to individual families. These assignments are passed from generation to generation. Grazing assignments are also granted to families who own cattle or horses. Lands not in free-use by tribal members are leased to others, Indians or non-Indians.

The Rocky Boys Indian Reservation is located approximately 15 miles south of Havre, Montana (Figure RB-1) and covers about 107,615 acres in Hill and Chouteau Counties. The Burlington Northern Railroad and U.S. Route 87 pass through the western part of the reservation. A paved highway leads from U.S. 87 at Box Elder to the Rocky Boys Agency. Both can also be reached by a paved road leaving U.S. 87 about 1 mile north of Laredo. County Route 237 provides access to the eastern part of the reservation and is paved almost to the headwaters of Beaver Creek (Figure RB-2).

Numerous dirt and gravel roads provide good access to almost all of the reservation, but most of these roads are impassable during the winter months. Commercial airline service is available in Great Falls.

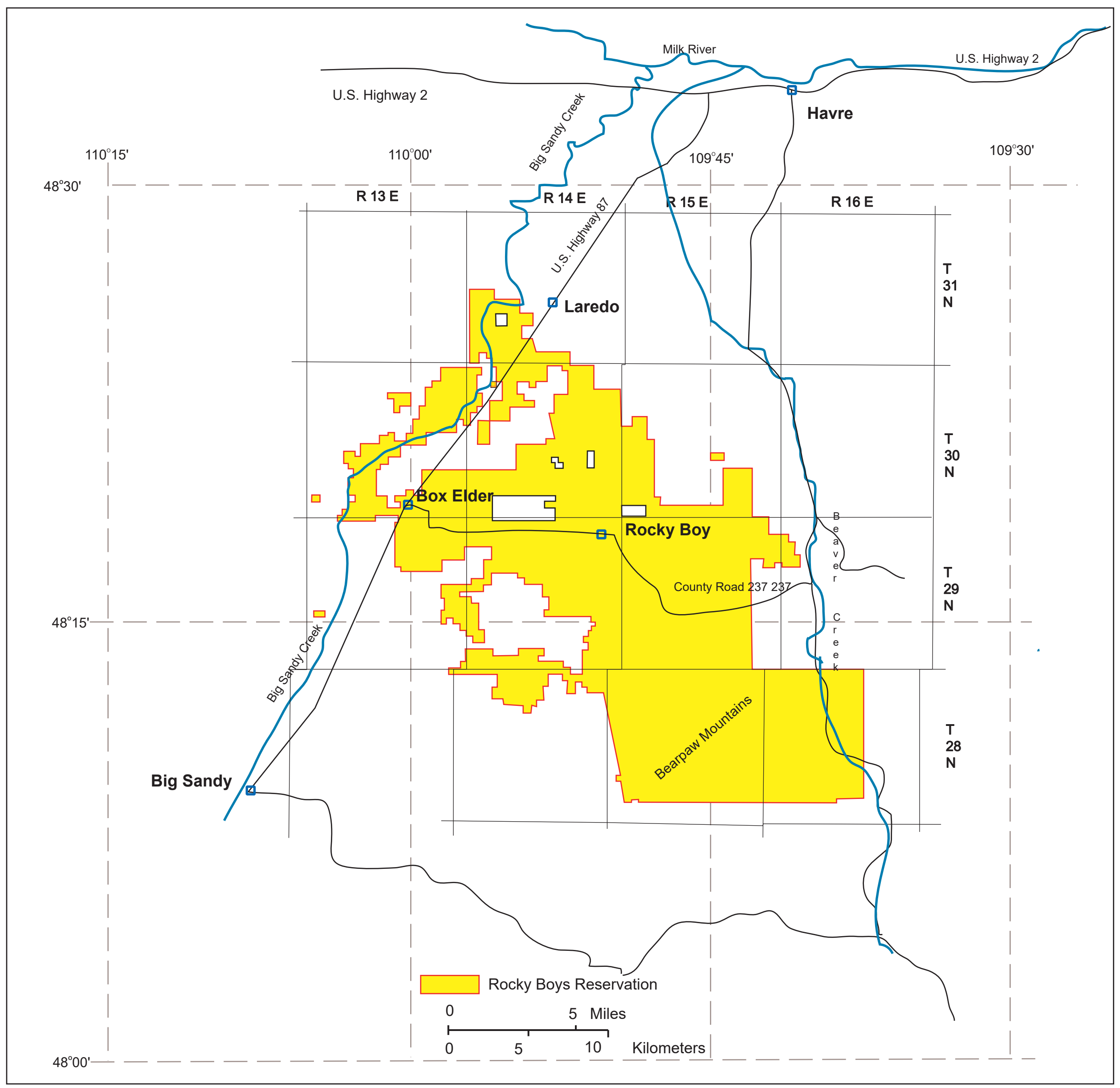


FIGURE RB-2. Rocky Boys Indian Reservation (modified after McNary, 1981).

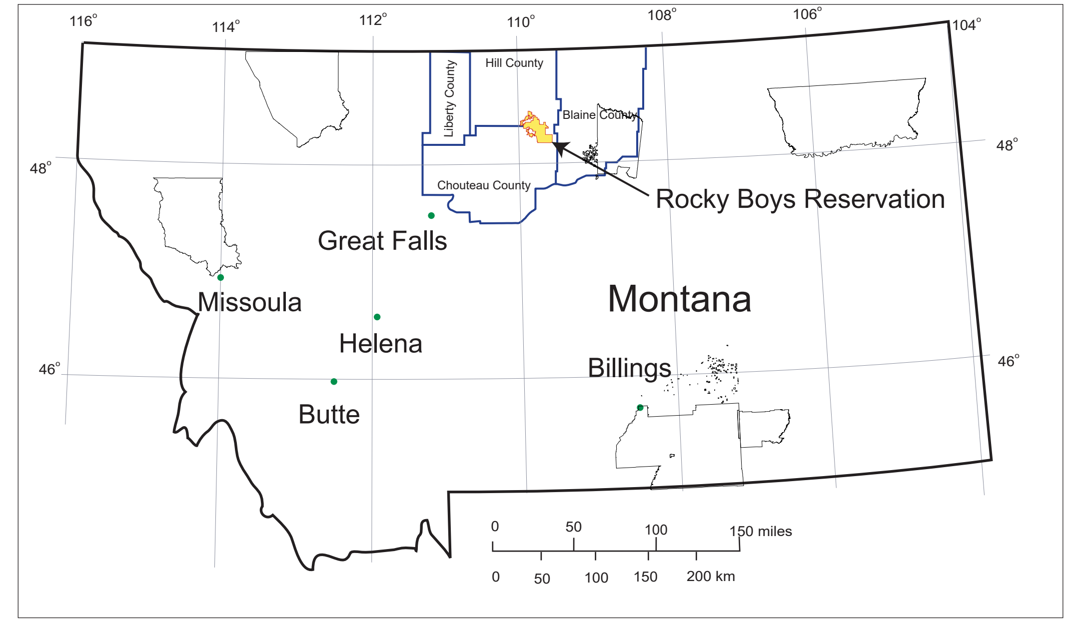


FIGURE RB-1. Location of Rocky Boys Indian Reservation, (modified after McNary, 1981).

PHYSIOGRAPHY AND CLIMATE

Rocky Boys Indian Reservation can be divided into three distinct physiographic units: alluvial flatlands, an upland surface, and the Bearpaw Mountains. The alluvial flatlands, locally known as Laredo Flats, are west of Highway 87 between Laredo and Box Elder and include the valley of Big Sandy Creek. The valley is the ancestral channel of the Missouri River. It is bounded by low bluffs made up of glacial drift. The valley is filled with gravel deposited by the ancestral Missouri River and glacial drift reworked by Big Sandy Creek (McNary, 1981).

The upland surface extends for about 5 miles from a line connecting Laredo and Box Elder southeast to the foothills of the Bearpaw Mountains (Figure RB-2). The surface is varied, ranging from plains floored by glacial till capping sedimentary rock, to buttes and ridges, coulee topography and badlands. Buttes and ridges are capped by resistant igneous rock. High alluvial terraces are present along the stream valleys. Pediment surfaces extend down the northern and western flanks of the bordering mountains.

The Bearpaw Mountains include most of the eastern and southern parts of the reservation (Figure RB-2). The mountains are made up of both intrusive and extrusive rocks (Figure RB-4). Several thousand feet have been eroded from the original surface, and the terrain has been thoroughly dissected by streams forming a dendritic drainage pattern. The mountain stream valleys tend to be narrow and have steep slopes.

Box Elder, Big Sandy, and Beaver Creeks and their tributaries are the major drainages on the reservation. Most of the streams in the Bearpaw Mountains are perennial. Except for the major creeks, the streams in the flatlands are intermittent.

Climatic conditions on the reservation vary depending on proximity to the mountains. Temperatures are warmer and precipitation is less in the plains areas. Most precipitation occurs in May, June, July, and August. Sudden thunderstorms are common in August. Summers are hot with temperatures of 90°F to 100°F. Winters are cold and severe with temperatures as low as -40°F. Stiff, gusty winds are common all year long.

REGIONAL STRUCTURE

Most of the principal structures in the central Montana region coincide with major lineaments (Figure RB-3). Regional structure is varied and made up of many faults, domes, and basins adjacent to the probable east-southeast extension of the Lewis and Clark Lane (Maughan and Perry, 1986). The lane is thought to be an ancient rift in the margin of the craton and can be projected from the Cordilleran miogeosyncline through western Montana into the continental interior (Figure RB-3). Many structures in central Montana seem to be associated with lineaments that cross the region along west-northwest trends that approximately parallel the trend of the Lewis and Clark Lane. The Nye-Bowler fault zone (Figure RB-3) occurs at the southern edge of the Lewis and Clark Lane, and the Lake Basin fault zone occurs along the approximate northern edge of the lane. The Musselshell lineament, the Flat Willow fault zone, and the Cat Creek fault zone, are parallel with the Nye-Bowler fault zone and the Lake Basin fault zone and have been the principal loci of tectonic movements within central Montana (Maughan, 1993).

Other structures are related to regional lineaments oriented along northwesterly and northeasterly trends (Figure RB-3). 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 (Figure RB-3). These northeast-southwest and northwest-southeast trending lineaments also have been the loci for many 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 late Precambrian and early Paleozoic times. Pronounced structures have formed at later times throughout the Phanerozoic, and especially during several episodic epeirogenic intervals during Middle to Late Devonian, Early Pennsylvanian to Early Permian, and Late Cretaceous and Early Tertiary time.

Central Montana was differentially elevated during Middle Late Devonian time and the older Paleozoic rocks were eroded from more elevated areas. The Devonian structures, although poorly known, 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 a return to north-south compression. Most faults reflect vertical movement, but the numerous en echelon faults of the Lake Basin zone suggest a shear component to Cretaceous aged structures along that lineament (Maughan, 1993).

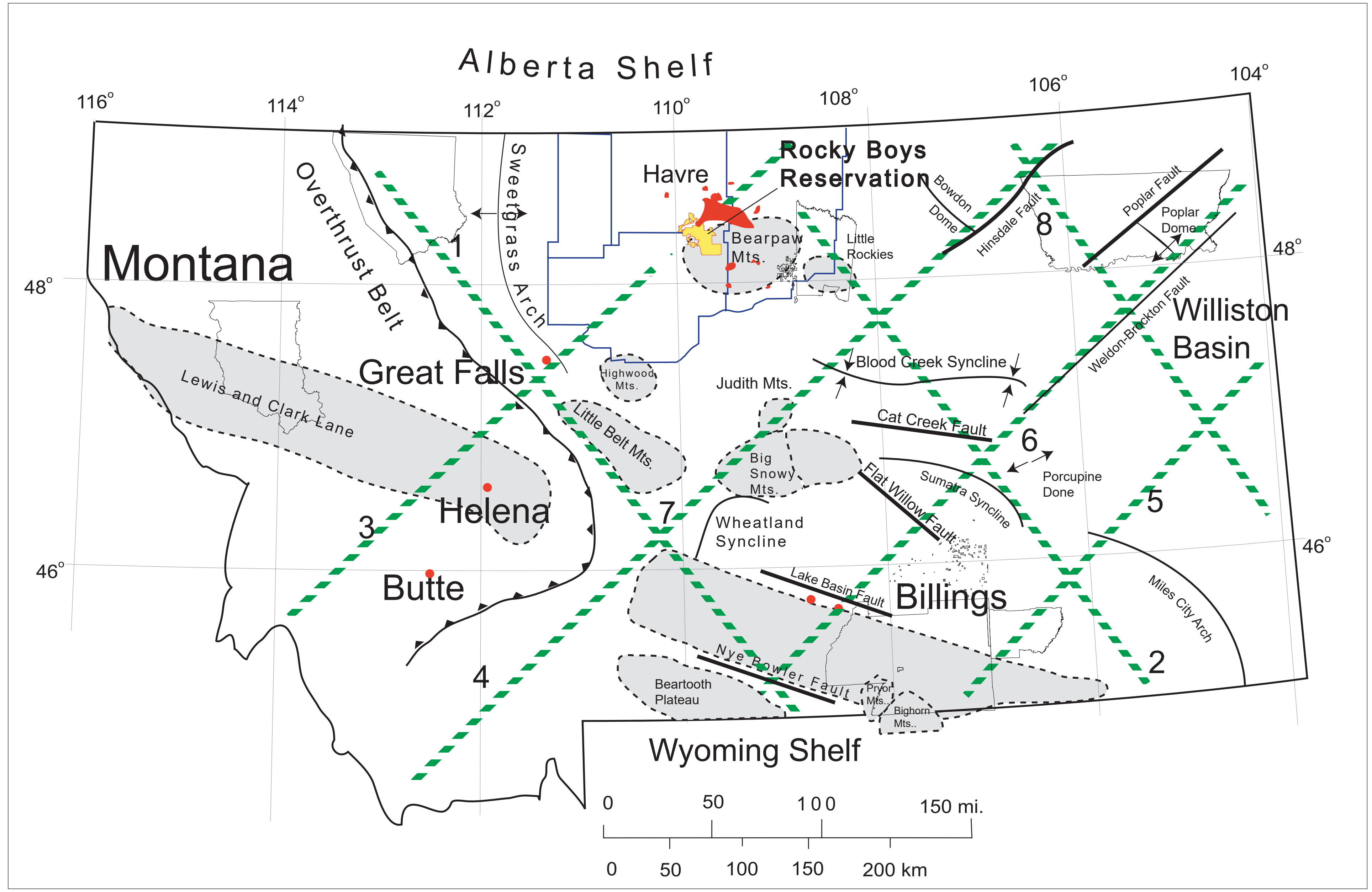


FIGURE RB-3. Principal structural features of Montana, major lineaments: 1, Bridger; 2, Chadron; 3, Great Falls; 4, Greenhorn; 5, Greybull; 6, Snake River-Yellowstone; 7, Musselshell; 8, Cedar Creek (modified after Maugahn and Perry, 1986). Other reservation outlines are also shown.

STRUCTURE AND GEOLOGIC HISTORY

Figure RB-4 is located along 48 degrees north latitude and illustrates structure, rock units and their relative thicknesses from the east margin of the overthrust belt on the west to the Williston Basin on the east. The Reservation is located on the east structural slope of the Sweetgrass arch and the central Montana uplift, (Figure RB-5) where Paleozoic and Mesozoic rocks descend into the Williston Basin of eastern Montana, North Dakota, and Canada (Grose, 1972).

This structural slope (Figure RB-5) is not uniform, but is interrupted by numerous uplifts caused by intrusion of igneous rocks in such ranges as the Sweetgrass Hills, Little Rocky Mountains, Moccasin, and Judith Mountains. The Bearpaw Arch extends toward the Basin nearly at right angles to the slope of the regional structure, and the reservation is situated on the crest and northwest flank of the arch.

Marine sedimentary rocks were deposited during part of Paleozoic and Mesozoic time. Near the end of the Mesozoic time, uplift of the Rocky Mountains to the west shed sandy sediments eastward and sedimentation changed from marine to continental. Some of the Mesozoic rocks are favorable host rocks for coal, oil, and gas (Mc Nary, 1981). The seas left Montana during Cenozoic (Paleocene) time and streams deposited coarse conglomeratic sediments in early Eocene (Wasatch) time.

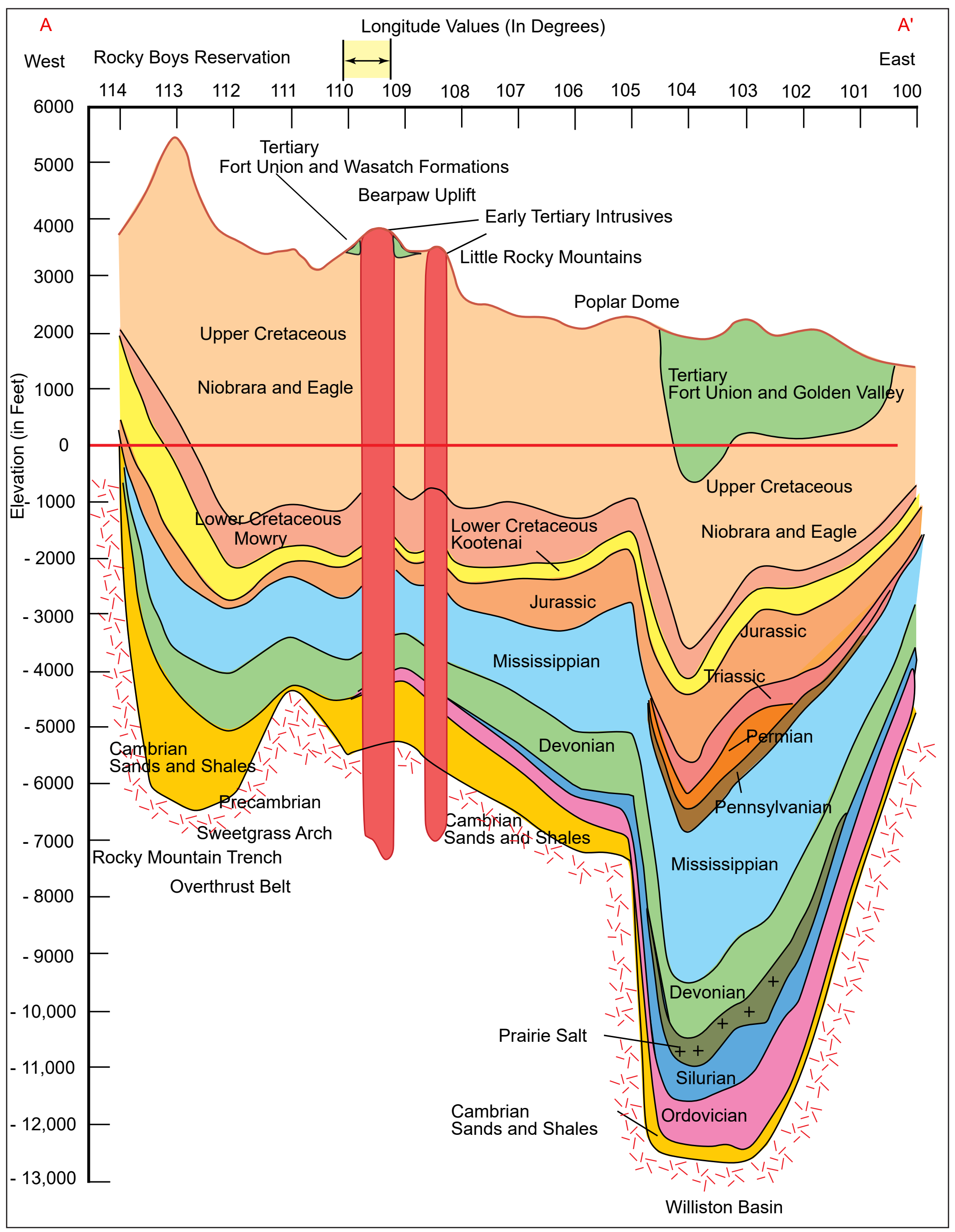


FIGURE RB-4. Diagrammatic cross-section along N48 degrees North Latitude.

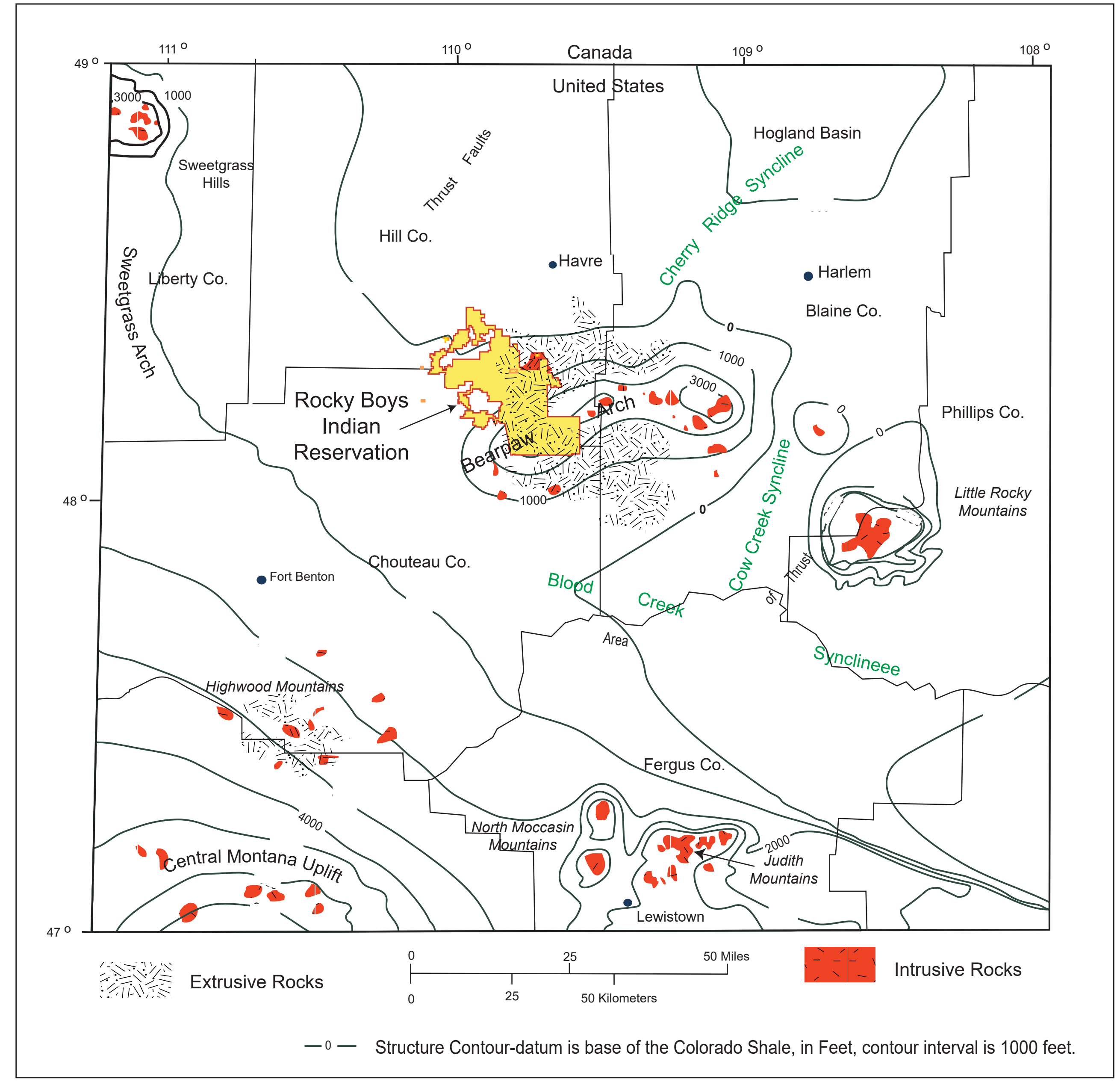


FIGURE RB-5. Regional structural setting of the Rocky Boys Indian Reservation (modified after Lindsey and others, 1977).

The Bearpaw Arch (Figure RB-5) rose in middle Eocene time, causing the Eagle Sandstone and younger rocks to break away from the rising Bearpaw Arch and slide down the north and south flanks of the arch (Reeves, 1946). The principal zones of sliding were along clay beds in the Colorado Shale. As slippage took place, faulting occurred in the beds overlying the thrust planes.

This complex history resulted in irregular zones of gas accumulation on the north and south sides of the arch that require intensive exploration to discover (Mc Nary, 1981). Each field's boundaries are determined by faults and each field has its own reservoir seal and hydrostatic pressure. These features are well-illustrated by Tiger Ridge Field located partially on the reservation.

Shortly after the rise of the Bearpaw Arch, alkalic magmas intruded the arch, and volcanic eruptions spread breccias and tuff over the arch to form the Bearpaw volcanic field (Figure RB-5). Eruption of similar rocks formed the nearby Highwood Mountains at about the same time. Sliding is thought by (Schmidt and others, 1964) to have preceded volcanism, but Hearn (1976) believes that sliding followed volcanism and involved the volcanic rocks in the slides, pulling the Bearpaw volcanic field away from the crested area of the arch. Streams breached the Bearpaw volcanic field in mid-Tertiary and late Tertiary time, exposing stocks and plugs of igneous rocks.

The distribution of the major rock types and important structures are shown on the geologic map of the reservation (Figure RB-6). The geologic map was compiled from maps by Hearn (1976), Pecora and others (1957a, 1957b), Kerr and others (1957), Stewart and others (1957), and Lindvall (1956, 1961).

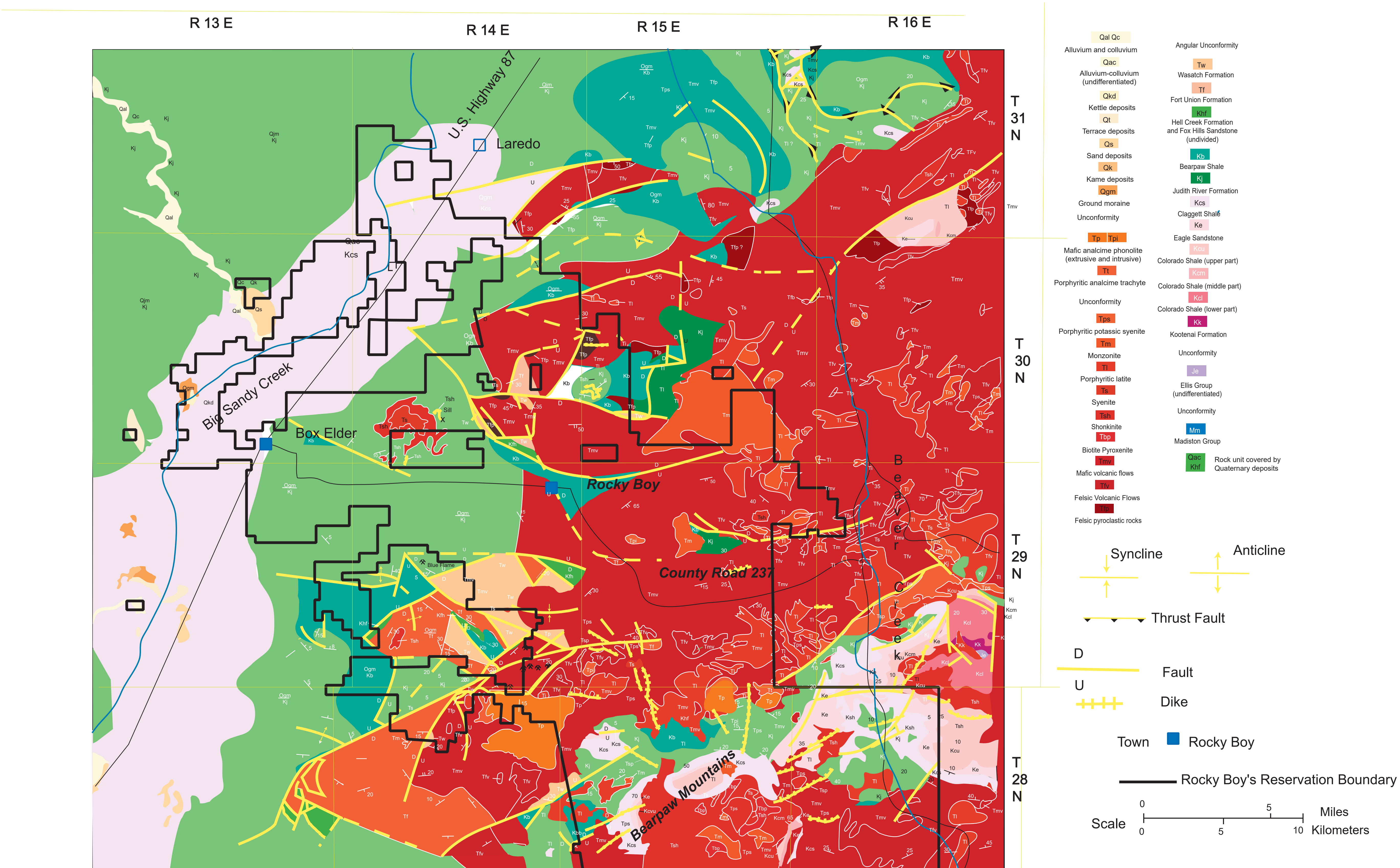


FIGURE RB-6. Geologic map of the Rocky Boy's Indian Reservation (after Hearn, 1976, Pecora and others, 1957a, 1957b, Kerr and others, 1957, Stewart and others, 1957, and Lindvall, 1956, 1961).

STRATIGRAPHY

Intrusive and extrusive rocks make up a thickness of 16,000 feet (McNary, 1981) and a section of almost 11,000 feet of sedimentary rocks which rest unconformably on Precambrian rocks (Barrs, 1972 and McNary, 1981).

Cambrian Period

Cambrian rocks in Montana consist of a sequence of marine sandstone, shale, and limestone, deposited across the early Paleozoic Rocky Mountain shelf during a broad eastward transgression of the Cambrian Cordilleran Sea (Figure RB-7). This sequence becomes progressively younger from west to east. During Middle and Upper Cambrian time, Northern Montana was a broad, relatively stable shelf covered by a shallow sea with local islands (Peterson, 1985). During Cambrian time the Sioux arch to the east was a source of coarse-grained clastics. Sediment graded from coarse-grained clastics to the east into shales and limestones to the west (Figure RB-7).

Thickness of the Cambrian rocks varies from over 3000 feet in the Montana Disturbed Belt to less than 100 feet at the eastern edge of the Williston Basin. Cambrian rocks on the Rocky Boys Reservation are about 1000 to 1100 feet thick.

Cambrian Rocks on the Rocky Boys Indian Reservation rest unconformably on Precambrian metamorphic rocks and are a sequence of marine sandstones, with interbedded limestones and shale that are broken down into two formations:

Emerson Formation (Late Middle to Late Cambrian) - fine sandstone, siltstone, and shale with thin impure carbonates.

Flathead Sandstone (Late Middle Cambrian) - coarse clastic rocks, conglomerates, and medium to coarse sandstones.

Reservoir quality sandstone and fractured quartzites with reservoir quality are present in the Deadwood Formation in the Williston Basin and the Bighorn Basin. The Deadwood is the time equivalent of the lower part of the Emerson Formation on the Reservation. Oil was discovered in 1978 in clastic Cambrian reservoirs of the Newporte field of North Dakota. Dark-gray marine shale beds in the upper Cambrian of the Williston Basin are probably the source rocks for gas in Cambrian sandstone reservoirs in the Williston Basin.

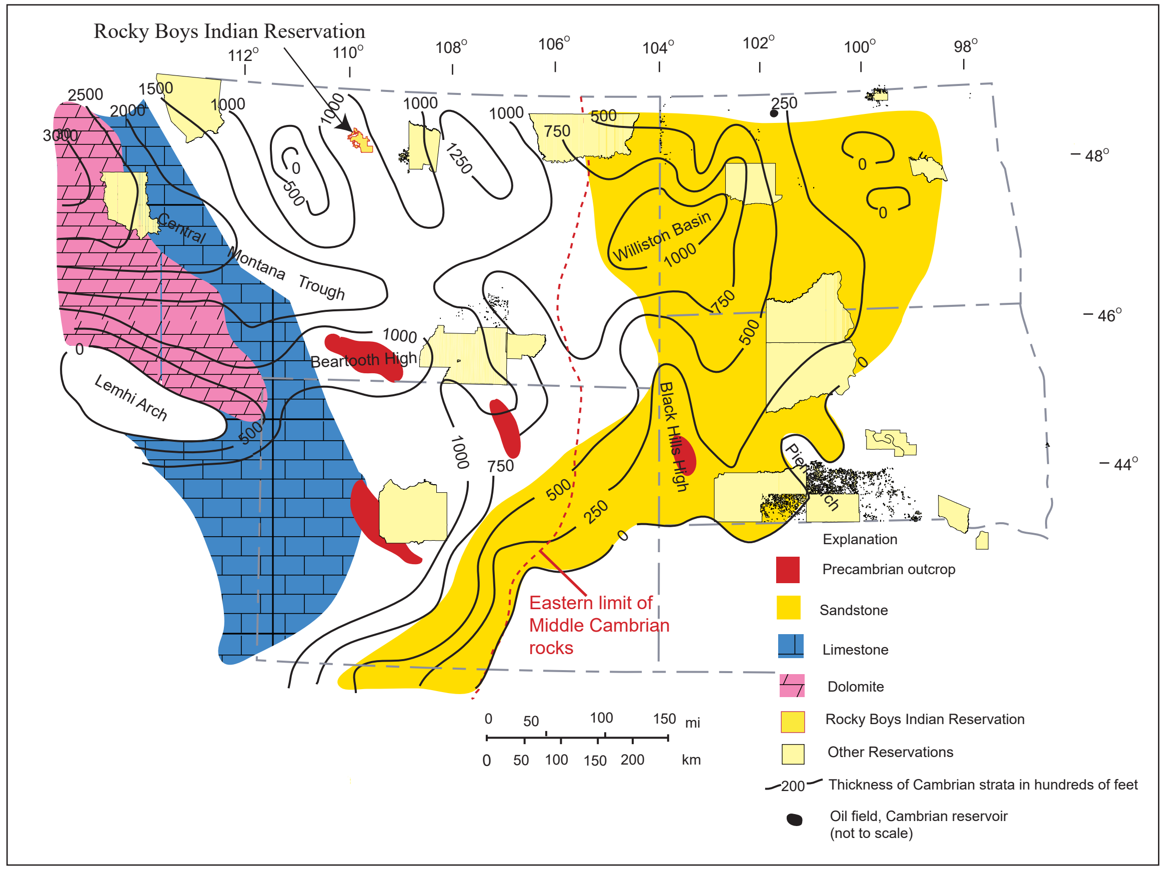


FIGURE RB-7. Thickness and general facies of Cambrian Strata (modified after Peterson, 1985).

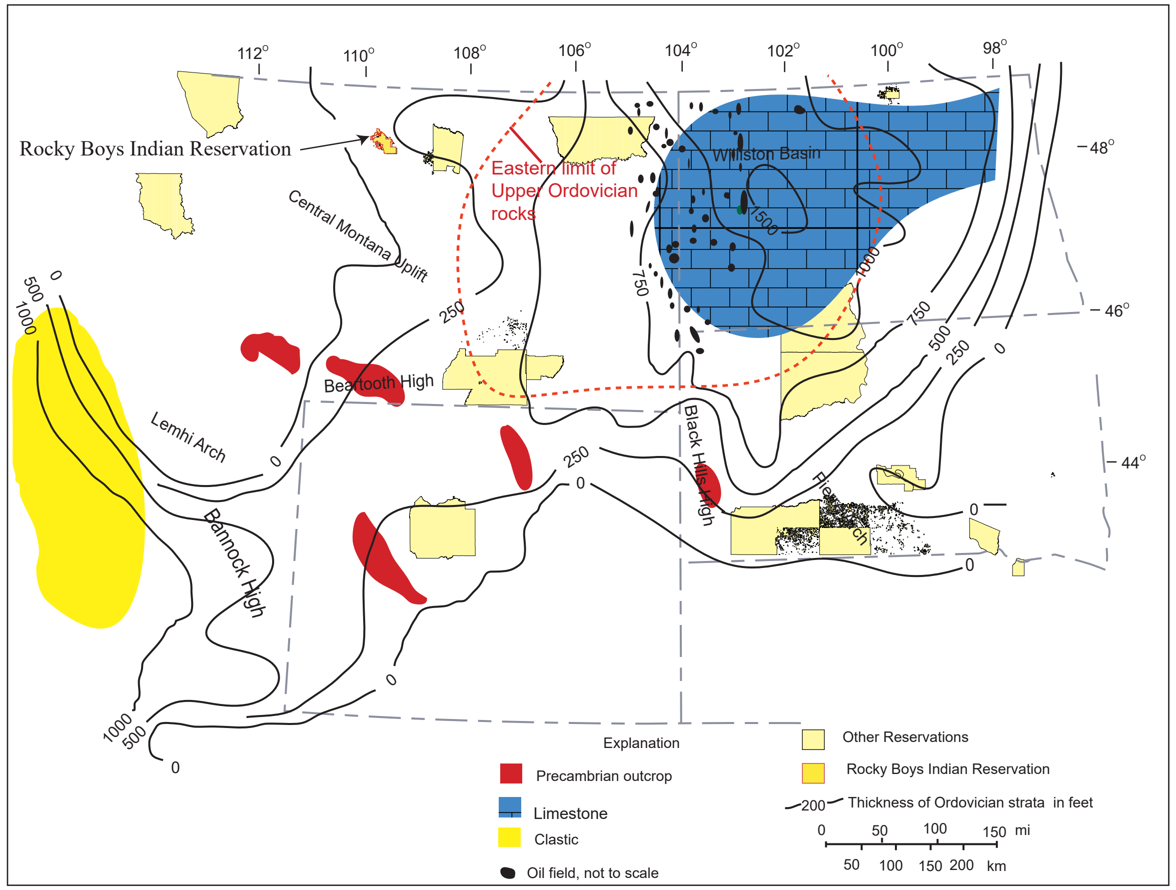


FIGURE RB-8. Thickness and general facies of Ordovician Strata (modified after Peterson, 1985).

Ordovician Period

The Rocky Boys Reservation, and most of Montana, was a relatively stable shelf during Ordovician time (Figure RB-8). The early and middle Ordovician equator passed through the Williston Basin, where Ordovician sediments were deposited unconformably on the Cambrian Deadwood Formation as part of a broad shelf-carbonate province that extended from Nevada to Saskatchewan and included the present Williston, Bighorn, and Powder River Basins (Campen, 1993). Ordovician sediments beneath the Rocky Boys Reservation rest unconformably on the Flathead Sandstone and are represented by less than 50 feet of Bighorn Dolomite.

Bighorn Dolomite - The Bighorn Dolomite of the northern Powder River and Bighorn Basins are time equivalents of the Red River Formation of the Williston Basin. Beneath the reservation it is made up of more than 80% dolomite.

Oil occurs in early, middle, and late Ordovician rocks in the Rocky Mountain region. The main productive formations are the Bighorn Dolomite and the Red River Formations. The gray shales of the underlying Lander and Winnepeg Sandstones are probable source rocks for most petroleum accumulations in Ordovician and Silurian carbonate reservoirs in the central plains and northern Rocky Mountain areas. They do not appear to be present beneath the Rocky Boys Reservation.

Silurian Period

Silurian rocks are not present beneath the Rocky Boys Reservation (Gibbs, 1972).

Devonian Period

In the Rocky Mountain region, Devonian rocks were deposited on a shallow, cratonic shelf that bordered the Cordillera. Middle Devonian and older Paleozoic rocks were partially eroded from highlands within and adjacent to the central Montana trough prior to Late Devonian time (Peterson and Smith, 1986). Deposition during late Devonian time was influenced by the complex interaction of epeirogenic warping of the craton and sea-level change. During late Devonian time, the craton divided into four shallow marine basins, all separated by low-lying arches, among them the Central Montana uplift, the Cedar Creek uplift and the Bearpaw anticline. The arches influenced sedimentation but were not prominent enough to be source areas of clastic sediment (Baars, 1972). Upper Devonian facies on the Rocky Boys Reservation were deposited as multiple transgressive and regressive marine cycles characterized by intertonguing of siliclastic sediments of terrigenous origin grading into carbonate rocks (Maughn, 1993). On the reservation, this sequence is about 750 feet thick (Figure RB-9), and is represented by the Three Forks Shale, Birdbear Formation and Jefferson Group.

The Three Forks Shale grades westward onto the Potlatch anhydrite of western Montana; it is made up of siltstone and shale with less than 20% carbonate. It is about 120 feet thick in the subsurface beneath the reservation.

The Birdbear Formation is a finely crystalline, light colored carbonate rock commonly capped with anhydrite, which is up to 125 feet thick. Its contact with the overlying Three Forks Shale is conformable in paleo-depressions, but erosional on positive surfaces.

The Jefferson Formation is 500 feet thick beneath the reservation and is made up of a series of incomplete cycles. The cycles grade upward from basal fine-grained clastics, to argillaceous carbonates capped by anhydritic dolomite and anhydrite.

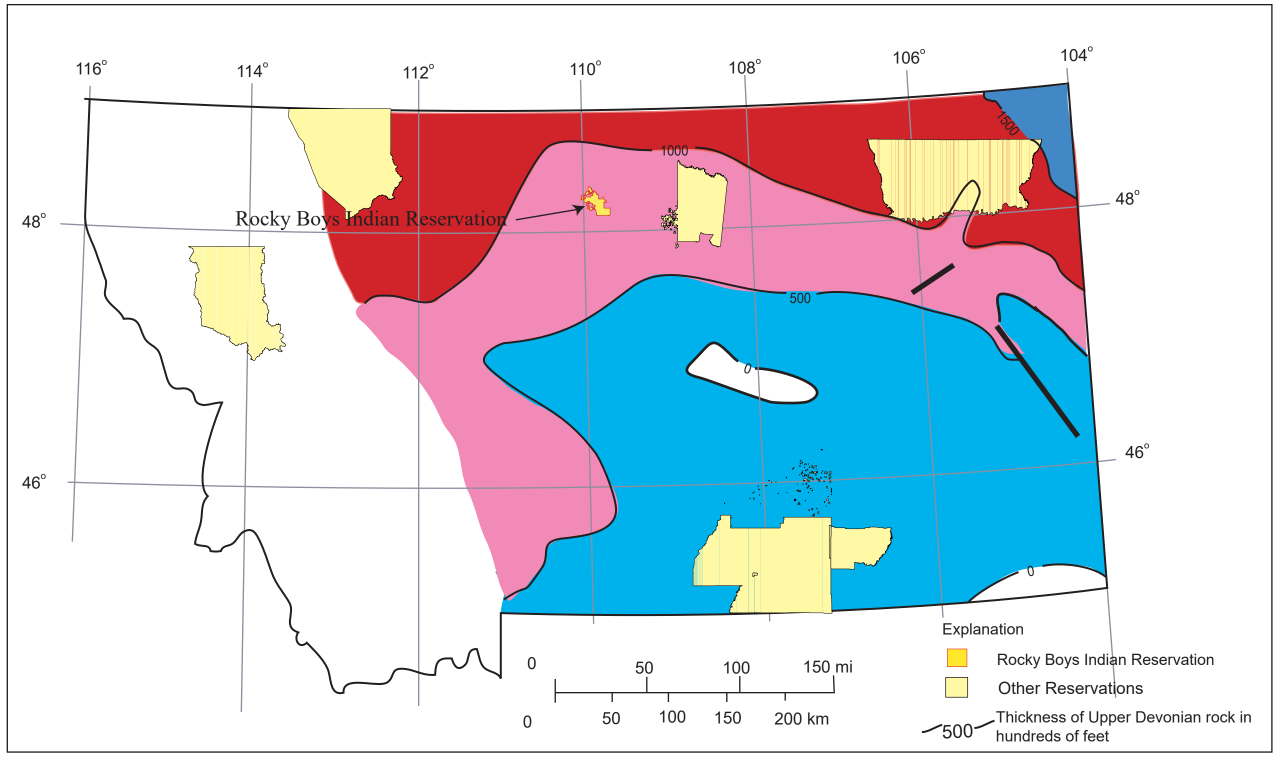


FIGURE RB-9. Thickness of Upper Devonian rocks in Montana (modified after Baars, 1972).

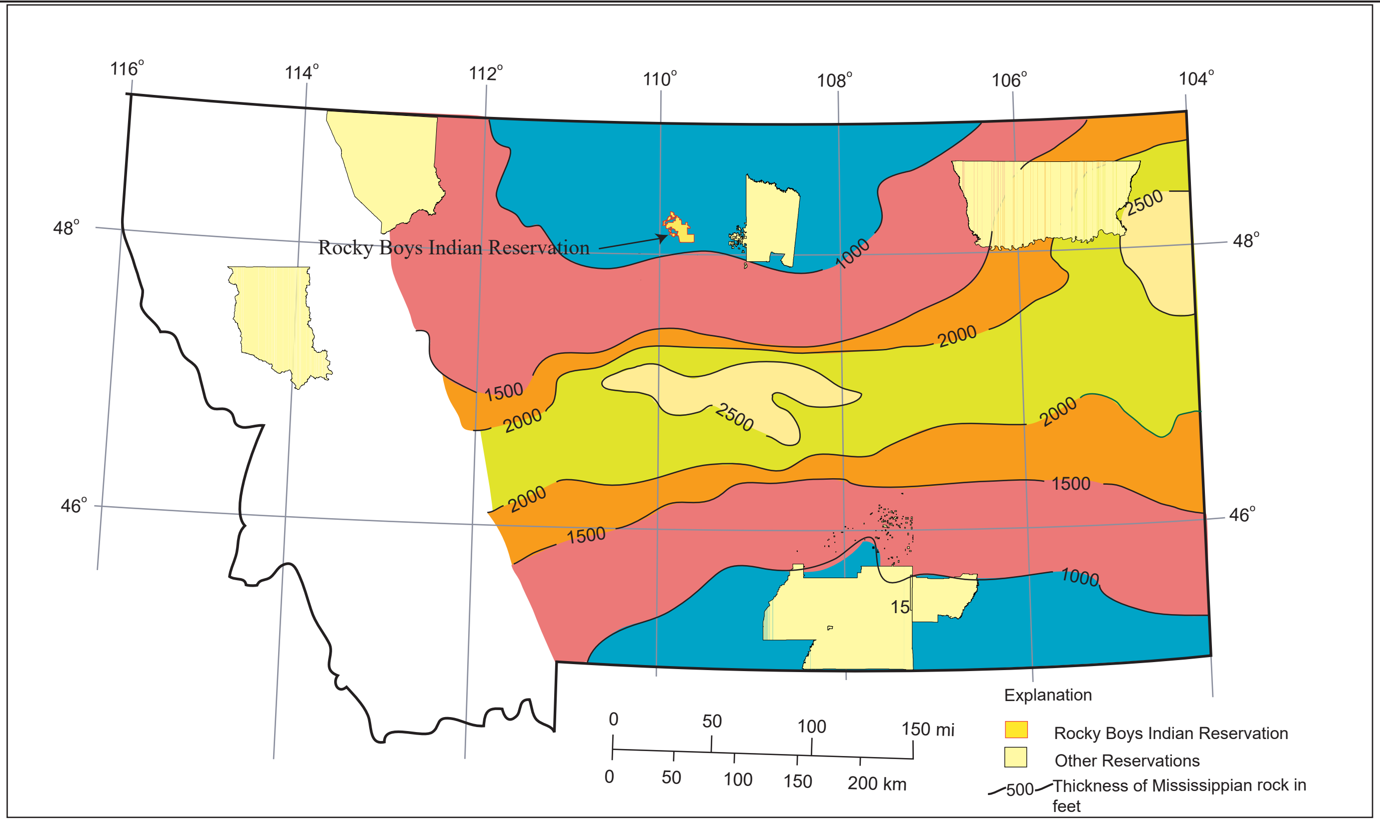


FIGURE RB-10. Thickness of Mississippian strata in central and eastern Montana (modified after Craig, et al, 1972).

Mississippian Period

During late Devonian and Early Mississippian time the black shales and siltstones of the Devonian-Mississippian Bakken, Exshaw, Englewood Formations and the Sappington Member of the Three Forks Formation were deposited in adjacent basins. However in the area of the reservation, these upper Devonian, lower Mississippian rocks were not deposited or were eroded in Mississippian time (Sandberg and Mapel, 1967).

The tectonic framework during early Mississippian time was similar to that of late Devonian time, with shallow basins developing between the low-lying arches. During middle and late Mississippian time a decrease in the supply of argillaceous and fine grained detrital material resulted in deposition of carbonates in shallow, normal marine waters. Deposition during Mississippian time, on the Rocky Boys Reservation, is represented by the Madison Group. The Madison Group is about 1000 feet thick in the reservation area (Figure RB-10) and is divided into four members:

The Paine Shale is a calcareous shale and shaley carbonate.

The Lodgepole Limestone Member consists of dolomite and chert at the base with gray, argillaceous and cherty, thin to medium-bedded limestone. The upper part is commonly medium to thick-bedded, dolomitic limestones and dolomites.

The Mission Canyon Limestone Member conformably overlies the Lodgepole. This formation is dolomitic limestone and dolomite, with anhydrite.

The Charles Member is an anhydrite overlain by tan to pink, anhydritic dolomites.

The reservoirs of the Madison Group produce from approximately 300 oil fields in the Williston, Powder River, and Bighorn Basins. Both matrix and fracture porosity are present. The black organic shales of the Bakken Shale Member and its equivalents, are considered to be the main source rock for most of the Mississippian oil produced from the Williston, Bighorn and Powder River Basins. These shales are considered both source rocks and targets of horizontal drilling in the Williston Basin and eastern Montana. The Bakken-Sappington and Exshaw facies of central and western Montana are not present beneath the reservation.

Pennsylvanian Period
No Pennsylvanian rocks are present on the reservation.

Permian Period
No Permian rocks are present on the reservation.

Triassic Period
No Triassic rocks are present on the reservation.

Jurassic Period
During Jurassic time, deposition of sediments in the area of the Rocky Boys Reservation occurred on the broad western continental shelf. The early through middle and continuing through the middle upper Jurassic sediments record three main regional marine transgressive-regressive events; 1) the Sawtooth-Gypsum Springs-lower Twin Creek cycle of Middle Jurassic age, 2) the Rierdon-lower Sundance-upper Twin Creek-Preuss cycle of early Late Jurassic age, and 3) the Swift-Stump-upper Sundance cycle Late Jurassic age. Each of the cycles is separated by a regional unconformity and each is successively more widespread than the previous period. Latest Jurassic time is represented by the continental vari-colored shale and sandstone beds of the dinosaur bearing Morrison Formation (Peterson, 1985). In late Jurassic time marine deposition was followed by continental deposition represented by the Morrison Formation. The thickness of Jurassic rocks in Montana and on the Rocky Boys Reservation is shown in Figure RB-11.

Jurassic rocks on the reservation are members of the Ellis Group and rest unconformably on the Madison Limestone. The Ellis Group crops out on the southern boundary of the reservation and is subdivided into three formations from youngest to oldest, Swift, Rierdon, and Piper:

The Swift Formation is made up of 110 feet of marine sandstone and shale.

The Rierdon Formation is composed of 75 feet of limestone and green-gray limey shale, with evaporites.

The Piper Formation is composed of limestone and gray shale with evaporites. It is 100 feet thick on the reservation.

The Morrison Formation is made up of a 75 foot thick series of channel sandstones, typically encased in green and purple shales. The contact of the Rierdon and the Morrison Formations is conformable, even though it represents a change in depositional environment from marine to continental.

The oldest Jurassic rocks present on the reservation are represented by the Piper Formation. During deposition of the Piper Formation, a large positive feature known as Belt Island was beginning to emerge in western Montana. Belt Island contributed very little sediment, but influenced patterns of sedimentation by restricting normal marine circulation to areas to the north and west. The red gypsum facies of the Piper Formation and the Rierdon Formation were deposited in a restricted marine area south and east of the emerging Belt Island. The Swift Formation was deposited in a shallow, open marine environment, generally thought to be part of a "Mediterranean-type" sea that extended inland from the Pacific Ocean through British Columbia. The Morrison Formation was deposited in fluvial, lacustrine and flood-plain environments. Clastic material was derived chiefly from erosion of sedimentary rocks to the west in central Idaho.

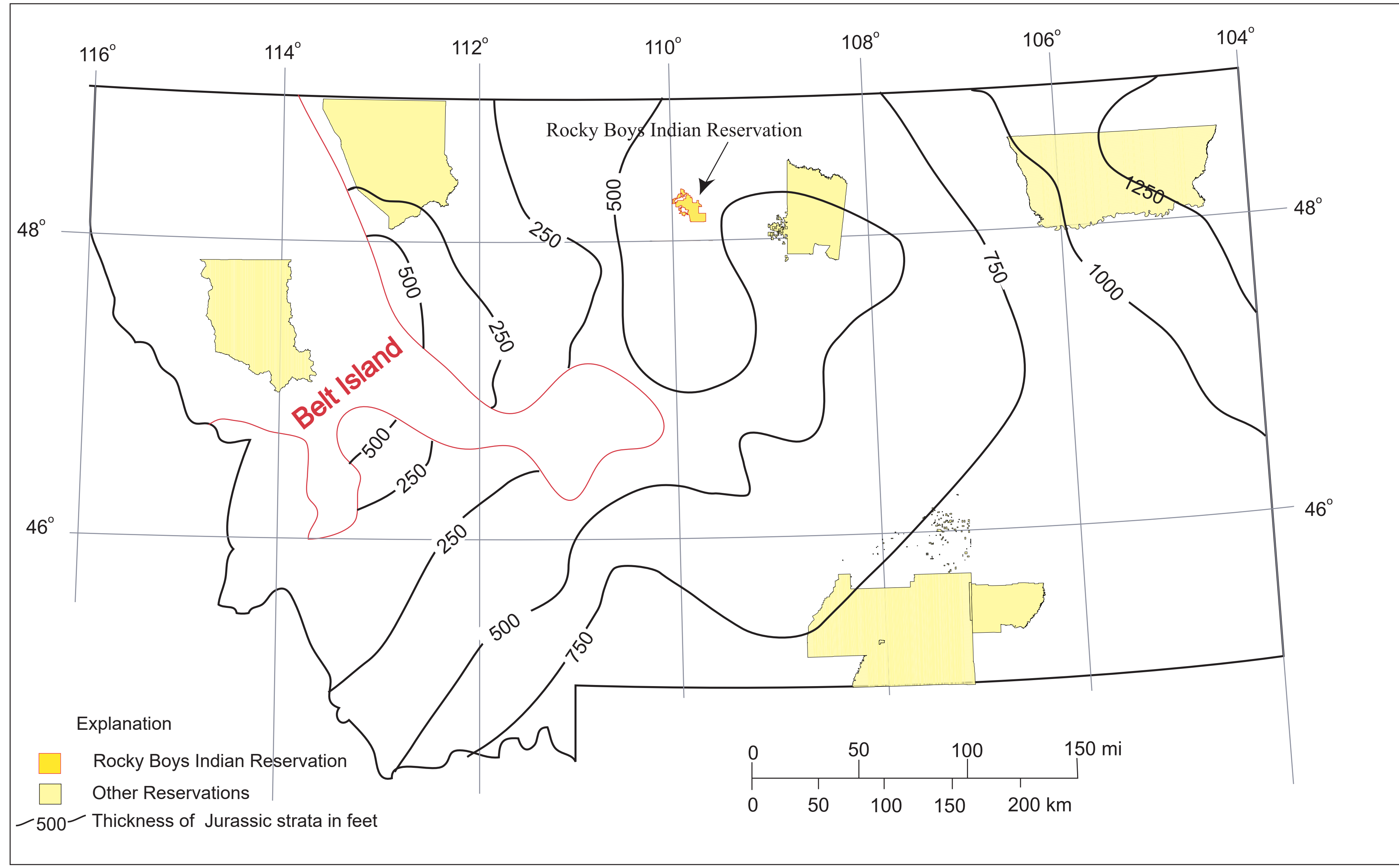


FIGURE RB-11. Thickness of Jurassic strata in Montana (modified after Peterson, 1972).

Jurassic Period *(continued)*

Figure RB-12 shows the paleogeography of the western U.S. in late Middle Jurassic to early Late Jurassic time (Callovian-Oxfordian). This time interval represents the maximum extent of the marine Sundance Formation in Wyoming, the upper part of the San Raphael Group in Utah and Arizona, and the Swift Formation in Montana. A marine basin lay cratonward of a plateau-like uplift that coincided with a wide volcanic arc. The axis of a north-south trending high in western Colorado probably controlled the distinct north-south coastal margin there. An elevated plateau merged southward with the Mogollon highland. This highland marked the northern terminus of the Chihuahua trough as seen on Figure RB-12 (Lawton, 1994).

Figure RB-13 shows the paleogeography of the western U.S. in Late Jurassic time (late Oxfordian-Kimmeridgian) and the distribution of depositional environments of the Morrison Formation. Accretion of arc terrain in the foothills of the Sierra Nevada caused an abrupt westward shift of subduction and abandonment of previous arc terrain in Nevada. Arc magmatism in California and Nevada persisted immediately following arc accretion, but became quiescent in Tithonian time. Wind directions (thick arrows, in Figures RB-12 and RB-13) indicate eolian foresets. Thin arrows indicate fluvial dispersal. The alluvial plain expanded eastward with time. Backarc extension of the Chihuahua trough was accompanied by mafic magmatism.

Both the Middle and Upper Jurassic rocks of northern and central Montana contain organic-rich shales, which are potential source rocks. This facies is present in the Rierdon, Swift, and Morrison Formations on the Rocky Boys Indian Reservation (Campen, 1993).

Cretaceous Period

Cretaceous sediments on the Rocky Boys Indian Reservation accumulated in and adjacent to the broad north-trending Cretaceous epeiric seaway which was present throughout most of Cretaceous time. To the west the seaway was bordered by the Cordilleran thrust belt. It was underlain and bordered to the east by the cratonic platform (Figure RB-14). Sedimentation was controlled by tectonic activity associated with the Sevier and Laramide orogenies. Many of the source rocks and major reservoir rocks of the Northern Rocky Mountain region were deposited during transgressions and regressions of the Cretaceous sea.

Lower Cretaceous

Sediments deposited in the area of the Reservation during Lower Cretaceous time were part of a foreland sedimentary package that formed an eastward thinning foreland wedge on the east side of the North American thrust belt. At the end of Jurassic time, the shelf was covered with a blanket of varicolored mud, sands, gravel, silt, and lacustrine sediments. At the beginning of Lower Cretaceous time these sediments were incised by down-cutting fluvial systems responding to a low-stand of sea level (Porter et al., 1993). The Lower Cretaceous section above the basal conglomerates and sandstones is dominated by shale, with sandstone and conglomerate tongues (Figures RB-15 a and b and Figure RB-16).

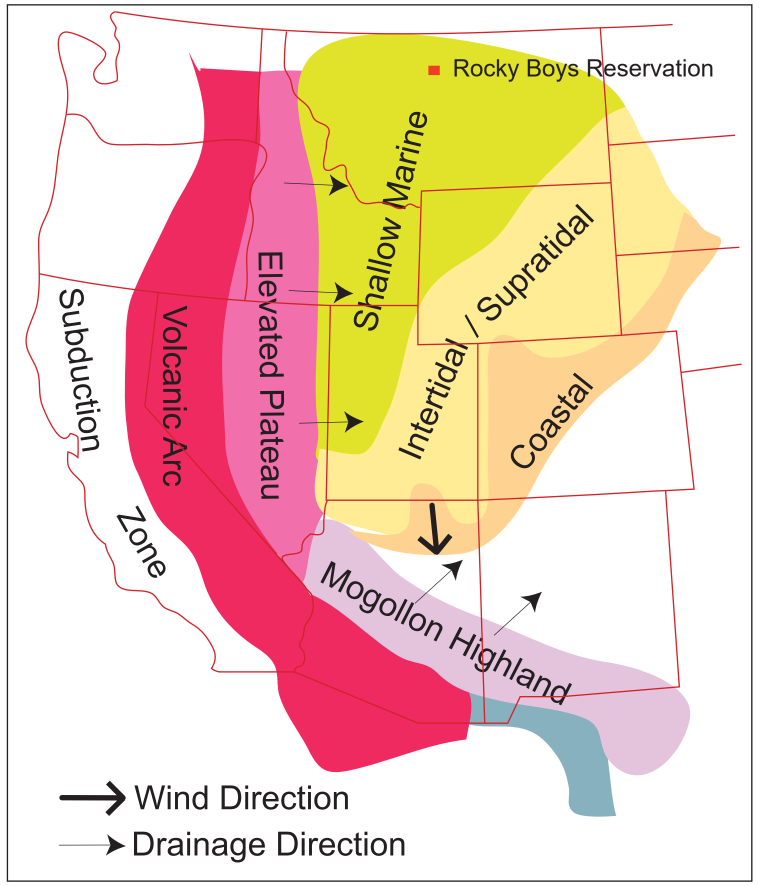


FIGURE RB-12. Middle to early late Jurassic (Swift/Rierdon) paleoenvironments (modified after Lawton, 1994).

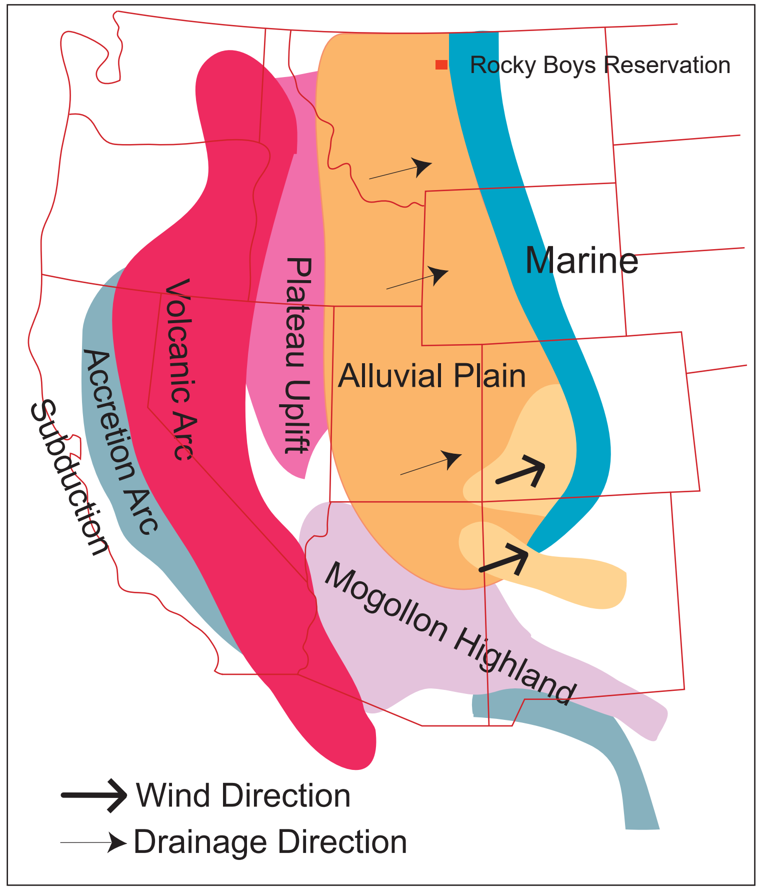


FIGURE RB-13. Late Jurassic (Morrison) paleoenvironments (modified after Lawton, 1994).

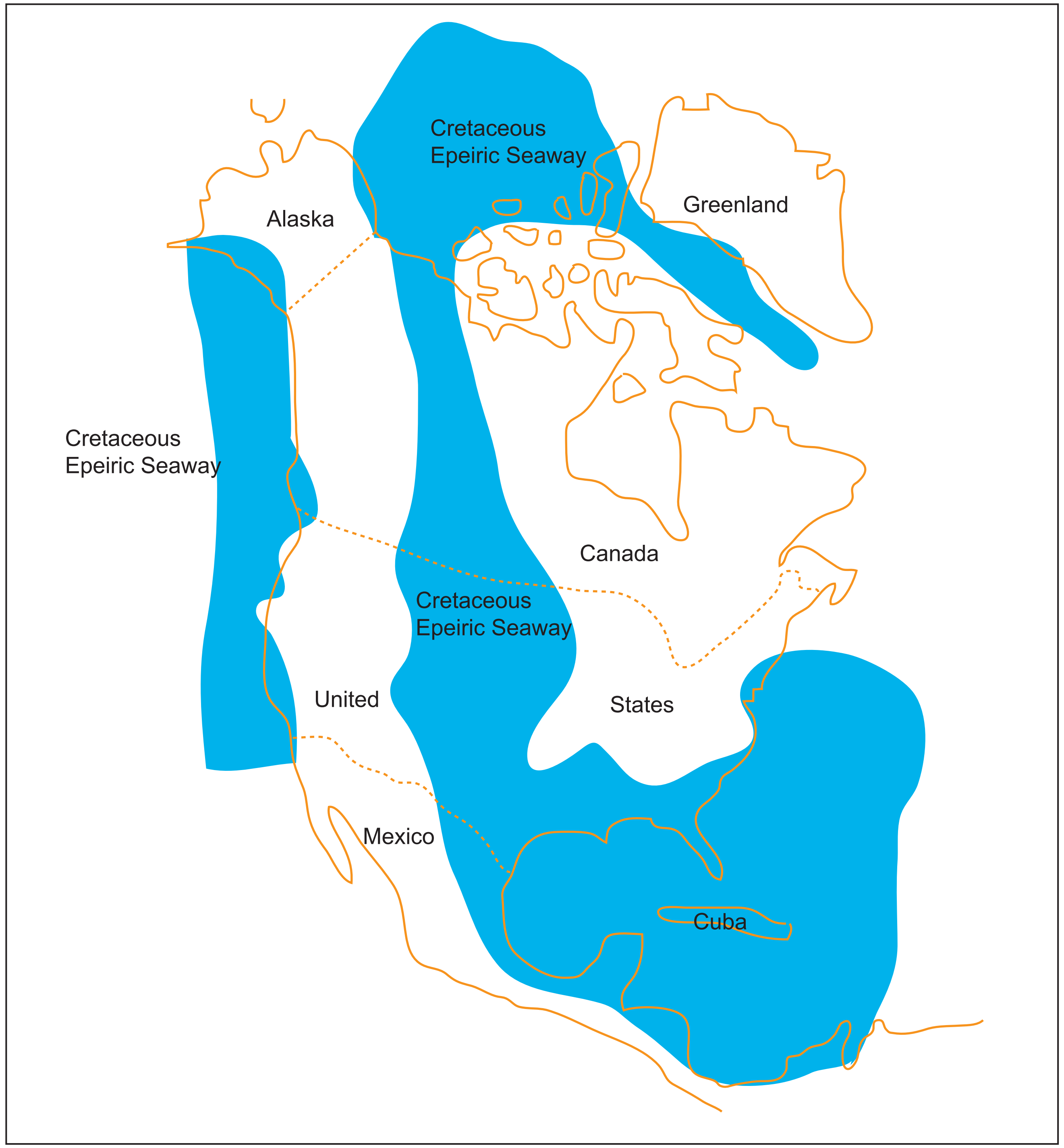


FIGURE RB-14. Paleogeographic map of North America during Late Cretaceous time, showing the Cretaceous seaway (modified after Rice and Shurr, 1980).

Lower Cretaceous

Lower Cretaceous time is characterized by deposition of thick marine shale, interbedded with thin siltstone and sandstone. This lithology suggests recurrent movement to the west and rapid rates of subsidence and deposition along the shoreline of the Western Cretaceous Seaway (Figure RB-15 a).

The Kootenai Formation unconformably overlies the Morrison Formation and is 250 feet thick. The Kootenai Formation is composed of non-marine sandstone, variegated siltstone and shale and dark gray limestone, with thin beds of carbonaceous shale and lenticular sandstone beds. The base of the Kootenai Formation is characterized by sandstone, locally known as the Third Cat Creek Sandstone. The Third Cat Creek Sandstone is thought to be equivalent to the Pryor Member of the Cloverly Formation.

The Thermopolis / Skull Creek Shale is about 700 feet thick and is the lateral equivalent of the Newcastle Shale. On the reservation, it is a black marine shale, with sandstone and bentonite beds, concretionary iron rich claystone, and thin beds of glacounitic claystone. The basal Skull Creek Formation is thought to be the equivalent of the Fall River Sandstone and also known as the "Rusty Beds" member. A silty sandstone occurs near the base of the Mowry Shale; it is locally known as the Bow Island Sand and may be the equivalent of the Muddy Sandstone.

The Mowry Shale is from 50 to 100 feet thick and overlies the Thermopolis/Skull Creek Shale on the reservation. It consists of thin-bedded to very finely laminated marine shale, and very fine grained sandstone. It is characterized by abundant fish scales. The top of the Mowry Shale is marked by a prominent bentonite bed.

Upper Cretaceous

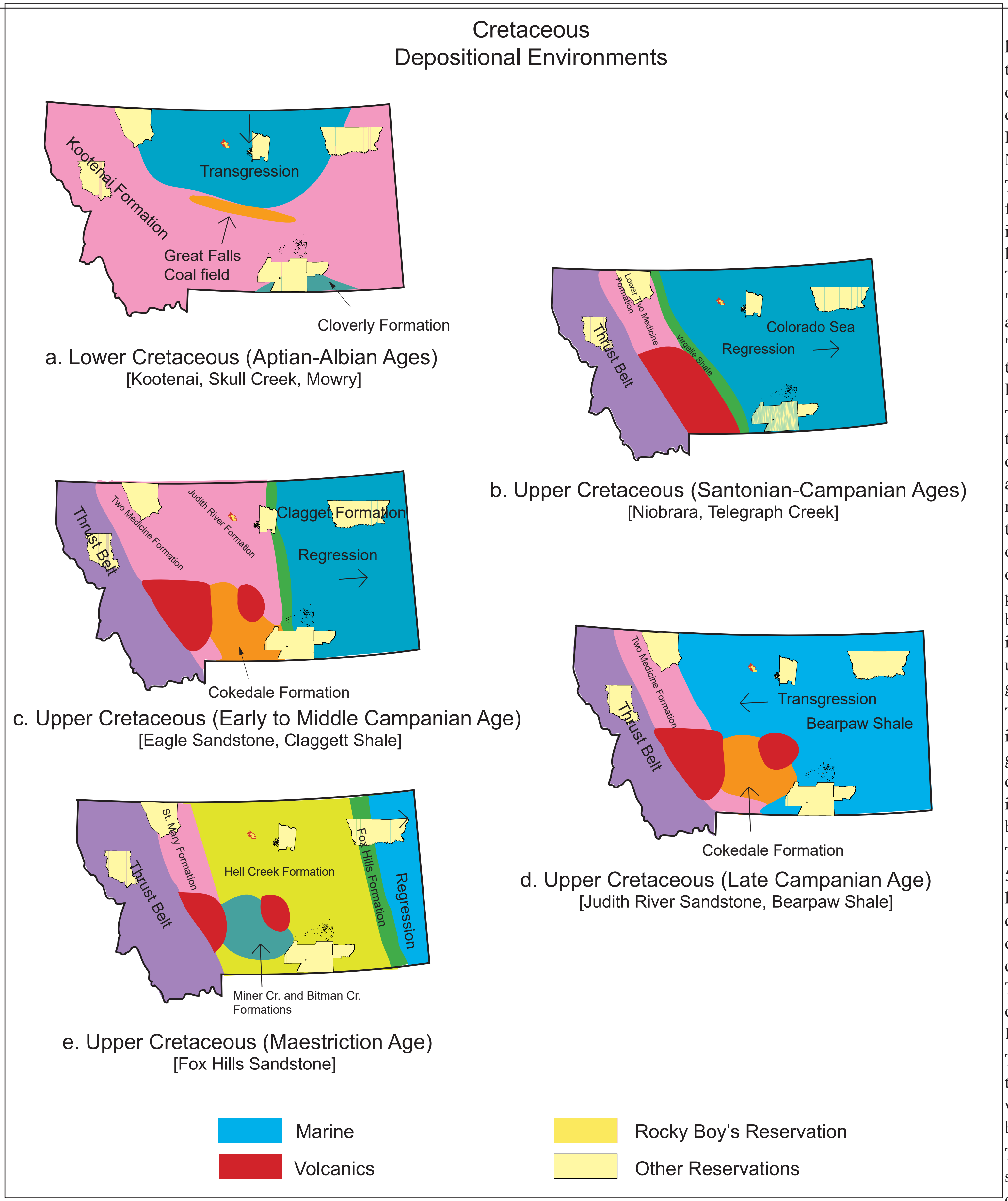
The Upper Cretaceous is characterized by a series of marine and non-marine transgressive and regressive clastic sequences dominated by an epicontinental sea. Laterally extensive bentonite beds represent volcanic episodes within this time frame. During mid- to late-Cretaceous time, the foreland was broken by eastward-younging Laramide uplifts that sequentially deformed the sedimentary wedge (Figures RB-15 b-e).

The Bell Fourche Shale (Colorado Group Member) is 200 feet thick on the reservation. It is a dark gray, nonfossiliferous shale with mudstone and siltstone. A chert pebble unit occurs about 150 feet below the base of the Greenhorn Limestone.

The Greenhorn Limestone (Colorado Group Member) is from 20 to 40 feet thick and is a blue gray, thin-bedded silty and sandy limestone, calcareous and non-calcareous shale with marine fossils.

The Carlile Shale (Colorado Group Member) is 250 feet thick on the reservation. It conformably overlies the Greenhorn Limestone and is made up of black silty and sandy, hard non-fossiliferous, marine shale. It contains no bentonite beds. A limey layer containing ammonites is present about 200 above the base.

The Niobrara Shale (Colorado Group Member) is 600 feet thick on the reservation and is characterized by dark-gray, very thinly laminated marine shale, numerous bentonite beds up to 18 inches thick, thin sandstone beds, thin limestone beds, limestone concretions, and diagnostic marine fossils. The Niobrara Shale is correlative with the Colorado Shale of the Bighorn and Powder River Basins. Volcanic activity in the Elkhorn Mountains of west central Montana was the source of the bentonite.



FIGURES RB-15 a to e. Cretaceous depositional environments (modified after Horner, 1989).

The Telegraph Creek Formation (Montana Group Member) is 300 feet thick on the reservation, and consists of gray to brownish gray, inter-layered, thin-bedded sandstone, mudstone, and shale and thin lenses of concretionary limestone with diagnostic marine fossils. The Telegraph Creek Formation marks the beginning of the "Claggett" cycle and is characterized by intermittent transgressions and regressions of the Cretaceous Sea. The regressive stages of the "Claggett" cycle are characterized by a number of prograding clastic tongues, the Elk Basin Sandstone Member, Telegraph Creek Formation and The Eagle Sandstone.

The Eagle Sandstone (Montana Group Member) is 275 feet thick on the reservation. It is composed of a series of light-brown sandstone deposited in marine and brackish water, thin-bedded shale, siltstone and thin carbonaceous mudstone. The lower Virgell Sandstone member is a massive bluff-forming sandstone as much as 80 feet thick. The top of the Eagle Sandstone is locally characterized by one or more chert-pebble conglomerate beds. The Eagle Sandstone overlies the Telegraph Creek Formation and represents a regressive phase of the Cretaceous Seaway. Regionally, it is a series of thick, blanket-like sandstones deposited in wave-dominated deltaic and interdeltaic environments. It is overlain by nonmarine rocks. The upper part of the Eagle Sandstone locally yields abundant natural gas.

The Claggett Shale (Montana Group Member) is 500 feet thick and is a brownish-gray to brown, fissile marine shale with light-gray gypsiferous claystone and bentonite beds. The Claggett Shale contains numerous limestone concretions with diagnostic marine invertebrate fossils. The basal portion is characterized by multiple bentonite beds. The Claggett Shale is equivalent to the Pierre Shale.

The Judith River Formation (Montana Group Member) is from 550 to 650 feet thick on the reservation and is composed of a light-gray, non-marine sandstone, light-gray siltstone and gypsiferous claystone. There are local reddish-brown lignite beds and carbonaceous shales. The lower part of the formation is characterized by massive, thick-bedded, ledge-forming sandstone. The upper part of the formation is characterized by dark-brown, cross-bedded, concretionary sandstone lenses and oyster shell beds. Lignite beds are extensive.

The Bearpaw Shale (Montana Group Member) is 1200 feet thick on the reservation and is composed of dark-gray fissile marine shale, with light-gray gypsiferous claystone and light-gray to cream bentonite beds in the lower one third. Marine fossils are common.

The Fox Hills Sandstone is a light-gray, thin to thick-bedded marine sandstone with minor interbedded shale and siltstone, weathering to dark yellow and brown. The Fox Hills Sandstone and the Hell Creek Formation have a combined thickness of 500 to 600 feet.

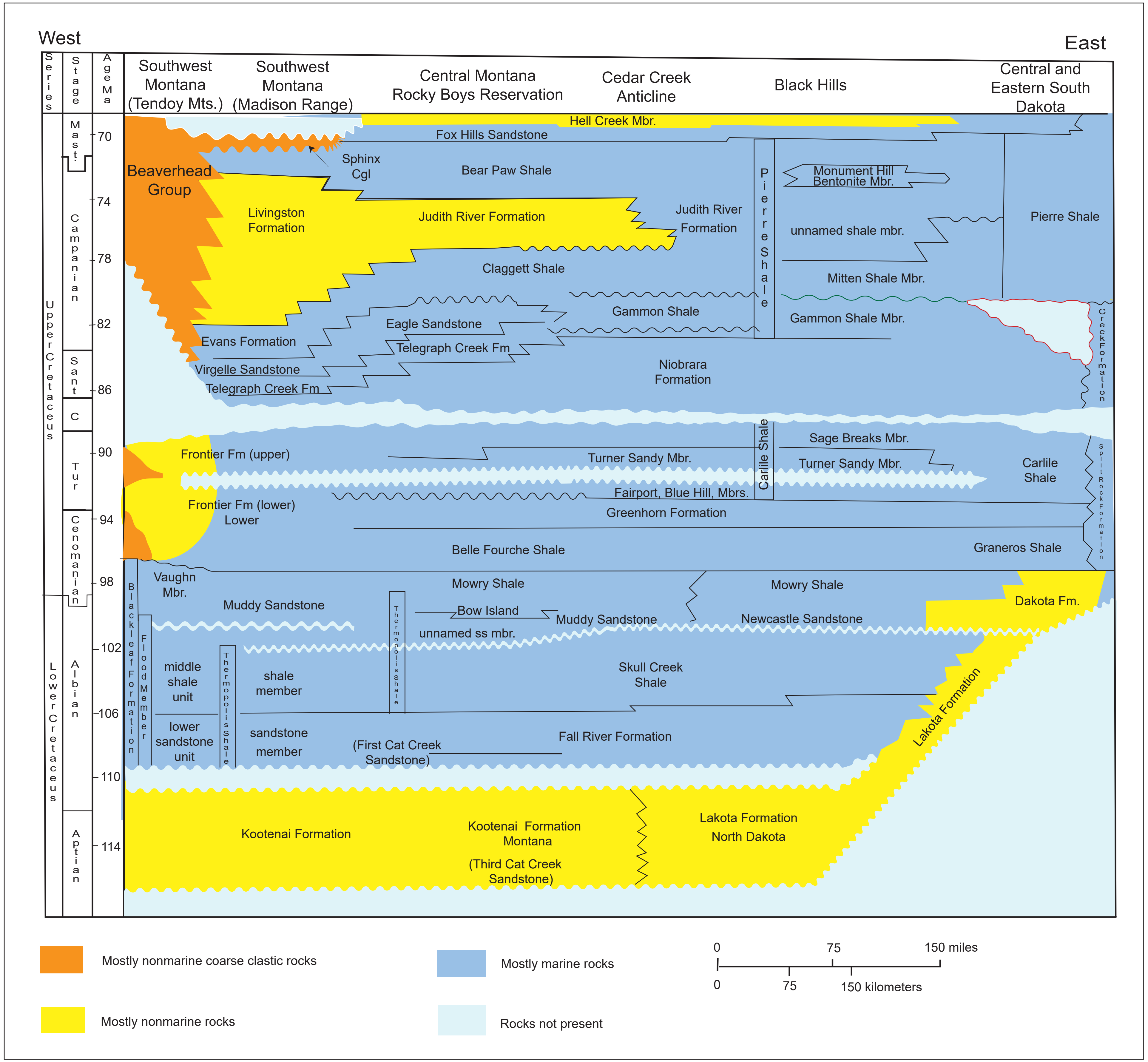


FIGURE RB-16. West-east chronostratigraphic cross section of Cretaceous rocks from southwestern Montana to eastern South Dakota (modified after Dyman et. al, 1994).

Upper Cretaceous *(continued)*

The Hell Creek Formation is a gray to light-brown, locally massive, non-marine sandstone, with brown sandstone concretions, white to light-colored siltstone, claystone and shale, partly calcareous with abundant calcareous concretions. A brownish-gray, carbonaceous, bentonitic claystone occurs near the base.

Tertiary Period

The Fort Union Formation conformably overlies the Hell Creek Formation and is composed of yellowish-gray and grayish-brown, thick-bedded, ledge-forming, nonmarine sandstone; light-gray, thin-bedded sandstone; greenish-gray siltstone and sandy shale; bentonitic siltstone, carbonaceous shale; and mineable coal beds.

The Wasatch Formation conformably overlies the Fort Union Formation and is characterized by variegated beds of nonmarine siltstone, cross-bedded sandstone, bentonitic mudstone and claystone. Channel-boulder conglomerate lenses occur in the upper part. It contains numerous fossil teeth and plants. Intrusive and extrusive rocks unconformably overlie the Wasatch Formation. They occur as plugs, dikes, sills, flows, and flow breccias. Compositions range from potassic syenite to biotite pyroxenite.

Quaternary

Pleistocene deposits are characterized by terraces, sand deposits, kame, ground moraine and kettle deposits. Terraces, are made up of unconsolidated, interbedded silt, sand, and gravel. Sand deposits, including dune deposits, are characterized by unconsolidated, light-brown to gray, well-sorted, medium- to fine-grained sand. Kettle deposits are characterized by dark-gray, plastic clay containing small amounts of silty clay, silt, and sand. Kame deposits are unconsolidated, stratified or semistratified, light-brown sand and gravel containing small amounts of silt and clay. Ground moraine deposits are characterized by compact, but unconsolidated, unstratified mixtures of buff to light-gray clay, silt, and sand containing small amounts of pebbles, cobbles, and boulders.

Recent

Recent deposits include alluvium and colluvium, consisting of unconsolidated, interbedded clay, silt, sand, and gravel. Coarse rubble and mud locally accumulated as colluvium and landslides.

PLAY SUMMARY TABLE

Reservation: Rocky Boy's
Geologic Province: North Central Montana
Province Area: North Central Montana (62,500 sq. miles)
Reservation Area: 947 sq. miles (606,080 acres)

Total Production (by province-1996)

Oil: North Central Montana
Gas: 440 MMBO
NGL: 1.1 TCFG

Undiscovered resources and numbers of fields are for Province-wide plays. No attempt has been made to estimate number of undiscovered fields within the Rocky Boy's Indian Reservation.

	Play Type	USGS Designation	Description of Play	Oil or Gas	Known Accumulations	Drilling depths	Favorable factors	Unfavorable factors
1	Upper Cretaceous Biogenic Gas Play	2809	Porous and permeable sandstones of Upper Cretaceous age (Eagle and Judith River) Biogenic gas accumulations.	Biogenic Gas	Equivalent to accumulations at Tiger Ridge. 3.5 TCF from numerous fields in state	700-3000 ft.	1) Gas shows southern end of reservation 2) Shallow drilling 3) Structures present; domes faults 4) Source rock-self source	1) No production on reservation 2) Lack of well control 3) Reservoir rock unknown 4) Size of accumulation unknown
2	Lower Cretaceous Sandstones	2808	Stratigraphic traps; discontinuous sands, updip pinchouts. Stratigraphic pinchouts of fluvial and near-shore sandstones in equivalents of the Swift and Kootenai Formations.	Both	534 MMBO 1.3 TCFG (Montana cumulative production)	1000-4000 ft.	1) Gas shows north and west of reservation 2) Structures present; domes, faults 3) Source rock/ self source	1) No production on reservation 2) Lack of well control 3) Reservoir rock unknown 4) Size of accumulation unknown 5) Mountains, strong hydraulic gradient-flushed? 6) Lack of well control
3	Jurassic Ellis Group	2807	Folded structures, porosity controlled by matrix or fractures.	Both	83.5 MMBO 180 BCFG (numbers include Bowes, Sawtooth, Firemoon, Swift, Piper, Sundance, Morrison and Rierdon).	1,000-6,700 ft.	1) Structures exist; folds faults, domes 2) Reservoir rock exists 3) Regionally thermally mature	1) No production on reservation 2) Rocks exposed to at the surface in the Little Rocky Mountains: strong hydraulic gradient-flushed? 3) Lack of well control
4	Mississippian and Devonian Carbonates	2805	1) Jurassic/Mississippian regional unconformity traps 2) Devonian structural traps	Both	541 MMBO 220 BCFG (numbers include Mississippian Charles, Ratcliff, Mission Canyon, Heath, Midale, Lodgepole, Nisku, Duperow, Dawson Bay and Winnepegosis).	1,300-7,000 ft.	1) Structures exist; folds, faults, domes 2) Reservoir rock exists 3) Regionally thermally mature	1) No production on reservation 2) Rocks exposed at the surface in the Little Rocky
5	Devonian Shales	2811 2812	1) Devonian Bakken and Three Fork shales unconventional play. Thermally mature shale areas.	Gas	225 MMBO 223 BCFG (numbers from Bakken and Three Forks shales and include portions of the Williston Basin)	700-3000 ft.		
6	Cambrian, Ordovician Sandstones*	2802	Coarse sands trapped as pinchouts or on deeper structures.	Both	638 MMBO 236 BCFG (Montana portion of the Williston Basin only).	1,700-7,000 ft.	1) Structures exist; folds, faults, domes 2) Reservoir rock exists	1) No existing production within province 2) Rocks exposed at the surface in the Little Rocky Mountains: strong hydraulic gradient-flushed? 3) Source rock unknown 4) Thermal maturity unknown 5) Lack of well control

Upper Cretaceous Biogenic Gas Play

GENERAL CHARACTERISTICS

Late Cretaceous source rocks were generally not buried deeply enough for oil generation in the North-Central Montana Province. The total thickness of Late Cretaceous rocks on the reservation is about 4500 feet. Sandstone reservoirs vary from less than 1,000 ft. to about 4,000 ft. deep. Most Late Cretaceous natural gas is methane-rich biogenic gas formed from the breakdown of organic matter by anaerobic bacteria at relatively low temperatures. Some biogenic gas in Montana occurs in widely dispersed continuous-type accumulations in low-permeability reservoirs with hydrodynamic control; this resource is considered unconventional (continuous-type). However, only conventional undiscovered accumulations in water-driven, structurally and stratigraphically trapped reservoirs are included in this play.

RESERVOIRS: The Shallow Cretaceous Biogenic Gas Play is characterized by accumulations in shallow reservoirs in predominantly clastic rocks of the Upper Cretaceous Montana Group such as the Eagle Sandstone (Figure RB-18). Similar reservoirs occur in Upper Cretaceous rocks such as the Bow Island/Muddy Sandstone and the Fall River Sandstone. Boundaries of the play are defined by the distribution of Late Cretaceous predominantly marine sandstone and siltstone, as defined by Rice and Shurr (1980).

The best gas accumulations are in late Cretaceous reservoirs in permeable shoreface and shelf sandstones. Tiger Ridge Field, in Hill and Blaine Counties, produces gas from regressive shoreface sandstone reservoirs in the Eagle Sandstone that are, in part, fault controlled. At Bowdoin Dome in Phillips County, production is from thin-bedded, low-permeability sandstone reservoirs in the Carlile Shale; however, reservoirs at Bowdoin are considered unconventional for this assessment. Reservoirs in low-permeability marine chalk of the Greenhorn Formation, which is approximately equivalent to the Marias River Shale, produce some gas at the north end of Bowdoin field and are also considered unconventional for this assessment.

TRAPS: Stratigraphic trapping of gas within both clastic and carbonate reservoirs may be due to permeability barriers related to facies changes, and to the distribution of fracture systems. Many stratigraphic traps are, in part, structurally controlled, such as at Bowes field.

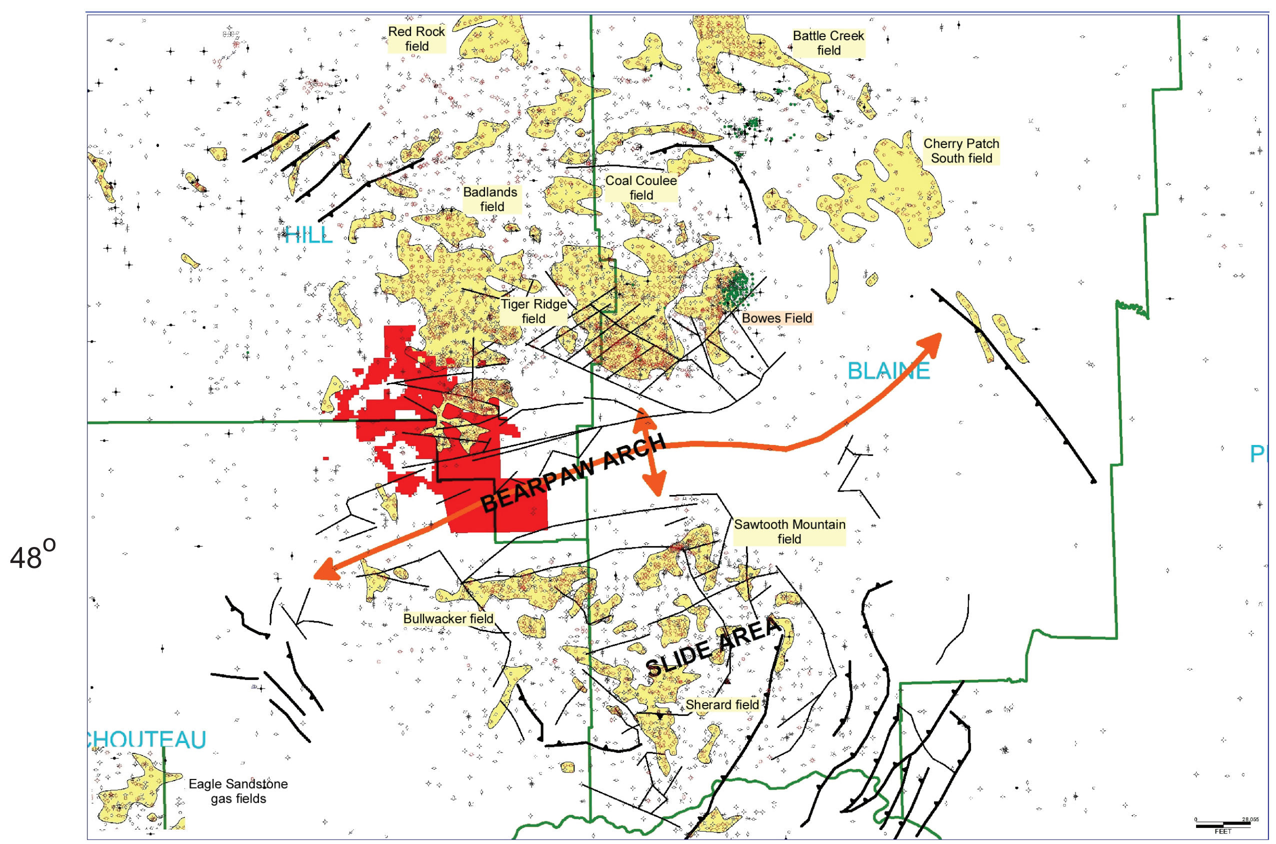


FIGURE RB-17. Tectonic features in the area of the Rocky Boys Indian Reservation (updated and modified after McNary, 1981).

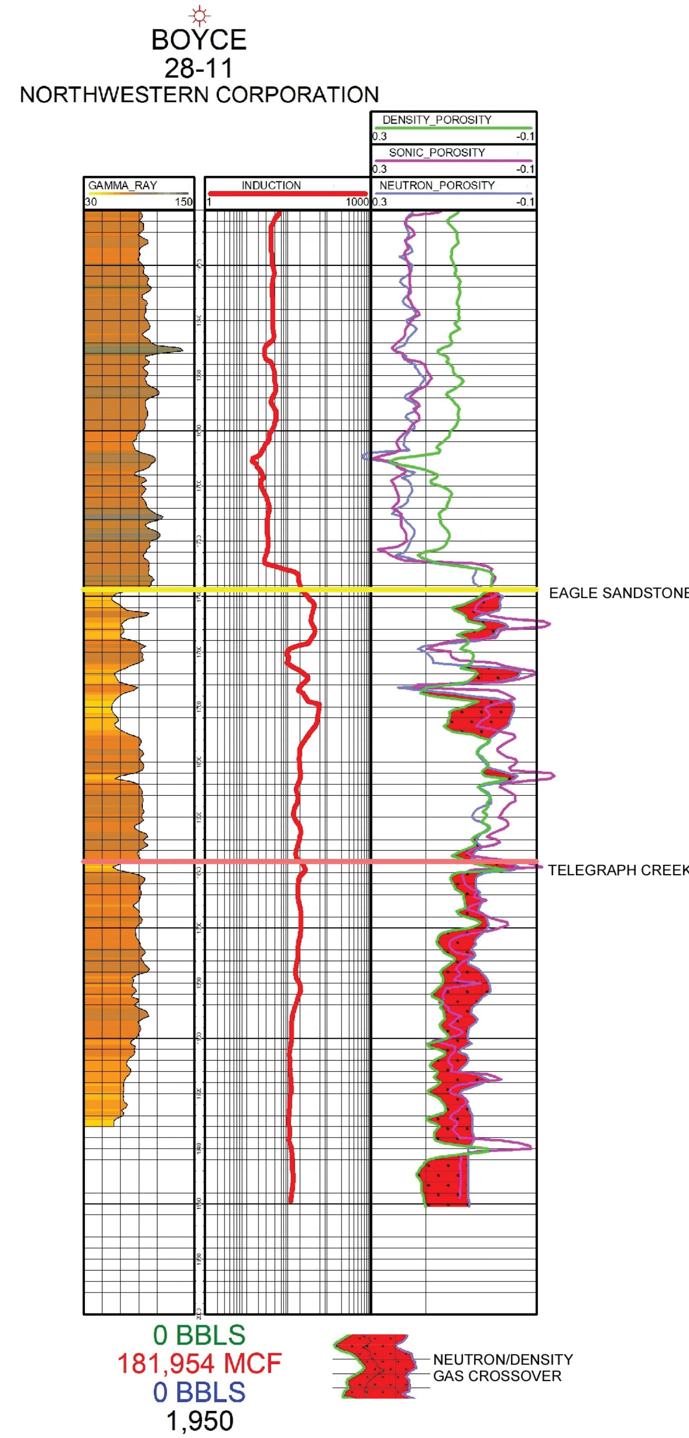


FIGURE RB-18. Type log of Eagle Sandstone in the Tiger Ridge field within the Rocky Boys Indian Reservation.

EXPLORATION STATUS: Currently, more than a dozen significant fields produce biogenic gas from Late Cretaceous reservoirs in north-central Montana. Of these, at least four have a poorly-developed to well-developed water drive system; these include Sherard, Leroy, Tiger Ridge, and Battle Creek fields.

RESOURCE POTENTIAL: The play has resulted in 628 completions in the Eagle sandstone or equivalent reservoirs surrounding Rocky Boys reservation, and the future potential for undiscovered gas continues. Development is somewhat limited due to economic considerations associated with biogenic-rich reservoirs and because of the need for more pipeline and transportation infrastructure. Many potential reservoirs are considered unconventional (continuous-type). Many of the larger structures have been extensively drilled, but possibilities still exist for smaller sized accumulations.

Pipeline and transportation infrastructure are available in the area of the reservation. To date, 545 wells have been drilled in and around the boundary line of Rocky Boys Reservation. Of those wells, 63% were completed as gas wells. Nearly all of these wells were completed in the Eagle sandstone, with lesser completions in the Judith River and Virgille sandstones. Well total depths are typically between 1500 and 2000 feet. 281 BCFG have been produced, averaging a little over 1 BCF per well. Significant portions of the reservation have yet to be explored and in areas where numerous fault blocks are present (Figure RB-17). Although much of the prospective areas southeast of Laredo field (T30N R13E) contains volcanic flows at the surface, drill holes show that sedimentary strata, including the Eagle Sandstone, underlie the volcanic rocks. Gravity sliding has moved igneous rocks over sedimentary terrain at many places in the Bearpaws, so that even proximity to a stock may not rule out gas potential (Hearn, 1976). Fault blocks may contain numerous exploration possibilities, some of which have yet to be drilled (Lindsey and others, 1977). Bullwacker field is a good analog example for this play (Figure RB-19 and 20). Other fields south of the reservation are Sherard and Sawtooth.

Tiger Ridge Field in Blaine and Hill Counties is a representative example of the Shallow Cretaceous Biogenic Gas Play. The field discovery well was drilled in 1966. This well off sets a dry hole that had TD'd in the Mississippian Madison. More than 880 wells have produced gas (94 percent methane) from the Eagle Sandstone and Judith River Formation in a field area of approximately 115,000 acres. Production occurs at an average depth of 1,000 ft. in a 135 ft. thick pay zone that has an average porosity of 26 percent. Tiger Ridge had an ultimate production projection of 760 BCFG in 1999, but has actually produced over 1 TCFG. This represents about 50 percent of the projected production of the entire province (2.1 TCFG).

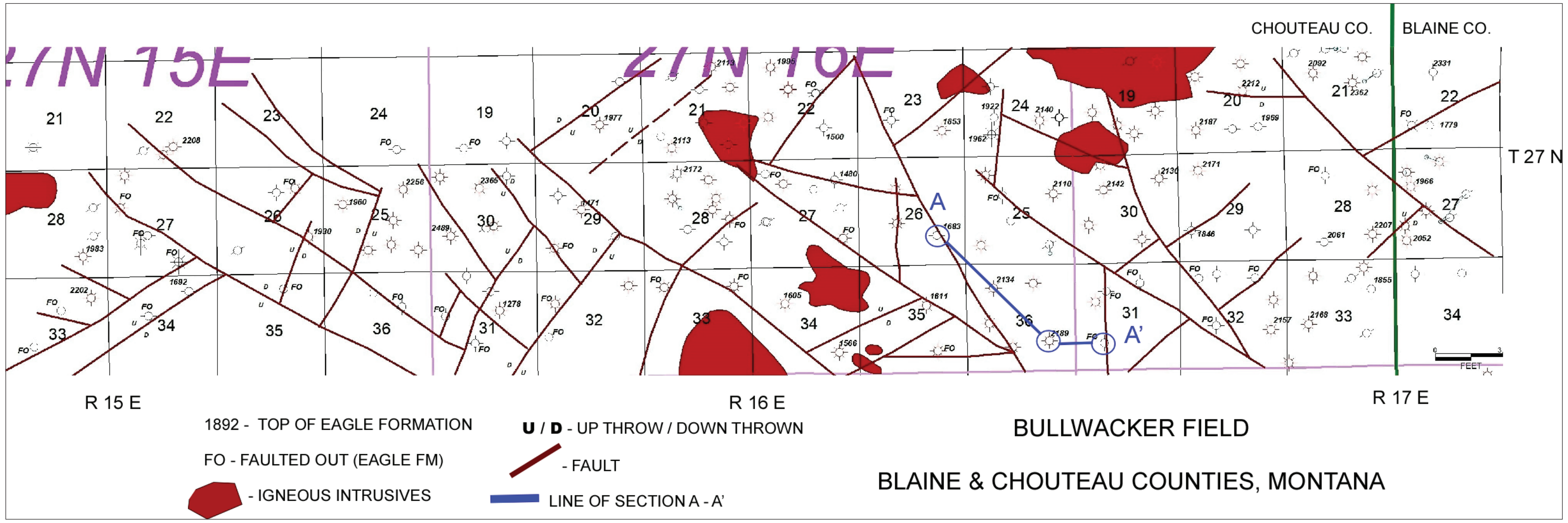


FIGURE RB-19. Map of Bullwacker Field (after Ervin-Cleveland and Shepard 1985).

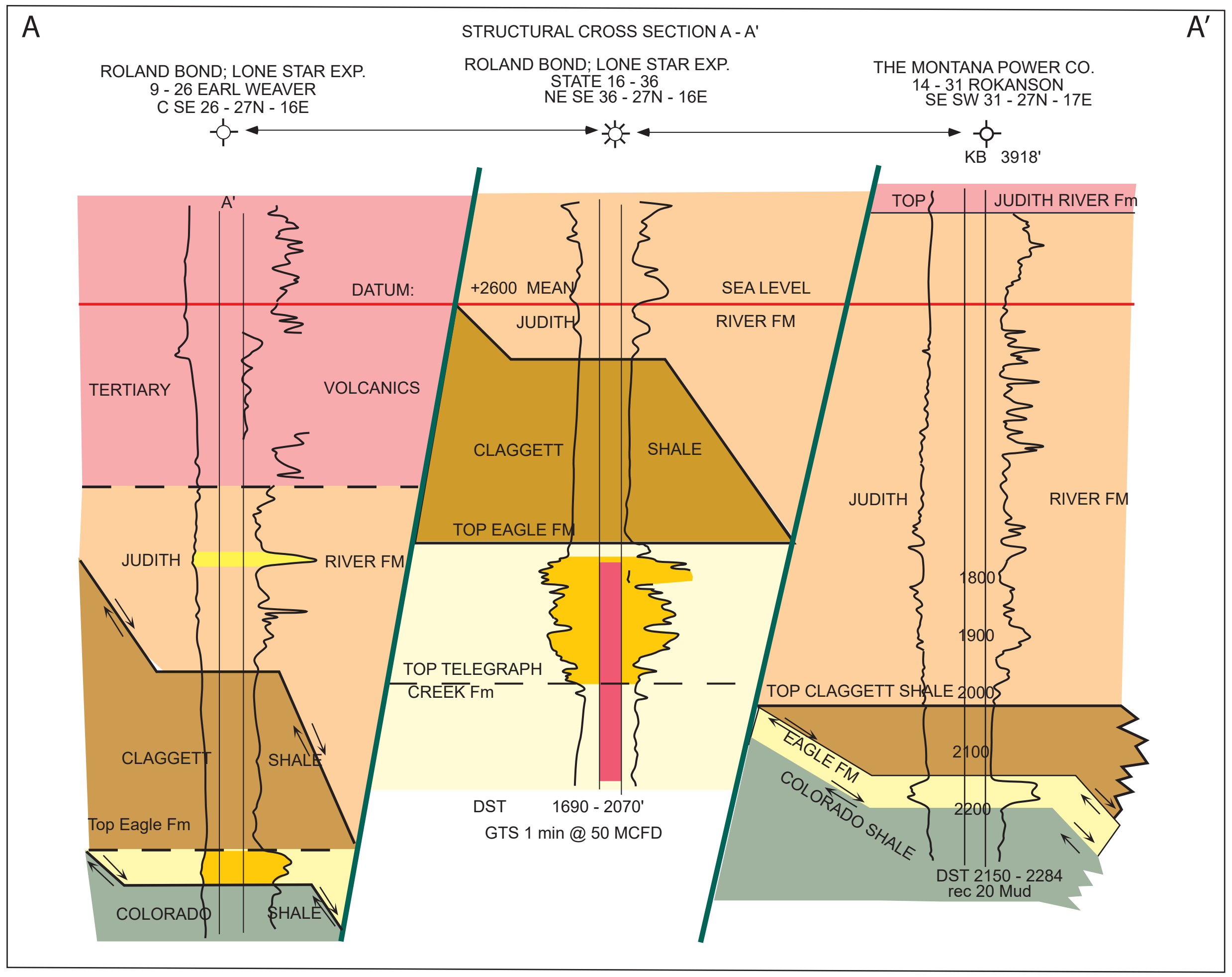


FIGURE RB-20. Structural cross-section A-A', Bullwacker Field (after Ervin-Cleveland and Shepard 1985).

Bullwacker Field Parameters

T.27 N., R.15-17 E. Chouteau and Blaine Counties, Montana
(after M. Ervin-Cleveland and G.W. Shepard 1985).

Gas is produced from the Eagle Sandstone. Porosities range from 16-26%, however the permeabilities are very low. Generally the wells must be artificially fractured before they will produce. The natural flow of the wells ranges from too small to measure up to 691 MCFPD. After fracing, the wells flowed from 247 to 4,190 MCFPD.

SURFACE FORMATIONS AND ELEVATION:	Predominantly Tertiary volcanics; surface elevation ranges from 3,800-4,700 feet.
DISCOVERY WELL AND DATE:	General Crude-Gregory, Henderson #1, Sec. 27, T27N-RI7E, Eagle discovery, 10-21-67.
OLDEST HORIZON PENETRATED:	Mississippian
HORIZONS WITH SHOWS:	Cretaceous Eagle and Judith River Formations.
NATURE OF TRAP:	Fault traps.
AREA OF TRAP:	Individual fault blocks.
NO. OF PRODUCING WELLS:	120, Abandoned Wells: 21
SHUT IN/TEMPORARILY ABANDONED WELLS:	9 Shut in Gas Wells
DRY HOLES:	62
MAJOR OPERATORS:	Montana Power Company, Roland S. Bond, Lone Star Exploration.
DRILLING AND CASING PRACTICES:	Rotary drilling to TD, log, case, perforate and stimulate.
TESTING PRACTICES:	DST after log analysis.
MARKET:	Montana Power Company.
PRODUCING FORMATION:	Cretaceous Eagle Formation.
LITHOLOGY, CONTINUITY, THICKNESS:	Continuous, fine-medium grained, calcareous sandstone, avg. gross thickness of 150 feet.
AVG. DEPTH (& MSL):	Due to extensive faulting, the top of the Eagle ranges from 1, 230 feet (+ 2,862 feet) to 2,800 feet, (+ 1, 292 feet).
POROSITY/PERMEABILITY:	16% avg. porosity, permeability data not available.
OIL, GAS COLUMN:	(Water Contact MSL) - N/A
AVG. NET PAY THICKNESS:	40 feet
AREA THIS RESERVOIR:	9,300 acres
BO/MCF PER ACRE-FOOT:	134 MCF/AF
DRIVE MECHANISM:	Depletion
CHARACTER OF OIL/GAS:	Nitrogen-7.66, Carbon Dioxide-.04, Hydrogen Sulphide-0, Methane-84.72, Ethane-3.97, Propane-1.89, Isobutane-.41, N-Butane-.57, Isopentane-. 19, N-Pentane-. 14, Hexane Plus-.41
GROSS BTU/CU.FT. @ ST&P:	1,042
WATER RW, SALINITY:	Rw =0. 69 ohms @ 78 degrees
F. AVG. SATURATION:	Sw=55%
INITIAL AND PRESENT PRESSURE:	Initial 613 psia., present 141psia
TEMPERATURE:	78 degrees F
INITIAL POTENTIAL (HIGH, LOW, AVG.):	High
DECLINE RATE:	12-15%
PRESENT DAILY AVG. PRODUCTION:	1,594 MCF
AMOUNT OF WATER PRODUCED:	None
COMPLETION/PERFORATION/TREATMENT:	Set casing, perforate, and stimulate.
CUMULATIVE PRODUCTION:	92.2 BCF
EST. ULTIMATE PRIMARY RECOVERY:	115 BCF

Coal Bed Methane

The U.S.G.S. has not evaluated the coal bed methane resources of Central Montana, however coal is present in three formations on the Rocky Boys Reservation. The Judith River Formation was deposited during Cretaceous time (middle of the Montana Group), and the Fort Union Formation was deposited during Paleocene time (Figure RB-22). The Eagle Sandstone was deposited during Upper Cretaceous time. It reportedly contains coal beds (Lindsey and others, 1977). Because all three formations are present beneath the reservation, resources of coal bed methane are probably present and merit evaluation, particularly because of nearby gas collection and transportation facilities. The following text is a brief summary of the known coalfields on and adjacent to the reservation.

Big Sandy Coalfield

The Big Sandy coalfield encompasses an area of about 345 sq. mi. in T25 to 28N-R13 and 14E, and T25 and 26N-R15E. The thickest, most extensive beds of sub-bituminous coal are in the Fort Union Formation in the vicinity of the Mackton and Mack Mines, about 6.5 mi. east of the town of Big Sandy in Sec. 18, T28N-R14E (Figure RB-21), (Bowen, 1914). The coal beds in the Big Sandy field are in down-dropped fault blocks of the Fort Union Formation. Because of the glacial drift and alluvium that cover the area, the structure cannot easily be interpreted. Fort Union coal was mined from late 1800 to around 1930. Fort Union coal was

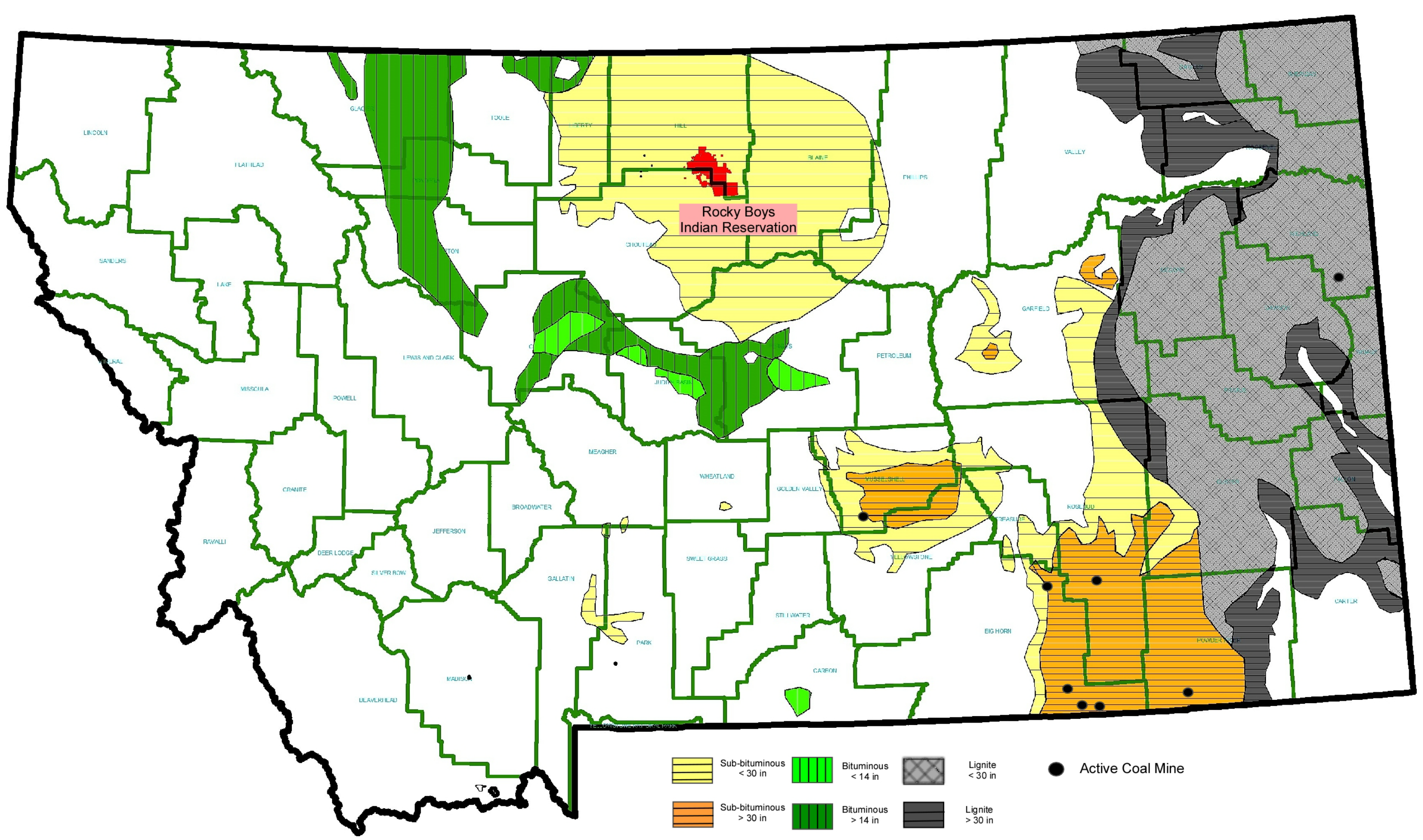


FIGURE RB -21. Coal deposits and active coal mines of Montana (after Combo et. al 1949)

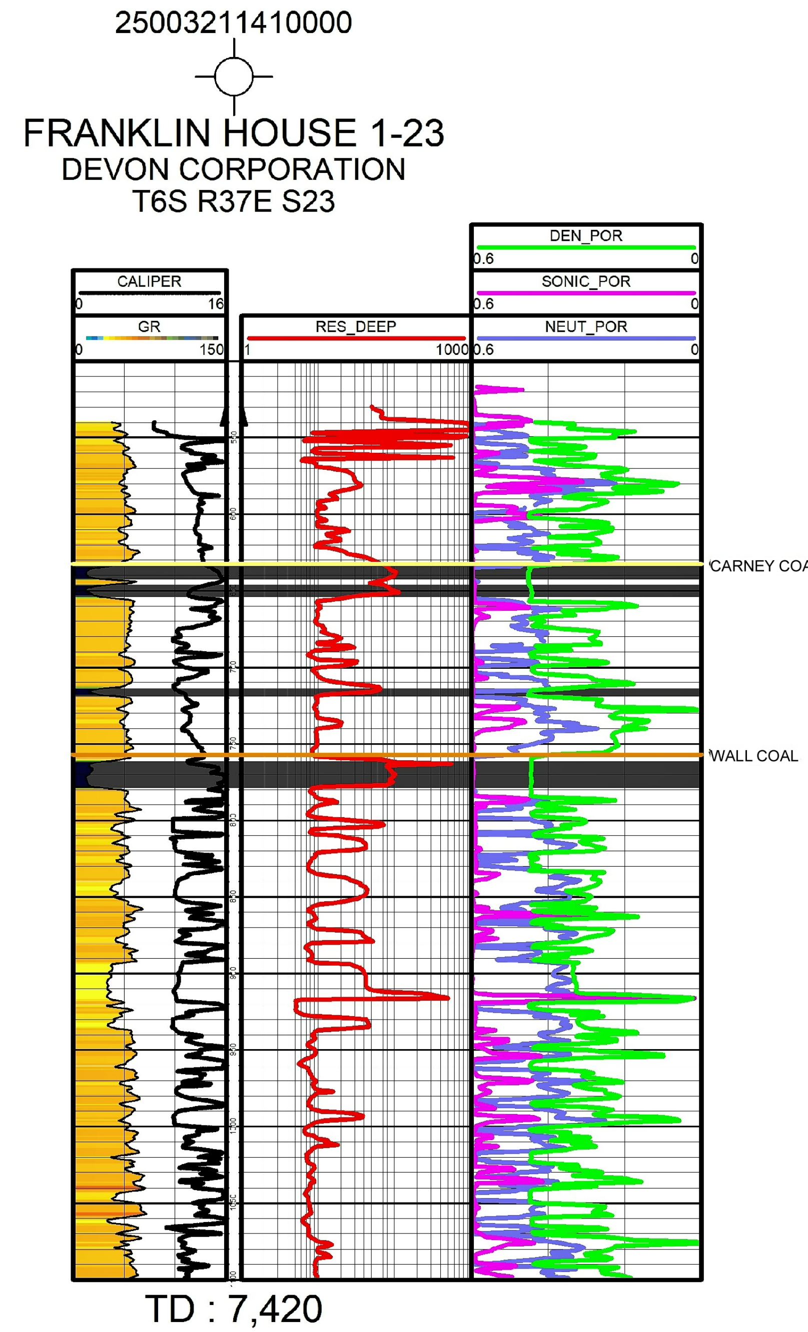


FIGURE RB -22. Fort Union coal type log.

Milk River Coalfield

The Milk River coalfield extends along the Milk River from about 15 mi. west of Havre to about 5 mi. east of Harlem. The field contains about 22 mines (Pepperberg, 1910a). Coal in the Milk River Field is sub-bituminous and ranges from about 8,500-10,000 Btu (British thermal units) per pound. The Havre district is the best-known part of the Milk River field. Coal in the Milk River Coalfield is described as occurring "in the Upper Cretaceous Montana Group rocks (Bearpaw Shale, Judith River Formation, Claggett Shale, and Eagle Sandstone) and in the Tertiary Fort Union Formation. The sedimentary strata have been extensively faulted by thrust faults closely associated with folds. The faults commonly offset the coal beds, both laterally and vertically, and have tilted them to high angles" (Pepperberg, 1910). Coal beds in the Milk River field are lenticular and range in thickness from a fraction of an inch to more than 9 ft. In the Havre district, at the western part of the field, beds are thicker and the coal is of better quality than in the eastern part. Each mine commonly has one workable coal bed, but in some areas, two, three, or even four beds are found in the upper part of the Judith River Formation, from 10-150 ft. below the base of the Bearpaw Shale (Pepperberg, 1910).

LOWER CRETACEOUS SANDSTONES GAS PLAY

This play encompasses production from the Blackleaf, Cutbank, Bow Island, Dakota (Fall River), Cat Creek, Sunburst, Lakota, Kootenai, Mosser, Moulton, Mowry and Muddy Sandstones. Production is both oil, gas and gas liquids. More than 534 MMBO and 1.3 TCFG have been produced from these rocks in Montana (Figure RB-23). They are composed mainly of marine and fluvial sandstones deposited during transgressive/regressive phases of the Cretaceous epeiric seaway that stretched from northern Canada to the Gulf of Mexico.

RESERVOIRS: The reservoirs are typically transgressive shelf marine sandstones and regressive deltaic, overbank or fluvial incised channels (Figures RB-24 & RB-25).

SOURCE ROCKS: Important source rocks are the Jurassic phosphatic shales and dark gray shales within the Cretaceous such as the Kootenai, Blackleaf and Marias River (Hayes 1984). Other possible source rocks are Mowry, Skull Creek and Shell Creek marine shales. TOC values average 2.4 weight percent for the Marias River (Cone member) with vitrinite reflectance values of .6 % over the crest of the Sweetgrass Arch (Dyman, 1987). Dolson and others (1993) have reported the Bakken shale to be a source of oil in Cretaceous sandstones along the Sweetgrass Arch. Thermally mature within the disturbed belt to the west, Bakken oils probably migrated updip into much shallower porous sandstones further east.

TIMING AND MIGRATION: Most Lower Cretaceous source rocks are not deep enough to be thermally mature over the structures they produce from. Oil generation most probably occurred in the deeper buried disturbed belt sediments to the west and then migrated eastward. Cretaceous source rocks within the Big Horn Basin are known to have reached maturity during the Paleocene (Fox et al., 1996) and a similar scenario could have existed in western Montana.

TRAPS: Large fields are structural in nature, draped over prominent anticlinal structures. Most traps have a stratigraphic component associated with them, usually this involves an updip pinchout or facies change.

EXPLORATION STATUS AND RESOURCE POTENTIAL: The play is relatively well explored over prominent structures. Isolated smaller fields are certain to be discovered as drilling progresses in the region. Most production is less than 2500 feet in depth. Major fields include the Cut Bank, Cat Creek, Bell Creek, Blackfoot, Fred & George Creek, Graben Coulee, Kevin Sunburst, Old Shelby, Prairee Dell and Whitlash.

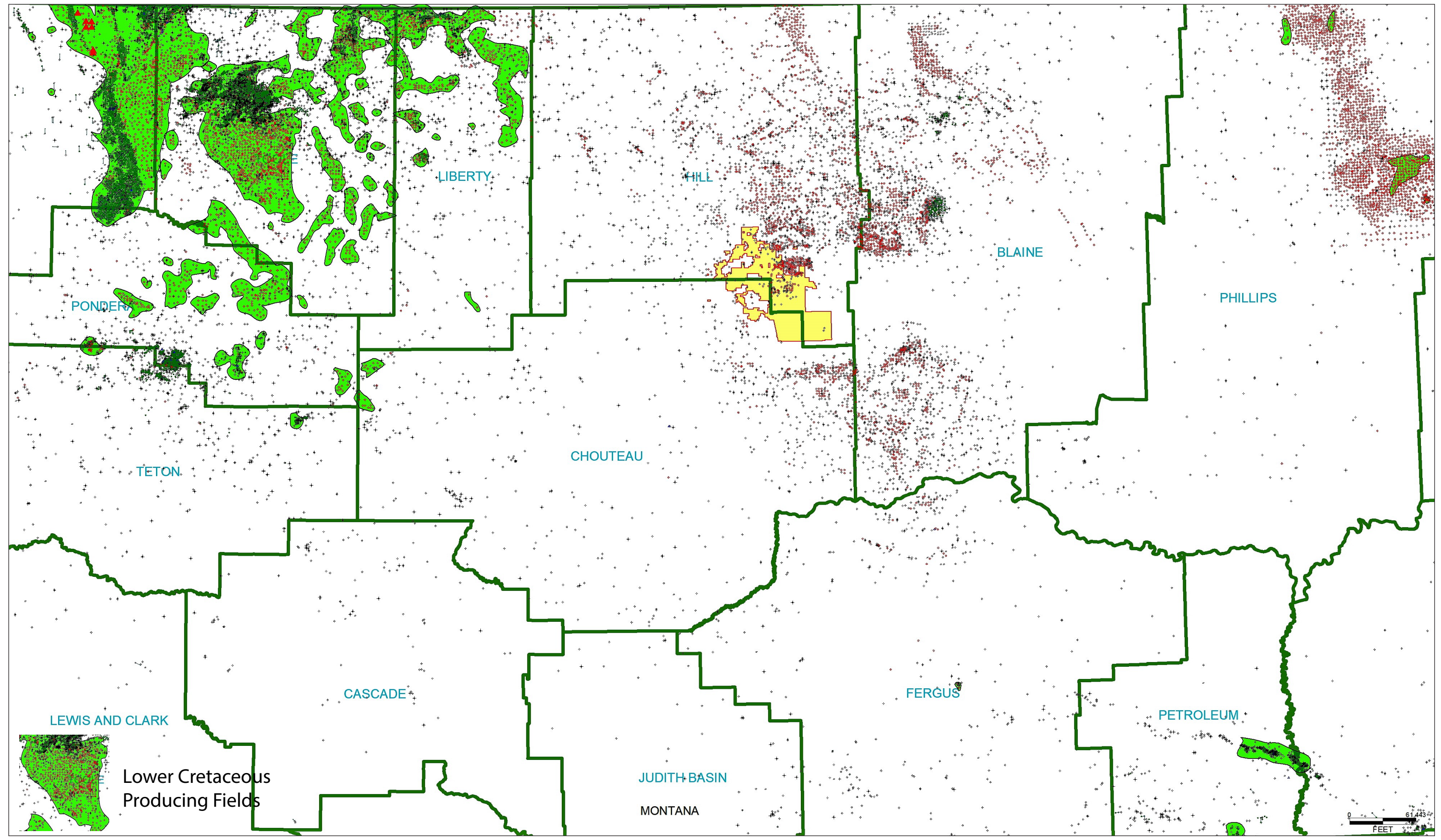


FIGURE RB -23. Lower Cretaceous production map surrounding Rocky Boy Indian Reservation.

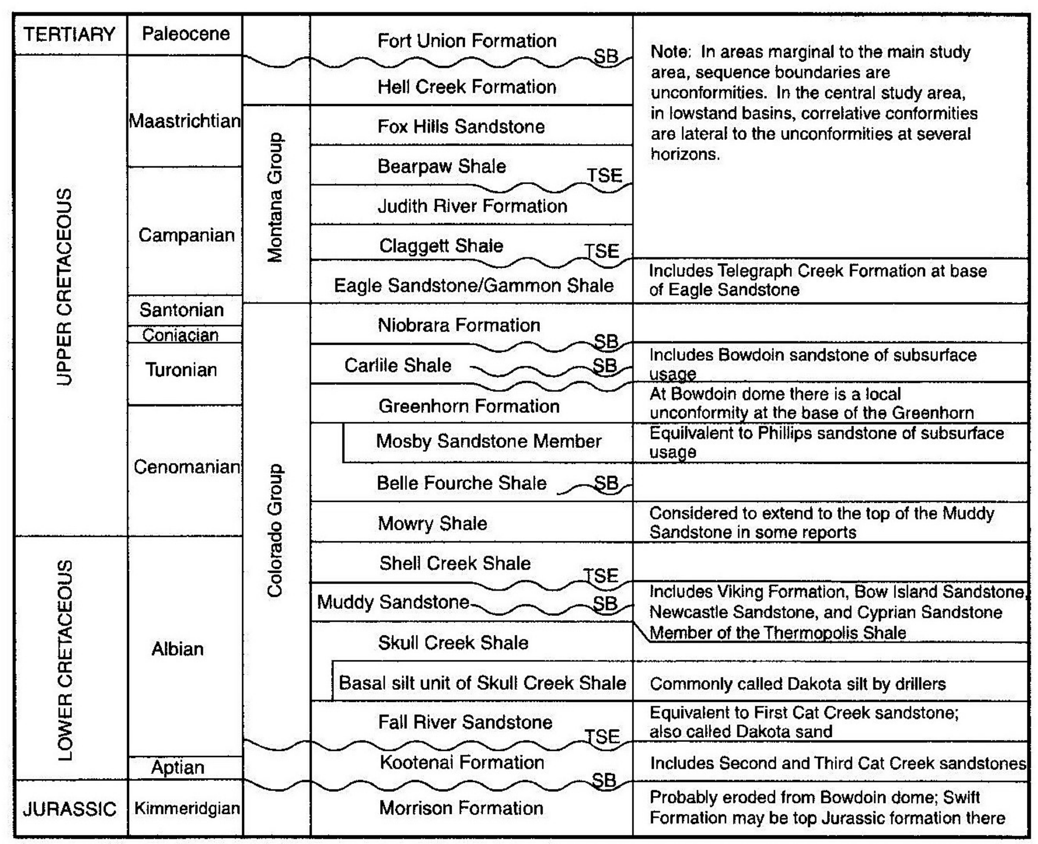


FIGURE RB -24. Cretaceous Stratigraphy in Central Montana (after Condon, 2000).

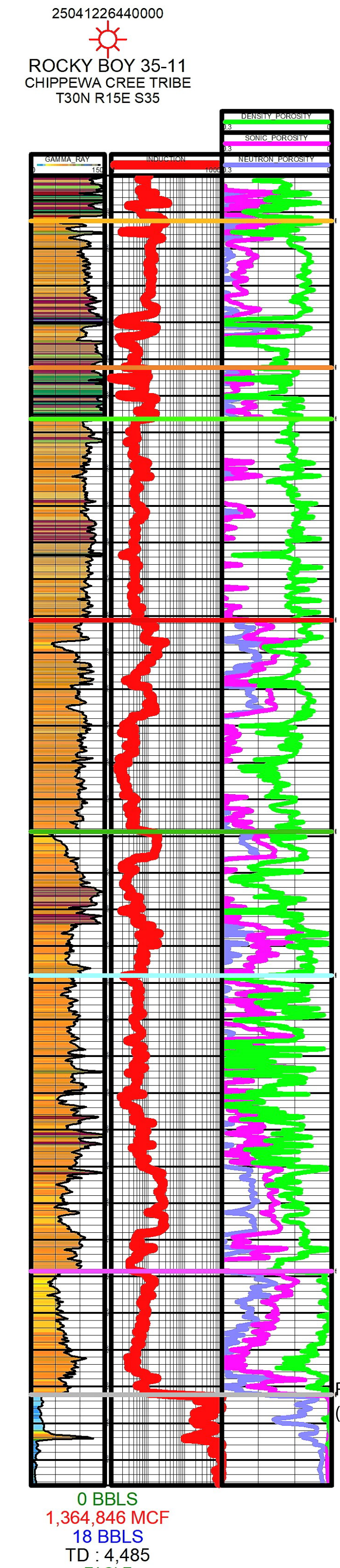


FIGURE RB -25. Lower Cretaceous Type Log Rocky Boys Reservation.

JURASSIC- ELLIS GROUP PLAY

GENERAL CHARACTERISTICS

This play is defined by oil and gas accumulations mainly in stratigraphic traps occurring in fluvial and deltaic sandstone reservoirs of Jurassic and Cretaceous age. The play covers most of the area of the province except for the Little Belt Mountains. On the Rocky Boys Reservation it includes predominately clastic facies of the Jurassic Sawtooth, Swift, and Morrison Formations, Lower Cretaceous Kootenai Formation, Upper Cretaceous Colorado Group, and Upper Cretaceous Montana Group. These units are approximately 3,000 ft. thick in the area of the reservation. The base of the Jurassic section varies in depth from 1,000-5,000 ft. Jurassic and Cretaceous strata are combined in the play because of similarities in depositional environment and facies, trapping mechanisms and source rocks.

RESERVOIRS: The best reservoir rocks include fluvial to near-shore marine sandstones of the Swift, Sawtooth, Morrison, Kootenai, Fall River and Bow Island (Muddy). Valley-fill fluvial channels form major reservoirs at Cutbank Field along the updip northern end of the Sweetgrass Arch. Jurassic reservoirs of the Sawtooth and Swift Formations generally occur in lenticular, laterally discontinuous marine sandstones. Permeability barriers associated with environments of deposition, diagenetic alteration of sandstones, and Laramide folding and faulting strongly affect the quality of reservoirs. Kootenai Sandstone reservoirs (2nd and 3rd Cat Creek sands of drillers' usage) are well developed and of good quality where they are adjacent to and sealed by flood plain and inter-distributary mudstone.

SOURCE ROCKS: The most important source rocks are dark-gray phosphatic shales of Jurassic age, and Cretaceous dark-gray shales in the Kootenai, Mowry and Skull Creek Shales and their stratigraphic equivalents (Gautier, 1996). Generally, the organic material in these shales is thermally immature except where buried to greater depths near the disturbed belt or very near Tertiary intrusive and volcanic rocks, as on the reservation. TOC values average 2.4 weight percent for the Cone Member of the Marias River Shale in the disturbed belt near Glacier National Park in Glacier County, and vitrinite reflectance values average 0.6 percent along the crest of the Sweetgrass Arch.

TRAPS: Most reservoir traps are stratigraphic and in the northwest these stratigraphic traps are enhanced by structure; they were filled with hydrocarbons migrating updip from source rocks in deeper parts of the disturbed belt. The relative importance of stratigraphic versus structural factors in trap definition for Jurassic and Cretaceous reservoirs is difficult to define. Updip shale beds form effective seals in the Jurassic-Cretaceous section. Drilling depths range from less than 1,000 to 6,000 ft.

Bowes Field Parameters	
SURFACE FORMATIONS AND ELEVATION:	Bearpaw shale and Judith River Fm., 2,800 feet.
EXPLORATION METHODS:	Subsurface mapping.
OLDEST HORIZON PENETRATED:	Cambrian
HORIZONS WITH SHOWS:	Jurassic Sawtooth, Piper, Cretaceous Eagle Fm.
NATURE OF PLAY:	Structural dome.
AREA OF PLAY:	Approx. 2,500 acres
NO. OF PRODUCING WELLS:	113 (Sawtooth), 62 (Eagle SS)
DRILLING AND CASING PRACTICES:	Older wells are open hole completed; present wells are perforated and acidized.
PRODUCING FORMATION:	Jurassic Sawtooth Fm.
LITHOLOGY:	Sandy dolomite to dolomitic sand, oolitic to dense limestone.
AVG. DEPTH:	3,500 feet
POROSITY/PERMEABILITY:	1.7-25.4% porosity, 0.01-264 md
AVG. NET PAY:	30 feet (est.)
CHARACTER OF OIL/GAS:	19 degrees API
WATER SALINITY:	0.095 @ 132 degrees F (0.43 @ 75 degrees F)
AVG. SATURATION:	31%
Initial and Present Pressure: Pi = 1,664; Pp = N/A	
Temperature: 132 degrees F	
Cumulative Production: 8,911,885 BO	

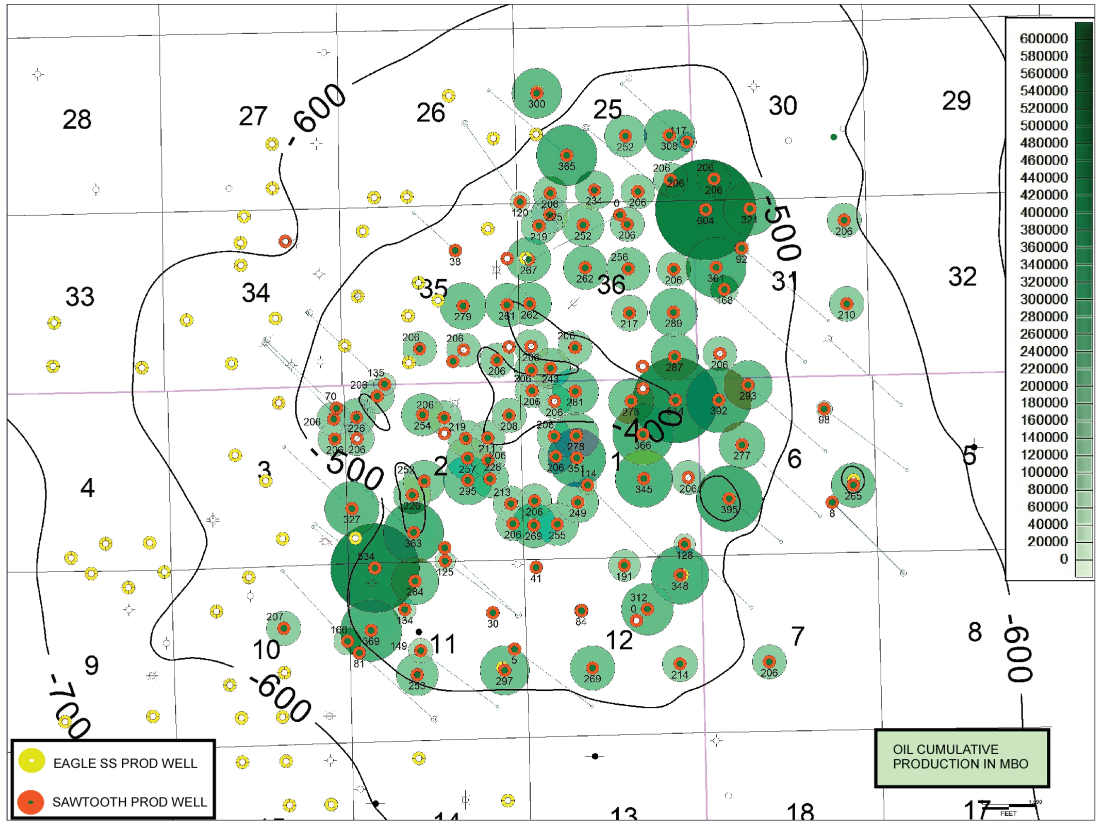


FIGURE RB-26. Structure on top of Sawtooth Formation, Bowes Field, Montana. Bubbles reflect cumulative oil production from the Sawtooth sandstone.

EXPLORATION STATUS: The play has been moderately explored, in part, because of early attention to surface oil seeps and subsequent discoveries at shallow depths (usually less than 2,500 ft.). Thirty-five significant oil and gas reservoirs have been found in the play since the 1919 discovery at the Cat Creek field. Cutbank field in Glacier and Toole Counties is one of the largest fields in the play. The field was discovered in 1926 and has produced more than 100 MMBO and 300 BCFG from fluvial and deltaic sandstone reservoirs of the Swift Formation (locally named the Cutbank Sandstone. This sand is present on the reservation). One hundred eighty-seven wells produce from an average depth of 3,300 ft. in the field, which covers more than 65,000 acres. The most productive gas reservoir, the Cutbank sandstone, was deposited in a widespread fluvial channel system; the sandstone pinches out against Jurassic strata on the east to form a large valley-fill trap. Sandstone reservoirs of the Blackleaf Formation are generally less productive than sandstone reservoirs in the Kootenai Formation.

RESOURCE POTENTIAL: Future potential is estimated to be low for oil and moderate for gas because all the large stratigraphic and structural traps have been defined by exploration through the years. Future exploration opportunities exist for small reservoirs.

ANALOG EXAMPLE: Bowes Field, a dome with approximately 200 feet of structural closure (Figure RB-26), was discovered in August, 1949 by the Northern Ordinance Company. The discovery well, No. 1 Guertzgen, SW NW NE Section 6, T31N, R19E (Figure RB-27), production tested the Jurassic Piper Formation at 200 BOPD. Average well production is much lower because reservoir quality varies considerably from well to well (Bennett, 1985). The field is located 24 miles east of the reservation. Although the Bowes Field does not have any extensions that approach the reservation, the geologic control on both oil and gas at Bowes provides insight to the type of target that may be sought elsewhere in northern Montana and possibly on the reservation. Oil in the Bowes Field occurs in the middle and upper Piper-Sawtooth Formations of the Ellis Group (Hunt, 1956). At Bowes, the Piper has been divided into three members: the lowermost Tampico Shale Member (78 feet thick), the middle Firemoon Limestone Member (76 feet thick), and the uppermost Bowes Member (50-60 feet of sandy limestone, sandstone, and shale). The upper 30 ft. of the Firemoon Limestone and the lower part of the Bowes Member have porous oil-producing zones. The upper part of the Bowes Member passes from nonporous shale and limestone in the southern part of the field to permeable sandstone and limestone in the northern part, so that the thickness of the oil-producing zone is much greater in the north. Such local sandstones in the upper Bowes Member are the source of production in the Dollard trend of Saskatchewan, (Lindsey and others, 1977).

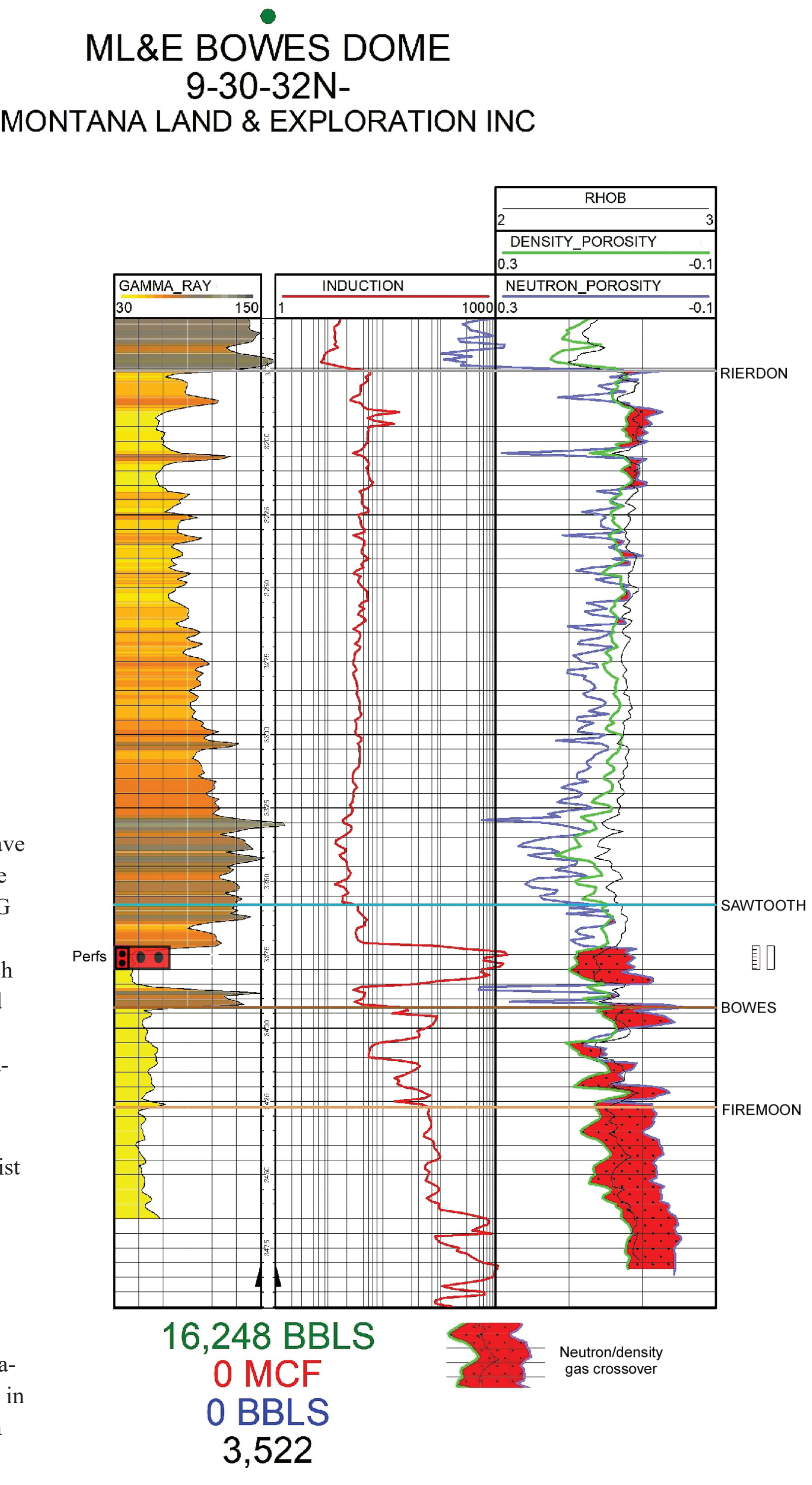


FIGURE RB-27. Log of producing well Sawtooth interval, Bowes Dome.

Mississippian and Devonian Carbonates Play

GENERAL CHARACTERISTICS

The play is characterized primarily by oil accumulations in carbonate reservoirs of Mississippian and Devonian age in both structural and stratigraphic traps. The play includes predominantly carbonate rocks of the Mississippian Madison Group and Devonian Nisku. The play extends throughout the area of the province, although these rocks vary in reservoir quality and thickness. On the reservation, Mississippian rocks are approximately 1000 feet thick.

RESERVOIRS: Reservoir rocks consist of primarily oolitic and bioclastic carbonate banks, mounds and karst zones in the Mississippian Madison Group. Dolomitization, which may be associated with near-shore salinity variations, is greatest along a line trending northwestward from the Little Belt Mountains. Widespread paleokarst reservoirs in the middle and upper part of the Madison Group are the result of post-Mississippian erosion. In addition, dolomitized sub-tidal carbonate banks within the Madison Group are excellent reservoirs where they are interbedded with supratidal anhydrite. Productive zones vary from about 10 to 100 ft. in thickness.

SOURCE ROCKS: Source rocks are organic rich shale laminae within the lower Mississippian Lodgepole Limestone, and the upper Mississippian Heath shale. The Heath is the uppermost unit in the Big Snowy Group, which overlies the Madison Group in the Central Montana Trough. Vitrinite reflectance values vary from 0.49-0.55 percent in the Heath shale in southern Fergus County, Montana, indicating that they are thermally immature and are at or immediately below the oil generation window. Vitrinite reflectance values in the Heath shale in Petroleum and Garfield Counties however are in the 0.69-0.84 percent range with TOC values of up to 9 weight percent (Gautier, 1996). These source rocks are generally thermally mature to marginally mature in the central part of the play.

TRAPS: Stratigraphic traps are the result of selective dolomitization of limestone, facies barriers in carbonate-evaporite sequences, and paleosol and karst systems. Most traps have been enhanced by Laramide folding and faulting. Oil found in several Jurassic Sawtooth reservoirs may have been generated in Mississippian source rocks in places where Jurassic reservoirs unconformably overlie Sun River (Madison) dolomite reservoirs. Many Madison Group traps (such as the Pondera field) are strongly influenced by Laramide faulting and folding. Drilling depths to the top of the Devonian vary from approximately 2,700-7,500 ft., but the average depth is about 3,000-4,000 ft. Evaporite and shale reservoir seals are present in the Devonian-Mississippian section.

Because trapping mechanisms include discontinuous porosity zones and structural traps, a concern may be breached in Mississippian and older units exposed to the atmosphere in the Little Rocky Mountains to the south and east of the reservation. The top of the Mission Canyon is cavernous and forms an excellent aquifer. This strong, hydrodynamic flow from south to north may have "flushed", hydrocarbons from the older rocks (Figures RB-28 and RB-29).

EXPLORATION STATUS: Hydrocarbons have been produced in the play since 1922 when oil was discovered in the Madison at the Kevin-Sunburst field (Figure RB-30). Six reservoirs greater than 1 MMBO are identified for this play. Typical of these is Pondera field, discovered in 1927. It produces from a 15 ft. thick pay zone in a paleokarst dolomite reservoir in the Sun River at an average depth of 1,950 ft. Reservoir porosity in the field averages 16 percent and oil gravity is 34 API. A total of 480 wells had been completed in a field area of 9000 acres. Greater than 54 MMBO had been produced to the end of 2019. The Mississippian section is moderately well explored in the northwestern part of the play. Devonian oil production is present in 58 wells, most of them within the Kevin-Sunburst and Kevin East fields. Cumulative production is commonly between 50 and 200 MBO. Oil shows have been reported in the Nisku from several wildcat wells in the southern part of the Sweetgrass Arch area in the 1980s.

RESOURCE POTENTIAL: Future potential is moderate for oil and low for gas, mainly in smaller fields. Larger structures have been drilled without success, but opportunity exists for small fields.

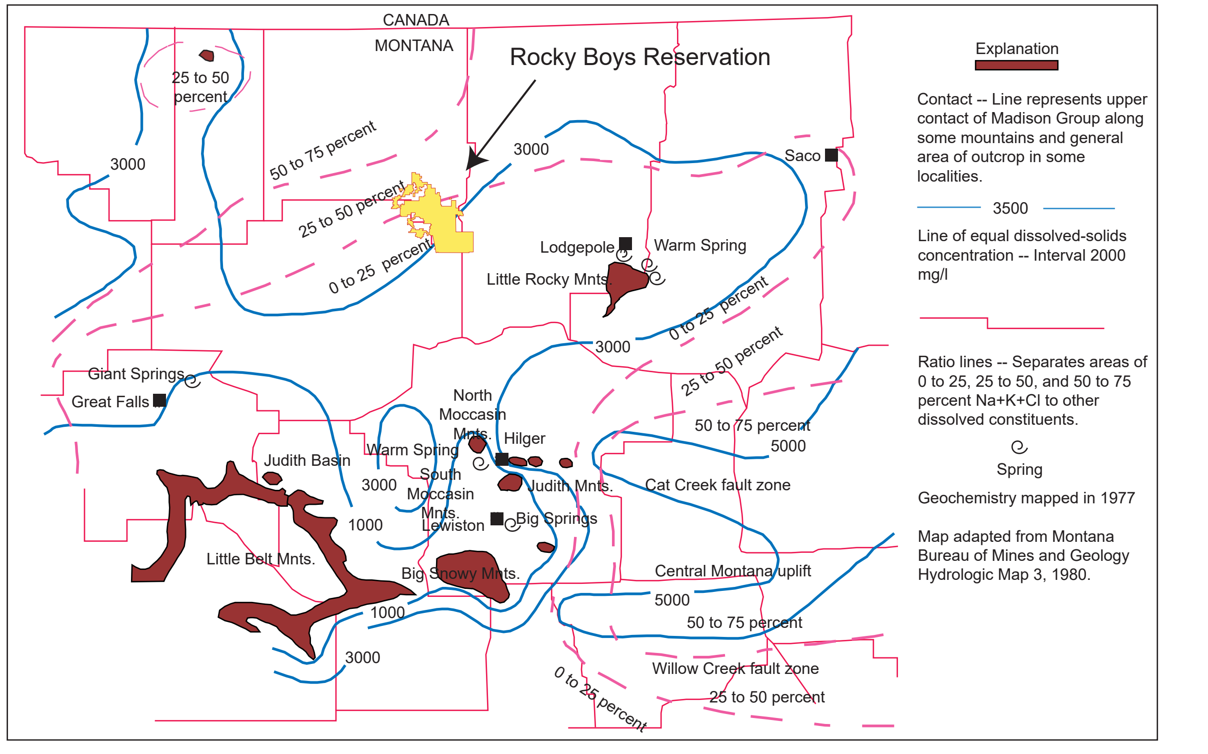


FIGURE RB-29. Dissolved solids concentration and ratio of sodium, potassium, and chloride to dissolved solids concentration in water of the Madison Group, Montana (modified after Feltis 1993).

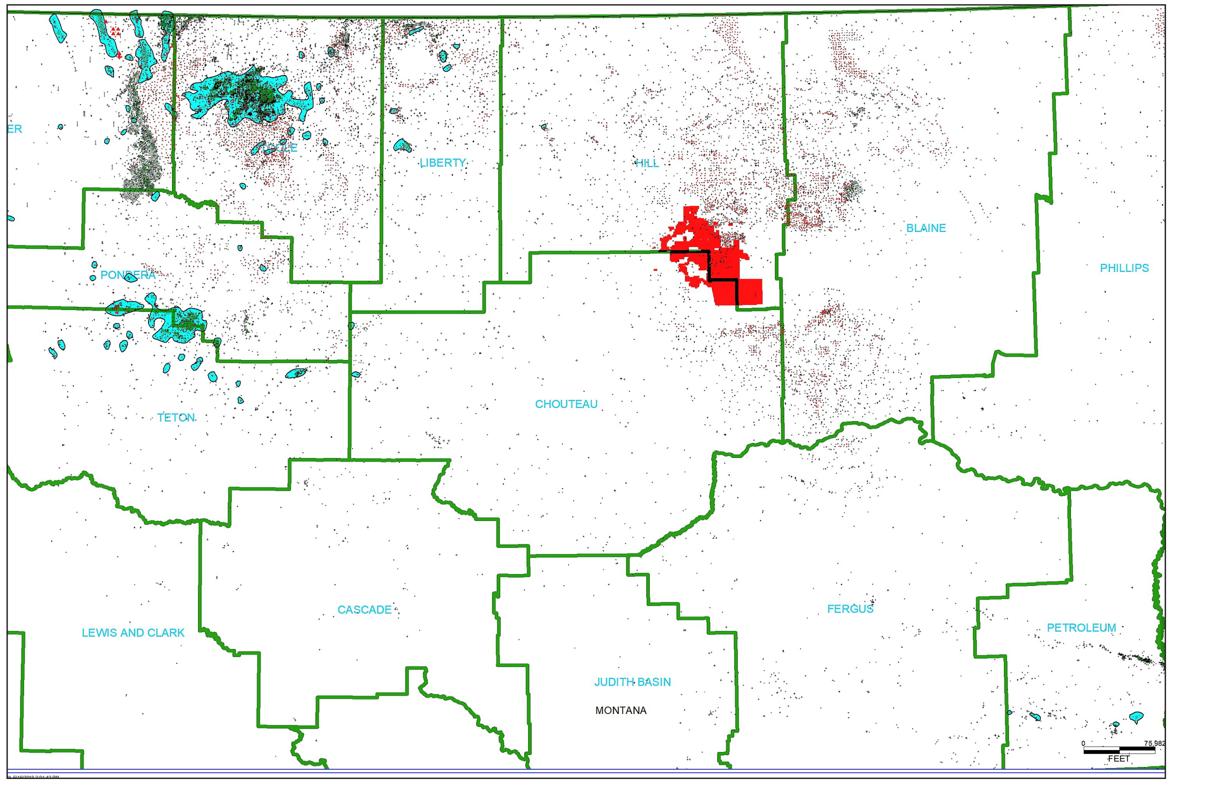


FIGURE RB-30. Mississippian and Devonian production in light blue.

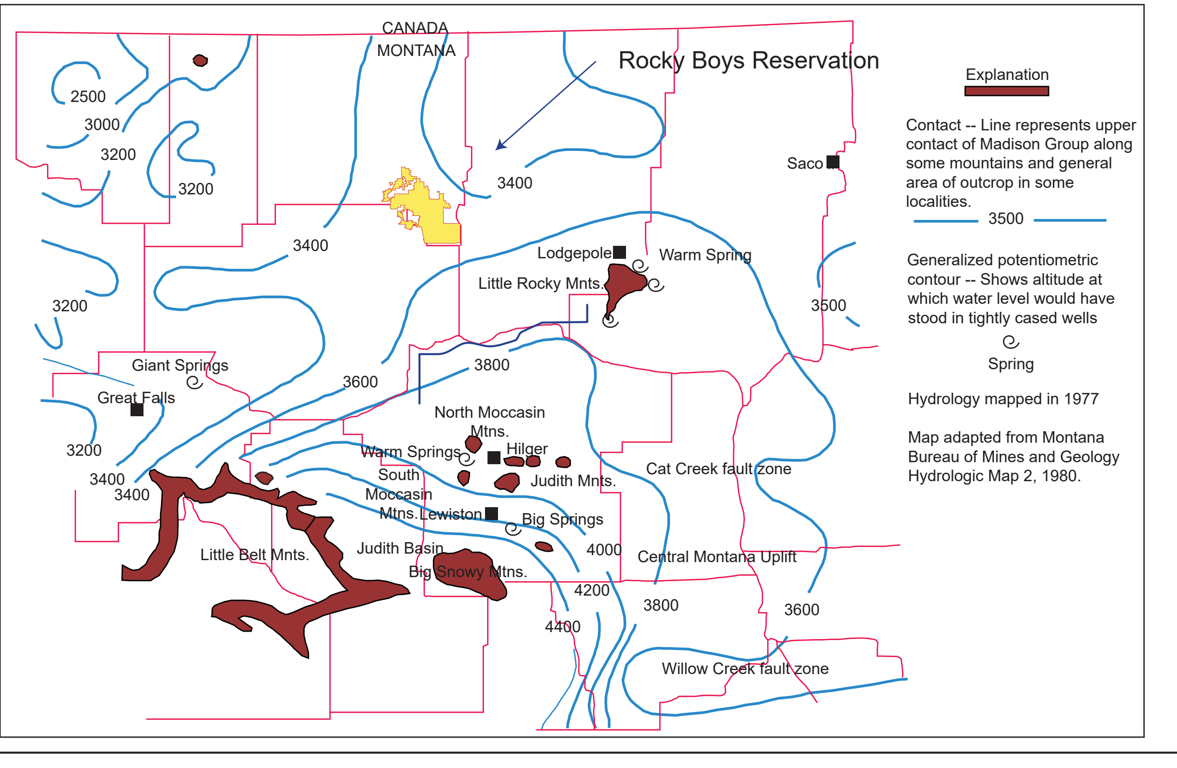


FIGURE RB-28. Potentiometric surface of water in the Madison Group, central Montana (modified after Feltis 1993).

FRACTURED-FOLDED ANTICLINES IN MISSISSIPPIAN - DEVONIAN CARBONATES PLAY

GENERAL CHARACTERISTICS

The play is characterized primarily by oil accumulations in carbonate reservoirs of Mississippian & Devonian age (Figure RB-32). Structural traps are controlled by the distribution of fracture systems generated during Laramide and post-Laramide structural events. The play includes carbonate rocks of the (1) Devonian Souris River, Duperow, Nisku, Potlatch, and Three Forks Formations; (2) Mississippian Madison Group (Figure RB-31). The play extends throughout the area of the province although rocks vary in reservoir quality and thickness (Figure RB-33). The play includes stratigraphically or structurally trapped oil and gas where carbonate facies play an important role in trapping.

RESERVOIRS: Known reservoirs include carbonate rocks of many different facies, as structure controls the distribution of trap types.

SOURCE ROCKS: Source rocks include shale in the Three Forks Formation (Sappington Member), Lodgepole Limestone, and Heath Formations (Cole and Daniel, 1984). Vitrinite reflectance varies from 0.49 to 0.55 percent in Heath shale in southern Fergus County, indicating that the source rocks are thermally immature and are at or immediately below the oil generation window. Ro values of 0.69 to 0.84 percent and TOC values of up to 9 weight percent for Heath shale. Ro values of 0.49 to 0.66 percent and TOC values of up to 2 weight percent for the Mowry Shale in Petroleum County and in Garfield County immediately east of the province (Gautier, 1996). TOC values average 2.4 weight percent for the Marias River Shale (Cone Member) in the disturbed belt near Glacier National Park in Glacier County. Vitrinite reflectance values average 0.6 percent along the crest of the Sweetgrass Arch. In the Williston Basin, organic matter in the Bakken Shale is primarily sapropelic kerogen which averages 11 weight percent TOC. These source rocks are generally thermally mature to immature in the central part of the play, but are mature to over-mature in the disturbed belt to the west. In the western part of the play, Devonian and Mississippian hydrocarbons migrated eastward from source areas within the disturbed belt. Sun River reservoirs are thought to have a Bakken Shale source along the Sweetgrass Arch (Gautier, 1996). The Bakken Shale is thermally mature (Ro = 1.5 percent) in the disturbed belt to the west and northwest, and oils may have migrated updip into traps along the arch (Gautier, 1996).

TRAPS: Most traps are controlled by Laramide folding and faulting. Oil produced from several Jurassic fields may have been generated in Mississippian source rocks in places where Jurassic reservoirs unconformably overlie Sun River (Madison) dolomite reservoirs. Average drilling depth to the top of the Devonian varies from approximately 2,700-7,500 ft. Evaporite and shale sealing beds are present in the Devonian-Mississippian section.

EXPLORATION STATUS AND RESOURCE POTENTIAL: Hydrocarbons have been produced in this play within the province. Potential for undiscovered accumulations may be greatest in the disturbed belt to the west of the province where larger undrilled structures exist. Some potential exists in the southern part of the province for small fields.

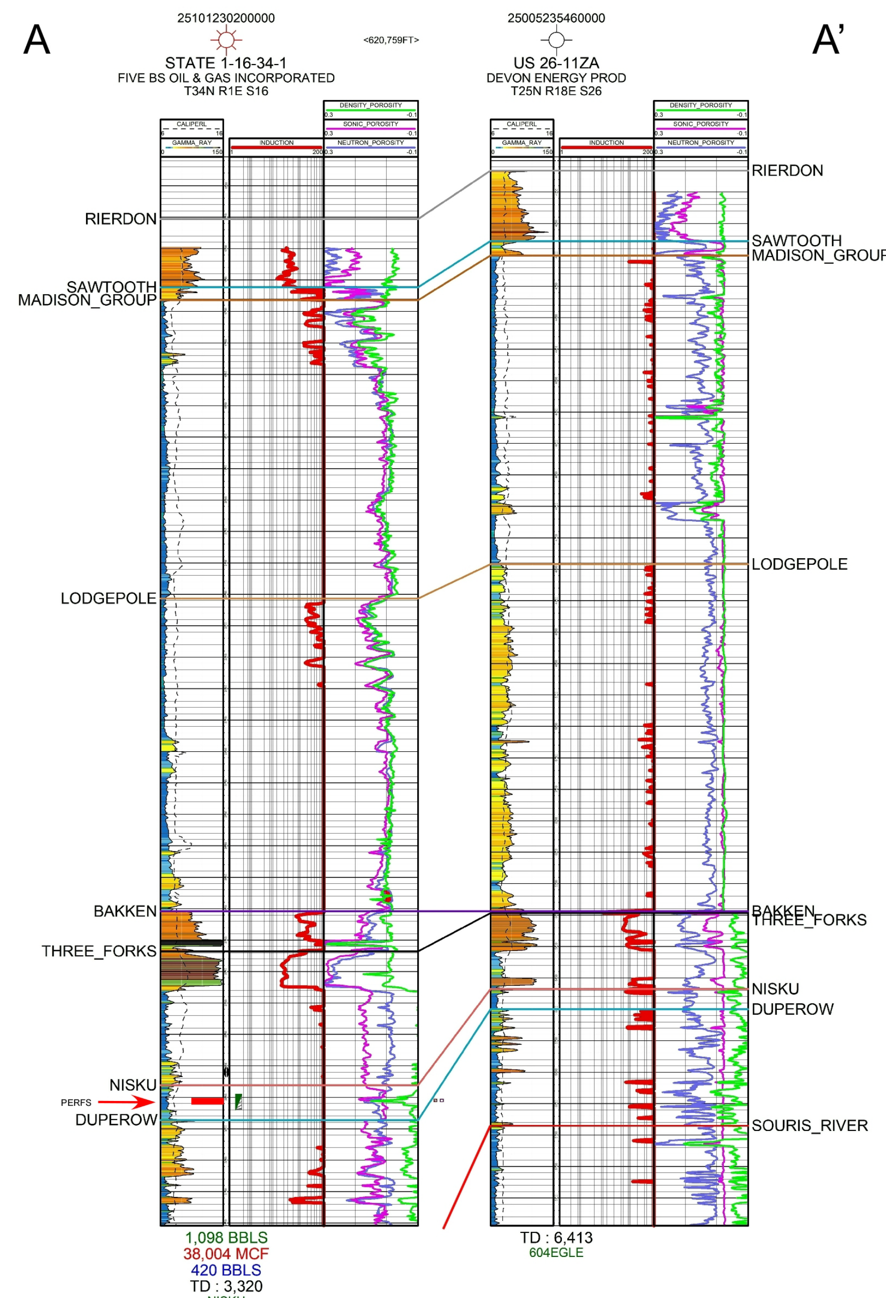


FIGURE RB-33. Mississippian and Devonian log cross section A -A'.

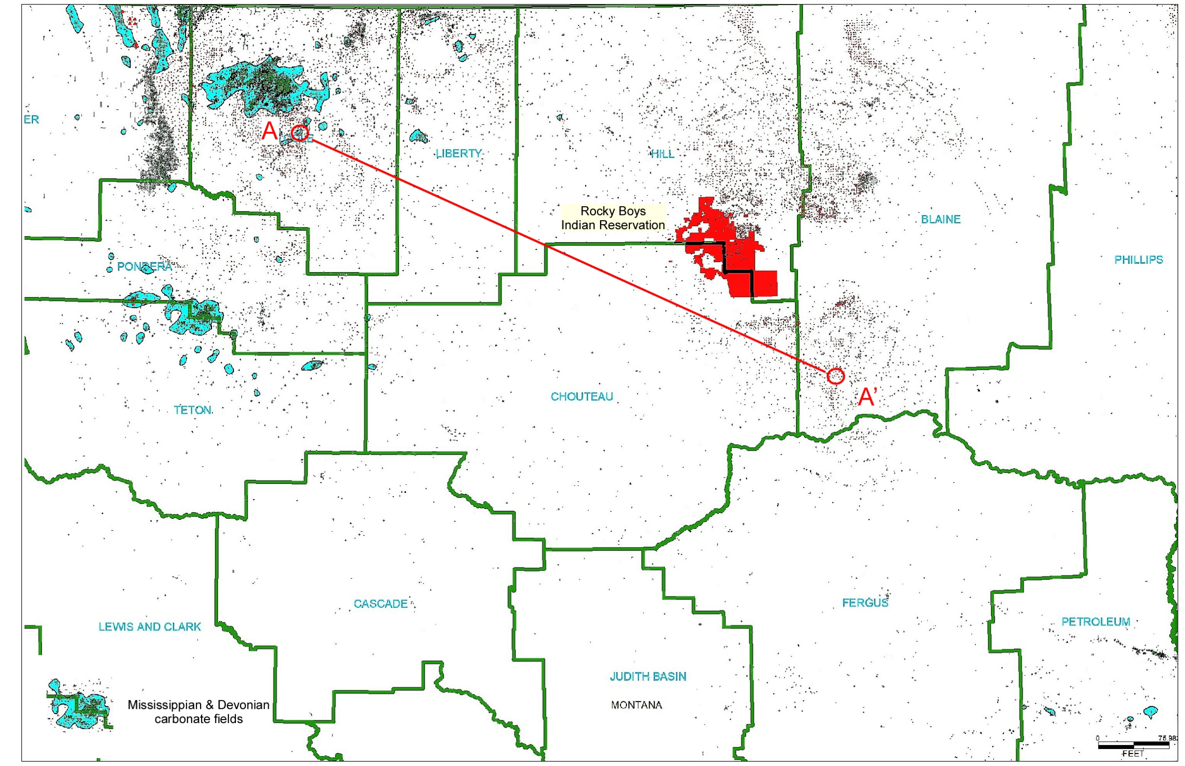


FIGURE RB-32. Mississippian and Devonian carbonate production near Rocky Boys Indian Reservation.

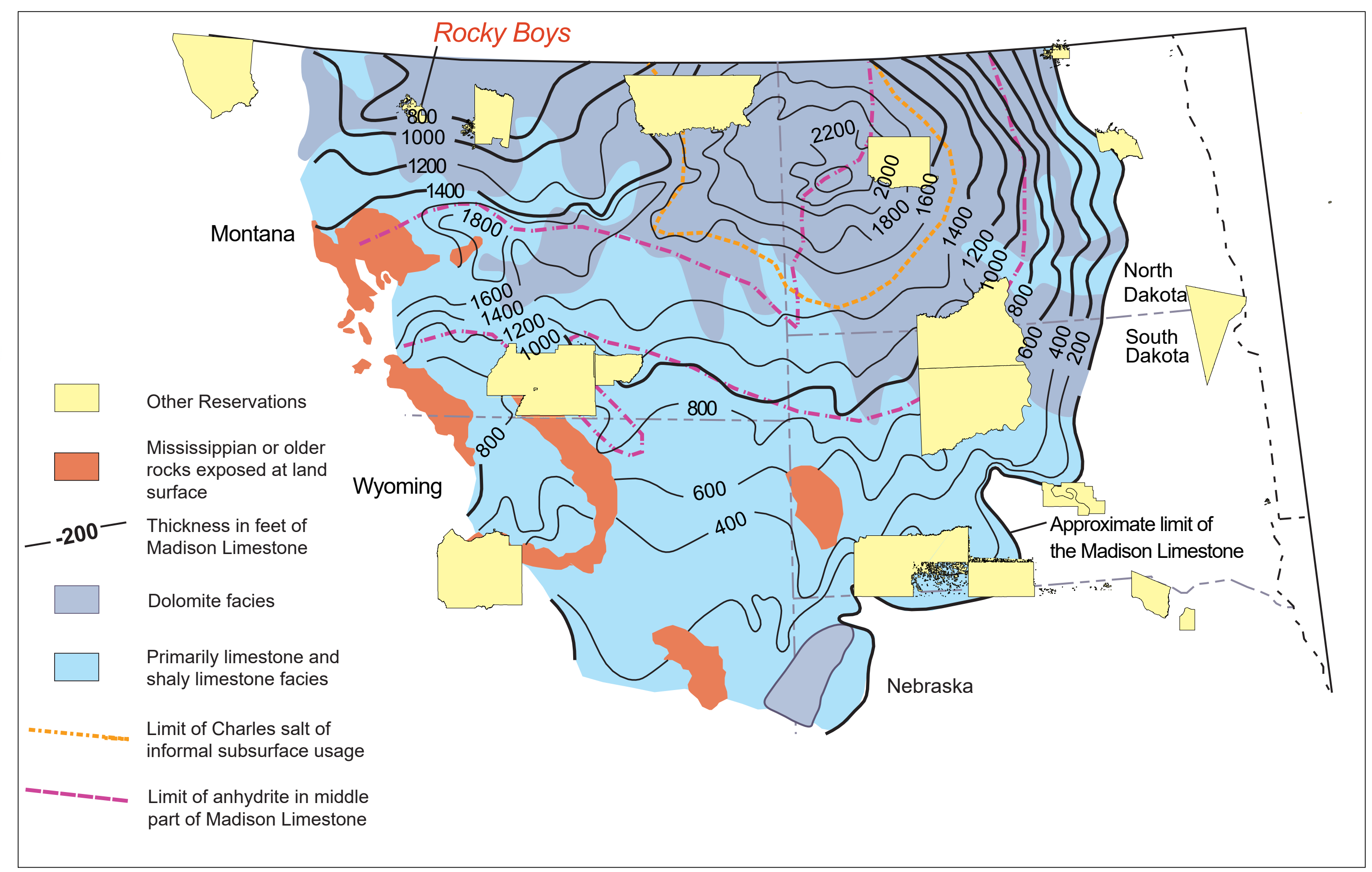


FIGURE RB-31. Thickness and general facies of Madison Group and equivalent rocks (after Peterson 1987).

DEVONIAN SHALES PLAY

GENERAL CHARACTERISTICS

RESERVOIRS:

Bakken/Three Forks formations consist of highly organic shales, dolomitic siltstones with supratidal carbonates developing on the periphery of the depocenter in the Williston Basin (Figure RB-34). The Bakken Shale thins dramatically westward (Figure RB-35) into the Rocky Boys Indian Reservation where it is consists of a black shale no more than 5 feet thick. The Three Forks thins in the direction of the Sweetgrass Arch and changes facies from a peritidal/supratidal silty dolomite to a shaly siltstone with lower limestone units. Oil and gas production to the northwest targets the upper member shale/siltstone unit.

SOURCE ROCKS:

Source rocks consist of organic shale and siltstones of the Bakken and lesser units of the Three Forks.

TRAPS:

The Three Forks is a resource (unconventional) oil and gas play representing a regressive sequence which lies unconformably over the Nisku formation. In the region surrounding the Rocky Boys Indian Reservation, the Three Forks changes to a more anhydritic in composition (Figure RB-36) and is considered the eastern tongue of the Potlatch Anhydrite (Brown, 1984). The best reservoir can be expected near structures active during the Antler orogeny (Nekhorosheva, 2014)

RESOURCE POTENTIAL:

The Bakken/Three Forks has proven itself worthy of world class oil & gas reservoir designation in the Williston Basin. Production has expanded westward to the western Montana basins area where sufficient burial and thermal maturation of the organic shales has provided yet another area where oil and gas can be found. Continued exploitation of this resource play in Montana will determine how far and wide this unconventional play extends.

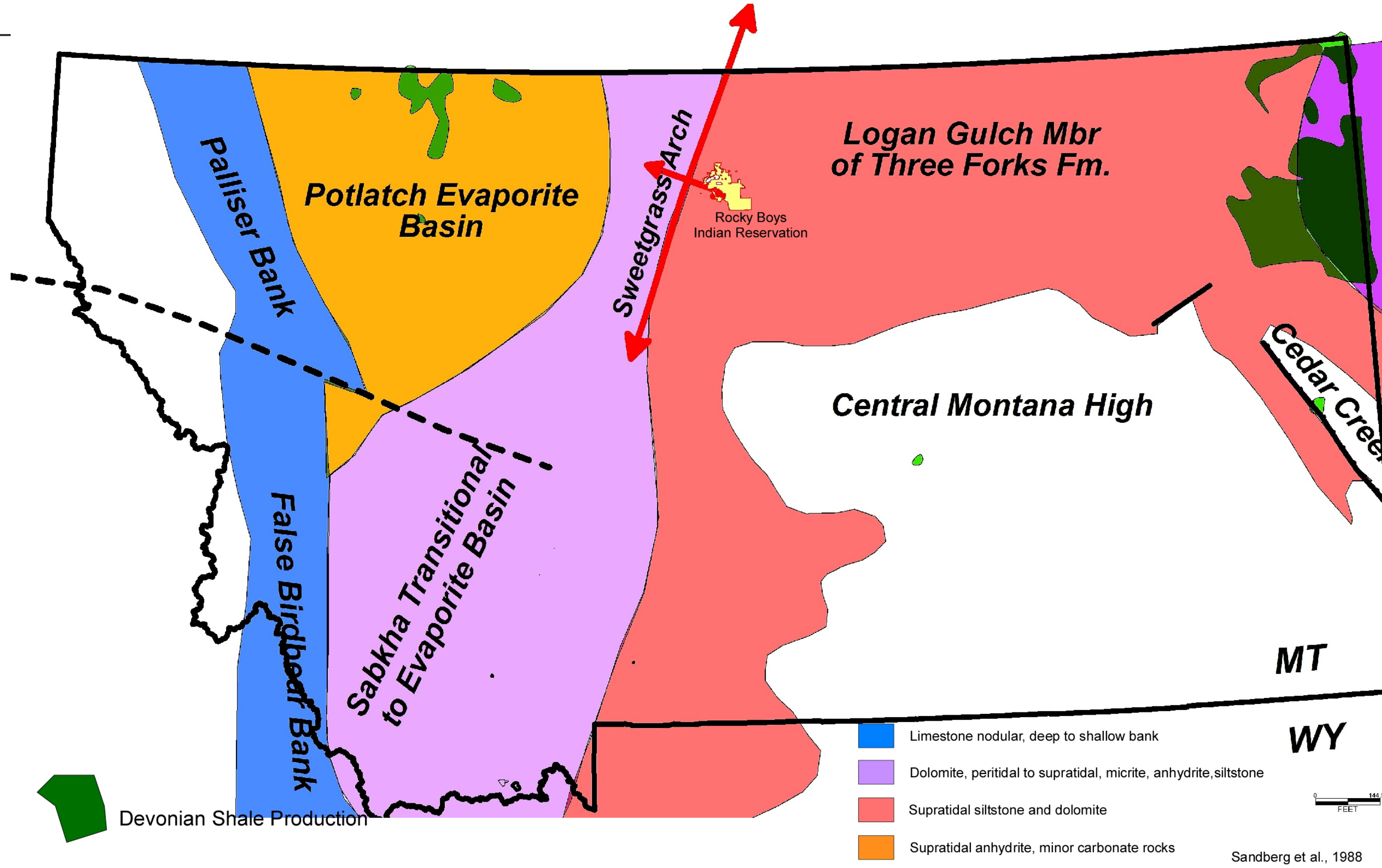


FIGURE RB-34. Devonian paleogeography with Devonian Shale production (modified after Sandberg et al, 1988).

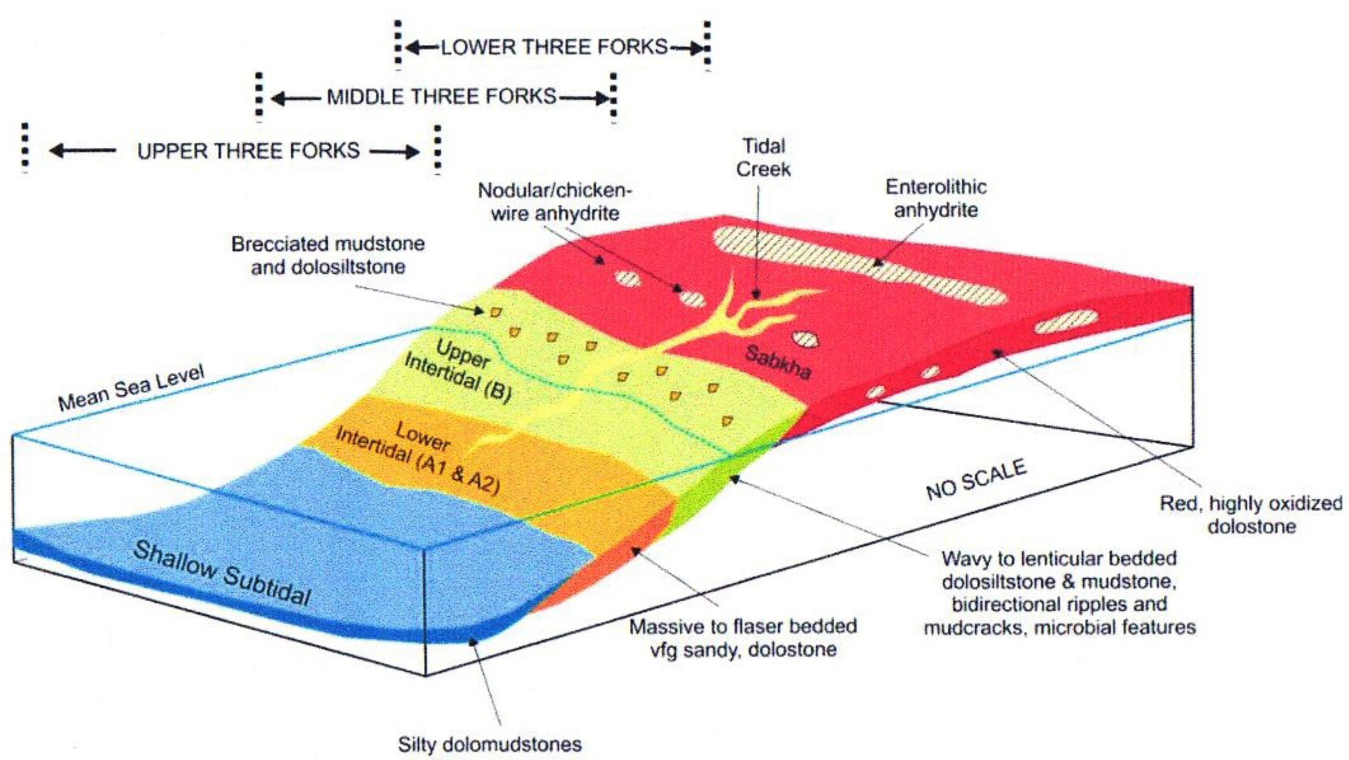


FIGURE RB-36. Three Forks schematic depositional model (from Sonnenberg 2017).

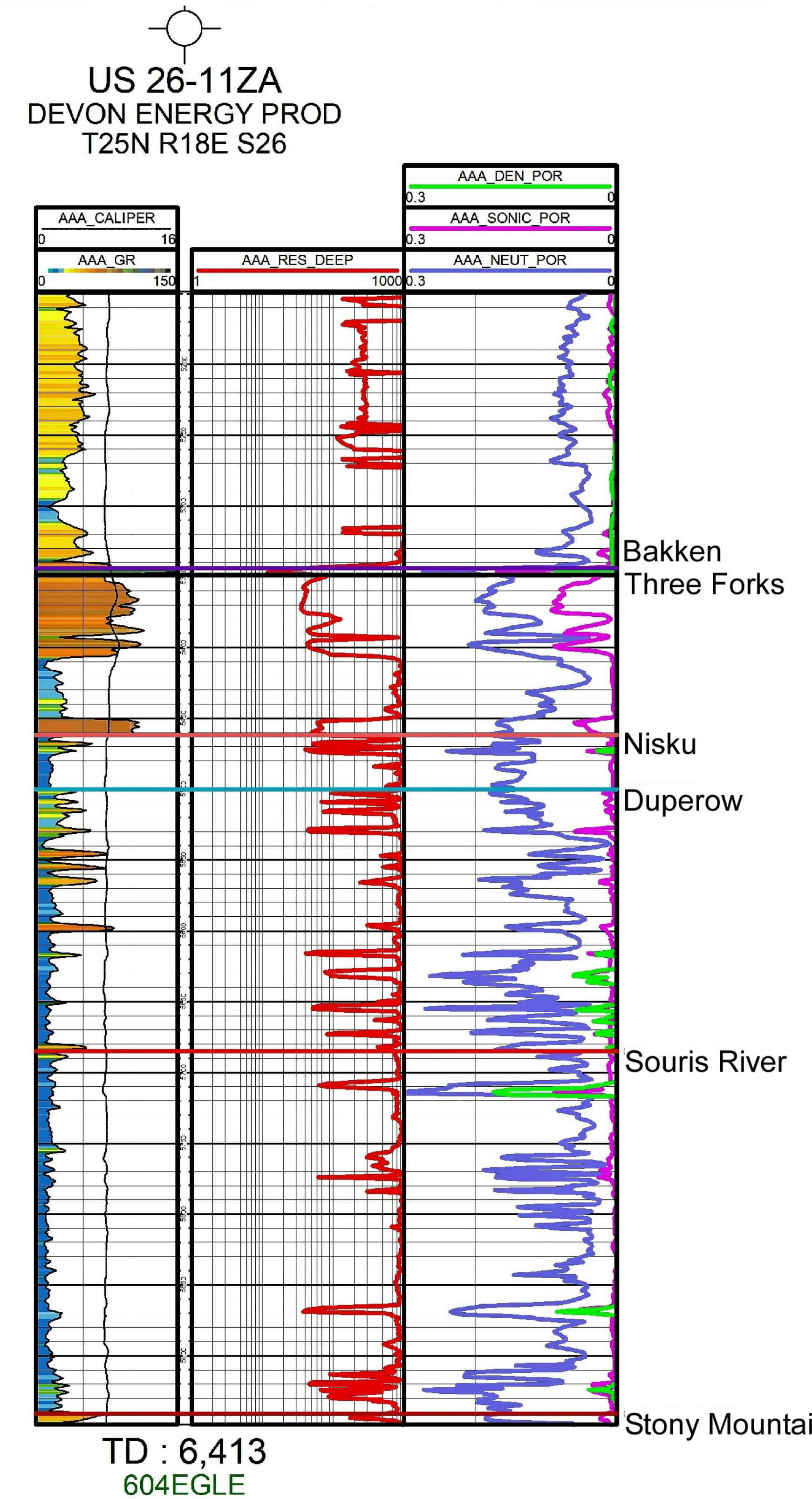


FIGURE RB-35. Bakken / Three Forks Type Log.

CAMBRIAN-ORDOVICIAN SANDSTONES PLAY

GENERAL CHARACTERISTICS

The boundary of this hypothetical play is based on the distribution of Cambrian and Ordovician sandstone. Cambrian rocks are approximately 1,200 feet thick on the reservation (Figure RB-37). Ordovician strata are less than 50 feet thick on the reservation because of pre-Late Devonian erosion. The Cambrian-Ordovician Sandstones Play includes the Cambrian Flathead and equivalent sandstone throughout the province except along the crest of the Sweetgrass Arch (Figure RB-38). By the mid-1980's, more than 60 wells penetrated Cambrian strata in the region (Gautier, 1996) (Figure RB-39), but facies relationships within these rocks have not been well defined. No Cambrian production occurs in the province at this time.

RESERVOIRS: Reservoir and source-rock lithologies include quartz- and lithic-rich sandstone of the Flathead Formation. No production has been established to date within the Rocky Boys Reservation or the adjacent Bearpaw Uplift. The Flathead interval is well exposed in the Little Rocky Mountains at the southern end of the reservation. It is a fine-grained sandstone with some interbedded conglomeratic lenses and thick shale intervals (Figure RB-37). Because the Cambrian Flathead sandstone is exposed at the surface to meteoric influx, a hydrodynamic flow gradient from south to north may have flushed hydrocarbons from the older rocks.

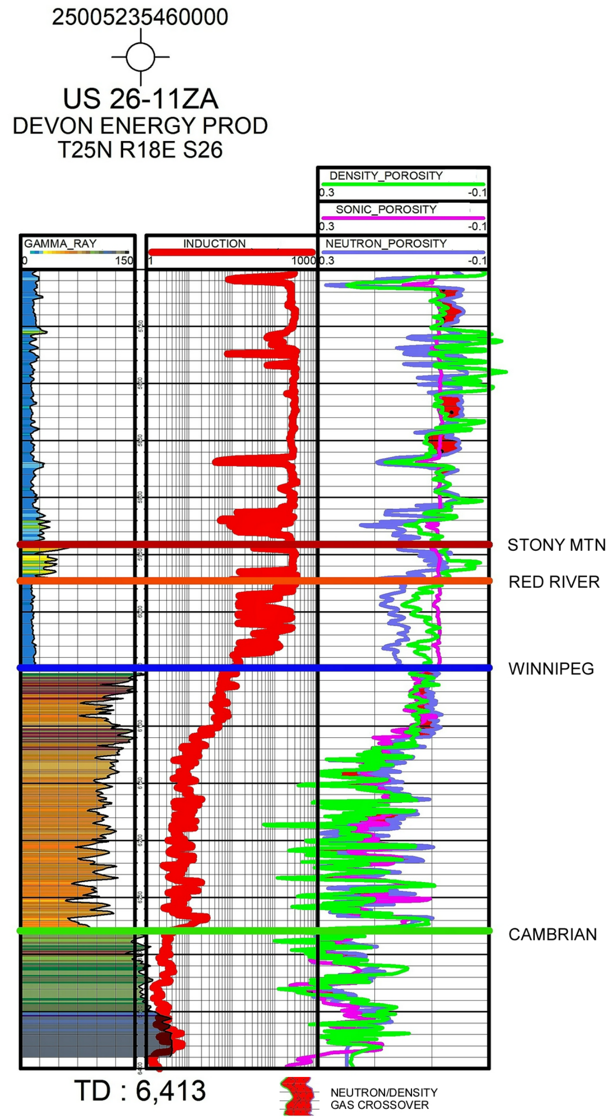


FIGURE RB-38. Cambrian - Ordovician Type Log.

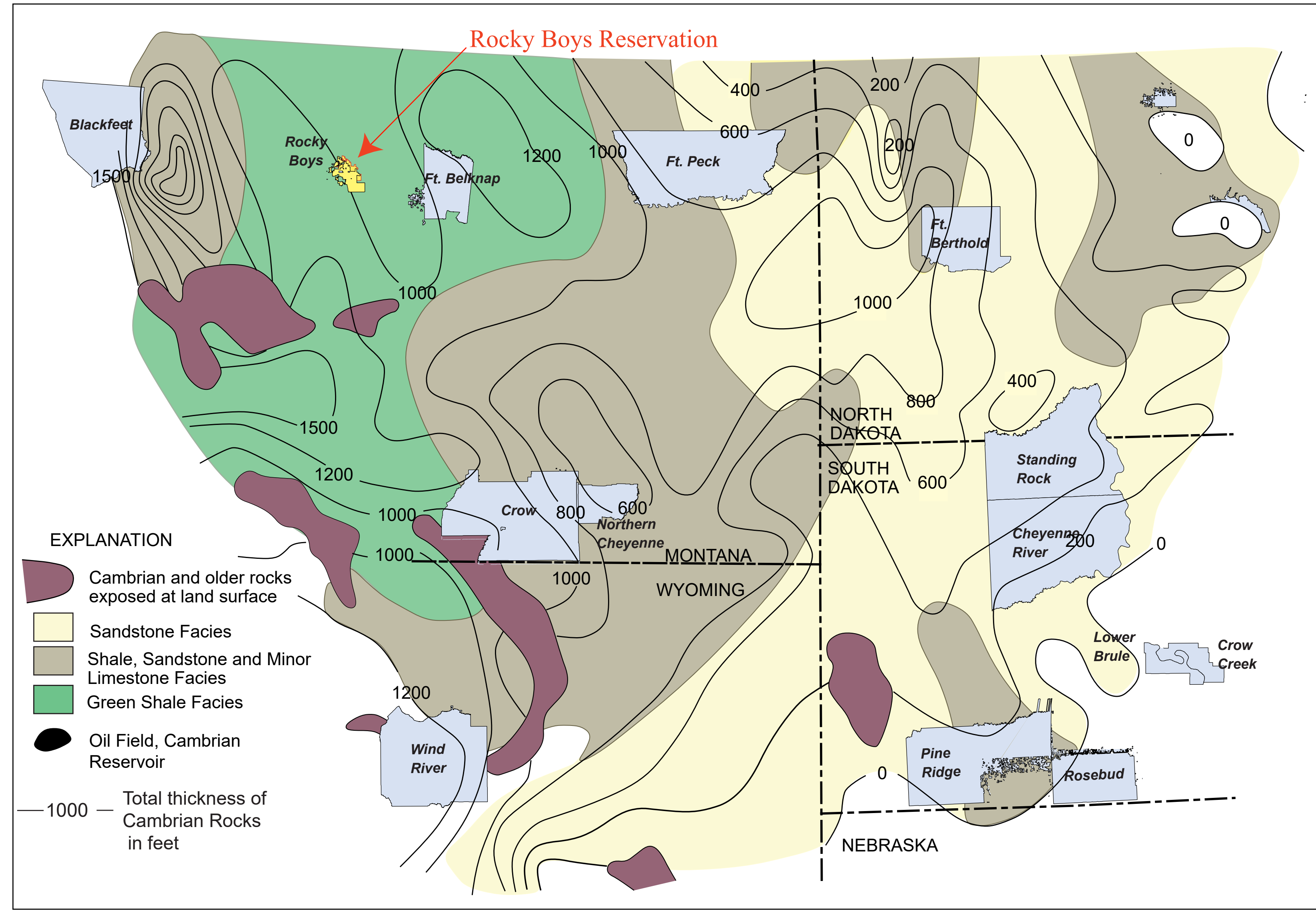


FIGURE RB-37. Thickness and general lithology of Cambrian Rocks (modified after Peterson, 1987).

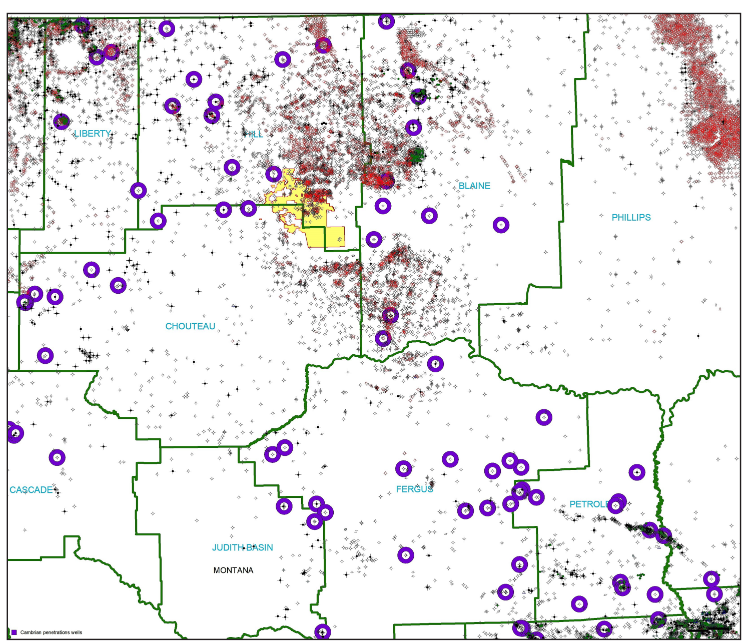


FIGURE RB-39. Wells that have penetrated Cambrian sediments.

The average depth to the top of the Cambrian, where present, varies from about 3,000-8,000 ft.

SOURCE ROCKS: The best source rocks are dark-gray marine shales including the Cambrian Gordon and Switchback Shales and their equivalent rocks, and shale beds of the Red River Formation. At present, no geochemical data are available to determine thermal maturity, type of organic matter, and timing and migration of hydrocarbons for lower Paleozoic strata in the province. Organic-geochemical data are not available for Cambrian shale, but these source rocks are generally considered poor to fair and assumed to be immature to marginally mature due to the shallow maximum burial depths.

TRAPS: The principal trapping mechanism would be permeability barriers in sandstone. Structural enhancement of existing traps may be common in areas of Laramide faulting and folding. The first Winnipeg (Flathead) production in Montana was reported in 1986 by Amerada Hess in Roosevelt County in the western part of the Williston Basin, to the east of the reservation. A wildcat well flowed about 3 MMCFG/D at a depth of 11,000 ft. Nyvatex Exploration reported high-gravity oil shows at a depth of 3,690 ft. in the Flathead Formation in their Friedman 26-1XD well in Cascade County (Sec. 26, T20N-R2E), also drilled in 1986.

RESOURCE POTENTIAL: Play attributes include a moderate probability of occurrence (probability=0.5) of source rocks of appropriate richness, but adequate thermal maturity, reservoir rocks, and traps are assumed present (probability=1.0). The play probability (probability of occurrence of an undiscovered accumulation of 1 MMBO or 6 BCFG) is therefore 0.5. Undiscovered fields are presumed to be small.

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