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Geologic Map of the Culbertson 30' x 60' Quadrangle (Surficial Emphasis), Roosevelt, McCone, and Richland Counties, Montana, and Divide and Williams Counties, North Dakota

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Mapped in stages: 1947—1980's
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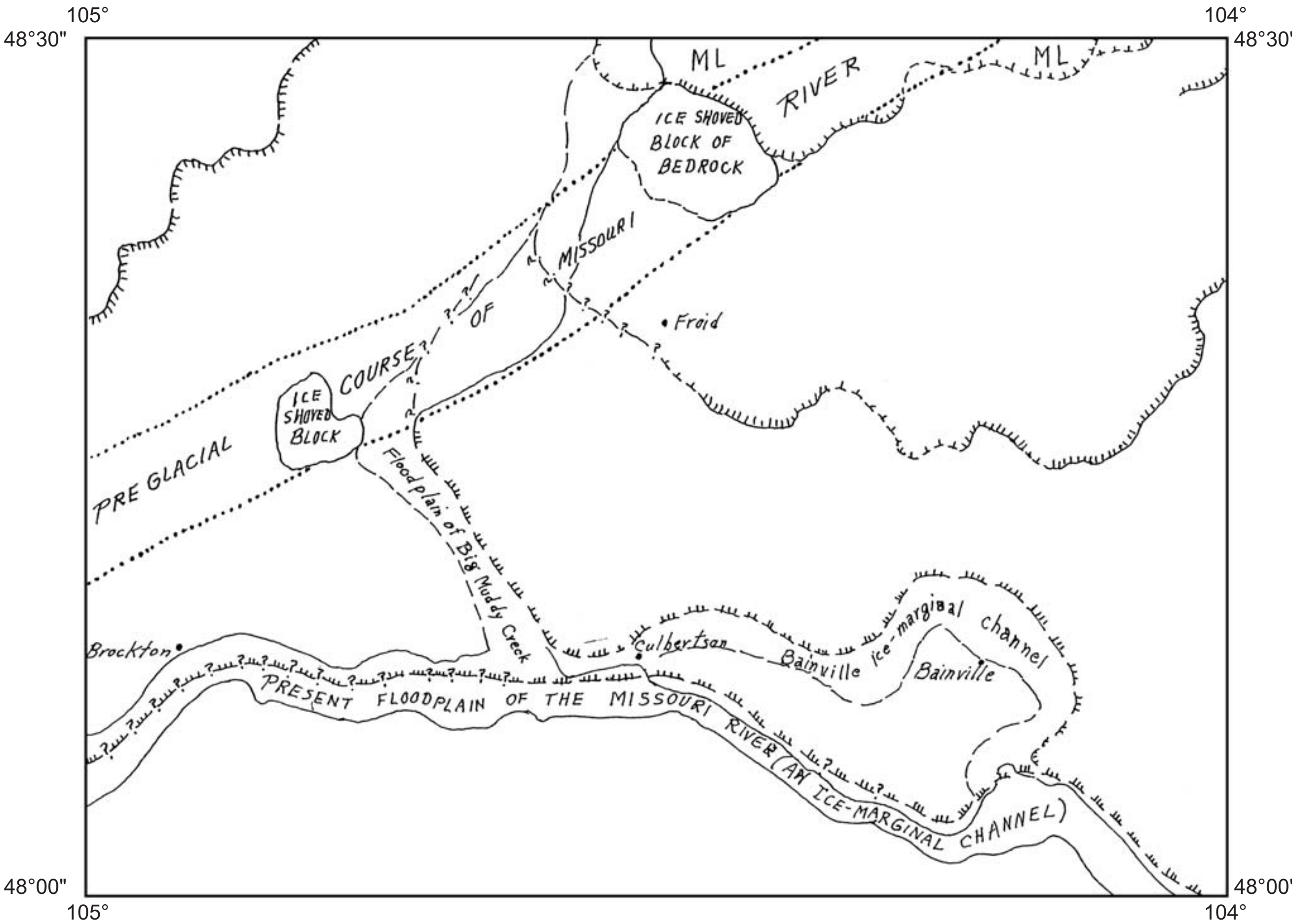
Note:

1. The geologic information on this map was prepared by the authors as part of field studies for the U.S. Geological Survey. Although the maps have been peer-reviewed for scientific interpretation, the report is preliminary and has not been edited to conform with U.S. Geological Survey publication standards.

2. The Montana Bureau of Mines and Geology is publishing this information with the cooperation of the U.S. Geological Survey and has not edited or reviewed the document.

3. The map is a scan of a map hand-drawn by the authors. The collar information is from documents provided by the authors. Layout of the final map was done by Susan Smith, Geologic Cartographer, MBMG.



ML	Extent of Medicine Lake readvance (14,000 YBP)
CH	Extent of Crazy Horse glaciation (Late Wisconsin)
←	Inferred direction of ice movement
(ice-marginal symbol)	Ice-marginal position, dashed where approximately located, tics on ice side
(dashed lines)	Course of the Pre-glacial Missouri River

Figure 1. Features and effects of glaciation in the Culbertson 30' x 60' quadrangle.

DESCRIPTION OF MAP UNITS

Qal Alluvium (Holocene and late Wisconsin)—Light-yellowish-brown, yellowish-brown, grayish-brown, and light-gray coarse to fine gravel, sand, silt, and clay deposited on floodplains and in stream channels. Poorly- to well-stratified; poorly- to well-sorted.

Most of the alluvium is yellowish brown and moderate brown; most of the clay plugs are yellowish brown, medium gray, or bluish gray. The upper several feet contain lenticular dark-brown or dark-gray beds alternating with light brown beds. Light-brown iron staining occurs as isolated blebs along rootlets and irregularly through some beds, staining individual laminae. Staining is prominent in some areas.

Floodplain alluvium is chiefly unconsolidated, well-sorted, silt and fine and medium sand; in valleys of some small streams it includes fine to coarse gravel. Silt and organic clay generally are present in discontinuous lenses or beds or are mixed with fine sand. In general, the upper part of the floodplain alluvium consists of unconsolidated, well-sorted very fine sand, silt, and clay, whereas the lower part (channel alluvium, and locally, outwash) consists of coarse sand and gravel. Vertical and horizontal facies changes within short distances are common. Grain size analyses of alluvium indicate great variation of texture: 28-58 percent clay, 5-60 percent silt, 4-100 percent sand, 0-14 percent granules, and 0-53 percent pebbles. In the Culbertson area, alluvium underlies flood plains that have scalloped (meander scroll) or braided surface patterns.

Seventeen test holes were drilled by the Bureau of Reclamation in the Ft. Kipp 7.5-minute quadrangle in sec. 6, T. 28 N., R. 55 E., and sec. 1, T. 28 N., R. 54 E. across the valley of Big Muddy Creek. The profile (Witkind, 1959, Plate 5) indicates that the center of the valley is underlain by 95 ft of clay, which is underlain by 12.2 m (40 ft) of clay, silt and sand; that rests on 6 m (20 ft) of sand and gravel (outwash?) which lies on bedrock. Five test holes were drilled southwest of the alluvial plain and indicate that there are two tills, each as much as 80 ft thick, on as much as 53 m (175 ft) of sand and gravel. The axis of an older buried valley is just south of the edge of the present alluvial plain of Big Muddy Creek. The total thickness of sand and gravel is 68.6 m (255 ft). In general, the alluvial fill in the Missouri River valley consists of (top to bottom): 30 m (98.4 ft) of clay and silt, 13 m (42.6 ft) of clayey or silty sand, and 6 m (20 ft) of sand and gravel. The alluvial deposits beneath the Missouri River and Big Muddy flood plains are not exposed (Witkind, 1959, p. 15). Much of the alluvium in the valley of Big Muddy Creek is the result of flooding. Deposition of clay, silt and sand during flooding has obscured or covered the meanders of the Missouri River and Big Muddy Creek. The presence of large swampy areas and lakes in the floodplain of Big Muddy Creek west of and north of Rocky Point indicates that the area is aggrading as a result of periodic extensive flooding. The flow of Big Muddy Creek through the north central part of the Ft. Kipp 7.5-minute quadrangle is probably slowed by alluvial fan building at the base of cliffs on the northeast side of the valley. The in-filling of Johnson Lake and the filled mouths of several creeks on the west side of the Big Muddy floodplain indicate that Big Muddy Creek cannot erode faster than aggradation is occurring in the north central part of the Ft. Kipp 7.5-minute quadrangle. Big Muddy Creek is underfit in a wide valley that was carved by a large volume of glacial meltwater during each glaciation of northeastern Montana

Qac Alluvial and colluvial deposits (Holocene and late Pleistocene)—Light-brown, brown, grayish-brown, and gray nonstratified or poorly-stratified gravel, sand, silt, and clay deposited by sheet wash, stream flow, and gravity processes on slopes. Primarily sheetwash alluvium, derived from bedrock outcrops and other surficial deposits higher on slopes and deposited by unconfined sheet flow and rill wash. Colluvium is generally present only on and below slopes steeper than 8 percent. Sheetwash alluvium is chiefly fine sand and silt with scattered granules and small pebbles; colluvium is chiefly gravel and sand or a heterogeneous mixture of boulders, cobbles, pebbles, and granules in a clayey to sandy matrix. Colors, textures, and particle lithologies vary, reflecting those of bedrock and surficial materials higher on slopes. The downslope surface profile of alluvial/colluvial deposits is concave upward. Sheetwash alluvium commonly interfingers with and overlaps flood-plain alluvium (Qal), and forms extensive fans and aprons on terraces in major valleys. Buried soils (humic horizons) are present locally in the sheetwash alluvium and colluvium. Fossil snail shells and vertebrate fossils are present locally. Unit includes small areas of windblown deposits that interfinger with and overlie sheetwash alluvium.

Alluvial fan and colluvial deposits consist of crudely stratified silt, silty clay, pebbly silt, sand, and gravel. The composition and color of the deposits vary considerably depending on the lithologies of the source bedrock and surficial materials. For example, the colluvium derived from outcrops of Bearpaw Shale is composed almost exclusively of fragments of weathered Bearpaw Shale. Where till is the source material, the resulting colluvium is pebbly clay that resembles till. Adjacent to outcrops of the Flaxville Formation colluvium is loose, poorly sorted, crudely stratified, slightly clayey, sandy gravel. Where it is derived from sandy beds of the Hell Creek Formation the alluvium and colluvium is nearly 100 percent sand.

Great variation in thickness within short distances is characteristic of fan alluvium and colluvium. The thickness ranges from zero at the edge of the upslope part of the deposit to the maximum thickness of 3 m (10 ft) where the colluvium is in contact with or interfingers with alluvial deposits. Generally, the thickness of colluvium is seldom more than 2 m (6 ft), and averages only 0.3 m (1 ft).

The thickness of alluvial fans ranges from zero at the apex and reaches a maximum about one-third or one-fourth of the distance to the toe. At the toe, the fan alluvium is thin and commonly it interfingers with the adjacent floodplain alluvium. Fans are as much as 15 m (50 ft) thick but average 3 m (10 ft) and seldom exceed 8 m (25 ft) thick. Generally, the deposits have not been mapped where they are less than 0.3 m (1 ft) thick

Qls Landslide deposit (Holocene and late Pleistocene?)—Slump, rockfall, and earthflow deposits (individual or in series) produced by gravity downslope movement of bedrock or surficial materials. Colors, textures, and lithologies vary, reflecting parent material. Size of detritus ranges from clay to blocks of sandstone and clinker as large as 3 m (10 ft) in diameter. Thicknesses of some landslide deposits are estimated to be as much as 30 m (100 ft)

Qe Eolium (Holocene and Pleistocene)—Light-brown to light-gray windblown silt (loess) and sand with some granules. Generally massive or crossbedded; quartz grains are commonly frosted. Buried soils (humic horizons) are present locally. Most of the sand grains are well-rounded quartz coated with organic matter; locally the grains are clean angular quartz.

The deposits of windblown sand and silt unconformably overlie all other map units in the area.

Four analyses of dune sand indicate that the dunes consist of 0-6 percent clay, 1-9 percent silt, and 85-99 percent sand. Two samples of loess indicate it consists of 10-20 percent clay, about 60 percent silt, and 20-30 percent sand.

Local relief in the sand dunes a few miles south of Johnson Lake and southeast of Medicine Lake is as much as 15 m (45 ft); therefore, the maximum thickness of eolium is probably approximately 17 m (57 ft). In interdune areas, the thickness is probably only a few meters. Generally, the thickness is 5 to 6 m. Parabolic dunes indicate winds from the northwest moved the sand southeastward from outwash deposits that are now buried under the floodplain of Big Muddy Creek. A general blanket of eolian silt and sand covers much of the Culbertson 30’ x 60’ quadrangle southeast of the floodplain of Big Muddy Creek. However, only areas of sand dunes are shown on the map; the soil surveys of Roosevelt and

Sheridan Counties indicate that eolium is much more extensive than in sand dune areas

Qc Clinker (Holocene and late Pleistocene)—Very resistant red, pink, orange, black, and yellow metamorphosed shale, siltstone, and sandstone of Fort Union Formation and locally till. Bedrock was baked by natural burning of underlying lignite. Locally, baked rock melted and fused to form buchite, a black, glassy, vesicular, or scoraceous rock. Clinker is very resistant to erosion and caps hills or knolls and forms ledges on steep slopes. The thickness is generally less than 6 m (20 ft) but locally may be as much as 20 m (66 ft)

Qp Pond deposits (Holocene and late Wisconsin)—Brown, dark-gray, or black fine sand, silt, and clay in depressions that retain ephemeral ponds. Commonly includes thin laminae of windblown sand and silt. Depressions in the till plain and other areas are partially or completely filled with dark, tough, plastic, organic, silty or sandy clay containing scattered granules and pebbles. Most deposits are less than an acre in aerial extent; a few are larger than 2.6 sq km (1 sq mi); all have flat surfaces. Shallow ponds form in them during wet weather but disappear during dry weather.

A sample from sec. 7, T. 26 N., R. 50 E. (22 km (15 mi) west of the quadrangle) was composed of 68 percent clay, 26 percent silt, and 6 percent sand. The organic content is high, about 7 percent of a sample as consumed during an ignition test.

The deposits are well bedded to massive; beds generally are thin. Natural exposures in pond deposits do not exist, but auger holes revealed as much as 5 m

(16 ft) of black or brown plastic, stiff clay, and scattered pebbles. Pond deposits are not indurated or cemented, and apparently do not contain concretions.

Pond deposits are as thick as 5 m (16 ft) thick, the average thickness is about 2 m (6 ft). Generally, the deposit is thickest near the center of the closed depression. The cross section of most deposits resembles that of a shallow bowl

Qo Glacial outwash deposits (Middle to late Pleistocene)—Light-brown, yellowish-brown, brown, and light-gray sand and gravel with minor silt, deposited by glacial meltwater streams. Generally horizontally bedded and well stratified; moderately well sorted to well sorted. Granules and larger clasts are subrounded to well rounded. Clast lithology consists of reworked erratic glacial pebbles, cobbles, and boulders of limestone, dolomite, granite, gneiss, and schist from Canada. Outwash deposits typically consist of 2-18 percent clay, 2-8 percent silt, 20-27 percent sand, 4-20 percent granules, 42-73 percent pebbles, and 2-5 percent cobbles. Most of the outwash deposits are thin, long, narrow sandy gravel fills in ice-marginal channels that formed between the ice margin and the higher ground, or beneath the ice margin. Most outwash deposits are less than 1.6 km (1 mi) long, but a few are as much as 8 km (5 mi) long; generally, they are less than 30 m (100 ft) wide, but some irregularly shaped outwash deposits are a mile wide. Outwash deposits associated with the Late Wisconsin Crazy Horse glaciation and earlier glaciations have not been differentiated as to age on the map; some ice-marginal channels appear to have been used more than once. The lower parts of some alluvial deposits may be outwash. Locally, some of the outwash deposits may be deltaic. In places, outwash may be overlain by a thin discontinuous veneer of till (Qt), glacial lake deposits (Qgl), and sheetwash alluvium (Qac). Those that formed during each advance were overridden and veneered by till and/or glaciolacustrine deposits. Most of the outwash deposits are about 3 m (10 ft) thick but some are as much as 6 m (20 ft) thick

Qic Ice-contact stratified deposits (Middle to late Pleistocene)—Brown to light-brown poorly to well-stratified, poorly- to well-sorted, fine to coarse sand and gravel with minor silt. Deposited by glacial meltwater flowing in channels beneath, within, or on top of ice and, subsequently, let down as the supporting or surrounding ice melted. Deposits are long, discontinuous, narrow and sinuous (eskers), or conical heaps or irregular ridges (kames).

Esker and kame deposits are poorly bedded and sorted. Local faults and tilted and contorted bedding in the deposits indicate collapse when the enclosing ice melted. Well-stratified silt, sand, or fine gravel beds commonly abut poorly sorted material, or, locally, lenses of till; crossbedding is pronounced in some beds in eskers and kames. Bedding along the sides of eskers tends to be parallel to the side slopes owing to collapse of the retaining ice walls.

The few exposures seen in the area indicate till is the material underlying esker and kame deposits. Till is on the sides and crests of some eskers and kames, indicating they were formed in and under ice. Locally, esker and kame deposits are overlain by alluvium, colluvium, lake deposits, the Kintyre Formation, and eolian deposits.

Esker and kame deposits occur together and in some places grade into each other. The dimensions of kames vary greatly. Their length ranges from 100 m (300 ft) to more than 1.6 km (1 mi), their height is as much as 30 m (100 ft), but few exceed 15 m (50 ft), and is generally less than 10 m (30 ft). Their width ranges from 91 to 609 m (300 to 2,000 ft), but most are less than 152 m (500 ft) wide. Many kames are round or subround, but a few are long and narrow. The dimensions of the eskers in the Culbertson area are as follows: widths range from 30 to 100 m (100 to 300 ft), but average 61 m (200 ft); heights range from a meter (3ft) to 20 m (60 ft) but average 3 m (10 ft); lengths range from a few hundred feet to nearly 3 km (2 mi). Thickness of the esker and kame deposits varies greatly within short distances. Generally, they are at least as thick as their height above the immediately adjacent till plain. Therefore, eskers are as much as 20 m (60 ft) thick and kames are as much as 30 m (100 ft) thick

Qgl Glacial lake deposits (Middle and Late Pleistocene)—Light brown and gray clay, silt and sand formed in shallow temporary glacial lakes. As the ice front retreated meltwater was impounded where the land sloped toward the ice. One of the largest temporary lakes was in the buried valley of the pre-glacial Missouri River west of Rocky Point and the flood plain of Big Muddy Creek. The deposits may underlie 40 square miles (64 sq. km). Several small glacial lakes formed between the retreating lobe of ice in the northeast corner of the Culbertson 30' x 60' quadrangle and a low drainage divide in the east central part of the 30' x 60' quadrangle. The glacial lake deposits are thin, generally 3 to 5 m (10 to 15 ft) thick, but locally may be as much as 20 m (60 ft). Analyses of glacial lake samples indicated that they range from 22 to 56% clay, 39 to 50% silt, and 2 to 30% sand

Qki Kintyre Formation (Pleistocene to Late Wisconsin)—Brown, olive-brown, light-brown, light-gray sand, sandy silt, clayey silt, and clay. Jensen and Varnes (1964, p. F34) reported that the formation consists of a basal clay, overlain by light-brown silt, fine sand interbedded with minor amounts of clay and silty clay. The upper half of the formation is dark-brown clay and silty clay. Jensen and Varnes (1964, p. F33) named the formation "for exposures near Kintyre, a siding on the Great Northern Railway about 8 km (5 mi) west of the town of Frazer" (80 km (50 mi) west of the Culbertson 30' x 60' quadrangle). The reader is referred to Jensen and Varnes (1964, p. F33-34) for a comprehensive description of the Kintyre Formation.

Jensen (1951b, p. 16) believes that the sediments were originally deposited on glacial ice, partly by slowly flowing glacial meltwater and partly as lacustrine deposits laid down in shallow ponds and lakes on the melting ice. The silts and clays in ponded waters are thinly laminated, whereas the deposits laid down by flowing water are somewhat coarser. As the underlying ice melted, the clay, silt, and sand deposits collapsed and was folded and fractured. Thickness of the formation is as much as 21 m (70 ft) (Jensen, 1951 b, p. 16) but generally ranges from 6 m (20 ft) to 21 m (70 ft). Three miles south of Wolf Point, the Kintyre Formation is 11 m (35 ft) thick. A log of a test hole drilled by the U.S. Bureau of Reclamation in sec. 10, T. 27 N., R. 52 E. indicated that the formation may be as much as 37.2 m (122 ft)

Qt Till (Pleistocene)—Heterogeneous mixture of clay, silt, sand, and gravel with rare to abundant cobbles and boulders deposited by continental ice sheets during at least three glaciations. Nonstratified or very poorly stratified; nonsorted or poorly sorted. Locally faintly layered, particularly near base and top. May be interbedded, intertongued, or intercalated with sand and gravel or clay and silt. Analyses of 28 samples of till indicated the tills are composed of 24-38 percent clay, 23-46 percent silt, 33-62 percent sand, 1-4 percent granules, 1-21 percent pebbles, and 1 percent cobbles.

Deposits representing three glaciations are present in northeastern Montana. The deposits of the two earliest (pre-Illinoian) glaciations have been informally named the Archer till (Fullerton and Colton, 1986). Only the upper member of the Archer till has been identified in the Culbertson 30' x 60' quadrangle. It is overlain by the late Wisconsin Crazy Horse till.

The Archer till was deposited by southwestward-moving ice. During the Crazy Horse glaciation (Late Wisconsin) regional ice movement was from the northeast. The surface till in much of the Culbertson quadrangle is the Crazy Horse till. It commonly contains lenses, pods, and stringers of sorted clay, silt, sand, and gravel. At lower altitudes the till includes subaqueous debris flow deposits. Clayey till is soft and sticky where damp. Clay minerals are dominantly montmorillonite. Till is mapped only where it is aerially extensive or where small outcrops are closely spaced. Thickness of the youngest till (Crazy Horse till) generally is less than 3 m (10 ft). Although the total thickness of all of the till units is generally less than 5 m (16 ft) it may be as much as 30 m (120 ft) thick in buried valleys.

Till generally is preserved only on rolling or relatively flat surfaces. In badlands and other areas of dissected bedrock, it was deposited only as a thin and discontinuous veneer. During interglacial and postglacial intervals, dissection was resumed in those areas and most of the till was removed. Where tills deposited during different glaciations are superposed, typically, each till is discontinuous laterally. Where till is mapped in areas of intense erosion, only small remnants of the Crazy Horse till has been preserved. Because of the discontinuous lateral distribution of the tills and the sparsity of exposures, the tills deposited during the three glaciations cannot be mapped as separate units

Crazy Horse till (late Wisconsin, late Pleistocene)—Yellowish-brown, grayish-brown, brown, brownish-gray, gray, or mottled clay loam and loam. Silty clay or clay where the ice incorporated lake clay and silt in the preglacial Missouri River and Big Muddy Creek valleys; sandy loam and loamy sand where ice incorporated older alluvial sand and gravel. Very calcareous; generally oxidized to depths less than 1.2 m (4 ft). Friable; granular or blocky structure. Loose or poorly consolidated; not extremely compact or hard. Slumps readily in exposures. Pencil-shaped columnar joints are common in oxidized till. White streaks of secondary carbonate and coatings of powdery gypsum (selenite) locally on joint surfaces. Selenite crystals less than 3 mm (⅛ in) long are present on joint surfaces locally; larger crystal, clusters of crystals, and crusts of selenite are absent. Iron oxide stains typically are present in matrix only adjacent to carbonate grains and granules; generally absent on joint surfaces. Manganese oxide stains very uncommon. Moderately pebbly to very pebbly; pebbles, cobbles, and boulders typically much more abundant than in older tills. Granules and pebbles are subangular to well rounded, dominantly erratic limestone and dolomite from Canada; some granite, gneiss, schist, quartzite, chert, sandstone, siltstone, shale; minor ironstone concretions, clinker, agate, silicified wood, and chalcedony. Lignite fragments are ubiquitous in the matrix. Cobbles and boulders are mostly erratic limestone, dolomite, granite, and gneiss. They litter till surfaces that have not been cultivated and cleared of large erratics.

The thickness of the till is as much as 5 m (16.4 ft) and as little as 30 cm (1 ft) but generally is only 1 m (3 ft) thick under upland areas

Kisler Butte till (Illinoian, late middle Pleistocene)—Pale-yellow, yellowish-brown, grayish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled calcareous clay loam, silty loam, and loam. Silty clay or clay where ice incorporated lake clay and silt in the ancestral Missouri River and Big Muddy Creek valleys; sandy loam or loamy sand where ice incorporated alluvial sand and gravel. Generally oxidized to depths less than 2.4 m (8 ft) where not covered by younger till, less than 1.5 m (5 ft) where covered by younger till. Commonly massive or with blocky structure. Typically very compact but not overconsolidated. Brittle where dry and tends to break around large sand grains and granules. Moderately resistant; typically does not slump in exposures. Parting irregular to platy. Columnar joints 1.25-2.5 cm (0.5-1 in) apart are common in oxidized till. White streaks of secondary carbonate and coatings of powdery gypsum (selenite) are common on joint and parting surfaces; selenite crystals less than 3 mm (0.12 in) long are common on joint surfaces; larger crystals, clusters of crystals, and crusts of selenite are absent. Iron oxide stains are common on joint surfaces and in oxidized matrix. Minor manganese oxide stains. Locally, granules of erratic limestone and dolomite are abundant. Kisler Butte till is sparingly to moderately pebbly; pebbles, cobbles, and boulders are less abundant than in Crazy Horse till. Granule and pebble composition is similar to that of Crazy Horse till but reworked clasts from older alluvial deposits (Tf) are more abundant. Cobbles are mostly quartzite, ironstone (siderite) concretions, and erratic limestone, dolomite, igneous, and metamorphic rocks from Canada. Erratic boulders are rare in exposures but locally are common as a lag concentrate on the surface. Physical and chemical characteristics of Kisler Butte and Crazy Horse tills are generally similar; the tills are distinguished with difficulty where they are not superposed or are poorly exposed. Thickness is generally 0.6-1.5 m (2-5 ft); rarely more than 2.4 m (8 ft)

Upper Member of Archer till (pre-Illinoian, early middle Pleistocene)—Pale-yellow, pale-yellowish-brown, pale-olive-brown, grayish-brown, brown, olive, yellowish-gray, brownish-gray, olive-gray, gray, grayish-black, or mottled clay loam, loam, silt loam, and sandy loam; locally loamy sand and light-gray calcareous loam and clay loam. Mechanical analyses show that the till is 25-30 percent clay, 25-40 percent silt, 25-40 percent sand, and 2-15 percent pebbles and cobbles. Colors are typically lighter hues than colors of younger tills; matrix is typically more sandy. Weakly to strongly calcareous. Generally oxidized throughout where less than 3 m (10 ft) thick and weathered profile was eroded. In buried valleys where till was not eroded subsequently, oxidation may extend to depths of 8-14 m (26-46 ft).

Till is overconsolidated, commonly massive, breaks into large irregular blocks. It is very resistant to erosion; thick till commonly erodes to form hoodoos, spires, and pinnacles, rarely slumps here exposed. Typically intensely jointed where oxidized. Vertical columnar joints commonly are 5-25 cm (2-10 in) apart; in places, oxidized till also has closely spaced horizontal joints and till breaks into plates or blade-like fragments. Individual gypsum (selenite) crystals 0.5-5 cm (0.25-2 in) long, clusters of crystals, seams of crystals, or crusts of crystals are common on joint surfaces or as joint fillings. Brownish-yellow and reddish-brown iron oxide stains and crusts are common on joint surfaces; black manganese oxide stains and crusts occur locally. Typically sparingly pebbly or nearly clast free; very gravelly where ice incorporated older sand and gravel. Granules and pebbles are subangular to well-rounded, chiefly erratic limestone and dolomite from Canada, quartzite, chert, and sandstone; some igneous and metamorphic rocks, ironstone (siderite) concretions, and chert; minor siltstone, shale, clinker, agate, silicified wood, and chalcedony. Large cobbles and boulders are rare in exposures; chiefly limestone, dolomite, granite, and schist from Canada. Where ice-incorporated gravel in terraces, clasts may be entirely reworked from the gravel.

The thickness of the till is highly variable but probably averages 5 m (16 ft); it is as much as 85 m (280 ft) thick 6 km (11 mi) north of Brockton

Qs Sprole Silt (middle Pleistocene)—Laminated yellowish-gray silt, clay, and silty clays as much as 100 ft thick which underlie till. The type locality of the silt is 9 km (6 mi) west of the Culbertson quadrangle in the NW ¼ of the SW ¼ of sec. 3, T. 27

N., R. 51 E.) in an abandoned gravel pit near an unnamed coulee. The exposure is 6 km (4 mi) east of Poplar and 3 km (2 mi) northwest of Sprole siding on the Great Northern Railroad.

The lower half of the Sprole silt is composed of well-stratified, thin-bedded, yellowish-gray silt and clay containing scattered pebbles. The upper half of the formation is siltier and bedding is less pronounced.

The Sprole Silt was deposited in a lake that formed when the ice advanced into the area and blocked the Missouri River. After their deposition, they were covered by at least 5 m (15 ft) of till.

No accurate figures on the thickness of the silt are available but thickness varies greatly within a short distance. The estimated thickness of an outcrop in sec. 3, T. 27 N., R. 51 E. is 30.5 m (100 ft). A thickness of 20 m (65 ft) was measured in sec. 13, T. 28 N., R. 50 E. The silt is about 18 m (60 ft) thick in sec. 27, T 29 N., R. 51 E. The formation thins westward from that outcrop within a short distance and becomes too thin to map but may be present in many places as silt, clay, and sand overlying the Wiota gravels and underlying the till.

Tf Flaxville Formation (Miocene and Pliocene) —Sand, silt, clay, and gravel.

Collier (1917) first described the Flaxville Formation from exposures near the town of Flaxville, 34 km (21 mi) north of the Culbertson 30’ x 60’ quadrangle. A year later, Collier and Thom (1918) renamed the unit the Flaxville gravels. In the Culbertson area, the term “Flaxville Formation” is again used since gravel actually is a minor part of the unit.

The Flaxville Formation is composed of several lithologic units. In nearly all exposures, the basal part of the formation is a coarse sandy quartzite gravel 6-15 m (20-50 ft) thick. Lenticular sandy and clayey strata 6-12 m (20-40 ft) thick overlie this part of the formation. Volcanic ash was found by Collier and Thom (1918, p. 182) in the gravel 77 km (55 mi) northwest of the Culbertson 30' x 60' quadrangle.

Clasts in the Flaxville Formation consists chiefly of well-rounded quartzite pebbles, although smooth, well-rounded cobbles and boulders as large as 30.5 cm (1 ft) in diameter are also common. Seventy percent of the pebbles are fine- to medium-grained quartzite, mostly grayish red but including some yellowish or grayish green. Twenty percent of the pebbles are moderate red jasperlike argillite and an even smaller percentage includes olive-gray to black argillite, chert, and agate. A minor, but distinctive, group of pebbles is composed of green tinguaite porphyry. Most of the pebbles, cobbles, and boulders in the formation are coated with a moderate yellowish-brown stain, probably iron oxide, which has penetrated the quartzites to depths of as much as 3 mm (⅛ inch).

Locally, the formation has been cemented by calcium carbonate to form sandstone and conglomerate. Individual beds in the formation range in thickness from 0.3 to 3 m (1 to 10 ft). Most beds are crossbedded, indicating much cutting and filling occurred as streams deposited the formation.

The formation unconformably overlies each of the older bedrock units. In places it is overlain by glacial and eolian deposits.

Vertebrate fossils of Pliocene age are abundant in the Flaxville Formation. Some of these were examined by Gidley (*in* Collier and Thom, 1918, p. 180), who concluded that "the beds from which these fragments were collected cannot be older than Miocene or younger than lower Pliocene." The fossils the author found were examined by Jean Hough who reported that they were of Pliocene age and probably early Pliocene. Bones of *Hipparion*, *Procamelus*, and mastodon were found.

The thickness of the formation varies considerably, but remnants average about 12 m (40 ft) thick. The unit thins to a featheredge around the borders of the mesa-like remnants in the northwest corner of the quadrangle. The formation unconformably overlies the Fort Union Formation, and in places it is overlain by glacial and eolian deposits

Tfu Fort Union formation (Paleocene)—Yellowish-brown sequence of interbedded continental deposits of sand, sandstone, siltstone, silt, clay, clayey shale, and lignite.

Weathering of outcrops of the Fort Union Formation generally produces lighter and brighter colors than those of the weathered Hell Creek Formation. For example, yellowish-gray shale weathers to light yellowish gray, and dark-grayish-orange sandstone weathers to pale yellowish brown. The formation is relatively free of organic matter other than in the carbonaceous shale and lignite beds.

The Fort Union Formation is conformably underlain by the Hell Creek Formation and unconformably overlain by the Flaxville Formation. The gradational contact between the Hell Creek and the Fort Union Formations is arbitrarily placed at the base of the lowest mappable lignite bed (Lepp, 1981, p. 21). No dinosaur bones were found above this bed at this locality; the absence of dinosaur bones has been used at other localities as a criterion for the recognition of the Fort Union Formation.

The Fort Union Formation has been divided into members but lateral and vertical facies changes and great distances from type localities made it impossible to use member names or map contacts between members. Lepp (1981, p. 20) indicated that the Tullock Member is 52 m (172 ft) thick. He stated that the Lebo Member is approximately 76 m (248 ft) thick. Lepp (1981, p. 23) found that 197 m (646 ft) of the Tongue River Member is exposed in the Culbertson 30’ x 60’ quadrangle. He stated that the member is 335 m (1100 ft) thick in the Williston area (30 km (20 mi) east of the Culbertson 30’ x 60’ quadrangle).

Four types of concretions are in the Fort Union—calcareous sandstone, siltstone, limonite, and pyrite. Most of the concretions seen in the field are sandstone and relatively few are siltstone, limonite, and pyrite. Some of the limy sandstone concretions show cone-in-cone structure. In the SE ¼ of the NE ¼ of sec. 21, T. 26 N., R. 53 E., several large sandstone concretions show very pronounced crossbedding. They are as much as 5 m (15 ft) high, 12 m (37 ft) wide, and 30-213 m (100-700 ft) long. The width of the area in which they occur is 50 m (150 ft) and the length of the area is 366 m (1,200 ft). The trend of their long axes is N. 60° E.

The colors of the different concretions vary widely. For example, the weathered pyrite concretions are dark yellowish brown, but the unweathered interiors of these pyrite concretions are greenish gray. Limonite concretions usually are disk shaped, are from 7.6 to 18 cm (3-7 in) thick, and are moderate yellowish brown to blackish red when weathered. The sandstone concretions range from yellowish gray to medium olive gray.

The beds in the formation are well sorted, and within any one bed there is little variation in grain size. Lateral facies changes are common. Channeling is present locally but is not common.

The contacts between the different kinds of beds range from sharp to gradational. Most of the exposures examined show gradational contacts between beds, but where channeling occurred or where there were short periods of nondeposition, sharp contacts may be seen.

Nearly all the fossils found were plant remains. Vertebrate fossils are very rare in the formation; only a few shells of *Unio* were found.

Silicified soil was found in several places, at several stratigraphic horizons. The best exposure is just south of Poplar in the NE ¼ of the NW ¼ of sec. 26, T. 26 N., R. 51 E., where the silicified soil contains abundant petrified logs. These were identified by Richard A. Scott as specimens of the conifer *Cupressaceae*(?). Petrified wood also was found in sec. 30, T. 30 N., R. 51 E.

The sediments of the Fort Union Formation were deposited by eastward-flowing streams meandering on a broad swampy flood plain that slowly subsided until at least 304 m (1,000 ft) of the formation accumulated in this area.

The Fort Union Formation contains many beds of lignite as much as several feet thick. The formation underlies most of the Culbertson area, and reserves of lignite are large. The lignite field of the Culbertson area was discussed by Smith (1910). Biewick and others (1990) evaluated the coal resources in the eastern part of the area. Several studies of coal resources in that area were made by Hardie and Arndt (1981, 1987, 1988, 1989, 1990), by Arndt and Hardie (1985), by Arndt, Hardie, and Kehn (1982a, 1982b) and by Hardie and Van Gosen (1986). Mudge and others (1977) analyzed the status of mineral resource information for the Fort Peck Indian Reservation.

The upper part of the Fort Union Formation was removed by erosion before the deposition of the Flaxville Formation. As a result of structural deformation, the thickness of the formation varies considerably throughout the area. The thickest remnant is in the northeast part of the area where approximately 284 m (930 ft) of strata remain (Hardie and Arndt, 1989)

Khc Hell Creek Formation (Upper Cretaceous)—Well stratified shales, siltstones, sandstones, and carbonaceous shales. The lower 15-30 m (50-100 ft) is predominantly a medium-tan friable sandstone; the upper half is gray siltstone and shale. The overall color of the formation is a somber greenish gray. Weathered surfaces of many bentonitic shale beds have a spongy appearance.

The lower half of the formation consists of beds of coarse sandstone composed of abundant dark minerals that contrast markedly with the underlying fine-grained, lighter colored sandstone of the Fox Hills Formation. Large-scale crossbedding in channels contrasts sharply with the underlying parallel-bedded sandstone of the Fox Hills Formation.

Large, log-shaped, crossbedded sandstone concretions are in the basal conglomeratic sandstone unit of the Hell Creek Formation, and are especially common in the lower 30 m (100 ft). The concretions are circular to oval in cross section and range in diameter from 1-2 m (3-6 ft) and in length from 3-10 m (10-30 ft). Spherical concretions, as much as 7.6 cm (3 in) in diameter, are also common in the sandy lower half of the formation.

The upper half of the formation consists mainly of sandstone, siltstone, claystone, shale, lignite, and carbonaceous claystone. Individual beds are generally 0.3-1 m (1-3 ft) thick and of uniform texture over short distances. Sandstone beds are more lenticular than siltstone and claystone beds. The rest of the unit consists of bentonitic and carbonaceous shale beds. The bentonitic shale outcrops have a characteristic spongy appearance caused by the swelling of the bentonite. The carbonaceous shales, which contain a large proportion of macerated plant fragments, are brown, thick bedded, and fissile. The strata generally are greenish gray but some are shades of light olive gray, brownish gray, and gray. Because of its dull color, the formation has been referred to informally by some writers as the "somber beds." The carbonaceous shale beds are as much as 2.7 m (9 ft) thick. In fresh exposures, the lignite is tough and dense, has a woody structure, contains silicified plant remains, and it slakes rapidly to a black powder when exposed to air. Silicified plant remains, pyrite, marcasite, gypsum, limonite, hematite, and numerous clay partings are common impurities in lignite beds.

The lower half of the formation is a conglomeratic sandstone that contains mud balls as much as 0.3 m (1 ft) in diameter, fragments of sandstone, limonite concretions, sparse well-rounded olive-gray quartzite pebbles several inches in diameter, and fragments of dinosaur bone and petrified wood. Many large blocks of lignite and silicified wood are also included locally. Some lignitized wood fragments and quartzite pebbles are present at and above the contact with the Fox Hills Formation, but none were found below this contact.

Dinosaur bones are prevalent throughout the formation, and in some areas are common enough to differentiate the strata in which they occur from the underlying Fox Hills Formation and the overlying Fort Union Formation. Most of the vertebrate remains found are of Triceratops (R.W. Brown, personal communication, 1951).

The range in color of the formation is virtually from black to white. The carbonaceous shale and lignitic beds are black and weather to grayish black; some of the sandstone beds that are nearly white in appearance are actually light yellowish gray and weather to about the same color. Shale beds are light gray or olive gray and weather to pale olive. Some of the sandstone is dusky yellow and dark yellowish orange and weathers to pale olive.

An analysis of approximately 548 m (1,800 ft) of measured sections of Hell Creek Formation revealed that 61 percent is sandstone, 4 percent is siltstone, 34 percent is claystone and shale, and 1 percent is carbonaceous shale.

The Hell Creek Formation unconformably overlies the Fox Hills Formation, conformably underlies the Tertiary Fort Union Formation, and fills channels in the Fox Hills Formation in many places. Most of the channels are 3-5 m (10-15 ft) deep but one 15 m (45 ft) deep was found on the south side of Redwater Creek. Channels are filled with fragments of limonite concretions and scattered gray quartzite pebbles (Bauer, 1925).

The unconformity between the Fox Hills and Hell Creek Formations is probably widespread in northeastern Montana (Brown, 1962, p. 9). It was found in several places in north Garfield County, and Bauer (1925, p. 344) found similar channels around the Freedom Dome, 120 km (75 mi) southwest of the area. We found conglomerate and quartzite pebbles in basal Hell Creek strata along U.S. Highway 10, 15 km (9 mi) southwest of Glendive, and along State Highway 7, 11.5 km (7 mi) north of Baker. These localities are near the Cedar Creek Anticline and are 128 km (80 mi) and 193 km (120 mi), respectively, south of the area.

The contact between the Hell Creek Formation and the overlying Fort Union Formation is gradational. Brown (1962, p. 9) has described the contact as follows: "The base of the Fort Union Formation is marked by a persistent lignitic zone or lignite bed, above which lignite beds are common and below which even discontinuous lignite beds are uncommon. At or within 15 m (50 ft) above the first persistent lignite bed, the somber colors typical of the Hell Creek Formation yield to brighter yellowish colors typical of the Fort Union Formation. Below this contact, dinosaur bones may be found but are lacking above it."

The continental Hell Creek Formation was deposited by streams flowing across a vast floodplain. The basal conglomerates probably were deposited by swiftly flowing streams and the finer grained upper half of the formation was deposited probably by more sluggish streams. Many of the beds of shale were probably deposited in shallow standing water.

The thickness of the formation ranges from 52 to 86 m (170-282 ft); the average is about 76 m (250 ft)

Kfh Fox Hills Formation (Late Cretaceous)—Shale and siltstone 18 m (60 ft) thick and an overlying continental cliff-forming sandstone as much as 10.6 m (35-40 ft) thick.

The colors of the lower transition beds become gradually lighter upward from the dark olive gray of the Bearpaw shale to light olive gray. Shale beds are darker than sandy beds, which are olive brown, yellowish brown, or dusky yellow. As the sandstone part of the formation weathers, it changes from pale yellowish brown to yellowish brown or to dark yellowish orange. The lower part of the formation consists of parallel-bedded layers of gray shale, siltstone, and fine-grained clean sandstone a few inches thick. These grade upward from more clayey beds at the bottom to more sandy crossbedded layers at the top. The upper part of the formation is a crossbedded fine-grained sandstone. In most places, spheroidal calcareous sandstone concretions predominate in a matrix of unconsolidated sand. Locally, however, the sand has been cemented by calcium carbonate into a ledge-forming sandstone.

The Fox Hills Formation is conformably underlain by the Bearpaw shale and unconformably overlain by the Hell Creek Formation. Stream channels, locally as much as 15 m (50 ft) deep, were cut into the Fox Hills Formation prior to deposition of the Hell Creek Formation. In these places, the overlying Hell

Creek Formation rests upon the transitional shale beds of the lower part of the Fox Hills Formation. The unconformity on the top of the Fox Hills Formation was first detected in Garfield County, Mont. (Brown, 1907), and was subsequently mapped in northern Garfield County by F.S. Jensen, R.W. Brown, J.O. Kistler, and R.B. Colton in 1950 and traced northward into the area.

Several types of concretions are in the formation. The largest and most abundant are disk shaped and occur in the upper sandstone part of the formation. Ball-shaped pyrite concretions as much as 5 cm (2 in) in diameter are common. Disk-shaped limonite or clay ironstone concretions as much as 15 cm (6 in) in diameter are abundant. Soft, white, round, very fine grained sand concretions as much as 5 cm (2 in) in diameter are scattered through some of the sandstone beds. Large disk-shaped aragonite concretions as much as 0.6 m (2 ft) in diameter and several inches thick are common in some strata in the transition beds.

All the cemented sandstone in the upper part of the formation above the transition beds is calcareous, but the transition beds are noncalcareous. Carbonaceous shale and lignite occur locally in the upper part of the formation.

The basal transition beds of the Fox Hills Formation were deposited in the same shallow sea in which the underlying Bearpaw shale was formed, but during Fox Hills time the sea gradually became shallower. Eventually, the shoreline migrated eastward, leaving the Culbertson area above sea level, and the uppermost part of the Fox Hills Formation was deposited in a littoral environment.

In most of the area, the lowermost silt and shale grade transitionally upward into sandstone, but along the north side of Redwater Creek in sec. 2, T. 26 N., R. 50 E. (15 km or 10 mi west of the Culbertson 30’ x 60’ quadrangle), a distinct unconformity can be seen. A suggestion of such a break is also present in the southeastern part of the adjoining Poplar quadrangle in sec. 4, T. 26 N., R. 52 E. Flores and Lepp (1983) also showed an unconformity between the Fox Hills and Hell Creek Formations.

The formation varies greatly in thickness within short distances, and in places it has been almost completely removed by erosion. Two miles to the west only 23 m (75 ft) of the formation remains. Lepp (1981, p. 12) indicated that the Formation is approximately 40 m (130 ft) thick

Kb Bearpaw Shale (Upper Cretaceous)—Olive-gray and dark-gray fissile marine shale containing numerous bentonite beds and fossiliferous concretionary zones. A complete discussion of these zones appears in Jensen and Varnes (1964, p. F5-F11).

The unit is chiefly olive-gray shale. Two mechanical analyses of the shale made by the Materials Testing Laboratory, Montana State Highway Commission, Helena, Mont., indicate that the shale consists of a silty, slightly sandy clay; clay and silt range from 62 to 67 percent and sand ranges from 33 to 38 percent. A wet analysis by the U.S. Corps of Engineers showed that weathered shale is 5 percent sand, 40 percent silt, and 55 percent clay (Jensen and Varnes, 1964, fig 18) (n.b. the title for fig. 18 belongs where the title for fig. 5 is; the title for fig. 5 belongs where the title of fig. 18 is). The clay fraction is tough, highly plastic, and has high compressibility. All outcrops in the Culbertson area are weathered; depth of weathering is at least 2 m (6 ft) and as much as 15 m (50 ft).

Bentonite interbedded in the shale occurs as beds or as disseminated particles, and because of its swelling properties imparts a spongy texture to the weathered surfaces of the shale. An examination of eight bentonite samples by Byrne and Farvolden (1959, p. 19) showed that montmorillonite is the only clay mineral present. The color of unweathered bentonite ranges from pale green to pale yellow. Lower contacts of the bentonite beds are sharp but upper contacts are gradational.

Two types of concretions occur in the Bearpaw shale. The most abundant concretions, composed of iron oxide and clay, are as much as15 cm (6 in) in diameter and are disk shaped. Other concretions consisting of medium-dark-gray nearly pure limestone are round, egg-shaped, or irregularly rounded, and their diameters range from 15 cm to 2 m (6 in to 6 ft); most are about 30 cm (1 ft). The interiors of many limestone concretions are full of shrinkage cracks; some have been partly filled with yellow calcite crystals and a few contain barite crystals. Many of the limestone concretions contain well-preserved fossils such as baculites and scaphites, but only a few of the ironstone concretions contain fossils and these are poorly preserved.

Several fossiliferous concretion horizons were recognized by Jensen and Varnes (1964) in the Fort Peck area but only the three uppermost zones are exposed in the Culbertson area. Here, the zones could not be traced laterally because of the general thick cover of till. The lowest concretions are found 61 m

(200 ft) below the top of the Bearpaw Shale and contain *Baculites compressus corrugatus*. The next higher zone, 30-48 m (100-160 ft) below the top of the Bearpaw Shale, is characterized by *Baculites* n. sp., specimens of which were found 2.4 km (1.5 mi) north and east of Oswego. The highest zone of concretions is characterized by *Baculites baculus* and *Discoscaphites* n. sp. and occurs about 12 m (40 ft) below the top of the Bearpaw Shale.

The Bearpaw shale was deposited in a sea as indicated by the numerous marine fossils. Bentonite beds and disseminated bentonite in the shale indicate that many volcanic eruptions occurred during the deposition of the shale (Byrne and Farvolden, 1959, p. 19).

The formation is transitional into beds of the Fox Hills Formation. The base of the Bearpaw Shale is not exposed in the area, but to the west it conformably overlies the Upper Cretaceous Judith River Formation. A comprehensive description of the Bearpaw Shale is in Jensen and Varnes (1964, p. F5-F11).

According to Collier and Knechtel (1939, p. 9), the formation is approximately 305 m (1,000 ft) thick in this part of Montana. F.S. Jensen (written communication, 1951) reports that the formation is more than 347 m (1,140 ft) thick. Bateman (*in* Colton and Bateman, 1956) reports that the thickness ranges from 335 to 361 m (1,095 to 1,186 ft). Because of poor exposures, no sections of the shale were measured; only the upper few hundred feet of the formation are exposed.

THE BROCKTON-FROID FAULT ZONE

The position of this fault zone is based on stratigraphic, structural, topographic, and photographic evidence. Drilling yielded additional information. Earthquake records are indicative of the presence of an active fault zone.

The bedrock geology of the area is relatively simple because only the Bearpaw Shale, and Fox Hills, Hell Creek, and Fort Union Formations of Cretaceous and Paleocene age are exposed along the fault (Colton, 1963 a, b and c). However, the geology of the surficial deposits is not simple; they almost completely mantle the bedrock, are nearly all of glacial origin, and comprise a wide variety of types. Extensive sand deposits and dunes mantle the middle and northeastern parts of the fault zone (Witkind, 1959). The picture is also complicated by the fact that the Pleistocene deposits were apparently involved in the faulting and dropped into the fault zone in many places.

The stratigraphic evidence is probably the most indicative of the presence of a fault zone. This evidence was obtained by measuring exposed stratigraphic sequences on each side of the fault zone and attempting to determine the amount of displacement. One mile northeast of Brockton, near a cemetery, strata on the north side of the fault zone are 75 feet higher than equivalent strata on the south side; the amount of horizontal displacement was not determined. Holes were drilled across the fault zone 11.2, 12.8, and 18.5 km (7, 8, and 11.5 mi) northeast of the exposures near the cemetery; three were drilled to depths of 29.3 m (96 ft) and the stratigraphic sequences on each side of the fault zone were compared. No correlation could be made across the fault indicating that the same sequence of beds was not penetrated and that perhaps at least 96 feet of displacement has occurred.

Aerial photographs of the fault zone suggest the presence of fault traces on the surface of the ground, especially in the area a few miles west of Froid. Aerial photographs suggest that the fault zone probably extends northeast of Medicine Lake but in that area extensive sand dunes and thick glacial deposits have almost completely covered it. Several other dark lines or lineaments, parallel to the fault zone probably indicate minor faults. Detailed mapping south of the Missouri River indicates that the faulting probably extends at least 24 km (15 mi) southwest of Brockton. The close parallelism of the fault and near alignment with the Weldon fault suggest that this feature may be part of a belt of en echelon faulting extending nearly 150 km (100 mi).

The topographic evidence for the fault consists of the following features: (1) there are several linear closed depressions in secs. 23, 28, and 31, T. 30 N., R. 55 E., and in sec. 1, T. 30 N., R. 54 E. With a few exceptions there is a pronounced topographic sag along the trace of the fault zone. (2) One of the most convincing lines of topographic evidence is the fact that the zone is very long and narrow, and crosses valleys and divides alike regardless of their orientation. (3) The topography in T. 28 N., R. 53 E. suggests that the shape of the line of hills just north of the fault is comparable to the shape of the line of hills south of the fault zone and recent faulting caused the 18.3 m (60 ft) difference in their maximum elevations; that figure is probably the minimum order of magnitude. The land surface northwest of the fault in the Calais quadrangle is approximately 30.5 m (100 ft) higher than the general land surface southeast of the fault zone.

Thick deposits of stratified drift are located in the fault zone; e.g., in sec. 16, T. 30 N., R. 55 E., in sec. 16, T. 28 N., and in NE ¼ sec. 30, T. 28 N., R. 55 E. These deposits were probably dropped into the fault zone either at the time of their formation or soon after. The results of drilling in sec. 35, T. 29 N., R. 55 E. indicate sand and gravel of glacial origin is 130 feet below the surrounding land surface. Along the north edge of sec. 36, T. 29 N., R. 53 E., stratified drift has evidently been dropped into the fault zone at least 36.6 m (120 ft) and possibly 42.6 m (140 ft).

Structural evidence indicating the presence of a fault was discovered during the making of the structure-contour map of the area. A.F. Bateman (written communication) discovered that the surface of the Greenhorn limestone is 61 m (200 ft) (lower) northwest of the fault zone than it is southeast of it. This conclusion was arrived at without prior knowledge of the fault zone. The plunging sharp monocline on Bateman's manuscript structure contour map coincided with a probable fault shown in a preliminary geologic map of the Fort Peck Indian Reservation (Colton, 1952). These two unpublished maps were subsequently combined (Colton and Bateman, 1956).

The last line of evidence suggesting the presence of a fault zone is the occurrence of earthquakes whose epicenters were along the fault zone in this area. During the night of October 31, 1935, plaster fell in several buildings in Wolf Point (Neumann, 1935, p. 38) which is 56 km (35 mi) west of Brockton. At 10:30 pm on June 24, 1943, a shock of intensity VI occurred in southern Sheridan and eastern Roosevelt counties (Bodle, 1943, p. 9). The shock was strongest around Homestead 90 km (6 mi) northwest of Froid and was felt by many people. Buildings swayed slightly and cracked and a well-constructed granary cracked so severely that wheat spilled out. One man north of Brockton who was out of doors during the earthquake reported that he felt the earth heaving up and down. Chimneys were damaged in Reserve 32 km (20 mi) north of Froid. An earthquake of minor intensity also occurred in 1944 (Bodle, 1944, fig 1). On October 26, 1946, between 1:45 pm and 2:30 pm an earthquake occurred in northeastern Montana (Bodle and Murphy, 1946, p. 8). It was short duration but felt throughout the general area. Residents of Wolf Point 56 km (35 mi) west of Brockton reported hearing a rumble followed by one short tremor, and large buildings swayed; people in the Plentywood area 51.5 km (32 mi) north of Froid reported a mild tremor of short duration.

No earthquakes in the area were reported during the period 1946 to 1962.

REFERENCES PERTINENT TO THE GEOLOGY

OF THE CULBERTSON 30' x 60' QUADRANGLE

Alden, W.C., 1932, Physiography and glacial geology of eastern Montana and adjacent areas: U.S. Geological Survey Professional Paper 174, 133 p.

Arndt, H.H., and Hardie, J.K., 1985, Lithic descriptions and geophysical logs of 83 U.S. Geological Survey coal exploratory holes in the eastern part of the Fort Peck Indian Reservation, Daniels, Roosevelt, and Sheridan Counties, Montana: U.S. Geological Survey Open-File Report 85-707, 254 p.

Arndt, H.H., Hardie, J.K., and Kehn, T.M., 1982a, Results of exploratory drilling for lignite in 1979, Fort Peck Indian Reservation, Daniels, Roosevelt, and Sheridan Counties, Montana: U.S. Geological Survey Open-File Report 82-480, 152 p.

_____1982b, Results of exploratory drilling for lignite in 1980, Fort Peck Indian Reservation, Daniels, Roosevelt, and Sheridan Counties, Montana: U.S. Geological Survey Open-File Report 82-538, 107 p.

Bauer, C.M., 1925, Quartzite pebbles at the base of the Lance Formation in Montana: American Association of Petroleum Geologists Bulletin, v. 9, no. 2, p. 344-346.

Biewick, L.R.H., Hardie, J.K., Williamson, Courteney, and Arndt, H.H., 1990, Evaluation of coal resources in the eastern part of the Fort Peck Indian Reservation, Montana: U.S. Geological Survey Bulletin 1869, 136 p.

Bergantino, R.N., 1984, Topographic map of the bedrock surface Wolf Point 1° x 2° Quadrangle, northeastern Montana, northwestern North Dakota, and southeastern Saskatchewan: Montana Bureau of Mines and Geology Open-File Report 151, scale 1:250,000.

Bodle, R.R., 1943, U.S. Earthquakes of 1943: U.S. Department of Commerce, Coast and Geodetic Survey Series No. 672.

_____1944, U.S. Earthquakes of 1944: U.S. Department of Commerce, Coast and Geodetic Survey Serial No. 682.

Bodle, R.R., and Murphy, L.M., 1946, U.S. Earthquakes of 1946: U.S. Department of Commerce, Coast and Geodetic Survey Series No. 714.

Brown, Barnum, 1907, The Hell Creek beds of the Upper Cretaceous of Montana: American Museum of Natural History Bulletin, v. 23, art. 33, p. 839-845.

Brown, R.W., 1962, Paleocene flora of the Rocky Mountains and Great Plains: U.S. Geological Survey Professional Paper 375, 119 p.

Byrne, P.J.S., and Farvolden, R.N., 1959, The clay mineralogy and chemistry of the Bearpaw Formation of southern Alberta: Alberta Research Council Geologic Division Bulletin 4, 44 p.

Collier, A.J., 1917, Age of the high gravels of the northern Great Plains [abs.]: Washington Academy of Science Journal, v. 7, p. 194-195.

_____1919, Geology of northeastern Montana: U.S. Geological Survey Professional Paper 120, p. 17-39.

Collier, A.J., and Knechtel, M.M., 1939, The coal resources of McCone County, Montana: U.S. Geological Survey Bulletin 905, 80 p.

Collier, A.J., and Thom, W.T., Jr., 1918, The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U.S. Geological Survey Professional Paper 108-J, p. 179-184.

Colton, R.B., 1952, Geology of the Otter Creek quadrangle, Montana: Admin. Rept. 84 p.

_____ 1956, The Brockton-Froid fault zone in northeastern Montana [abs.]: Geological Society of America Bulletin, v. 67, no. 12, p. 1792.

_____ 1958, Ice-crack moraines in northwestern North Dakota and northeastern Montana, *in* Guidebook, Ninth Annual Field Conference, Midwestern Friends of the Pleistocene: North Dakota Geological Survey Miscellaneous Series 10, p. 99-107.

_____ 1963a, Geologic map of the Brockton (15 minute) quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-362, scale 1:62,500.

_____1979a, Geologic map of the Bainville SW quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1110, scale 1:24,000.

_____1979b, Geologic map of the Three Buttes quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1111, scale 1:24,000.

_____1979c, Geologic map of the Bainville SE quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1112, scale 1:24,000.

_____1979d, Geologic map of the Dugout Creek quadrangle, Richland and Roosevelt Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1113, scale 1:24,000.

_____1982a, Geologic map of the Twomile Creek quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1413, scale 1:24,000.

_____1982b, Geologic map of the Cedar Coulee quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1414, scale 1:24,000.

Colton, R.B., and Bateman, A.F., Jr., 1956, Geologic and structure contour map of the Fort Peck Indian Reservation and vicinity, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-225, scale 1:125,000.

Colton, R.B., and Jensen, F.S., 1953, Crevasse fillings on the glaciated plains of northeastern Montana [abs.]: Geological Society of American Bulletin, v. 64, no. 12, pt. 2, p. 1542-1543.

Colton, R.B., Lemke, R.W., and Lindvall, R.M., 1961, Glacial map of Montana east of the Rocky Mountains: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-327, scale 1:500,000.

Colton, R.B., Naeser, N.B., and Naeser, C.W., 1986, Drainage changes in eastern Montana and western North Dakota during late Cenozoic time: Geological Society of America Abstracts with Programs, v. 18, no. 5, p. 347.

Donovan, J.J., 1988a, Groundwater and geologic data for northeastern Montana in the Wolf Point 1° x 2° quadrangle: Montana Bureau of Mines and Geology Open-File Report 208, 380 p.

_____1988b, Ground-water geology and high-yield aquifers of northeastern Montana: Montana Bureau of Mines and Geology Open-File Report 209, 116 p.

Donovan, J.J., and Bergantino, R.N., 1987, Ground-water resources of the Fort Peck Indian Reservation, with emphasis on aquifers of the preglacial Missouri River Valley: Montana Bureau of Mines and Geology Open-File Report 178, 41 p.

Flores, R.M., and Lepp, C.L., 1983, Environmental-stratigraphic cross sections of the Cretaceous Fox Hills Sandstone and Hell Creek Formation and Paleocene Fort Union Formation, Richland and Roosevelt Counties, Montana: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1554.

Fullerton, D.S., and Colton, R.B., 1986, Stratigraphy and correlation of the glacial deposits on the Montana plains, *in* Richmond, G.M., and Fullerton, D.S., eds., Quaternary glaciations in the United States of America: Quaternary Science Reviews, v. 5, p. 69-82.

Fullerton, D.S., Colton, R.B., and Bush, C.A., 2004, Limits of mountain and continental glaciations east of the Continental Divide in northern Montana and north-western North Dakota, U.S.A., *in* Ehlers, Juergen, and Gibbard, P.L., eds., Major Quaternary Glaciations—Extent and Chronology; Part II, North America: Amsterdam, Elsevier, p. 131-150.

Gott, G.B., Osterstock, R.W., and Witkind, I.J., 1948, Geologic map of the Blair, N.E. Quadrangle, Montana: U.S. Geological Survey Missouri River Basin Geologic Mapping and Mineral Resource Investigations, Missouri Souris, Montana, scale 1:20,000.

_____1948, Geologic map of the Brockton N.E. Quadrangle, Montana: U.S. Geological Survey Missouri River Basin Geologic Mapping and Mineral Resource Investigations, Missouri Souris, Montana, scale 1:24,000.

Gott, G.B., Prouty, C.E., Kaye, C.A., Smith, J.H., Dodson, R.H.T., and Witkind, I.J., 1948, Geology of Homestead Quadrangle, Montana: U.S. Geological Survey Missouri River Basin Geologic Mapping and Mineral Resource Investigations, Missouri Souris, Montana, scale 1:20,000.

Gott, G.B., and Witkind, I.J., 1947, Geologic map of the Smoke Creek Quadrangle, Montana: U.S. Geological Survey Missouri River Basin Geologic Mapping and Mineral Resources Investigations, Missouri Souris, Montana-North Dakota, scale 1:20,000.

Hardie, J.K., and Arndt, H.H., 1981, Results of exploratory drilling for lignite in 1978, Fort Peck Indian Reservation, Roosevelt County, Montana: U.S. Geological Survey Open-File Report 81-786, 66 p.

_____1987, Distribution, thickness, overburden, and structure contour maps of potentially recoverable lignite beds in the eastern part of the Fort Peck Indian Reservation, Montana: U.S. Geological Survey Open-File Report 87-674, 21 sheets, scale 1;100,000.

_____1988, Geology, structure, and coal beds of the Fort Union Formation in the eastern part of the Fort Peck Indian Reservation, Daniels, Roosevelt, and Sheridan Counties, Montana: U.S. Geological Survey Coal Investigations Map C-122-A, scale 1:100,000.

_____1989, Stratigraphy of the Fort Union Formation in the eastern part of the Fort Peck Indian Reservation, Daniels, Roosevelt, and Sheridan Counties, Montana: U.S. Geological Survey Coal Investigations Map C-122-B.

_____1990, Stratigraphic framework of coal beds in the Fort Union Formation, eastern part of the Fort Peck Indian Reservation, Daniels, Roosevelt, and Sheridan Counties, Montana: U.S. Geological Survey Coal Investigations Map C-122-C.

Hardie, J.K., and Van Gosen, B.S., 1986, Stratigraphic framework of coal beds underlying the northeast part of the Fort Peck Indian Reservation, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1775.

Hopkins, W.B., and Tilstra, J.R., 1966, Availability of ground water from the alluvium along the Missouri River in northeastern Montana: U.S. Geological Survey Hydrologic Investigations Atlas HA-224, 13 p., scale 1:96,000.

Howard, A.D., 1961, Cenozoic history of northeastern Montana and northwestern North Dakota, with emphasis on the Pleistocene: U.S. Geological Survey Professional Paper 326, 107 p.

International Exploration Company, 1980, Geology of the Wolf Point quadrangle: U.S. Department of Energy National Uranium Resource Evaluation Map GE-257, scale 1:250,000.

Jensen, F.S., 1951, Preliminary report on the geology of the Frazer quadrangle, Montana: U.S. Geological Survey Open-File Report 51-37, 29 p.

Jensen, F.S., and Varnes, H.D., 1964, Geology of the Fort Peck area, Garfield, McCone, and Valley Counties, Montana: U.S. Geological Survey Professional Paper 414-F, p. F1-F48.

Lepp, C.L., 1981, Depositional environments of upper Cretaceous-lower Tertiary rocks, western Williston Basin, Montana: Lubbock, Texas Tech University, Masters Thesis.

Mannerfelt, C.M., 1945, Några glacialmorfologiska formelement och deras vittnesbörd om inlandsisens avsmältningsmekanik i svensk och norsk fjällterräng (Some glaciomorphological forms and their evidence as to the downwasting of the inland ice in Swedish and Norwegian mountain terrain): Geografica Annaler, v. 27, p. 1-239 (English summary, p. 222-228).

Marcuson, W.F., and Krinitzsky, E.L., 1976, Dynamic analysis of Fort Peck Dam: U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi Technical Report S-76-1, p. 12-27.

Meek, F.B., and Hayden, F.V., 1962, Descriptions of new Lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils collected in Nebraska Territory, with some remarks on the rocks from which they were obtained: Philadelphia Academy of Natural Science Proceedings, v. 13, p. 415-447.

Meier, M.F., 1960, Mode of flow of Saskatchewan Glacier, Alberta, Canada: U.S. Geological Survey Professional Paper 351, 70 p.

Mudge, M.R., Rice, D.D., Sokaski, M., and McIntyre, G., 1977, Status of mineral resource information for the Fort Peck Indian Reservation, northeastern Montana: U.S. Bureau of Indian Affairs Administrative Report BIA-28, 123 p.

Neuman, Frank, 1935, United States Earthquakes, 1935: U.S. Department of Commerce, Coast and Geodetic Survey Serial Number 600.

Pescado, Pedro, Jr., and Brockmann, L.C., 1980, Soil survey of Richland County, Montana: U.S. Department of Agriculture, Soil Conservation Service.

Prichard, G.E., and Landis, E.R., 1955, Geology of the northern part of the Gerard Coal Field, Richland County, Montana: U.S. Geological Survey Coal Investigations Map C-24.

Prichard, G.E., and Landis, E.R., 1975, Coal resources and Cenozoic geology of the Girard Coal Field, Richland County, Montana: U.S. Geological Survey Bulletin 1310, 89 p.

Smetana, D.R., 1985, Soil survey of Roosevelt and Daniels Counties, Montana: U.S. Department of Agriculture, Soil Conservation Service, 193 p.

Smith, C.D., 1910, The Fort Peck Indian Reservation lignite field, Montana: U.S. Geological Survey Bulletin 381-A, p. A40-A59.

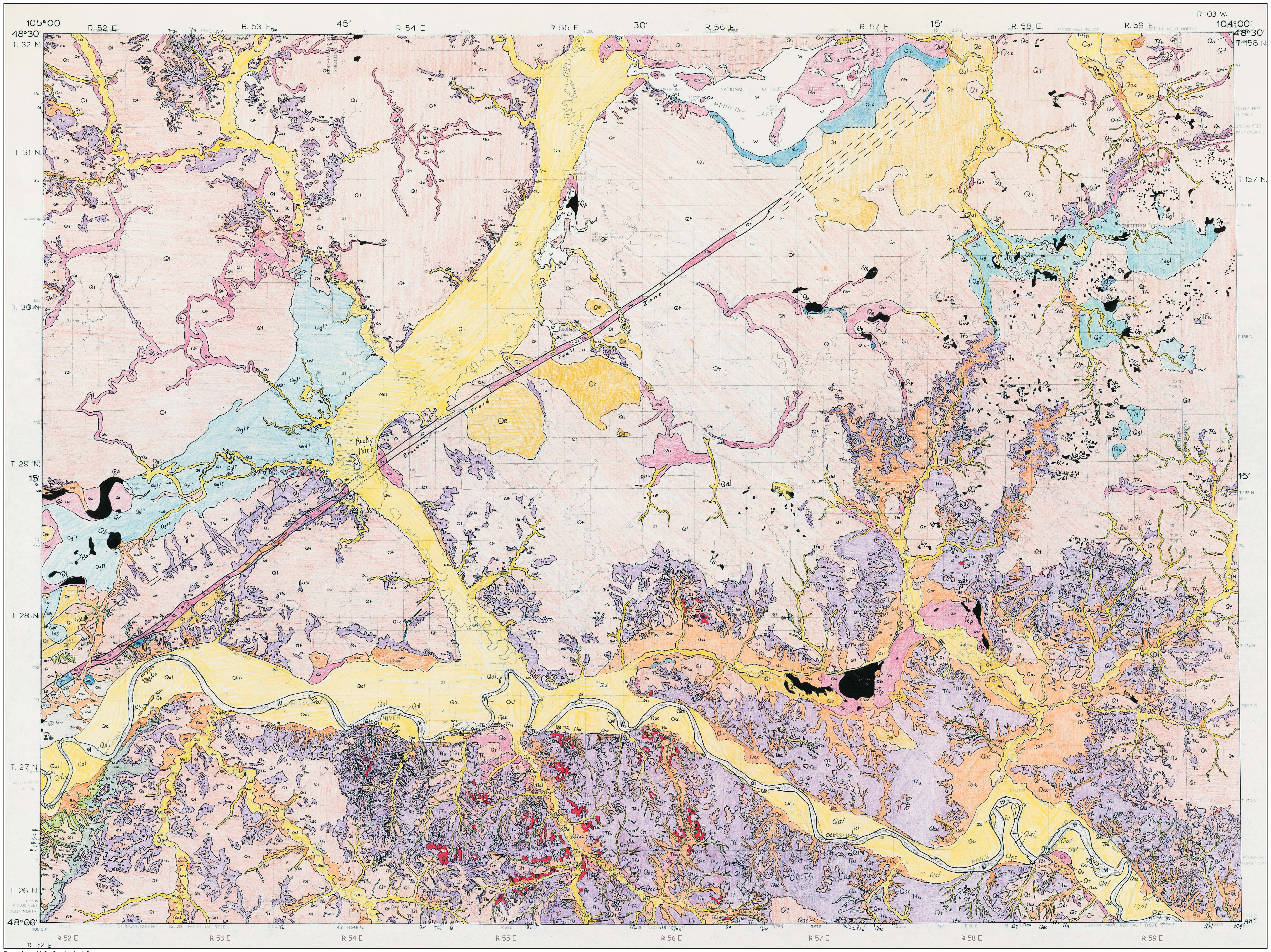
Spencer, M.A., 1986, Coal Resources of the Cedar Coulee 7 ½ minute quadrangle, Richland and Roosevelt Counties, Montana: Montana Bureau of Mines and Geology Geologic Map 44, 5 p.

______1987, Coal Resources of the Two Mile Creek and portions of adjacent Frog Coulee 7 ½ minute quadrangles, Richland County, Montana: Montana Bureau of Mines and Geology Geologic Map 45.

Swenson, F.A., 1955, Geology and ground-water resources of the Missouri River Valley in northeastern Montana: U.S. Geological Survey Water-Supply Paper 1263, 128 p.

Witkind, I.J., 1947, Geologic map of the Bainville No. 2 (15-minute) Quadrangle, Montana: U.S. Geological Survey Missouri River Basin Geologic Mapping and Mineral Resource Investigations, Missouri-Souris, Montana, scale 1:20,000.

Witkind, I.J., 1959, Quaternary geology of the Smoke Creek-Medicine Lake-Grenora area, Montana and North Dakota: U.S. Geological Survey Bulletin 1073, 80 p.



Base from U.S. Geological Survey
Culbertson 30' x 60' topographic quadrangle

KILOMETERS 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
MILES 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13

SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 20 METERS

MAP SYMBOLS

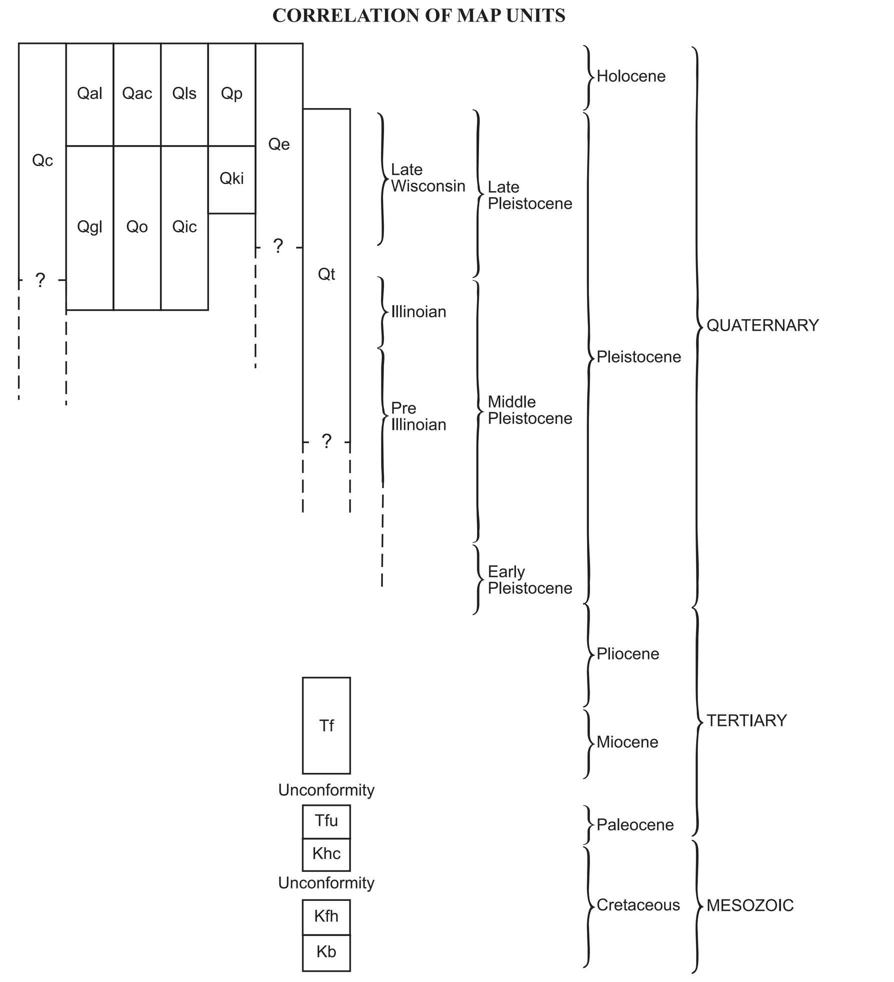
Contact: Dashed where approximated, dotted where concealed

Fault: Dashed where approximated, dotted where concealed

DESCRIPTION OF MAP UNITS

Qal	Qal	Alluvium (Holocene and late Wisconsin)
Qac	Qac	Alluvial and colluvial deposits (Holocene and late Pleistocene)
Qls	Qls	Landslide deposit (Holocene and late Pleistocene?)
Qe	Qe	Eolium (Holocene and Pleistocene)
Qc	Qc	Clinker (Holocene and late Pleistocene)
Qp	Qp	Pond deposits (Holocene and late Wisconsin)
Qo	Qo	Glacial outwash deposits (Middle to late Pleistocene)
Qic	Qic	Ice-contact stratified deposits (Middle to late Pleistocene)
Qgl ?	Qgl	Glacial lake deposits (Middle and Late Pleistocene)
Qki	Qki	Kintyre Formation (Pleistocene to Late Wisconsin)
Qt	Qt	Till (Pleistocene)
Qw	Qw	Wiota Formation (Pliocene to late Pleistocene)
Tf	Tf	Flaxville Formation (Miocene and Pliocene)
Tfu	Tfu	Fort Union formation (Paleocene)
Khc	Khc	Hell Creek Formation (Upper Cretaceous)
Kfh	Kfh	Fox Hills Formation (Late Cretaceous)
Kb	Kb	Bearpaw Shale (Upper Cretaceous)
W	W	Water

CORRELATION OF MAP UNITS



INDEX TO TOPOGRAPHIC MAPPING

105° 48°30' — 104° 48°30'

Beam School 12	Smoke Creek NE 12	Homestead NW 12	Homestead 12	Medicine Lake 12	Capeneys Lake 12	Sunnyhill School 8	Brush Mountain 8
Smoke Creek SW 12	Coyote Coulee 12	Rocky Point 12	Johnson Lake 12	Froid 12	Froid SE 12	Brush Mountain SW 8	Bull Butte 8
Brockton 1	Calais 1, 12	Fort Kipp 12	Culbertson 8, 12	McCabe West 8	McCabe East 8	Bainville 8	Red Bank Creek 8
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48°00' 105° — 104° 48°00'

Numbers refer to references listed in Sources of Geologic Mapping.

SOURCES OF GEOLOGIC INFORMATION

1. Colton, R.B., 1963a, Geologic map of the Brockton (15 minute) quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-362, scale 1:62,500.
2.____1979a, Geologic map of the Bainville SW quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1110, scale 1:24,000.
3.____1979b, Geologic map of the Three Buttes quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1111, scale 1:24,000.
4.____1979c, Geologic map of the Bainville SE quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1112, scale 1:24,000.
5.____1979d, Geologic map of the Dugout Creek quadrangle, Richland and Roosevelt Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1113, scale 1:24,000.
6.____1982a, Geologic map of the Twomile Creek quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1413, scale 1:24,000.
7.____1982b, Geologic map of the Cedar Coulee quadrangle, Roosevelt and Richland Counties, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1414, scale 1:24,000.
8.____unpublished geologic mapping
9. Prichard, G.E., and Landis, E.R., 1955, Geology of the northern part of the Gerard Coal Field, Richland County, Montana: U.S. Geological Survey Coal Investigations Map C-24.
10. Spencer, M.A., 1986, Coal Resources of the Cedar Coulee 7 ½ minute quadrangle, Richland and Roosevelt Counties, Montana: Montana Bureau of Mines and Geology Geologic Map 44, 5 p.
11.____1987, Coal Resources of the Two Mile Creek and portions of adjacent Frog Coulee 7 ½ minute quadrangles, Richland County, Montana: Montana Bureau of Mines and Geology Geologic Map 45.
12. Witkind, I.J., 1959, Quaternary geology of the Smoke Creek-Medicine Lake-Grenora area, Montana and North Dakota: U.S. Geological Survey Bulletin 1073, 80 p.

Note:

1. The geologic information on this map was prepared by the authors as part of field studies for the U.S. Geological Survey. Although the maps have been peer-reviewed for scientific interpretation, the report is preliminary and has not been edited to conform with U.S. Geological Survey publication standards.

2. The Montana Bureau of Mines and Geology is publishing this information with the cooperation of the U.S. Geological Survey and has not edited or reviewed the document.

3. The map is a scan of a map hand-drawn by the authors. The collar information is from documents provided by the authors. Layout of the final map was done by Susan Smith, Geologic Cartographer, MBMG.

Maps may be obtained from
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MBMG Open File 539

Geologic Map of the Culbertson 30' x 60' Quadrangle (Surficial Emphasis), Roosevelt, McCone, and Richland Counties, Montana, Divide and Williams Counties, North Dakota

By

Roger B. Colton, David S. Fullerton, and
William C. Ehler

U.S. Geological Survey

Mapped in stages: 1947—1980's
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