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Geologic Map of the Wolf Point 30' x 60' Quadrangle (Surficial Emphasis), Roosevelt, McCone, Valley, and Richland Counties, Montana

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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.

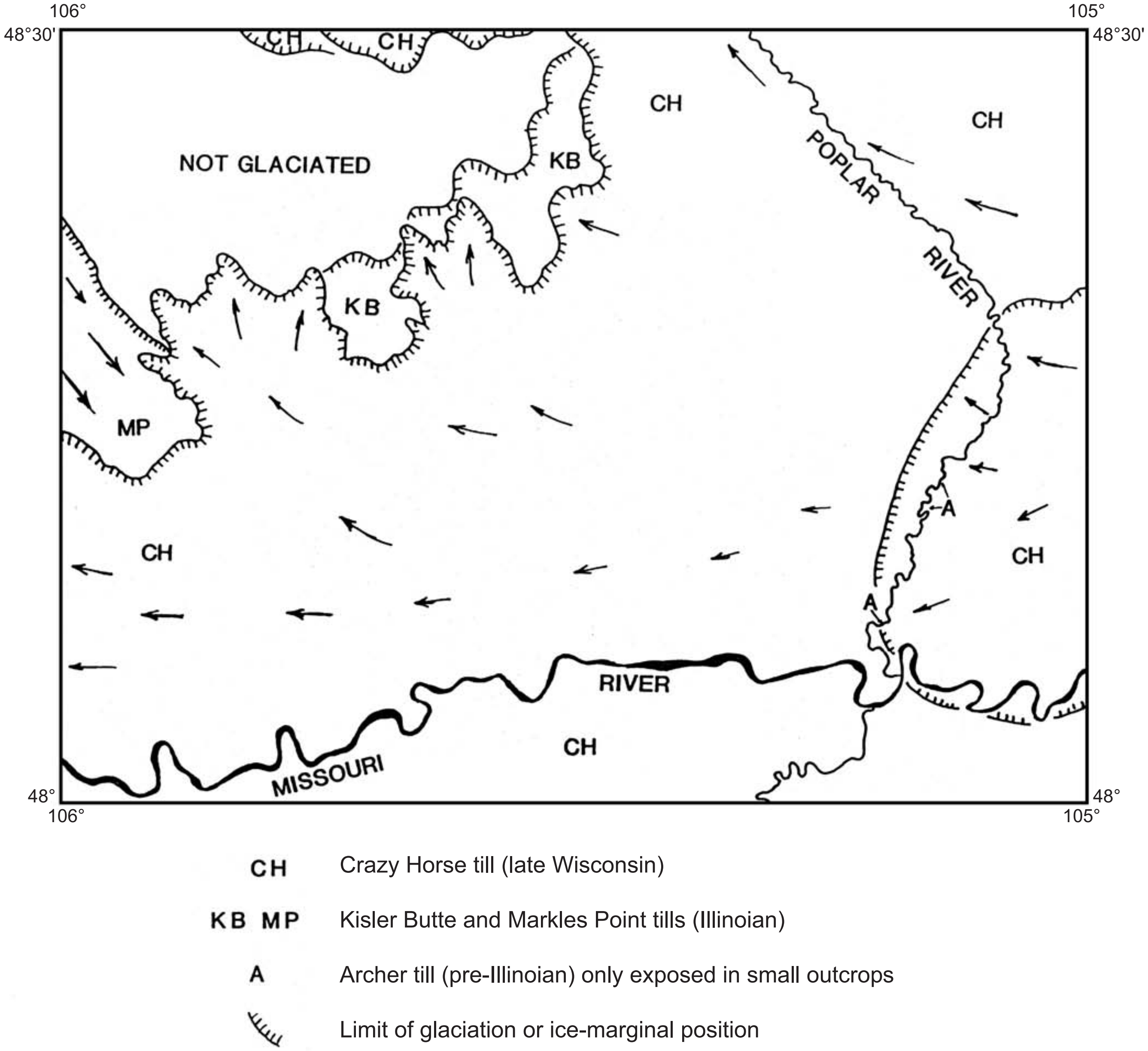

Figure 1. Distribution of till in the Wolf Point 30' x60' quadrangle. Arrows show inferred direction of ice movement.

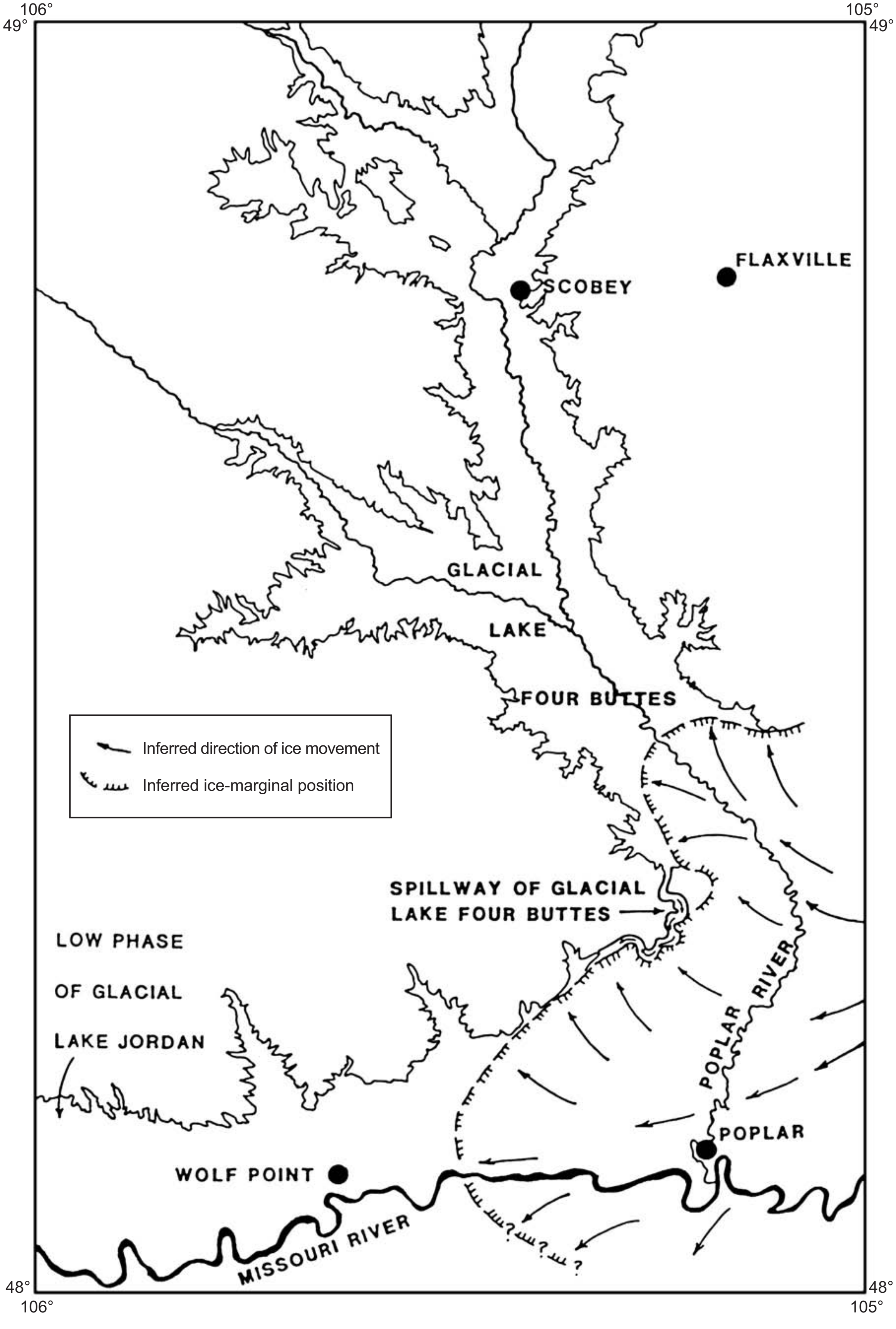

Figure 2. Approximate extent of the low phase of Glacial Lake Four Buttes.

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 beneath floodplains and in stream channels. Poorly to well stratified; poorly to well sorted.

Most floodplain alluvium is yellowish brown and moderate brown; most of the fill in clay plugs is yellowish brown, medium gray, or bluish gray. The upper several feet of floodplain alluvium contains lenticular dark-brown or dark-gray beds alternating with light-brown beds. Light-brown iron oxide stains are present adjacent to rootlets, as isolated blebs, and as irregularly stained individual laminae; staining is prominent in some areas.

Floodplain alluvium is chiefly unconsolidated, well-sorted silt and fine- and medium-grained sand; in valleys of some small streams it is fine to coarse gravel. Silt and carbonaceous clay are present generally in discontinuous lenses or beds or are mixed with fine sand. In most places, the floodplain alluvium overlies channel alluvium and, locally outwash or flood deposits composed of coarse sand and gravel. Vertical and horizontal facies changes in short distances are common. Grain size analyses of floodplain 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 Wolf Point area, flood plains in the Missouri River valley have scalloped (meander scroll) or braided patterns.

Test holes were drilled in alluvium in the Wolf Point, Frazer, and Nashua 15-minute quadrangles by the U.S. Bureau of Reclamation. In general the composite alluvial fill in the Missouri River valley (top to bottom) is silt, 3-6 m (10-20 ft) thick; clayey or silty sand, 3-6 m (10-20 ft) thick; clayey silt, 5-6 m (15-20 ft) thick; and sand and gravel, 3-6 m (10-20 ft) thick. The alluvial fill beneath the Missouri River flood plain is not exposed. Logs from wells and test holes in and near the cities of Wolf Point and Poplar indicate that sand and gravel more than 37 m (120 ft) thick underlies the modern or recent flood-plain deposits. In the Wolf Point municipal area, 5-6 m (15-20 ft) of brown silty alluvial clay overlies 22-24 m (70-80 ft) of sand that locally is clayey or gravelly. The latter sediments overlie 3-5 m (10-15 ft) of coarse outwash gravel or flood gravel. Cobbles as large as 7.6 cm (3 in) in diameter were brought to the surface from the basal gravel during a large-diameter augered test well at the northeast corner of the Wolf Point ball park. In most well and test hole logs, the gravel directly overlies the Bearpaw Shale of Cretaceous age. The maximum recorded thickness of the fill is 35 m (116 ft)

Qac Colluvium and alluvial fan deposits (Holocene and late Pleistocene)—Colluvium consists of 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. Much of it is sheetwash alluvium, derived from bedrock outcrops and other surficial deposits higher on slopes and deposited by unconfined sheet flow and rill wash.

Sheetwash alluvium is chiefly fine sand and silt with scattered granules and small pebbles. Colors, textures, and particle lithologies vary, reflecting those of the eroded bedrock and surficial materials. The downslope surface profile of the deposits is concave upward. Sheetwash alluvium commonly interfingers with and overlaps floodplain alluvium (Qal) along valley walls and it forms extensive fans and aprons on terraces in major valleys. Buried soils (humic laminae horizons) are present locally, snail tests and vertebrate fossils are present locally. Unit includes small areas of windblown deposits (Qe) that interfinger with and overlie sheetwash alluvium.

Colluvium is chiefly composed of crudely stratified silty clay, silt, pebbly silt, sand, and gravel or a heterogeneous mixture of boulders, cobbles, pebbles, and granules in a sandy to clayey matrix. The composition and color of the deposits vary, reflecting the lithologies of the source bedrock and surficial materials higher on the slopes. Colluvium derived from outcrops of Bearpaw Shale near Wolf Point is composed almost entirely of fragments of weathered shale. Where till is the source material, the colluvium is composed of nonsorted or poorly sorted pebbly clay that resembles till. Where derived from the Flaxville Formation or the “Wiota Gravel,” colluvium is uncemented, poorly sorted, crudely stratified, slightly clayey sandy gravel. Where derived from sandy beds of the Cretaceous Hell Creek Formation, it is nearly 100 percent sand. Colluvium commonly overlaps or intertongues with sheetwash alluvium on foot slopes. Buried soils (humic horizons) are present locally.

Great variation in thickness in short lateral distances is characteristic of both fan/apron sheetwash alluvium and colluvium. Generally, the thickness of colluvium is less than 2 m (6 ft), the average thickness is ~0.3 m (1 ft). Alluvial fan deposits typically are thickest about one-third to one-fourth the distance from the fan apex to the toe. At the toe, the fan alluvium commonly interfingers with floodplain alluvium.

The thickness of sheetwash fan and apron deposits generally is 3-8 m (10-25 ft), the maximum thickness is ~ 15 m (50 ft). Deposits have been mapped only where they are more than 0.3 m (1 ft) thick

Qls Landslide deposits (Holocene and late Pleistocene)—Slump, rockfall, and earthflow deposits (individual or in series) produced by downslope movement of bedrock and (or) surficial materials by mass-wasting processes. Sizes of particles range from clay to blocks of sandstone and shale as large as 3 m (10 ft) in diameter. Some landslide deposits are estimated to be as thick as 30 m (100 ft)

Qe Eolium (Holocene, Pleistocene and Pliocene)—Light-brown to light-gray windblown silt (loess) and sand containing scattered granules. Generally massive or crossbedded. Most of the sand grains are well-rounded quartz grains commonly frosted or coated with organic matter; locally, the quartz grains are clean and angular to well rounded. Buried soils (humic horizons) are present locally. Four analyses indicate that the dune sand consists of 0-6 percent clay, 1-9 percent silt, and 85-99 percent sand. Two analyses indicate that the loess consists of 10-20 percent clay, ~ 60 percent silt, and 20-30 percent fine sand.

Deposits of windblown sand and silt unconformably overlie all other map units in the quadrangle. They are not all of the same age. For example, those that overlie floodplain deposits of the Missouri River (unit Qal) are less than a century old, whereas the oldest deposits on the driftless parts of the Flaxville Plateau may be as old as late Pliocene. Most of the windblown sand and silt in the driftless area in this quadrangle probably is late Pleistocene or Holocene in age.

Northwest of this quadrangle, where very thick eolian deposits overlie gravel of the Flaxville Formation, loess in the lower part of the eolian deposits apparently is older than the Gauss-Matuyama geomagnetic polarity reversal (older than 2.582 Ma). A discontinuous veneer of unmapped eolium, generally less than 1 m (3 ft) thick but locally 4 m (13 ft) thick, is present on most flat or nearly flat surfaces throughout the quadrangle. Sand dunes in the southern part of the Poplar 7.5-minute quadrangle, on the Redwater Creek flood plain, are a few hundred feet long, and as much as 8 m (25 ft) high

Qp Pond deposits (Holocene and late Pleistocene)—Brown, dark-gray, or black fine sand, silt, and clay in ice-block or deflation depressions that retain ephemeral ponds. As revealed by auger holes, most depressions are partially filled or nearly filled with black to brown, tough, plastic, organic, silty clay or sandy clay containing scattered granules and small pebbles. Most deposits are less than an acre in areal extent; a few are larger than 2.6 sq km (1 sq mi); all have flat surfaces. Shallow ponds form in the depressions during wet weather but disappear during dry weather.

The pond deposits are well bedded to massive; beds generally are thin or the sediments are laminated. The deposits commonly include thin laminae of windblown sand and silt (Qe). 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 granules and pebbles. The pond deposits are not indurated or cemented, and apparently they do not contain concretions.

A sample from the SW ¼ of the SW ¼ of sec. 7, T. 26 N., R. 50 E. was 68 percent clay, 26 percent silt, and six percent sand. The organic content of the pond sediment is high – about seven percent of a sample from the SW ¼ of the SW ¼ of sec. 7, T. 26 N., R. 49 E., was consumed during an ignition test. Generally, the thickness of a pond deposit is greatest near the center; thickness is 1-5 m (3-16 ft)

Qo Glacial outwash deposits (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 lithologies in most places are similar to that of the Flaxville Formation and the Wiota Gravel, but reworked erratic glacial pebbles, cobbles, and boulders of limestone, dolomite, granite, gneiss, and schist from Canada are very common. Samples of outwash deposits consisted 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 deposits are thin, long, narrow, sandy gravel deposits that filled channels that formed between the ice margin and higher ground or beneath the ice margin. Most of the channel-filling deposits are less than 1.6 km (1 mi) long, but a few are as long as 8 km (5 mi). Generally they are less than 30 m (100 ft) wide, but some irregularly shaped deposits are 1.6 km (1 mi) wide.

Outwash deposits associated with the late Wisconsin Crazy Horse glaciation and the Illinoian Markles Point glaciation have not been differentiated on the map, some channels may have been active during both glaciations. Outwash underlies some alluvial deposits (see description of unit Qal). Locally outwash deposits may be deltaic. In places, outwash may be overlain by a thin discontinuous veneer of till, glacial lake deposits, or colluvium alluvium. Most of these deposits are about 3 m (10 ft) thick but some are as thick as 6 m (20 ft)

Qic Ice-contact deposits (late Pleistocene)—Yellowish-brown, brown, or gray, poorly stratified to well-stratified, poorly-sorted to well-sorted, fine to coarse sand and gravel with minor silt which were deposited by glacial meltwater in channels or tunnels beneath, within, or on ice. The deposits occur as long, narrow, discontinuous, sinuous ridges (eskers), or conical mounds or irregular ridges (kames). Most of the esker and kame deposits are composed almost entirely of gravel that was eroded from the Flaxville Formation by ice. Erratic glacial clasts are conspicuous, but generally are not common. Local small faults and folded, tilted, and contorted bedding indicate collapse when the enclosing or underlying ice melted. Well-stratified, well-sorted silt, sand, or fine gravel beds commonly sharply abut poorly sorted sediments. Locally, lenses of till or flowtill are common. In the few exposures, till underlies esker and kame deposits. Till or flowtill is draped over the sides and crests of some eskers and kames. Locally, the deposits are overlain by alluvium, lake deposits, or eolian deposits.

Kame and esker deposits are gradational in some areas. The dimensions of kames vary greatly. Lengths range from 100 m (300 ft) to more than 1.6 km (1 mi); thickness generally is less than 10 m (30 ft); but locally the relief is as great as 30 m (100 ft). Widths range from 91 to 609 m (300 to 2,000 ft), but most kames are less than 152 m (500 ft) wide. Many kames are conical hills or mounds; a few are long and narrow. Esker widths range from 30 to 100 m (100 to 300 ft), but average ~ 60 m (200 ft); heights range from one meter (3ft) to 20 m (60 ft); the average height is ~ 3 m (10 ft). Lengths range from a few hundred feet to nearly 3 km (2 mi). The thickness of esker and kame deposits varies greatly. Typically the thickness is slightly greater than the local relief. Therefore, esker deposits are more than 20 m (60 ft) thick and some kame deposits are more than 30 m (100 ft)

Qki Kintyre Formation (late Wisconsin)—Light-brown, olive-brown, brown, or light-gray sand, sandy silt, clayey silt, and clay. Jensen and Varnes (1964, p. F34) reported that the lower half of the formation typically consists of basal clay overlain by silt and fine sand that is interbedded with minor clay and silty clay. The upper half is clay and silty clay.

Jensen (1951b, p. 16) concluded that most of the sediments were deposited on stagnant glacial ice, partly by slowly flowing glacial meltwater streams and partly as lacustrine sediments in shallow ponds and lakes. The lacustrine silt and clay are thinly laminated, whereas the coarser fluvial deposits are bedded. As the underlying ice melted, the sediments collapsed and were folded. The Kintyre Formation overlies the youngest till in the quadrangle, and it was deposited during the last deglaciation. Three miles south of Wolf Point, the Kintyre Formation is 11 m (35 ft) thick. The log of a test hole drilled by the U.S. Bureau of

Reclamation one mile east of the Wolf Point 30’ x 60’ quadrangle indicates a thickness of 37.2 m (122 ft)

Qt Till (late Pleistocene and middle Pleistocene)—Heterogenous mixture of clay, silt, sand, and gravel containing rare to abundant cobbles and boulders; till was deposited by continental ice sheets during at least three glaciations. Nonstratified or very poorly stratified; unsorted or poorly sorted. It is locally faintly layered, particularly near the base and top. It may be interbedded, intertongued, or intercalated with sand and gravel or clay and silt. Analyses of 28 till samples indicated ranges of 24-38 percent clay, 23-46 percent silt, 33-62 percent sand, 1-4 percent granules, 1-21 percent pebbles, and 0-1 percent cobbles. Clay minerals in these deposits are dominantly montmorillonite. All of the tills have normal remanent geomagnetic polarity.

Till is mapped only where it is aerially extensive or where small outcrops are closely spaced. The map unit includes some glacial lake deposits (Qgl) that overlie till. Although the total thickness of all of the till units generally is less than 5 m (16 ft), the maximum thickness in buried valleys may be more than 30 m (100 ft).

Till generally is preserved only on rolling or relatively flat surfaces or in buried valleys. During each glaciation, where the ice moved over badlands or other areas of dissected bedrock, till was deposited only as a thin and discontinuous veneer. During the subsequent nonglacial interval, dissection resumed and most of the till was removed and the badlands were restored. Where tills deposited during different glaciations are superposed, typically, each till is discontinuous laterally. Crazy Horse Till may be at the surface in one exposure, but in other exposures nearby either Markles Point or Archer Till may be at the surface. In areas of intense erosion, typically only small remnants of the younger, less resistant, Crazy Horse and Markles Point Tills have been preserved, and most of the exposed till is the more resistant pre-Illinoian Archer Till. Because of the discontinuous lateral and surface distribution of tills of different ages and the sparsity of exposures, the Crazy Horse, Markles Point, and Archer Tills have not been mapped separately

Crazy Horse Till (late Wisconsin)—Yellowish-brown, grayish-brown, brown, brownish-gray, gray, or mottled clay-rich loam and loam. Silty clay or clay where the ice incorporated lake-clay and silt; sandy loam and loamy sand where the 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. Clayey till is soft and sticky where damp and slumps readily at outcrops. Pencil-shaped columnar joints are common in oxidized till. Contains white streaks of secondary calcium carbonate and coatings of powdery gypsum (selenite) locally on joint and parting surfaces. Selenite crystals less than 3 mm (⅛ in) long are present on joint surfaces locally. Larger crystals, clusters of crystals, and crusts of selenite are absent. Iron oxide stains typically are present in matrix adjacent to carbonate grains and granules; but generally they are absent on joint surfaces; manganese oxide stains are uncommon. Moderately pebbly to very pebbly; pebbles, cobbles, and boulders of Canadian provenance typically are more abundant than in older tills. Granules and pebbles are subangular to well rounded, dominantly erratic limestone and dolomite from Canada; but include some granite, gneiss, schist, quartzite, chert, sandstone, siltstone, and shale; very minor ironstone concretions, agate, silicified wood, and chalcedony. Lignite fragments are ubiquitous in the matrix. Cobbles and boulders are chiefly erratic limestone, dolomite, granite, and gneiss; however where the ice incorporated clasts from the Flaxville Formation or the Wiota Gravel, quartzite cobbles are abundant. Cobbles and boulders litter till surfaces that have not been cleared for cultivation. The thickness of Crazy Horse Till typically is 0.5-3 m (3-10 ft); locally is 5 m (16 ft).

The Crazy Horse Till in the southern part of the Wolf Point 30’ x 60’ quadrangle and in parts of the adjacent Glasgow, Culbertson, and Plentywood 30’ x 60’ quadrangles is characterized by hundreds of till ridges 15-61 m (50-200 ft) wide, as high as 6 m (20 ft), as long as 4 km (2.5 mi), and 198-366 m (650-1,200 ft) apart. Individual ridges are too small to be shown as map units at this scale; they are shown at 1:62,500 scale on geologic maps of the Oswego, Wolf Point, Chelsea, and Poplar 15-minute quadrangles (Colton, 1955, 1963d, 1963e, 1963f). The belt of ridges extends from Wiota to a point 11 km (7 mi) southwest of Westby, a distance of 155 km (110 mi). A few gaps interrupt the continuity of the pattern of ridges. The width of the belt ranges from 7 to 30 km (5 to 20 mi) and the average width is 11 km (7 mi). Most of the ridges are long and either parallel or concentric, but in some areas short ridges intersect the long ridges at angles of 30°-45°. In several areas, the ridges form a geometric pattern similar to that of intersecting crevasses on Saskatchewan glacier, as described by Meier (1960).

In many areas the ridges are similar to the “ice-crack moraines” described by Sproule (1939). Those ridges apparently are crevasse fillings (Colton, 1958); they are not moraines. During deglaciation, crevasses formed in the marginal zone. Where the underlying saturated, soft, plastic Crazy Horse Till was intersected by a crevasse, till was squeezed into the crevasse. After the ice melted, the ridges of till remained. In other areas in the belt of ridges, some of the long, parallel or concentric ridges may be washboard moraines or annual moraines that formed at the ice margin. Crosscutting or overlapping relationships in some areas indicate that minor readvances of the ice margin occurred between intervals of ridge formation. The overridden ridges were not obliterated during the readvances; they are overlain by a thin, discontinuous veneer of younger till. Crosscutting relationships are well displayed west of Oswego, adjacent to U.S. highway 2

Kisler Butte Till (Illinoian)—Pale-yellow, yellowish-brown, grayish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled calcareous clay loam, loam, and silt loam. Silty clay or clay where the ice incorporated lake clay and silt; sandy loam or loamy sand where the ice incorporated alluvial sand and gravel. Generally oxidized to depths less than 2.4 m (8 ft) where not covered by younger till, to depths less than 1.5 m (5 ft) where covered by younger till. Commonly massive or with blocky structure. Typically very compact, and overconsolidated, but not dense and hard. Brittle where dry; clayey till is sticky where damp. Commonly breaks around large sand grains and granules. Moderately resistant; typically does not slump at outcrops. Parting is irregular to platy. Columnar joints, 1.25-2.5 cm (0.5-1 in) apart, are common in oxidized till. White streaks of secondary calcium carbonate and coatings of powdery gypsum (selenite) are common on joint and parting surfaces; selenite crystals less than 5 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 the oxidized matrix, but crusts of iron oxide are not present on joint surfaces; manganese oxide stains are not abundant. Sparingly to moderately pebbly; pebbles, cobbles, and boulders generally are less abundant than in Crazy Horse Till. Granules and small pebbles of erratic limestone and dolomite are very abundant locally. Granule and pebble composition is similar to that of Crazy Horse Till, but reworked clasts from older alluvial deposits are more abundant. Cobbles are mostly quartzite, ironstone (siderite) concretions, erratic limestone, dolomite, and igneous and metamorphic rocks from Canada. Erratic boulders are rare in exposures but locally are common as a lag concentrate on the surface. The physical and chemical characteristics of the Kisler Butte and Crazy Horse Tills are generally similar, and the tills are not easily distinguished where they are not superposed or where they 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)—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 or sand. Colors of oxidized till typically are lighter hues than those of younger tills in the same area; matrix typically is more sandy. Weakly to strongly calcareous. Generally oxidized throughout where less than 3 m (10 ft) thick or where weathered profile was partly eroded prior to burial by younger till. In buried valleys where till was not eroded, oxidation may extend to depths of 8-14 m (26-46 ft). The Archer Till is overconsolidated and very dense; typically it is massive, and it breaks into large irregular blocks. Where dry, it is extremely hard; clayey till is sticky where damp. It is very resistant to erosion but where this till is thick it commonly erodes to form hoodoos, spires, and pinnacles; it rarely slumps in outcrops. Typically it is 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 are present locally. Typically sparingly pebbly or mostly clast free; but very gravelly locally where ice incorporated large quantities of sand and gravel. Granules and pebbles are subangular to well-rounded, chiefly limestone and dolomite from Canada; includes quartzite, chert, and sandstone; some igneous and metamorphic rocks, ironstone (siderite) concretions, and chert; minor siltstone, shale, agate, silicified wood, and chalcedony. Large cobbles and boulders are rare in exposures, chiefly limestone, dolomite, granite, and schist from Canada. The thickness of the till varies greatly – the average thickness is ~ 4.6 m (15 ft), it may be at least 85 m (280 ft) thick in some buried valleys

Qs Sprole Silt (middle Pleistocene)—Laminated yellowish-gray and gray silt, silty clay, and clay. The lower half of the formation typically is well-stratified, thinly-bedded or laminated silt, silty clay, and clay with scattered granules and pebbles. The upper half is chiefly massive or thickly-bedded silt, with or without scattered granules and pebbles. In some outcrops the silt has no apparent structure and resembles loess (e.g., in sec. 6, T. 28 N., R. 51 E.). Locally (e.g., in sec. 6, T. 27 N., R. 52 E.), beds of Sprole Silt were intensely folded and deformed by overriding ice. The Sprole Silt overlies the Wiota Gravel and extensive areas of bedrock. In nearly all surface exposures, the lake deposit is overlain by Archer Till. In some outcrops the Sprole Silt is represented by bedded or laminated clay, silt, and sand less than one meter (3.3 ft) thick, sandwiched between Wiota Gravel and Archer Till. The remanent geomagnetic polarity of the formation has not been determined. However, lake sediments in the same stratigraphic position and of the same age in the Yellowstone River valley southeast of the Wolf Point quadrangle have normal remanent polarity; the lake was dammed by the advancing Archer glacier, and the Archer Till has normal remanent polarity. Consequently, the sediments are younger than the Matuyana-Brunhes geomagnetic polarity reversal (younger than 788 ka). Thicknesses typically range from a few meters to 30.5 m (100 ft)

Qw Wiota Gravel (middle Pleistocene, early Pleistocene, and late Pliocene)—Mainly fluvial deposits of light-brown, brown or gray sand, silt, clay, and fine to coarse gravel. The lower part generally is moderately-well-bedded and poorly-sorted to moderately-well-sorted sand and gravel with lenses of silt and sand (channel alluvium). The upper meter (3.3 ft) or so commonly is crossbedded or parallel-bedded sand and silt with lenses of clay. In some exposures the upper part may be flood-plain alluvium; in other exposures the sand and silt may be a coarse facies of the overlying Sprole Silt lake beds, rather than part of the Wiota Gravel. Textures may vary abruptly, laterally and vertically – coarse gravel is replaced laterally in less than one meter by a deposit that consists entirely of sand, silt, and clay. In places the fluvial (and lacustrine?) sediment grades laterally into poorly-sorted colluvium and sheetwash alluvium. Locally, the gravel and sand are cemented by secondary calcium carbonate, forming conglomerate. Pebbles and cobbles are dominantly gray, pink, green, and brown, well-rounded quartzite and argillite, which were reworked from the Flaxville Formation; more than 90 percent of the cobbles are quartzite. The quartzite clasts commonly are very smooth and are pitted by percussion marks. Sandstone pebbles are locally abundant. Pebbles and cobbles of tinguaite (from the Bearpaw Mountains), porphyritic syenite (from the Bearpaw Mountains and Sweetgrass Hills), and reworked limestone, dolomite, granite, gneiss, and other igneous and metamorphic rocks from Canada are rare. The pebble fraction includes minor chert, vein quartz, chalcedony, and silicified wood. The thickness of the Wiota Gravel at outcrops is 3-6 m (9-20 ft) but might exceed 10 m (30 ft).

The Wiota Gravel has been distinguished from the Flaxville Formation primarily on the basis of altitude; a lithostratigraphic distinction is not justified. In some areas, the youngest (topographically lowest) remnant of Flaxville Formation and the oldest (topographically highest) remnant of Wiota Gravel are distinguished arbitrarily. Much (if not most) of the gravel in a Wiota deposit is reworked from older Flaxville and Wiota deposits. In most exposures, gravel constitutes only a fraction of the Wiota Gravel. Consequently, the lithologic term is inappropriate. However, redefinition of the Flaxville and Wiota deposits is not within the scope of this description. For this map, the nomenclature of Jensen (1952), Colton (1955), and Jensen and Varnes (1964, p. F28) is retained.

The Wiota Gravel is widespread but discontinuous. All of the deposits in the Wolf Point 30’ x 60’ quadrangle are on the north side of the Missouri River valley. The sediments are preserved as multiple terrace remnants, separated by risers of eroded bedrock along the valley sides.

The gravel is more resistant to erosion than are the overlying till or the underlying bedrock. Deposits of Wiota Gravel commonly are indicated by subtle sub-horizontal dry zones along valley walls, attributed to the high porosity of the gravel and sand and retention of moisture in the overlying and underlying materials. Some areas of unmapped Wiota Gravel beneath younger deposits have been identified in drill holes and from well data.

In the Wolf Point 30’ x 60’ quadrangle, the basal contact of a terrace deposit with bedrock slopes eastward or northeastward (downstream) and southward or southeastward (toward a topographically lower deposit or the buried bedrock valley of the ancestral Missouri River). The Wiota Gravel was deposited during lateral planation – incision of the Missouri river occurred as the river migrated southward or southeastward. At times, the river incised its channel deeply (forming a riser to a terrace) before lateral planation was renewed. On the basis of test hole and well data, the ancestral Missouri and Yellowstone Rivers were deeply incised into bedrock at the time of the advance of the earliest Pleistocene (early Archer) glacier in northeastern Montana.

Jensen (1952), and Jensen and Varnes (1964, p. F29) observed rare igneous and metamorphic clasts from the Canadian Shield in low-altitude Wiota Gravel in the vicinity of Nashua, west of the Wolf Point 30' x 60' quadrangle. Witkind (1959), reported that clasts of Canadian provenance are uncommon but conspicuous in Wiota Gravel east and northeast of the quadrangle; Colton (1962) noted that many pebbles from the Canadian Shield are included in the Wiota Gravel northeast of the Wolf Point quadrangle. Reworked erratic clasts from Canada are also present in many deposits of the Wiota Gravel in the Wolf Point 30' x 60' quadrangle. Jensen and Varnes (1964, p. F30) hypothesized that the erratic clasts were derived from a pre-Wisconsin ice sheet that did not extend as far south as the Wiota Gravel outcrops in which they were observed. Witkind (1959, p. 15-16) suggested that these erratic clasts indicate either: 1) reworking of gravel from the Flaxville Formation by glacial meltwater, 2) deposition "under periglacial conditions," 3) deposition as outwash during an "early Pleistocene glaciation," or 4) erosion of the "local till of an early Pleistocene glacier."

Although the Wiota Gravel has been referred to as "preglacial gravel" in many publications, some of the deposits post-date one or more late Pliocene continental glaciations on the Northern Plains. Pliocene glaciation is recorded in the adjacent Scobey, Opheim, and Glasgow 30' x 60' quadrangles (Colton et al. unpublished and 1989a and 1989b) in Montana and in the Wood Mountain 1° x 2°

quadrangle in Saskatchewan north of the Opheim quadrangle. The Pliocene and earliest Pleistocene glacial periods were separated by a nonglacial interval of ~1.5 million years, during which the landscape was greatly modified by erosion. Canadian erratic clasts apparently are not present in the topographically highest (oldest) deposits of Wiota Gravel or in the older Flaxville Formation in Montana. They are present in some topographically lower (younger) deposits, however. Both the erratic-bearing gravel and the erratic-free gravel are overlain by the middle Pleistocene Archer Till. Boulders of Canadian provenance are present as lag or residual accumulations on some of the higher Wiota deposits and on some Flaxville deposits in the adjacent Scobey and Opheim 30’ x 60’ quadrangles. They are believed to be all that remain of the Pliocene drift. The younger Wiota sediments that contain Canadian erratics were deposited during or after the Pliocene glaciation(s); the older Wiota sediments that do not contain erratics were deposited prior to the glaciation(s). Although none of the erratic-bearing sediments in Montana are interpreted to be from Pliocene glacial outwash, it is nevertheless considered that erratics were residual from the erosion of late Pliocene glacial and proglacial deposits and were incorporated into the younger deposits by repeated reworking of gravel during the nonglacial interval of ~ 1.5 million years between Pliocene and Pleistocene glaciations

Tf Flaxville Formation (Miocene and Pliocene) —Gravel, sand, silt, clay.

Collier (1917, p. 35) first described the Flaxville Formation from outcrops near the town of Flaxville, 34 km (21 mi) north of the Wolf Point 30’ x 60’ quadrangle. Collier and Thom (1918) renamed the unit the “Flaxville Gravels.”

In the Wolf Point area, the name Flaxville Formation is used because gravel is only a minor part of the unit.

The Flaxville Formation is composed of several units. In nearly all exposures, the basal part of the formation is coarse, sandy, quartzite gravel 6-15 m (20-50 ft) thick. Lenticular sandy and clayey beds, 6-12 m (20-40 ft) thick, overlie the gravel. Volcanic ash in the gravel was observed by Collier and Thom (1918, p. 182) 32 km (20 mi) northwest of the Wolf Point 30’ x 60’ quadrangle, in secs. 19 and 20, T. 35 N., R. 43 E.

Clasts in the Flaxville Formation are chiefly well-rounded quartzite pebbles, although smooth, well-rounded cobbles and boulders as large as 1 ft in diameter also are common. Most of the pebbles are grayish red, but some are yellowish green or grayish green. Approximately seventy percent of the pebbles are quartzite; about twenty percent of the pebbles are red argillite and a smaller percentage are olive-gray, gray, or black argillite. Some deposits contain scattered clasts of chert, chalcedony, agate, and silicified wood as well. A minor, but distinctive, lithology of pebbles is green tinguaite porphyry from the Judith Mountains. Most of the pebbles, cobbles, and boulders have a moderate yellowish-brown patina, probably iron oxide, which has penetrated the quartzite clasts to depths of as much as 3 mm (⅛ of an inch).

Locally, the formation has been cemented by secondary calcium carbonate to form sandstone and conglomerate. Individual beds range in thickness from 0.3 to 3 m (1 to 10 ft). Most of the sand and gravel is crossbedded, indicating that much cutting and filling occurred during deposition.

Although the organic content of the formation is very low, Russell (1950, p. 58) observed two gravel units separated by a fossil soil, 7.6 cm (3 in) thick, indicating a hiatus. R.B. Colton observed thin carbonaceous beds within the Flaxville Formation a few miles north of the Wolf Point quadrangle.

Vertebrate fossils of Pliocene age are found in the Flaxville Formation. Some 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 collected by R.B. Colton were examined by Jean Hough (written communication) who concluded that they were of Pliocene age, probably of early Pliocene age. Bones of *Hipparion*, *Procamelus*, and mastodon were identified.

The formation unconformably overlies older bedrock units. In places it is overlain by younger glacial, glaciolacustrine, glaciofluvial, eolian, colluvial, and alluvial deposits. The thickness of the formation varies considerably. A maximum thickness of 49 m (160 ft) was measured in sec. 35, T. 33 N., R. 43 E., the average thickness is approximately 12 m (40 ft). The unit thins to a feather edge around the borders of the dissected terrace remnants

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

Weathered outcrops of Fort Union Formation typically are lighter and brighter colored than those of the underlying Hell Creek Formation. 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 that in the carbonaceous shale and lignite beds.

The Fort Union Formation conformably overlies the Hell Creek Formation. The gradational contact between the Hell Creek and the Fort Union Formation is arbitrarily placed at the base of the lowest mappable lignite bed. South of Wolf Point, the base of the formation is placed at the base of the Z coal or lignite bed of Collier and Knechtel (1939, p. 3). Dinosaur fossils have not been found above the Z coal at that locality; the apparent absence of dinosaur fossils has been used at other localities as a criterion for recognition of the Fort Union Formation.

The thicknesses of partial sections of the Fort Union formation that were measured by R.B. Colton range from 24 to 63.6 m (79.6 to 208.7 ft) thick. Only the lower part of the Fort Union Formation is represented. In those sections, 30 percent of the formation is sandstone, 1 percent is siltstone, 59 percent is shale, 5 percent is carbonaceous shale, and 5 percent is lignite. The thicknesses of the different lithologies vary greatly from one section to another.

Four types of concretions are present in the Fort Union Formation: calcareous sandstone, siltstone, limonite, and pyrite. Most of the calcareous concretions observed in the field are sandstone and are yellowish gray or medium olive gray. Some have 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 have very pronounced crossbedding. The maximum measured dimensions are: 5 m (15 ft) thick, 12 m

(37 ft) wide, and 30-213 m (100-700 ft) long. The trend of the long axes of the concretions is N. 60° E.

The colors of the concretions vary. The exteriors of weathered pyrite concretions are dark yellowish brown; the unweathered interiors of are greenish gray. Limonite concretions typically 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 particles in beds in the formation are uniformly sorted. Lateral changes in the facies are common. Channel structures are present locally, but they are not common. Most contacts between beds are gradational, but are locally sharp.

Nearly all the fossils observed were plant remains. Vertebrate fossils are very rare. A few specimens of *Unio* were found.

Silicified fossil soils were observed at several sites, 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 a fossil soil contains silicified logs. The logs were identified by Richard A. Scott of the U.S. Geological Survey (written communication) as specimens of the conifer *Cupressaceae*(?), Fossilized 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 meandering streams on a broad swampy flood plain that slowly subsided until more than 304 m (1,000 ft) of sediment had accumulated in this area. The formation includes many beds of lignite; some are several feet thick. The formation underlies approximately one-third of the Wolf Point quadrangle, and reserves of lignite in the Fort Union Formation are large. Lignite beds and reserves in McCone County were described by Collier and Knechtel (1939), and the lignite field in the Wolf Point area was described by Smith (1910). Biewick and others (1990) evaluated the coal resources in the eastern part of the Wolf Point quadrangle. Several studies of coal resources in that area were published 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 prior to 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 Wolf Point quadrangle where approximately 146 m (480 ft) of strata remain

Hell Creek Formation (Upper Cretaceous)—Consists of well stratified shale, siltstone, sandstone, 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.

The lower half of the formation consists of beds of coarse-grained sandstone, composed of abundant dark minerals that contrast markedly with the underlying fine-grained, light 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, calcareous 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). They commonly preserve trough crossbedding in the cemented sandstone. Spherical concretions, as much as 7.6 cm (3 in) in diameter, are also common.

The upper half of the formation consists mainly of sandstone, siltstone, claystone, 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. Some shale outcrops have a characteristic spongy appearance caused by the swelling of included bentonite. The carbonaceous shales, which contain abundant macerated plant fragments, are brown, 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 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 and cobbles 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 basal contact with the underlying Fox Hills Formation; 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 these fossil vertebrate remains are of Triceratops (R.W. Brown, personal communication, 1951).

Several pieces of fossil wood were found in conglomeratic beds in the lower part of the formation. Most of the wood is silicified, but some is limonitized. A log, 1.5 m (5 ft) long and 15 cm (6 in) in diameter, was found in sec. 21, T. 32 N., R. 44 E. Richard A. Scott, U.S. Geological Survey (personal communication), examined fragments of this log and identified it as petrified wood of the conifer *Cupressaceae*(?). Fragments of several other logs were found in that area. Several logs of coniferous wood were found in the NE ¼, NE ¼, sec. 26, T. 26 N., R. 51 E. A fragment of petrified wood from the NW ¼, NW ¼, sec. 28, T. 27 N., R. 48 E., was identified by Scott as broad-rayed dicotyledonous wood suggestive of *Platanus* (sycamore).

The formation ranges broadly in color 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 very 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 the Hell Creek Formation consists of 61 percent sandstone, 4 percent siltstone, 34 percent claystone and shale, and 1 percent 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. The channels contain 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. The authors 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) 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 beds in the upper half of the formation were deposited probably by more sluggish streams. Many of the beds of shale probably were 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)—Composed of 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 underlying dark olive gray marine Bearpaw Shale to light olive gray. Shale beds are darker than sandy beds, which are interbedded 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 light olive gray shale, siltstone, and fine-grained, clean sandstone in beds 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 sandstone has been cemented by calcium carbonate to form resistant ledges of sandstone.

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 beds 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 sandstone 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 of the transitional beds.

A few poorly preserved pelecypods were found in the lower part of the formation. Several specimens of *Ophiomorpha nodosa* were found near Redwater Creek in sec. 3, T. 26 N., R. 50 E., and were identified by R.W. Brown (personal communication).

The basal transition beds of the Fox Hills Formation were deposited in the same shallow sea in which the underlying Bearpaw Shale accumulated, but during Fox Hills time the sea gradually became shallower. Eventually, the shoreline migrated eastward, leaving the Wolf Point 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., a distinct unconformity can be seen. A suggestion of such a break is also present in the southeastern part of the 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 Fox Hills Formation varies greatly in thickness within short distances, and in places it has been almost completely removed by erosion. In the SW ¼, NE ¼, sec. 26, T. 27 N., R. 52 E., only a few feet of the formation remains. In the SE ¼, NE ¼, sec. 2, T. 26 N., R. 50 E., where only basal beds are present, the formation is 34 m (111 ft) thick. Two miles to the west it is 23 m (75 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. Mechanical analyses of two samples 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; the content of clay and silt ranges from 62 to 67 percent and the content of sand ranges from 33 to 38 percent. A wet analysis by the U.S. Army Corps of Engineers showed that weathered shale contains 5 percent sand, 40 percent silt, and 55 percent clay (Jensen and Varnes, 1964, fig. 18) (n.b. the title for fig. 18 is transposed with that of fig. 5). The clay fraction is tough, highly plastic, and has high compressibility. All outcrops in the Wolf Point area are weathered; depth of weathering is at least 2 m (6 ft) and as much as 15 m (50 ft).

Bentonite occurs as beds or is disseminated in shale. Its swelling properties impart a spongy texture to weathered surface of the shale. Several beds of bentonite crop out locally but none are well enough exposed to map. 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 bentonite beds are sharp, but upper contacts are gradational.

Two types of concretions occur in the Bearpaw Shale. The most abundant type is composed of iron oxide and clay; they are as much as15 cm (6 in) in diameter and are disk shaped. The other type consists of medium-dark-gray nearly pure limestone, and is round, egg-shaped, or irregularly rounded. Their diameters range from 15 cm to 2 m (6 in to 6 ft); most are about 30 cm (1 ft). Many limestone concretions contain 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 marine fossils such as baculites and scaphites; a few of the ironstone concretions contain fossils which are poorly preserved.

Several horizons of fossiliferous concretions in the Bearpaw Shale were recognized by Jensen and Varnes (1964, p. F6-7 and Plate 2) in the Fort Peck area, but only the three uppermost zones are exposed in the Wolf Point area. The zones could not be traced laterally because of the general thick cover of till. The lowest concretion zone is 61 m (200 ft) below the top of the Bearpaw Shale and it contains *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 the 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. The Bearpaw Shale is comprehensively described by 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 outcrops, no sections of this shale were measured; only the upper few hundred feet of the formation is exposed

GEOLOGIC HISTORY

During Late Cretaceous time, the area was covered by a shallow sea in which the Bearpaw Shale was laid down. Bentonite beds scattered through the formation record numerous distant volcanic eruptions. Subsequently, as the sea receded toward the east, the lower part of the Fox Hills Formation was deposited in offshore marine waters. Nonmarine conditions followed as the sea receded still farther, and the upper sandstone unit of the Fox Hills Formation was deposited along the seashore. Uplift and erosion followed and the Fox Hills Formation was deeply eroded. The continental Hell Creek and Fort Union Formations were deposited by streams and in lakes on this surface.

Evidently no deformation occurred during the deposition of the Hell Creek Formation and the Fort Union Formation. Some deformation occurred before the deposition of the Flaxville Formation because the erosional surface, on which it was deposited, in Miocene and Pliocene times, bevels outcrops of the Fort Union Formation. Some post-Flaxville deformation occurred – the formation has been eroded from the Poplar Anticline and the Bowdoin Dome. Lenses of unaltered volcanic ash in the Flaxville Formation record distant Miocene and Pliocene eruptions.

Upper parts of the Flaxville Formation were eroded and redeposited during late Pliocene and early Pleistocene time. Continued erosion and redeposition of the Flaxville-type gravels in Pleistocene time resulted in the formation of some pediment-like surfaces veneered with Wiota Gravel. Terraces of Wiota Gravel were also formed as straths along the ancestral Missouri River.

Most of the Wolf Point area was glaciated at least three times during the Pleistocene (Fullerton and Colton, 1986; Alden, 1932; Colton, Lemke, and Lindvall, 1961). As the ice moved into the area from the east and west, the northeastward drainage of the area was blocked, lakes formed along the edge of the ice, and meltwater spilled over divides and cut channels along the margin of the ice.

After the various benches and terraces of Wiota Gravel were formed, they were buried by Sprole Silt, deposited in a lake that formed in front of an advancing glacier. The ice stood for a time at the Poplar Moraine, contributed debris to it and to the lake in which the Sprole Silt accumulated. The ice then advanced over the moraine and the Sprole Silt and deposited till on top of them.

During the Late Wisconsin readvance, the ice again advanced westward to the area of Glasgow. Glacial lakes Glasgow, Redwater, and Lambert existed at the time of the late Wisconsin readvance. Large kame moraines formed early in the recessional stage.

A series of short-lived glacial lakes existed along the margin of the lobes of ice that flowed in the valleys that are tributary to the Poplar and the Missouri Rivers, as indicated by ice-marginal channels that cut across the remnants of the Flaxville Formation in the Todd Lakes and Tule Valley quadrangles. These segments of ice marginal channels were the controlling spillways for the glacial lakes that existed in the middle and east forks of Tule Creek in the Tule Valley quadrangle, in the north fork of Tule Creek, and in Boxelder Creek.

In the Long Creek East and Long Creek West 7½’ quadrangles there is an ice-marginal channel about 11 km (7 mi) long and .8 km (.5 mi) wide that trends south and southwestward through the drainage divide between the Missouri and Poplar Rivers. It was the spillway for the large glacial lake (glacial Lake Four Buttes) which was held in by an ice lobe in the Poplar River Valley (fig. 2). The lake is inferred to have spilled over the divide at an altitude of 762 m (2,500 ft). Water eroded the spillway channel 24 m (80 ft) lower to 738 m (2,420 ft) before the front and margins of the lobe of ice in the Poplar River Valley wasted back enough to allow the lake to drain. The spillway-ice-marginal channel ends at a large gravel deposit inferred to be a deltaic deposit of gravel in the low phase of glacial Lake Jordan (fig. 2), which was formed by damming by the lobe of ice in the Missouri River Valley. The altitude of the surface of the lake is inferred to have been 707 m (2,320 ft).

Many moraines and ice-marginal meltwater channels formed during the recession of the ice from the sides of the lobe. As the glacier wasted, the front of the lobe stagnated and broke mainly along crevasses. This front part of the ice lobe floated in the glacial lake, and as the lake level fell the ice was lowered onto the underlying muddy till so that the soft till was squeezed up into the open crevasses. The ridges of till remaining after the enclosing ice melted show a fossil crevasse pattern.

A mass of stagnant drift-covered ice 14.5 km (9 mi) long and 8 km (5 mi) wide, was left southeast of Poplar, and dammed the Missouri River to form Lake Poplar. When the ice front wasted back and uncovered part of the overridden Poplar moraine in sec. 26, T. 29 N., R. 51 E., lake water spilled over it, through a channel, in that section at an altitude of 732 m (2,200 ft), and flowed southeast on or through ice to the low spot in the divide a few miles northwest of Brockton. The pattern of ice-crack moraines suggests that the course of the water was probably guided by crevasses in the stagnant ice. The ice in the southwestern part of T. 28 N., R. 52 E., and the eastern part of T. 28 N., R. 51 E., stagnated and melted in place. The lake level gradually lowered to 640 m (2,096 ft), as downcutting of the spillway to its present altitude occurred.

The Missouri River Valley, was trenched 36 m (120 ft) below its present flood plain. Alluvial filling of the Missouri River trench and the valley of Big Muddy Creek occurred in postglacial time.

Since the retreat of the late Wisconsin glacier, alluvium and colluvium have been deposited and sand dunes have formed on the alluvium and on till. Lake deposits have filled many of the small closed depressions (kettles) that existed in morainal topography and in abandoned meanders on alluvial plains.

Geologic mapping of the Wolf Point 30’ x 60’ quadrangle was done on 15’ topographic maps, which had been compiled by the U.S. Geological Survey from General Land Office township plots at 1:31,680. These maps had a contour interval of 6 m (20 ft) and were made for the whole Fort Peck Indian Reservation in 1890. Geologic contacts were adjusted to these old plane-table topographic maps (Colton, 1964). All eight 15’ quadrangles in the Wolf Point 30’ x 60’ quadrangle were published as geologic quadrangle maps or as miscellaneous investigations maps (Colton, 1955, 1963a, b, c, d, e, f, g). In the 1970’s, the Energy Lands Project made it necessary to compile the Wolf Point 30’ x 60’ quadrangle at a scale of 1:100,000. The eight geologic maps were reduced photographically from a scale of 1:62,500 to a scale of 1:100,000 and compiled on a base enlarged from the Army Map Service 1:250,000 scale topographic map of the Wolf Point 1° x 2°quadrangle. When a new base map of the Wolf Point 30’ x 60’ quadrangle (1:100,000 scale) became available in 1979, the 1:100,000 scale compilation was photographically transferred to the new base. The geologic contacts which were adjusted to the old topographic maps have not been readjusted to the new topographic base map

REFERENCES PERTINENT TO THE GEOLOGY OF THE WOLF POINT 30’ x 60’ QUADRANGLE

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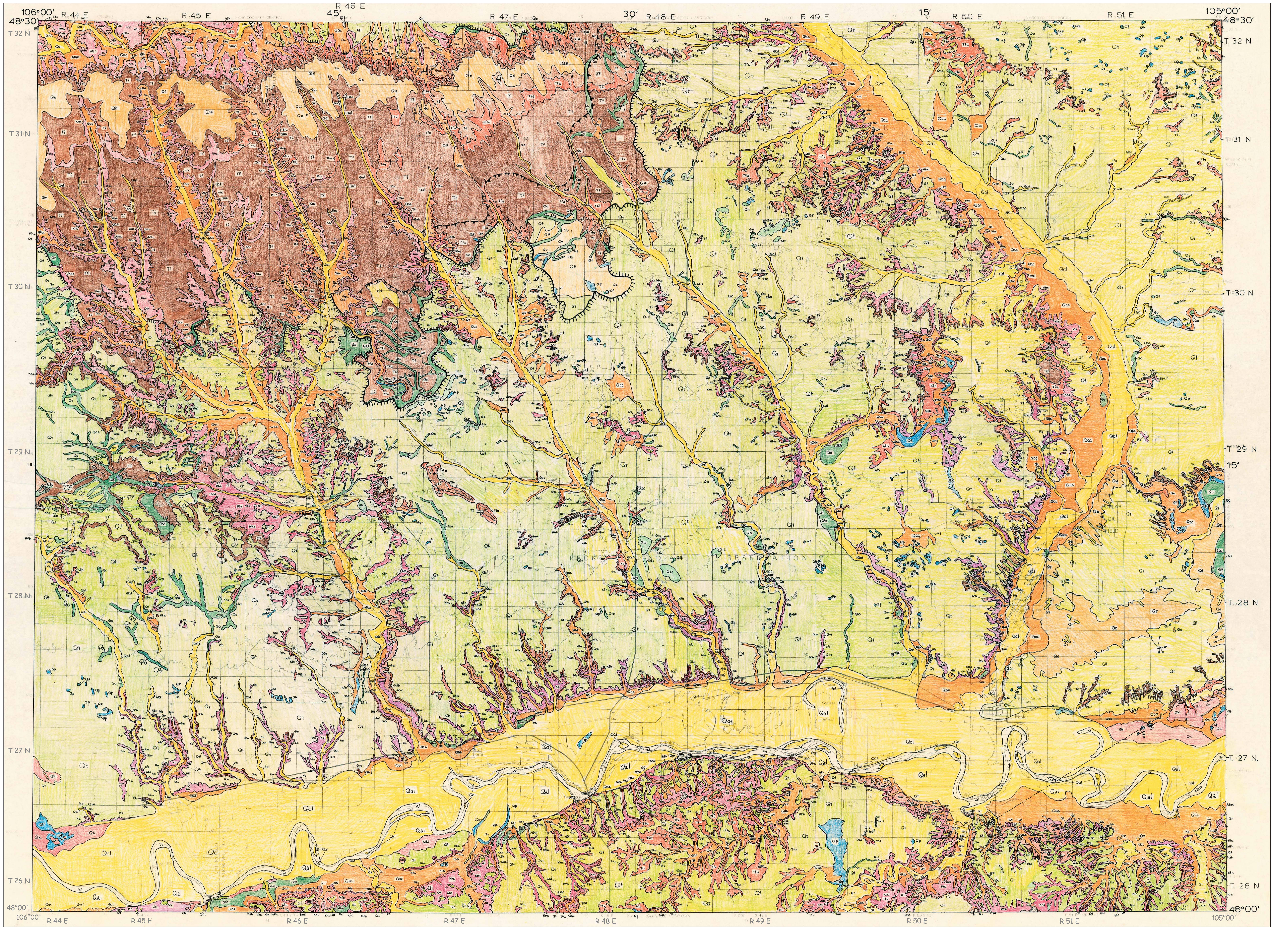


Base from U.S. Geological Survey
Wolf Point 30' x 60' topographic quadrangle

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

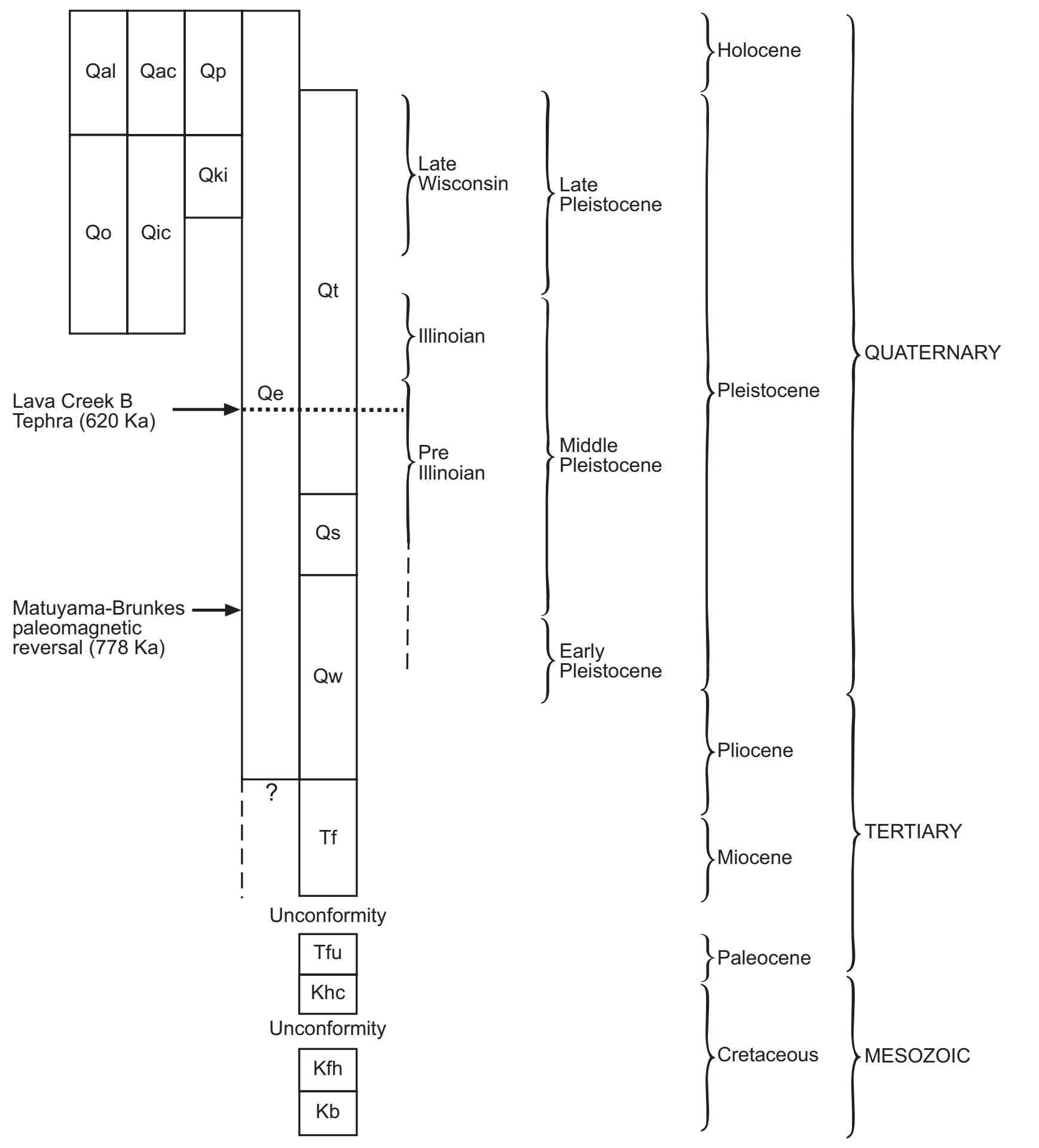
Limit of re-advance of Wisconsin glaciation; tics on ice side

Approximate limit of Illinoian glaciation; teeth are on ice side

DESCRIPTION OF MAP UNITS

Qal	Qal	Alluvium (Holocene and late Wisconsin)
Qac	Qac	Colluvium and alluvial fan deposits (Holocene and late Pleistocene)
Qe	Qe	Eolium (Holocene, Pleistocene, and Pliocene)
Qp	Qp	Pond deposits (Holocene and late Pleistocene)
Qo	Qo	Glacial outwash deposits (late Pleistocene)
Qic	Qic	Ice-contact deposits (late Pleistocene)
Qki	Qki	Kintyre Formation (late Wisconsin)
Qt	Qt	Till (late Pleistocene and middle Pleistocene)
Qs	Qs	Sprole Silt (middle Pleistocene)
Qw	Qw	Wiota Gravel (middle Pleistocene, early Pleistocene, and late Pliocene)
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 (Upper Cretaceous)
Kb	Kb	Bearpaw Shale (Upper Cretaceous)

CORRELATION OF MAP UNITS



INDEX TO TOPOGRAPHIC MAPPING

106° 48°30' — 105° 48°30'

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Todd Lakes 8	Todd Lakes SE 8	Tule Valley West 9	Tule Valley East 9	Sims Spring 4	Long Creek West 4	Long Creek East 5	Geddart Lake 5
Oswego NE 1, 6	Flynn Creek North 1, 6	Wolf Point NW 2	Wolf Point NE 2	Chelsea NW 3	Chelsea 3	Badger Creek 7	Poplar NE 7
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48°00' 106° — 48°00' 105°

Numbers refer to references listed in Sources of Geologic Mapping.

SOURCES OF GEOLOGIC MAPPING

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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.

Maps may be obtained from
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MBMG Open File 542

Geologic Map of the Wolf Point 30' x 60' Quadrangle (Surficial Emphasis), Roosevelt, McCone, Valley, and Richland Counties, Montana

By

Roger B. Colton, David S. Fullerton, Barbara Jarvis,
William C. Ehler, and Margaret S. Ellis

U.S. Geological Survey

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