MBMG Open File 540

Geologic Map of the Plentywood 30' x 60' Quadrangle (Surficial Emphasis), Sheridan, Roosevelt, and Daniels Counties, Montana, and Divide and Williams Counties, North Dakota

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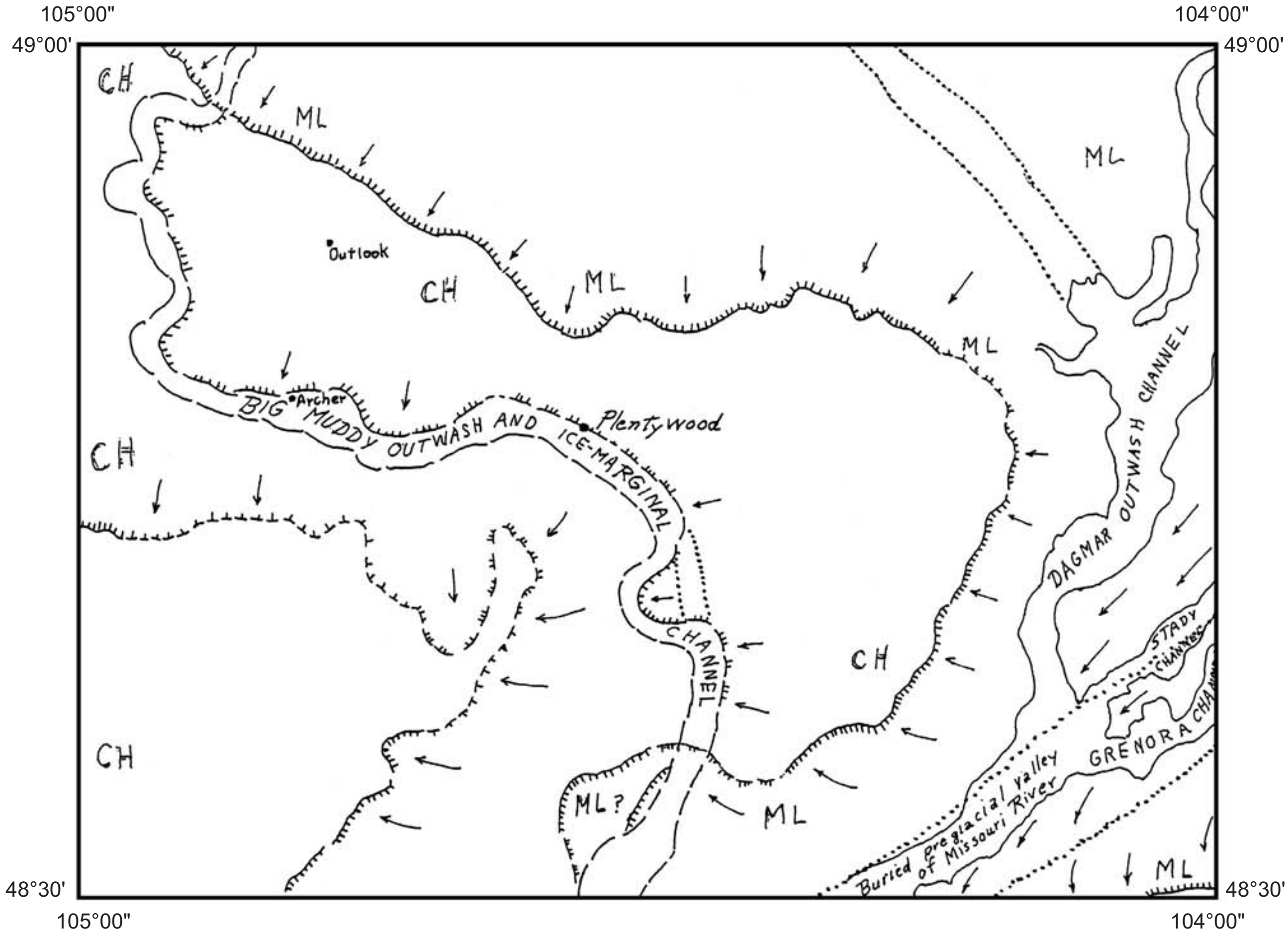
Note:

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.



Buried channel

Ice-marginal channel or spillway

ML Area covered by Medicine Lake readvance (14,000 YBP)

Limit of Medicine Lake readvance

CH Extent of Crazy Horse glaciation (Late Wisconsin)

Inferred direction of ice movement

Deposits of Archer and Kistler Butte glaciations are covered and not mapped

Figure 1. Buried and abandoned drainage in the Plentywood 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. It is poorly to well stratified, and poorly to well sorted. In the Plentywood quadrangle, alluvium is underlain by glacial outwash, especially under the floodplain of Big Muddy Creek.

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 of the alluvium commonly 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. Iron staining is prominent in some areas.

Flood-plain alluvium deposited by Big Muddy Creek underlies about 100 square km (65 square mi) of the quadrangle. The alluvium is composed mostly of thin beds of fine sand, silt, and clay, and is rich in organic matter.

Moist alluvium is generally light yellowish gray (5Y 7/2) to medium brown (5YR ¾), but many beds are tan; most of the moist clay beds are gray. Dry alluvium is commonly gray. The upper several feet contains a few dark-brown or black beds alternating with light grayish brown. Light-brown iron staining occurs as isolated blebs along rootlets and as irregular streaks in individual laminae.

Beds range from less than 1 inch to 2 feet in thickness. Bedding is virtually horizontal with little conspicuous channeling. Some irregularities in bedding are due to irregularities in the surface of deposition. Individual channels in some cutbanks are a few feet deep and 10 to 15 feet wide.

Shells of fresh-water clams (*Anodonta*) occur in the alluvium. Plant fragments are abundant.

The total thickness of the alluvial deposits in the quadrangle is not known. The only data which indicate the thickness of alluvial deposits are from well logs and resistivity tests north of Medicine Lake. Wells drilled into the alluvium of Big Muddy Creek have penetrated lenses of gravel at depths of 50 feet. This suggests that the alluvium is 50 feet thick. Resistivity tests (Edwards 1951) made along the road north of the town of Medicine Lake and on the west side of the railroad tracks in sec. 13, T. 32 N., R. 55 E., by the U.S. Bureau of Reclamation indicate that bedrock is at a depth of 150 feet.

Saturated alluvial deposits have low stability and heavy losses of fill can be expected across swampy areas through lateral and vertical displacement of clayey alluvium. Sandy alluvium makes more stable fill if it is well compacted and drained.

Alluvial deposits are commonly saturated with water owing to the high water table and, therefore, are difficult to work, but good compaction can be achieved. In abandoned meanders, former oxbow lakes, and other depressions that are poorly drained, the ground-water table is within a few feet of the surface or at the surface; it is at a similar height in irrigated areas. Permeability ranges from high in sandy beds to very low in silt and clay beds.

Sand, silt, and clay beds can be easily worked with hand and power tools. Cribbing, timbering, and other support is necessary for underground installations and large excavations. The sand and silt will stand in cuts up to 60° for short periods of time but soon erodes or slumps back to slopes of less than 45°.

A mechanical analysis of a sample of alluvium from the SW ¼ NE ¼ sec. 14, T. 32 N., R. 55 E., showed that it consisted of 25 percent clay, 69 percent silt, and 6 percent sand. The coefficient of sorting was 2.84. The plastic limit was 25, and specific gravity was 2.69. A second sample from NE ¼ NW ¼ sec. 22, T. 34 N., R. 55 E., indicated that alluvium in that area was 62 percent clay, 36 percent silt, and 2 percent sand. It had the following Atterberg limits: liquid limit, 62; plastic limit, 29; plastic index, 33; specific gravity, 2.71

Qp Pond deposits (Holocene)—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. Hundreds of closed 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 areal extent; a few are larger than 2.6 sq km (1 sq mi); all have relatively flat surfaces. Because there are so many and are so small, they are shown in black on the map and not labeled. Shallow ponds form in them during wet weather but disappear during dry weather.

Mechanical analyses were made of two samples of pond deposits. About 50 percent of the samples consisted of clay, 42 percent was silt, and 8 percent was sand. The two samples had liquid limits of 46 and 76 and plastic limits of 36 and 38. The plastic indices were 10 and 38. Specific gravity was 2.50 and 2.62.

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 some scattered pebbles. Pond deposits are not indurated or cemented.

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

Pond deposits can be excavated by hand and power tools. However, wet, tough, plastic, sticky clay is difficult to handle. Because of local high water tables, poor permeability, and the lack of surface drainage, water control will be a problem in excavations. The deposits have low slope stability in both artificial and natural cuts, but excavations will stand if the clay is dried with well points; otherwise cribbing and timbering will be necessary. Pond deposits in closed depressions provide poor foundation conditions unless the depression is properly drained

Qe Eolium (Holocene and Pleistocene and Pliocene)—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. A veneer of eolium, generally 1 m (3 ft) thick, but locally 4 m (13 ft) thick, is present on most flat or nearly flat surfaces throughout the quadrangle. The soil survey of Sheridan County (Richardson and Hanson, 1977) indicates that eolium is much more extensive in the southeastern corner of this map (east of the Medicine Lake Migratory Waterfowl Refuge).

Deposits of windblown sand were mapped in two small areas in the western part of sec. 11, T. 32 N., R. 55 E. A mantle of eolian silt too thin to map covers large parts of the quadrangle. The sand dunes are the result of wind action. Other eolian deposits have formed along fences where piles of tumbleweeds have trapped sand and silt blowing off fields.

Dune sand is composed of medium- to fine-grained sand and less than 10 percent silt; it is noncohesive. The color ranges from light tan to brown. The organic content is low but there are some humified layers. Fine sand and silt of windblown origin is similar to the dune sand but does not have the typical dune form. It forms a thin silty veneer overlying glacial till. The sand is dark brown owing to organic coatings on individual grains. No fossils have been found in the dune sands and other eolian deposits.

Dune sand and other eolian deposits are easily worked with hand and power tools, but slopes of excavations need to be graded to the angle of repose for sand. The sand has fair to good bearing strength and moderately poor to good strength in embankments and fills. Slight amounts of frost heaving occur in dune and other eolian sand. Sand-dune terrain drains rapidly, but thin sand deposits on till drain more slowly. The sand has fairly high permeability and can be used for pervious fill.

Some compaction can be expected; the sand requires the movement of equipment over it to produce vibrations for dense compaction. Sand of uniform size will not compact and cannot be used to make a stable fill without the addition of smaller sizes to act as a binder. The dune and other eolian sand makes a fairly good subgrade, but it is poor for unsurfaced roads. The sand will drift, and frequent maintenance is required.

The eolian sand is very poor for concrete owing to its uniformly fine grain size. A sample of eolian sand was collected from the NW ¼ NE ¼ SW ¼ sec. 1, T. 32 N., R. 55 E., and from NW ¼ SE ¼ NW ¼ sec. 11, T. 33 N., R. 55 E. The results were nearly identical and showed that about 5 percent was clay sized, 7 percent was silt sized, and 88 percent was sand sized. The specific gravity of these two samples was 2.64. The coefficients of sorting were 1.31 and 1.86, respectively

Qls Landslide deposits (Holocene)—Large slump blocks of Fort Union Formation and till. Many small deposits have not been shown. Composition is that of the parent material affected by landsliding. Thickness is variable but may be as much as 10 m (33 ft). Sizes of particles range from clay to blocks of sandstone a few meters in diameter

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 the parent 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 it forms 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 (Qe) that interfinger with and overlie sheetwash alluvium.

The composition and color of the alluvial fan and colluvial deposits vary considerably depending on the lithologies of the source bedrock and surficial materials. 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. Composition is variable but averages 43 percent clay, 42 percent silt, and 15 percent sand.

Great variation in thickness within short distances is characteristic of fan alluvium and colluvium. Generally, the thickness of colluvium is less than 3 m

(10 ft), seldom more than 2 m (6 ft), and averages only 0.3 m (1 ft). There is actually a range from zero at the edge of the upslope part of the deposit to the maximum thickness where the colluvium is in contact with or interfingers with alluvial deposits.

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

Qo Glacial outwash deposits (Middle and late Pleistocene)—Light-brown, yellowish-brown, brown, and light-gray sand and gravel with minor silt, deposited by glacial meltwater streams. Generally horizontally bedded, well stratified and moderately well sorted. Granules and larger clasts are subrounded to well rounded. Clast lithology in most places is similar to that of the Flaxville Formation, but reworked erratic glacial pebbles, cobbles, and boulders of limestone, dolomite, granite, gneiss, and schist from Canada are conspicuous. 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. Lithology is approximately 55 percent quartzite, 25 percent limestone and dolomite, and 9 percent granite. Thickness is as much as 52 m (171 ft); however, most deposits are 6 to 15 m (19.6 ft to 49 ft) thick.

The lithology of the outwash deposits that cover the Flaxville formation cannot be distinguished easily from the underlying gravel from which they were largely derived. Scattered outwash gravel deposits along Big Muddy Creek are exposed in several pits near the town of Plentywood (Colton, 1951, p. 264-266). These gravel deposits are extensive (Colton, 1962, pl. 38) and have been traced up the valley of Big Muddy Creek to a point 9 miles north of Daleview where the border of the Medicine Lake readvance crosses the old abandoned valley of Big Muddy Creek.

Outwash deposits overlie the Fort Union formation and till. It is overlain by alluvium, colluvium, pond deposits, and eolian deposits.

The thickness of the outwash deposits in Big Muddy Valley ranges from 0 to an inferred 135 feet. A thickness of more than 20 feet was observed in many places. Drilling for seismic shot holes a few miles west of Plentywood indicated that a thickness of 70 to 120 feet is common (Colton, 1962, Plate 38)

A large sheet of pitted outwash stretches from the northeast corner of the Plentywood quadrangle to Medicine Lake. It is 3.2 to 5 km (2 to 3 mi) wide and approximately 48 km (30 mi) long. Witkind (1959, Plate 3, profile E) indicated that the sand and gravel in the Dagmar pitted outwash channel is approximately 30 m (100 feet) thick (based on Edwards, 1951). Witkind (1959, chart 1) also wrote that outwash deposits are as much as 56 m (185 ft) thick.

Two other pitted outwash channels join the Dagmar pitted outwash channel in the southeast corner of the Plentywood 30’ x 60’ quadrangle. They are: The Genora Channel and the Stady Channel. Witkind (1959, pages 44-47) has described these and other channels and the reader is referred to his lengthy discussion.

A wide range in size of material occurs in this unit. Beds of boulders more than 46 cm (18 in) in diameter were observed in some places (Witkind (1959, chart 1). Cobble gravels were noted in sec. 34, T. 33 N., R. 55 E. Most of the formation is composed of sand and pea-sized material. In general, the formation is a sandy gravel.

Pebble counts indicate the following average percentage composition of the Plentywood formation: quartzite 1%, granite (Canadian), 9%, dark aphanitic pebbles 4%, chalcedony 4%, dolomite and limestone (Canadian) 25%, quartzite (Flaxville) 55%, other 2%.

The gravel fill is younger than the older drift mantling the quadrangle and contemporaneous with the Medicine Lake drift from which it is derived.

The drainage on the outwash deposits is excellent and permeability is high. Water-retaining structures should not be built in the deposits without impermeable linings. The deposits are easily worked with hand and power tools. The presence of quartzite, chert, and agate suggests a poor concrete aggregate for high-alkaline cement, but it is used for concrete aggregate for lack of more suitable material; crushing is necessary to obtain angular material. Deposits of the Plentywood formation have been used extensively as a source of road metal. Good road bases can be constructed from deposits that contain enough sand, silt, and clay to act as a binder. The large areal extent of the deposits indicates the large volume of gravel reserves available for use as aggregate and road metal and for other uses.

Mechanical analyses of representative samples were made by the Materials Testing Laboratory of the Montana State Highway Commission. The results showed the following size distribution: 6 percent silt, 23 percent sand, 12 percent granules, and 59 percent pebbles or larger

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 composed of gravel derived from the Flaxville Formation and numerous clasts of granite, gneiss, limestone-dolomite and other erratic clasts from Canada, and consequently, these deposits are similar except for a small percentage of erratics.

Esker and kame deposits are generally poorly bedded and sorted, but 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. Local faults and tilted and contorted bedding in the deposits indicate collapse when the enclosing ice melted.

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, and eolian deposits.

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 23 m (70 ft) thick and kames are as much as 30 m (100 ft) thick.

` One discontinuous segmented esker 6 miles west of Westby is approximately 8 km (5.5 mi) long. Parts are as much as 10 m (30 ft) above the outwash channel it is in. The width varies, but is as much as 100 m (328 ft) but averages 60 m (197 ft). Another esker is 10 miles northwest of Westby; it extends into Canada an unknown distance. It is approximately 2 miles long in the U.S., 10 m (32 ft) high, and 150 m (492 ft) wide. Witkind's map (1959, Plate 1) showed a few eskers in the east central edge of the Plentywood 30' x 60' quadrangle. Witkind also mapped kame terrace deposits along the Dagmar Channel on Plate 1

Qgl

Glacial lake deposits (middle and Late Pleistocene)—Light brown and gray clay, silt and sand formed in temporary glacial lakes rimmed by or impounded by ice. Thickness is generally 3 to 5 meters but may be as much as 20 meters. Analyses of glacial lake samples indicated that they range from 22 to 56% clay, 39-50% silt, and 2-30% sand.

Most of the glacial lake deposits are in the northeast quarter of the Plentywood 30' x 60' quadrangle. Many of the small ones formed in areas rimmed by melting ice and are probably only a few meters thick. However, one large glacial lake area appears to occupy the sag representing the buried ice-marginal channel that extends from the International Border southeastward to a point 6.5 km (4 mi) northeast of Comertown. The glacial lake deposits are estimated to be less than 3 m (10 ft) thick

Qt Till (early, middle and late Pleistocene)—Most glacial deposits in the area consist of till deposited as a blanket over older deposits except where removed by postglacial erosion. The till surface is characterized by gently sloping swells, sags, closed depressions, and a few linear ridges.

The till is tough and compact when dry, but plastic when wet. It is a highly impermeable, calcareous, unstratified and unsorted, unconsolidated to moderately consolidated, heterogenous mixture. It is predominantly clay, but also includes silt, sand, pebbles, cobbles, and boulders. Some of the erratic boulders from Canada are several feet in diameter.

The till is oxidized in most exposures and is commonly yellowish brown; the unoxidized till is bluish gray. Thin lenses of sand and sandy gravel are intercalated within the till. Some exposures of till show an indistinct to distinct horizontal layering of fissility. Vertical, prismatic, contraction-type jointing is well developed in many of the larger exposures.

The Plentywood 30' x 60' quadrangle was glaciated at least 5 times (Fullerton and Colton, 1986): the first time during pre-Illinoian time; the second during Illinoian time; and the third, fourth, and fifth during Wisconsin time. The oldest glaciation is now represented by scattered Canadian-type erratics around the edges of high remnants of the Flaxville Formation at altitudes as great as 833 m (2800 ft) near Flaxville (10 km (6 mi) west of the Plentywood 30’ x 60’ quadrangle). The till resulting from the two earliest glaciations has been named the Archer till (Fullerton and Colton, 1986); it is exposed north of Archer along the road to Outlook. This is Parizek’s phase No. 1 (Parizek, 1964, p. 29).

The third glaciation to affect the Plentywood area occurred in late Wisconsin time. The till deposited during this glaciation which began approximately 150,000 years ago and is named the Kisler Butte till (Fullerton and Colton, 1986). Kisler Butte is 10.5 km (6.5 mi) southeast of Archer.

Two minor late Wisconsin glaciations advanced southward across the 49th parallel to a point 10.5 km (6.5 mi) north of Plentywood. These late Wisconsin tills have been termed the Crazy Horse till, two and three (Fullerton and Colton, 1986, chart 1). Crazy Horse Creek is 10.5 km (6.5 mi) southwest of Plentywood.

A readvance about 14,000 (14 C) years before present deposited the Medicine Lake drift which is present 10.5 km (6.5 mi) north of Plentywood and near the town of Medicine Lake in the southeast corner of the quadrangle.

The surface of the till deposited during the Late Wisconsin Medicine Lake readvance about 14,000 years ago, is characterized by hundreds of closed depressions as much as 12 m (40 ft) deep. The closed depressions were left after blocks of ice enclosed in the till melted out. Much of the Medicine Lake till sheet represents stagnation moraine. Local relief in the extensive areas of swell and swale topography is as much as 20 m (66 ft) but generally is only 10 m (33 ft).

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, each till is commonly discontinuous laterally. Crazy Horse till may be at the surface in one exposure, and in other exposures Archer till may be at the surface. Where till is mapped in areas of intense erosion, only small remnants of the younger Crazy Horse have been preserved and most of the exposed till is the more resistant pre-Illinoian Archer till. Because of the discontinuous lateral distribution of the tills and the sparsity of exposures, the tills deposited during several 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. Very calcareous; generally oxidized to depths of as much as 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 where the till is oxidized. 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, which are mostly erratic limestone, dolomite, granite, and gneiss, 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 1 ft but generally is only 1 m (3 ft) thick

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. 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)

Archer till upper Member (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. 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, however where found, they are 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 15 ft.

Mechanical analyses of samples of till show that it consists of 65 percent silt and clay, probably derived chiefly from the Fort Union formation, 30 percent sand-sized material, and 5 percent pebbles, cobbles and larger sizes. Seventy percent of the 5-percent fraction consisting of pebbles and cobbles is quartzite from the Flaxville formation. The remainder consists of various igneous, metamorphic and sedimentary rocks from Canada.

Mechanical analyses were made of two samples of till from sec. 17, T. 34 N., R. 54 E., and from NW ¼ NE ¼ NW ¼ sec. 10, T. 32 N., R. 55 E. the results were nearly identical and showed that 35 percent was clay, 36 percent silt, 28 percent sand, and 1 percent granule size or larger. The Atterberg limits of these two samples were: liquid limit, 175 and 32; plastic limit, 22 and 20; plastic index, 153 and 12. Specific gravity of both was 2.69. One sample had a coefficient of sorting (Trask, 1932, p.67) of 8.30 (poorly sorted).

Qw Wiota Formation (Pliocene to Late Pleistocene)—Light-brown, brown or gray sand, silt, clay, and fine to coarse gravel. Unit is well stratified to poorly stratified and poorly to well sorted

In the Plentywood 30' x 60' quadrangle, several pebbles that are Canadian igneous and metamorphic rock types were found in the upper part of pre-till gravel deposits Witkind (1959 chart 1) that seem to be identical in overall appearance, altitude (below 827 m (2,700 ft)) and lithology with those sand and gravel deposits at Wiota (Jensen and Varnes, 1964). Jensen and Varnes report (1964, p. F29 and F30) that the Wiota gravels are mostly clay, silt, sandy silt, and sand and that gravel is a minor component. Outcrops in the Plentywood area also indicated gravel is a minor part; therefore, the name is changed to Wiota Formation.

The pebbles and cobbles of the Wiota Formation are about 98 percent quartzite; about 1 ½ percent consists of amorphous and cryptocrystalline silica.

The remaining one-half percent consists of green porphyry (tinguaite) and glacial erratics. The quartzite stones are smooth and well rounded; the larger pebbles and cobbles have abundant shallow crescentic percussion fractures. Most of the quartzite in the pebbles is medium to fine grained, but some is very fine grained or finely conglomeratic. Red, brown, gray, and green pebbles are common, but predominance of the first two imparts a reddish-brown color to exposures.

Mechanical analyses were made of two samples of the Wiota Formation. About 5 percent of the samples consisted of clay, 5 percent silt, 15 percent sand, 5 percent granules, and 70 percent pebbles. The two samples had liquid limits of 19.7 and 26. both samples were non-plastic. One sample analyzed in the engineering Geology Laboratory in Denver had the following Atterberg limits: liquid limit 22; plastic limit 13; plastic index 9. The specific gravity was 2.70.

The range in size of particles in the coarse fraction is from granules to 8-inch cobbles, but the average is about 10 mm in diameter. The great range in size indicates that the strata were deposited by both high- and low-velocity streams.

The Wiota Formation is a source of road metal and concrete aggregate. All pebbles are strong and the percentage of deleterious reactive material is small. The stones are well rounded and crushing is necessary to obtain angular material. Careful exploration along outcrops is necessary when searching for usable gravel deposits because of lateral facies changes and the variable ratio in thickness of gravel to thickness of overburden.

Mechanical analyses of samples indicate that the Wiota Formation is poorly graded and contains a large percentage of sand. The lower part of the formation generally consists of moderately well-bedded sandy gravel containing numerous lenses of medium-grained sand and silt. The upper part is generally finer grained and contains intercalated lenses of clay. The formation grades laterally within short distances from deposits consisting entirely of sand, silt, or clay to those consisting of coarse gravel. Because it was stream deposited, the texture of the formation varies from outcrop to outcrop and most exposures exhibit crossbedding. A few feet of silt and fine- to medium-grained sand generally constitute the top of the deposit.

The Wiota Formation unconformably overlies each of the bedrock formations and in turn is unconformably overlain by younger Pleistocene deposits, generally till. In glaciated areas, deposits of the Wiota Formation were overridden and buried by the advancing glaciers, and till was deposited on them. Contacts with underlying units are generally sharp, but contacts with overlying units are not always sharp, especially where the upper part of the Wiota Formation was partly incorporated into the overlying till. Frost action has tended to obscure the upper contact of the Wiota Formation where thin surficial deposits such as loess, alluvium, and colluvium overlie the gravels.

The age of the Wiota Formation probably ranges from Pliocene to late Pleistocene. Some of the higher older, parts of the formation were probably deposited just after the last and lowest parts of the Flaxville Formation were laid down in late Pliocene time, whereas the youngest and lowest parts were deposited just prior to the pre-Illinoian glaciation.

The thickness of the Wiota Formation varies widely within any given deposit. Jensen and Varnes (1964, p. F28) state that the thickness of the formation is commonly 3-6 m (9-20 ft) and that the maximum observed is 10 m (30 ft) at the type locality Wiota railroad junction which is 104 km (65 mi) south-south west of the Plentywood 30’ x 60’ quadrangle

Tf Flaxville Formation (Miocene and Pliocene) —Composed of sand, clay, and gravel. West of the quadrangle it includes beds of marl and volcanic ash but none were found in the Plentywood quadrangle. The formation consists of fluvial deposits reworked many times during a long period of tectonic quiescence and erosion when all but the most stable constituents were removed and were not replenished because of the low relief of the source area.

Collier (1917, p. 194-195) first described the formation; it has been discussed at length by Collier and Thom (1918, p. 179-184). It was named from exposures near the town of Flaxville 6.4 km (4 mi) west of the quadrangle. Collier (1917, p. 35) first called the unit “the Flaxville Formation” but a year later with Thom (1918) he renamed it “the Flaxville gravels.” The author, as a result of Colton’s mapping, advocates that the unit be called the Flaxville Formation because the supposedly distinctive gravel is actually a minor part of the unit.

The formation underlies approximately 150 sq km (100 sq mi) in the quadrangle Colton, 1962, Plate 38. Areas of Flaxville Formation occur at altitudes between 2,500 and 2,650 ft and underlie high level plateaus. They are the remnants of a once-continuous sheet of gravel which extended at least as far east as Alkabo, N. Dak. (A.D. Howard, written communication).

The formation is eroded slowly because of its permeability. The mesalike areas are being eroded only along the margins mostly by undercutting in the more easily eroded Fort Union formation. The typical outcrop is a rounded knob projecting through the mantle of till. It unconformably overlies the Fort Union formation and is overlain by glacial deposits.

The thickness ranges from 0 to more than 100 feet. The maximum thickness can only be estimated from the topography because no well records are available and no exposures show the total thickness; the average is probably 50 feet.

The formation is composed of several different lithologic units. The basal unit, which is 6-15 m (20-50 ft) thick is nearly everywhere composed of quartzitic gravel and sand.

Sandy and clayey strata 6-12 m (20-40 ft) thick, overlie the gravel and sand unit. One hundred twelve km (70 mi) west of the quadrangle, in secs. 19 and 20, T. 35 N., R. 43 E., volcanic ash was found by Collier and Thom (1918, p. 182). They presented a generalized section of that locality and gave the following approximate thicknesses:

Flaxville formation:	feet
Marl, containing scattered quartzite pebbles	15
Sandstone, cemented with calcite	30
Volcanic ash, white to yellow, very pure but mixed with the underlying gravel at the base	15
Gravel, more or less cemented	20
Total thickness	80

Fort Union formation:

About 70 percent of the pebbles in the gravel members of the formation consists of fine- to medium-grained quartzite. The average diameter of the pebbles is 1 ½ inches; boulders as much as 1 foot in diameter are a minor component of the gravel. The pebbles, cobbles, and boulders are smooth and well rounded. Most are moderate yellowish brown (10YR 5/4). Broken pebbles show a thin rind of weathering about 1/8 of an inch thick. Some broken pebbles are distinctly stratified; the darker parts are dark yellowish brown (10YR 4/2). Twenty percent of the pebbles are moderate red (5R 4/4) when dry but are dark reddish brown (10R ¾) when wet. Grayish-red quartzite pebbles (10R 4/2) become dark reddish brown (10R ¾) when wet. A minor percentage of the pebbles are dusky yellow green (5GY 5/2) or grayish green (10GY 5/2); when wet, they are one value darker. A small number of pebbles are olive gray (5Y 3/2) to black argillite, whereas others are chert and agate. A minor but distinctive lithologic type consists of green tinguaite porphyry whose feldspar phenocrysts are distinctly zoned. These pebbles apparently came from the Judith Mountains 200 miles west of the area.

Locally, the formation has been cemented by calcium carbonate to form concretionary sandstone and conglomerate.

The organic content of the Flaxville formation is low. However, Russell (1950, p. 58) found two gravel beds separated by a weathered zone and 3 inches of fossil soil a few miles north of Flaxville. No lignite beds were found but thin discontinuous carbonaceous beds were noted.

Many vertebrate fossils have been found in the formation. Those found by Collier and Thom were examined by Gidley (*in* Collier and Thom, 1918, p. 180-181) who concluded that "…the beds from which these fragments were collected cannot be older than Miocene or younger than Lower Pliocene."

Fossils found by the author 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.

Zircons from volcanic ash in the Flaxville Formation were examined by Nancy Briggs Naeser for fission tracks (Colton, Naeser, and Naeser, 1986). Three samples of ash were dated as follows:

SE¼ sec. 11, T. 36 N., R. 44 E.; age, 9.6±.9 million years

SE¼ sec. 8, T. 34 N., R. 46 E.; age, 6.4±1 million years

SE¼ sec. 19, T. 35 N., R. 43 E.; age, 8.7±1.1 million years

These localities are west of the Plentywood 30' x 60' quadrangle.

Mechanical analyses were made from three samples of the Flaxville formation collected at the following localities: (a) SE 1/4 sec. 8, T. 33 N., R. 54 E., (b) SW ¼, SE ¼ NW ¼ sec. 11, T. 34 N., R. 54 E.; and (c) from the top of a hill in the NE 1/4 sec. 11, T. 34 N., R. 53 E. The results were not identical but have been averaged as follows: 2 percent clay, 3 percent silt, 31 percent sand, 3 percent granules, 60 percent pebbles, and 1 percent cobbles. The coefficient of sorting (7.28) shows that this is a poorly sorted deposit. One sample had a plastic limit of 28. Specific gravity was 2.65

Tfu Fort Union Formation (Paleocene)—Underlies all of the Plentywood quadrangle. It consists of a thick yellowish-brown sequence of continental deposits of interbedded sand, sandstone, siltstone, silt, clay, clayey shale, and lignite. The formation was named by Meek and Hayden (1862) from exposures along the north side of the Missouri River (56 km (35 mi) south of the report area).

The author has not subdivided the formation into members because facies changes made it impossible to recognize the subdivisions north of the Missouri River that have been used to the south and southwest such as the Tullock member, the Lebo shale member, the Tongue River member, and the Sentinel Butte member.

The formation is well exposed in the northeast, the northwest, and the southwest corners of the quadrangle. The sediments comprising the formation are generally soft, erode easily, and thus crop out only in areas of active erosion. Erosion of the strata tends to produce a rolling landscape but there are some definite benches formed by more resistant clinker or sandstone beds.

Weathered outcrops are lighter colored; unweathered yellowish-gray shale (5Y 6/2) weathers light yellowish gray (5Y 7/2) and unweathered dark-grayish orange sand (10YR 6/4) weathers pale yellowish brown (10YR 7/2).

The formation has a maximum thickness of about 1,265 feet in the quadrangle; the maximum exposed thickness is about 600 feet. The thickness of the formation varies considerably throughout the area because the upper part of the formation has been removed by erosion, both before and after deposition of the Flaxville formation. As a result of the regional southeastward dip, the formation is thickest in the eastern part of the quadrangle.

The Fort Union formation is conformably underlain by the Hell Creek formation and unconformably overlain by the Flaxville formation of Miocene or Pliocene age and deposits of Quaternary age.

Sandstone and sand beds constitute more than half the total thickness of the strata. Clay beds account for about one-third, and carbonaceous shale, shale, lignite, siltstone, and limestone make up the rest of the section.

A distinctive gray bed, which is variable between two end members, a bentonitic clay and an olive-gray sand, is apparently the only bed recognizable throughout the quadrangle (Bauer, 1914). The thickness of this bed ranges from 10 to 40 feet. It can be traced eastward from Redstone and southward along the west valley wall of Big Muddy Creek to a point a few miles north of Reserve where it is covered by gravel deposits.

Concretions are of five types: sandstone or sand cemented by calcium carbonate, siltstone, limonite, pyrite, and limestone.

Sandstone concretions are the main type found in the formation but limonite and pyrite concretions are fairly common. The weathered pyrite concretions are dark yellowish brown (10YR 4/2). The unweathered interior of the pyrite concretions is greenish gray (5GY 5/1). The limonite concretions are generally disk shaped and their thickness ranges from 3 to 7 inches. The limonite concretions are moderate yellowish brown (10YR 5/4) but they weather to blackish red (5R 2/2). The weathered sand concretions and sandstone concretionary beds range from yellowish gray (5Y 7/2) to medium olive gray (5Y 5/1) in color.

Large log-shaped sandstone concretions were found in several places in the quadrangle. In the SW ¼ NW ¼ sec. 24, T. 33 N., R. 54 E., the long axes of the concretions are oriented N. 50° W. The concretions in that area are 15 feet long, 8 feet wide, and 3 feet high. At the corner common to secs. 13, 14, 23, and 24, T. 33 N., R. 54 E., the long axes of the concretions are oriented N. 85° W. Some of these concretions are 77 feet long, 5 feet wide, and 4 feet high. Many large crossbedded sandstone concretions are in sec. 8, T. 33 N., R. 54 E. They are as much as 100 feet long, 25 feet wide, and 10 feet high. Their long axes trend S. 80° E.

Some of the limy concretions show cone-in-cone structure. The color of the limestone concretions is dark gray but weathers buff. The organic content in the carbonaceous shale and lignite beds is high. Otherwise, the formation is relatively free of organic matter.

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, however, and gradual changes laterally are the rule. Contacts between beds range from sharp to gradational but most exposures show gradational contacts between beds. However, where channeling or short periods of nondeposition have occurred, there are sharp contacts.

Locally, beds overlying lignite have been baked to a red rock (known as pseudoscoria or clinker) by burning of the underlying lignite beds. Such outcrops are in the northwestern part of the quadrangle near Redstone. The fire that burned the coal has been ascribed to lightning, prairie fires, man, or spontaneous combustion. It is not known when most of the clinker was formed, but in 1911, E.K. Soper (field notes) reported that an outcrop of coal in the SW ¼ NE ¼ sec. 17, T. 33 N., R. 53 E. was burning. He stated that all the outcrops of clinker examined in that township showed signs of recent burning.

Vertebrate fossils are very rare in the Fort Union formation. Parts of a skeleton and several teeth found in sec. 10, T. 32 N., R. 54 E. were identified by Louis Gazin of the U.S. National Museum as remains of the genera *Claenodon* and *Tricentes* (primitive carnivores) of middle Paleocene age. Many fossil leaves and plants found in the formation were identified by Roland W. Brown of the U.S. National Museum as Paleocene in age.

Four samples of the Fort Union formation were collected in the SE ¼ SE ¼ sec. 16, T. 34 N., R. 55 E. from a bentonitic clay bed, a hard clay bed, a friable siltstone, and a friable sandstone. About 68 percent of the bentonitic clay was clay sized and the remainder was all silt. The Atterberg limits on this sample were: liquid limit, 170; plastic limit, 41; plastic index, 129; specific gravity, 2.59.

About 54 percent of the hard-clay bed was of clay-sized material and the remainder was silt. The Atterberg limits of the hard-clay sample were: liquid limit, 39; plastic limit, 27; plastic index, 12; specific gravity, 2.75. The coefficient of sorting was 2.06.

About 16 percent of the sample of siltstone was clay-sized material, 76 percent was silt, and 8 percent was sand-sized material. The Atterberg limits of the siltstone sample were: liquid limit, n.d. (not determined); plastic limit, 27; plastic index, n.d.; specific gravity, 2.73.

The sample of sandstone was composed of 18 percent clay, 14 percent silt, and 68 percent sand. The Atterberg limits were: liquid limit, 38; plastic limit, 25; plastic index, 13; specific gravity, 2.54. The coefficient of sorting (Trask, 1932, p. 67) was 2.31.

One other sample was collected in SE ¼ SE ¼ sec. 19, T. 33 N., R. 54 E. and was composed of 4 percent clay sized material, 16 percent silt, and 80 percent sand. It had a specific gravity of 2.68. The coefficient of sorting (Trask, 1932, p. 67) was 1.35.

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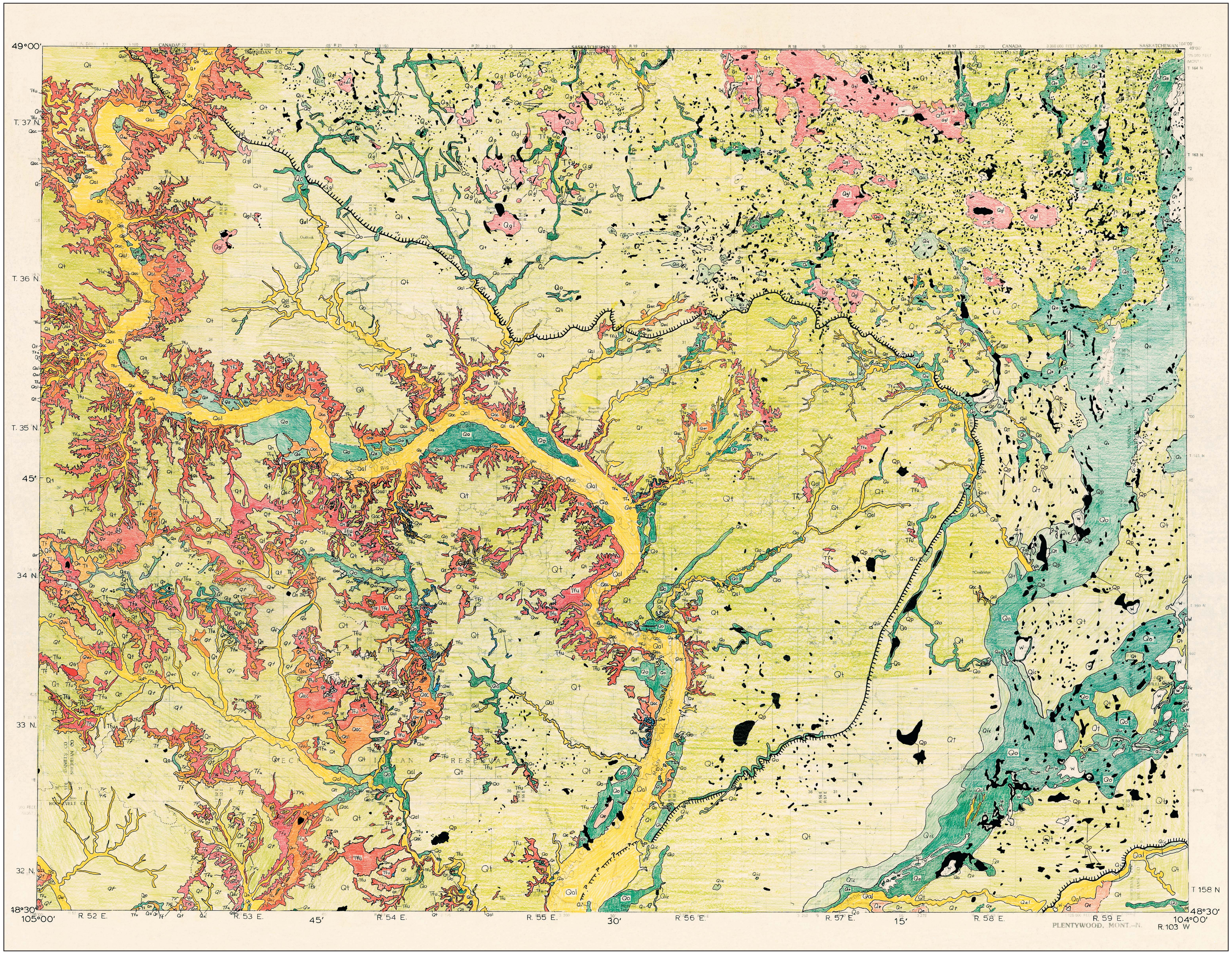


Base from U.S. Geological Survey
Plentywood 30' x 60' topographic quadrangle

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

MAP SYMBOLS

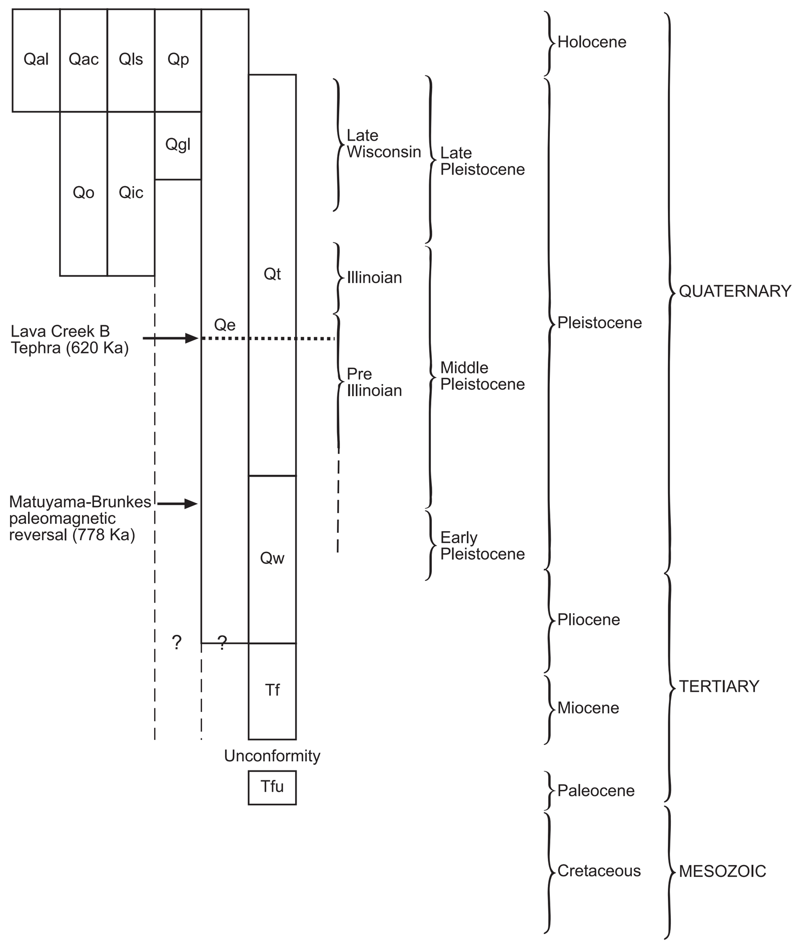
Contact: Dashed where approximated, dotted where concealed

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

DESCRIPTION OF MAP UNITS

- Qal — Alluvium (Holocene and late Wisconsin)
- Qp — Pond deposits (Holocene)
- Qe — Eolium (Holocene and Pleistocene and Pliocene)
- Qls — Landslide deposit (Holocene)
- Qac — Alluvial and colluvial deposits (Holocene and Late Pleistocene)
- Qo — Glacial outwash deposits (Middle and Late Pleistocene)
- Qic — Ice-contact stratified deposits (Middle to Late Pleistocene)
- Qgl — Glacial lake deposits (Middle and Late Pleistocene)
- Qt — Till (Early, Middle and Late Pleistocene)
- Qw — Wiota Formation (Pliocene to Late Pleistocene)
- Tf — Flaxville Formation (Miocene and Pliocene)
- Tfu — Fort Union formation (Paleocene)
- W — Water

CORRELATION OF MAP UNITS



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Soo 4, 5, 8	Thornwood Ranch 4, 5, 8	Flagstaff Hill 3, 5, 6	Alkali Coulee 2, 3, 5, 6	Reserve 2, 5, 6, 9, 10	Reserve SE 2, 5, 6, 9, 10	Dagmar 2, 5, 6, 9, 10	Brush Lake 2, 5, 6, 9, 10

Numbers refer to references listed in Sources of Geologic Mapping.

Geologic mapping in the Plentywood 30'x60' quadrangle was done on Department of Agriculture aerial photographs (scale 1:20,000) in 1948, 1949, and 1954. No topographic maps were available then. Geologic mapping was revised in the late 1970s by Fullerton and Colton using 1974 USGS aerial photography GS-VDOY, scale 1:30,000, and by using new 7.5' topographic maps.

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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 540

Geologic Map of the Plentywood 30' x 60' Quadrangle (Surficial Emphasis), Sheridan, Roosevelt, and Daniels Counties, Montana, and Divide and Williams Counties, North Dakota

By

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U.S. Geological Survey

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