QUATERNARY GEOLOGIC MAP OF THE DAKOTAS 4° X 6° QUADRANGLE, UNITED STATES

State compilations by
David S. Fullerton, John P. Bluemle, Lee Clayton, Fred V. Steece, Merlin J. Tipton, Richard Bretz, and Joseph E. Goebel

Edited and integrated by
David S. Fullerton

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NOTE 1: This map is a product of collaboration of State geological surveys and the U.S. Geological Survey and is designed for both scientific and practical purposes. It was prepared in two stages. First, separate maps and map explanations for the parts of States included in the quadrangle were prepared by the compilers. Second, the maps were combined, integrated, and supplemented by the editor. Map unit symbols were revised to a uniform system of classification and map unit descriptions were prepared by the editor from information received from the compilers and from additional sources. Diagrams accompanying the map were prepared by the editor,

Some differences in mapping or interpretation in different areas were resolved by correspondence. Most of the remaining differences, apparent along State boundaries, reflect differences in philosophies of mapping, and should encourage further investigation.

Surficial deposits have been mapped and described in less than forty percent of the conterminous United States. Traditionally, mapping of surficial deposits has focused on glacial, alluvial, eolian, lacustrine, marine, and landslide deposits. Slope and upland deposits have been mapped in detail only in restricted areas. However, much engineering construction and many important problems of land use and land management occur in regions that have extensive slope and upland deposits (residuum and colluvium, for example). These materials commonly have different physical characteristics. Therefore, an effort has been made to classify, map, and describe them on the basis of published and unpublished substrata and subsoil data and the distribution and physical and chemical characteristics of bedrock parent materials. The classification is crude, but it represents a first step toward a more refined and useful product.

For scientific purposes, the map differentiates Quaternary surficial deposits on the basis of a combination of criteria, such as lithology or composition, texture or particle size, structure, genesis, stratigraphic relationships, and age, as shown in the correlation diagram and tables and indicated in the map unit descriptions. Deposits of some constructional landforms, such as end moraines, are distinguished as map units or symbols. Deposits of erosional landforms, such as stream terraces, are not distinguished, although alluvial, glaciofluvial, and lacustrine deposits that are distinguished as map units may be terraced. Differentiation of sequences of alluvial deposits is not possible at this scale. Most individual landslide deposits are too small to be shown at this scale, but areas in which landslide deposits are abundant are distinguished as map units.

For practical purposes, the map is a surficial materials map. Materials are distinguished on the basis of lithology or composition, texture or particle size, and other physical and chemical characteristics. It is not a map of soils as soils are recognized and classified in pedology or agronomy. Rather, it is a generalized map of soils as recognized in engineering geology, or of substrata or parent materials in which pedologic and agronomic soils are formed. As a materials map it serves as a base from which a variety of maps for use in engineering, land-use planning, or land-management projects can be derived and from which a variety of maps relating to Quaternary geologic history can be derived.

ANCESTRAL DRAINAGE AT TIME OF EARLIEST QUATERNARY GLACIATION

The ancestral rivers in the Dakotas 4° x 6° quadrangle (yellow) were tributaries of the ancient Missouri River drainage system. The ancestral Missouri River flowed northeastward to the vicinity of Lake Manitoba, ultimately reaching the sea in the Hudson Lowland in Canada (arrow barb indicates direction of flow where buried valley no longer is delineated, owing to lack of subsurface information). The present course of the Missouri River (dotted line), now a tributary of the Mississippi River, was established during the latest (late Wisconsin) glaciation (phase 4). The ancestral Cheyenne River, presently heading southwest of the Black Hills in Wyoming, was the master stream of a drainage network that included all of the rivers shown in this quadrangle. The Cheyenne River flowed northward in the northeast comer of the quadrangle and joined the ancestral Missouri River southwest of Lake Manitoba, in Manitoba. Drainage network was compiled from small-scale county maps of buried bedrock valleys in North Dakota and South Dakota, large-scale maps of buried bedrock valleys in Montana, Saskatchewan, and Manitoba, and well and test hole data in Montana and North Dakota.

The drainage network west of the present Missouri River in the Dakotas 4° x 6° quadrangle was similar to the present network. The presence of terraced alluvium on both walls of most of the east-trending major valleys indicates that the rivers have shifted laterally and have been incised, but the trends of the valleys and drainage divides were similar to the trends of the present valleys and divides. At this scale the present drainage network west of the Missouri River reflects the ancestral network. The courses of the major ancestral rivers east of the present Missouri River are marked by broad, deep, buried bedrock valleys. Those channels are crossed by a complex network of younger, southward and southeastward trending, buried glacial diversion channels that is not shown. Rivers were diverted southward to the Mississippi River drainage system during several glaciations. In some areas, a river became intrenched in diversion channels during an interglaciation, only to be diverted again during a later glaciation.

LOCATION OF IMPORTANT STRATIGRAPHIC SECTION—Stratigraphic units listed from youngest to oldest; rank terms of informal units not capitalized

1) Mercer County sec. 12, N. Dak.—Type section for Charging Eagle Formation (Sackreiter, 1973; Ulmer and Sackreiter, 1973). Late Wisconsin upper member of Snow School Formation, 3.0 m till: middle Pleistocene Charging Eagle Formation (alluvium with glacial erratic clasts), 13.2 m sand and silt: middle Pleistocene, 0.7 m lake clay and silt
2) Mercer County sec. 6. N. Dak.—Reference section for Charging Eagle Formation (Sackreiter, 1973; Ulmer and Sackreiter, 1973). Late Wisconsin upper member of Snow School Formation, 0.5 m till; middle Pleistocene upper member of Medicine Hill Formation, 5.0 m till; middle Pleistocene Charging Eagle Formation (alluvium with glacial erratic clasts), 5.0 m sand and silt
3) Five stratigraphic sections (3A-3E) on shore of Garrison Reservoir west of Riverdale, McLean County, N. Dak. All five sections indicated by single symbol on map

   Riverdale sec.—Type section for Oahe Formation (Clayton and others, 1976). Holocene and late Wisconsin Oahe Formation, 3.1 m eolian silt and sand with buried soils (Bickley, 1972: Ulmer. 1973: Ulmer and Sackreiter, 1973; Clayton and others, 1976); late Wisconsin Napoleon till (Bluemle, 1971a, b), Braddock Formation (Bickley, 1972), and upper member of Snow School Formation (Ulmer, 1973: Ulmer and Sackreiter, 1973), 6.6 m till: late Pleistocene, 1.25 m gravel: Illinoian Mercer till (Bluemle, 1971a, b) and upper member of Horseshoe Valley Formation (Ulmer, 1973; Ulmer and Sackreiter, 1973), 1.25 m till; Illinoian, 0–0.2 m gravel; Illinoian Mercer till and upper member of Horseshoe Valley Formation, 3.5 m till; middle Pleistocene Dead Man till (Bluemle, 1971 a, b) and upper member of Medicine Hill Formation (Ulmer, 1973; Ulmer and Sackreiter, 1973), 8.5–14.4 m till

   McLean County sec. 5—Type section for Snow School Formation (Ulmer, 1973: Ulmer and Sackreiter, 1973). Holocene and late Wisconsin Oahe Formation, 1.2 m eolian silt (loess): late Wisconsin Snow School Formation, 4.9 m till (upper and middle members), 2.0 m sand and gravel (tower member; middle Pleistocene Lipper member of Medicine Hill Formation, 1.5 m till

   McLean County sec. 4—Type section for Horseshoe Valley Formation and reference section for Medicine Hill Formation (Ulmer, 1973; Ulmer and Sackreiter, 1973). Holocene and late Wisconsin Oahe Formation, 0.4 m eolian silt (loess); late Wisconsin Snow School Formation. 1.0

m till (upper member), 0.5 m sand (lower member; Illinoian upper member of Horseshoe Valley Formation, 3.5 m till: middle Pleistocene upper member of Medicine Hill Formation, 2.0 m till

McLean County sec. 10—Type section for Medicine Hill Formation and reference section for Snow School and Horseshoe Valley Formations (Ulmer, 1973; Ulmer and Sackreiter, 1973). Holocene and late Wisconsin Oahe Formation, 3.3 m eolian silt (loess) with buried soils; late Wisconsin Snow School Formation, 5.6 m till (upper and middle members); Illinoian upper member of Horseshoe Valley Formation, 4.0 m till: middle Pleistocene upper member of Medicine Hill Formation, 12.0 m till

Dead Man Coulee sec.—Type section for Coleharbor Group (Ulmer, 1973; Ulmer and Sackreiter, 1973) (all stratigraphic units are included in Coleharbor Group), Late Wisconsin Napoleon till (Bluemle, 1971a, b) and upper member of Snow School Formation (Ulmer, 1973: Ulmer and Sackreiter, 1973), 4.6–6.1 m till: late Wisconsin lower member of Snow School Formation, 0–1.5 m gravel: Illinoian Mercer till (Bluemle, 1971a, b) and upper member *of* Horseshoe Valley Formation (Ulmer, 1973; Ulmer and Sackreiter, 1973), 7.7 m till; Illinoian lower member *of* Horseshoe Valley Formation, 1.2–2.1 m outwash sand and gravel; middle Pleistocene Dead Man till (Bluemle, 1971a, b) and upper member *of* Medicine Hill Formation (Ulmer, 1973: Ulmer and Sackreiter, 1973), with truncated calcic paleosol, 4.6–6.1 m till; middle Pleistocene Charging Eagle Formation (Ulmer, 1973: Ulmer and Sackreiter, 1973), 0.9 m lake silt, 0.6–0.9 m outwash gravel

4) Testhole REAP No. 16, N. Dak.—Late Wisconsin Napoleon till, 4.6 m tell; Illinoian, 7.8 m tell; Pleistocene, 3.1 m sand, 1.5 m silt. 0.6 m gravel, 3.1 m silt: middle Pleistocene, 31.0 m till, 11.3 m gravel, 14.4 m till; bedrock (Groenewold and others, 1979)

5) Testhole REAP No. 9, N. Dak.—Late Wisconsin Napoleon till, 7.4 m till: Illinoian, 0.9 m till with thin gravel at top; Pleistocene, 0.9 m till with truncated calcic paleosol; middle Pleistocene, 9.8 m till: bedrock (Groenewold and others, 1979)

6) Beulah sec., N. Dak.—Late Pleistocene, 2.75 m gravel, sand, and silt; Illinoian, 0.76 m till; middle Pleistocene, 1.68 m till, 0.91 m take silt, 0.46 m sand and gravel; middle or early Pleistocene, 0.30 m iron oxide-cemented gravel; bedrock. (Groenewold and others, 1979)

7) Kinneman Creek sec., N. Dak.—Holocene and late Wisconsin (?), 0.30 m sand and gravel; late Wisconsin Napoleon till, 0.60 m till: erosion surface and stone line; Illinoian. 0.60 m till: middle Pleistocene, 1.83 m till with truncated calcic paleosol (Groenewold and others, 1979)

8) Boring No. 3, Witmer Hall. University of North Dakota—Type section for Brenna Formation and Falconer Formation (Harris and others, 1974). Holocene and late Wisconsin Sherack Formation, 11.0 m lake clay and silt; late Wisconsin Brenna Formation, 8.6 m lake clay: late Wisconsin Falconer Formation. 12.0 m till; late Wisconsin Wylie Formation, 5.5 m lake clay, 2.8 m lake sand

9) North Dakota State Highway Department Structure I-29-89 Boring 2—Type section for Argusville Formation (Arndt, 1977). Holocene, 2.4 m alluvium and take silt and clay; Holocene Sherack Formation, 0.6 m take silt and clay; late Wisconsin Brenna Formation, 13.8 m lake clay: late Wisconsin Argusville Formation, 5.5 m lake clay; late Wisconsin, 7.1 m till

10) Snake Curve sec., Minn. (composite of two secs.)—Holocene, 4.6 m lake sand; Holocene Sherack Formation, 4.6 m lake silt; Holocene and late Wisconsin (?) Poplar River Formation, 7.7 m alluvial sand and gravel with log that yielded ^{14}C age of 9,980±150 B.P. (I-4853); late Wisconsin Huot Formation, 4.6 m till; late Wisconsin Wylie Formation, 0.3 m lake clay and silt; late Wisconsin Red Lake Falls Formation, 0–6.1 m till: late Pleistocene, 0.6–1.5 m oxidized take silt and clay, 0–1.5 m oxidized subaqueous debris flow deposit, 1.5 m to more than 4.6 m oxidized till (Moran and others, 1971; Harris and others, 1974)

11) Three Creeks sec., Minn.—Type section for Gervais Formation (Harris and others, 1974). Late Wisconsin Huot Formation, 4.6 m till; late Wisconsin Wylie Formation, 1.2 m lake clay and silt; late Wisconsin Red Lake Falls Formation, 1.8–6.7 m till; late Wisconsin or early Wisconsin, 4.88 m till; Illinoian Marcoux Formation, 5.4 m sand. cobble pavement, 0.15 m till; Illinoian Gervais Formation, 6.4 m till with wood chips, twigs, and logs near base, 1.5 m lake silt with thin peat lenses and abundant wood, spruce log yielded ^{14}C age >46,900 B.P. (Birm-522) (Harris and others, 1974; Ashworth, 1980)

12) Clearwater sec., Minn.—Type section for Huot, Wylie. Red Lake Falls, and Marcoux Formations (Harris and others, 1974). Late Wisconsin Huot Formation, 4.3 m till: late Wisconsin Wylie

Formation, 1.5 m lake clay and silt: late Wisconsin Red Lake Falls Formation, 5.8 m till; Illinoian Marcoux Formation, 8.3 m till

13) Powerline sec., Minn.—Type section for St. Hilaire Formation (Harris and others, 1974). Late Wisconsin Red Lake Falls Formation, 8.6 m till; early Wisconsin St. Hilaire Formation, 0.6 m till; Illinoian Marcoux Formation, 5.2 m till

14) Spring Lake sec., S. Dak.—Type section for Java local fauna (composite section from road cut and drill hole; Martin, 1973). Late Wisconsin, 0.6–0.9 m till; middle Pleistocene Java Formation of Hedges (1987). 15 m fluvial sand with mollusc and mammal fossils; bedrock. Another drill hole nearby (Hedges, 1987) revealed late Wisconsin till, late Wisconsin outwash sand and gravel, late Wisconsin till, late Wisconsin outwash sand and gravel, middle Pleistocene Java Formation, bedrock. Vertebrate fossils from Java Formation assigned to middle Irvingtonian land mammal age (Pinsof, 1985) or early Irvingtonian land mammal age (Lundelius and others, 1987; Repenning, 1987 and written commun., 1988)

DESCRIPTION OF MAP SYMBOLS

CONTACT

IT ICE-THRUST TERRAIN—Bedrock and surficial deposits that were thrust, stacked, and deformed by glacial ice. Mapped areas chiefly from Clayton, Moran, Bluemle, and Carlson (1980), with modification from maps of individual counties. Some very small areas are exaggerated to allow portrayal at this scale. Maps showing additional areas of ice-thrust terrain in North Dakota (J.P. Bluemle, unpub. maps, scale 1:250,000) were made available after this map was completed. Chiefly (1) steeply tilted bedrock blocks overlying till and stratified sediments, (2) stacked or imbricated slices of bedrock, till, and stratified sediments, forming concentric or parallel ridges, (3) deformed masses of bedrock and surficial deposits characterized by overturned folds, and (4) isolated blocks, isolated irregular masses, or isolated, relatively smooth, nearly equidimensional hills down-glacier from source depressions (Moran and others, 1980; Bluemle and Clayton, 1984). Some ice-thrust materials are covered by till that was deposited by overriding ice; surfaces locally were streamlined by overriding ice. Thickness 10–100 m

DISTAL MARGIN OF ICE-THRUST TERRAIN ASSOCIATED WITH A GLACIAL ADVANCE LIMIT OR STILLSTAND OF ICE MARGIN

LIMIT OF LATE WISCONSIN GLACIAL ADVANCE OR STILLSTAND OF ICE MARGIN—Dashed where inferred, dotted where concealed; ticks on side of advance. Limit of late Wisconsin glaciation in North Dakota based on surface morphology of till and stratified sediments, distribution of till, ice-marginal drainage relationships, topographic restrictions to ice flow, and data from water wells, auger holes, and test borings (see unit **txb**)

INFERRED LIMIT OF PRE-WISCONSIN GLACIATION—Ticks on side of advance. Limit in South Dakota from Howells (1979, 1982); limit in North Dakota from Benson (1953), Howells (1979, 1982), and Clayton, Moran, Bluemle, and Carlson (1980). In North Dakota, delineated by distribution of erratic boulders, not by distribution of till

WASHBOARD MORAINES OR MINOR MORAINES—Shown as unit **tlx** locally in South Dakota

CREST OF END MORAINE RIDGE—In areas mapped as ground moraine or stagnation moraine

DIRECTION OF ICE MOVEMENT INDICATED BY STRIATIONS—Mapped only in James lobe region in South Dakota

ICE-MOLDED LANDFORM—Drumlin, rock drumlin, flute, or groove

ESKER—Direction of transport indicated by chevrons

WIND DIRECTION INDICATED BY DUNE ORIENTATIONS

DEFLATION BASIN OR LARGE BLOWOUT DEPRESSION

RELICT PERMAFROST POLYGONS

F MANMADE LAND—Strip mines, mine spoil, and Garrison Reservoir dam and causeway

DESCRIPTION OF MAP UNITS

(Map unit thicknesses ranges are typical ranges: in some areas units may be thinner than given range)

HOLOCENE

jea SLUMP-BLOCK, EARTHFLOW, AND MUDFLOW LANDSLIDE DEPOSITS—Products of gravitational downslope movement of bedrock or surficial materials

Slump-block deposits—Masses of bedrock and unconsolidated materials that have rotated or slid downslope as a unit, with little or no flow: physical properties of transported materials are not altered greatly and original textures, stratification, bedding, and sedimentary structures of slumped materials are retained. Slump-block scarps in places more than 400 m in length; crown scarp displacements generally less than 9 m. Typically low hummocky ridges separated by long closed depressions. Some deposits stabilized and grass covered, with discontinuous veneer of eolian silt (**el**) on hummocks and sheetwash alluvium (**wla**) in depressions. Thickness generally 3–20 m, locally 35 m

Earthflow deposits—Heterogeneous mixtures of clay, silt, and sand with scattered clasts, transported and deposited as a result of slow flow of wet, but not necessarily saturated, disintegrated bedrock and surficial materials. In some areas, most of deposit is reworked slump-block deposits; in other areas, chiefly reworked till, eolian silt (**el**, ***elb***), sheetwash alluvium (**wla**), or colluvium. Most deposits are less than 30 m wide and less than 45 m long. Commonly composed of debris derived from gully walls. Deposits typically occur in gullies and in fans at mouths of gullies in dissected slump-block deposits or on foot slopes. Thickness 1–5 m, locally more than 10 m

Mudflow deposits—Heterogeneous mixtures of clay and silt with scattered clasts, transported and deposited as a result of rapid flow of saturated unconsolidated materials and disintegrated shale. Typically composed of debris washed from exposed shale surfaces or debris derived from collapse of gully walls. Commonly in fans at mouths of gullies or on foot slopes. Thickness 1–5 m

HOLOCENE AND LATE WISCONSIN

al ALLUVIUM—Reddish-brown, yellowish-brown, brown, yellowish-gray, brownish-gray, gray, black, or mottled clay, silt, sand, and gravel. Calcareous; partly or completely oxidized. Clasts angular to well rounded; lithologies reflect compositions of other surficial materials and bedrock. Included in other map units in many areas. Deposits include flood-plain alluvium and underlying channel alluvium. Includes alluvial-fan deposits, alluvium in low terrace remnants, alluvial-fill deposits (**alr**), slackwater lake deposits and outwash sand and gravel (**llf**), organic slough or marsh deposits, bedrock outcrops, and, in glaciated region, remnants of outwash and ice-contact sand and gravel (**gs**, **gg**, **kg**) and lake clay, silt, sand, and gravel (**lca, lss, lsa**). Locally overlain by sheetwash alluvium (**wla**) or eolian sand and silt (***ed***, ***es***, ***el***). Thickness 1–9 m, locally more than 23 m

Flood-plain alluvium—Chiefly poorly to well-sorted silty clay, sandy clay, clayey silt, silt, sandy silt, and fine sand with scattered pebbles. Stratified; commonly with faint bedding or horizontal bedding; local layers or lenses of gravel. Clayey alluvium soft and sticky where damp or hard where dry. Lignite fragments ubiquitous in many areas; locally fossiliferous. Weakly developed buried soils (humic horizons) locally

Channel alluvium—Chiefly loose, poorly to well-sorted, stratified fine to medium pebbly sand and (or) coarse sand and gravel; cobbles and boulders common to abundant in some areas. Generally crossbedded or with horizontal or lenticular bedding. Locally fossiliferous; locally cemented by calcium carbonate

wla LOAMY OR CLAYEY SHEETWASH ALLUVIUM[1]—Pale-yellow, yellowish-brown, olive-brown, brown, olive, yellowish-gray, olive-gray, brownish-gray, gray, black, or mottled alluvium transported and deposited by unconfined overland flow and rill wash. Typically either (1) clay, silty clay, silty clay loam, and clay loam, (2) clay loam, silt, silt loam, and sandy loam, or (3) sand and silty sand. Nonstratified to moderately well stratified; poorly to moderately well sorted. Massive, thinly laminated, or with weak horizontal bedding. Disseminated organic matter abundant in many areas; local buried soils (humic horizons). Generally calcareous and alkaline; saline in many areas. Clast free, with scattered granules and small pebbles, or with stringers, pods, and lenses of granule or pebble gravel. Commonly interbedded with well-sorted, pebbly, coarse silt and very fine sand; in places, mixed, intercalated, or interbedded with eolian sand and silt (***ed***, ***es***, ***el***) or

alluvium (**al**). Clayey alluvium soft, sticky, and plastic where damp or tough, hard, and blocky where dry; clay minerals dominantly montmorillonite. Granules and pebbles chiefly local clastic sedimentary rocks, lignite, clinker, and ironstone; minor erratic carbonate, igneous, and metamorphic clasts in glaciated region. Cobbles and boulders generally absent. Locally fossiliferous. Mapped in North Dakota west of Missouri River; included in other units elsewhere. Occurs in fans and aprons and on foot slope; in glacial diversion channels and sluiceways; in swales, sloughs, and depressions and other poorly drained areas. Includes narrow ribbons of inset alluvium (**al**) deposited by underfit streams; also includes small areas of till (**txb**), disintegration residuum, lake clay, silt, and sand (**lca**, **lss**), and organic slough or marsh deposits. Thickness 1–4 m, locally 10 m

wlc LOAMY OR CLAYEY SHEETWASH ALLUVIUM[1] AND LAKE DEPOSITS—Complex map unit of sheetwash allusion (**wla**) and older lake clay, silt, and sand (**lca**, **lss**). Sheetwash alluvium chiefly in fans and aprons, overlapping lake deposits. In glacial diversion channels and sluiceways, commonly overlies a thick complex fill deposit that includes one or more till units, includes small areas of till (**tlx**, **txb**). Mapped in northwest quarter of quadrangle. Thickness of sheetwash alluvium 1–5 m, locally 15 m; thickness of lake deposits 2–10 m, locally more than 30 m

lca LAKE SILT AND CLAY—Pale-yellow, yellowish-brown, reddish-brown, olive-brown, brown, olive, yellowish-gray, brownish-gray, olive-gray, dark-greenish-gray, bluish-gray, or mottled calcareous silt and clay. Well bedded to massive; commonly laminated, locally varved. Local thin discontinuous beds, lenses, or stringers of sand or fine gravel. Chiefly silt near margins of larger lake basins; uppermost 1–2 m in places is massive silt. Graded bedding or ice rip-up clasts of silt and clay present locally. Folded and contorted in some areas, but generally not faulted; raised rims 0.2–4 m high around some ice-walled lake deposits. Soft to firm and cohesive; hard where dry or sticky and plastic where damp; commonly breaks into large blocks. Generally clast free; rafted pebbles, cobbles, and boulders present locally; clasts generally absent on surface. Clay minerals dominantly montmorillonite in North Dakota and South Dakota, illite and smectite in Minnesota. Locally fossiliferous. Terraced in some areas; gullies common adjacent to larger streams that dissect the deposits. Flat to hummocky surface topography; local undrained depressions 1–9 m deep. Occurs beneath flat plains and small basins formerly occupied by glacial lakes and as ice-walled lake deposits. Locally overlies marl, an extremely calcareous and fossiliferous diatomite. Thin and discontinuous in some areas. Includes lake silt and sand (**lss**) where units **lca and lss** have not been distinguished. Includes some lake sand and gravel (**lsa**, **lga**), particularly on margins of larger basins, and includes extensive areas of wave-washed or current-scoured till with a thin, discontinuous veneer of lake silt and clay. Also includes some areas of alluvium (**al**), small lake delta deposits (**ldb**), and subaqueous density-current fan deposits (**lda**). In places overlain by eolian sand and silt (**ed**, ***es***, ***el***), sheetwash alluvium (**wla**), alluvial fan deposits, or organic slough or marsh deposits. Thickness 2–15 m, locally more than 45 m

lss LAKE SILT AND SAND—Yellow, grayish-yellow, yellowish-brown, brown, yellowish-gray, brownish-gray, gray, black, or mottled calcareous silt and sand with minor clay and gravel. Well stratified; well sorted. Commonly horizontally bedded fine or medium sand containing scattered granules or small pebbles interbedded or intercalated with massive or bedded silt containing scattered dropstones; in some areas chiefly bedded silt or laminated silt and fine sand. Commonly slumped, faulted, and contorted on slopes. Locally very carbonaceous; lignite fragments ubiquitous. Locally fossiliferous. Sand locally pebbly; clasts chiefly limestone, dolomite, granite, basalt, and other erratic lithologies. Deposits of open lakes and ice-walled lakes; locally collapsed where sediments were deposited on or adjacent to stagnant or dead ice. Includes areas of lake sand and gravel (**lsa**, **lga**) in beach ridges, spits, and offshore bars, lake silt and clay (**lca**), lake delta deposits (**ldb**), and subaqueous density-current fan deposits (**lda**). Locally overlain by alluvium (**al**), sheetwash alluvium (**wla**), or eolian sand and silt (**ed**, ***es***, ***el***). Blowouts common locally. Thickness 1–6 m, locally more than 20 m

lsa LAKE SAND AND GRAVEL—Pale-yellow, grayish-yellow, yellowish-brown, brown, olive, brownish-gray, olive-gray, gray, or mottled calcareous very fine to coarse sand, gravelly sand, and gravel. Moderately well stratified or well stratified. Typically coarse to medium sand and poorly to well-sorted gravel with interbeds of clay, silt, and fine sand in uppermost 1–2 m; well-sorted fine to very fine sand and silt below. Sand and silt generally crossbedded or with thin horizontal beds; local graded bedding or ripple-drift lamination. Gravel crudely bedded to well bedded; poorly

sorted to well sorted; crossbedded. Sand generally well rounded grains of quartz and feldspar; locally chiefly shale fragments. Clasts chiefly subangular to rounded granules and pebbles of erratic igneous and metamorphic rocks, dolomite, and limestone; shale clasts locally abundant. Locally fossiliferous; weakly developed buried soils (humic horizons) in places. Strongly contorted, with hummocky topography, where sediments were deposited on stagnant or dead ice. Occurs as shore and nearshore deposits in beach ridges, spits, and offshore bars and as offshore sheet deposits. Ridges may be composed of pebble gravel, gravelly sand, sandy gravel with silt lenses, or pebbly sand. In places, overlies silty marl, an extremely fossiliferous diatomite. Includes some lake delta deposits (**lda**) and lake gravel (**lga**). Also includes areas of lake clay, silt, and sand (**lca**, **lss**), alluvium (**al**), outwash sand and gravel (**gg**), and organic slough or marsh deposits. In many areas, overlain by eolian sand and silt (**ed**, **es**, **el**). Thickness 0.2–4 m, locally more than 10 m

lga LAKE GRAVEL—Grayish-yellow, yellowish-brown, brown, brownish-gray, or gray, calcareous pebble and cobble gravel with medium to coarse sand matrix. Well stratified; well sorted. Clasts chiefly subrounded or rounded, resistant igneous and metamorphic rocks derived from till and other surficial materials in same area. Shore and nearshore deposit in beaches, offshore bars, and spits formed in glacial Lake Agassiz. Mapped in northeast corner of quadrangle; included in unit **lsa** elsewhere. Thickness 1 m to more than 4 m

*e*d DUNE SAND—Pale-yellow, yellowish-brown, grayish-brown, brown, brownish-gray, gray, or mottled windblown sand in dunes. Typically calcareous, loose, well-sorted, homogeneous, fine to medium sand with faint bedding or crossbedding. Chiefly rounded or well-rounded quartz grains; locally arkosic. Quartz grains clear or frosted. Locally stained yellowish brown or pale reddish brown by iron oxides. Typically oxidized to depths greater than 3 m. In places contains weakly developed buried soils (humic horizons). Chiefly coalesced dunes; local relief generally 3–15 m. Mostly stable, with grass cover; local blowouts. Includes some eolian silt and sheet sand (**el**, **es**), alluvium (**al**), and bedrock outcrops. Thickness 1–15 m, maximum thickness more than 23 m

*e*s EOLIAN SHEET SAND—Pale-yellow, yellowish-brown, grayish-brown, brown, brownish-gray, gray, or mottled windblown sand in blanketlike deposits with only local low dunes. Typically calcareous, loose, well-sorted, homogeneous, fine to very coarse sand with faint bedding or crossbedding. Chiefly rounded or well-rounded quartz grains; grains frosted or clear. Locally stained yellowish brown or pale reddish brown by iron oxides. Typically oxidized to depths greater than 3 m. In places contains weakly developed buried soils (humic horizons). Mostly stable, with grass cover; local blowouts. Includes some eolian silt and dune sand (**el**, **ed**), alluvium (**al**), and bedrock outcrops. Thickness 1–3 m

*e*l EOLIAN SILT (LOESS)—Pale-yellow, yellow, yellowish-brown, brown, yellowish-gray, brownish-gray, gray, black, or mottled silt and silt loam; some very fine sand. Calcareous; generally oxidized throughout. Typically nonstratified, well-sorted silt with minor very fine sand; locally very faintly bedded silt and very fine sand. In places contains streaks of clayey silt or clay or contains scattered granules and pebbles. Typically massive, blocky, friable, and weakly compact; stands in nearly vertical faces in exposures. Dry loess commonly has conspicuous columnar joints. Contains weakly developed buried soils (humic horizons) in some areas; locally fossiliferous. Basal part commonly mixed or intercalated with underlying deposit. Locally mixed or intercalated with sheetwash alluvium (**wla**). Modified by solifluction, creep, and other mass-wasting processes in many areas. Occurs as a mantle of windblown material draped over older topography and deposits. Mapped only in selected areas where thickness is more than 1 m; also present as a patchy or continuous mantle in many other areas (Flint, 1955; Clayton and others, 1976). Thickness 1–3 m; maximum thickness 15 m

*e*u EOLIAN SAND AND SILT—Undifferentiated dune sand (**ed**), sheet sand (**es**), and loess (**el**). Thickness 1–3 m

jca LANDSLIDE DEPOSITS, CLAYEY DISINTEGRATION RESIDUUM, AND SHEETWASH ALLUVIUM[1]—Clayey disintegration residuum and sheetwash alluvium (**xce**), distinguished from that unit by the presence of abundant landslide deposits (**jea**). Includes some colluvium, 0.5–3 m thick, consisting of bedrock float blocks and other materials transported and deposited by creep. Extensive outcrops of shale in many areas. Locally overlain by eolian silt (**el**, **elb**). Mapped in southwest quarter of quadrangle. Thickness of landslide deposits 1–20 m, locally 35 m; disintegration residuum less than 1 m; sheetwash alluvium 0.5–2 m, locally more than 4 m

jcb LANDSLIDE DEPOSITS, CLAYEY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND GLACIAL DEPOSITS—Complex unit similar to **jca**, distinguished from it by the presence of discontinuous till of late Wisconsin age (**tlx**, **tlu**), generally less than 2 m thick, and glacial erratics. Mapped in southwest quarter of quadrangle

jxa LANDSLIDE DEPOSITS, BOULDERY COLLUVIUM[3], AND SHEETWASH ALLUVIUM[1]—Complex map unit on steep slopes and foot slopes. Mapped in two areas in central part of quadrangle

Landslide deposits—Chiefly slump-block, earthflow, and mudflow deposits (**jea**). Thickness 2–10 m, locally 30 m

Colluvium—Gravelly clay, gravelly sand, or sandy gravel derived from till (**tlx**), dissected landslide deposits (**jea**), and dissected ice-thrust deposits (**IT**). Commonly bouldery or cobbly; very shaly in places. Includes some solifluction deposits (**nld**) composed of reworked till. Thickness less than 15 m

Sheetwash alluvium—Similar to unit **wla**, but texture varies from clay to sandy loam. Derived from till (**tlx**), landslide deposits (**jea**), colluvium, and ice-thrust deposits (**IT**). Occurs in fans and aprons on foot slopes, and in depressions and other poorly drained areas. Thickness 1–3 m, locally more than 5 m

xce CLAYEY DISINTEGRATION RESIDUUM[2] AND SHEETWASH ALLUVIUM[1]—Yellowish-brown, olive-brown, grayish-brown, brown, olive, olive-gray, brownish-gray, gray, or mottled clay, silty clay, clay loam, or loam. Slightly to highly calcareous; mildly to strongly alkaline. Hard and blocky where dry or plastic, sticky, and slippery where damp. Clasts dominantly angular or subangular fragments of micaceous and bentonitic shale or soft clayey shale; local fragments of siltstone or sandstone. Selenite crystals, ironstone concretions, and redeposited pyrite, marcasite, or siderite crystals common. Landslide deposits (**jea**) common to abundant in some areas. Includes areas of alluvium (**al**, **agu**, **alo**), eolian silt **(elb),** and minor colluvium. Bedrock outcrops common; includes extensive areas of dissected shale. Mapped in southwest quarter of quadrangle

Residuum—Nonstratified; nonsorted; massive or with faint relict stratification. Loosely consolidated or compact. Iron oxide stains common. Shale fragments common to abundant, particularly in lower part; locally consists of thin layers of platy shale fragments. In many areas, overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**, **elb**). Thickness less than 1 m

Sheetwash alluvium—Similar to unit **wla**. Thickness 1–3 m, locally more than 9 m

xcf CLAYEY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND GLACIAL DEPOSITS—Complex unit similar to unit **xce**, distinguished from it by the presence of discontinuous till of late Wisconsin age (**tlu**, **tlx**), generally less than 2 m thick, and glacial erratics. Includes small areas of alluvium (**al**, **alo**, **agu**), and alluvial-fill deposits (**alr**); may include small areas of exhumed pre-Wisconsin till (**txc**). Mapped in southwest quarter of quadrangle

xlk LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1] AND COLLUVIUM[3]—Yellowish-orange, pale-yellow, yellowish-brown, grayish brown, olive-brown, brown, olive, maroon, yellowish-gray, brownish-gray, olive-gray, gray, brownish-black, black, white, or mottled loam, clay loam, or silty clay loam; locally silty clay, sandy loam or loamy sand. Calcareous; clasts dominantly angular or subangular sandstone, siltstone, claystone, and fissile shale; local fragments of limestone, silcrete, clinker, silicified wood, or lignite. Small landslide deposits (**jea**) present locally. Includes some alluvium (**al**, **alq**), clinker (**qs**), and bedrock outcrops. Mapped in North Dakota along west boundary of quadrangle

Residuum—Nonstratified; nonsorted; commonly with faint relict stratification. Loosely consolidated or compact. Bedrock fragments common to abundant, particularly in lower part. In places, surface is littered with residual boulders, cobbles, and pebbles of silcrete or case-hardened bentonite or siltstone; boulders locally wind abraded and polished. Locally overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**). Thickness less than 1 m

Sheetwash alluvium—Similar to unit **wla**. Thickness 0.5–4 m, locally more than 4 m

Colluvium—Nonstratified or faintly stratified; nonsorted. Loosely consolidated or compact. Typically angular and subangular boulders, cobbles, and pebbles in a clayey to sandy matrix; local rubble of silcrete, sandstone, siltstone, limestone, or clinker boulders, cobbles, and pebbles. Locally includes large float blocks of bedrock. Occurs on steep slopes in hilly terrain and on more gentle slopes below bedrock ledges, escarpments, and terrace and bench margins. Thickness 0.3–4 m, locally more than 8 m

xll LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xlk**, distinguished from it by the presence of thin or discontinuous till of late Wisconsin age (**tlx**, **txb**), generally less than 2 m thick, and glacial erratics. Till locally baked and fused as a result of natural burning of underlying lignite beds. Includes small areas of alluvium (**al**), slackwater lake deposits (**llf**), outwash and ice-contact sand and gravel (**gg**, **kg**), alluvial-fill deposits (**alr**), and bedrock outcrops. May include small areas of exhumed pre-Wisconsin till (**txc**). Mapped in northwest quarter of quadrangle

xln LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND COLLUVIUM[3] —Yellow, brownish-yellow, yellowish-brown, grayish-brown, brown, grayish-olive, olive, yellowish-gray, brownish-gray, olive-gray, bluish-gray, gray, black, white, or mottled loam, silt loam, clay loam, and silty clay loam; locally silty clay, clay, sandy loam, or loamy fine sand. Noncalcareous to highly calcareous; mildly to very strongly alkaline. Clasts chiefly fine grained sandstone, siltstone, claystone, and micaceous clayey shale; minor fissile carbonaceous shale, limestone, glauconitic sandstone, silicified wood, clinker, and lignite. Landslide deposits (**jea**) common to abundant locally. Includes areas of alluvium (**al**, **alq**, **agu**), eolian silt (**elb**), and bedrock. Mapped along west boundary of quadrangle

Residuum—Nonstratified; nonsorted; commonly with faint relict stratification. Generally loose or poorly consolidated; compact where clayey. Bedrock fragments common to abundant in most areas, particularly in lower part. Locally developed in Tertiary or Cretaceous volcanic ash or bentonitic clay; forms, "gumbo" that is hard where dry or very sticky, plastic, and slippery where damp. Calcium carbonate concretions 1 m or larger in diameter present locally; small concretions of limonite or marcasite common in some areas. Residual crystals or crystallized spheres and rosettes of selenite common. Silicified logs as long as 5 m present on surface locally. Overlain by thin or discontinuous eolian sand and silt (**ed**, ***es***, ***el***, ***elb***) in many areas. Thickness less than 1 m

Sheetwash alluvium—Similar to unit **wla**. Thickness 0.5–2 m, locally more than 4 m

Colluvium—Nonstratified or faintly stratified; nonsorted. Typically angular and subangular boulders, cobbles, and pebbles in a clayey to sandy matrix. Loosely consolidated or compact. Locally includes large float blocks of bedrock. Occurs on steep slopes in hilly terrain and on more gentle slopes below bedrock ledges, escarpments, and terrace and bench margins. Thickness 0.3–4 m, locally more than 8 m

xlo LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xln**, distinguished from it by the presence of thin or discontinuous till of late Wisconsin age (**tlu**, **tlx**, **txb**), generally less than 2 m thick, and glacial erratics. Includes areas of alluvium (**al**, **alq**), alluvial-fill deposits (**alr**), outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, and sand (**lca**, **lss**), and bedrock outcrops. May include areas of exhumed pre-Wisconsin till (**txc**). Mapped in North Dakota east and west of Missouri River

xlr LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Disintegration alluvium, sheetwash alluvium, and colluvium are yellow, yellowish-brown, olive-brown, brown, olive, yellowish-gray, brownish-gray, olive-gray, gray, or mottled loam, silt loam, clay loam, and silty clay loam; minor sandy loam. Weakly to highly calcareous; moderately alkaline. Clasts chiefly sandstone, siltstone, and shale; minor limestone. Landslide deposits (**jea**) present locally. Includes areas of alluvium (**al**, **alq**), alluvial-fill deposits (**alr**), outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, and sand (**lca**, **lss**), and bedrock outcrops. Glacial deposits chiefly discontinuous till of late Wisconsin age (**tlx**, **tlu**, **txb**), less than 2 m thick, and glacial erratics. May include small areas of exhumed pre-Wisconsin till (**txc**). Mapped east and west of Missouri River in west-central part of quadrangle

Residuum—Nonstratified; nonsorted; faint relict stratification and sedimentary structures common. Loosely consolidated or compact. Bedrock fragments common to abundant, particularly in lower part. Locally developed in bentonite. Surface locally littered with wind-abraded blocks or boulders of quartzitic sandstone or sandstone. Locally overlain by thin or discontinuous eolian sand and silt (**ed**, ***es***, ***el***). Thickness less than 1 m

Sheetwash alluvium—Similar to unit **wla**. Thickness 0.5–2 m, locally more than 4 m

Colluvium—Nonstratified or faintly stratified; nonsorted. Loosely consolidated or compact. Typically angular or subangular boulders, cobbles, and pebbles of sandstone, siltstone, and shale in a loamy

or sandy matrix; local rubble of sandstone and siltstone. Locally includes large float blocks of bedrock. Occurs on steep slopes in hilly terrain and on more gentle slopes below bedrock ledges, escarpments, and terrace and bench margins. Thickness 0.3–4 m, locally more than 8 m

xla LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND COLLUVIUM[3]—Yellowish-brown, olive-brown, grayish-brown, brown, olive, olive-gray, brownish-gray, gray, or mottled loam, clay loam, or silty clay loam; locally silty clay or clay. Weakly to highly calcareous; mildly to strongly alkaline. Clasts dominantly angular or subangular soft shale, platy shale, or siltstone: minor sandstone or limestone. Landslide deposits (**jea**) present locally. Includes areas of alluvium (**al**, **agu**), eolian silt (**elb**), and bedrock outcrops. Mapped in South Dakota along west boundary of quadrangle

Residuum—Nonstratified; nonsorted; massive or with faint relict stratification. Loosely consolidated or compact. Bedrock fragments common, particularly in lower part. In some areas, overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**). Thickness less than 1 m

Sheetwash alluvium—Similar to unit **wla**; commonly saline. Thickness 0.5–2 m, locally more than 4 m

Colluvium—Nonstratified or faintly stratified; nonsorted. Loosely consolidated or compact. Typically angular or subangular boulders, cobbles, and pebbles of sandstone, siltstone, shale, and limestone. Locally includes large float blocks of bedrock. Occurs on steep slopes in hilly terrain and on more gentle slopes below bedrock ledges, escarpments, and terrace and bench margins. Thickness 0.3–4 m, locally more than 8 m

xlf LOAMY DISINTEGRATION RESIDUUM[2] AND SHEETWASH ALLUVIUM[1]—Yellowish-brown, olive-brown, brown, grayish-brown, olive, gray, or mottled loam, clay loam, silty clay loam, and silt loam; locally very fine sand, silty clay, or clay. Weakly to highly calcareous; mildly to very strongly alkaline. Clasts dominantly clayey shale. In many areas, chiefly sheetwash alluvium with only minor disintegration residuum. Includes areas of alluvium (**al**), minor colluvium, landslide deposits (**jea**), and bedrock outcrops. Mapped in South Dakota along west boundary of quadrangle

Residuum—Nonstratified; nonsorted; massive or with faint relict stratification. Loosely consolidated or compact. Shale fragments common, particularly in lower part. In some areas, overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**). Thickness less than 1 m

Sheetwash alluvium—Similar to unit **wla**. Includes local alkali "slickspots." Thickness 0.3–2 m, locally more than 6 m

xsc SANDY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND COLLUVIUM[3]—Pale-yellow, yellowish-brown, olive-brown, grayish-brown, brown, olive, yellowish-gray, olive-gray, brownish-gray, gray, white, or mottled loamy fine sand, loamy sand, fine sand, fine sandy loam, and sandy loam; locally loam, silt loam, silty clay loam, clay loam, silty clay, or clay. Weakly to highly calcareous; mildly to very strongly alkaline. Clasts chiefly soft sandstone and siltstone; some shale and limestone. Includes areas of alluvium (**al**), eolian silt (**elb**), landslide deposits (**jea**), and bedrock outcrops. Mapped in one area in South Dakota west of Missouri River

Residuum—Nonstratified; nonsorted; massive or with faint relict stratification and sedimentary structures. Generally loosely compact. Bedrock fragments common to abundant, particularly in lower part. In some areas, overlain by eolian sand and silt (**ed**, **es**, **el**, **elb**)

Sheetwash alluvium—Similar to unit **wla**. Thickness 0.3–2 m, locally more than 4 m

Colluvium—Stony debris derived from bedrock outcrops higher on slopes. Locally cobbly. May include some solifluction deposits (**nld**). Thickness 0.3–2 m, locally more than 6 m

HOLOCENE TO EARLY MIDDLE PLEISTOCENE(?)

alr ALLUVIAL-FILL DEPOSIT—Complex fill of slackwater lake deposits and outwash sand and gravel (**llf**), sheetwash alluvium (**wla**), lake clay, silt, and sand (**lca**, **lss**), and eolian sand and silt (**ed**, **es**, **el**) of Holocene and late Wisconsin age, and older sediments of similar compositions and genesis. Fill locally includes late Wisconsin till (**tlu**, **tlx**, **txb**) and (or) pre-Wisconsin till (**txc**). Occurs in terrace remnants on walls of Missouri River valley. Includes some inset younger alluvium (**al**) and bedrock outcrops. Locally overlain by sheetwash alluvium (**wla**) or eolian sand and silt (**ed**, **es**, **el**). Thickness 3–35 m, locally more than 45 m

elb EOLIAN SILT (LOESS)—Pale-yellow, yellow, yellowish-brown, reddish-brown, brown, yellowish-gray, brownish-gray, gray, black, or mottled windblown silt, silt loam, and very fine sand. Calcareous;

local white or pale-gray filaments, powdery interstitial fillings, or nodules of secondary calcium carbonate. Generally oxidized. Typically nonstratified, massive, well-sorted silt with minor very fine sand; locally faintly bedded silt and very fine sand. In places contains streaks or pods of clayey silt or clay or contains scattered granules and pebbles. Unconsolidated or weakly compact; stands in nearly vertical faces in exposures. Columnar joints common. Friable; blocky structure. Silt and sand grains dominantly quartz and accessory minerals. In places, stained yellowish brown, reddish brown, or brown by iron oxides. Locally fossiliferous; contains buried soils (humic horizons) in some areas. Thin or discontinuous deposits of till (**tlx**, **tlu**, **txc**) may be intercalated in loess in glaciated areas. Locally mixed or intercalated with sheetwash alluvium or colluvium; modified by creep, collluviation, solifluction, and other mass-wasting processes in many areas. Occurs as a mantle of windblown material draped over older topography and deposits, chiefly on upland surfaces. Mapped in southwest quarter of quadrangle where loess is a continuous mantle more than 1 m thick; also present as an unmapped patchy or continuous thin mantle over other map units in many other areas. Includes areas of alluvium (**al**, **alo, agu),** disintegration residuum, sheetwash alluvium, and colluvium (**xce**, **xln**, **xla**, **xsc**), landslide deposits (**jea**, **jca**), and bedrock outcrops. The stratigraphy, paleontology, and chronology of the deposits are very poorly known. Probably includes loess that is temporally equivalent to the Bignell, Peoria, and Loveland Formations and older eolian deposits farther south in Nebraska. Thickness 1–3 m, locally more than 15 m

jcc LANDSLIDE DEPOSITS, CLAYEY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND GLACIAL DEPOSITS—Complex unit similar to unit **lca**, distinguished from it by the presence of discontinuous till of pre-Wisconsin age (**txc**), generally less than 1 m thick, and glacial erratics. Mapped in southwest quarter of quadrangle

xcg CLAYEY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], AND GLACIAL DEPOSITS —Complex unit similar to unit **xce**, distinguished from it by the presence of discontinuous till of pre-Wisconsin age (**txc**), generally less than 1 m thick, and glacial erratics. Includes small areas of alluvium (**agu**). In places overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**, **elb**). Mapped west of Missouri River in west-central part of quadrangle

xlm LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xlk**, distinguished from it by the presence of thin or discontinuous till of pre-Wisconsin age (txc), generally less than 1 m thick, and glacial erratics. Includes areas of alluvium (**al**, **alq**). Locally overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**). Mapped west of Missouri River in northwest quarter of quadranqle

xlp LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xln**, distinguished from it by the presence of thin or discontinuous till of pre-Wisconsin age (**txc**), generally less than 1 m thick, and glacial erratics. Overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**) in many areas. Mapped west of Missouri River in west-central part of quadrangle

xls LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xlr**, distinguished from it by the presence of discontinuous till of pre-Wisconsin age (**txc**), generally less than 1 m thick, and glacial erratics. Till and glacial erratics included in unit **xlr** are both late Wisconsin and pre-Wisconsin in age. Includes small areas of alluvium (**al**, **agu**). Overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**, **elb**) in many areas. Mapped west of Missouri River in west-central part of quadrangle

xlb LOAMY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xla**, distinguished from it by the presence of discontinuous till of pre-Wisconsin age (**txc**), generally less than 1 m thick and glacial erratics. Includes small areas of alluvium (**al**, **agu**). Locally overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**). Mapped west of Missouri River in west-central part of quadrangle

xsd SANDY DISINTEGRATION RESIDUUM[2], SHEETWASH ALLUVIUM[1], COLLUVIUM[3], AND GLACIAL DEPOSITS—Complex unit similar to unit **xsc**, distinguished from it by the presence of thin or discontinuous till of pre-Wisconsin age (**txc**), generally less than 1 m thick, and glacial erratics. Includes small areas of alluvium (**al**, **agu**). In places overlain by thin or discontinuous eolian sand and silt (**ed**, **es**, **el**, **elb**). Mapped west of Missouri River in west-central part of quadrangle

HOLOCENE TO PLIOCENE(?)

qs BAKED AND FUSED BEDROCK (CLINKER)—Bedrock that was baked and fused as a result of natural burning of lignite beds. Brick-red to dark-red, salmon pink, orange, yellow, green, brown, maroon, dark-purple, gray, white, or black sandstone, siltstone, and claystone. Intensity of alteration diminished upward. Lower part commonly massive, with flow structures; bedding and sedimentary structures of original bedrock destroyed. Local slaglike masses with ropy surfaces, or low-density rock with open fissures, pores, and pockets resembling scoria. Where original bedrock was clayey, commonly massive and hard; breaks into plates or brittle chips with conchoidal fracture. Upper part typically retains bedding and sedimentary structures of original bedrock commonly brecciated by collapse caused by removal of underlying lignite flow structures absent except in chimneys that project upward. Polygonal columnar jointing common in places: breaks in short columnar fragments or chunky blocks. Locally includes till that also was baked and fused. Clinker is very resistant to weathering and erosion; forms ledges and rims or caprock on buttes and hills. On flat and gentle slopes, commonly overlain by less than 2 m of loamy residuum; on moderate to steep slopes below clinker outcrops includes colluvium of blocks, boulders, cobbles, and pebbles of clinker in a sandy to clayey matrix. Clinker blocks and boulders on surface commonly covered by lichens. Mapped in North Dakota west of Missouri River where outcrops are extensive. Thickness 2–30 m

LATE WISCONSIN

tc CLAYEY TILL (Falconer and Huot Formations in Minnesota and North Dakota)—Olive-brown, grayish-brown, olive-gray, gray, or mottled calcareous clay, silty clay, and silty clay loam. More clayey toward the south. Nonstratified; nonsorted; typically no apparent structure. Contorted beds of silt common locally particularly in upper part in places contains chalky inclusions or inclusions of oxidized older till. Very local interbeds of sand and fine gravel. Slickensides common. Slumps in outcrops in many areas. Sparingly pebbly to pebbly scattered cobbles; boulders very rare. Clasts chiefly limestone and dolomite minor shale and erratic igneous and metamorphic rocks. Chiefly derived from offshore glacial-lake sediment that was incorporated by ice during the Edinburg phase glacial readvance (phase 15, table 1). Commonly overlain by discontinuous lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**), alluvium (**al**), or organic marsh deposits. Thickness 3–5 m, locally more than 20 m

LOAMY TILL—Olive-brown, brown, olive, olive-gray, gray, or mottled calcareous clay loam, silt loam, silty clay loam, and loam; locally sandy loam or clay texture is similar to that of other tills in this quadrangle that are classed as loamy tills. The letter symbol, indicative of clayey till in the adjacent Minneapolis quadrangle (Goebel and others, 1983), is used to retain continuity of the unit in the two quadrangles. Nonstratified; nonsorted. Clasts chiefly pebbles and cobbles of shale and limestone; minor erratic igneous and metamorphic rocks. Includes some alluvium (**al**), outwash and ice-contact sand and gravel (**gs**, **gg**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**, **lga**), and organic slough or marsh deposits

tcf Ground moraine—Thickness 2–20 m

tcf End moraine—Broad ridges, typically with hummocky topography and deep ice-block depressions. Thickness 10–50 m

tcf Stagnation moraine—Broad areas of hummocky collapsed topography lacking distinct morainal ridges. Nonintegrated drainage; lakes, ponds, and marsh-filled sloughs common. Thickness 2–50 m

tkt COLLAPSED TILL AND LAKE DEPOSITS—Complex unit of till, lake clay and silt, and blocks of sand, gravel, and bedrock. In many areas, deposit is pale yellow, yellowish-brown, yellowish-gray, brownish-gray, gray, or mottled calcareous silt, silt loam, or silty clay till; generally much more silty than typical loamy till (**tlx**) in same region. Inclusions of bedded silt, sand, and minor gravel common in till. In other areas, deposit is chiefly poorly indurated, faintly bedded lake silt and minor clay. Locally, deposit is a nonsorted, nonbedded mixture of angular, subangular, and rounded blocks of sand, gravel, and bedrock in a loose silty matrix. Collapsed deposits commonly are tilted, faulted, or contorted on slopes and in low areas, undisturbed on hilltops. Relief generally 3–9 m; surface generally smooth, with numerous small, shallow depressions. Chiefly till and offshore sediments of glacial Lake Agassiz deposited on stagnant or dead ice in northeastern

quarter of quadrangle. Includes areas of alluvium (**al**), uncollapsed till (**tlx**), lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**), and organic slough or marsh deposits. Thickness less than 3 m

LOAMY TILL—Pale-yellow, grayish-yellow, yellowish-brown, reddish-brown, brown, olive, olive-brown, yellowish-gray, brownish-gray, olive-gray, gray, or mottled calcareous loam, silt loam, sandy clay loam, and sandy loam; locally very sandy or gravelly. Nonstratified or very poorly stratified; nonsorted or poorly sorted. Commonly interbedded with or contains discontinuous lenses of sand and gravel. Generally very pebbly; some cobbles and boulders. Pebbles, cobbles, and boulders dominantly erratic limestone, dolomite, and igneous and metamorphic rocks. Lignite chips and limonite blebs abundant in many areas. Locally contains blocks or masses of ice-thrust bedrock. Includes areas of till washed by streams and by waves and currents in glacial lakes, with surface litter of cobbles and boulders or discontinuous cover of lake clay, silt, sand, and gravel (**lca**, **lss, lsa**) or lake delta deposits (**ldb**). Also includes areas of outwash and ice-contact sand and gravel (**gg**, **kg**), alluvium (**al**), and organic slough or marsh deposits. Commonly covered by thin eolian sand and silt (**ed**, **es**, **el**). Wood beneath unit **tlw** and older late Wisconsin till 17 km north of quadrangle boundary yielded a ^{14}C age of 28,340±1,000 B.P, (W-2450; Moran and others, 1973). Mapped near north boundary of quadrangle in North Dakota

tlw Ground moraine—Includes areas of collapsed supraglacial sediment with less than 3 m of local relief; maximum slope angles generally less than 4°. Thickness 1–5 m, locally 12 m

tlw End moraine—Broad hummocky ridges or narrow sharply defined ridges, commonly with undrained depressions and lag cobbles and boulders on surface. Thickness 3–15 m, locally 20 m

LOAMY TILL—Yellowish-brown, olive-brown, grayish-brown, brown, brownish-gray, olive-gray, gray, or mottled very calcareous silt loam and loam; locally sandy loam, clay loam, or silty clay. Nonstratified; nonsorted or poorly sorted. Lenses or pockets of sand and gravel common. High content of expandable clay minerals (smectite); lesser illite, kaolinite, and chlorite. Pebbles chiefly shale, limestone, and dolomite; minor basalt, diabase, granite, chert, and sandstone. Locally cobbly or bouldery; boulder concentrations common on surface; large boulders chiefly granite. Disintegration ridges common in some areas. Includes areas of alluvium (**al**). Outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**), and organic slough or marsh deposits. Locally overlain by thin, patchy eolian silt (**el**). Mapped in eastern part of quadrangle

tlg Ground moraine—Thickness 2–25 m, locally more than 30 m

tlg End moraine—Broad ridges, typically with hummocky topography and closed depressions. Boulders common on distal slopes and crests of ridges; lake silt and clay (**lca**) common in swales and depressions between ridges. Thickness 2–30 m, locally 50 m

tlg Stagnation moraine—Broad areas of hummocky collapsed topography lacking distinct morainal ridges. Nonintegrated drainage; lakes, ponds, and marsh-filled depressions and sloughs common. Till typically more sandy than till of ground moraine; commonly interbedded with clay, silt, sand, and gravel. Thickness less than 15 m, locally 50 m

LOAMY TILL—Yellowish-orange, grayish-orange, pale-orange, pale-yellow, grayish-yellow, reddish-brown, yellowish-brown, olive-brown, grayish-brown, brown, brownish-olive, olive, maroon, yellowish-gray, brownish-gray, olive-gray, bluish-gray, bluish-black, olive-black, or mottled calcareous clay loam and; in some areas silt loam, silty clay loam, silty clay, or sandy clay loam. Locally very gravelly or matrix dominantly either sand, silt, or clay. In places, interbedded with, intercalated with, or contains lenses, pods, and stringers of clay, silt, sand, or gravel. Nonstratified; nonsorted or very poorly sorted. Compact; commonly massive; cohesive to friable; locally mealy. More clayey till typically soft and sticky where damp; hard and blocky where dry. Clay minerals dominantly montmorillonite. Weakly developed joints locally; joint surfaces may be coated with calcium carbonate or iron oxides, or selenite crystals less than 3 mm long may be oriented parallel to joint surfaces. Nearly pebble free to very pebbly; cobbles and boulders rare to abundant. Pebbles chiefly subangular to rounded erratic limestone, dolomite, and granite in upper part of thick till: angular to subrounded shale, siltstone, and sandstone pebbles and lignite fragments abundant in thin till and lower part of thick till. Cobbles and boulders chiefly subangular to well-rounded erratic igneous and metamorphic rocks, limestone, and dolomite. Clasts of older till and clasts of lignite as large as 2 m in diameter common in some areas. Glaciotectonic blocks of shale tens or hundreds of meters in length and several meters in thickness included in till locally. Disintegration ridges common in many areas. Undrained shallow depressions very abundant in

many areas. Includes unmapped ice-thrust deposits (**IT**), flowtill, and landslide deposits (**jea**). Includes extensive areas of till washed by streams and by waves and currents in glacial lakes, with surface litter of cobbles and boulders or discontinuous cover of lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**, **lga**). Also includes lake underflow density-current fan deposits (**lda**), lake delta deposits (**ldb**), alluvium (**al**), sheetwash alluvium (**wla**), outwash arid ice-contact sand arid gravel (**gg, kg**), organic slough and marsh deposits, and bedrock. In west half of quadrangle in North Dakota, includes areas of exhumed pre-Wisconsin till (**txc**). Locally covered by eolian sand and silt (**ed**, **es**, ***el***)

tlx Ground moraine—Includes areas of collapsed supraglacial sediment with less than 3 m of local relief; maximum slope angles generally less than 4°. Thickness 1–15 m, locally 30 m

tlx Washboard moraine—Ground moraine with swell-and-swale topography. Subdued, irregular, discontinuous, concentric or parallel ridges in groups or clusters. Local relief generally 2–5 m, with intervening troughs or depressions. Ridges sharply defined from air but inconspicuous on ground. Shown as a map unit only in parts of South Dakota; shown by symbol in North Dakota. Other areas of washboard moraines in South Dakota were mapped by Gwynne (1951) and Flint (1955). Thickness 3–20 m, locally more than **30 m**

tlx End moraine—Broad, hummocky ridges or narrow, sharply defined ridges, commonly with undrained depressions and lag cobbles and boulders on surface. Relief locally more than 30 m. Till end moraine deposits locally are replaced laterally by kame end moraine deposits that are included in map unit. Some ridges in areas mapped as ground moraine are shown by symbol, in northwest corner of quadrangle, north of Garrison Reservoir, wide belt of end moraine with northeast-southwest trend may be a buried end moraine of pre-Wisconsin till (**txc**) that is overlain by a thin oxidized veneer of late Wisconsin ground moraine. Thickness 6–40 m, locally 60 m

tlx Stagnation moraine—Broad areas of hummocky collapsed topography lacking distinct morainal ridges. Nonintegrated drainage; lakes, ponds, arid marsh-filled depressions and sloughs common. Relief locally more than 50 m; slope angles generally 5–15 percent. Includes collapsed glacial sediment (till and flowtill), collapsed ice-walled supraglacial lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**), and collapsed outwash and ice-contact sand and gravel (**gg**, **kg**). Glacial, glaciolacustrine, glaciofluvial, and alluvial sediments were redeposited by mass movement (flow and sliding) as a result of melting of buried ice for several thousand years after deglaciation. Boundaries between stagnation moraine and ground moraine in some areas are transitional and contacts are arbitrary. Thickness 6–30 m, locally more than 60 m

tla LOAMY TILL (Tazewell Till in northeastern South Dakota and southwestern Minnesota)—Yellowish-brown, olive-brown, grayish-brown, brown, yellowish-gray, olive-gray, brownish-gray, bluish-gray, gray, or mottled very calcareous loam and clay loam; locally sandy loam. Nonstratified; nonsorted or poorly sorted. Compact and firm; commonly blocky and fissile. Upper part locally sandy, pebbly, and ferruginous. Locally interbedded or intercalated with, or contains lenses, pods, and stringers of sand and gravel. High content of expandable clay minerals (smectite); illite more abundant than kaolinite. Typically oxidized throughout; less intensely oxidized than unit **tll** and more intensely oxidized than units **tlg** and **tlx**. Commonly jointed; iron oxide stains on joint surfaces. Pebbly to very pebbly; local surface concentrations of cobbles and boulders. Pebbles chiefly subangular to well rounded erratic limestone, dolomite, and igneous and metamorphic rocks; minor shale, sandstone, and ironstone. Boulders chiefly subangular to subrounded limestone, dolomite, and granite. Surface smooth to gently undulating; low hills and broad swales and depressions; no sharp ridges, eskers, lakes, or swamps; surface typically not as stony as surface on younger till (**tlg**, **tlx**). Till generally thin; older till (**tll**) exposed in some areas. Wood from base of till yielded ^{14}C ages of 22,900±1,000 B.P. (GX-3439) and 26,150+3,000-2,000 (GX-2864) (Beissel and Gilbertson, 1987; Lehr and Gilbertson, 1988; Gilbertson and Lehr, 1988). Includes areas of alluvium (**al**), sheetwash alluvium (**wla**), outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, and sand (**lca**, **lss**), and organic slough and marsh deposits. Locally overlain by less than 2 m of eolian silt (**el**). Thickness 2–5 m, locally 18 m

LOAMY TILL—Pale-yellow, grayish-yellow, pale-yellowish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled calcareous loam, silt loam, clay loam, and silty clay loam. Texture typically more coarse and oxidized color more yellow than texture and oxidized color of unit **tlx** to east. Nonstratified; nonsorted or very poorly sorted. Cohesive to friable. May be interbedded or

intercalated with or may contain stringers, pods, and lenses of gravel, sand, silt, and clay. Generally moderately pebbly; pebbles chiefly locally derived angular or subrounded siltstone, shale, sandstone, and lignite; less abundant erratic limestone, dolomite, and igneous and metamorphic rocks and locally derived limestone, silicified wood, and clinker, Cobbles and boulders chiefly subangular and subrounded erratic limestone, dolomite, and granite. Shale pebbles much less abundant than in unit **tlx** to east. Thin and discontinuous; includes extensive areas of bedrock overlain by scattered erratic boulders and cobbles. May include small areas of exhumed pre-Wisconsin till (**txc**). Includes areas of alluvium (**al**), sheetwash alluvium (**wla**), outwash ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, and sand (**lca**, **lss**), and organic slough and marsh deposits, and bedrock. Commonly overlain by eolian sand and silt (***ed***, ***es***, ***eu***). Mapped east of Missouri River in North Dakota and South Dakota adjacent to river

tlu Ground moraine—Thickness less than 2 m in North Dakota, locally more than 10 m in South Dakota

tlu End moraine—Broad hummocky ridges, commonly with undrained depressions and lag cobbles and boulders on surface. Mapped only in South Dakota. Thickness more than 30 m, locally 100 m

tlu Stagnation moraine—Broad areas of hummocky collapsed topography lacking distinct morainal ridges. Nonintegrated drainage; lakes, ponds, and marsh-filled depressions arid sloughs common. Includes collapsed till and flowtill, collapsed ice-walled supraglacial clay, silt, sand, and gravel (**lca**, **lss**, **lsa**), and collapsed outwash and ice-contact sand and gravel (**gg**, **kg**). Mapped only in South Dakota. Thickness commonly more than 30 m, locally 100 m

CLAYEY TO SANDY TILL—Yellow, brownish-yellow, grayish-yellow, yellowish-brown, olive-brown, grayish-brown, brown, olive, olive-gray, yellowish-gray, brownish-gray, bluish-gray, gray, or mottled calcareous silty clay, clay loam, and loam; minor silt loam, clay, loamy sand, sandy loam, loam, and silt loam. Matrix derived chiefly from local bedrock. Nonstratified; nonsorted or very poorly sorted. Locally faintly layered. Compact and cohesive to only slightly consolidated. In places, breaks into irregular chunks. Clayey till typically soft and sticky where damp, hard and blocky where dry. Clay minerals dominantly montmorillonite. In places, interbedded or intercalated with, or contains lenses, pods, and stringers of clay, silt, sand, and gravel. In some areas till has prominent, nearly vertical joints 5–10 cm apart in upper part; joints commonly thinly coated with secondary calcium carbonate or iron oxides; some joints contain selenite crystals as long as 2 mm, oriented parallel to joint surfaces. In other areas, joints are irregularly spaced or absent. Nearly pebble free to very pebbly; cobbles and boulders common, especially in upper part. In most areas, pebbles chiefly subangular to rounded erratic limestone, dolomite, granite, gneiss, and greenstone; lesser local sandstone, siltstone, claystone, shale, lignite, ironstone, clinker, silicified wood, agate, vein quartz, and chert. Shale pebbles much less abundant than in unit **tlx**. In some areas pebbles are dominantly local bedrock. Cobbles and boulders chiefly subangular to rounded erratic limestone, dolomite, granite, granodiorite, greenstone, and quartzite, and local sandstone, quartzitic sandstone, silcrete, and ironstone. Glaciotectonic blocks or masses of bedrock (**IT**) are included in till locally. Extensively eroded in many areas. Includes areas of cobble and boulder concentrations on bedrock surfaces and areas where exhumed older till (**txc**) is at the surface. Very locally, till has been baked and fused as a result of natural burning of underlying lignite beds. Includes areas of alluvium (**al**, **alq**), sheetwash alluvium (**wla**), alluvial-fill deposits (**alr**), slackwater lake deposits (**llf**), lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**), outwash and ice-contact sand and gravel (**gg**, **kg**), solifluction deposits (**nld**), organic slough and marsh deposits, landslide deposits (**jea**, **jcb**), disintegration residuum, sheetwash alluvium, and colluvium (**xcf**, **xli**, **xll**, **xlo**, **xlr**), clinker (**qs**), and bedrock outcrops. Locally overlain by eolian sand and silt (**ed**, ***es***, ***el***). Mapped west of Missouri River in North Dakota.

Map unit **txb** includes drift assigned to the Napoleon and Verone glaciations and part of the drift assigned to the Dunn glaciation by Clayton, Moran, Bluemle, and Carlson (1980) and Clayton, Moran, and Bluemle (1980). The informal Napoleon drift was inferred to be early Wisconsin in age, the informal Verone drift was inferred to be early Wisconsin or pre-Wisconsin in age, and the informal Dunn drift was inferred to be pre-Wisconsin in age. The drifts of the three hypothetical glaciations were not distinguished on the basis of sedimentologic or stratigraphic criteria; the Verone and Dunn drifts were distinguished solely on the basis of the relative abundance of surface erratic boulders.

The morphology of end moraine and stagnation moraine deposits mapped as unit **txb** in this quadrangle is similar to that of end moraine and stagnation deposits assigned to the late Wisconsin Snow School Formation in northwestern North Dakota and the informal Crazy Horse till in northeastern Montana, in the adjacent Big Horn Mountains 4° x 6° quadrangle (table 2). Limestone and dolomite granules and pebbles at and very near the till surface in most places are intact. Erratic igneous and metamorphic clasts at and on the surface in most places are firm and intact; hornblende and biotite are the only minerals that are significantly decomposed. Soils developed in the till are the same as those developed in units **tlx** and **tlu** to the north and east in North Dakota. Also, stratigraphic sections and detailed records of auger holes and test holes in the region in which unit **txb** is mapped (Croft, 1970; Trapp, 1971; Randich, 1975; Ackerman, 1977; Groenewold and others, 1979) indicate that the youngest till is late Wisconsin in age.

Unmapped outwash deposits (**gg**) that head along the south margin of the belt of stagnation moraine between Garrison Reservoir and the Knife River merge with late Wisconsin slackwater lake and outwash deposits (**llf**) in the Knife River valley; the stagnation moraine and the ground moraine and stratified deposits farther south are products of a single glaciation (Benson, 1953). Fossiliferous marl enclosed in flowtill in the same belt of stagnation moraine 5 km west of the quadrangle boundary yielded a ^{14}C age of 11,200±300 B.P. (W-402; Benson, 1953; Rubin and Alexander, 1958). Somewhat younger ^{14}C ages were obtained from younger stagnation moraine (**tlx**) east of the Missouri River in Burleigh County, N. Dak. (10,100±300 and 9,990±300 B.P.; W-1434 and W-1436) and north of Garrison Reservoir in Ward County, N. Dak. (10,350±300 and 10,330±300 B.P.; W-1817 and W-1818) (Kume and Hansen, 1965; Levin and others, 1965; Pettyjohn, 1967; Moran and others, 1973). The ^{14}C age indicates that buried ice remained south of Garrison Reservoir as late as 11,200±300 B.P. That age, the nonintegrated drainage and sharpness of the hummocks in the stagnation moraine, and the morphologic relations of the stagnation moraine, ground moraine, and stratified deposits indicate that the Napoleon drift in that area is late Wisconsin in age (Groenewold and others, 1979).

The limit of late Wisconsin glaciation in North Dakota has not been defined by stratigraphic criteria. Published interpreted limits differ greatly. The limit on this map is merely a guess, based on surface morphology, ice-marginal drainage relationships, data from water wells, auger holes, and test borings, and published descriptions of deposits compiled by the editor. In some areas the limit may be farther southwest than shown

txb Ground moraine—Generally thin and patchy; thickness 0.5–4 m, locally more than 8 m

txb End moraine—Broad hummocky ridges or narrow sharply defined ridges; cobbles and boulders common to abundant on surface. Some narrow ridges in areas mapped as ground moraine or stagnation moraine are indicated by symbol. Thickness 4–10 m, locally more than 20 m

txb Stagnation moraine—Broad areas of hummocky collapsed topography lacking distinct morainal ridges. Nonintegrated drainage. Typically small hills separated by closed depressions; ephemeral ponds and marsh-filled sloughs and depressions common. Thickness 4–10 m

kg ICE-CONTACT SAND AND GRAVEL—Pale-yellow, brownish-yellow, grayish-yellow, reddish-brown, orange-brown, yellowish-brown, olive-brown, grayish-brown, brown, olive, olive-gray, yellowish-gray, brownish-gray, gray, black, or mottled calcareous sand and gravel with minor silt. Textures may vary laterally and vertically. Locally boulder or cobble gravel. Commonly interbedded with or contains lenses or masses of clay, silt, till, or flowtill. Poorly to well sorted; poorly to well stratified; irregularly bedded to well bedded. Faults, folds, slumps, and collapse structures common. Locally cemented by calcium carbonate in horizontal zones; local intense iron oxide stains on some clasts. Clasts subangular to well rounded; composition reflects that of local till. Typically shale is much less abundant than in till, but locally shale is very abundant. In most areas, pebbles dominantly erratic limestone, dolomite, and igneous and metamorphic rocks; minor locally derived sandstone, siltstone, claystone, shale, lignite, ironstone, and chert. Cobbles and boulders dominantly erratic limestone, dolomite, and igneous and metamorphic rocks; cobbles and boulders common on surface. Topography typically hummocky to knobby, or isolated mounds; commonly pitted with ice-block depressions. Occurs in kames, kame terraces, kame deltas, eskers, and ice-fracture fillings. Some eskers shown by symbol. Included in outwash sand and gravel (**gg**) in many areas. In South Dakota, in southeast quarter of quadrangle, may include some exhumed kame and kame terrace deposits of Illinoian or pre-Illinoian age. Includes some outwash sand and gravel (**gs**, **gg**), lake clay, silt, sand, and gravel (**lca**, **lss, lsa, lga**), lake delta

deposits (**ldb**), alluvium (**al**), till, and organic marsh deposits. Locally overlain by till or flowtill as thick as 5 m; in some areas overlain by eolian sand (**ed**, ***es***, ***el***). Thickness 3–20 m, locally more than 30 m

gs OUTWASH SAND—Pale-yellow, brownish-yellow, yellowish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled calcareous fine to coarse sand or silty sand with scattered pebbles and small cobbles; local beds of pebble or cobble gravel or lenses or thin beds of silt. Poorly to well stratified; poorly to well sorted. Bedding dominantly planar, but cut-and-fill crossbeds common. Chiefly quartz and feldspar grains. Clasts subangular to rounded, chiefly erratic limestone, dolomite, and igneous and metamorphic rocks; some local shale, ironstone, and chert. Grades laterally into outwash sand and gravel (**gg**). Occurs in terrace remnants and outwash plains and as meltwater channel fills. Surfaces may be smooth or pitted with ice-block depressions. Includes some alluvium (**al**), lake silt, sand, and gravel (**lss**, **lsa, lga**), and organic slough and marsh deposits. Locally veneered by thin eolian silt (***el***). Mapped only in Minnesota; included in outwash sand and gravel (**gg**) *else*where. Thickness 1–10 m

gg OUTWASH SAND AND GRAVEL—Pale-yellow, brownish-yellow, yellowish-brown, reddish-brown, orange-brown, olive-brown, grayish-brown, brown, olive, olive-gray, brownish-gray, gray, black, or mottled calcareous sand and gravel with some silt and clay. Stratified; poorly to well sorted. Sand typically with tabular or lenticular bedding; local cut-and-fill crossbeds. Gravel typically with horizontal bedding; commonly intercalated or interbedded with sand and silt. Local lenses or pockets of silt or clay; in places includes masses of flowtill or till. South and west of Missouri River, chiefly horizontally bedded sand and silt over sand and gravel. Iron oxide stains common; gravel locally cemented by secondary calcium carbonate or iron oxides. Cobbles and boulders common to abundant where outwash deposits head near end moraine deposits or ice-contact deposits. Clasts subangular to well rounded. Clast lithology varies with that of local bedrock and other surficial materials in vicinity. Clasts chiefly limestone, dolomite, granite, and shale; gneiss, schist, slate, sandstone, siltstone, claystone, ironstone, chert, or clinker common locally; lignite clasts common to abundant in some areas. Surfaces typically flat to undulating or gently rolling; locally pitted with ice-block depressions. Occurs in terrace remnants, valley trains, outwash plains, fans, and aprons, and as delta topset beds and meltwater channel fills. In southeastern part of quadrangle, includes areas of bouldery catastrophic flood deposits in abandoned outlet channels of glacial Lake Agassiz (Matsch, 1983). Includes some till, ice-contact sand and gravel (**kg**), ice-walled lake deposits (**lca**, **lss**), inset alluvium (**al**), and organic slough and marsh deposits. In many areas, overlain by eolian sand and silt (**ed**, ***es***, ***el***). Thickness 1–10 m, locally more than 30 m.

Much of the sand and gravel mapped as outwash in this quadrangle is early postglacial alluvium. Precipitation and runoff were greater than at present for several thousand years after initial deglaciation (Clayton, 1967), and glacial, ice-contact, glaciofluvial, and glaciolacustrine sediments were eroded and redeposited as alluvial fills. The surface morphology, lithology, and sedimentary structures of the outwash and early postglacial alluvium are similar and the deposits have not been distinguished on published maps

lda LAKE DENSITY—CURRENT UNDERFLOW FAN DEPOSIT—Pale-yellow, grayish-yellow, yellowish-brown, brown, brownish-gray, olive-gray, gray, or mottled calcareous silt, sand, and gravel. Well stratified; generally well sorted. Chiefly laminated silt and very fine sand interbedded with thin layers of clay or fine to coarse sand. West margin of deposit locally coarse sand and fine gravel. Average grain size decreases from west to east and from top to bottom. Foreset beds absent; basal sediments typically are clay, but are not delta bottomset beds. Silt and sand crossbedded or horizontally bedded; ripple-drift lamination common. Strongly contorted, with hummocky collapse topography, where sediments were deposited on stagnant or dead ice. Clasts chiefly granules and pebbles of shale and mixed lithologies derived from surficial sediments and bedrock eroded by glacial lake drainage. Subaqueous fan formed where drainage from glacial Lake Souris entered glacial Lake Agassiz in southeast corner of North Dakota (Brophy and Bluemle, 1983; Fenton and others, 1983). In many areas, fan deposits are overlain by shore and nearshore lake sand and gravel (**lsa**) in beaches and offshore bars and by sheet sand distributed by waves and currents after deposition of underflow fan sediments. Fan deposits and shore and nearshore lake sand and gravel commonly overlain by eolian sand and silt (**ed**, ***es***, ***el***). Thickness 3–30 m, locally 60 m

ldb LAKE DELTA DEPOSIT—Pale-yellow, grayish-yellow, yellowish-brown, brown, brownish-gray, olive-gray, or mottled calcareous gravel, sand, silt, and clay. Well stratified; generally well sorted. Sand and some gravel along proximal margins of deltas, grading to silt and fine sand interbedded with clay in distal areas. Bottomset beds clay; horizontal and foreset bedding common in gravel and sand; crossbedding common in sand and silt. Average grain size generally decreases downward and from apex to distal margin. Clasts chiefly shale and mixed lithologies derived from surficial deposits in source drainage basins. Includes some lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**) and alluvium (**al**). Locally overlain by eolian sand and silt (**ed**, ***es***, ***el***). Mapped in basin of glacial Lake Dakota in northeastern South Dakota. Thickness 3–10 m, locally more than 18 m

llf SLACKWATER LAKE DEPOSITS AND OUTWASH SAND AND GRAVEL—Yellowish-brown, grayish-brown, brown, olive, olive-gray, brownish-gray, gray, or mottled clay, silt, sand, and gravel in remnants of superposed valley fills west of Missouri River and south of Garrison Reservoir. Calcareous; stratified. Includes inset alluvium (**al**). Commonly overlain by sheetwash alluvium (**wla**) or eolian sand and silt (**ed**, ***es***, ***el***). Thickness 2–9 m

Youngest fill—Moderately well sorted to well-sorted, horizontally bedded outwash gravel and coarse sand (**gg**). Clasts dominantly pebbles, cobbles, and boulders of erratic limestone, dolomite, granite, granodiorite, gneiss, schist, and amphibolite; minor local bedrock lithologies. Present only locally

Intermediate fill—Dominantly either uniform coarse silt and very fine sand or moderately well sorted to well-sorted, laminated, fine to coarse sand, silty sand, and silt interbedded with medium and coarse sand. Layers and lenses of lignitic sand, clay, or silt common; local gravel lenses. Uppermost 0.3–1.2 m locally churned by frost action and soil creep. Clasts chiefly granules and pebbles of sandstone, siltstone, claystone, silcrete, shale, ironstone, lignite, clinker, and chert derived from local bedrock. More extensive areally than younger and older fills. Chiefly a slackwater lake deposit

Oldest fill—Moderately well sorted to well-sorted, horizontally bedded or crossbedded outwash sand and gravel (**gg**). In places, partly cemented by iron oxides. Clast lithologies similar to those in youngest fill. Locally overlain by discontinuous till (**txb**) or flowtill

nld LOAMY SOLIFLUCTION DEPOSIT[4]—Yellowish-brown, grayish-brown, brown, brownish-gray, gray, or mottled sandy loam, loam, silt loam, clay loam, and silty clay. Generally calcareous. Poorly stratified or nonstratified; poorly sorted or nonsorted. Typically faintly stratified with scattered granules and pebbles; cobbles and boulders common in places. Locally massive with few or no rock fragments. Chiefly reworked till (**tlx**). Typically occurs in apronlike deposits at bases of slopes. Includes areas of till (**tlx**) and sheetwash alluvium (**wla**); includes some mudflow deposits similar to those in unit **jea**. Mapped in southern part of James lobe area northeast of Missouri River. Thickness 2–4 m

LATE WISCONSIN TO PLIOCENE(?)

alq ALLUVIAL GRAVEL, SAND, AND SILT—Reddish-brown, yellowish-brown, brown, olive, yellowish-gray, brownish-gray, olive-gray, gray, or mottled gravel, sand, and silt. Generally calcareous where not leached. Stratified; chiefly either well-sorted sand and silt, moderately well sorted pebbly sand with thin beds and lenses of gravel, poorly sorted pebble and cobble gravel, or poorly sorted gravel, sand, and silt, all typically overlain by bedded or massive silt or sandy silt. Gravel locally cemented by secondary calcium carbonate or by iron or manganese oxides. In unglaciated region, clasts chiefly angular to rounded ironstone, sandstone, siltstone, claystone, shale, and silcrete and minor silicified wood, chert, chalcedony, and clinker derived from local bedrock; some granite, felsite, porphyry, feldspar, and phyllite from Black Hills region west of quadrangle. In glaciated region, clasts also may include subrounded and rounded pebbles, cobbles, and boulders of erratic granite, granodiorite, gneiss, schist, amphibolite, limestone, and dolomite. Occurs in terrace remnants in drainage basin of Cannonball River, west of Missouri River. Stratigraphy locally complex, including multiple superposed units of channel and flood-plain alluvium, slackwater lake deposits, eolian sand and silt, sheetwash alluvium, and buried paleosols. Includes some younger alluvium (**al**), landslide deposits (**jea**), disintegration residuum, sheetwash alluvium and colluvium (**xln**, **xlo**, **xlp**), and bedrock outcrops. Commonly overlain by sheetwash alluvium (**wla**) and eolian sand and silt (**ed**, ***es***, ***el***). Thickness 1.5–3 m, locally more than 5 m

agu ALLUVIAL GRAVEL, SAND, SILT, AND CLAY—Reddish-brown, yellowish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled gravel, sand, silt, and clay. Generally calcareous where not leached; arkosic, subarkosic, or quartzose. Poorly to well sorted; poorly to well stratified. Crossbedded or with horizontal or lenticular bedding. Clasts dominantly granules and pebbles; cobbles and small boulders more common in older (higher) terrace remnants. Clasts chiefly angular to well-rounded ironstone and limestone concretions, sandstone, orthoquartzite, limestone, siltstone, shale, conglomerate, chert, flint, vein quartz, agate, chalcedony, silicified wood, jasper derived from local bedrock. Some clasts of feldspar, granite, felsite, porphyry, phyllite, quartzite, and other igneous and metamorphic lithologies from Black Hills region west of quadrangle. Clinker clasts common locally in Grand River drainage basin. In glaciated region, clasts may include boulders, cobbles, and pebbles of erratic limestone, dolomite, granite, granodiorite, greenstone, gneiss, and schist. Occurs in terrace remnants as much as 140 m higher than flood plains of Grand, Moreau, and Cheyenne Rivers and tributaries in South Dakota west of Missouri River. Stratigraphy locally complex, including multiple superposed units of flood-plain and channel alluvium, sheetwash alluvium, slackwater lake deposits, eolian sand and silt, and buried paleosols. Landslide deposits common below risers of terrace remnants. Areal extent greatly exaggerated in parts of Cheyenne River drainage basin, where unit includes large areas of disintegration residuum, sheetwash alluvium, and colluvium (**xce**, **xcf**, **xcg**, **xln)**, landslide deposits (**jca**, **jcb**), younger alluvium (**al**), and bedrock. Commonly overlain by eolian sand and silt (**ed**, **es**, ***el***, ***elb***) 0.2–5 m thick; locally overlain by sheetwash alluvium (**wla**). Thickness 2–9 m, locally 15 m

alo ALLUVIAL SAND AND GRAVEL—Reddish-brown, yellowish-brown, brown, yellowish-gray, brownish-gray, gray or mottled sand and granule or pebble gravel with minor silt and clay. Generally calcareous where not leached. Poorly to well stratified; poorly to well sorted. Crossbedded or with horizontal or lenticular bedding. Generally loose or weakly compacted. Most deposits derived from present drainage basin; igneous and metamorphic rocks from Black Hills region to west rare or absent. Clasts dominantly angular to well-rounded granules and pebbles; cobbles and small boulders more common in older (higher) terrace remnants. Clasts chiefly ironstone and limestone concretions, chert, chalcedony, and vein quartz; minor orthoquartzite, sandstone, siltstone, and shale. In glaciated region, clasts may include boulders, cobbles, and pebbles of erratic limestone, dolomite, granite, granodiorite, basalt, gabbro, greenstone, gneiss, and schist. Occurs in terrace remnants in drainage basin of Bad River in southwest corner of quadrangle. Stratigraphy locally complex, including multiple superposed units of flood-plain and channel alluvium, sheetwash alluvium, slackwater lake deposits, and eolian sand and silt and buried paleosols. Landslide deposits common below risers of terrace remnants. Areal extent greatly exaggerated west of limit of glaciation, where unit includes large areas of disintegration residuum and sheetwash alluvium (**xce**), landslide deposits (**jca**), younger alluvium (**al**), and bedrock. Commonly overlain by eolian sand and silt (**el**, **es**, **ed**, **elb**) 0.2–5 m thick; locally overlain by sheetwash alluvium (**wla**). Thickness 2–9 m, locally 15 m

ILLINOIAN

tll LOAMY TILL ("Iowan" till in South Dakota and Minnesota)—Grayish-orange, pale-yellow, brownish-yellow, yellowish-brown, olive-brown, brown, brownish-gray, olive-gray, bluish-gray, blackish-gray, gray, or mottled silt loam and loam. Generally calcareous; locally leached to depth of more than 1 m where not covered by eolian silt. More intensely oxidized than units **tla**, **tlg**, or **tlx**; oxidized throughout in most exposures. Nonstratified; nonsorted or very poorly sorted. In places contains lenses, pods, and stringers of stratified silt, sand, and gravel. Generally compact, but not tough; locally friable or crumbly. Where compact, till is weakly to strongly jointed; joint fillings of calcium carbonate and iron and magnesium oxides common. Calcium carbonate coatings on pebble surfaces in some areas. Sparingly pebbly to very pebbly; scattered cobbles and boulders. Pebbles chiefly subangular to rounded limestone and dolomite less than 1 cm in diameter; lesser granite, gneiss, schist, diorite, basalt, quartzite, slate, sandstone, shale, ironstone, and chert. Cobbles and boulders chiefly subrounded limestone, dolomite, and granite. Clay minerals dominantly expandable minerals (smectite). Well-integrated drainage; smooth, undulating to gently rolling topography with swales and broad shallow depressions. Markedly more dissected than units **tla**, **tlg**, and **tlx**. Includes subdued, eroded remnants of end moraine and small eroded remnants of

pre-Wisconsin outwash and ice-contact gravel, sand, and silt. Pre-Illinoian loamy till, mapped in adjacent Minneapolis, Des Moines, and Platte River 4° x 6° quadrangles, locally is exposed beneath unit **tll**. Includes areas of alluvium (**al**), sheetwash alluvium (**wla**), outwash and ice-contact sand and gravel (**gg**, **kg**), and lake clay, silt, sand, and gravel (**lca**, **lss**, **lsa**). Commonly covered by eolian silt (**el**) 1–10 m thick. Till currently is interpreted to be Illinoian in age (Lehr and Gilbertson, 1988). Thickness 2–12 m, locally more than 30 m

ILLIN0IAN AND PRE-ILLINOIAN(?)

txc DISCONTINUOUS CLAYEY TO SANDY TILL, GLACIOFLUVIAL DEPOSITS, AND ERRATIC BOULDER CONCENTRATIONS—Glacial and glaciofluvial deposits on present drainage divides and upland surfaces. At least some deposits in South Dakota are older than alluvium (**agu**) in a terrace remnant more than 100 m higher than flood plain of present Grand River (Stevenson, 1960). May include deposits of more than one glaciation (table 2). Discontinuous; includes areas of disintegration residuum, sheetwash alluvium, and colluvium (**xcg**, **xlm**, **xlp**, **xls**, **xlb**, **xsd**), alluvium (**alq**, **agu**, **ago**), landslide deposits (**jea**, **jcc**), and bedrock. Commonly overlain by thin or discontinuous eolian sand and silt (**es**, **el**, **elb**)

Till—Reddish-brown, yellowish-brown, brown, yellowish-gray, or gray clay, silty clay, clay loam, silt loam, loam, sandy loam, or loamy sand. Generally weakly calcareous at depth; generally oxidized throughout. Nonstratified; nonsorted or very poorly sorted. Locally strongly jointed, with intense iron and manganese oxide stains and crusts on joint surfaces. Typically stony; abundant pebbles, cobbles, and boulders of erratic granite, granodiorite, greenstone, gneiss, schist, diorite, gabbro, and amphibolite. Pebbles and granules of limestone and dolomite present at depth in some places but cobbles and boulders of limestone and dolomite rare or absent. Thickness 0.2–2 m, locally more than 3 m

Glaciofluvial deposits—Reddish-brown, yellowish-brown, yellowish-gray, or gray outwash silt, sand, and gravel. In some areas, chiefly crossbedded silt and fine to medium sand with interbeds and lenses of coarse sand and gravel; in other areas, chiefly granule or pebble gravel with minor sand. Cobbles and boulders common to abundant. Clasts dominantly subrounded or rounded erratic granite, greenstone, granodiorite, gneiss, diorite, gabbro, and amphibolite (50–67 percent igneous and 7–13 percent metamorphic lithologies) and minor angular to rounded, locally derived, ironstone, sandstone, and orthoquartzite. In places, cemented by iron and manganese oxides. Locally deposit consists of two superposed stratigraphic units of similar materials separated by a pronounced erosional unconformity. Thickness 0.2–2 m

Boulder concentrations—Rubbly deposits of boulders, cobbles, and minor pebbles in a silty or sandy matrix, commonly directly overlying bedrock. Clasts typically 97–98 percent erratic granite, greenstone, gneiss, schist, gabbro, diorite, and amphibolite. Typically fewer than 1 percent of cobbles and boulders are dolomite or limestone; locally pebble fraction at depth is 10–15 percent dolomite and limestone. Boulders subangular to rounded, as large as 3 m in diameter; some boulders and cobbles striated. Most clasts are embedded in matrix; typically, only upper surfaces of boulders are exposed; where boulders are not embedded, matrix commonly has been removed by deflation. In many areas, entire deposit is covered by eolian silt (**el**, **elb**) 0.2–1.5 m thick. Carbonate clasts are preserved only where protected by enclosing matrix. Where not enclosed in matrix or not covered by silt, minerals in coarse-grained igneous and metamorphic boulders typically are intensely weathered; some clasts are partly decomposed. Many deposits are aligned in distinct northwest-southeast patterns on present drainage divides. Some may have been formed as "boulder belts" by glacial ice; others may be lag concentrations derived from till. In South Dakota, deposits have been referred to as "till residuum," "boulder till residuum," or the "Miscol till residuum" (Stevenson, 1957, 1959a, 1959b, 1960; Pettyjohn, 1961). Those deposits probably are late Pliocene in age. Only the most extensive boulder concentrations are mapped; less extensive concentrations are included in disintegration residuum, sheetwash alluvium, colluvium, and glacial deposits (**xcg**, **xlm**, **xlp**, **xls**, **xld**, **xsd**). Thickness 0.3–2 m

PRE-PLIOCENE

Rb DISSECTED BEDROCK (BADLANDS)—Dominantly dissected, barren bedrock eroded by sheetwash and sheet floods. Fifty to 95 percent of area typically is bedrock. Erosional topography typically narrow crested or rounded ridges or isolated, rounded hills of bedrock, Erosional landforms are

separated by narrow, steep gullies and ravines graded to broader valley floors. All minor streams are intermittent; sediments were transported chiefly during flash floods. Typically, 80 percent or more of surface is slopes steeper than 20° many slopes are steeper than 40°. Slopes steeper than 20° have little or no disintegration residuum cover and little or no vegetation. Slopes between 8° and 20° commonly have a thin or discontinuous, grass-covered mantle of disintegration residuum. Slopes more gentle than 8° commonly are covered by fans and aprons of sheetwash alluvium (**wla**) or small deposits of fan sand and gravel. Some slopes terminate in miniature pediments. Narrow deposits of coarser channel alluvium (**al**) are inset into sheetwash alluvium on broader gully and ravine floors. Surfaces of erosional landforms locally are covered by thin, patchy, alluvial sand and gravel, lag granules, pebbles, and cobbles, or eolian sand and silt. The sod-covered disintegration residuum on the summits of many erosional remnants is more resistant than the bedrock, and the sod protects the summits from erosion. Includes local landslide deposits (**jea**) and minor colluvium on slopes below sandstone ledges. Mapped only in selected areas

R BEDROCK

[1]Sheetwash alluvium, for purposes of this map, is material transported and deposited by unconfined running water, chiefly sheetflow and rill wash.

[2]Disintegration residuum, for purposes of this map, is material derived by in-place mechanical disaggregation of clastic bedrock, with no appreciable lateral transport. Upland surfaces west of the Missouri River in this quadrangle were intensely deflated during the late Pleistocene. The residuum commonly is less than 60 cm thick, and pedologic soils typically extend through the residuum to bedrock. The colors, textures, structures, and most other descriptive aspects of the materials are chiefly products of pedogenesis, rather than mechanical disaggregation of the bedrock.

[3]Colluvium, for purposes of this map, is material transported and deposited by slow mass-wasting processes, chiefly creep

[4]Solifluction deposit, for purposes of this map, is a general term for material transported and deposited by viscous flow of unconsolidated debris saturated with water.

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