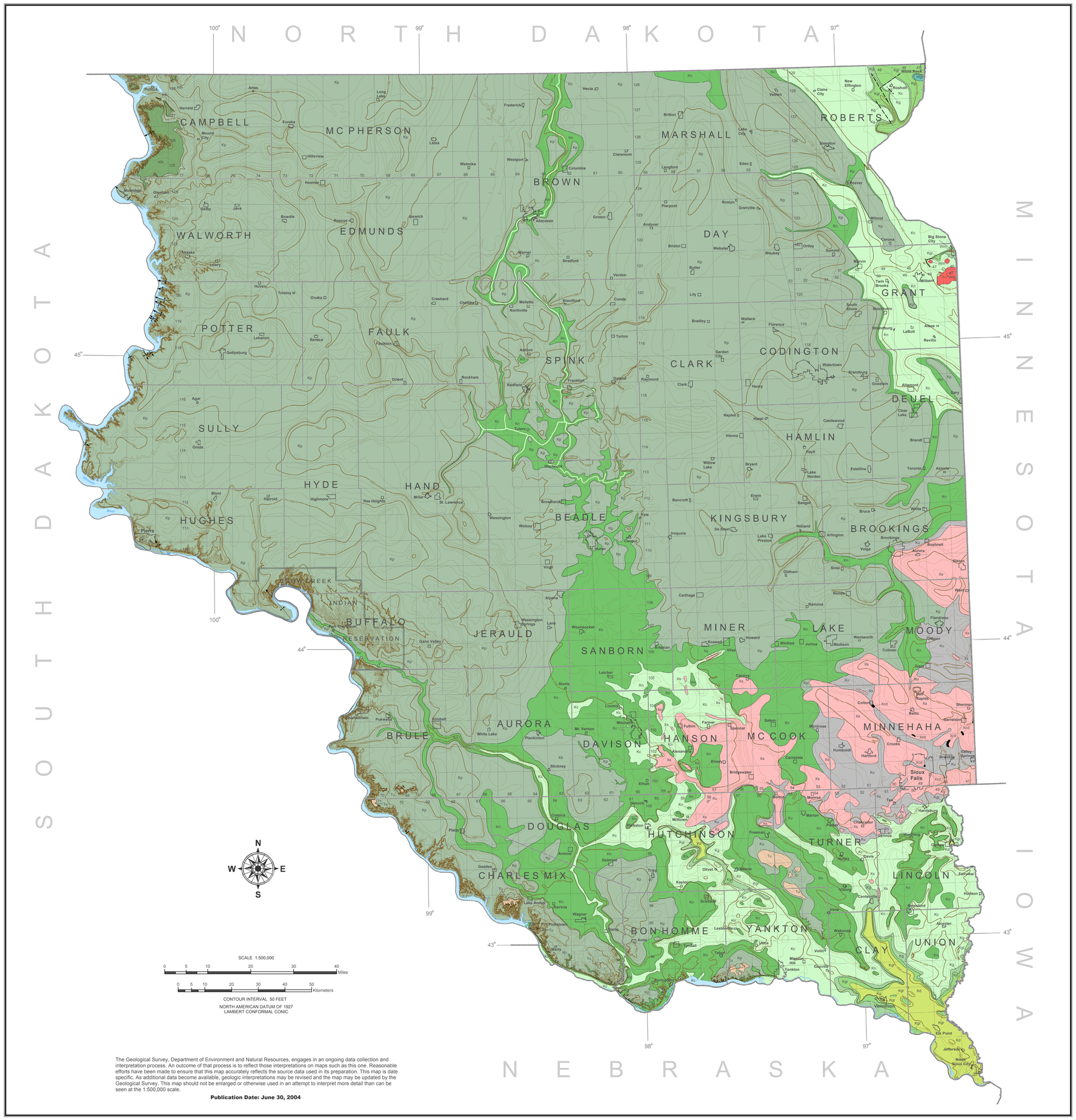


SCALE 1:500,000

0 5 10 20 30 40 Miles

0 5 10 20 30 40 50 Kilometers

CONTOUR INTERVAL 50 FEET

NORTH AMERICAN DATUM OF 1927
LAMBERT CONFORMAL CONIC

The Geological Survey, Department of Environment and Natural Resources, engages in an ongoing data collection and interpretation process. An outcome of that process is to reflect those interpretations on maps such as this one. Reasonable efforts have been made to ensure that this map accurately reflects the source data used in its preparation. This map is date specific. As additional data become available, geologic interpretations may be revised and the map may be updated by the Geological Survey. This map should not be enlarged or otherwise used in an attempt to interpret more detail than can be seen at the 1:500,000 scale.

Publication Date: June 30, 2004

DESCRIPTION OF MAP UNITS

(Order of rock description does not always indicate stratigraphic position; refer to correlation chart)

Tu — **Tertiary, undifferentiated** (Pliocene to Miocene) - Light greenish-brown and light yellowish-tan to orangish-brown clay, silty clay, and fine sand; light-brown to pink siltstone; green, massive, orthoquartzite conglomerate; and multicolored quartz- and feldspar-rich sand and gravel. Includes equivalents of the Ogallala Group Ash Hollow, Valentine, and Fort Randall Formations. Also includes the Thin Elk, Bon Homme, Herrick, Medicine Root, and "western derived" gravels. Thickness up to 70 ft (21 m).

Kfh — **Fox Hills Sandstone** (Upper Cretaceous) - Bluish-green to green, white to dark-gray, and yellow to tan, carbonaceous and iron-stained, cross-bedded, very fine- to coarse-grained, glauconitic sandstone and siltstone. Interbedded with gray and green to brown shale and silty shale. Thickness up to 200 ft (61 m).

Kp — **Pierre Shale** (Upper Cretaceous) - Blue-gray to dark-gray, fissile to blocky shale with persistent beds of bentonite, black organic shale, and light-brown chalky shale. Contains minor sandstone, conglomerate, and abundant carbonate and ferruginous concretions. Thickness up to 1,000 ft (305 m).

Kn — **Niobrara Formation** (Upper Cretaceous) - White to dark-gray argillaceous chalk, marl, and shale. Weathers yellow to orange. Contains thin, laterally continuous bentonite beds, chalky carbonaceous shale, minor sand, and small concretions. Thickness up to 150 ft (46 m).

Kc — **Carlile Shale** (Upper Cretaceous) - Dark-gray to black, silty to sandy shale with several zones of septarian, fossiliferous, carbonate concretions. Contains up to three sandstone units in the upper portion of the formation and sandy calcareous marl at the base. Thickness up to 330 ft (100 m).

Kg — **Greenhorn Formation** (Upper Cretaceous) - Gray shale, mudstone, marl, calcarenite, and shaly limestone grading upward into light-gray to tan, alternating marl and thin-bedded, fossiliferous limestone. Thickness up to 40 ft (12 m).

Kgr — **Graneros Shale** (Upper Cretaceous) - Dark-gray, noncalcareous, pyritic, poorly fossiliferous shale, with numerous sandstone layers at the base. Thickness up to 110 ft (36 m).

Kd — **Dakota Formation** (Upper to Lower Cretaceous) - Light- to reddish-brown, medium- to coarse-grained quartz and minor feldspar sandstone grading upward to a fine- to medium-grained, quartz and minor feldspar sandstone. Contains a middle, gray silty clay unit, and interbeds of gray to dark-gray shale in the upper portion. Thickness up to 450 ft (137 m).

Ku — **Cretaceous, undifferentiated** (Upper to Lower Cretaceous) - Black opaline spiculite, gray to black shale, yellow-brown to gray chalk, gray silty clay, and pink quartz-rich sandstone. Includes the Split Rock Creek Formation and other near-shore facies of the Dakota Formation, Graneros Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, and Pierre Shale. Thickness up to 400 ft (122 m).

Xcd — **Corson Diabase** (Lower Proterozoic) - Black, intermediate- to coarse-grained diabase composed of plagioclase, pyroxene, and olivine.

Xs — **Sioux Quartzite** (Lower Proterozoic) - Pink and reddish to tan, siliceous, fine- to coarse-grained, iron-stained orthoquartzite with minor metamorphosed conglomerate and mudstone layers. Estimated thickness greater than 1,000 ft (305 m).

Wgr — **Granite** (Upper Archean) - Felsic coarse-grained granite, includes white, silty clay weathering residuum which grades downward to a pink, white, and gray siltstone.

Wm — **Milbank Granite** (Upper Archean) - Pink to dark-red, coarse-grained granite composed of orthoclase, quartz, and biotite.

SYMBOLS

CONTACT

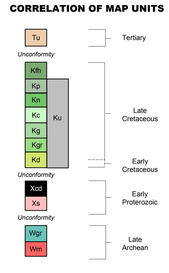
FAULT - Location of fault. Bar and ball on downthrown side. Dashed where approximate.

FOLD LINES - Location of fold. Arrow on fold axis indicates direction of plunge. Dashed where inferred.

ANTICLINE

SYNCLINE

CORRELATION OF MAP UNITS



South Dakota Department of Environment & Natural Resources — Geological Survey

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DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Steven M. Pirner, Secretary

DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
David Templeton, Director

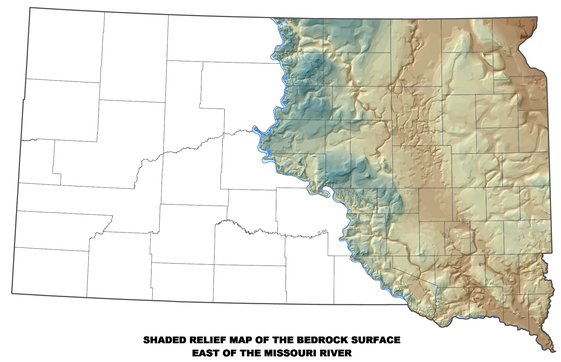
GEOLOGICAL SURVEY
Derric L. Iles, State Geologist

Bedrock Geologic Map Showing Configuration of the Bedrock Surface in South Dakota East of the Missouri River

Dennis W. Tomhave and Layne D. Schulz

2004

MAP AREA



SHADED RELIEF MAP OF THE BEDROCK SURFACE EAST OF THE MISSOURI RIVER

DISCUSSION

The mapped area is within the glaciated part of South Dakota, east of the Missouri River. The bedrock surface is mantled by Pleistocene-age glacial sediment of many glacial stages throughout most of the map area. The mantle includes loess which overlies the glacial sediment in many areas. Additionally, the mantle locally includes Holocene-age alluvial, colluvial, and lacustrine sediments. This combined overburden ranges from a thin veneer to more than 1,000 feet thick on the Coteau des Prairies in northeastern South Dakota.

Bedrock deposits shown on the map include, from oldest to youngest: Late Archean- to Early Proterozoic-age Milbank Granite, Granite, Sioux Quartzite, and Corson Diabase; Late Cretaceous-age Dakota Formation, Graneros Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, Pierre Shale, and Fox Hills Sandstone; and undifferentiated Tertiary-age sediment (Ogallala Group formations are included in this map unit). In areas surrounding or near the Sioux Quartzite on the map, a variety of unidentified Late Cretaceous facies are encountered which are mapped as Cretaceous, undifferentiated (Split Rock Creek Formation is included in this map unit).

Bedrock crops out along the Missouri River bluffs, along many rivers and creeks, and other areas where the glacial sediment has been removed by erosion. Milbank Granite crops out in Grant County. Sioux Quartzite crops out in Davison, Hanson, Minnehaha, McCook, and Turner Counties. Corson Diabase crops out in Minnehaha County. Greenhorn Formation crops out in Union and Grant Counties. Carlile Shale crops out in Clay, Davison, Hanson, Roberts, and Union Counties. Niobrara Formation crops out in Bon Homme, Brule, Buffalo, Charles Mix, Clay, Davison, Hanson, Jerauld, Lincoln, Roberts, and Yankton Counties. Pierre Shale crops out in Bon Homme, Brown, Brule, Buffalo, Campbell, Charles Mix, Clay, Davison, Day, Edmunds, Hughes, Hyde, Jerauld, Marshall, McPherson, Potter, Roberts, Spink, Sully, Walworth, and Yankton Counties. Undifferentiated Late Cretaceous sediment crops out in Minnehaha, McCook, and Turner Counties. Undifferentiated Tertiary sediment crops out in Bon Homme, Brule, Charles Mix, Jerauld, and Yankton Counties.

The topography of the bedrock surface is the result of a complex preglacial and glacial history. Prior to glaciation, the mapped area was drained by a network of well-developed river systems, and would resemble much of the land west of the Missouri River as it is today. Rivers such as the Grand, Moreau, and Cheyenne were tributaries of an ancestral river which flowed east to the James River lowland, then north to the Red River lowland, and on to Hudson Bay. Rivers such as the Bad and White were tributaries of an ancestral river system which flowed southeast to the Mississippi River valley and on to the Gulf of Mexico. Glaciation changed the landscape with glaciers scouring the land surface and meltwater streams cutting deeply incised channels in some of the ancestral river valleys. These deep channels are very narrow, at times less than a quarter of a mile wide. Bedrock elevations of less than 900 feet are common in the north-central and southeastern portions of the mapped area. No attempt was made to completely contour these deep channels. The Missouri River valley is an example of a deeply incised ice-marginal meltwater channel. Early glaciation did extend westward across the Missouri River valley, evidenced only by isolated deposits and sparse erratics.

Sources of data used in compiling the map include the following: (1) Lithologic logs of test holes and wells on file with the Geological Survey and Water Rights Programs, Department of Environment and Natural Resources; (2) Published and unpublished geologic maps of the Geological Survey Program, Department of Environment and Natural Resources; and (3) U.S. Geological Survey 1:24,000 scale digital elevation data.

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