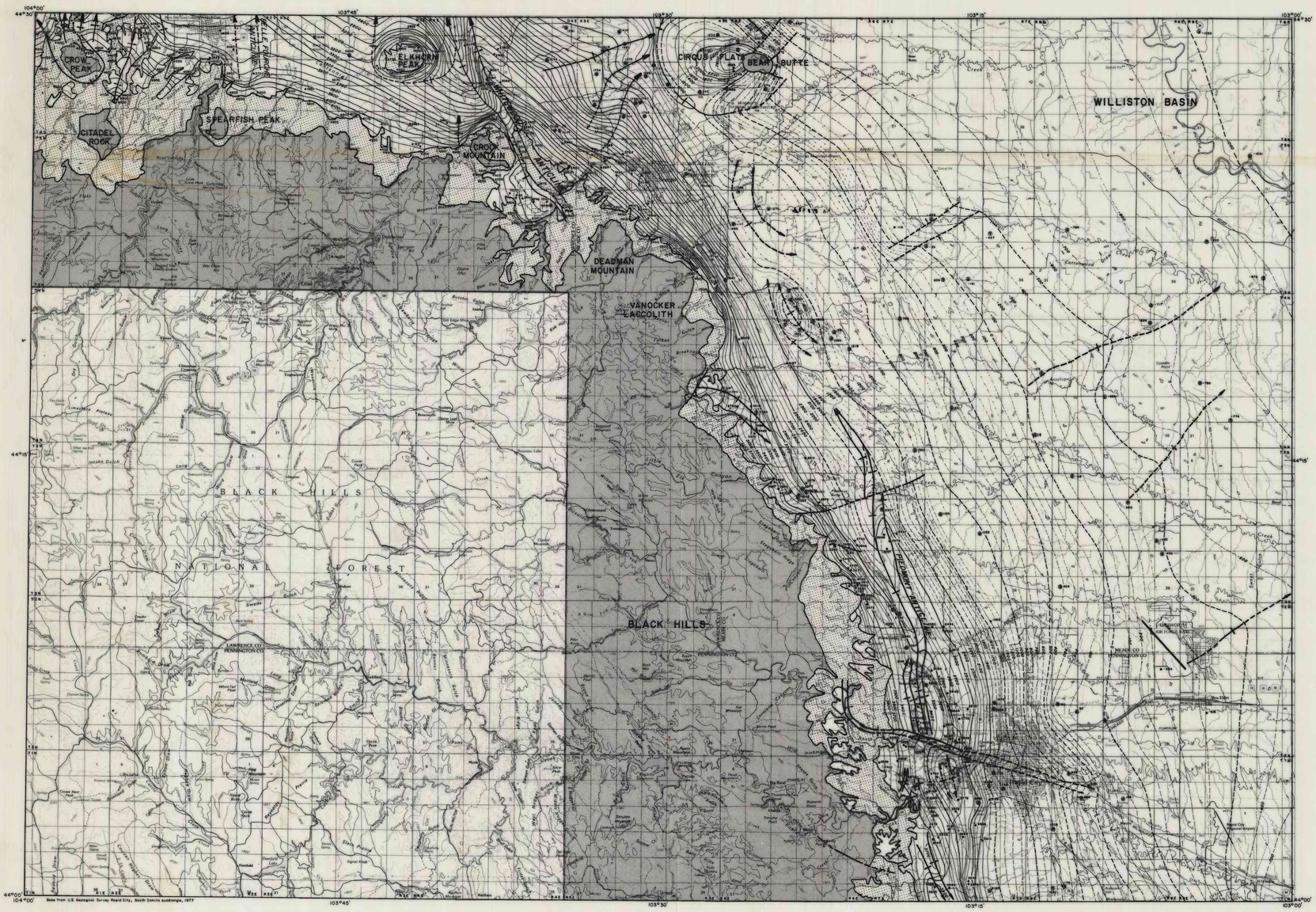
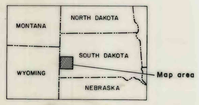
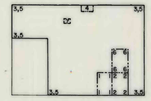
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the
SOUTH DAKOTA DEPARTMENT OF WATER AND NATURAL RESOURCES
and the
BLACK HILLS CONSERVANCY SUBDISTRICT

WATER RESOURCES INVESTIGATIONS
REPORT 85-4233







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GEOLOGIC STRUCTURE AND ALTITUDE OF THE TOP OF THE MINNELUSA FORMATION, NORTHEASTERN BLACK HILLS, SOUTH DAKOTA

by

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1985

INTRODUCTION

The U.S. Geological Survey, in cooperation with the South Dakota Department of Water and Natural Resources and the Black Hills Conservancy Sub-District, began an investigation of the sedimentary aquifers in the Black Hills in 1981 in anticipation of increased use of ground water for municipal and industrial supply. The purpose of the 3-year project was to determine the availability and quality of ground water in the sedimentary bedrock aquifers in the Black Hills of South Dakota and Wyoming. The project was limited to three bedrock units, which are in order of increasing age: the Cretaceous Inyan Kara Group, Permian and Pennsylvanian Minnelusa Formation, and Mississippian Madison (or Pahasapa) Limestone.

This map was prepared as a result of the project to show the geologic structures and the altitude of the top of the Minnelusa Formation in the northeastern Black Hills. It can be used in conjunction with topographic maps to estimate the approximate depth to the Minnelusa Formation at a specific site. The Minnelusa Formation was mapped because it is the deepest aquifer with an extensive data base. A similar map for the northern Black Hills and Bear Lodge Mountains also has been prepared (Peter and others, 1987).

SOURCES OF DATA

The geologic data used to compile this map were obtained from geologic maps and logs of water wells and oil-and-gas exploration wells. This information is on file in offices of the South Dakota Department of Water and Natural Resources in Pierre, South Dakota, and the U.S. Geological Survey in Rapid City, South Dakota. The data were derived from interpretation of drillers' logs and geophysical logs of the wells. In areas where there were no wells penetrating the Minnelusa Formation, the depth to the top of the Minnelusa was estimated from logs of shallow wells and from maps of surface geology. The depth to a shallower geologic unit, usually the Cretaceous Fall River Formation of the Inyan Kara Group, was added to the thickness of the geologic formations between the shallow unit and the top of the Minnelusa Formation to obtain an estimate of the depth to the top of the Minnelusa. Thicknesses measured in the nearest well were used in the estimates because some geologic formations vary in thickness more than 100 ft within the study area. The location of many of the well sites was field verified during the study. The altitude of the land surface was obtained from topographic maps with contour intervals varying from 10 to 40 ft.

GEOLOGIC STRUCTURE

This map shows the configuration of the structural features in the northeastern Black Hills. The Black Hills are surface features of the Black Hills uplift, an irregular, dome-shaped anticlinal uplift trending northwest and formed during the Laramide orogeny.

The Minnelusa Formation, as well as most of the other geologic units, has been folded within and near the Black Hills uplift into anticlines, synclines, and monoclines. Two large anticlines, the Belle Fourche and the Whitewood, terminate in the northern Black Hills in the northern part of the study area. The Whitewood anticline is the largest of the two, extending as much as 40 mi to the north, outside the study area (Lisenbee, 1983).

Smaller anticlines and synclines parallel the Minnelusa Formation outcrop in the eastern Black Hills. The longest of these, the Piedmont anticline in T. 2 N. and T. 3 N., R. 7 E., extends from Rapid City to Piedmont, where it is offset by a fault (Lisenbee, 1983). Two smaller folds northeast of Tilford, in T. 4 N. and T. 3 N., R. 6 E., were interpreted from logs of units shallower than the Minnelusa Formation. There are no wells penetrating the Minnelusa Formation in the vicinity of these two small folds and, as a result, their location and configuration are only approximated.

A monocline trending nearly east transects the Minnelusa west of Rapid City in T. 1 N., R. 7 E. (Cattermole, 1969). This monocline may extend east of Rapid City, approximately parallel to Rapid Creek, based on projected depths to the Minnelusa Formation using logs of wells penetrating shallower units.

Domal structures and many peaks in the northern part of the study area are formed by Tertiary intrusive rocks. The most evident of these are Crow Peak, Citadel Rock, Spearfish Peak, Elkhorn Peak, Crook Mountain, Circus Flats, Bear Butte, and Deadman Mountain. Specifically, Circus Flats and Bear Butte form the Circus Flat Laccolithic Complex and Deadman Mountain is part of the Vanocker Laccolithic Complex (Lisenbee, 1983). These two complexes are the largest of the intrusive bodies in the study area.

Faults do not appear to be common features in the northeastern Black Hills. The Victoria Creek fault is southwest of Rapid City in T. 1 N., R. 6 E., and R. 7 E. (Cattermole, 1969), and is the longest fault in the study area. A fault in T. 3 N., R. 6 E. and R. 7 E. appears to displace the Piedmont anticline, based on outcrop patterns (Lisenbee, 1983). Shorter faults of large (more than 300 ft) displacement radiate from Bear Butte (DeWitt, 1973). Faults may occur at depth along the northeastern boundary of the Vanocker Laccolithic Complex, southeast of Sturgis, in an area where the Minnelusa Formation is steeply dipping. There are inadequate data to test this hypothesis; however, a steep potentiometric gradient in the Minnelusa aquifer, that is formed by the upper part of the Minnelusa Formation, indicates there is some kind of discontinuity (U.S. Geological Survey, unpublished records, Rapid City, S. Dak.). Similarly, a steep gradient in the potentiometric surface of the Madison aquifer, which is formed by the Madison Limestone, indicates a discontinuity in the eastern part of Rapid City; however, the Minnelusa Formation appears not to be significantly faulted in the Rapid City area (U.S. Geological Survey, unpublished records, Rapid City, S. Dak.).

ALTITUDE OF THE TOP OF THE MINNELUSA FORMATION

The Minnelusa Formation generally dips northeasterly, from the Black Hills uplift into the Williston basin. The rock units dip more steeply than does the land surface. As a result, although the top of the formation crops out in the Black Hills at an altitude of about 3,600 to 4,300 ft above sea level, it is about 1,000 ft below sea level, or about 3,600 ft below land surface in the northeastern corner of the study area.

LITHOLOGY OF THE MINNELUSA FORMATION

The upper 250 to 300 ft of the Minnelusa Formation is Permian in age and the remainder is Pennsylvanian in age (Robinson and others, 1964, p. 8). The formation consists of interbedded sandstone, sandy dolomite and limestone, shale, siltstone, gypsum, and anhydrite.

The Minnelusa Formation is overlain by the Opeche Formation or Shale and is underlain by the Madison Limestone, which is called the Pahasapa Limestone in the Black Hills. The top of the Minnelusa Formation is relatively easy to identify during drilling or from lithologic descriptions because the uppermost bed of the Minnelusa usually is a buff, yellow, or pink sandstone and the lowermost bed of the Opeche Formation or Shale is red shale, siltstone, or sandstone. Although there are limestone beds in the lower part of the Minnelusa, they are gray, and commonly bedded, whereas the Madison or Pahasapa Limestone is buff or cream-colored in the subsurface and massive, with bedding not distinguishable. The contact between the Minnelusa Formation and the Madison Limestone is unconformable (Cattermole, 1969).

A typical section of the Minnelusa Formation cropping out on Rapid Creek, 3 mi west of Rapid City, is described as follows (from Darton and Paige, 1925, p. 9):

Minnelusa Formation:	Thickness, in feet
Sandstone, red, crinkled and brecciated	110
Sandstone, soft, yellowish gray, cross-bedded	20
Sandstone, gray, flaggy, cross-bedded; massive near base	16
Sandstone, rough, limy	10
Concealed	8
Limestone, pink, sandy	2
Sandstone and gray sandy limestone	8
Concealed	20
Limestone, sandy	3
Sandstone, thin bedded and concealed	14
Limestone, sandy, fossiliferous	2
Sandstone, red, thin bedded	8
Limestone, fossiliferous	3
Sandstone, soft, thin bedded, gray; massive in middle	26
Limestone, sandy; contains many fragments of fossils	6
Sandstone, thin-bedded to shaly, soft, yellow	11
Sandstone, gray, massive	8
Sandstone, yellow, thin bedded, soft; mostly massive below	40
Limestone, pink, sandy	4
Sandstone, gray; massive above, thin bedded below	8
Limestone, gray; massive above, thin bedded and pink calcareous shales below	6
Sandstone, massive	5
Limestone, pink, fossiliferous	2
Sandstone and sandy limestone	40
Shale, red, on Pahasapa limestone	20
Total	400

Anhydrite, known to be present in the subsurface but generally missing in the outcrop, probably was removed by ground-water solution from this section, producing the breccia in the uppermost 110 ft. Breccias are typical of the upper part of the Minnelusa outcrop. The concentration of sulfate in the water in the Minnelusa aquifer changes from less than 100 mg/L (milligrams per liter) near the outcrop to more than 1,000 mg/L 5 to 10 mi downdip and downgradient from the outcrop (U.S. Geological Survey, unpublished records, Rapid City, S. Dak.). This indicates that in the 5- to 10-mi zone near the outcrop, anhydrite, the source of the dissolved sulfate, is partially or totally missing.

The thickness of the Minnelusa Formation in the study area varies from 370 to 700 ft, based on sections reported by Darton and Paige (1925, p. 8-9) and lithologic and geophysical logs. In general, it thickens from the north where it ranges from about 400 to 500 ft thick, to the south, where it ranges from 600 to 700 ft thick. The Minnelusa is thinnest in the outcrop area and where it has been cut by intrusives.

HYDROLOGY

The upper part of the Minnelusa Formation contains more permeable beds and breccias and yields water to wells, whereas the lower part of the Formation is less perneable and is a confining or leaky confining unit separating the Minnelusa and the underlying Madison aquifer. Coarse-grained sandstone, solution openings, and breccias are the principal sources of permeability in the upper part of the Minnelusa. Wells completed in the upper part of the Minnelusa have yields that exceed 100 gal/min in some areas, and at least one well is reported to flow 1,000 gal/min.

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METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System of Units (SI):

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
gallon per minute (gal/min)	0.06308	liter per second

EXPLANATION

MINNELUSA FORMATION--Pattern shows general area of outcrop.

MINNELUSA FORMATION ABSENT

CONTACT

ANTICLINE--Showing trace of axial plane and direction of plunge. Dashed where approximately located.

SYNCLINE--Showing trace of axial plane and direction of plunge. Dashed where approximately located.

MONOCLINE--Showing trace of axial plane. Dashed where approximately located.

ANTICLINAL

SYNCLINAL

FAULT--U indicates upthrown side; D indicates downthrown side.

STRUCTURE CONTOUR--Shows altitude of the top of the Minnelusa Formation. Dashed where approximately located. Contour interval, in feet, is variable. National Geodetic Vertical Datum of 1929.

CONTROL POINT--Location of water well or oil or gas exploration well or altitude of contact. Number is known altitude, in feet, above or below National Geodetic Vertical Datum of 1929 for the top of the Minnelusa Formation.

CONTROL POINT--Location of water well or oil or gas exploration well. Number is projected altitude, in feet, above or below National Geodetic Vertical Datum of 1929 for the top of the Minnelusa Formation.

U.S. GOVERNMENT PRINTING OFFICE: 1986-557-761