DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1687

Base from U.S. Geological Survey State base map, Montana, Wyoming, North Dakota, South Dakota, and Nebraska, 1:500,000

SCALE 1:1 335 000

CONTOUR INTERVAL 500, 100, 200, AND 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology from I. D. Ames (U.S. Geological Survey, written commun., 1981); Bayley and Muehlberger (1968); Darton (1951); Dobbin and Erdmann (1955); Kelly (1980) e.d. 1981 a-g; Keefer (1974); Love and others (1955); Ross and others (1955); Wilde ??? p.??? quadrangles by Love and various others (1977-80); Pierce (1979); and U.S. Geological Survey and American Association of Petroleum Geologists (1961). Structural features modified from maps by W. E. Cooley from many sources. Linear features from Cooley (1983, p.A1).

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1986—W80080

DIVISIONS OF POTENTIAL FRACTURE PERMEABILITY BASED ON DISTRIBUTION OF STRUCTURES AND LINEAR FEATURES IN SEDIMENTARY ROCKS, NORTHERN GREAT PLAINS—ROCKY MOUNTAINS REGION OF MONTANA, NORTH DAKOTA, SOUTH DAKOTA, WYOMING, AND NORTHERN NEBRASKA

By
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1986

EXPLANATION

DIVISION OF FRACTURE TRACES IN SEDIMENTARY ROCKS OF CENOZOIC TO PRECAMBRIAN AGE—Eastern and central North and South Dakota and northern Nebraska include only Cenozoic to Pennsylvanian rocks at the surface and at relatively shallow depths; the area of shallow thrust faulting in north-central Montana includes mainly Cretaceous rocks. Fractures in the deeper rocks in these areas vary, depending on the local structure. Large areas of western Montana are underlain by Precambrian sedimentary rocks.

The divisions are arranged from areas with fractures that may have the smallest effect on fracture permeability (division 1) to areas with fractures that may have the largest effect (division 5), by judgement on the basis of the type and distribution of structures and the distribution of linear features. In certain areas the divisions are subdivided into parts indicated by A, B, or C (for example 2A, 2B, and 2C) that indicate the potential differences in fracture permeability within that division. The lettered parts of the division also are arranged from smallest potential fracture permeability (division 2A) to largest (division 2C)

Division 1—Area only near the synclinal axis of Kennedy basin near the Nebraska-South Dakota State line

Division 2—North and South Dakota generally; North Dakota: Broad eastern flank of Williston basin. South Dakota: Buried Chadron and Sioux arches and Sioux uplift

Division 3—Areas of large basins or synclinal areas. Montana: Bighorn, Bull Mountains, Hogeland, and Powder River basins; wide synclinal areas of northeastern Montana. North Dakota: Western part of Williston basin, including Nesson anticline. Wyoming: Bighorn, Great Divide, Green, Powder River, Washakie, and Wind River basins; northern part of Denver basin

Division 4—Areas generally occupying broad domes, arches, and structural slopes in an intermediate structural position between the structural highlands and the large basins. Montana: Bowdoin dome, Miles City and Sweetgrass arches; some relatively small basins in the Crazy Mountains; areas containing anticlines along the flanks of the Bighorn Basin. Wyoming: Casper arch; Hanna, Laramie, and Shirley basins and other small basins in mountainous areas; areas containing anticlines along the flanks of the Bighorn Basin

Division 5—Areas occupying structural highlands. Montana: Bighorn Mountains; Beartpaw arch; Porcupine dome; Cedar Creek and Cat Creek anticlines; areas along major monoclines; and area of shallow thrust faulting in north-central Montana. South Dakota: Black Hills uplift. Wyoming Bighorn Mountains; Black Hills and Hartville uplifts; part of the Casper arch; areas along major monoclines; areas of thrust faulting in central and southern Wyoming

DUNE DEPOSITS OF QUATERNARY AGE—These deposits form a widespread mantle on the sedimentary rocks of southern South Dakota and northern Nebraska

NORTHERN BOUNDARY OF THE DUNE DEPOSITS

IGNEOUS AND METAMORPHIC ROCKS

Volcanic rocks of Cenozoic to Mesozoic age

Igneous and metamorphic rocks of Cenozoic, Mesozoic, and Precambrian age

STRUCTURAL FEATURES

Boundary of shallow thrust faulting in north-central Montana. Many of the faults present at the surface do not extend to the basal Cretaceous rocks or older strata. Potential fracture permeability of the surface and shallow rocks involved in the faulting is believed to be mainly division 5. Potential fracture permeability of the underlying basal Cretaceous and older rocks probably ranges from division 3 to division 5, depending principally on the local structure

Eastern boundary of the significantly disturbed rocks, including the Overthrust Belt, in western Montana and southwestern Wyoming. Rocks in the Overthrust Belt are fractured extensively and most would be classified in division 5

Eastern edge of the Lewis Overthrust in northwest Montana

Fault. (Faults are not shown in southern Wyoming.)

Approximate location of axial plane of an anticline showing direction of plunge

Approximate location of axial plane of a syncline showing direction of plunge

Approximate location of axial plane of a monocline

Direction of strike and dip of sedimentary rocks determined mainly from the Landsat imagery and from close spacing of contacts shown on the State geologic maps

Linear feature (lineament or linear trend) more than 30 miles in length

INTRODUCTION

The principal map shows geologic fold and fault structures and linear features, which indicate fracture traces in sedimentary rocks in most of Montana, all of North Dakota, South Dakota, and Wyoming, and in northern Nebraska. Fractures associated with the fold and fault structures and the linear features may affect the potential fracture permeability of consolidated rocks. Divisions of potential fracture permeability are shown by the colors on the map. The map was prepared as a part of the U.S. Geological Survey's Northern Great Plains Regional Aquifer-System Analysis (RASA). The objective of the Northern Great Plains RASA is to define the availability and quality of the ground water and to evaluate the effects of developing this resource (U.S. Geological Survey, 1979).

Fractures, consisting of joints and faults, affect the hydrologic regime of many aquifers in the Northern Great Plains area. Fracture traces in rocks such as limestone, dolomite, and fine-grained sandstone are important because fracture traces can be used to help assess the potential capability of the rocks to transmit ground water. Springs commonly occur along joints, bedding planes, and faults. However, in a given area, mapped fractures may or may not be related to fracture (secondary) permeability, which is dependent on the size of the fracture openings and the extent to which the fractures are interconnected.

The density of fractures and their effect on potential fracture permeability are greatest along the main structural features and along or near intersections of linear features (Lueder and Simons, 1962; Moore, 1976). Geologic inspections indicate that sedimentary rocks are more extensively fractured in at least certain more open fractures along faults, anticlines, monoclines, and in places where rocks are tightly folded. Sedimentary rocks are less fractured in synclines and in areas where the strata are nearly horizontal. Linear features (linear trends or lineaments) also are important in determining areas having concentrations of fracture traces, particularly in areas containing only gentle structures.

PRINCIPAL STRUCTURAL FEATURES USED IN DETERMINING DISTRIBUTION OF FRACTURE TRACES

Geologic structure provides a basis in determining the distribution of fracture traces. Types of folds that affect fracture traces include uplifts, arches, domes, anticlines, monoclines, synclines, and basins. In general, rocks in the structurally uplifted areas are more deformed and fractured, contain more open fractures, and therefore have relatively greater potential fracture permeability, whereas rocks near the axes of the structural basins and along synclines tend to be less deformed and have lesser potential fracture permeability. Rocks folded along the axes of anticlines and monoclines generally are more deformed than are the surrounding rocks. Rocks along arches and on flanks of basins are in intermediate structural positions. These rocks are more deformed than the rocks occupying the basins and less deformed than the rocks in the uplifts. Thus they have intermediate fracture density with fewer openings than rocks in uplifts and more openings than rocks of the basins.

Although faults are present throughout the region, most are located in Montana and Wyoming. Normal faults generally affect fracturing only in a narrow zone near the fault, whereas thrust faults, present only in Montana and Wyoming, may be associated with tilting, folding, and extensive fracturing of rocks throughout a wide area. Fracturing is particularly extensive in the Overthrust Belt of western Wyoming and Montana.

Linear features—linear trends or lineaments—occur as straight or slightly curved lines that form an intricate, nearly rectangular pattern on the Earth's surface. The linear features shown on the map are not identified as to type or origin, although most of them probably represent fractures (joints or faults) or fracture zones. Most are believed to be the surface expression of fractures or fracture zones that extend upwards from zones of structural weakness in the Precambrian basement rocks. Many of the linear features, particularly in the plains, were tentatively identified from subtle tonal differences observed on Landsat imagery of farming areas, areas of gentle relief, or areas containing extensive surficial deposits.

The linear features shown on the map were plotted from false-color infrared composites of Landsat imagery at a scale of 1:500,000. Only the linear features longer than 30 miles are shown on the map. All linear features plotted from the Landsat imagery, including those less than 30 miles in length, are shown on other maps of, Montana, North Dakota, South Dakota and northern Nebraska, and Wyoming (Cooley, 1983a, b, c, d). For the area of central and eastern North and South Dakota, a mosaic of Landsat imagery (scale 1:5,000,000; U.S. Soil Conservation Service, 1974) also was used to detect linear features as an aid in determining the delineation of the divisions of fracture traces that may affect potential fracture permeability.

Regional gravity maps also were used in determining the distribution of the fractures in some parts of the study area. Gravity highs and lows and areas having closely spaced gravity lines tend to reflect anomalous structural conditions at depth. Rocks along gravity highs and in areas of closely spaced gravity lines are believed to be more extensively fractured than rocks in other areas. Unfortunately, gravity maps have been compiled only for southeastern Montana, western North and South Dakota, and part of eastern Wyoming—the Powder River and Williston basins.

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LOCATION OF STUDY AREA (SHADED).

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225.