STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

MISCELLANEOUS INVESTIGATIONS 4

SOUTH DAKOTA'S GROUND WATER NEEDS AND SUPPLIES

by
Allen F. Agnew, Merlin J. Tipton, and Fred V. Steece

Testimony before the Select Committee on National Water Resources, U. S. Senate, at a Hearing in Huron, South Dakota, on September 25, 1959

Science Center
University of South Dakota
Vermillion, South Dakota
June, 1962

FOREWORD

The following statement and memorandum of transmittal concerning South Dakota's Ground Water Needs and Supplies, prepared by the South Dakota Geological Survey, were presented by the State Geological Survey before the U. S. Senate's Select Committee on National Water Resources at a hearing in Huron, South Dakota, on October 27, 1959. Part of this testimony was published in Part 6 of the report of the U. S. Senate, 86th Congress, First Session, pursuant to Senate Resolution 48, in March, 1960, (p. 1040-1047, and map following p. 968).

Since that time the State Geological Survey has received numerous requests for copies of this material. As a result, it is presented herein. Except for bringing the maps up to date, and making several minor changes in wording, the report and covering memorandum are the same as when they were presented in October, 1959, because South Dakota's Ground Water Needs and Supplies are substantially the same now as they were $2\frac{1}{2}$ years ago.

The State Geological Survey welcomes inquiries regarding the geology of this major economic resource of South Dakota.

Allen F. Agnew
State Geologist

Vermillion, South Dakota
June 5, 1962

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October 24, 1959

MEMORANDUM OF TRANSMITTAL

TO: The Honorable Robert Kerr, Chairman, and other distinguished Senators of the Select Committee on National Water Resources

FROM: Allen F. Agnew, State Geologist

SUBJECT: Ground water in South Dakota--estimated requirements and supplies

The United States is not short of water. The average yearly precipitation for the Nation as a whole is about 30 inches. About 70 percent of this water returns to the atmosphere by natural evaporation and transpiration. The remaining 30 percent (9 inches) is the supply that is theoretically manageable. However, only a third of this manageable supply is actually withdrawn from the streams and from the ground. Out of this one-third (or 3 inches), one inch is consumed by evaporation and transpiration, and two inches is returned to the streams and ultimately reaches the ocean. Thus, the total amount that finally escapes to the ocean is eight inches, which is nearly 90 percent of the manageable supply.

The water-use situation is equally interesting. Industrial and irrigation withdrawals are about equal; however, 60 percent of the irrigation water is consumed, while only 2 percent of the industrial water is consumed. Ten percent of all public water used is consumed. Irrigation accounts for 80-90 percent of all water that is consumed.

Considering the United States as a whole, the water problem cannot be a problem of total quantity of water, because we withdraw only one-third of the manageable supply, and consume only one-tenth of it. Therefore, the National problem must be one of water management and water use. Water management concerns those who make decisions about water, as well as those who carry out a plan of action for water development, use, or conservation. The State Geological Survey is not a manager, but the managers are the people such as the State Water Resources Commission who prescribe action or take action by legislation, by use of other authority, by application of rules, and by legal decision.

Organized emphasis on water and water planning has begun in several states, including Texas and California. In recent years the U. S. Congress has strongly emphasized planned water development.

Current predictions indicate that the National withdrawal of water by 1980 will be double the withdrawal in 1955. Withdrawals and artificial consumptive use could be doubled, and still remain well within the National average manageable supply. However, water withdrawal could not be doubled in all parts of the United States except by a complicated and excessively costly system of regional transfers of water from basin to basin. For example, in some parts of the Southwestern United States, water use may have to be reduced within the next generation because stored reserves of ground water will not last indefinitely.

On the whole, however, the National water-withdrawal pattern is very wasteful, and forecasts about the future should be gloomy only if they assume that such wastefulness will continue. Records of water use, however, make it obvious that much of the prospective increase in water demand could be met simply by more efficient use of the water that is being withdrawn. Increased demand already has been met by improved efficiency of use and re-use in several plants in the steel industry. It has been met by public supply systems where waste water is reclaimed and re-used. Another good illustration is the petroleum industry. About 41 barrels of water must be circulated to process one barrel of crude oil. In some plants no water is re-used, and the circulation consists of 100 percent new water. For the petroleum industry as a whole, about 27 percent is new water. However, in plants where short supply forces conservation and re-use, only about 5 percent is new water.

Most uses of water (except for power generation) damage quality--they raise the temperature, alter the chemical nature, add to the suspended-sediment load, or all three. Industrial chemical waste, sewage and other organic contaminants, salt leached from the soil in irrigated areas, sediment produced in areas where man has disturbed the cover of vegetation, all depreciate the quality and the usability of water. This problem is beginning to loom larger all the time. Many of the Nation's streams, including some large ones, already are little better than open sewers. An unfavorable salt balance is evident in some irrigated areas of the Western United States. Such problems have been widely publicized. Many of them can be overcome by control of wastes and by water treatment. That is, quality control can be improved by liberal application of technology and money, and by leaving enough water in streams to dilute the unavoidable waste.

From a beginning that dates back to the 1930's, and by concentrated activity in the last 10 years or so, the South Dakota State Geological Survey has put a large share of its effort into collecting basic data on water, and working on both long-range and short-range problems. As you are well aware, water was taken for granted, and there was little public support for a program with long-range broad objectives, until very recently.

Significant water problems developed in the United States during the drought years of the 1930's. Thereafter, World War II created a sudden demand for expansion of many water developments, and for new supplies for a large number of defense industries, for military installations, and for the enlarged operations of governmental agencies, especially in the Federal Government. It is fortunate, indeed, that World War II occurred during a climatic wet period; had the war years been at a time of drought, economic distress in the Nation would have been magnified.

In the decade following the war, the importance of long-range water planning became widely recognized. A large number of State and Federal Government agencies, commissions and advisory committees, citizens groups, and professional societies made many studies. In short, the need for intensified and systematic water programming and projects is now generally and widely recognized. Considerable ground remains to be covered, however, before it is recognized that, with a mobile, annually renewable resource which is controlled by natural laws, sound programming and planning requires a broad base of scientific support.

The kinds of data and scientific information that are needed for water development can be acquired only at considerable expense. Knowledge is costly, but it is cheap compared to the cost of ignorance. Knowledge can eliminate the high cost of guesswork in the construction of projects.

The purpose of the South Dakota State Geological Survey, by basic policy and the traditions of the nearly 70 years of public service, is scientific. In our water-resources program we collect basic data as the raw materials with which to do our work; we analyze and interpret the data and express their meanings in water-supply appriasals; we determine and analyze the processes and factors that control water in natural and artificial environments, and we express these factors in terms of scientific principles; and we publish this information. The work of the South Dakota State Geological Survey with water, in short, provides a scientific basis for water management, such as is carried out by the South Dakota State Water Resources Commission. In the case of specific developments, it provides the scientific means for determining the consequences of management actions that have been taken, for predicting the consequences of actions that may be taken, and for choosing between alternate actions.

In summary, sufficient water is available for present needs and for a very large increase in use. Too much water has been wastefully and shortsightedly used in the past, and conservation and far-sighted scientific management are essential. Nature distributes water poorly, for our purposes, but enough water is available so that artificial redistribution can meet many local problems. The basic problem is economic: what can we afford to spend? New development costs could be reduced by more efficient use of supplies that are already available. A most important problem during the near future will be that of improving control of the chemical quality of water, for all purposes.

Where do the functions of the South Dakota State Geological Survey fit into this picture of the future? A good development program and a plan of action must be based on scientific evidence of how much water is available, where it is available, and what kind of water it is. We propose to continue to obtain this kind of information and to translate it into terms that are useful to water managers.

SOUTH DAKOTA'S GROUND WATER NEEDS AND SUPPLIES

by
Allen F. Agnew, State Geologist

Prepared by Merlin J. Tipton and Fred V. Steece

September 25, 1959

INTRODUCTION

In 1955, South Dakota used an average of 243 million gallons of water per day, of which 76 percent or 185 million gallons was derived from ground water (MacKichan, 1957). This was the highest ratio of ground water use to total water use of any State. This means that South Dakota has had to rely heavily on wells for its water supply. It is this ground water supply with which the State Geological Survey is concerned, because a knowledge of the geology of the formations from which this ground water is obtained will be a tremendous aid in developing future water supplies in South Dakota.

The depths to this ground water and the formations from which it is obtained vary considerably in different parts of the State. There is a natural division between shallow and deep ground water, and between the eastern glaciated part of the State and the western non-glaciated part of the State (fig. 1).

SHALLOW GROUND WATER

Eastern South Dakota

That part of South Dakota east of the Missouri River is covered by glacial deposits which vary from a thin veneer to more than 700 feet thick; it is these glacial deposits that provide almost all of the shallow ground water in eastern South Dakota. The only other sources of shallow ground water in this part of the State are the Recent alluvial deposits (table 1) along the major rivers and their tributaries, the ancient river channels buried beneath the glacial deposits, and the bedrock.

The shallow ground water obtained from the glacial deposits generally comes either from small sand lenses in the glacial debris, or from large sand and gravel plains called outwash deposits (fig. 2). The sand lenses do not provide large quantities of water, but most of them are capable of producing enough for individual farm needs. These sand lenses usually vary to such a degree that their size, shape, extent, and depth cannot be outlined accurately without drill hole or geophysical information.

The outwash plains, except where they are thin, provide large quantities of water, in many places enough to irrigate or enough for municipal supplies. These outwash plains occur at the surface and

Table 1.--Stratigraphic Units Present in South Dakota

Time Rock Chart

Era	System	Formation or Rock Type
Cenozoic	Recent	alluvial deposits
	Quaternary	glacial deposits
	Tertiary	sands, silts, clays
Mesozoic	Cretaceous	Hell Creek
		Fox Hills
		Pierre
		Niobrara
		Carlile
		Greenhorn
		Graneros
		Dakota
	Jurassic	Morrison
		Sundance
Paleozoic	Pennsylvanian	Minnelusa
	Mississippian	Madison (Pahasapa)
	Devonian	limestones and dolomites
	Silurian	limestones and dolomites
	Ordovician	limestones, sandstones and shales
	Cambrian	sandstones and shales
Precambrian	Precambrian	Sioux Quartzite, and granite

are as much as 100 feet thick. In contrast to the sand lenses, they have a characteristic surface expression and therefore can be outlined very accurately. The State Geological Survey has mapped many such plains in several parts of eastern South Dakota in the past few years (fig. 15), and has found them to have great potential value for future water development. The only outwash plain that has been exploited to any great degree as yet is the Parker-Centerville plain (Tipton, 1957) along the Vermillion River in Turner County, where more than 70 irrigation wells are now pumping--Sept., 1959. However, there are many more undeveloped plains in South Dakota which contain enough water for irrigation, industrial or municipal uses. These include the Big Sioux Valley plain (Steece, 1958; Lee, 1958) along the eastern border of South Dakota, the Missouri River plain (Jorgensen, 1960), the Vermillion River plain from Turner County southward to the Missouri River plain; and several other outwash plains (fig. 2) not associated with major rivers. All of the outwash plains shown in Figure 2 are large; not included are innumerable small ones, too small for the scale of the map. Most of the outwash plains shown in Figure 2 have not as yet been investigated in detail, so their potential value is not accurately known. But, as an example, three that have already been mapped--the Parker-Centerville outwash, the Big Sioux Valley outwash, and the Missouri Valley outwash in the Yankton-North Sioux City area (Jorgensen, 1960)--show a supply of approximately 2000 billion gallons of water, (enough to supply the whole State for 27 years at the rate of use during 1955).

Recent alluvium is also a source of shallow ground water in eastern South Dakota, but usually does not provide the quantities needed for more than individual farm wells. These alluvial deposits are found along rivers, streams, and creeks.

The buried channels of ancient (pre-glacial) rivers are another source of shallow ground water, and some of them could produce large quantities of water. However, these deposits have not yet been studied in detail in South Dakota; nevertheless, they should be included in any future water development program.

Bedrock, where it is close to the surface, is another source of shallow ground water in eastern South Dakota, but owing to the usually thick cover of glacial deposits, shallow water from this source has been developed in only a few places. The Sioux Quartzite is locally used as a source of shallow water in Davison, Hanson, McCook, and Minnehaha Counties (fig. 11), although it does not provide large quantities. The Niobrara Marl [and Codell Sandstone] also provide shallow ground water where they are near the surface in southeastern South Dakota (figs. 4 and 5).

Western South Dakota

In general, shallow water supplies are difficult to obtain in western South Dakota, and are not a major source of water in that part of the State. The only shallow sources of water in western South Dakota are in alluvial plains and terraces, and surface bedrock formations. Except along streams, the surface of western South Dakota is composed of bedrock, and about half of this bedrock is Pierre Shale. The Pierre Shale itself is not a good source of water and consequently most of the ground water in the Pierre Shale area is derived from deep sources.

The alluvial plains and terraces along the major rivers and their tributaries provide enough water for individual farms, and in places could produce larger quantities of water. They are such small areas that they do not constitute a major source of water in this part of the State.

The bedrock, where composed of sand, is a good source of shallow ground water. In the northwestern part of the State the Fox Hills Sandstone (fig. 3 and table 1) provides a shallow source of good water, locally in large quantities (for areas mapped, see fig. 13). The Hell Creek Formation (table 1) in this northwestern area has some sand zones which provide shallow water for farm use. The Tertiary sands in the south-central and southwestern part of the State (for areas mapped, see fig. 14) also provide good sources for shallow water. In the Black Hills area the bedrock limestones and sandstones, where near the surface, provide good sources of shallow water. Generally, however, alluvial sources are used for ground water supplies, especially where the granite crops out in the central part of the Hills.

Owing to the small amount of rainfall in the western part of the State, and to the limited supply from shallow sources, water is a very scarce and highly prized commodity which deserves the study of all agencies related to finding water supplies.

DEEP GROUND WATER

Deep ground water provides much of the water used in the State of South Dakota. Thousands of wells have been drilled into the artesian aquifers, especially the Dakota sandstones (Newcastle, Fall River, Lakota). Although these Dakota sandstones have lost much of their artesian head in the last 50 years, many places in the State still have flowing wells from this source. In addition, many other deeper formations also contain large quantities of untapped water. The State Geological Survey has prepared reports of artesian ground water in many parts of the State (fig. 12).

Any future water development should include a conservation program of plugging the "wild" flowing artesian wells. These "wild" wells have reduced the piezometric (pressure) head of the flows tremendously since the artesian formations were first tapped. As an example, the artesian pressure at Woonsocket dropped from 250 pounds per square inch in 1890 to less than 25 pounds in 1950. The plugging of the "wild" wells will greatly curtail this rapid decrease in pressure, and will stop a needless waste of water.

The chief potential sources of deep ground water in South Dakota are:

1. Fox Hills Formation (fig. 3): sand and sandy clay; as much as 250 feet thick.
2. Niobrara Marl (fig. 4): chalk and marl; becomes sandy westward; about 200 feet thick in the central part of the State, 120 feet thick in the east, and 400 feet thick in the west.
3. Codell Sandstone Member of Carlile Shale (fig. 5): Carlile Shale includes the 50-foot thick Codell Sand in parts of southeastern South Dakota.
4. Dakota Group (fig. 6): interbedded sands and shales; as much as 400 feet thick; several productive sands.

5. Sundance (fig. 7): The Sundance is chiefly sand; as much as 350 feet thick. Several sands are water-bearing in Black Hills area. "Sundance" artesian sand is productive in central South Dakota.

6. Minnelusa Formation (fig. 8): mostly limestone and dolomite with interbedded shale and sandstone; as much as 500 feet thick; several productive zones.

7. Madison (Pahasapa) Limestone (fig. 9): chiefly limestone and dolomite; as much as 900 feet thick; several productive zones.

8. Ordovician-Cambrian (fig. 10): Ordovician Red River Limestone, Winnipeg Sandstone, and Cambrian Deadwood Sandstone in northwestern half of State; [Ordovician and Cambrian] sandstones in southeastern corner of State.

9. Sioux Quartzite (fig. 11): Massive silica-cemented hard quartzite and thin interbedded "shales". Water occurs in highly jointed and fractured areas.

Of the rock units discussed above, several have been important sources of water over the years, although most of them contain highly mineralized water. Probably the most important and best known of these is the group of Dakota sandstones; nearly all the deep artesian wells in the State have their source in these sandstones. Second in importance is the Fox Hills Formation especially where it is at or near the surface. The Fox Hills yields adequate supplies of high-quality water both for domestic and industrial use. The Codell Sandstone is an important source of relatively shallow artesian water of good quality in southeastern South Dakota. The "Sundance Sand" and Minnelusa Formation also provide large volumes of water that is rather high in mineral content, in both central South Dakota and the Black Hills area.

Water from the other rock units discussed is also likely to be high in mineral content.

FUTURE DEVELOPMENT

The plans for the South Dakota State Geological Survey in the next 20 years call for a large amount of geologic mapping of ground water resources. Many sources of ground water in South Dakota have not yet been studied either geologically or hydrologically, and it is the plan of this Department to study as many of those sources, in cooperation with the State Water Resources Commission, as budgetary limitations will permit. Presently, approximately 40 percent of the annual budget of the State Geological Survey is being spent on studies of ground water. In addition, the 1959 State Legislature appropriated $10,000 per year (which is being matched by the Federal Government) to the State Geological Survey for cooperative investigations with the U. S. Geological Survey dealing with specific ground water problems in South Dakota.

Certain glacial deposits in the Eastern South Dakota area are good water sources and need to be studied further, as they have the potential to provide much of the future water needed in this part of the State. The western part of the State badly needs an up-to-date artesian water study much like those that have been carried out recently in the eastern part of South Dakota by the State Geological Survey (Barkley, 1952 and 1953; Erickson, 1954 and 1955).

In addition to the general studies referred to above, many of the water supply problems in South Dakota are local in nature and must be studied individually, because of the locally different and complex problems involved. Many such studies of the geology of local ground water problems have been published by the State Geological Survey (fig. 17).

It has been shown that water problems already exist in South Dakota, and undoubtedly will become more acute in the future. Many of these problems will be readily solved by a proper study of the geology and hydrology of the ground water resources. Agencies such as the State Geological Survey should have substantially increased budgets so that they can devote increased effort to the study of their specific phases of the program.

If this coordinated and accelerated program of study is carried out, most of the immediate water needs of South Dakota will be provided for, and many of the future water problems will be solved.

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Figure I.

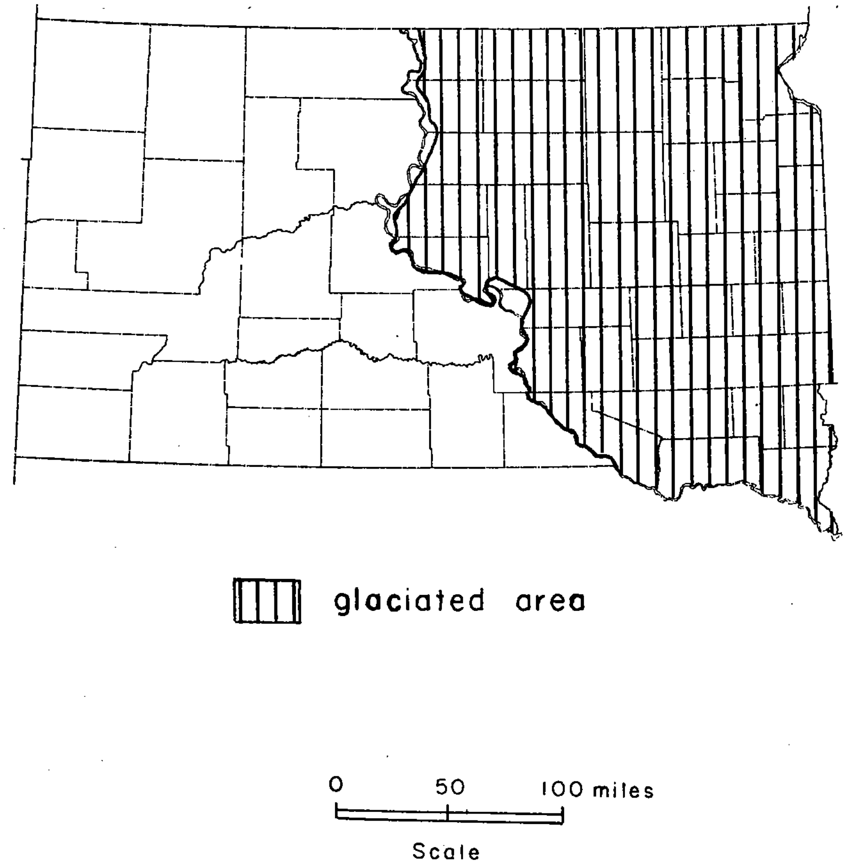


Figure 2.

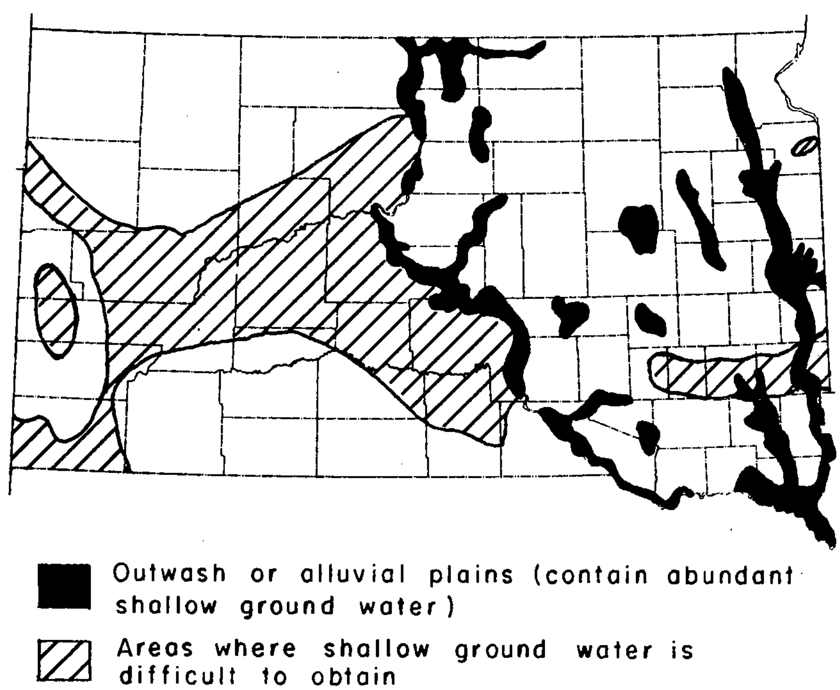
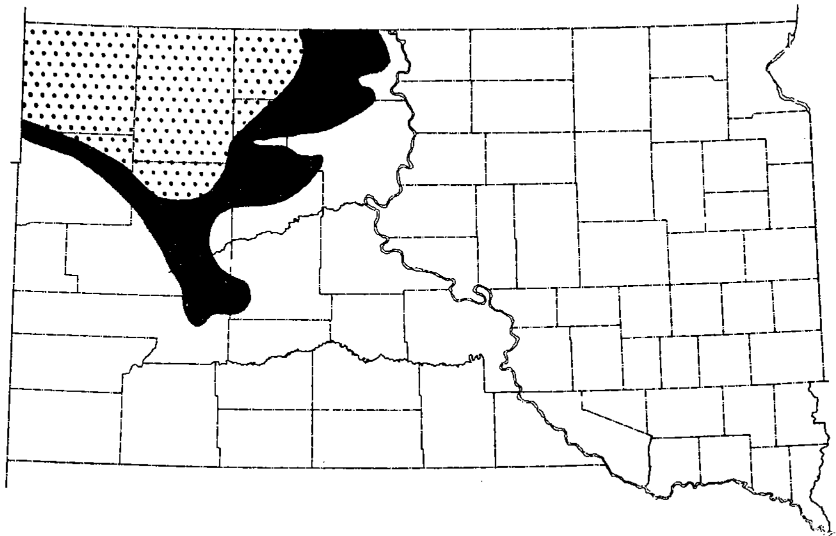


Figure 3.



Fox Hills Formation

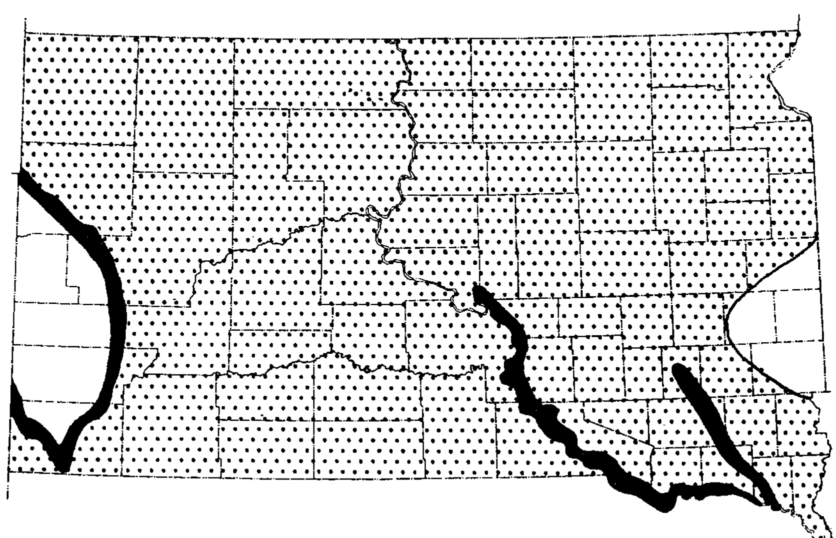
outcrop

subsurface distribution

0 50 100 miles

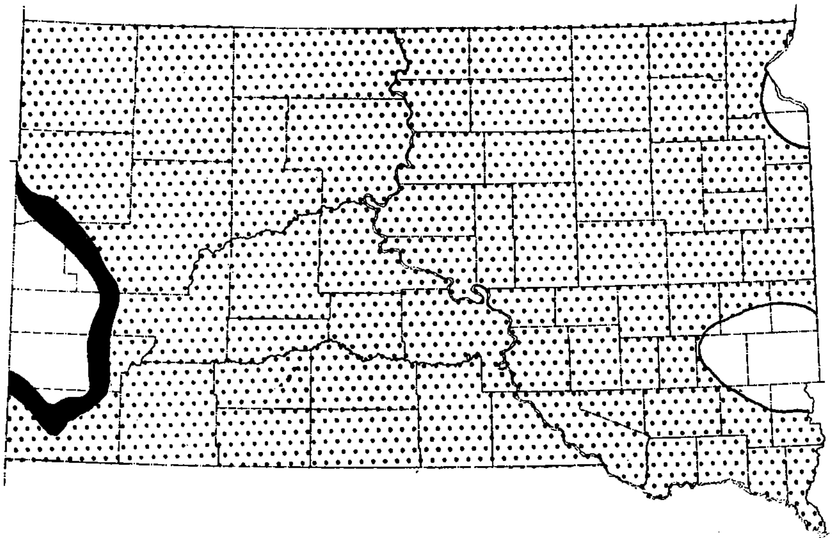
Scale

Figure 4.



Niobrara Marl

Figure 5.



Carlile Shale
(including Codell Sand)

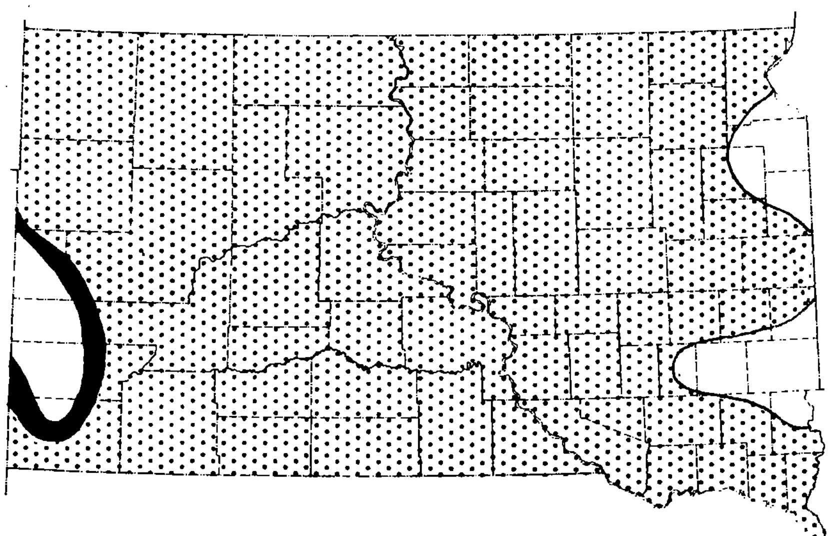
outcrop

subsurface distribution

0 50 100 miles

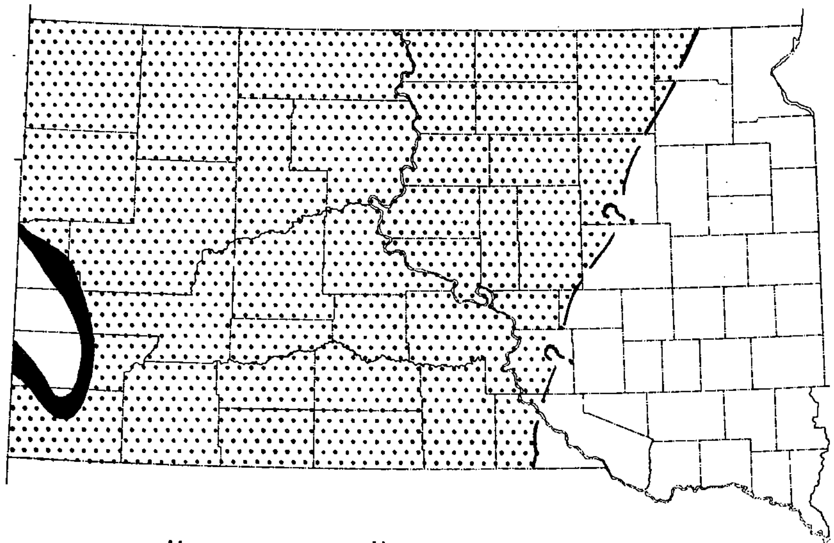
Scale

Figure 6.



Dakota Group

Figure 7.



"Sundance" Sandstone

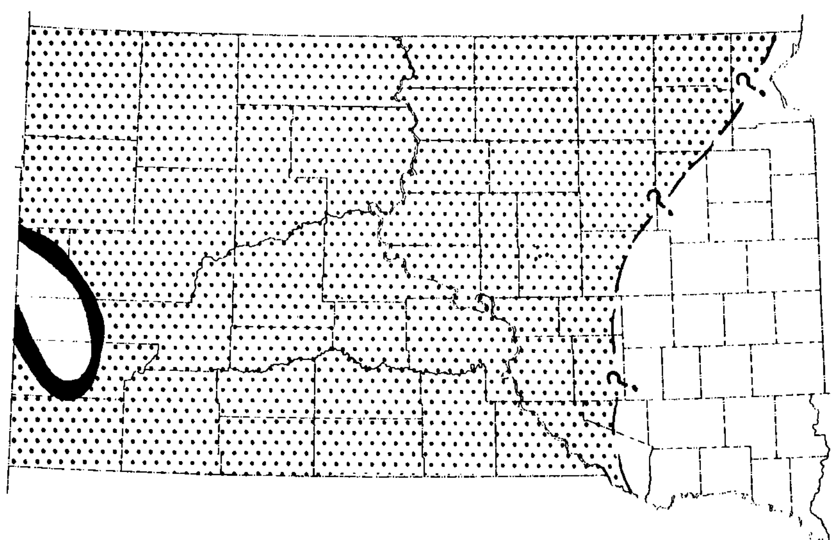
outcrop

subsurface distribution

0 50 100 miles

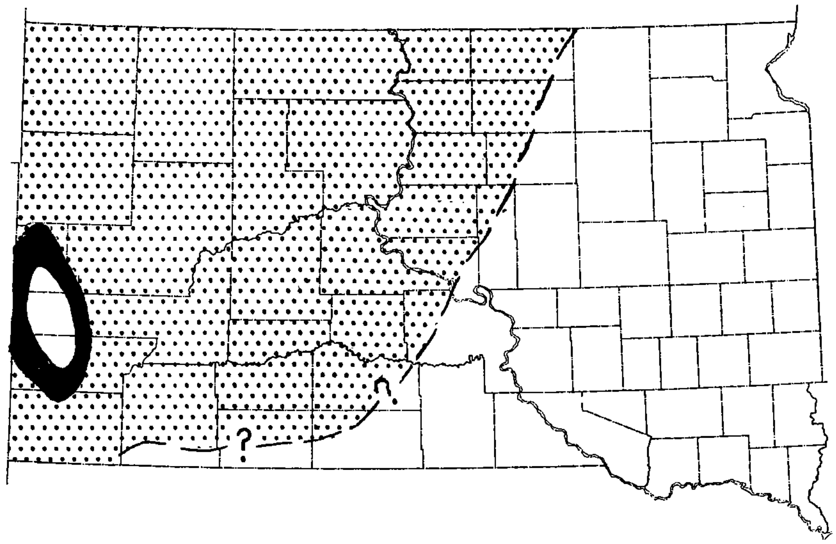
Scale

Figure 8.



Minnelusa Formation

Figure 9.



Madison (Pahasapa) Limestone

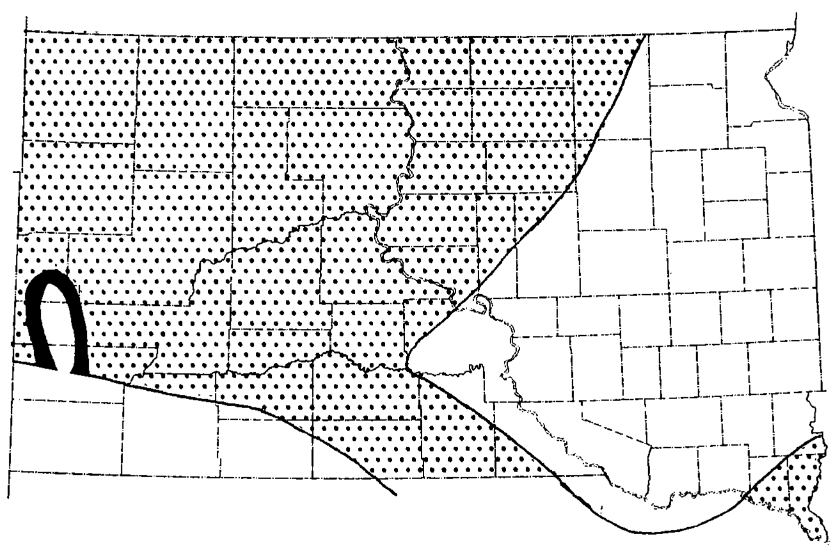
outcrop

subsurface distribution

0 50 100 miles

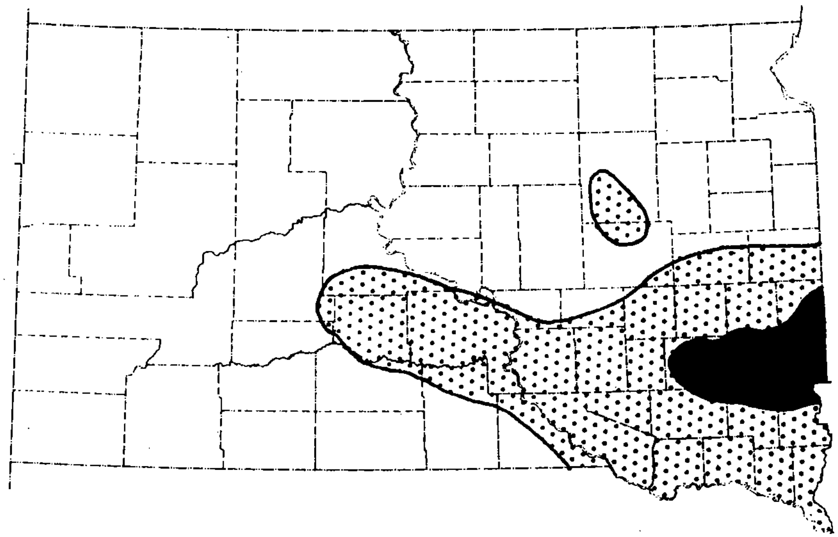
Scale

Figure 10.



Ordovician and Cambrian limestones and sandstones

Figure 11.



Sioux Quartzite

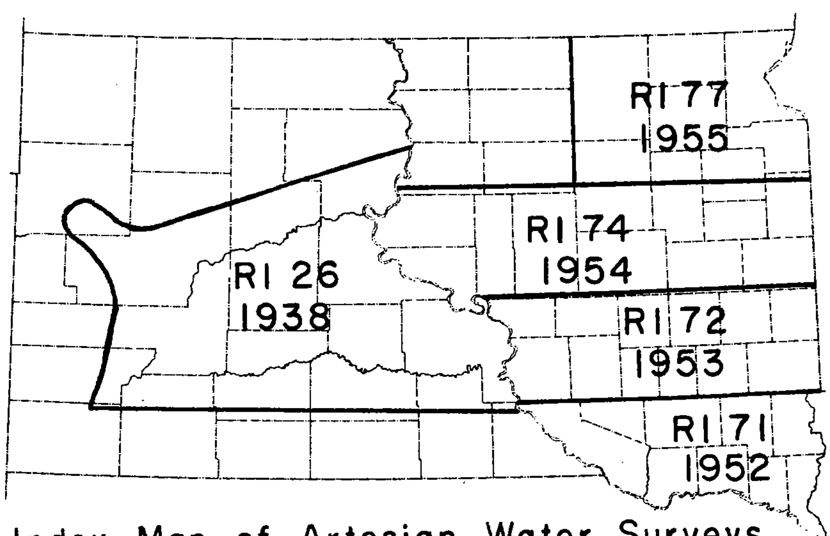
outcrop

subsurface distribution

0 50 100 miles

Scale

Figure 12.



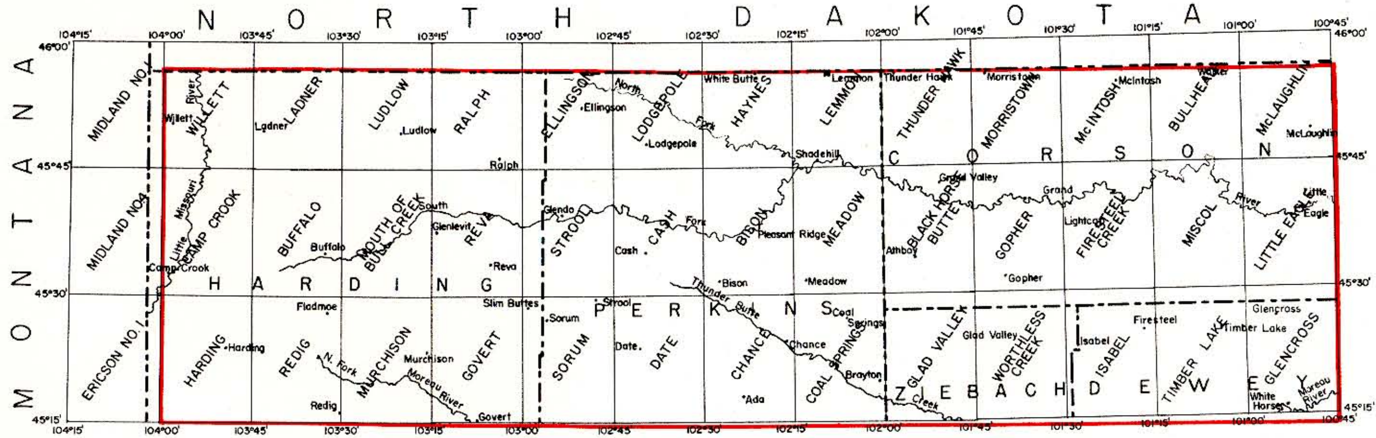
Index Map of Artesian Water Surveys

RI 71 Area covered by one report

(RI = Report of Investigations)

(Figure shows date of publication)

Figure 13.



INDEX MAP

OF

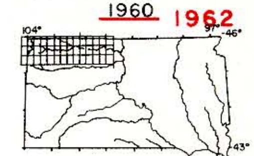
GEOLOGIC QUADRANGLES

OF THE

COAL AREA OR

CRETACEOUS TABLELANDS

1960 1962



Quadrangle Locations

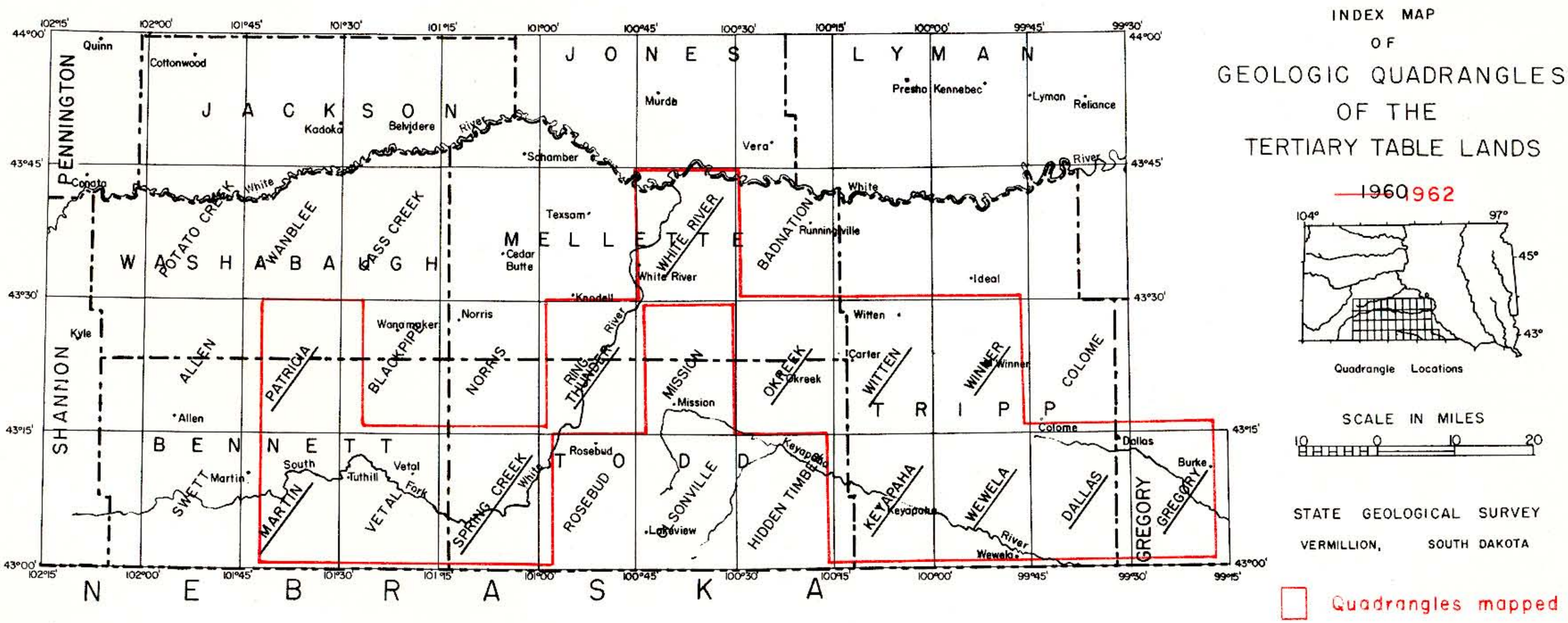
SCALE IN MILES

10 0 10 20

STATE GEOLOGICAL SURVEY

VERMILLION, SOUTH DAKOTA

Quadrangles mapped


INDEX MAP
OF
GEOLOGIC QUADRANGLES
OF THE
TERTIARY TABLE LANDS
1960
962
104°
97°
45°
43°
Quadrangle Locations
SCALE IN MILES
10
0
10
20
STATE GEOLOGICAL SURVEY
VERMILLION, SOUTH DAKOTA
Quadrangles mapped
PENNINGTON
JACKSON
JONES
LYMAN
SHANNON
WASHABAUGH
MELLETTE
BENNETT
TODD
TRIPP
GREGORY
NEBRASKA
POTATO CREEK
WANBLEE
PASS CREEK
WHITE RIVER
BADNATION
ALLEN
PATRICIA
BLACKPIPE
NORRIS
RING THUNDER
MISSION
OKREEK
WITTEN
WINNER
COLOME
SWETT
MARTIN
VETAL
SPRING CREEK
ROSEBUD
SONVILLE
HIDDEN TIMBER
KEYAPAHA
WEWELA
DALLAS
GREGORY
Quinn
Cottonwood
Kadoka
Belvidere
Murdo
Vera
Presho
Kennebec
Lyman
Reliance
Conata
Schamber
Texsam
Cedar Butte
White River
Runningville
Ideal
Kyle
Kodell
Wanamaker
Norris
Witten
Carter
Okreek
Winner
Allen
Mission
Colome
Dallas
Burke
Martin
South
Tuthill
Vetal
Fork
Rosebud
Lakeview
Keyapaha
Wewela
White
River
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43°45'
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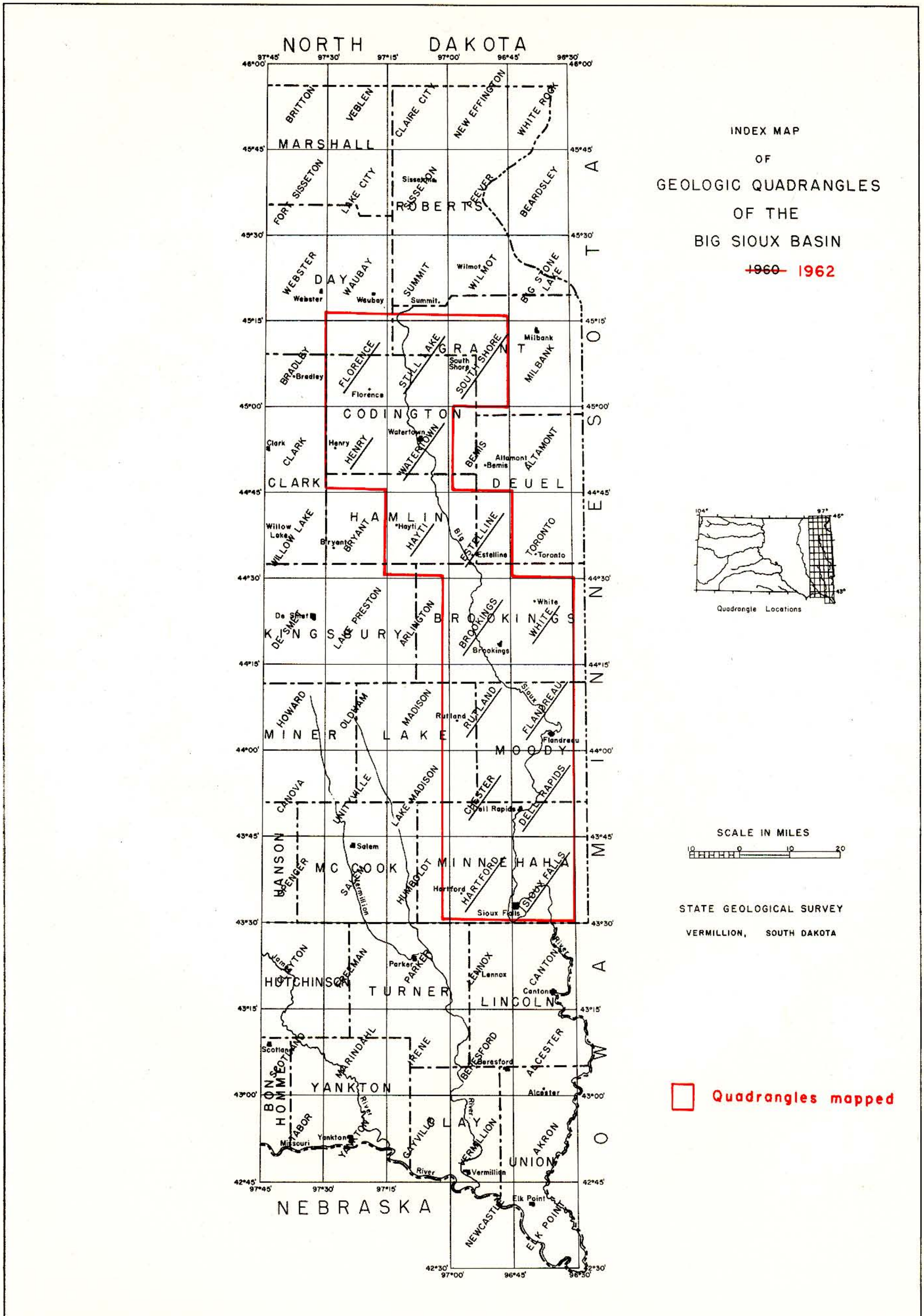
101°45'
101°30'
101°15'
101°00'
100°45'
100°30'
100°15'
100°00'
99°45'
99°30'
99°15'

Figure 14.

Figure 15.



INDEX MAP
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GEOLOGIC QUADRANGLES
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NORTH DAKOTA
NEBRASKA
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BRITTON
VEBLEN
CLAIRE CITY
NEW EFFINGTON
WHITE ROCK
MARSHALL
FORT SISSETON
LAKE CITY
SISSETON
PEEVER
BEARDSLEY
ROBERTS
WEBSTER
WAUBAY
SUMMIT
WILMOT
BIG STONE LAKE
DAY
BRADLEY
FLORENCE
STILL LAKE
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Quadrangle Locations
SCALE IN MILES
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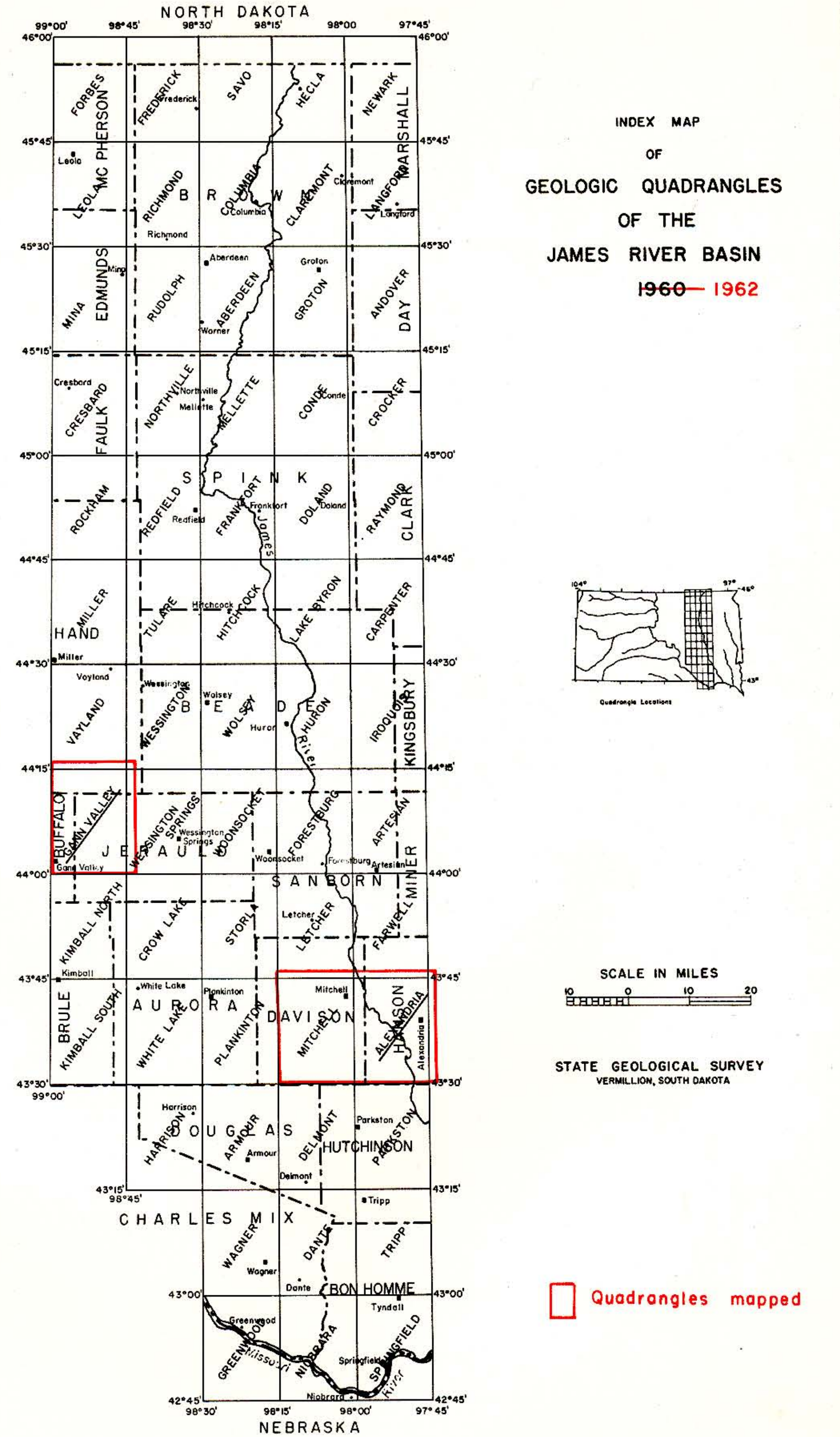
VERMILLION, SOUTH DAKOTA
Quadrangles mapped


NORTH DAKOTA
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JAMES RIVER BASIN
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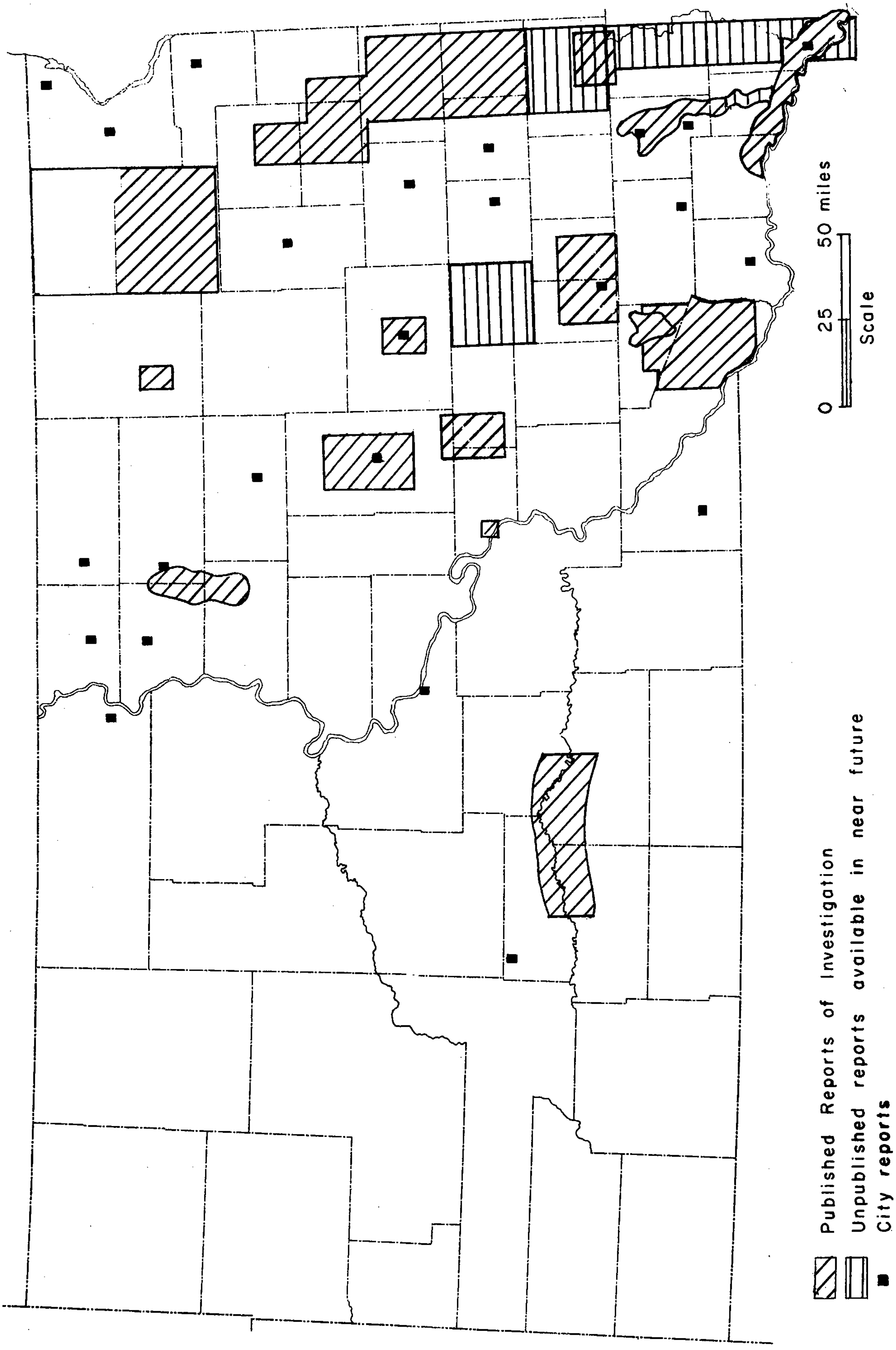
Quadrangle Locations
SCALE IN MILES
STATE GEOLOGICAL SURVEY
VERMILLION, SOUTH DAKOTA
Quadrangles mapped

Figure 17.



Published Reports of Investigation
Unpublished reports available in near future
City reports
0 25 50 miles
Scale