STATUS OF MINERAL RESOURCE INFORMATION FOR THE STANDING ROCK INDIAN RESERVATION, NORTH DAKOTA AND SOUTH DAKOTA

By

Lee R. Rice
U.S. Bureau of Mines

Richard Bretz
South Dakota Geological Survey

Administrative Report BIA-41
1978

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SUMMARY AND CONCLUSIONS

Known and/or potential mineral resources of the Standing Rock Indian Reservation that can be developed with existing technology include lignite, petroleum, natural gas, uranium, sand and gravel, rock, clay and shale, and bentonite and volcanic ash. Only the development of potential petroleum and uranium resources promise to yield revenues to the Standing Rock Sioux Tribe; other resources may provide needed construction materials and help reduce dependence on imported materials, but are not likely to be commercially developed.

Lignite reserves, though substantial, are of limited commercial value at this time because of their distance from potential markets and because of diverse land ownership. Moderate potential exists for the development of small petroleum fields, but little potential is indicated for development of natural gas resources. There is an unknown, although probably small, potential for the discovery and development of shallow subsurface uranium deposits. Enough sand and gravel, rock, clays, and shales are present on the reservation to meet anticipated local construction requirements. No metallic mineral resources of any significance are known to occur.

Petroleum exploration should be encouraged by a concerted study of all existing petroleum exploration data to identify prospective areas and help evaluate the potential of this resource. Some initial pilot studies of the surface and subsurface stratigraphy and depositional environments of the exposed Upper Cretaceous and Paleocene units should be encouraged to evaluate their uranium potential.

INTRODUCTION

This report was prepared for the Bureau of Indian Affairs by the U.S. Bureau of Mines and the U.S. Geological Survey under an agreement to compile and summarize available information on the geology, mineral resources, and economic development potential of certain Indian lands. Source materials were published and unpublished reports and personal communications. There was no fieldwork.

The Standing Rock Reservation includes all of Sioux County, North Dakota, and Corson County, South Dakota. In addition, the southern boundary of the reservation takes in portions of 219 sections in Dewey County (3,561.11 acres) and part of 103 sections in Ziebach County, South Dakota (1,731.91 acres) (Figure 1). The 2,320,275-acre reservation is bounded on the north by Cedar Creek and the Cannonball River and on the east by the impounded Missouri River waters of Lake Oahe (Figure 2). The Cheyenne River Indian Reservation abuts the Standing Rock Reservation on the south, and the eastern boundaries of Perkins and Adams Counties delimit the reservation to the west at the 102d meridian.

There are several communities on the reservation: McIntosh and Fort Yates are the county seats of Corson and Sioux Counties. Tribal headquarters for the Standing Rock Sioux Tribe is at Fort Yates. Approximately 4,700 Indians reside on or adjacent to the reservation. According to the 1970 census, the total population of Sioux and Corson Counties is 8,626.

Commercial air transportation is available at Bismarck, 39 miles north of the reservation. Surface transportation by bus and train is available, and hard-surfaced, all-weather roads and numerous graveled and graded roads serve the area. U.S. Highway 12 crosses the reservation east to west, and State Highways 6, 63, and 65 provide connecting routes north and south across the reservation.

Previous Work

Although the areas adjacent to the Missouri River were described in the account of the Lewis and Clark expedition of 1804-1806 (Lewis and Clark, 1814), and the region of the Standing Rock Reservation was visited by F. V. Hayden in 1853-1854 (Meek and Hayden, 1956), the first official study of the area was not until 1884 when Willis (1885) studied the lignite resources of the Great Sioux Reservation. Calvert, Beekly, Barnett, and Pishel studied the geology of the Standing Rock and Cheyenne River Indian Reservations in 1909 (Calvert and others, 1914).

Several other investigations were conducted on the Standing Rock Indian Reservation. Comprehensive published reports are those of Bluemle (1975), Calvert, Beekly, Barnett, and Pishel (1914), Denson (1950), Morgan and Petsch (1945), and Randich (1975). Reports on smaller areas include those of Artzner (1974), Lindberg (1944), Mello (1969), Rothrock (1947), Russell (1926), Strassberg (1954), Waage (1968), and Wilson (1922b). Numerous paleontological studies and regional stratigraphic studies include all or part of the reservation.

Land Status

Under the terms of the 1868 Treaty of Fort Laramie, the Sioux accepted a territory extending to the western slopes of the Black Hills bounded by the Niobrara River on the south, the Missouri River on the east, and the Cannonball River on the north. Congress created seven separate reservations for the Sioux in 1889 (25 Stat. 888) and established the present Standing Rock Reservation boundary. This boundary encompasses 3,625 square miles in Sioux County, North Dakota, and Corson, Dewey, and Ziebach Counties, South Dakota. Ownership of more than 60 percent of the land within the reservation boundary no longer resides with the Standing Rock Sioux Tribe or with tribal members. The division of surface ownership is shown on Figure 3, and the distribution of the 294,840.41 acres of remaining tribal land within the reservation boundary is shown on Figure 4.

Locally mineral and surface ownership have been severed, so the status of mineral ownership within the reservation boundary is less clearly defined than is the surface ownership. Four categories of mineral ownership on the reservation include: (1) surface and mineral ownership residing with allottees or non-Indians (including government agencies), (2) surface and mineral ownership residing with the Standing Rock Sioux Tribe, (3) tribal ownership of the mineral estate but not the surface, and (4) lands where mineral ownership may reside with the tribe but could not be readily determined. Figure 4 shows the relationships of lands in these categories to the total area of the reservation. The distribution of lands in these categories is shown on Figure 5, which illustrates the fragmented surface and mineral ownership. Extensive development of any mineral resource may thus involve allottees and non-Indian owners as well as the Standing Rock Sioux Tribe.

Map Coverage

Recent topographic maps covering the entire area of Corson and Sioux Counties are the Bismarck and McIntosh sheets of the Army Map Service 1:250,000 series, published by the United States Geological Survey. These maps have a contour interval of 100 feet and a scale of approximately 4 miles to the inch.

Several maps of the United States Geological Survey 7½-minute quadrangle series provide excellent topographic coverage for nearly all of both Corson and Sioux Counties as shown on Figure 6. Contour intervals are 10 or 20 feet and the scale is 1:24,000 (2,000 feet to the inch).

Geologic maps covering nearly all of Corson County have been published by the South Dakota Geological Survey (Figure 7). These maps provide planimetric control and geologic data at a scale of 1:62,500 (about 1 mile to the inch).

Physiography

The Standing Rock Indian Reservation lies within the Missouri Plateau division of the Great Plains physiographic province (Rothrock, 1943, p. 8, and Knudson, 1974).

The South Dakota portion is subdivided into the Cretaceous Tablelands and Pierre Hills subdivisions (Rothrock, 1943, p. 8) whereas the North Dakota portion is subdivided into the glaciated and unglaciated Missouri Plateau subdivisions (Knudson, 1974) (Figure 8).

The Cretaceous Tablelands portion is characterized by uplands of low relief containing ponds and lakes. Eroded areas form flattopped and conical buttes and sparsely vegetated badlands. Locally relief is as much as 100 to 250 feet, particularly in the badland areas near major drainages and on the buttes.

The Pierre Hills portion is characterized by smooth rounded hills and gentle slopes and valleys, except for areas near major drainages. The buttes and badlands are much less prevalent than in the Cretaceous Tablelands area.

The glaciated Missouri Plateau portion is characterized by a rolling to hilly erosional topography, with scattered boulders and other evidence of glaciation. General relief is low, but locally ranges from 250 to 500 feet.

The unglaciated subdivision of the Missouri Plateau is similar in all respects to the glaciated portion except that the surface is devoid of boulders or other evidence of glaciation.

Cedar Creek and the Cannonball River form the northern boundary, the Missouri River forms the eastern boundary, and the Grand River flows through the southern portion of the reservation. These streams are perennial and are characterized by moderately wide alluvial valleys and a succession of terraces. The Oahe Reservoir has flooded the alluvial valley of the Missouri and the alluvial valleys of the Grand and Cannonball near their mouths.

Altitudes on the reservation range from more than 2,600 feet in the extreme west to less than 1,650 feet in the extreme southeast.

GEOLOGY

General

Geology of the Standing Rock Indian Reservation is dominated by a thick sedimentary rock sequence. Neither igneous nor volcanic rocks are present.

Outcrops in Corson and Sioux Counties are of shales, silts, clays, and sands of both Paleocene and Cretaceous age. Weathering products of these sediments as well as glacially derived material, consisting primarily of boulders of igneous and metamorphic rocks with isolated remnants of outwash, till, and loess, comprise the surface deposits.

Oil tests and deep-water borings reveal a geologic section consisting of several thousand feet of sedimentary strata overlying the Precambrian basement complex of igneous and metamorphic rocks (Table 1).

Stratigraphy

Outcropping Rock Units

Rocks of Tertiary age exposed in the Standing Rock Indian Reservation are the Pliocene Ogallala Formation(?) and the Paleocene Tongue River, Cannonball, and Ludlow Formations of the Fort Union Group. Those of Upper Cretaceous age are the Hell Creek Formation, Fox Hills Formation, and the Pierre Shale (Figure 9). These units are covered locally by Holocene and Pleistocene alluvium, terrace deposits, loess, and glacial drift.

The Ogallala Formation(?), which may actually be Hell Creek or Fox Hills siliceous sandstone, consists of up to 10 feet of green-gray silica cemented sandstone, which caps several buttes in eastern Corson County. The Tongue River Formation, which occurs only in the extreme northwestern corner of the reservation as scattered erosional remnants, consists of 25 feet of sandstone with a few clay pebbles (Stevenson, 1956b). The Cannonball Formation, of which only the lower 100 feet or less is preserved (Denson, 1950), consists of poorly exposed sandstone and mudstone, which occurs on the divide between the Grand and Cannonball Rivers. The Ludlow Formation consists of 65 to 250 feet of sands, silts, sandy and silty clays, and numerous lenses of calcareous sandstone. At the base are one or more lignite seams from 0 to 34 inches thick and associated sediments designated the Shadehill lignite facies; from 25 to 80 feet above the base are one or more lignite seams from 1 to 34 inches thick and associated sediments designated the Hillen lignite facies.

The Hell Creek Formation, the youngest Upper Cretaceous unit, ranges from 330 to 430 feet thick. In South Dakota the formation consists of the Upper Hell Creek Unit, the middle Isabel-Firesteel Lignite Facies, and the Lower Hell Creek unit; in North Dakota, it consists of the Pretty Butte Member, the Huff Member, the Fort Rice Member, the Breien Member, and the Crowghost Member. The Isabel Firesteel bed continues into North Dakota but does not receive formal recognition. The Breien Member of North Dakota is a marine tongue which does not extend far, if at all, into South Dakota. Locally unconformable below the Hell Creek is the Fox Hills Formation, with an average thickness of 250 feet (Denson, 1950), which consists of, in South Dakota, from top to bottom, the Colgate, Bullhead, Timber Lake, and Trail City Members. The North Dakota sequence is the same, except that the Trail City Member is not recognized. Gradationally below the Fox Hills is the Pierre Shale, which underlies all of the reservation, and is as much as 1,400 feet thick (Morgan and Petsch, 1945); however only the upper 300 feet is exposed and consists of the Elk Butte, Mobridge, and Virgin Creek members. The Mobridge Member tends to lose its identity to the west and northwest, where it and the overlying Elk Butte are called the Upper Pierre unit (Stevenson, 1959, 1960a,b; Pettyjohn, 1961).

Subsurface Rock Units

The exposed Paleocene and Late Cretaceous units are underlain by about 9,000 feet of older sedimentary rocks, as listed in Table 1.

Structure

The Standing Rock Indian Reservation is in the eastern and southeastern part of the Williston Basin, a north- to northwest-trending structural feature that extends from South Dakota into Canada. The United States portion of the Williston Basin is as much as 300 miles wide (east-west) and 400 miles long (north-south). It is bounded on the east and southeast by the Canadian Shield and Sioux Ridge, on the south by the Kennedy Basin, on the southwest and west by the Chadron Arch, Black Hills, Cedar Creek Anticline, and Poplar Dome and continues into Canada as the Moose Jaw Synclinorium (Figure 10).

The main structural feature of the reservation area is the east flank of a large northwest- to north-trending syncline, known as the Lemmon Syncline, which defines the axis of the Williston Basin. A series of smaller, poorly defined anticlines and synclines lie on the eastern flank of the Lemmon Syncline (Figure 10) which may define the southward extension of the Nesson anticline. Rock units in the area dip very gently to the northwest, but locally dip to the north, west, and east in the areas of the more conspicuous folds. The structural relief is approximately 2,500 feet; the structurally highest parts being in the eastern and southeastern edge of the reservation, and the structurally lowest parts in the extreme northwestern corner of the reservation. Smaller, subsidiary folds are common on or near the reservation, and, although irregular, tend to occur in two sets, one trending northwest and the other trending northeast. Where these sets intersect, small, low amplitude anticlinal and domal structures were formed, with reported closures of 45 to 50 feet (Wilson, 1922b) and, in adjacent Emmons County, of 30 to 80 feet (Fisher, 1952).

No major faults are known to cross the reservation, but numerous small normal faults, a few grabens, and a few reverse faults occur on or near the reservation. Displacement along the faults is usually less than 3 feet (Curtiss, 1952), and only rarely is as much as 50 to 60 feet (Curtiss, 1954b), or 100 feet (Denson, 1950; Russell, 1926).

GEOPHYSICS

Geophysical surveys are used to define the structure and characteristics of subsurface rock strata. These include magnetic, radiometric, seismic, resistivity, and gravity surveys. Many geophysical surveys were made on parts or all of the Standing Rock Indian Reservation, but many of the survey data gathered by private companies are confidential and unpublished. However, some data have been published as gravity and magnetic maps (Carlson, 1950; Jordan, 1940; Petsch, 1959, 1967; U.S. Geological Survey and South Dakota Geological Survey, 1975).

Figure 11 is the Bouguer gravity anomaly map of the reservation adapted from a gravity anomaly map of the United States (American Geophysical Union, and the U.S. Geological Survey, 1964). The minus 70-milligal anomaly astride the state line in north central Corson County and south central Sioux County is indicative of igneous Precambrian rocks at depth (Schoon and McGregor, 1974; Lidiak, 1971).

Results of a ground magnetometer survey of Corson, Dewey, and Ziebach Counties were published by the South Dakota Geological Survey (Petsch, 1959). Data from this survey for the South Dakota portion of the reservation are presented on Figure 12. This map reveals much about the basement complex and the structure of Corson County (Lidiak, 1971). The Mahto North and South, Mobridge, and Trail City highs imply the presence of either ridges or prominences on the Precambrian surface or compositional changes in the basement rocks in this area and, in the former case, indicate possible structural traps for petroleum. The moderately steep gradients on these highs suggest moderate gradients in the Precambrian surface that might have been caused by faults in the basement complex, if indeed, the highs are not due to compositional changes.

MINERAL RESOURCES

General

Mineral resources of the Standing Rock Indian Reservation include lignite, natural gas, geothermal energy, rock, clay, shale, volcanic ash, and sand and gravel. These appear to be the only commodities with potential for commercial development with existing technology. In addition, petroleum and uranium are potential resources. Currently there are 75 leases for petroleum and natural gas on tribal and allotted lands. Much of the private, non-Indian lands also are under lease.

Energy Resources

Lignite

<u>General.</u>--The first survey of lignite resources in the area of the reservation was made by Willis in 1884 (Willis, 1885). He found "beds of inferior lignite" and concluded, "It may be definitely said there is no workable coal of any kind within the area surveyed."

Work by Calvert, Beekly, Barnett, and Pishel (1914) concluded, "The quantity is not sufficient to justify the establishment of an extensive mining plant, even if the lignite were of good quality. Mining will therefore continue to be limited (as it now is) to a few small prospects where lignite is taken out for local consumption."

Some lignite seams in the Ludlow Formation are as much as 33 inches thick, but they are of limited extent and occur only in the northwestern parts of the reservation (Denson, 1950; Stevenson and others, 1954b; Stevenson and Loken, 1957). The outcrop trace of this lignite in the South Dakota portion of the reservation is shown on Figure 13.

More extensive deposits occur in a zone approximately 40 to 80 feet above the base of the Hell Creek Formation, and have been traced over wide areas of the reservation (Denson, 1950) (Figure 13). This lignite is referred to as the Isabel-Firesteel.

The carbonaceous material in the Ludlow and Hell Creek Formations is almost black or very dark brown, has a brown streak, and contains enough moisture so that appreciable slacking occurs upon exposure to air (Searight, 1930). This material is classified as lignite by the U.S. Bureau of Mines and the U.S. Geological Survey. The deposits of the Standing Rock Indian Reservation are thin and lenticular, and average less than 1,000 feet in width and 2 and 3 feet in thickness (Curtiss, 1954).

Representative analyses of the Hillen, Shadehill, and Isabel Firesteel lignites are listed in Table 2. In general, the lignite contains between 30 and 40 percent moisture, about 20 to 30 percent fixed carbon, and has a low heating value.

Production.--There are several mines in Corson, Dewey, and Zieback Counties, in the South Dakota portion of the reservation (Figure 13). U.S. Bureau of Mines records (Table 3) indicate that lignite production from Corson County did not exceed 40,000 tons per year during the peak mining period from 1938 to 1944. After 1944, the mines in Corson County operated only intermittently.

There is little information about lignite production in the North Dakota section of the reservation (Sioux County). Denison (1950) reports that there were three mines four miles south of Porcupine in T. 131 N., Rs. 83 and 84 W., but no evidence remains of any operations. The maximum lignite thickness in this area is 28 inches (Calvert and others, 1914, p. 45). As Sioux County was part of Morton County until 1914, there is no way to determine if any of the listed production in Table 3 for Morton County was derived from the reservation. Production from Morton County was first recorded in 1884, however, Wilder and Wood (1903) give an extensive account of workings and development of lignite mining in North Dakota, but they do not indicate any development in the area of what is now Sioux County.

Reserves.--Although outcrops of the Hell Creek Formation extend over nearly half of the reservation, the highly variable nature of the Isabel Firesteel lignite facies makes it difficult to estimate lignite reserves. Searight (1931) estimated that 5,381,000 tons of lignite of thickness greater than 30 inches occur in the Dewey County portion of the reservation north of Isabel. Drill-hole data shown on Figure 13 indicate no minable lignite present in Corson County west of R. 19 E. or north of T. 22 N. Also, there appears to be almost no lignite remaining in the Ziebach County portion of the reservation. The U.S. Bureau of Mines estimates lignite reserves of 30,000,000 tons for Corson County (Hamilton and others, 1975, p. 204). This estimate represents reserves of acceptable quality and quantity deemed to be minable at a profit under existing market conditions. A study of the lignite reserves of North Dakota (Pollard and others, 1972) indicated a lack of commercial lignite in Sioux County. Thus, the lignite reserves of the Standing Rock Indian Reservation total about 35.4 million tons.

Mining Methods.--Early mine operators employed horsedrawn drag scrapers along lignite outcrops where the relatively thin overburden could readily be removed. Steam shovels later were employed in mining, permitting removal of thicker overburden and enabling mining to extend further from the outcrop. Eventually, draglines were used to strip overburden, and power shovels removed the lignite (Van Sant, 1959).

Mining operations continued to be small scale in Corson County; mines were operated intermittently when price and demand made such ventures profitable. As lignite at established pits thinned or decreased in quality, because of partings or included carbonaceous shale, or when the overburden became too thick, new pits were opened nearby.

Potential Development.--The potential for using lignite from the Standing Rock Reservation for power generation, or in carbonization, hydrogenation, or gasification facilities appears remote because of the limited reserves and the distance from any potential market. Moreover, the diverse pattern of surface and mineral ownership will create difficulties in the commercial development of lignite.

Petroleum

General.--Petroleum is not being produced on the Standing Rock Indian Reservation, but exploration and drilling are expected to continue.

Three shows of oil and gas have been found in drill holes on the reservation. The test holes are listed in Table 4 and their locations are shown on Figure 14. Of these wells, only three penetrated to the Precambrian. Correlations between some of the holes are shown on Figure 15.

The nearest producing fields are the Lantry "field" in Dewey County, about 60 miles south of the center of the reservation, and in Harding County, South Dakota, and Bowman County, North Dakota, about 120 airline miles west of the center of the reservation.

Geologic Setting and Controls.--The Standing Rock Indian Reservation is near the southeast edge of the Williston Basin. The deepest part of the basin occurs near Williston, North Dakota, where the sedimentary sequence overlying basement granite is believed to be 16,000 to 20,000 feet thick (Hamke and others, 1966).

Pre-Cretaceous sediments within the basin thin or pinchout eastward and southeastward onto the Canadian Shield in central and eastern North and South Dakota. Intermittent uplift of this land mass caused onlapping, offlapping, and erosional pinchouts of all strata below the Cretaceous (Miller, 1971). Unconformities at the base of the Jurassic sedimentary rocks, at the base of the Triassic, at the base of the Permian, at the base of the Pennsylvanian, at the top and bottom of the Devonian, and at the bottom of the Ordovician may provide traps for petroleum (Anderson, 1974).

Three large structures are of regional significance: the Nesson anticline, the Poplar anticline, and the Cedar Creek anticline (Figure 11). All three of the large structures were the sites of petroleum discoveries, but only the Nesson anticline might extend into the northwestern and western portion of the reservation.

<u>Exploration.</u>--Although drilling on the reservation has been relatively limited, a great deal of geophysical exploration has taken place. A summary of the 27 oil tests drilled to date is presented in Table 4. Many of these holes failed to test all of the deeper favorable zones; 6 holes did not penetrate to greater than 3,500 feet (Jurassic), and a majority of the drill holes (15) did not reach below the Mississippian. Only three drill holes extended to the Precambrian. Thus, the Standing Rock Indian Reservation remains largely unexplored.

<u>Lease Status.</u>--More than 16,000 acres of tribal and allotted lands have been leased for oil and gas (Table 5). Chevron Oil Co. is the major lease holder with oil and gas leases on 13,112 acres of tribal and allotted lands. Chevron's leases on private, government, tribal, and allotted lands in Corson and Sioux Counties total approximately 380,000 acres (Griffin, 1977). These leases are for periods of 5 and 10 years and are due to expire in October 1980.

In 1974, the Tribal Council placed a moratorium on all natural resource leases of reservation lands (Resolution No. 51-75, passed Sept. 6, 1974). The moratorium was to remain in effect until pending Federal strip mining legislation was passed, and a study of the impacts of resource development on "Tribal lifestyle, cultural values, and livelihood" was completed by the Tribe.

<u>Potential Resources.</u>--There is some possibility of finding small pools of oil and/or gas on the Standing Rock Indian Reservation. Most of these pools will be stratigraphic traps, as no large, well developed structural traps are known.

The potential of the various rock units beneath the reservation are discussed below in order of decreasing age and depth (see Table 1). This discussion is based largely on Sandberg and Prichard (1964, p. 157-159), Reishus (1968, p. 21-22), Schoon (1971, p. 32-36, 38), Schoon (1972, p. 11, 14), and somewhat on North Dakota Geological Society (1962).

Cambrian rocks are productive of hydrocarbons in only a few localities in the United States and are considered to be unproductive in the Williston Basin area; therefore the Deadwood Formation has little or no potential.

The Winnipeg Formation is considered by Sandberg and Prichard to be of secondary importance in potential production. This unit has yielded many promising oil shows in the northern Williston Basin, but may be largely flushed of hydrocarbons in the reservation.

The Ordovician Red River Formation has one of the greatest potentials for petroleum production in the area, as many of the producing fields in extreme northwestern South Dakota and extreme southwestern North Dakota are in this unit. A few of the wells on or near the reservation obtained oil shows in this unit.

The Stony Mountain Formation has produced a few oil shows in North Dakota, but there is no production and the potential is low.

The Ordovician-Silurian Stonewall Formation, the Silurian Interlake Group, and the Devonian formations, which produce some of the oil in Montana and North Dakota, are considered to have a potential of secondary importance, due to limited extent or thinness.

The Lodgepole, Mission Canyon, and Charles Formations, which comprise the Madison Group, have a very high potential. These units, along with the Red River Formation, are responsible for 80 to 90 percent of the petroleum production in the United States portion of the Williston Basin. Although oil shows from these intervals were encountered on the reservation, the incidence is not particularly high, so the potential may not be as high as originally assessed in 1964 by Sandberg and Prichard.

The Kibbey Sandstone, which produces some oil and displays quite a few oil shows in North Dakota, should have some potential in the reservation, as units above and below it have good potential. It merits at least some drill stem testing to determine its future.

The Pennsylvanian Amsden Formation and Permo-Pennsylvanian Minnelusa Formation have high potential in the area, as the Barker Dome Field in Harding County, South Dakota produces from the Minnelusa. Also, the Minnelusa unit is productive in the Powder River Basin in Wyoming and has yielded many shows of oil on the flanks of the Black Hills. The potential for stratigraphic traps is high, as the formation is a complex of shales, sandstones, limestone, dolomites, and anhydrites. Schoon (1972, p. 22) considers it to be the potential oil producing "sleeper," at least in Harding and Butte Counties. The unit, along with the Amsden, certainly merits consideration on the reservation.

The Permo-Triassic Spearfish Formation yields a few oil shows and a little production in North Dakota, but the pay zones are in lithologic subunits that are probably not present on the reservation, so its potential is small.

The Jurassic rocks have little or no potential, with the possible exception of the Sundance Formation, which may prove to have a small potential. Since the formation consists of interbedded shales and sandstones, potential stratigraphic traps are quite possible.

The Lower Cretaceous Inyan Kara Group (Lakota Formation and Fall River Sandstone) has a possibility for hydrodynamic traps, but stratigraphic traps are believed to be less numerous than in the overlying Newcastle-Dakota interval (Schoon, 1972, p. 11).

The units at the shallowest depth that have the greatest potential for oil production are in the Newcastle-Dakota interval. No commercial oil well production from the Dakota exists at the present time in North and South Dakota, but Cretaceous sandstones that are age and stratigraphically equivalent to the Dakota do produce at several localities in Montana and Wyoming adjacent to the Black Hills.

Natural Gas

General.--Although small quantities of natural gas occur on the reservation, current development of this resource does not seem warranted. However, future price increases may see development of this resource for local use.

Occurrence and Extent.--Natural gas was recovered from water wells in the central part of South Dakota shortly before 1900. Gas was separated from water and used for heating, cooking, and power generation in the city of Pierre during the 1890's. This gas occurs in the Dakota Sandstone (Newcastle) aquifer and is not accompanied by shows of oil. Figure 14 shows the extent of the Pierre gas field in Corson County.

Production and Uses.--Except for the commercial use of natural gas in the city of Pierre from about 1894 to 1913, no systematic production or use of this resource has been attempted (Agnew, 1961). The maximum rate of production from a well in the Pierre field was about 85,000 cubic feet of gas per day, but this rate dropped to about 15,000 cubic feet per day within 6 years (Schoon, 1971). Annual production from the Pierre field is very small, being limited to heating or cooking on ranches where gas is produced from water wells.

Uranium

General.--No surface occurrences of uranium have been reported from the Standing Rock Indian Reservation (Curtiss, 1955a, p. 97). The Williston Basin area contains uranium in the Paleocene sedimentary rocks west and northwest of the reservation, notably in the North and South Belfield areas of Billings County, North Dakota (Noble, 1973) and in the Cave Hills and Slim Buttes areas of Harding County, South Dakota (Schnabel, 1975).

Other uranium occurrences in North Dakota are in the Little Badlands area of Stark County, the Sentinel Butte area of Golden Valley County, the Chalky Buttes area of Slope County, and the Medicine Pole Hills of Bowman County. Those in South Dakota are in the Short Pine Hills area of Harding County and the Lodgepole Buttes area of Perkins County (Jacob, 1976, p. 6).

These known surface occurrences, coupled with recent studies on the Fox Hills Formation (Cvancara, 1976a), the Hell Creek and Ludlow Formations (Moore, 1976), the Cannonball Formation (Cvancara, 1976b), and the Tongue River and Sentinel Butte Formations (Jacob, 1976) suggest a possibility of shallow subsurface occurrences of uranium in the Standing Rock Indian Reservation.

Geologic Setting and Controls.--The uranium was most likely derived from volcanic ash. Downward moving water leached the uranium from the ash. The reducing action of the lignite precipitated the uranium.

The most likely target areas in which to search for epigenetic uranium are below the volcanic ash (see Bentonite and Volcanic Ash section), particularly in eastern Sioux County, where the ash rests on or near the top of the Bullhead Member, and in the permeable sandstone of the Timber Lake Member. This epigenetic uranium would be leached from the volcanic ash by ground-water action and redeposited in lower permeable units containing organic material.

The potential for shallow subsurface syngenetic and epigenetic deposits of uranium on the reservation, particularly from the Fox Hills and Hell Creek, is favorable and warrants more detailed surface and subsurface stratigraphic work.

Geothermal Energy

Geothermal Gradients.--The rate of increase of temperature with depth below the surface of the earth is called the geothermal gradient and varies widely from one location to another; it is a function of rock type and proximity to a heat source.

A value for the geothermal gradient (G) can be obtained from the relationship:

$$G = \frac{100(T - t)}{D}$$

If T is the formation temperature (in degrees Fahrenheit) at depth, t is the mean annual temperature at ground level (ºF), and D is the distance in feet from the surface to the depth of temperature measurement, then G will represent the rate of change of temperature in ºF per 100 feet of depth. The average worldwide geothermal gradient is about 1.6 ºF/100 feet.

The mean annual temperature at the surface in the area of the Standing Rock Reservation is approximately 40ºF. Using this value and the reported bottom-hole temperatures and artesian flow temperatures from oil tests and selected water wells on the reservation, a table of calculated geothermal gradients in the reservation area has been prepared (Table 6). These data show anomalously high geothermal gradients in wells bottomed in the Hell Creek, Fox Hills, and Newcastle Formation and anomalously low geothermal gradients for wells penetrating to the Precambrian basement. These conditions indicate a possible disequilibrium of thermal waters in strata above the Precambrian, a condition that may reasonably be expected to occur in a large structural basin where circulating groundwater may reach several thousand feet below the surface before migrating upslope, transporting geothermal heat from the deeper portions to the flanks of the basin. The number of data points is too small, however, to place much emphasis on the apparent anomalies. Figure 16 is an isogeothermal gradient map of the reservation derived from the data in Table 6.

Development Potential.--Development of the geothermal resources of the Standing Rock Reservation does not appear likely. The near-normal geothermal gradients in the area and the relatively low temperatures encountered at reasonable depths do not make convincing arguments for the investment in equipment necessary to utilize the available heat energy.

NONMETALLIC MINERAL RESOURCES

Nonmetallic resources of the Standing Rock Indian Reservation include sand and gravel, stone, volcanic ash, clay, and shale.

Sand and Gravel

Sand and gravel are the only mineral commodities currently produced from the reservation and annual production is valued at approximately $50,000. Most of the material is obtained from borrow pits near points of use (Figure 17). Good quality concrete aggregate is relatively scarce south and west of the Missouri River and Lake Oahe. Terraces along major streams provide a ready source of sand and gravel, but shale pebbles and concretions in the material render it generally unsuitable for concrete aggregate (Carlson, 1964). Some butte-capping sandstone units are mined and crushed to provide road material.

Supplies of sand and gravel appear sufficient for local use, but the relatively small size of individual deposits and the distance from potential markets indicate that there is little potential for expansion of sand and gravel operations on the reservation.

Stone

Glacial boulders and sandstone are the two types of stone available for use in concrete aggregate and as riprap on the reservation.

Sandstones of the Fox Hills Formation form butte caps in the eastern and central parts of the reservation. The end use of this material, however, is strongly dependent on the cementing material and inclusions. The cements generally are calcite, opal, and silica, but also include clays and iron oxides. Only silica-cemented sandstone (quartzite) is suitable for concrete aggregate because the other cementing materials either are too weak or they react chemically to weaken the finished concrete. Most of the sandstones are suitable for riprap and are widely employed for this purpose.

Glacial boulders are less widely used than sandstone, but are readily available over much of the eastern half of the reservation (Figure 10). These consist of granite or related igneous rock, but some schist and quartzite boulders also are present. They are used as a base course in road construction and as riprap on exposed embankments, stock dams, and irrigation ditches.

Although there are ample supplies of stone on the reservation for local use, the small size of individual deposits and the distance from any potential market severely limit any development of this resource.

Volcanic Ash

A bed of volcanic ash occurs in Sioux County in T. 130 N., Rs. 82, 83, and 84 W. (Manz, 1962). The deposit has not been studied in Sioux County, but a similar deposit in southern Morton County was found to be about 7 feet thick (Laird and Mitchell, 1942). About 15 miles east of the Missouri River in Emmons County, near Linton, a bed of volcanic ash 26 feet thick lies 15 feet above the top of the lower part of the Fox Hills Formation, and about 45 feet above the Pierre Shale (Fisher, 1952). Because these deposits have not been extensively studied, there is no known correlation between the deposits in Sioux, Morton, and Emmons Counties, but the deposits presumably represent the same bed of volcanic ash.

Suitable volcanic ash is extensively used in road construction, concrete admixtures and aggregates, railroad ballast, abrasive materials, and absorbents. Several hundred tons of ash from the deposit near Linton could be calcined to form an acceptable pozzolan for use as an admixture in portland cement concrete. In addition, the work showed that the dried material could be mixed with lime and used to stabilize shaly soils for use as a road base.

Clay and Shale

Clay and shale occur in all outcropping formations on the Standing Rock Indian Reservation. Potential products from these materials include specialized clays such as bentonite, structural products such as brick and tile, pottery and refractory materials, and construction products such as cement material, lightweight aggregate, and road materials.

Bentonite commonly occurs throughout Cretaceous sediments in North and South Dakota (Budge, 1926), but it seldom occurs in sufficient thickness or is of adequate quality to constitute an economic deposit. Several thin but non-commercial bentonite layers occur in outcrops of the Pierre Shale and the Hell Creek Formation. There are no known occurrences of other specialized clays, such as china clay, fire clay, or Fuller's earth, on the reservation (Holmes and Van Sant, 1968; Manz, 1953).

Common clay occurring in the Pierre Shale has been widely used for the manufacture of brick and other structural clay products in South Dakota (Manz, 1973a), but local demand can probably be filled by the nearby brick plant at Mandan, North Dakota.

Ceramic clays, pottery clays, and refractory material may be present in some portions of the Hell Creek Formation and the Pierre Shale, but they have not been studied.

Lightweight aggregate is made from the Pierre Shale at Rapid City, South Dakota (Cole and Zellerstrom, 1954), and might be used for this purpose on the reservation (Manz, 1954).

The bentonitic clays and shales generally are not suitable for road material because they become plastic and very slippery when wet. Gravel from butte-capping sandstones and from glacial boulders are combined with weathered shale and lime to prepare suitable road material. No extensive development of clay and shale for road material is likely.

RECOMMENDATIONS

Further study of the oil and gas possibilities of the Standing Rock Indian Reservation is warranted. Such a study should assemble all available drill-hole and geophysical data to determine the most prospective portions of the reservation for future exploration.

A limited field study to explore for uranium-bearing lignites is recommended.

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TABLE 1. -- Stratigraphic sequence on Standing Rock Indian Reservation, in part from drill-hole data (Agnew and Tychsen, 1965; Carlson, 1960; Carlson and Anderson, 1965; Carlson and Eastwood, 1962; Clayton, Moran, and Bickley, 1976; Dow, 1967; Feldman, 1972; Frye, 1964, 1969; Hansen, D. E., 1955; Kume, 1963; North Dakota Geological Survey, 1973; North and South Dakota Geological Survey open file oil and gas test data; Petroleum Information files; Reishus, 1968; Schoon, 1971; South Dakota Geological Survey Geol. Quad. maps; U.S. Geological Survey and South Dakota Geological Survey, 1964, 1975)

System	Series	Group or Formation	Member	Description	Thickness (feet)
QUATERNARY	HOLOCENE	Alluvium		Clay, silt, sand and gravel on floodplains of present drainages	0-120
QUATERNARY	HOLOCENE	Landslide deposits		Jumbled, slumped blocks of bedrock, particularly the Hell Creek, Fox Hills, and Pierre, in the breaks near major drainages	varied
QUATERNARY	PLEISTOCENE AND HOLOCENE	Loess (SD) Oahe Formation (ND) (divided into 4 members based largely on color)		Wind-blown silt, with lesser amounts of clay and sand, mantling gently sloping surfaces and uplands	0-6.56
			Riverdale Member	Lower submember grayish brown Middle submember light brownish gray Upper submember grayish brown	As much as 3.28
			Pick City Member	Light gray	As much as 3.28
			Aggie Brown Member	Lower submember light brown Upper submember dark gray to very dark gray	0.33-1.64
			Mallard Island Member	Very pale brown; sandiest and most dolomitic member	0.33-3.28
		Terrace deposits		Sand and gravel, minor amounts of silt and clay	0- 25
	PLEISTOCENE	Glacial drift (SD) - Coleharbor Formation (ND)		Till, till residuum occuring as boulders, outwash, and lake sediment composed of sand, gravel, clay, and silt often complexly interbedded; occurs as patchy remnants, particularly in South Dakota portion of reservation, becoming thicker and less patchy in North Dakota portion of reservation	0-340
ARY	PLIO-CENE	Ogallala Formation(?)		Green-gray silica-cemented sandstone (orthoquartzite), forming the cap rock of a few buttes and mesas in eastern Corson County; may be orthoquartzite beds in either the Hell Creek or Fox Hills Formations	As much as 10
		UP: Tongue River Formation		Tan to rose medium-grained sandstone with occasional clay pebbles; occurs as scattered erosional remnants in the northwest corner of reservation	As much as 25
		UP: Cannonball-Ludlow Formations		Interfingering facies relationship between marine Cannonball and nonmarine Ludlow Cannonball is poorly consolidated, very fine- to fine-grained, light to medium brownish yellow	As much as 100

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TERTI	PALEOCENE	Fort Union Gro		weathering sandstone and light gray-weathering, sandy mudstone	
				Ludlow is gray to buff, medium- and fine-grained, arkosic and graywacke sands and silts, clayey sands, and sandy clays with numerous slabby lenses of calcareous sandstone. Locally contains the Shadehill Lignite Facies at the base and the Hillen Lignite Facies from 25 to 80 feet above the base. The lignite facies consist of one or more thin seams of black blocky or fissile lignite and associated sands, clays, and peat clays.	65-250
				Hillen Lignite Facies	0- 40
				Shadehill Lignite Facies	0- 70
		Hell Creek Formation	Upper Hell Creek (SD)	Lenticular bentonitic clays, silts, sands, and peat-clays; scattered iron-manganese concretions and quartzose sandstones on surface	300-350
			Pretty Butte and Huff Members (ND)	Bentonite, bentonitic shale and some channel sandstone, with common Fe-Mn nodules	10- 15
				Channel sandstones, with bentonites and bentonitic shales	As much as 90
			Isabel-Firesteel Lignite Facies (SD)	Black, blocky, sub-bituminous coal, lignite and brown clay-peat beds. Buff to red, burned claystone (pseudo scoria) locally	0- 25
			Fort Rice Member (ND)	Lignitic and bentonitic shales, thin sandstones, and siderite nodules	40- 60
			Lower Hell Creek (SD)	Medium- to dark-gray lenticular bentonitic clays, silts, sands, peat-clay beds; a few iron-manganese concretions	30- 80
			Breien and	Brown weathering, greenish brown, glauconitic sand with Ophiomorpha; marine tongue confined to Sioux County portion of reservation	0- 20
			Crowghost Members (ND)	Lignitic, bentonitic shales, a few sandstones, common siderite nodules	20- 30
		Fox Hills Sandstone	Colgate Sandstone Member	Thin-bedded, gray, siliceous cemented, fine-grained, graywacke, sandstone; crossbedded, ripple-marked, few limonitic concretions	15- 35 (SD) 5- 40 (ND)
			Bullhead Member	Thin, alternating beds of light gray to buff, very fine-grained graywacke sand and dark to brown-gray fissile, silty clay; local limonitic concretions	As much as 110
			Timber Lake Member	Massive to laminated and cross-bedded, buff to light-gray sandstone; reddish-brown calcareous and ferruginous sandstone ledges, nodular cemented areas, and limonitic concretions.	110-230 (SD) As much as 130 (ND)
	EOUS		Trail City Member	Mottled, buff, sandy silt and silty clay; local beds of brown, fine-grained graywacke sandstone and scattered layers with sandy, gray to brown, lenticular fossiliferous limestone concretions; not recognized in North Dakota.	80-200

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CRETACEOUS	UPPER CRETAC	Pierre Shale	Elk Butte Member	Dark-gray bentonitic clay; contains numerous reddish-brown layers, yellow calcite concretions, thin bentonite beds, and silt at the top	As much as 290
			Mobridge Member	Buff and gray, slightly calcareous clay in lower part; numerous thin marl layers in lower and middle part; and light-buff calcareous clay in upper part. Loses identity to west and northwest where it and the above member are called Upper Pierre.	As much as 230
			Virgin Creek Member	Dark-gray, fissile, siliceous shale with numerous bentonites in the lower part and white limestone concretions in the upper part	As much as 225
			Verendrye Member	Brown bentonitic clay with few bentonite beds and numerous ferruginous concretions	As much as 180
			DeGrey Member	Light-gray siliceous blocky shale in the lower part and gray clay with iron-manganese concretions in the upper part; numerous bentonite beds throughout	As much as 160
			Crow Creek Member	Buff to gray marl with 0.5 to 1 foot thick reddish brown siltstone at base. This may not extend to reservation	As much as 10
			Gregory Member	Light gray to buff bentonitic shale; few bentonite beds; many concretions and calcareous layers; a few marl beds. Loses its identity to the west.	As much as 125
			Sharon Springs Member	Black, fissile, organic shale with abundant fish scales; numerous bentonite beds at the base	120
			Gammon Ferruginous Member	Light-gray mudstone and shale with abundant concretions and thin beds of siderite; slightly calcareous at base. Pinches out to the east and may not underlie all of reservation.	0-140
		Niobrara Formation		Light to dark gray, highly calcareous chalk with white specks and several bentonite beds	As much as 385
		Carlile Shale	Codell Sandstone Member	White to gray sandstone	0- 70
				Medium to dark-gray shale with scattered ironstone concretions	As much as 350
		Greenhorn Limestone		Light- to dark-gray fossiliferous limestone, interbedded with dark-gray calcareous shale with white specks	As much as 95
		Belle Fourche Shale		Dark gray shale with limestone and ironstone concretions and a few bentonite beds. To the east this and underlying unit known as Graneros Shale.	As much as 140
	TACEOUS	Mowry Shale		Medium gray siliceous shale with Mowry bentonite marking the top	As much as 285
		Newcastle Sandstone	Dakota Sandstone	Newcastle Formation is white to light-gray fine-grained sandstone with some shaly intervals. Dakota Sandstone is white, fine to medium grained sandstone. These are tongues, which extend westward from the main body of the formation. These tongues are stratigraphically higher than the Newcastle.	0- 85 0- 60

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	LOWER CRE	Skull Creek Shale		Medium- to dark-gray shale, with sandy and/or siliceous shale at the base	As much as 260
		Inyan Kara Group	Fall River Sandstone	Well-bedded, fine-grained sandstone with interbeds of gray to black shale	As much as 150
			Fuson Shale	Variegated gray shale, noted in some drill logs	0- 20(?)
			Lakota Formation	Claystone, siltstone, locally massive poorly sorted sandstone, carbonaceous shale, coal, shale, and limestone	As much as 200
JURASSIC	UPPER JURASSIC	Morrison Formation		Variegated clay and shale with some gray siltstone and sandstone	As much as 150
		Sundance Formation		White sandstone, in part glauconitic, interbedded with gray, green, and brown shale	As much as 300
	MID. JUR.	Piper Formation		White to brown fine-grained limestone; interbedded with variegated shale	As much as 200
TRIASSIC		Spearfish Formation		Reddish shale, silty shale, anhydrite, dolomitic siltstone, and clay; interbedded. Anhydrite and dolomite most numerous near base	As much as 200
PERMIAN		Minnekahta Limestone		White to lavender to pink, dense, fine-grained dolomitic limestone	As much as 50
		Opeche Shale		Dark reddish brown shale, silty shale and siltstone	As much as 50
		Minnelusa Formation		Varicolored, red-brown, purple, and green shales; reddish-orange, pink to white, angular to round, medium- to fine-grained sandstone; pink to buff dolomitic sandstone; cream to pinkish-gray limestone; reddish dolomite, anhydritic dolomite, and anhydrite	As much as 350
PEN-NSYLVANIAN		Amsden Formation		Interbedded sandstone, shale, and carbonates	As much as 250
MISSISSIPPIAN		Big Snowy Group	Kibbey Sandstone	White to gray, medium to coarse-grained sandstone with some limestone and silty shale. Sometimes separated into Big Snowy and underlying Kibbey sandstone in drill logs.	As much as 350
		Madison Group	Charles Formation	White to light tan, lithographic limestone; inter-bedded with white to light blue and light brown anhydrite	As much as 350
			Mission Canyon Limestone	White to light-tan, fine-grained to oolitic, fossiliferous limestone; some anhydrite	As much as 470
			Lodgepole Limestone	Gray and light- to medium-brown, fine- to medium-grained limestone; in part oolitic, fossiliferous, and sucrosic	As much as 600
		Englewood-Bakken Formations		Englewood is shale, shaly and silty limestone, dolomitic limestone, calcareous siltstone and dolomitic siltstone. Bakken is sandstone, silty limestone, and limestone interfingering and interbedded, overlain by black shale.	0- 35
		Three Forks Shale		Interbedded greenish to reddish gray dolomitic siltstone red and green shale; and fine- to medium-grained sandstone	As much as 50

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DEVONIAN	Birdbear Formation		Light-gray to medium brownish-gray, finely crystalline, porous, fossiliferous dolomite and limestone	As much as 60
	Duperow Formation		Light brown, fine-grained limestone, dolomite, and anhydrite; interbedded with thin gray shale	As much as 175
	Souris River Formation		Varicolored shale, red dolomitic siltstone, anhydrite and limestone, alternating	As much as 70
	Dawson Bay Formation		Limestone and dolomitic limestone. Present only in extreme northern portion of reservation.	0- 10
	Winnipegosis Formation		Fine-grained silty and argillaceous carbonate in lower part; limestone and anhydrite in upper part. Present only in northwestern part of reservation.	0- 50
SILURIAN	Interlake Group		Light-tan to brown dolomite; white to light-gray limestone; gray shale; fine-grained clastics at base	0-250
ORDOVICIAN	Stonewall Formation		Finely crystalline dolomite with a few thin beds of shale and anhydrite	0- 75
	Stony Mountain Formation	Gunton Member	Limestone	0- 50
		Stoughton Member	Shaly limestone	85- 95
	Red River Formation		Light- to medium-gray and light-brown limestone and dolomite; in part vuggy	As much as 625
	Winnipeg Formation	Roughblock Member	Fine-grained calcareous siltstones and sandstones	45- 70
		Ice Box Member	Greenish-gray, generally noncalcareous shale	100-135
		Black Island Member	Clean quartzose sandstone	0- 30
CAMBRIAN	Deadwood Formation		Sandstone at base and top, with shale and carbonate in the middle	250-550
PRECAMBRIAN			Igneous and metamorphic rocks	

|| indicates possible correlation

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TABLE 2. - Analyses of lignites from the Standing Rock Indian Reservation

Location and reference	Facies	Moisture (percent)	Volatile matter (percent)	Fixed carbon (percent)	Ash (percent)	Sulfur (percent)	Btu (as received)	Btu (dry basis)	Btu (moisture and ash free)
OUTCROP............... NW 26, 23N, 19E (Stevenson and others, 1954a, Morristown Quad.)	Hillen Lignite	45.40	29.37	9.69	15.54	0.66	3,515	6,438	8,999
OUTCROP............... NE 6, 22N, 22E (Stevenson and Loken, 1957, McIntosh Quad.)	......do......	45.19	28.30	14.86	11.65	0.44	4,018	7,331	9,310
OUTCROP.............. NESW 1, 17N, 17E (Curtiss and others, 1954c, Glad Valley Quad.)	Shadehill Lignite	32.84	38.56	20.32	8.28	0.27	6,300	9,381	10,700
Unnamed Mine.......... NWNW 24, 21N, 17E (Stevenson and others, 1954b, Thunder Hawk Quad.)	......do......	37.52	27.45	7.87	27.16	0.24	3,100	4,962	8,777
WATAUGA AREA.......... 23N, 21E (Stevenson and others 1954a, Morristown Quad.)	......do......	42.26	32.60	15.02	10.12	0.70	4,657	8,065	9,780
OUTCROP............... NW 19, 21N, 21E (Calvert and others, 1914)	Isabel-Firesteel Lignite	30.5	23.0	34.4	12.1	0.39	6,940	9,990	12,100
OUTCROP............... SW 1, 129N, 88W (Calvert and others, 1914)	......do......	33.1	25.5	36.1	5.3	0.69	7,470	11,160	12,120
OUTCROP............... NE 5, 129N, 88W (Calvert and others, 1914)	......do......	32.1	25.6	31.7	10.6	1.19	6,820	10,040	11,910
OUTCROP............... SE 4, 129N, 88W (Calvert and others, 1914)	......do......	32.5	27.1	34.6	5.8	0.37	7,250	10,740	11,750
OUTCROP............... SE 34, 20N, 19E (Curtiss and others, 1954a, Black Horse Butte Quad.)	......do......	25.67	33.69	18.19	21.73	0.40	5,219	7,021	9,922
OUTCROP............... 14, 19N, 19E (Curtiss and others, 1954a, Black Horse Butte Quad.)	......do......	38.53	29.68	24.50	7.29	0.45	6,298	10,246	11,624
OUTCROP.............. SWNW 19, 21N, 23E (Stevenson and Loken, 1957, McIntosh Quad.)	......do......	38.26	32.69	19.56	9.49	0.38	5,132	8,312	9,822
ANDERSON MINE......... SWSE 7, 18N, 20E (Searight, 1930)	......do......	34.98	25.34	31.15	8.53	0.31	6,854	10,541	12,133
BLACKHORSE MINE....... NESE 34, 21N, 22E (Curtiss and others, 1954b, Firesteel Creek Quad.)	......do......	33.39	26.67	20.02	19.92	0.38	5,527	8,298	11,838
CEDAR BOY MINES....... SESW 11, 20N, 20E (Curtiss and others, 1954d, Gopher Quad.)	......do......	41.07	30.26	22.74	5.93	0.33	5,732	9,727	10,815
HILL MINE............. SWSE 7, 18N, 20E (Curtiss and others, 1954d, Gopher Quad.)	......do......	34.94	33.08	27.69	4.29	0.29	7,363	11,317	12,116
HILL MINE (Run of mine) 7, 18N, 20E (Aresco and others, 1960)	......do......	36.3	25.4	31.7	6.6	0.51	7,020	11,020	12,294
KELLER MINE........... SWSW 36, 19N, 21E (Curtiss and others, 1954b, Firesteel Creek Quad.)	......do......	25.98	38.04	29.89	6.09	0.48	7,712	10,419	11,353
KELLER MINE (Run of Mine) 36, 19N, 21E (Aresco and others, 1957)	......do......	36.3	25.4	32.2	6.1	0.32	7,040	11,050	12,222
KENNEDY MINE.......... SESW 7, 18N, 20E (Searight, 1930)	......do......	34.90	27.57	32.69	4.84	0.30	7,101	10,908	11,784
ZUBROAD MINE.......... SESW 29, 21N, 21E (Curtiss and others, 1954d, Gopher Quad.)	......do......	41.07	32.20	20.78	5.95	0.39	5,586	9,479	10,544

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TABLE 3. - Lignite production from Standing Rock Indian Reservation

Year	Total North and South Dakota production (short tons)	Production from study area (short tons)	Portion of total N. and S. Dakota production from study area	Counties included in "production from study area" Figures[1]
1884	35,000	35,000	*[2]	Morton[3]
1885	25,000	25,000	*	Morton
1886	25,995	25,995	*	Morton
1887	21,470	0	*	No record of production from study area.
1888	34,000	34,000	*	Morton, Stark, and Ward
1889	28,907	28,907	*	Do.
1890	30,000	30,000		Do.
1891	30,000	30,000	*	Do.
1892	40,725	40,725	*	Do.
1893	49,630	19,000	*	Morton
1894	42,015	8,951	*	Do.
1895	39,197	14,337	*	McLean and Morton
1896	78,050	24,930	*	Morton
1897	77,246	29,271	*	Do.
1898	83,895	12,920	*	Do.
1899	98,809	18,850	*	Do.
1900	129,883	27,428	*	Do.
1901	166,601	52,850	*	Do.
1902	226,511	18,317	*	Do.
1903	278,645	13,500	*	Do.
1904	266,128	10,663	*	Do.
1905	317,542	26,100	*	Do.
1906	305,689	23,194	*	Do.
1907	347,760	10,690	*	Do.
1908	320,742	20,850	*	Do.
1909	422,047	18,634	*	Do.
1910	399,041	23,250	*	Do.
1911	502,628	20,034	*	Do.
1912	499,480	36,326	*	Do.
1913	495,320	40,486	*	Do.
1914	518,535	34,323	*	Do.
1915	538,671	0	0.0	No production from study area.
1916	643,798	0	0.0	Do.
1917	798,590	0	0.0	Do.
1918	727,675	0	0.0	Do.
1919	855,376	0	0.0	Do.
1920	961,402	0	0.0	Do.
1921	872,456	0	0.0	Do.
1922	1,335,316	0	0.0	Do.
1923	1,395,779	0	0.0	Do.
1924	1,212,570	0	0.0	Do.
1925	1,339,067	0	0.0	Do.
1926	1,384,672	408	0.0	Corson and Harding
1927	1,540,446	720	0.0	Do.
1928	1,663,859	700	0.0	Do.

Continued

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TABLE 3. - Lignite production from Standing Rock Indian Reservation--Continued

Year	Total North and South Dakota production (short tons)	Production from study area (short tons)	Portion of total N. and S. Dakota production from study area Figures[1]	Counties included in "production from study area"
1929	1,874,984	4,716	0.3	Corson, Dewey, and Ziebach
1930	1,712,967	625	0.0	Corson and Ziebach
1931	1,546,792	993	0.1	Do.
1932	1,788,732	3,246	0.2	Do.
1933	1,841,647	7,395	0.4	Corson, Harding, and Ziebach
1934	1,796,295	3,210	0.2	Corson and Ziebach
1935	1,968,753	5,162	0.3	Corson, Dewey, and Harding
1936	2,256,666	0	0.0	No production from study area.
1937	2,297,816	0	0.0	Do.
1938	2,098,157	43,164	2.1	Corson, Dewey, and Harding
1939	2,180,747	44,907	2.1	Corson and Dewey
1940	2,284,519	61,077	2.7	Do.
1941	2,379,713	65,730	2.8	Do.
1942	2,590,554	48,226	1.9	Do.
1943	2,540,866	38,909	1.5	Corson
1944	2,392,919	22,887	1.0	Corson, Dewey, and Meade
1945	2,546,764	0	0.0	No production from study area.
1946	2,571,628	1,370	0.1	Corson
1947	2,774,480	0	0.0	No production from study area.
1948	2,990,083	1,804	0.1	Corson
1949	2,392,474	2,280	0.1	Do.
1950	3,260,973	0	0.0	No production from study area.
1951	3,252,377	28,350	0.9	Corson and Dewey
1952	2,983,752	0	0.0	No production from study area.
1953	2,886,229	3,147	0.1	Corson
1954	W	W	*	Production figures withheld
1955[4]	3,127,869	0	0.0	No production from study area.

W Withheld to avoid disclosing company confidential data.
[1] Production figures of several counties often are combined to avoid disclosing company confidential data.
[2] Percentage figures omitted because no lignite production actually occurred on the Standing Rock Reservation.
[3] Sioux County was not formed until Sept. 3, 1914; prior to that time, it was a part of Morton County.
[4] No lignite production has been reported from the study area after 1955.
SOURCE: U.S. Bureau of Mines.

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TABLE 4. - Oil tests on the Standing Rock Indian Reservation

Year completed	Name of test well	Location: Section	Location: Township	Location: Range	Total depth	Formation(s) tested	Bottom hole Formation
1952	Shell No. 1 Winter.................	CNWSW 11	22N	19E	9,010	Greenhorn, Dakota, Charles, Madison, Ordovician	Precambrian
1953	Youngblood No. 1 Winter............	CSWSW 23	22N	19E	5,822	Charles, Mission Canyon	Lodgepole
1953	Youngblood No. 1 Macheel...........	CSWSW 8	21N	19E	5,822	Mission Canyon	Lodgepole
1954	Youngblood No. 1 Draskovich........	SESE 20	23N	22E	7,465	Mission Canyon	Winnipeg
1954	Ohio No. 1 Standing Rock Sioux Tribe	NESW 29	131N	80W	5,906	no tests	Winnipeg
1957	Shell No. 22-12 Everidge...........	SENW 12	18N	19E	6,468	no tests	Red River
1957	Shell No. 11-23 Government.........	NWNW 23	19N	18E	5,777	no tests	Lodgepole
1961	Kilroy, Swindler No. 1 Scholl......	CNENW 26	18N	21E	6,128	Charles, Red River	Red River
1965	Wilhite No. 1 State................	SESW 36	22N	21E	6,680	Red River	Red River
1969	Koch No. 1 Bickel..................	SWSE 4	18N	23E	3,100	Mowry	Morrison
1969	Koch No. 1 Kline...................	SWSE 25	20N	22E	3,147	no tests	Fall River
1969	Koch No. 1 State...................	SWSE 32	23N	27E	3,050	Mowry	Morrison
1969	Cayman Murphy No. 1 "A" State......	SWSW 8	21N	24E	5,230	no tests	Duperow
1969	Koch No. 1 Schott-Knudson..........	NWNE 35	21N	26E	2,935	Mowry	Morrison
1969	Koch No. 1 Richter.................	SESE 4	19N	25E	2,904	Mowry	Morrison
1969	Koch No. 1 Green...................	SESE 31	22N	24E	3,079	Mowry	Dakota
1969	Cayman Murphy No. 1 "B" State......	SESE 12	21N	24E	4,039	Niobrara	Charles
1969	Cayman Murphy No. 1 "C-2" State....	NWSE 16	22N	23E	4,424	no tests	Charles
1969	Cayman Murphy No. 1 State..........	NENE 10	22N	24E	4,315	no tests	Charles
1969	Cayman Murphy No. 4 "B" State......	NWSE 16	20N	25E	3,567	no tests	Charles
1970	Consolidated No. 1 Tribal..........	SWNW 32	20N	18E	7,515	Mission Canyon, Red River	Winnipeg
1973	Gruy No. 1 Kary....................	SWSW 35	133N	81W	3,890	no tests	Charles
1974	Bartlett No. 1 Guyer...............	SWSW 20	23N	23E	7,650	Charles, Mission Canyon, Lodgepole	Precambrian
1975	Webb No. 7-5 Huber.................	SWNW 7	22N	23E	6,711	no data	no data
1976	Cockrell No. 1 Lillegaard..........	SENE 13	22N	18E	7,650	no tests	Red River
1976	Chevron No. 13-5 Bailey............	NWNE 5	21N	21E	7,400	Mission Canyon, Red River	Precambrian
1977	Gruy No. 1 Mossett.................	SWSW 32	130N	81W	4,100	no tests	Madison

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TABLE 5. - Oil and gas leases of tribal and allotted lands of the Standing Rock Indian Reservation

Lease No. 14-20-A10-	Location TWP.	Location Range	Location Section and subdivision	Date lease issued	Term	T=Tribal A=Allotted lands	Lease holder	Acreage
2093	19N	22E	1; SW/4	8-8-69	10 years	A	Chevron Oil Co.	160.00
2094	19N	22E	2; S/2NE/4	..do..	...do...	T	......do......	80.00
2095	19N	22E	2; lot 4, SW/4NW/4	..do..	...do...	T	......do......	465.55
	20N	22E	34; S/2NE/4,NW/4,SE/4					
2096	19N	22E	3; SW/4	..do..	...do...	A	......do......	160.00
2097	19N	22E	9; NW/4	..do..	...do...	T	......do......	160.00
2098	19N	22E	11; NW/4	..do..	...do...	T	......do......	160.00
2099	19N	22E	12; SE/4	..do..	...do...	T	......do......	160.00
2100	20N	22E	13; lots 1,4,5, NE/4	8-7-69	...do...	A	......do......	374.20
	20N	23E	18; lots 1,2, E/2NW/4					
2101	20N	22E	13; lots 6,7,12,13, SW/4SE/4	..do..	...do...	A	......do......	143.20
2102	19N	23E	6; lots 1,2,6,7, S/2NE/4,E/2SW/4	8-8-69	...do...	T	......do......	309.80
2103	19N	23E	28; N/2	..do..	...do...	T	......do......	320.00
2104	19N	23E	33; N/2	..do..	...do...	A	......do......	640.00
			28; S/2					
2105	19N	23E	29; NE/4	..do..	...do...	A	......do......	160.00
2106	19N	23E	29; SW/4	..do..	...do...	A	......do......	160.00
2107	19N	23E	29; SE/4	..do..	...do...	A	......do......	160.00
2108	19N	23E	30; lots 3,4, E/2SW/4	..do..	...do...	A	......do......	151.50
2109	19N	23E	33; SW/4	8-9-69	...do...	A	......do......	160.00
2110	19N	23E	33; SE/4	8-8-69	...do...	A	......do......	160.00
2111	20N	23E	19; lot 1	..do..	...do...	T	......do......	18.40
2112	20N	23E	19; lot 3	..do..	...do...	T	......do......	34.10
2113	20N	23E	19; lot 6, NW/4SE/4	..do..	...do...	T	......do......	86.10
2114	20N	23E	20; N/2NE/4,N/2S/2NE/4,N/2S/2S/2NE/4	8-9-69	...do...	A	......do......	140.00
2115	20N	23E	29; S/2S/2N/2NW/4	8-8-69	...do...	T	......do......	20.00
2116	20N	23E	29; SE/4SW/4	..do..	...do...	T	......do......	40.00
2117	20N	23E	30; lots 7,20, NE/4SW/4	..do..	...do...	T	......do......	70.41
2118	21N	24E	3; lots 1,2, S/2NE/4	8-16-69	...do...	A	......do......	160.79
2119	21N	24E	3; lot 4, S/2NW/4,SW/4	8-8-69	...do...	T	......do......	600.06
			9; NE/4					
			10; NW/4					
2120	21N	24E	4; S/2 [923/945 interest]	..do..	...do...	T	......do......	320.00
2121	21N	24E	5; S/2					
			6; lots 6,7, E/2SW/4,SE/4	..do..	...do...	T	......do......	633.75
2122	21N	24E	9; S/2					
			10; SW/4,W/2SE/4	..do..	...do...	T	......do......	560.00
2123	21N	24E	10; E/2SE/4					
			15; W/2NE/4,NW/4	..do..	...do...	A	......do......	320.00
2124	21N	24E	15; E/2NE/4	..do..	...do...	A	......do......	80.00
2125	21N	24E	15; S/2	..do..	...do...	A	......do......	320.00
2126	22N	24E	19; NE/4	8-6-69	...do...	A	......do......	160.00
2127	22N	24E	20; SW/4	8-8-69	...do...	A	......do......	160.00
2128	22N	24E	20; SE/4	8-7-69	...do...	A	......do......	160.00
2129	22N	24E	29; NE/4	8-8-69	...do...	T	......do......	160.00
2130	22N	24E	32; NE/4	8-7-69	...do...	A	......do......	160.00
2131	22N	24E	32; SE/4	..do..	...do...	A	......do......	160.00
2132	22N	24E	33; SW/4	8-9-69	...do...	A	......do......	160.00
2133	22N	24E	33; S/2SE/4	8-8-69	...do...	T	......do......	80.00
2134	22N	24E	34; NW/4	8-11-69	...do...	A	......do......	160.00
2135	22N	24E	34; SW/4	8-7-69	...do...	A	......do......	160.00
2136	22N	24E	34; N/2SE/4	8-8-69	...do...	T	......do......	80.00
2137	19N	22E	4; lots 3,4, S/2NW/4	..do..	...do...	A	......do......	159.82
2138	19N	23E	29; NW/4	8-28-69	...do...	A	......do......	160.00
2139	20N	22E	15; SW/4	8-15-69	...do...	A	Southland Royalty Co.	160.00
2140	20N	22E	22; E/2	8-18-69	...do...	T	......do......	800.00
			27; N/2					
2141	20N	22E	24; SE/4	8-15-69	...do...	A	......do......	160.00
2142	20N	22E	26; SW/4SW/4	8-18-69	...do...	T	......do......	40.00
2143	20N	22E	36; NW/4	8-15-69	...do...	A	......do......	160.00
2144	20N	23E	17; NE/4	8-18-69	...do...	T	......do......	160.00
2145	20N	23E	17; NW/4	8-15-69	...do...	A	......do......	160.00
2146	20N	23E	18; E/2	..do..	...do...	A	......do......	320.00
2147	20N	22E	15; E/2	..do..	...do...	A	......do......	320.00
2148	20N	22E	15; NW/4	..do..	...do...	A	......do......	160.00
2149	19N	23E	30; NE/4	9-25-69	...do...	A	Chevron Oil Co.	160.00
2150	21N	24E	18; lots 1,2, E/2NW/4	9-17-69	...do...	A	......do......	155.09
2151	20N	23E	20; SE/4	9-24-69	...do...	A	......do......	160.00
2152	19N	23E	5; lots 3,4, S/2NW/4	12-18-69	...do...	A	......do......	159.07
2153	20N	22E	23; SE/4	8-15-69	...do...	A	Southland Royalty Co.	320.00
			26; NE/4					
2184	22N	24E	32; SW/4 [8/9 interest]	8-7-69	...do...	A	Chevron Oil Co.	160.00
2185	19N	23E	25; SE/4	8-28-69	...do...	A	International Nuclear Corp.	160.00
2851	21N	20E	12; NE/4	9-4-75	5 years	T	Chevron Oil Co.	160.00
2852	21N	21E	5; lot 1, S/2NE/4,NW/4SE/4	..do..	...do...	T	......do......	159.93
2853	21N	21E	6; lots 1,2, S/2NE/4,SE/4	9-9-75	...do...	A	......do......	318.26
2854	21N	21E	7; lots 1,2, E/2NW/4	9-4-75	...do...	T	......do......	157.98
2855	21N	21E	10; N/2,N/2SE/4,SE/4SE/4	..do..	...do...	T	......do......	440.00
2856	21N	21E	15; SW/4	..do..	...do...	T	......do......	160.00
2857	21N	21E	16; S/2SW/4	9-9-75	...do...	A	......do......	80.00
2858	21N	21E	21; W/2	9-4-75	...do...	T	......do......	320.00
2859	21N	21E	23; S/2	..do..	...do...	T	......do......	320.00
2860	22N	21E	20; SE/4	9-9-75	...do...	A	......do......	160.00
2861	22N	21E	30; lots 1,2,3,4, E/2W/2	..do..	...do...	A	......do......	314.12
2862	22N	21E	32; E/2	..do..	...do...	A	......do......	320.00
75 Total Leases							Total Acreage	16,032.13

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TABLE 6. - Calculated geothermal gradients from drill-hole data in the vicinity of the Standing Rock Indian Reservation

Well or drill hole	Location Section	Township	Range	Depth of temp. measurement (feet)	Measured temperature (°F)	Calculated geothermal gradient (F°/100 feet)	Formation
N. Dak. State Water Com. Test Hole No. 4523......	NENE 31	130N	84W	466	56.3	3.50	Hell Creek
N. Dak. State Water Com. Test Hole No. 4525......	SESE 5	129N	88W	466	53.6	2.92	Hell Creek
Koch No. 1 Schott-Knudson........................	NWNE 35	21N	26E	2,593	92	2.01	Newcastle
Herndon No. 1 Merkel.............................	SESE 27	17N	27E	4,322	126	1.99	Red River
N. Dak. State Water Com. Test Hole No. 4526......	NENE 30	131N	89W	809	55.4	1.90	Fox Hills
Consolidated No. 1 Tribal........................	SWNW 32	20N	18E	5,490	143	1.88	Mission Canyon
Love Water Well..................................	SENE 7	18N	29E	2,300	83	1.87	Newcastle (?)
Koch No. 1 Kline.................................	SWSE 25	20N	22E	3,147	98	1.84	Inyan Kara Gp.
Koch No. 1 State.................................	SWSE 32	23N	27E	2,717	89	1.80	Newcastle
Youngblood No. 1 Winter..........................	SWSW 23	22N	19E	5,823	144	1.79	Kibbey
Wilhite No. 1 State..............................	SESW 36	22N	21E	6,494	154	1.76	Red River
Koch No. 1 Green.................................	SESE 31	22N	24E	3,078	94	1.75	Newcastle
Ohio No. 1 Standing Rock Sioux Tribe.............	NESW 29	131N	80W	5,906	142	1.73	Winnipeg
Koch No. 1 Richter...............................	SESE 4	19N	25E	2,904	90	1.72	Morrison
Shell No. 22-12 Everidge.........................	SENW 12	18N	19E	6,468	149	1.69	Red River
Herndon No. 1 Young..............................	NWNE 1	16N	20E	5,960	140	1.68	Red River
Koch No. 1 Bickel................................	SWSE 4	18N	23E	3,100	92	1.68	Morrison
Murphy No. 4 Cayman-Murphy-State-B...............	NWSE 16	20N	25E	3,561	99	1.66	Charles
Shell No. 14-18 Greis............................	SWSW 18	17N	18E	5,700	134	1.65	Englewood
Claymore Water Well..............................	SWSW 16	21N	30E	2,688	84	1.64	Newcastle (?)
Youngblood No. 1 Draskovich......................	SESE 20	23N	22E	7,465	161	1.62	Deadwood (?)
Murphy-Cayman No. 1 "B" State....................	SESE 12	21N	24E	4,039	105	1.61	Charles
Shell No. 11-23 Government.......................	NWNW 23	19N	18E	5,775	132	1.59	Lodgepole
Murphy-Cayman No. 1 State........................	NENE 10	22N	24E	4,315	108	1.58	Charles
Murphy-Cayman No. 1 "C-2" State..................	NWSE 16	22N	23E	4,424	110	1.58	Charles
Kilroy-Swindler No. 1 Scholl.....................	NENW 26	18N	21E	6,128	135	1.55	Red River
Youngblood No. 1 Williams-Macheel................	SWSW 8	21N	19E	5,820	130	1.55	Lodgepole
Gruy No. 1 Kary..................................	SWSW 35	133N	81W	3,890	100	1.54	Charles
Thurston Water Well..............................	SWNW 34	20N	26E	2,336	75	1.50	Newcastle (?)
Webb Resources No. 7-5 Huber.....................	SWNW 7	22N	23E	6,711	140	1.49	Red River (?)
Gruy No. 1 Hatzenbuhler..........................	NESE 22	134N	81W	4,504	104	1.42	Mission Canyon
Murphy-Cayman No. 1 "A" State....................	SWSW 8	21N	24E	5,230	112	1.38	Duperow
Bartlett No. 1 Guyer.............................	SWSW 20	23N	23E	7,650	142	1.33	Precambrian
Shell No. 1 Winter...............................	NWSW 11	22N	19E	8,445	150	1.30	Precambrian
Youngblood No. 1 Galvin..........................	SESE 25	16N	22E	6,324	118	1.23	Precambrian

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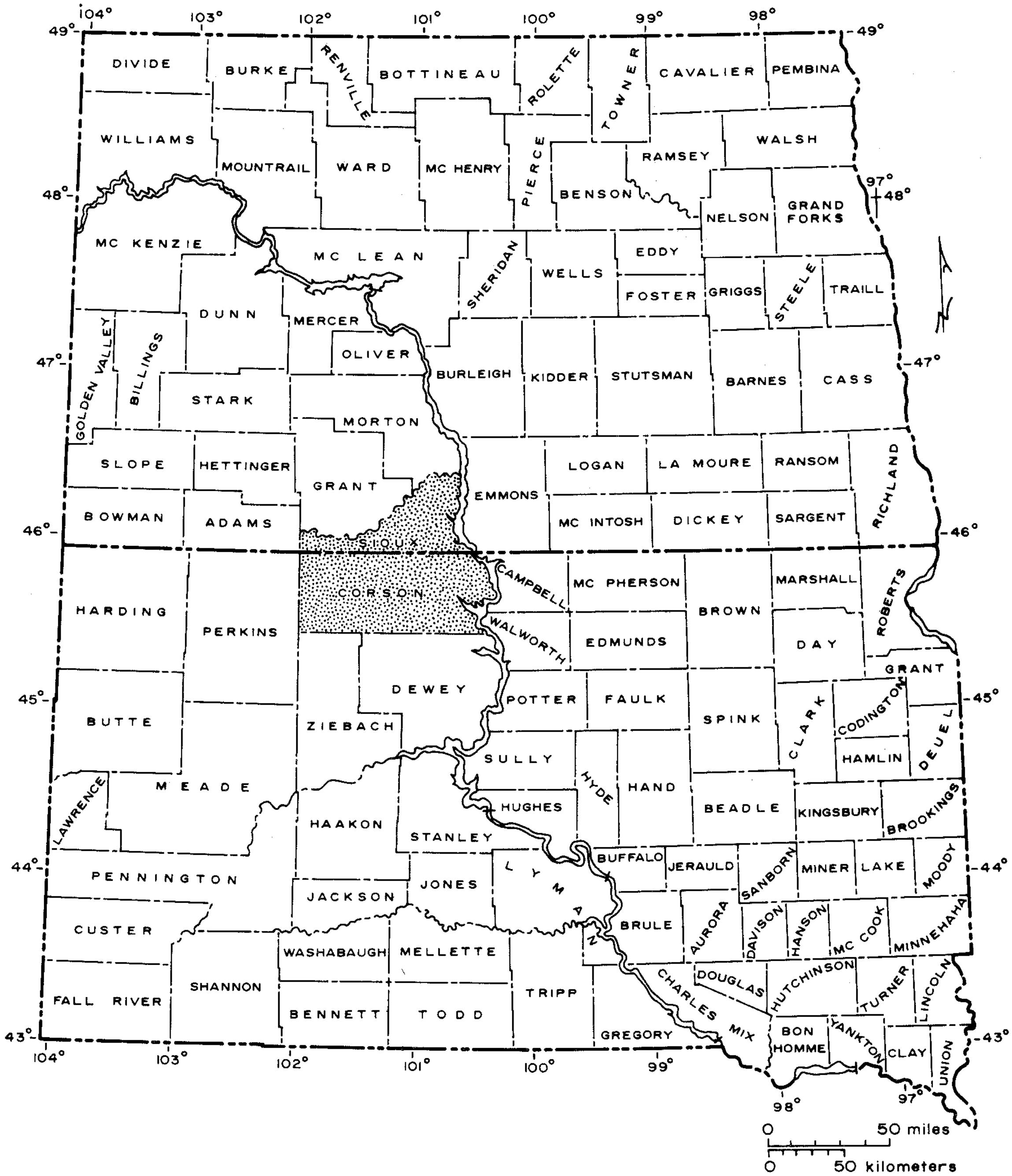

Figure 1. Map of North and South Dakota showing location of Standing Rock Indian Reservation.

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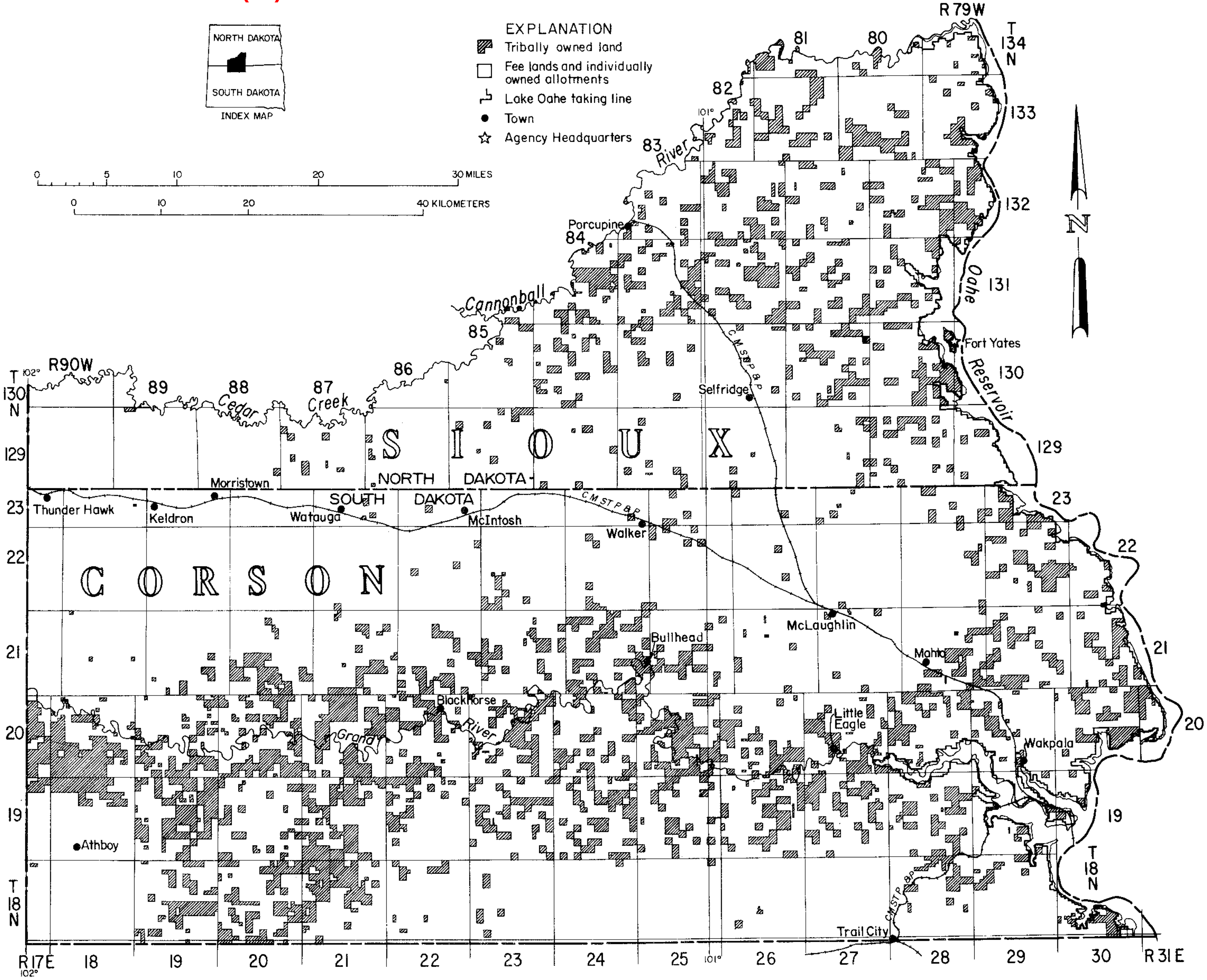

Figure 2. Map showing surface ownership.

SURFACE OWNERSHIP

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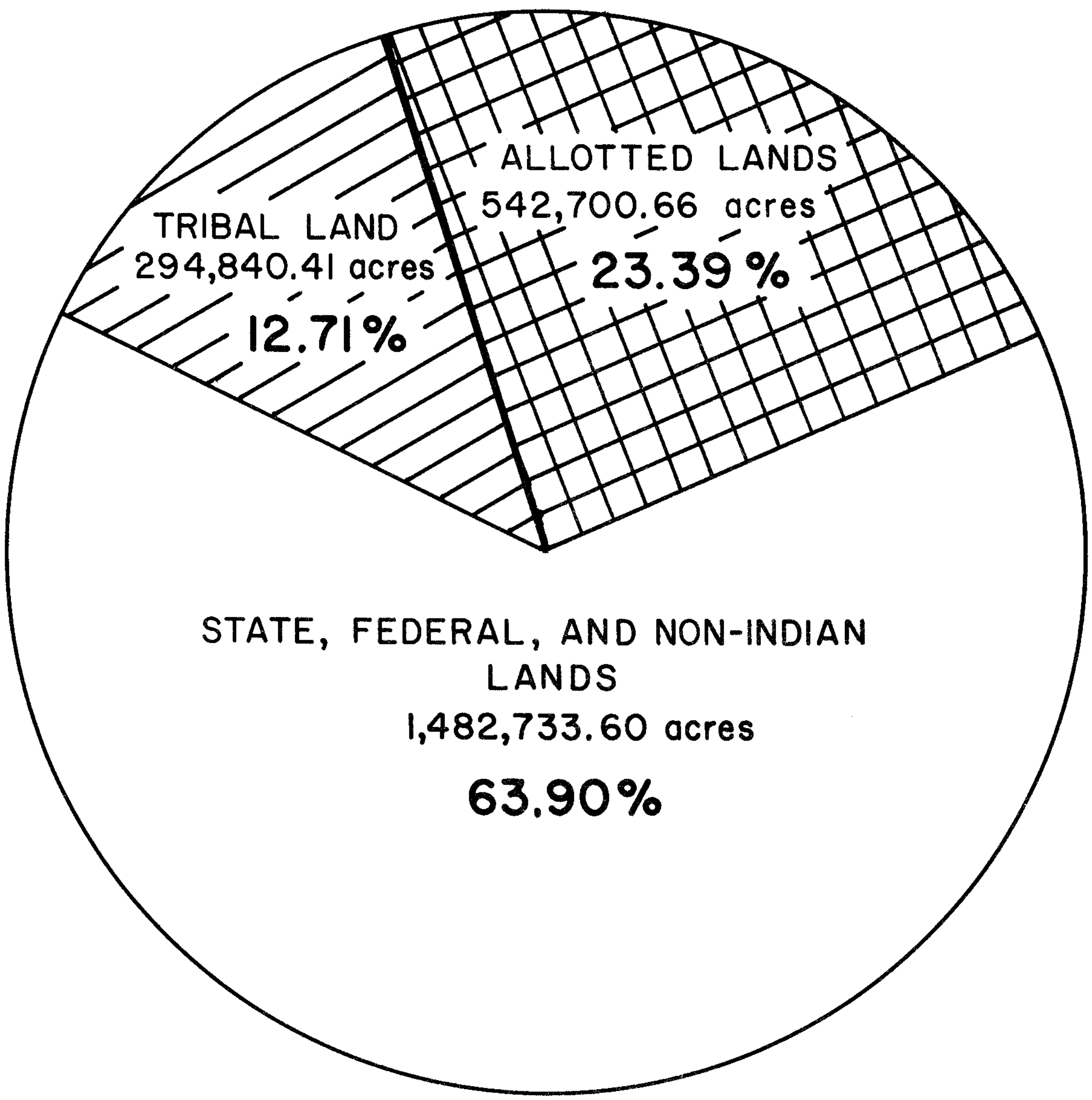

TOTAL AREA OF RESERVATION, 2,320,274.67 ACRES

Figure 3. Diagram showing percentage of surface ownership.

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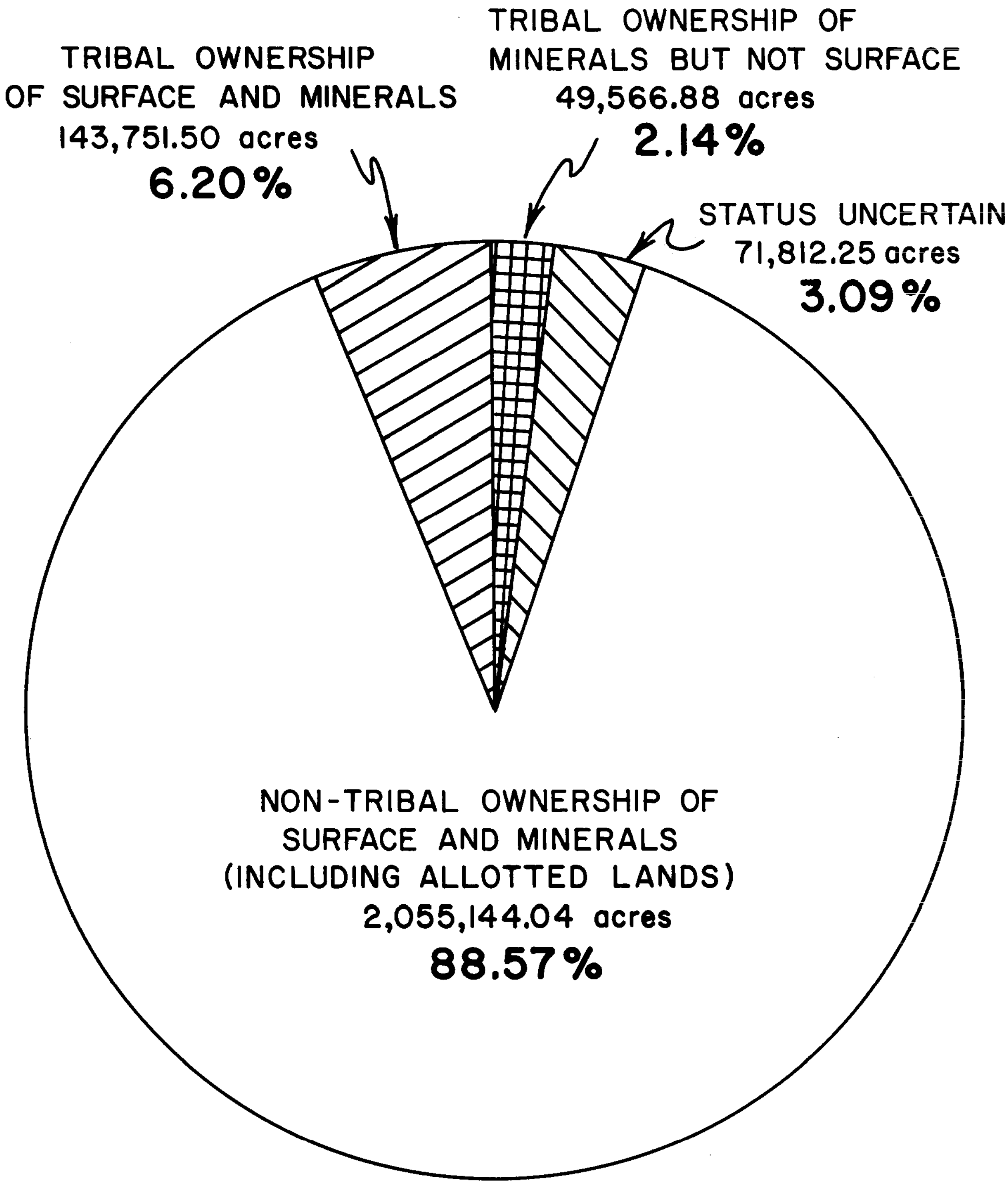
MINERAL AND SURFACE OWNERSHIP



TOTAL AREA OF RESERVATION, 2,320,274.67 ACRES

Figure 4. Diagram showing percentage of mineral and surface ownership.

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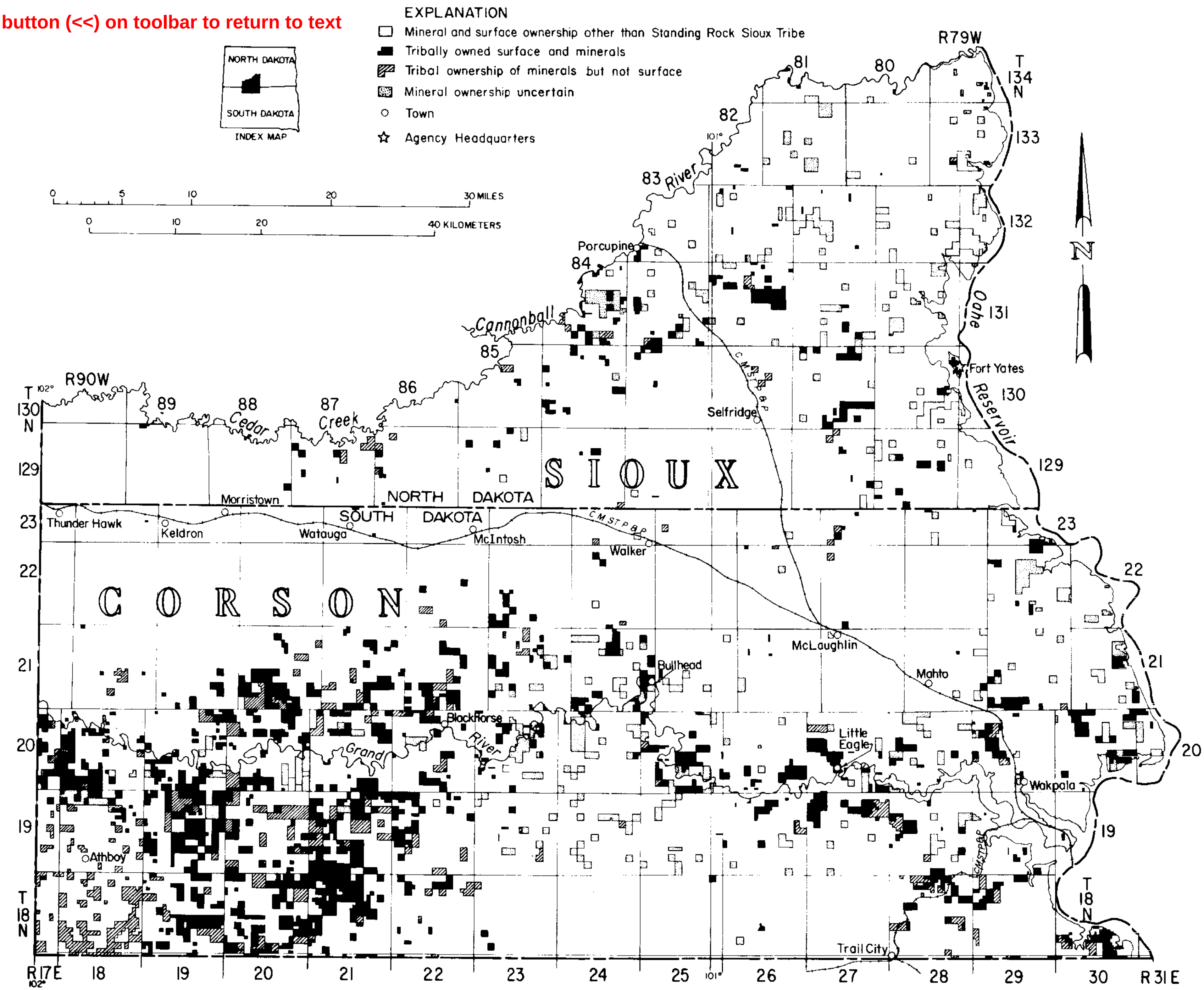

Figure 5. Map showing mineral ownership.

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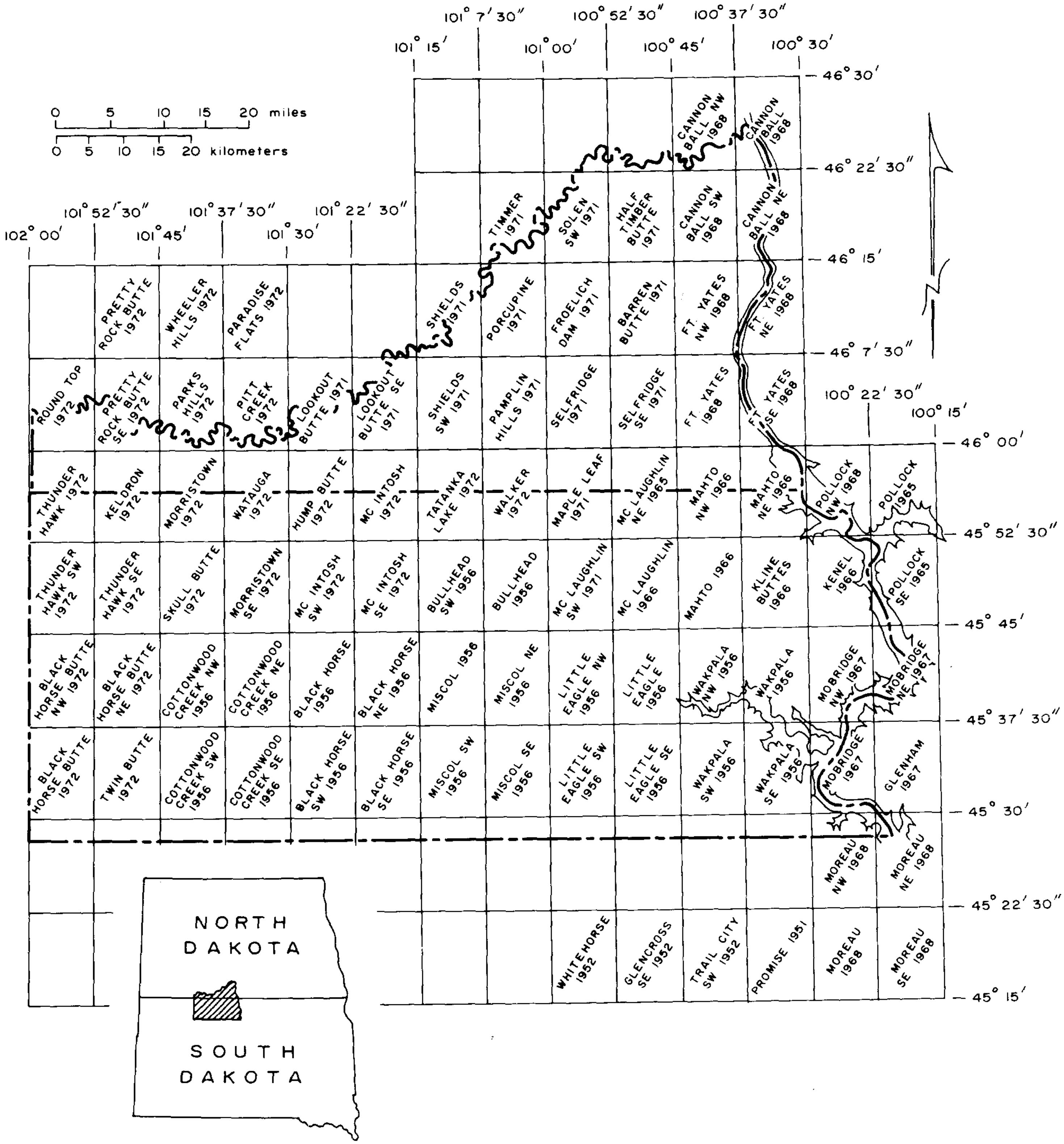

Figure 6. Index map showing U.S. Geological Survey 7 1/2-minute quadrangle topographic map series available for the Standing Rock Indian Reservation.

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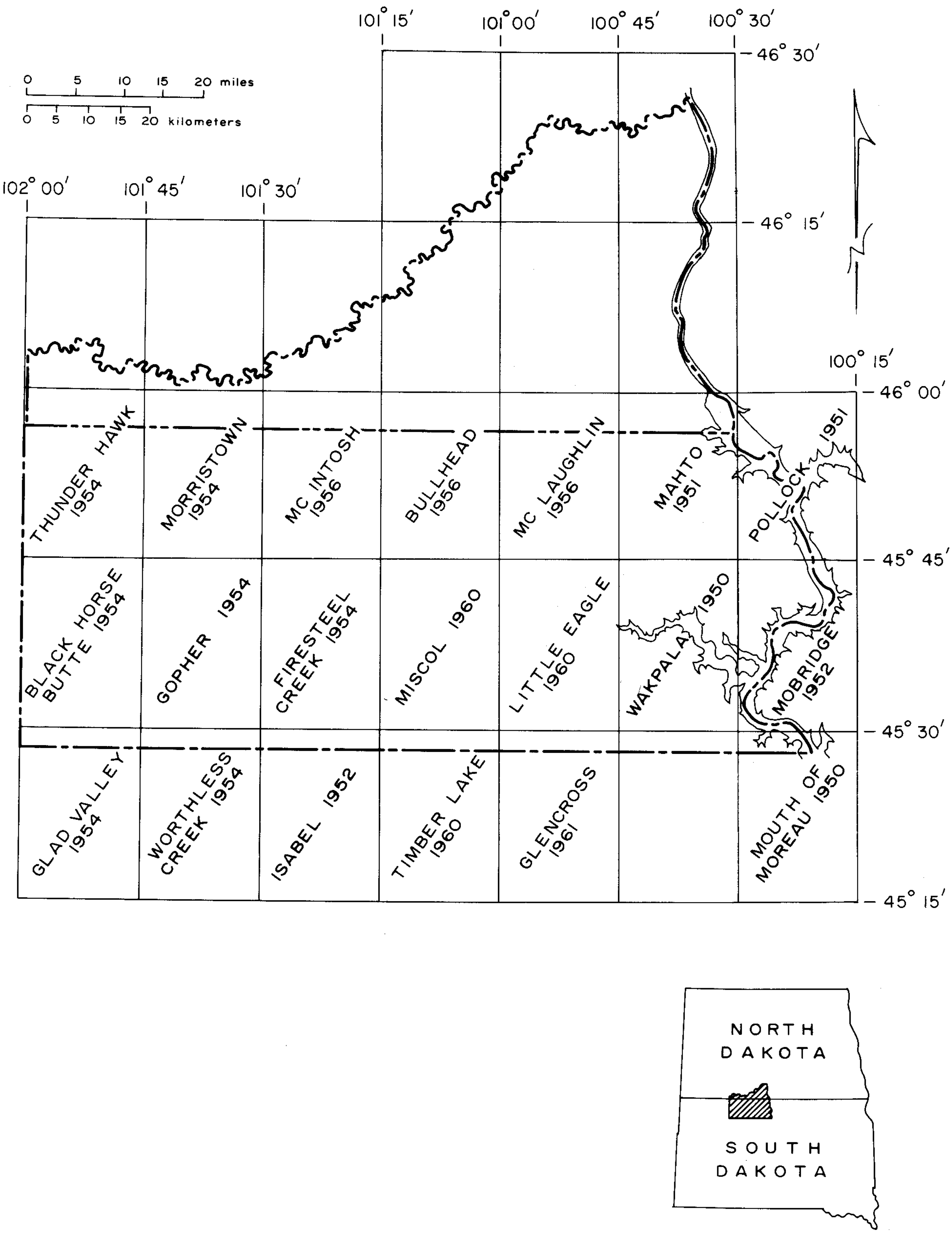

Figure 7. Index map showing geologic quadrangle maps of the South Dakota portion of the Standing Rock Indian Reservation published by the South Dakota Geological Survey.

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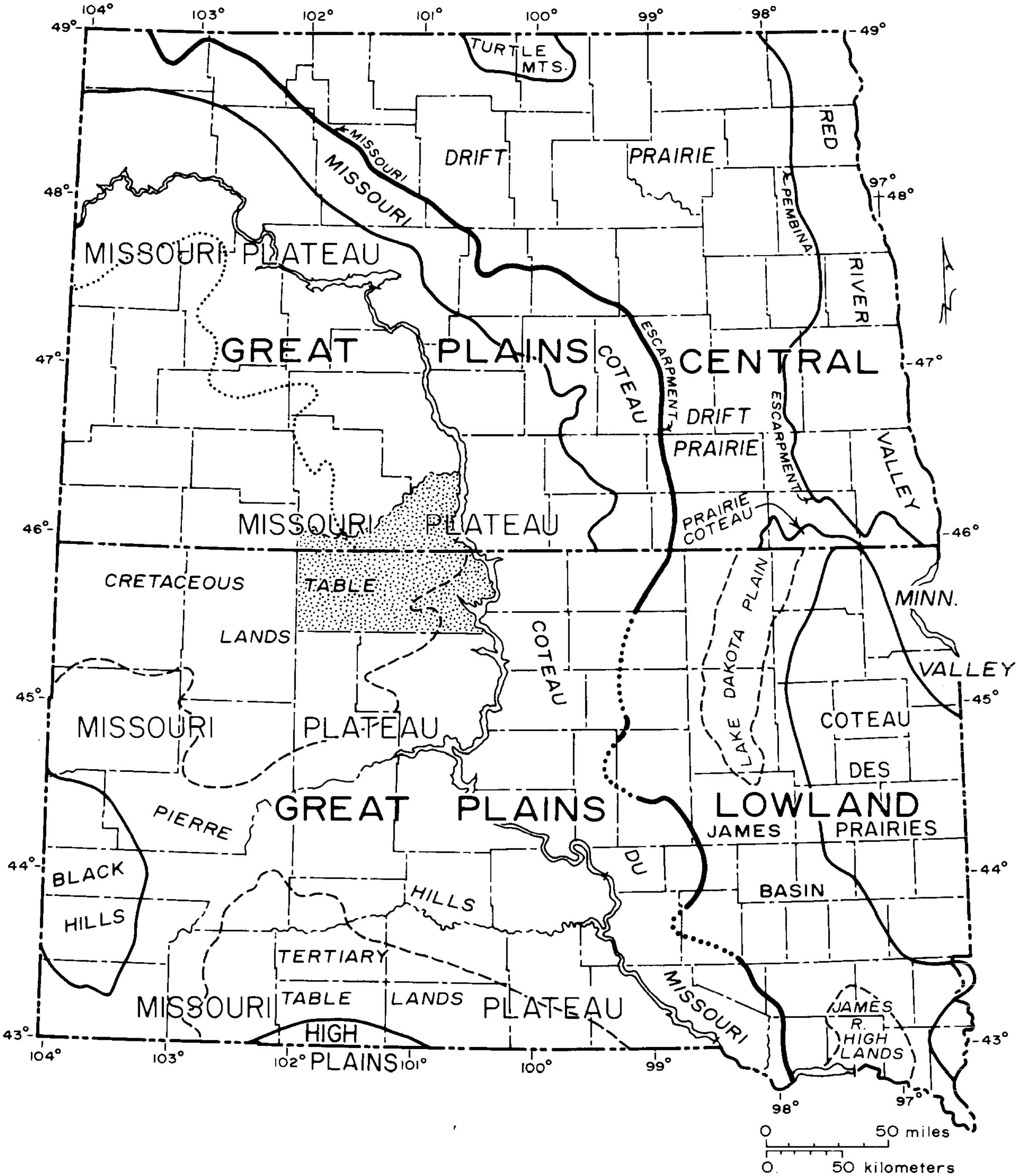

Figure 8. Map showing Standing Rock Indian Reservation with respect to physiographic divisions, North and South Dakota (after Rothrock-1943, Flint-1955, and Knudson-1974).

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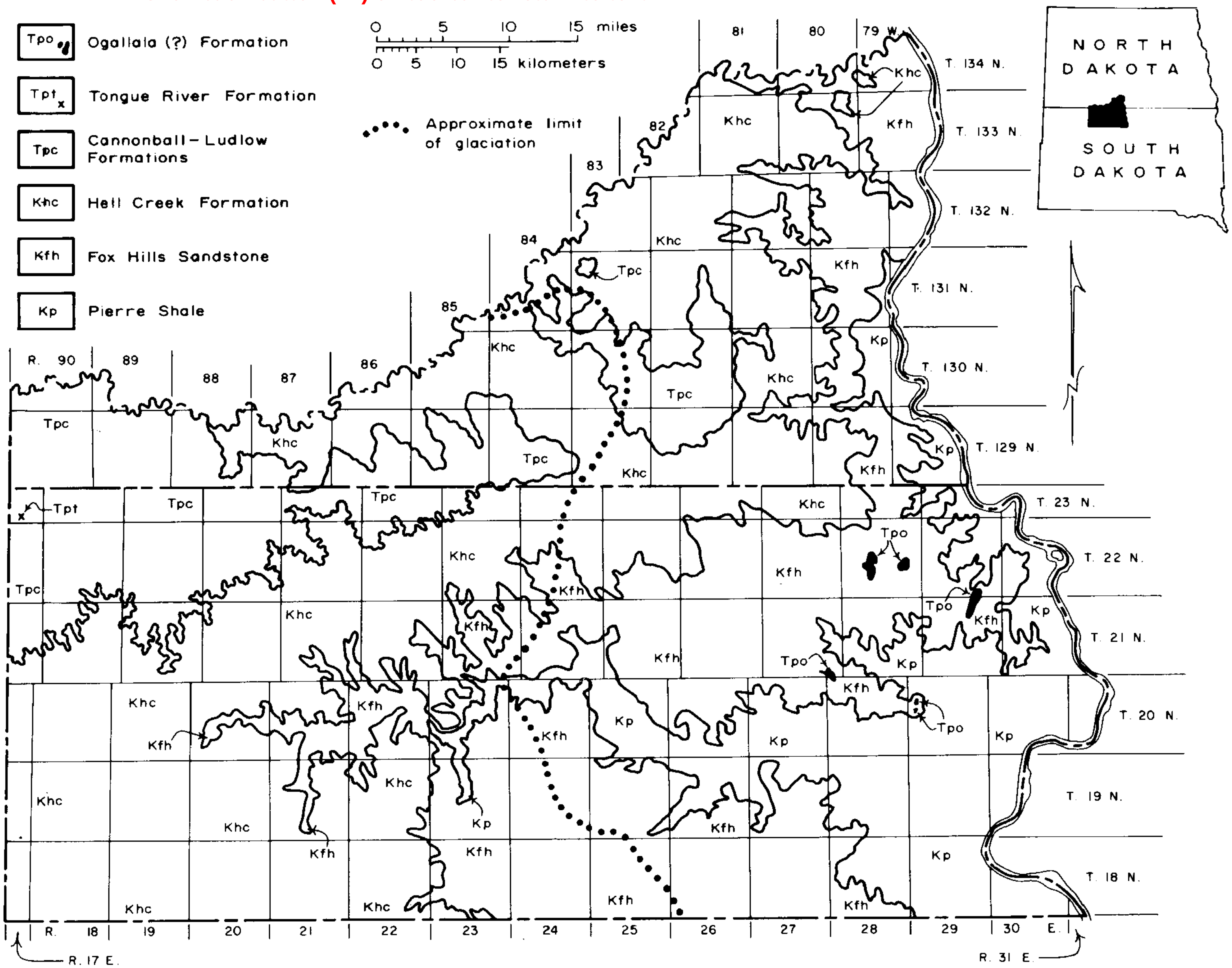

Figure 9. Map showing outcrop area of geological formations on the Standing Rock Indian Reservation (adapted from Denson, 1950; Baldwin and Glass, 1950; Baldwin, 1951a; Stevenson, 1954b,c, 1957a; Flint, 1955; Colton, Lemke, and Lindvall, 1963; Bluemle, 1975).

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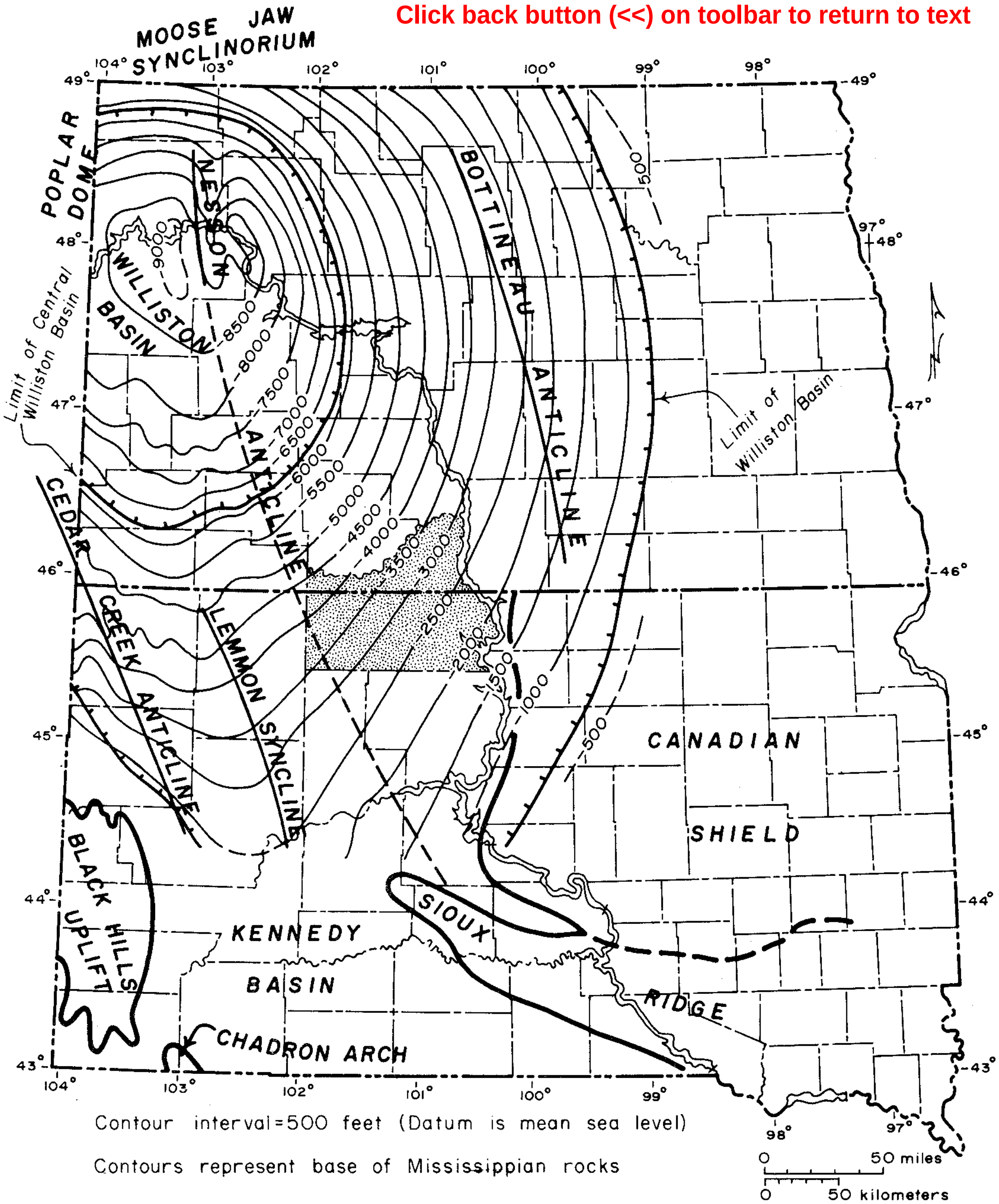

Figure 10. Map showing structural setting of the Standing Rock Indian Reservation (adapted from Sandberg, 1962; Hamke and others, 1966; and Miller, 1971).

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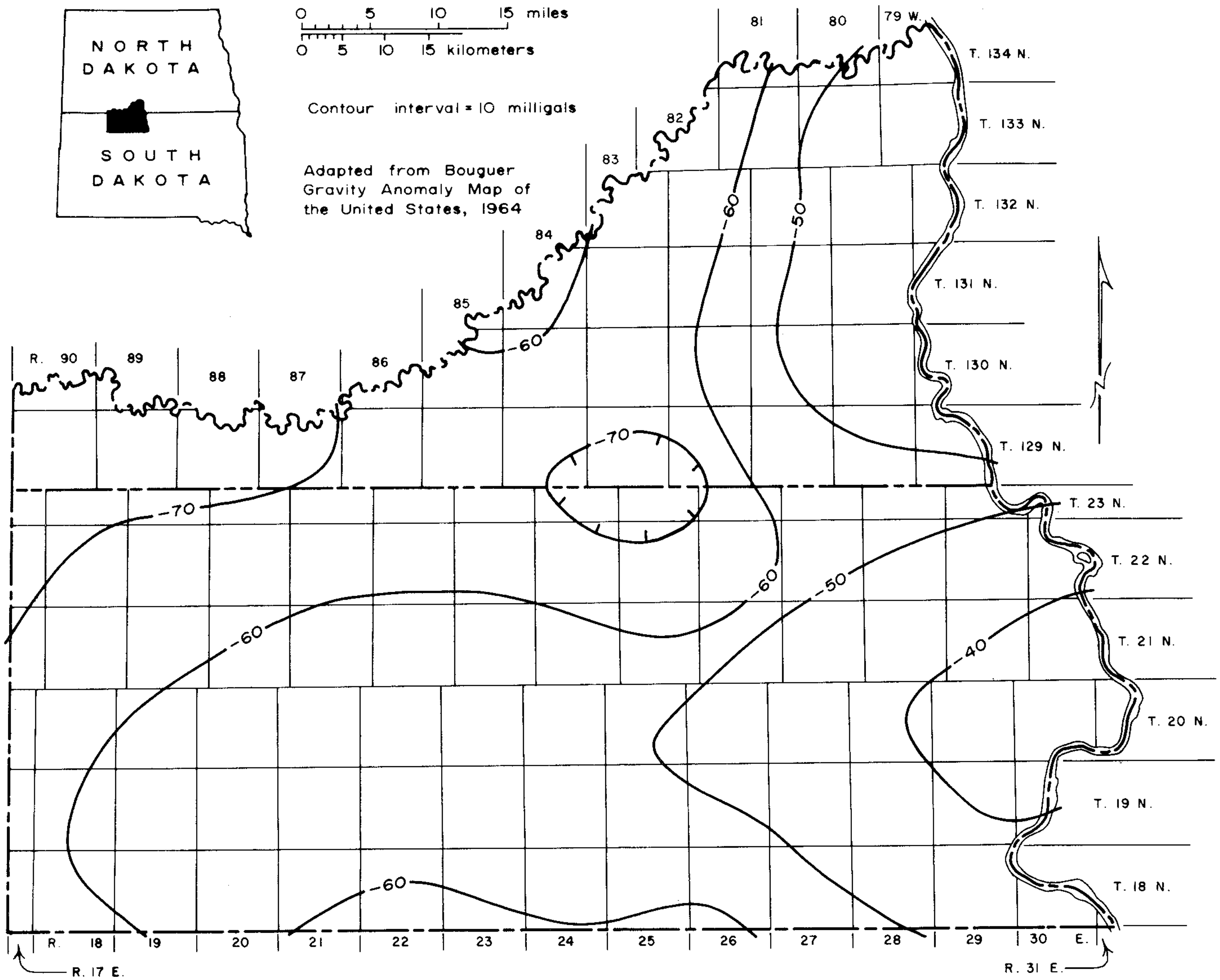

Figure 11. Map showing Bouguer free-air gravity anomalies on the Standing Rock Indian Reservation.

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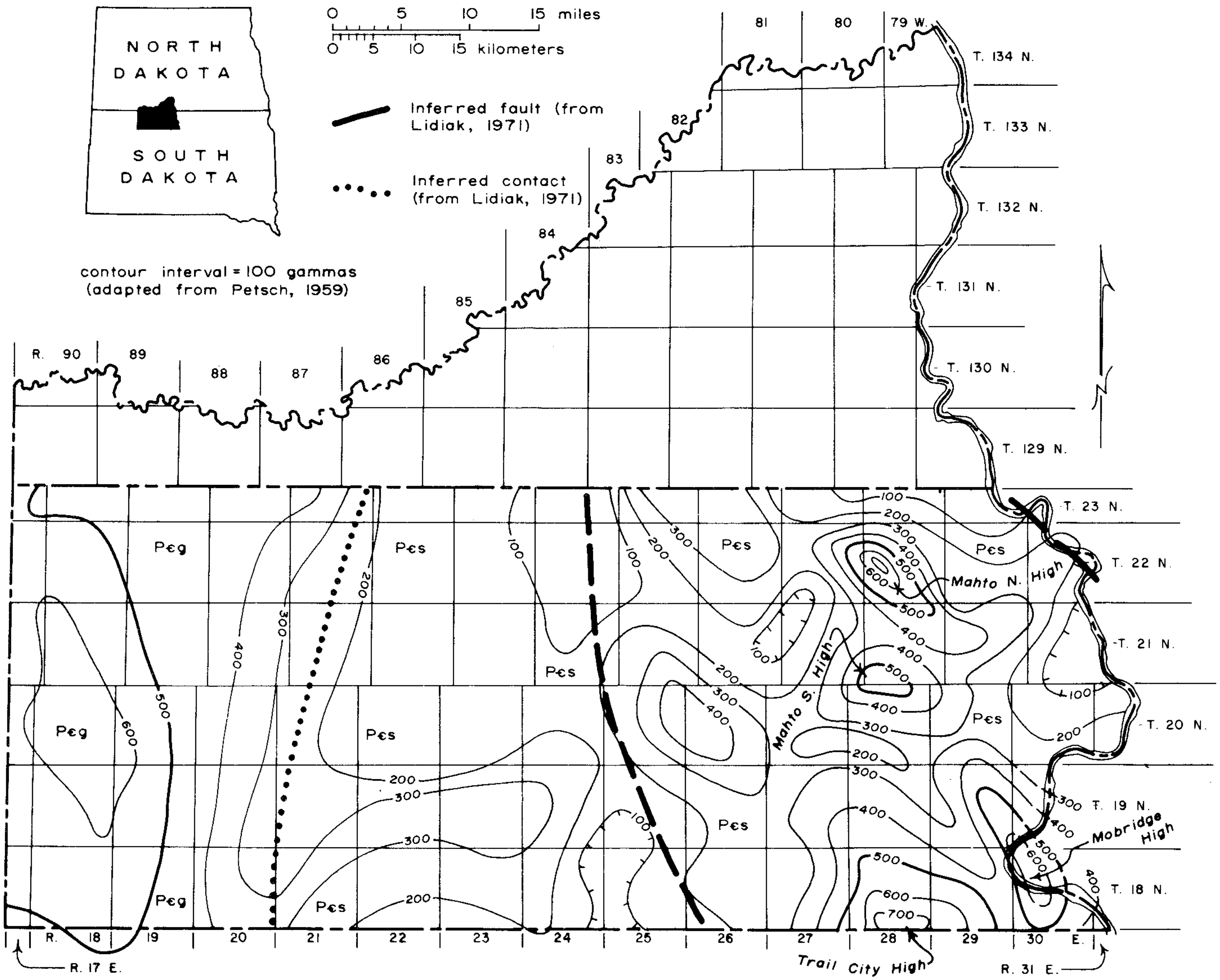

Figure 12. Map showing results of ground magnetometer survey of the South Dakota portion of the Standing Rock Indian Reservation (granite and schist from Lidiak, 1971).

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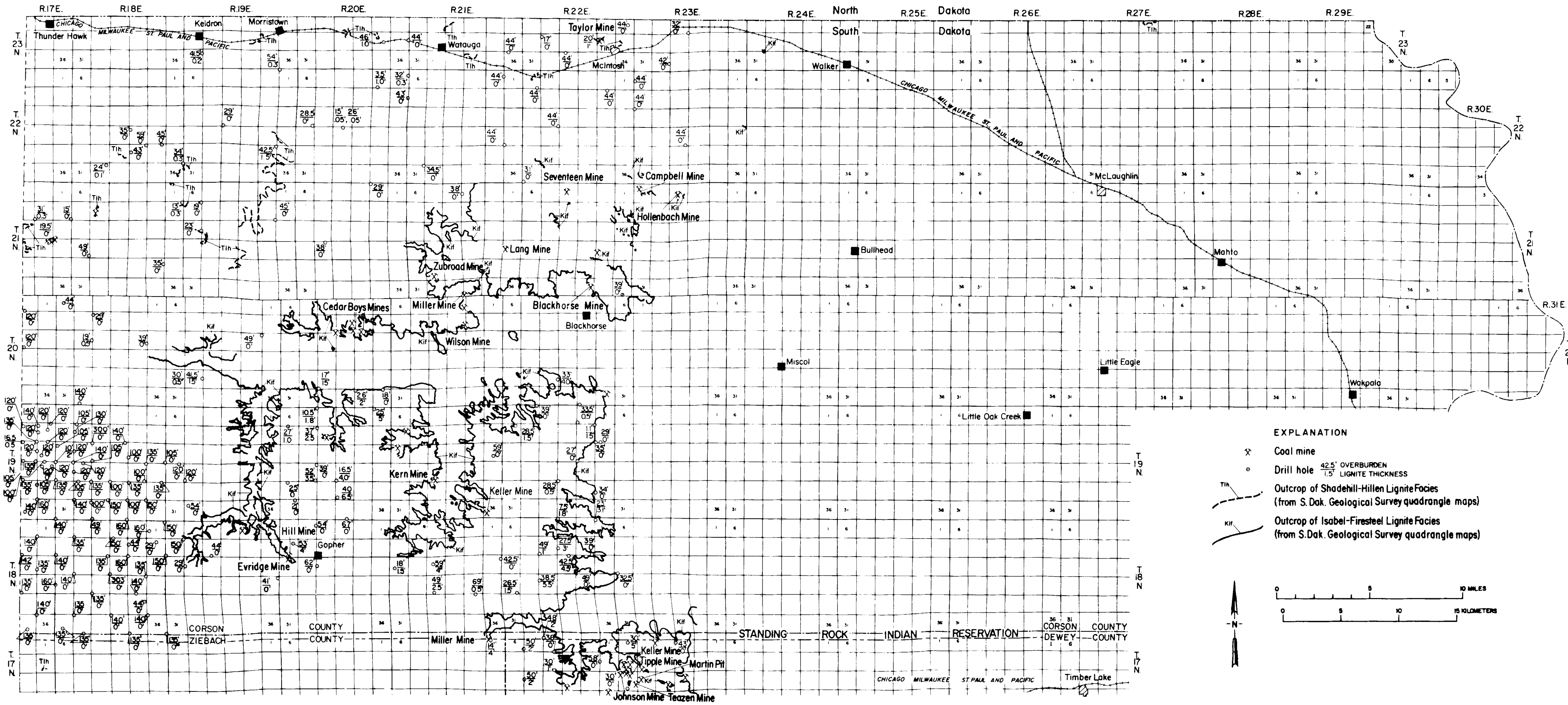

Figure 13. Map showing coal resources.

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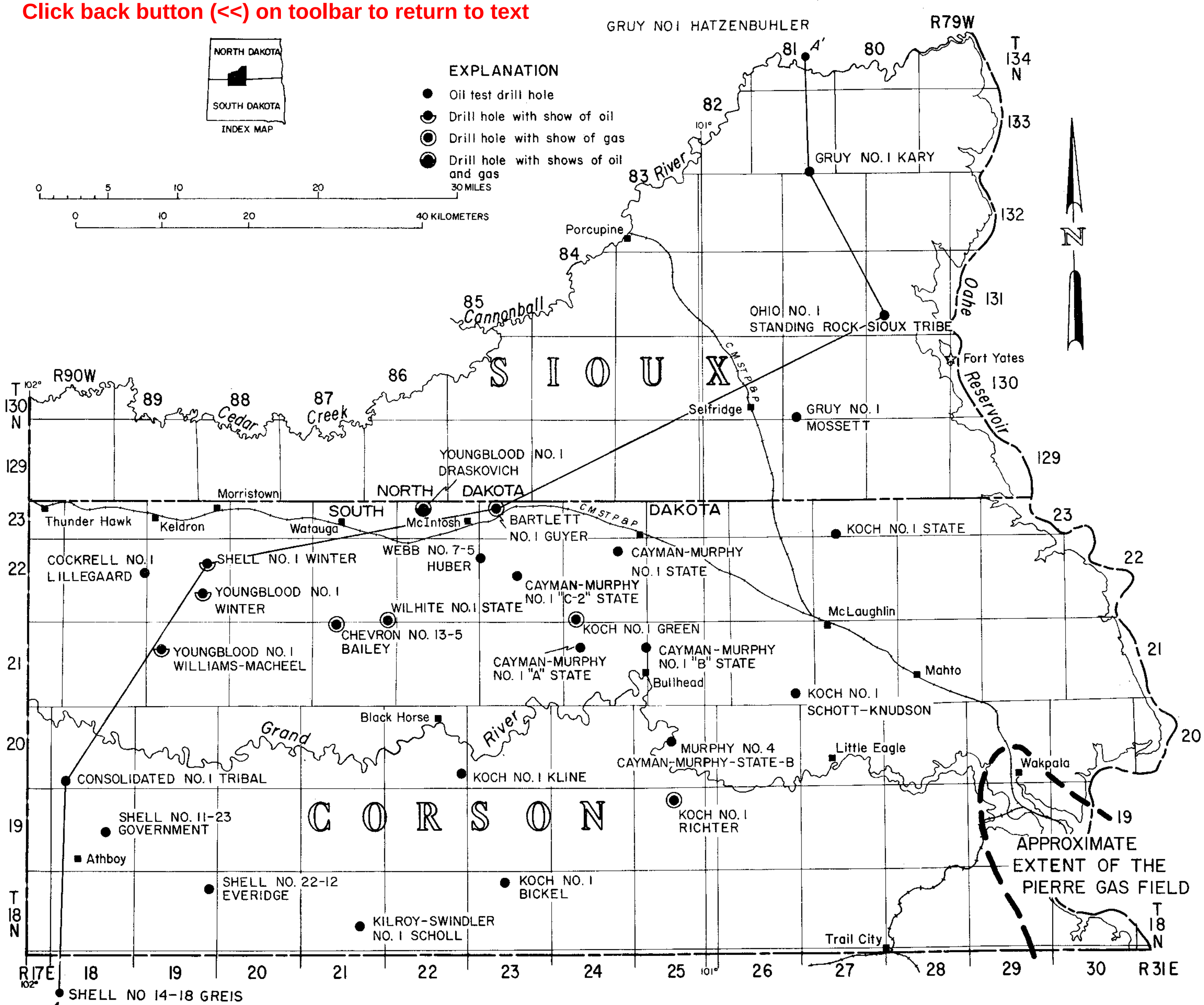

Figure 14. Map showing location of drill holes for oil and gas.

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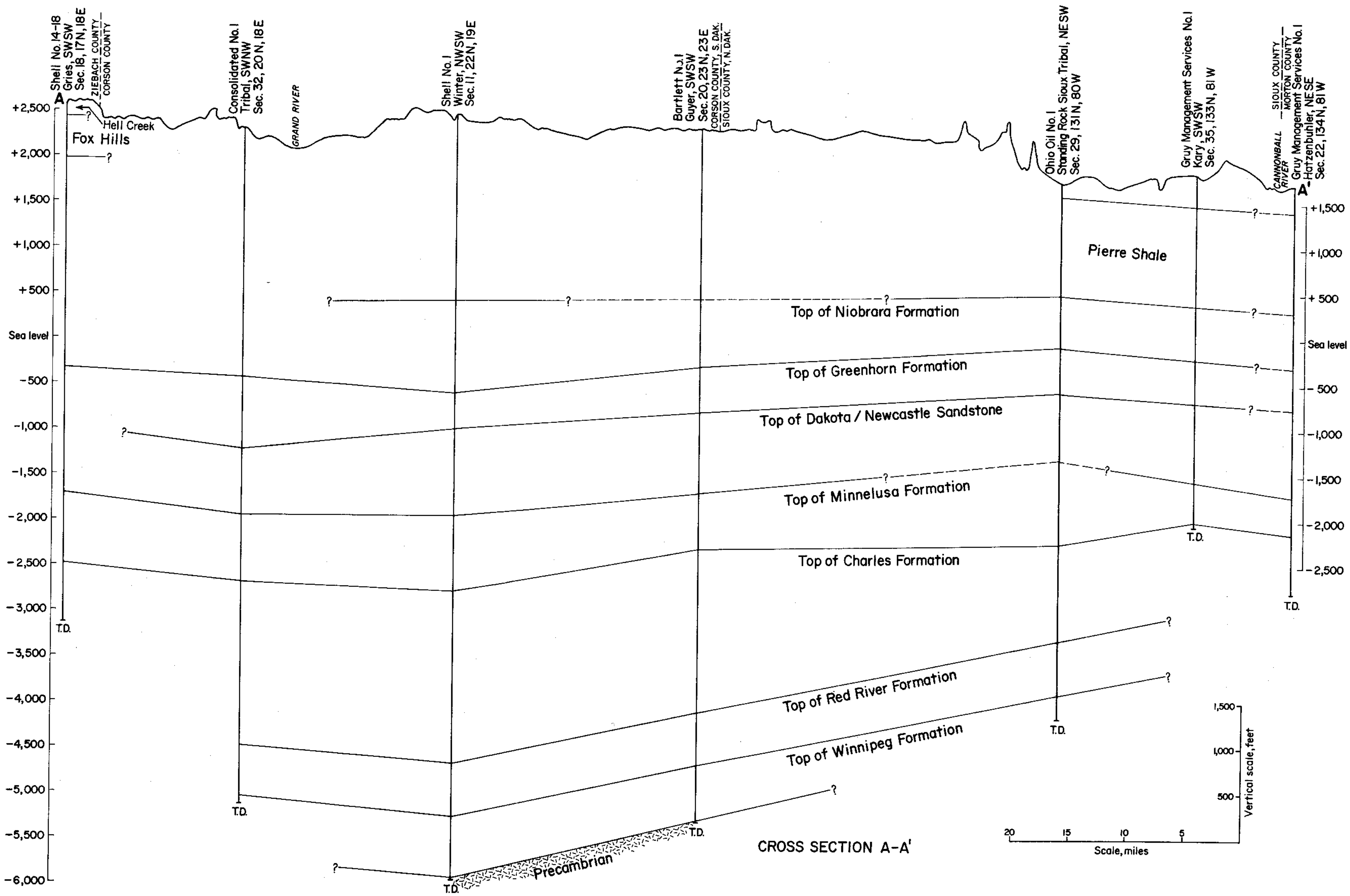

Figure 15. Cross section AA' through drill holes (see Figure 14 for location).

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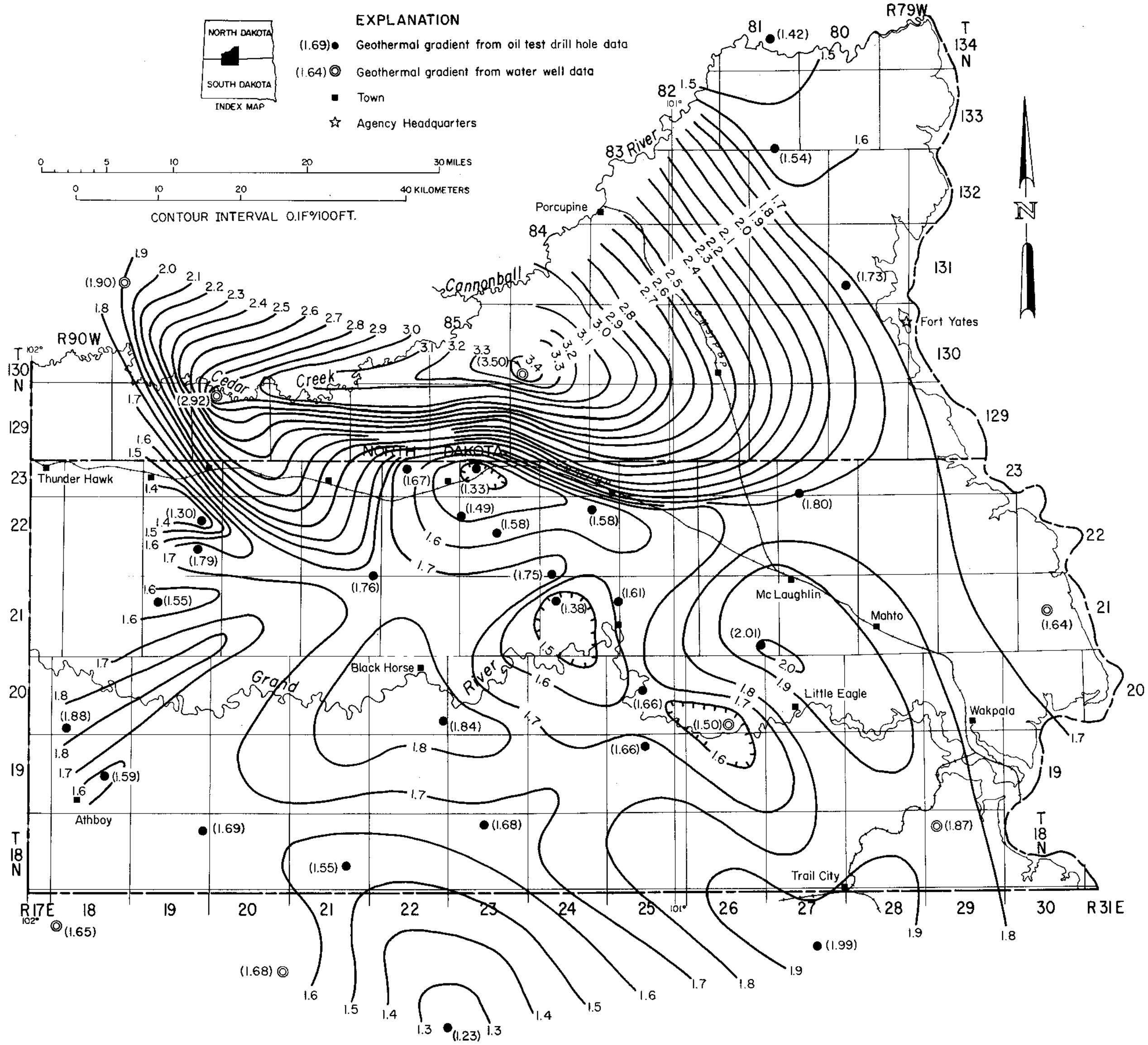

Figure 16. Map showing geothermal gradients.

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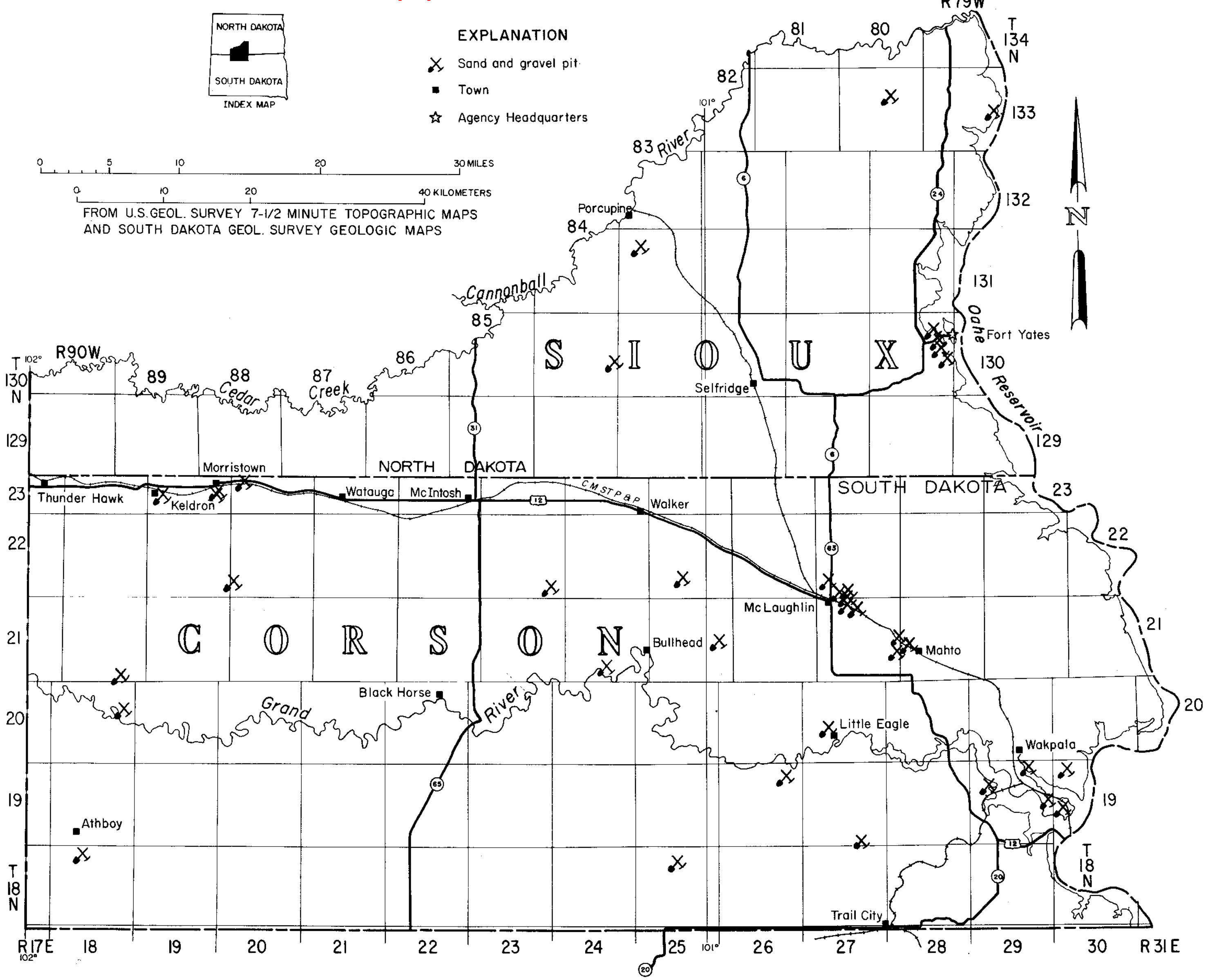

Figure 17. Map showing location of sand and gravel pits.