STATUS OF MINERAL RESOURCE INFORMATION FOR THE CHEYENNE RIVER INDIAN RESERVATION, SOUTH DAKOTA

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SUMMARY AND CONCLUSIONS

Mineral resources of the Cheyenne River Indian Reservation include lignite, petroleum, natural gas, clay, shale, rock, sand and gravel, and geothermal energy. Only the development of petroleum resources promises to yield revenues to the Cheyenne River 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. These reserves may be extensive enough to operate a mine-mouth steam-electric power generating facility. Moderate potential exists for the development of small petroleum fields, but little potential is indicated for development of natural gas resources. 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.

Some potential exists for geothermal energy for space heating purposes; such use could reduce the consumption of other energy resources on the reservation and yield economic benefits to consumers, but probably would not provide revenue for the tribe.

Surface and mineral ownership records of lands within Dewey and Ziebach Counties should be reviewed and brought up to date. Lands with lignite reserves or potential should be considered for lease. 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. Limited studies of the geothermal potential of the Cheyenne River Indian Reservation also seem warranted.

INTRODUCTION

This report was prepared for the Bureau of Indian Affairs by the Geological survey and the Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral resources, and potential for economic development of certain Indian lands. Source material was published and unpublished reports, as well as personal communication.

The report presents essentially the results of a literature search, although a brief visit to the reservation was made in October 1975 to gather additional information.

Land Status

According to the 1868 Treaty of Fort Laramie, the Sioux accepted a territory bounded by the western slopes of the Black Hills on the west, the Niobrara River on the south, the Missouri River on the east, and the Cannonball River on the north. The boundary of this territory was amended by the Treaty of 1876, which opened the Black Hills to settlement. Seven separate reservations for the Sioux were created by Congress in 1889 (25 Stat. 888); this Act established the present reservation boundary encompassing 2,804,894 acres and comprising the present Dewey and Ziebach Counties as shown in Figure 1.

Later acts of Congress in 1909 and 1910 opened unallotted and unsold reservation lands to non-Indians for homesteading, thereby establishing the "ceded and diminished lands" boundary also shown in Figure 1.

A land-consolidation program was established at a meeting of the Cheyenne River Sioux Tribal Council on February 10, 1938. The purpose of this program was to prevent further alienation of trust lands within the consolidated boundary and to reacquire non-trust lands within the boundary. Figure 1 shows this consolidated boundary and the present extent of allotted and trust lands.

Construction of the Oahe Dam commenced in 1948. This flood control project on the Missouri River, authorized by the 1944 Flood Control Act, impounded 23 million acre-feet of water in Lake Oahe and required 95,148 acres of allotted and trust lands, further reducing the size of the Cheyenne River Indian Reservation. Table 1 summarizes the present extent of land holdings of the Cheyenne River Indian Reservation as obtained from records of the Bureau of Land Management.

TABLE 1

Summary of Present Land Status, Cheyenne River Indian Reservation, South Dakota

Classification	Acreage	Percentage of total
Privately owned, non-Indian lands (alienated)	1,290,242	46.00
Tribally owned lands	911,467	32.50
Allotted lands	503,483	17.95
Lake Oahe project lands	95,148	3.39
Government-owned land	4,554	0.16
Total area of reservation	2,804,894	100.00

Most of the land in the northwestern part of the reservation is in private ownership. Bureau of Land Management records may not accurately reflect title changes within the reservation boundary since 1965 and the actual land status and particularly the mineral ownership of these lands cannot be determined readily.

Location and Access

The Cheyenne River Indian Reservation is in north-central South Dakota (Figure 2) and is bounded on the south by the Cheyenne River and on the east by the impounded Missouri River waters of Lake Oahe. The Standing Rock Indian Reservation bounds the Cheyenne River Indian

Reservation on the north, and Meade and Perkins Counties bound the reservation on the west.

The nearest towns are Mobridge, about 5 miles north of the reservation boundary and across Lake Oahe, and Pierre, about 33 miles southeast of the reservation. Several small communities are on the reservation; Timber Lake and Dupree are the county seats of Dewey and Ziebach Counties, and Eagle Butte is the tribal headquarters for the Cheyenne River Sioux Tribe.

Approximately 4,300 Indians reside on or adjacent to the reservation in Dewey and Ziebach Counties. According to the 1970 census the total population of these counties was 7,391.

Transportation into this area is somewhat restricted. The nearest commercial airport is at Pierre. The reservation is served by hard-surfaced, all-weather roads and by numerous graveled and graded roads (Figure 1). U.S. Highway 212 crosses the reservation from east to west, and State Highways 8, 63, and 65 interconnect to form a north-south route across the reservation. Two spurs of the Chicago, Milwaukee, St. Paul, and Pacific Railroad extend rail service to Isabel and across the reservation to Faith.

Most of the land in Dewey and Ziebach Counties is used for agriculture (94.8 percent); pasture and range lands predominate (84.6 percent).

Climate

The length of the normal frost-free growing season is between 105 and 135 days. Summers in the area are hot, and winters are cold; the mean annual temperature is 45ºF, with extremes of -35ºF and +115ºF. Throughout the year, the average wind velocity is about 12 miles per hour. Average annual precipitation is less than 16 inches, most of it occurring in the growing season, but there are moderate amounts of snowfall (about 36 inches) during the winter.

PHYSIOGRAPHY

The Cheyenne River Indian Reservation lies within the Cretaceous Tablelands and Pierre Hills subdivisions of the Missouri Plateau division of the Great Plains physiographic province (Rothrock, 1943, p. 8), with the major portion of the reservation lying within the Pierre Hills subdivision (Figure 3).

The Cretaceous Tablelands portion is characterized by uplands of low relief containing numerous small ponds and lakes. Eroded areas form isolated flat-topped and conical buttes and sparsely vegetated badlands. General relief is low, but locally is as much as 200 feet, particularly in the badland areas near major drainages and on the buttes (Figure 4).

The Pierre Hills portion is characterized by smooth rounded hills and gentle slopes and valleys, except for a few areas near major drainages. The buttes and badlands are much less prevalent than in the Cretaceous Tablelands area. General relief is low, but locally is as much as 150 to 200 feet, especially near the major drainages.

The Cheyenne River forms the southern boundary, the Missouri River forms the eastern boundary, and the Moreau River flows through the northern portion of the reservation. These streams are perennial and are characterized by moderately wide to very wide alluvial valleys and a succession of terrace levels. The Oahe Reservoir has flooded the alluvial valley of the Missouri and the alluvial valleys of the Cheyenne and Moreau near their mouths. Major tributaries to the Cheyenne are the southeasterly flowing Cherry Creek, Cottonwood Creek, Herbert Creek, and Rousseau Creek; major tributaries to the Moreau are the southeasterly flowing Thunder Butte Creek, Irish Creek, Red Earth Creek, and Little Moreau River and the northerly flowing Virgin Creek. All of these tributaries are intermittent streams. Elevations on the reservation range from over 2,400 feet in the west to under 1,500 feet in the extreme southeast.

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 Cheyenne River Reservation was visited by F. V. Hayden in 1853-1854 (Meek and Hayden, 1856), 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 have been conducted on or near the Cheyenne River Indian Reservation. The most comprehensive published reports are those of Gries and Henkes (1963), Calvert, Beekly, Barnett, and Pishel (1914), Morgan and Petsch (1945), and Denson (1950). Reports of smaller areas include those of Wilson and Ward (1922 and 1923), Wilson (1922b and 1925), Russell (1925a and b), Searight (1931), Gries (1939), Rothrock (1947), and Black (1964). There also have been extensive studies of the surface drainage and groundwater of the reservation (Colby, Hembree, and Jochens, 1953; Darton, 1896; Maclay, 1952; Robinson, 1936; Rothrock and Robinson, 1931; Upham, 1890).

MAP COVERAGE

The most recent topographic maps covering the entire area of Dewey and Ziebach Counties are the McIntosh and Pierre sheets of the Army Map Service 1:250,000 series, published by the U.S. 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 U.S. Geological Survey 7½-minute quadrangle series provide excellent topographic coverage along the Cheyenne and Moreau Rivers and along Lake Oahe as shown in Figure 5. Contour intervals are 10 or 20 feet and the scale is 1:24,000 (2,000 feet to the inch).

Geologic maps covering portions of the reservation have been published by the South Dakota State Geological Survey (Figure 6). These maps provide planimetric control and geologic data at a scale of 1:62,500 (about 1 mile to the inch).

GEOLOGY

General

Geology of the Cheyenne River Indian Reservation is dominated by a thick sedimentary rock sequence. Neither igneous nor volcanic rocks have intruded these sedimentary rocks on the reservation.

Outcrops in Dewey and Ziebach Counties are of shales, silts, clays, and sands. A few outcrops of Tertiary sandstone and shale are in the extreme northwest portion of the reservation. Outcrops elsewhere in the reservation are of Cretaceous marine sandstones and shales (Figure 7). Weathering products of these sediments and some glacially derived boulders of igneous and metamorphic rocks comprise the surface deposits.

Oil tests and deep-water borings have revealed a geologic section consisting of several thousand feet of sedimentary strata overlying the Precambrian basement complex of igneous and metamorphic rocks (Table 2).

Stratigraphy

Outcropping Rock Units

Rocks exposed in the Cheyenne River Indian Reservation are the Ludlow Member of the Fort Union Formation of Tertiary age, and the Hell Creek Formation, Fox Hills Formation, and the Pierre Shale of Late Cretaceous age. These units are covered locally by alluvium and terrace deposits along the major drainages, particularly the Cheyenne, Missouri, and Moreau Rivers, and their larger tributaries.

The Ludlow Member consists of forty to sixty feet of silty clays and sandy siltstone. At the base are one or more lignite seams from one to six inches thick designated the Shadehill coal facies.

The Hell Creek Formation, the youngest Upper Cretaceous unit, ranges from 250 to 300 feet thick (Denson, 1950). The formation consists of the Upper Hell Creek Unit, the middle Isabel-Firesteel Lignite Facies, and the Lower Hell Creek unit. Locally unconformable below the Hell Creek is the Fox Hills Formation, with an average thickness of 250 feet (Denson, 1950), which consists of, from top to bottom, the Colgate, Bullhead, Timber Lake, and Trail City Members. 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 700 feet is exposed (Denson, 1950). The exposed members are the Elk Butte, Mobridge, Virgin Creek, Verendrye, and DeGrey. The upper two members tend to lose their identity to the west and northwest where they are called the Upper Pierre unit (Stevenson, 1960; Pettyjohn, 1961; Black, 1964).

Subsurface Rock Units

The exposed Late Cretaceous units are underlain by 6,000 feet or less of older sedimentary rocks, as listed in Table 2.

Structure

The Cheyenne River Indian Reservation is in the southeastern part of the Williston Basin, a large, north to northwest trending structural feature that extends from South Dakota into Canada. In South Dakota it is as much as 200 miles wide (east-west) and 180 miles long (north-south). In South Dakota it is bounded on the east and southeast by the Canadian Shield and Sioux Ridge, on the south by the Kennedy Basin, and on the southwest and west by the Chadron Arch and Black Hills (Figure 8). The structural configuration of the South Dakota part of the Williston Basin is shown on maps by Morgan and Petsch (1945), Petsch (1953), Steece (1961), and Schoon (1971). Regional dip in the reservation area is to the northwest and ranges from 10 to 15 feet per mile according to Morgan and Petsch (1945), and from 10 to 25 feet per mile, according to Curtiss (1952 and 1954b).

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 South Dakota portion of the Williston Basin. A series of smaller, poorly defined anticlines and synclines lie on the eastern flank of the Lemmon Syncline (Figure 8) which may define the southward extension of the Nesson anticline. Rocks 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; dip is generally less than one degree, but locally is as much as four or five degrees (Wilson and Ward, 1923), and eight to ten degrees (Russell, 1925a). The structural relief, as shown by Schoon (1971), is approximately 900 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 are formed, with closures generally being 40 to 50 feet (Russell, 1925a), but attaining closures of 80 feet (Wilson, 1925).

No major faults are known to cross the reservation, but numerous small normal faults, a few grabens, and a few reverse faults have been noted on or near the reservation. Displacement along the faults is usually less than a foot to three or four feet (Searight, 1931), and only rarely is as much as 40 to 50 feet (Russell, 1925a), or 65 feet (Stevenson, 1960).

GEOPHYSICS

Geophysical surveys often attempt to define the subsurface structure and characteristics of rock strata. These include magnetic, radiometric, seismic, resistivity, and gravity surveys. Many geophysical surveys have been made on parts or all of the Cheyenne River Indian Reservation, but many of the survey data gathered by private companies are confidential and are not published. However, some data are published as gravity and magnetic maps and in reports (Carlson, 1950; Jordan, 1940; Jordan and Rothrock, 1940; Petsch, 1959, 1965, 1967, U.S. Geological Survey and South Dakota Geological Survey, 1964, 1975).

Figure 9 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 -70-milligal anomalies in the southern part of Dewey County are indicative of igneous Precambrian rocks at depth (Schoon and McGregor, 1974; Lidiak, 1971). The gradient from north to south across the map suggests a decreasing thickness of sediments above the basement complex.

Results of a ground magnetometer survey of Corson, Dewey, and Ziebach Counties were published by the South Dakota Geological Survey in 1959 (Petsch, 1959). Data from this survey for the Cheyenne River Indian Reservation are presented in Figure 10. This map reveals much about the basement complex and the structure of Dewey and Ziebach Counties (Lidiak, 1971). The Lantry high and the Rousseau Creek high imply the presence of ridges or prominences on the Precambrian surface in these areas and indicate possible structural traps for petroleum. The steep gradients on the west flank of the Lantry anomaly and on the north flank of the Rousseau Creek anomaly suggest large gradients in the Precambrian surface that might have been caused by faults in the basement complex.

More detailed geophysical surveys should provide additional information concerning the structure of the subsurface rocks (Wilson, 1936). A study of privately held data in conjunction with published surveys likely would prove very useful in evaluating additional petroleum prospects on the Cheyenne River Indian Reservation.

MINERAL RESOURCES

Mineral resources of the Cheyenne River Indian Reservation include lignite, petroleum, natural gas, geothermal energy, rock, clay, shale, and sand and gravel. These appear to be the only commodities potentially subject to commercial development with existing technology. Currently there are leases for petroleum and natural gas on parts of the reservation.

Energy Resources

Lignite

General.--Bailey Willis (1885) made the first survey of the lignite resources in the area of the Cheyenne River Indian Reservation and found "beds of inferior lignite." He concluded "It may be definitely said there is no workable coal of any kind within the area surveyed."

Later, work by the U.S. Geological Survey in 1909 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." (Calvert, and others, 1914).

Lignites from North and South Dakota were once widely used as locomotive fuel, but this was discontinued when better grades of fuel became available from Montana and Wyoming (Todd, 1898). Lignite from Dewey and Ziebach Counties has been used mainly for space heating in homes, businesses, and public buildings (Rothrock, 1932).

When other fuels have been scarce or expensive, lignite production from this area has increased.

Some lignites of the Shadehill coal facies at the base of the Ludlow Formation are as much as 33 inches thick, but they are present in only a very limited area of the reservation (Denson, 1950). Lignite also occurs in a zone about 80 feet above the base of the Hell Creek Formation in the northwestern part of the reservation (Lockwood, 1947). This is the Isabel-Firesteel "coal" and it occurs mainly along the divide between the Grand and Moreau Rivers, mostly in northwestern Dewey County, but also extends westward into Ziebach County.

In all discussions of the lignite from the Isabel-Firesteel area, there arises a question on the classification of the material as coal or lignite. Publications of the South Dakota State Geological Survey regard the material in the Hell Creek Formation as a coal because of its chemical and heating properties. However, U.S. Bureau of Mines and U.S. Geological Survey publications regard this material as a lignite because of its overall physical and chemical properties and its high moisture content.

Isabel-Firesteel Lignite Facies.--On the Cheyenne River Indian Reservation, lignite occurs in thin, discontinuous, lenticular beds, mainly in the Isabel-Firesteel Lignite Facies of the Hell Creek Formation, although a few beds do occur above and below this facies. Denson (1950, p. 7) states that the lenticular beds average less than 1,000 feet in areal extent and 2 to 3 feet in thickness. The beds are most abundant from 40 to 80 feet above the base of the Hell Creek, but most of the minable lenses occur about 65 feet above the base in the Isabel-Firesteel Lignite Facies. Their distribution is sporadic; the same stratigraphic interval may have 2 or more beds in one area and no beds in another. The distribution of this facies is shown on Figure 11.

The general characteristics of the lignite are as follows: almost black or very dark brown, brown streak, moderately brittle, and with a dull luster on fresh surfaces. Less common varieties have a tough, woody texture and a high percentage of noncombustible material or ash. Horizontal lamination is generally distinct, owing to the interbedded black and dark brown beds. The lignite contains considerable amounts of fossil resin bodies, which are subspherical or ovoid in shape, and range from microscopic up to a quarter of an inch in diameter. The resin, which comes from the wood and plant materials that formed the lignite, is pale yellow, transparent, and very brittle. Sub-elliptical bodies of pyrite and marcasite as much as a quarter of an inch in diameter are rare impurities in the lignite (Denson, 1950, p. 6).

Slacking, the breakdown of coal due to alternate wetting and drying of the particles, has been studied by Searight (1931 and 1932), who concludes that the Hell Creek coals are generally moderately slacking.

Analyses showing the high moisture and low sulfur and Btu of the Isabel-Firesteel Lignite Facies are listed in Table 3.

Production.--Commercial lignite production from Dewey and Ziebach Counties was first reported in 1913, although small mines intermittently produced some fuel for local use before that time (O'Harra, 1919; Rothrock, 1932). Annual production from Dewey and Ziebach Counties, as shown in Table 4, probably never exceeded 50,000 tons per year (in reporting coal production figures, several different producing counties often are grouped together). Production figures commonly do not include minor production from certain small mines or by individual landowners for their own use.

TABLE 3

Analyses of Lignite from the Isabel-firesteel Area

Location & references	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Sulfur (%)	Btu (as rec'd)	Btu (dry basis)
Reese mine	22.88	41.24	29.61	6.27	0.51	7,515	9,745
SESE 23, 16 N, 20 E							
(Curtiss, 1954, Worthless Creek quad.)							
King mine	39.44	39.44	11.37	10.10	.33	5,043	8,327
SESE 27, 16 N, 19 E							
(Curtiss, 1954, Glad Valley quad.)							
Robbins mine	34.96	30.33	28.80	5.91	.30	7,144	10,984
near Isabel							
(Searight, 1930, RI No. 3)							
Baker mine	37.4	40.8	47.4	11.8	.6	6,730	10,740
Isabel							
(Aresco and others, 1957)							
Dewey mine (2' lump)	36.7	42.4	50.1	7.5	.6	7,230	11,410
Do....(2 x ½" lump)	35.3	41.9	48.2	9.9	.7	7,230	11,160
Do....(½" x 0 lump)	37.8	38.8	45.4	15.8	.9	6,480	10,420
Firesteel							
(Aresco and others, 1958)							
Dewey mine (2" lump)	36.0	42.2	49.6	8.2	.7	7,220	11,280
Do....(2 x ½" lump)	35.9	42.5	49.1	8.4	.7	7,270	11,350
Do....(½" x 0 lump)	34.8	40.7	47.7	11.6	1.3	7,080	10,870
Firesteel							
(Aresco and others, 1960)							
Firesteel mine (2" lump)	33.4	43.2	46.7	10.1	.9	7,330	11,000
Do....(2 x ½" lump)	32.8	42.4	42.8	14.8	1.6	7,140	10,630
Do....(½" x 0 lump)	32.1	38.8	38.5	22.7	1.4	6,440	9,490
Firesteel							
(Aresco and others, 1962)							
Averages	34.6	40.4	41.2	11.0	.8	6,910	10,570

Reserves.--Although the Hell Creek Formation extends over about 580 square miles in the northwestern part of the Cheyenne River Indian Reservation, the Isabel-Firesteel lignite facies is very thin or absent south of the Moreau River (Curtiss, 1954). Moreover, some areas contain thick partings of carbonaceous clay called "blackjack" (Searight, 1930), which has no fuel value and is difficult to separate from the lignite. Where the "blackjack" is more than a few inches thick, the lignite is uneconomic. Because the thickness of the Isabel-Firesteel lignite facies is highly variable and because information is sketchy on the presence and thickness of "blackjack," reliable estimates of lignite reserves in the area of the reservation are difficult to derive (Searight, 1931).

The South Dakota Geological Survey has estimated the lignite reserves in the Glad Valley, Worthless Creek, and Isabel quadrangles (Figure 6) based on outcrop, mine and drill-hole data. (Curtiss and others, 1954a; Curtiss and others, 1954b; Curtiss and others, 1952). Their tonnage estimates are computed for minimum 30-inch seam thicknesses, with specific gravity of 1.25 or 1,700 tons per acre-foot, and are divided into three categories: (1) measured reserves--lignite located within 0.5 miles of outcrops, strip mines, or drill holes; (2) indicated reserves--located between 0.5 and 1.5 miles from outcrops, strip mines, or drill holes; and (3) inferred reserves--located more than 1.5 miles from outcrops, strip mines, or drill holes. Estimates of lignite reserves by the U.S. Geological Survey (Brown, 1952) similarly divide the resource into these same three categories utilizing essentially identical criteria as employed by the State Geological Survey. U.S. Bureau of Mines lignite tonnage estimates are based on thickness, depth, and reliability of data. These estimates yield figures for the relatively small portion of the total resource for which quality and quantity have been reasonably determined and which is deemed to be minable at a profit under existing market conditions (Hamilton, White, and Matson, 1975). Table 5 summarizes the estimates.

TABLE 5
Lignite Reserves in Dewey and Ziebach Counties, South Dakota
[lignite quantities in short tons]

	South Dakota Geological Survey[1]	U.S. Geological Survey[2]/	U.S. Bureau of, Mines[3]/
Measured	62,443,825	138,100,000	131,000,000
Indicated	69,272,200	6,000,000	-
Inferred	41,498,700	-	-
Total[4]	173,214,725	144,100,000	131,000,000

[1]=Estimates presented in the text to geologic quadrangle maps.
[2]=Estimates presented by Brown, 1952.
[3]=Estimates presented by Hamilton and others, 1975.
[4]=This total includes some lignite reserves from adjacent Corson County because of map coverage.

Mining Methods.--Individual landowners have mined lignite from the deposits in Dewey and Ziebach Counties since about 1890, although commercial development did not commence until about 1913. Early mine operators employed horse drawn drag scrapers along lignite outcrops where the relatively thin overburden could be removed readily. Steam shovels later were employed in the commercial mines and permitted removal of thicker overburden, enabling production to extend further from the outcrop. Still later, draglines such as the one in Figure 12, stripped the overburden and power shovels removed the lignite.

All mining operations remained relatively small. As lignite at existing pits thinned, or when too much "blackjack" or overburden was encountered, new pits were opened. Thus, the region between Isabel and Firesteel and west to the reservation boundary is studded with small, abandoned pits as shown in Figure 13. The locations of the more significant mines are shown in Figure 11, but no commercial production from these mines has been reported since 1967.

Potential.--The potential for using Dewey and Ziebach County lignites in carbonization, hydrogenation, or gasification facilities is not promising because of limited deposit thickness, diverse ownership, and distance from potential markets for the product. Measured lignite reserves of 131 million tons (see Table 5) having an average heat content of 6,910 Btu per pound as received (see Table 4) are sufficient to fuel a 1,000-megawatt steam-electric generating facility throughout a 20-year project life (assuming a generating plant consumption of 9,200 Btu per kilowatt-hour generated; Baumeister, 1958).

The complicated pattern of diverse surface and mineral ownership in this part of the reservation and the meager amount of allotted and trust lands suggest that any large-scale lignite development would be difficult to assemble. Moreover, the limited tribal land holdings probably would net few benefits to the Cheyenne River Sioux Tribe. Perhaps the greatest net benefits might accrue to the tribe from disposal of existing mineral and surface rights in this area and purchase of alienated lands within the consolidation boundary.

Prior to planning any large-scale development a complete review and updating of the surface and mineral rights of all lands with lignite potential is necessary. This could best be accomplished by the Bureau of Indian Affairs in cooperation with the Bureau of Land Management.

Petroleum

General.--Petroleum is the only mineral resource now being developed on the Cheyenne River Indian Reservation. Several areas are under lease and although discoveries to date have been modest, exploration and drilling are continuing.

Oil and gas, which may or may not be associated, are generally formed from marine sedimentary rocks by processes of heat, pressure, and biological and chemical activity. These processes "squeeze" the hydrocarbons out of the organic matter in the source rocks. Once they are "squeezed" out, they migrate, generally laterally and upward, through porous and permeable rock units, eventually escaping at the surface, unless they encounter a barrier to migration. The barrier will generally be an impermeable rock layer in the sedimentary sequence, and will form either a structural or stratigraphic trap. Structural traps are usually found in structural highs, such as the crests of anticlines or domes, or else along fault zones, where the permeable reservoir rocks are offset and abut impermeable layers. Stratigraphic traps form in uniformly dipping rocks by changes in the porosity and permeability of the reservoir rocks. Combination traps are very common. Formation water, if present, will be separated from the hydrocarbons and will either escape at lower levels or will be retained below the hydrocarbons. Structural traps can be located by careful surface mapping and geophysical techniques, while stratigraphic traps require more "guesswork" and a careful study of the depositional environment of the sedimentary units, with the use of outcrop and drill hole samples, driller's logs, and electrical and gamma ray logs.

Two wells near Lantry produce some oil. Shows of oil and gas have been encountered in other drill holes on or near the reservation. The oil and gas test holes drilled on or near the reservation are listed in Table 6 and their locations are shown in Figure 14. Of these wells, only one well penetrated to the Precambrian (Figure 15).

The following well casing data, production interval data, and production data for the two wells near Lantry were supplied by Fred Steece (personal communication, 1976). The Investors No. 2 Brings-the Horses well produces from the Red River Formation and has 8⅝ inch surface casing to 165 feet, and 5½ inch production casing from 165 to 5,087 feet. The producing intervals are from 5,022 to 5,029 feet, where there are 14 perforations per foot and from 5,053 to 5,057 feet, where there are 8 perforations per foot. Production from this well through the end of 1975 is 17,868 barrels. When this hole was drilled, core was cut from 5,020 to 5,076 feet and 15 feet of oil saturation was encountered.

The L. L. Tuck No. 1 Little Skunk well also produces from the Red River and has 8⅝ inch surface casing to 170 feet, and 5½ inch production casing from 170 to 5,020 feet. The producing interval is from 5,018 to 5,020 feet, where there are 4 perforations per foot. Production from this well through the end of 1975 is 2,367 barrels. The well is producing about 600 to 700 barrels per month to May 1976.

Aside from these two wells, the nearest officially designated producing fields are in north-central Harding County, about 130 airline miles northwest of the center of the reservation.

Geologic Setting and Controls.--The Cheyenne River Indian Reservation is situated near the edge of the Williston basin, on its southeast flank. The Williston basin is a large structure extending southward from Canada into northeastern Montana, western North Dakota, and northwestern South Dakota (Mallory, 1972). The deepest part of the basin occurs near Williston, N. Dak., 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 pinch out southeastward onto the ancient Siouxia land mass in southeastern South Dakota. Intermittent uplift of this land mass caused onlapping, offlapping, and erosional pinchouts in all strata below the Cretaceous, providing stratigraphic traps for petroleum (Miller, 1971).

Modest surface expressions denote several deep-seated structures within the Williston basin. Of these structures, three are large and are of regional significance: the Nesson anticline, the Poplar anticline, and the Cedar Creek anticline (Figure 8). Other areas of possible folding are suggested by isopach maps, but minor folding cannot be determined by the number of present control points. All three of the large structures have been the sites of petroleum discoveries, but only the Nesson anticline might extend into Dewey and Ziebach Counties, South Dakota.

Unconformities at the base of the Jurassic sedimentary rocks, at the base of the Triassic, at the base of the Big Snowy Group in the Mississippian, at the top of the Devonian, at the top of the Silurian, and at the top and bottom of the Ordovician may provide traps for petroleum.

Exploration and Production.--During the 1920's, the South Dakota Geological Survey published a number of circulars containing detailed structural data derived from stratigraphic measurements in portions of Dewey and Ziebach Counties (Lupton and Marks, 1924; Russell, 1925a; Ward and Wilson, 1922; Wilson, 1922a, 1922b, 1925; Wilson and Ward, 1923). One structure was explored in 1924, but other structures remained unexplored until the 1950's, although several authorities cited the possibilities of finding oil in this area (Gries, 1951; Lindsey, 1953; Petsch, 1942; Rothrock, 1955; Thom, 1922; Wilson, 1923). Between 1953 and the present, 38 oil tests have been drilled on the Cheyenne River Indian Reservation (Agnew, 1959; Agnew and Gries, 1960a, b; Agnew and Lange, 1961; Balster and others, 1971; Brown, 1959; Hansen and Trout, 1963; Petroleum Information files; Schoon, 1970; South Dakota Geological Survey (undated oil and gas test maps)). Table 6 summarizes data from these tests.

The wells drilled in 1924 and 1928 tested only relatively shallow formations. Some of the more recent wells also have failed to explore possibilities offered by the deeper strata; for example, the Investors Drilling Ventures No. 1 Collins well, drilled in 1971, was only a little over 3,000 feet deep and tested only the Newcastle Sandstone.

The drilling activity recently has been centered in the Lantry area, and five drill holes have achieved initial pumped production of petroleum. Only the Investors No. 2 Brings-The-Horses and Tuck No. 1 Little Skunk are now producing, and their sustained production rates have not been disclosed.

Thus, Dewey and Ziebach Counties, as yet, have been incompletely explored. Exploration is continuing, and a number of leases are outstanding.

Lease Status.--Figure 16 shows the current leases on the Cheyenne River Indian Reservation; all are in the Lantry area in Dewey County. Several of these leases have not yet been evaluated by drilling. Additional lease requests are being considered by the Cheyenne River Sioux Tribe, and a lease sale may be held in 1976 or 1977.

Potential Resources.--There is some possibility of finding small pools of oil and/or gas on the

Cheyenne River 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 2). This discussion is based largely on Sandberg and Prichard (1964, p. 157159), 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 North Dakota portion of the Williston Basin, but may be largely flushed of hydrocarbons in South Dakota.

The Ordovician Red River Formation has one of the greatest potentials for petroleum production in the State, as six of the seven producing fields in South Dakota are in this unit. Many of the wells drilled to or through this unit on or near the reservation obtained oil shows in this interval.

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 Interlake Group, and the Devonian Duperow and Birdbear Formations, and Three Forks Shale, which produce some of the oil in Montana and North Dakota, are considered to have a potential of secondary importance in South Dakota.

The Lodgepole, Mission Canyon, and Charles Formations, which comprise the Madison Group, have a very high potential for production in South Dakota. 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. None of the fields in South Dakota produce from this interval, however, and shows of oil from these units have not been particularly high, so their potential in South Dakota 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 South Dakota, as units above and below it have good potential. It merits at least some drill stem testing to determine its future.

The Permo-Pennsylvanian Minnelusa Formation has high potential in the State, as the Barker Dome Field in Harding County produces from this interval. Also, this 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. 11) considers it to be the potential oil producing "sleeper," at least in Harding and Butte Counties. The unit 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. This interval has been analyzed in definitive studies by Schoon (1971 and 1972), in which he outlines some target areas that are quite amenable to further testing. He states (1971, p. 34) that it was originally thought that the Dakota had been entirely flushed of hydrocarbon accumulations by the artesian water that flows through the unit, but analyses of the water indicate that a large area of the state is underlain by Dakota that contains connate sodium-chloride type water. This means that this portion of the unit has not been flushed. The entire reservation area is underlain by this unflushed portion of the Dakota. No commercial oil wells producing from the Dakota exist at the present time in 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.

Via subsurface studies, Schoon delineates four tongues of the Dakota Sandstone, the lower-most consistent tongue being the Newcastle Sandstone. He points out that these tongues are only the most widespread and best developed and that there are numerous other tongues not delineated by him. He further clarifies that the use of his isopach (thickness) maps of the sandstone tongues should be used only as a rough guide in oil exploration.

In a discussion of the area immediately to the northeast and north of the Black Hills, where the northwest and west trending tongues of the Dakota Formation were not opened by truncation following the Black Hills uplift, Schoon (1971, p. 35) lists the following potential petroleum traps in the Dakota:

1. Where tongues of the Dakota Formation cross noses or anticlinal structures.
2. Where tongues of the Dakota terminate updip toward the Black Hills. This may occur anywhere west of the axis of the Williston Basin.
3. Where tongues of the Dakota in plan view exhibit convexity updip.
4. Where closed anticlines and stratigraphic traps exist in the area of sodium-chloride type water.
5. Where beach bar and channel deposits are present.

Of these five potential petroleum traps all except the second may occur on the reservation. One target area that Schoon specifically mentions is a southwestward extending tongue of Dakota Sandstone in north central South Dakota that should be tested on its updip side. The best chances of petroleum traps in the Dakota-Newcastle interval are west of the axis of the Williston Basin (Figure 8), but the area east of the axis of the basin, which includes the reservation, cannot be entirely discounted. However, Schoon (1972, p. 11) states that the Newcastle Sandstone east of the basin axis may be devoid of oil due to its escape from the unit prior to and after the uplift of the Black Hills.

Development Potential.--As previously noted, the Cheyenne River Indian Reservation is situated in a portion of the Williston basin where stratigraphic and structural traps may contain petroleum (Austin and Hammond, 1962; McCaslin, 1972; Wulf and Gries, 1963). Petroleum on the reservation has been confirmed by discovery wells, but the extent of the potentially productive area has not yet been fully determined. The development potential can best be summarized as a fairly good possibility for development of one or more small fields (Miller, 1971).

Recommendation for Further Study.--An in-depth study dealing with all of the stratigraphic and structural data obtainable for Dewey and Ziebach Counties, seeking to delineate the most highly prospective areas of the reservation, would appear to be the next step in any concerted oil exploration program for the Cheyenne River Indian Reservation.

In conjunction with such an investigation, a careful study of the mineral and surface ownership status of all land in Dewey and Ziebach Counties would be necessary.

Natural Gas

Although natural gas occurs on the Cheyenne River Indian Reservation, further development of this resource does not seem warranted because of the known small quantities of gas available.

Occurrence and Extent.--Natural gas was recovered from water wells in the central part of South Dakota shortly before 1900. Gas was separated from produced 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 17 shows the extent of the Pierre gas field as determined by gas occurrences in wells driven to the Dakota Sandstone.

Production and Uses.--With the exception of the commercial use of this natural gas in the city of Pierre from about 1894 to 1913, no extensive production or use of this gas has been attempted (Agnew, 1961). The maximum recorded production in 1910 from one of the Pierre wells was about 85,000 cubic feet of gas per day, but this rate dropped to about 15,000 cubic feet per day by 1916 (Schoon, 1971). A few ranches use the natural gas from their water wells for heating or cooking, but annual production is very small.

Gas from the municipal wells at Pierre was analyzed by the Carter Oil Co. and was found to consist predominantly of methane (74.80 percent), ethane (13.20 percent), and propane (10.70 percent); this composition yields a calculated heating value of about 1,300 Btu per cubic foot.

The limited extension of the Pierre gas field into the reservation and the small indicated gas production from this field suggests little potential for additional development except as an adjunct to water development. If large volumes of water, from which gas is also being produced, are withdrawn from the Dakota Sandstone the gas may find limited use for local heating.

Geothermal Resources

General.--Naturally occurring thermal waters or live steam may be utilized to supplement or supplant other energy sources. Thermal waters can be employed for domestic or industrial heating. Live steam can be used for heating, industrial processes, and electric power generation. The geothermal resources of South Dakota occur largely as hot water aquifers.

Reported drill-hole temperatures are interpreted by Schoon and McGregor (1974) to indicate anomalous heat flow and potential for geothermal energy development beneath a portion of the Cheyenne River Indian Reservation. The present investigation concludes that nonequilibrium conditions in the Dakota-Newcastle aquifer explain the apparent anomaly and does not infer significant potential for geothermal energy development.

Thermal Waters.--Neither recent volcanic activity nor hot springs occur in the vicinity of the Cheyenne River Indian Reservation. Deep water wells and oil tests within the reservation boundary have encountered hot waters, suggesting the possible existence of a geothermal resource.

Water from the municipal well at Philip, in Haakon County, south of the reservation, has a temperature of 158ºF, and the municipal well at Midland, S. Dak., yields 200 gallons per minute of 160ºF water. (Approximately 184,000 Btu per minute.) Midland utilizes this water to heat the public school buildings. Ranchers in the area reportedly use the hot water from their deep artesian wells to heat their buildings. Schoon and McGregor (1974) have computed the geothermal gradients based on temperature data from many wells in South Dakota and conclude that a moderate geothermal anomaly exists in southern Ziebach County. The use of geothermal heat could reduce significantly the quantities of other energy sources needed for heating purposes on the Cheyenne River Indian Reservation.

Geothermal Gradients.--It has long been known from bore holes and deep mining operations that rock temperature increases with depth. The geothermal gradient or rate of increase of temperature with depth, however, varies considerably from place to place and is a function of the rock type and proximity to a heat source. In an area of normal or average geothermal gradient, it would be possible to obtain a desired temperature simply by drilling a deep hole. In a practical sense, the cost of drilling and the paucity of fluids in Precambrian basement rock that could be circulated to the surface prevent this type of endeavor. In areas of high geothermal gradient, however, greater temperatures can be reached at intermediate depths and the groundwater in strata above the crystalline basement complex may facilitate heat transfer to the surface.

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 Fº per 100 feet of depth. The average worldwide geothermal gradient is about 1.6 Fº/100 feet.

Based on reported bottom-hole and artesian flow temperatures, and assuming a mean annual temperature at the surface of 45ºF, the geothermal gradients for many of the drill holes in Dewey and Ziebach Counties have been calculated (Table 7). Adolphson and LeRoux (1968) report variations in gradients determined from drill holes along the Missouri River, but these variations are not large and no attempt has been made to apply averages or corrections to the data presented in Table 7.

The data in Table 7 reveal anomalously high geothermal gradients in wells penetrating the Dakota or Newcastle aquifers while deeper wells show less anomalous gradients. This implies that water temperatures in the Dakota or Newcastle Sandstone are actually higher than the temperatures of underlying formations and suggests that the anomalies reported by Schoon and McGregor (1974) must be modified.

Figure 18 is an isogradient map of the Cheyenne River Indian Reservation prepared from the geothermal gradients calculated for wells penetrating the Dakota or Newcastle Sandstone. This contrasts strongly with Figure 19, which shows isogradients determined only from deep well data. It appears that the Dakota and Newcastle Sandstone are not in thermal equilibrium with underlying rock units and that geothermal gradients calculated from measurements in these formations cannot be used to predict temperatures at greater depths. It seems probable that the lateral continuity and relatively high permeability of the Dakota and Newcastle Sandstones (Gries, 1959) permit groundwater that has been heated to greater temperatures in deeper portions of the Williston basin to circulate upslope where it is not in equilibrium with overlying and underlying strata.

Development Potential.--Extensive development of geothermal energy on the Cheyenne River Indian Reservation appears unlikely; however, the geothermal heat could provide reliable and inexpensive heating for domestic needs. A more detailed examination of all drill-hole data should be undertaken to determine the actual extent and magnitude of any geothermal anomalies on the Cheyenne River Indian Reservation.

Nonmetallic Mineral Resources

The nonmetallic mineral resources available in Dewey and Ziebach Counties include sand and gravel, rock, and clay and shale.

Sand and Gravel

Sand and gravel deposits on the west side of the Missouri River are much thinner and are generally of poorer quality than the extensive glacial gravels east of the river. Much of the coarser material in the deposits of the Cheyenne River Indian Reservation is derived from the sedimentary bedrock of the area. Concretions constitute most of the coarse material; these may be composed of argillaceous limestone, lime and iron-oxide cemented clays, or iron-manganese carbonate. All of these materials are unsuitable for concrete aggregate. Most of the gravels contain a high percentage of sand and extensive screening is necessary before an acceptable road surfacing material is obtained.

In contrast, the sands are relatively free of undesirable material, and some can be utilized in concrete without washing. Screening is usually necessary, however, to remove the coarse, undesirable fraction.

Some sand is used locally for concrete, and gravel is produced as needed for highway construction and maintenance. There is little potential for significant expansion. The locations of sand and gravel pits are shown on Figure 20.

Rock

Two types of rock available for concrete aggregate and for riprap on the Cheyenne River Indian Reservation are glacial boulders and sandstone.

Glacial boulders are scattered throughout the northeastern part of the reservation and represent the more enduring portion of glacial debris brought into the area by advancing ice sheets (Figure 7). Although some of the boulders are schists and quartzite, most are granite or related igneous rock, and are a convenient source of riprap for facing exposed embankments or as a base course for road construction.

Butte-capping sandstones of the Fox Hills Formation have been more widely used than the glacial erratics. The suitability of a specific sandstone is dependent upon its cementing material and on the intended application of the sandstone. Siliceous, opaline, and calcite cements are in sandstones of the Fox Hills Formation in Dewey and Ziebach Counties. In addition, iron oxides are the cementing material in some sandstones of the Hell Creek Formation. Calcite and iron oxide cemented sandstones tend to be weak and unevenly cemented. Opaline cement reacts in concrete aggregate and causes deterioration of the final product. Only quartzite (silica-cemented sandstone) is suitable for most applications, but hardness and durability also make it more difficult and costly to mine and crush for use.

Sufficient rock is available on the reservation to meet anticipated construction needs; however, the lack of large quantities of readily obtained rock and the large distances between the reservation and any other market preclude development of this resource for other than local use.

The Colgate Sandstone Member of the Fox Hills Formation and some of the sandstone lenses in the Hell Creek Formation possess good strength, due to a siliceous cement, and can be used locally for building and foundation stone and as flagstone. The other sandstones are either largely unconsolidated or are friable and therefore of little use as building and ornamental stone.

The lignite coal beds in the Hell Creek Formation have burned in a few places and have produced pseudoscoria, a reddish claystone, which can be used locally as an ornamental stone. The amount of these products is very limited so no large market could ever be established for them.

Clay and Shale

Clay and shale, which make up the bulk of the rocks exposed on the Cheyenne River Indian Reservation, are found in large amounts in the Pierre Shale and Hell Creek Formation, and in lesser amounts in the Fox Hills Formation. Currently, none are being utilized. Past studies investigated the possibility of using the clay and shale as ceramic or pottery material, refractory material, brick and tile material, cement material, lightweight aggregate, and road material. However, the small local demand and great distance from other potential markets indicate little potential for development of a viable industry based on lightweight aggregate or structural clay product manufacture.

Ceramic or Pottery Material.--Certain clays from the Upper Cretaceous have been used rather extensively in the manufacture of pottery in North Dakota and these same clays are found as underclays beneath the coal beds in the Hell Creek Formation of South Dakota and, therefore, could doubtless be used for the same purpose (Rothrock, 1944, p. 201).

An analysis of a Hell Creek underclay from the Robbins coal mine in the southwest quarter of section 22, T. 17 N., R. 22 E., Dewey County, is as follows (Rothrock, 1944, p. 201):

SiO_2	62.20 percent
Fe_2O_3	4.10
Al_2O_3	19.28
Mn_3O_4	0.16
CaO	1.26
MgO	2.34
K_2O	---
Na_2O	---
SO_3	0.02
Moisture	2.20
Loss on ignition	5.99
TOTAL	97.55

Fournier (1969) reported that the Hell Creek Formation contains ceramic clay, but that no analyses have been made to determine its potential.

Refractory Material.--Refractory clay is used to make fire brick, furnace linings, and other materials which must withstand high temperatures. An essential requirement of this type of clay is a high silica content. The possibility of using portions of the Pierre Shale for this purpose has been discussed by Rothrock (1944, p. 203, 205) and Curtiss (1951, p. 70, 80). Rothrock (1944) mentions two portions of the Pierre which might be of use as refractory clays, the lowest stratigraphically being the Agency Siliceous Shale Facies of the DeGrey Member and the highest being a siliceous wedge in the Virgin Creek Member. He states that the Agency crops out at the mouth of the Moreau River and is exposed along the Missouri River south of Pierre. The siliceous wedge in the Virgin Creek crops out 6 to 8 miles north of the mouth of the Moreau and thickens northward to Mobridge and beyond. Curtiss (1951) states that only the lower Virgin Creek Member is siliceous in the vicinity of Mobridge. A chemical analysis of the lower Virgin Creek is as follows (Curtiss, 1951, p. 70):

Silica (SiO_2)	71.24 percent
Iron oxide (Fe_2O_3)	1.20
Alumina (Al_2O_3)	11.32
Lime (CaO)	1.60
Magnesia (MgO)	1.70
Sulfur trioxide (SO_3)	0.13
Carbon dioxide (CO_2)	0.86
Volatile matter	5.74
TOTAL	93.79

In an investigation of the Pierre Shale near Mobridge for the possibility of lightweight aggregate production, Cole and Zetterstrom (1954, p. 20, 25, 27) found both of the lower Virgin Creek samples to be refractory.

Brick and Tile Material.--The possibility of using Pierre Shale for brick and tile products has been briefly mentioned by Gries (1942, p. 71), Rothrock (1944, p. 203), and Rothrock (1947, p. 23-24). Gries states that most of the Pierre should be satisfactory for the production of common red brick and tile. Rothrock (1944) agrees and states that nearly every town along the Missouri River had a brick plant in the 1890's. He states that the Pierre offers a limitless source of material for brick and tile, with the noncalcareous beds offering the best possibilities, and specifically mentions the upper Virgin Creek and the noncalcareous portion of the Mobridge as potential sources. He cautions that care must be taken to avoid zones that are too calcareous and bentonitic as these will adversely affect the quality of the product. The proper amount of calcareous material will, however, yield a brick that is yellow in color. At the present time, the brick and tile market is supplied by better quality products from other geologic sources.

Cement Material.--Curtiss (1951, p. 71) states that the lower part of the Virgin Creek Member of the Pierre should make an excellent raw material for Portland cement manufacture, as the quantity of silica (SiO_2) is sufficient to mix adequately with a lime rock containing about 75 percent of calcium carbonate ($CaCO_3$), there is enough alumina (Al_2O_3) and iron oxide (Fe_2O_3) for fluxing, and the percentage of magnesia (MgO) and sulfur is well within the limitations (see the chemical analysis under the Refractory Material section).

Lightweight Aggregate.--The possibility of producing lightweight aggregate from the clays and shales of South Dakota is discussed by Moe (1952), Cole and Zetterstrom (1954), and Karsten (1956). The following is based largely on their reports.

The lightweight aggregate material that can be produced from clay and shale in South Dakota is a manufactured type, wherein appropriate clay and shale material is heated until it expands. The expanded particles, in order to produce a good aggregate material, should possess the following qualities: light weight, strength, a rounded edge particle, low water absorption, uniform particle-size gradation, chemical inertness, and low production cost.

In an attempt to find material with these qualities, Moe (1952, p. 6-7) collected 33 samples from various stratigraphic units and tested these for their potential. Seven of these sampling localities were in Dewey County on or near the reservation. His tests revealed that the Virgin Creek Member of the Pierre offered the best possibilities for lightweight aggregate production. He specifically mentions several promising localities near Promise.

Cole and Zetterstrom (1954), in an investigation of materials suitable for production of lightweight aggregate in North and South Dakota, collected seven samples near Mobridge for analysis. Based on their findings, the lower Virgin Creek, Elk Butte, and noncalcareous portion of the Mobridge have good possibilities as lightweight aggregate material. The investigators caution, however, that further sampling and testing would be required before a lightweight aggregate plant could be put into production in the area.

Based on the above investigations, the upper, nonsiliceous portion of the Virgin Creek Member offers the best possibilities as lightweight aggregate material on the reservation. The Elk Butte and Mobridge Members have less desirable characteristics, but still offer some potential.

Road Material.--Rothrock (1944, p. 205) and Curtiss (1951, p. 80) state, respectively, that the Agency Siliceous Shale Facies of the DeGrey Member and the lower, siliceous portion of the Virgin Creek Member can be used as road surfacing material since they do not form a sticky gumbo when wet.

Metallic Mineral Resources

Iron-Manganese

Harrer (1964, p. 59) reports that iron-manganese concretions and nodules from the Hell Creek Formation occur as terrace gravel concentrates along the Grand, Moreau, and Cheyenne Rivers. No estimates of the quantity of these has been made. The iron occurs as siderite, hematite, and limonite. No development of this resource can be expected in the immediate future.

Iron-manganese concretions containing up to 17 percent manganese occur in the Pierre Shale of South Dakota (Curtiss, 1955; Pesonen, Tullis, and Zinner, 1949). Concretionary zones occur on the reservation, but the low grade and disseminated nature of these deposits does not suggest any economic possibilities at this time.

Copper

In the drill log of the Carter Oil Co. Stratigraphic Test No. 2 in Stanley County, south of the reservation boundary, the company geologist noted "much chalcopyrite" in a black bituminous shale near the base of the Minnelusa Formation, 2,700 feet beneath the surface (Baker, 1947). No amplification of this observation is made in the publication and no similar observations have been reported in borings on the Cheyenne River Indian Reservation. Thus, it is unlikely that any significant metalliferous deposits occur at reasonable depths in Ziebach or Dewey Counties.

RECOMMENDATIONS

A complete review of the ownership of the surface and subsurface mineral rights should be made. This would best be accomplished in coordination with the Bureau of Land Management.

To further assess the petroleum potential a detailed study should be made of all available drill hole data. The drilling of additional water wells and oil and gas test holes will provide additional information on possible oil and gas accumulations.

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Table 2.--Stratigraphic sequence on Cheyenne River Indian Reservation, in part from drill-hole data (Petroleum Information files)

System	Series	Group or Formation	Member	Description	Thickness (feet)
QUATER-NARY	HOLOCENE	Alluvium		Clay, silt, sand and gravel on floodplains of present drainages	0-30
		Terrace Deposits		Sand and gravel, minor amounts of silt and clay	0-15
TERTIARY	PALEO-CENE	Fort Union Formation	Ludlow Member	Sandstone and shale with Shadehill coal facies (lignite) at base. Scattered erosional remnants in NW corner of reservation.	40-60
CRETACEOUS	UPPER CRETACEOUS	Hell Creek Formation	Upper Hell Creek	Lenticular bentonitic clays, silts, sands, and peat-clays; scattered iron-manganese concretions and quartzose sandstones on surface	300-350
			Isabel-Firesteel Lignite Facies	Black, blocky, sub-bituminous coal, lignite and brown clay-peat beds. Buff to red, burned claystone (pseudo scoria) locally	0-6
			Lower Hell Creek	Medium- to dark-gray lenticular bentonitic clays, silts, sands, peat-clay beds; a few iron-manganese concretions	50-75
		Fox Hills Formation	Colgate Sandstone Member	Thin-bedded, gray, siliceous, fine-grained, graywacke sandstone; crossbedded, ripple-marked, few limonitic concretions	15-35
			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 35
			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
			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	80-200

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Table 2.--Continued

System	Series	Group or Formation	Member	Description	Thickness (feet)
CRETACEOUS	UPPER CRETACEOUS	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. Loses identity to west and northwest where it and the next lower member are called Upper Pierre.	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	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 1/2 to 1 foot thick reddish brown siltstone at base. This may not extend to reservation from east.	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 underly 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

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Table 2.--Continued

System	Series	Group or Formation	Member	Description	Thickness (feet)
CRETACEOUS	UPPER CRETACEOUS	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
	LOWER CRETACEOUS	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. Boundary between 2 formations crosses reservation in an easterly and northeasterly direction. Tongues of the Dakota extend into Newcastle area but are stratigraphically higher.	As much as 140 As much as 270
		Skull Creek Shale		Medium- to dark-gray shale with thin glauconitic siltstone near middle.	As much as 220
		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

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Table 2.--Continued

System / Series		Group or Formation / Member		Description	Thickness (feet)
JURASSIC	UPPER JURASSIC	Morrison Formation		Variegated clay and shale with some gray siltstone and sandstone	As much as 180
		Sundance Formation		White sandstone, in part glauconitic, interbedded with gray, green, and brown shale	As much as 320
	MIDDLE JURASSIC	Piper Formation		White to brown fine-grained limestone; interbedded with variegated shale	As much as 90
TRIASSIC AND PERMIAN		Spearfish Formation		Reddish shale, silty shale, anhydrite, dolomitic siltstone, and clay; interbedded. Anhydrite and dolomite most numerous near base	As much as 170
PERMIAN		Minnekahta Limestone		White to lavender or pink, dense, fine-grained dolomitic limestone	As much as 50
		Opeche Shale		Dark reddish brown shale, silty shale and siltstone	As much as 50
PERMIAN AND PENNSYLVANIAN		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 320
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 460
		Madison Group	Charles Formation	White to light tan, lithographic limestone; interbedded with white to light blue and light brown anhydrite	As much as 290
			Mission Canyon Limestone	White to light-tan, fine-grained to oolitic, fossiliferous limestone; some anhydrite	As much as 200
			Lodgepole Limestone	Gray and light- to medium-brown, fine- to medium-grained limestone; in part oolitic, fossiliferous, and sucrosic	As much as 435
		Englewood Formation		Pink dolomitic siltstone and varicolored shale	As much as 75

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Table 2.—Continued

System Series	Group or Formation Member	Description	Thickness (feet)
DEVONIAN	Three Forks Shale	Interbedded greenish to reddish gray dolomitic siltstone; red and green shale; and fine- to medium-grained sandstone	As much as 50
	Birdbear Formation	Light-gray to medium brownish-gray, finely crystalline, porous, fossiliferous dolomite and limestone	As much as 115
	Duperow Formation	Light brown, fine-grained limestone, dolomite, and anhydrite; interbedded with thin gray shale	As much as 195
	Souris River Formation	Varicolored shale; red dolomitic siltstone, and anhydrite	As much as 30
SILURIAN AND ORDOVICIAN	Interlake Group	Light-tan to brown dolomite; white to light-gray limestone; gray shale; fine-grained clastics at base	As much as 50
ORDOVICIAN	Stony Mountain Formation	Brownish-gray, fine-grained dolomite at top; green waxy shale and siltstone at base	As much as 75
	Red River Formation	Light- to medium-gray and light-brown limestone and dolomite; in part vuggy	As much as 550
	Winnipeg Formation	Fine-grained quartz sandstone at base; green, splintery to subwaxy shale with black phosphate nodules; interbedded with siltstone at top	100-180
ORDOVICIAN AND CAMBRIAN	Deadwood Formation	White to reddish-orange, fine- to medium-grained quartz sandstone and dolomite; contains green shale partings and locally abundant glauconite	180-330
PRECAMBRIAN		Igneous and metamorphic rocks	

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Table 4.--Lignite production from Dewey and Ziebach Counties, South Dakota

Year	Total South Dakota production (short tons)	Production from study area (short tons)	Portion of South Dakota production from study area (percent)	Counties included in "Production from study area" figures[1]
1913....	10,540	858	8.1	Dewey
1914....	11,850	4,855	41.0	Do.
1915....	10,593	5,645	53.3	Dewey and Harding
1916....	8,886	2,326	26.2	Dewey, Ziebach, and Harding
1917....	8,042	3,092	38.4	Do.
1918....	7,942	2,579	32.5	Do.
1919....	14,417	5,991	41.6	Do.
1920....	12,777	6,769	53.0	Dewey, Ziebach, Meade, and Harding.
1921....	7,553	2,682	35.5	Do.
1922....	7,752	2,267	29.2	Dewey, Ziebach, Meade, and Harding, also wagon mines.
1923....	10,379	2,911	28.0	Do.
1924....	12,043	3,819	31.7	Ziebach and Harding
1925....	14,447	9,320	64.5	Dewey, Ziebach, and Meade
1926....	14,428	6,720	46.6	Dewey and Ziebach
1927....	12,507	7,025	56.2	Dewey, Ziebach, and Meade
1928....	13,929	8,553	61.4	Do.
1929....	12,854	4,716	36.7	Dewey, Ziebach, and Corson
1930....	12,810	4,505	35.2	Do.
1931....	27,485	19,793	72.0	Do. (Dewey production 18,800 tons)
1932....	49,074	38,972	79.4	Do. (Dewey production 35,726 tons)
1933....	59,375	51,365	86.5	Dewey, Ziebach, Corson, and Harding (Dewey production 43,970 tons)
1934....	42,407	33,585	79.2	Dewey, Ziebach, and Corson (Dewey production 30,375 tons)
1935....	13,243	5,162	39.0	Dewey, Corson, and Harding
1936....	41,331	33,136	80.2	Dewey and Harding
1937....	26,444	26,444	100.0	Do.

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Table 4.--Lignite production from Dewey and Ziebach Counties, South Dakota--Continued

Year	Total South Dakota production (short tons)	Production from study area (short tons)	Portion of South Dakota production from study area (percent)	Counties included in "Production from study area" figures[1]
1938....	48,058	43,164	89.8	Dewey, Corson, and Harding
1939....	49,495	44,907	90.7	Dewey and Corson
1940....	66,085	61,077	92.4	Do.
1941....	70,825	65,730	92.8	Do.
1942....	53,415	48,226	90.3	Do.
1943....	40,589	0	0.0	
1944....	26,827	22,887	85.3	Dewey, Corson, and Meade
1945....	24,445	17,092	69.9	Dewey
1946....	16,946	13,029	76.9	Do.
1947....	16,618	10,427	71.3	Do.
1948....	29,094	27,290	93.8	Do.
1949....	26,429	24,149	91.4	Do.
1950....	38,694	38,694	100.0	Dewey, Ziebach, and Corson, and Amador County, Calif.
1951....	28,325	28,325	100.0	Dewey and Corson
1952....	0	0	0.0	
1953....	23,671	20,524	86.7	Dewey
1954....	W	W	100.0	Dewey (approximately 20,000 tons from one mine)
1955....	25,782	25,782	100.0	Dewey
1956....	24,519	24,519	100.0	Do.
1957....	21,118	21,118	100.0	Do.
1958....	19,571	19,571	100.0	Do.
1959....	22,125	22,125	100.0	Do.
1960....	20,448	20,448	100.0	Do.
1961....	17,805	17,805	100.0	Do.
1962....	17,914	17,914	100.0	Do.
1963....	16,561	16,561	100.0	Do.
1964....	13,000	13,000	100.0	Do.
1965....	10,000	10,000	100.0	Do.
1966....	9,500	9,500	100.0	Do.
1967[2]...	5,000	5,000	100.0	Do.

W Withheld to avoid disclosing company confidential data.
[1]Production figures of several counties often are combined to avoid disclosing company confidential data.
[2]No lignite production has been reported from the study area since 1967.

Source: U.S. Bureau of Mines.

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Table 6.--Oil tests in Dewey and Ziebach Counties, South Dakota

Year	Name of well	Location: Section	Location: Township	Location: Range	Total depth	Formation(s) tested
1924....	Irish Creek Oil Co. No. 1........	SE 17	15 N	20 E	2,680	Greenhorn Limestone
1928....	Cosden No. 1 Tanburg............	SENW 9	11 N	19 E	3,604	Minnelusa Formation
1953....	Youngblood No. 1 Galvin..........	SESE 25	16 N	22 E	6,325	Silurian, Englewood Formation (drilled to basement, but only performed drill stem test on Englewood)
1953....	Kerr-McGee No. 1 Wallace Cook....	SWNWSW 32	13 N	22 E	5,991	Red River Formation
1953....	Ward Dayton No. 1 Olsen..........	NENESE 35	12 N	20 E	5,342	Newcastle Sandstone Mission Canyon Limestone Red River Formation
1953....	Kerr-McGee No. 1 Brammer.........	SENW 20	13 N	20 E	6,300	Charles Formation Red River Formation
1955....	Herndon No. 1 Young..............	NWNE 1	16 N	20 E	5,970	Silurian Formation
1955....	Herndon No. 1 State..............	SWNW 34	13 N	24 E	4,900	Red River Formation
1955....	Herndon No. 1 Butler.............	NENE 21	12 N	19 E	5,590	Do.
1957....	Phillips Kerr-McGee No. 1 Nelson	NWSE 18	13 N	18 E	3,305	Morrison-Sundance Formation
1957....	Phillips No. 1 State.............	SENW 20	11 N	23 E	3,002	Do.
1957....	Shell No. 14-18 Greis............	SWSW 18	17 N	18 E	5,700	Mission Canyon and Lodgepole Limestones.
1960....	Amerada No. 1 Cheyenne River.....	SESW 20	14 N	18 E	3,610	Newcastle Sandstone Morrison-Sundance Formation
1960....	Amerada No. 1 Briscoe............	NWNE 33	16 N	18 E	5,158	Newcastle Sandstone Minnelusa Formation Charles Formation
1963....	Cities Service No. 1 Jensen......	NWNE 21	12 N	22 E	5,300	Red River Formation
1964....	Pendak No. 1 Cowan...............	SESE 21	13 N	22 E	5,703	Do. Winnipeg Shale
1965....	Bueno No. 1 Holloway-State.......	NWNW 4	12 N	22 E	5,056	Red River Formation
1967....	Amerada No. 1 Trent..............	SWNE 26	16 N	18 E	6,410	Newcastle Sandstone Mission Canyon Limestone Bird Bear Formation Red River Formation
1967....	Gulf Oil No. 1 Jewett............	NWNW 12	13 N	27 E	4,700	Winnipeg Shale
1970....	Investors No. 1 Holloway......... (initial daily production; 24 barrels of oil)	NENW 4	12 N	22 E	5,066	Red River Formation
1970....	Investors No. 1 State............	NESW 11	12 N	22 E	5,145	Do.
1970....	Investors No. 2 Holloway.........	SWNE 4	12 N	22 E	5,035	Do.
1970....	Investors No. 1 Cowan............	SESE 20	13 N	20 E	5,830	Do.
1970....	Investors No. 7 Holloway.........	NWSW 4	12 N	22 E	5,078	Do.
1970....	Investors No. 1 Eulberg..........	NWSE 14	13 N	21 E	5,247	Do.
1970....	Investors No. 1 Cook.............	NWSE 8	12 N	22 E	5,117	Do.
1970....	Investors No. 6 Holloway.........	SENW 4	12 N	22 E	5,062	Do.
1970....	Investors No. 1 Brooks...........	NESE 6	12 N	22 E	5,200	Do.
1970....	Investors No. 2 Cook............. (initial daily production; 4 barrels of oil).	SESW 32	13 N	22 E	5,068	Do.
1971....	Investors No. 2 McLellan.........	NENW 17	12 N	22 E	5,126	Do.
1971....	Investors No. 2 Brings-The-Horses (initial daily production; 240 barrels of oil)	NESE 30	13 N	22 E	5,087	Do.
1971....	Investors No. 1 Cook.............	NESW 32	13 N	22 E	5,090	Do.
1971....	Investors No. 1 Anna Red Bird....	SENE 30	13 N	22 E	5,128	Do.
1971....	Investors No. 3 Little Skunk.....	NWNW 29	13 N	22 E	5,103	Do.
1971....	Investors No. 1 Little Skunk..... (initial daily production; 25 barrels of oil)	SWSW 29	13 N	22 E	5,099	Do.
1971....	Investors No. 1 Collins..........	NWSE 23	12 N	20 E	3,079	Newcastle Sandstone
1971....	Investors No. 3 Holloway.........	SENE 4	12 N	22 E	5,055	Red River Formation
1971....	Investors No. 3 Brings-The-Horses	NWSE 30	13 N	22 E	5,118	Do.
1971....	Norris Oil No. 1 Cheyenne........	SESW 25	15 N	21 E	5,582	Do.
1975....	Tuck No. 1 Little Skunk.......... (initial daily production; 65 barrels of oil)	SWSE 29	13 N	22 E	5,020	Do.

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Table 7.-- Calculated geothermal gradients from drill-hole data in Dewey and Ziebach Counties, South Dakota

Well or drill hole	Location: Section	Location: Township	Location: Range	Depth (feet)	Temperature (°F)	Calculated geothermal gradient (F°/100 feet)	Formation
Cherry Creek School.................	32	8 N	22 E	1,878	106	3.36	Dakota Sandstone[1]
Red Scaffold School.................	SE 6	9 N	19 E	2,385	119	3.18	Newcastle Sandstone[1]
Clavel water well..................	13	10 N	23 E	1,800	100	3.16	Do[1].
Cheyenne Agency.....................	SESE 2	12 N	31 E	1,337	79 - 80	2.70	Dakota Sandstone[2]
V. E. Ranch (water well)............	29	15 N	30 E	2,200	91.5	2.17	Inyan Kara Group
Phillips No. 1 State................	SENW 20	11 N	23 E	3,000	107	2.11	Fall River Formation
Bueno No. 1 Holloway-State..........	NWNW 4	12 N	22 E	5,056	150	2.10	Red River Formation
V. E. Ranch (water well)............	26	15 N	30 E	2,215	90	2.09	Inyan Kara Group[1]
Eagle Butte Boarding School.........	27	12 N	24 E	3,020	107	2.09	Do.
Whitehorse..........................	12	15 N	26 E	2,021	85	2.04	Newcastle Sandstone
Investors No. 1 Anna Red Bird.......	SENE 30	13 N	22 E	5,122	144	1.96	Red River Formation
Eagle Butte.........................	SWSW 17	12 N	24 E	4,322	128	1.95	Lodgepole Limestone
Investors No. 1 Cowan...............	SESE 20	13 N	22 E	5,832	156	1.92	Winnipeg Formation
Herndon No. 1 Merkel................	SESE 27	17 N	27 E	4,322	126	1.90	Red River Formation
Investors No. 1 Wallace Cook........	NESW 32	13 N	22 E	5,073	139	1.88	Do.
Ward Dayton No. 1 Olsen.............	NESE 35	12 N	20 E	5,320	144	1.88	Do.
Investors No. 1 Little Skunk........	SWSW 29	13 N	22 E	5,083	139	1.87	Do.
V. E. Ranch (water well)............	36	14 N	29 E	2,505	90	1.84	Inyan Kara Group
Phillips No. 1 Nelson...............	NWSE 18	13 N	18 E	3,310	103	1.78	Fall River Formation
Bartells Ranch......................	8	15 N	31 E	2,266	84	1.77	Inyan Kara Group
Investors No. 2 McLellan............	NENW 17	12 N	22 E	5,126	134	1.76	Red River Formation
Investors No. 2 Brings-The-Horses...	NESE 30	13 N	22 E	5,083	132	1.73	Do.
Amerada No. 1 D. Briscoe............	NWNE 33	16 N	18 E	5,160	132	1.71	Lodgepole Limestone(?)
Kerr-McGee No. 1 Brammer............	SENW 20	13 N	20 E	6,300	152	1.71	Deadwood Formation
Investors No. 7 Holloway............	NWSW 4	12 N	22 E	5,078	130	1.69	Red River Formation
Investors No. 3 Little Skunk........	NWNW 29	13 N	22 E	5,101	130	1.69	Do.
Investors No. 1 Eulberg.............	NWSE 14	13 N	21 E	5,247	132	1.68	Do.
Cities Service No. 1A Jensen........	NWNE 21	12 N	22 E	5,079	133	1.68	Do.
Herndon No. 1 Butler................	NENE 21	12 N	19 E	5,590	137	1.66	Do.
Norris No. 1 Cheyenne...............	SESW 25	15 N	21 E	5,580	136	1.65	Do.
Investors No. 1 Brooks..............	NENE 6	12 N	22 E	5,200	130	1.65	Do.
Pendak No. 1 Cowan..................	SESE 21	13 N	22 E	5,700	137	1.63	Deadwood Formation
Herndon No. 1 Young.................	NWNE 1	16 N	20 E	5,960	140	1.61	Red River Formation
Shell No. 14-18 Greis...............	SWSW 18	17 N	18 E	5,700	134	1.58	Englewood Formation
Kerr-McGee No. 1 Wallace Cook.......	NWSW 32	13 N	22 E	5,992	138	1.57	Precambrian granite
Amerada No. 1 Trent.................	SWNE 26	16 N	18 E	4,871	145	1.56	Mission Canyon Limestone
Amerada No. 1 Cheyenne River........	SESW 20	14 N	18 E	3,610	99	1.52	Spearfish Formation(?)
Investors No. 2 Wallace Cook........	SESW 32	13 N	22 E	5,069	121	1.52	Red River Formation
Investors No. 3 Holloway............	SENE 4	12 N	22 E	5,036	120	1.51	Do.
Investors No. 2 Holloway............	SWNE 4	12 N	22 E	5,019	120	1.51	Do.
Investors No. 1 Holloway............	NENW 4	12 N	22 E	5,066	120	1.50	Do.
Investors No. 1 M. Cook.............	NWSE 8	12 N	22 E	5,117	121	1.50	Do.
Herndon No. 1A O'Leary..............	SESW 13	15 N	23 E	5,146	121	1.49	Do.
Investors No. 6 Holloway............	SENW 4	12 N	22 E	5,068	119	1.48	Do.
Investors No. 1 State...............	NESW 11	12 N	22 E	5,144	120	1.48	Do.
Gulf No. 1 Jewett...................	NWNW 13	13 N	27 E	5,336	120	1.42	Precambrian(?)[3]
Herndon No. 1 State.................	SWNW 34	13 N	24 E	4,897	108	1.30	Red River Formation
Youngblood No. 1 Galvin.............	SESE 25	16 N	22 E	6,324	118	1.17	Precambrian

[1]Produced natural gas.
[2]Natural gas reported but not produced.
[3]No drill logs available below 4,700 feet.

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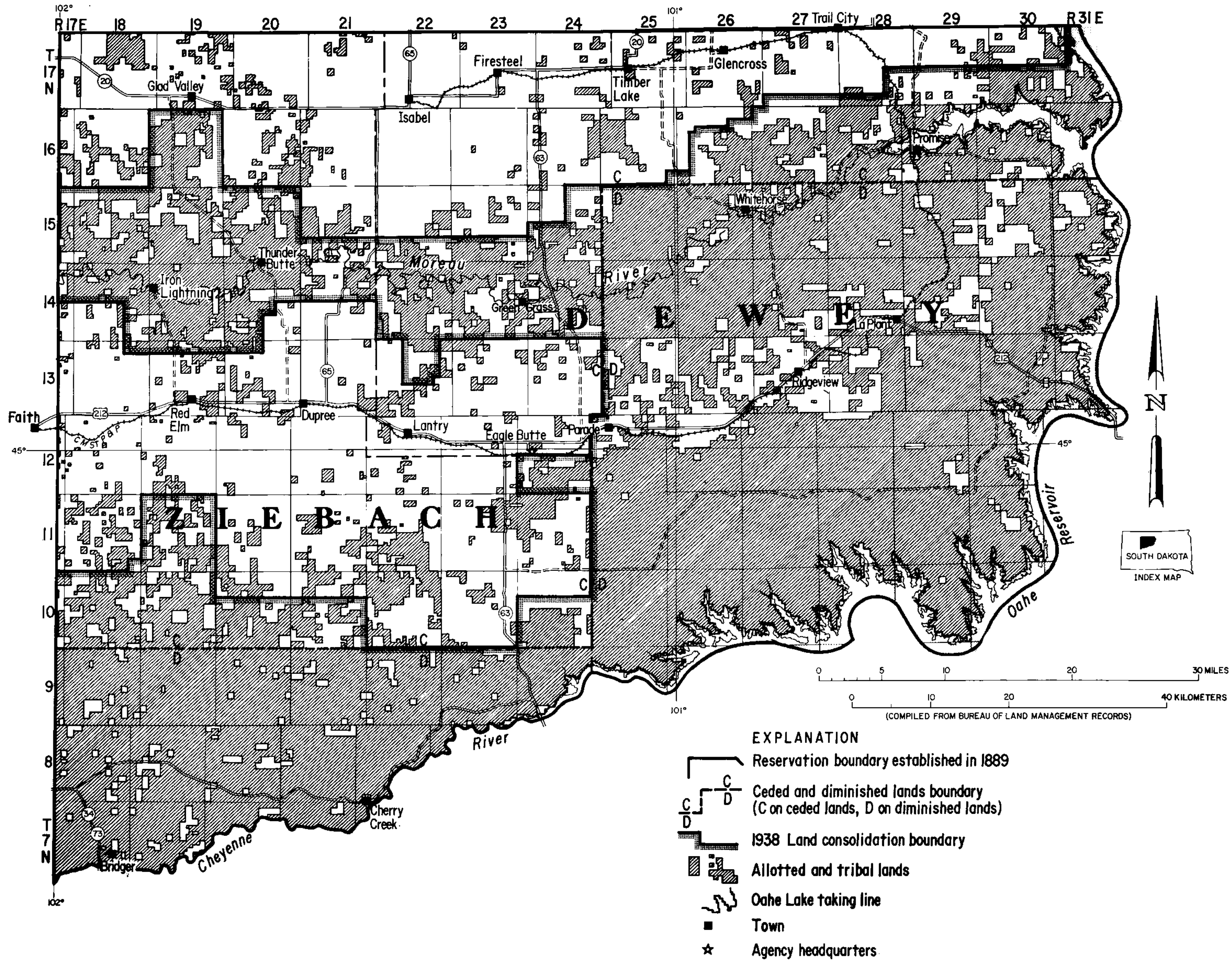

Figure 1. Map showing land status on Cheyenne River Indian Reservation.

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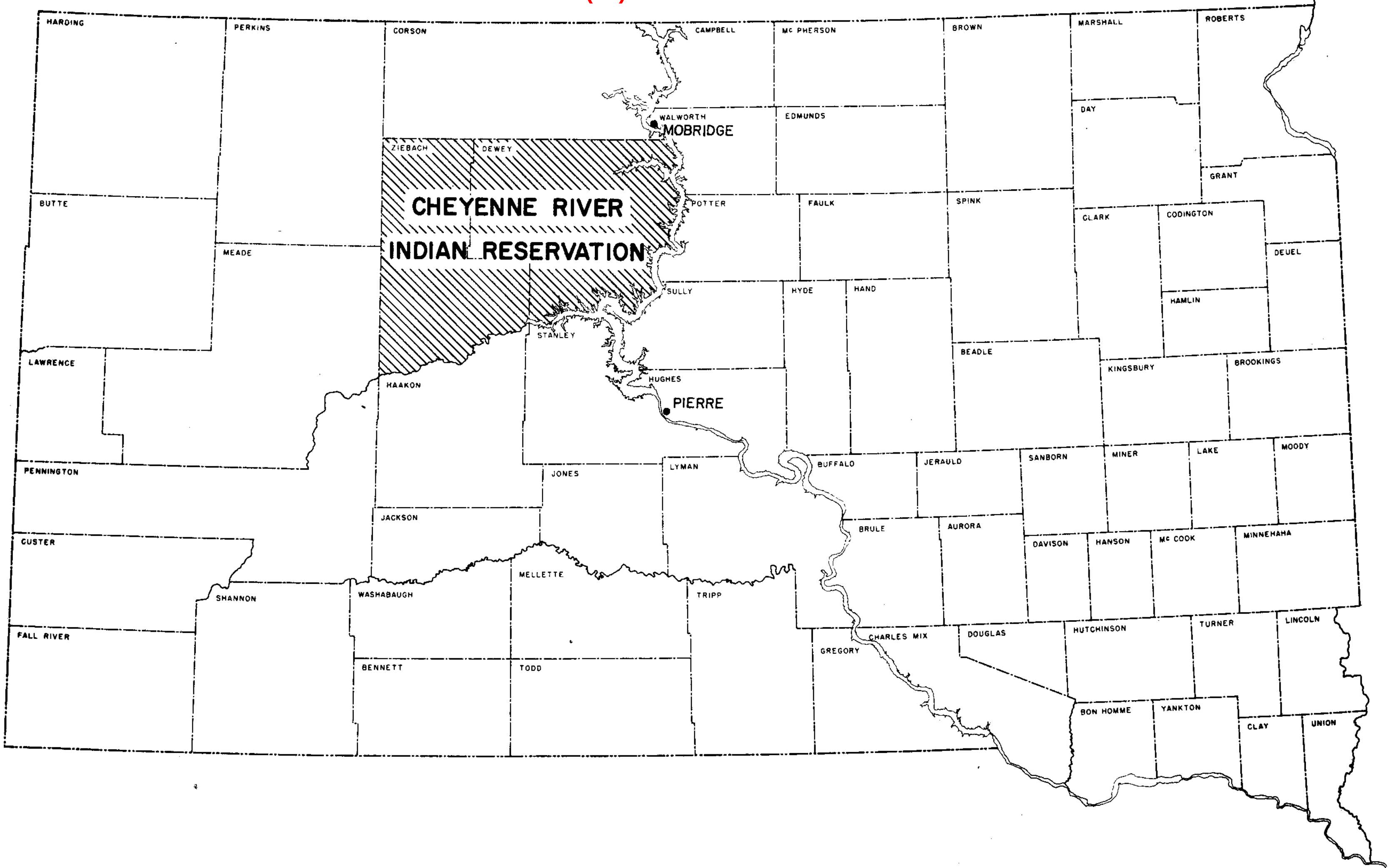

Figure 2. Map of South Dakota showing location of Cheyenne River Indian Reservation.

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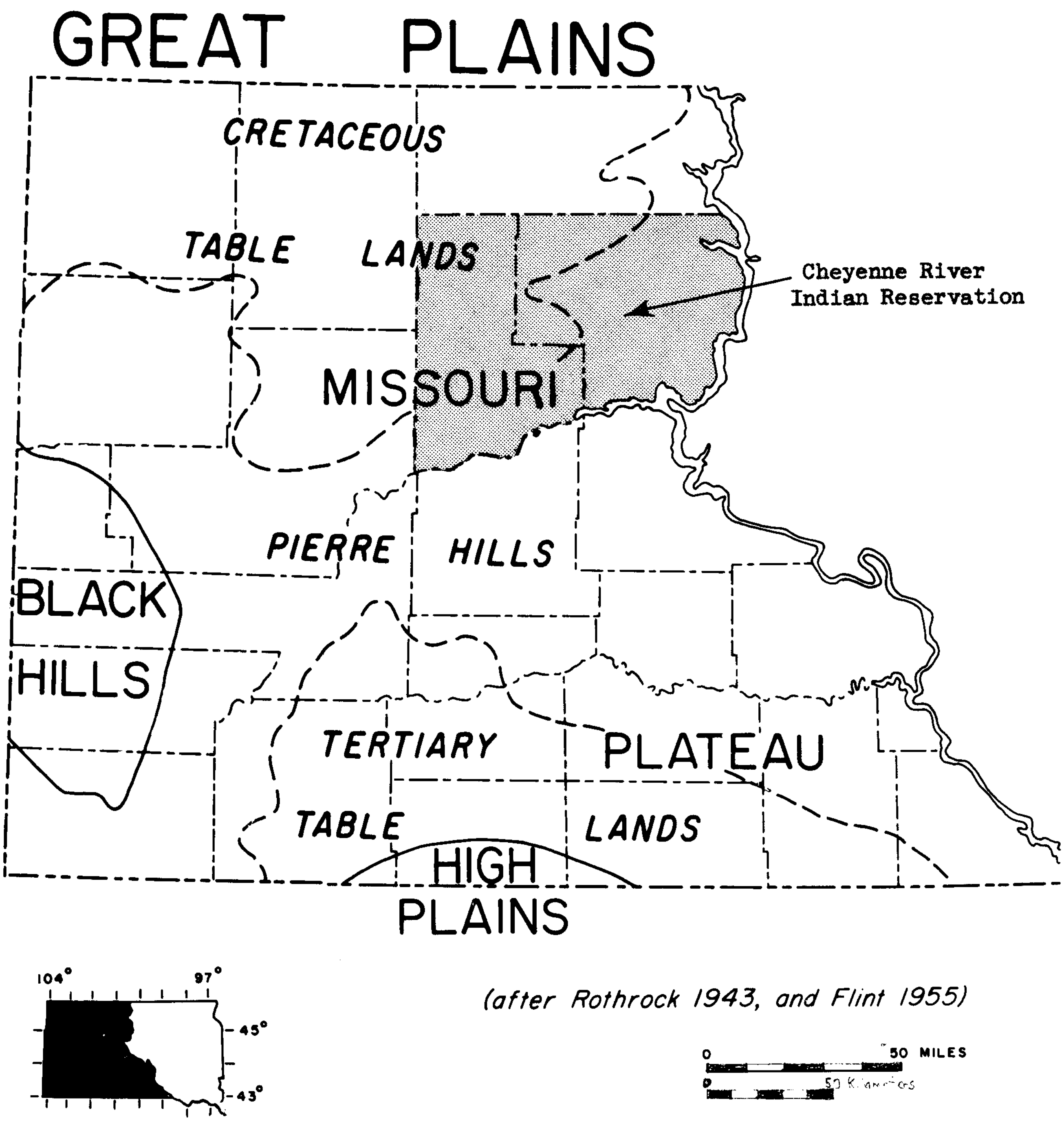

Figure 3. Map showing Cheyenne River Indian Reservation with respect to physiographic divisions, Western South Dakota.

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Figure 4. Photograph of prairie surface of Cheyenne River Indian Reservation.

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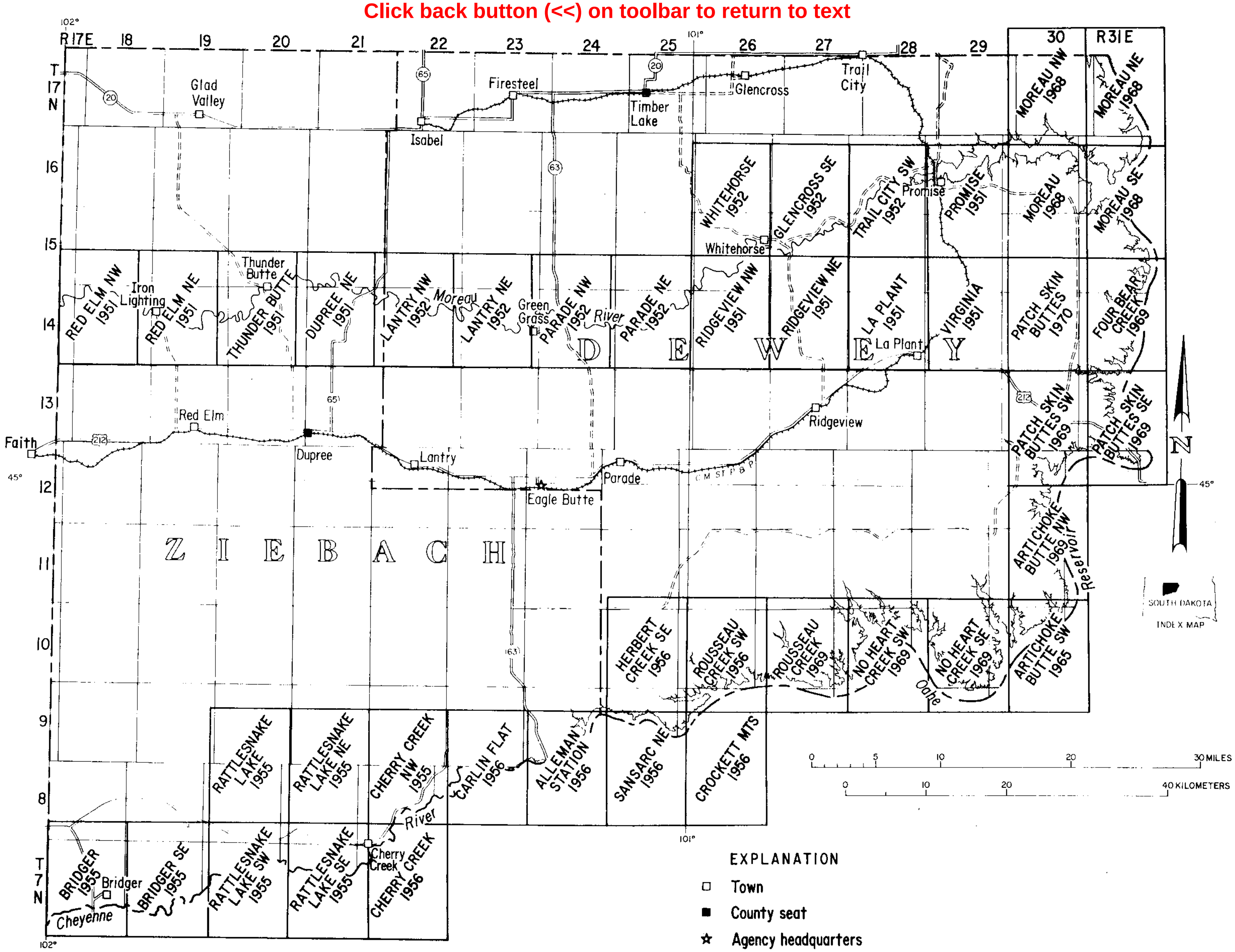

Figure 5. Index map showing U.S. Geological Survey 7 1/2-minute quadrangle topographic map series available for the Cheyenne Indian Reservation.

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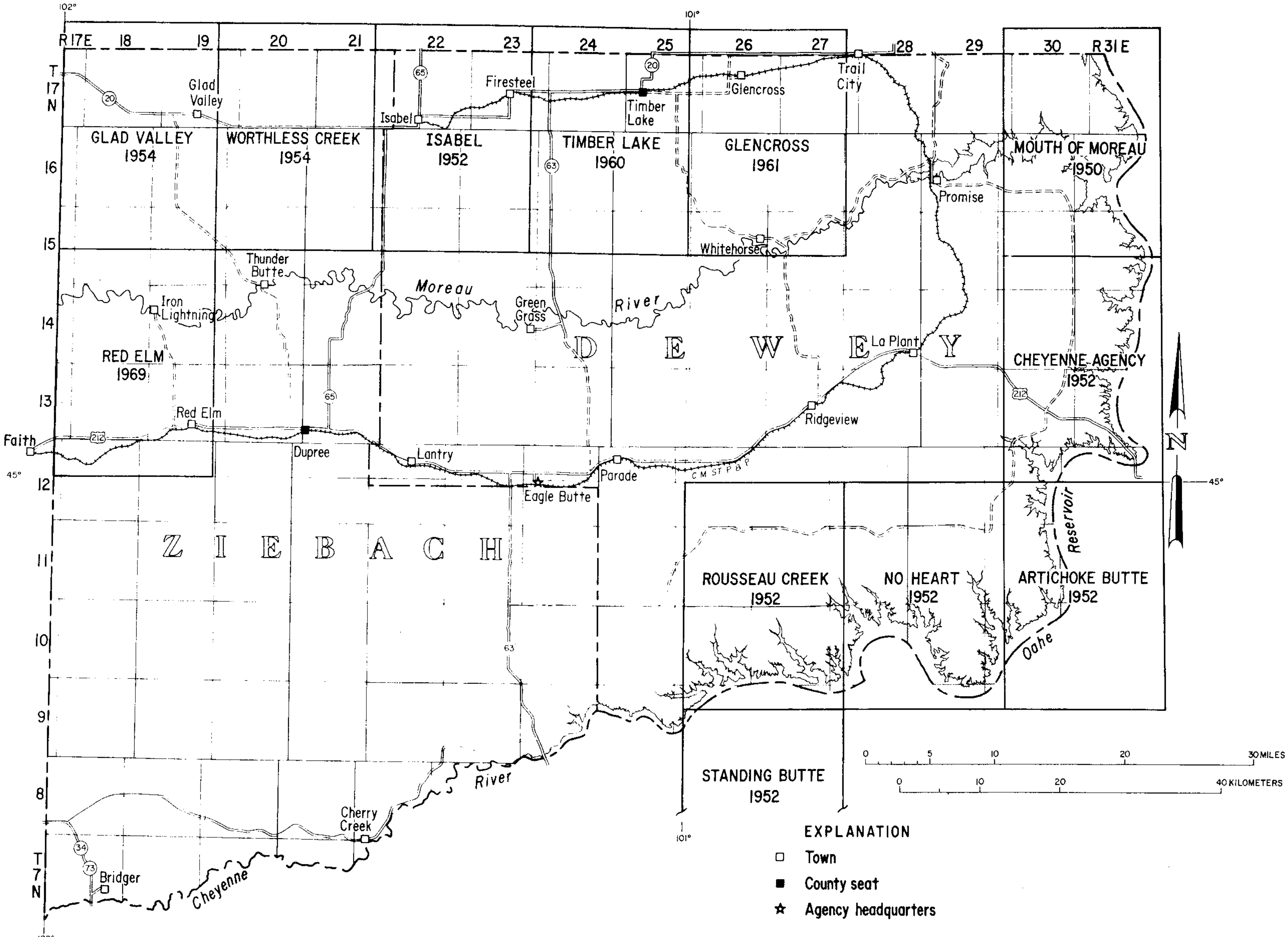

Figure 6. Index map showing geologic quadrangle maps of parts of the Cheyenne River Indian Reservation published by the South Dakota Geological Survey.

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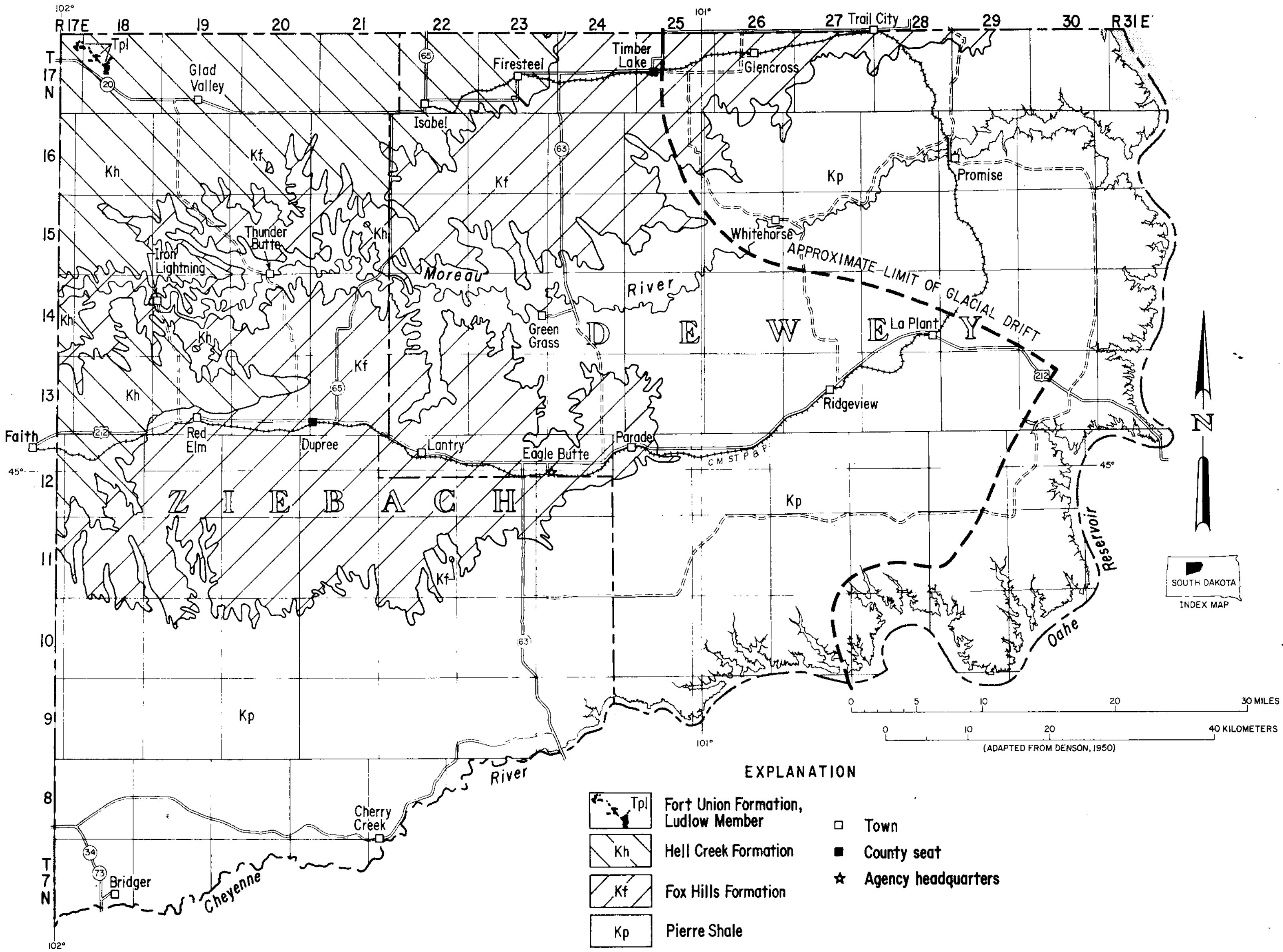

Figure 7. Map showing outcrop area of geologic formations on the Cheyenne River Indian Reservation.

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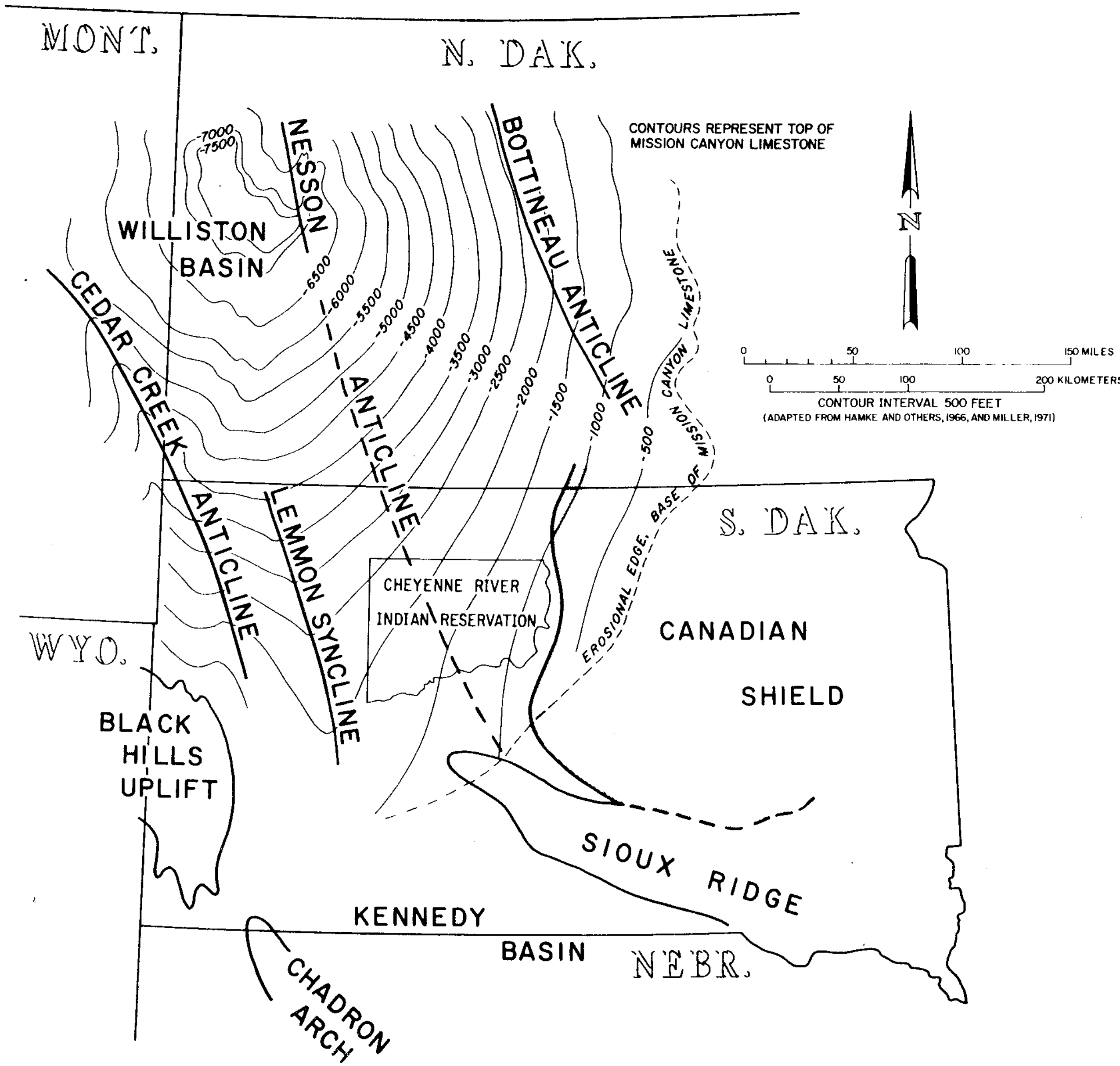

Figure 8. Map showing structural setting of the Cheyenne River Indian Reservation.

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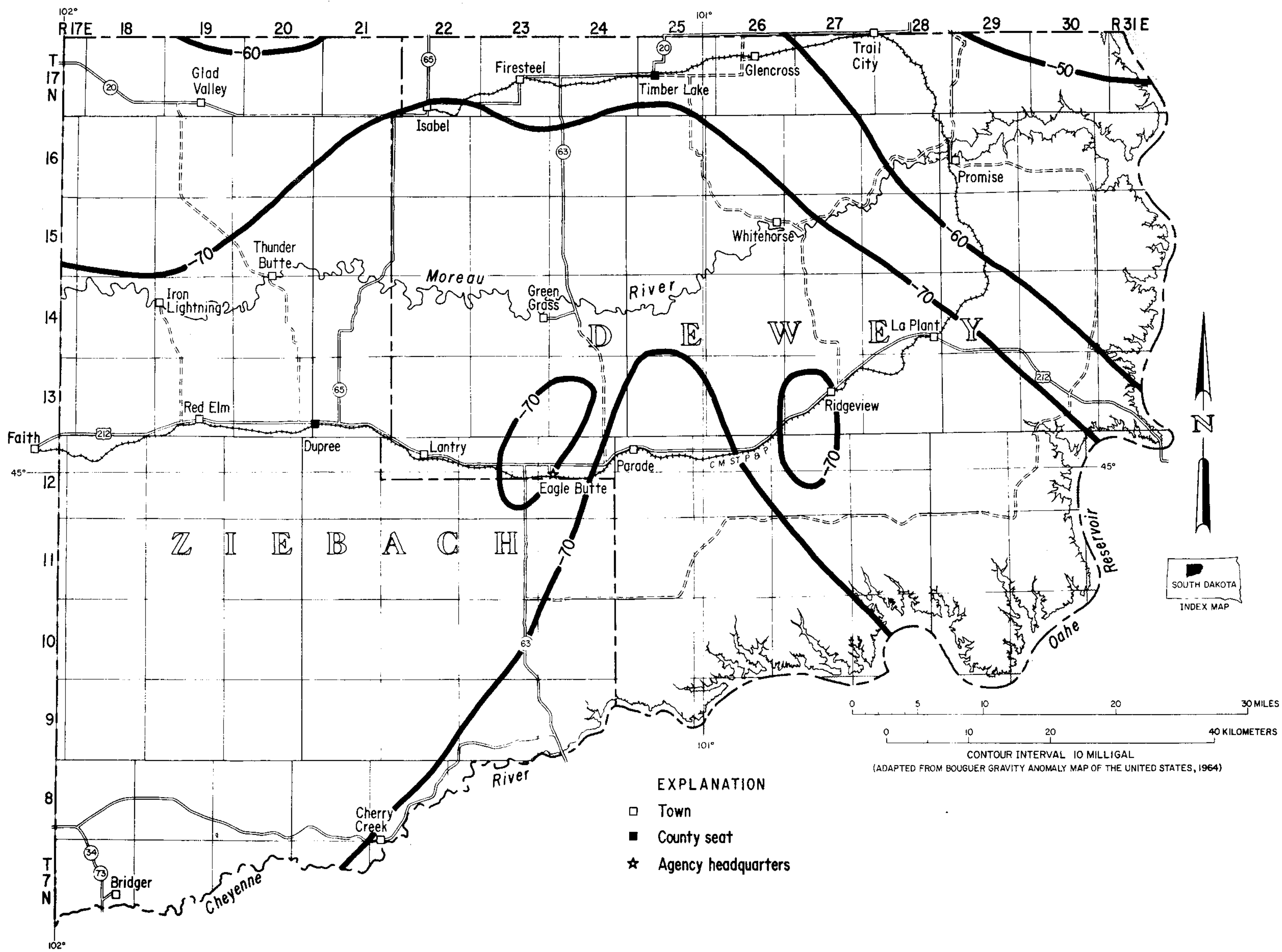

Figure 9. Map showing Bouguer free-air gravity anomalies on the Cheyenne River Indian Reservation.

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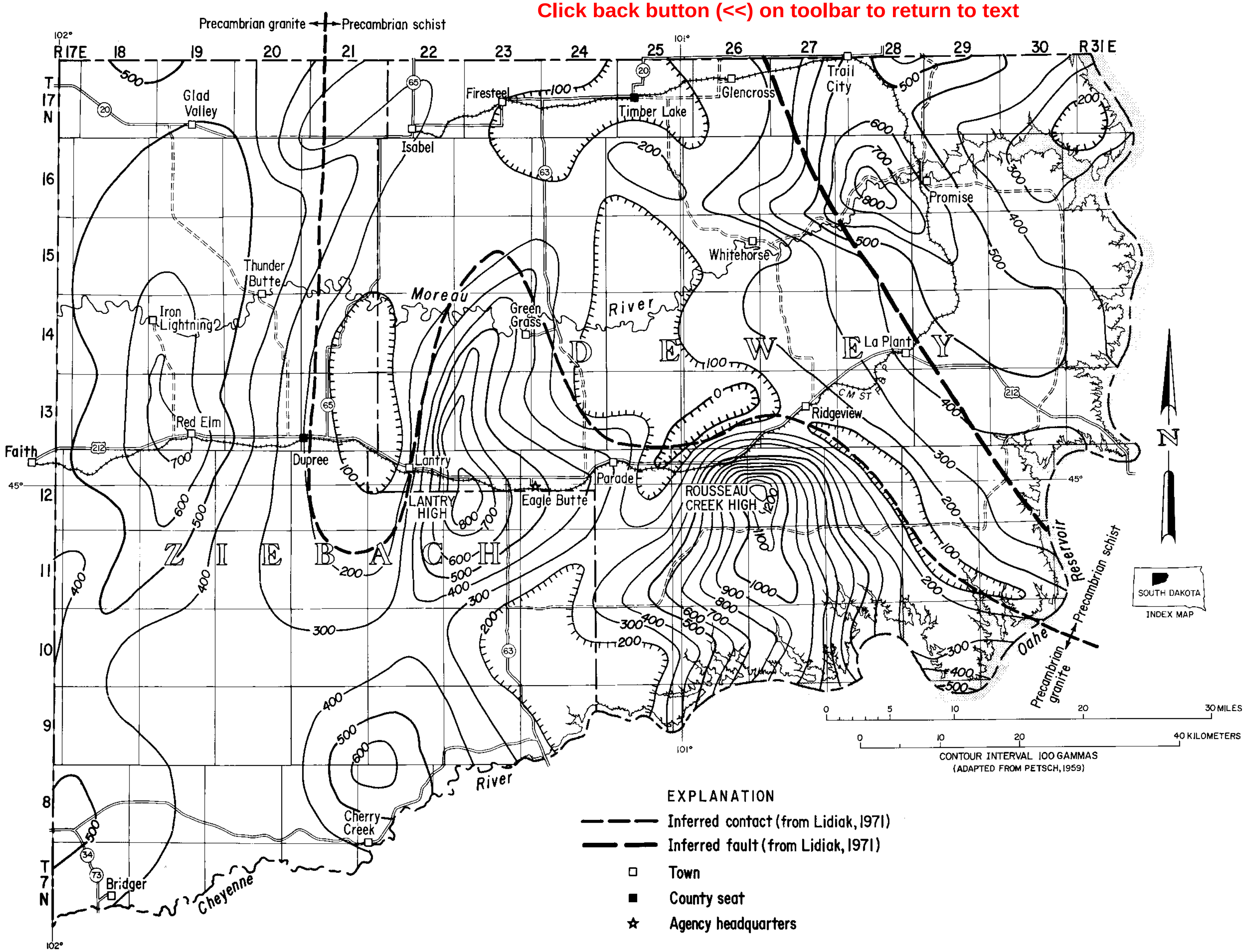

Figure 10. Map showing results of ground magnetometer survey of the Cheyenne River Indian Reservation.

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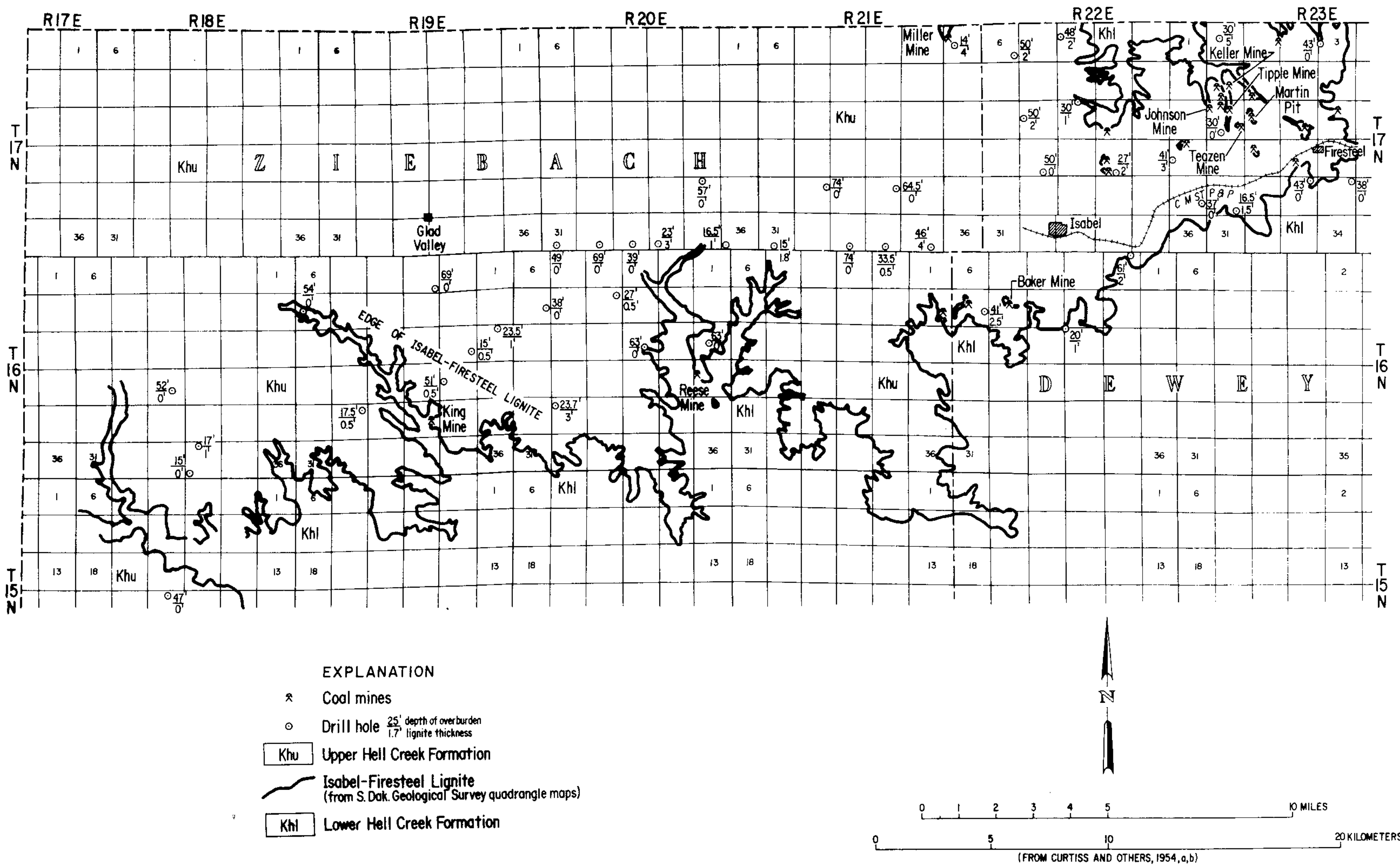

Figure 11. Map showing outcrop of Isabel-Firesteel lignite facies, drill hole data, and coal mines on the Cheyenne River Indian Reservation.

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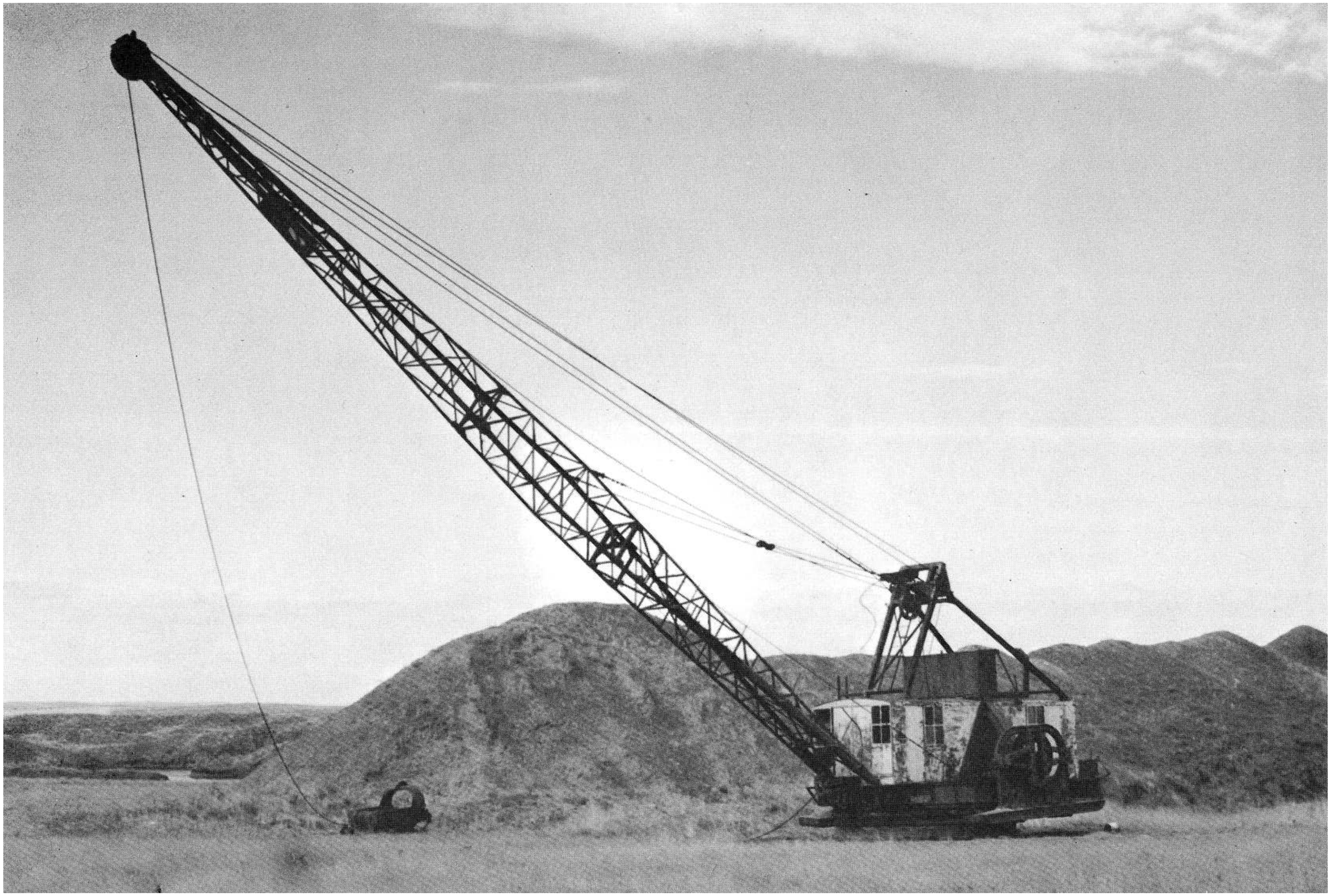

Figure 12. Photograph of dragline used to strip overburden from lignite seams, Cheyenne River Indian Reservation.

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Figure 13. Photograph of abandoned lignite pits near Firesteel, Cheyenne River Indian Reservation.

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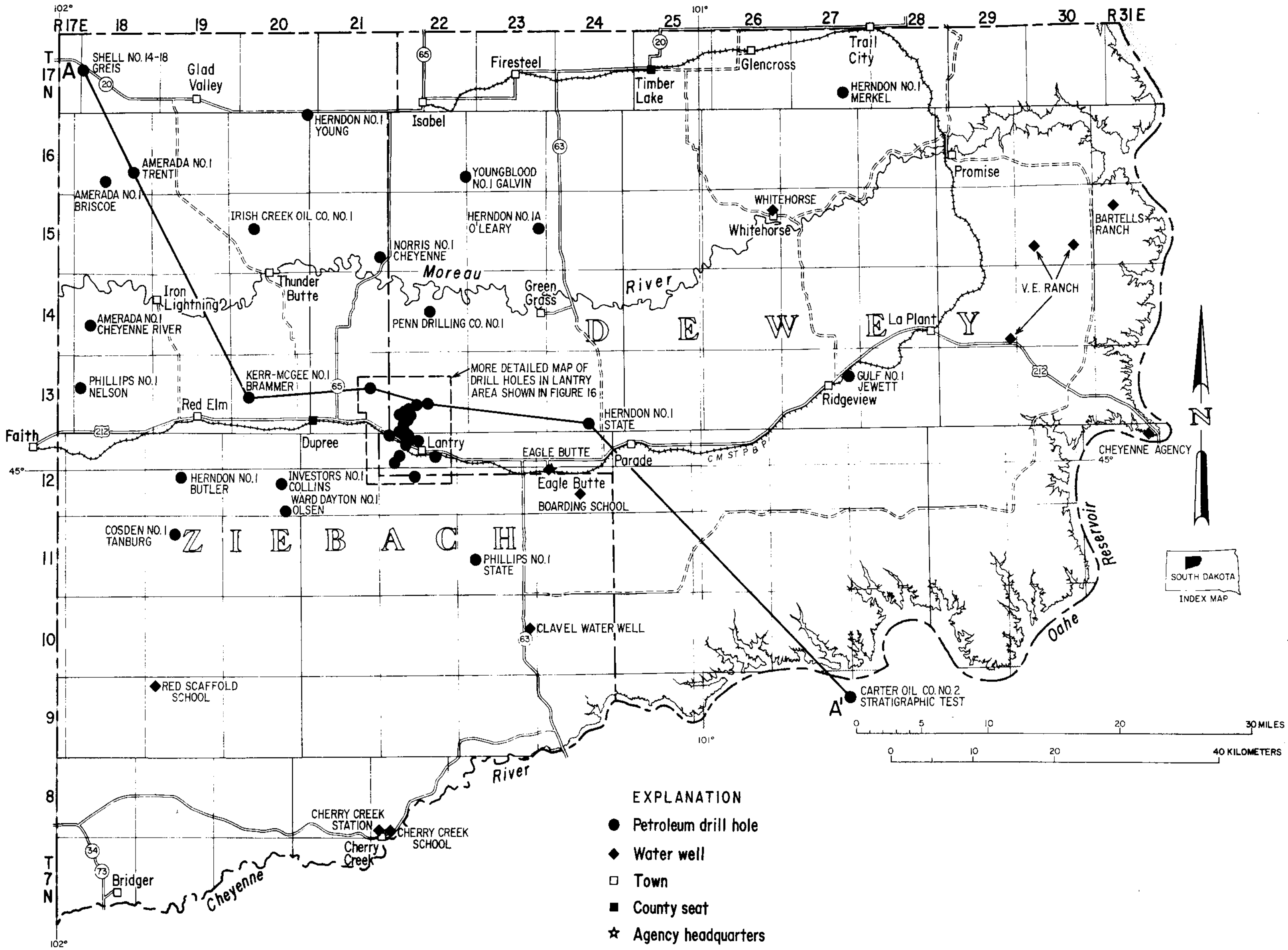

Figure 14. Map showing location of test wells on the Cheyenne River Indian Reservation.

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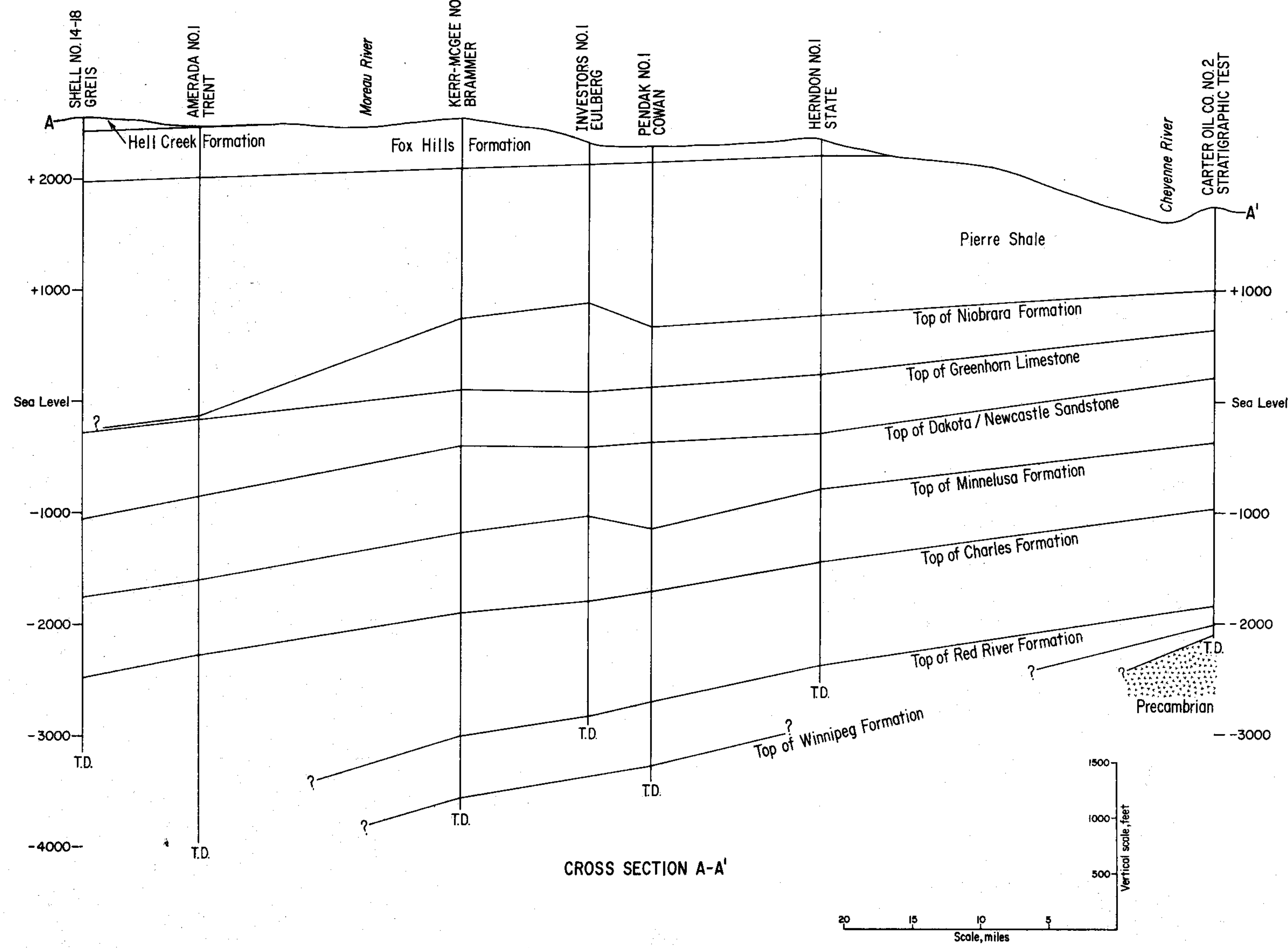

Figure 15. Cross-section through test wells on the Cheyenne River Indian Reservation (see Figure 14 for location).

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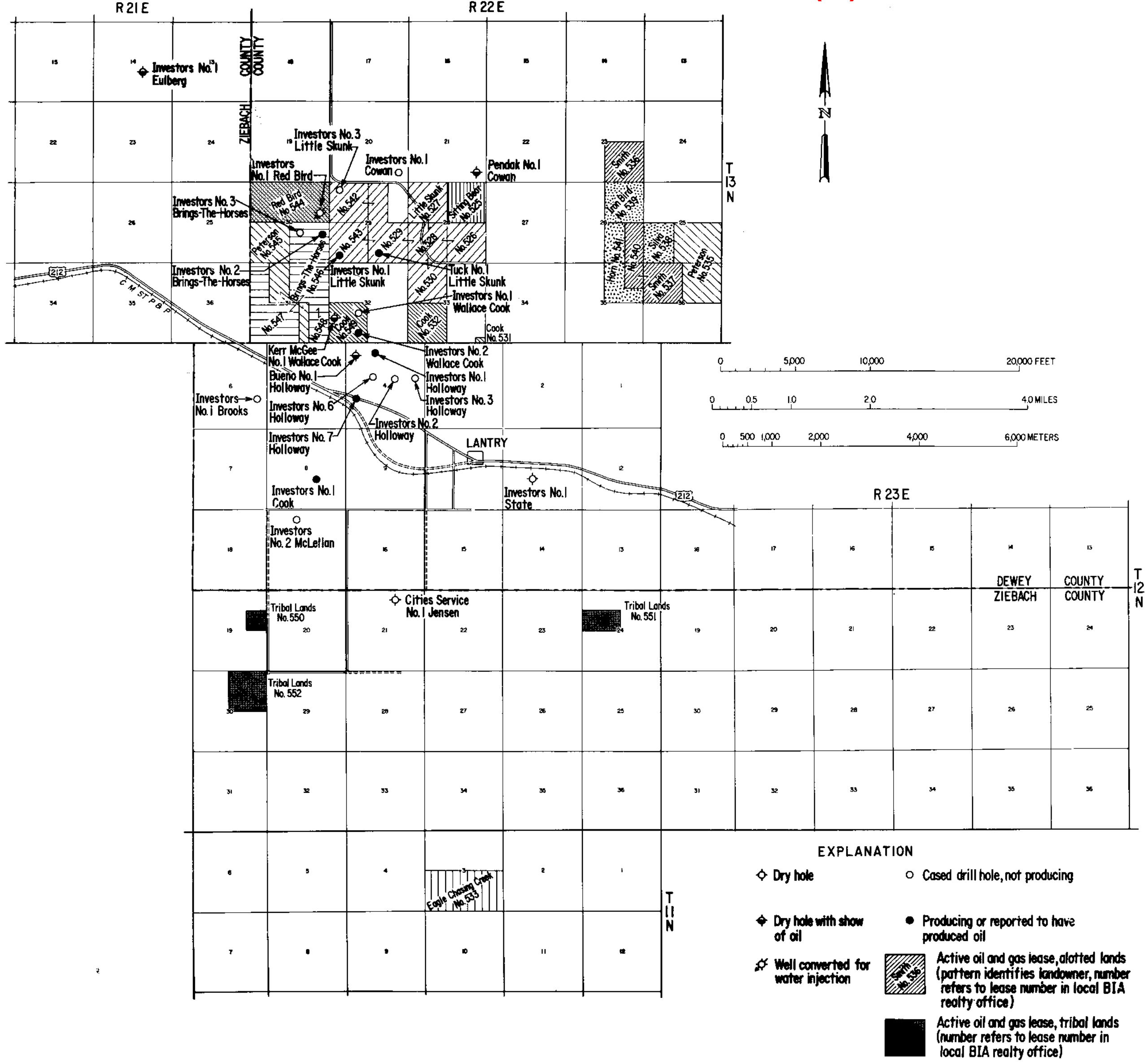

Figure 16. Map showing status of oil leases in the Lantry area, Dewey County, South Dakota.

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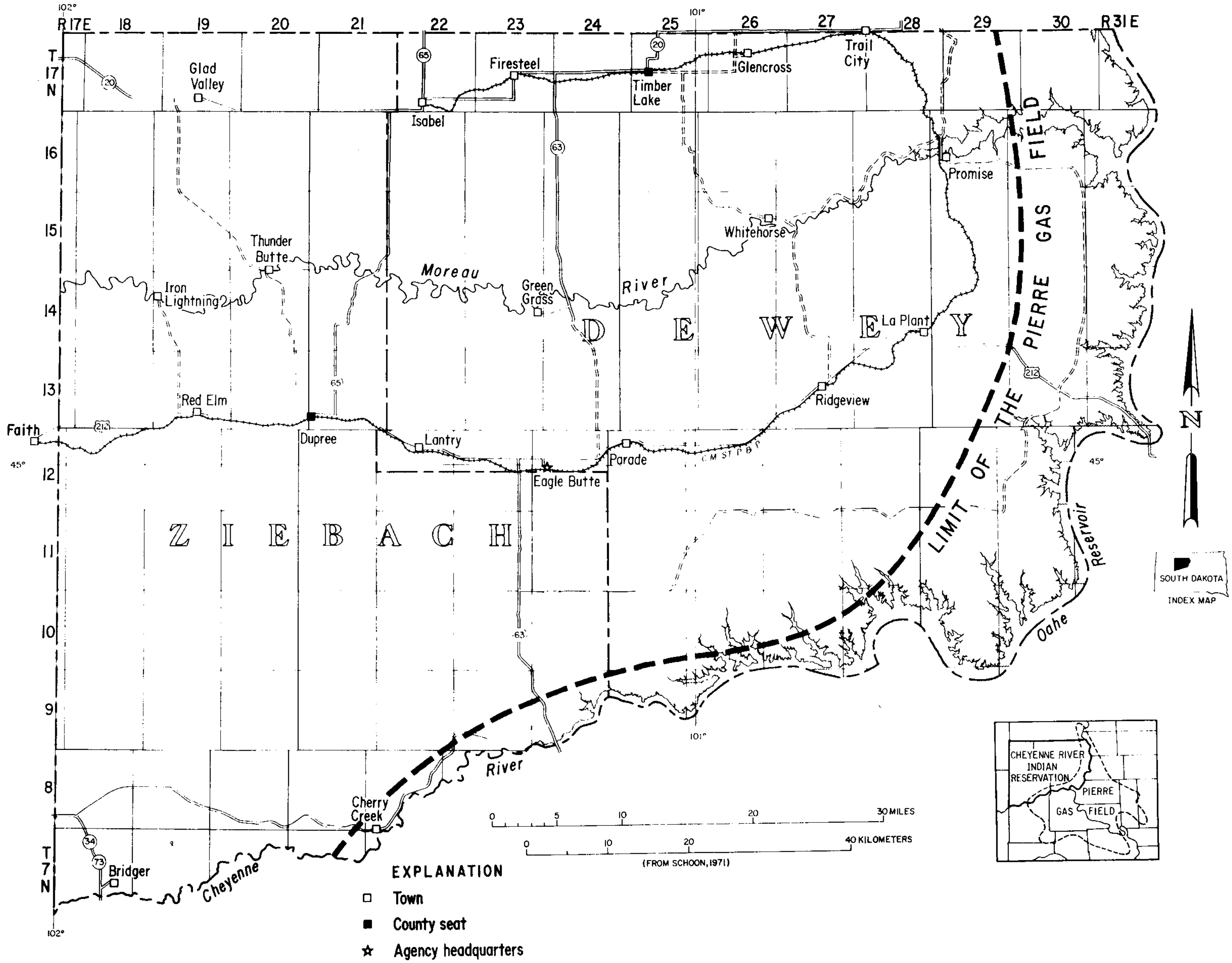

Figure 17. Map showing the approximate western boundary of the Pierre gasfield in Dewey and Ziebach Counties, South Dakota.

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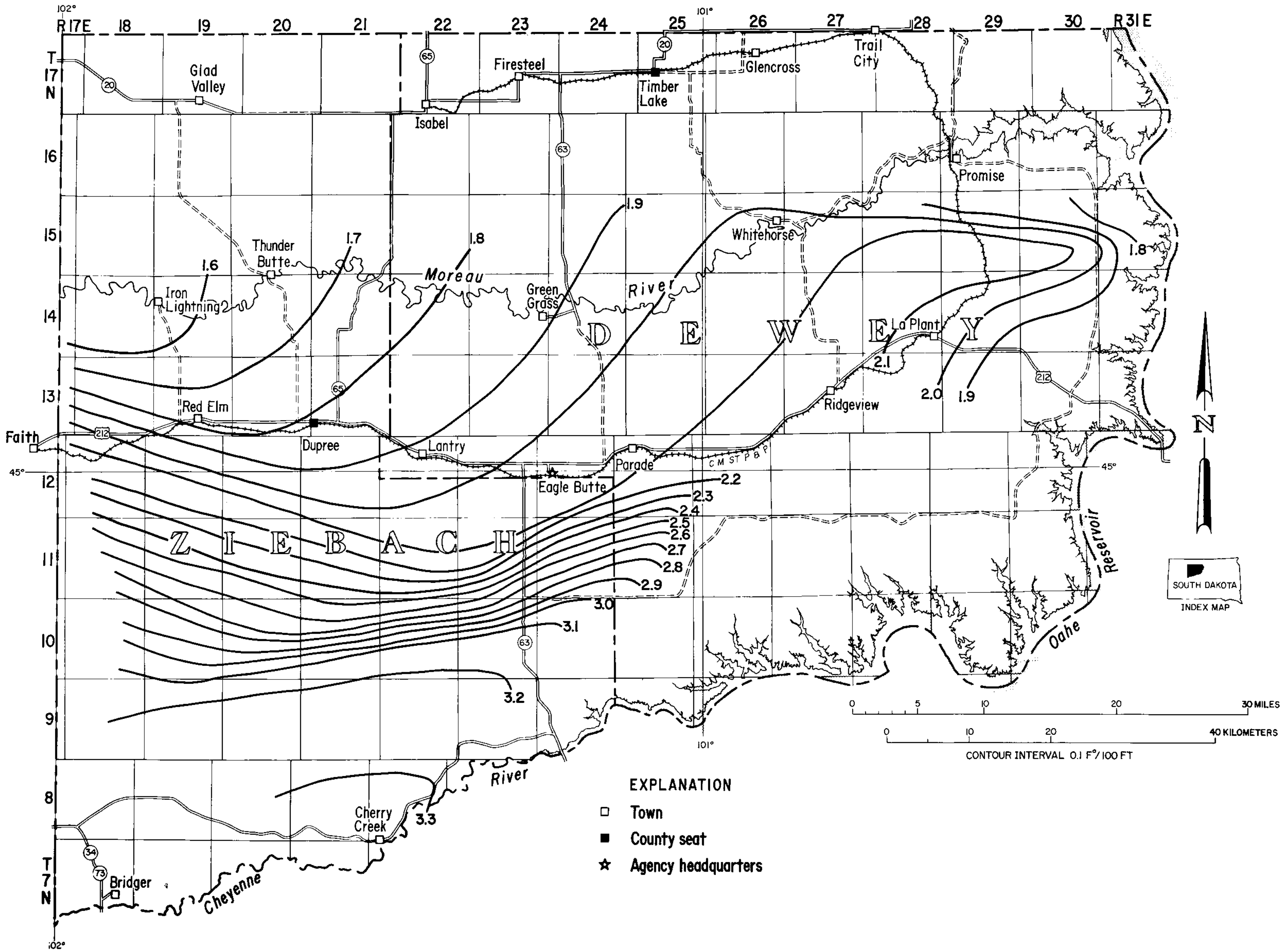

Figure 18. Isogeothermal gradient map of Cheyenne River Indian Reservation based on Dakota and Newcastle aquifer temperature.

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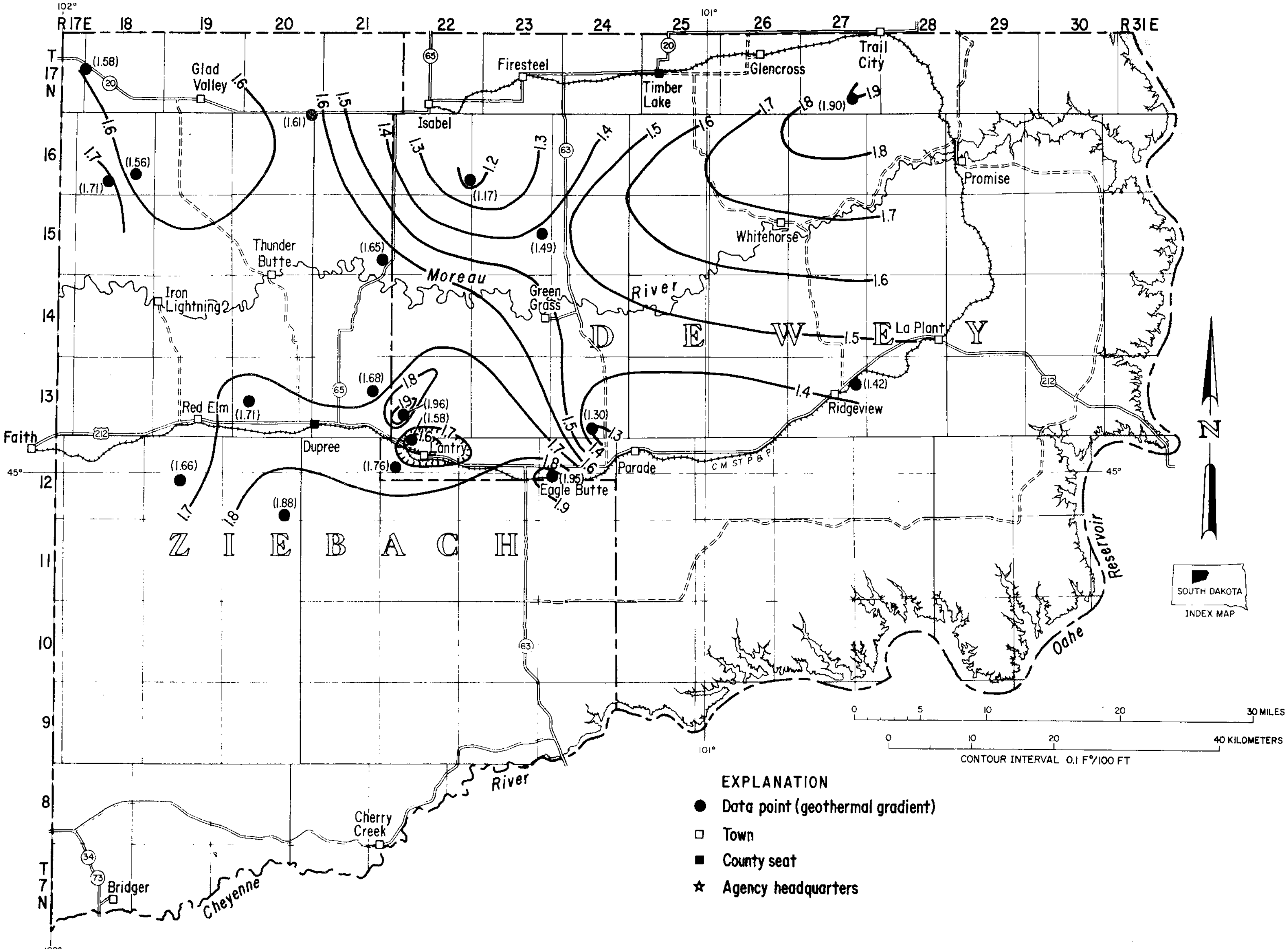

Figure 19. Isogeothermal gradient map of Cheyenne River Indian Reservation based on temperature data from formations below Dakota and Newcastle sandstones.

Click back button (<<) on toolbar to return to text

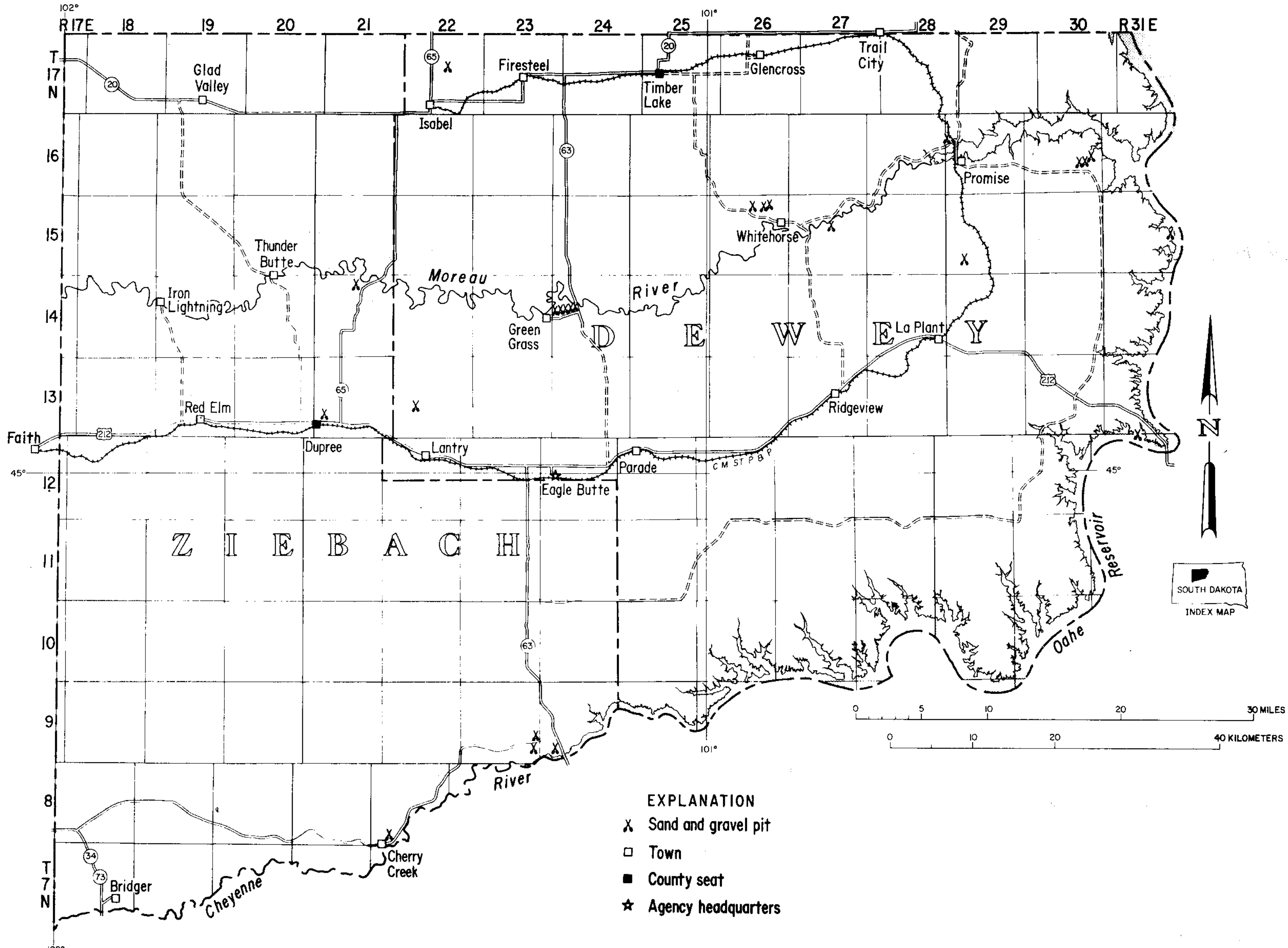

Figure 20. Map showing locations of sand and gravel pits in Dewey and Ziebach Counties, South Dakota.