STATUS OF MINERAL RESOURCE INFORMATION FOR THE PINE RIDGE INDIAN RESERVATION, SOUTH DAKOTA

By

W. H. Raymond
R. U. King
U. S. Geological Survey

J. P. Gries
U. S. Bureau of Mines

Administrative Report BIA-12
1976

CONTENTS

SUMMARY

The Pine Ridge Reservation contains potential mineral resources of oil and gas, uranium and a large variety of nonmetallic commodities. To date only 10 wildcat wells for oil and gas have been drilled on the reservation and while none were productive the thin stratigraphic sequence with unique structural and stratigraphic traps offers good exploration potential. Anomalous amounts of uranium have been detected in groundwater on the reservation, and paleochannels offer exploration targets for potentially commercial amounts. Utilization of significant amounts of nonmetallic commodities that occur on the reservation must await the development of local markets. Zeolites, volcanic ash for abrasives, clay, and sand and gravel, like many nonmetallics, are large bulk, low value materials that cannot compete with similar widespread material when transportation costs must be added to their raw value. Small, but possibly profitable, "cottage" industries might be based on production of pottery clay, agate and other semi-precious mineral specimens.

INTRODUCTION

This report was prepared for the U. S. Bureau of Indian Affairs by the U. S. Geological Survey and the U. S. Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral and energy resources, and potential for economic development of certain Indian lands. Sources were published and unpublished reports as well as personal communication. There was no field work. The Pine Ridge Indian Reservation, southeast of the Black Hills in southwestern South Dakota, covers an area of about 90 miles by 50 miles. It is bounded on the south by the Nebraska state line and on the north, in part, by the Badlands National Monument and the White River. The eastern edge of the reservation is a common boundary with the Rosebud Indian Reservation. The Fall River-Shannon County line forms most of the western boundary (Figure 1).

The terrain is generally rolling prairie, dissected in many places, especially to the north, into typical badlands topography. Most of the higher prairie is covered by windblown sands that form dunes, blowouts, and thin sheets. The southern part of the reservation is crossed by Pine Ridge (Figure 2), which is probably a fault scarp, and which supports the growth of scattered pine and cedar trees. Well-developed sandhills are the dominant features along the southern boundary of the reservation.

The reservation is somewhat remote and largely undeveloped. Cattle ranching is the major activity; some of the prairie lands are under cultivation, producing mainly hay for livestock. A large tract, in the northern parts of Shannon and Washabaugh Counties, is included in the "Rapid City Air to Air Gunnery Range"; and another large tract, in Bennett County, is designated as the La Creek National Wildlife Refuge.

The major communities in the reservation are near U. S. Highway 18, which crosses the reservation in an east-west direction in the southern part of the area. State Highway 73, connecting U.S. Highway 18 and Kadoka, is the only major north-south highway. All other roads, a few of which are paved, are secondary, and provide access to a number of small villages.

PREVIOUS INVESTIGATIONS

Previous work in the reservation includes a number of special studies of small areas; broad studies of which the reservation was a part; and several projects by the South Dakota State Geological Survey which include stratigraphic research and geologic mapping including some economic consideration.

Some detailed mapping was done in northwestern Shannon County (King and Raymond, 1971), but only a few samples were taken. Most of the area of the reservation was mapped, at a scale of 1:125,000 in 1971 (Ellis and Adolphson). Little other mapping has been done with topographic control except for a few projects which have covered very small areas.

The geologic data and interpretation contained in this report are based largely on maps and reports by Harksen (1960, 1966, 1967), Collins (1959, 1960), Sevon (1960, 1961, 1961a), Adolphson and Ellis (1969), Ellis (1971) and the present writers.

GEOLOGY

Setting

The northern half of the reservation is best described as badlands; and the southern one-third is largely covered by sandhills. The south-central part of the reservation is a combination of these two features.

About 5,000 feet of sedimentary rocks, consisting of shale, limestone, volcanic ash, silt, sand, and gravel deposits are exposed in the Pine Ridge Reservation. These range in age from Cretaceous to Quaternary. The rocks of Cretaceous age are marine in origin and all younger deposits are of continental origin.

The dominant structural feature of the Pine Ridge Indian Reservation is a broad, west-northwest trending, graben that includes a number of broad, gentle folds which are generally parallel to the faults (Figure 2). The southwestern side of the graben is bounded by a portion of the Pine Ridge escarpment, also known locally as the White Clay Fault and "Pine Ridge Structure" of Clark (1967), which is the surface expression of a large fault downthrown to the northeast. The northeast side of the graben is a series of nearly parallel normal faults of small displacement, all downthrown to the south where observed (Raymond and King, 1976). The most conspicuous swarm of these small faults is visible in the "wall of the badlands" in the Badlands National Monument.

Stratigraphy

Rock units on the reservation are listed in Table 1. A simplified geologic map (Figure 3) shows the distribution of major outcropping units including the approximate locations of the contacts between the Pierre Shale and the basal White River Group (Chadron Formation) and between the Upper White River Group (Brule Formation) and the basal Arikaree Group (Rockford Member of the Sharps Formation). The oldest outcropping units, the Carlile Shale and the Niobrara Formation of Late Cretaceous age, are exposed only in the valley of the White River about 10 miles south of the town of Oglala. The Pierre Shale (also of Late Cretaceous age), which overlies the Niobrara Formation, occupies low-lying portions of the west and northeast areas of the reservation.

Explanation for Figure 3

Age	Symbol	Stratigraphic Units
Miocene	Ta	Arikaree Group, includes all rocks along the Oligocene - Miocene boundary
Oligocene	Tw	White River Group, includes Chadron and Brule Formations
Late Cretaceous	Kp	Pierre Shale
	Kn	Niobrara Formation
	Kc	Carlile Shale

Contact

Structure

The major fault system influencing the geology of the region trends west-northwest and is related to the graben mentioned previously (Figure 2). The Pine Ridge structure -- White Clay Fault -- Dunham (1961), is thought to have a displacement of about 1200 ft. (Clark, 1967, p. 13) which is downthrown to the north, and forms the southern boundary of the graben. According to Dunham (1961), the faults dips 55 NE. The northern side of the graben of small displacement (5-50 ft.) has been exposed (Raymond and King, 1976). These faults are all downthrown to the south; and, according to Clark, (1967, p. 10-13) there are several other faults between "the wall" and the Pine Ridge escarpment which combine to account for the other half of the graben (Figure 2).

Northeast-trending faults have been observed about 5 miles west of the town of Interior, north of the reservation (Raymond and King, 1976). The existence of others may be inferred by the trend of drainages such as the White River in northern Shannon County.

Broad, gentle folds, whose northwest-trending axes are roughly parallel to the boundary faults lie within the graben. In general, these folds are so subtle as to be overlooked by casual observation. Gentle doming has been detected as topographic irregularities on the upper surface of the Pierre Shale. This is evident where Pierre Shale crops out at the same or higher level than adjacent beds of the Cenozoic White River Group. Domes occur at Battle Creek Canyon, southeast of Red Shirt, Bear Creek-north northeast of Scenic, upper Sage Creek and Dillon Pass in the Badlands National Monument, along the White River between the towns of

Conata and Interior, near East Dry Creek about 6 miles east northeast of Interior, and over a large area, perhaps not related to the rest, known as the Chadron Arch (Darton, 1918) part of which is located about 15-20 miles south of Red Shirt. There are doubtless other folds concealed by rocks of the White River Group.

MINERAL RESOURCES

General

The Pine Ridge Indian Reservation contains resources of oil and gas, uranium, molybdenum, gold, zeolites, clay-shale, bentonitic Fuller's Earth, sand and gravel, limestone, and barite. The geologic occurrence and relative abundances of these resources in exposed rocks on the reservation are summarized in Table 2. There have been 10 wildcat wells for oil and gas drilled on the reservation but none have been productive. Continued exploration might find commercial deposits of uranium in paleo-channels. Utilization of significant quantities of nonmetallic commodities must await development of local markets. Sand and gravel deposits might become important if there are local road--building projects. Small, but possibly profitable, "cottage" industries might be based on production of pottery clay, agate, and other semiprecious mineral specimens.

Energy Resources

Petroleum and Natural Gas

General

No oil or gas has been produced on the Pine Ridge Reservation, but the area is underlain by 3,300 to 4,500 feet of prospective sedimentary strata, ranging in age from Ordovician to middle Tertiary (Table 1). Of these strata, the Red River and Minnelusa Formations produce elsewhere in South Dakota; the Minnelusa, Sundance, Morrison, Lakota, Fall River, and Newcastle produce oil in northeastern Wyoming; and the "J" (Newcastle), "G", and "D" sandstones yield oil and gas in the west central part of Nebraska.

Ten wildcat wells have been drilled on the reservation. Although there has been no production, income to the tribe and individuals has been provided in the form of bonus payments and delay rentals. Exploration companies, attracted by the faulting in the southwest corner of the reservation, drilled oil tests as early as 1917. It is unlikely that leasing arrangements at that time consisted of anything more than a nominal bonus paid to validate the lease agreement. Modern leasing practices, with delay rentals, probably were inaugurated in 1945 when Amerada Petroleum Corporation conducted a deep well exploration program in Fall River and Shannon Counties, South Dakota, and in Dawes and Sioux Counties, Nebraska. Small scale leasing of tribal and allotted lands has continued intermittently to the present.

Mineral and oil or gas leases on the Pine Ridge Reservation are administered under procedures outlined in the Code of Federal Regulations (CFR). Leases are awarded to the highest responsible bidder for a bonus consideration in addition to stipulated rentals and royalties. Royalty is 16 ⅔ percent of the value of oil and gas produced; leases are for a term of 10 years from the date of approval, and so much longer thereafter as oil or gas may be produced in economic quantities.

A total of 4,074 acres of tribal and allotted land is currently under oil and gas lease as a result of a sale held on June 15, 1972. A total of $12,222.06 was paid in bonuses; the average bid brought $3.00 per acre. These leases have been renewed annually, although no drilling has been done by the Lessee, Lone Star Gas Co., 301 South Harwood Street, Dallas, Texas 75201.

The annual rentals which accrue to the tribe or to individuals are as follows: 3 tribal tracts totalling 480 acres. Rental is $598.92 per year. 17 allotted tracts totalling 3,594 acres. Rental is $4,493.63 per year.

Potential Producing Units

Ordovician rocks underlie the northeastern corner of the reservation (Figure 4). Sandstones at the base of the Winnipeg Formation have yielded promising shows of oil in Harding County, S. Dak., and were explored by several test wells in counties just to the east of the reservation in 1964-1967. The Red River Formation yields oil in Harding County, and small quantities have been recovered from wells in Dewey County, 90 miles north of the Pine Ridge Reservation.

In eastern Wyoming, three sandstone units within the Pennsylvanian Minnelusa sandstone are productive. These are the Converse sandstone at the top of the formation, the Leo sandstones just below the middle, and the Bell sandstone close to the base (Table 1). The Converse sandstone is abundantly productive west of the Black Hills, in Crook and Campbell Counties. It has been a minor producer at Lance Creek and Little Buck fields, but it is generally water-bearing south and east of the Black Hills. The Leo sandstone is the most important reservoir at Lance Creek; it produces from several other places in Niobrara County, and from several wells on the Barker Dome, Custer County, S. Dak. A show of oil was reported from the Minnelusa Sandstone in the Gulf Oil Co. No. 1 Jacquot test in Bennett County, on the Pine Ridge Reservation (Figure 5).

The Minnelusa Sandstone ranges in thickness from over 900 feet in the southwest and northeast corners, to as little as 600 feet in the east central part of the Pine Ridge Reservation (Figure 5). Thinning occurs both at the top and bottom of the formation; sandstones corresponding to the Leo are probably everywhere present beneath the reservation.

Under the southern half of the reservation, the Minnelusa Sandstone rests directly on granite. In other areas where Pennsylvanian rocks lie directly on granite, oil is frequently trapped in the "wash" or weathered granite overlying the bedrock. No test hole in this area should be stopped until fresh basement rock is reached.

The dominantly red Permian Opeche Formation, Minnekahta Limestone, and the Triassic Spearfish Formations underlie only the western half of the Reservation; they are not known to be oil productive anywhere in the surrounding area.

The Jurassic Sundance Formation consists of a series of greenish-gray marine shales that suggest a potential for good sandstone development at the top and bottom. Both upper and lower Sundance sandstones produced oil at Lance Creek, and shows of oil have been reported from several wells in western South Dakota. In general, the Sundance sandstones are fine grained and tight, but they may vary in permeability and porosity in southwestern South Dakota.

The Morrison Formation consists of variegated nonmarine clays with occasional sandstone beds at the top or near the middle. The sandstone produces oil and gas at Lance Creek, but is generally unproductive elsewhere in the area. Noncommercial oil was found in the Morrison sandstone in the Woodward No. 4 Schmitt test in the NE¼NE¼NW¼ sec 4, T 12 S, R. 4 E., Fall River County, S. Dak. This test was just north of Ardmore, and about 33 miles west of the Shannon County line. No other oil and gas shows are known from the Morrison Formation in western South Dakota or northwestern Nebraska.

Sandstones of the Early Cretaceous Lakota Formation carry abundant artesian water in this area, but no oil shows have been reported. The Lakota is a minor producer of oil at Mule Creek in Niobrara County, Wyo. where the sands are fine--grained, thin, and not extensive.

The Early Cretaceous Fall River Sandstone contains artesian water adjacent to the Black Hills and throughout western South Dakota and adjacent States. It has produced oil from fields along the eastern flank of the Powder River Basin in Niobrara, Weston, and Crook Counties, Wyo. One or two small shows of oil have been reported from wells in southwestern South Dakota.

The thick Dakota Sandstone (Late Cretaceous) of eastern South Dakota and Nebraska fingers out westward into a series of sandstone tongues interbedded with shales of the Graneros Group (Figure 6). In descending order these are known as the "D", "G", and "J" sandstones. These sandstones are prolific producers of oil and gas in many fields in west-central Nebraska. The "J" sand is the approximate equivalent of the Newcastle and Muddy sandstones of eastern Wyoming. Noncommercial gas has been found in the Newcastle sandstone along the crest of the Chilson anticline, north of Armore, Fall River County, and a few oil shows have been reported southeast of the Black Hills. A trace of gas was reported from the Dakota Sandstone in the old Slim Butte test in Shannon County, and an oil show was recorded from the Gulf No. 1 Jacquot test in Bennett County.

Thin sandstones reported from the Late Cretaceous Carlile shale section in southwestern South Dakota may be eastern equivalents of the Wall Creek sandstones of Wyoming, or the Codell sandstone of Kansas and Nebraska. The Niobrara chalk commonly carries small quantities of gas, but the formation appears too tight in this area for commercial accumulations. No sandstones are known in the Pierre shale in this area which could serve as reservoir rocks.

The oil and gas potential of the light colored, nonmarine Tertiary rocks of the Pine Ridge Reservation is poor.

Potential Oil and Gas Traps

The general structure of the pre-Tertiary rocks beneath the reservation is synclinal, with the fold axis plunging northeasterly into the Williston Basin (Figure 7). The steep rise on the southwest side is caused by the northwest-trending Cambridge arch of Nebraska. Superimposed on that arch is the Chadron dome, the north flank of which brings rocks as old as the Carlile Shale to the surface a short distance west of the town of Pine Ridge (Dunham, 1961; Ellis, 1971). The structure in the southwest corner of the reservation is complicated by the poorly defined White Clay fault zone (Dunham, 1961) or Pine Ridge Structure,-(Figure 2), of uncertain displacement, which juxtaposes Niobrara Formation on the south side against Miocene sandstones on the north. This fault zone extends from south of the town of Pine Ridge west-northwest into Fall River County (Dunham, 1961). Other faults may complicate the structure in southwestern Shannon and Fall River Counties (DeGraw, 1971, p. 14).

Any of the Ordovician, Permo-Pennsylvanian, Jurassic or Cretaceous rocks which have been mentioned earlier, has potential as oil and gas reservoirs on the crests of gentle anticlines present on the reservation. Inclined strata exposed along the highway northwest of Oglala suggest the presence of at least three such folds.

Permeable zones due either to variations in cementation or sorting, or to unusual sand accumulations within the Minnelusa or Sundance Formations, are possible anywhere within the area, but will be exceedingly difficult to locate even with sophisticated seismic surveys.

If the magnetic anomalies (Figure 8) are interpreted as buried knobs or ridges of Precambrian rock, there is a possibility of oil entrapment in the gentle structural high which may have developed by differential compaction of the overlying sediments. If these magnetic highs represent local uplift and folding, the structures are probably Laramide or post-Laramide in age, and again, there would be the opportunity for a purely structural trap on the crest of the structure, or for accumulation where linear stratigraphic traps may be localized along the flank of the uplifted area.

The Fall River, Newcastle ("J" or Muddy) and the higher "G" and "D" sandstones offer an infinite variety of stratigraphic traps (Schoon, 1971, p. 14-15).

Clean bar and channel sands have been mapped on the outcrops of the Fall River sandstone in the Black Hills area; similar sands produce oil and gas on the west side of the Black Hills on the east flank of the Powder River basin. Other sandstone might have accumulated throughout western South Dakota as the Cretaceous sea advanced eastward. Production from the Newcastle or "J" sand is confined to distributary channel fillings and sandbars in western Nebraska and eastern Wyoming. Channels similar to the Skull Creek-Mush Creek and Osage-Fiddler Creek distributary channels are on the east side of the Black Hills, but have not yet been proved to be oil bearing.

Stratigraphic traps may be associated with offshore bars, distributary channels, and strand lines of the Early Cretaceous seas (Gries, 1962, p. 170). On the basis of an unpublished thesis (Roadifer, 1962, unpub. MS thesis, S. D. School of Mines), Gries (1963, p. 191) directed attention to the presence of "D", "G", and "J" sands of Nebraska in the Shannon-Fall River County area. There is an almost complete lack of information on the thickness, distribution, and character of the Lower Cretaceous sandstones because of the absence of water wells on the Pine Ridge Reservation. These data are needed before stratigraphic traps can be located.

Exploration Activity

Magnetic surveys. The South Dakota State Geological Survey made a vertical intensity magnetometer survey of Fall River, Custer and Shannon Counties during the summer of 1959 (Petsch, 1960). It was reconnaissance in nature, and stations were approximately 5 miles apart. Vertical intensities range from less than 100 gammas in a belt extending southeast through the settlement of Porcupine, to 1,075 gammas near Oglala (Figure 8). A second high anomaly centers southwest of Chimney Butte, in the middle of T 40 N, R 44 W. A less pronounced magnetic high lies northwest of Kyle, in the W½, T. 40 N., R. 41 W. There is a suggestion of a fourth high just south of the Nebraska state line, between R. 40 W., R. 42 W..

The following year the survey covered Bennett and Washabaugh Counties (Petsch, 1961). Values were generally close to 250 gammas. A moderately high anomaly is indicated northeast of Martin; the highest reading was obtained in the southwest corner of T. 38 N., R. 36 W. Generally high readings between Martin and the anomaly at Kyle suggest a broad regional high trending N; 59º W. Again, increasing values toward the Nebraska State line indicate a high magnetic anomaly to the south between R. 39 W., R. 40 W. This high may form an east-west alignment with the one described in the previous paragraph.

Drilling of similar magnetic highs elsewhere in South Dakota has shown that the anomalies are related to the Precambrian rocks in either of two ways; they be structurally high areas on the Precambrian surface, either buried knobs or post-Cambrian folds, or they may be local areas of mafic Precambrian rocks having high magnetic susceptibility as compared with the usual gneiss, schist, granite, or quartzite.

Gravity Survey. During the summer of 1960, the South Dakota Geological Survey, with the financial support of the National Science Foundation, made a regional gravity survey in western South Dakota, that extended in an east-west direction from near Fairburn, Custer County, to south of Draper, Jones County. The area covered is about 140 miles east-west and as much as 36 miles north-south. The southern edge of the surveyed area extends 10 to 15 miles south into northern Shannon and Washabaugh Counties on the Pine Ridge Reservation.

The resultant gravity map showing Bouguer Gravity anomalies was published by the State Survey (Tullis, 1963, Pl. 1 & 2). Because of the lack of deep drilling in the area, it can only be suggested that variations in Bouguer anomalies are due to variations in the rock composition of, and the depth to, the Precambrian basement rocks. None of the minor gravity anomalies can be correlated with the surface rocks.

Drilling. Ten holes for oil and gas were drilled on the Pine Ridge Reservation between 1917 and 1972 (Table 3, Table 4, and Figure 9).

In 1917, the Midwest Refining Co.'s Slim Butte test was drilled by cable tool in sec. 24, T. 36 N., R. 48 W., just south of Slim Butte, Shannon County. The well was started in the Niobrara chalk and reached the base of the Minnekahta Limestone at a depth of 2,445 feet. A show of gas was reported in what would now be called the "D" sand at 875 feet.

Another cable tool test was drilled 2½ miles southwest of the town of Pine Ridge in 1921 by a group from Sheridan County, Nebr. The State Geological Survey lists the well in its records as the No. 1 Loafer Camp. The company was known at one time or another as the Big Chief Oil Co., the Sheridan Oil Co., and as the Gillespie Oil Co. The hole is in sec. 16, T. 35 N., R. 45 W., Shannon County, and started in the lower part of the Sharon Springs member of the Pierre formation, close to the White Clay fault, and reached a reported depth of 1,160 feet. There were no reported shows of oil or gas.

In 1945, Amerada Petroleum Corp. drilled the No. 1 Red Eagle test in sec. 25, half a mile south of the Old Slim Butte well. It also was started in Niobrara chalk and bottomed in granite at a total depth of 3,367 feet. Sample cuttings were saved, and electrical logs were run. A drill stem test in the sandy zone between the basal Minnelusa Formation and the granite recovered only 48 feet of drilling mud.

The Martin, et al, No. 1 Bucks test, in sec. 20, T. 36 N., R. 41 W., started in Miocene sandstone in May 1952 and was abandoned on July 17 when the bit became stuck in the lower part of the Minnelusa Sandstone at a depth of 3,985 feet. Part of the drill string was left in the hole. Sample cuttings were filed with the State Geological Survey. There were no oil and gas shows and the hole was not logged.

The H. O. English No. 1 Kocer well was drilled in 1952 in sec. 30, T. 37 N., R. 36 W., about 7 miles southeast of Martin, Bennett County. This test started in the Monroe Creek (Miocene) Sandstone, and was abandoned in the Morrison Formation at a total depth of 3,370 feet. Sample cuttings were filed with the State Geological Survey, and electric logs were run. There were no oil and gas shows and no drill stem tests.

In 1966, Gulf Oil Co. drilled the No. 1 Jacquot stratigraphic test in sec. 10, T 39 N., R. 37 W., Bennett County. The test reached Precambrian basement at a depth of 4,551 feet; shows of oil were reported in the Dakota and Minnelusa Sandstones. Mechanical difficulties prevented logging the hole. In 1967, Gulf drilled the No. 1 Barber test in sec. 11, T. 40 N., R. 35 W., Washabaugh County. The test reached the Precambrian at 4,441 feet; no shows of oil and gas were reported.

Webb Resources, Inc., drilled their No. 30-16 Linehan test in sec. 30, T. R., 17 N., R. 45 W., Shannon County, in 1970. Electric logs were run to total depth in the Minnelusa Sandstone; no shows of oil and gas were reported. This well is located over a strong high anomaly (Figure 8), but as it did not go to basement rock it offers no clue as to the cause of the anomaly.

In 1972, Petroleum Engineering and Management Corp. drilled two tests in the Slim Butte area. The No. 1 Ronald Sandoz test in sec. 30, T. 36 N.,

R. 47 W., Shannon County, a mile east of the old Amerada test, recovered water in a drill stem test in the Fall River Sandstone, and was bottomed at 1,755 feet in the Morrison Formation. The No. 1 Ruth Sandoz test, in sec. 24, T. 36 N., R. 48 W., Shannon County, is ¼ mile west of the old Midwest test. There were three drill stem tests in the Dakota Sandstones between 870 and 983 feet, but no fluid recovery and no show of gas. The hole bottomed at 1,200 feet in the Skull Creek Shale.

Results are not available of any other geological or geophysical surveys, or of core drilling on the reservation, In October 1975 a privately financed survey in T. 11 S., R. 9 E., Fall River County, (just west of the reservation) attempted to define the westward extension of reservation faults.

Oil Shale

The Sharon Springs Member of the Pierre Shale and certain organic-rich beds within the underlying Niobrara Formation, are classified as low-grade oil shales. Naturally burned outcrops have been reported from several points along the Missouri River, and Dunham (1961) and Stach and Harksen (1973) have reported similar burned areas west of the town of Pine Ridge (Figure 10). Laboratory tests on two samples of Sharon Spring shale from sec. 8, T. 35 N., R. 46 W., yielded 2.8 and 1.0 gallons of oil per ton (Dunham, 1961, p. 23). Harksen (oral commun., October 1975) reports that recoveries of up to 6 gallons per ton were obtained in tests by the State Geological Survey. These recoveries compare with a yield of up to 75 gallons per ton for high grade Green River shales of Wyoming and Colorado.

Thus, oil shales on the Pine Ridge Reservation are much lower grade than other known extensive resources and probably will remain undeveloped in the foreseeable future.

Uranium

Commercial uranium deposits in beds of the White River Group, or in sedimentary rocks presently or formerly overlain by White River sediments, have been discovered in western South Dakota, Wyoming, North Dakota, and Montana (Moore and Levish, 1955). Ore produced from a sandstone channel in the Chadron Formation was by a small mine at the south end of Hart Table (NE ¼, sec. 31, T. 3 S., R. 13 E.), about 3 miles north of the Pine Ridge Reservation boundary. The ore-forming mineral has been identified as uranocircite, a yellow-green, nonfluorescent barium uranyl phosphate. The source of the uranium is probably the overlying volcanic ash in the Brule Formation.

Dunham (1961) between 1954 and 1961, studied the uranium potential of 375 square miles northeast of Chadron, Nebr., that included northeastern Dawes County and northwestern Sheridan County, Nebr., and about 118 square miles in southwestern Shannon County on the Pine Ridge Reservation. No economic deposits of uranium were discovered. One zone of high radioactivity occurs in a 5-foot zone at the base of the Eocene weathering zone, regardless of which Cretaceous formation the weathering affected. The highest values were found where the weathering surface was developed on the Niobrara Formation. Dunham concluded that uranium compounds were leached from the overlying Cretaceous shales as weathering and erosion progressed, and were redeposited at the interface between the weathered and unweathered material. He found a second concentration of uranium values associated with a gypsum and dolomite facies of the Brule Formation, well developed in Dawes County, Nebr., but not known to extend onto the reservation.

Uranium also occurs at Indian Creek southwest of Scenic in the basal part of the Ahearn Member of the Chadron Formation. These small and discontinuous deposits are in sandstone and conglomerate units that have filled the old Red River Valley (Clark, 1937) which was cut into the Pierre Shale, probably in late Eocene time.

Uranium and molybdenum were precipitated from groundwater moving through the porous and permeable sedimentary rocks. Locally, the southern wall of this old valley is within the boundary of the reservation. (Figure 11). The Red River Valley occurrences have been exposed by erosion, but other similar but concealed valleys may be at the Chadron-Pierre contact, of which approximately 250 miles are on the reservation.

Uranium has been found in small amounts in the Indian Creek area, in channel sands in the upper Chadron and in the Brule Formation in zones representing perched water tables.

Uranium in water samples (Denson, 1970) from wells and springs in the reservation are listed in Table 5, and is present over a wide area in the reservation in sufficient amounts to suggest possible other deposits of the Indian Creek type in stratigraphically or structurally favorable areas.

TABLE 5
Uranium in Water on the Pine Ridge Reservation

Sample No. KSD	Source	Sec	T. (N)	R. (W)	Rock Unit	ppb	pH
13W	well	SE¼, 27	37	44	Fall River	7	7.4
34W	spring	SW¼, 12	41	46	Brule	14	---
35W	do	12	41	46	do	8	8.2
38W	well	SE¼, 10	37	46	do	34	8.6
39W	do	SW¼, 3	37	46	do	11	8.3
40W	do	NW¼, 1	35	42	Arikaree?	4	8.0
41W	do	8	37	37	do	4	8.0
42W	do	18	37	37	do	<1	8.0
49W	do	SW¼, 31	42	39	Brule	7	8.4
50W	do	NE¼, 33	42	36	do	7	8.3
51W	do	NE¼NW¼, 25	40	39	do	13	8.7
52W	do	do	do	do	do	9	8.7
53W	do	SW cor., 34	38	41	Rosebud	7	8.2
54W	do	NW¼, 15	40	40	Brule	14	8.7
55W	spring	SW¼SW¼, 30	43	38	do	9	8.0
56W	do	NW¼NE¼, 4	42	38	do	5	8.3

No uranium has been found in the sandstones or clays of the Arikaree or Oglala Groups. Mineralization, similar to that in the White River sandstones, might be in channel sandstones of the Miocene and Pliocene formations, because there is uranium in the groundwater in these units. However, a suitable environment for precipitation and concentration of uranium has not been found in them.

Metallic Mineral Resources

Molybdenum

Molybdenum is associated with some of the uranium. It occurs in uneconomic but significant amounts at Indian Creek, south of Scenic, and in some of the shales near the town of Pine Ridge (Dunham, 1961). The mineralogy of the molybdenum is not well understood; but, in general, it occurs as water soluble yellow and blue (ilsemannite) oxides at the outcrop and probably as an amorphous black sulfide (jordisite) underground.

Gold

Detrital (placer) gold has been recovered in small amounts from the basal Ahearn Member at Indian Creek and gravel samples collected from modern streams and from older alluvial gravels (Raymond, written commun., 1976). Samples were from high bench gravels above the White River and from sheet gravels found on some of the highlands between Scenic and the Black Hills, just north of the reservation. The particles of native gold are small, not exceeding 0.5 mm and average about 7 colors per 300-pound sample. In addition to gold, the heavy concentrates locally contain abundant quantities of garnet, staurolite, tourmaline, and barite. Less abundant diverse and rare elements are commonly present in these heavy mineral concentrates.

Gold, garnet, staurolite, tourmaline, and rare earth elements are known to occur in the Black Hills which is, presumably, the source of some of the gravel in the area.

Perhaps if a gravel pit were developed in the gold-bearing gravels, recovery of the gold might be feasible. It is doubtful there is sufficient gold for development of a mining operation for only the precious metal.

Nonmetallic Mineral Resources

General

Nonmetallic mineral resources are present on the reservation. Figure 10 shows known locations of several types.

Zeolites

Zeolites are crystalline hydrated aluminosilicates of the alkali and alkaline earth elements. They are useful industrially in petroleum refining, removal of undesirable elements from industrial waste, and as industrial dessicants and fillers. Most industrial zeolites used in the United States are synthetic. Naturally occurring zeolites are mined and utilized in Japan; beds of similar nature are known in many places in the United States. Commercial demand for natural zeolites in the United States must await industrial acceptance of the natural product. Use of South Dakota zeolites will require that they be competitive in quality, volume, and accessibility with large deposits known in other Western states.

Zeolites in sedimentary deposits commonly form by alteration of silicic volcanic ash. The zeolites, clinoptilolite and erionite, occur in some layers of volcanic ash in Oligocene and Miocene rocks which crop out on the Pine Ridge Reservation. The Rockyford Ash Member of the Sharps Formation is the largest known unit of zeolite-rich volcanic ash in the region. Clinoptilolite, and minor amounts of erionite, constitute approximately 40-50% (Sheppard and Gude, oral commun., 1975) of samples taken from the Rockyford Ash Member at Sheep Mountain Table where the unit is as much as 50 feet thick (Raymond and King, 1976).

Evaluation of the zeolite content of a unit of rock is difficult because no convenient way is known to quantify the zeolite content of a particular sample and because the content is likely to vary greatly in different layers through a vertical section. Presently, estimates are made using a combination of X-ray diffraction and thin-section analyses (Sheppard and Gude, oral commun., 1975).

The Rockyford Ash Member has been mapped as far north as the Pinnacles and Cedar Pass in the Badlands National Monument (Raymond and King, 1976) where it is about 30 ft thick. Little is known of the thickness and distribution of this unit in the reservation. Some mapping near the northern edge of the reservation has shown that it is present in significant thicknesses from Lost Dog Creek on the east to Cedar Butte on the west, and it has been observed in the vicinity of Sharps Corner.

In the northern portion of the Pine Ridge Reservation, the Rockyford Ash Member is well-exposed and overburden is generally thin. The thickest known exposure in the reservation is at Sheep Mountain Table, near the southern boundary of the Badlands National Monument. Exposures to the east are covered by varying thicknesses of windblown sands. In some places the cover may be as thick as 100 feet but elsewhere, the sand occurs in thin, smooth sheets which may be only a few inches to a few feet thick.

Volcanic Ash

Volcanic ash of commercial quality is abundant on the Pine Ridge Reservation (Nicknish, 1967). Ash of similar quality is mined commercially in eastern Nebraska and in Kansas for use as an abrasive and additive to scouring powders. Natural deposits of this material are called "magnesia" by local residents.

The volcanic ash formed by tremendous explosions accompanying volcanic eruptions in the Yellowstone Park area, and was transported by the wind in a generally southeasterly direction. Remnants of such ash falls are abundant in Oligocene and Miocene sedimentary rocks in Wyoming, South Dakota, Nebraska, and Kansas. Much of the ash was removed by erosion as it fell, some was mixed with sand and clay and redeposited in impure form, and some apparently was covered and preserved in almost its original form.

The Rockyford Ash Member is the thickest and purest ash bed on the reservation, and is widely distributed in northern Shannon County. (Nicknish, 1963), (Table 6). It forms the white layer so conspicuous at the south end of Sheep Mountain Table, and on the cliffs south of White River and west of the mouth of Porcupine Creek. The bed reaches a maximum measured thickness of 55 feet on the south end of Sheep Mountain Table, 5 to 12 feet on Cedar Butte, 2 to 14 feet east of the Rockyford church, 4 to 21 feet at Chimney Butte, and 14 feet on the Bloom Ranch (sec. 13, T. 40 N., R. 44 W.).

The ash is a mass of tiny glass shards, accompanied by minor quantities of quartz, biotite mica, sanidine, andesine, clay, and amphibole. Index of refraction of the glass ranges between 1.492 and 1.504, which classifies it as a rhyolite. The ash is highly silicic (Table 6).

Thinner, areally restricted lenses of volcanic ash are reported from the Valentine and Ash Hollow formations in the southeastern part of the Pine Ridge Reservation. Sevon (1960) calls attention to an 11-foot bed of ash in the NE¼SE¼ sec.17, T. 38 N., R. 33 W., at the extreme eastern edge of Bennett County. An accessible outcrop of clean ash is in the NE¼NE¼SW¼ sec. 15, T. 35 N., R. 44 W. (Gries, oral commun., 1976).

Because of its sharp character and uniform hardness (approximately 5.0 on the Moh scale of hardness), volcanic ash or pumice is widely used as a polishing agent and abrasive. It is also used as a pozzolan, as a filler, and as an inert carrier in insect sprays. Modest tonnages are produced in Custer County, Nebr., and in Lincoln and Norton Counties, Kans.

The material has a market value of 3-4 cents a pound, so it must be mined and transported cheaply to the points of consumption. Material in western South Dakota will have no economic value until local markets are developed.

Bentonite

Bentonite is composed mainly of the clay mineral montmorillonite. Montmorillonite swells greatly or becomes very sticky and greasy when wet, depending on the relative content of sodium or calcium.

Bentonite is derived by alteration of volcanic ash which has settled in the ocean or in lakes and ponds. In the Pine Ridge reservation it occurs at several stratigraphic horizons in the Pierre Shale and in the Chadron and Brule Formation.

The Sharon Springs member of the Pierre Shale is notable for the number and thickness of bentonite beds interspersed with the dark organic shale. Dunham (1961, p. 33) has reported as many as 40 beds more than 0.1 foot thick. One bed, 25 to 30 feet above the contact with the underlying Niobrara Formation, is consistently more than 3 feet in thickness. At the town of Ardmore, Fall River County, from which this bentonite bed has received its name, the clay is a pure, low-swelling, yellow, calcium-bentonite. It was used for many years by the Refinite Co., Omaha, Nebr., in base-exchange water softeners. Mining began in 1917, and ceased in 1951 because of a fire at the plant and the increasing popularity of artificial resins.

The Ardmore clay is not suitable for drilling mud, and is inferior to many other bentonites for sealing, binding, or other uses of bentonite. It is a reasonably effective sealant for dams, ditches, and ponds, except that it takes a much greater quantity of the low-swelling type than it does of a high--swelling sodium bentonite. Nevertheless, it has been used (because of its availability) for sealing irrigations canals on the Angostura project in Fall River County, and for sealing stock dams.

The Ardmore bed attains a thickness of nearly 4 feet in southwestern Shannon County. An outcrop in sec. 16, T. 35 N., R. 47 W., south of the Pine Ridge-Slim Butte road, can be traced for several miles, south of the White Clay fault. Small tonnages of clay could be obtained by stripping along this outcrop; however, as the bed dips steeply, the overburden increases rapidly downdip, and mining would be practical for a strip only a few feet wide in most places.

There is at present no market for this clay. Should such a market develop, or should a means of upgrading this clay be perfected, the extensive deposits in Fall River County, close to the Burlington and Chicago and Northwestern railroads, would have a competitive advantage over the more isolated deposits on the Pine Ridge Reservation. A rather substantial reserve could be established.

If the existing White Clay irrigation project should be renovated, or if other proposed irrigation projects should be built, this bentonite might be utilized for sealing high water loss areas along the canals.

In the Chadron and Brule Formations, bentonite occurs in relatively thin beds, usually mixed with fluvial debris. The material is often a mixture of Oligocene ashfalls and bentonite derived from exposures of Pierre Shale and younger bentonite beds upstream. Chadron bentonites contain a very high silt or sand content, and have low swelling properties, hence, the Chadron clays on the Pine Ridge Reservation presently have no economic value.

Ceramic Clay

For many years prior to World War II local clay was used by instructors and students in pottery-making classes as part of the vocational training at the Pine Ridge School. This work has been discontinued, but more recently the clay has been used by Ella Irving, who has operated an Arts and Crafts shop at Pine Ridge. The clay is buff to red-variegated when raw, and fires to an attractive red-brown that may be considered the hallmark of Oglala Sioux pottery. It has been obtained from one or more pits located on a ridge in the SW¼NW¼SW¼ sec. 13, T. 35 N., R. 45 W., roughly 1 mile southwest of the Oglala Community School at Pine Ridge (Figure 12), and has been described (Van Sant, 1960) as follows: "The clay consists of bands, galls, and waves of white, yellow, brown, red, purple and gray. The fine-grained smooth talc-like clay contains mixtures of kaolinite, halloysite, and some montmorillonite and possibly illite – all clay minerals." A section through part of a pit is as follows:

Description	Thickness (ft.)
Soil, sand and gravel	0 - 5?
Clay, yellowish-gray	6
Clay, variegated (pottery)	3
Clay, grayish-orange	4 - 5
Bottom of exposure.	

Beds above and below the clay are calcareous. The described units are all part of the Niobrara Formation, but are also part of the Eocene weathered zone (Table 1).

Samples collected by Van Sant were kiln-tested at the Salt Lake City Metallurgical Research Center of the Bureau of Mines. Excerpts from the detailed report on the pottery clay are as follows:

Raw material

Color:	light brown
Atterberg	39 ml H_2O 7B 7C
Working:	plastic - smooth - not sticky
Drying shrinkage:	5.5 percent

Slow firing

T, °F	Color	Hardness	Shrinkage, percent	Absorp, percent	App sp. gr.	Remarks
1800	moderate reddish orange	hard	7.5	20.0	2.80	
2000	pale reddish brown	very hard	15.0	8.3	2.75	
2100	dark reddish brown	do.	19.0	.5	2.59	
2200	blackish red	do.	19.0	0.0	2.57	
2300	very dusky red	do.	16.0	1.2	2.35	cracked in cooling
2400	olive black	do.	12.0	2.9	2.15	do.

Remarks: If fired around 1,800ºF. could possibly be used for structural bricks, and when fired from 2,050ºF. it could be used as a mixer for sewer pipe. At 2,300ºF. it started blebing.

A sample was collected by Van Sant from a bed of yellow gray fine grained sandy clay several tens of feet thick that overlies the highly colored Brule clay beds in sec. 7, T. 35 N., R. 45 W.

This clay was deemed suitable only for common brick. The U. S. Geological Survey made a more extensive field examination of the clays at the Pine Ridge area in 1960 (Shultz, 1961). Sixteen samples were tested at the U. S. Bureau of Mines laboratory, Norris, Tenn. This study confirmed that the best ceramic clays are present where the Eocene (?) weathering zone is developed on the

Niobrara formation. Weathered clay at the top of the Pierre Formation, when mixed with 20 percent sand, is suitable for common brick.

Other Possible Uses for Clay

Van Sant (1960) suggested that the variegated clay should be tested to see if it could also be used in the natural state for carving into bookends, lamp bases, and similar ornamental objects. Some clays, while still containing their natural moisture are soft and can be readily carved, but will subsequently dry and harden without cracking or slaking. He cites a Utah halloysite clay used for carved and lathe-turned ornaments and figures.

Fragments of Pierre shale found in Black Pipe Creek, Washabaugh County, also have the property of drying and hardening without breaking. The material, locally called black pipestone, is carved and drilled to shape, then smoked and rubbed to a dark-gray highly lustrous finish, and is used locally for making pipes and animal and other ornamental figures.

Lightweight Aggregate

Lightweight aggregate for use in concrete can be formed by quickly heating certain shales or clays in a rotary kiln. At high temperature, the shale becomes semiplastic, into a cellular mass having high strength and low density.

Material from several zones within the Pierre Shale have good bloating properties. An aggregate plant at Rapid City uses material from a weathered zone within the upper part of the Pierre Shale to produce a satisfactory product under the Haydite license. Widely scattered sampling of the Pierre Shale by the S. Dakota State School of Mines and the S. Dakota State Geological Survey indicates that suitable raw material can be found in nearly every outcrop area. Satisfactory material might be found on the reservation, either along the Cheyenne or White River breaks, or in the southwestern corner of Shannon County.

Several high-montmorillonite clays from Tertiary beds do not exhibit good bloating properties (Schultz, 1961, p. 16). Because of high initial capital outlay and the need for a local market, most lightweight aggregate plants are located near actively growing population centers. Therefore, it is not feasible for a lightweight aggregate plant to be planned in the Pine Ridge area under present conditions.

Porcellanite, Clinker, or Scoria

Spontaneous burning of kerogen-rich layers in the Niobrara Formation and in the Sharon Springs Member of the Pierre Shale is fairly common on outcrops along the Missouri River, and a few miles west of Pine Ridge. The burned rock is hard, dark red to black, partially fused material locally called clinker or scoria, and greatly resembles the material formed by the burning of coalbeds in the Western States (Dunham, 1961; Stach and Harksen, 1973). Similar material has been widely used as a road metal and for railroad ballast in North Dakota, Wyoming, and Montana. Material from many small burned outcrops could be used on the Pine Ridge Reservation on a limited scale for surfacing driveways, parking areas, etc.

Diatomaceous Earth

Diatomaceous earth, or diatomite, is composed of the microscopic fossil remains of aquatic plants known as diatoms. The chemical composition is opal ($SiO_2.nH_20$). The United States produces about half a million tons per year for the following uses: filtration, insulation, filler, absorbent abrasive, pozzolan, ceramics, etc. Crude material is valued at about $5.00 per ton at the pit; the weighted average value for all diatomite in 1973 was $59.26 per ton at the mill.

Sevon (1961, p. 28, 69) described a bed of diatomaceous marl at the top of the Valentine formation, in and just east of the Pine Ridge Reservation. Most of this material is too thin and too impure to have potential value. He calls particular attention to a deposit nearly 6 feet thick in secs. 21 and 28, T. 37 N., R. 32 W., just east of the reservation line, which may approach economic value.

Building Stone

Local rock has been used to a limited extent for rough stone work in foundations, culverts, well curbing, stone walks, riprap on dams, and for retaining walls.

Sandstone, cemented with calcite, silica, or opal, forms ledges in the channel sandstones of the Chadron, Brule, and Ash Hollow Formations, that cemented by silica forms a quartzite, which in counties to the east of the reservation is crushed for aggregate. That cemented with calcite is generally too friable, and that with opaline cement is undesirable for concrete..

Laterally persistent beds of creamy white, flaggy, dense limestone as much as 4 feet occur about 150 feet above the base of the Monroe Creek sandstone in the northeastern part of the reservation (Collins, 1960). An outcrop in NW¼ sec. 16, T. 39 N., R. 37 W., is illustrated in Figure 13. An equally good outcrop is cited by Collins (1960) in the NE¼ sec. 13, T. 39 N., R. 36 W. who states that this limestone has been crushed in adjacent areas for use as a concrete and bituminous aggregate. Most of the outcrops are on fairly steep slopes. It would not be difficult to collect a few tens of tons at any of several locations, but to quarry any great quantity would require removal of extensive overburden.

Lenses of fairly pure limestone from a few inches to 2 feet in thickness, may be found in the upper part of the Chadron clays, just below the contact with the Brule Formation. These are pond limestones, probably of algal origin. No attempt has been made to use them.

Limited quantities of impure, slabby limestone could also be obtained from the Niobrara Formation in southwestern Shannon County. Good outcrops are conspicuous in sec. 16, T. 35 N., R. 47 W.

Mineral Specimen Material

The Pine Ridge Reservation abounds in rock and mineral varieties that are sought by amateur collectors or "rock hounds". A few varieties are of scientific value, and should be collected only by qualified persons with proper authorization, but most are prized only for their shape, color, or ability to take a fine polish. Collecting the latter type of material for resale by the piece, or in the form of mineral sets, could be a source of supplemental income for members of the reservation. The specimen-type material is described below in alphabetical sequence, with no regard to its scarcity or value.

Agate

The term agate is applied to many siliceous rocks which have a layered structure, particularly if the successive bands are of different colors. Fortification agates, in which the banding is sharp and rudely concentric, are the most highly prized. In western South Dakota these are called Fairburn agates because they are most abundant in gravels along Battle Creek between Fairburn and the Cheyenne River. The Fairburn agates originate in cavities in the limestone or dolomite layers of the Minnelusa Sandstone, and are found only in gravels which originated in the Black Hills. A few Fairburn agates have been found on the reservation, apparently in older gravels that were deposited before the Cheyenne River assumed its present course.

Layers of "moss" agate are known in the Tertiary strata in adjacent Nebraska. This is probably the source of moss agates found in gravels associated with White River.

Vaguely banded chert pebbles are abundant in the Cheyenne River gravels and in the high gravels in northern Shannon and Washabaugh Counties. Although not strictly agates, they take a high polish and are acceptable to many collectors. They are collectively known as "prairie" agates.

Barite

The mineral barite ($BaS0_4$) occurs as narrow veinlets in the Brule Formation at many places along the northern edge of the reservation. The veins are usually ¼ to ½ inch thick, and may extend for many feet. The barite occurs in the form of glassy clear cleavage fragments, and is also found in placer deposits in streams draining areas where the Brule clays crop out.

Rosettes of gray barite, from ¼ inch to 2 inches in diameter, are associated with bentonite beds, and may be found in the Sharon Springs bentonites in southwestern Shannon County. The rosettes have a characteristic, rough, external appearance, and a radiating internal structure.

Very beautiful, amber-colored crystals of barite up to several inches in length have been found in septarian concretions in the Pierre shale in the vicinity of Wasta. Similar crystals may reasonably be expected in Pierre concretions along the Cheyenne and White Rivers within the reservation boundaries.

Chalcedony

Veins of chalcedony, from paper thin to two or more inches thickness, are common features of the Brule Formation. Veins are nearly vertical, and may often be followed for several hundred feet. The chalcedony is dull, waxy, gray. Todd (1898) called attention to a bluish variety called "sapphirine", which may have some value as a semi-precious gem stone. Some varieties of chalcedony from the northern part of Shannon county fluoresce brilliant pink and green under ultraviolet light.

Gypsum

Two varieties of gypsum ($CaS0_4.2H_20$) are relatively abundant. Cleavages of selenite, often mistakenly called "isinglass" are abundant in the Cretaceous shales, particularly in the Sharon Springs Member and in the "Eocene Weathering" zone. Clusters or rosettes of selenite occur at the contact between the weathering zone and the overlying Chadron clays in southwestern Shannon County, and locally along White River on the northern boundary of the reservation. Where chalcedony is common, it locally has replaced the gypsum in the rosettes.

Satinspar, the fibrous form of gypsum, is reported to be abundant in the Brule clays near the mouth of Porcupine Creek (Todd, 1898, p. 132).

Jasper

Pebbles of highly colored red, yellow, and orange jasper are abundant in the gravel at the base of the Chadron Formation, and in gravels associated with terraces along the White and Cheyenne Rivers. The material takes a high polish, and is prized by amateur lapidarists.

Petrified Wood

Petrified wood, in fragments up to 1 foot or more in diameter, is plentiful in the gravels associated with the white sandstones at the base of the Chadron Formation, and in some of the terrace gravels along the Cheyenne River. It all appears to have been derived from erosion of the Lakota sandstone around the Black Hills. Fragments of cycads have also been found along the Cheyenne River.

Pyrite

Nodules or concretions of pyrite or fool's gold (FeS_2) are common in unweathered parts of the Cretaceous shales. They are encountered while drilling or digging wells, in excavations, and in fresh cutbanks along the major streams. Upon weathering at the surface, they alter to limonite ($2Fe_20_3.3H_20$) but retain the same crystal form, which often appears to be an intergrowth of many cubes.

Sand-Calcite Crystals

The sand-calcite crystals, which occur at Snake Butte (or Devil's Hill) in the SW¼,sec. 14, T. 40 N., R. 39 W., are world famous. The quarry lies atop a butte on the Bloom Range, and is visited by permission only. Here, calcite having the crystal form of a hexagonal scalenohedron modified by rhombohedrons, has grown with a layer of sand, giving crystals that are about 60 percent sand and 40 percent calcite. Single crystals and intergrowths of crystals, called "sand roses" form a ledge several feet in thickness.

Sand and Gravel

General

The South Dakota State Department of Transportation records indicate that the royalty for gravel during the past 25 years has ranged from $0.05 to $0.10 per ton, or per cubic yard (approximately 2,700 pounds). Sand, used as filler, has ranged from a low of $0.03 per cubic yard to $0.10 per ton. The quality of the material and the distance from the job have been the prime factors in determining the royalty. Table 7 lists recent production for the three counties which comprise the Pine Ridge Reservation.

TABLE 7

Sand and Gravel Production, Pine Ridge Reservation (Source - USBM Minerals Yearbook)

County	1968	1969	1970	1971	1972	1973
Bennett tons	----	----	15,000	----	----	----
Value	----	----	-W-	----	----	----
Shannon tons	66,000	92,000	45,000	47,000	-W-	29,000
Value	$64,000	$94,000	$34,000	$35,000	-W-	$11,000
Washabaugh tons	111,000	70,000	-W-	-W-	----	----
Value	$111,000	$70,000	-W-			

---- No production reported

-W- Withheld to avoid disclosing confidential information

The gravels on the Pine Ridge Reservation fit into two categories: (a) gravels at low elevations deposited on flood plains and terraces along the present day streams, and (b) high gravels deposited from ancient streams originating in the Black Hills prior to the development of the Cheyenne River. The former are probably all of Pleistocene and Recent age; the latter are apparently Pliocene in age.

The older gravels are of higher quality than the locally derived younger gravels, as their coarse fractions are high in quartz, chert, feldspar, and fragments of igneous and metamorphic rocks. The coarse fraction of the younger gravels is from Tertiary sedimentary rock. Sandstone, cemented with calcium carbonate, silica, or opal; fresh water limestone; chalcedony; and fragments of limestone and clay ironstone concretions are the common constituents.

The sand fraction of both gravels is high in silica and correspondingly low in the undesirable softer materials found in the larger size fractions. Some of the sand is suitable for concrete aggregate and for asphalt mix. Sand from the Valentine, Ash Hollow, and Sand Hills Formations has also been used for asphalt mixes in Nebraska (Gries, 1964, P. 42).

Although the Pine Ridge Reservation has an abundance of low quality sands and gravels suitable for road work, most of it is alkali reactive, and sand for masonry and aggregate for concrete must be imported. Crushed Minnekahta limestone from the Black Hills, and sand from Oral, along the Cheyenne River, are brought by truck from the west, and sand and gravel originating in Nebraska is also brought by truck from Rushville and other points along the Chicago and Northwestern Railway.

White River Terrace Gravels

Dunham (1961) has described the gravels on both sides of White River near the Nebraska--Reservation line. The deposits lie on terrace remnants from 130 to 210 feet above present low water. All of the gravels along White River, contain windblown sand and water-worked silt interlayered with the coarser material. Windblown material commonly caps the gravel terraces.

The coarser fraction of these gravels consists of (a) well cemented gray sandstone similar to that in the limestone concretions in the Arikaree Formation, (b) angular fragments of blue and gray chalcedony from the White River beds, (c) pebbles from gravels in the Chadron Formation, (d) cobbles of green shale from the Eocene "paleosol" zone, and (f) fossiliferous limestone from concretions in the Pierre shale. The ancestral White River, which deposited these gravels, meandered over a valley as much as 7 miles wide. (Dunham, 1961, p. 157-158).

Extensive deposits of gravel are found along White River west of Oglala, at elevations generally less than 100 feet above the stream. A typical pit is in the NE¼ sec. 2, T. 37 N., R. 47 W. (see Figure 1). The gravel and sand are interstratified with laminated silty clay. Most fragments are less than 2 inches in greatest diameter, but there are angular fragments more than 1 foot across, and consist mainly of Tertiary limestone and calcareous sandstone. Clay-ironstone concretion fragments, and some chalcedony, are present locally.

Terrace gravels near Rockyford lie about 80 feet above the present stream channel. The gravels are exposed in pits in the SE¼SE¼ sec. 24, T. 41 N., R. 44 W., and in the SW¼SW¼ sec. 19, T. 41 N., R. 43 W. (Figure 15).

Where the White River leaves the northeastern corner of the reservation, there are remnants of terraces at levels 160 to 275 feet above the present valley floor (Rothrock, 1942, p. 6). The terraces are underlain by sand, gravel, and silt to an average depth of 6 to 8 feet. The small pit in the NE¼ sec.

28, T. 44 N., R. 33 W., appears to be in the upper of these two terraces.

Gravels in Present Channel of White River

The South Dakota Geological Survey tested the valley fill along White River in a 27-mile long area south of Kadota by drilling and restivity traverses (Rothrock, 1942). Results indicate a valley fill, 18 to 40 ft. thick, at an average depth of 25 feet below the present flood plain. The fill material includes clay, silt, and gravel. The upper several feet are fine silt and clay and the lower parts are coarse sand and gravel deposited as bars of irregular shape and distribution. Logs of test holes and mechanical analyses of recovered material have been tabulated by Rothrock (1942). The composition of the coarse material in one hole (V-l-C, depth 26-27 ft.) is as follows:

	Percent
Flint and chert	9
Chalcedony	33
Vein quartz	23
Light-gray, concretionary limestone	10
Dark-gray, concretionary limestone	2
Porous lime caliche	2
Pyrite	2
Iron (limonite)	21

Other samples cited by Rothrock contain more chert, chalcedony, and quartz, and much less pyrite and limonite. Some samples contain minerals and rocks that originated in the Black Hills, but they have been derived largely from local Tertiary gravels since the White River does not drain the Black Hills.

Thin Elk Gravels

Remnants of a high gravel, found along a line extending southeastward from near Hisle to northwest of Tuthill, have been described as remnants of an early Pliocene stream which once extended from the Black Hills to Little White River (Figure 16). The remnants of gravel from this stream extend in a closely spaced line from sec. 4, T. 40 N., R. 39 W., southeast to sec. 22, T. 37 N., R. 36 W. They are missing along the southeast flowing portion of Little White River and reappear at a pit in sec. 17, T. 36 N., R. 33 W. They were formerly called the Hisle gravels (Sevon, 1960, 1961, 1961a; Gries, 1964) but were renamed the Thin Elk by Harksen and Green (1971).

Individual deposits are erratic, occurring as pockets or bars of coarse gravel interbedded with layers of fine sand and silt. A few feet of overlying silt and soil are usually present. Selective mining and extensive screening are usually necessary to obtain a uniform product (Figure 17, Figure 18, Figure 19, and Figure 20). Many of the known deposits of this gravel have been depleted.

The coarser constituents are quartz, feldspar, metamorphic rock, chert, and locally derived sandstone and limestone concretion fragments. In some deposits 90 percent of the pebbles are quartz and feldspar, obviously derived from the pegmatites of the southern Black Hills. The fine material is quartz sand; concentrations of small red garnets are conspicuous in some pits.

Medicine Root Gravels

An extensive belt of gravel deposits, now lying 650 feet above White River, is considered by Harksen (1966) to represent remnants of channel fill of a late Pliocene or early Pleistocene stream which drained the Black Hills area prior to the development of the present Cheyenne River (Figure 16). It probably indicates a later channel than the one represented by Thin Elk gravels. A good exposure of these gravels occurs in the northeast quarter of T. 41 N., R. 39 W., just east of the intersection between the highway from Interior to Allen and Wanblee-Potato Creek road. The well sorted gravel consists of quartz, chert, limestone, and clay-ironstone concretion fragments.

High Gravel Near Pine Ridge

Gravels of local origin, probably related to an earlier course of White Clay Creek, cap low hills and form terraces. Gravel from a pit south of the Oglala Community School, in the SW¼NW¼ sec. 13, T. 35 M., R. 45 W., has been used locally for road surfacing and fill. The material is poorly sorted, and consists of the pebbles and cobbles of limestone and calcareous sandstone from Tertiary concretions. Large, angular fragments of boulder size are of locally derived siltstone and clay. The sand fraction is mostly quartz. The gravel is 8 to 10 feet thick, and has a thin cover of soil.

Sand and Gravel Studies by State Department of Transportation

The State Department of Transportation has sampled and tested many gravel deposits on the reservation, and the results are on open file at Pierre. Some of the deposits have been developed, and some have been depleted. Localities for which analyses are available are listed in Table 8, Table 9 and Table 10.

TABLE 8

Locations of Highway Materials in Bennett County Tested by State Department of Transportation, on Open File at Pierre. These Are Filed by Commodity (Filler, Sand, Gravel) Then by Pit No.

Pit No.		LOCATION Sec.	T.(N.)	R.(W.)	Remarks
4 - 01	NE¼,	1	36	38	Filler
02	NW	20	37	34	do.
03	NE	36	36	38	do.
04	SW	26	37	40	do.
05	SE	24	37	39	do.
06	SW	8	37	37	do.
07	SE	6	37	36	do.
08	SW	32	37	37	do.
09	SW	8	38	36	do.
4 - 01	NE	24	36	38	Sand (dune sand)
02	NW	20	36	37	Sand (dune sand)
03	SW	36	38	34	Sand
04	SE	33	38	35	Sand, Pit No. 1
05	SE	33	38	34	Sand, Pit No. 2
06	NW	7	38	36	Gravel, Pit No. 1
07	SW	7	38	36	Gravel
08	NE	29	38	36	Gravel
09	SE	20	38	36	Gravel
10	NW	10	37	36	Sand
11	E½	6	39	37	Gravel
12	SE	2	36	39	Sand
13	NW	11	39	36	Sand
14	NW	6	39	37	Gravel
15	NE	10	38	38	Gravel
16	SE & SW	18	36	37	Sand
17	NW	15	37	37	Sand
18	NW	13	37	36	Sand and gravel
19	NE	19	36	37	Sand and Gravel
21	NW	28	38	36	Gravel
22	SE	23	37	36	Gravel
23	SE	22	37	36	Gravel
24	NE	27	38	36	Gravel
25	SE	21	38	36	Gravel
26	NE	28	39	37	Gravel

TABLE 9

Locations of Highway Materials in Shannon County Tested by State Department of Transportation, on Open File at Pierre. These Are Filed by County, Commodity (Filler, Sand, Gravel) Then by Pit No.

A. FILLER

Pit No.		Sec	LOCATION T (N.)	R. (W.)	Remarks
57 - 01	SW¼	15	35	44	Filler.
02	SE	36	37	43	do.
03	SW	31	36	43	do.
57 - 01	SE	35	38	47	Gravel, Pits 2 & 2a.
02	SE & SW	3	37	48	Gravel
03	NE	2	37	47	Gravel
04	SW	28	37	47	Gravel
05	SW	12	36	47	Gravel
06	NE	14	36	47	Gravel
07	SE	14	36	47	Gravel
08	NE	23	36	47	Gravel
09	SE	16	41	47	Gravel
10	NE	15	38	41	Gravel
11	NE	7	40	41	Gravel
12	NW	8	40	41	Gravel
13	NW	12	37	41	Gravel
13	SW	1	37	41	Gravel
14	NW	15	37	47	Gravel
15	SE	8	37	46	Sand
16	SE	9	37	46	Gravel and sand
17	SE	18	40	45	Gravel
18	SW	17	40	44	Gravel
18	SE	18	40	44	Gravel
20	SE	24	41	44	Gravel
21	NW	30	41	43	Gravel
22	S½	29	43	41	Gravel
22	SE	30	43	41	Gravel
22	NE	31	43	41	Gravel
22	N½	32	43	41	Gravel

TABLE 10

Locations of Highway Materials in Washabaugh County Tested by State Department of Transportation, on Open File at Pierre. These Are Filed by County , Commodity (Filler, Sand, Gravel Then by Pit No.

Pit No.		Sec.	LOCATION T. (N.)	R.(W.)	Remarks
66 - 01	NE¼	20	42	35	Filler
02	Lot 1	31	44	35	Filler
66 - 01	SE	18	43	35	Gravel
02	NW	20	43	35	do.
02	NE	19	43	35	do.
03	SW	7	41	38	do.
04	SW	20	43	38	do.
05	SWSW	35	41	40	do.
06	NESW	35	41	40	do.
07	NE	29	40	35	Gravel(magnesium)
08	NE	4	41	33	Gravel
09	NW	31	41	39	do.
10	SW	35	41	40	do.
11	SW	35	41	40	do.
12	NE	36	41	40	do.
13	NW	19	41	34	do.
13	SW	18	41	34	do.
14	E½	5	43	35	do.
15	NW	30	43	36	do
16	NW	4	42	38	do.
17	NW	23	43	39	do.
18	NE	6	43	35	do.
19	SW	12	41	39	do.
20	SE	23	43	39	do.
21	NE	6	43	35	do.
22	NE	28	44	33	do.
23	NW	28	44	33	do.
24	SE	22	43	39	do.
25	NE	36	41	40	do.
26	NW	12	41	39	do.
27	SW	31	40	37	do.
28	SE	13	43	36	do.
29	NW	36	40	38	do.
30	NE	35	40	38	do.
30	NW	36	40	38	do.
31	SW	17	43	35	do.
32	NE	11	41	39	do.
33	NW	29	43	38	do.
34	NW	8	41	33	do.
35		12	43	40	do.
36	NW	31	42	34	do.
37	NW	19	41	33	do.
38	NW	24	44	35	do.
39	SE	35	42	35	do.
39	SW	36	42	35	do.

RECOMMENDATIONS

Petroleum and Natural Gas

Ordovician, Pennsylvanian, Permian, Jurassic, and Cretaceous rocks beneath the Pine Ridge Indian Reservation include reservoir rocks which are productive in South Dakota, Wyoming, and Nebraska. Oil or gas shows have been reported in test wells on and in counties adjacent to the Pine Ridge Reservation.

Although the general thinness of the sedimentary section (3300 to 4500 feet) probably rules out any large accumulations of oil and gas, the numerous potential pay zones, the relatively shallow drilling depths, and the small number of test holes to date, all combine to make the Pine Ridge Reservation an attractive prospecting area.

In the southwestern corner of the area, detailed field mapping, such as is being done by the State Geological Survey, coupled with shallow core drilling to define the structure of covered areas, might delineate possible oil traps associated with known faults and gentle anticline. Over much of the rest of the Pine Ridge Reservation, seismic studies will probably be necessary to locate deep structural or stratigraphic traps.

The economic potential for oil and gas can be evaluated further only by drilling.

Uranium and Molybdenum

Detailed mapping, at a scale of 1:24,000, should be undertaken to determine if potential uranium and molybdenum traps occur in paleochannels filled with rocks of the Ahearn Member. This mapping can be accomplished best by first examining aerial photographs for the contact between the black Pierre Shale and the white Chadron Formation should be distinct. Color air photos can be used with reasonable economy to delineate localities where highly-colored Eocene(?) soil is present on the upper surface of the Pierre shale. The absence of the Eocene(?) soil is a clue to the presence of channels in the Pierre Shale.

Field checking, subsequent to the air photo examinations, should be accompanied by scintillometer surveys and sampling of paleo-channel sediments for uranium and molybdenum. Water samples also should be analyzed for anomalous amounts of the two elements.

Zeolites and Volcanic Ash

The volume of rock containing potentially valuable zeolites and abrasive materials in the Rockyford Member is substantial, but the value of these materials cannot be known until local markets develop. The extent of these potential resources can be determined by mapping the Rockyford Member, measuring its thickness at several places, and analyzing samples for zeolite content. The mapping can be done largely on aerial photos because of the white color of the ash and its unique weathering characteristics.

Ceramic Clay

Adequate high grade pottery clay is available for a much expanded production of Sioux pottery. The highly colored raw pottery clay should be tested to determine if it can be used for ornamental objects without firing.

REFERENCES

Adolphson, D. C., and Ellis, M. J., 1969, Basic hydrologic data, Pine Ridge Reservation, South Dakota: South Dakota Geol. Survey, and South Dakota Water Resources Commission, Water Resources Report, no. 4, 75 p.

Baker, C. L., 1951, Yardangs (abs): Geol. Soc. Amer. Bull., v. 62, (no. 2, pt. 2), p. 1532.

Clark, John, 1937, The stratigraphy and paleontology of the Chadron formation in the Big Badlands of South Dakota: Carnegie Mus. Annals., v. 25, p. 263-272.

Clark, John, and others, 1967, Oligocene sedimentation stratigraphy, paleoecology, and paleo--climatology in the Big Badlands of South Dakota: Fieldiana: Geology Memoirs, v. 5, p. 13-15.

Collins, S. G., 1959, Geology of the Martin quadrangle: South Dakota Geol. Survey, map with text on back, 1960, Geology of the Patricia quadrangle: South Dakota Geol. Survey, map with text on back.

Connolly, J. P. and O'harra, C. O., 1929, The mineral wealth of the Black Hills, South Dakota School of Mines, Bull. 16, p. 273-379.

Darton, N. H., 1909, Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, p. 128-130.

_____,1918 , The structure of parts of the central Great Plains: U. S. Geol. Survey Bull. 961, pt. II, p. 1-26., 1951, Geologic map of S. Dak.: U. S. Geol. Survey.

DeGraw, H. M., The Pre-Oligocene surface in western Nebraska -- in relation to structure and subsequent topographies: Guidebook to the Late Pliocene and Early Pleistocene of Nebraska. Univ. of Nebraska, Cons. and Survey Div., Nebraska Geol. Survey, 109 p. and maps.

Denson, N. M., 1970, Uranium analyses of ground and surface water samples collected by U. S. Geological Survey during 1954-1956: U. S. Geol. Survey open-file report.

Dunham, R. J., 1961, Geology of uranium in the Chadron area, Nebraska and South Dakota: U. S. Geol. Survey open file report prepared on behalf of the Atomic Energy Comm., 243 p., map in pocket. (Yale PhD thesis)

Ellis, M. J., 1971, Hydrogeology of the Pine Ridge Indian Reservation, South Dakota: U. S. Geol. Survey Hydrol. Inv. Atlas HA-355.

Gries, J. P, 1962, Lower Cretaceous stratigraphy of South Dakota and the eastern edge of the Powder River Basin, in Wyoming Geol. Assoc. Guidebook, 17th Ann. Field Conf., Powder River Basin, 1962: p. 162-172.

_____,1963, Geology of the Southern Black Hills, in Rocky Mountain Assoc. of Geol., 14th Field Conf., Guidebook to the geology of the northern Denver Basin and adjacent uplifts: p. 189-195.

_____,1964, Mineral resources and their potential on Indian lands. Pine Ridge Reservation, Shannon, Washabaugh, and Bennett Counties, S. Dak.: U. S. Bur. Mines Prelim. Rept., Missouri Basin Studies, 66 p.

Gries, J. P., and Mickelson, J. C., 1964, Mississippian carbonate rocks of western South Dakota and adjoining areas, in Third Internat. Williston Basin Symposium: p. 109-118.

Harksen, J. C., 1960, Geology of the Sharps Corner quadrangle: South Dakota Geol. Survey, map with text on back.

_____,1966, The Pliocene-Pleistocene Medicine Root gravel of southwestern South Dakota: Southern California Acad. Sci. Bull., v. 65, p. 251-257. Also issued as South Dakota Geol. Survey, reprint no. 9.

_____,1967, Geology of the Porcupine Butte quadrangle: South Dakota Geol. Survey, map with text on back.

Harksen, J. C., and Macdonald, J. R., 1969, Guidebook to the major Cenozoic deposits of southwestern South Dakota: South Dakota Geol. Survey, Guidebook 2, 103 p.

Harkson, J. C. and Green, Morton, 1971, The Thin Elk Formation, Lower Pliocene, South Dakota: South Dakota Geol. Survey Rept. Inves. 100, 7 p., folding tables.

Kepferle, R. C., 1959, Uranium in Sharon Springs member of Pierre Shale, South Dakota and northeastern Nebraska: U. S. Geol. Survey Bull. 1046-R, p. 577-604. (Laboratory analysis, water from Sharon Springs member, sec. 16, T. 35 N., R. 47 W., p. 596).

King, R. U., and Raymond, W. H., 1971, Geology of Map of the Scenic Area, Pennington, Shannon, and Custer Counties, South Dakota, U. S. Geol. Survey Misc. Inv. Map I-662.

Legg, James, 1973, Significant geologic sites, Pine Ridge Indian Reservation, Pine Ridge, South Dakota: Oglala Sioux Tribal Planning Center, Oglala Sioux Tribe, Bob Escoffee, Dir, 50p.

Moore, G. W., and Levish, Murray, 1955, Uranium-bearing sandstone in the White River Badlands, Pennington County, South Dakota: U. S. Geol. Survey Circ. 359, 7 p., folding map.

Moxon, A. L., Olson, O. E., and Searight, W. V., 1939, Selenium in rocks, soils, and plants. Tech. Bull. Agri. Exp. Sta., South Dakota State Coll., Tech. Bull. 2, 94 p.

Nicknish, J. M., and Macdonald, J. R., 1963, Basal Miocene ash in White River Badlands, South Dakota. South Dakota Geol. Survey, Misc. Inves. no. 7, 9 p.

Petsch, Bruno, 1960, Magnetometer map of Custer, Fall River, and Shannon Counties: South Dakota Geol. Survey Oil and Gas Inves. map no. 9, map with text on back.

_____,1961, Magnetometer map of Bennett and Washabaugh Counties: South Dakota Geol. Survey, Oil and Gas Inves. map no. 7, map with text on back.

Raymond, W. H., and King, R. U., 1976, Geologic map of the Badlands National Monument, South Dakota: U. S. Geol. Survey Misc. Inv. Map I-934 (in press).

Rothrock, E. P., 1942, A hydrologic study of the White River valley: South Dakota Geol. Survey Rept. Inves. 41, 32 p., folding map.

Schoon, R. A. 1971, Geology and hydrology of the Dakota Formation in South Dakota: South Dakota Geol. Survey Rept. Inves. 104, 55 p.

Schultz, L. G., 1961, Preliminary report on the geology and mineralogy of clays on the Pine Ridge Indian Reservation, South Dakota, with a chapter on usability tests by H. P. Mamlin, U. S. Bureau of Mines: U. S. Geol. Survey open file report 269. (Available at Denver, Colo., and at State Geol. Survey, Vermillion, South Dakota.)

Sevon, W. D., 1960, Geology of the Spring Creek quadrangle: South Dakota Geol. Survey, map with text on back.

_____,1961, Stratigraphy of the Oglala group of a portion of southwestern South Dakota: Univ. Illinois unpub. doctoral thesis, 92 p.

_____,1961a, Geology of the Vetal quadrangle: South Dakota Geol. Survey, map with text on back.

Sheppard, R. A. 1975, Zeolites, in Mineral and water resources of South Dakota, U. S. Congress, Committee on Interior and Insular Affairs, 94th Congress, 1st Session, p. 155-157.

Stach, R. L., and Harksen, J. C., 1973, Fused sediments near Pine Ridge, South Dakota: Proc. South Dakota Acad. Sci., v. 52, p. 194-199.

Todd, J. E., 1898, Geology of South Dakota: South Dakota Geol. Survey Bull. 2, 139 p.

Tullis, E. L., 1963, Gravity survey of southwestern South Dakota: South Dakota Geol. Survey Rept. Inves. 94, 2 maps in pocket.

Van Sant, J. N., 1960, Clays in Indian lands near Pine Ridge, South Dakota: unpub. U. S. Bureau of Mines memorandum dated January

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

Table 1
Stratigraphic Section, Pine Ridge Reservation.

System and Series	Unit Group, Formation, Member	Maximum Thickness (feet)	Character and distribution
Holocene	Alluvium	100	Clay, silt, fine-grained sand, and gravel in modern flood plains; locally derived. Older bench gravels, not related to present drainage, of large lateral extent, 10-50 feet thick, with significant heavy mineral content. In the Patricia Quadrangle (Collins, 1960), limy gravels present; some sand and gravel, derived from the west, contains fragments of Precambrian rocks.
	Eolian deposits	10 - 50	Tan unconsolidated fine- to medium-grained quartz sand, loess in dunes and blowouts (yardangs of Baker, 1951) on uplands. In northwestern part of reservation.
	Sand Hills Formation	200	Fine-grained, dune-sand, in part grass-stablized dunes, covers all older formations in southeastern part of reservation.
Tertiary			
Pliocene	Ogallala Group		
	Ash Hollow Formation	200	Light gray to grayish-brown, unconsolidated to indurate, fine- to medium-grained, calcareous to arkosic sand with some gritty marls and volcanic ash. In the Vetal and Spring Creek quadrangles, east of the reservation, contains small deposits of flaggy limestone up to 1 ft. thick and pure volcanic ash as much as 4 ft. thick (Sevon, 1960 and 1961). Diatomaceous earth, as much as 6 ft. thick is exposed laterally for 200 - 300 feet in lower part of formation along valley walls.
	Valentine Formation	175	Light gray to greenish-gray fine- to medium-grained arkosic sandstone, siltstone and clay, some gravel and volcanic ash.

Continued

Table 1

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

Stratigraphic Section, Pine Ridge Reservation (cont'd).

System and Series	Unit Group, Formation, Member	Maximum Thickness (feet)	Character and distribution
Tertiary (Cont.)			
Miocene	Arikaree Group		
	Rosebud Formation	250	Reddish-buff to brown, interbedded sandstone, siltstone, and clay; abundant concretions; montmorillonite clay balls and silica-cemented clays present.
	Harrison Formation	150'	Gray to pinkish-gray massive calcareous sandstone and siltstone with layers of concretionary nodules, and lenses of garnetiferous sandstone.
	Monroe Creek Sandstone	350	Grayish-buff to light brown, poorly consolidated, massive, fine-grained quartzose sandstone and siltstone, characteristically cliff-forming.
	Sharps Formation	400	Pinkish-tan, massive, poorly consolidated, fine-grained, calcareous and feldspathic sandstone and siltstone; scattered calcareous nodules and concretions.
	Rockyford Ash Member	50	At base of formation; one or more beds of massive, white volcanic ash with high percentage of zeolites.
Oligocene			
	White River Group		
	Brule Formation		
	Poleslide Member	270	Yellow to tan mudstones, with considerable admixture of volcanic ash; sand in channel fills.
	Scenic Member	130	Tan, yellow, gray, red, and greenish-tan mudstones and siltstones; thin beds of fine-grained sandstone; fine-grained sandstone and conglomerate in channel fills.

Continued

Table 1

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

Stratigraphic Section, Pine Ridge Reservation (cont'd).

System and Series	Unit Group, Formation, Member	Maximum Thickness (feet)	Character and distribution
Tertiary (Cont.)			
Oligocene (Cont.)			
	White River Group (Cont.)		
	Chadron Formation		
	Peanut Creek Member	30	Greenish gray and tan to orange, mudstones; sparse conglomerate channel fills.
	Crazy Johnson Member	40	Greenish gray conglomeratic channel fills; gray, green and bluish-gray mudstones.
	Ahearn Member	80	Green and red-mottled sandstones with subordinate gray, green and tan mudstones; commonly an arkosic, conglomeratic basal unit; conglomeratic channel fills are common.
Eocene - IMPORTANT ZONE OF WEATHERING.			
Cretaceous			
Upper Cretaceous			
	Pierre Shale	2000	Dark gray, fissile, carbonaceous, marine shale and mudstone; contains several zones of bentonitic beds and concretions; lithology variable, upper part especially where in contact with Chadron Formation -- generally deeply weathered and altered to red, yellow, and orange claystone
	Sharon Springs Member	------	Dark gray fissile shale with numerous bentonite beds.
	Niobrara Formation	325	Upper third is yellowish-gray to pale-yellow limestone. Where in contact with Chadron Formation is deeply weathered to red, yellow, and orange noncalcareous claystone. Lower two-thirds is light grayish-yellow to brownish yellow calcareous shale with thin interbeds of dark gray shale.

Continued

Table 1

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

Stratigraphic Section, Pine Ridge Reservation (cont'd).

System and Series	Unit Group, Formation, and Member	Maximum Thickness (feet)	Character and distribution
Cretaceous (Cont.)			
Upper Cretaceous (Cont.)			
	Carlile Shale	300	Upper 100 feet is dark gray noncalcareous shale containing persistent zones of large limestone concretions; middle 60 feet is silty shale and fine-grained crossbedded sandstone: lower 140 feet is silty, calcareous gray shale with silty limestone concretions.
	THE CARLILE SHALE IS THE OLDEST OF THE ROCK UNITS EXPOSED ON THE RESERVATION.		
	Greenhorn Limestone	70	Limestone and calcareous shale.
	Belle Fourche Shale	300	Dark gray marine shale.
	Dakota Sandstone	300	Several sandstones interbedded with buff to gray shale or clay. Sandstone beds designated, in descending order, the "D", "G", and "J" sandstones (fig. 7) the latter is approximate equivalent to Newcastle and Muddy sandstones of eastern Wyoming.
	Skull Creek Shale	230	Dark gray marine shale.
Lower Cretaceous			
	Fall River Sandstone)	250 - 300	Transgressive marine sandstone with interbedded clays.
	Lakota Formation)		Non-marine sandstone with interbedded clays, especially near top.

Continued

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

Table 1

Stratigraphic Section, Pine Ridge Reservation (cont'd).

Systems and Series	Unit Group, Formation, Member	Maximum Thickness (feet)	Character and distribution
Jurassic	Morrison Formation	100	Gray-green shale with thin sandstones - non-marine.
	Sundance Formation	300	Light gray-green shale, fine-grained sandstone, and thin limestones. Marine.
Triassic			
	Spearfish Formation	300	Red shale, siltstone, and anhydrite. Only under west half of reservation.
Permian	Minnekahta Limestone	40	Dense, light brown to pink limestone; only under west half of reservation.
	Opeche Formation	100	Red siltsone with thin anhydrite beds, thinnest under central part of reservation.
Pennsylvanian			
	Minnelusa Sandstone	900	Dolomite, sandstone, anhydrite, red and black shales.
	Converse Sandstone		At top.
	Leo Sandstone		Below middle.-- Consists of a 2 or 3 sandstones separated by dense dolomites, thin anhydrites, and thin layers of black, radioactive shale.
	Bell Sandstone		Near base.
Mississippian			
	Madison Limestone	300	Limestone and dolomite, cavernous in part; present only under northern edge of reservation.
	Englewood	40	Pink shaly limestone; only under northern edge of reservation.
Devonian	MISSING.		
Silurian	MISSING.		

Continued

Table 1

Stratigraphic Section, Pine Ridge Reservation (cont'd).

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

System and Series	Unit Group, Formation, Member	Maximum Thickness (feet)	Character and distribution
Ordovician	Red River Formation	100	Mottled brown dolomite; under NE corner of reservation.
	Winnipeg Formation	100	Green shale with basal sand; underneath NE corner of reservation.
Cambrian			
	Deadwood Formation		Missing except possibly under NW corner of reservation.
Precambrian			Reported to be pink granite.

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

Table 2

Summary of mineral resource occurrences in rocks exposed on the Pine Ridge Indian Reservation.
See discussion of oil and gas for subsurface resources.

STRATIGRAPHIC UNIT	ENERGY RESOURCES		NONMETALLIC RESOURCES					METALLIC RESOURCES	
	Uranium	oil and gas	Zeolites	Clay and shale	Bentonite	Sand and gravel	Barite	Molybdenum	Gold
Alluvium						V.A.			
Ash Hollow Formation			S	M					
Rosebud Formation				A					
Harrison Formation				M		M			
Sharps Formation			V.A.	S			S		
Brule Formation	S		A	M			S		
Chadron Formation	M			M	M	A	S	S	S
Pierre Shale				V.A.	A		S	A	
Niobrara Formation				M				S	
Carlile Shale			V.A.	V.A.					

V.A. = Very abundant A = Locally abundant M = Modest amounts S = Small amount

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

Table 3

Oil and gas tests, Pine Ridge Reservation, 1917-1975

Well No.	Name and location	Date	Total Depth (ft.)	Formation	Remarks
1.	Midwest No. 1 Slim Butte NW¼SE¼ sec. 24-36N-48W.	1917	2445	Minnekahta	CT hole. Tr. gas 875-890 feet.
2.	Big Chief No. 1 Gillepsie E½NE¼ sec. 16-35N-45W.	1921	1160	Dakota(?)	CT hole. No tests shows.
3.	Amerada No. 1 Red Eagle NW¼NE¼ sec. 25-36N-48W.	1945	3367	Precambrian	Log: IES. DST 3291-3368. Core 3362-67; rec. 4½' granite.
4.	English-Martin No. 1 Euchs NE¼SW¼ sec. 20-36N-41W.	1952	3985	Minnelusa	No tests-no logs-fish in hole.
5.	English No. 1 Kocer SW¼SW¼ sec. 30-37N-36W.	1952	3370	Morrison	Logs: IES. No shows.
6.	Gulf No. 1 Jacquot NE¼SE¼ sec. 10- 39N-37W.	1966	4551	Precambrian	Strat. test. Oil shows in Minneulusa and Dakota.
7.	Gulf No. 1 Barber NW¼SW¼ sec. 11-40N-35W.	1967	4441	Precambrian	No shows; no cores; no tests.
8.	Webb Resources No. 30-16 D. Linehan SE¼SE¼ sec. 30-37N-45W.	1970	3595	Minnelusa	Logs: IES-BHC-GR. No shows.
9.	P. E. & M. No. 1 Ron Sandoz NE¼NW¼ sec. 30-36N-47W.	1972	1754	Morrison	Logs: DIL-CNL-GR-FDC-C; 4 cores; DST in Fall River.
10.	P. E. & M. No. 1 Ruth Sandoz NE¼SW¼ sec. 24-36N-48W.	1972	1200	Fall River	Logs: DIL-FDC-GR-CNL 3 DST in Dakota sands.

CT	cable tool drill	IES	induction electric log	BHC	borehole compensated sonic log
DST	drill stem test	GR	gamma ray log	CNL	compensated neutron density log
ES	resistivity log	DIL	dual induction laterolog	FDC	compensated formation density log

Table 4

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

Formation tops, test wells on Pine Ridge Reservation, South Dakota 1/

Formation	WELL NUMBERS 1	2	3	4	5	6	7	8	9	10
Niobrara				1385	1854		1700	733		
Greenhorn			405		2385	2400	2050	1344	441	471
Greenhorn limestone			420	1690	2418			1371	452	496
Dakota sandstone	860		815	1950	2716	2720	2450	1722	897	870
Skull Creek shale	1090		1050	2275	3078	2970		1947	1120	1091
Fall River-Lakota	1385		1299	2420	3168	3100	2900	2210	1400	
Morrison shale			1680	2665	3314		3100	2450	1680	
Sundance			1801	2918						
Spearfish redbeds	2165		2105	3048				2900		
Minnekahta limestone	2410		2340	3220				3062		
Opeche redbeds			2390	3245				3095		
Minnelusa			2520	3320		3650	3600	3224		
Precambrian			3350			4450	4300			

1/ See table 3 for well number and total depth of hole.

Table 6 Click back button (<<) on toolbar to return to text

Chemical composition of Rockyford ash as determined by emission spectrograph (Nicknish and MacDonald, 1963)

Locality	SiO_2	Al_2O_3	PERCENT CaO	Fe_2O_3	MgO	MnO_2	TiO_2	Na_2O	K_2O
Cedar Pass T. 3 S., R. 18 E.[1/]	68.00	13.50	2.20	2.28	1.10	0.043	0.54	1.20	3.40
Norbeck Pass T. 3 S., R. 17 E.[1/]	69.00	13.20	2.40	2.80	1.30	0.030	0.52	1.00	3.30
Sheep Mountain Table T. 43 N., R. 44 W.	64.50	12.60	2.40	2.60	1.30	0.051	0.53	1.60	3.60
Cedar Butte T. 41 N., R. 44 W.	64.50	11.70	2.20	2.10	0.90	0.030	0.33	1.00	4.20
Bloom Ranch T. 40 N., R. 44 W.	70.00	12.70	2.40	2.60	1.20	0.077	0.47	2.50	3.60
Grass Creek T. 39 N., R. 45 W.	68.00	13.60	2.60	3.30	1.70	0.051	0.61	1.70	3.10

1/ Not within boundary of Pine Ridge Reservation.

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

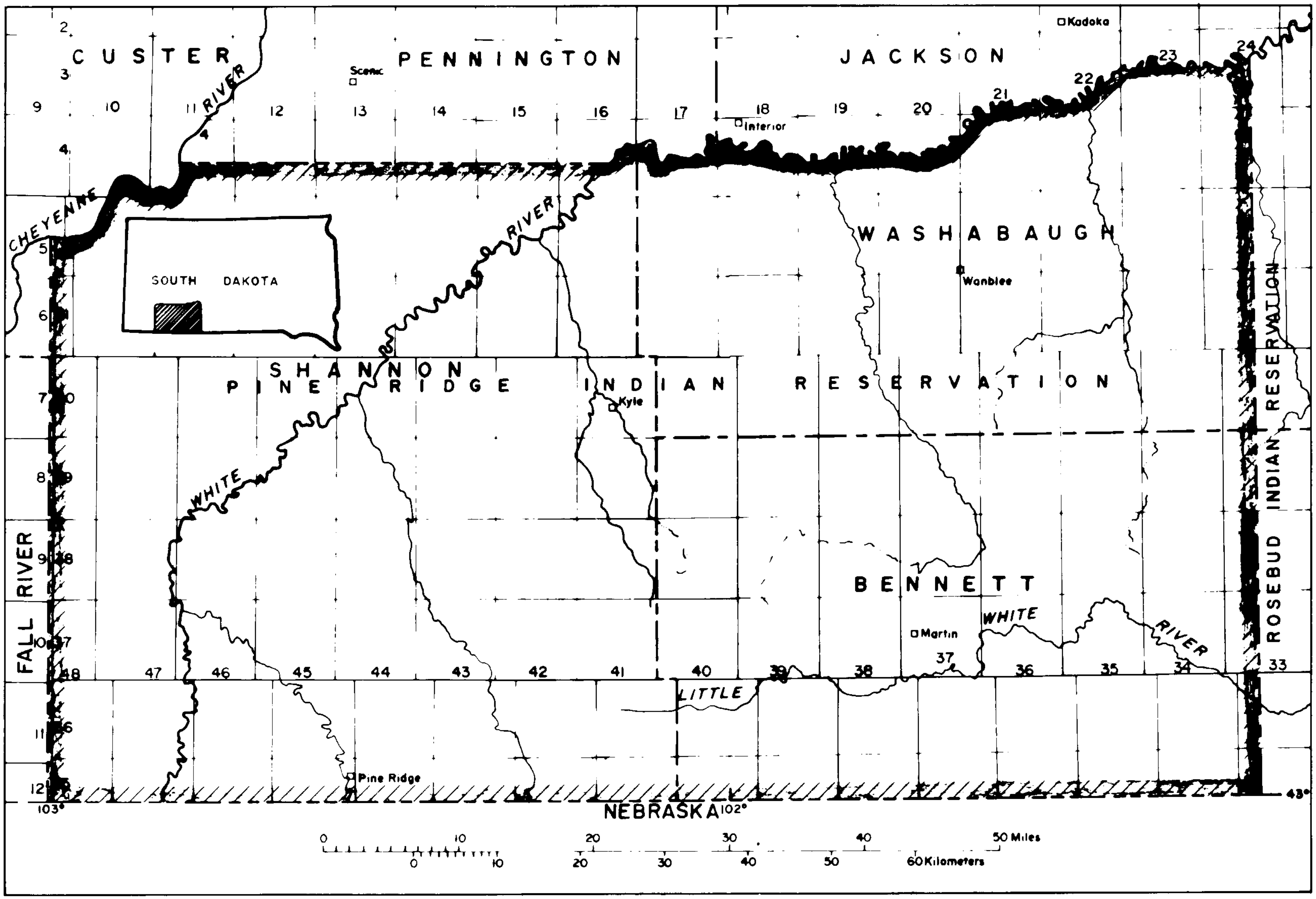

Figure 1. Index map of the Pine Ridge Indian Reservation, South Dakota (includes some non-Indian lands).

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

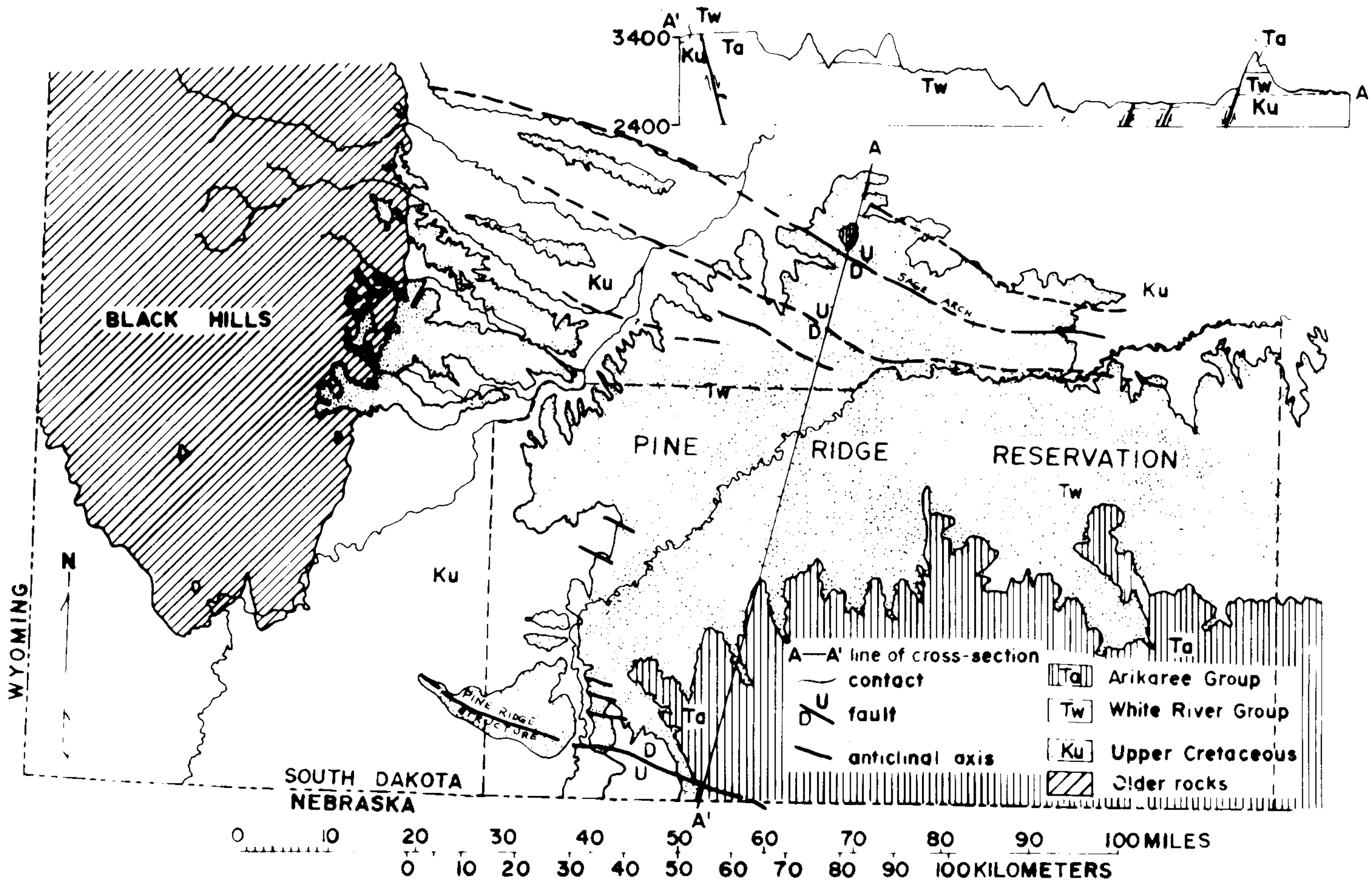

Figure 2. Generalized geologic map of Southwestern South Dakota and diagrammatic cross-section showing general geology and structural features (modified from Clark, 1967, p. 13-14).

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

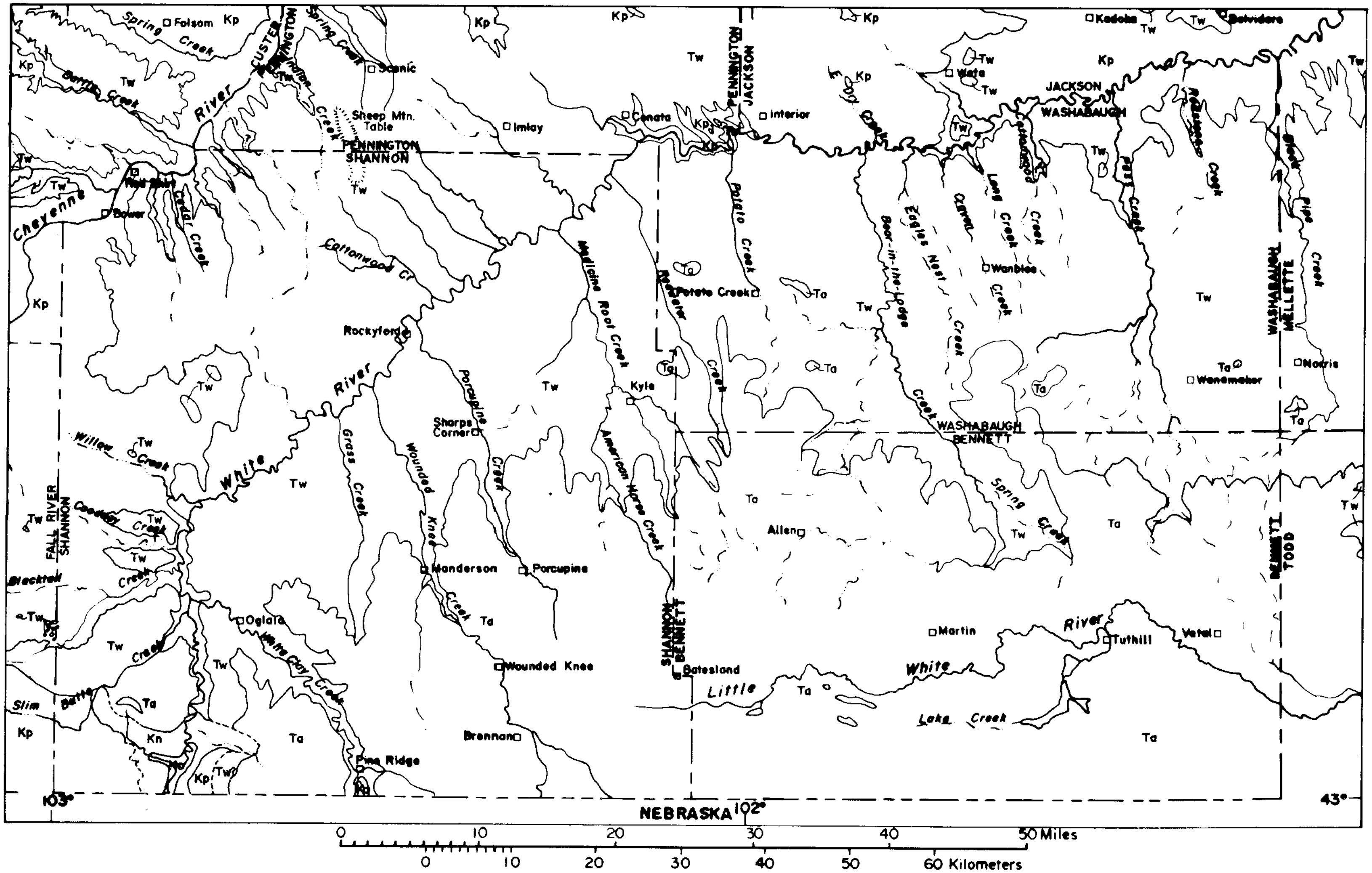

Figure 3. Map of the Pine Ridge Indian Reservation and vicinity, South Dakota, showing areas underlain by various geologic units. Modified from Darton (1951).

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

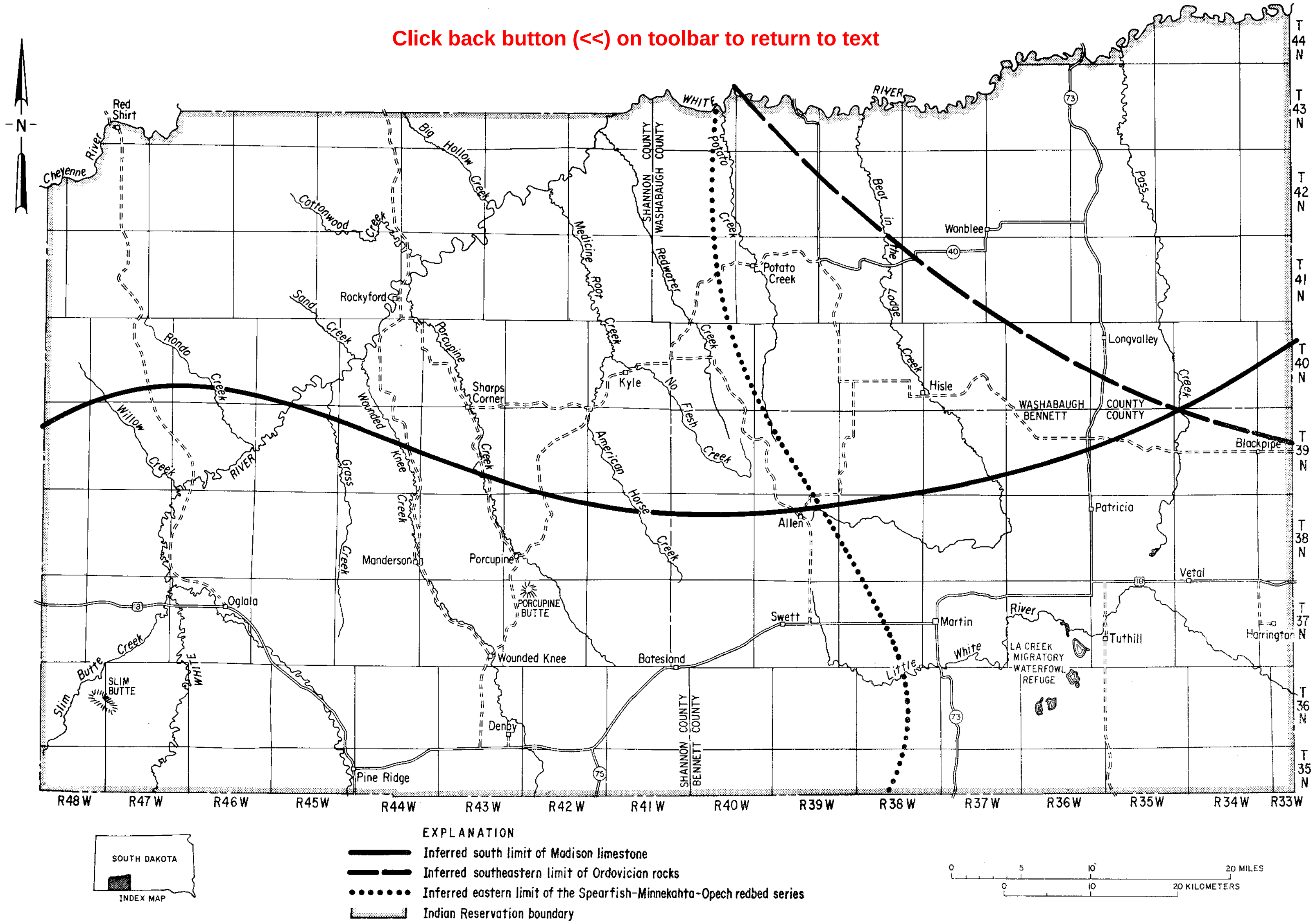

Figure 4. Map showing inferred limits of strata which do not underlie the entire Reservation (compiled by J.P. Gries, 1976).

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

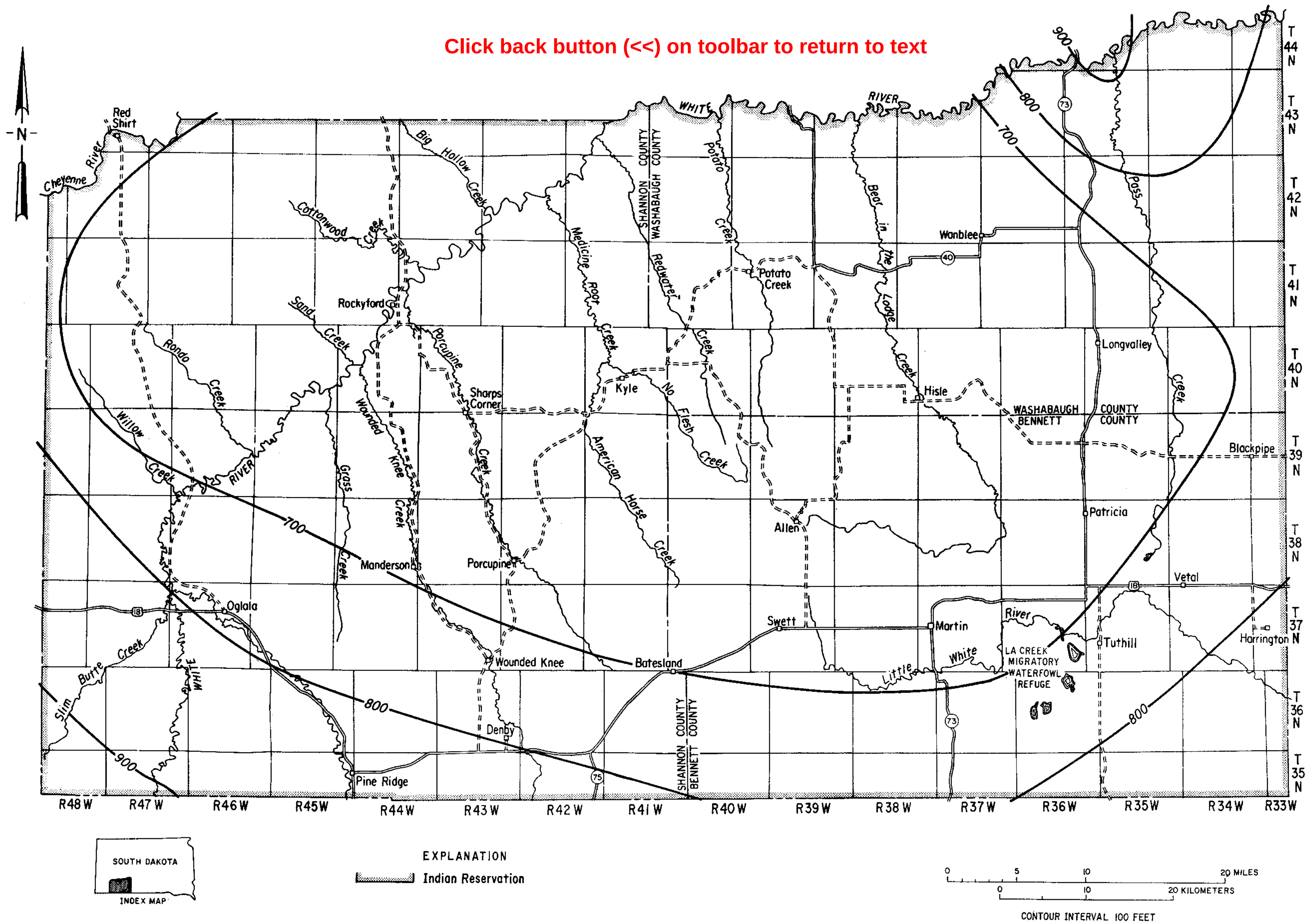

Figure 5. Isopach map of the Minnelusa Sandstone, Pine Ridge Reservation (compiled by J.P. Gries, 1976).

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

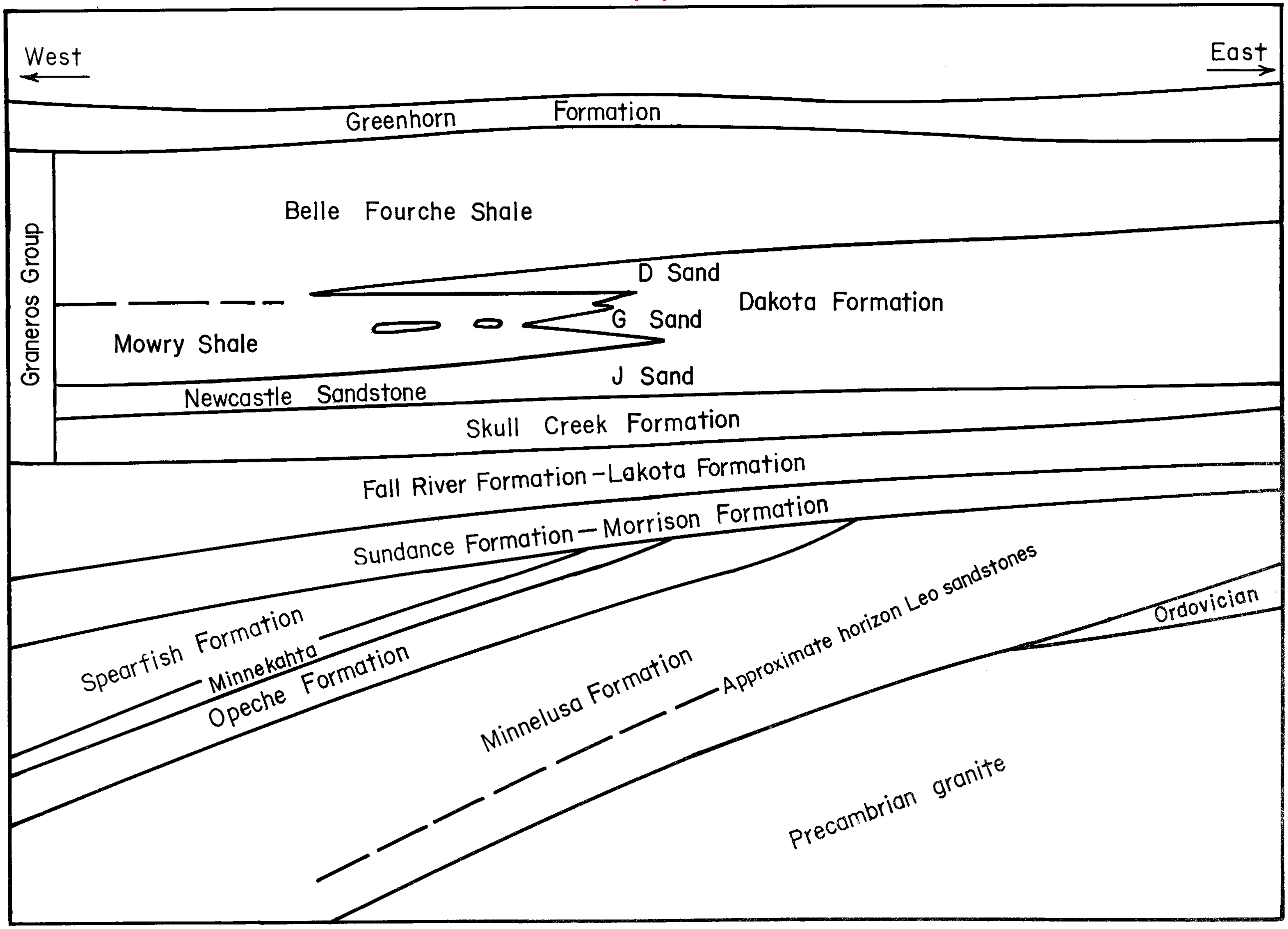

Figure 6. Idealized cross-section, looking north, showing stratigraphic relations of rock units underlying Pine Ridge Indian Reservation. A section across the northern edge of the Reservation would show Madison limestone beneath the Minnelusa formation. Not to scale.

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

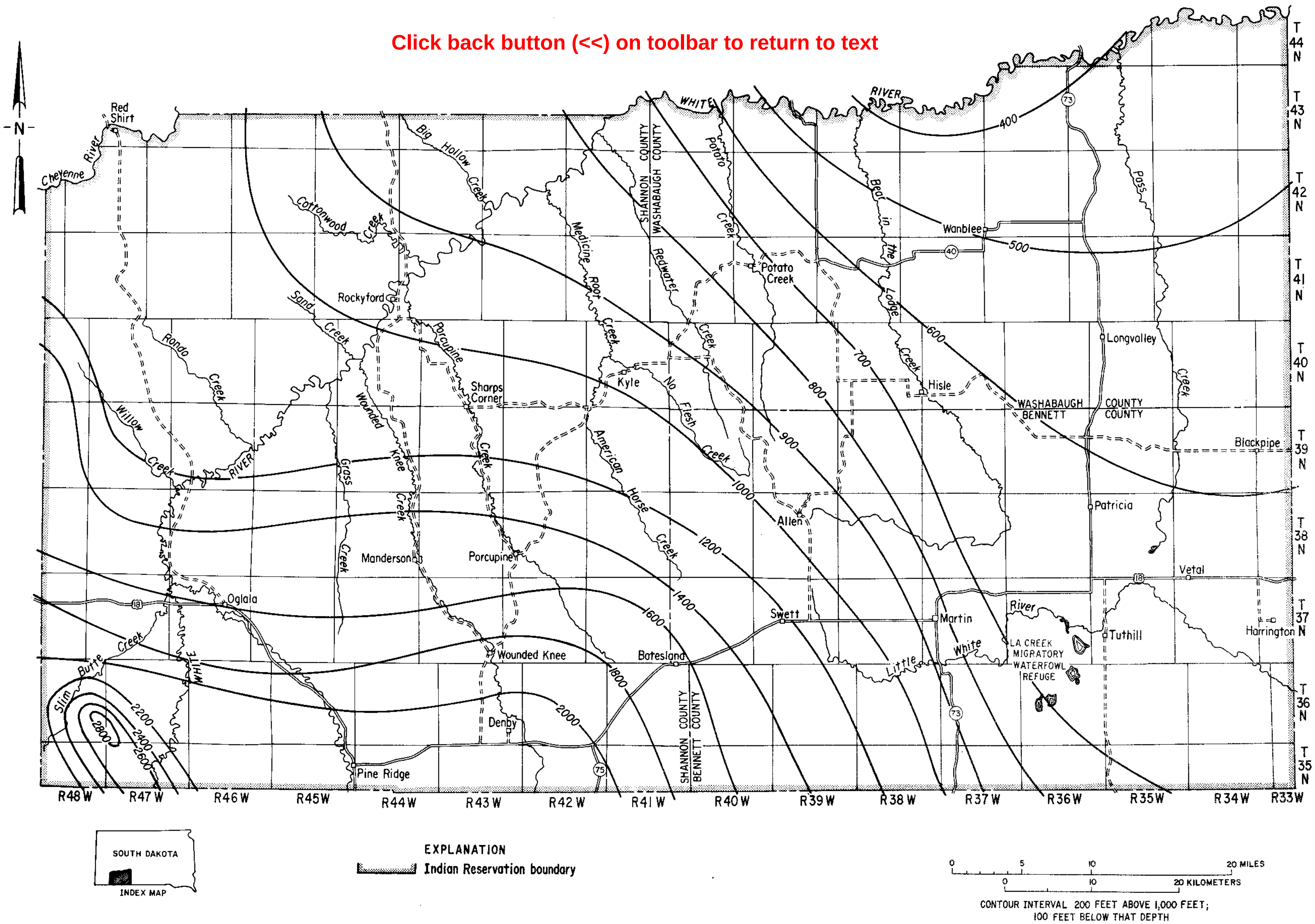

Figure 7. Generalized structure map of the Pine Ridge Indian Reservation. Contours drawn on top of Greenhorn limestone. Compiled by J.P. Gries, 1976.

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

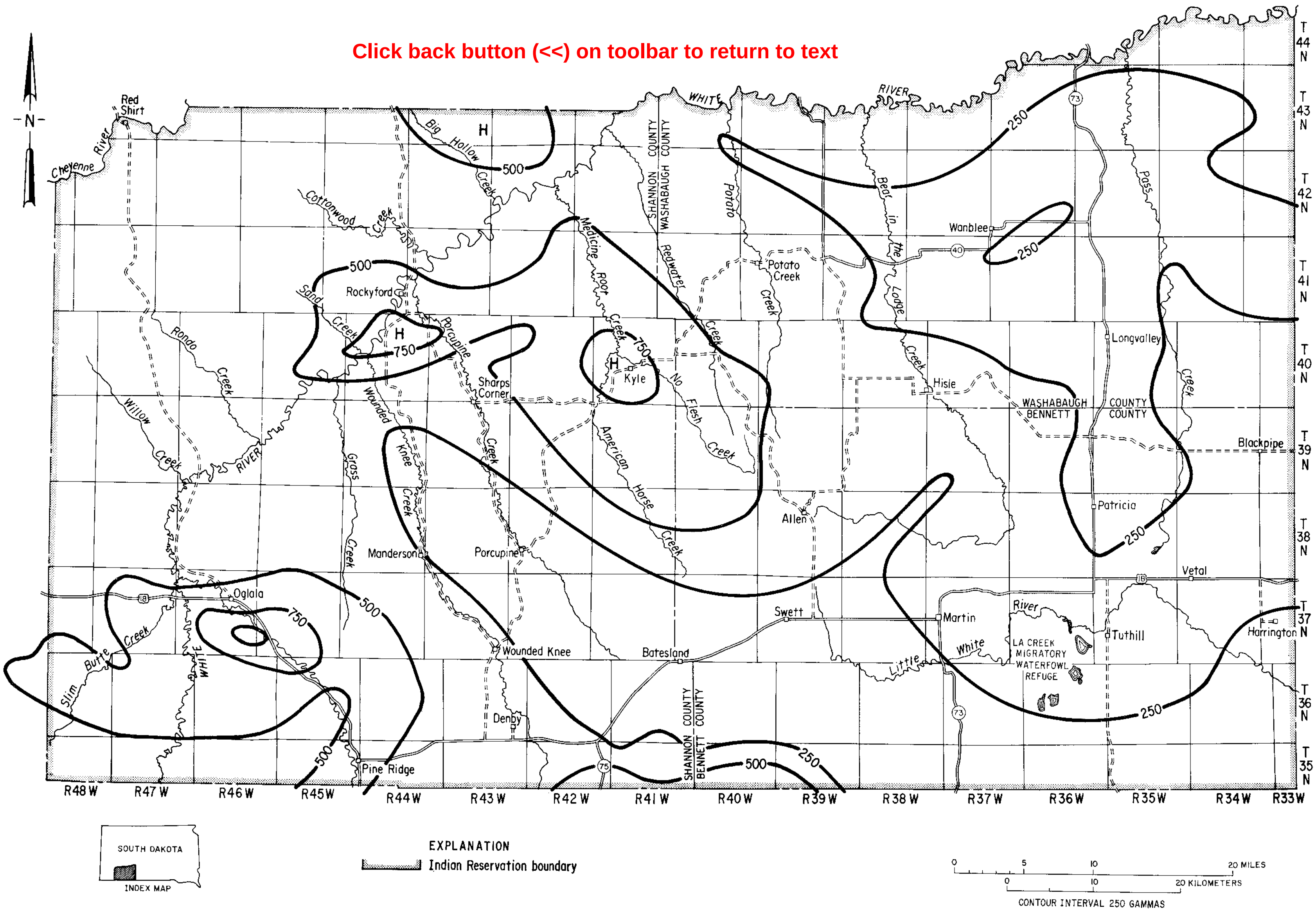

Figure 8. Generalized map of magnetic anomalies, Pine Ridge Reservation (after Petsch 1960, 1961).

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

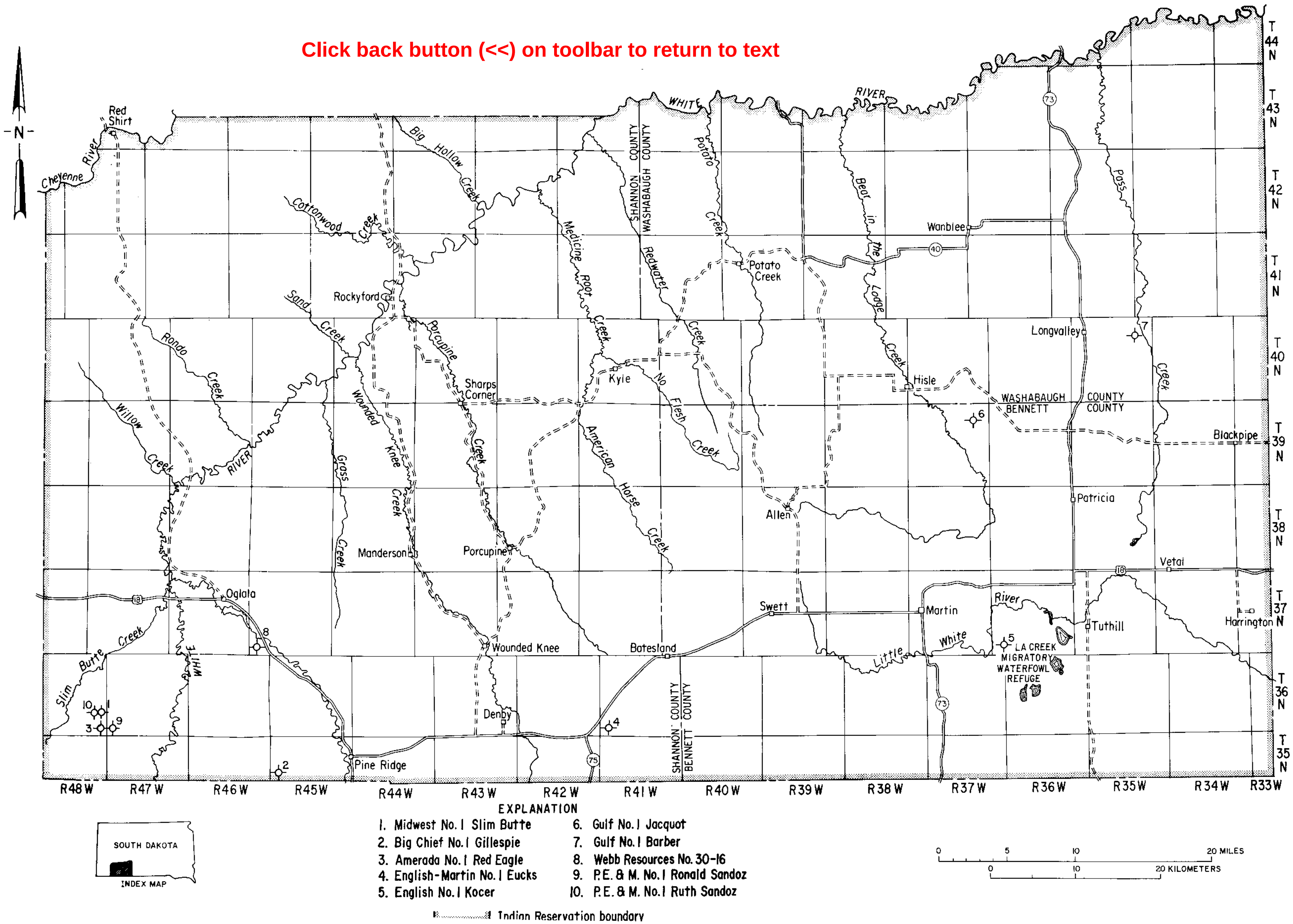

Figure 9. Map showing oil and gas test holes on the Pine Ridge Indian Reservation.

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

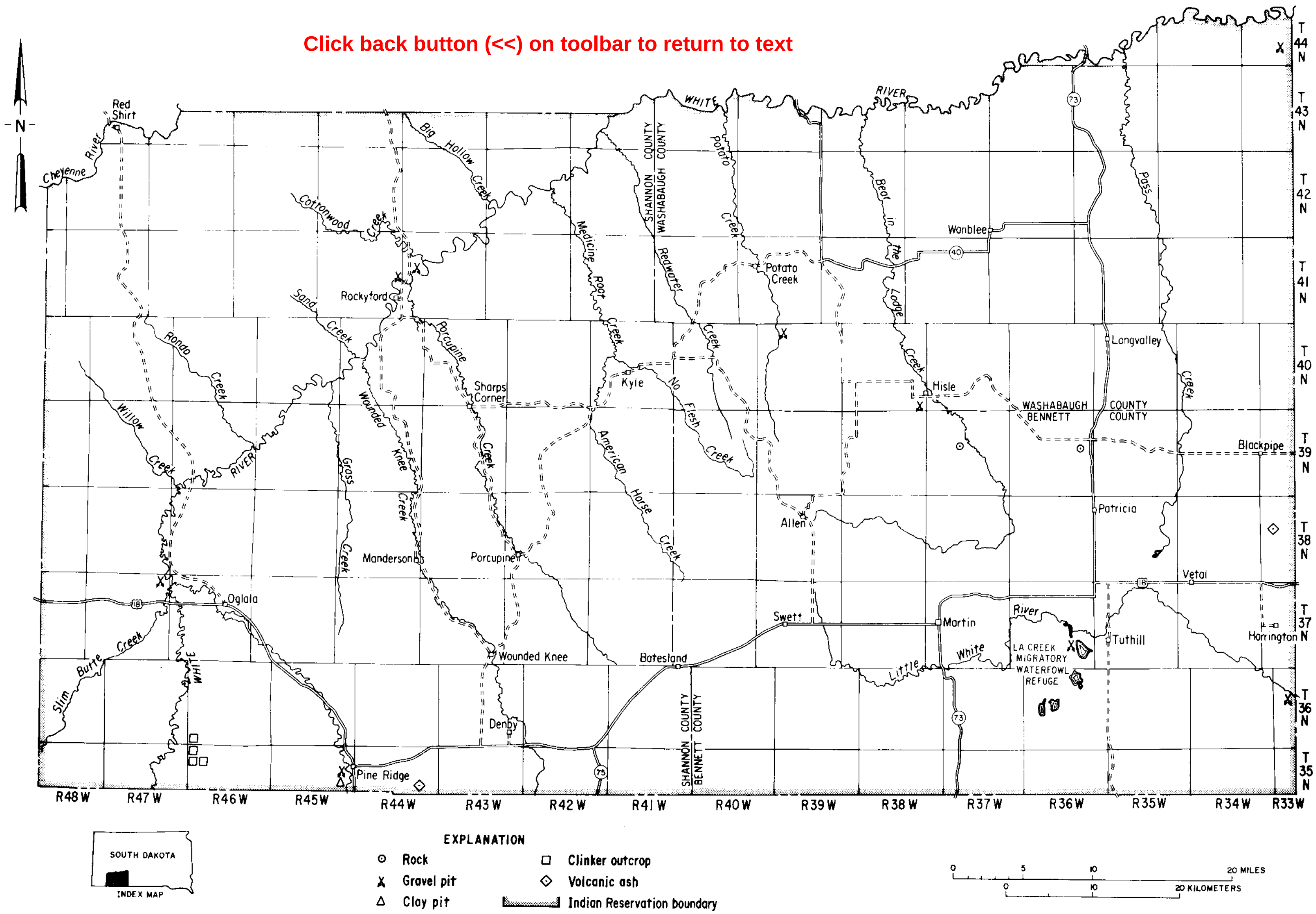

Figure 10. Map showing non-metallic localities mentioned in the text.

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

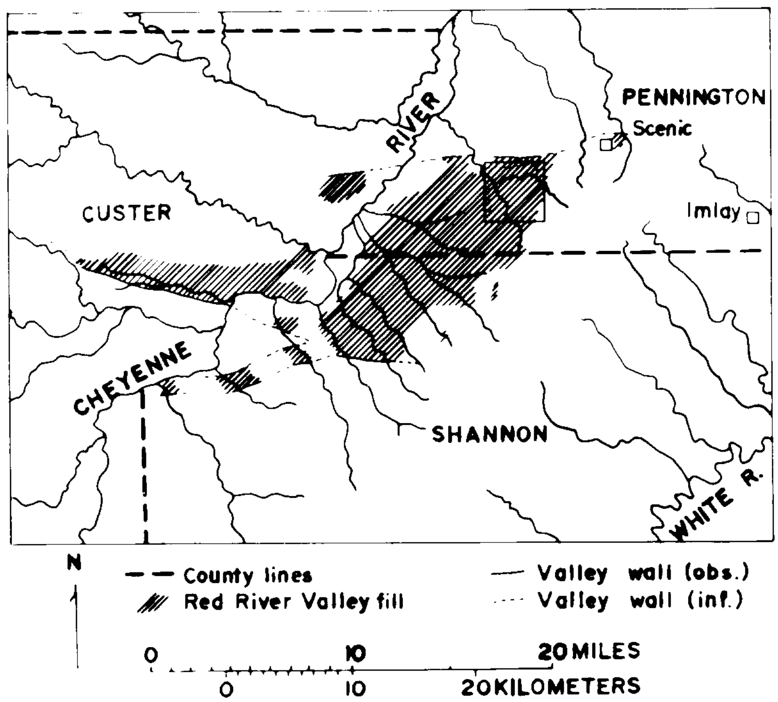

Figure 11. Map showing location of the old Red River Valley (Clark, 1937 p. 266). The square southwest of Scenic indicates the area of known uranium-molybdenum mineralization at Indian Creek.

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

Figure 12. Photograph of clay pit southwest of Oglala Community School, SW1/4NW1/4SW1/4 sec. 13, T. 35N., R. 45W., Shannon County. Pit is in deeply weathered zone of the Niobrara Formation and is source of clay for Sioux pottery.

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

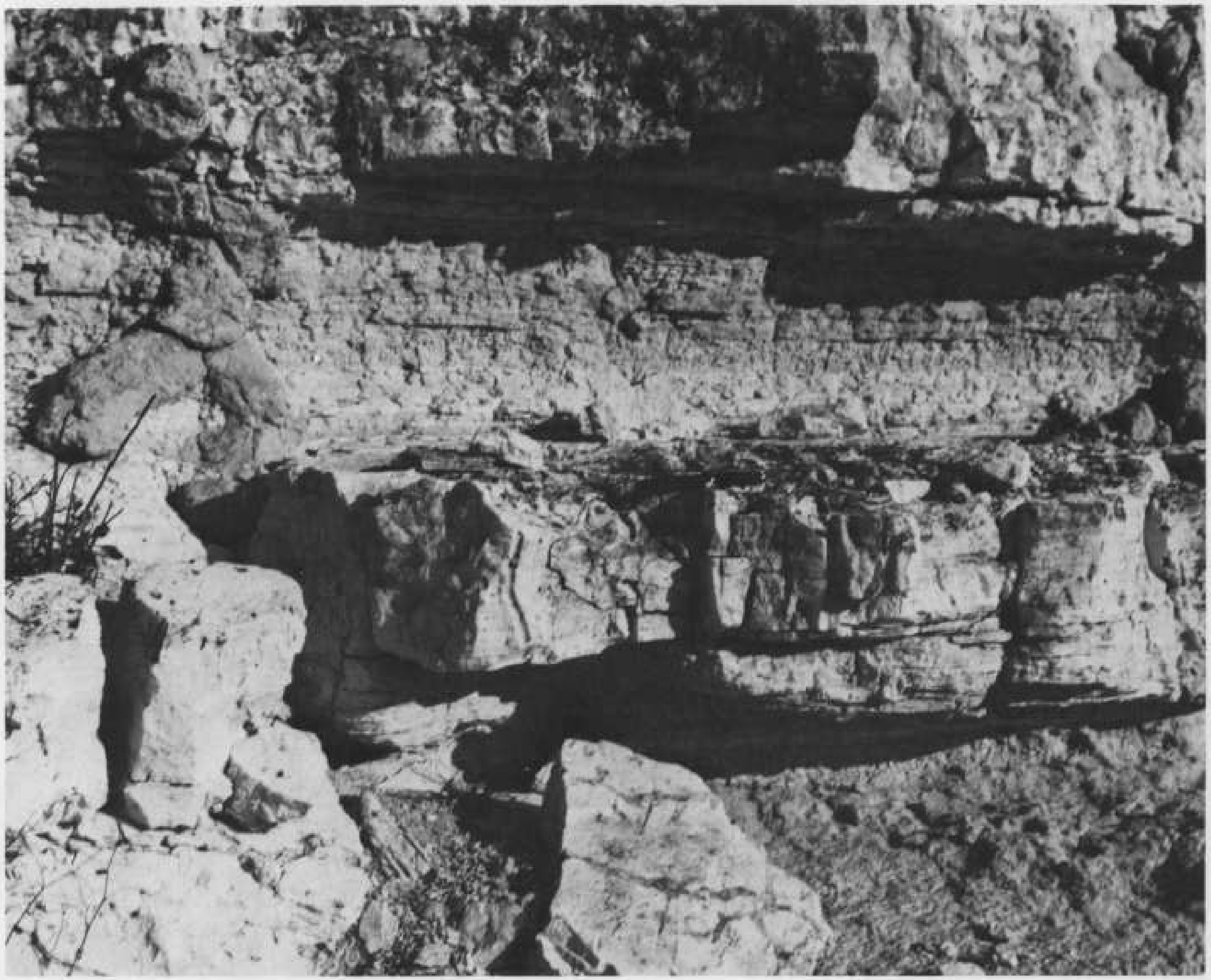

Figure 13. Photograph showing outcrop of limestone, Mellette facies of Monroe Creek Sandstone on butte east of the Hisle-Martin road, sec. 16, T. 39N., R. 37W., Bennett County. Pen in center is 5 1/2 inches long.

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

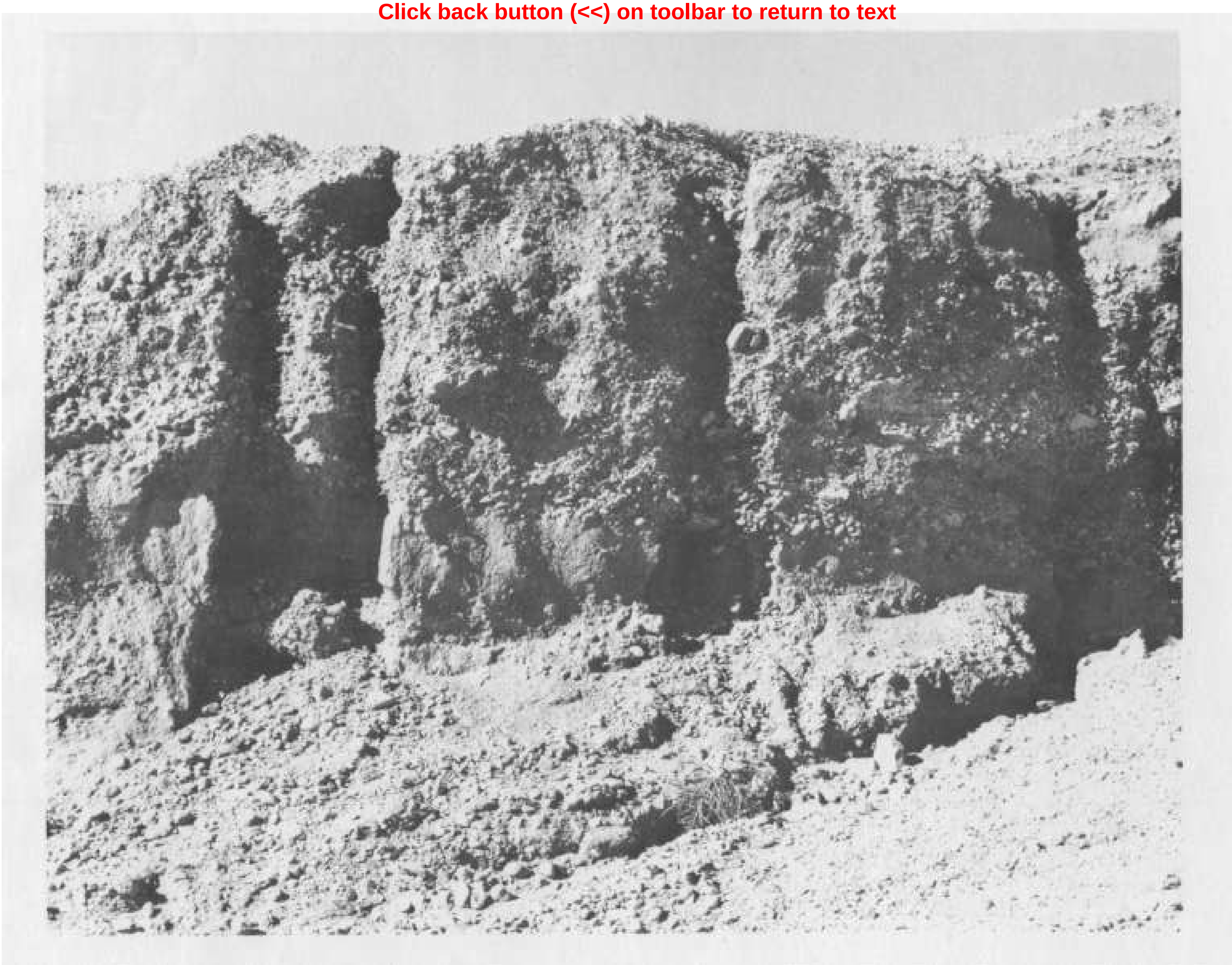

Figure 14. Photograph of pit in White River terrace gravel west of Oglala, NE1/4 sec. 2, T. 37N., R. 47W., Shannon County. Verticle face about 8 feet high.

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

Figure 15. Photograph of White River terrace gravels near Rockyford, Shannon County. Outcrop in pit operated by Bureau of Indian Affairs in SW1/4SW1/4 sec. 19, T. 41N., R. 43W. Verticle black object is fountain pen, 5 1/4 inches long.

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

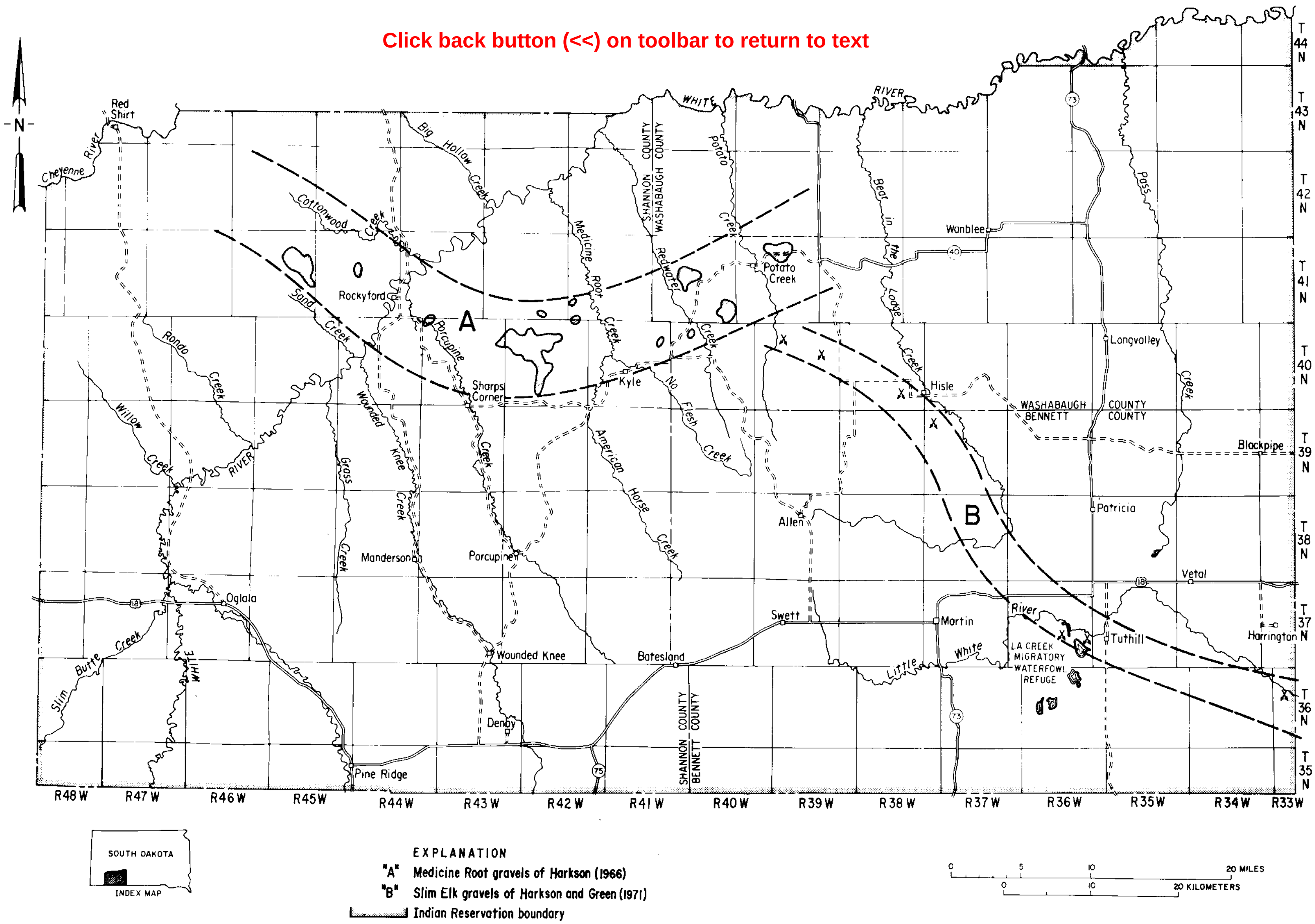

Figure 16. Map showing remnants of high stream gravels, deposited by streams draining the Black Hills before the development of the Cheyenne River drainage system.

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

Figure 17. Photograph of typical knob covered with Thin Elk gravel. Right side opened up with bulldozer cut. NE corner sec. 17, T 38N., R. 36W., Bennett County, South Dakota.

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

Figure 18. Closeup of Thin Elk gravel shown in Figure 17. Pen (5 1/4 inches long) indicates size of largest cobbles.

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

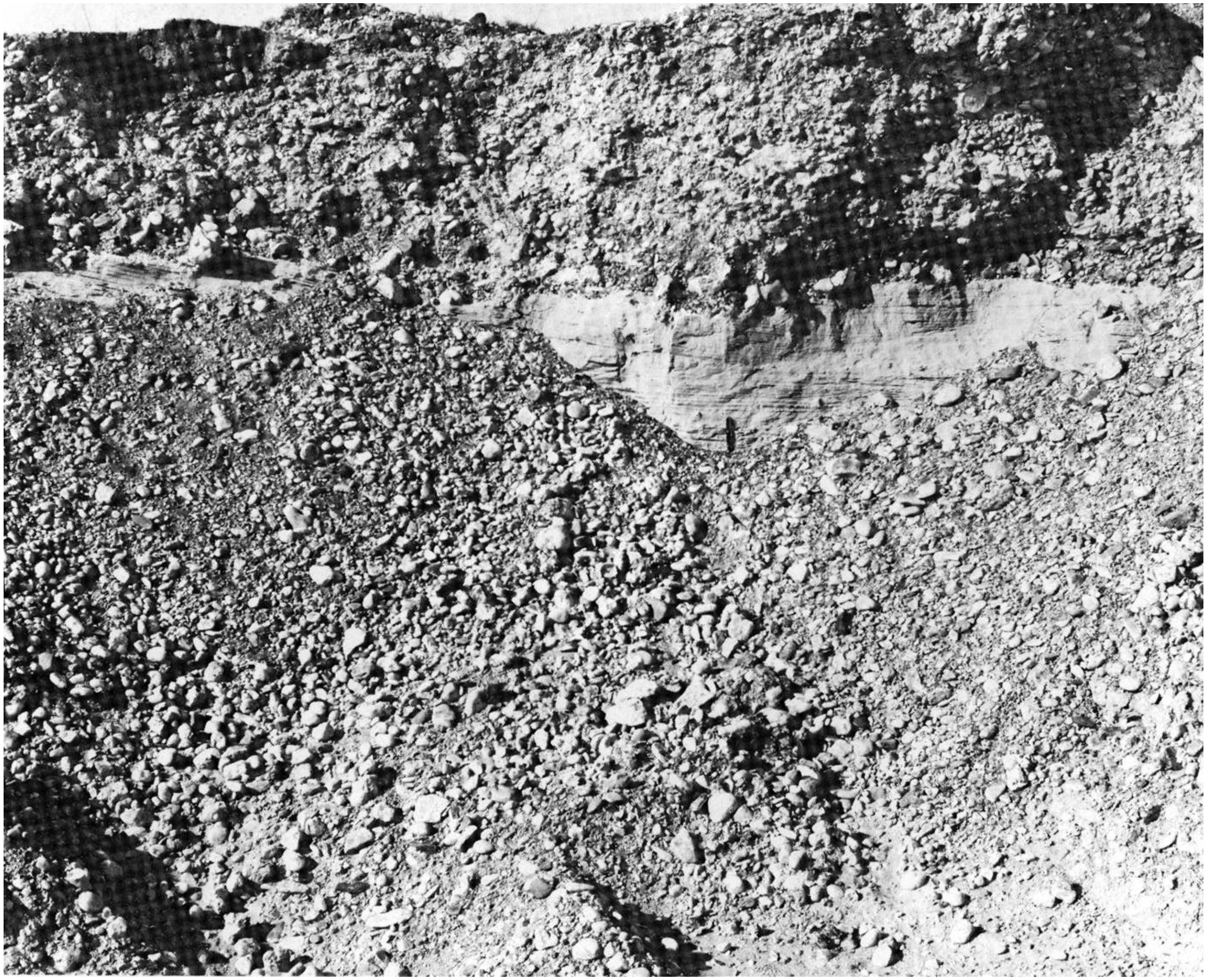

Figure 19. Photograph of Thin Elk gravel, north pit of O.J. Wheeler, in SW1/4 sec. 36, T. 40N., R. 38W., Washabaugh County, South Dakota. Overlying the silt layer is an inch or so of highly garnetiferous sand. Pen (5 1/4 inches long) at base of salt bed.

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

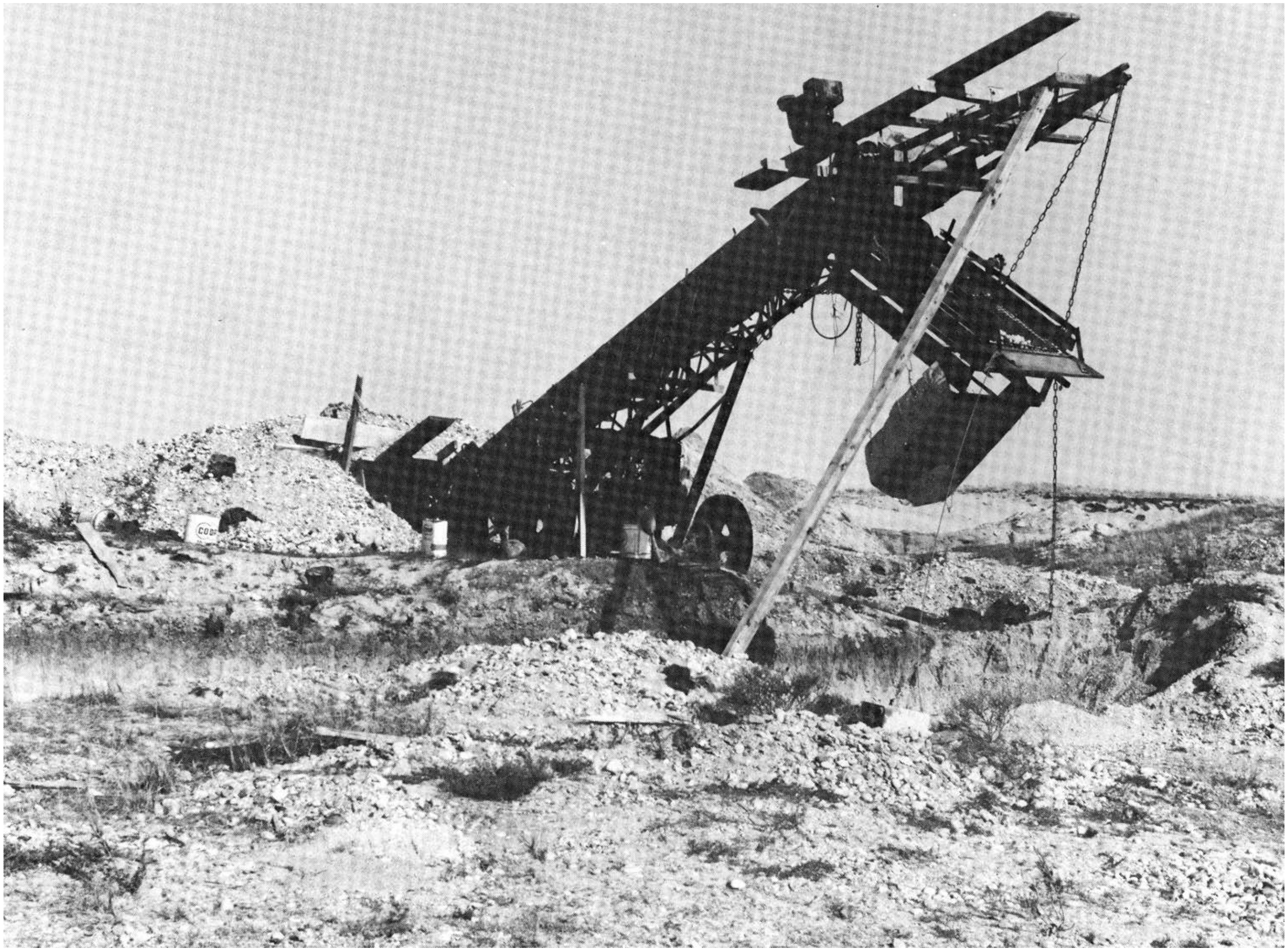

Figure 20. Photograph of Thin Elk gravel pit. Screening equipment in south pit of O.J. Wheeler SW1/4 sec. 36, T. 40N., R. 38W., Washabaugh County.