STATUS OF MINERAL RESOURCE INFORMATION FOR THE FORT BERTHOLD INDIAN RESERVATION, NORTH DAKOTA

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SUMMARY AND CONCLUSIONS

Identified mineral resources of the Fort Berthold Indian Reservation include petroleum, lignite, gravel and sand, clinker, clay, salt, and potash; resources of uranium and leonardite may exist. No metallic mineral deposits are known. Petroleum and lignite are the most valuable mineral resources. Petroleum and natural gas are currently produced; total royalties are more than $3.2 million.

Although oil production from the Antelope Oil Field in the northwest corner of the reservation has declined, potential for additional deeper production from the same structure in the Ordovician Red River and Silurian horizons should be investigated. The Pierre Formation offers potential gas production. Additional geophysical prospecting and test drilling is needed over large unexplored areas of the reservation to determine oil and gas potential.

A large, potential, strippable lignite resource exists. Future work on the reservation should be primarily concerned with detailed investigation of the lignite.

Materials such as gravel and sand, clinker, and clay are adequate to meet local construction needs but large-scale development is unlikely. Deeply buried salt and potash deposits may one day provide additional revenue if recovery proves economically feasible. Chances of finding uranium ore are slight.

INTRODUCTION

This report has been prepared for the U.S. Bureau of Indian Affairs by the U.S. Bureau of Mines and U.S. Geological Survey under an agreement to compile and summarize available information pertaining to geology, mineral and energy resources and potential for economic development of certain Indian lands. Source material included published and unpublished reports, personal communications with individuals familiar with the area, and files of State and Federal agencies. No field investigation was conducted.

Area Location and Access

Fort Berthold Indian Reservation comprises parts of Dunn, McKenzie, McLean, Mercer, Mountrail, and Ward Counties in west-central North Dakota (Figure 1), near the confluence of the Missouri and Little Missouri River valleys. Total area is about 1,530 square miles, approximately 11 percent of which is covered by waters impounded by Garrison Dam (Lake Sakakawea). The lake divides the reservation into four distinct areas, here referred to as the western, southern, eastern, and north-central segments.

Although reservoir waters somewhat impede travel between the four land segments, most of the reservation is accessible over a system of State highways and local roads. Rail service is provided to the northern part of the reservation by the Soo Line Railroad. A main east-west line of the Burlington Northern passes within 7 miles of the reservation, roughly paralleling the southern boundary.

Past Investigations

Previous work in the Fort Berthold Indian Reservation involved studies on lignite, mineral resources, and water by the United States Geological Survey and the United States Bureau of Mines. The North Dakota Geological Survey has included portions of the reservation in the appropriate county reports concerning geology and water.

M. E. Bluemle (1975) mapped the entire reservation at a scale of 1:125,000.

Present Study and Acknowledgments

The material in this report is based partly on groundwater studies, which were compiled jointly by the North Dakota Geological Survey, the United States Geological Survey, and the North Dakota State Water Commission for McLean (Bluemle, 1971a; Klausing, 1971, 1974), Mercer (Carlson, 1973; Croft, 1970, 1973), and Mountrail (Clayton, 1972; Armstrong, 1969, 1961), counties which comprise about 60 percent of the reservation area. Additional unpublished information was available from similar studies now underway in Dunn and McKenzie Counties. The geologic map of Dunn County (Clayton, 1970) was useful for that portion of the reservation.

We acknowledge the assistance of Mr. Sidney Anderson, chief of the Subsurface Section of the North Dakota Geological Survey, and Mr. Erling Brostuen, geologist with the survey. Ms. Joanne Groenewold, University of North Dakota geolibrarian, compiled a list of references.

Land Status

The Fort Berthold Indian Reservation was established by the Fort Laramie Treaty of September 17, 1851, for the Arikara, Mandan, and Hidatsa Tribes of Indians who later united to form the Three Affiliated Tribes. Executive Orders and Congressional Acts have limited the reservation to its present boundaries (Figure 2). The act of June 1, 1910, 36 Stat. 455, opened unallotted and unsold reservation lands to non-Indians, thus creating the "ceded and diminished lands" boundary shown in Figure 2. It was assumed by many that only the remaining lands comprised the Fort Berthold Indian Reservation. A Federal appeals court (8th Cir. 1972), however, ruled that the 1910 Act did not change reservation boundaries and that the "homestead" (ceded) area remained a part of the reservation (City of New Town vs. United States, 454 F 2d 121).

Public Law 437 and the Act of July 31, 1947 (amended October 29, 1947) made provision for lands inundated by the Garrison Dam reservoir. Table 1 summarizes the present extent of land holdings on the Fort Berthold Indian Reservation. Most of the north and northeast part of the reservation (the homestead area) is in private ownership. Land status data are from Bureau of Indian Affairs records.

Clearly 54 percent of the reservation's subsurface mineral rights are owned by the Three Affiliated Tribes. Mineral rights in the diminished reservation area are all tribally owned with the exception of 164.09 acres owned by the Federal government. The Tribes also retain mineral ownership for 110,623.13 acres of the homestead area. Lands in the Garrison reservoir area were severed.

TABLE 1
Summary of Land Ownership, Fort Berthold Indian Reservation, North Dakota

Classification	Acreage	Percentage of total
Diminished Reservation Area		
Tribally-owned lands	57,954.20	5.91
Allotted lands	360,438.57	36.76
Government-owned land	164.09	.01
Privately owned (alienated) land	55,865.14	5.70
Subtotal	474,422.00	48.38
Reservoir Taking Area	152,359.95	15.54
Homestead (ceded) Area	353,792.59	36.08
Total area of reservation	980,574.54	100.00

Physiography

The Fort Berthold Indian Reservation includes land that ranges from rugged badlands to rolling plains. Altitudes range from about 1,850 feet at Lake Sakakawea to over 2,600 feet on Phaelen's Butte near Mandaree. The reservation is within the Northern Great Plains Physiographic Province and may be divided into four physiographic units: (1) the Coteau Slope; (2) the Missouri River trench (now flooded); (3) the Missouri Plateau; and (4) the Little Missouri Badlands (Figure 3) (Knudson, 1974). South of Lake Sakakawea the reservation has a bedrock surface with scattered areas of glacial drift. North of the lake, glacial deposits predominate and only patches of bedrock crop out. The landscape reflects this distribution of sediments: south of the lake, hills and badlands are common; north of the lake the glaciated topography is mainly undulating to rolling.

The reservation area north of Lake Sakakawea is part of the Coteau Slope, which has both erosional and glacial landforms with glacial predominating. Gentle slopes characterize 50 to 80 percent of the area and local relief ranges from 50 to 200 feet. The Little Missouri Badlands lie adjacent to the Little Missouri River south and west of Lake Sakakawea as well as in a few restricted areas along the Missouri River. They consist of rugged, deeply-eroded, hilly land in which gentle slopes characterize only 20 to 50 percent of the area and local relief is commonly over 500 feet. Areas other than badlands south and west of the lake are part of the Missouri Plateau. In these areas, gentle slopes characterize about 50 to 70 percent of the area and local relief ranges from 300 to 500 feet.

The Missouri and Little Missouri Rivers and their larger tributaries have cut deeply into the bedrock and glacial deposits of various compositions. The Missouri River is 300 to 500 feet below the upland plain. Near the western boundary of the reservation, the Little Missouri River has eroded a channel more than 600 feet deep. Occasional ridges and bare buttes extend as much as 400 feet above the plain.

GEOLOGY

Stratigraphy

Subsurface

Formations below the Bullion Creek Formation are not exposed on the reservation. The deeper formations, down to the Precambrian rocks at depths as great as 16,000 feet, are known from exploratory wells and oil wells (Figure 4). Their general character is described in Table 2. Subsurface data are severely limited over most of the reservation where extensive areas have had no exploratory drilling.

Surface

General

Glacial deposits cover most of the reservation northeast of the Missouri River (Bluemle, 1975) (Figure 5). Elsewhere, continental sedimentary rocks of Paleocene are found at the surface (Carlson, 1959).

Formations exposed on the reservation include the Eocene Golden Valley Formation and the Pleistocene Coleharbor Formation.

TABLE 2

Generalized Stratigraphic Section of Sedimentary Rocks, Fort Berthold Indian Reservation

Quaternary System

Coleharbor Group. Clay, sand, silt, and gravel with dispersed organic material; pebbly, sandy, silty clay with limestone, dolomite, granite, gneiss, and basalt pebbles (till); associated inorganic bedded clay, silt, sand, and gravel; glacial, river, lake, and windblown sediment; Pleistocene and Holocene; up to 400 feet thick.

Tertiary System

Golden Valley Formation. Clay, white to yellow in outcrop, sandy, kaolinitic; shale, gray in outcrop, carbonaceous; fine sandstone and siltstone; nonmarine; lower member capped by a thin bed of lignite or chert; Eocene; 200 feet thick.

Sentinel Butte Formation. Silt, sand, clay, sandstone, and lignite, gray brown; river, lake, and swamp sediment; Paleocene; 200 feet thick.

Bullion Creek Formation. Silt, sand, clay, sandstone, and lignite, yellow-brown; river, lake, and swamp sediment; Paleocene; 600 feet thick.

Slope Formation. Silt, sand, clay, and sandstone, gray-brown to yellow-brown; river, lake, and swamp, and some marine sediment; Paleocene; 300 feet thick.

Cannonball Formation. Sand, shale, and sandstone, olive-brown; marine shoreline and off shore sediment. Paleocene; 300 feet thick.

Ludlow Formation. Silt, sand, clay, and sandstone, gray-brown to yellow-brown; lignitic; river, lake, and swamp sediment. Paleocene; 200 feet thick.

Cretaceous System

Hell Creek Formation. Sand and sandstone, light gray; clay and silt, brownish gray in outcrop, bentonitic; manganese-oxidestained concretions; river sediment and some marine sediment; 150 feet thick.

Fox Hills Formation. Sandstone, white, massive; shale, brown, silty; sand, reddish-brown, medium-grained; ferrugenous nodules, highly fossiliferous; sandstone ledges; marine; 300 feet thick.

Pierre Formation. Shale, light to dark gray, slaty to flaky, siliceous, bentonitic, ironstone concretions, pyritic, streaked with Jarosite and bentonite layers, gypsum encrusted phosphate nodules; 2000 feet thick.

Niobrsra Formation. Shale, calcareous, medium light gray to medium gray; contains calcareous "white specks" known in Canada as the "First White Specks"; has been used as cement rock; 100 feet thick.

Carlile Formation. shale, noncalcareous, medium dark gray to black; large, ellipsoidal concretions with abundant selenite; 400 feet thick.

Greenhorn Formation. Shale, calcareous, soft, dark gray; limestone, shaly, thin-bedded; contains Inoceramus fragments and Globigerina; contains calcareous "white specks" known in Canada as the "Second White Specks"; good electric and radioactivity log marker; 150 feet thick.

Belle Fourche Formation. Shale, micaceous, medium dark gray to dark gray; bentonite, white to light blue-gray; 300 feet thick.

Mowry Formation. Shale, flaky, soft, medium to dark gray, bentonitic; bentonite; top of Mowry picked on geophysical log markers, white to light blue-gray; 150 feet thick.

Skull Creek Formation. Shale, soft, medium to dark gray; 100 feet thick.

Fall River and Lakota Formations. Upper: marine sandstone, fine to coarse, quartzose, light gray; shale, silty, lumpy, gray. Lower: nonmarine sandstone, medium to coarse, angular to subroundet, quartzose; commonly contains light brown iron carbonate siltstone spherulites (pellets) ant gray shale streaks; 400 feet thick.

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Jurassic System

Morrison Formation. Shale and siltstone, light gray green to varicolored; soft, pyritic; thin interbedded sandstone and limestone; argillaceous; occasional small amounts of coal; 200 feet thick.

Swift Formation. Shale, dark gray to greenish, fissile, waxy, silty, calcareous, glauconitic; local limestone and sandstone; 350 feet thick.

Rierdon Formation. Shale, medium dark to olive gray, red to varicolored near base, calcareous, interbedded buff to brown, tense limestone; limestone, buff to brown, dense, fossiliferous, earthy, silty, locally dolomitic and cherty to sandy and clayey, oolitic; sandstone, light gray, fine to coarse, calcareous; 325 feet thick.

Piper Formation. Limestone and dolomite, white, brown, and gray, fossiliferous, finely crystalline; sandstone, fine-grained; shale, gray-green to purple or red, some siltstone and gypsum; anhydrite, white; 300 feet thick.

Triassic System

Spearfish Formation. Siltstone, reddish orange (redbeds); thin interbeds of reddish orange, fine-grained sandstone, frosted grains, slightly calcareous, local shale lenses; halite, clear, massive, large crystals; local anhydrite, whitish to pinkish; traces of pyrite and dolomite; 400 feet thick.

Permian System

Minnekahta Formation. Limestone, cream, pink, and purple mottled, chalky to sublithographic, argillaceous, anhydrotic; 40 feet thick. Opeche Formation. Shale, orange-red, dolomitic, locally silty, streaks of anhytrite and gypsum; halite; 250 feet thick.

Broom Creek Formation. Sandstone, pinkish gray to pale reddish brown, fine to medium grained, subangular to well rounded, locally dolomitic; dolomite, pinkish gray to grayish red, microcrystalline, locally anhydrotic; interbedded grayish red shale; 250 feet thick.

Pennsylvanian System

Amsden Formation. Sandstone, light gray to pale red, fine-grained, calcareous, dolomite, argillaceous; shale, red to dark gray to greenish gray, calcareous, blocky fissility; dolomite, gray to pale red, microcrystalline, arenaceous; 150 feet thick.

Alaska Bench Formation. Limestone, pinkish gray to pale yellowish brown and pale red, nonporous, micritic, ostracodes common; interbedded shale, grayish red to grayish purple and varicolored; 50 feet thick.

Tyler Formation. Shale and limestone, medium and dark gray to red and varicolored, carbonaceous near base; local sandstone lenses; 200 feet thick.

Mississippian System

Otter Formation. Shale, gray to greenish, variegated near basin edge, carbonaceous, thin-bedded; sandstone, light brown to white, fine to medium grained; limestone, fossiliferous, oolitic, thin-bedded; 200 feet thick.

Kibbey Formation. Siltstone and shale, reddish; large frosted quartz grains in lower part; limestone, white, dense, (excellent marker on geophysical logs); sandstone, reddish, fine to medium grained, rounded; interbedded gypsum; 250 feet thick.

Madison Formation. Limestone, brownish gray to pale yellowish brown and light to medium gray, fine, fragmental, sucrosic to sublithographic, dense, oolitic in part; 2000 feet thick.

Bakken Formation. Shale, black, fissile, carbonaceous, noncalcareous, (gray to reddish or yellowish near basin margin); dolomite, gray, argillaceous;

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siltstone and sandstone, gray, fine-grained, feldspathic, pyritic; 80 feet thick.

Devonian System

Three Forks Formation. Siltstone and shale, greenish gray, grayish orange and grayish red, interbedded and interlaminated, dolomitic, anhytritic; anhydrite interbedding, white; sandstone, fine-grained; siltstone, coarse-grained, locally at the top of the formation ("Sanish Sant"); 150 feet thick.

Birtbear Formation ("Nisku"). Limestone with some dolomite, light gray to medium brownish gray, thick-bedded, finely crystalline, porous, fossiliferous, anhydrite, brownish to medium gray; 100 feet thick.

Duperow Formation. Limestone, gray to grayish brown, microcrystal-line to lithographic, nonporous; dolomite, brown to gray brown, microcrystalline to sucrosic, anhydrotic, porous and permeable; interbedded anhytrite, shale, argillaceous limestone, and dolomite, siltstone, and scattered sand grains; 150 feet thick.

Souris River Formation. Dolomite and limestone, light to dark gray and brownish gray, crystalline to dense, anhydritic, argillaceous or silty in part; siltstone and shale interbedding; 300 feet thick.

Dawson Bay Formation. Limestone, gray to brown, tense, fossil-ferous, argillaceous, silty and sandy near the eastern limit; dolomite, brown, microcrystalline to microgranular, porous; 100 feet thick.

Prairie Formation. Evaporites; potassium and sodium salts interbedded with thin anhydrite bets; potash deposits; 250 feet thick.

Winnipegosis Formation. Limestone and dolomite, dark gray to light yellow brown, crystalline, dense, argillaceous; shale, greenish gray to red, silty, dolonitic; thin anhydrite interbedding; 300 feet thick.

Ashern Formation. Shale, brick red to grayish orange, thin bedded, dolomitic; anhytrite inclusions; 75 feet thick.

Silurian System

Interlake Formation. Dolomite and dolomitic limestone, light brownish gray to light gray, finely crystalline to pelletoital fragmental and microgranular, vuggy porosity, cherty, thin anhydrite interbedding in central basic area; silty and sandy near the base; 1,000 feet thick.

Ordovician-Silurian Systems

Stonewall Formation. Dolomite and limestone, light brownish gray, finely crystalline; thin anhydrite interbedding in central basin area; 110 feet thick.

Ordovician System

Stony Mountain Formation. Dolomite, brownish gray to yellowish brown, finely crystalline; limestone, medium dark gray, fossiliferous; shale, dark gray, calcareous, fossiliferous; thin anhytrite in central basin area; sandy zones near top; 170 feet thick.

Red River Formation. Limestone, mottled yellowish to brownish gray; fragmental, fossiliferous, dolomitic, argillaceous; anhydrite beds; 650 feet thick.

Roughlock Formation. Sandstone and siltstone, light gray, finegrained, calcareous; shale, greenish gray, calcareous, silty; 20 feet thick.

Icebox Formation. Shale, greenish gray, splintery to fissile, waxy, noncalcareous, black phosphate nodules; some sand lenses; 130 feet thick.

Black Island Formation. Sandstone, mottled light gray, fine to medium grained, well rounded to subangular, frosted, quartzose, some pyrite; 110 feet thick.

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Cambrian-Ordovician Systems
   Deadwood Formation. Limestone, light gray, fragmental, slightly glauconitic;
      sandstone, fine to medium grained, quartzose, rounded to subrounded; shale,
      grayish red to greenish and medium gray; 700 feet thick.

Precambrian
   Churchill Province rocks of western North Dakota; syenite, granulite, granite,
      and diabase.
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Bullion Creek and Sentinel Butte Formations

The Bullion Creek Formation (Clayton, 1977) is about 600 feet thick over most of the reservation, and crops out along the Missouri River bluffs near the Four Bears Bridge in the northwest corner of the reservation (Figure 5). In these areas, the Sentinel Butte Formation has been removed by erosion. The Sentinel Butte Formation is about 500 feet thick where it is preserved under the Golden Valley Formation.

The Bullion Creek Formation underlies the western half of North Dakota, much of eastern Montana, and parts of Wyoming and Saskatchewan; it was named after a tributary of the Little Missouri River in Golden Valley County, North Dakota. It corresponds to strata that were formerly known as Tongue River Formation in North Dakota. The Sentinel Butte Formation may be largely restricted to the western half of North Dakota; it was named after Sentinel Butte in Golden Valley County.

The Bullion Creek and Sentinel Butte Formations consist of alternating, nearly horizontal layers of sediment that range from a fraction of an inch to many feet thick. Layers of silt and clay make up about 60 percent of the Sentinel Butte Formation and probably about 80 percent of the Bullion Creek Formation.

Landslides commonly occur in silt and clay of these two formations where slopes are steep. Landslides are common in areas of Sentinel Butte Formation having badlands topography, and to a lesser degree in hilly topography.

Sand layers make up about 35 percent of the Sentinel Butte Formation and perhaps 15 percent of the Bullion Creek Formation. The sand is cohesive and forms a hard, rilled surface where it is exposed along river bluffs. Several sand layers 5 to 50 feet thick occur in the Sentinel Butte Formation; sand layers are generally thinner in the Bullion Creek Formation.

Less than one percent of the Bullion Creek and Sentinel Butte Formations is sandstone, which occurs as lenses or discontinuous layers only a few feet thick. Cementation is by calcium carbonate.

Dense limestone lenses a few feet thick occur throughout the Bullion Creek and to a lesser extent in the Sentinel Butte Formation. The lenses are particularly abundant at the formational contact between the Bullion Creek and Sentinel Butte.

North Dakota lignite occurs primarily in the Ludlow, Bullion Creek, and Sentinel Butte Formations. On the Fort Berthold Reservation several dozen lignite beds from an inch to a few feet thick make up about 3 percent of the formations. Beds 10 to 15 feet thick have been reported in drill hole logs or in mines. They are lenticular and change greatly in thickness within short distances.

The Bullion Creek and Sentinel Butte Formations are distinguished on the reservation primarily by the presence of a thick sand layer at the base of the Sentinel Butte Formation and by their different colors.

Golden Valley Formation

The Golden Valley Formation, named for the town of Golden Valley in Mercer County, occurs on several buttes and ridges in the area between Twin Buttes and Mandaree. It is distinguished from the Sentinel Butte Formation by its much brighter colors, greater amounts of mica and kaolinite clay and lack of thick lignites. The formation has been divided into a lower and upper member (Hickey, 1966).

The lower member consists of three units: 1) a lower gray silt and clay; 2) a middle white or orange clay; and 3) an upper gray silt and clay. The clay is mainly kaolinitic and quartz; small flakes of mica are common. Samples of clay from the middle unit contain between 12 percent and 26 percent alumina, one of the highest grade ceramic clays in North Dakota. The middle unit of the lower member is the source of clay used at the brick plant at Hebron and the sewer-pipe plant at Dickinson.

The upper member consists of a lower sandy unit and an upper clayey unit. The lower unit consists mainly of light brown to gray, crossbedded, fine sand along with some sandstone, silty sand, sandy silt, clayey silt, and silty clay. The sand is largely quartz, but contains considerable mica. Sandstone of the lower unit of the upper member caps the Blue Buttes just west of the reservation, and caps several ridges and buttes on the reservation. The upper clayey unit consists of silty clay, clay, and some clayey silt. The clay layers are tough, waxy bentonite, which is brilliant green or blue beneath the water table. The bentonite quickly oxides to light brown on exposure to air. Some of the bentonite layers are as much as 3 to 5 feet thick.

Cole Harbor Formation

The Coleharbor Formation named for the town of Coleharbor in McLean County, covers about 40 percent of the Fort Berthold Indian Reservation and consists of glacial fill and sand and gravel (Figure 5). It is most widespread north and east of Lake Sakakawea. The formation reaches a maximum thickness of more than 400 feet in the White Shield area and south of New Town (Figure 6) (Bluemle, 1971). Individual layers or lenses of clay, sand, or gravel range is from a few inches to many tens of feet thick and extend horizontally from a few feet to many miles. The formation consists of about 85 percent pebbly, sandy clay; 10 percent sand and gravel, and about 5 percent silt and clay.

One particular body of silt and clay of the Coleharbor Formation is distinctive enough to be described separately. It is best exposed in 50 foot shore bluffs of Lake Sakakawea ¾ mile north of

Crow Flies High Butte (SW¼ SE¼ sec. 11, T. 152 N., R. 93 W.), where it is underlain by cemented gravel of the Coleharbor Formation. It is tan silt and clayey silt in a uniform sequence of hundreds of horizontal layers ½ to 4 inches in thickness. It fills the New Town sag to at least ½ mile southeast of New Town. It is overlain by sand and gravel of the Coleharbor Formation at an elevation of about 2,000 feet in much of the western part of the New Town sag. This body of silt and clay is more than 200 feet thick.

Structure

The Fort Berthold Indian Reserve is about 15 miles east of the center of the Williston Basin which contains approximately 16,000 feet of strata. In the eastern part of the reservation bedrock dips gently westward into the center of the basin, generally at less than 10 feet per mile, although in some small structures dips may exceed 150 feet per mile.

The north-trending Nesson anticline parallels the western boundary of the reservation, passing between the center of the Williston Basin and the western boundary of the reservation (Laird, 1951; Laird and Folsom, 1956) . The Antelope anticline extends southeastward from the Nesson anticline into the northwest corner of the reservation (Figure 7).

Even though much of the reservation is mantled with glacial deposits, it is possible to define certain surface markings, mainly lineaments, on air photos that probably indicate structural relationships. These linear features are largely a reflection of fractures in the underlying rocks and are emphasized by vegetation and topography. Their widespread nature makes them useful for quickly determining major fault trends.

The Antelope anticline, the only structure that currently yields oil on the reservation, may be a drag fold associated with the Bismarck shear zone (Figure 7 and Figure 8). The Four Bears block (so named because Four Bears Bridge is on it) is apparently locked onto the block northeast of the Bismarck shear zone and is being dragged northwestward along with it. This movement is evidently being accommodated by the Antelope terminator fault. The Bullion Creek-Sentinel Butte formational contact can be traced along Lake Sakakawea to the Four Bears Bridge west of New Town where it is well exposed slightly above the bridge abutments. The contact cannot be traced beyond a sag filled with post-Paleocene sediments about six miles south of New Town. Sentinel Butte strata only are present above the reservoir level for several miles south of the sag, and it appears that the contact has been displaced downward along a northwest-trending fault. This terminator fault is evidently the southern end of the Four Bears block. The beds south of the fault are downthrown to fill the gap downward by the more rapid movement of the Four Bears block and the block northeast of the Bismarck shear zone to which it is attached. Glacial till and loess lying on top of the faulted Bullion Creek and Sentinel Butte beds in the fault zone are undisturbed.

MINERAL RESOURCES

General

Petroleum is currently produced in the northwest corner of the reservation. Gravel quarries have been developed in several areas. Lignite, although extensive, has been used only as a local fuel. No metallic mineral deposits are known.

Wells, test holes, and sample localities mentioned throughout this report are numbered according to their location in the public land division system. The first numeral of a given number depicts the township, the second indicates the range, and the third denotes the section number. Lower-case letters indicate the location within a section, that is, the quarter section, quarter-quarter section, and quarter-quarter-quarter section (Figure 9). For example, well 149-94-29abc is in the SW¼ NW¼ NE¼ sec. 29, T. 149 N., R. 94 W. Designations n, s, e, or w are used when location descriptions cannot be further divided into quarters. Consecutive numbers are assigned if more than one locality is within a designated tract.

Energy Resources

Petroleum and Natural Gas

General

Extensive oil exploration began in North Dakota during the late 1940's. Initial discovery, in 1951, was made on the Nesson anticline in Williams County about 50 miles north-northwest of the reservation. Since that time, several fields have been developed in the western part of the state (Figure 10). Oil was first discovered on the reservation on December 6, 1953, with completion of the Pan American Petroleum Corporation Woodrow Starr No. 1 (well 152-94-21dcl, Figure 5). Subsequent development has been concentrated in this same general area, the southern part of the Antelope field. Between 1953 and 1976, 30 wells were drilled which produced nearly 8 million barrels of oil and over 9 billion cubic feet of natural gas (statistics from U.S. Geological Survey, Table 3; the North Dakota Geological Survey reports total oil production as 7.4 million barrels, Table 4). Seventeen wells are in operation (1977), including 12 producing, three water injection, and two salt water disposal. Four wells are shut-in (Figure 11). Production has been from two zones, the Antelope-Madison and the Madison-Sanish (designated the Sanish and Bakken horizons by Storch and Ball, 1972) (Figure 12).

Antelope Field

The producing interval of the Madison Group consists of about 174 feet of fractured, fragmental, and oolitic limestone of the lower Charles and upper Mission Canyon Formations (Figure 12). Top of the pay interval is approximately 9,000 feet below the surface. Average porosity is 4.75 percent. The oil has a gravity of 39.8° API and a Beta factor of 1.687. Reservoir pressure has declined from an initial 4,207 psig to 1,984 psig in June 1976. Development is on 80-acre spacing.

Production from the Sanish zone is from a 20-foot interval of sandstone, siltstone, and shale in the Sanish sand member of the Devonian age Three Forks Formation. Top of the pay interval is about 10,600 feet below the surface. Average porosity is 7.37 percent. Gravity of the oil is 43.8° API; the Beta factor is about 1.1. The initial reservoir pressure was 7,670 psig; as of June 1976, average pressure was 1,293 psig. Development is on 160-acre spacing.

Based on past production and well performance, it has been concluded that "both reservoirs in the Antelope field are under volumetric control" (Folson, Carlson, and Anderson, 1959, p. 34). Both are being depleted.

The Antelope Field is developed on an asymmetric anticline that trends N. 40° W., with either a steeper dipping limb or a fault on the northeast flank of the structure (Figure 8). In either case, the closure of the fold increases with depth, at least down to the Madison, the closure being greater than 10 feet on the Greenhorn Formation and 80 feet on the Madison.

Nitrogen in Gas Fields

Large accumulations of free nitrogen gas are reported in the Nesson anticline area from the Pennsylvanian Minnelusa and Amsden Formations (Marchant, 1966). During earlier years of petroleum development in North Dakota, these accumulations created dangerous situations--blowouts occurred on several drill sites where nitrogen zones having abnormally high pressures were penetrated unexpectedly (Hamke, Marchant, and Cupps, 1966). From a beneficial standpoint, Marchant (1966) concluded that nitrogen reserves in the Antelope field are sufficient to warrant consideration for use in petroleum production operations. Possible uses include gas injection for pressure maintenance, gas lift production of oil and water, inert-gas slug to improve efficiency of waterfloods, and inert-gas blankets to prevent corrosion, vaporization, and explosions in crude or refined petroleum storage facilities.

Exploratory Drilling

In addition to the Antelope field wells, 34 exploratory holes (Figure 4, Table 5) were drilled in the reservation. The most significant oil and gas shows were from drill stem tests in wells 147-98-5cd and 147-93-8bb at the south end of the Antelope field trend. The first well, Carter 1 Edward Lockwood, recovered 415 feet of free oil from the Mission Canyon Formation, 30 feet from the Sanish and Bakken horizon, and 60 feet from the Devonian age Duperow Formation. The second, Miami Oil 1 Hairy Robe Estate, recovered 360 feet of free oil from the Mission Canyon and 425 feet from the Duperow (Storch and Ball, 1972).

As of March 4, 1977, approximately 14,554 acres were under oil and gas lease (Figure 4); several leased areas have not been drilled.

Potential Oil and Gas

The Fort Berthold Indian Reservation is near some of the more productive oil structures in North Dakota. Several discoveries have been made 6 to

12 miles from the reservation in Dunn County (early 1977). These discoveries are in the Ordovician Red River, Silurian Interlake, Devonian Duperow, and Mississippian Madison Formations. Oil is produced from the Madison Formation in the Blue Buttes Field 1 ½ miles west of the reservation; from the Madison and Duperow Formations in the Croff Field 6 miles west of the reservation; and from the Madison Group and Duperow Formation in the Bear Den Field 6 miles west of the reservation.

A well completed in April 1977 in the NW¼ SW¼ sec. 23, T. 152 N., R. 95 W., about 5 miles northwest of the reservation in McKenzie County, had an initial potential production of 2082 barrels of oil per day as well as a large amount of gas. This is the largest production of any well in North Dakota. The well produces from the Silurian.

Most of the wells in the Antelope Field are completed in the Mississippian, although there is some Silurian production in the field off the reservation. As oil is known to occur in Silurian strata, some of the abandoned Mississippian producer or dry holes should be deepened to test the Silurian and also the Ordovician Red River Formation.

In spite of its proximity to North Dakota's major oil production, much of the reservation is completely unexplored with regard to its potential for hydrocarbons. About 26 entire townships do not contain an exploratory well and another 13 have only one well. Most wells have not penetrated deeper than the Mississippian.

Numerous northwest-trending lineations, visible on high- altitude photos and parallel to the Antelope structure, might be indications of subsurface structure.

Gas is produced from the sand in the Pierre Formation on the Cedar Creek anticline in southwestern North Dakota. Pierre sand development is erratic in the reservation area, but in some places, it appears sufficient to warrant further exploration.

Generally, the great depths to potential petroleum-producing horizons, along with the lack of surface geologic expression of potential producing structures, make it necessary to rely on geophysical prospecting to locate new oil fields.

Lignite

General

The lignite field of North Dakota covers about 32,000 square miles in the western part of the state (Figure 13). Lignite-bearing formations underlie all or portions of 29 counties (Ford, Bacon, and Davis, 1951). Brant (1953) estimated that lignite beds at least 2 ½ feet thick are present throughout the area, except for approximately 4,000 square miles bordering the eastern edge of the field. Pollard, Smith, and Knox (1972) estimated 4.1 billion tons of strippable lignite present in the deposits shown in Figure 13.

Sediments exposed in the lignite field range in age from Late Cretaceous to Oligocene. Nearly all minable lignite occurs in the Fort Union Group and most of the estimated reserves are in the Bullion Creek (Tongue River) Formation. The Sentinel Butte Formation also contains beds of lignite although tonnages are relatively small. The noncoal-bearing marine Cannonball Formation of the Fort Union Group grades laterally into the Ludlow Formation which does contain minable lignite beds. An aggregate thickness of lignite beds in Bowman County is 39 feet, 11 inches (Hares, 1928). Because of the limited areal extent of the Ludlow Formation, reserves are small. Formations other than those of the Fort Union Group containing lignite are the Golden Valley and the Hell Creek (Cretaceous) Formations; lignite occurrences in these formations are generally insignificant.

Although there has been no systematic study of the minability of lignite on the reservation, several investigations of the lignite have been made. Reconnaissance studies were made by Wilder (1902) and Smith (1908). Pishel (1912) mapped lignite outcrops on the reservation east of the Missouri River. A similar study of lignite west of the Missouri River was by Bauer and Herald (1921). Lignite beds in the Minot region, adjacent to the eastern segment, were mapped by Andrews (1939). Lignite resources in the state were calculated by Ford, Bacon, and Davis (1951) and Brant (1953). The Brant study provides an excellent summary of earlier investigations. A field reconnaissance of mineral deposits on the reservation was by the U.S. Bureau of Mines (Harrer, 1961). North Dakota Geological Survey county water resource bulletins (Pettyjohn, 1968; Armstrong, 1969; Croft, 1970; and Klausing, 1971 and 1976) have included recent company and individual drill log data.

Occurrence and Distribution

Lignite outcrops have been thoroughly examined (Figure 14); many additional exposures are inundated by waters of Lake Sakakawea. Much subsurface information concerning the occurrence and thickness of beds may be obtained from records of well logs (Figure 15).

Lignite beds are lenticular and may range from a few inches to several feet thick within short distances (the thickest bed encountered, 26 feet, was penetrated by drill hole 147-88-llbaal at a depth of 147 feet). Bauer and Herald (1921) report some outcrops are continuous for 30 miles or more. Beds are essentially flat-lying; nowhere does the dip exceed 2 ½ degrees.

<u>Western segment.</u>--Bauer and Herald (1921) mapped 14 lignite beds (designated A-N) at least 2 feet thick in the western segment. Logs from drill holes support these data. Many holes intersect 10 or more beds and numerous localities in the segment are underlain by 5-foot lignite beds within 100 feet of the surface. These beds constitute strippable reserves in the rolling upland areas.

<u>Southern segment.</u>--Outcrops in the southern segment were also mapped by Bauer and Herald (1921); 13 beds (BB-NN) were found. Bed designations probably correlate with those of the western segment. Lignite beds are thinner than those in the western segment and drill logs commonly show only four to eight beds. Several areas may contain strippable reserves but the thicker beds are probably too deep to be surface-mined.

Eastern segment.--Information on lignite occurrences in this segment is more abundant for the western and southern parts (those lands within the "diminished reservation" boundary) than for the remaining portions which are blanketed by glacial drift. Pishel (1912) mapped five lignite beds 2 ½ feet thick beds 1, la, 2, 2a, and 3, although no more than three beds were found at one locality. Lignite beds greater than 5 feet thick were intersected by most drill holes within the "diminished reservation," often within 100 feet of the surface. Large tonnages of lignite might be present. In the northern and northeastern parts of the segment, glacial drift is more than 300 feet thick locally.

North-central segment.--Glacial cover exceeds 100 feet over most of the area and data pertaining to lignite occurrences are limited. Pishel (1912) mapped beds 1, 2, and 3, in the Missouri River Valley, and several drill logs in the central part of the segment show lignite beds greater than 5 feet thick with less than 100 feet of glacial overburden.

Resources and Reserves

Resource estimates contained in Table 6 have been adapted from Brant (1953) and Harrer (1961). Nearly 18 billion tons of lignite are reported. Although these figures differentiate between thicknesses of lignite beds, they do not consider overburden and, therefore, do not reflect the amount of minable lignite. The reserve base, as defined by the U.S. Bureau of Mines and U.S. Geological Survey (1976), includes beds of lignite 60 inches or more thick which can be surface-mined--generally those that occur at depths no greater than 120 feet. Estimates include only lignite from measured and indicated categories of reliability (Hamilton, White, and Matson, 1975). Most mining operations in North Dakota are working in lignite beds from 8 to 10 feet thick, where overburden is usually from 40 to 80 feet thick (Wiebmer, 1977).

Figure 16 depicts generalized areas where drill holes have intersected lignite beds greater than 5 feet thick within 100 feet of the surface; a continuous thickness of overburden between data points is assumed. For a rapid estimation of the potential reserve base, it was assumed that a 5-foot thickness of lignite, although not necessarily a continuous bed, persists throughout the individual areas outlined in Figure 16. No additional tonnage consideration was given for areas underlain by beds greater than 5 feet thick nor for areas where drill logs report » re than one 5-foot bed. The area underlain by strippable lignite delineated in Figure 16 is about 190,000 acres. The product of this area in acres and the 5-foot assumed thickness, multiplied by 1,760 (the approximate in place weight in short tons of a bed of lignite 1 acre in extent and l-foot thick) suggests a strippable reserve base approximating 1.67 billion tons. More precise reserve estimates might be made from outcrop and drill log data.

Characteristics

Coals of North Dakota are classed by rank as lignite on the basis of physical and chemical properties. They are high in moisture and volatile matter, and low in fixed carbon and heating value compared to other coals. Lignites often slack or disintegrate when exposed to air and, because of the amount of heat generated during oxidation, piles of broken lignite are subject to spontaneous combustion.

Analyses

Average analyses of North Dakota lignite samples are listed in Table 7. The lignite is low in sulfur--less than 1 percent (DeCarlo, Sheridan, and Murphy, 1966). The average ash content of less than 7 percent is lower than ash contained in the average coal produced in the United States (Sheridan, 1976).

Trace Elements in Lignite Ash

Spectrographic analyses (Table 8) indicate the presence of 22 trace elements in detectable concentrations in lignite ash. All samples were from outside the reservation and, because of variability between and within mines sampled, an average composition would be misleading. However, the following generalizations may be useful.

Uranium has been extracted from lignite ash but none of the samples analyzed in Table 8 were radioactive. Germanium has also been recovered from certain coal ash but the amount shown by analysis of the lignite ash is less than 0.003 percent (Corey and others, 1959). Harrer (1961) stated that two samples from within the reservation did not contain economically valuable metals.

When comparing trace element compositions of North Dakota lignites with those from coals of the Eastern Interior region, Zubovic (1973) notes that beryllium, copper, chromium, nickel, and vanadium are lower in the lignites.

Utilization

Coals are utilized primarily in three ways--combustion, gasification, and carbonization. With the exception of a relatively small amount of lignite used for industrial and domestic heating and for the production of charcoal briquets, all lignite mined in North Dakota is used as fuel for powerplants. Future markets may be for electrical generation and industrial applications other than heating.

TABLE 8

Trace Element Content of Lignite Ash*

Element	Minimum range, percent	Maximum range, percent
Silver	0.00001 to 0.0001	0.0001 to 0.001
Boron	0.01 to 0.01	0.1 to 1.0
Barium	0.1 to 1.0	1.0 to 10.0
Beryllium	0.00003 to 0.0003	0.0003 to 0.003
Bismuth	0.00003 to 0.0003	0.0003 to 0.003
Cobalt	0.0003 to 0.003	0.001 to 0.01
Chromium	0.003 to 0.03	0.03 to 0.3
Copper	0.003 to 0.03	0.1 to 1.0
Gallium	0.001 to 0.01	0.01 to 0.1
Germanium	0.00003 to 0.0003	0.0003 to 0.003
Lithium	0.003 to 0.03	0.03 to 0.3
Manganese	0.03 to 0.3	0.1 to 1.0
Molybdenum	0.0001 to 0.001	0.001 to 0.01
Nickel	0.001 to 0.01	0.003 to 0.03
Lead	0.003 to 0.03	0.01 to 0.1
Tin	0.003 to 0.03	0.01 to 0.1
Strontium	0.1 to 1.0	0.3 to 3.0
Vanadium	0.001 to 0.01	0.01 to 0.1
Ytterbium	0.00003 to 0.0003	0.0001 to 0.001
Yttrium	0.0003 to 0.003	0.001 to 0.01
Zinc	<0.001	0.003 to 0.03
Zirconium	<0.0003	0.03 to 0.3

*From Sondreal, Kube, and Elder, 1968. Analyses were semi-quantitative with results reported within tenfold ranges. Analyses cover 14 samples from 8 mines.

TABLE 9

Summary of North Dakota Mine Reclamation Law

Law and date	North Dakota Century Code, Chapter 38-14, Reclamation of Strip Mined Lands, effective January 1, 1970.
Regulating agency	Public Service Commission.
Permit fees	A non-refundable filing fee of $250 plus a refundable fee of $10 per acre or fraction of an acre for all lands included within the permit area which will be affected by mining during the permit term. The $10 per acre fee may be refunded to the operator in the event the operator's application is rejected by the Commission.
Bond requirements	Bond shall be $1,500 for each acre or portion thereof of land to be affected by surface mining for the ensuing year. However, a larger bond may be required if the Commission shall determine that the cost of reclamation may exceed $1,500.

Penalty for failure to comply	Any person who violates the chapter or any permit condition or regulation implementing the chapter, shall be guilty of a misdemeanor and shall also be subject to a civil penalty not to exceed $10,000 per day of such violation.
Reclamation requirements:	
Plan	Required. A reclamation plan in such form and detail as the Commission shall require, covering the land to be affected must be submitted at the time of application for a permit. The operator may not engage in surface mining until Commission approval of the reclamation plan.
Backfilling and grading	The mined area must be backfilled and regraded to the gentlest topography consistent with adjacent unmined landscape elements in order to develop a postmined landscape. Lands outside the permit area affected by road construction and related mining activities shall also be restored.
Soil removal	All soil material within the permit area that is suitable for plant growth must be saved, segregated, and re-spread.
Replanting	The operator shall sow, set out, or plant upon the affected land described in the reclamation plan and map, seeds, plants, cuttings or trees, shrubs, grasses, or legumes as shall be approved in writing by the Commission.
Penalty for failure to reclaim	Reclamation shall be completed within 3 years after termination of the permit term. This reclamation period may be extended from year to year for a period of 5 years. If further extension is necessary to accomplish acceptable reclamation, the Commission shall either make an additional extension or declare forfeiture of the surety bond on such land not satisfactorily reclaimed.
Adverse impact on water supply	If a surface owner's domestic or livestock water supply has been disrupted or diminished in quality or quantity by surface mining operations, the operator shall, at no cost to the surface owner, make such repairs, alterations, or construction as will ensure the delivery to the surface owner of that quality of water available prior to mining.
Substitution of lands	Not permitted.
Mining and reclamation reports	The operator shall submit by October 25 of each year of the permit term, a map showing pit locations with a description of the lands affected.

The most important use of lignite will probably continue to be as fuel for power plants. Special considerations must be given to equipment design because of the high moisture content, difficult pulverization characteristics, and special ash properties of lignite. Lignites are valuable, however, for their unusually low sulfur content.

Lignite has several characteristics that make it a superior fuel for gasification. It is a reactive fuel and will gasify at lower temperatures than other coals. Also, it is noncaking; that is, it does not pass through a plastic range and become soft and sticky when heated as do bituminous coals (Gronhovd, 1973). In the gasification process, lignite is converted to water gas, passed over a catalyst, and, with heat and pressure applied, forms a condensed mixture of hydrocarbon vapors. The types of hydrocarbons depend on the process and catalyst used, but gaseous products are suitable for use as a direct source of energy or as a raw material for the synthesis of chemicals, liquid fuels, or other gaseous fuels. Individual products are recovered by petroleum refining methods (Landis, 1973b). The nation's first commercial coal gasification conversion facility is scheduled to come on line in March 1982. The Lurgi process plant is to be in Mercer County, south of the reservation (Figure 17) and will annually convert 4.5 million tons of lignite into 46 billion cubic feet of high Btu synthetic gas (Wiebmer, 1977).

Since 1972, the U.S. Energy Research and Development Administration (ERDA) has conducted field experiments on in situ gasification at Hanna, Wyoming, in a 25- to 30-foot thick coalbed 400 feet below the surface. The coal is burned in place; low Btu gas, produced by the combustion process, is extracted.

Lignite can be used to produce coke suitable for use in blast furnaces, but the process is not yet economically feasible. There is, however, the possibility that carbonization and briquetting of lignite may achieve a coke substitute for other purposes. The Bureau of Mines (Parry and others, 1953) has conducted considerable research in carbonization of Texas lignite and some work has been done on North Dakota lignite. A commercial lignite carbonization plant has been in operation about 45 miles south of the reservation near Dickinson, Stark County, since about 1928.

Markets

Most consumers of North Dakota lignite are in the state but some are in Minnesota and South Dakota. Although the most economical use of lignite is at minemouth facilities, North Dakota lignite is transported from Gascoyne, Bowman County, to the Big Stone plant near Milbank in Grant County, South Dakota, about 400 miles (Johnson and Middleton, 1974). It is probable that most large lignite consumers are contractually committed and any new development of lignite would necessarily serve new markets. Figure 17 shows planned or proposed energy facilities in western North Dakota.

Transportation

Because lignite is a bulk commodity, the cost of transportation from mine to market accounts for a large part of the price paid by the consumer.

Transporting lignite by water-slurry pipeline methods has not proven feasible; unlike coal, lignite tends to decrepitude excessively during transit and the separation of solids from water at the use point is difficult (Gronhovd, 1973). Barge transport on Lake Sakakawea may be a possibility but the unit train concept is probably the most viable form of haulage.

A Unit train consists of a dedicated set of haulage equipment loaded at one origin, unloaded at one destination each trip, and moving in both directions on a predetermined schedule (Glover, Hinkle, and Riley, 1970). Such a concept permits maximum use of capital equipment and is elastic enough to be applied to a variety of situations and under a variety of conditions. Although sophisticated loading and unloading facilities are required, existing rails are utilized and costs are relatively low. Special cars have been designed for the Big Stone unit trains that feature 100-ton capacity cars equipped with hinged roof covers designed to allow rapid loading and unloading. The roofed design keeps rain or snow out of the cars and also helps retain heat, thus reducing freezing problems. Roofs also prevent windblown loss of lignite and eliminate dusting along the route (Johnson and Middleton, 1974).

Mining Methods

First recorded commercial lignite production was in 1884 from small underground mines. Until 1927, lignite was mined chiefly by the room-and pillar method. Surface mining gradually replaced underground methods and, at present, large-scale open pit or strip mines predominate.

There are several reasons for this change. Foremost is the fact that rocks above and below the lignite beds are soft and unconsolidated. In most underground mines, it was necessary to leave 2 feet or more of lignite in the roof, and in some areas a comparable amount in the floor for support (Brant, 1953). Comparatively large pillars were also necessary, resulting in a low percentage recovery of the lignite. By contrast, current strip mining practice in North Dakota results in about a 90 percent recovery (Pollard, Smith, and Knox, 1972). Development time is shorter and mining hazards are less in surface operations. Surface mining is less labor intensive, percentage recovery is greater, and costs per ton are much lower than those of underground operations.

Environmental Considerations

Environmental aspects of surface mining western coals have received widespread attention from numerous public interest groups. Primary concerns are the effects of mining on an already short water supply and rehabilitation of the land after mining. With adequate engineering and planning, combined with proper safeguards and conscientious reclamation practices, land disturbed by surface mining can be returned to a productive condition.

Developmental Potential

Lignite tonnages on the reservation appear to be adequate to support large-scale development; strippable reserves are probably sufficient for either an electric generating plant or a gasification facility. In situ gasification of deep beds warrants consideration. Lignite as heating fuel for the reservation could be recovered on a smaller scale.

Uranium

Uranium in weakly radioactive lignite was discovered in North Dakota in 1948 by Wyant and Beroni (1950) of the U.S. Geological Survey. In August 1954, lignitic material containing 0.10 percent or more uranium oxide (U_3O_8) was discovered in northwestern South Dakota and by year's end, the ensuing prospecting rush had spread into western and southwestern North Dakota. Exploration continued from 1955 to 1957. During that time, small shipments for test purposes were made from scattered prospects. Experimental work toward development of a suitable extraction process was conducted by the Atomic Energy Commission over a several-year period, and by 1962 contractual agreements were made for mining the uraniferous lignites. Periods of intense mining activity occurred during the mid-1960's; the practice at that time was to either mine the lignite and burn it in kilns, or to burn it in place and then ship the ash to uranium mills for processing. By 1968, lignite mining for uranium in the state had ceased.

Radioactive rocks have been reported in all Tertiary age units in southwestern North Dakota with the exception of the Cannonball Formation (Bergstrom, 1956). Although a few uranium occurrences have been found in claystones, siltstones, and sandstones, impure lignite beds contain most of the uranium deposits discovered in the Williston basin area (Jacob, 1965) (Figure 18).

There is no evidence that uranium ore deposits occur on the Fort Berthold Reservation.

Nonmetallic Mineral Resources

Gravel, Sand, and Clinker

General

Gravel and sand deposits occur in both glacial drift and river terrace (fluvial) deposits. Major use in the Great Plains area is for construction aggregate. Clinker is widely used in southwestern North Dakota as a substitute for gravel in secondary roads and occurs in beds throughout the area. Table 10 lists production statistics from 1964 to 1976.

TABLE 10

Annual Production and Royalties from Gravel Operations on Port Berthold Indian Reservation, 1964-1976

Year	Number of operations	Production (cubic yards)	Royalty value($)
1964	2	69,752	4,883
1965	1	450	36
1966	5	13,958	1,122
1967	4	42,847	4,240
1968	3	10,200	1,020
1969	1	3,000	300
	1*	784*	118*
1970	2	4,726	473
1971	7	44,858	5,621
1972	4	49,947	7,857
1973	1	3,708	742
1974	1	175,000	35,000
1975	1	13,725	2,745
1976			
Total	--	432,955	64,157

*Clinker production

Source: Bureau of Indian Affairs, New Town, North Dakota.

Occurrence and Distributione

Figure 19 shows the location of past sand and gravel pits and quarries. Presumably, substantial reserves remain.

Areas of glacial outwash in T. 148 N., R. 89 W., W ½ secs. 24 and 25, T. 148 N., R. 91 W., and sec. 12, T. 147 N, R. 88 W. are described by Dingham and Gordon (1954). Harrer (1961) delineates significant outwash deposits along Little Shell and other creeks in T. 150 N., R. 92 W., along Lucky Mount Creek in T. 149 N., R. 90 W., and in secs. 9 and 16, T. 152 N., R. 93 W. Gravel and sand also occur in kames and kame terrace deposits in secs. 13, 14, 23, and 24, T. 147 N., R. 91 W. Two morainal areas about 100 feet thick were noted (Harrer, 1961); one in T. 148 N., R. 89 W., covers 10 square miles and another in Tps. 147-147 N., Rs. 90-91 W., covers 3 square miles.

Fluvial deposits occur in many areas along the Missouri River valley and its tributaries. Most in the eastern and southern segments, however, have been flooded by Lake Sakakawea. In the valley of Lucky Mound Creek, T. 149 N., Rs. 89-90 W., a high terrace deposit is one of the largest potential sources of gravel in the eastern segment (Dingham and Gordon, 1954).

Clinker is formed by the baking of shale overlying burning lignite beds although clay, silt, and sand partings within a bed may also be bakehardened or fused. The term "scoria," a volcanic lava fragment, is erroneously used for "clinker" in parts of North Dakota. Clinker and ash beds are common in outcrops along the many creeks as well as in the eroded areas along Lake Sakakawea and the Little Missouri River. The following exposures were reported by Harrer (1961):

T. 151 N., R. 95 W., sec. 24

T. 150 N., R. 95 W., secs. 13 and 24, near west boundary of reservation

T. 150 N., R. 94 W., secs. 9 and 19, along road and Bears Den Creek

T. 148 N., R. 95 W., secs. 22, 23, 27, 34, and 35, which includes the Sams Creek and Little Missouri River drainages

T. 148 N., R. 94 W., secs. 24 and 25, along Moccasin Creek

T. 148, R. 93 W., secs. 19, 20, 21, 27, and 28

T. 147 N., R. 94 W., secs. 6, 8-10, and 14-16, along the Little Missouri River and tributaries

T. 147 N., R. 93 W., secs. 3, 7, 10, 11, 13-18, 20-24, and 26-28, along the Little Missouri River and tributaries

T. 147 N., R. 92 W., secs. 18, 19, and 30, along the Little Missouri River

T. 147 N., R. 91 W., secs. 13, along road

T. 147 N., R. 89 W., secs. 2, 3, 34, 35, and 36, along Six Mile and North Beaver Creeks

T. 146 N., R. 90 W., sec. 3

T. 146 N., R. 89 W., secs. 1, 3, and 11-14, along Beaver Creek and tributaries

T. 146 N., R. 88 W., secs. 7-9, 16, 18

Developmental Potential

Many gravel and sand pits can be developed to supply local needs. Gravel deposits on the reservation have been described as iron-stained and partly clayey with a wide range in material size and sand to gravel proportion. Sand deposits examined (Harrer, 1961) also were "generally of poor quality, clayey, and too remote to be developed." Each deposit must be tested individually.

Clinker, like gravel and sand, may provide a limited source of income. Clinker is suitable for road metal as a substitute for gravel, but the probability of large scale development is low.

Clay

Several types of clay occur on the reservation. Clays are in the Paleocene Bullion Creek and Sentinel Butte Formations, in the Eocene Golden Valley Formation, and in the Pleistocene Coleharbor Formation (Manz, 1953, 1954).

Gray, bentonitic clays of the Bullion Creek and Sentinel Butte Formations are exposed in valleys throughout the reservation. Some of the clay may be of ceramic quality and, locally, the clays are suitable for making brick and lightweight aggregate. The clays have also been tested as possible sources of alumina (Hansen, 1959), but most of them contained only 10 to 15 percent alumina.

The lower members of the Golden Valley Formation consist of light to dark gray, kaolinitic clay with zones of limonitic concretions. The upper part of the lower member is a 4- to 7-foot thick bed of white, sandy, kaolinitic clay which is partly splotched with yellow to orange limonite stains caused by weathering.

Clays of the Coleharbor Formation, found in many places on the reservation, consist of a mixture of sand, gravel, cobbles, and boulders in a clay matrix and have no commercial value. The

U.S. Bureau of Mines tested 28 clay samples from the reservation (Harrar, 1961). Eight were considered to be of no possible value for manufacture of clay products; two might be suitable as bloating clays to make lightweight aggregates; five clays, although not directly usable, could be blended with less plastic clays to make a variety of fire-clay products. Twelve of the clays sampled could be used for the manufacture of structural brick. One clay sample is of intermediate-duty refractory quality and another is of low-duty refractory quality.

All of the sampled clays from the Golden Valley Formation have physical properties suitable for some use in the manufacture of clay products. Clays from the Blue Butte area are suitable for common and structural bricks, sewer pipe, and bloated lightweight aggregate. Golden Valley Formation clays from the southwest corner of the reservation (T. 148 N., R. 95 W.) are suitable for common brick and, when blended with other clays, could be used for stoneware or other heavy clay products. Clays from the Bear Creek-Hans Creek divide area (T. 147 N., R. 92 W.) could be used for such things as common brick or mixed with other clays for structural brick and tile or fire-clay products.

Bullion Creek and Sentinel Butte Formation clays have some potential. Clays from T. 152 N., R. 94 W. could be used for common brick and second-grade structural brick. Clays from T. 150 N., R. 94 W. might be used alone for fire-clay products, but might be blended with other materials. A clay sampled in T. 148 N., R. 94 W. is suitable for structural brick and might be blended with other clays for sewer pipe.

Sentinel Butte Formation clay from T. 150 N., R. 92 W. could be used to add plasticity to other clays and the blend made suitable for structural brick and sewer pipe. Other Sentinel Butte clays from T. 147 N., R. 92 W. could be used to make common brick or possibly a slip clay for glazing the interior of sewer pipe.

Saline Deposits

Halite (NaCl)

Extensive drilling for petroleum in western North Dakota has established the existence of widespread salt (halite, NaCl) deposits (Anderson and Hansen, 1957). Ten salt beds occur at depths between 6,000 and 14,000 feet (Harrer, 1961). Figure 21 shows the relative stratigraphic position of salt beds underlying the reservation.

The entire reservation is underlain by at least four salt beds and in the western segment all 10 salt beds are present. Their composite thickness exceeds 650 feet. Areal extent and thickness of each bed is indicated in Figure 22a and Figure 22b.

Salt beds underlie hundreds of square miles and could probably be developed for most industrial requirements. Salt beds are of varying purity and detailed studies would be required to establish quality and quantity of the deposits. Salt is currently mined by solution methods near Williston; this operation would compete with any future salt development on the reservation. A Missouri River Basin Study of the reservation's resources and development potential (Bureau of Indian Affairs, 1971) states that "the salt deposits may well become an important mineral resource and their potential for development would be better served if more information were available to the public."

Potash

Deposits of the mineral sylvite (potassium chloride, KCl), or more Correctly, sylvinite (a mixture of sylvite and halite), are in the Devonian Prairie Formation. Potash, a general term for potassium compounds, is used in this report rather than the mineralogical terms. Carlson and Anderson (1966) mapped six potash zones with an aggregate thickness of more than 40 feet in the Williston basin along the Canadian border.

S. B. Anderson (written commun., 1977) identifies three potash members in the reservation at a depth of about 11,000 feet (Figure 23). The Esterhazy, the lowest member of the sequence, is about 25 to 30 feet below the Belle Plain Member. Approximately 100 feet separate the Belle Plain Member from the Mountrail, the highest member. Both the Esterhazy and Belle Plain Members have been correlated stratigraphically with potash zones in Saskatchewan, Canada. The Mountrail Member may be equivalent to the Patience Lake Member in Canada but has not been traced across the border from North Dakota. Much of the data pertaining to the potash beds of the reservation have been gained from gamma ray well log interpretation rather than from drill core and, hence, the quality of the potash has not been established. Potash beds within the members mined in Saskatchewan contain between 25 and 40 percent K_2O (Anderson, 1964a).

Deposits are too deep to be mined by conventional methods but solution mining of potash, similar to the method of salt recovery at the Williston operation, has proven successful in Utah and Saskatchewan. Depth of the North Dakota potash may be an advantage in solution recovery; increased temperatures and pressures are advantageous for differential solution of potash and the salts with which they are associated (Carlson and Anderson, 1966). Increase in demand for potash in the future may make utilization of reservation deposits economically feasible (Bureau of Indian Affairs, 1971).

Leonardite

Leonardite, a soft, earthy, coal-like substance, occurs with most lignite outcrops in North Dakota. Leonardite has been developed commercially on a small scale for use as a dispersant, for viscosity control in oil-well drilling muds, as a stabilizer for ion-exchange resins in water treatment, and as a water-soluble, brown stain for wood finishing. Because the constituents are humic acids, experimental work has been conducted on a potential use as soil conditioner and fertilizer (Fowkes and Frost, 1960).

There is no published information concerning quality or quantity of leonardite on the reservation. In general, deposits are usually from 1 to 6 or 8 feet thick under a shallow, porous cover. Quality may range widely from one locality to another, sometimes grading into beds of unaltered lignite (Fowkes, 1973).

RECOMMENDATIONS FOR FURTHER WORK

Some methods of exploration for additional oil and gas reserves include: 1) deepening existing test holes to the Silurian or possibly to the Ordovician Red River Formation, both of which show promise of being major producers in the region; 2) reevaluating test holes which penetrate the Pierre to find gas-bearing strata that may have been overlooked earlier as well as additional testing of the Pierre; 3) encouraging intensive geophysical prospecting; and especially 4) encouraging additional test drilling.

Lignite probably affords the greatest potential source of Tribal income. A large potential exists in many parts of the reservation, but with possible exception of lands explored in T. 148 N., R. 88 W., and T. 147 N., Rs. 87 and 88 W., lignites remain essentially uncorrelated and areas of recoverable reserves are not well defined. An accurate assessment of the lignite reserves is essential to long-range planning.

A comprehensive survey should be instituted involving correlation and surface mapping of the economically important lignite beds. Additional drilling (probably to depths less than 200 feet) may be required in certain areas to supplement mapping. If suitable deposits of clinker, clay, or sand and gravel can be found, local industry might be developed.

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Table 3. - Annual production and royalties from petroleum and natural gas, Fort Berthold Indian Reservation, North Dakota

Year	Petroleum Quantity (barrels)	Petroleum Production value ($)	Petroleum Royalty value ($)	Natural gas Quantity (MCF)	Natural gas Production value ($)	Natural gas Royalty value ($)
1954	76,896	162,329	20,291	22,816	2,282	285
1955	105,669	282,547	39,371	54,146	5,415	677
1956	142,126	383,456	56,991	36,801	3,652	457
1957	237,382	741,949	94,525	101,395	10,155	1,269
1958	457,297	1,424,044	178,006	105,231	11,978	1,497
1959	597,606	1,760,570	220,071	260,567	26,072	3,259
1960	624,212	1,840,668	230,084	515,233	43,166	5,396
1961	580,913	1,709,236	213,657	553,978	38,670	4,834
1962	593,589	1,749,874	218,734	644,690	49,928	6,241
1963	542,307	1,595,805	201,541	665,755	56,065	7,077
1964	637,586	1,695,657	213,951	653,170	38,713	4,869
1965	511,351	1,589,520	200,881	564,485	37,368	4,729
1966	514,662	1,469,955	185,876	522,241	42,588	5,377
1967	457,027	1,290,590	163,820	587,550	44,684	5,617
1968	462,813	1,408,824	179,422	1,207,792	76,891	9,642
1969	280,550	863,018	109,777	717,444	57,751	7,220
1970	215,807	669,027	85,474	459,806	40,639	5,081
1971	192,051	640,892	81,951	389,189	33,667	4,213
1972	189,459	633,008	80,926	221,834	39,036	4,906
1973	167,098	624,950	79,946	209,607	38,728	4,844
1974	161,007	832,623	106,360	267,425	51,045	6,383
1975	129,750	695,377	89,001	164,529	33,370	4,174
1976	103,259	603,839	77,344	186,697	44,253	5,551
Total	7,980,417	24,667,758	3,128,000	9,112,381	826,116	103,598

Source: U.S. Geol. Survey, Conservation Div., Oil and Gas Leasing Br., Casper, Wyoming (written commun., 1977)

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Table 4. - Cumulative petroleum production by well, Fort Berthold Indian Reservation, North Dakota[1/]

Well number	Name	Production history	Status[2/]	Cumulative production[3/] (barrels)	Producing horizon
152-95-12ca	F514	March 1959 - July 1967	W.I.	121,486	Madison
152-95-12dd	G513	July 1958 - Present	Prod.	142,210	do.
152-94-18bb	H512	August 1957 - Present	Prod.	162,130	do.
152-94-18cd	I509D	--	S.W.D.	3,921	do.
152-94-7ca	I514	December 1956 - July 1973	S.I.	235,396	do.
152-94-18da	J510	January 1959 - January 1966	W.I.	71,324	do.
152-94-18ab	J512	June 1957 - Present	Prod.	364,257	do.
152-94-7db	J514	February 1957 - July 1971	S.I.	146,903	do.
152-94-18ad	K511	July 1958 - March 1967	W.I.	129,778	do.
152-94-7dd[4/]	K513	July 1957 - Present	Prod.	482,836	do.
	(Price Lewis Unit 1)	April 1957 - July 1968	P. & A.	300,607	Sanish
152-94-17bb	L512	September 1957 - Present	Prod.	252,334	Madison
152-94-8cb[4/]	L514	November 1957 - June 1974	S.I.	187,512	do.
	(Daniel Hopkins 1)	January 1957 - August 1968	P. & A.	442,202	Sanish
152-94-17bd[4/]	M511	May 1957 - Present	Prod.	280,012	Madison
	(Harvey A. Hopkins)	February 1958 - December 1970	P. & A.	160,779	Sanish
152-94-17db	N510	July 1957 - December 1976	P. & A.	63,585	Madison
152-94-22cc	Dora Hopkins 1	March 1955 - August 1968	P. & A.	151,631	Sanish
152-94-27cb	Drags Wolf 1	December 1966 - Present	Prod.	57,047	do.
152-94-27bc	Drags Wolf Heirs 1	July 1959 - February 1977	P. & A.	60,380	do.
152-94-21bc	Ella Many Ribs 1	September 1956 - December 1966	Prod.	199,540	do.
152-94-21cc	Ella Many Ribs "A" 1	February 1957 - Present	Prod.	94,363	do.
152-94-17dc	Gilbert T. Rhode 1	December 1956 - September 1965	P. & A.	28,018	do.
152-94-17ab	Harvey A. Hopkins 3	May 1958 - Present	Prod.	928,063	do.
152-94-16bc	Harvey A. Hopkins "B" 1	January 1959 - August 1968	P. & A.	122,594	do.
152-94-7cb	Helen G. Price 3	September 1957 - September 1957	S.I.	62	do.
152-94-21ac	K. Hopkins 1	December 1957 - May 1977	P. & A.	488,451	do.
152-94-28ac	Louis Drags Wolf 1	June 1955 - January 1974	P. & A.	167,971	do.
152-94-28bc	New Year Many Ribs 1	November 1954 - August 1968	P. & A.	38,305	do.

Continued

Table 4. - Cumulative petroleum production by well, Fort Berthold Indian Reservation, North Dakota[1]
(continued)

Well number	Name	Production history	Status[2]	Cumulative production[3] (barrels)	Producing horizon
152-94-16cc	Rose Hopkins Hand 1	August 1958 - Present	Prod.	468,665	Sanish
152-94-16dc	Rose Hopkins Hand 2	April 1959 - November 1971	S.W.D.	137,489	do.
152-94-21dc1	Woodrow Starr 1	December 1955 - July 1958	P. & A.	279,254	do.
152-94-21dc2	Woodrow Starr 1-A	October 1958 - Present	Prod.	662,682	do.
				7,431,787	

1/ Source: North Dakota Geological Survey--Official oil production statistics (September 1976).
2/ Status as of August 22, 1977. Abbreviations used: P. & A., plugged and abandoned; Prod., producing; S.I., shut in; S.W.D., salt water disposal; W.I., water injection.
3/ Production as of July 1, 1976.
4/ Dual production reported.

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Table 5. - Petroleum exploratory wells, Fort Berthold Indian Reservation, North Dakota[1/]

Well number	Lease name	Total depth (feet)	Completion date	Formation Name	Formation Depth (feet)	Depth to first salt (feet)	Core descriptions and test results
152-93-16bb	F-11-16-I	12,540	6-16-66	Mission Canyon	9,100		D.S.T. (drill stem test) - recovered 536' mud; 242' water cut mud; no core.
152-90-30bb	1 Stolpman	8,345	9-15-69	Midale	7,915		D.S.T. - recovered 364' mud cut salt water; 1,536' salt water; no core.
152-88-19bc	1 Spletstoser	7,778	11-16-60	--	--		No cores or tests.
152-87-28bc	1 A. J. Rensch	7,390	7-29-73	State A	7,156		Core recovered 5' anhydrite; 9' dolomite and limestone; 46' anhydrite.
151-94-29cc	1 Bull's Eye	9,627	5-7-65	Mission Canyon	9,320		D.S.T. - recovered 1,500' mud; 18' mud cut salt water; 630' very slightly gas cut black sulfur water.
151-94-19dc	1 T. Yellowface	11,405	3-25-60	Mission Canyon	9,152		Zones 1, 4 - unsuccessful production tests.
				Sanish	10,717		Spotty fluorescence; odor; D.S.T. - 40' oil/gas cut mud; production tests unsuccessful.
				Duperow	11,043		360' oil/gas cut mud; 4,450' salt water.
151-94-17cc	1 Heart Heirs	9,330	11-19-65	Mission Canyon	9,010		Zone 1 - salt water only; Zone 4 - 135' gas/oil cut salt water; Zone 5 - black sulfur water.
151-94-10ad	1 Drags Wolf	11,100	3-20-70[2/]	Mission Canyon	8,829	6,180	Zones 3, 4 - 2' free oil; 180' oil/gas cut mud; 700' oil/gas cut salt water.
				Sanish	10,432		No tests
				Duperow	10,756		Salt water only.
151-94-10bb	1 Drags Wolf	12,209	2-1-69	Bakken	10,300		D.S.T. - recovered 40' gas cut mud.
				Sanish	10,421		No test.
				Duperow	10,735		No test.
				Interlake	--		D.S.T. - 246' salt water.
151-93-10aa	1 Johnson	11,472	11-13-64	Bakken	10,603		D.S.T. - 34' mud. No cores.
151-90-34cb	1-34 Wahner	11,530	3-19-73	Bakken	9,706		D.S.T. - recovered 300' mud.
151-90-28dd	1 Vorwerk	13,253	4-23-68	Nesson	8,270		D.S.T. - recovered 110' muddy water; 307' black sulfur water; no core.
151-90-13ba	1 Bartelson	8,606	3-21-68	Charles Salt	7,516		D.S.T. - recovered 80' mud; no core.
				Mission Canyon	8,088		D.S.T. - recovered 130' black sulfur water.

Continued

Table 5. - Petroleum exploratory wells, Fort Berthold Indian Reservation, North Dakota[1/] (continued)

Well number	Lease name	Total depth (feet)	Completion date	Formation Name	Formation Depth (feet)	Depth to first salt (feet)	Core descriptions and test results
151-88-26ca	1-A McGuire	7,800	3-14-73	Charles	7,044		D.S.T. - recovered 623' mud.
151-88-21cd	1-A Walsh	7,860	12-10-74	Glenburn	7,759		Cored 7,650'-7,770' recovered 60' anhydrite; 6' anhydrite; 2' limestone; 10' anhydrite and dolomite; 30' anhydrite; 4' limestone; 4' limestone; no porosity, permeability; no tests.
151-88-20bd	1 Zieman	7,900±	11-8-75	--	--		Data is held "tight" at this time.
151-88-18bd	1-A Chinberg	7,940	12-26-73	Sherwood	7,788		D.S.T. - recovered 450' gas; 460' gas and slightly mud cut water; 2,255' gas cut black salt water.
151-88-8da	1-A Wells	7,859	10-15-74	--	--		D.S.T. - 7,472'-7,499'; recovered 660' muddy water; 192' salt water; no core. Tops held "tight."
150-94-33cb	1 Rabbit Head	11,630	12-21-64	Mission Canyon	9,420		Zones 3-5 - 270' gas cut muddy salt water.
				Sanish	10,962		25' mud.
150-94-30ab	1 L. Bird's Bill	10,811	9-13-59	Mission Canyon	9,190	6,340	Zone 3 - 3,330' black sulfur salt water.
				Sanish	10,962		Spotty oil staining; poor to fair porosity; drill stem and production tests unsuccessful.
150-94-20cd	1 Mathew's	9,564	1-20-57	Mission Canyon	9,100	6,290	D.S.T. - Zone 1 - 310' mud.
150-93-4bd	1 Ft. Berthold "A"	12,612	10-1-66	Duperow	11,072		D.S.T. - salt water only.
				Souris River	11,450		D.S.T. - salt water only.
150-92-9ba	1 J. Dancing Bull	11,280	9-5-60	Mission Canyon	8,738		D.S.T. - salt water only.
				Nisku	10,388		D.S.T. - salt water only.
				Duperow	10,790		D.S.T. - salt water only.
150-88-29dd	1 Myrtle Jorgenson	7,930	2-2-76	Midale	7,560		D.S.T. - 25' mud; 180' salt water cut mud.
149-93-24ac	F-34-24-P	11,331	9-30-54	Mission Canyon	9,033	7,150	Zones 1, 2 - dead oil residue at horizontal breaks in core.
				Sanish	10,598		No shows in core; D.S.T. - gas cut muddy water; production tests unsuccessful.
				Duperow	10,943		Solid crystalline salt in core; D.S.T. - gas cut salt water.
149-91-22bd	F-22-22-1	13,481	5-8-55	Mission Canyon	8,656	8,365	Zones 4, 5 - scattered oil staining, porosity; D.S.T. - Zone 6 - unsuccessful.
				Sanish	10,076		Scattered pinpoint porosity; D.S.T. - 100' mud.
				Duperow	10,400		D. S. T. - 210' salt water with slight show of oil; no deeper commercial hydrocarbons present.

Continued

Table 5. - Petroleum exploratory wells, Fort Berthold Indian Reservation, North Dakota[1/] (continued)

Well number	Lease name	Total depth (feet)	Completion date	Formation Name	Formation Depth (feet)	Depth to first salt (feet)	Core descriptions and test results
149-90-5ab	1 Wolf	8,650	8-27-56	Mission Canyon	8,326	6,076	D.S.T. - 300' mud; 435' salt water.
148-90-1ab	1 Youngbear	8,595	2-16-68	Mission Canyon	8,006		D.S.T. - 1,754' slightly oil/sulfur cut salt water; 1,036' slightly sulfurous water.
148-89-30bd	1-A Delaittre-Jones	8,240	11-12-73	Sherwood	8,060		Core recovered 60' anhydrite. No other tests.
147-93-8bb	1 H. Robe Estate	13,780	10-10-70	Mission Canyon Sanish Duperow	9,016 10,534 10,850		D.S.T. - 8,400' gas; 360' oil/gas cut salt water. D.S.T. - 2,294' slightly oil cut mud. D.S.T. - 608 Mcfpd; 730' gas; 425' free oil; 285' salt water. No core.
147-93-8dc	1 Bad Gun	9,700	4-5-61	Mission Canyon	8,945		D.S.T. - 455' muddy salt water; 93'salt water.
147-93-5bc	1 E. Lockwood	9,207	10-5-56	Mission Canyon	9,021	6,900	Zones 3, 4 - slight oil staining; vertical fractures; 21' vugular porosity.
147-93-5cd	1 E. Lockwood	11,104	10-9-54	Mission Canyon Bakken Duperow	8,940 10,388 --		Zone 3 - 415' free oil; production tests unsuccessful. D.S.T. - 30' free oil; 400' oil/gas cut mud; completion unsuccessful. 60' free oil; 350' gas cut salt water.
146-91-11cb	1 Benson	9,562	4-22-55	Mission Canyon	8,534	6,240	D.S.T. - 270' mud; 810' black sulfur water.

1/ All data current to July 21, 1977; all wells are plugged and abandoned.
2/ This well was originally completed January 4, 1956, re-entered on February 28, 1970, and re-completed on date shown. The original drill stem tests were negative, except for 40' of very slightly gas cut mud in the Bakken and Sanish horizons.

Source: Petroleum Information Well Tickets, Denver, Colorado; Storch and Ball, 1972.

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Table 6. - Estimated lignite resources, Fort Berthold Indian Reservation, North Dakota[1/]
(million short tons)

Township, range	Measured 2.5 - 5	Measured 5 - 10	Measured 10+	Indicated 2.5 - 5	Indicated 5 - 10	Indicated 10+	Inferred 2.5 - 5	Inferred 5 - 10	Inferred 10+
				(bed thickness in feet)					
T. 152 N., R. 95 W.	1.5	0.1	--	4.5	--	--	81.8	--	--
T. 152 N., R. 94 W.	.5	6.5	--	83.9	10.9	--	294.3	--	--
T. 152 N., R. 93 W.	2.4	1.0	0.1	8.8	.5	2.6	16.0	0.2	--
T. 152 N., R. 92 W.	13.1	6.8	8.0	--	40.3	10.2	11.0	5.5	--
T. 152 N., R. 91 W.	5.9	3.8	37.0	6.4	22.9	76.1	110.6	7.3	--
T. 152 N., R. 90 W.	2.8	4.9	6.3	8.5	33.1	31.3	94.2	4.6	--
T. 152 N., R. 89 W.	2.8	--	--	14.5	--	--	119.0	--	--
T. 152 N., R. 88 W.	--	--	--	--	--	--	174.4	--	--
T. 152 N., R. 87 W.	--	--	--	--	--	--	30.3	52.0	--
T. 151 N., R. 95 W.	.7	.2	--	9.9	3.2	--	79.2	3.9	--
T. 151 N., R. 94 W.	48.8	82.9	--	100.5	227.2	--	66.8	151.4	--
T. 151 N., R. 93 W.	4.2	28.7	4.6	32.0	46.5	--	112.6	--	--
T. 151 N., R. 92 W.	6.5	--	--	27.2	--	--	121.1	--	--
T. 151 N., R. 91 W.	9.0	--	--	8.3	--	--	33.9	--	--
T. 151 N., R. 90 W.	3.6	--	--	20.5	--	--	90.0	--	--
T. 151 N., R. 89 W.	--	--	--	--	--	--	98.2	--	--
T. 151 N., R. 88 W.	--	--	--	--	--	--	227.5	--	--
T. 151 N., R. 87 W.	--	--	--	--	--	--	64.1	72.0	--
T. 150 N., R. 95 W.	.4	1.6	--	4.2	8.8	9.7	76.0	7.3	--
T. 150 N., R. 94 W.	33.7	154.0	--	86.9	347.2	--	178.2	72.0	--
T. 150 N., R. 93 W.	76.1	3.1	--	61.9	15.9	--	83.5	.9	--
T. 150 N., R. 92 W.	25.0	--	--	35.5	--	--	6.6	--	--
T. 150 N., R. 91 W.	.3	--	--	--	--	--	.6	--	--
T. 150 N., R. 90 W.	2.0	--	--	21.5	--	--	76.5	--	--
T. 150 N., R. 89 W.	--	--	--	--	--	--	145.7	--	--
T. 150 N., R. 88 W.	--	--	--	--	--	--	283.0	13.9	--
T. 150 N., R. 87 W.	--	--	--	--	4.2	--	22.2	115.3	--
T. 149 N., R. 95 W.	.3	--	--	5.6	.1	--	108.7	1.0	--
T. 149 N., R. 94 W.	10.9	1.9	--	90.4	1.3	--	1,019.2	41.7	--
T. 149 N., R. 93 W.	28.5	--	--	171.6	9.5	--	702.9	115.8	--

Continued

Table 6. - Estimated lignite resources, Fort Berthold Indian Reservation, North Dakota[1/] (continued)
(million short tons)

Township, range	Measured 2.5 - 5	Measured 5 - 10	Measured 10+	Indicated (bed thickness in feet) 2.5 - 5	Indicated 5 - 10	Indicated 10+	Inferred 2.5 - 5	Inferred 5 - 10	Inferred 10+
T. 149 N., R. 92 W.	86.6	--	--	135.3	--	--	373.8	--	--
T. 149 N., R. 91 W.	26.5	--	--	110.9	--	--	248.3	--	--
T. 149 N., R. 90 W.	2.3	1.1	--	4.8	--	--	18.4	--	--
T. 149 N., R. 89 W.	--	--	--	--	--	--	176.7	--	--
T. 149 N., R. 88 W.	--	--	--	--	6.9	--	253.4	57.0	--
T. 149 N., R. 87 W.	--	8.0	--	--	63.9	--	50.4	54.3	--
T. 148 N., R. 95 W.	3.2	3.8	--	18.5	13.7	--	532.3	.1	--
T. 148 N., R. 94 W.	5.8	.3	--	110.3	20.7	--	1,296.5	28.7	--
T. 148 N., R. 93 W.	45.8	.9	--	87.6	--	--	902.3	--	--
T. 148 N., R. 92 W.	28.0	4.0	--	67.2	1.1	--	511.3	--	--
T. 148 N., R. 91 W.	2.5	--	--	6.5	--	--	35.6	--	--
T. 148 N., R. 90 W.	.7	--	--	6.1	--	--	23.1	--	--
T. 148 N., R. 89 W.	2.2	16.8	--	40.1	26.3	--	197.3	--	--
T. 148 N., R. 88 W.	--	--	--	30.8	--	--	246.9	14.9	--
T. 147 N., R. 94 W.	10.3	8.3	12.5	31.1	51.3	10.7	229.8	28.1	--
T. 147 N., R. 93 W.	68.0	10.5	--	177.4	8.7	--	388.9	7.9	--
T. 147 N., R. 92 W.	64.8	3.5	--	115.7	13.0	--	296.7	3.8	--
T. 147 N., R. 91 W.	21.2	--	--	188.7	--	--	711.3	--	--
T. 147 N., R. 90 W.	8.6	--	--	48.7	--	--	206.0	24.1	--
T. 147 N., R. 89 W.	4.2	17.0	--	20.8	18.3	--	15.9	54.4	--
T. 147 N., R. 88 W.	5.6	2.0	--	15.9	1.8	--	28.6	4.5	18.2
T. 147 N., R. 87 W.	6.7	4.8	--	19.4	11.9	--	3.2	--	24.9
T. 146 N., R. 92 W.	21.8	14.0	--	45.0	54.0	--	407.0	37.8	--
T. 146 N., R. 91 W.	.6	.1	--	12.1	5.9	--	369.1	--	--
T. 146 N., R. 90 W.	--	--	--	1.9	--	--	283.6	16.6	--
T. 146 N., R. 89 W.	1.5	2.3	--	13.0	25.9	--	167.9	114.7	--
T. 146 N., R. 88 W.	.5	1.0	2.0	3.3	2.1	8.3	15.6	6.9	29.1
Totals..........	696.4	393.9	70.5	2,113.7	1,097.1	148.9	12,518.0	1,118.6	72.2

Estimated total lignite resources....... 18,229.3

1/ Adapted from Brant (1953) and Harrer (1961).

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Table 7. - Average analyses of lignite samples, as received, western North Dakota

Number of samples	Number of counties	Proximate Analyses (percent)				Ultimate Analyses (percent)					Heating value (Btu/lb)	Source
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Sulfur	Oxygen		
4	1	37.5	26.7	29.4	6.4	7.0	40.1	0.7	0.5	45.4	6,798	Allen and Parry, 1954
102 1/	17	37.5	26.4	28.4	8.9	--	--	--	1.4	--	6,727	Aresco, Haller, and Abernethy, 1960
9	9	36.4	26.6	30.2	6.7	--	--	--	.7	--	6,990	Fieldner, Rice, and Moran, 1942
2,925	21	35.2	--	--	6.8	--	--	--	.4	--	7,030	Hamilton, White, and Matson, 1975
212	6	37.2	26.3	30.3	6.2	6.9	40.7	.6	.6	45.0	6,890	Sondreal, Kube, and Elder, 1968

1/ Average based on arithmetic mean as calculated from moisture-free values.

Numbers may not total 100 due to independent rounding.

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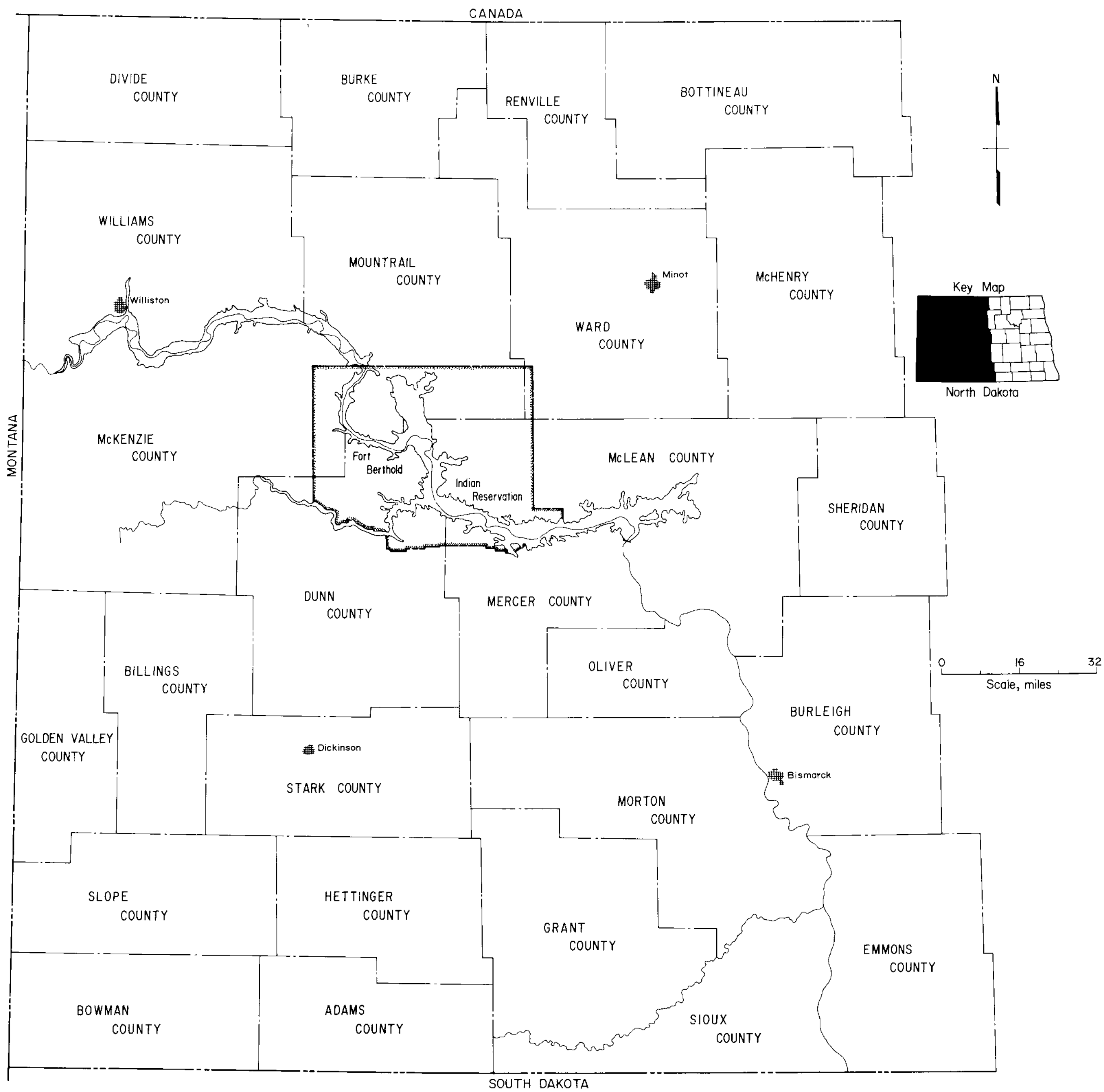

Figure 1. Index map of Fort Berthhold Indian Reservation, North Dakota.

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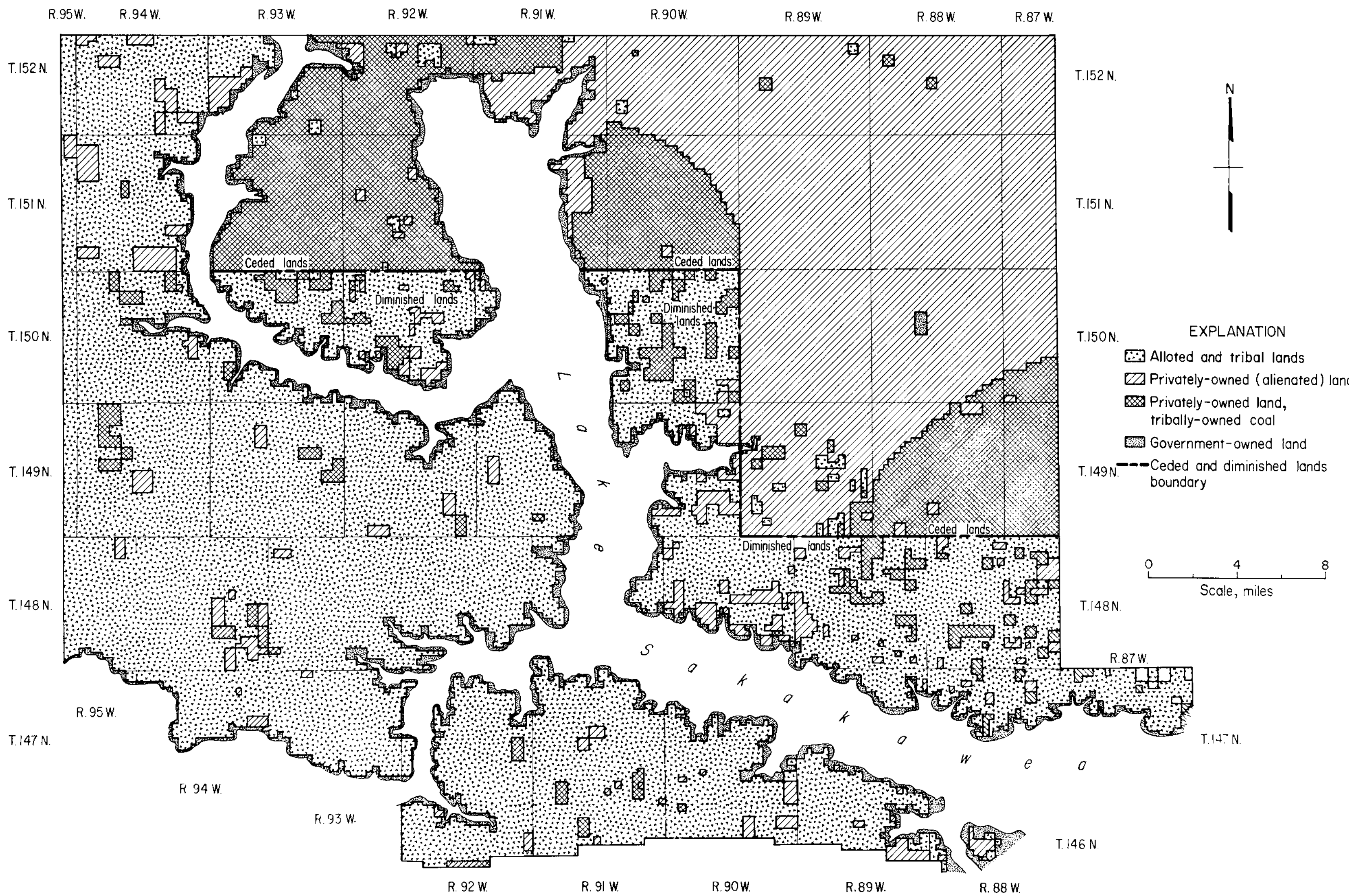

Figure 2. Map showing land and mineral ownership status, Fort Berthold Indian Reservation, North Dakota.

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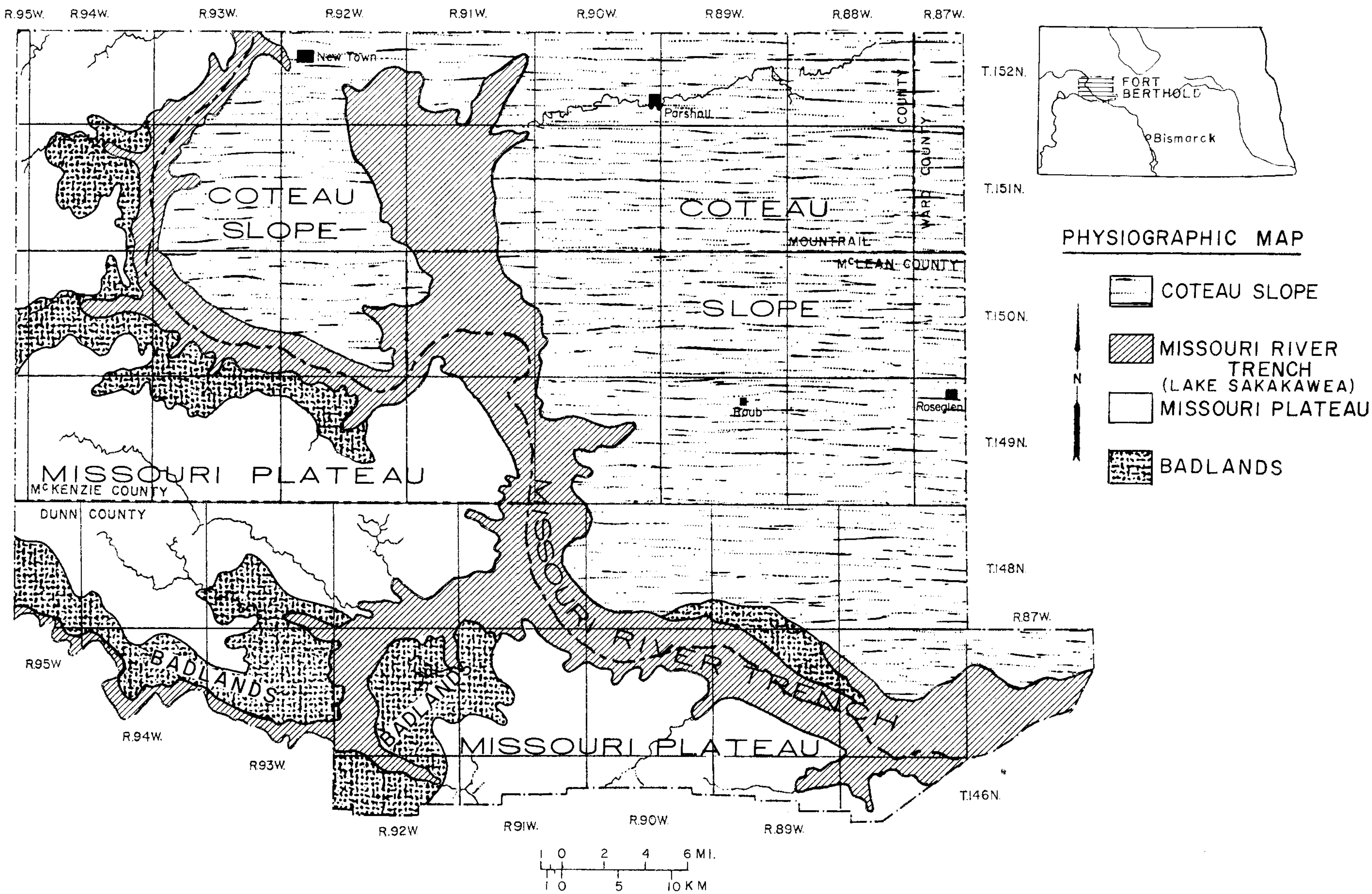

Figure 3. Physiographic map of the Fort Berthold Indian Reservation.

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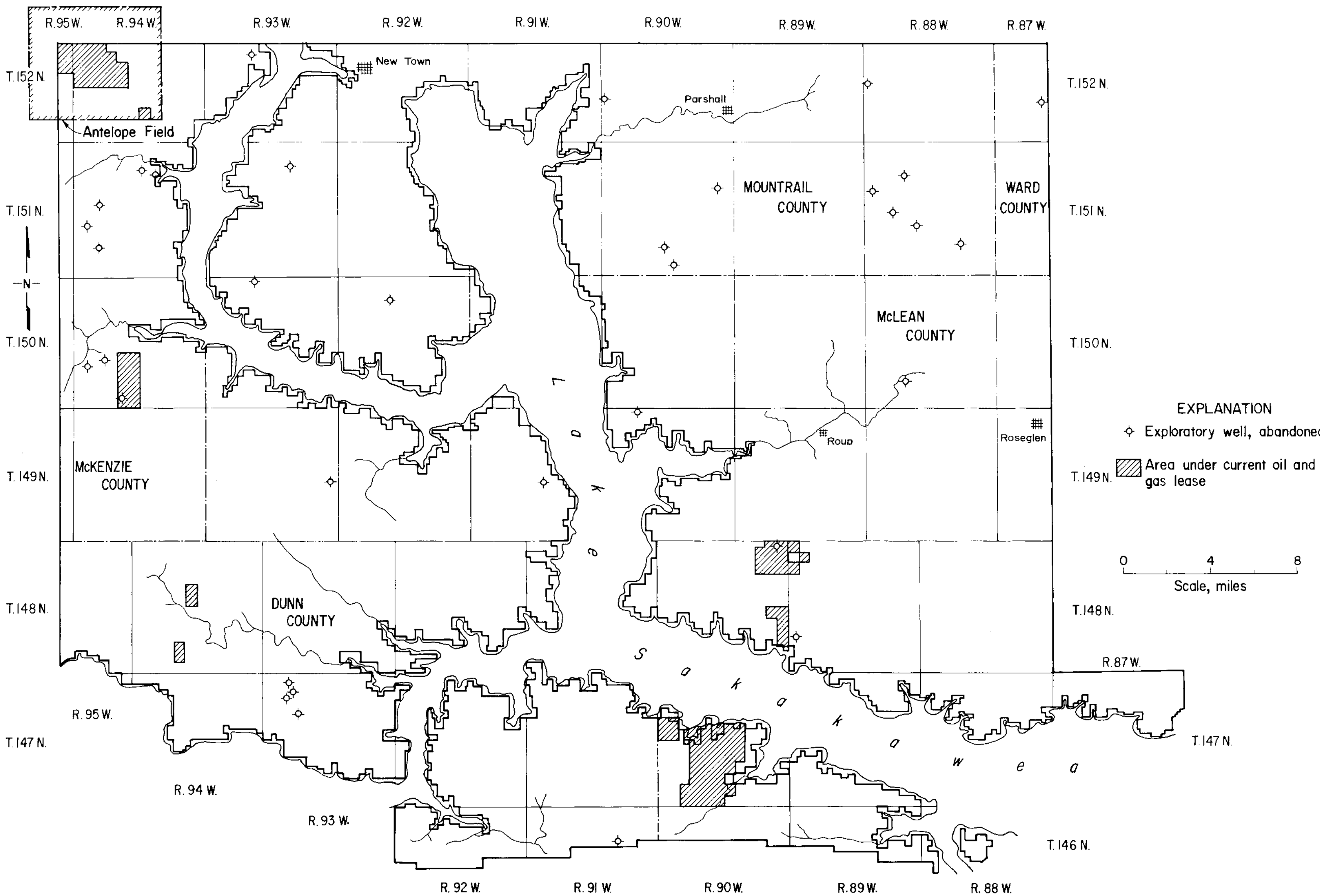

Figure 4. Map showing locations of petroleum exploratory wells and current leasing status, Fort Berthold Indian Reservation. (adapted from Storch and Ball, 1972)

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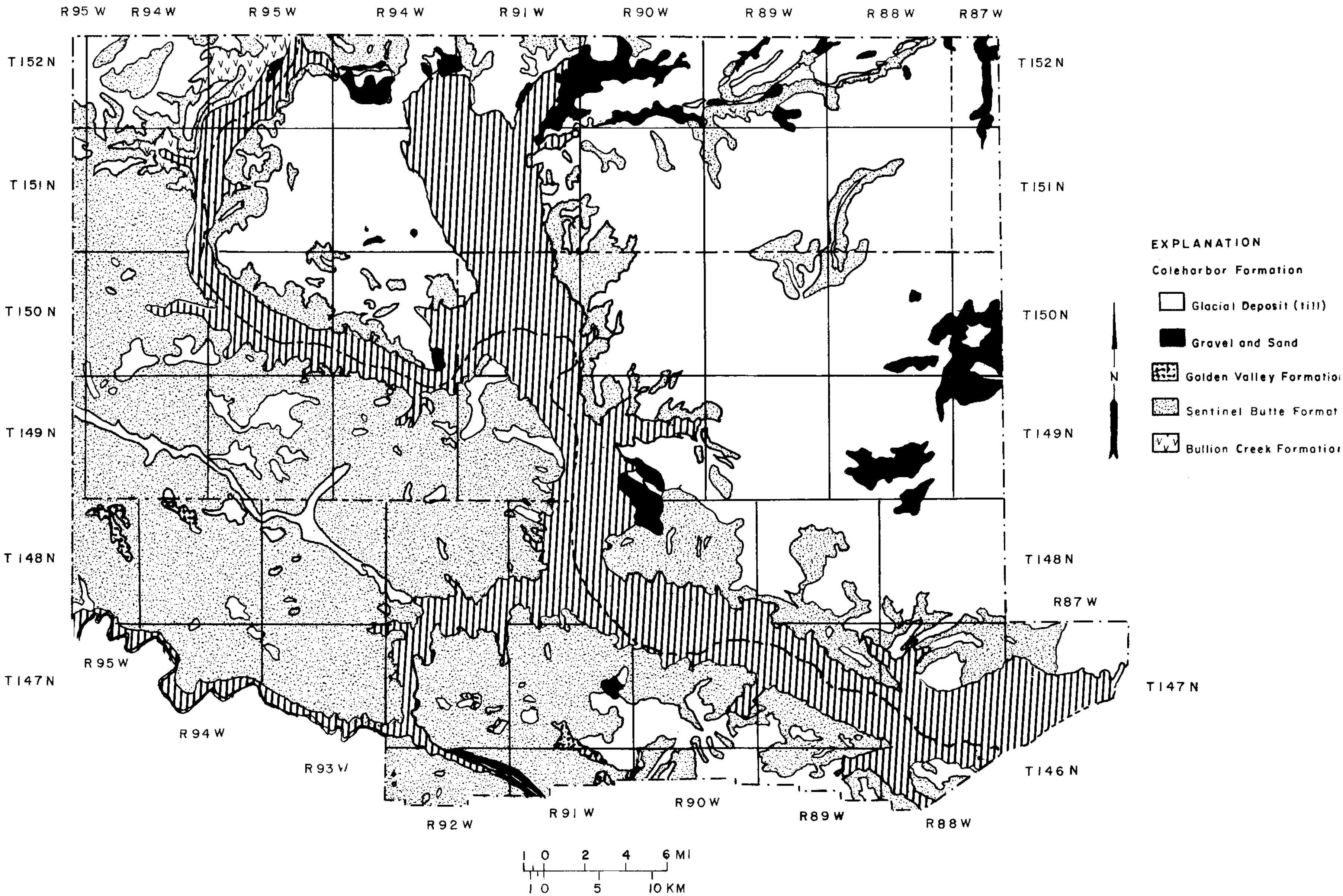

Figure 5. Geologic map of the Fort Berthold Indian Reservation.

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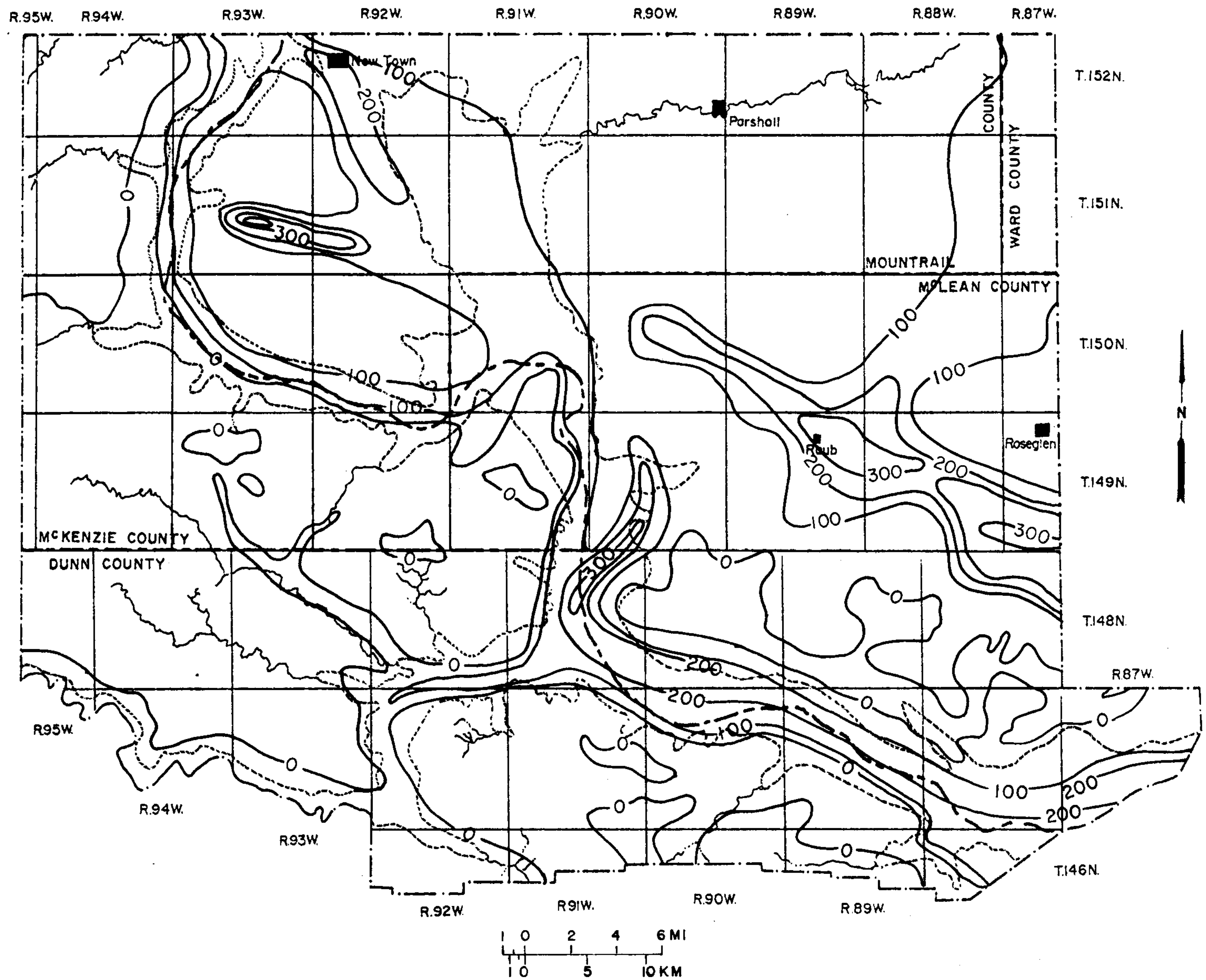

Figure 6. Isopach map showing thickness of the Coleharbor Formations on the Fort Berthold Indian Reservation. Isopachous interval: 100 feet.

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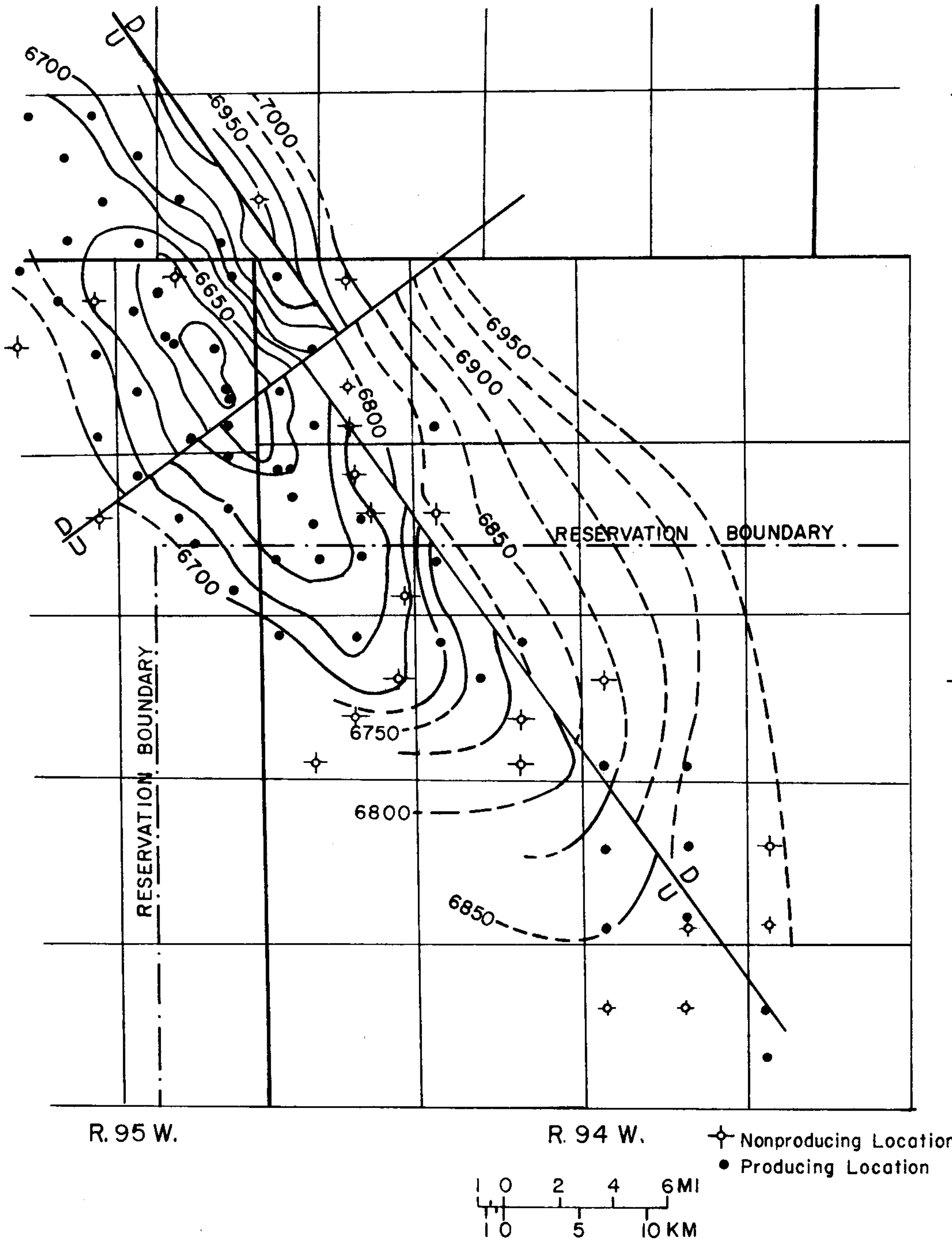

Figure 7. Structure map of the Antelope Anticline showing producing and nonproducing well locations. Structure on the Rival Subinterval (faulting inferred). Illustration modified from Preliminary Report on the Antelope-Madison and Antelope-Sanish Pools by Folson, C.B., Carlson, C.G., and Anderson, S.B. (1959). Contour interval: 50 feet.

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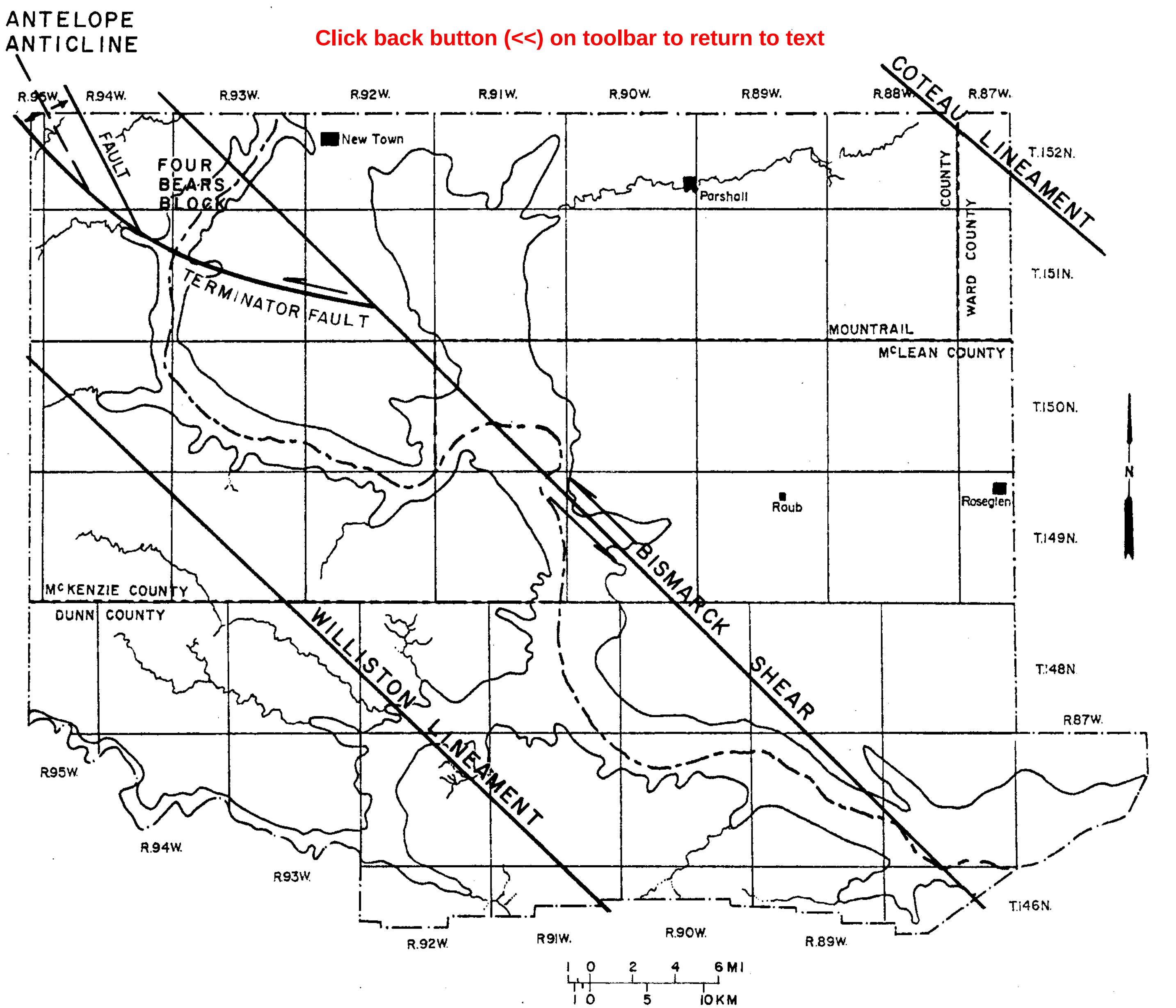

Figure 8. Map showing main geologic structure elements on the Fort Berthold Indian Reservation, North Dakota.

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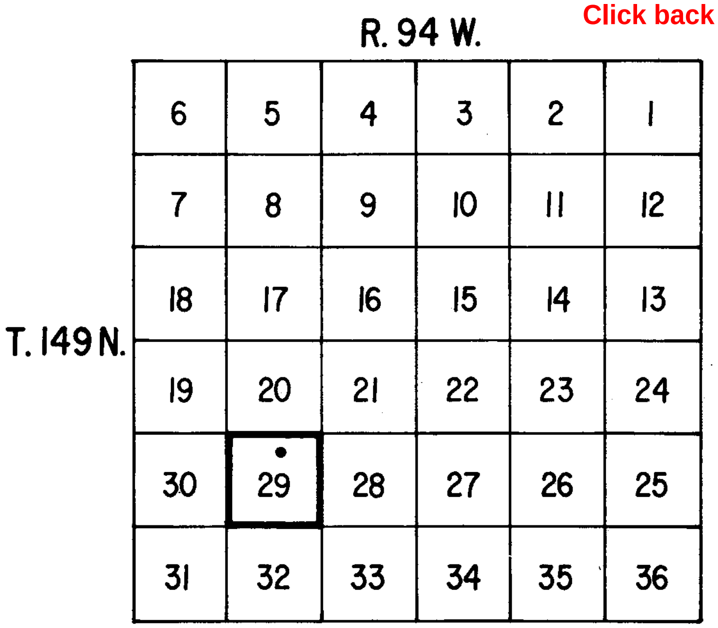

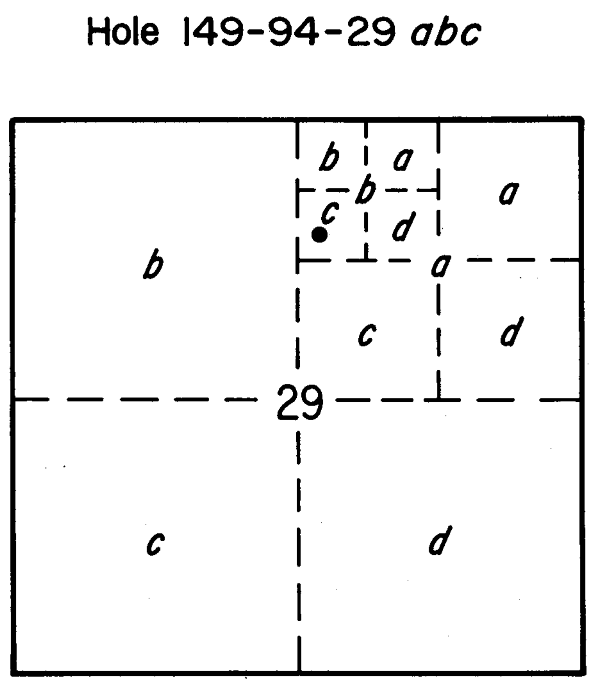

Figure 9. Diagram showing well-location numbering system on Fort Berthold Indian Reservation.

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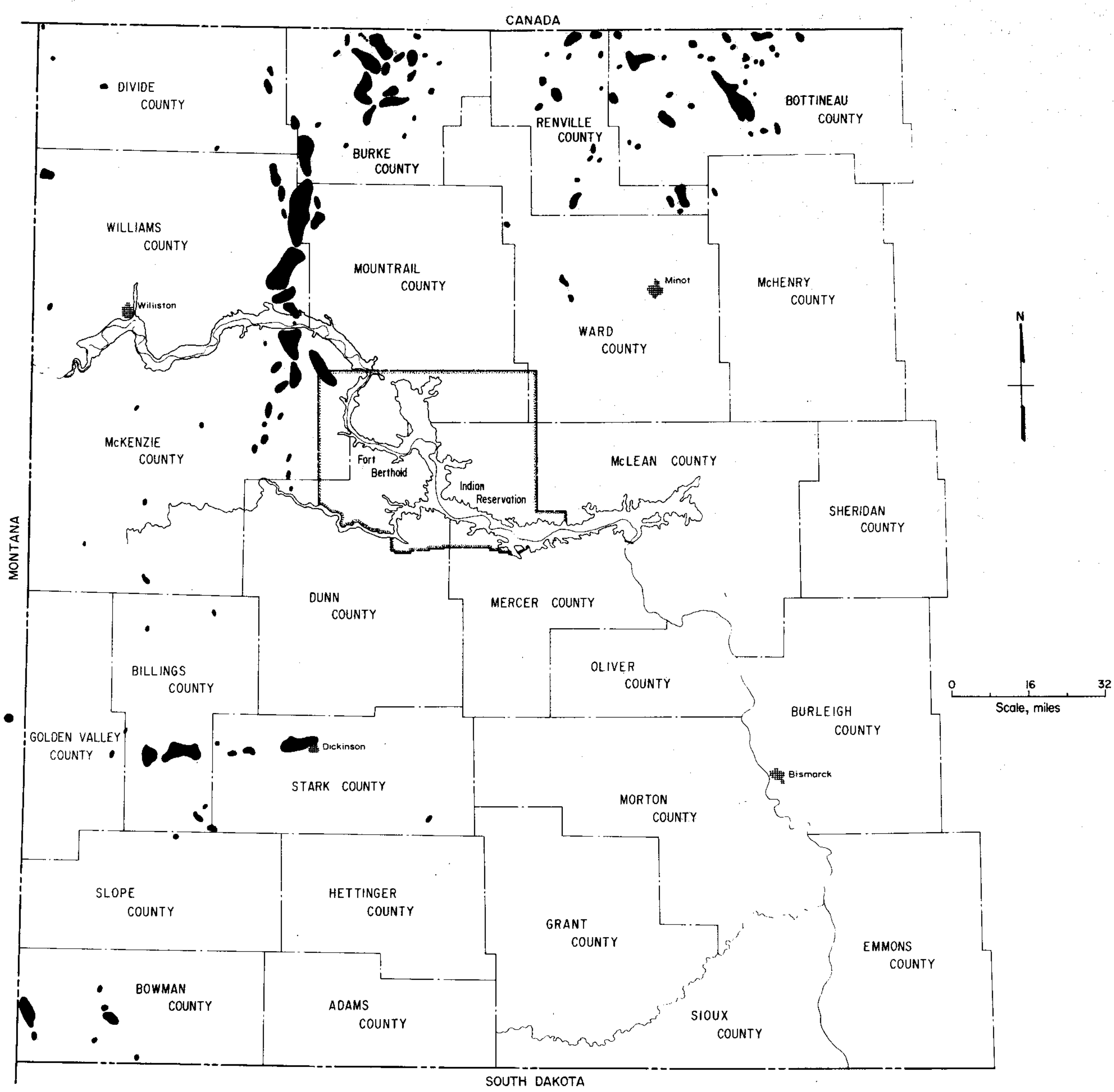

Figure 10. Map showing location of petroleum and natural gas fields in western North Dakota.

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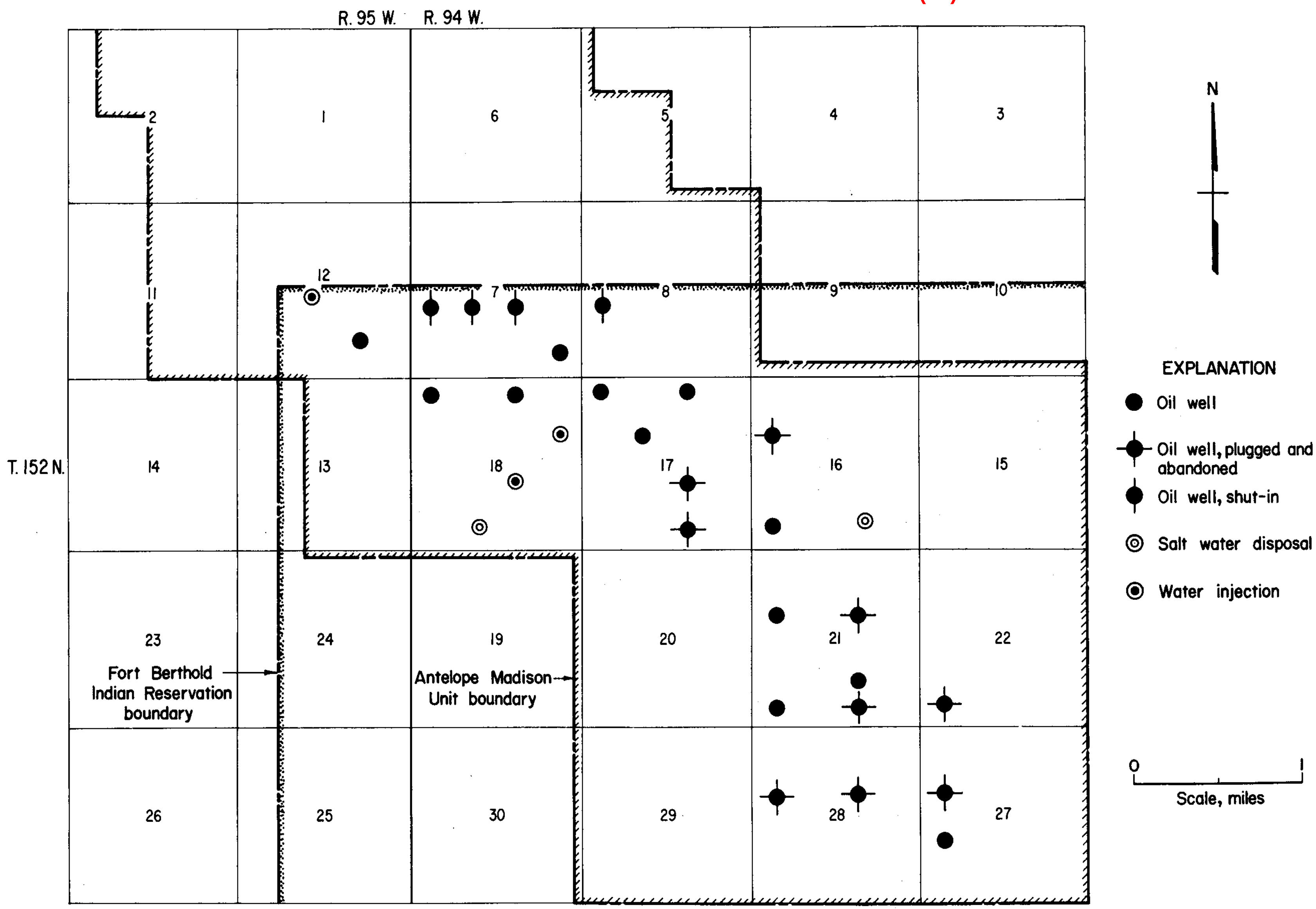

Figure 11. Map showing location of productive petroleum wells, Antelope field, Fort Berthold Indian Reservation.

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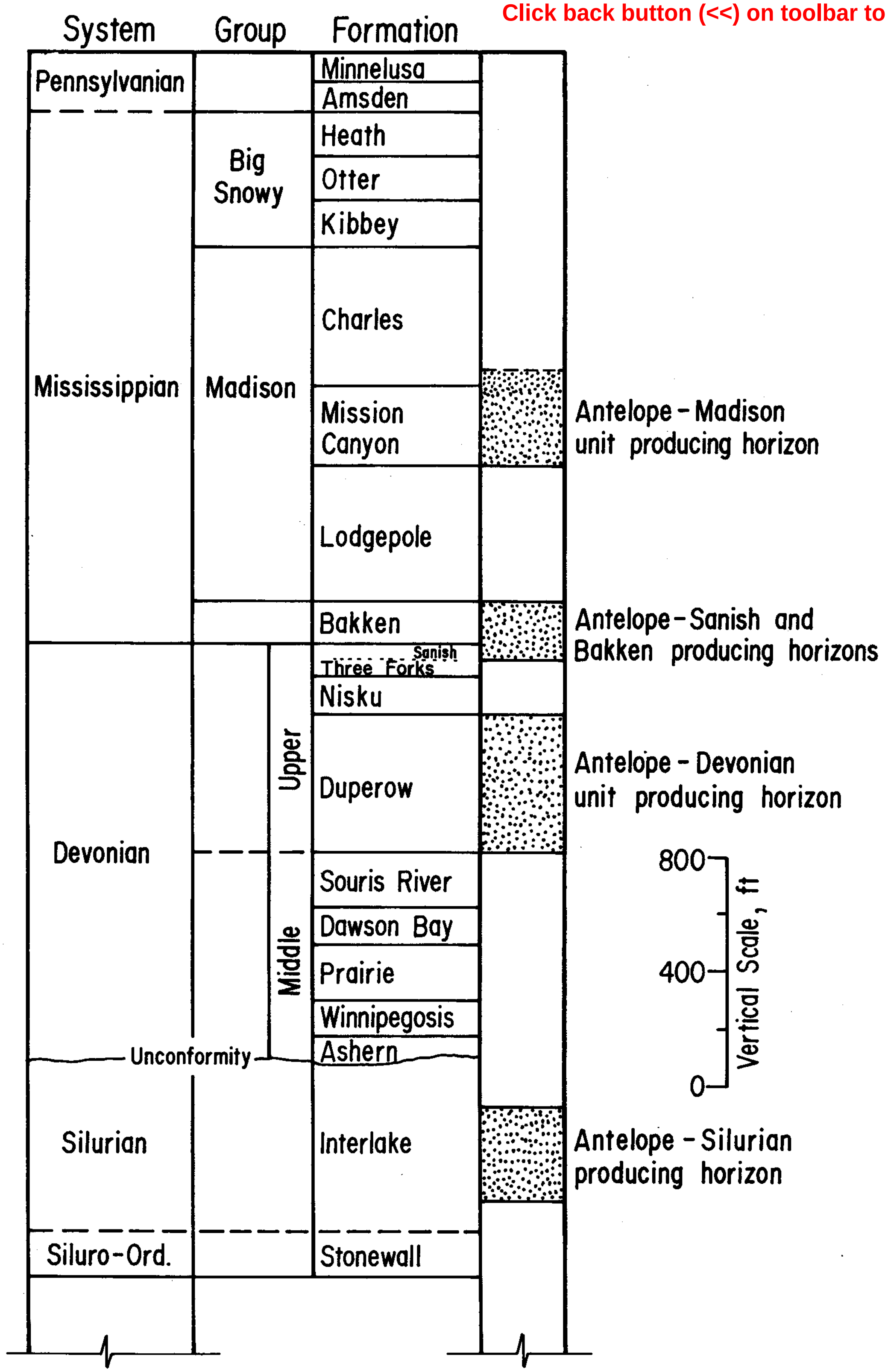

Figure 12. Partial stratigraphic section showing petroliferous horizons in the Antelope field, western North Dakota. (From Storch and Ball, 1972).

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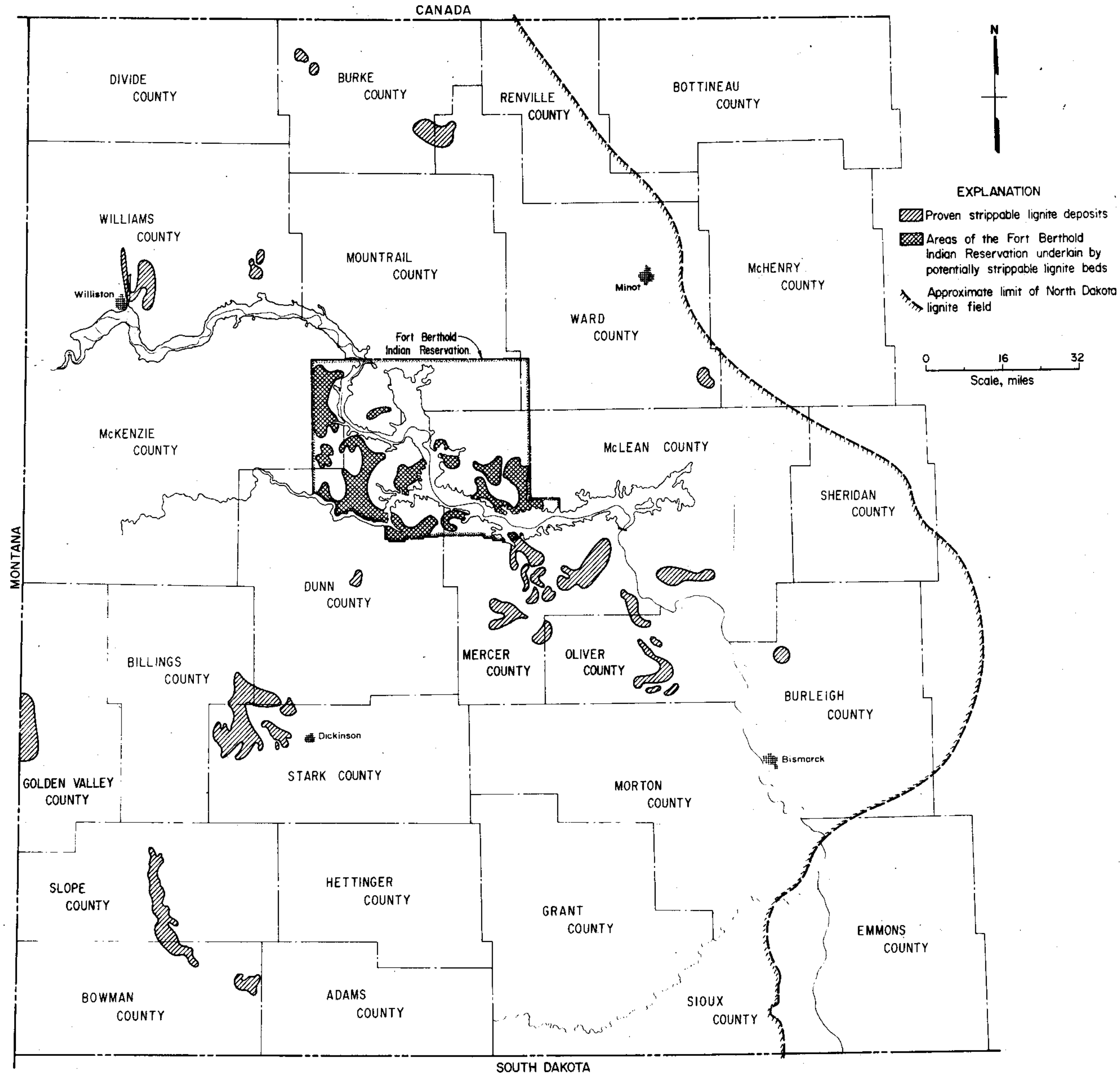

Figure 13. Map showing extent of the North Dakota lignite field (from Pollard, Smith, and Knox, 1972).

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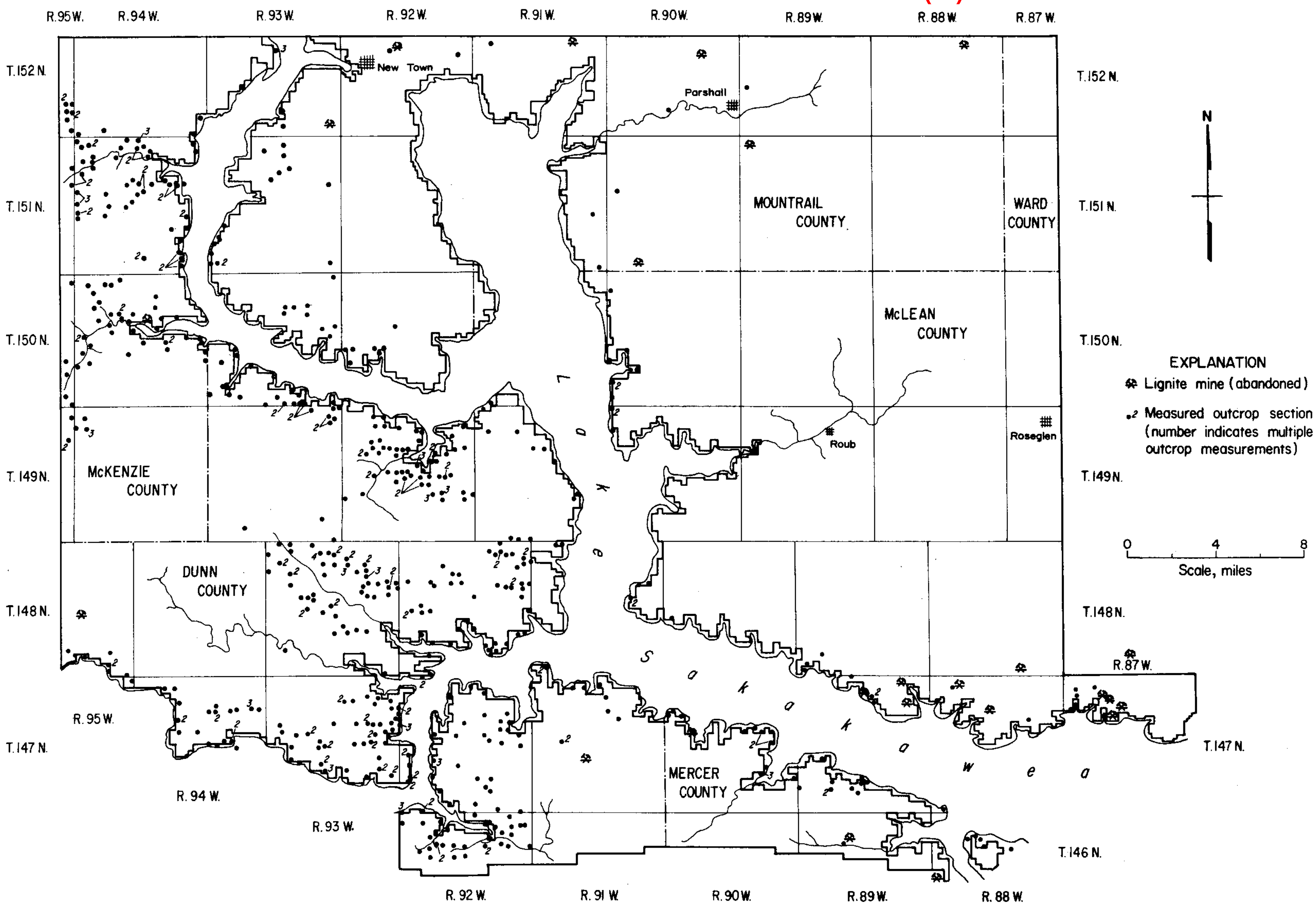

Figure 14. Map showing locations of measured lignite outcrops, Fort Berthold Indian Reservation.

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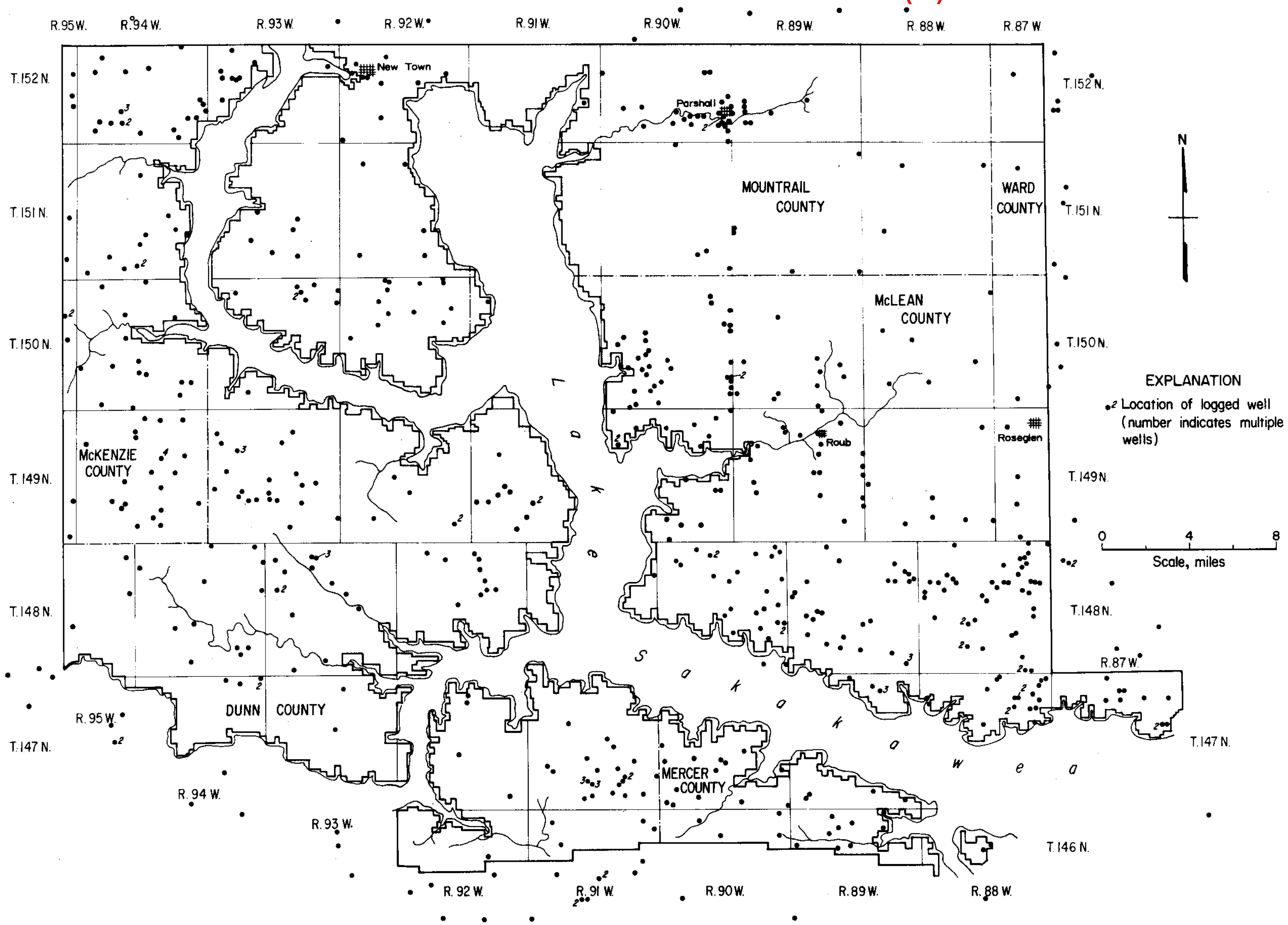

Figure 15. Map showing locations of logged wells, Fort Berthold Indian Reservation.

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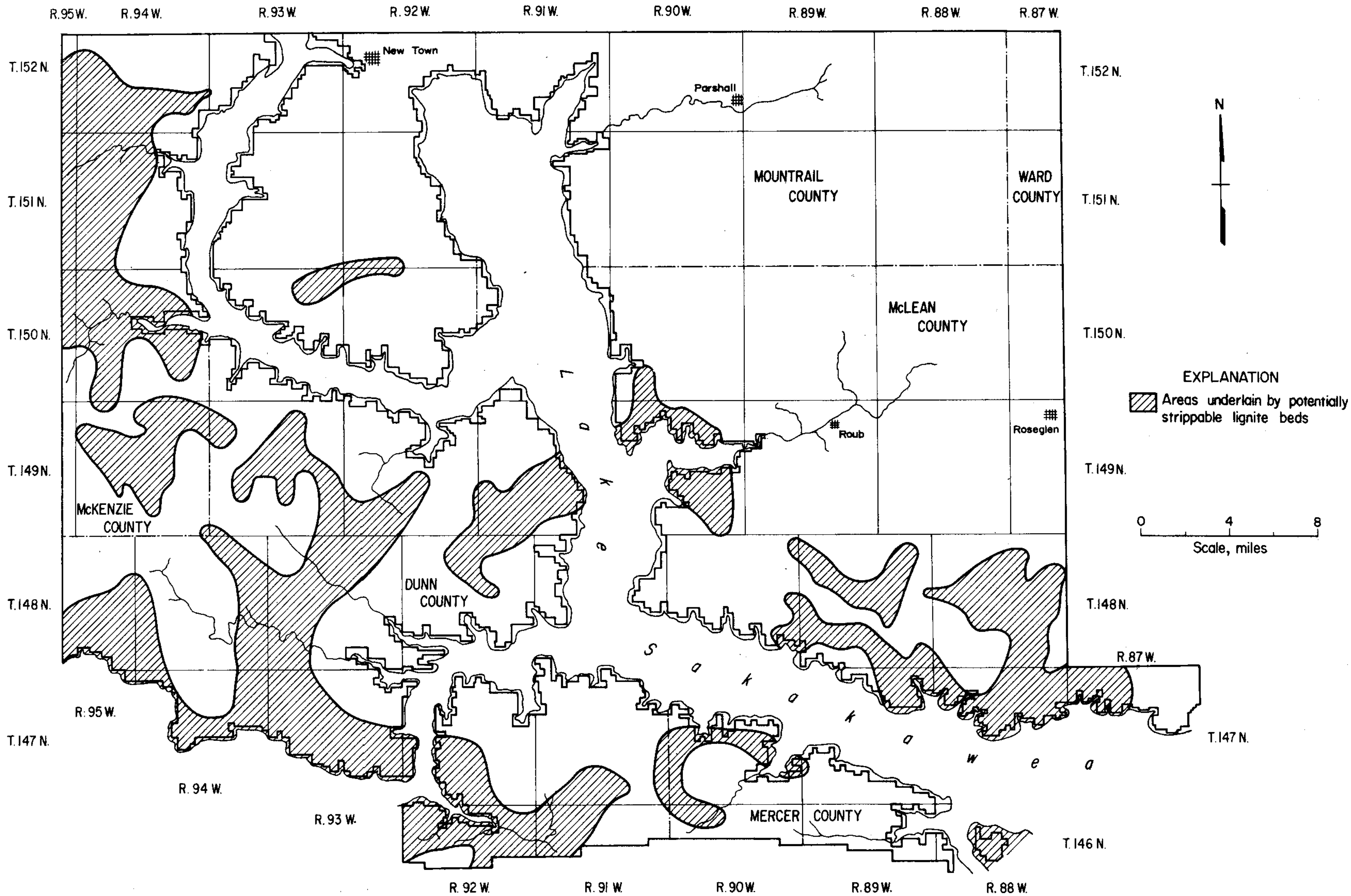

Figure 16. Map showing areas underlain by potentially strippable lignite beds, Fort Berthold Indian Reservation.

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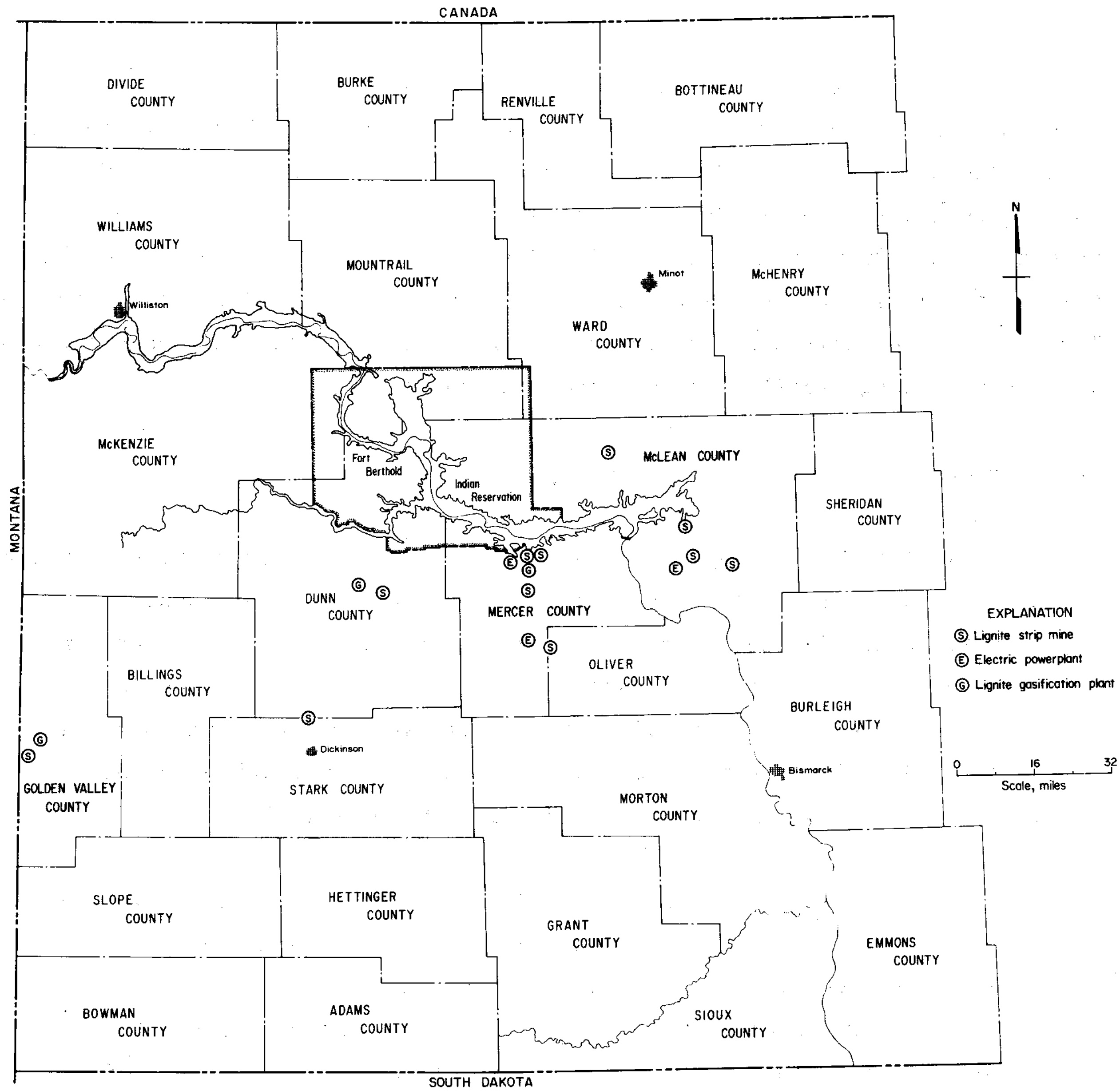

Figure 17. Map showing locations of future fuel-related projects in western North Dakota (from Corsentino, 1976; Groenewold, 1977; and C.H. Rich, Jr., U.S. Bur. of Mines, Denver, Colo., oral commun., 1977).

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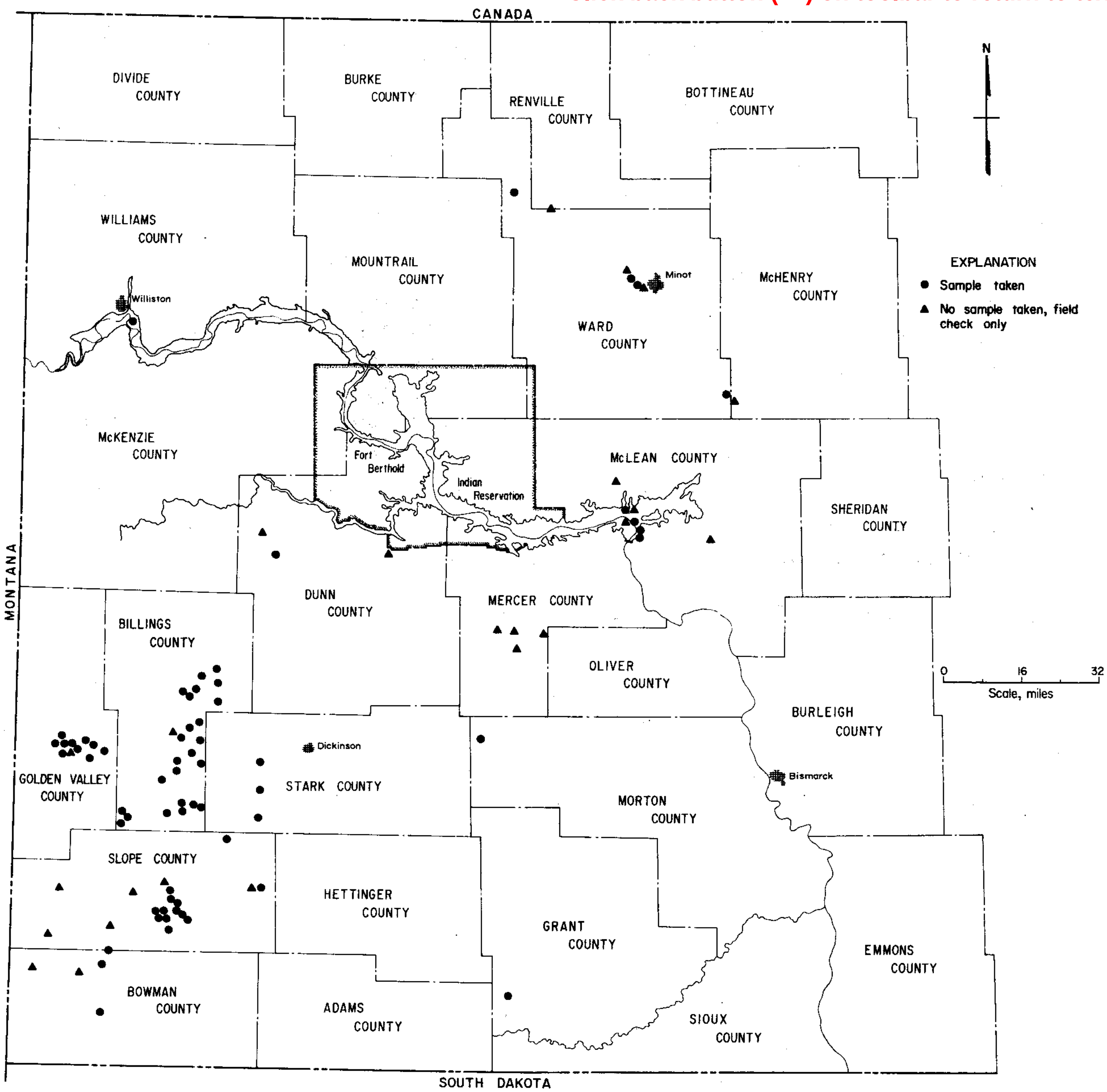

Figure 18. Map showing locations of uraniferous lignite samples, western North Dakota.

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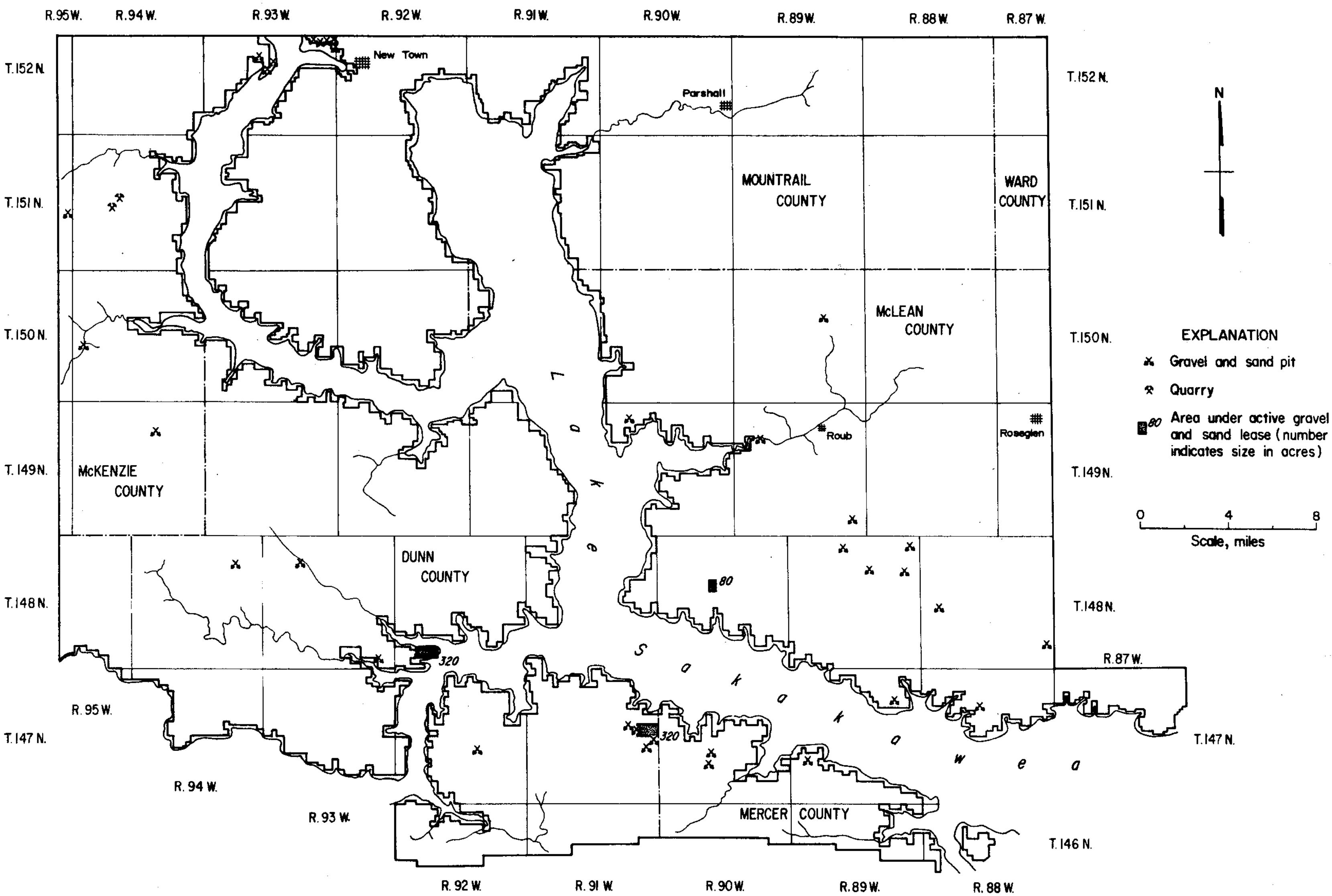

Figure 19. Map showing locations of gravel pit and quarries and areas under lease for sand and gravel, Fort Berthold Indian Reservation.

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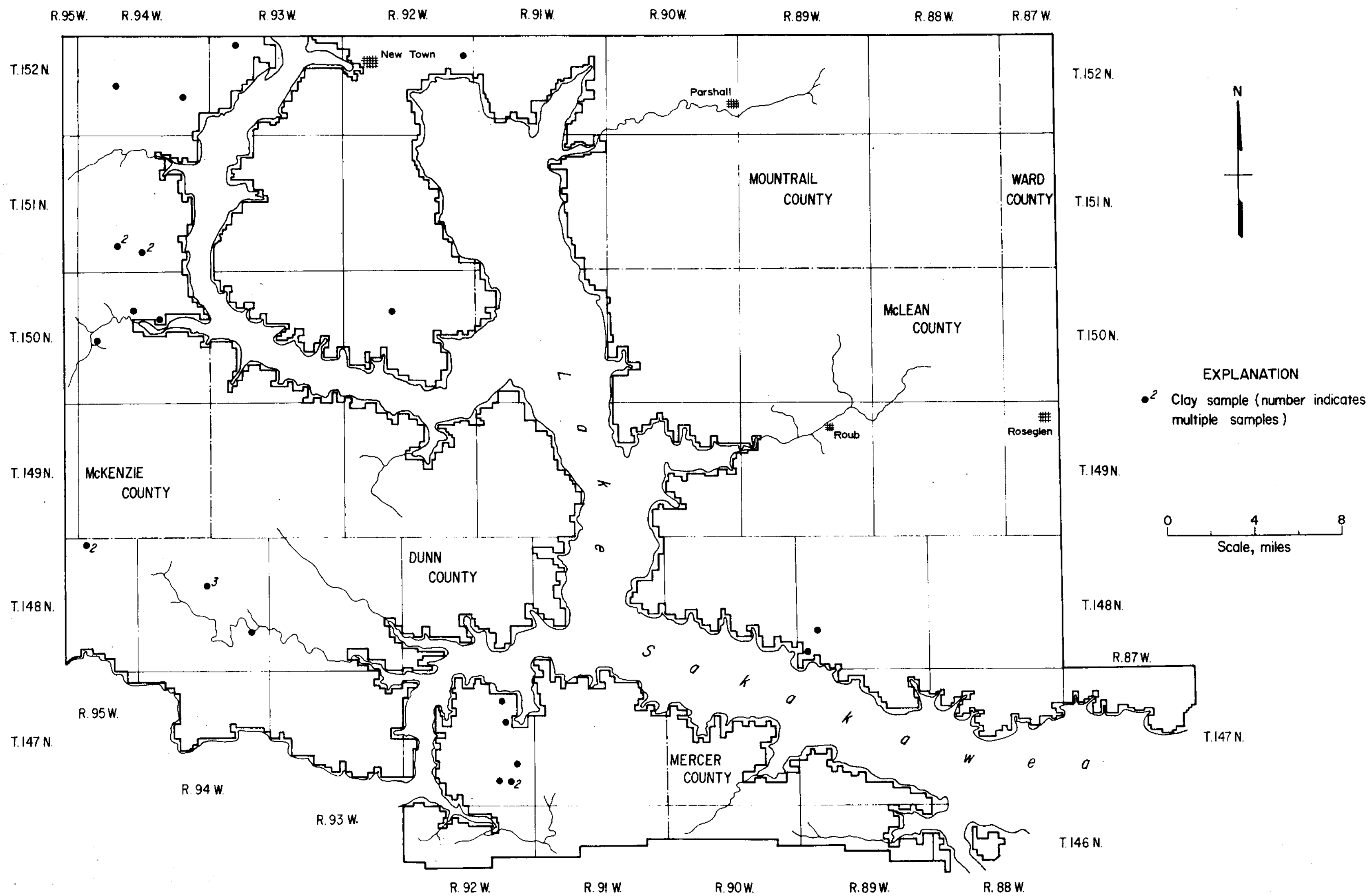

Figure 20. Map showing clay sample localities, Fort Berthold Indian Reservation.

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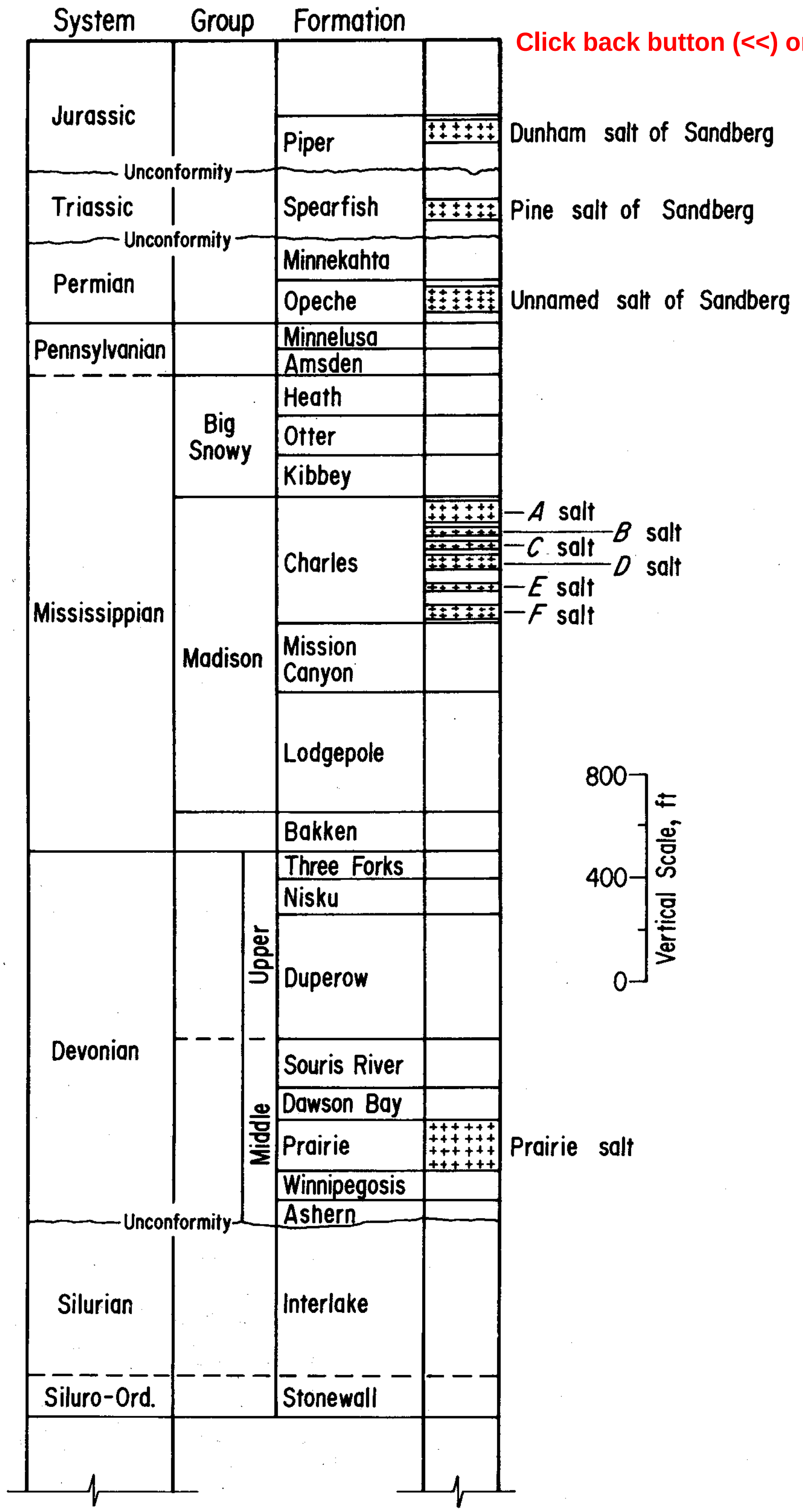

Figure 21. Partial stratigraphic section showing position of salt beds underlying Fort Berthold Indian Reservation (from Anderson, 1964b). (Nomenclature is not necessarily that accepted by the U.S. Geological Survey.)

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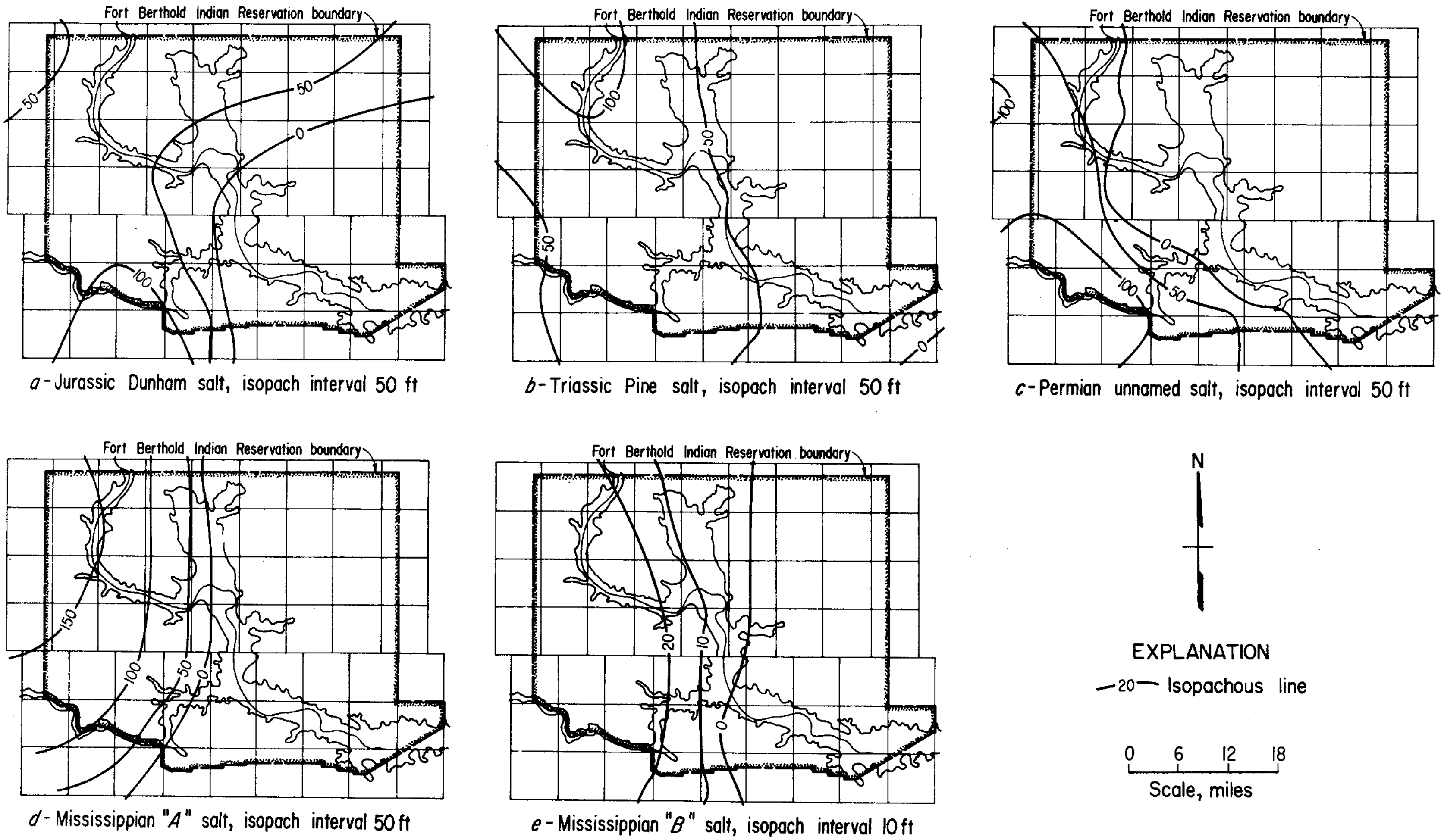

Figure 22a. Isopach maps of salt beds, Fort Berthold Indian Reservation.

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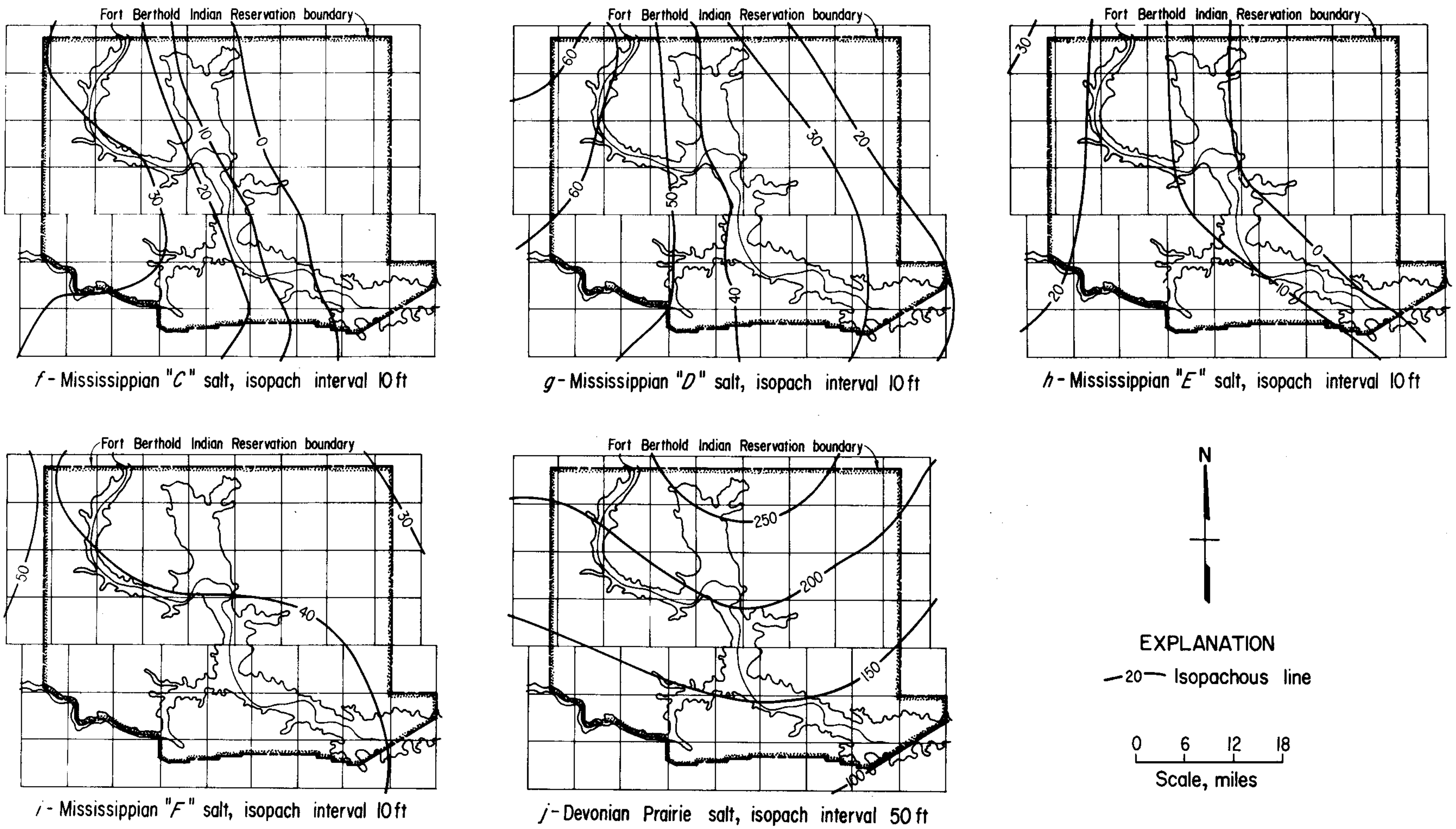

Figure 22b. Isopach maps of salt beds, Fort Berthold Indian Reservation.

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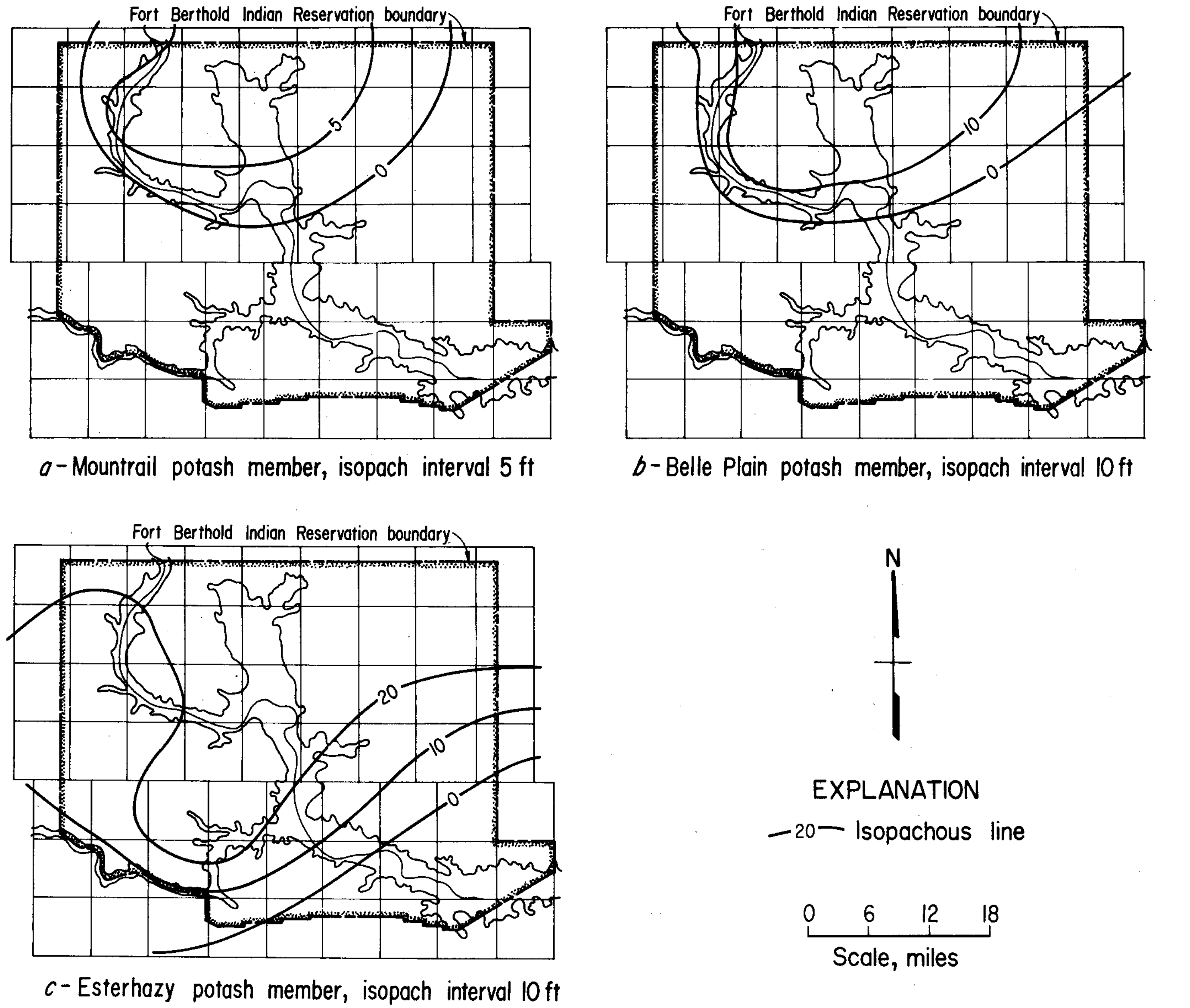

Figure 23. Isopach maps of potash members of the Devonian Prairie Formation, Forth Berthold Indian Reservation (from S.B. Anderson, North Dakota Geological Survey, written commun., 1977).