STATUS OF MINERAL RESOURCE INFORMATION FOR THE FORT PECK INDIAN RESERVATION, NORTHEASTERN MONTANA

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SUMMARY AND CONCLUSIONS

Petroleum and natural gas and lignite are the most important mineral resources on the Fort Peck Indian Reservation. Oil is being produced and lignite resources are sufficient to support large-scale surface mining. Deposits of salt, potash, clay, shale, bentonite, clinker, sand, gravel, silica, and possibly sodium sulfate are present. Some lignite may contain significant quantities of leonardite, montan wax, and uranium.

Additional petroleum and natural gas discoveries are likely. Geologic and geophysical surveys should be conducted in favorable, though still unexplored, areas.

The eastern part of the reservation contains three large lignite deposits that can be mined by surface methods. Further exploration aimed at finding other deposits should be undertaken.

The clay, shale, bentonite, sand, gravel, and silica deposits should be examined to obtain additional information as to their quality and size.

INTRODUCTION

The Fort Peck Indian Reservation occupies about 1,456 square miles (931,792 acres) in Valley, Roosevelt, Daniels, and Sheridan Counties in northeastern Montana (Figure 1 and Figure 2). The reservation has natural boundaries on three sides; the Missouri River on the south, Porcupine Creek on the west, and Big Muddy Creek on the east. The northern boundary is along the upper part of the second tier of sections through township 33 N., from the east side of Range 39 E. to the east side of Range 55 E.

The Fort Peck Indian Reservation is in the Northern Great Plains and typically has rolling uplands that are dissected by the Missouri and Poplar Rivers and their tributaries. The Missouri River is the largest stream in the area, flowing eastward at a gradient of about 1 foot per mile. The Poplar River flows south across the central part of the reservation to join the Missouri River at Poplar. The altitude ranges from about 3,050 feet in the northwestern part of the reservation to less than 1,900 feet in the southeastern part.

The main settlements are in the valley of the Missouri River, along U.S. Highway 2 (Figure 2); the largest city is Wolf Point. The largest nearby city is Glasgow, about 15 miles west of the southwest corner of the reservation. A few Post Office stations are in the northern part of the reservation.

State Highway 13 extends north through the center of the reservation and State Highway 247 (not on map) extends across the northwest corner. Several unsurfaced county roads are present, but not shown on Figure 2. The main line of the Burlington Northern Railroad extends across the southern edge of the reservation, parallel to U.S. Highway 2, and a branch line extends north on the east side of Big Muddy Creek.

Cattle grazing and wheat farming, extensive in the upland areas, are the main industry. There is production of oil in the central and northwestern parts. Sand and gravel and lignite are the other principal mineral commodities that have been produced.

Previous Investigations

The reservation and adjacent areas have been of much geologic interest since Lewis and Clark traveled up the Missouri River in 1805. The Hayden survey included the region in its studies of the Nebraska territory (Meek and Hayden, 1862; Meek, 1876). An early study evaluated the exposed lignite beds (Smith, 1910) in the reservation.

In 1946 geologic studies in and near the reservation provided data for the U.S. Bureau of Reclamation. Numerous maps and reports were prepared by Colton (1955, 1962, 1963a-j, and 1964a and b); Colton and Bateman (1956); Colton, Lemke, and Lindvall (1961); Witkind (1959); and Jensen and Varnes (1964). A recent study near the reservation is an unpublished mineral resource survey of the Charles M. Russell National Wildlife Range (Wolfbauer and Rice, 1976).

The reservation's mineral resources and their potential were evaluated by Henkes and Magill (1970). Ayler, Smith, and Deutman (1969) described coal deposits in Montana that are minable by surface methods. Three of these deposits are on the reservation. The lignite, salt, and potash deposits have been described by the Great Northern Railway Co. (Burlington Northern, Inc.; 1953-1955, 1959, 1965, 1966). Witkind (1959) described geology and mineral resources in the northeastern part of the reservation.

Present Investigation

This report was prepared for the U.S. Bureau of Indian Affairs by the U.S. Geological Survey and the U.S. Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral and energy resources, and potential for economic development of certain Indian Lands. Sources of information were published and unpublished reports as well as personal communication with various individuals. Resource computer files of the Geological Survey and the Bureau of Mines were searched for reference to specific mineral deposits in northeastern Montana. No field work was done.

GEOLOGY

General

The Fort Peck Indian Reservation is in the western part of the Williston Basin (Figure 3), an exceptionally large sedimentary basin during much of Paleozoic and Mesozoic time. More than 10,000 feet of sedimentary strata underlie the area, of which about 1,900 feet is exposed at the surface (Figure 4). As much as 357 feet of Quaternary and late Tertiary unconsolidated sediment overlie the sedimentary rocks.

Stratigraphy

The outcropping sedimentary rocks are Late Cretaceous and Early Tertiary in age (Table 1). They are mostly shale and siltstone with lesser amounts of sandstone and some thin beds of bentonite and thin to thick beds of lignite. The oldest unit is the Bearpaw Shale of which only about 400 feet is exposed, in the southern and western part of the reservation (Figure 3). The shale either forms badland topography or a terrain of small hills having gentle slopes (Jensen and Varnes, 1964, p. 5).

The Fox Hills Sandstone overlies the Bearpaw and consists of a lower transitional marine shale overlain by a thick sandstone. The shale mostly weathers in slopes like that of the Bearpaw Shale, whereas the sandstone forms a conspicuous yellowish brown to dark yellowish orange rimrock (Jensen and Varnes, 1964, p. 11-12). The Fox Hills is exposed along the east side of Little Porcupine Creek and in the south-central part of the reservation (Figure 4). It was eroded in the western part of the reservation prior to deposition of the Flaxville Gravel.

TABLE 1

Rock Units Exposed in the Fort Peck Indian Reservation

(from Colton and Bateman, 1956; and Colton, 1962, 1963a-j)

Quaternary System
- Pleistocene and Recent
  - Alluvium, fine to coarse flood-plain deposits of Missouri River and major tributaries. Chiefly silt with local gravel lenses. Deposits are 15 to 30 feet thick in valley of smaller tributaries, but may be more than 150 feet thick along the Missouri River.
  - Kintyre Formation, buff brown clay, silt, and sand; well bedded, some crossbedding, locally contorted; thickness up to 150 feet.
  - Plentywood Formation, poorly sorted and bedded gravel deposits 25 to 50 feet thick containing cobbles and boulders. Terrace remnants of a valley train of glacial origin.
  - Glacial till, consists of older and younger glacial tills, unstratified, compact, highly impervious, heterogeneous mixture ranging in size from clay to boulders. Generally 15 feet thick; locally as much as 250 feet thick.

Tertiary System
- Miocene or Pliocene
  - Flaxville Gravel, sand and gravel, 90 percent of which is brown and red quartzite and argillite. Caps highland areas ranging in altitude from 2,400 to 3,000 feet. Mostly 30 to 50 feet thick, but locally may be more than 80 feet thick. Well stratified and well sorted, consisting of about 5 percent silt, 35 percent sand, 60 percent pebbles, and a few cobbles.
- Unconformity
- Paleocene
  - Fort Union Formation, interbedded gray clay, buff silt, lignite, buff calcareous sandstone, brown carbonaceous clay, olive-gray sand, gray bentonitic clay, and silty limestone concretions. Well sorted and stratified. Marked lateral variations. About 1,100 feet thick. Lower contact arbitrarily placed at base of lowest mappable lignite bed.
- Gradational contact

Cretaceous System
  - Hell Creek Formation, well-stratified shales, siltstones, sandstones, and carbonaceous shales about 280 feet thick. Overall appearance is somber greenish gray. Weathered surfaces of bentonitic shale beds have spongy texture. Lower 50 to 100 feet is mostly medium-tan sand, locally cemented to sandstone. Contains vertebrate remains. A few quartzite pebbles locally in basal 50 feet.

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Unconformity
Montana Group
   Fox Hills Sandstone, consists of upper sandstone unit 50 to 80 feet thick
   underlain by transitional marine shale unit 35 feet thick. Lower unit
   consists of thin-bedded, well-laminated shale grading to silt toward top.
   Upper sandstone contains numerous concretions. Upper parts of formation
   locally eroded prior to Hell Creek sedimentation.
Gradational contact
   Bearpaw Shale, dark olive-gray, slightly fissile semi-consolidated jointed
   clayey shale. Contains ellipsoidal concretions of several kinds, many
   containing marine fossils. A few sandy shale beds in upper part. About
   1,100 feet thick, of which only the upper 400 feet crops out. Thin benton-
   ite lenses present; bentonite is also disseminated through some shales.
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The Hell Creek Formation overlies the Fox Hills Sandstone and is mainly shale and siltstone with interbedded ledge-forming sandstone. The outcrop area in the central and north central part of the reservation is much dissected by coulees whose steep sides are locally interrupted by ledges of cross-bedded sandstone; the sandstone ledges cap buttes in the upland area (Jensen and Varnes, 1964, p. 18). The formation is absent in the western part of the reservation as a result of pre-Flaxville erosion.

The thick (1,400 feet) Fort Union Formation overlies the Hell Creek, and consists mainly of clay, silt, sandstone and lignite (Table 1). Some of the clay is bentonitic. The formation forms a grass-covered rolling landscape with some sandstone benches (Colton, 1962, p. 245). Colton (1962, p. 279-282) describes 12 of the more important lignite beds (2-9 feet thick) in and north of the northeast part of the reservation, and notes that there are many local beds less than 2 ½ feet thick.

The Fort Union Formation (Colton and Bateman (1956), and Colton (1955, 1962, 1973a-j) includes, in descending order, the Tongue River and Lebo Members of the Fort Union and the Tullock Member of the Lance Formation as mapped south of the reservation by Collier and Knechtel (1939). The lignite beds are more common in the lower and middle parts of the combined units (the Fort Union Formation).

The Fort Union, in general, dips eastward and the thickest sequence of strata are in the eastern part of the reservation. In the area between Poplar and Little Porcupine Creeks the Fort Union is locally absent and Flaxville gravel rests unconformably on the Hell Creek Formation (Figure 4). The formation is absent west of the Middle Fork of Wolf Creek and the upper reaches of Cottonwood Creek.

The Flaxville Gravel is a widespread deposit of sand and gravel of Miocene or Pliocene age that caps highland areas in much of the central and northern parts of the reservation (Figure 4). Collier and Thom (1918, p. 182) record 15 feet of pure volcanic ash in the Flaxville north of the reservation in secs. 19 and 20, T. 35 N., R. 43 E. Colton (1963d, g, h, i, j; 1964) reports thin, impure, and lenticular deposits of volcanic ash in the northern part of the reservation.

The Wiota gravel (Jensen, 1959b), is pre-glacial and of post-Flaxville age; it lies at altitudes ranging from about 2,100 to about 2,400 feet. Most of the deposits are on terraces north of the Missouri River. Typically, the lower part of a deposit contains moderately well bedded sandy gravel and many lenses of sand whereas the upper part is commonly silt and fine- to medium-grained sand with intercalated clay lenses (Jensen and Varnes, 1964, p. 29).

Till deposits from Pleistocene continental glaciation mantle much of the reservation (Colton, Lemke, and Lindvall, 1961). There are two ages of deposits (Colton, 1955, 1962, 1963a-j, and 1964), but only the very thick deposits are shown on Figure 4. The north central upland area is unglaciated (Colton, Lemke, and Lindvall, 1961).

Melt-water channels, ice-crack, recessional, lateral, and end moraines, and undrained depressions are common features (Colton, Lemke, and Lindvall, 1961). Outwash, kame, and esker deposits also are common and are mostly composed of sand and gravel (Colton, 1955, 1962, 1963a-j, and 1964).

Alluvium, colluvium, pond, and eolian deposits are widespread. The thickest alluvium is in the Missouri River valley where it may be more than 130 feet thick (Colton, 1955; Swenson, 1955). Colluvium is along the sides of most valleys. Ponded deposits are in most of the undrained depressions in the glaciated area (Colton, 1955, 1962, 1963a-j, and 1964). Dune sand is common in the vicinity of Brockton, on the uplands south of Little Cottonwood Creek, northeast of Tule Creek and along the northern border north of the upper reaches of the East Fork of the Little Porcupine Creek (Colton, 1963a, 1964).

Structure

The structure is shown on Figure 3 and Figure 5. The main features are the Poplar Dome, the east flank of the Bowdoin Dome and the Brockton-Froid fault zone (Colton and Bateman, 1956). Associated with the Poplar Dome are the Opheim Syncline and the Bredette, Wolf Creek, and Oswego Noses. The Bowdoin Dome includes about 200,000 acres and has a closure of about 750 feet; the dips are gentle and range between 20 and 50 feet per mile (Schroth, 1953, p. 140).

The Brockton-Froid fault zone extends northeast across the southeast corner (Colton and Bateman, 1956); other small faults in the area are shown by Colton (1963).

MINERAL RESOURCES

General

Mineral resources of value or potential value in the Fort Peck Indian Reservation include petroleum and natural gas, lignite, sand and gravel, clay and shale, bentonite, sodium sulfate, potash, salt, silica, leonardite, montan wax, riprap, and clinker. Of these, petroleum and natural gas and lignite are the most important. The reservation has no potential for metallic mineral resources.

Energy Resources

Petroleum and Natural Gas

General

Petroleum was first discovered on the Fort Peck Indian Reservation in October 1951, when oil was tested from the Mississippian Charles Formation on the east flank of Poplar dome, which is now part of the East Poplar field. There are presently 15 oil fields in the reservation, 10 of which are producing oil as of January 1, 1977 (Figure 6). These fields were discovered between 1951 and 1964. Gas is produced locally for use on the leases in the East Poplar field.

Oilfield Stratigraphy

Strata ranging in age from Cambrian to Tertiary, except for Permian, have been penetrated in oil and gas wells (Table 2). Most systems have potential reservoirs and also organic-rich shales which may be source beds. Many of the units were described by Knechtel (1959) in the Little Rocky Mountains approximately 100 miles to the west; however, nomenclature, thicknesses, and general descriptions of the units as shown in Table 2 and described in the text are from subsurface control. Mallory (1972) discusses the stratigraphy and geologic history of the Rocky Mountain region. Wolfbauer and Rice (1976) summarize the stratigraphy of the Charles M. Russell Wildlife Refuge southwest of the reservation.

The oldest beds penetrated by drilling are shales assigned to the Cambrian Emerson Formation which is overlain by approximately 780 feet of Ordovician and 200 feet of Silurian sediments. This Ordovician and Silurian sequence is almost entirely limestone and dolomite with the exception of the lower 100 feet or more which is mostly sandstone of the Winnipeg Formation.

Although no Lower Paleozoic reservoirs produce within the reservation, nearby fields yield petroleum and natural gas from the Ordovician Red River Formation. These accumulations may be related to thinning over paleostructures (Ballard, 1969, p. 16-17). Dow (1974, p. 1255) identified the medial shale of the Winnipeg Formation as the source rock for most of the lower Paleozoic oil in the Williston basin. The western limit of this shale unit is probably within the reservation. The basal part of the Ordovician Stony Mountain Formation is also a potential source bed in this area.

The Devonian system is about 900 feet thick at East Poplar field and is dominantly carbonate with minor shale, siltstone, and anhydrite. The Bakken Formation overlaps the Devonian-Mississippian boundary and is black, organic-rich shale and siltstone. The Prairie Formation, which attains a maximum thickness of 525 feet in the deepest part of the Williston basin with a thick halite sequence, is absent in most of the area because of solution.

The Birdbear Formation, or Nisku Formation of subsurface usage, is the major producing reservoir within the reservation. The Winnipegosis Formation produces oil east of the reservation in structural traps where fracturing has increased the permeability (Kinard and Cronable, 1969).

The Upper Devonian-Lower Mississippian Bakken shale has been identified by Dow (1974, p.

1257) as the principal source of oil for Mississippian Madison reservoirs in the Williston basin. Dow (1974, p. 1260) also concluded that oil in the Birdbear Formation in northeastern Montana came from the Bakken shale where the two were juxtaposed by faults. However, some of the Birdbear and other Devonian oil was probably generated in local source beds. Probable marine source beds are present in most of the Devonian formations.

The Mississippian System is represented by the Madison and Big Snowy Groups which attain a thickness of about 2,500 feet. The lower Madison Group is predominantly limestone with some anhydrite, dolomite, shale, and evaporites in the upper Charles Formation which is the main reservoir in the Poplar and Bredette fields. The Big Snowy group is composed of sandstone, siltstone, shale, and minor limestone.

Pennsylvanian rocks unconformably overlie the Big Snowy Group and consist of siltstone, shale, and minor sandstone and limestone of the Tyler Formation and carbonates of the Minnelusa Formation.

Over 100 feet of red sandstone, siltstone, and shale of the Triassic Spearfish Formation rest unconformably on Pennsylvanian rocks and are unconformably overlain by Jurassic strata.

The Jurassic sequence consists of approximately 1,100 feet of shale, sandstone, limestone, dolomite, and anhydrite. The Late Jurassic Morrison Formation along with the Early Cretaceous Kootenai Formation are probably the only nonmarine units in the subsurface.

Cretaceous sediments below the Fox Hills Sandstone are about 4,000 feet thick and are predominantly shale with sandstone and siltstone limited to the Judith River, Muddy, Fall River, and Kootenai Formations. The Judith River Formation locally produces gas at the East Poplar field. On Bowdoin dome, west of the reservation, the Upper Cretaceous Carlile and Greenhorn intervals produce dry gas over a large area.

Productive Structures

The main structural feature within the reservation is the Poplar dome, a northwest-trending asymmetrical anticline of Laramide age (Figure 5). The western part of the reservation includes the east flank of the Bowdoin dome, also a Laramide feature.

Other significant structures are the northwest trending Bredette, Oswego, and Wolf Creek noses plus the Opheim syncline (Figure 5). These are undoubtedly related to a major northeasterly and northwesterly trending lineament block system as detailed by Thomas (1974) in the greater Williston basin-Blood Creek syncline area. Although the exact cause of these lineaments, which are well expressed on aerial photographs, is not known, they suggest a general weakness of the basement which undoubtedly had an effect on the geological and petroleum history of the area as shown by the following examples.

Ballard (1969) related Red River production in northeastern Montana to depositional thins along proposed lineaments. Oil accumulated in the Charles "Radcliffe" zone in algal pelletoid mounds which Hansen (1966) postulated were controlled by paleomovement along trends of weakness. Entrapment of oil in the Kibbey Sandstone at Weldon field was enhanced by regional westward truncation of the reservoir beds during post-Pennsylvanian to pre-Jurassic time along the Weldon fault (Edmisten and Foster, 1969). Sandberg and Mapel (1967) showed offset of Devonian indicative of paleomovement along the Weldon fault which trends into the Brockton-Froid fault zone in the study area. Other lineaments undoubtedly cross the reservation and may have had an effect on both stratigraphy and hydrocarbon accumulations.

Production

As of January 1976, cumulative production from the 15 fields (Figure 6) was 57,556,463 barrels valued at $157,311,633 (Table 3). Cumulative production from each field ranged from 1,979 barrels (Wolf Creek) to 41,712,665 barrels (East Poplar). Ten of the fields produced less than 1 million barrels each.

No gas fields have been discovered on the reservation. However, natural gas is produced from the Tule Creek oil field. In 1974, 162,220 Mcf were produced. McCulloch Interstate Gas Corp. operates a natural gas liquids extraction plant near the Tule Creek oilfield (Figure 6). The East Poplar oilfield produces a small amount of gas, which is used in operations at the field.

TABLE 3

Cumulative Oil Production, Value, and Reserves for Oil Fields, Fort Peck Indian Reservation*

Field	Cumulative value to 1-1-76 (dollars)	Cumulative production to 1-1-76 (barrels)	Reserves on 1-1-76 (barrels)	Producing formations
Benrud	530,011	208,751	0	Nisku (Dev.)
East Benrud	6,017,265	1,888,989	111,000	Nisku
Northeast Benrud	2,320,866	845,136	135,000	Nisku
Bredette	413,000**	185,176**	0	Charles "C" (Miss.)
North Bredette	1,160,000**	488,554**	0	Miss.
Chelsea Creek	43,764	11,548	0	Nisku
Mineral Bench	361,636	139,554	1,000	Charles "C" Duperow (Dev.)
East Poplar	111,440,686	41,712,665	3,881,000	Madison & Heath (Miss.) Nisku
Northwest Poplar	2,828,552	613,640	473,000	Charles "C"
Red Fox	1,000,677	348,577	18,000	Nisku
Tule Creek	18,591,494	6,708,279	1,291,000	Nisku
East Tule Creek	5,281,883	1,904,019	195,000	Nisku
South Tule Creek	1,721,998	612,264	89,000	Nisku
Volt	5,597,526	1,887,332	839,000	Nisku
Wolf Creek	2,275	1,979	0	Madison
TOTALS	157,311,633	57,556,463	7,033,000	

*Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division.

**Henkes and Magill, 1970, p. 19.

Oil Fields

General.--The East Poplar field, the largest on the reservation, and its extension, the Northwest Poplar field, are centered about 10 miles north-northeast of Poplar (Figure 6). The Tule Creek, East Tule Creek, South Tule Creek, Benrud, East Benrud, Northeast Benrud, Red Fox, Volt, Wolf Creek, and Chelsea Creek fields are centered about 18 miles north of Wolf Point. The Bredette and North Bredette fields are about 30 miles north of Poplar. The Mineral Bench field is about 26 miles north-northeast of Poplar.

East Poplar.--The East Poplar field (Figure 6 and Figure 7) was discovered in 1952 in T. 28 and 29 N., R. 50 and 51 E., Roosevelt County. The discovery well, Murphy Oil Corporation's East Poplar No. l, was in the SW ¼ NE ¼ sec. 2, T. 28 N., R. 51 E. Initial production was 625 barrels per day of 41° API gravity oil from the Charles Formation of the Madison Group. Perforations were from 5,668 to 5,680 feet and from 5,799 to 5,814 feet (Henkes and Magill, 1970, p. 25). The Charles "C" zone has about 25 feet of net pay with an average porosity of 11 percent and underlies about 18,000 acres. The oil has been trapped in a dome-like structure with a natural water drive.

The depths of the formation tops, in feet, below the Kelly bushing (elevation 2,123 feet), penetrated by the discovery well are as follows: Judith River 752; Fall River Sandstone 3,178; Morrison 3,505; and Mission Canyon 5,940. Total depth of the hole is 9,163 feet (Henkes and Magill, 1970, p. 26).

In 1956, oil was discovered in the Kibbey Sandstone (Mississippian) from a zone 5,231 to 5,243 feet deep. The discovery well, in SW ¼ NE ¼ sec. 27, T. 28 N., R. 51 E., initially produced 54 barrels per day. Production was discontinued because it was noncommercial (Henkes and Magill, 1970, p. 25).

The Poplar dome is about 30 miles long and 25 miles wide with about 300 feet of closure. The East Poplar oil field is subsidiary dome on its northeastern flank which covers an area about 8 miles long and 5 miles wide with a closure of about 100 feet (Perry, 1970, p. 82).

In May 1969, oil was obtained from the Heath Formation (Mississippian) through the reworked Polumbus Huber No. 1 well in the NE ¼ sec. 10, T. 28 N., R. 51 E. Initial pumped production was 245 barrels of oil and 50 barrels of water per day from perforations between depths of 4,864 and 4,882 feet (Henkes and Magill, 1970, p. 25). The combination structural and stratigraphic trap underlies about 480 acres and has a natural water drive. The producing zone has about 8 feet of net pay with an average porosity of 11 percent. Oil gravity is 38° API.

Oil was discovered in February 1969 in the Nisku Formation (Devonian) when the E. A. Polumbus Huber No. 5 well was drilled in the SW ¼ NE ¼ sec. 10, T. 28 N., R. 51 E. The well initially produced 51 barrels of oil and 475 barrels of water per day. Daily oil production increased to about 200 barrels but soon declined to about 150 barrels while water production increased to 1,200 barrels. Perforations were between 7,262 and 7,264 feet (Henkes and Magill, 1970, p. 25). The pool underlies about 320 acres and has about 12 feet of net pay with an average porosity of 8 percent. The field has a natural water drive. Water produced is injected into the Fall River sandstone and Judith River Formation. Production data are in Table 4.

TABLE 4

Production Data, Number of Wells, and Reserves, East Poplar Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*		
		Heath (Miss.)	Madison**	Nisku (Dev.)
1966	889,626	0	70	0
1967	732,519	0	70	0
1968	674,917	0	61	0
1969	730,658	4	58	1
1970	706,247	4	59	3
1971	629,411	4	58	2
1972	538,045	3	60	1
1973	512,646	3	58	1
1974	497,395	3	59	1
1975	467,585	3	63	1

*Number wells at end of year. Producing formations: Heath (Miss.), Madison (Miss.) Nisku (Dev.).
**Charles and Mission Canyon Formations (Miss.) Cumulative production to January 1, 1976, was 41,712,665 barrels. Estimated reserves as of January 1, 1976, are:

Heath	88,000 barrels
Madison	3,728,000 barrels
Nisku	65,000 barrels
TOTAL	3,881,000 barrels

Probable water drive in all three formations. Estimated ultimate recoveries:

Heath	79 barrels/acre ft.
Madison	100 barrels/acre ft.
Nisku	65 barrels/acre ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1966 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

Northwest Poplar.--The Northwest Poplar oilfield (Figure 8) was discovered in 1952 when the Ajax Oil Company McGowan No. 1 well was completed in the SE ¼ SW ¼ sec. 10, T. 29 N., R. 50 E. Initial pumped production was 75 barrels of oil and 25 barrels of water per day from the Charles Formation of the Madison Group. Perforations were between depths of 6,164 and 6,189 feet. Both surface geology and seismic data were aids in defining the prospect (Henkes and Magill, 1970, p. 26). The producing zone has about 16 feet of net pay with an average porosity of 10 percent and underlies about 800 acres.

Production data, number of wells, and reserves are given in Table 5.

TABLE 5
Production Data, Number of Wells, and Reserves, Northwest Poplar Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	21,212	5	0
1965	19,522	5	0
1966	20,830	4	0
1967	20,199	5	0
1968	18,479	5	0
1969	14,432	1	0
1970	17,112	3	0
1971	16,282	3	0
1972	11,322	2	0
1973	13,885	3	0
1974	11,968	3	0
1975	121,265	9	0

*Number of wells at end of year.

Producing formation: Charles (Miss.).

Cumulative production to January 1, 1976, was 613,640 barrels.

Estimated reserves as of January 1, 1976, are 473,000 barrels.

Probable water drive.

Estimated ultimate recovery: 78 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

Tule Creek.--The Tule Creek oilfield (Figure 9) was discovered when the Murphy Oil Corporation's E. O. Sletvold No. 1 well was drilled in the SE ¼ SE ¼ sec. 18, T. 30 N., R. 48 E. It was completed October 27, 1960, at a total depth of 8,478 feet. Initial production was 476 barrels per day of 46º API gravity oil from the Nisku Formation. The oil is confined in a structural trap at a depth of about 7,500 feet. The producing zone has an area of about 1,160 acres, thickness of 25 feet, average porosity of 15 percent, and natural water drive. Produced water is injected into the Judith River and Fall River Sandstone. Production wells were drilled on 160-acre spacing. Perforations in the discovery well, the deepest in the field, are between 7,660 and 7,692 feet (Henkes and Magill, 1970, p. 27). Surface geology and seismic data were guides to finding the field (Henkes and Magill, 1970, p. 27).

Formation tops penetrated by the discovery well are as follows: Judith River 1,422; Eagle 1,933; Greenhorn 3,088; Fall River Sandstone 3,970; Swift 4,348; Rierdon 4,828; Piper Limestone 5,101; Spearfish 5,374; Otter 5,462; Kibbey 5,598; Madison 5,811; Bakken 7,536; Three Forks 7,545; Nisku anhydrite 7,627; Duperow 7,718; Souris River 8,140; and Dawson Bay 8,400. Total depth is 8,470 feet. (Henkes and Magill, 1970, p. 27.)

Table 6 gives production data.

TABLE 6

Production Data, Number of Wells, and Reserves, Tule Creek Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	564,480	7	0
1965	515,096	7	0
1966	493,786	7	0
1967	460,794	7	0
1968	457,642	6	0
1969	448,749	6	0
1970	399,656	6	0
1971	319,181	6	1
1972	266,998	5	1
1973	229,003	5	1
1974	202,706	5	1
1975	165,385	5	1

*Number of wells producing at end of year. Producing formation: Nisku (Dev.)

Cumulative production to January 1, 1976, was 6,708,279 barrels.

Estimated reserves as of January 1, 1976, are 1,291,000 barrels.

Probable water drive.

Estimated ultimate recovery: 276 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

East Tule Creek.--The East Tule Creek oilfield (Figure 9) was discovered on October 28, 1964 with the completion of Murphy Oil Corporation's Bridges No. 1 well in the SE ¼ NE ¼ sec. 15, T. 30 N., R. 48 E. Perforations in the discovery well were between depths of 7,490 and 7,508 feet (Henkes and Magill, 1970, p. 28). Initial pumped production was 411 barrels per day of 43º API gravity oil from the Nisku Formation. The oil is confined in a structural trap with a water drive. The producing area, about 400 acres, has about 30 feet of net pay with an average porosity of 18 percent. Produced water is injected into the Judith River Formation. The field has 160-acre well spacing. Production data, number of wells, and reserves are given in Table 7.

TABLE 7
Production Data, Number of Wells, and Reserves, East Tule Creek Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	47,855	2	0
1965	374,684	2	0
1966	342,847	2	0
1967	279,866	2	0
1968	230,396	2	0
1969	175,056	2	0
1970	120,687	2	0
1971	101,703	2	0
1972	89,413	2	0
1973	70,976	2	0
1974	43,646	2	0
1975	26,890	2	0

*Number of wells at end of year.
Producing formation: Nisku (Dev.). Cumulative production to January 1, 1976, was 1,904,019, barrels.
Estimated reserves as of January 1, 1976, are 195,000 barrels.
Probable water drive.
Estimated ultimate recovery: 175 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

South Tule Creek.--The South Tule Creek oilfield (Figure 9) was discovered June 19, 1964, when the Brinkerhoff Track No. 1 well in the SE ¼ NW ¼ sec. 36, T. 30 N., R. 47 E. was completed. Total depth of the well is 7,360 feet. Initial production was 84 barrels per day of 43º API gravity oil. The oil is confined in a structural trap with a natural water drive. The producing horizon (Nisku) has about 8 feet of net pay and averages 12 percent porosity. Estimated size of the field is 400 acres. The produced water is injected into the Judith River Formation and Fall River Sandstone. Two offset wells were drilled; one initially produced 80 barrels per day, and the other was a dry hole (Henkes and Magill, 1970, p. 28).

Production data are in Table 8.

TABLE 8

Production Data, Number of Wells, and Reserves, South Tule Creek Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	25,579	1	0
1965	57,920	1	0
1966	69,646	2	0
1967	93,750	3	0
1968	87,217	3	0
1969	81,583	3	0
1970	54,023	3	0
1971	45,406	3	0
1972	32,401	3	0
1973	29,665	3	0
1974	18,342	3	0
1975	16,422	3	0

*Number of wells at end of year.

Producing formation: Nisku (Dev.).

Cumulative production to January 1, 1976, was 612,264 barrels.

Estimated reserves as of January 1, 1976, are 89,000 barrels.

Probable water drive.

Estimated ultimate recovery: 219 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

Benrud.--The Benrud oilfield (Figure 6) was discovered December 7, 1961, by the Calvert Exploration Company with their No. 1 Listug-Olson "A" well in the NE ¼ SW ¼ sec. 34, T. 31 N., R. 47 E. Initial production was 498 barrels per day of 43° API gravity oil from the Nisku Formation at a total depth of 7,620 feet. The producing zone has about 22 feet of net pay with an average porosity of 16 percent. The oil is trapped in a small structural dome (about 80 acres) with a natural water drive. Produced water is injected into the Judith River Formation.

Production data, number of wells, and reserves are given in Table 9.

TABLE 9

Production Data, Number of Wells, and Reserves, Benrud Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	23,011	1	0
1965	31,268	1	0
1966	29,084	1	0
1967	16,915	1	0
1968	11,967	1	0
1969	5,455	1	0
1970	2,529	0	1
1971	49	0	1
1972	16,192	1	1
1973	9,047	1	1
1974	8,103	1	1
1975	200	1	1

*Number of wells at end of year.

Producing formation: Nisku (Dev.).

Cumulative production to January 1, 1976, was 208,751 barrels.

Estimated reserves as of January 1, 1976, are zero.

Probable water drive.

Estimated ultimate recovery: 119 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

East Benrud.--This field (Figure 6) was discovered by the Murphy Oil Corporation with their Tribal No. l-A well, completed December 13, 1962, in the SE ¼ NW ¼ sec. 36, T. 31 N., R. 47 E. at a total depth of 7,804 feet. Initial production was 503 barrels per day of 46º API gravity oil from the Nisku Formation. The producing zone is about 7,500 feet deep and has about 22 feet of net pay with an average porosity of 15 percent. The field contains a structural trap with a productive area of about 480 acres and a natural water drive. Produced water is injected into the Judith River Formation.

Production data are listed in Table 10.

TABLE 10

Production Data, Number of Wells, and Reserves, East Benrud Oil Field,fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	176,289	1	0
1965	129,877	1	0
1966	111,420	1	0
1967	101,267	1	0
1968	100,267	1	0
1969	175,605	2	0
1970	170,302	2	0
1971	150,216	2	0
1972	151,549	3	0
1973	157,129	3	0
1974	122,761	3	0
1975	128,014	3	0

*Number of wells at end of year.
Producing formation: Nisku (Dev.).
Cumulative production to January 1, 1976, was 1,888,989 barrels.
Estimated reserves as of January 1, 1976, are 1,111,000 barrels.
Probable water drive.
Estimated ultimate recovery: 284 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

Northeast Benrud.--The Northeast Benrud oilfield (Figure 6) was discovered September 10, 1964, by the Murphy Oil Corporation. The discovery well, Mule Creek-Allotted No. 1, is in the SW ¼ SE ¼ sec. 20, T. 31 N., R. 48 E. Initial production was 408 barrels per day of 46° API gravity oil from the Nisku Formation. Perforations in the discovery well were between the depths of 7,620 and 7,625 feet and between 7,637 and 7,643 feet (Henkes and Magill, 1970, p. 23). The producing zone has about 23 feet of net pay with an average porosity of 16 percent. The oil is in a structural trap with a natural water drive. The productive area underlies about 160 acres. Produced water is injected into the Judith River Formation.

The depths to the formation tops, in feet below the Kelly bushing (elevation 2,704 feet), penetrated by the discovery well are as follows: Judith River Formation 1,438; Eagle 1,968; Niobrara 2,817; Greenhorn 3,153; Graneros 3,343; Fall River Sandstone 4,078; Swift 4,412; Rierdon 4,834; Piper Limestone 5,113; Nesson 5,260; Spearfish 5,391; Otter 5,435; Kibbey 5,563; Madison 5,818; Bakken 7,502; Three Forks 7,507; Nisku 7,589; and Duperow 7,687. Total depth is 7,865 feet (Henkes and Magill, 1970, p. 23).

Table 11 gives production data, number of wells, and reserves.

TABLE 11

Production Data, Number of Wells, and Reserves, Northeast Benrud Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	50,504	1	0
1965	176,364	1	0
1966	182,354	2	0
1967	152,099	1	0
1968	90,016	1	0
1969	50,629	1	0
1970	35,816	1	0
1971	28,666	1	0
1972	23,212	1	0
1973	20,013	1	0
1974	18,956	1	0
1975	16,507	1	0

*Number of wells at end of year.

Producing formation: Nisku (Dev.). Cumulative production to January 1, 1976 was 845,136 barrels.

Estimated reserves as of January 1, 1976, are 135,000 barrels.

Probable water drive.

Estimated ultimate recovery: 267 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

Volt.--The Volt oilfield (Figure 10) was discovered July 11, 1964, when the Murphy Oil Corporation's Courchene No. 1 well was completed. It is in the SE ¼ SW ¼ sec. 4, T. 30 N., R. 36 E., Roosevelt County. Initial production was 145 barrels of oil and 60 barrels of water per day. Production is from the Nisku Formation through perforations between depths of 7,304 and 7,311 feet. (Henkes and Magill, 1970, p. 28.)

The depths of the formation tops, in feet below the Kelly bushing (elevation 2,726 feet), penetrated by the discovery well are as follows: Judith River 1,327; Fall River Sandstone 3,967; Rierdon 4,753; Kibbey 5,368; Madison 5,572; Bakken 7,174; Nisku 7,272; and Duperow 7,372 (Henkes and Magill, 1970, p. 28 and 29).

The Nisku productive area (approximately 800 acres) has about 14 feet of net pay with an average porosity of 20 percent. The oil is confined in a structural trap with a natural water drive. Produced water is injected into the Judith River Formation.

Production data, number of wells, and reserves are given in Table 12.

TABLE 12

Production Data, Number of Wells, and Reserves, Volt Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	40,850	2	0
1965	153,420	5	0
1966	266,712	5	0
1967	230,929	6	0
1968	215,009	4	0
1969	176,867	4	0
1970	155,970	4	0
1971	140,403	4	2
1972	133,281	4	2
1973	120,894	4	2
1974	125,513	5	1
1975	110,100	5	1

*Number of wells at end of year.

Producing formation: Nisku (Dev.).

Cumulative production to January 1, 1976, was 1,887,332 barrels.

Estimated reserves as of January 1, 1976, are 839,000 barrels.

Probable water drive.

Estimated ultimate recovery: 241 barrels/acre-ft.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and Listed Oil and Gas Fields.

Oil was also discovered in the Charles Formation on April 21, 1965, when the Murphy Oil Corporation's Trimble No. 1 well was reworked. The well, in the NE ¼ NE ¼ sec. 8, T. 30 N., R. 46 E., was originally drilled into the Devonian at 7,437 ft but abandoned in 1963. The well was reworked and perforations are between 5,891 and 5,909 feet in the Charles "C" zone (a show of oil was found in this zone when the well was drilled). Initial pumped production was 16 barrels of 40º API gravity oil and 33 barrels of water per day. Net pay averages about 7 feet thick with an average porosity of 8 percent. The pool is in a structural trap with a natural water drive, and is estimated to underlie about 40 acres. Estimated ultimate recovery is 89 barrels per acre-foot. The Charles "C" zone has produced between 17,000 and 26,000 barrels of oil.

Bredette.--The abandoned Bredette oilfield (Figure 6) is about 30 miles north of the town of Poplar. The field was discovered in May 1955 by the California Company in their Elizabeth Grimm No. 1 well, in sec. 13, T. 32 N., R. 49 E. Initial production was 140 barrels of 40º API gravity oil and 31 barrels of water per day from perforations between depths of 6,537 and 6,545 feet. The producing formation was the Charles "C" zone. Five months after the field was discovered, eight wells had been drilled; four were noncommercial. Seismograph data indicate the Bredette field, in secs. 12 and 13, T. 32 N., R. 49 E., is on a northwest-southwest trending anticline (Henkes and Magill, 1970, p. 23). The reservoir rock is a fractured microcrystalline, anhydritic and dolomitic limestone with some porosity (Henkes and Magill, 1970, p. 23 and 24).

The formation tops and their depths, in feet below the Kelly bushing (elevation 2,423 feet), penetrated by the discovery well are as follows: Judith River 1,565; Greenhorn 3,202; Muddy 3,742; Fall River 4,056; Rierdon 4,894; Piper Limestone 5,173; Spearfish 5,488; Heath 5,590; Otter 5,691; Kibbey 5,805; Charles 6,056; Mission Canyon 6,603; Lodgepole 7,237; Bakken 7,731; Three Forks 7,790; Nisku 7,895; Duperow 7,986; Souris River 8,475; Interlake 9,013; Stony Mountain 9,317; Red River 9,442; and Winnipeg 9,731. Total depth is 9,761 feet (Henkes and Magill, 1970, p. 23).

Peak production was 97,886 barrels in 1956 from five wells. The last recorded production was 2,922 barrels in 1960 (Henkes and Magill, 1970, p. 24).

Table 3 lists production data for this field.

North Bredette.--The North Bredette field (Figure 6) which has not produced since 1965, is in sec. 1, T. 32 N., R. 49 E. and secs. 28 and 34, T. 33 N., R. 49 E. It was discovered in May 1956 by the California Company with their Paulson No. 1 well which is in the SW ¼ sec. 34, T. 33 N., R. 49 E. Initial production was 114 barrels of 38º API gravity oil per day from the McGowan and "C" zones of the Charles Formation.

The producing zones are fractured, microcrystalline, anhydritic and dolomitic limestone with an average net pay zone of about 25 feet. The depths to the formation tops, in feet below the Kelly bushing (elevation 2,695 feet), penetrated by the discovery well are as follows: Judith River 1,874; Fall River 4,358; Charles 6,262; Mission Canyon 6,784; and Lodgepole 7,410. Total depth is 7,475 feet (Henkes and Magill, 1970, p. 24). All six of the field's wells were completed as flowing wells. However, within 2 months, oil flow usually terminated because of excess water and pumping became necessary (Perry, 1960, p. 82). In 1958 the field produced 151,261 barrels of oil from five wells (Perry, 1960, p. 82).

Table 3 lists production data.

Red Fox.--The Red Fox oilfield (Figure 6) was discovered in April 1967 when the Murphy Oil Corporation's Red Fox No. 1 well was completed in the SE ¼ NE ¼ sec. 17, T. 30 N., R. 38 E. Perforations were between 7,694 and 7,698 feet and 7,704 and 7,711 feet (Henkes and Magill, 1970, p. 27). Initial pumped production was 443 barrels of 46º API gravity oil and 148 barrels of water per day from the Nisku Formation.

The depths of the formation tops, in feet below the Kelly bushing (elevation 2,707 feet), penetrated by the discovery well are as follows: Greenhorn 3,092; Fall River 3,950; Spearfish 5,366; Kibbey 5,742; Madison 5,844; Bakken 7,571; Nisku 7,670; and Duperow 7,758. Total depth is 7,775 feet (Henkes and Magill, 1970, p. 27). The producing zone averages about 10 feet of net pay with an average porosity of 18 percent. The field is confined to a structural trap with a natural water drive.

Production data, number of wells, and reserves are given in Table 13.

TABLE 13

Production Data, Number of Wells, and Reserves, Red Fox Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1967	101,565	l	0
1968	106,583	l	0
1969	73,838	1	0
1970	27,690	1	0
1971-72	16,988	1	0
1973	7,961	1	0
1974	7,201	1	0
1975	6,751	1	0

*Number of wells at end of year. Producing formations: (Dual Completion) Duperow (Dev.) and Charles "C" (Miss.).

Cumulative production to January 1, 1976, was 348,577 barrels.

Estimated reserves as of January 1, 1976, are 18,000 barrels.

Probable water drive.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and listed Oil and Gas Fields.

Mineral Bench.--The Mineral Bench oilfield (Figure 6), a one-well field, was discovered on January 31, 1965 when the Tenneco Oil Company's Nesbit No. 1 well was completed in the NE ¼ NE ¼ sec. 4, T. 31 N., R. 51 E. Initial production was 214 barrels of 33º API gravity oil per day from the Duperow Formation between the following depths: 8,802 to 8,816; 8,870 to 8,872; and 8,876 to 8,886 feet. After two offset dry holes were drilled, the discovery well was reworked. Production from the reworked well was 237 barrels of 38º API gravity oil and 10 barrels of water per day from the Charles "C" zone through perforations at depths of 7,121 to 7,126 and 7,143 to 7,145 feet. The Duperow producing zone has about 24 feet of net pay with an average porosity of 11 percent. The Charles "C" zone has about 16 feet of net pay with an average porosity of 11 percent. Both producing zones are structural traps with a natural water drive. The productive area of the Duperow zone underlies about 40 acres, and the Charles "C" zone, about 160 acres. Produced water is injected into the Dakota-Lakota Formation.

The formation tops penetrated by the discovery well were at the following depths, in feet below the Kelly bushing (elevation 2,658 feet): Spearfish 5,824; Amsden 5,939; Charles 6,520; Mission Canyon 7,148; Nisku 8,448; Duperow 8,564; and Interlake 9,547. Total depth is 9,676 feet (Henkes and Magill, 1970, p. 24 and 25).

Table 14 lists the production data, number of wells and reserves for this field.

TABLE 14

Production Data, Number of Wells, and Reserves, Mineral Bench Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1964	0	0	0
l965	34,240	l	0
l966	34,290	l	0
l967	16,465	l	0
1968	13,797	l	0
1969	8,551	1	0
1970-72	23,129	1	0
1973	6,016	1	0
1974	1,937	1	0
1975	1,129	1	0

*Number of wells at end of year. Producing formations: (Dual Completion) Duperow (Dev.) and Charles "C" (Miss.).
Cumulative production to January 1, 1976, was 139,554 barrels.
Estimated reserves as of January 1, 1976, are 1,000 barrels.
Probable water drive.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and listed Oil and Gas Fields.

Chelsea Creek.--The Chelsea Creek field, an abandoned one-well field, was discovered April 29, 1972, when the Calvert Petro Funds No. 1 Federal well was drilled in SE ¼ SW ¼ sec. 33, T. 30 N., R. 48 E. Total depth is 7,545 feet. Initial production was 160 barrels per day from the Nisku Formation. The oil is confined in a structural trap with a natural water drive.

Table 15 gives the production data and number of wells.

TABLE 15

Production Data, Number of Wells, and Reserves, Chelsea Creek Oil Field, Fort Peck Indian Reservation.

Year	Production (barrels)	No. producing wells*	No. shut-in wells*
1972	3,881	1	0
1973	5,428	1	0
1974	1,327	1	0
1975	912	0	0

*Number of wells at end of year. Producing formations: (Dual Completion) Duperow (Dev.) and Charles "C" (Miss.).

Cumulative production to January 1, 1976, was 11,548 barrels.

Estimated reserves as of January 1, 1976, are zero barrels.

Probable water drive.

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Reviews 1964 to 1975 inc., Summary of Producing Oil Fields and listed Oil and Gas Fields.

Wolf Creek.--The Wolf Creek field (Figure 10), abandoned in 1956, is in sec. 14, T. 30 N., R. 46 E., Roosevelt County. It was discovered in December 1952 when the Continental Oil Company's Fast No. 1 well was completed. Initial pumped production was 185 barrels of 32º API gravity oil and 65 barrels of water per day from the Madison Formation. Perforations are between depths of 6,409 and 6,437 feet. Cumulative production from two wells was 1,979 barrels of oil.

The depths of the formation tops, in feet below the Kelly bushing (elevation 2,727 feet), penetrated by the discovery well are as follows: Judith River 920; Fall River Sandstone 3,925; Rierdon 4,806; Kibbey 5,510; Charles 5,574; and Mission Canyon 6,110. Total depth is 6,448 feet (Henkes and Magill, 1970, p. 29).

Oil Refining

The Tesoro Petroleum Company refinery, with a charge capacity of 2,700 barrels of crude oil per day, is the only oil refinery on the reservation (Figure 6). In 1975, 690,142 barrels of crude oil were refined. Nearby fields supplied 686,624 barrels and the balance was imported from Canada. Between 1970 and 1974 the crude oil refined yearly ranged from 515,831 barrels in 1970 to 861,309 barrels in 1969.

Transportation and Markets

An 8-inch gas pipeline crosses the southwest corner and south-central part of the reservation. This pipeline runs from the Bowdoin gas field to Poplar where it connects with a line to Williston, N. Dak. A 4-inch oil pipeline connects the Tule Creek field with the East Poplar field. A 12-inch oil pipeline runs from the East Poplar field to Regina, Sask. A 10-inch oil pipeline runs south from the East Poplar field to join a 16-inch pipeline at Cabin Creek and extends south into Wyoming. The major pipelines are shown in Figure 6.

There is a ready market for oil and gas in Montana. The state imports about 81 percent of the oil that it refines (Table 16).

Potential Resources

The occurrence of petroleum and natural gas accumulations is related to their different modes of origin within the generally recognized three stages of thermal maturation of organic matter in sedimentary rocks: (1) immature--biological processes at shallow depths in accumulating sediments generate gas consisting of methane; (2) mature--thermal cracking processes generate liquid hydrocarbons (oil) and high molecular-weight gas; and (3) post-mature--gas, consisting of methane, is generated by destruction of liquid hydrocarbons and higher molecular-weight gases and by conversion of organic matter to carbon-rich residues and volatile compounds in response to increasingly severe thermal cracking processes. Thermal cracking processes are controlled by temperature and duration of time (geologic time) factors. Temperature is controlled primarily by depth of burial.

Another important element in the formation of hydrocarbons is the deposition of organic-rich sediments and (or) carbonates. The amount and type of hydrocarbon (oil or gas) generated depends on the volume of source rock and the concentration and type of organic matter it contains. When sufficient hydrocarbons are generated and expelled, they migrate along vertical and horizontal pathways until trapped in porous, permeable reservoir rock.

In the Fort Peck Reservoir area west of the reservation, Mississippian and older Paleozoic rocks have probably generated oil, if adequate source beds are present (Wolfbauer and Rice, 1976). Based on criteria of Baker (1972) and Momper (1972) and data from Wolfbauer and Rice (1976) and Williams (1974), organic-rich intervals in the Ordovician Winnipeg, Red River., and Stony Mountain Formations are considered as source beds for Ordovician and Silurian oil because they are in close contact with reservoirs that contain oil in adjacent areas. The Bakken shale is an excellent source bed for Upper Devonian and Mississippian reservoirs. Shaly interbeds in the Madison Group are potential source beds for Mississippian oil. Devonian shales are probable sources of oil for Devonian reservoirs.

Oil accumulations in the Fort Peck Indian Reservation have been both structurally and stratigraphically entrapped. Any remaining accumulations will probably be stratigraphic with only subtle structural control. To the east, stratigraphic traps in the Red River Formation and Charles "Radcliffe" are localized along basement lineaments which may extend to the reservation. Local structure combined with porosity and permeability variations and fracturing of Devonian carbonate units such as the Winnipegosis, Dawson Bay, and Birdbear Formations are possible traps for Devonian oil. Also, cyclical deposition of carbonates interbedded with shales and evaporites in the Souris River and Duperow Formations may form additional Devonian stratigraphic traps.

Future discoveries that produce over six million barrels each will probably be in stratigraphic traps. A favorable location for an oilfield with this type of trap is in T. 29 N., R. 52 E. and within Lower Cretaceous, Upper Jurassic, Lower Pennsylvanian, and Mississippian strata.

Most of the future discoveries will probably be in structural traps that individually produce less than two million barrels. Favorable locations are in T. 30 N., R. 53 E. and T. 31 N., R. 51 E. Structural traps could be in Devonian, Mississippian, Silurian, and Ordovician strata.

More extensive shallow, biogenic gas accumulations of the immature stage which may exist in the Poplar field area should be reexamined. Significant resources of this type in low permeability sandstone and siltstone in the Bowdoin field to the west have been primarily stratigraphically controlled.

Total known reserves on the reservation are 7,033,000 barrels (Table 3). Future exploration may increase the reserves. Conditions considered favorable for oil exploration on the reservation are:

(1) Newly discovered oil commands a high price.

(2) Oil is currently produced on the reservation.

(3) The reservation is underlain by sedimentary rocks that could contain oil and gas in stratigraphic traps. The most favorable rocks are of Lower Cretaceous, Upper Jurassic, Lower Pennsylvanian, and Mississippian age.

(4) In December 1974, a 1,400,000 barrel oilfield (Big Muddy Creek) was discovered six miles east of the southeast border of the reservation. The discovery well penetrated the Interlake (Silurian) and Red River (Ordovician) Formations for a total depth of 11,963 feet. Initial production was 1,246 barrels per day. Both formations produce oil from a structural trap with a natural water drive. Cumulative production in 1975, from both formations, was 306,968 barrels of oil valued at $4,003,556 (3 Red River wells and 1 Interlake well). The Interlake Formation is estimated to contain a productive area of about 320 acres with an ultimate recovery of 200,000 barrels. The productive area of the Red River Formation is estimated to be 960 acres with an ultimate recovery of 1,200,000 barrels. This discovery demonstrated that a small structure can produce more than 1 million barrels of oil.

(5) Not all of the potentially favorable structures on the reservation have been tested.

Factors considered unfavorable for oil exploration on the reservation are:

(1) Rocky Mountain oil costs about twice as much to find as Midcontinent oil, according to a large independent oil company.

(2) Most of the conspicuous structures have probably been tested.

(3) Nine of 15 oilfields are 1-, 2-, or 3-well fields and are surrounded by dry holes. Because the cost of drilling dry holes substantially increases total production costs, 1-, 2-, or 3-well fields are often noncommercial.

(4) Seven of the 15 reservation oilfields will produce less than one-half million barrels each (Table 3).

Environmental Aspects

All well sites should be graded and planted with grass after the well is completed. Wells and pumping equipment should have automatic devices that will halt production when abnormal conditions occur. All storage tanks should be enclosed by dikes and should be equipped with floating roofs to reduce the escape of hydrocarbons into the air.

Lignite

General

Lignite is a major resource in the Fort Peck Reservation. Numerous lignite beds occur in the Fort Union Formation in the eastern half of the reservation (Smith, 1910). Some beds are widespread but most are lenticular; they are a northern extension of the Montana lignite field which has been studied by many. Smith (1910) studied the lignite in the reservation and Colton (1962) studied the lignite in northeastern Montana. The same strata to the south were studied by Collier and Knechtel (1939), to the east by Beekley (1912), and to the north by Bauer (1914b). All conclude that it is difficult to correlate beds of lignite from one area to another, partly because they are lenticular and partly because they are extensively concealed by younger deposits. The area in which the Fort Union Formation occurs and the abandoned lignite mines are shown on Figure 11.

The Fort Union strata mostly dip at a low angle to the east. In the north central and central parts of the reservation the tilted beds are truncated by the Flaxville gravel. Therefore, the oldest strata of the Fort Union crop out in those areas, as well as in the southeastern part of the reservation. The younger strata crop out in the northeastern part.

Northeast of Brockton (Figure 2) the lignite beds dip 25 to 135 feet per mile to the east (Smith, 1910). Smith (1910, p. 46-47) lists 10 lignite beds in a composite section 884 feet thick. The lignite beds range in thickness from 2 to 9 feet; the lowermost bed is 7.7 feet thick.

West of the West Branch of Poplar River and Cottonwood Creek are exposures of numerous beds of lignite of the Fort Union Formation (Smith, 1910). Here the Fort Union is overlain by relatively thin glacial deposits on the lower elevation and thicker deposits of Flaxville gravel and dune sand on the upland area (Colton, 1963c, d, j, and 1964a). In the area southeast of the junction of Cottonwood Creek and West Branch of Poplar River, Smith (1910, p. 57) lists a measured section (242.8 feet thick) that contains 9 lignite beds which range in thickness from 5 inches to 6 ½ feet. He (1910, p. 56-57) lists another section (180 ft 10 in.) at the east end of the bench south of the west branch of Poplar River with 6 lignite beds that range in thickness from 5 inches to 6 feet; most are less than 3 feet thick. Smith (1910, p. 58) lists 4 lignite beds north of Cottonwood Creek in a section (about 63 feet); each bed is less than 2 feet thick.

Several lignite beds are in the northeastern part of the reservation (Smith, 1910; Bauer, 1914b; and Colton, 1962). Good exposures are on the south side of Wolf Creek, and along Coulee Creek. The important beds are shown graphically on Figure 12. Their reserves as of 1962 are shown on Table 17. These lignite beds should be in strata equivalent to the lower part of the Tongue River Member of the Fort Union Formation

Colton (1962, p. 281) reports the average thickness of individual lignite beds in the northeastern part of the reservation to range between 2.8 and 9 feet. These contain a measured reserve of 32,952,800 short tons, and an inferred reserve of 61,487,500 short tons (Colton, 1962, p. 279).

Deposits

Fort Kipp.--The Fort Kipp lignite deposit, in the southeastern part of the reservation, contains two beds (Figure 13). The upper or Fort Peck bed ranges in thickness from 3 to 9 feet and averages 5.4 feet. The underlying Fort Kipp bed is 7 to 10 feet thick, and averages 8.5 feet. Intervening rock, mainly claystone between the two coal beds, ranges in thickness from 7 to 49 feet with an average of 27.

The lignite beds dip about 80 feet per mile, generally northeasterly, as shown by Figure 14, Figure 15, and Figure 16. However, there are local variations in dip.

The overlying strata are mainly claystone, but some sandstones and calcareous siltstones also are present. These are generally irregularly interbedded and poorly indurated. Well indurated silt and sand concretions with carbonate nuclei are randomly distributed throughout the overlying strata. These are small and should not adversely affect mining (Burlington Northern, Inc., 1975, p. 177). Glacial till covers most of the area.

The topography is characterized by gently rolling hills. Maximum depth of the coal beds is about 200 feet (Figure 17 and Figure 18).

Lignite resources and overburden ratios are listed in Table 18.

Reserve.--The Reserve lignite deposit is in T. 32 N., R. 55 E., T. 33 N., R. 54 E., and T. 33 N., R. 55 E., west of the towns of Reserve and Medicine Lake (Figure 11 and Figure 19). Figure 19 depicts structure contours of the No. 1 bed and the 50- and 100-foot isopachous lines of the overburden. The No. 1 bed, which is the most important, has been designated the Coal Mine lignite bed by Colton (1962, p. 279, 280). It dips generally to the southeast about 16 feet per mile, but ranges from f lat in some areas to as much as 80 feet per mile in others. Coal thicknesses average 7.5 feet.

Assuming a 100-foot overburden limit, the No. 1 bed underlies 18, 237 acres and contains 246 million tons of lignite. Approximately 1,471 million cubic yards of overburden cover the bed, giving an overburden-to-coal ratio of 6 cubic yards to 1 ton (Great Northern Railway Co., 1967, unpublished report). About 23 million tons of lignite in the deposit are north of the reservation boundary (Figure 19).

A lower bed, the No. 2, is 2 feet thick in the northern part of the deposit and thickens in the south. In T. 32 N., R. 55 E. it is about 18 feet below the No. 1 bed and averages 5 feet thick. In this township, an unnamed bed lies about 18 feet below the No . 2 bed . It ranges from 1 to 4 feet in thickness. An upper bed, also unnamed, overlies the No. 1 bed in the northern part of the area. Although locally it may be as much as 6 feet thick, it is not persistent. Resources in these beds are unknown.

Medicine Lake.--The Medicine Lake lignite deposit is mainly in T. 32 N., R. 54 E., but extends into secs . 35 and 36 , T. 33 N., R. 53 E., sec . 31, T. 33 N., R. 53 E., and sec. 31, T. 33 N., R. 54 E. (Figure 11 and Figure 20). It is probably an extension of the Reserve deposit, which is about four miles to the east. The thickest lignite bed, identified as the Timber by Colton (1962, p. 280), averages about 9 feet thick. The bed underlies an area of 3,740 acres and contains 58 million tons under less than 110 feet of overburden (Ayler and others, 1969, p. 60).

An additional bed in the area, called the local bed D by Colton (1962, p. 280), is about 3 feet thick. He calculated the measured resources to be 294,000 tons and indicated resources to be 1,134,000 tons.

Other Deposits.--Other lignite beds underlie the southeastern part of the reservation in the Brockton-Culbertson area. The A bed, locally known as the Big Dirty, is near the contact of the Fort Union and the Hell Creek Formations. The bed crops out extensively in T. 28 N., R. 53 E., as shown in Figure 11, but has been burned along its outcrop in secs. 21 and 22. The following bed section was reported from the center of sec. 21, T. 28 N., R. 53 E. (Smith, 1910, p. 47).

	feet	inch
Roof, clay		
lignite	2	2
clay		1
lignite	2	7
lignite, dirty		4
lignite	2	6
Total lignite	7	7

The A bed dips to the east about 100 feet per mile. It underlies the area between its outcrop eastward to the reservation boundary on Big Muddy Creek (Smith, 1910, p. 47). The bed is estimated to contain about 400 million tons.

Three additional lignite beds are in the Brockton-Culbertson area (Smith, 1910, p. 48). A 5 foot bed of lignite lies about 15 feet above the A bed. It has a l-foot clay parting near its top. Bed B is about 300 feet above bed A and is extremely variable in thickness, ranging from 1 foot to 5-½ feet in secs. 30 and 31, T. 28 N., R. 54 E. Bed C is about 115 feet above bed B and only about 2 feet thick. The resources in these beds have not been estimated.

Lignite exposures have been reported in the eastern part of the reservation on Smoke Creek and Sauerkraut Coulee (Witkind, 1959, pl. 1). Scattered occurrences are along the Poplar River and Cottonwood Creek in the central and northern part of the reservation, as well as north of the town of Wolf Creek (Smith, 1910, pl. III). Exposures are few, mainly because of the glacial till that mantles these areas. Estimate of resources in these beds is not possible at this time.

Resources

The lignite resources of the major beds in the Fort Kipp, Reserve, and Medicine Lake deposits total 617 million tons. Minor associated beds will add to the resources. In the southeastern part of the reservation the A bed contains an estimated 400 million tons. Substantial resources probably occur in the Smoke Creek and Sauerkraut Coulee areas; the extent of those in the central part of the reservation are unknown.

Characteristics

The rank of the coal on the reservation is lignite A. Coal of this rank has a high moisture content, heat contents range from 6,300 to 8,300 Btu per pound on a mineral matter free basis, and is nonagglomerating and noncoking.

Analyses of lignite samples from drill cores are listed in Table 19. They average 36.7 percent moisture and 6,637 Btu per pound. Ash is low to intermediate but sulfur varies widely, ranging from 0.32 percent to 2.28 percent. The high sulfur content of a few samples is probably due to pyrite. An investigation of Montana lignites by the Bureau of Mines also indicated large variations in sulfur percentages (Cooley and Ellman, 1975, p. 145, 146).

Lignite is tough and fibrous when freshly mined, but it tends to disintegrate or slack when exposed to weather, particularly when alternately dampened and dried or exposed to heat. It heats when oxidized which can lead to spontaneous combustion. Special precautions must be observed when lignite is stored in piles for long periods. The U.S. Bureau of Mines and the U.S. Army Corps of Engineers have developed a safe and stable storage method (Ellman, 1963, p. 42-44), which is commonly followed to provide emergency fuel supplies for industrial users.

Mining Methods

Underground Mining.--A few small underground lignite mines on the reservation formerly supplied local markets. Production was limited; none were operating on the reservation in 1975 (Lawson, 1976, p. 41, 42).

The Alton mine is in NE ¼ sec. 20, T. 28 N., R. 54 E. (Figure 11). A 10º slope was driven through siltstone to the 9-foot-thick Fort Kipp bed. Room and pillar mining method was used (Figure 21). Because the depth of cover was only 25 feet, many rooms have caved to the surface, forming vertically-walled depressions as much as 30 feet long, 10 to 15 feet wide, and as much as 15 feet deep (Henkes and Magill, 1970, p. 10). About 6.8 acres have been disturbed by mining. Production from 1942 to 1952 when the mine was abandoned was 32,037 tons (Henkes and Magill, 1970, p. 10). Production prior to 1942 is not recorded.

The Simons-Gilligan mines are in SE ¼ sec. 16, T. 28 N., R. 53 E. (Figure 11). The lignite, probably the A bed, is 12 to 14 feet thick with cover of 30 to 50 feet of clayey material and siltstone. Only 7 to 8 feet of the bed's thickness was mined. Mining terminated in 1941 and the portals were reported caved in 1965 (Henkes and Magill, 1970, p. 11). The workings underlie about 1.35 acres (Figure 22).

Other small underground lignite mines have been reported in the Brockton area, near Wolf Creek, and in Coal Mine Coulee (Colton, 1962, p. 280).

Underground mining of the reservation's lignite is unlikely in the foreseeable future because of the high cost and difficult working conditions.

Surface Mining.--Surface mining accounted for 54 percent of the U.S. coal production in 1975 and is projected to account for approximately two-thirds by 1985 (Hunter, 1976, p. 56). Five large active surface coal mines are in eastern Montana. Production from them in 1975 was 21,786 thousand tons, including 300 thousand tons of lignite. Production is expected to increase to 41.0 million tons a year by 1980 and the number of mines to nine (Glass, 1974, p. 19, 20).

The lignite in the Fort Kipp, Reserve, and Medicine Lake deposits can be mined by surface methods. Lignite has been mined from the Medicine Lake deposit at the Wolf Creek mine (Figure 11 and Figure 20). Total production from this small surface mine was between 13,000 and 15,000 tons. It has been closed since 1960 (Henkes and Magill, 1970, p. 11).

The reservation's flat-lying beds and subdued topography make area mining the most applicable method. At area surface mines, the topsoil is removed, usually by scraper-loaders. The overburden is then drilled and broken by explosives, removed by draglines and/or power shovels, and deposited in an adjacent cut where the coal has been previously removed. Next, the exposed coal is drilled and blasted, loaded by power shovels or front end loaders, and hauled to the shipping site.

Rehabilitation of mined land has received much attention in recent years. It includes topsoil removal, overburden leveling, topsoil replacement, surface manipulation to trap rain and snow, revegetation, and possibly fertilizing and irrigation. A study by the National Academy of Sciences (1974, p. 53) concluded that there "presently exists technology for rehabilitating certain western sites with a high probability of success." These sites include those with more than 10 inches of annual precipitation. The annual precipitation on the reservation is about 13 inches and, therefore, should be sufficient for successful rehabilitation. However, rehabilitation is essentially site specific and depends on many factors other than precipitation, such as soil composition, topography, vegetation, and projected land use. The average rehabilitation cost for three mines in eastern Montana, according to a recent Bureau of Mines study, is about $3,560 per acre (Persse and others, 1976).

Coal beds in Montana are commonly aquifers and are often used by farmers and ranchers as sources of water. Surface mining may disrupt flow patterns through these aquifers. Fortunately, the amount of disturbed land at any time will be small so that only local disruptions should occur. A study of aquifers disturbed by surface mining in southeastern Montana disclosed no indications of adverse post-mining hydrologic conditions (Van Voast and Hedges, 1975, p. 30).

A recent study of the capital investment and operating costs for surface coal mines in the Northern Great Plains indicates that the coal selling price is markedly sensitive to production rate and bed thickness (Table 20). Based on this the lignite selling price from large surface mines on the reservation would be on the order of $4.86 to $6.58

per ton. Montana lignite sold for an average price of $5.04 per ton in 1975. The lower selling prices of coal from mines in thicker beds (25 to 50 feet) are included in Table 20 to show the relatively favorable competitive position enjoyed by the large surface mines now operating in the Northern Great Plains.

TABLE 20

Estimated selling price for coal from surface mines in the Northern Great Plains.

Production (million tons/year)	Bed thickness (feet)	Selling price (dollars/ton)
3.68	10	6.58
5.52	15	4.86
9.20	25	3.39
18.40	50	2.39

Source: Basic Estimated Capital Investment and Operating Costs for Coal Strip Mines, 1976, U.S. Bur. Mines, IC 8703.

Markets

Electrical Power Generation.--In 1975 electric utilities consumed approximately 404 million tons or 72 percent of the total domestic supply (Westerstrom, 1976, p. 40). Because electrical power consumption is expected to increase 7.1 percent per year, coal consumption will continue to rise (Bonneville Power Administration, 1973, p. 13). Thus, the electric utilities will be the most important market for reservation coal.

Coal specifications for power plant use include the usual properties, such as moisture, ash, sulfur, and heat content. Also of importance are the softening temperature, initial deformation temperature, fluid temperature, and fouling characteristics of the ash. These properties should be determined in any future investigation of reservation coals.

Coal contracts for electrical power plants specify limits on moisture, ash, and sulfur content; penalties are assessed for exceeding specified limits. Similarly, a minimum heat content is specified. Ash and sulfur can usually be reduced and the heat content increased by mechanical cleaning.

In pulverized coal firing, ash fusion characteristics determine whether the ash can be removed from the furnace in either the liquid or dry form. For example, coal with an ash softening temperature above 2,600ºF cannot be used in cyclone furnaces (Spicer and Leonard, 1968, p. 3-22). The fusion characteristics of the coal ash commonly depend on the amount of bases and acids in the ash. These terms have a different meaning in pyrochemistry than in normal wet chemistry. In pyrochemistry, the bases are Fe_2O_3, CaO, MgO,

Na_2O, K_2O; the acids are SiO_2, $A1_2O_3$, and TiO_2. An ash analysis of a lignite sample from the Fort Kipp prospect, Fort Kipp bed SW ¼ NE ¼ sec. 9, T. 28 N., R. 54 E. is as follows (Burlington Northern, Inc., 1975, p. 197).

Ash analysis (percent of ash)

Loss on ignition	SiO_2	$A1_2O_3$	Fe_2o_3	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O	SO_3
1.0	22.4	13.5	13.0	0.3	0.3	12.4	6.1	1.6	0.6	21.9

Most modern power plants operate with steam temperatures above 1,000ºF. These high temperatures occasionally cause a new type of fouling deposit to form on boiler tubes. The source of these deposits are some sodium and potassium compounds found in the coal, particularly the chlorides, which decompose in the flame, are vaporized, and combine with SO_3. These alkali or alkali-iron sulfates then condense on the boiler tubes. Coal ash containing 2 to 5 percent Na20 is considered medium fouling for Western coals; higher Na_2O contents may cause severe fouling (Winegartner and Ubbens, 1974, p. 6). Some boiler manufacturers, recognizing that most of the alkali associated with fouling problems is in the form of chlorides, evaluate fouling potential by analyzing the coal for chlorine. Chlorine content above a critical value ranging from 0.3 to 0.5 percent can lead to fouling (Sondreal and others, 1968, p. 21).

The Environmental Protection Agency (EPA) requires that no more than 1.2 pounds of sulfur dioxide per million Btu can be emitted into the atmosphere. To comply with this regulation, the lignite must contain less than 0.44 percent sulfur, and this assumes it averages 6,650 Btu/pound and that 10 percent of the sulfur remains in the ash (Zachar and Gilbert, 1968, p. 5-24). However, recent tests of lignite-burning power plants indicated that about 10 to 40 percent of the sulfur remained in the ash; in one test the ash retained 73 percent (Gronhovd and others, 1974, p. 102).

A coal property that is important in pulverized firing is grindability, which is a composite physical property dependent on hardness, toughness, strength, tenacity, and fracture. Grindability is commonly measured by the Hargrove grindability test which is a standard test of the American Society of Testing Materials.

Some trace elements in coal may be hazardous when emitted into the atmosphere in the form of vapors or fine particles during combustion. These include mercury, selenium, beryllium, cadmium, arsenic, lead, antimony, thallium, vanadium, chromium, manganese, nickel, and zinc (Davidson and others, 1974, p. 1107; Linton and others, 1975, p. 8523.

Semiquantitative analyses of ash from four lignite beds on the reservation are listed in Table 21 (Great Northern Railway Co., 1953-1955).

Gasification.--Natural gas has been one of the cheapest and most convenient fossil fuels. The heat content is high, and natural gas is virtually nonpolluting. These attributes caused the consumption of natural gas to grow at a rate of 5.4 percent per year between 1947 and 1971 as compared to 3.1 percent per year for total energy consumption. However, gas consumption declined 3 percent in 1974 and 7 percent in 1975, while proven reserves also continued to decline (Koelling, 1976, p. 109). By the year 2000, about 20 percent of the gas consumed could be synthetic natural gas from coal. This would require 300 million tons of coal per year for about 57 plants each producing 250 million cubic feet of gas per day (Dupree and Corsentino, 1975, p. 42). Although no significant production is expected before 1980, the synthetic natural gas industry could be a future market for the reservation's coal.

First generation gasification plants will probably use proven foreign technology based on the Lurgi gasifier. Lignite is particularly suitable as a feed stock because it is non-agglomerating and highly reactive. Also, lignite from the reservation can easily meet the ash requirements (under 30 percent) for gasification by the Lurgi process.

The cost of a first-generation, 250 million cubic-feet-per-day gasification plant, which is the minimum feasible size, is estimated to be more than $1 billion (Winegartner, 1976, p. 58). The cost of synthetic natural gas to be manufactured between 1981 and 2006 in North Dakota and delivered to Michigan is expected to average about $3.00/Mcf (Mermer, 1975, p. 226). Another estimate places the cost close to $4.00/Mcf (Hammond, 1976, p. 193). At the present time, a synthetic natural gas industry appears likely to develop in the United States only with the help of some form of government subsidy.

Much research is being directed toward the development of new gasification technology. Among second generation processes are the Hygas, Bi-gas, Cogas, Synthane, and the $C0_2$ Acceptor process. The latter is of particular interest as it is being developed to gasify lignite. Which processes will be the most economical cannot be determined at this time. Each will reduce gas costs by approximately 10 to 15 percent over first generation processes (Elliott, 1975, p. 284).

Underground gasification may be applicable to some of the deeper lignite beds on the reservation. The heat content of the gas is low, but it could be used near the gasification site for electrical power generation and industrial uses or upgraded to the quality of natural gas. An advantage is that a clean fuel would be produced. Also, underground mining would be eliminated, along with its low productivity and health and safety problems; surface mining would also be eliminated along with its environmental concerns. Waste disposal problems would be eliminated because the ash would remain underground. However, techniques that might insure uniform gas flow and quality have not been well developed. There may be problems with subsidence as well as contamination of groundwater. Nevertheless, underground gasification may offer a solution to the utilization of some reservation lignite resources.

Synthetic Liquid Fuels.--There are no commercial synthetic liquid fuel plants in the United States, and no significant production is anticipated before 1985. However, by 2000, production is expected to reach 0.7 million barrels a day and require 91 million tons of coal a year (Dupree and Corsentino, 1975, p. 46).

Most coal liquefaction processes now being developed in the United States are directed toward converting bituminous coal. Bituminous coal is preferred over lignite because of its higher hydrogen-to-oxygen ratio. Also, large reserves of bituminous coal are available in the Eastern United States where there is great demand for liquid fuels.

Nevertheless, research continues on lignite liquefaction mainly because of the large inexpensive Western reserves. Several processes involve the destructive distillation of lignite to produce char, tar, oils, and gas. Important objectives are to maximize the liquid yield and develop ways of utilizing the byproduct char (Friedman and others, 1975, p. 217). Char can be burned in power plants, gasified, or used to make formed coke.

Carbonization analyses of lignites from several deposits on the reservation are given in Table 22. The oil yield would be significantly larger with the processes now being developed.

TABLE 22

Carbonization Analyses of Lignite (percent, moisture-free coal) 500ºC.

Constituent	Fort Kipp deposit: Fort Peck bed	Fort Kipp deposit: Fort Kipp bed	Medicine Lake deposit: No. 1 bed, Timber Coulee bed	Reserve deposit: No. 1 bed, Coal Mine bed
Char	72.8	72.5	70.9	70.1
Water	8.7	8.0	9.9	9.4
Tar	6.0	6.1	5.2	6.5
Light oil	1.7	1.6	1.3	.8
Gas	10.9	11.5	11.7	12.4
H_2S	.3	.5	.7	6

Source: Lignite Drilling Program Williston Basin, North Dakota and Montana, Report No. 1, 1953-1955, Great Northern Railway Co. (now Burlington Northern, Inc.) Mineral Resources and Development Dept.

Metallurgical Uses.--The short supply and high cost of coking coal has stimulated interest in making artificial coke from noncoking coal. Lignite or lignite char can be converted into formed coke which is used to fuel blast furnaces or as a reducing agent in other metallurgical processes. A plant at Kemmerer, Wyoming, is currently producing 300 tons of formed coke per day from noncoking coal for phosphorous production.

Iron may also be produced by direct reduction using char or semicoke made by the carbonization of lignite (Landers, 1965, p. 52). The limited reserves and escalating costs of oil and natural gas have led to investigations which use coal as an alternate fuel for indurating iron taconite pellets. Experiments at the Twin Cities Metallurgical Center indicate that lignite would be suitable. About 100 pounds of lignite would be required to produce each ton of pellets (Kaplan, 1975, p. 348).

Cement Manufacture.--In the past few years, nearly all cement manufacturers have had to consider coal as a primary fuel. Many have acquired coal reserves or signed long-term contracts to assure a reliable coal supply.

A temperature of 3,000°F must be maintained in a cement kiln (Landers, 1965, p. 55). This temperature cannot be obtained from raw lignite because of its low heat content. However, the heat content, which must exceed 10,000 Btu/pound, can be increased sufficiently by drying lignite (Leonard and McCurdy, 1968, p. 3-25; Landers, 1965, p. 55).

Transportation

General.--Local-markets are limited and can utilize only a small quantity of the reservation's lignite. If large-scale mines are developed, the energy contained in the lignite will have to be utilized in distant markets. The markets will be supplied in two ways, by unit trains or slurry pipelines. Alternatively, the lignite could be converted near the mine to high-quality energy forms such as electrical power, gas, or liquid fuels. These, in turn, could be transported to distant markets.

Unit trains.--The reservation is provided with rail service by Burlington Northern, Inc. The main line passes through the southern part of the reservation immediately north of the Missouri River. A line east of the reservation runs north from Bainville to Plentywood. From here, the line, about 12 miles north of the reservation, runs west.

Unit trains consist of special purpose rail haulage equipment specifically designed to transport coal over long distances. They are loaded at the mine site, travel over existing rail lines to specific destinations, are unloaded, and returned directly to the mine--all on a predetermined schedule. The significant economies achieved by unit train transportation over conventional rail transportation are mainly the result of three principal factors: design efficiency, equipment balance, and intensive use (Glover and others, 1970, p. l). Unit trains are advantageous over other transportation systems because they use existing rail lines. Thus, capital cost is relatively low and lead-time between planning and full-scale operation is minimized.

A recent study lists the cost of moving coal in a unit train as about 1.2 cents per ton-mile for 500 miles, 1.0 cents per ton-mile for l,000 miles, and 0.9 cents per ton-mile for 1,500 miles (Wasp, 1976, p. 29).

Transportation costs can be reduced by removing a substantial part of the lignite's moisture. Experiments at the Grand Forks Energy Research Center showed that the moisture content could be reduced from 39 percent to 12 percent by a simple drying operation (Ellman and others, 1975, p. 322). Another advantage is that dried lignite has a higher heat content and is a superior product for powerplant utilization.

Slurry Pipelines.--Another method of transportation to distant markets is by slurry pipeline. With this method, coal is crushed and ground extremely fine, water is added, and the resultant mixture pumped through pipelines. In Arizona 300 tons of coal per hour are transported in an 18-inch-diameter pipeline 273 miles from a surface mine to a powerplant. The coal is ground to 325-mesh and mixed with an equal weight of water to form the slurry.

An advantage of pipelines is that they are continuous transportation systems. Manpower and energy requirements are low. They are safer and more environmentally acceptable than unit trains in that there is no hazardous grade crossings, noise, or dust. A disadvantage is the large water requirement--about 600 acre-feet per million tons of coal--and the slurry must be dewatered before it can be used.

The cost of transporting 25 million tons of coal per year a distance of l,000 miles is estimated at 0.5 cents per ton-mile (Wasp, 1976, p. 29). Costs increase sharply with both decreased volume and distance. Each initial slurry pipeline will require a coal resource of about 750 million tons. The known surface-minable resources on the reservation are insufficient to support a large slurry pipeline system, but additional exploration could establish sufficient resources on the reservation and in adjacent areas. Also, feeder pipelines from smaller deposits may be practical if slurry pipelines become a more established transportation method. Pneumatic feeder pipelines have also been proposed (Rieber and others, 1975, p. IV-2). A recent study indicated that about half of the coal exported from the Northern Great Plains will be transported via slurry pipelines and about half by unit trains (U.S. Department of Interior, 1975, p. 305).

Mine-Site Energy Conversion

If the reservation's coal is to be converted to high-quality energy forms such as electrical power, synthetic natural gas, or liquid fuels at or near the mine site and transported to distant markets, one of the primary considerations will be an adequate water supply. A base load l,000 megawatt electrical power plant will require 4.7 million tons of lignite per year (80 percent capacity factor, 6,650 Btu per pound lignite). The water requirements are estimated to be 12,000 to 15,000 acre-feet per year if a wet natural draft cooling tower is used (Northern Great Plains Resources Program, 1975, p. 71). A dry tower will require only 2,000 acre-feet per year, but dry towers cost more than three times as much to build as natural draft wet towers (Woodson, 1971, p. 77). Thus, there is considerable economic incentive to locate power plants at sites where relatively large supplies of cooling water are available. Nevertheless, a power plant in the 300 megawatt range with two dry cooling towers is under construction at Wyodak, Wyoming.

The "best estimate" of the water requirements for a 250 Mscf per day coal gasification plant in the Northern Great Plains is 9,500 acre-feet per year (Northern Great Plains Resources Program, 1975, p. 72). The water requirement of a coal liquefaction plant producing 100,000 bbl per day is 25,000 acre-feet per year (U.S. Department of Interior, 1975, p. 79). These estimates assume that wet cooling towers are used; water requirements are reduced by approximately one-half with dry cooling towers.

Water for coal development in northeastern Montana can probably be provided by the Missouri River system without major storage facilities (U.S.

Department of Interior, 1975, p. 308). However, water pipelines and aqueducts will be needed. Even with extensive coal development in Montana, mine-site electrical power generation is not expected to be large; most of the coal will be used for synthetic natural gas conversion or exported (U.S. Department of Interior, 1975, p. 305).

Mine-site conversion of lignite will generate large quantities of ash. Much research is being directed toward utilizing ash by-products, especially fly ash, from electrical generating plants. Fly ash is used in cement manufacture, concrete construction as an aggregate, concrete products, soil amendments, plant-growth stimulants, soil stabilization, abrasives, lightweight aggregate, and water purification, as well as a filler material in tile, rubber, paint, putty, and asphalt (Quilici, 1973, p. 5). Experiments at the University of North Dakota have demonstrated that excellent brick can be made from a mixture of 25 percent fly ash and 75 percent clay (Manz, 1973, p. 205). A mixture of fly ash, lime, and aggregate (called poz-o-pac) is used for road building in North Dakota. Because of its high alkali content, lignite fly ash can be used in flue gas desulfurization units of power plants (Sondreal and Tufte, 1975, P- 65).

In 1975, 60 million tons of ash were produced, but only 16.4 percent were processed. With the probable scarcity of large markets near the reservation, most of the ash will constitute a disposal problem. Fortunately, it can be buried along with the spoil at surface mines.

Uranium

Coal commonly contains trace elements that may be recovered in the future. For example, a recent study of U.S. uranium resources indicated that little high-grade uranium ore remains to be discovered (Lieberman, 1976, p. 431). Therefore, western lignite deposits have been suggested as a possible future source of uranium. Uranium content above 25 ppm (parts per million) will be significant. It will be concentrated in the ash to about 250 ppm. Other trace elements of interest, which may be recovered from coal, are gallium, germanium, selenium, tellurium, thallium, and vanadium.

Nonmetallic Mineral Resources

Bentonite

Bentonite is a clay mineral used mainly in the manufacture of iron (taconite) ore pellets, foundry sands, and oil-well drilling mud. Numerous beds of bentonite are in the Bearpaw Shale in the western and southwestern part of the reservation (Colton and Bateman, 1956; and Jensen and Varnes, 1964). Some beds of bentonite and bentonitic shale are in the Hell Creek Formation southwest of the area (C. A. Wolfbauer and D. D. Rice, written commun., 1976).

In the southwestern part of the reservation and adjoining Fort Peck area bentonite beds are common throughout all of the exposed Bearpaw Shale except the upper 255 feet (Jensen and Varnes, 1964, pl. 2), and the thickness of the beds is as much as 18 inches. In the Charles M. Russell Wildlife Refuge, Wolfbauer and Rice (1976) record beds in the Bearpaw as much as 6 ½ feet thick. They had 18 bentonite samples tested, all of which were considered unsuitable for use as drilling mud, but of good enough quality to be a binder for foundry sands and possibly taconite pellets. The samples they obtained from the Hell Creek are not suitable for use in foundry sand. As noted by Wolfbauer and Rice (1976) economical mining of bentonite is dependent upon thin strippable overburden.

A small amount of bentonite has been mined near Brockton in S ½ NE ¼ SW ¼ sec. 21, T. 28 N., R. 53 E. (Henkes and Magill, 1970, p. 31). The deposit is about 2 feet thick. Some test results [sample FP-65-20, Table 23] indicate that the properties approach those of commercial bentonite (Henkes and Magill, 1970, p. 31).

Other bentonite deposits were reported in the Medicine Lake area in SE ¼ sec. 9, T. 32 N., R. 54 E., and SW ¼ sec. 10, T. 32 N., R. 54 E. (Henkes and Magill, 1970, p. 31). Test results of a sample from the first location [sample FP-65-18, Table 23] indicate that it is of lower quality than the bentonite in the Brockton area, but should be suitable as a ditch or pond sealant (Henkes and Magill, 1970, p. 31).

The resources in these deposits are unknown. Additional deposits may be present in the Bearpaw shale which is found over much of the reservation.

In 1975, bentonite production in the U.S. was about 3.2 million dry tons per year and is expected to reach 6.5 million dry tons per year by 2000 (Auer, 1976, p. 29). Most of this projected increase will result from more oil and gas well drilling and major expansions in the taconite industry. The former will continue to use high-grade sodium bentonite, but the latter is expected to use more abundant and lower quality calcium bentonite. Bentonite is also used as a feed supplement for livestock and as a sealant for ponds and reservoirs. Because of the increased consumption, the reservation's bentonite may supply these expanding markets.

Salt

The sedimentary rocks on the reservation contain substantial quantities of salt (NaCl). A deposit ranging from 0 to 180 feet thick underlies the reservation in Mississippian rocks at a depth ranging from about 5,000 to 8,000 feet (Figure 23) (Great Northern Railway Co., 1959).

Salt also occurs in the underlying Devonian strata (Figure 24). The thickness of this deposit is more than 200 feet in the northeastern part of the reservation. Its depth is about 10,000 feet. Additional salt deposits may be present in rocks of Triassic and Permian age (Great Northern Railway Co., 1965, p. 2).

The widespread occurrence of more accessible salt deposits elsewhere make those on the reservation of little economic interest at this time.

Potash

The thick salt deposit of Devonian age that underlies the reservation contains as many as three potash beds ranging in thickness from l to 7 feet (Figure 25).

Solution mining has been suggested as the best method for developing these potash beds. The inherently high temperatures at the depth of these beds should reduce evaporation costs. In addition, the availability of adequate water supplies and low cost energy in the form of lignite will be advantageous (Great Northern Railway Co., 1965, p. 17, 21). A thin bed of potash, similar to those on the reservation, has been mined experimentally in the

Carlsbad Basin, New Mexico; the experiment was considered successful in both a technical and practical sense (Davis and Shock, 1970, p. 96). Successful solution mining of potash on a commercial scale in south-central Saskatchewan, Canada, by Kalium Chemicals, Ltd., a subsidiary of PPG Industries, Inc., has been reported, but the details have not been disclosed (Husband, 1971, p. 141, 142). In July 1976, Kalium Chemicals, Ltd. drilled an exploration hole in Bottoneau County, North Dakota. The potash beds intersected in this hole are an extension of the same ones that underlie the reservation.

U.S. production of potash has been about 2.7 million tons (K_20 equivalent) per year for the past decade. The potash resources on the reservation are likely to be developed only when demand increases and an economical solution-mining method is developed.

Sodium Sulfate

Hydrous sodium sulfate is known as Glauber's salt and used principally in pulp and paper industry in manufacture of kraft paper; it is also used in container and plate industries, in curing hides, in the dye and coal tar industry, in stock feeds, in medical and chemical industries, in rayon and textiles, and in the metallurgical industry.

The salt occurs as crusts, as crystals intermixed with mud, and as massive beds in certain intermittent lakes. Lakes known to contain hydrous sodium sulfate are just east of the reservation in eastern Sheridan County and further east in North Dakota (Grossman, 1949; Binyon, 1951, 1952; Sahinen, 1956; and Witkind, 1952 and 1959). According to Witkind (1959, p. 64) many of the lakes are saline, which does not necessarily indicate the presence of a sodium sulfate. In general the deposits are within undrained depressions of which the walls and floors commonly consist of till (Witkind, 1959, p. 71). Witkind (1959, p. 73) suggested that the deposits in this region were localized along channels that formed marginal to the ice front and the renewed advance of the glacier partly or completely buried the channel with till; it thus became a buried valley with surface depressions.

In the reservation there are numerous types of glacial lakes and ponds (Figure 26). The areas shown as many small pond deposits are mostly depressions as much as half a mile across in the till plain (Colton, 1955). Most larger pond deposits shown on Figure 26 are in ice-marginal and outwash channels (Colton, 1955, 1962, 1963a-j, 1964a; Witkind, 1959; and Jensen and Varnes, 1964).

Lake deposits in depressions above buried channels are in the area northwest of Wolf Point (Colton, 1955, 1963e), north and northeast of Chelsea (Colton, 1963b), south of Sargent Creek (Colton, 1963g), west of the upper reaches of Smoke Creek (Colton, 1964), northwest of Poplar (Colton, 1963f), east of Wolf Creek, and west of Medicine Lake (Colton, 1963). The lakes are small; most are less than 100 acres.

The potential for deposits of hydrous sodium sulfate in the reservation has not been established. Brush Lake, about 15 miles east of the reservation, is the nearest lake described by Witkind (1959, p. 68) that contains sodium sulfate. The deposits in Montana have not been considered economically important because of their remote locations and small sizes (Weisman and Tandy, 1975, p. 1086).

However, the large price increase from $23.99/ton in 1974 to $45.20/ton in 1975 could stimulate interest in these smaller and more remote deposits (Klingman, 1976, p. 158).

Clay and Shale

Large deposits of clay and shale are in and near the reservation, but present data are inadequate to determine their suitability for various manufacturing uses, such as lightweight aggregate, common and facing brick, tile, pottery, and other stoneware. Most clay and shale deposits in eastern Montana have a low kaolinitic clay content and are rarely well suited for manufacture of heavy ceramic wares such as brick, tile and pottery (Knechtel and Weis, 1965).

Some beds of clay shale in the Fort Union Formation in Montana, however, have been found suitable for use in manufacturing common and facing bricks, tile, and pottery. Many clay deposits in Daniels and Sheridan Counties, north of the reservation, have been sampled and tested by Sahinen, Smith, and Lawson (1960); their location and ceramic properties are shown in Table 24 and Table 25. Samples 186, 203, and 204 are from the Bearpaw Shale, and the latter two are from the southern part of the reservation. The rest of the samples are from the Fort Union Formation, north and northeast of the reservation. The same strata, however, should occur in the northern part of the reservation.

Almost all samples from the Fort Union are suitable for use in making common brick and some of them are suitable for use in various types of ceramic products.

The shale samples from the Bearpaw Shale are not suitable for use in making brick or ceramic products.

Expandable clay or shale for use as lightweight aggregate is present in the Bearpaw Shale in and near the reservation. The presence of admixed bentonite in the shales is a key indicator of their suitability as use for lightweight aggregate (Sahinen, 1957). Two samples of bentonitic clay-shale (samples 203 and 204) appear to be suitable for use as lightweight aggregate.

Southwest of the reservation in the Charles M. Russell Fish and Wildlife Refuge, 19 samples from the Bearpaw Shale and one sample of glacial till were tested by Wolfbauer and Rice (1976). Only four of the shale samples were not suitable for lightweight aggregates.

Very little testing of the clay deposits on the reservation has been done. No deposit has been identified as a source of material suitable for the manufacture of ceramic products such as structural and face brick, drain tile, vitrified pipe, quarry tile, flue tile, conduit, pottery, stoneware, and roofing tile. The reservation should be explored for clay deposits and samples tested for plasticity, green strength, dry strength, drying and firing shrinkage, vitrification range, and fired color.

Sand and Gravel

Deposits of sand and gravel are widespread in the reservation (Colton, 1964) (Figure 27) and range in age from Tertiary to Recent. Most deposits are unsuitable for use as concrete aggregate as they commonly contain quartzite, chert and agate pebbles.

The largest and most extensive deposit of sand and gravel comprises the Flaxville Formation, which covers vast areas in the north central and northwestern parts of the reservation (Colton and Bateman, 1956). Overburden is absent on the deposit in the driftless area except south of Cottonwood Creek where dune sand (as much as 12 feet thick) mantles the gravel (Colton, 1964). In general the Flaxville is well stratified and well sorted, consisting of about 5 percent silt, 35 percent sand, 60 percent pebbles, and a few cobbles (Colton and Bateman, 1956). It is mostly between 30 and 50 feet thick. However, Colton (1964) suggested that individual prospects should be drilled first to determine the quality and quantity of sand and gravel because some parts of the formation are mostly clay and sand.

The Flaxville is a vast resource of sand and gravel in the reservation where-it covers about 750 square miles (Colton in Jensen and Varnes, 1964). In the Wolf Creek area Colton (1955) noted that the largest remnant of the Flaxville plain is about-40 feet thick and covers about 3 square miles. He estimated the reserve of the deposit at about 25,000,000 cubic yards of sand and gravel.

Wiota gravel deposits are common along the southern and southeastern margins of the reservation (Figure 27). The gravel deposits are preglacial and are commonly on benches along the Missouri River and lower reaches of Big Muddy Creek. The Wiota gravel deposits are at altitudes ranging from 2,550 to 2,000 feet (Colton, 1955; and Jensen, 1952b). Some of them have been sources for road metal and aggregate from numerous pits along U.S. highway 2 (Figure 27). The deposits commonly contain poorly sorted sand and gravel and sand lenses in the lower part with pebbles as much as 7 inches across, and silt and fine- to medium-grained sand with intercalated clay lenses in the upper part (Jensen and Varnes, 1964; and Colton, 1955). The deposits are commonly overlain by till.

The Plentywood Formation occurs along the west side of Big Muddy Creek (Colton, 1962). It is commonly more than 20 feet thick and may be as much as 125 feet thick. Mechanical analyses of representative samples of the deposits show them to consist of 6 percent silt, 23 percent sand, 12 percent granules, and 59 percent pebbles or larger (Colton, 1962, p. 266). The pebbles are mostly carbonate and quartzite (Colton, 1962, p. 265). The gravel has been used for road metal and provides a good foundation material. The volume of the deposit in secs. 1, 11, and 12, T. 32 N., R. 55 E., which covers about 1 square mile and is at least 30 feet thick, is about 30,976,000 cubic yards (Colton, 1962, p. 283).

Glacial outwash deposits are common on terraces along some of the larger tributaries of the Missouri River and in meltwater channels in and marginal to the till-covered areas (Colton, 1955, 1962, 1963a-j; Jensen and Varnes, 1964; and Witkind, 1959). They have been local sources for road metal in the southern and eastern parts of the reservation (Figure 27). The deposits are commonly linear and of narrow width. An example is in the northeast part of the reservation where Colton (1962, p. 263) records them as much as 50 feet thick, commonly less than 100 feet wide, and as much as 5 miles long. They overly till and commonly are overlain by alluvial, colluvial, and eolian deposits. The outwash deposits consist of sandy gravel and silt with pebbles of quartzite, carbonate, and granite. The estimated reserve of a large body of outwash gravel in secs. 16, 17, 20, 21, 28, and 34 of T. 28 N., R. 44 E., and sec. 3, T. 27 N., R. 44 E. is 5 million cubic yards (Jensen and Varnes, 1964, p. 36).

Eskers and kames contain deposits of sand and gravel that have been used locally in the reservation as road metal (Figure 27). Esker deposits are sinuous ridges of poorly sorted stratified sand and gravel as much as 60 feet thick; they contain boulders as much as 2 feet across (Colton, 1963a-j). Colton (1955) describes the deposits in the Wolf Creek area as 1 ¼ miles long, 100 feet wide, and about 15 feet high. An esker deposit in the eastern part of the area is about 20 feet high and about one mile long (Witkind, 1959, p. 49).

Kame deposits contain rudely stratified and poorly sorted sand and gravel, about 100 feet thick, with boulders as much as 2 feet across (Colton, 1963a-j). In the Wolf Creek area there are many low gravel hills, each about 30 feet high, covering nearly 100 acres (Colton, 1955). Kame deposits in the eastern part of the area are 30 to 50 feet high (Witkind, 1959, p. 48).

Alluvium, consisting of gravel, fine sand, sandy silt, silty sand, and clay, is in the valley of the Missouri River and its tributaries (Figure 27). The deposits are as much as 150 feet thick along the Missouri River. Elsewhere the thickness of the alluvium ranges from a thin veneer to as much as 100 feet. The problem of removing the overlying fine-grained sediment limits their use (Jensen and Varnes, 1964, P- 39).

Eolian deposits as dune sand are present in the area north of Poplar, north and east of Brockton, south of Cottonwood Creek, northeast of Tule Creek, northeast of the upper reaches of little Porcupine Creek, and locally west of Big Muddy Creek. The deposits consist mostly of medium to fine-grained sand and less than 10 percent silt (Colton, 1962, p. 270) and are as much as 20 feet thick (Colton, 1955; and 1963a, b, c, f, h, i, ;).

Extensive industrial development in eastern Montana, resulting from the availability of vast energy resources, could create a strong demand for local sand and gravel for road building and construction. An ideal deposit should be free of clay, silt, and organic material and contain about 60 percent gravel and 40 percent sand (Goldman, 1975, p. 1037).

Testing procedures to determine the quality of sand and gravel have been devised by the American Society for Testing Materials. Principal tests are for toughness, abrasion resistance, soundness, organic content, grading, specific gravity, absorption, thermal incompatibility, and alkali-aggregate reactivity. The latter is of particular interest because aggregates with a high silica content, such as quartzites and chalcedony, react with alkalies in portland cement to form an alkali-silica gel. This reaction causes expansion, cracking, and deterioration of concrete. Sand and gravel from the Wiota gravel and Flaxville Formation are composed almost entirely of quartzite and chalcedony in some areas (Colton, 1962, pl. 37). The composition of stream and outwash deposits may be similar. Methods for controlling alkali-silica reactivity include the use of portland cement with less than 0.6 percent total alkali, adding reactive materials such as diatomite or fly ash (Dunn, 1975, p. 100).

The average at-plant price of sand and gravel in 1975 was $1.50/ton (Pajalich, 1976, p. 146). The average price at major distribution points is approximately double the at-plant price (Dunn, 1975, p. 101). Sand and gravel sources are characteristically located close to markets to minimize transportation costs. Prices are increasing because of rising land values, antipollution and rehabilitation requirements, local zoning regulations, and, in some areas, severance taxes. These factors are tending to increase the distance between sources and markets. Therefore, resources on the reservation eventually could be utilized in distant markets. However, annual growth of the sand and gravel industry is projected to be only 3.9 to 4.7 percent for the balance of this century (Goldman, 1975, p. 1040). Consequently, large-scale utilization of the reservation's resources in distant markets is unlikely in the near future.

Silica

The high silica content of many of the gravel deposits on the reservation suggests their use as a siliceous raw material. For example, Colton (1962, p. 259) reported that the cobbles and pebbles of the Wiota gravel in the Otter Creek area contain 99.5 percent quartzite, amorphous silica and cryptocrystalline silica. The crushed cobbles and pebbles as well as natural sand may be suitable as a refractory sand or a filter medium. They may also be useful as a raw material for flint glass and chemical manufacture; impurity limits are given in Table 26 (Murphy, 1975, p. 1045). The well-rounded cobbles and pebbles may be satisfactory as a medium for grinding ceramic clay in tube mills; a very low iron content is a necessary requirement.

TABLE 26

Maximum Allowable Impurity Contend in Sillica Sand Used for Flint Glass and Chemical Manufacture.

Impurity	Maximum content (percent)
Iron	0.015-0.030 0.05-0.15 for amber glass
Alumina	0.20
Calcium and Magnesium Oxides	0.05 for glass 0.15 for chemical use
Alkalies	0.01
Cobalt	None
Chromium	None
Copper	None

Source: Industrial Minerals and Rocks, 4th ed., p. 1045.

Clinker

Clinker, as used here, is baked and fused roof of a burned coal bed and some of it is vitrified and in part bricklike; commonly it is red. The thickness of rock affected by burning partly depends on the thickness of lignite consumed, and the proportion of easily altered shale above the lignite bed. Thick clinker beds commonly reflect thick lignite beds. Clinker is used mostly as road metal and railroad ballast and locally as roofing granules and walkways. In the reservation clinker is present in secs. 21 and 22, T. 28 N., R. 53 E., in the upper, reaches of Smoke Creek, locally on the west and east sides of Wolf Creek, and along Otter Creek (Smith, 1910). The fact that clinker beds are extensive else where in eastern Montana and Wyoming plus the lack of local markets restricts their economic development.

Riprap

Glacial boulders constitute the only material in the area suitable for riprap. In extensive cultivated areas, boulders have been piled near, section corners (Witkind, 1959, p. 75; Colton, 1962, p. 282). Piles of boulders are present in many places northwest of Poplar, north of Oswego, and northwest of Brockton (Colton, 1964). The boulder piles in the northeastern part of the reservation range from 2 to 40 cubic yards, they consist of limestone, dolomite and a variety of igneous and metamorphic rocks (Colton, 1962). The boulders are as much as 10 feet across; they average about 2 feet (Witkind, 1959, p. 57).

Leonardite

Leonardite, a naturally occurring oxidation product of lignite, may occur on the reservation. It is soft and earthy with a lower heat content than lignite.

Leonardite is added to drilling mud to stabilize the suspensions and to regulate consistency for pumping and removing the cuttings. Also, it is added directly to soils as a conditioner. Humic acids can be chemically extracted from leonardite as well as lignite and added to soil to improve its texture and tilth. They also help mobilize and release nutrients otherwise unavailable to plants (Abbott, 1963, p. 86). Experiments at the Grand Forks Coal Research Laboratory, U.S. Bureau of Mines, showed that humic acids were beneficial to plant growth (Cooley and others, 1970, p. 164).

Montan Wax

Montan wax is a natural mineral wax which can be extracted from some lignites. The processed wax varies from white to nearly dark brown in color and has a melting point of 170 to 200ºF. Its uses are in electrical insulation materials, paints, wood fillers, shoe polishes, floor waxes, rubber mixtures, high-grade candles, impregnations and waterproofings, leather dressings, inks, carbon papers, protective coatings, greases, phonograph records, and (investment) castings (California Division of Mines and Geology, 1976, p. 202; Bostwick, 1975, p. 471). Some lignites may contain as much as 20 percent wax (Ladoo, 1920, p. 6). A minimum wax content of 10 percent has been reported necessary for a lignite to be an economical source (California Division of Mines and Geology, 1976, p. 202).

Before World War II, montan wax was imported into the United States from Germany and Czechoslovakia. Since 1948, a plant at Ione, California, which extracts it from local lignite, has supplied all national needs.

SOCIAL EFFECTS FROM RESOURCE DEVELOPMENT

Development of the reservation's lignite resources by surface mining would provide jobs and incomes for local residents. A mine with an annual production of 9.2 million tons would require 213 employees (Katell and others, 1976a, p. 28). Mining and shipment of the lignite to distant markets probably would not seriously disrupt the lifestyles of the residents. The social effects due to development of the other mineral resources would be similar.

The development of an energy park or large coal-oil-gas (COG) complex on or near the reservation could have far-reaching social impacts. The construction of a COG complex has been proposed immediately west of the reservation near Glasgow, Montana (Corsentino, 1976, p. 94). About 5 to 20 percent of the capital invested in an energy development is required for local services (Gilmore, 1976, p. 538). Zoning and land use planning is necessary to shape community development. Residents must be trained for the new jobs. New housing, schools, sanitation services, roads, shopping facilities, etc. must be provided.

RECOMMENDATIONS FOR FURTHER WORK

1. Large areas of the Fort Peck Indian Reservation remain untested by drilling and several oil fields with reserves of one to three million barrels of oil may be undiscovered at this time. In addition, shallow gas accumulations in the Poplar field area may be larger than indicated with potential commercial production in the future.

Future exploration should be directed toward two types of studies. First, thermal maturation and source rock studies should be utilized to learn at what specific subsurface intervals liquid hydrocarbons were generated and to identify organic-rich source beds within these horizons. In addition, discovered oils should be separated into genetic types and related to specific source sequences. Then, vertical and horizontal migration pathways can be mapped and related to reservoirs and traps.

Second, detailed stratigraphy of all systems with emphasis on reservoirs in mature horizons should be done to locate potential stratigraphic traps such as subtle facies changes or porosity and permeability changes. Attention should be paid to how these changes may be related to paleo-movement along basement lineaments. This study should include the examination of all available well logs, core, and dig cuttings. Sophisticated seismic data can also greatly aid in these studies.

A program of geologic mapping and drilling is recommended for the area containing the Fort Union Formation (Figure 4) as a means of establishing the continuity and correlation of lignite beds in the reservation, of determining lignite quality, and of refining resource evaluations according to depth, bed thickness, location, and lignite constituents including ash and sulfur. Surface mapping is recommended at a scale of 1:24,000, where information on the lignite beds from any source is lacking. Drilling to depths of 200-500 or more feet should accompany mapping to aid in correlation of individual lignite beds and to give information on bed thickness and overburden characteristics. Laboratory analyses will be required to determine lignite quality. The data should identify potential sites for mining.

The data obtained in the lignite study will provide critical information for developing other resources. Systematic mapping and drill hole data should provide information on deposits of sand, gravel, and clay, water-bearing horizons, and should provide pertinent data on structure features that might have a bearing on the accumulation of oil and gas.

2. Surface mining is the most practical method for large-scale development of the reservation's lignite resources. The surface mining potential of some specific areas has been determined, but should be evaluated for the remaining geologically favorable areas. Topographic mapping on a scale of 1:24,000 would be helpful.

3. Present or possible future uses will dictate the requirements for rehabilitating surface mined land. Baseline studies are needed to establish these requirements. Farm and range potential should be determined. The plant-animal ecosystem of all prospective mine areas should be studied.

4. Surface mining with its disturbances of shallow aquifers may cause local disruptions in water supplies. The impact of these disruptions and their areal extent should be determined prior to mining.

5. An exploration program to establish the reservation's bentonite resources is needed. Representative samples should be collected and tested to determine their quality.

The clay and shale resources on the reservation should be evaluated to determine their extent and suitability for commercial uses such as in structural ceramic products and expanded aggregate.

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Table 2.--Correlation chart for Fort Peck Indian Reservation showing producing intervals (oil-O; gas-G). Thicknesses generalized for East Poplar field from Colton and Bateman (1956) and Powell (1955)

System	Group	Formation	Thickness	Production
TERTIARY		Flaxville Gravel	30-80 ft	
		Fort Union Formation	1,400+ ft	
CRETACEOUS	Montana Group	Hell Creek Formation	220-280 ft	
		Fox Hills Sandstone	85-120 ft	
		Bearpaw Shale	1,095-1,186 ft	
		Judith River Formation	90-136 ft	G
		Claggett Shale	226-283 ft	
		Gammon Shale	695-770 ft	
	Colorado Group	Niobrara Formation	208-267 ft	
		Carlile Shale	200-232 ft	
		Greenhorn Formation	181-218 ft	
		Belle Fourche Shale	345-406 ft	
		Mowry Shale		
		Muddy Sandstone	27-54 ft	
		Skull Creek Shale	215-275 ft	
		Fall River Sandstone	72-205 ft	
		Kootenai Formation	253-416 ft	
JURASSIC		Morrison Formation	11-34 ft	
	Ellis Group	Swift Formation	373-415 ft	
		Rierdon Formation	112-124 ft	
		Piper Formation	365-413 ft	
		Nesson Formation[1]		
TRIASSIC		Spearfish Formation	21-134 ft	
PENNSYLVANIAN		Minnelusa Formation	74-239 ft	
		Tyler Formation	42-171 ft	O
MISSISSIPPIAN	Big Snowy Group	Heath Formation		
		Otter Formation	129-172 ft	
		Kibbey Sandstone	126-172 ft	
	Madison Group	Charles Formation	605-755 ft	O
		Mission Canyon Limestone	490-755 ft	O
		Lodgepole Limestone	592-593 ft	
		Bakken Formation	24-33 ft	
DEVONIAN	Jefferson Group	Three Forks Formation	92-124 ft	
		Birdbear Formation[2]	87 ft	O
		Duperow Formation	≈980 ft	O
		Souris River Formation		
		Dawson Bay Formation		
		Winnipegosis Formation		
SILURIAN		Interlake Formation[1]	≈200 ft	
ORDOVICIAN		Stone wall Formation[1]	≈780 ft	
		Stony Mountain Formation		
		Red River Formation		
		Winnipeg Formation		
CAMBRIAN		Emerson Formation		

1/ of economic usage

2/ Nisku Formation of economic usage

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Table 16--Crude oil refined in Montana in 1975, barrels

Field	Big West Oil Co.	Continental Oil Co.	Exxon Company	Farmers Union	Phillips Petr. Co.	Tesoro Petr. Co.	Westco Ref. Co.	Totals by fields
Big Wall		70,441						70,441
Cat Creek		29,465		100,537				130,002
Cut Bank	205,574				1,256,401		1,168,132	2,630,107
Devil's Basin		1,207	81					1,288
Elk Basin		489,977	369,655	357,331				1,216,963
Flat Coulee							123,777	123,777
Fred & George Creek	408,564							408,564
Ivanhoe		34,125						34,125
Key Coulee		90,922	21,827	21,497				134,246
Kelley			44,081					44,081
Kevin-Sun Burst	563,851							563,851
Lodge Grass		7,401						7,401
Mason Lake		5,753						5,753
Melstone				16,517				16,517
Pondera					247,670			247,670
Ragged Point		200,935						200,935
Rosebud		142,994						142,994
Richey SW						18,120		18,120
Snyder		6,082						6,082

Continued

Table 16.--Crude oil refined in Montana in 1975, barrels--Continued

Field	Big West Oil Co.	Continental Oil Co.	Exxon Company	Farmers Union	Phillips Petr. Co.	Tesoro Petr. Co.	Westco Ref. Co.	Totals by fields
Sumatra-Stensvad		623,523	428,258	920,879				1,972,660
Tule Creek & Others						472,479		472,479
Whitlash					220,425			220,425
Winnett Junction				49,117				49,117
Wolf Springs			15,323					15,323
Volt						196,025		196,025
Total Montana Oil	1,177,989	1,702,825	879,225	1,465,878	1,724,496	686,624	1,291,909	8,928,946
Canadian Oil Imported	31,335	8,960,007	5,605,841	4,339,467	433,060	3,518		19,373,228
Wyoming Oil Imported		5,808,714	8,614,936	5,372,711				19,796,361
Total Montana, Canadian & Wyoming Oil	1,209,324	16,471,546	15,100,002	11,178,056	2,157,556	690,142	1,291,909	48,098,535

Source: Department of Natural Resources and Conservation of the State of Montana, Oil and Gas Conservation Division, Annual Review 1975, p. 5.

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Table 17.--Summary of lignite reserves in the northeastern part of the Fort Peck Indian Reservation

From Colton (1962, p. 281)

*In Fort Peck Indian Reservation

Bed and township	Reserves, in acres			Average thickness of bed (feet)	Acre-feet			Short tons		
	Measured	Indicated	Inferred		Measured	Indicated	Inferred	Measured	Indicated	Inferred
Richardson lignite bed:										
T. 35 N., R. 55 E.	765			6	4,590			8,032,500		
T. 34 N., R. 65 E.	4,414	7,066	301	6	26,484	42,396	1,806	46,347,000	74,193,000	3,160,500
T. 34 N., R. 54 E.	153	1,655	11,133	6	918	6,930	66,798	1,606,500	12,127,500	116,896,500
T. 33 N., R. 55 E.	8	1,380	2,172	6	38	8,280	13,032	84,000	14,490,000	22,806,000
Coal Mine lignite bed:										
* T. 33 N., R. 55 E.	70	227		3	210	881		367,500	1,541,750	
* T. 32 N., R. 55 E.	1,204	1,533		4	4,816	6,132		8,420,000	10,731,000	
Timber Coulee lignite bed:										
* T. 32 N., R. 54 E.	1,147	1,917		9	10,323	17,253		18,065,250	30,192,750	
Local bed *A*:										
* T. 32 N., R. 55 E.	797	2,886		3	2,391	8,658		4,184,250	15,151,500	
Local bed *K*:										
* T. 33 N., R. 54 E.	203	205		2.8	568	574		994,000	1,004,500	
* T. 33 N., R. 55 E.	21			2.8	58			102,500		
Local bed *D*:										
* T. 32 N., R. 54 E.	56	216		3	168	648		294,000	1,134,000	
Local bed *M*:										
T. 34 N., R. 54 E.	266			3	798			1,386,500		
Local bed *P*:										
T. 34 N., R. 53 E.	320	354		3	960	1,062		1,680,000	1,857,500	
Local bed *Q*:										
T. 34 N., R. 53 E.	683	225		3.3	2,254	743		3,834,500	1,300,250	
Local bed *T*:										
* T. 33 N., R. 53 E.	100	328		3	300	984		525,000	1,732,000	
Local bed *U*:										
T. 35 N., R. 55 E.	354	630		3	1,062	1,890		1,858,500	3,307,500	
T. 34 N., R. 55 E.		64		3		192			336,000	
Local bed *V*:										
T. 34 N., R. 55 E.	212	370		6	1,272	2,220		2,126,000	3,885,000	
Total of all lignite reserves regardless of thickness								99,908,300	172,984,250	142,863,000
Grand total of all reserves										415,755,550

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Table 18--Resources and overburden ratios, Fort Kipp lignite deposit.

Overburden thickness above Fort Kipp bed, feet	0-25	25-50	50-75	75-100	100-125	125-150	150-175	175-200
Resources in Fort Peck bed, tons x 1,000	0	17,613	26,556	19,782	17,750	12,396	8,789	4,872
Resources in Fort Kipp bed, tons x 1,000	25,367	37,254	42,006	21,290	28,077	19,607	13,902	7,707
Overburden ratio, yds. per ton lignite	1.35	2.46	3.79	5.45	7.11	8.77	10.43	12.44
CUMULATIVE DATA								
Maximum overburden above Fort Kipp bed, feet	25	50	75	100	125	150	175	200
Resources in Fort Peck and Fort Kipp beds, tons x 1,000	25,367	80,233	148,796	199,868	245,694	277,697	300,389	312,968
Overburden ratio, Cu. yds. per ton lignite	1.35	2.11	2.88	3.54	4.21	4.73	5.16	5.44

Source: The Fort Kipp lignite deposit, northeastern Montana, Great Northern Railway Co. (now Burlington Northern, Inc.) Report No. 26

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Table 19--Analyses of lignite from the Fort Peck Indian Reservation, Montana.

Deposit	Bed	Location	Proximate analyses, percent: Moisture	Volatile matter	Fixed Carbon	Ash	Ultimate analyses, percent: Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Heat content (BTU/lb)	Ash softening temp. (F°)
Fort Kipp	Fort Peck	Center, SW¼ NE¼ Sec. 25, T. 28 N., R. 54 E.	36.5	24.8	30.9	7.7	0.44	6.7	40.6	0.7	43.8	6,750	2,160
Fort Kipp	Fort Peck	SW¼ NE¼ Sec. 9, T. 28 N., R. 54 E.	33.2	24.6	28.1	14.0	.60	6.3	38.1	.6	40.4	6,360	2,210
Fort Kipp	Fort Peck	NE¼ NE¼ Sec. 20, T. 28 N., R. 54 E.	35.9	27.5	30.4	6.2	.32	-- 1/	--	--	--	7,143	2,548
Fort Kipp	Fort Kipp	SW¼ NE¼, Sec. 9, T. 28 N., R. 54 E.	34.5	25.3	29.9	10.3	1.10	6.5	39.9	.7	41.5	6,640	2,130
Fort Kipp	Fort Kipp	NE¼ NE¼ Sec. 20, T. 28 N., R. 54 E.	37.1	27.0	30.6	5.3	.25	--	--	--	--	6,970	2,481
Reserve	1	NW Corner Sec. 14, T. 33 N., R. 54 E.	34.5	26.5	25.0	14.0	2.28	--	--	--	--	6,343	2,149
Reserve	2	NW Corner Sec. 14, T. 33 N., R. 54 E.	42.5	23.6	25.2	8.8	.78	--	--	--	--	6,007	2,118
Reserve	1	Center N½ W Line Sec. 19, T. 33 N., R. 55 E.	38.5	24.8	29.0	7.6	.42	--	--	--	--	6,599	2,245
Medicine Lake	1	NW Corner NE Sec. 9, T. 32 N., R. 54 E.	37.0	26.3	29.5	7.2	.98	--	--	--	--	6,870	2,418
Medicine Lake	1	Center Sec. 23, T. 32 N., R. 54 E.	37.4	26.3	28.5	7.7	.68	--	--	--	--	6,692	2,360
AVERAGE Fort Peck Indian Reservation			36.7	25.7	28.7	8.9	.79	6.5	39.5	.7	41.9	6,637	2,282
Montana lignites 2/			34.0	26.2	30.8	8.9	1.07	6.3	43.4	.7	40.0	6,829	2,330

1/ Analyses not available.

2/ U.S. Bureau of Mines Report of Investigation 7158.

Source: The Fort Kipp Lignite Deposit, Northeastern Montana, Great Northern Railway Co. (now Burlington Northern, Inc.) Report No. 26, also published 1975, Energy Resources of Montana, Montana Geological Society, 22nd Annual Publication; Lignite Drilling Program Williston Basin, North Dakota and Montana, Great Northern Railway Co. Report No. 1.

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Table 21--Semiquantitative analyses of lignite ash (percent)

Element or Compound	Fort Kipp deposit		Medicine Lake deposit	Reserve deposit
	Fort Peck bed	Fort Kipp bed	No. 1 bed, Timber Coulee bed	No. 1 bed, Coal Mine bed
U_3O_8	0.003	nil	nil	nil
Aluminum 1/	16	19	13	19
Silicon 1/	8	8	12	8
Magnesium	11	12	11	10
Calcium	16	12	8	13
Iron	8	4	6	7
Chromium	.003	.002	.002	.002
Titanium	.09	.1	.1	.1
Copper	.0002-0.002	.0002-0.002	.0002-0.002	.0002-0.002
Manganese	.3	.1	.2	.1
Nickel	.0007- .007	.0007- .007	.0007- .007	.0007- .007
Vanadium	trace	trace	trace	trace
Sodium	.8	.4	.4	1

Continued

Table 21.--Semiquantitative analyses of lignite ash (percent)--Continued

Element or Compound	Fort Kipp deposit: Fort Peck bed	Fort Kipp deposit: Fort Kipp bed	Medicine Lake deposit: No. 1 bed, Timber Coulee bed	Reserve deposit: No. 1 bed, Coal Mine bed
Boron	0.3	0.5	0.2	0.3
Potassium	2/	.2 -1.0	2/	.2 -1
Zirconium	trace	trace	trace	trace
Barium	trace	trace	trace	trace
Strontium	trace	trace	trace	trace
Germanium	.004	.004	.004	.004

1/ Aluminum contents are abnormally high with respect to silicon contents. These may have been reversed in the original tabulation.

2/ Not detected.

Source: Lignite Drilling Program Williston Basin, North Dakota and Montana, Report No. 1, 1953-1955, Great Northern Railway Co. (now Burlington Northern, Inc.), Mineral Resources and Development Dept.

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Table 23--Bentonite test data, Fort Peck Indian Reservation. 1/

Sample	Swelling capacity in milliliters of 2.0-gram sample	Grit, percent +325 mesh	Yield, bbl per ton	Viscosity in centipoises for slurry with 6 percent clay by weight	Viscosity for slurries containing various clay percentages			
					Clay, percent	Viscosity, centipoises	Clay, percent	Viscosity, centipoises
FP-65-18	6.5	12.0	25.4	1.5	15.0	4.2	22.0	20.0
FP-65-20	21.5	2.0	51.3	2.7	10.0	9.7	11.0	17.7

Wall building properties - for slurries containing 6 percent clay by weight

Sample	Filtrate in milliliters for indicated time in minutes			Thickness of cake in 1/32 inch	Clay mineral, identified by D.T.A.
	2	15	30		
FP-65-18	22.6	58.0	78.0	0.4	Montmorillonite
FP-65-20	3.0	8.6	11.1	0.2	do

1/ Analyzed by the Nonmetallics Laboratory, Bureau of Mines, Albany, Oreg.

Source: Mineral Resources and Their Potential on Indian Lands, 1970, U.S. BuMines Prelim. Report 179.

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Table 24. Location of samples listed in table 25

(From Sahinen, Smith, and Lawson, 1960)

Sample No.	Field No.	Location	Sec.	Twp.	Rge.
186	6-31	Bearpaw fm., 23 mi. N. Glasgow, Valley Co.	19	32N	40E
187	6-32	Ft. Union fm., ridge 2½ mi. N. Richland, Daniels	23	36N	43E
188	6-33	Ft. Union fm., 12 mi. W. Four Buttes, Daniels	5	35N	45E
189	6-34	Ft. Union fm., 3.1 mi. E. Flaxville, Daniels	12	35N	50E
190	6-35	Ft. Union fm., 4.4 mi. E. Redstone, Sheridan	12	35N	52E
191	6-36	Ft. Union fm., 4.4 mi. E. Redstone, Sheridan	11	35N	52E
192	6-37	Ft. Union fm., 0.7 mi. N. Archer, Sheridan Co.	9	35N	53E
193	6-38	Ft. Union fm., 0.7 mi. N. Archer, Sheridan Co.	9	35N	53E
194	6-39	Ft. Union fm., 1 mi. N. St. Hwy. 5, 3 mi. W. Plentywood	17	35N	54E
195	6-40	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
196	6-41	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
197	6-42	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
198	6-43	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
199	6-44	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
200	6-45	Ft. Union fm., 3.9 mi. N. Culbertson, Roosevelt	6	28N	56E
201	6-46	Ft. Union fm., 3.4 mi. S. Culbertson, Roosevelt	34	28N	56E
202	6-47	Ft. Union fm., 3.4 mi. S. Culbertson, Roosevelt	34	28N	56E
203	6-48	Bearpaw fm. at Oswego, Valley County	27	27N	45E
204	6-49	Bearpaw fm. at Nashua, Valley County	31	28N	42E

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Table 25.--Ceramic properties of clay and shale in and near the Fort Peck Indian Reservation

(From Sahinen, Smith, and Lawson, 1960)

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
186	L 34 H 74	Fired bricks were cracked							Not suitable
187	L 28 H 58	6.4	1	1,750 to 1,950	1,600 1,750 1,950	0.6ex 0.0 0.3	tan tan lt. red	SS S HS	Common brick, some alkali scum
188	L 29 H 49	7.1	1	1,750 to 1,950	1,600 1,750 1,950	0.67ex	tan tan red	SS S HS	Common brick
189	L 20 H 38	5.4	?	1,950 to 2,400	1,950 2,150 2,300	0.0 1.8 2.7	buff buff buff	S HS HS	Common brick, face brick, etc. good ceramic clay
190	L 20 H 36	5.2	1	1,950 to 2,000	1,650 1,850 2,050	0.3ex 0.3 0.60	tan lt. red lt. red	SS SS SS	Common brick w/ careful handling & firing
191	L 30 H 54	7.4	9½	2,000 to 2,100	1,800 2,000 2,200	0.0 4.3 --	tan dk. red green	SS S HS	Common brick, w/ careful firing
192	L 24 H 44	6.9	4	2,000 to 2,075	1,650 1,850 2,050	0.0 0.0 0.6	tan tan red	SS SS S	Common brick, with careful firing
193	L 28 H 43	6.5	2	1,900 to 2,000	1,600 1,750 1,950	0.3ex 0.0 1.2	tan lt. red lt. red	SS SS S	Common brick
194	L 25 H 36	6.3	5	2,000 to 2,100	1,650 1,850 2,050	0.9ex 0.0 0.3	lt. red lt. red buff	SS SS S	Good ceramic clay, common brick, pottery

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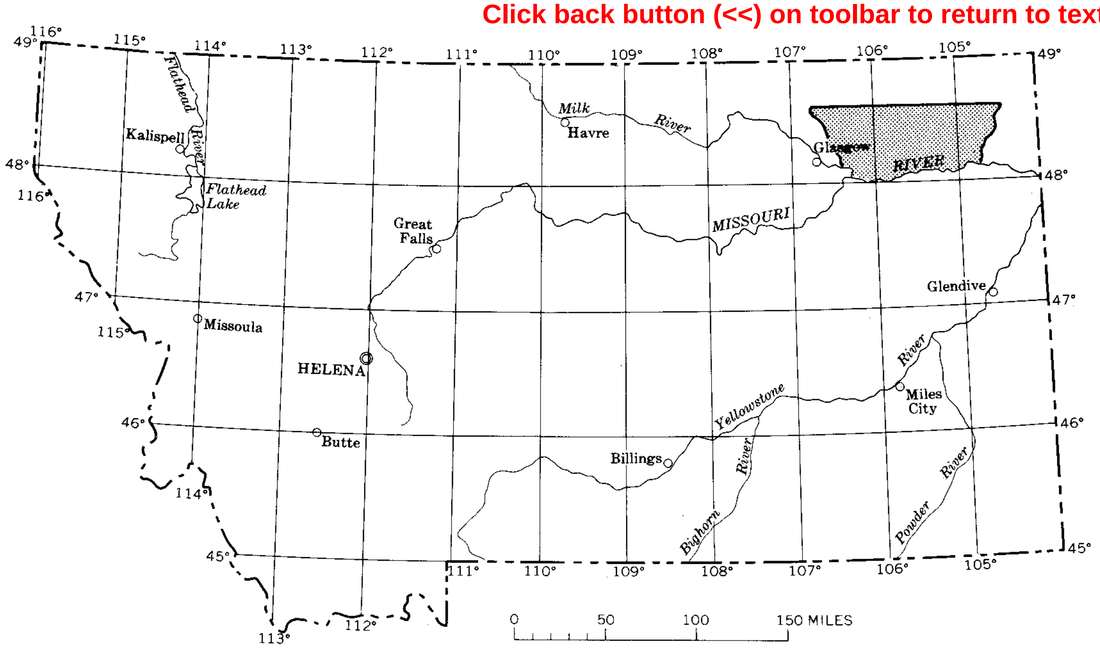

Figure 1. Index map of Montana showing location of Fort Peck Indian Reservation.

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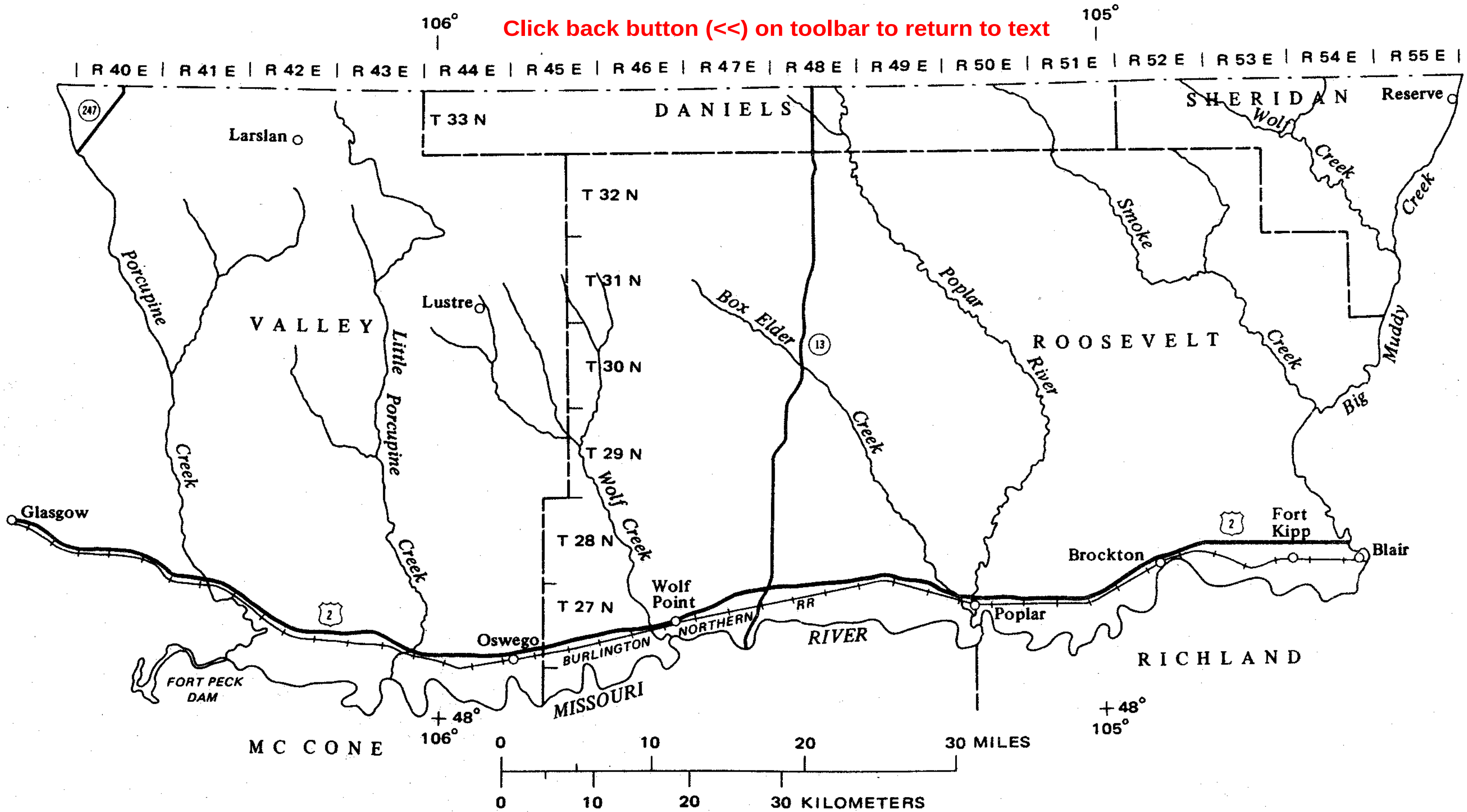

Figure 2. Index map of Fort Peck Indian Reservation, Northeastern Montana.

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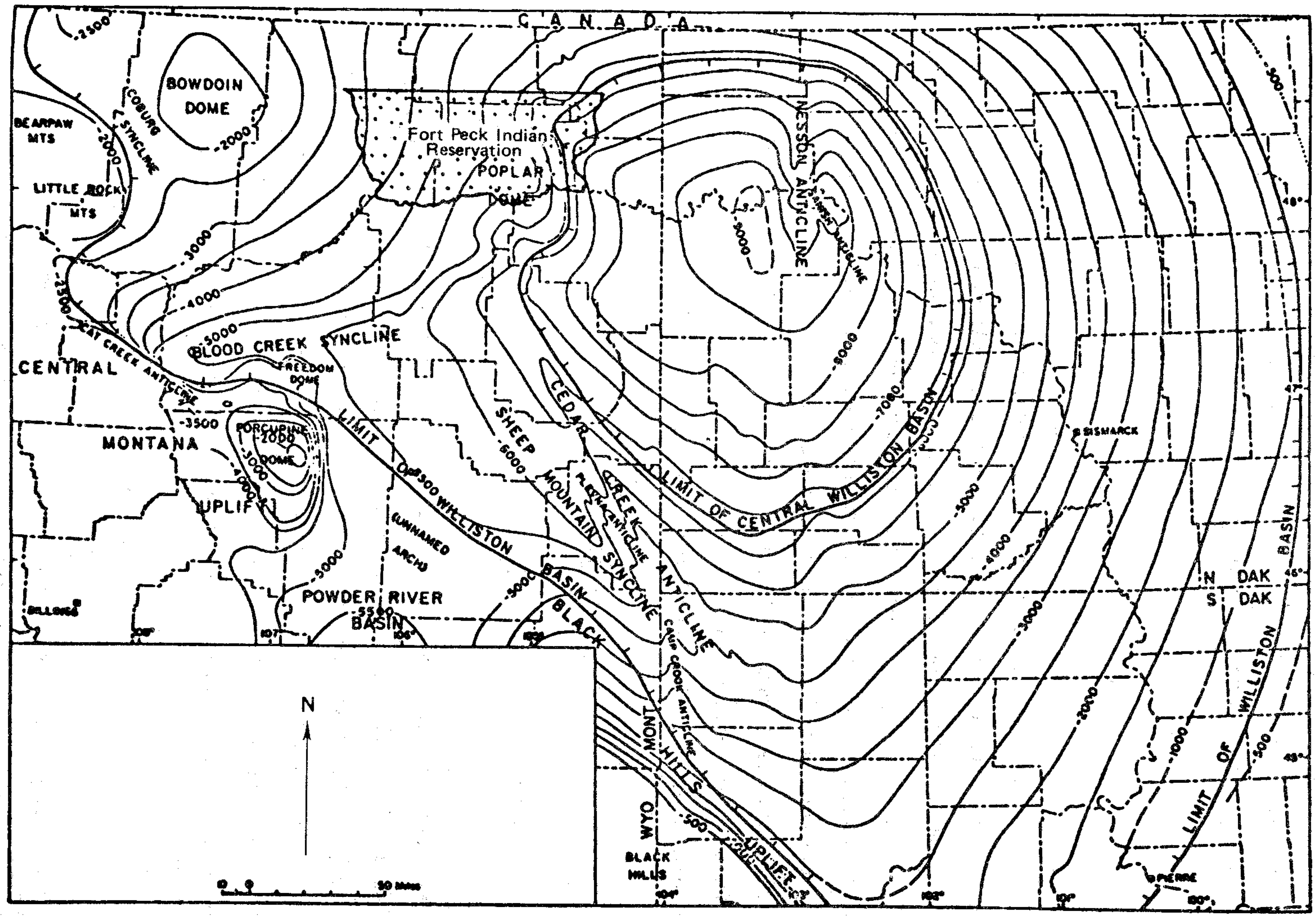

Figure 3. Map showing location of Williston Basin, major structural features, and Fort Peck Indian Reservation. Structure contours drawn at 500 foot intervals on base of Mississippian rocks (after Sandberg, 1962).

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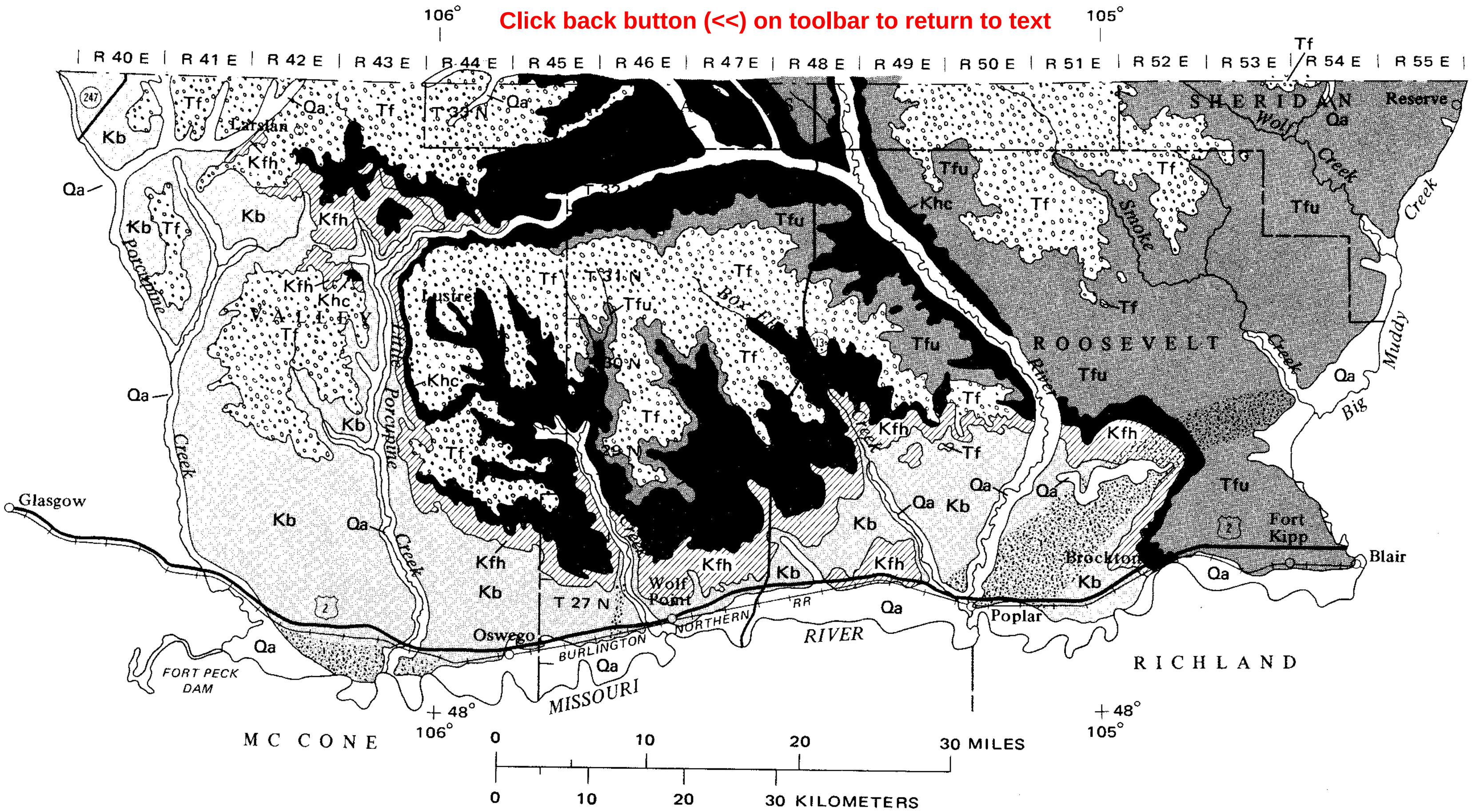

Figure 4. Geologic map of the Fort Peck Indian Reservation. Qa, Alluvium; Tf, Flaxville gravel; Tfu, Fort Union Formation; Khc, Hell Creek Formation; Kfh, Fox Hills Sandstone; and Kb, Bearpaw Shale. Area of thick glacial deposits shown by stippled pattern (from Ross, Andrews, and Witking, 1955).

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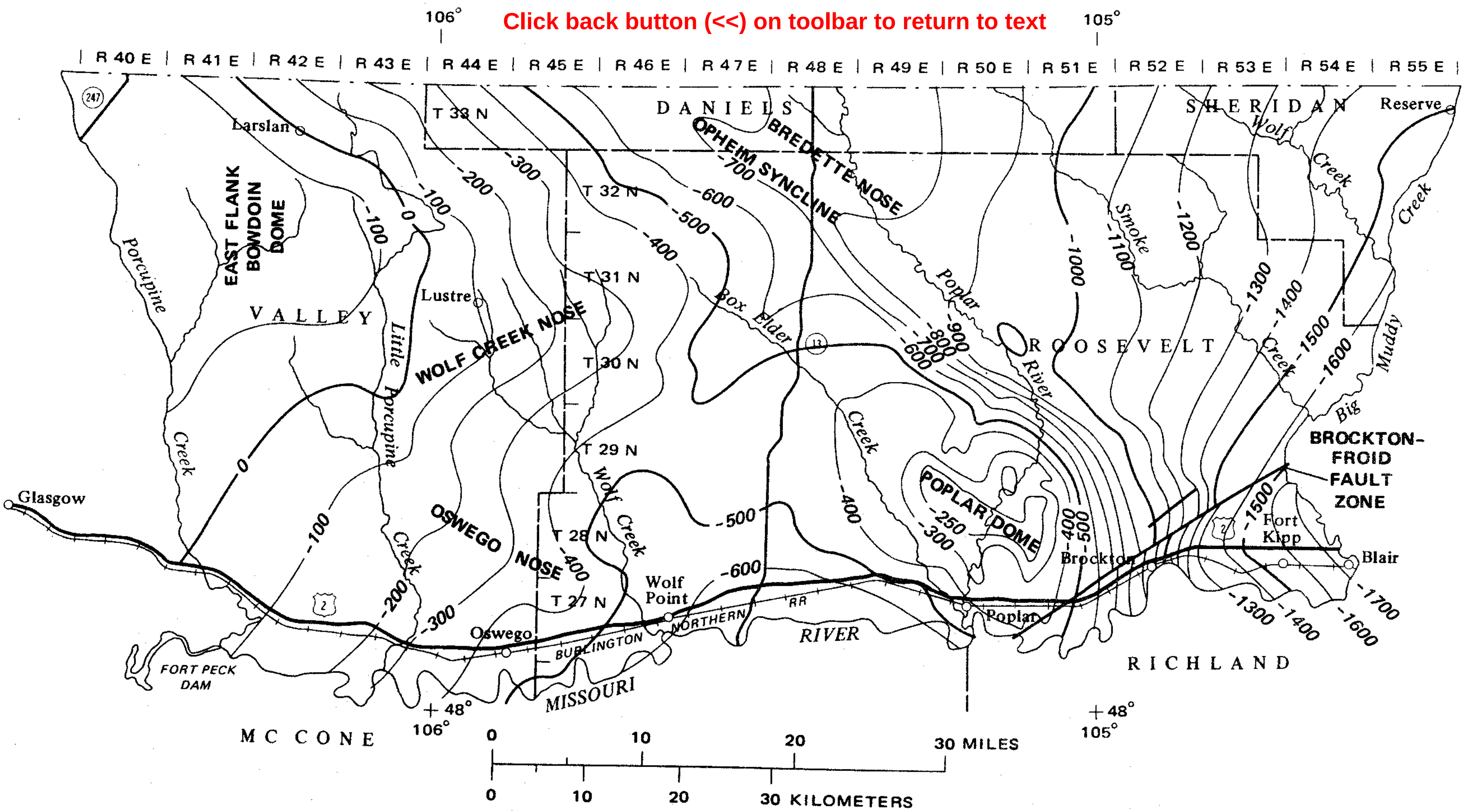

Figure 5. Structure map of the Fort Peck Indian Reservation. Contours drawn on top of the Greenhorn Limestone equivalent. Datum is mean sea level (from Colton and Bateman, 1956).

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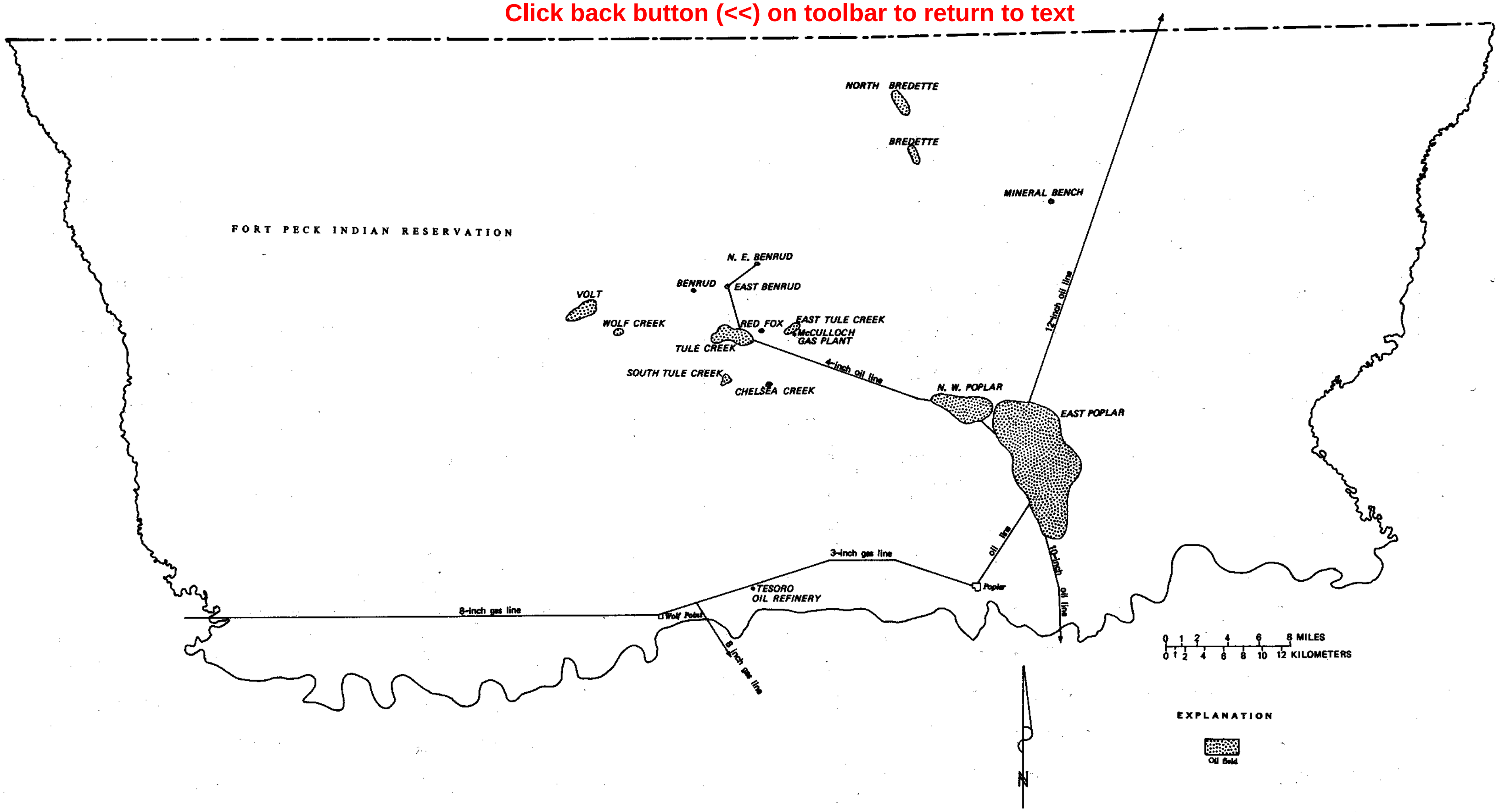

Figure 6. Map showing oilfields, oil and gas pipelines, Fort Peck Indian Reservation (modified from Oil and Gasfields, Pipelines and Refineries, Montana Board of Oil and Gas Conservation, 1973).

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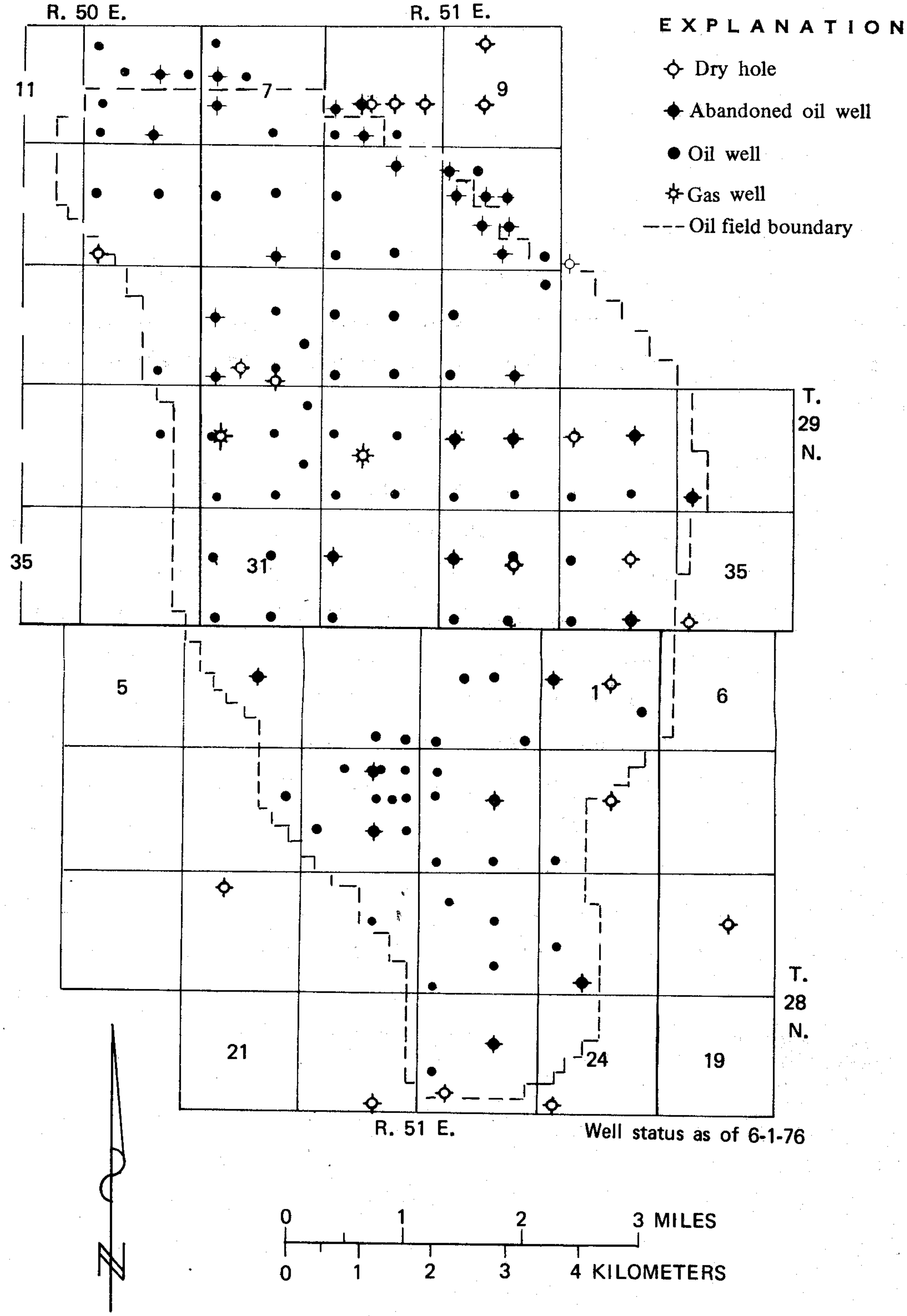

Figure 7. Map showing East Poplar oilfield, Fort Peck Indian Reservation (modified from Henkes and Magill, 1970).

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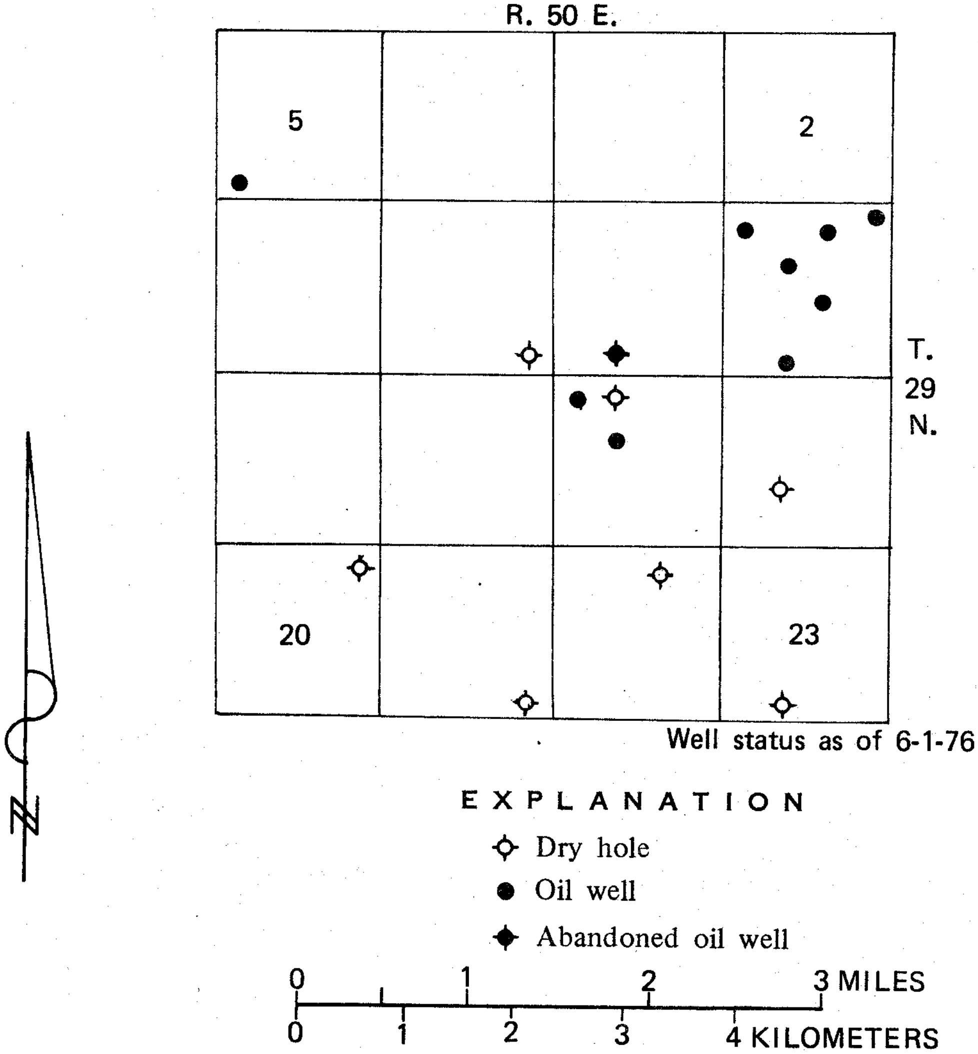

Figure 8. Map showing Northwest Poplar Oilfield, Fort Peck Indian Reservation (modified from Henkes and Magill, 1970).

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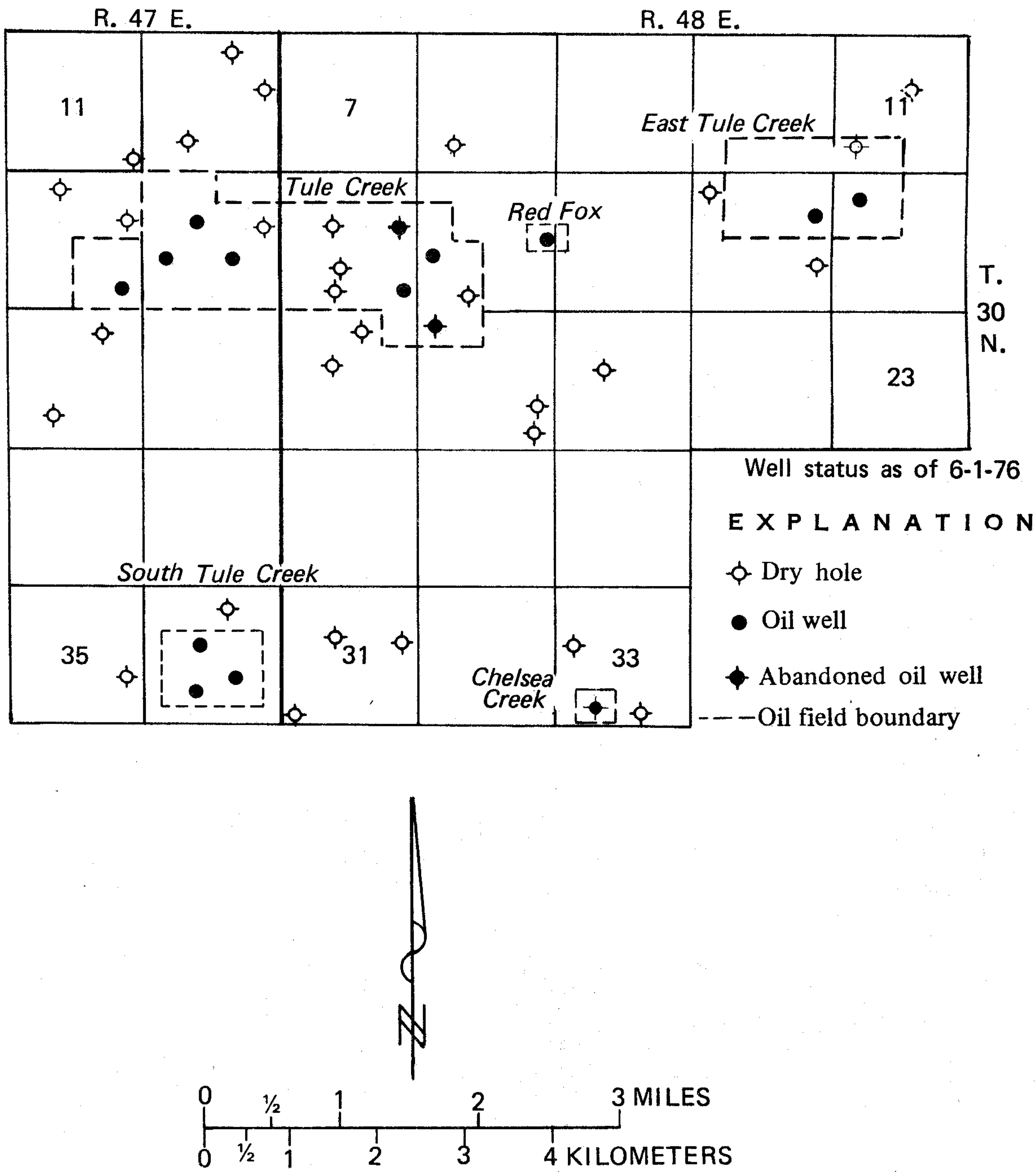

Figure 9. Map showing Tule Creek, East Tule Creek, South Tule Creek, Red Fox, and Chelsea Creek oilfields, Fort Peck Indian Reservation (modified from Henkes and Magill, 1970).

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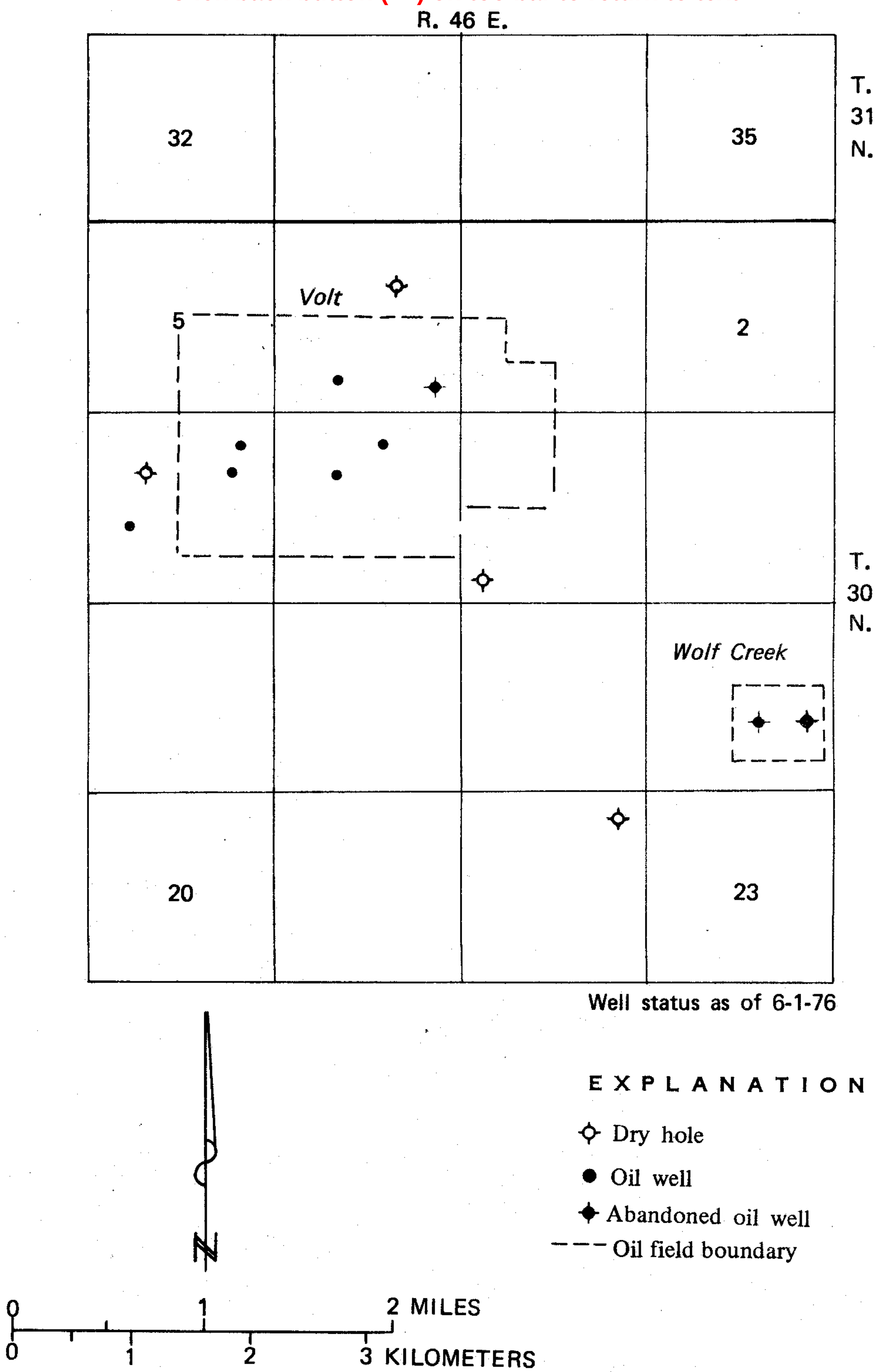

Figure 10. Map showing Volt and Wolf Creek oilfields, Fort Peck Indian Reservation (modified from Henkes and Magill, 1970).

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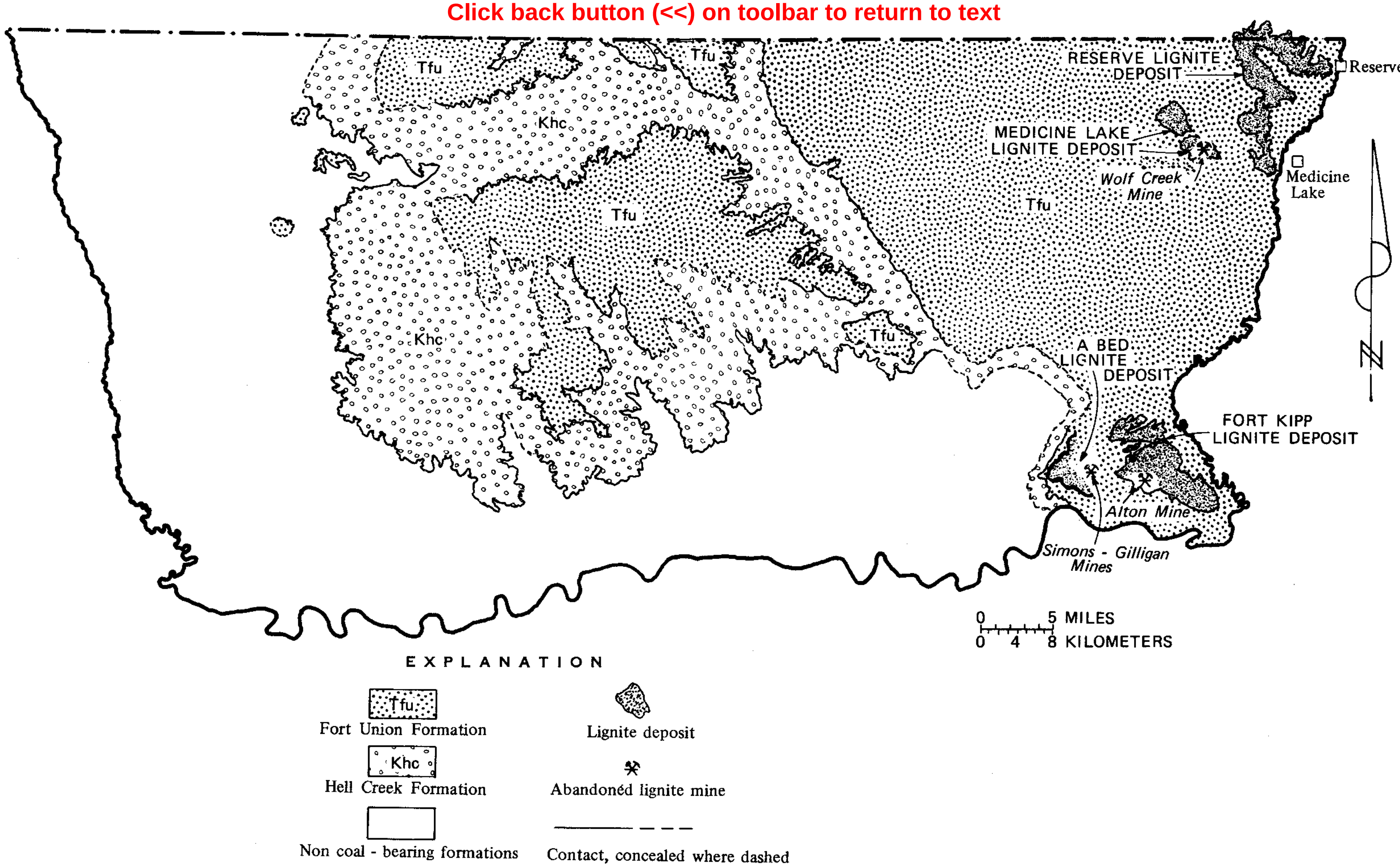

Figure 11. Map showing lignite deposits, Fort Peck Indian Reservation (modified from Smith, 1910; Colton and Bateman, 1956).

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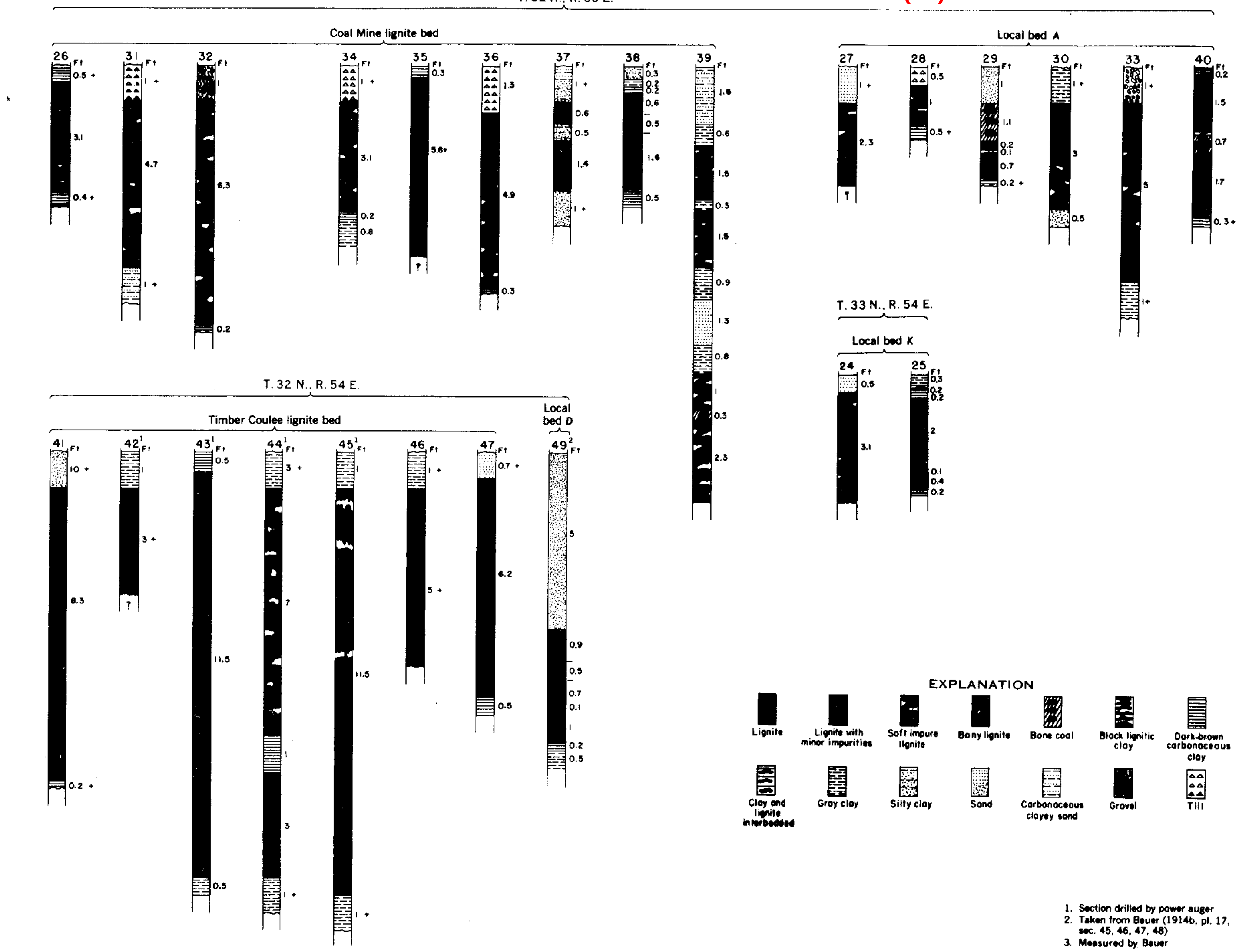

Figure 12. Sections of lignite beds in the Northeastern part of the Fort Peck Indian Reservation (adapted from Colton, 1962, pl. 40).

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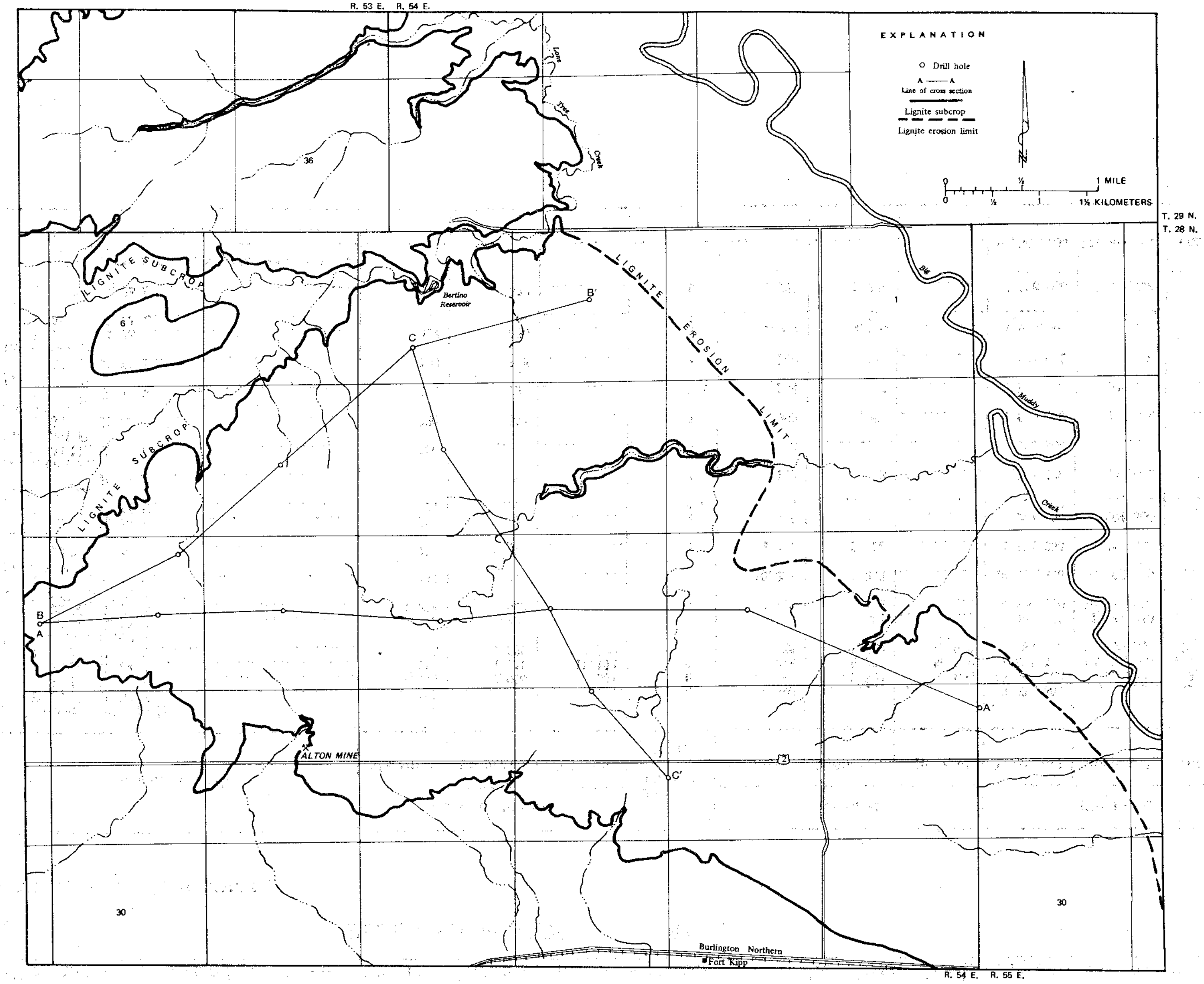

Figure 13. Map showing Fort Kipp lignite deposit, Fort Peck Indian Reservation (modified from Burlington Northern, Inc., 1975).

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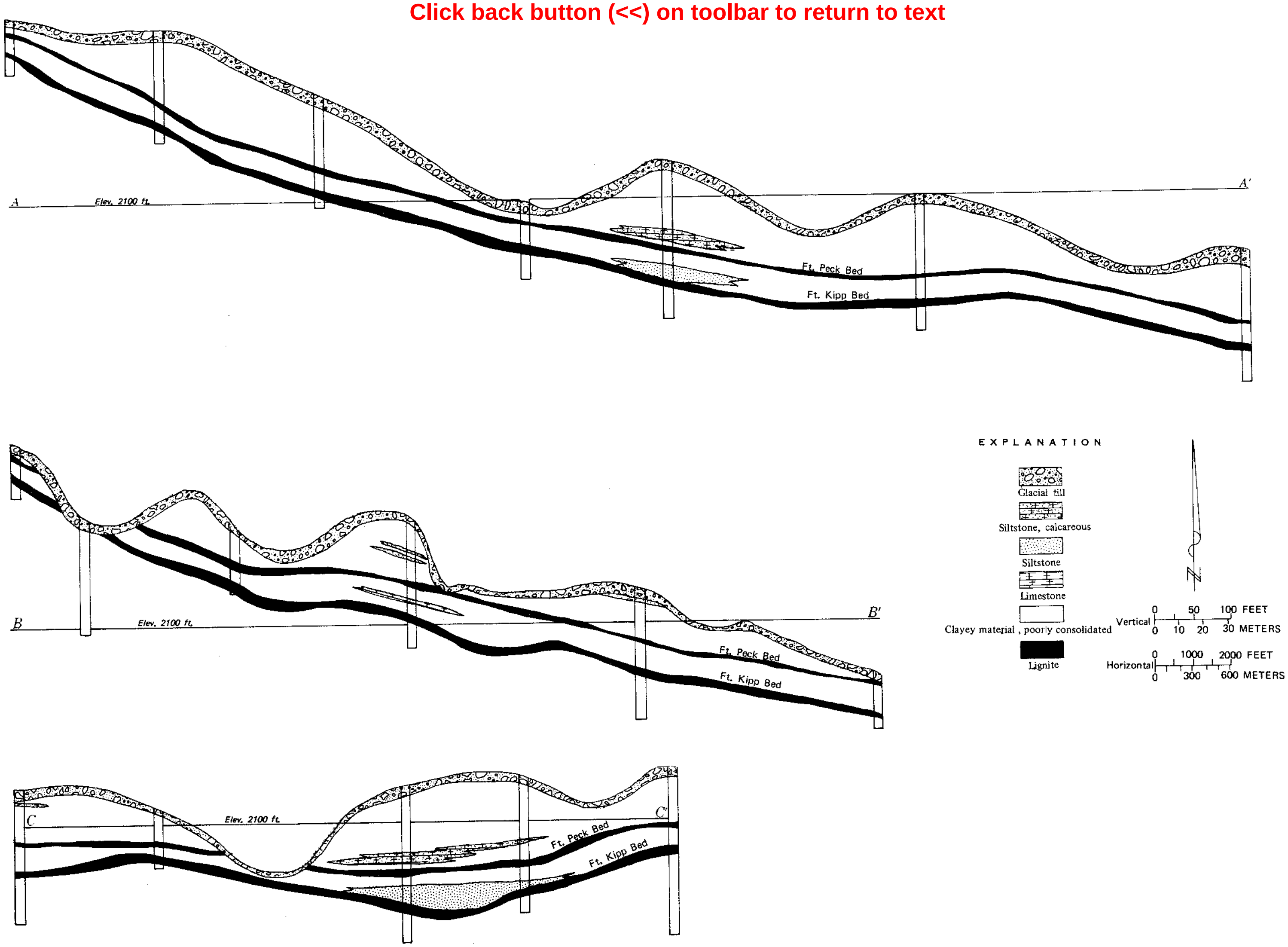

Figure 14. Cross sections of the Fort Kipp lignite deposit. For line of sections see Figure 13 (modified from Burlington Northern, Inc., 1975).

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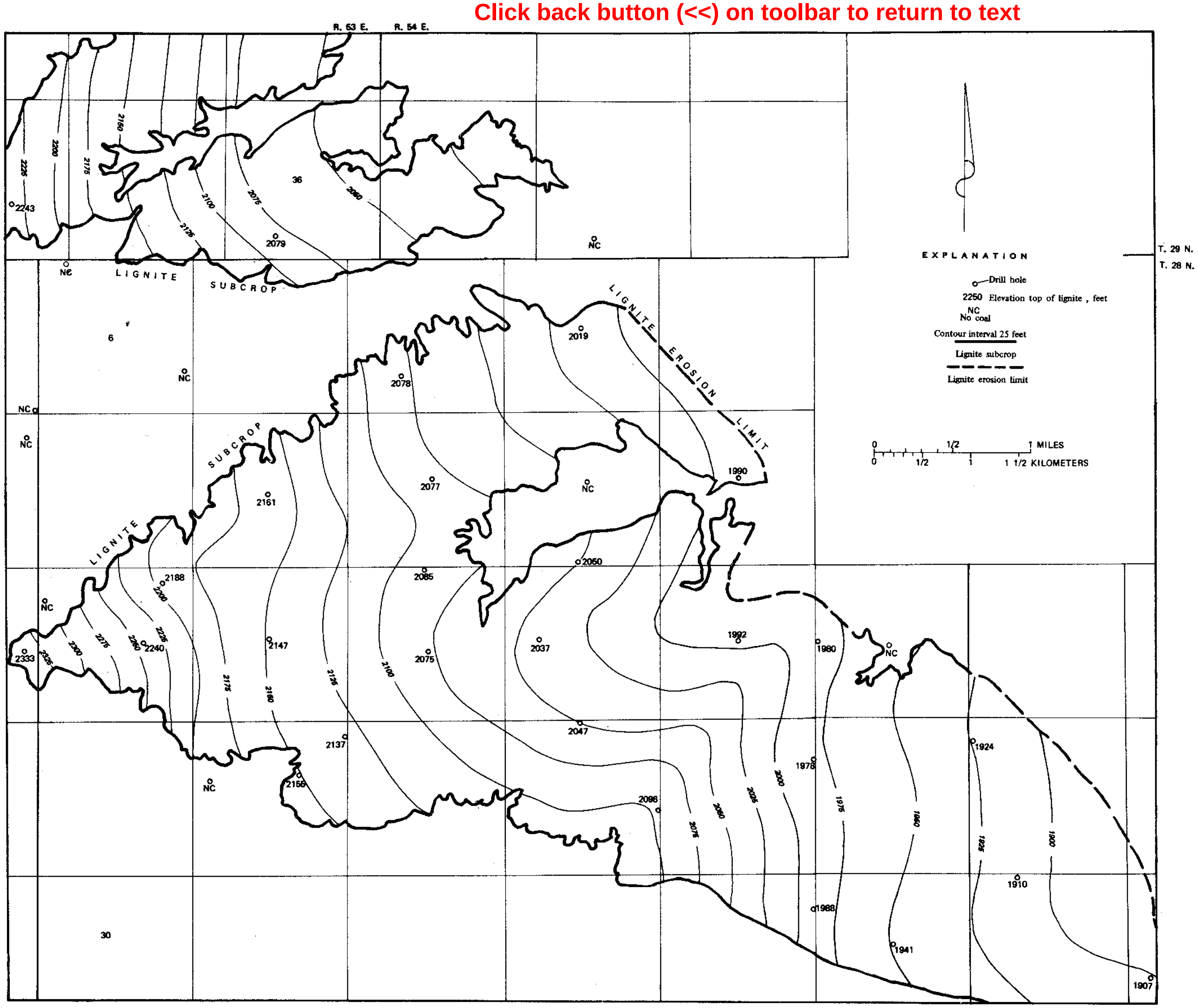

Figure 15. Structure contour map of the Fort Peck lignite bed, Fort Kipp lignite deposit, Fort Peck Indian Reservation (modified from Burlington Northern, Inc., 1975).

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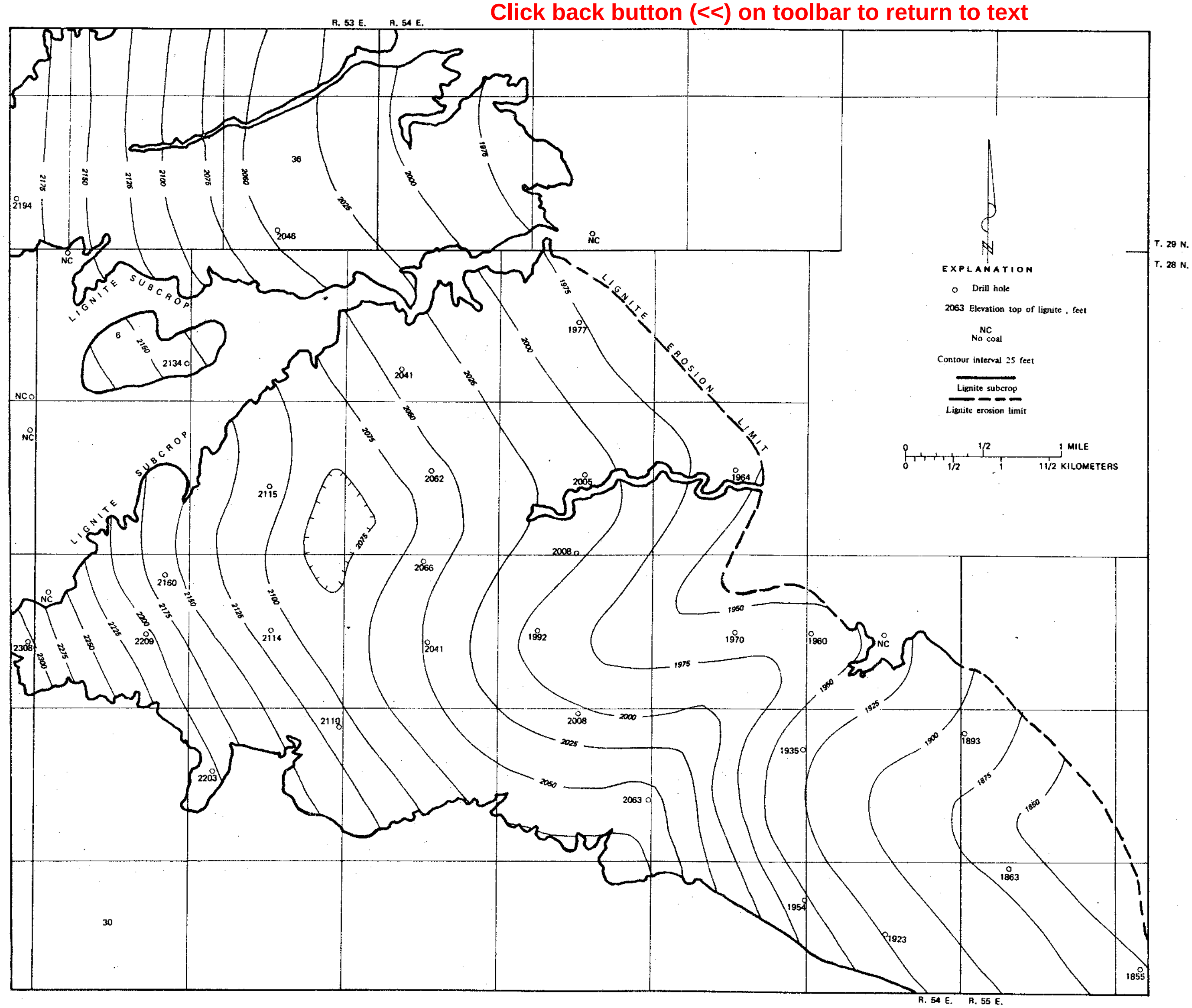

Figure 16. Structure contour map of the Fort Kipp lignite bed, Fort Kipp lignite deposit, Fort Peck Indian Reservation (modified from Burlington Northern, Inc., 1975).

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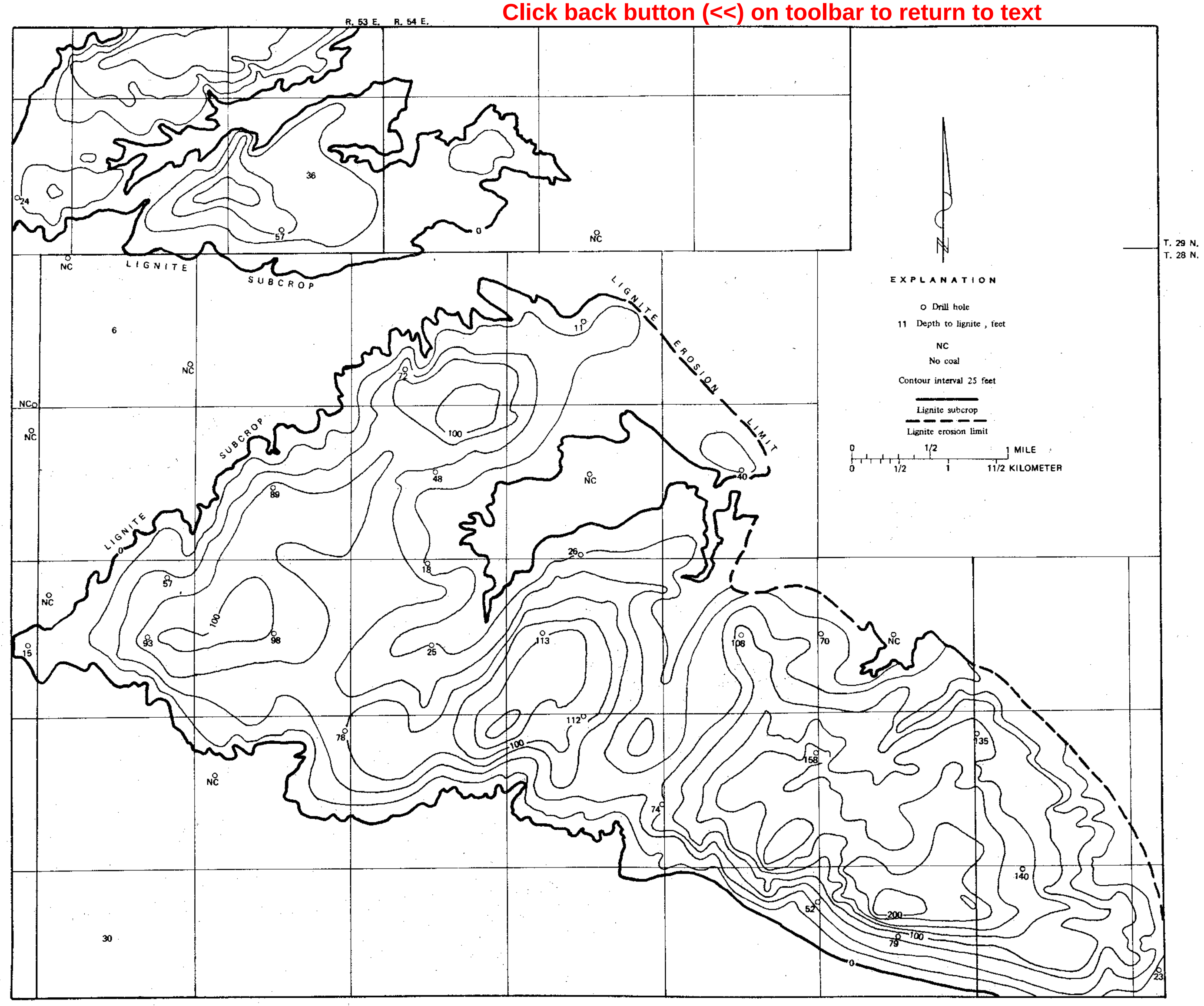

Figure 17. Isopach map of strata overlying the Fort Peck lignite bed, Fort Kipp lignite deposit, Fort Peck Indian Reservation (modified from Burlington Northern, Inc., 1975).

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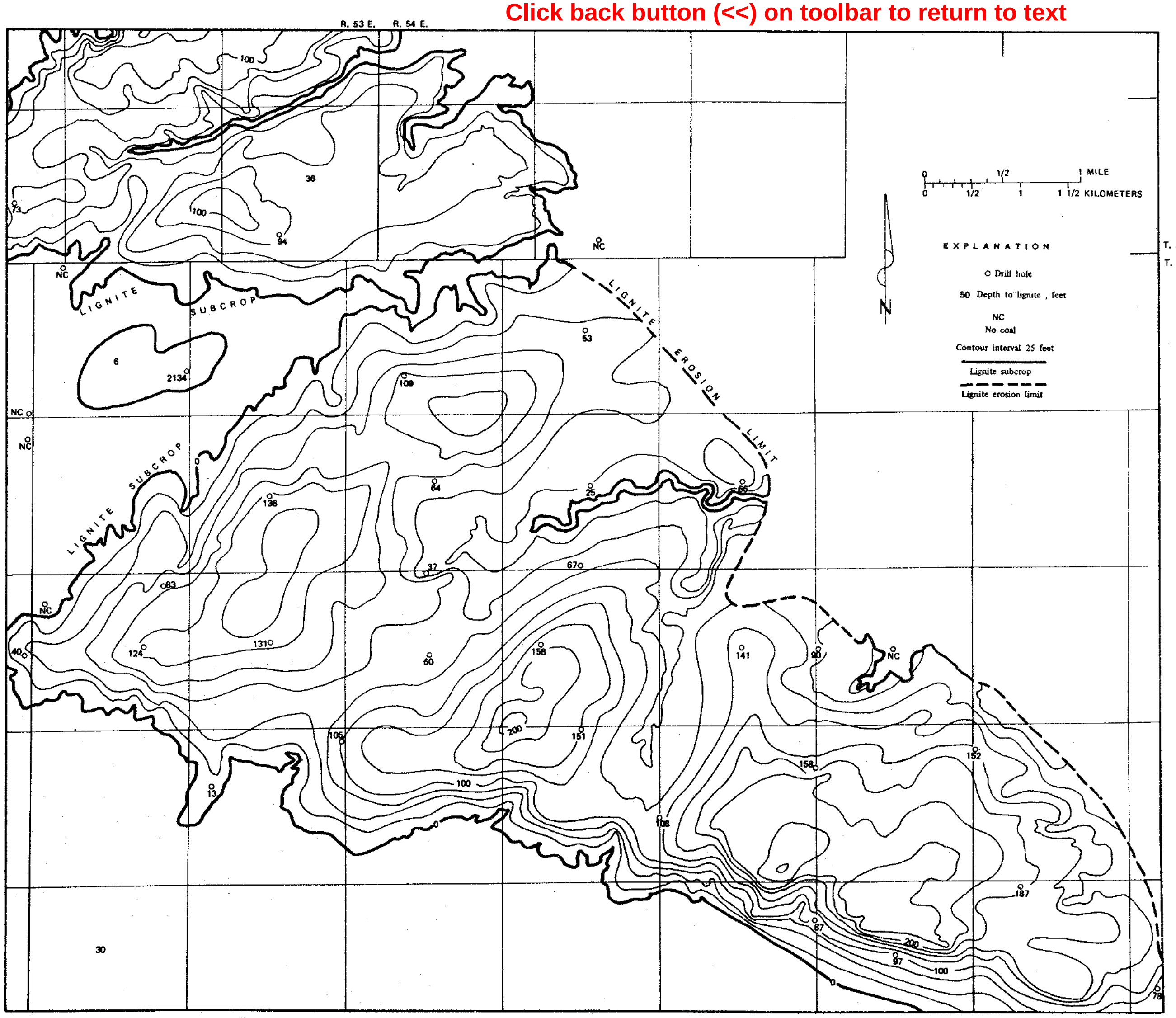

Figure 18. Isopach map of strata overlying the Fort Kipp lignite bed, Fort Kipp lignite deposit, Fort Peck Indian Reservation (modified from Burlington Northern, Inc., 1975).

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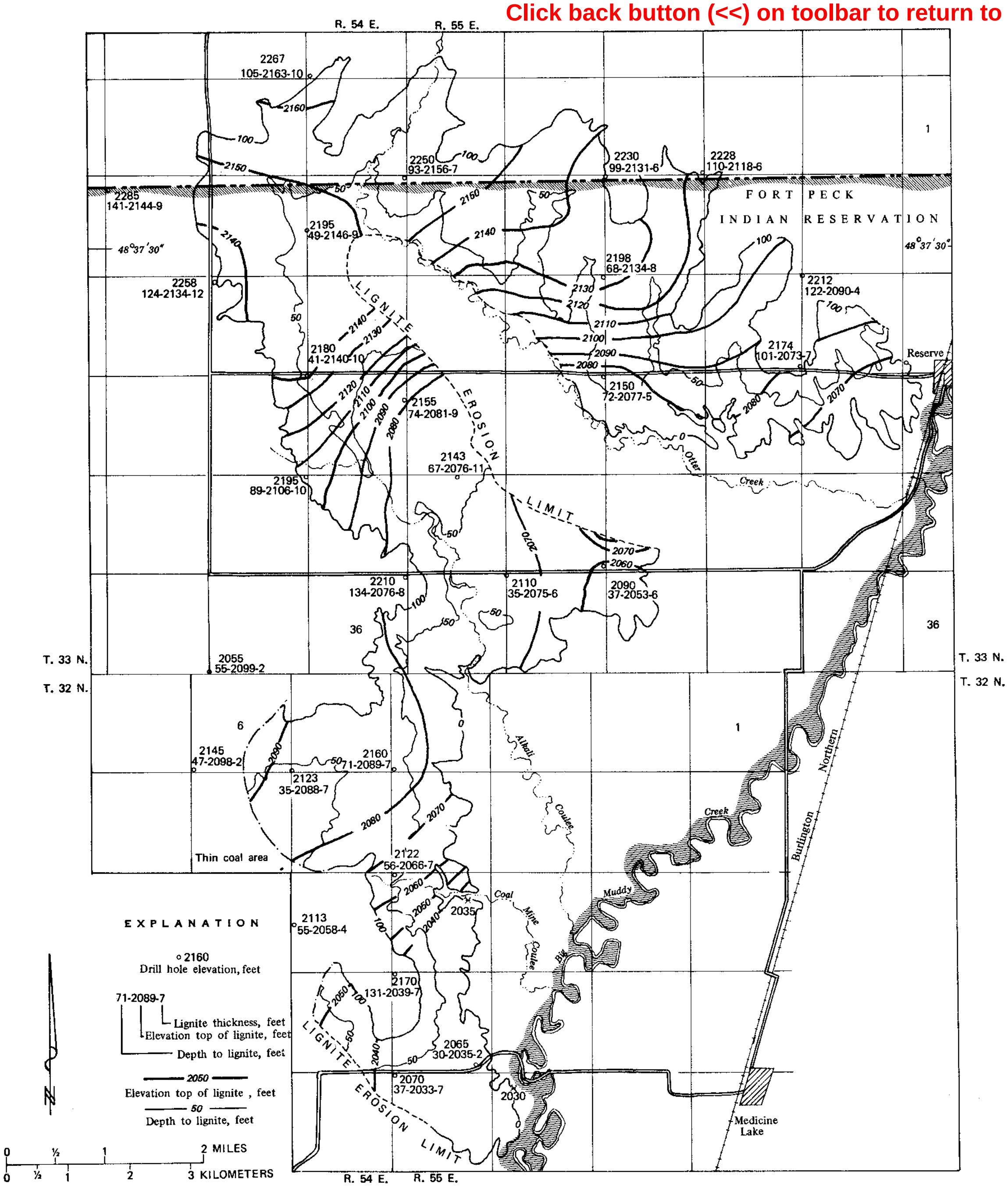

Figure 19. Map showing Reserve lignite deposit in and near Fort Peck Indian Resrvation (modified from Ayler, Smith, and Deutman, 1969 and unpublished Great Northern Railway Co. report).

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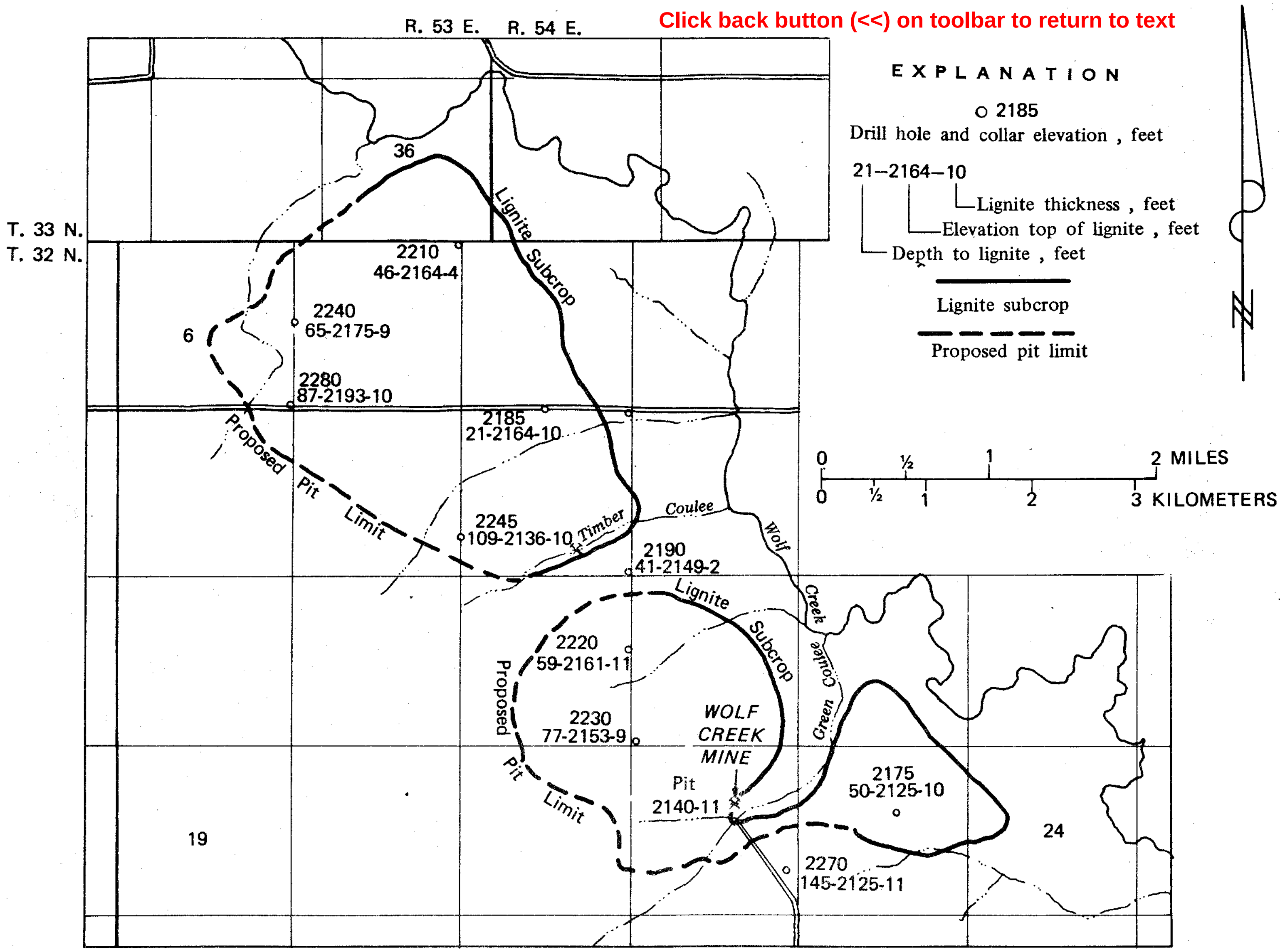

Figure 20. Map showing Medicine lake lignite deposit, Fort Peck Indian Reservation (modified from Ayler, Smith, and Deutman, 1969 and unpublished Great Northern Railway Co. report).

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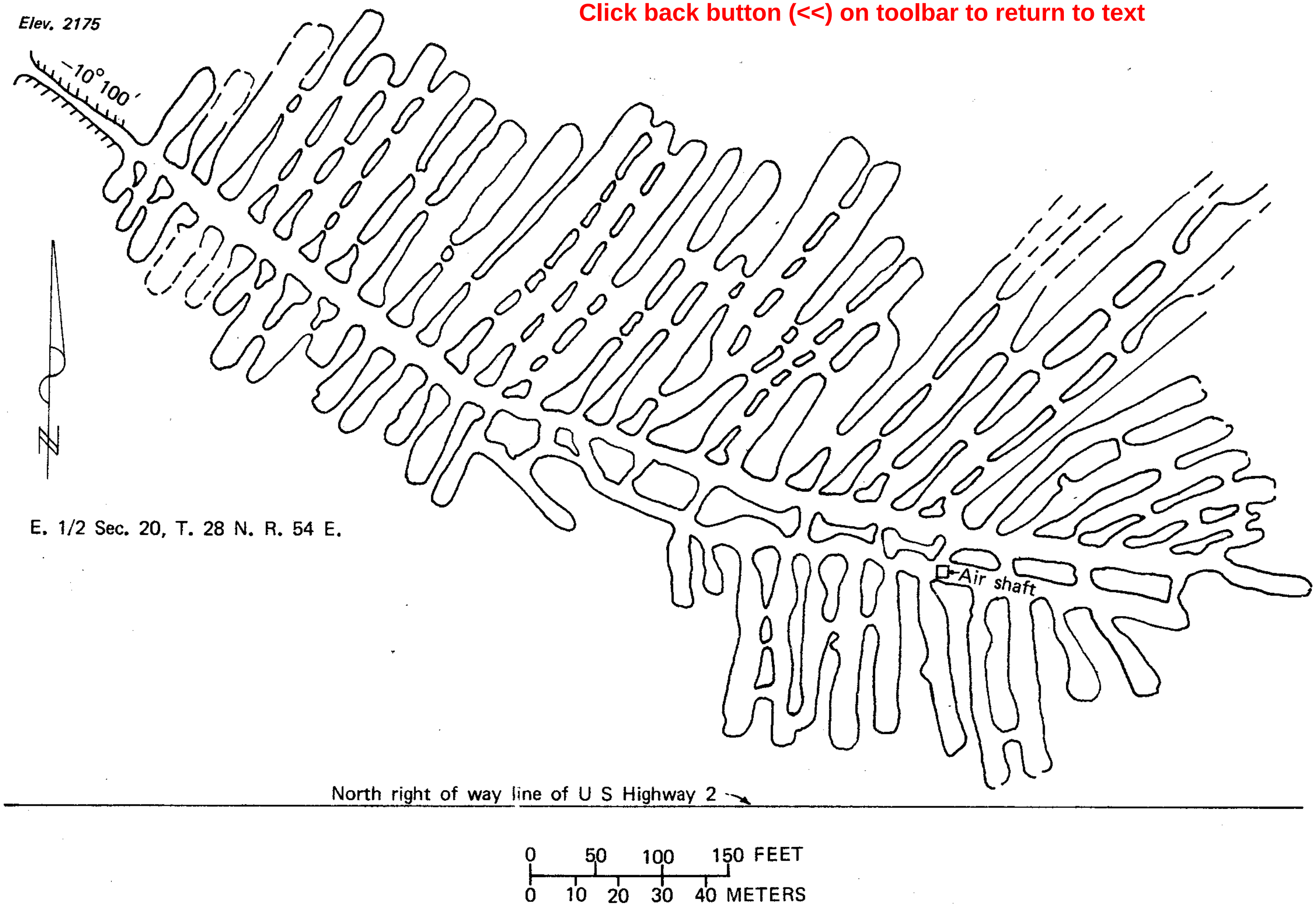

Figure 21. Map showing underground workings of Alton lignite mine, Fort Peck Indian Reservation (from Henkes and Magill, 1970).

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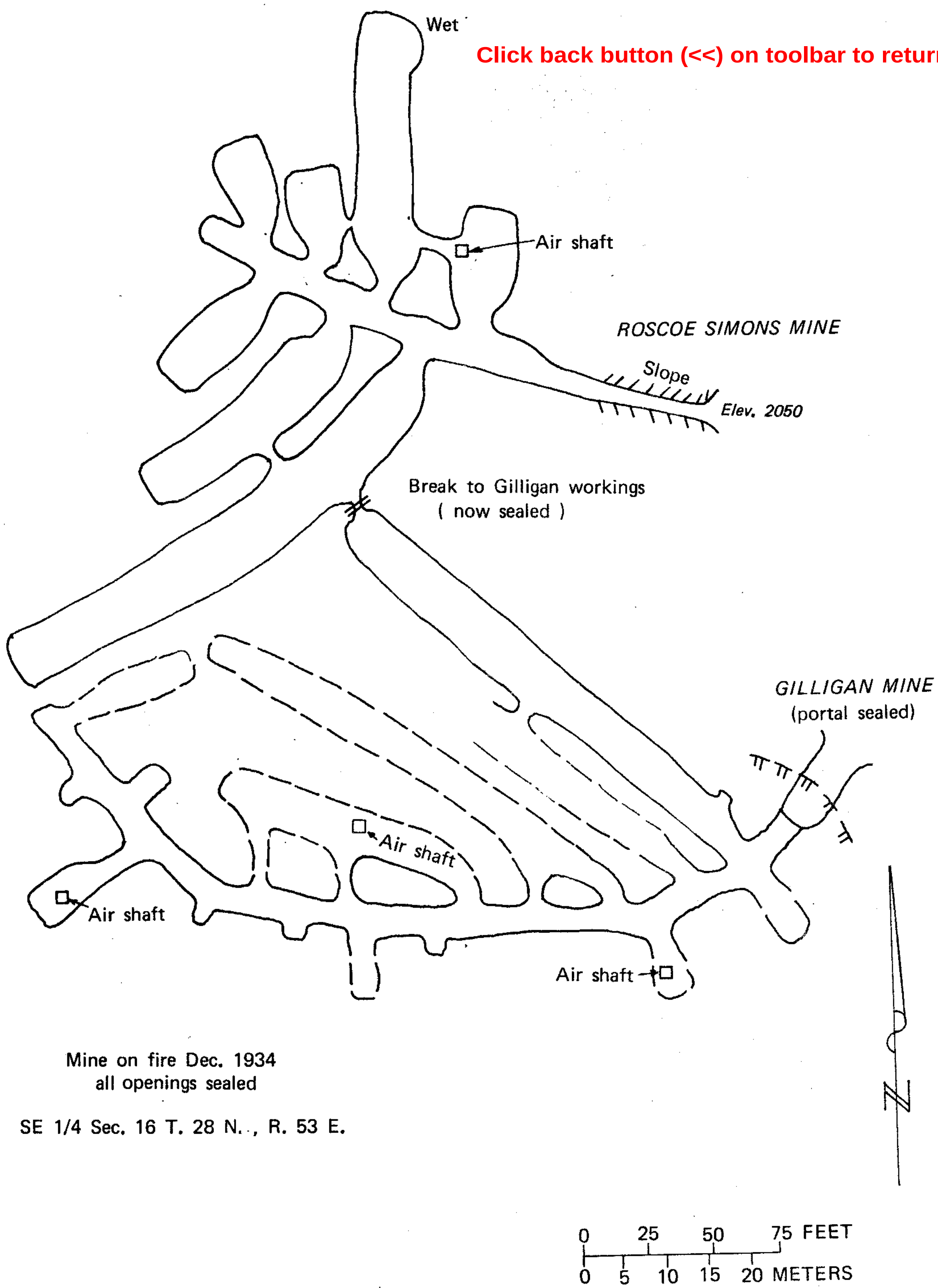

Figure 22. Map showing underground workings of Simon-Gilligan lignite mines, Fort Peck Indian Reservation (from Henkes and Magill, 1970).

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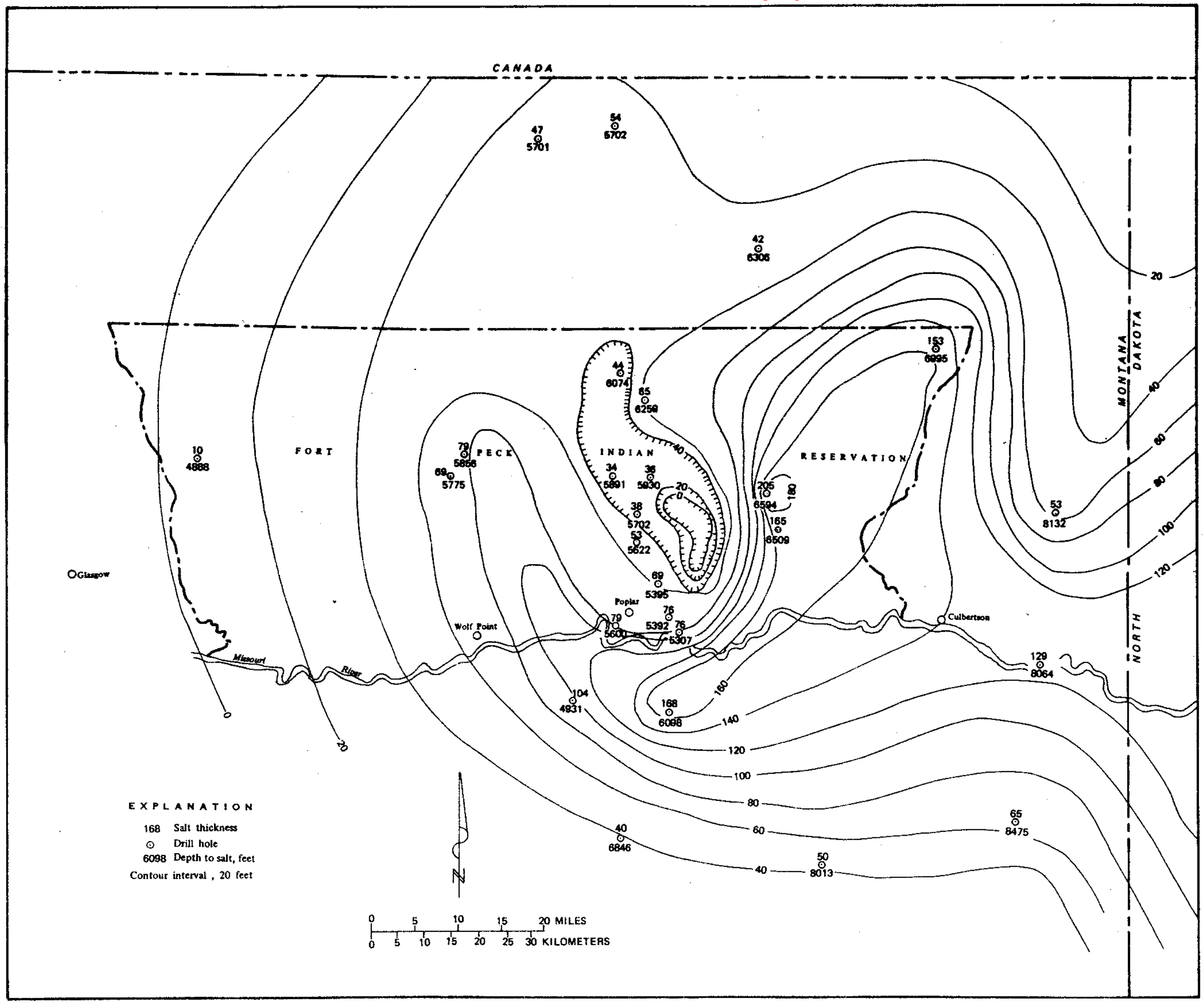

Figure 23. Isopach map of Mississippian salt bed, Fort Peck Indian Reservation and vicinity (from Henkes and Magill, 1970; Great Northern Railway Co., 1959).

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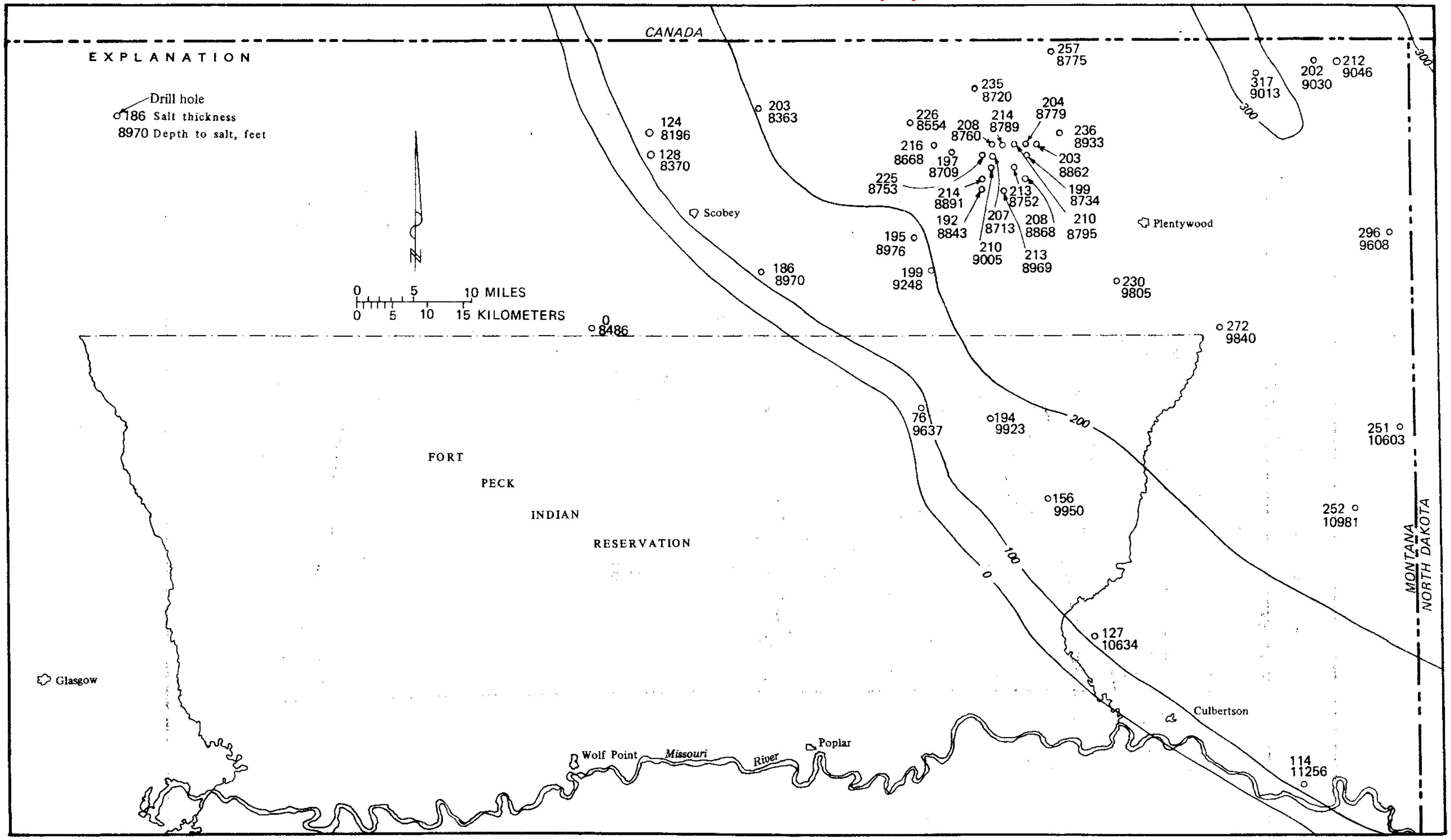

Figure 24. Isopach map of Devonian salt bed, Fort Peck Indian Reservation and vicinity (from Great Northern Railway Co., 1965).

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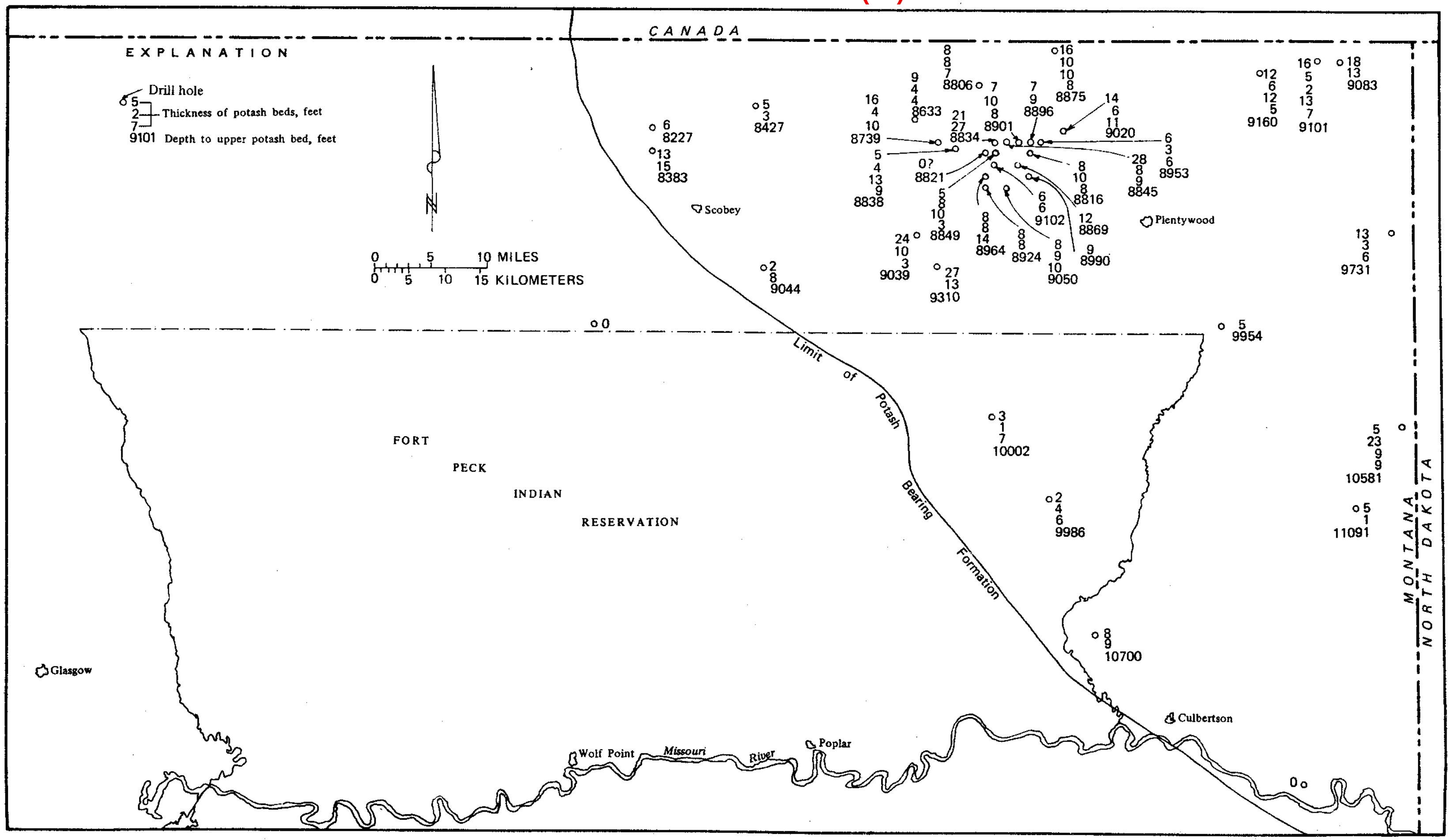

Figure 25. Map showing drill hole data in Devonian potash beds, Fort Peck Indian Reservation and vicinity (modified from Great Northern Railway Co., 1965).

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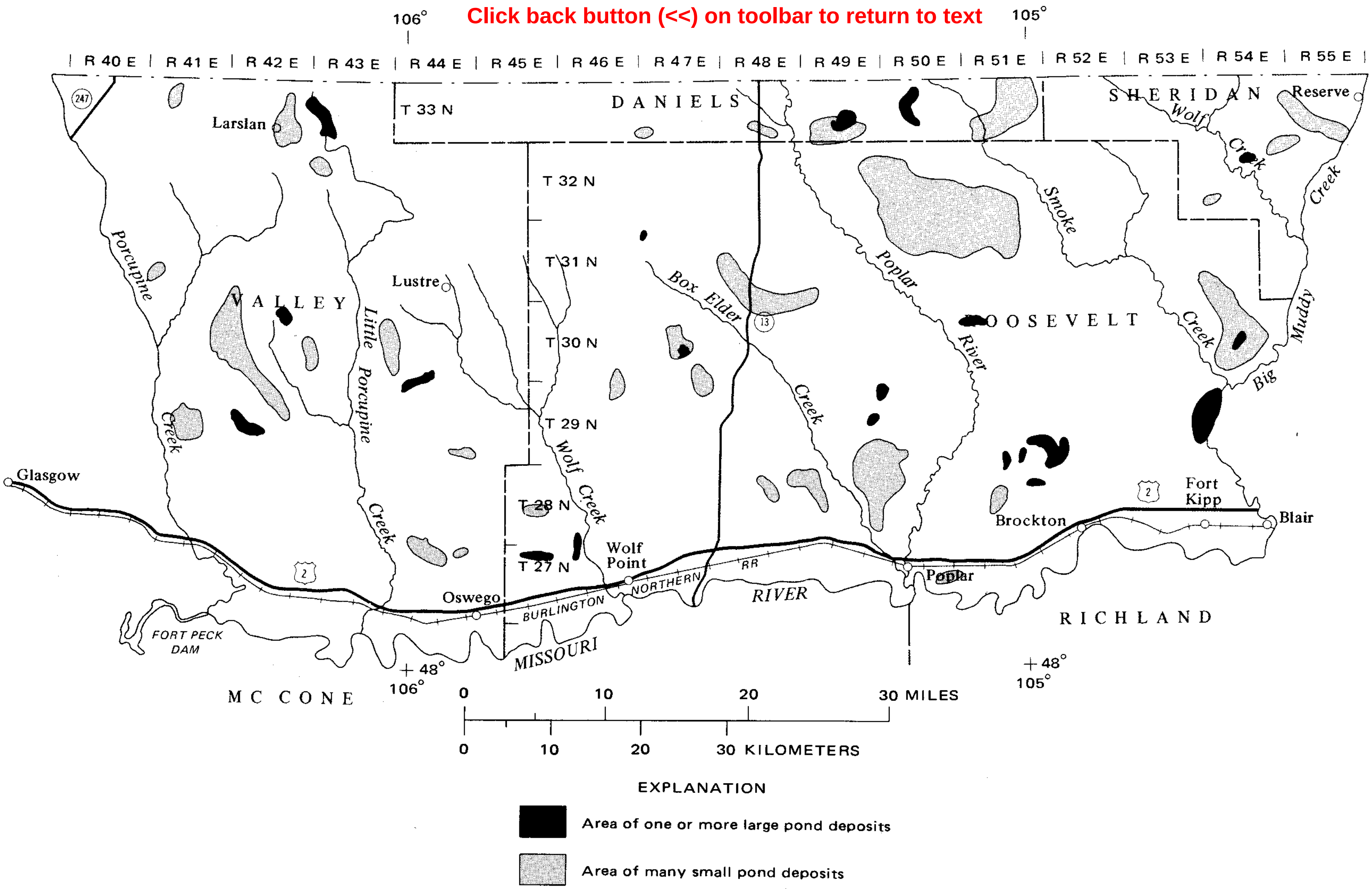

Figure 26. Map showing pond deposits on Fort Peck Indian Reservation (Colton, 1955, 1962, 1963a-j, 1964a; Witkind, 1959; and Jensen and Varnes, 1964).

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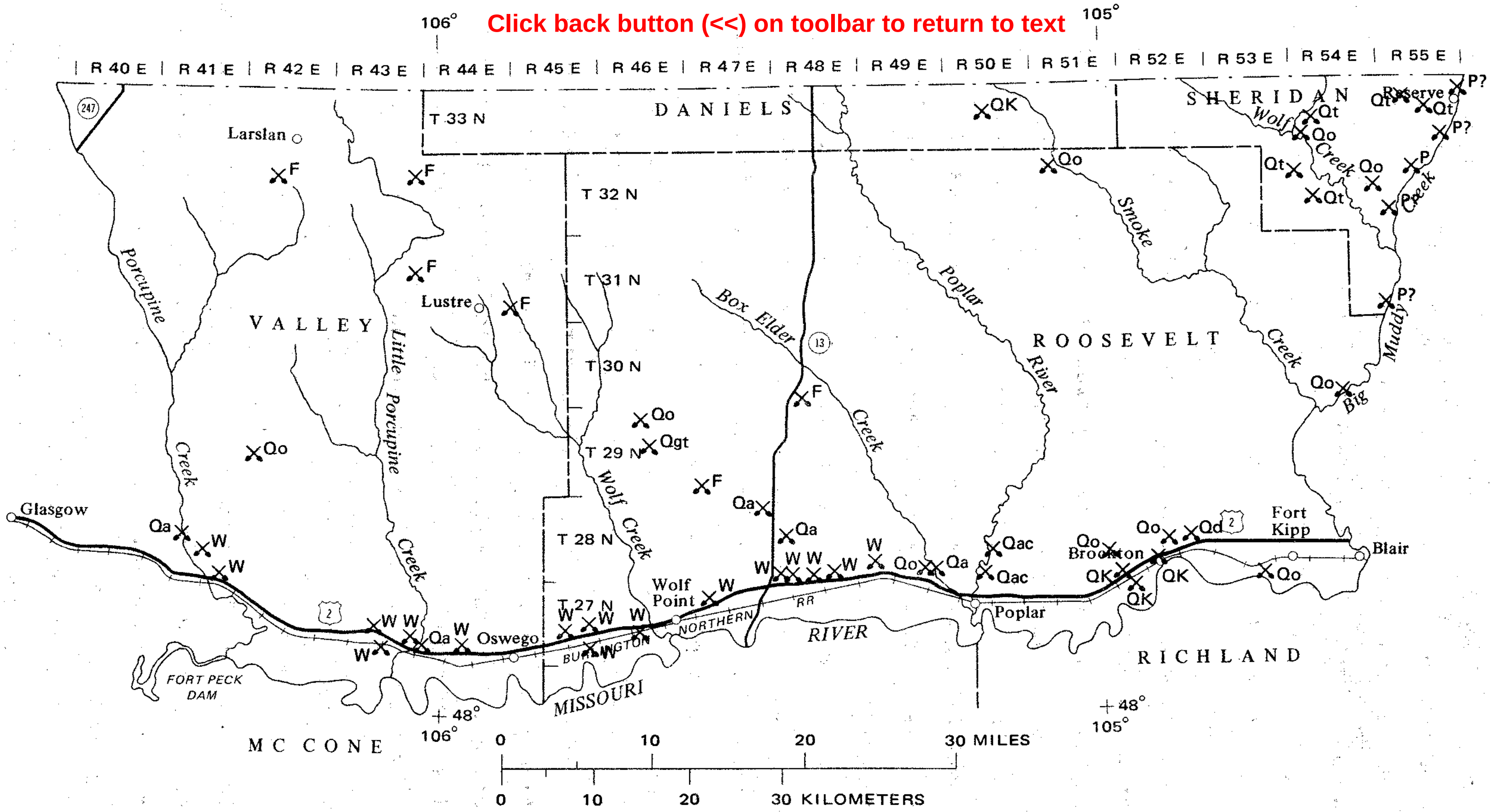

Figure 27. Map showing reported sand and gravel pits and the source in the Fort Peck Indian Reservation. Qa, alluvium; Qd, dune; Qac, fan alluvium and colluvium; Qo, outwash; Qgt, younger till; Qt, till; W, Wiota gravel; P, Plentywood gravel; F, Flaxville; ? where uncertain. (Colton, 1955, 1962, 1963a-j, 1964a; Witkind, 1959; and Jensen and Varnes, 1964).