STATUS OF MINERAL RESOURCE INFORMATION FOR THE UTE MOUNTAIN INDIAN RESERVATION, COLORADO AND NEW MEXICO

By

W. P. Pratt
and
J. H. Irwin
U. S. Geological Survey

W. C. Henkes,
U. S. Bureau of Mines

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SUMMARY AND CONCLUSIONS

The mineral resources now being produced on the Ute Mountain Indian Reservation are petroleum, natural gas, and small quantities of sand and gravel. It is probable that, with increasing demands for energy coupled with higher prices for crude oil and natural gas, there will be increased exploration in the Four Corners area.

The shallow production in the fields from Ramona to Aztec Wash will continue to be erratic but, because of the relatively low drilling and operating costs, these fields will continue to attract venture capital. Production from the fossil reefs in the Paradox Member of the Hermosa Formation in the Cache, Marble Wash, and Towaoc fields along the Utah boundary has been somewhat disappointing. Location of productive wells in the reef material has been frustratingly erratic. Numerous deep wells have been drilled along the southeast extension of the Paradox Member without success. The density of drilling is not sufficient to deny the presence of additional Paradox oilfields, but results to date are discouraging.

Increased petroleum exploration may be attracted to the reservation by lease terms more favorable to the companies, for example, by slightly reduced royalties. The discovery rate and production do not justify more stringent royalty or lease terms at this time.

The most favorable possibilities for coal production appear to be in the Menefee Formation near and south of the Colorado-New Mexico border, and in the Fruitland Formation in San Juan County. It is doubtful that additional field work would add materially to the data assembled by Shomaker and Holt (1973).

The new agreement with Mobil Oil Corp. for uranium exploration will result, at least, in additional information concerning the economic geology of the reservation. If commercial deposits of uranillm are found, the economic impact on the reservation will be significant. Geologic structural data from uranium exploration drill holes may encourage additional drilling for oil and natural gas.

The titaniferous sandstones on the reservation probably merit some study. Because of its light weight and corrosion resistant properties, use of titanium metal is expected to expand. It is recommended that the titaniferous sandstones be mapped in detail and research undertaken to process and mine the deposits.

The presence of copper minerals and propylitic alteration associated with the igneous rocks of the Ute Mountains could indicate "porphyry copper" deposits at depth, even though the surface indications are not promising. Depth to possible ore could be as much as 3,000 feet. Geochemical studies might delineate promising target areas for exploration by diamond drilling.

INTRODUCTION

This report was prepared for the U. S. Bureau of Indian Affairs by the U. S. Geological Survey and the U. S. Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral and energy resources, and potential for economic development of certain

Indian lands. Sources of information were published and unpublished information, and person l communication. There was no field work.

PHYSIOGRAPHY

The Ute Mountain Indian Reservation is in southwestern Colorado and northwestern New Mexico. According to the U. S. Department of Commerce (1974, pp. 170-171), it has a total area of 595,787 acres (241,294 ha), consisting of 557,878 acres (225,941 ha) of tribal lands, 9,549 acres (3,831 ha) of allotted lands, 28,410 acres (11,506 ha) of tribal fee lands, and 40 acres (16 ha) of Federally-owned lands. The reservation is generally a compact geographic unit with only a few isolated tracts along the northern boundary (Figure 1).

The reservation ranges in altitudes from about 4,600 feet (1,400 m) along the San Juan River near Four Corners (the junction of the States of Arizona, Utah, Colorado, and New Mexico) to 9,977 feet (3,043 m) on Ute Peak. Most of the western part of the reservation is semiarid, eroded grasslands with some "badlands" topography near the Utah boundary. North of the grasslands is the Sleeping Ute Mountain with a cover of scrub cedar, oak, and juniper. The eastern and southeastern parts of the reservation consist of the deeply-cut canyons and mesas of Mesa Verde and Tanner Mesa; this region is also covered by scrub cedar and juniper.

The principal stream on the reservation is the perennial Mancos River which enters near the northeast corner, flows southwestward through the area, and leaves about 6 miles (10 km) east of Four Corners (Figure 1). The San Juan River flows for 3 or 4 miles (5-6 km) across the extreme southwest corner of the reservation. Navajo Wash is a perennial stream flowing southward a few miles west of Mesa Verde.

The only paved highways in the reservation are U. S. Highways 160 and 666 and State Highways 41 and 789 (Figure 1). Two maintained gravel roads cross the reservation: one follows the Mancos River canyon to the eastern part of the reservation then southward toward Farmington; the other goes westward from Towaoc to the Cache oilfield then on to Aneth, Utah. Other roads are generally trails passable only to four-wheel-drive vehicles or pickup trucks.

Towaoc is the only town on the reservation. It is the site of the Ute Mountain Indian Agency and the residence of most of the people on the reservation. As of April, 1975, the resident Indian population in and near the reservation was 1,335. The nearest large town is Cortez, Colo., about 16 miles (26 km) northeast of Towaoc (Figure 1). With a population of about 6,000 it is the principal market center for the area. South of the reservation in New Mexico are the towns of Shiprock, 30 miles (48 km) from Towaoc, and Farmington, 29 miles (47 km) east of Shiprock, with a population of about 23,800.

SOCIO-ECONOMIC FACTORS

According to the Bureau of Indian Affairs (BIA), 40 percent of the total population of working age is in the 16 to 24-year range and 65 percent is in the 16 to 35-year bracket. Of the 211 employed persons, 63 had earnings of $5,000 or more per year and 148 had earnings of less than $5,000.

With an unemployment rate of 45 percent, it probably can be assumed that most of the unemployed are in the prime age groups for workers and are trainable.

The labor force for 1975 is shown in Table 1.

TABLE 1
Resident Indian population of working age, 1975
(Bureau of Indian Affairs, 1973, 1975)

Age group	Total	Male	Female
16 - 44	549	243	306
45 - 64	92	41	51
65 and over	45	20	25
Not in labor force*	129	40	89
Potential labor force	557	264	293
Employed	211	158	53
Not employed	346	106	240
Not employed, but seeking work	250	86	164

* Includes: Students, 16 years or over; men and women who are physically or mentally disabled, retired, institutionalized, etc.; and women for whom no child-care substitutes are available.

GEOLOGY

We are grateful to Robert J. Hite, Robert B. O'Sullivan, and Charles W. Spencer of the U. S. Geological Survey for providing information that was helpful to us in preparing this report.

PREVIOUS GEOLOGIC INVESTIGATIONS

The geology of the Ute Mountain Indian Reservation and adjacent areas has been described in numerous reports and maps, which have been used in the preparation of this report. Most pertinent is a report on the geology and availability of ground water of the reservation by Irwin (1966). For further details the reader should consult the following publications:

Ekren and Houser, 1965 (Ute Mountains area)
Wanek, 1959 (Mesa Verde area)

Hayes and Zapp, 1955 (Barker dome - Fruitland area)

Baltz, Ash, and Anderson, 1966 (Upper Cretaceous-Lower

Tertiary stratigraphy, western San Juan Basin)

Fassett and Hinds, 1971 (Fruitland Formation and Kirtland Shale)

Haynes, Vogel, and Wyant, 1972 (Geologic map, Cortez 1º x 2º quadrangle)

O'Sullivan and Beikman, 1963, (Geologic map, Shiprock 1º x 2º quadrangle)

GEOLOGIC SETTING AND ROCK UNITS

The Ute Mountain Indian Reservation is on the Four Corners platform of the Colorado Plateau, and most of it is underlain by gently dipping sedimentary rocks of Mesozoic age. Most of the rocks exposed on the reservation are sandstones, shales, and mudstones of Cretaceous age; the oldest sedimentary formation exposed is of Jurassic age and the youngest consolidated rocks are Tertiary (Table 2). The oldest units crop out along the northernmost boundary of the reservation, and the exposed sedimentary rocks become progressively younger toward the south and east; in general this reflects the higher topographic position of the Mesa Verde plateau. The principal area of non-sedimentary rocks in the reservation is the Ute Mountains, which are formed of Late Cretaceous or Tertiary igneous rocks.

Older sedimentary formations pertinent to this report, not exposed on the Reservation but occurring in the subsurface, include, in descending order, the Kayenta Formation and Wingate Sandstone of the Glen Canyon Group of Jurassic age, the Dolores (Chinle), Shinarump, and Moenkopi formations of Triassic age, the Cutler and Rico formations of Permian age, and the Hermosa Formation of Pennsylvanian age. The Paradox Member of the Hermosa, characterized by its content of salt and gypsum, is significant to this review because it is the producing horizon for oil wells in the northwest corner of the Reservation (see under Mineral Resources). In that area it lies at depths of about 5700 to 6000 feet (about 1740 to 1830 m) below the surface.

The geologic formations exposed on the reservation are briefly described below, from oldest to youngest (Table 2). On the geologic map (Figure 2), some of these formations are grouped together for better legibility.

Triassic(?) and Jurassic Systemsv

Navajo Sandstonev

The Navajo Sandstone, the oldest formation exposed, crops out along the south flank of McElmo dome (see under Geologic Structure) in McElmo Canyon, sec. 31, T. 36 N., R. 17 W. It is a grayish pink to orange fine-grained sandstone with conspicuous crossbedding. The Navajo weathers into rough, rounded surfaces, commonly pitted, and usually forms cliffs. The outcrop is nearly devoid of soil and vegetation. The base of the Navajo Sandstone is not exposed in the McElmo Canyon area; hence the total thickness is not known. According to Ekren and Houser (1965, p. 7), the Navajo is about 300 feet thick at Sand

Creek, a tributary of McElmo Creek (5 miles east of the Karla Kay mine and one mile north of the Reservation).

Jurassic Systemv

San Rafael Groupv

The San Rafael Group within the reservation is represented by the Entrada Sandstone, the Summerville Formation, and the Junction Creek Sandstone; the Todilto Limestone may be present in the subsurface in the eastern part.

Entrada Sandstonev

The Entrada Sandstone is exposed in the canyon of McElmo Creek, and is in the subsurface throughout the rest of the reservation. It lies unconformably over the Navajo Sandstone. In the Ute Mountains area, the Entrada Sandstone consists of two units, a lower silty unit and an upper sandstone unit. The lower unit is reddish-brown, fine grained silty sandstone. It weathers into characteristic rounded forms, commonly called hoodoos, and in places forms a soft bench between the more massive cliffs of the underlying Navajo Sandstone and the upper sandstone member of the Entrada. It is about 20 feet thick in the McElmo Canyon area, but may not be present everywhere in the subsurface in the area.

The upper unit is white to pink or orange, fine-grained sandstone, 70 to 80 feet thick in the McElmo Canyon area (Ekren and Houser, 1965 p. 8). The unit is highly crossbedded, and weathers to form a conspicuous characteristic "slick rock" rounded cliff.

Summerville Formationv

The Summerville Formation lies conformably above the Entrada Sandstone, and is exposed only near the northern reservation boundary, where McElmo Canyon cuts through the southern part of McElmo Dome. It consists of a sequence of reddish-brown silty fine-grained sandstone interbedded with pale-red to brown siltstone or mudstone. In the McElmo Canyon area the unit becomes more sandy toward the top, and a sandstone bed near the top is 20 feet thick (Ekren and Houser, 1965, p.113.) Here the thick bed forms a conspicuous ledge, but in other places the formation generally forms a moderate slope with thin sandstone ledges. The Summerville Formation is approximately 140 feet thick in McElmo Canyon, and apparently maintains a fairly consistent thickness throughout the reservation.

Junction Creek Sandstonev

Overlying the Summerville Formation is the conspicuous cliff-forming Junction Creek Sandstone, which is exposed in McElmo Canyon and in one small outcrop just south of Sentinel Peak. It is pale red to light brownish gray fine to medium grained sandstone, with indistinct flat beds to high-angle crossbedding. The thickness of the Junction Creek ranges widely, owing to channeling of the formation before Morrison deposition; in the

McElmo Canyon area it is from 230 to 300 feet thick. The formation is probably present in the subsurface throughout the reservation.

Morrison Formationv

The Morrison Formation throughout the Colorado Plateau has been separated into four members, which are, in ascending order: the Salt Wash Sandstone Member, the Recapture Shale Member, the Westwater Canyon Sandstone Member, and the Brushy Basin Shale Member (Craig and others, 1955). The Morrison crops out in McElmo Canyon and around the Ute Mountains. It apparently overlies the Junction Creek Sandstone conformably in the reservation, but fluvial channeling occurs locally at the contact.

The Salt Wash Sandstone Member in the reservation consists of interbedded sandstone and mudstone. The sandstone units are greenish-gray to pinkish-gray fine- to medium-grained sandstone, and range from a few feet to 20 feet thick. The mudstone units are dusky red and greenish gray. The sandstone units are crossbedded, they form small ledges between the less resistant mudstone units, and in McElmo Canyon they form an irregular benchlike steep glove above the more massive vertical cliff of the Junction Creek Sandstone. The thickness of the Salt Wash varies greatly in the reservation, owing to intertonguing and gradation with adjacent units. In the McElmo Canyon area the Salt Wash is 100 to 250 feet thick, but in at least one outcrop just south of the east toe of the Ute Mountains, the Salt Wash is not present (Ekren and Houser, 1965, p. 14) and the Recapture Member lies directly on the Junction Creek Sandstone.

The Recapture Shale Member intertongues with and grades into the Salt Wash, and the unit is not everywhere recognizable in the northern part of the reservation. The overlying Westwater Canyon Sandstone Member intertongues with and grades up into the Brushy Basin Member. It is thin in the northern part and is probably not recognizable a short distance north of McElmo Creek. Where the two middle members can be distinguished, the Recapture Member is typically composed of grayish pink, fine- to medium-grained sandstone, interbedded with dark reddish brown siltstone and mudstone, and characteristically weathers to a soft steep slope.

The Westwater Canyon Member is typically yellowish gray fine- to coarse-grained sandstone interbedded with green and red bentonitic mudstone. The Recapture is 0 to 75 feet thick, and the Westwater Canyon is 50 to 125 feet thick in McElmo Canyon. Both members thicken abruptly south of the McElmo area, and each is about 200 feet thick in the southwestern part of the reservation.

The Brushy Basin Shale Member consists of variegated mudstone containing considerable amounts of bentonitic clay interbedded with siltstone and siliceous sandstone. The mudstone and siltstone units are predominantly pinkish gray to light greenish gray; the bentonitic clay causes the mudstone to weather to a characteristic frothy surface. The sandstone units are fine-grained and are light yellowish or greenish gray. Conglomerate and conglomeratic sandstone are present but not common. Where the member is capped by the more resistant Burro Canyon and Dakota Formations, it weathers to a steep multicolored slope with small ledges of sandstone. The Brushy Basin Member ranges in thickness from 150 to 300 feet in the Ute Mountains area.

Cretaceous Systemv

Burro Canyon Formationv

The Jurassic-Cretaceous boundary cannot be precisely located in most of the reservation because of intertonguing, lithologic gradation, and lack of fossils. The Cretaceous Burro Canyon Formation is predominantly green mudstone interbedded with lenses of conglomerate and conglomeratic sandstone. Where mudstone of the Burro Canyon overlies mudstone of the Brushy Basin, the contact seems to be conformable, and there is no indication of a break in sedimentation. In places in the Four Corners area, basal sandstone lenses of Burro Canyon intertongue with the Brushy Basin mudstone. Near Four Corners, the Burro Canyon Formation cannot be recognized as a mappable unit, and the mapped Dakota Sandstone rests on the Brushy Basin.

The mudstone units of the Burro Canyon are generally grayish green or grayish-red and have a characteristic hackly weathered appearance. The mudstone is generally not bentonitic, and thus differs from the bentonitic frothy-weathering mudstone of the Brushy Basin (Ekren and Houser, 1965, p. 19). The conglomeratic sand stone and sandstone lenses are fine to medium-grained, commonly crossbedded, white to light gray, and weather pale brown. The pebbles of the conglomeratic sandstone are principally red, white, green, or gray chert and are as large as 2 inches in diameter. The conglomeratic lenses form rough cliffs or steep ledges, where they are thickest. They are most evident in the northern part of the project area, particularly in McElmo Canyon. South of McElmo Canyon these units are rare and are commonly absent. Where the conglomerate and sandstone are not present, it is difficult to map the contact between the Burro Canyon and the Brushy Basin. In mapping the Ute Mountains area, Ekren and Houser (1965, p. 14). placed the contact where the rocks change from hackly weathering mudstone of the Burro Canyon to frothy-weathering mudstone of the Brushy Basin Member of the Morrison. Along the San Juan River in the extreme southwestern part of the reservation, the Burro Canyon could not be distinguished as a continuous mappable unit.

The Burro Canyon ranges in thickness from 0 to approximately 200 feet in the McElmo Canyon area. Its occurrence in the east half of the reservation is not known, as it does not crop out, and data obtained from well logs are inadequate.

Dakota Sandstonev

The Dakota Sandstone in the reservation lies disconformably over the Burro Canyon Formation. Where the Burro Canyon is not present or cannot be recognized, the Dakota lies unconformably on the Brushy Basin Member of the Morrison Formation. The Dakota is exposed in the vicinity of the

Ute Mountains and along the west boundary of the reservation. It crops out or is in the subsurface throughout the reservation, except in the relatively few areas where older rocks are exposed. In the eastern part, it lies at considerable depth under an accumulation of several thousand feet of younger Cretaceous rocks.

The Dakota is composed of several sandstone units interbedded with carbonaceous shaly claystone, mudstone, and some thin coal beds. The basal sandstone unit is commonly conglomeratic. In a general way, the Dakota can be separated into three parts: a lower unit consisting of sandstone or conglomeratic sandstone, a middle unit consisting of carbonaceous black mudstone and silty sandstone, and an upper unit consisting of sandstone. The sandstone beds are generally light gray to light yellowish gray, and are very fine-grained to medium grained. They generally are weakly cemented with limonite and are moderately porous and friable. Much of the sandstone is crossbedded. The mudstone beds are medium gray to black and usually contain abundant carbonaceous material. They also generally contain abundant fine sand and are commonly interbedded with thin-bedded platy gray sandstone stringers.

Thin lenticular beds of low-grade coal occur throughout the Dakota but are generally more concentrated in the middle and upper parts. The coal beds range from a few inches to a few feet in thickness.

A conspicuous feature is the hard dark-red ironstone beds. They are generally about a foot thick, and are more common in the middle part of the Dakota. The ironstone is generally well cemented with limonite or hematite and weathers blocky or knobby, forming an irregular ledge.

The Dakota weathers to form steep ledges and cliffs; the mudstone units form slopes between the steep ledges of the sandstone units. The bedding planes are generally conspicuous, particularly where the unit crops out on gently sloping weathered surfaces in the area surrounding the Ute Mountains. In the McElmo Canyon area, the Dakota caps most of the mesas. Where the exposed Dakota is relatively flat, it is covered with a thin mantle of windblown sand and soil with knobby sandstone occasionally cropping out in sheltered places or in places cleared by sheet wash from desert rainstorms.

The thickness of the Dakota ranges from 100 to 160 feet and averages about 135 feet.

The Dakota is the main aquifer for stock water on the reservation. Although it does not yield large quantities of water to wells, most of the Dakota wells are dependable for small quantities. All the wells tapping the Dakota are in the western half of the reservation.

Mancos Shale v

The Mancos Shale is exposed extensively in the western half of the reservation. It forms gently rolling hills and low ridges throughout the southwestern part. Where the overlying, more resistant Point Lookout Sandstone is present in the cliffs along the west edge of Mesa Verde, the Mancos forms a steep dissected slope below the caprock.

The Mancos lies conformably above the Dakota Sandstone. In many places, the transition from beach deposition of the Dakota to marine deposition of the Mancos left deposits of yellow-gray poorly cemented clayey sandstone with indistinct bedding at the base of the Mancos. These deposits are about 35 feet thick.

The Mancos Shale consists almost entirely of gray to dark-gray mudstone, but contains many thin sandy limestone lenses and limestone concretions. About 75 feet above the base is a persistent interval of thin-bedded dense light-gray limestone, which ranges from 10 to 40 feet in thickness and forms low benches covered with flat limestone fragments.

An interval of distinctive yellowish-brown sandy fossiliferous limestone and gray to brown shale, called the Juana Lopez Member of the Mancos Shale (Ekren and Houser, 1965, p. 24), has been recognized throughout the reservation. The Juana Lopez occurs from 475 to 525 feet above the base of the Mancos. On the flanks of the Ute Mountains, the member is locally exposed in cuestas, such as "The Mound". The member is present throughout the Ute Mountains, but in many places it is hidden by debris. South of the mountains, the Juana Lopez forms a prominent escarpment that is exposed throughout the southwestern part of the reservation. The unit ranges in thickness from a few feet in parts of the mountains to 50 feet south of the mountains.

In the Ute Mountains area, a light-gray coarse-grained glauconitic sandstone lies on, or a few feet above, beds of the Juana Lopez Member of the Mancos Shale. Ekren and Houser (1965, p. 24) mapped this sandstone with the Juana Lopez.

Gallup Sandstonev

As the Mancos is traced south into the San Juan Basin, its character becomes less uniform and it is divisible into several members, which interfinger with sandstone units of both coastal-margin and nonmarine origins. One of these units is the Gallup (Tocito) Sandstone, which is equivalent in age to the lower part of the Mancos but is younger than the Juana Lopez Member (Molenaar, 1973). Although the Gallup is not well enough developed to be mapped as a unit in the area of Mancos outcrop on the Reservation, it is recognized in the subsurface as apparently isolated lenses that have produced oil in the Ramona Aztec Wash group of fields, and it is even more persistent farther southeast in the area of the Horseshoe-Gallup and Verde-Gallup fields (Figure 1).

Mesaverde Groupv

The Mesaverde Group was named from its exposures in the broad dissected mesa that forms the eastern part of the reservation. The group is divided into three units, in ascending order: the Point Lookout Sandstone, for Point Lookout on the north rim of Mesa Verde; the Menefee Formation, for exposures on Menefee Mountain near Mancos; and the Cliff House Sandstone, for the ruins of cliff houses in Mesa Verde National Park.

Point Lookout Sandstonev

The Point Lookout Sandstone is the basal formation of the Mesaverde Group. It is exposed in the steep sides and canyons of Mesa Verde, where it forms a cliff above the steep slopes of the Mancos Shale. Several isolated patches of sandstone, which are considered to be Point Lookout, crop out high in the Ute Mountains. One of the larger exposures is on Hermano Peak, known as "The Knees."

The Point Lookout in the Mesa Verde area was divided informally into two members by Wanek (1959, p. 685); Zapp (1949); and Barnes, Baltz, and Hayes (1954). The lower member is composed of interbedded yellowish-gray thin sandstone beds and medium-gray sandy mudstone. This member is transitional into the underlying Mancos Shale through intertonguing and gradational relations; the contact is placed arbitrarily at the base of the lowest sandstone bed. The thickness of the lower member ranges from 80 to 125 feet in the Mesa Verde area. The upper sandstone member of the Point Lookout is fine- to medium-grained massive yellowish-gray to white sandstone. The unit is thick to massively bedded, and crossbedded. It forms the most conspicuous cliffs in the area, which commonly have overhanging faces. The upper member intertongues with both the lower member and the overlying Menefee Formation. The upper member is 200 to 250 feet thick, and the entire Point Lookout Sandstone ranges in thickness from 300 to 450 feet.

Menefee Formationv

The Menefee Formation consists of shale, carbonaceous shale, coal, and siltstone beds alternating with lenticular sandstone beds. The sandstone is gray to grayish orange, fine to medium-grained, and thick bedded, and forms rounded ledges; many of the sandstone beds are not continuous and grade laterally into shale and siltstone. The shale is dark gray and generally sandy. The carbonaceous shale is dark brown and is generally associated with the coal beds. The Menefee throughout the Mesa Verde area contains coal beds of commercial significance; Wanek (1959, p. 689) and Hayes and Zapp (1955), subdivided the Menefee into an upper coal member, a middle barren member, and a lower coal member. In some areas, particularly the lower canyon of the Mancos River, the coal beds have been burned and are strikingly colored with bright hues or orange and red.

The Menefee crops out in steep slopes between the Point Lookout and Cliff House, where all three formations are exposed around the rim of Mesa Verde and in the canyons dissecting the mesa. The Menefee ranges in thickness from about 340 feet in the northern part of Mesa Verde to about 800 feet along the Colorado-New Mexico State line. The formation is wedge-shaped and intertongues considerably with the underlying Point Lookout and the overlying Cliff House.

Cliff House Sandstonev

The Cliff House Sandstone is the surface rock over most of Mesa Verde. The massive sandstone forms vertical cliffs; benches are formed in the more shaly units between the sandstone beds. The upper sandstone has niches and alcoves along the shaly sandstone at the base, and many of the cliff-dweller ruins in the National Park area are in these alcoves.

The sandstone beds of the Cliff House are very fine to fine-grained thick-bedded units with large-scale crossbedding. The thinly bedded shaly sandstone units between massive sandstone beds are interbedded with thin beds of siltstone and coal.

The thickness and composition of the Cliff House varies within the Mesa Verde region. Near Mancos the formation is shaly, and the shale interfingers with the sandstone beds and wedges out toward the south. Along Mancos Canyon the unit is composed of relatively thickbedded sandstone, forming irregular cliffs; shaly sandstone units lie between the more massive upper and lower sandstone beds. In the New Mexico part of the reservation, the formation consists of two massive sandstone beds separated by approximately 350 feet of shaly sandstone. The thickness of the Cliff House in the reservation ranges from 200 to 400 feet because of intertonguing; the maximum thickness is about 400 feet in Mesa Verde National Park.

Lewis Shalev

The Lewis Shale overlies the Cliff House Sandstone of the Mesaverde Group, and is present only in the southeast corner of the reservation. The unit consists of dark-gray to greenish-gray sandy shale and some beds of very fine grained sandstone. It contains some limestone and numerous thin yellow concretionary layers. The Lewis is 735 feet thick near the south boundary of the reservation at Westwater Canyon. It intertongues with the underlying Cliff House, and the contact is transitional.

Pictured Cliffs Sandstonev

Overlying the Lewis Shale is the Pictured Cliffs Sandstone. It is exposed as a narrow band in the Hogback in the southeastern part of the reservation (Figure 1), and consists of light-yellow to light-gray fine to fine-grained sandstone and interbedded gray shale, particularly in the lower part. The formation is 290 feet thick near the southern reservation boundary at Westwater Canyon. It grades into both the underlying Lewis Shale and the overlying Fruitland Formation.

Fruitland Formationv

The Fruitland Formation overlies the Pictured Cliffs Sandstone in the southeast corner of the reservation. It consists of irregularly bedded sandstone, shale, and coal. The coal beds are distributed throughout the formation, but are more abundant and generally thicker in its lower portion. The unit is about 250 feet thick. It intertongues with the Pictured Cliffs below and is gradational into the Kirtland Shale above.

Kirtland Shalev

The Kirtland Shale, which overlies the Fruitland Formation,,is divided into three members -- the lower member, the Farmington Sandstone Member, and the upper member; all three members are exposed in a few outcrops in the southeastern part of the reservation. The lower and upper members consist mainly of gray to grayish-brown shale interbedded with soft yellowish-gray sandstone. Minor amounts of carbonaceous and light sandy shale occur throughout the irregularly bedded units. The middle unit, the Farmington Sandstone Member, is a series of soft olive-gray and brown, irregularly crossbedded, fine to medium-grained sandstones. The formation is 1,160 feet thick a few miles east of the reservation boundary.

Tertiary Systemv

Ojo Alamo Sandstonev

Light to dark-brown conglomeratic sandstones, overlying the Kirtland Shale in an area of less than half a square mile in the extreme southeast corner of the reservation, have been identified by Fassett and Hinds (1971) as the Ojo Alamo Sandstone of Paleocene age. They are the youngest consolidated sedimentary rocks in the reservation.

Cretaceous or Tertiary Systemsv

Igneous rocksv

The Ute Mountains are formed by an extensive group of laccoliths, sills, dikes, and stocks. Several small igneous bodies also occur on Mesa Verde.

The igneous rocks of the Ute Mountains occur as laccoliths, bysmaliths, sills, and dikes that are radially distributed with regard to three stocks -- Black Mountain, "The Knees" (Hermano Peak), and a concealed Ute Peak mass (Figure 1). The rocks are porphyries, and form a series "that ranges from microgabbro through quartz monzonite. Field mapping indicates that the earliest intrusive rock was microgabbro, followed by diorite, granodiorite, and finally quartz monzonite" (Ekren and Houser, 1965, pl. 1). All the igneous bodies were intruded into or between the sedimentary rocks, probably about the same time as the intrusion of other laccolithic mountains on the Colorado Plateaus --from Late Cretaceous to the middle Tertiary.

Several small plugs and associated dikes of igneous rocks of Tertiary age crop out in the sedimentary rocks along Mancos Canyon and Rock Canyon (Figure 2; dikes not shown). Wanek (1959, p. 701) identified the rock of these igneous bodies as minette, a basaltic rock which contains abundant biotite flakes and olivine crystals.

Tertiary(?) and Quaternary Systemsv

The surficial deposits are not shown on the geologic map (Figure 2) because they generally form a veneer only a few feet or a few tens of feet thick, and do not obscure important bedrock relationships.

Pediment depositsv

Pediment gravel is extensive in the area surrounding the Ute Mountains, and on Mesa Verde, on Chapin Mesa and along the Montezuma La Plata county line.

The discontinuous pediment gravel of the Ute Mountains area extends radially away from the mountains -- in many places for several miles. The surfaces have been formed at various levels probably because of local conditions of load, discharge, and base level. The gravel deposits are more resistant to erosion than the underlying Mancos Shale; thus, later dissection has left isolated low buttes south of the mountains.

The deposits on these surfaces are predominantly composed of pebbles, cobbles, and boulders of igneous origin. The thickness of the pediment gravel ranges from 1 to 40 feet. In many places the gravel is mantled with several feet of windblown silt and very fine sand.

Quaternary Systemv

Colluvial depositsv

Deposits of colluvium--talus, slopewash, and landslides -- occur extensively on the slopes of the Ute Mountains. The talus deposits consist of igneous pebbles, cobbles, and boulders lying at the base of, or on steep slopes below, their source rock; they are included in the areas shown as TKi on the geologic map (Figure 2). Other colluvial deposits mostly cover Mancos Shale and are not shown separately on the map.

Alluviumv

Alluvial deposits, including a few low, narrow terrace deposits, occur along ma;or tributaries; the largest deposits are along the Mancos River and in the Towaoc area. The alluvium of Mancos River consists of silt, sand, clay, and some gravel. The thickness of the alluvium is not known, but is probably more than 80 feet in the Mancos Farms area (Figure 1). Near Towaoc the alluvium is composed of clay, silt, fine sand, and gravel. The finer materials were derived from the surrounding Cretaceous shale and sandstone; the coarser pebbles and cobbles are igneous fragments derived from the Ute Mountains intrusive rocks. The thickness ranges from 20 to 75 feet. The alluvium is thickest in channels cut into the underlying Mancos Shale by older streams that may or may not follow the present drainage patterns.

Away from the Ute Mountains, the smaller tributaries to the Mancos River have small amounts of alluvium intermittently deposited throughout their reaches.

GEOLOGIC STRUCTUREv

Generalv

In broad aspect the Ute Mountain Indian Reservation lies on a structural platform between the Monument uplift, about 40 miles to the west, and the San Juan basin immediately to the southeast. Superimposed on this platform are several smaller structures that give the reservation its own character (Figure 3); these are the Ute dome, the Mesa Verde basin, and the Hogback monocline, and even more locally, the McElmo dome, the Barker dome and anticline, and the Southern Ute dome. The following brief descriptions of these structures are adapted from the cited reports.

Ute domev

Ute dome (Figure 3) is probably entirely the result of injection of magma and principally of three stocks at "The Knees," Black Mountain, and Ute Peak (Ekren and Houser, 1965, p. 50). The dome is nearly circular in plan and averages about 10 miles in diameter. On its western side, the dome merges with west- and southwest-plunging folds, and its western edge is poorly defined. The southwest flank of the dome may be underlain by a large intrusive mass, and an irregular-shaped anticline that plunges westward from the northwest flank of the dome may also be underlain by an igneous mass, at least in part.

Other folds along the western flank do not appear to be closely related to igneous activity. They are closely associated with zones of fracturing that may be tectonic and unrelated to igneous activity.

Sentinel Peak dome, a smaller structural dome on the southern flank of Ute dome, has about 900 feet of structural relief and has been breached by erosion. Upper beds of the Junction Creek Sandstone are exposed in the central part of the dome, and these beds are cut by a small dike of granodiorite porphyry that is connected to a miniature laccolith intruded into the Recapture Shale Member of the Morrison Formation. The Sentinel Peak dome almost certainly overlies an intrusive igneous body.

Mesa Verde basinv

The Mesa Verde basin (Figure 3) is a broad downwarp that is generally reflected by the surface topography of Mesa Verde and occupies most of the area between Ute dome and the Hogback monocline; the center of the basin coincides closely with the lowest part of the Mesa Verde upland in T. 32 N., R. 15 W. Structural closure on the basin is probably on the order of 200-300 feet; it is limited because of its nearness to the Hogback monocline.

Hogback monoclinev

The Hogback monocline (Figure 3) trends northeasterly across the southeast part of the reservation, where it is reflected in small hogbacks formed by steeply dipping sandstone beds of the Pictured Cliffs sandstone (Hayes and Zapp, 1955). The dips in this area are mostly between 20º and 30º. The change in dip toward the San Juan Basin is relatively abrupt, and only a short distance from the steepest part of the monocline the dips in the basin are only 1 or 2 . On the northwest side of the monocline the beds flatten somewhat more gradually to an essentially horizontal position, except at the Southern Ute and Barker domes. Between the two areas of nearly horizontal beds, which are only 2 to 4 miles apart, there are several thousand feet of structural relief.

McElmo domev

The McElmo dome is immediately north of the Ute Mountains, and only the southernmost part of it lies within the reservation (Ekren and Houser, 1965, p. 51). Its structure is well exposed in

McElmo Canyon, which cuts through its southern flank. The dome is asymmetric, steepest on the south where the maximum dip is about 9 ½. Except for the south side, the flanks of the dome pass into a series of five anticlines, only two of which extend into the reservation. A moderately sharp anticline plunges southeast ward from McElmo dome in the vicinity of Ute Peak. It is asymmetric, with a steeply dipping southwest side. A poorly defined anticline extends southwest from McElmo dome about 4 miles, almost parallel to a graben that lies to the north. The total area affected by McElmo dome and its satellitic anticlines is about 20 miles east to west and 10 miles north to south.

Barker dome and anticlinev

Barker dome and anticline are on the east flank of the Mesa Verde basin, at the east side of the reservation. The dome is slightly elongated north and south, and extends northward for several miles as the Barker anticline. Maximum closure is at least 200 feet.

Southern Ute domev

Southern Ute dome (Figure 3) is a small, nearly round dome about a mile wide, immediately southeast of Barker dome (Hayes and Zapp, 1955). Its eastern and southern flanks are formed by a bend in the Hogback monocline, and its western flank is formed by the eastern limb of a southwesterly plunging syncline that separated Southern Ute dome from Barker dome.

Faultsv

Ute Mountains areav

Steeply dipping normal faults occur in the Ute Mountains area on the south, southwest, and northwest flanks of Ute dome, and on the southwest flank of McElmo dome (Ekren and Houser, 1965, p. 52). The greatest concentration of faults is on the northwest flank of Ute dome. Two sets of faults appear to have formed simultaneously in this vicinity; one set strikes nearly west, the other northeast. The west-striking faults parallel west-trending folds and have displacements that rarely exceed 30 feet. The northeast-trending faults appear to be extensions of a zone of faulting that cuts the southwest flank and the central part of McElmo dome. This zone curves to a nearly east strike and continues toward Cortez, Colo. The faults along this zone form a graben on the southwest flank of McElmo dome and have displacements of as much as 180 feet, the greatest known in the Ute Mountains area.

Southern Ute Dome areav

Most of the faults in this area are concentrated on a bend in the Hogback monocline south of Southern Ute dome (Hayes and Zapp, 1955). The strikes of these faults range from N. 70 W. to N. 90 W. Some faults are downthrown to the north; others are downthrown to the south. Apparently the majority are high-angle normal faults. The two longest faults southeast of Southern Ute dome have curved traces owing to actual curves in the fault planes rather than to the effect of topography on dipping fault planes. Two miles southwest of Southern Ute dome, two strike faults die out as small monoclinal flexures.

MINERAL RESOURCES

ENERGY RESOURCESv

Petroleum and Natural Gasv

Generalv

Petroleum and natural gas are the most significant mineral commodities on the reservation. Information compiled by the Conservation Division of the U. S. Geological Survey (Table 3) shows that the tribe received $1.2 million in royalties from production of these commodities in the 5-year period from 1970 through 1974. Income in 1974 was nearly $400,000. The effect on tribal income of the commodity price increases starting in 1973 is clearly evident in Table 3. Although petroleum output declined 38.6 percent in the 5-year period, royalty income increased 60.1 percent; natural gas production increased by 23.1 percent but income increased 137.4 percent; output of natural gas liquids dropped by 62.6 percent but royalty income was down by only 22.4 percent. Total royalty income nearly doubled--up 94.8 percent.

Geologic Controlsv

Oil and natural gas originate in rocks rich in organic matter, and then migrate into adjacent porous and permeable layers, through which they tend to move laterally and upward in the direction of lower pressure. They may eventually move all the way to the surface, but if their upward movement is impeded, they may be trapped into oil or gas "pools". Two different kinds of geologic situations may impede oil and gas movement and form pools; either stratigraphic traps or structural traps, depending on whether they are due to changes in the composition of the layer in which the oil or gas is moving, or changes in the structure (form) of the layer. Changes in composition, or stratigraphic traps, are caused by a decrease in the porosity or permeability of the layer, so that the fluid becomes trapped in a lensor wedge or sinuous-shaped body of porous rock; traps of this kind account for the production in the western and central parts of the reservation -- the Cache-Towaoc and Ramona-Aztec Wash groups of fields. Structural traps occur where a continuous layer of porous rock has been bent upward into a dome or a fold, so that oil or gas moves up along the layer toward the crest and then cannot escape; these account for the production in the southeastern part of the reservation.

Production and Reservesv

On the reservation are five oil- and gasfields that are significant in size and production and three or more areas with minor or currently insignificant production. The oil and gas fields occur in four geographic groups (Figure 1) which will be described here in order from northwest to southeast across the Reservation.

Cache-Towaoc Group of Fieldsv

The wells in the Cache-Towaoc group produce oil and some gas from stratigraphic traps in the reef trend of the Ismay zone of the Paradox Member of the Hermosa Formation (Pennsylvania), at depths of about 5700-6100 ft (about 1740-1860 m). From north to south, the fields are as follows:

Desert Canyon Oilfield.-- Desert Canyon oilfield was a one-well field discovered in November 1959, and abandoned in 1968. Phillips Petroleum Co. drilled the Desert Canyon No. 2, SE¼SE¼SE¼ sec. 11, T. 34 N., R. 20 W., Montezuma County, to a total depth of 6,090 feet (1,857 m) and completed it for an initial flow gage of 280 barrels of oil per day. Oil was trucked to the Four Corners Pipe Line terminal at Aneth, Utah. Cumulative production to abandonment in 1968 was 60,741 barrels of oil and 132,098 thousand cubic feet (3.7 million m3) of gas (R.M.A.G., 1962, p. 108; Colo. Oil & Gas Comm., 1968, Part II, p. 52).

Cache Oilfield.--The Cache oilfield, in Tps. 34-35 N., R. 20 W., Montezuma County (Figure 4) was discovered in October 1964 by Pan American Petroleum Corp. (now Amoco Production Co.). The discovery well, Veach No. 1, C NW¼NW sec. 2, T. 34 N., R. 20 W., was completed for an initial flow gage of 1,434 barrels of 42 -45 gravity API oil per day.

At the end of 1974, 10 wells were producing and most of the others had been converted to water injection wells for reservoir pressure maintenance. Production in 1974 was 115,297 barrels of oil and 107,178 thousand cubic feet of marketed natural gas. Cumulative production to year end 1974 was 2,943,252 barrels of oil and 5,999,041 thousand cubic feet of gas (Colo. Oil and Gas Comm., p. 70).

Marble Wash Oilfield.--The Marble Wash oilfield (Figure 5) was discovered in November 1958 when the California Co., Calco Superior Ute Tribal No . 2 well was successfully completed between 5, 761 and 5,851 feet (1,757-1,785 m). The well was in the NE¼NE¼ sec. 15, T. 33 ½ N., R. 20 W., and the initial pumping potential was 38 barrels of 41 gravity oil and 24 barrels of water per day. Although the discovery well had a low initial production some subsequent wells drilled along trend to the northwest had higher initial potentials--as much as 1,178 barrels of oil per day in the NE¼SE¼ sec. 9.

The discovery well was recompleted in the upper Hermosa Formation (Pennsylvanian) and in 1974 produced 3,624 barrels of oil for a cumulative amount of 5,570 barrels.

Production from the Paradox in 1974 was 24,779 barrels of oil and 21,689 thousand cubic feet of natural gas (marketed). Cumulative production to the end of 1974 was 565,501 barrels of oil and 1,018,194 thousand cubic feet (614,167 m3) of gas (Colo. Oil & Gas Comm.,1975, p. 70).

Towaoc Oilfield.--The Towaoc field was discovered in February 1959. The discovery well, The Texas Co. (now Texaco), Ute Mountain Tribal No . 1 , C SW¼ SE¼ sec . 21 , T . 33 ½ N ., R. 20 W., was drilled to a total depth of 5,888 feet (1,796 m) and completed for an initial gage flowing of 1, 256 barrels of oil per day. A second producer was drilled to the southeast in the NE¼SE¼ sec. 21, and completed for a flow gage of 488 barrels of oil per day. By 1974, the discovery well had been abandoned and the remaining well produced 3,015 barrels of oil during the year for cumulative production of 374, 688 barrels (Colo. Oil and Gas Comm., 1975, p. 71).

Ramona - Aztec Wash Group of Fieldsv

The wells in the Ramona - Aztec Wash group have had small and sporadic production of oil from lenses of Gallup Sandstone or unnamed sandstone lenses in the Mancos Shale (Cretaceous), all at depths of a few hundred feet. From north to south the fields are:

Ramona Oilfield. The Ramona oilfield discovery well, the Bush Drilling Co., Ute No. 15-7, NE¼ NE¼ sec. 15, T. 33 N., R. 18 W., Montezuma County, was completed on March 23, 1965 at total depth of 324 feet (99 m) and initially pumped 24 barrels of oil per day. The field was extended to the SE¼ section 10 and numerous dry holes were drilled. In 1974, the field was classified as temporarily abandoned and there was no production. Cumulative production at that time was 1,392 barrels of oil (Colo. Oil and Gas Comm., 1975, p. 71).

Chipeta Oilfield.--In October, 1974, shallow Gallup (Cretaceous) oil production was found in the southeastern part of T. 33 N ., R. 18 W., Montezuma County. The discovery well, Ute Production Co., Ute Mountain No. 35-51, NW¼ NE¼ sec. 35, T. 33 N., R. 18 W., was drilled to total depth 308 feet (94 m) and pumped one barrel of 39 gravity oil plus four barrels of water per day. Another lens of the producing sand was found in the SE¼ sec. 22, about a mile (1.6 km) northwest of the discovery. Production in the field during 1974 was 182 barrels of oil.

Mancos River Oilfield.--The Mancos River oilfield (called Mancos Creek by the U. S. Geol. Survey) is in sections 10, 11, 14, and 15, T. 32 N., R. 18 W., Montezuma County. The field was discovered in May 1927, when 40º gravity oil was found in a stray sandstone in the Mancos Shale, at a depth of about 375 feet (114 m). The early history of the field is clouded by poor records and conflicting reports, but it appears that approximately 33 shallow wells were drilled in the vicinity before the field was abandoned in 1949 (R.M.A.G., 1954, p. 65). Sporadic drilling and production have occurred since then and the Colorado Oil and Gas Commission (1975, p. 70) reported two wells produced 735 barrels of oil in 1974; cumulative production was 17,963 barrels.

Aztec Wash Oilfield.--The Aztec Wash oilfield in the northwest part of T. 32 N., R. 17 W., Montezuma County was discovered in November 1961, when the California Co., Ute Mountain No. 9 well, in the center of the NW¼ SW¼, sec. 8, T. 32 N., R. 17 W., was successfully completed, pumping two barrels of oil per day. Production was from the shallow Gallup Sandstone in the interval 899 to 904 feet (207 to 276 m). A flurry of drilling occurred and oil-productive lenses were found in the south half of section 16 and the north half of section 21 (initial production ranged from 1 to 32 barrels of oil per day) and in the SE¼ of section 10. In 1974, two wells produced 1, 295 barrels of oil and cumulative production to the end of 1974 was 16 , 016 barrels (Colo . Oil and Gas Comm., 1975 , p . 70) .

Horseshoe-Verde Group of Fieldsv

The Horseshoe and Verde fields both produce oil from the Gallup Sandstone, and both are significant fields, together having a cumulative production of over 8. 8 million barrels from the reservation through 1974 .

Horseshoe-Gallup Oilfield. --In June 1957, Arizona Exploration Co. completed the Horseshoe Canyon "B" No. 1 well in the SW¼NW¼NW¼ sec. 3, T. 30 N., R. 16 W., San Juan County, New Mexico (Figure 6). The well had an initial potential pumping of 120 barrels per day of 42 gravity API oil from a depth of 1,610-1,654 feet (491-504 m). Subsequent development wells had initial productions ranging from less than 50 barrels per day to over 3,000 barrels of oil per day. The producing area, including the unitized area, extends both northwest and south southeast from the Ute Mountain Indian Reservation. Records of the New Mexico Oil and Gas Engineering Committee list 169 pumping wells, 101 water injection wells, and 89 shut-in or temporarily abandoned wells in the entire field. Production from the 47 wells on the reservation (45 in the unit and 2 outside) totaled 64,682 barrels of oil in 1974 and cumulative production to the end of 1974 was 1,969,156 barrels (N. Mex. Oil and Gas Eng. Comm., 1975, p. 13-17). The field has pipeline outlets to both the Texas-New Mexico Pipe Line Co. 16-inch (41 cm) line to Jal, N. Mex., and the Four Corners Pipe Line Co. 12 inch (30 cm) line to Bisti, N. Mex.

Verde-Gallup Oil field . --Covering an area roughly 5 miles wide (8 km) and 9 ½ miles long (15 km), the area of the Verde-Gallup field is the largest in the reservation (Figure 7). The field was discovered in October 1955 when the C. M. Carl, Ute No. 1, SW¼ SE¼ SE¼ sec. 14, T. 31 N., R. 15 W., San Juan County, was completed for an initial pumping gage of 190 barrels of oil per day. Production was from about 2,336 feet (712 m). Later wells were completed in the field for initial gages ranging from 5 to 588 barrels per day. By the end of 1974, nearly 200 wells had been drilled in the field, 37 were pumping, and the rest had been abandoned or shut in. Oil production from the field within the reservation in 1974 was 36,194 barrels and cumulative production at year end was 6, 904, 705 barrels (N. Mex. Oil & Gas Eng. Comm., 1975, pp. 33-35).

Barker Dome and Ute Dome Gasfieldsv

The Barker Dome and Ute Dome gas fields both have a history of early (1920s) discovery of gas in the Dakota Sandstone -- but no production owing to lack of market outlets -- followed by later discoveries and production of gas from the Paradox Member of the Hermosa Formation. Both fields are located on anticlinal structures.

Barker Dome Gasfield.--The Barker Dome gas field (Figure 8), was discovered in 1924 by an exploratory well in sec. 32 , T. 32 N., R. 14 W., San Juan County, New Mexico. Although natural gas flowed from the Dakota Sandstone at an estimated rate of 10 million cubic feet (283,000 m^3) per day, there was no market and the well was plugged and abandoned. In March 1945, the Aztec Oil and Gas Co., Barker No. 9, sec. 21, T. 32 N., R. 14 W., was successfully completed in Pennsylvanian rocks for an initial potential of 42 million cubic feet (1,189,000 m) of gas per day (R.M.A.G., 1962, pp. 36-39).

The gas trap is an anticlinal structure with a water drive. Productive zones are the Dakota Sandstone and the Paradox and Pinkerton Trail Members of the Hermosa Formation. The Dakota produced 7 billion cubic feet of gas before depletion in 1947. It was used temporarily for gas storage but reportedly is again producing Dakota gas (Matheny, p. 47). Cumulative production from the Pennsylvanian as of January 1, 1975 was 187,669,719 thousand cubic feet (5,314 million m3) of gas and 78,623 barrels of oil (Colo. Oil and Gas Comm., p. 39; N. Mex. Oil and Gas Eng. Comm., 1975, p. 140).

Original recoverable gas reserves were estimated to be 315 billion cubic feet (R.M.A.G., p. 37). On that basis, remaining reserves as of January 1, 1975 were 127 billion cubic feet (3.6 billion m).

Ute Dome Gasfield.--Situated on a small anticline just south of Barker Dome in secs. 25, 34-36, T. 32 N., R. 14 W., and secs. 1-3, 10, 11, T. 31 N., R. 14 W., the Ute Dome field was discovered in 1921 when gas was found in the Dakota Sandstone. Because of lack of market outlets, little or no activity occurred until after World War II. In 1948, gas was discovered in the deeper Paradox Member when a well in the NE¼ SE¼ sec. 36, T. 32 N., R. 14 W., was completed flowing 13.1 million cubic feet (370,954 m) of gas per day from about 8,300 feet (2,530 m). Subsequent wells drilled in the field had completion gages as high as 28.9 million cubic feet (818,360 m3).

In 1974, 13 wells produced 875.2 million cubic feet (24.8 million m3) of gas and 31,735 barrels of oil from the Dakota Sandstone (N. Mex. Oil & Gas Eng. Comm., 1974, pp. 160-161). Cumulative production from the Dakota was 5,668 billion cubic feet (160 million m) of gas and 65,367 barrels of oil.

In the same year, the New Mexico Oil and Gas Engineering Committee (p. 161) reported seven wells produced 4.1 billion cubic feet (116 million m) of gas, from the Paradox and had cumulative production, at yearned, of 36.6 billion cubic feet (1.04 billion m).

Resource Potentialv

On the basis of past exploration and production, the main potential for future discoveries of oil and gas in the reservation would be in stratigraphic traps in the Paradox Member of the Hermosa Formation, or structural traps in the Gallup Sandstone. Resources in "stray" sandstones in the Mancos Shale are probably too small to justify the amount of systematic exploration required to discover them.

The known oil and gas fields in the Paradox are in stratigraphic traps consisting of porous limestones that originated as algal reefs and oolite banks. The Paradox underlies the entire reservation in the subsurface (except where it is penetrated by stocks and dikes in the Ute Mountains), and productive zones are known to occur both at the west edge of the reservation (Cache-Towaoc group of fields) and a short distance east of the reservation (Alkali Gulch gas field). According to the available drilling information, the intervening area north of T. 32 N. and east of R. 19 W. has very few holes to the depth of the Paradox. The potential for discovery in this area of one or more fields comparable in size to the Marble Wash or Cache fields would seem t:o be strong enough to justify an exploration program of at least one or two deep holes in each township, except close to the Ute Mountains stocks. An added incentive to such a program would be the potential for carbon dioxide gas from the Leadville Limestone (Mississippian) such as that now being exploited in the McElmo Dome area.

The Gallup Sandstone probably does not extend as a continuous unit very far north of the New Mexico-Colorado line (see Molenaar, 1973), and it seems likely that the potential of the Gallup on the reservation has already been adequately tested.

Coalv

The coal resources of the reservation occur in the Dakota, Menefee, and Fruitland Formations of Upper Cretaceous age. As the coal beds were originally deposited as integral members of the stratigraphic sequence, their general distribution and structure are covered in the section on "Geology", and no separate discussion of geologic controls is necessary. Two recent studies of coal resources and reserves in the Ute Mountain and Southern Ute reservations have been made (Shomaker and Holt, 1973; and Speltz, 1975). This discussion is based largely on those studies.

The Dakota Formation crops out in the western and northwestern part of the reservation and is assumed to underlie the entire reservation. The coalbeds are generally thin and lenticular. Shomaker and Holt (p. 4) give an average bed thickness of 3 feet (0.9 m) in the drill hole logs they examined and 7.1 feet (2.2 m) as the average total coal thickness. They estimate 2.4 billion tons (2.2 billion t) of Dakota coal at depths of 1,000 feet (305 m) or less under 300 square miles (77,760 ha) and an additional 4.9 billion tons (4.4 billion t) at depths greater than 1,000 feet (305 m).

Speltz (p. 28), in discussing the entire Dakota coal basin in west-central and southwestern Colorado, describes the Dakota coal as being ". . . of low quality usually high-volatile B or C bituminous in rank . . . (with) a large percentage of impurities such as shale partings, sand, and bone." A mean of 17 coal analyses (Table 4) shows: moisture 5.4 percent, volatile matter 33.5 percent, fixed carbon 56.3 percent, ash 10 percent, and sulfur 0.7 percent; heating value was 12,390 Btu per pound. The low quality, thinness, and lenticularity of these coals make them economically unattractive under present conditions.

TABLE 4.

Average coal analyses in southwestern Colorado.

Formation	Moisture, percent	Volatile matter, percent	Fixed carbon, percent	Ash, percent	Sulfur, percent	Heating value, Btu, lb
Dakota	5.4	33.5	56.3	10.0	0.7	12,390
Menefee	3.9	39.7	52.7	7.5	1.5	13,120
Fruitland	5.4	36.8	49.0	8.8	.9	12,660

Source: Speltz, C. N., Strippable Coal Resources of Colorado: Bur. Mines IC (pending publication).

The Menefee Formation (Cretaceous) has a coal-bearing zone in the upper 200 to 400 feet (61 - 122 m) and another in the lower part of the formation. The formation is present throughout the eastern part of the reservation. The formation is widely exposed along the walls of the many canyons in the area. Shomaker and Holt (p. 4-5), estimate 10.8 million tons (9.8 million t) of coal are recoverable at auger depths of 200 feet (61 m). They estimate in their table 7, total reserves of 3.6 billion tons (3.3 billion t) at depths between 250 and 500 feet, (76 and 152 m); 109 million (98.0 million t) between 500 and 1,000 feet (152 and 305 m); and 294 million (267 million t) between 2,000 and 3,000 feet (610 and 915 m). Under present marketing conditions only the coal recoverable by auger drilling is considered economically available.

Speltz (p. 33) gives a mean of 270 samples of "as received" Menefee coal from La Plata County: Moisture 3.9 percent, volatile matter 39.7 percent, fixed carbon 52.7 percent, ash 7.5 percent, and sulfur 1.5 percent; heating value was 13,120 Btu's per pound. The coal is described as high-volatile A, B, or C bituminous in rank.

Coal of the Fruitland Formation (Cretaceous) is present only in the southeast quarter of T. 31 N., R. 15 W., and in the southern and eastern parts of T. 31 N., R. 14 W., San Juan County, New Mexico. Strippable coal is present in a relatively narrow band along the outcrop. Shomaker and Holt (pp. 6-7) estimated 14. 4 million tons (13.1 million t) of coal are available at stripping depths of 120 feet (36. 6 m) or less in T. 31 N., R. 15 W., in beds ranging in thickness from 3. 5 feet (1.1 m) in a single bed to 20. 5 feet (6. 25 m) in combined thickness. In the same area, reserves of 9 million tons (8.2 million t) are estimated to depths of 250 feet (76 m). In the rest of the area, Shomaker and Holt estimate 16.2 million tons (14.7 million t) at 250 feet (76 m) or less. At depths of 500 to 1,000 feet (152 to 305 m) they estimate 203 million tons (184 million t) of reserves and from 2, 000 to 3, 000 feet (610 to 915 m), an additional 24 million tons (21. 8 million t).

Speltz (p. 33) describes the Fruitland coal in southern Colorado as high-volatile A or B bituminous and gives a typical analysis: Moisture 5.4 percent, volatile matter 36.8 percent, fixed carbon 49.0 percent, ash 8.8 percent, and sulfur 0. 9 percent ; heating value was 12, 660 Btu ' s per pound.

An earlier study (Wanek, 1959) gave measured and indicated and inferred reserves by township for the eastern part of the reservation. His estimate (table 6, p. 713) for recoverable coal at depths less than 1,000 feet (305 m) for all categories and formations was 1.4 billion tons (1. 3 billion t).

Uraniumv

Uranium deposits have been found north, west, and south of the reservation but there is no recorded production from the reservation itself. Nearest uranium prospects are those reported just north of the Sleeping Ute Mountains along McElmo Creek. Four of the prospects appear to be concentrations along a series of northeast-trending faults; three are associated with the Entrada Formation (Jurassic) and one with the Navajo Sandstone (Jurassic-Triassic). Two of the prospects are bedded deposits. At the Karla Kay mine. sec. 32, T. 36 N., R. 18 W., the radioactivity occurs in a sandstone and mudstone conglomerate in the Burro Canyon Formation. Chemical analyses indicate 0.012 to 0.019 percent uranium oxide (U308) and radiometric analyses indicates a range (four samples) from less than 0.001 to 0.016 percent equivalent uranium oxide. There has been no production from the occurrence. At the Coffin prospect, sec. 34 , T. 36 N., R. 18 W., the radioactivity is in the Entrada Sandstone. Assays showed 0.09 percent uranium oxide and 1.0 percent vanadium oxide (V205) (Ekren and Houser, 1965, p. 66).

Early in January 1976, the Ute Mountain tribal council entered into a lease contract with Mobil

Oil Corp. for the purpose of exploration and, if successful, the possible underground mining of uranium ore and associated minerals (Rogers, 1976). The proposal, as described in Bureau of Indian Affairs, FES 75-94, covers an area of 162,176 acres (65,681 ha) in the southwestern part of the reservation west of U. S. Highway 160-666 and south of the Sleeping Ute Mountains. The exploration phase would extend over approximately 4 years. Starting with 65 holes on 2-mile (3.22 km) centers, the operator would attempt to find and delineate--with more closely-spaced drilling--a minable uranium ore body; the target would be the Westwater Canyon Member of the Morrison Formation. After an apparent economic ore body(ies) is found, a mining and processing plan would be prepared with the assistance of the Bureau of Indian Affairs and the Geological Survey.

METALLIC MINERAL RESOURCESv

Generalv

No metallic mineral resources have been developed on the reservation. However, there are known titanium bearing sandstones and copper prospects.

Titaniumv

The occurrence of sandstones containing titanium in the San Juan Basin was reported at the 8th Annual Field Conference of the New Mexico Geological Society in 1957 (Chenoweth, 1957). A detailed study was made by the U. S. Bureau of Mines (Dow and Batty, 1961) which describes approximately 50 occurrences along the western side of Mesa Verde; all but six are on the Ute Mountain Indian Reservation. Seven of the deposits are in secs. 1, 2, 11, and 12 of unsurveyed T. 33 N., R. 17 W., south of Cortez; one is in sec. 28 of unsurveyed T. 33 N., R. 16 W.; four are in secs. 15 and 22-24 of unsurveyed T. 32 N., R. 17 W.; and the rest are in Tps. 31-32 N., Rs. 15-16 W., San Juan County. Dow and Batty (1961, table 8, p. 44) report the weighted average content of the deposits as 2.78 percent titanium oxide (TiO2); 0.42 percent zirconium oxide (ZrO2); 12.76 percent iron; and 0.03 percent equivalent thorium oxide (eThO2). The titanium is found largely in three minerals ilmenite, anatase, and leucoxene.Total tonnage of all deposits is estimated to be at 693,000 tons (628,871 t) of titaniferous sandstones.

The deposits are actually in the Menefee Formation but, because of their resistance to erosion, they occur as remnants on the massive white sandstone of the underlying Point Lookout Formation (Dow and Batty, 1961, p. 40). No reference to placer deposits of titanium minerals on the reservation are known. Because of the small size of the individual deposits, it is unlikely that these resources will be economically usable in the future.

Major use of titanium is in the form of titanium dioxide (TiO2) for white pigment in paints, papers, and plastics. The metal is valuable for its lightweight and corrosion resistant properties. Use of the metal is expected to expand.

Copperv

The igneous intrusions of the Sleeping Ute Mountain complex offer the only possibility for the significant occurrence of metallic minerals. Ekren and Houser (1965, p. 66-67) describe three copper prospects in the central and northern part of the Sleeping Ute Mountains. The Little Maude mine, sec. 14, T. 35 N., R. 18 W., is in the south face of Mabel Mountain in ".. . baked and sheared limy mudstone of the Mancos shale. .." The mineralization follows a northeast-trending shear zone that is probably an extension of the Ute Creek dike.

On the north side of the mountains, the Ute Creek dike shows mineralization derived from hydrothermal solutions related to the igneous activity of the Sleeping Ute Mountains. Several prospect pits have been dug along the dike and show sparse copper oxidation.

North of the reservation, along McElmo Creek in sec. 34, T. 36 N., R. 18 W., the Battle Rock mine is in a mineralized shear zone striking N. 75 W. Some copper carbonates are present along with limonite and hematite (iron oxides).

Resource Potentialv

Although these prospects offer little commercial promise, they are important because the presence of copper minerals, in association with the igneous stocks of the Ute Mountains, is at least suggestive of the possibility of significant "porphyry copper" mineralization. The bulk of the known copper resources of the United States (and in fact the Western Hemisphere) is in deposits of this type, in which copper minerals are sparsely disseminated in and adjacent to stocks of granitic porphyries (Cox and others, 1973; Lowell and Guilbert, 1970), The Ute Mountains stocks, especially those of Black Mountain and "The Knees", have several features that are suggestive, but not diagnostic of a potential for disseminated copper mineralization of the porphyry type--their dimensions, composition, geologic setting, and age are similar to those of the "typical" copper porphyry described by Lowe and Guilbert, and many of the stock rocks contain alteration products typical of the outermost propylitic alteration zone of the copper porphyries (Ekren and Houser, 1965, p. 30-32). It is recommended that this potential be given at least a preliminary testing through geochemical and petrographic studies of the Black Mountain and "The Knees" stocks. Such studies would involve systematic detailed sampling of the outcrops to provide samples for (1) determination of the presence of pyrite or other sulfides, or "leakage haloes" containing copper or related elements, and (2) petrographic study to determine any significant zoning patterns in the hydrothermal alteration products. These preliminary studies would neither confirm nor deny the presence of exploitable ore, but positive results from the geochemical study would indicate that physical exploration (drilling) should be considered. The propylitic alteration products described by Ekren and Houser are associated with the outermost zone of alteration that typically surrounds copper porphyries, so that if copper ore is present it is probably at a depth of at least several hundred feet and perhaps as much as 2000 3000 feet. The final confirmation of the presence of ore could come only from drilling; the purpose of the preliminary studies suggested here would be only to help decide whether drilling is warranted, and if so, to find the best location for an exploratory hole.

NONMETALLIC MINERAL RESOURCESv

Generalv

Sand and gravel and stone are the only known nonmetallic mineral resources on the reservation. Only sand and gravel have been produced; stone resources are not developed.

Sand and Gravelv

Deposits of sand and gravel are widespread and abundant on the reservation. Supplies are much in excess of local needs. Several pits on the reservation are: a large one northeast of Towaoc in sec. 8, T. 33 ½ N., R. 17 W.; a large pit at Soda Point on the east side of Chapin Mesa about 2.5 miles (4 km) south of Mesa Verde National Park in about the NE ¼ of section 10 in unsurveyed T. 33 N., R. 15 W.; and two small ones along U. S. Highway 160 in sec. 22, T. 32 N., R. 20 W. Records of production are incomplete for use of sand and gravel for road maintenance and other needs on the reservation Use during a normal year may average about 50,000 cubic yards (38,000 m3). but in years when major road projects are underway, consumption is much higher. Price of pit-run sand and gravel is about $0.25/ton ($0.23/t).

Stonev

Although there are no stone quarries on or near the reservation, it is possible that suitable building stone may be found in the Point Lookout and Cliff House sandstone beds and in the igneous rocks of Sleeping Ute Mountain.

ECONOMIC DEVELOPMENT OF MINERAL RESOURCES

MINERAL LEASINGv

Leasing of minerals on Ute Mountain Indian Reservation is controlled by the provisions of the Omnibus Mineral Leasing Act of 1938, 25 USC Sections 396a-f (American Law of Mining, Sec. 2.31) with implementing regulations in 25CFR part 171. The U. S. Supreme Court has ruled that legal title to Indian lands is owned by the United States Government but its control of the lands is limited by its established trust responsibilities to act in the best interests of the Indians (FTC, Bur. of Competition, pp. 4-5).

Regulations governing mineral leasing on Indian lands allow considerable flexibility in determining specific terms and procedures, and permits the tribal governments to make changes in the general provisions that best serve the tribes' needs (FTC, Bur. of Competition, p. 40 et seq.). The following general provisions, from R. M. Min. Law Found., American Law of Mining provide a base on which specific lease terms may be established.

Leases may be made by the Ute Mountain

Tribal Council, with approval by the Secretary of the Interior or his authorized representative. Lease terms are for 10 years and as long thereafter as minerals are produced in paying quantities. Oil and gas leases must be offered for sale at a public auction or upon sealed bids but leases for other minerals may be negotiated and approved without public notice and sale.

The acreage of a single lease may not exceed 2,560 acres (1,036.8 ha) for all minerals except coal in which case larger areas may be approved by the Commissioner of Indian Affairs if in the interest of the tribe and necessary for a particular purpose. Annual lease rentals are $1.25 per acre for oil and gas leases and not less than $1. 00 per acre plus annual development expenditures of not less than $10. 00 per acre for other minerals.

Royalties on mineral production vary according to the mineral involved. For most minerals, the minimum royalty is 10 percent of the value of the mineral at the nearest shipping point. Royalties for oil and gas and natural gas liquids may not be less than 16. 67 percent (FTC, Bur. of Competition, p. 70). For gold and silver, the royalty is not less than 10 percent of the value of bullion shown by mint returns, less shipping charges to point of sale. Royalties on copper, lead, zinc, and tungsten are not less than 10 percent of the value of ores and concentrates after reduction, less shipping charges to point of sale. Coal royalty is not less than 10 cents per ton of mine run coal. The royalty on asphaltum and allied substances may not be less than 10 cents per ton of raw material nor less than 60 cents per ton of refined products.

Prospecting permits may be issued by the Superintendent with the consent of the tribal council.

Leasing of allotted lands is governed by the Indian Appropriation Act of 1909, 35 Stat. 783 (1909), 69 Stat. 540 (1955), 25 U. S.C. Sect. 396 (1958), and the regulations are spelled out in 25CFR Sect. 172. 1 to 172. 33.

MINERAL MARKETSv

The local market for mineral commodities probably is limited to sand and gravel and stone. Stone on the reservation would consist of sandstone and, perhaps, limited quantities of igneous rock from the intrusives of the Sleeping Ute Mountain.

For most of the mineral resources on the reservation, the national market would be the ultimate potential outlet. Petroleum and natural gas, coal, uranium, and copper require complex processing plants; the plants, in turn, require sufficient supplies of crude material to assure a steady, constant, and longtime flow through the processing system.

The reservation is handicapped in that rail transportation for high-bulk, low-value crude material is not readily available. The nearest rail outlet is the Denver & Rio Grande Western Railroad (D&RGW) at Ridgway, Colorado, 106 miles (171 km) northeast of Cortez across the San Juan Mountains; from Ridgway, it is an additional 47 miles (76 km) north to the D&RGW mainline at Delta, Colorado. To the south, the mainline of the Atchinson, Topeka & Santa Fe Railroad (AT&SF)

is at Gallup, New Mexico, 136 road miles (219 km) from Cortez.

Crude oil, natural gas, and natural gas liquids are moved to markets by pipeline. Crude oil from the northwestern part of the reservation goes into the Texas-New Mexico Pipe Line Co. 16-inch (41 cm) pipeline to Jal, in southeastern New Mexico and that from the southeastern part goes into either the Texas-New Mexico line or the Four Corners Pipe Line Co. 12-inch (30 cm) pipeline to Bisti, New Mexico. Natural gas is collected by El Paso Natural Gas Co. and Southern Union Gas Co. El Paso moves its gas to the San Juan processing plant west of Farmington for removal of gas liquids.

TOPOGRAPHIC MAP COVERAGE

The entire reservation is covered on U. S. Geological Survey topographic maps. Most of the coverage is at a scale of 1:24,000 (7 ½-minute quadrangles) except for two areas at a scale of 1:62,500 (15-minute quadrangles). One area of small scale mapping is along the extreme western edge of the reservation covered by the Aneth map sheet, published in 1962; the other area is the western side of the New Mexico extension of the reservation and is covered by Chimney Rock quadrangle, published in 1934.

The rest of the reservation is covered by the following 1:24,000 scale maps (the five quadrangles published in 1955 are now being updated):

Colorado quadrangles

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Cortez, 1965
Sentinel Peak, NE, 1955
Cortez, SW, 1955
Sentinel Peak, NW, 1955
Greasewood Canyon, 1966
Sentinel Peak, SE, 1966
Moccasin Mesa, 1967
Sentinel Peak, SW, 1966
Moqui Canyon, 1966
Tanner Mesa, 1966
Moqui, Se, 1955
Towaoc, 1966
Moqui, SW, 1955
Trail Canyon, 1966
Red Horse Gulch, 1966
Wetherill Mesa, 1966
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New Mexico quadrangles

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Heifer Point, 1963
Waterflow, 1963
La Plata, 1963
Youngs Lake, 1963
Purgatory Canyon, 1963
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TABLE 2. OUTCROPPING ROCKS OF THE UTE MOUNTAIN INDIAN RESERVATION

ERA	SYSTEM	SERIES	GROUP	GROUP AND FORMATION
CENOZOIC	QUATERNARY	Pleistocene & Holocene		Alluvium and colluvium
	TERTIARY(?) AND QUATERNARY			Pediment gravels
	TERTIARY	Paleocene		Ojo Alamo Sandstone
	CRETACEOUS OR TERTIARY			Intrusive igneous rocks
MESOZOIC	CRETACEOUS	Upper Cretaceous		Kirtland Shale Fruitland Formation Pictured Cliffs Sandstone Lewis Shale
			Mesaverde Group	Cliff House Sandstone Menefee Formation Point Lookout Sandstone
				Mancos Shale {Gallup Sandstone, Juana Lopez Member} Dakota Sandstone DISCONFORMITY
	? ?	Lower Cretaceous ? ? ? ? ?		Burro Canyon Formation
	JURASSIC	Upper Jurassic		Morrison Formation
			San Rafael Group	Junction Creek Sandstone Summerville Formation Entrada Sandstone UNCONFORMITY
	TRIASSIC(?) AND JURASSIC	Upper Triassic(?) and Jurassic	Glen Canyon Group	Navajo Sandstone

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TABLE 3. Petroleum and natural gas production and royalties from tribal lands, Ute Mountain Indian Reservation.

Year	Petroleum		Natural gas		Natural gas liquids		Total
	Production barrels	Royalty dollars	Production Mcf	Royalty dollars	Production gallons	Royalty dollars	Royalty dollars
1970	324,618.77	$111,650.48	5,375,686	$92,229.83	459,754	$442.68	$204,322.99
1971	285,349.95	90,749.72	4,954,535	90,468.72	730,048	957.64	182,176.08
1972	215,036.27	83,042.15	5,653,037	98,899.61	360,119	488.56	182,430.32
1973	203,120.48	107,616.42	5,975,357	158,242.11	138,169	189.99	266,048.52
1974	199,306.15	178,749.44	6,619,292	218,938.55	171,950	343.71	398,031.70

Source: U. S. Geological Survey, Conservation Division, Roswell, N. Mex.

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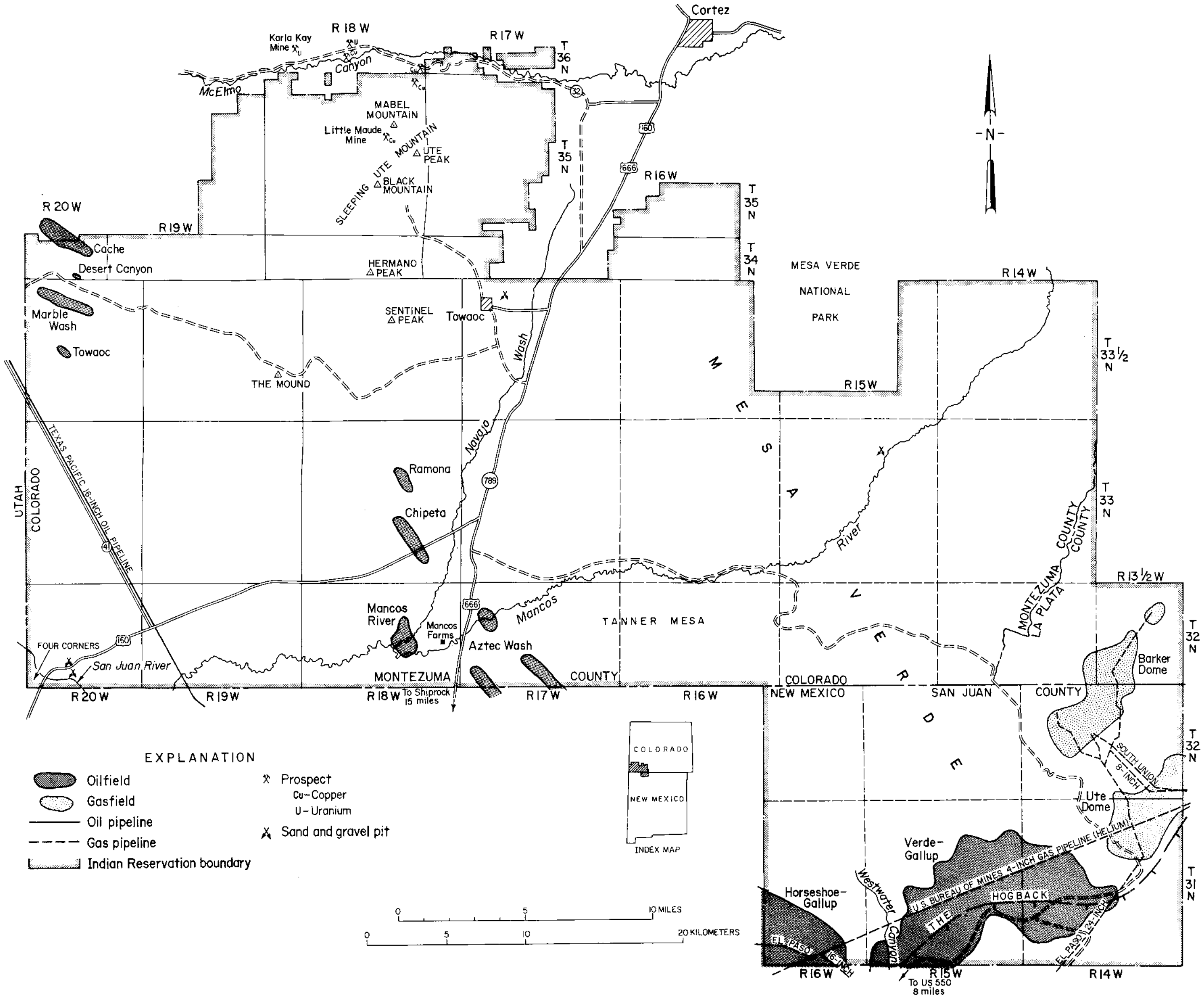

Figure 1. Geographic map of the Ute Mountain Indian Reservation

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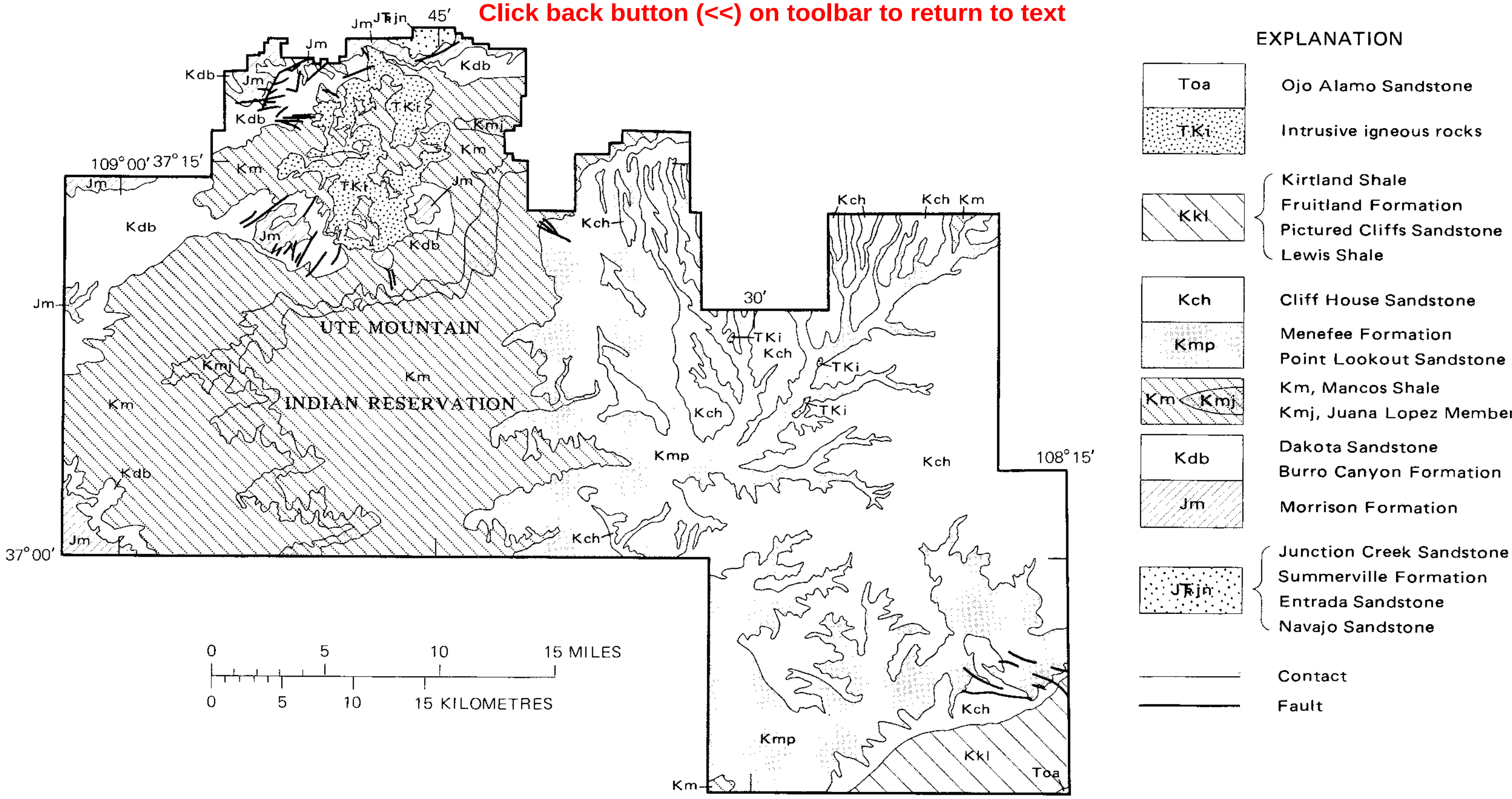

Figure 2. Geological map of the Ute Mountain Indian Reservation

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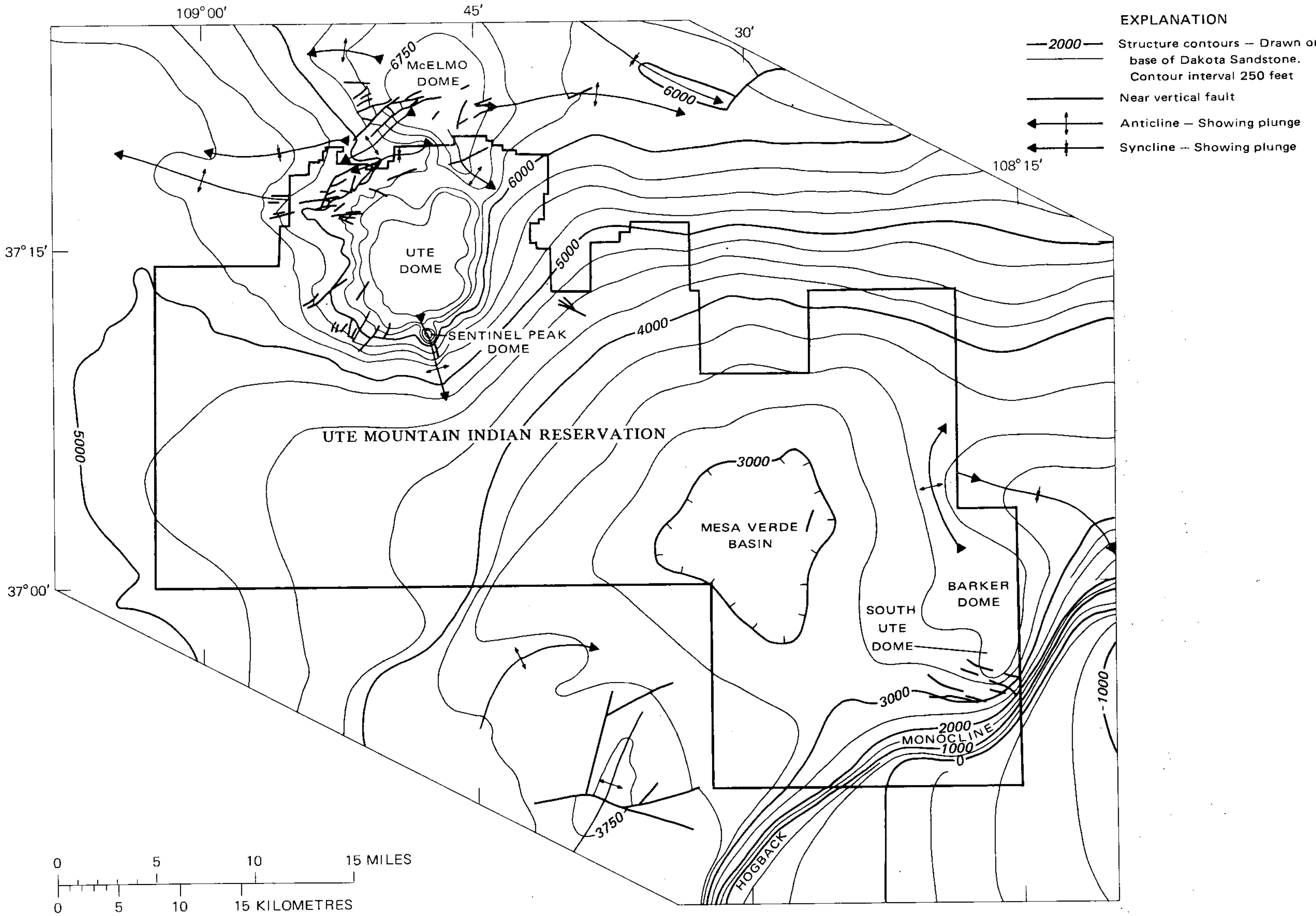

Figure 3. Tectonic map of the Ute Mountain Indian Reservation

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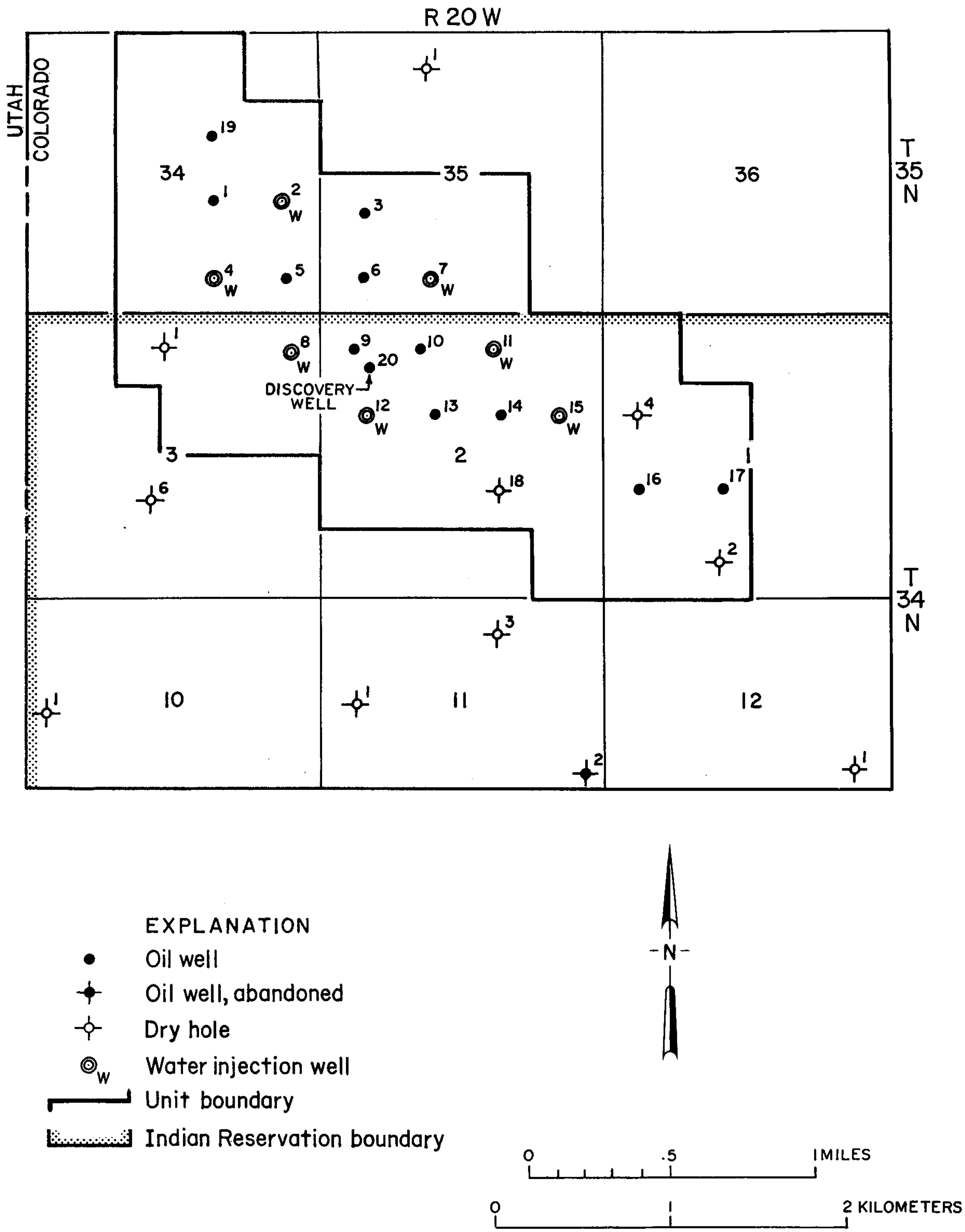

Figure 4. Map showing Cache Oilfield, Montezuma County, Colo. (adapted from U.S. Geol. Survey Cons. Div. Map No. Roswell 99)

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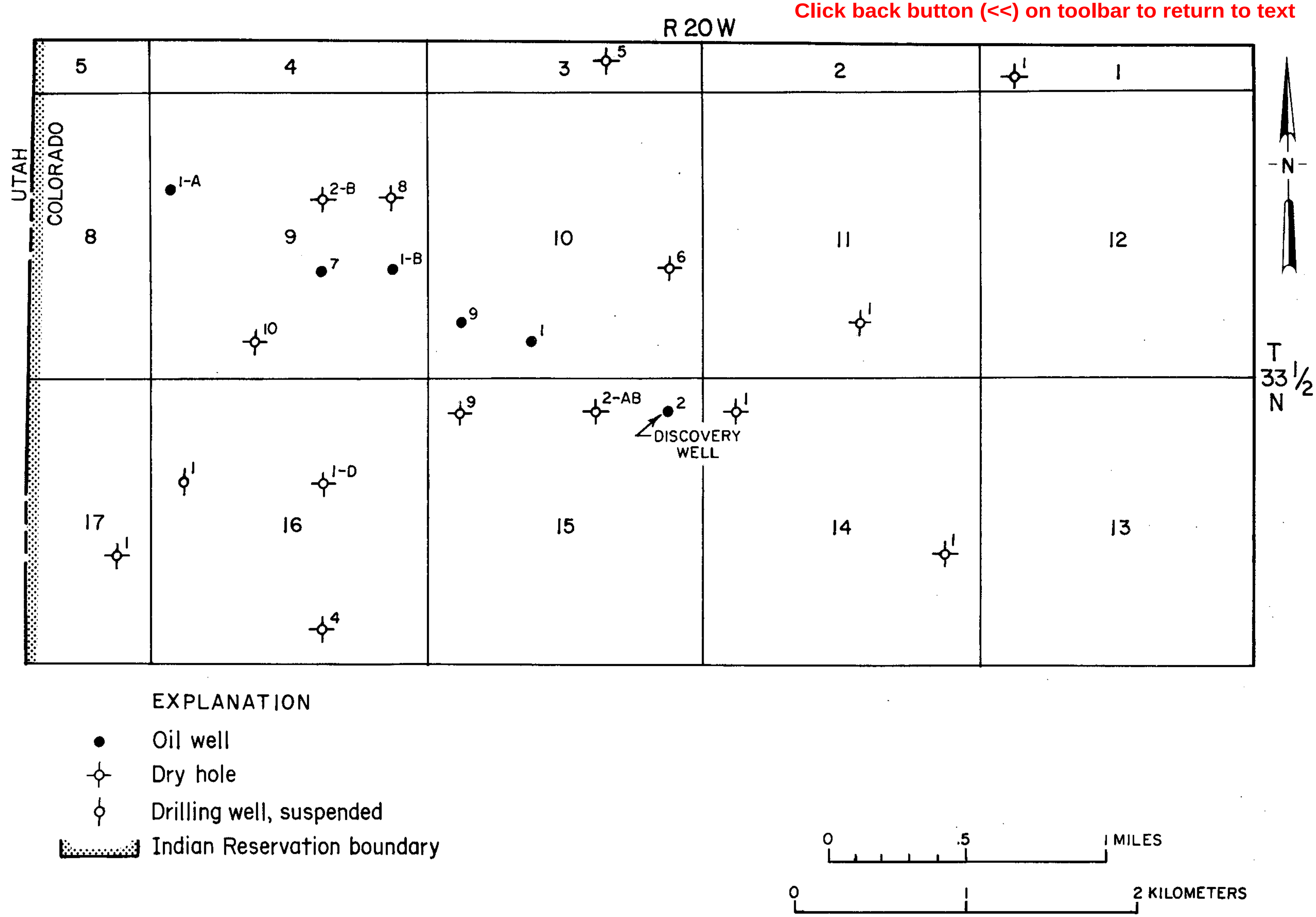

Figure 5. Map showing Marble Wash Oilfield, Montezuma County, Colo. (adapted from U.S. Geol. Survey Cons. Div. Map No. Roswell 98)

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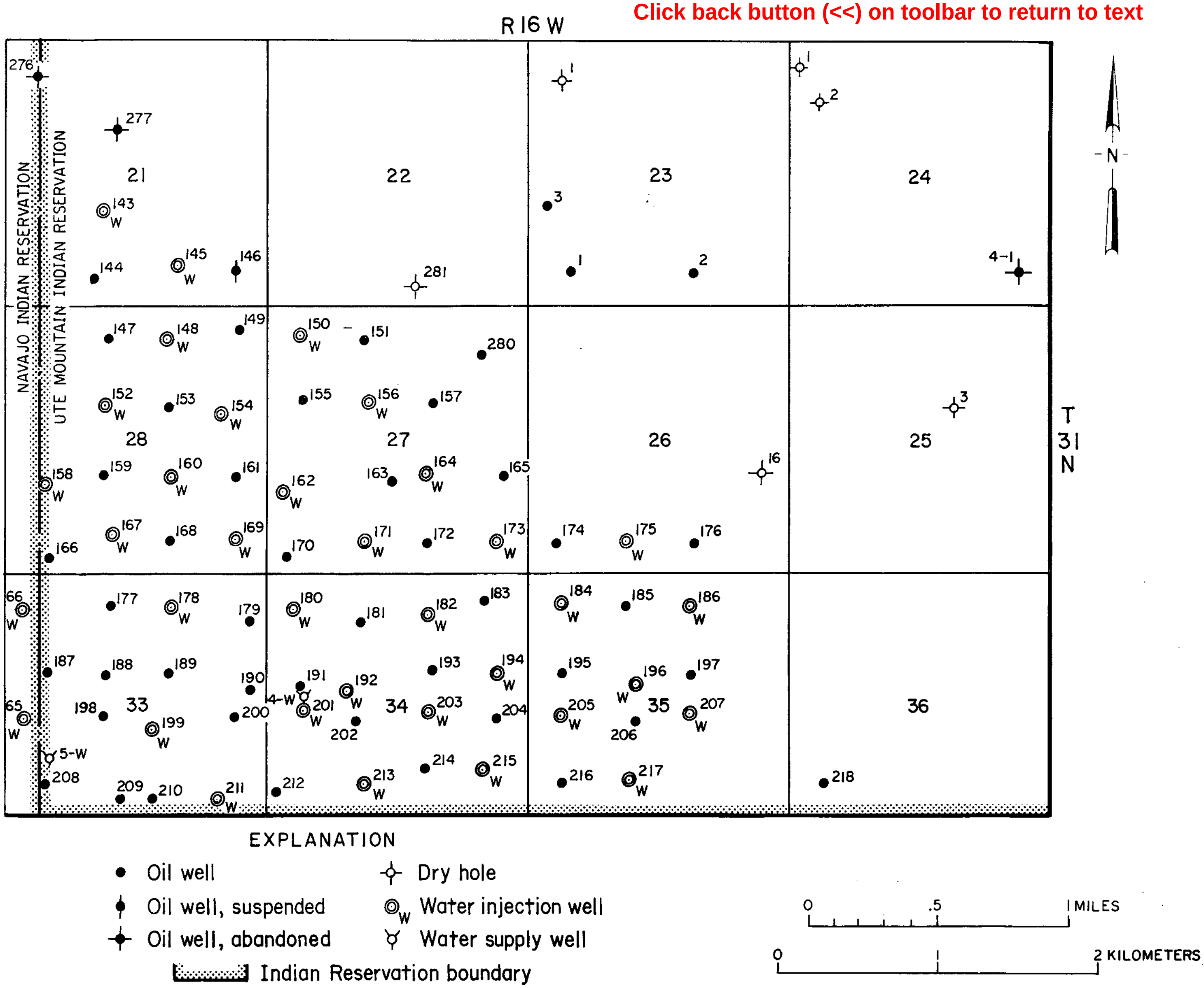

Figure 6. Map showing Horshoe-Gallup Oilfield, Ute Mountain Indian Reservation, San Juan County, N. Mex. (showing only the area inside the reservation) (adapted from U.S. Geol. Survey Cons. Div. Map No. Roswell 89)

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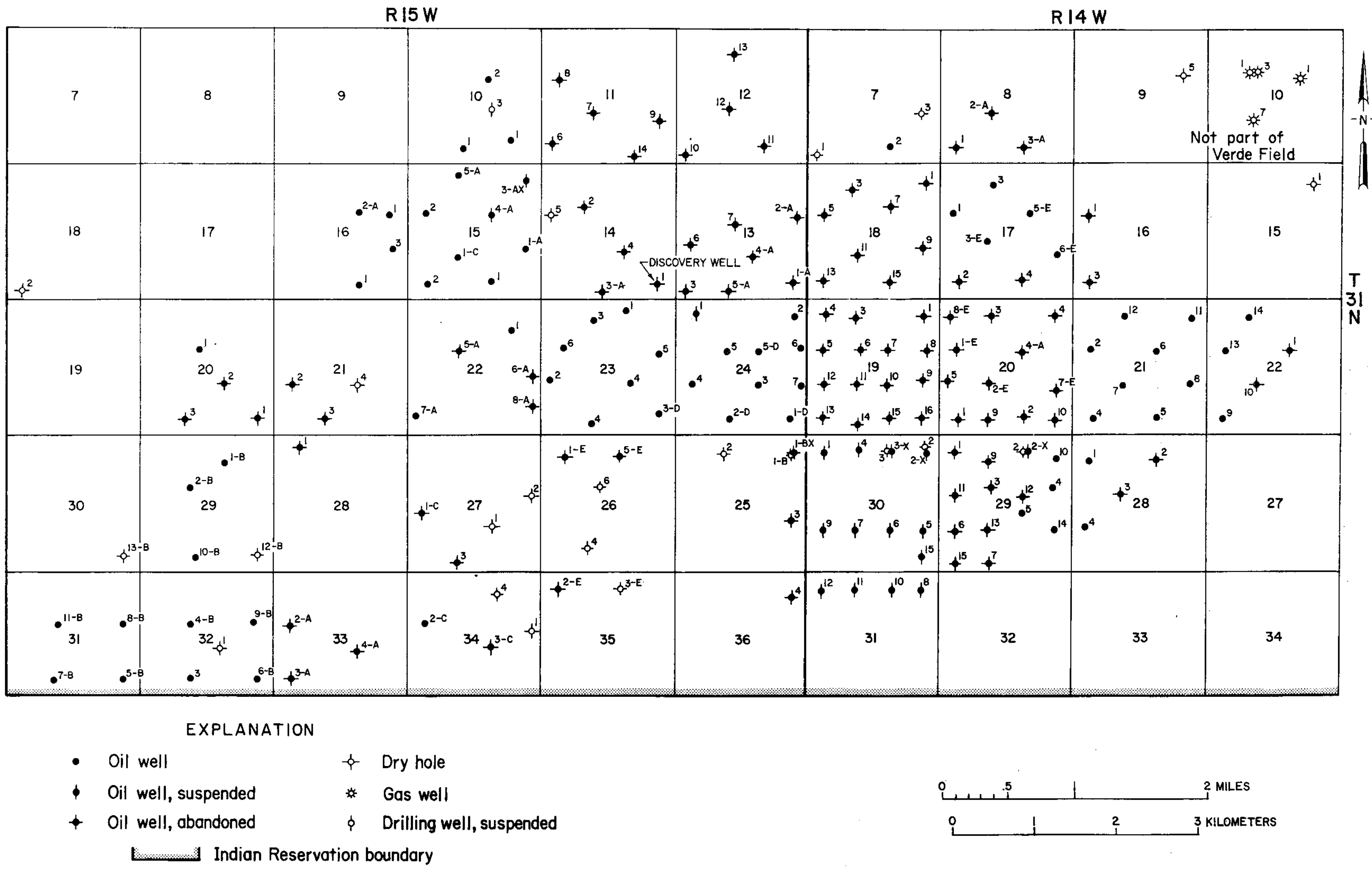

Figure 7. Map showing Verde-Gallup Oilfield, Ute Mountain Indian Reservation, San Juan County, N. Mex. (adapted from U.S. Geol. Survey Cons. Div. Map Nos. Roswell 89-90)

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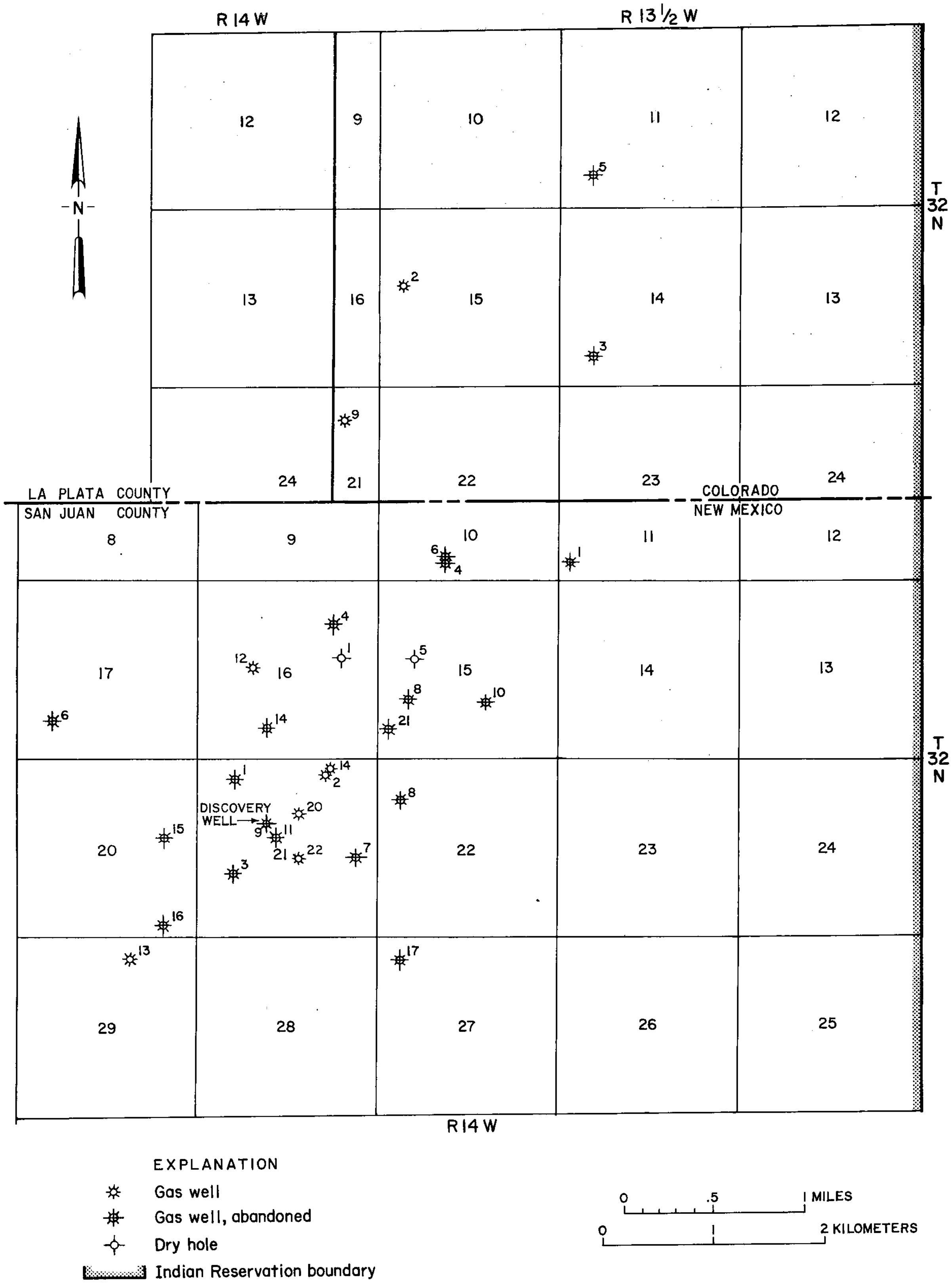

Figure 8. Map showing Barker Dome Gasfield, La Plata County, Colo., and San Juan County, N. Mex. (adapted from U.S. Geol. Survey Cons. Div. Map No. Roswell 90)