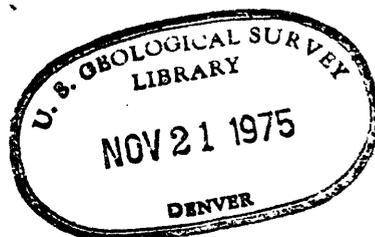


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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico



INTERPRETATION OF GEOLOGIC AND HYDROLOGIC DATA FROM THE
RAY-1 WELL, CITY OF GALLUP, MCKINLEY COUNTY, NEW MEXICO

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New Mexico State Engineer

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By

William L. Hiss and Jane G. Marshall

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INTERPRETATION OF GEOLOGIC AND HYDROLOGIC DATA FROM THE
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ABSTRACT

The Ray-1 well was to be the third production well completed in the city of Gallup Yah-ta-hey well field located about 7 miles (11 km) north of the city. The first string of casing collapsed during completion, however, and the well was abandoned before it could be tested. The lithology of the Upper Cretaceous Dalton Sandstone and Dilco Coal Members of the Crevasse Canyon Formation and the Gallup Sandstone was interpreted from geophysical logs and examination of the drill cuttings. These units appear to be similar to correlative strata encountered in the first two wells. A yield of approximately 700 gallons per minute (44 l/s), similar to the other wells in the Yah-ta-hey well field, is anticipated from the same aquifers when the Ray-1 replacement well is completed.

INTRODUCTION

Purpose and scope of the report

The city of Gallup, with the assistance of the New Mexico State Engineer and the U.S. Geological Survey, formulated long-range plans in 1967 to locate and develop ground-water supplies adequate for the future growth of the city.

An orderly expansion of the Yah-ta-hey well field located about 7 miles (11 km) north of the city of Gallup has been planned. The Ray-1 well was to be the third production well drilled in the well field. The U.S. Geological Survey, in cooperation with the New Mexico State Engineer, provided technical assistance during the final stages of drilling and later during the evaluation of data for the Ray-1 well. The formations penetrated during drilling were determined. Borehole geophysical logs were correlated and evaluated. The drill cuttings were examined and described. The first string of casing collapsed during completion, however, and the well was abandoned. Descriptions of the stratigraphic section penetrated and interpretations of the data collected during the drilling and logging of this well are made available in this report.

Previous related studies

The area between Gallup and Tohatchi was studied by the U.S. Geological Survey from 1967 through 1969 as part of the long-range plan to locate and develop additional ground water for the city of Gallup. The Muñoz-1 well, NE $\frac{1}{4}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T.16 N., R.18 W., was then drilled by the city of Gallup to evaluate several potentially productive aquifers. The Muñoz-1 well was abandoned after drilling equipment was lost in the uncased hole. Subsequently, the Muñoz-1-A production well was drilled and completed in 1969 approximately 250 feet (76 m) west of the Muñoz-1 well in the same section (fig. 1). The geology of the Gallup-Tohatchi area and the drilling and testing of the Muñoz-1 and Muñoz-1-A wells have been described by Mercer and Cooper (1970). The Erwin-1 well, SW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 7, T.16 N., R.18 W., the second production well in the Yah-ta-hey well field, was drilled in 1970. Mercer and Lappala (1972) have described the drilling and testing of this well.

Acknowledgment

Mr. Richard A. Allgood of Allgood, Sterling and Mataya, Engineers and Surveyors, Gallup, N. Mex., designed and then supervised drilling and construction of the Ray-1 well. The authors express appreciation to Mr. Allgood for his fine cooperation.

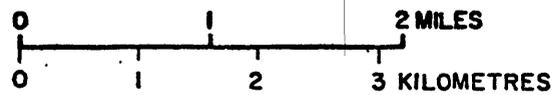
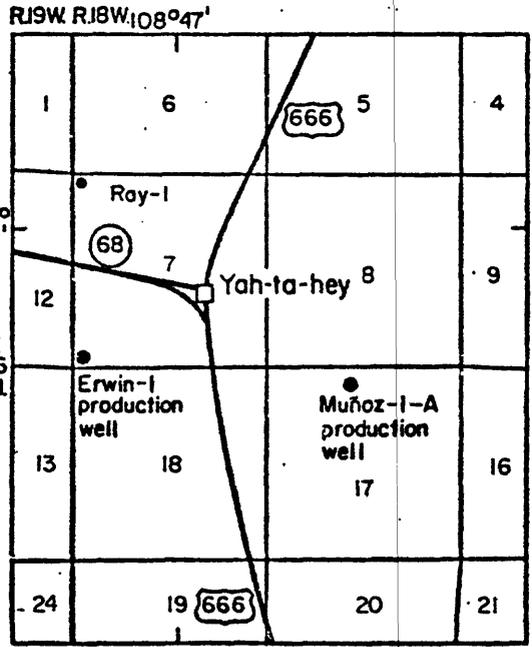
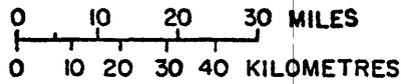
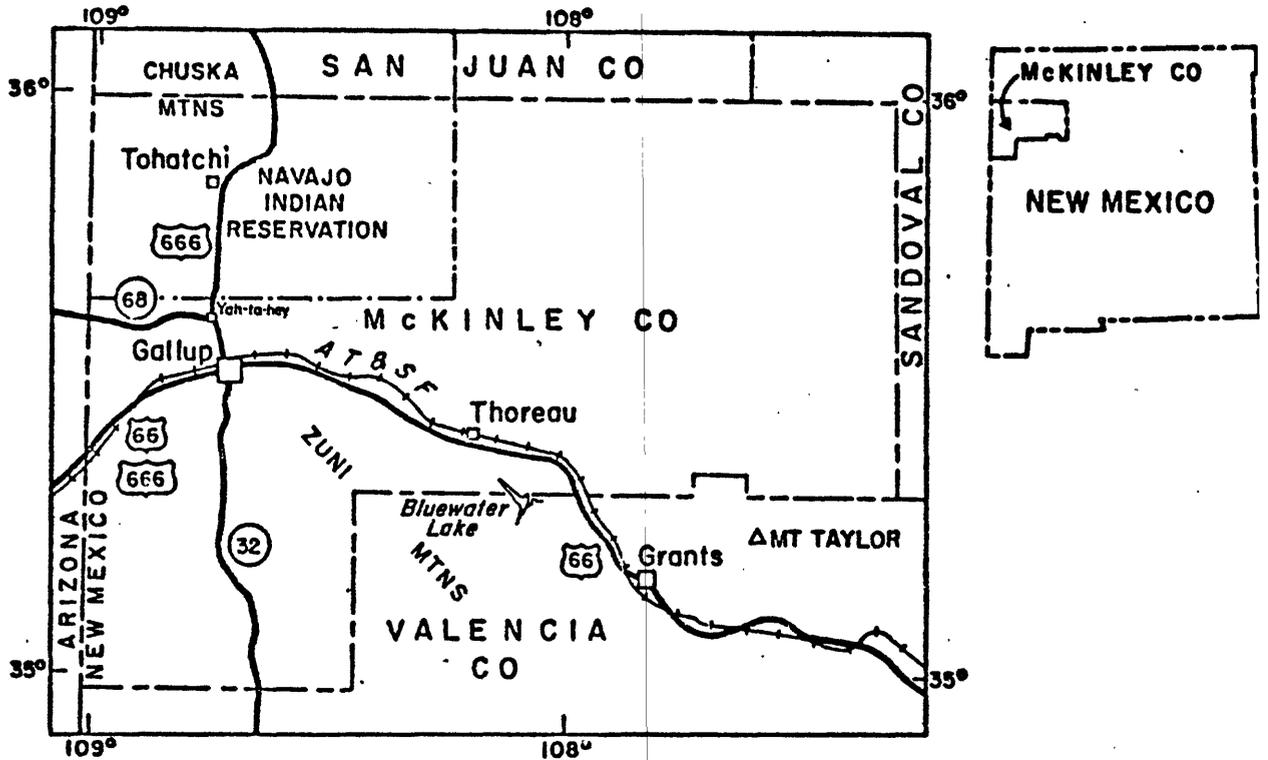


Figure 1.--Index maps showing location of Yah-ta-hey and city of Gallup well field.

RAY-1 WELL

Location of well site

The Ray-1 well is located in the NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 7, T.16 N., R.18 W., McKinley County, New Mexico (fig. 1). The exact position of the well is 100 feet (30 m) from both the north and west boundary lines of section 7. The Ray-1 well is located approximately 5,000 feet (1,524 m) due north and 9,000 feet (2,743 m) northwest of the Erwin-1 and Muñoz-1-A production wells, respectively, in the city of Gallup Yah-ta-hey well field.

Physiography

The Ray-1 well site is on the edge of a small cuesta at an altitude of 6,612 feet (2,015 m) above mean sea level. The sparsely vegetated, drab landscape is composed of alternating cuesta ridges and strike valleys eroded into Upper Cretaceous sedimentary rocks. The ridges are generally underlain by resistant sandstones, whereas the valleys are eroded into the soft shales, mudstones, coals, and siltstones that are interbedded with the thinner but more resistant sandstones. Local relief is generally less than 100 feet (30 m).

Local structure

The Ray-1 and Erwin-1 wells were drilled on the west flank, but very near the axis, of the Gallup sag (Kelley, 1967; and Mercer and Cooper, 1970, fig. 7). This northward-plunging syncline passes through T.15 N., R.18 W. west of the city of Gallup and is sub-parallel to State Highway 666 as far north as Tohatchi (Mercer and Cooper, 1970, fig. 7). The structural relief on top of the Gallup Sandstone is approximately 1,000 feet (305 m) between the latitudes of Gallup and Tohatchi, a distance of about 21 miles (34 km).

Well history

The Ray-1 well was spudded in on August 29, 1974, by Plains Drilling Company, Lyncan, Colo. The total depth of 2,142 feet (653 m) recorded by the driller was reached on September 20, 1974 (fig. 2). Borehole geophysical logs, including compensated-formation density, gamma-ray, caliper, dual-induction laterolog, and spontaneous-potential investigations, were run in the 9 7/8-inch (25 cm) pilot borehole by Schlumberger Well Services on September 21, 1974. The total depth of 2,148 (655 m) recorded by the logging company is slightly greater than the driller's reported total depth of 2,142 feet (653 m) (fig. 3). Well depths measured by Schlumberger Well Services have been chosen arbitrarily as the reference for this report. Other depths have been adjusted accordingly.

Subsequently, the upper 1,248 feet (380 m) of the pilot borehole was enlarged to 24 inches (61 cm) by reaming to accommodate 1,242 feet (379 m) of 16 inch (41 cm) internal diameter casing. The casing string apparently collapsed while it was being cemented into place after it had been run on November 7, 1974. The top of the constriction in the casing was determined to be at a depth of 885 feet (270 m). Attempts were made to salvage the well by swaging the casing. However, the efforts to enlarge the casing to the original internal diameter of 16 inches (41 cm) failed. The Ray-1 well was abandoned on February 1, 1975.

Interpretation of formations penetrated

The Upper Cretaceous Allison Member of the Menefee Formation is exposed at the well site. The well is bottomed in the Mancos Shale which was penetrated at a depth of 2,095 feet (639 m) (fig. 3).

The entire section from nearby wells has been interpreted and described previously by Mercer and Cooper (1970) and Mercer and Lappala (1972). An examination of the borehole geophysical logs suggests that the Allison and Cleary Coal Members of the Menefee Formation, and the Gibson Coal Member and the Bartlett Barren Member of the Crevasse Canyon Formation in the upper part of the stratigraphic section penetrated in the Ray-1 well are similar to that encountered in the Erwin-1, Muñoz-1, and Muñoz-1-A wells. These rocks are not considered to be capable of yielding water of desirable quality in the quantity needed for a municipal supply. Therefore, they are not discussed further in this report.

Description of possible production zones

The interpretation of the zones having a potential for yielding water in the Ray-1 well were made primarily from an examination of the borehole geophysical logs. The cuttings were generally only partly representative of the stratigraphic section due to the large content of cavings but were used as a guide to the lithology where possible.

The first prominent sandstone encountered was designated as the Dalton Sandstone Member of the Crevasse Canyon Formation following the practice of Mercer and Lappala (1972, p. 12). The top and base of the Dalton Sandstone Member were determined to be at depths of 1,415 and 1,490 feet (431 and 454 m), respectively, from the responses recorded on the formation density, dual-induction, and laterolog borehole geophysical logs (fig. 3). The drill cuttings recovered for this interval were of generally poor quality.^{1/} However, a sufficient amount of fine to medium-grained quartzarenite^{1/}

^{1/}Quartzarenite, "a sandstone that is composed primarily of quartz
...." (Gary, McAfee, and Wolf, 1972, p. 582).

was present in the cuttings to give some indication of the lithology (table 1).

From an interpretation of the borehole geophysical logs, the Dalton Sandstone Member appears to be composed of an upper sandstone bed slightly more than 30 feet (9 m) thick, an intermediate mudstone with interbedded siltstone, and a lower bed of fine to very fine-grained sandstone about 25 feet (8 m) thick. The large percentage of coal reported in the description of the drill cuttings from this interval most probably is due to sloughing of coal from coal-bearing beds higher in the stratigraphic section penetrated in this well. Visual estimates made by examining the formation density log indicate that the upper sandstone bed has an average porosity of 25 percent whereas two thin zones in the lower, finer grained sandstone bed have porosities ranging from 20 to 24 percent. Water produced from the Dalton aquifer will undoubtedly come mostly from the upper sandstone bed.

Two medium-grained quartzarenite beds were encountered near the middle of the Dilco Coal Member of the Crevasse Canyon Formation at depths of 1,582-1,593 feet (482-486 m) and 1,602-1,635 feet (488-498 m), respectively, from interpretation of the borehole geophysical logs (fig. 3). The porosity of the two beds is comparatively high, averaging 27 percent from visual inspection of the formation density log. These two sandstone beds should contribute a substantial amount of water to the overall production from the Ray-1 well.

The Gallup Sandstone, the principal aquifer in the Yah-ta-hey well field, was penetrated at a depth of 1,740 feet (530 m) from interpretations of the drilling time log, the borehole geophysical logs, and the drill-cutting samples (figs. 2 and 3; and table 1). The total thickness of the Gallup Sandstone is 355 feet (108 m). The Gallup Sandstone can be divided by interpretations of the logs and cuttings into upper and lower, medium to very coarse-grained quartz-arenite beds between the depths of 1,740 to 1,855 feet (530 to 565 m) and 1,982 to 2,095 feet (604 to 638 m), respectively, and a medial unit composed of interbedded siltstones, mudstones, and very thin sandstones. Visual estimates prepared from examination of the formation density log suggest that the average porosities of the upper and lower sandstone beds are 25 and 23 percent, respectively. Most of the water produced from the Gallup Sandstone in this area would undoubtedly come from the upper and lower sandstones.

Comparison to nearby wells

The Gallup Sandstone in the Erwin-1 and Muñoz-1 wells are 360 and 320 feet (110 and 98 m) thick, respectively, compared to a thickness of 355 feet (108 m) in the Ray-1 well. The revised correlation prepared by Mercer and Lappala (1972, p. 12 and 14) for the Muñoz-1 well was used in determining the comparative thickness of the Gallup Sandstone. The Dalton Sandstone Member of the Crevasse Canyon Formation varies from 63 to 75 feet (19 to 23 m) in thickness in the three wells. However, the underlying Dilco Coal Member, 220 and 240 feet (67 and 73 m) thick in the Erwin-1 and Ray-1 wells, respectively, apparently thins to only 118 feet (36 m) in the Muñoz-1 well. Sudden local changes in thickness of many of the Upper Cretaceous strata are not unusual in this area (Mercer and Lappala, 1972, p. 12).

CONCLUSIONS

Sandstones in the Dilco Coal Member and Dalton Sandstone Member of the Crevasse Canyon Formation and the Gallup Sandstone appear to have water-bearing characteristics similar to correlative strata found to be productive in the nearby Erwin-1 and Muñoz-1-A wells. This interpretation suggests that a combined yield of approximately 700 gallons per minute (44 l/s) could be anticipated from the aquifers in the nearby replacement well for the abandoned Ray-1 well.

Most of the water produced from the replacement well will come from the Gallup Sandstone. However, sandstone beds in the Dilco Coal Member and the Dalton Sandstone Member of the Crevasse Canyon Formation should yield significant quantities of water of similar quality.

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Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico

Note: Drill-cutting samples were collected at 5-and 10-foot (1.5 to 3 metre) intervals while the 9 7/8-inch (25 cm) pilot borehole was being drilled. Formation boundaries were determined from the responses recorded on the suite of borehole geophysical logs. In places the lithologic description was adjusted accordingly. The borehole geophysical logs were considered to be more dependable than the cuttings because of the differential lag time in circulating cuttings to the surface and the presence of cavings from previously drilled sections in the samples. Color symbols shown in parentheses following the color of the rock are from the "Rock-Color Chart, 1963," distributed by the Geological Society of America, New York, N. Y. Depth and intervals are given in feet. One foot = 0.3048 metres (m)

Sample descriptions and stratigraphic designation by J. G. Marshall

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System:		
Menefee Formation:		
Allison Member:		
Clay; 100 percent; pale-yellowish-brown		
(10 YR 6/2); slightly calcareous -----	10	10
Siltstone; 100 percent; grayish-orange		
(10 YR 7/4) to light-olive-gray (5 Y 6/1);		
medium to coarse silt; moderately to		
poorly indurated; slightly calcareous;		
rare limonite present -----	50	60

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Allison Member - Continued		
Sandstone; 100 percent; very light-gray (N 8); fine-grained; silty; moderately to well sorted; composed of subrounded frosted quartz grains; minor dark minerals; poorly indurated; calcareous -----	10	70
Siltstone; 100 percent; yellowish-gray (5 Y 8/1) to light-olive-gray (5 Y 6/1); medium to coarse silt; minor quartz crystals at 90 to 110 ft; some dark minerals and car- bonaceous streaks; moderately to poorly indurated; calcareous; minor sandstone fragments throughout interval -----	90	160
Sandstone; 85 percent; yellowish-gray (5 Y 7/2); fine-grained; moderately sorted; composed of frosted to clear subangular quartz grains; minor dark minerals and carbonaceous streaks; friable. Siltstone; 15 percent; yellowish-gray (5 Y 8/1) to light-gray (N 7); moderately to poorly indurated. Minor coal fragments -----	10	170

Table 1.--Sample-description log of Ray-1 pilot borehole,
city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness</u> <u>(feet)</u>	<u>Depth</u> <u>(feet)</u>
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Allison Member - Continued		
Siltstone; 100 percent; yellowish-gray (5 Y 8/1); silty to sandy; minor dark minerals and carbonaceous material; moderately indurated although poorly indurated at 250 to 280 ft; slightly calcareous to moderately calcareous.		
Sandstone fragments common -----	130	300
Siltstone; 95 to 100 percent; light- olive-gray (5 Y 6/1) to greenish-gray (5 GY 6/1); fine silt particles at 300 to 330 ft; minor dark minerals and car- bonaceous material; moderately indurated; slightly calcareous. Sandstone; 5 per- cent at 330 to 340 ft. Yellowish-gray (5 Y 8/1); fine to very fine-grained; composed of frosted to clear subangular quartz fragments; minor dark minerals; moderately well indurated with argilla- ceous and calcareous cement -----		
	70	370

Table 1.--Sample-description log of Ray-1 pilot borehole, city of

Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Allison Member - Concluded		
Siltstone; 100 percent; yellowish-gray (5 Y 8/1) to light-olive-gray; silty to sandy; minor dark minerals; some carbonaceous streaks at 420 to 430 ft; moderately to poorly indurated with depth; calcareous. Coal fragments at 400 to 410 ft; limonite staining at 410 to 420 ft -----	65	435
Cleary Coal Member:		
Sandy siltstone; 100 percent; yellowish- gray (5 Y 8/1) and light-olive-gray (5 Y 6/1) at 450 to 460 ft; poorly sorted; composed of subrounded frosted to clear quartz grains; minor dark minerals; rare carbonaceous streaks 440 to 450 ft; poorly to moderately indurated; moderately to slightly calcareous. Minor shaly fragments at 430 to 440 ft -----	35	470

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Cleary Coal Member - Continued		
Sandy siltstone; 100 percent; light-gray (N 7) becoming yellowish-gray (5 Y 8/1) and light-olive-gray (5 Y 6/1); sand particles composed mostly of clear to frosted subrounded quartz grains; minor dark minerals and carbonaceous streaks; moderately indurated; calcareous.		
Common coal fragments at 510 to 530 ft-	70	540
Siltstone; 100 percent; medium light-gray (N 6) to light-olive-gray (5 Y 6/1); moderately indurated; moderately calcareous to slightly calcareous at 550 to 560 ft. Minor coal fragments --	20	560
Siltstone; 100 percent; yellowish-gray (5 Y 8/1) to light-olive-gray (5 Y 6/1); minor dark minerals and carbonaceous streaks; moderately indurated; calcareous. Minor sandstone fragments at 560 to 570 ft -----	40	600

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Cleary Coal Member - Continued		
Siltstone; 100 percent; olive-gray (5 Y 6/1); minor dark minerals; rare carbonaceous streaks; moderately in- durated; slightly calcareous -----	30	630
Siltstone; 65 to 75 percent; light-olive- gray (5 Y 6/1) to light-brownish-gray (5 GY 6/1); minor dark minerals; carbon- aceous streaks at 640 to 650 ft; moder- ately indurated; slightly calcareous at 640 to 650 ft. Sandstone; 25 to 35 per- cent; yellowish-gray (5 Y 8/1), fine to medium-grained; moderately sorted; com- posed of frosted to clear subrounded quartz grains; some dark minerals; moder- ately indurated; calcareous -----	25	655

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Cleary Coal Member - Continued		
Siltstone; 100 percent; yellowish-gray (5 Y 8/1) trending to pinkish-gray (5 YR 8/1); minor dark minerals; carbonaceous streaks at 660 to 670 ft and 720 to 730 ft; moderately to poorly indurated; very slightly calcareous to moderately calcareous. Minor sandstone and coal fragments at 720-730 ft -----	75	730
Siltstone; 90 percent; yellowish-gray (5 Y 8/1), with minor dark minerals and carbonaceous material; moderately indurated; calcareous. Sandstone; 10 percent; yellowish-gray (5 Y 8/1); very fine-grained; moderately to well sorted; silty; composed of frosted subangular quartz grains and minor dark minerals; moderately indurated; calcareous. Minor coal fragments present -----	10	740

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Menefee Formation - Continued		
Cleary Coal Member - Continued		
Siltstone; 60 to 70 percent; light-olive-gray (5 Y 6/1); very fine silt size particles at 740 to 750 ft; minor dark minerals; carbonaceous streaks; moderately indurated; calcareous.		
Sandstone; 30 to 40 percent; yellowish-gray (5 Y 8/1) fine to medium-grained; moderately sorted; composed of frosted subangular quartz grains; minor dark minerals; moderately indurated; calcareous. Rare coal fragments -----	20	760

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness</u>	<u>Depth</u>
	<u>(feet)</u>	<u>(feet)</u>
Upper Cretaceous System - Continued		
Menefee Formation - Concluded		
Cleary Coal Member -Concluded		
Siltstone; 95 to 100 percent; light- olive-gray (5 Y 6/1) to yellowish- gray (5 Y 8/1); fine silt size particles grading to coarser silt; sandy from 780 to 800 ft; minor dark minerals; some carbonaceous streaks; moderately in- durated; calcareous. Sandstone; 5 per- cent or less; yellowish-gray (5 Y 8/1); very fine-grained; moderately sorted; composed of frosted subangular quartz fragments; minor dark minerals; moderately to poorly indurated; calcareous. Rare coal fragments at 800 feet -----		
	50	810
Crevasse Canyon Formation:		
Gibson Coal Member:		
Siltstone; 90 to 100 percent; light-olive- gray (5 Y 6/1); common carbonaceous streaks; minor dark minerals; moderately indurated; calcareous to slightly calcareous. Coal; 10 percent or less; black (N 1); vitreous-		
	20	830

Table 1.—Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Sandstone; 60 to 75 percent; light-gray (N 7) to yellowish-gray (5 Y 8/1); very fine to fine-grained; well sorted becoming moderately sorted; composed of frosted subrounded quartz frag- ments; common carbonaceous streaks and coal fragments; minor dark min- erals; moderately indurated; cal- careous. Siltstone; 20 to 30 percent; light-olive-gray (5 Y 6/1) to pale- yellowish-brown (10 YR 6/2) and some medium light-gray (N. 6) at 845 to 850 ft; carbonaceous streaks; moderately indu- rated; calcareous. Coal; 5 to 10 per- cent; black (N-1); vitreous to dull	---- 20	850

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Siltstone; 60 percent; light-olive-gray (5 Y 6/1) to medium light-gray (N 6); common carbonaceous streaks; poorly to moderately indurated; calcareous.		
Sandstone; 40 percent; yellowish-gray (5 Y 8/1); fine to very fine-grained; moderately sorted; composed of frosted subrounded quartz grains; some car- bonaceous streaks; minor dark minerals; moderately indurated; calcareous. Minor coal fragments -----	20	870
Siltstone; 95 percent or more; medium light-gray (N 6) to light-olive-gray (5 Y 6/1); with common carbonaceous material; moderately to poorly in- durated; calcareous. Coal; 5 percent or less; black (N 1); vitreous to dull. Minor sandstone fragments -----	20	890

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Siltstone; 60 percent; medium light-gray (N 6) to light-olive-gray (5 Y 6/1); common carbonaceous streaks; weakly to moderately indurated; calcareous. Coal; 40 percent; black (N 1); vitreous to dull. Minor sandstone fragments -----	10	900
Siltstone; 95 percent or more; olive-gray (5 Y 6/1) to medium light-gray (N 6); medium to coarse silt size particles; common carbonaceous streaks; moderately to weakly indurated; slightly calcareous. Coal; 5 percent or less; black (N 1); vitreous to dull -----	20	920

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Sandstone; 55 percent trending to 25 percent; very light-gray (N 8) to yellowish-gray (5 Y 8/1); very fine to fine-grained; moderately sorted; composed of frosted sub-rounded quartz grains; some carbonaceous material; minor dark minerals; moderately indurated; calcareous. Siltstone; 45 percent increasing to 75 percent; light-olive-gray (5 Y 6/1) to medium light-gray (N 6); common carbonaceous streaks; moderately indurated; calcareous.		
Common coal fragments -----	20	940
Coal; 100 percent; dark gray (N 3) to black (N 1). Common sandstone and siltstone fragments -----		
	10	950

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness</u> <u>(feet)</u>	<u>Depth</u> <u>(feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Siltstone; 65 percent decreasing to		
about 25 percent; light-olive-gray		
(5 Y 6/1) to yellow-gray (5 Y 8/1);		
minor dark minerals and carbonaceous		
material; moderately indurated; cal-		
careous. Sandstone; 25 per cent in-		
creasing to 75 percent; yellowish-		
gray (5 Y 8/1); very fine to medium-		
grained; moderately to well sorted.		
composed of clear to frosted sub-		
rounded quartz fragments; minor dark		
minerals and carbonaceous material;		
moderately indurated; calcareous.		
Coal fragments; 10 percent or		
less -----	20	970

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Siltstone; 95 to 100 percent; yellowish- gray (5 Y 8/1) becoming light-olive- gray (5 Y 6/1); minor dark minerals and carbonaceous material; moderately in- durated; calcareous. Sandstone; 5 per- cent or less; yellowish-gray (5 Y 8/1); medium to fine-grained; moderately sorted; composed of clear to frosted quartz grains; some dark minerals; moderately indurated; calcareous.	-----	30
Common coal fragments		1,000
Coal; 75 to 95 percent; medium-gray (N 5) dark-gray (N-3) to black (N-1); common silty particles. Siltstone; 25 per- cent decreasing to 5 percent; light- olive-gray (5 Y 6/1); common car- bonaceous material; moderately in- durated; calcareous	-----	20
		1,020

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
Siltstone; 90 percent decreasing to 40 percent; olive-gray (5 Y 6/1) becoming medium light-gray (N 6) and yellowish-gray (5 Y 8/1); often sandy; minor dark minerals and carbon- eous material; moderately indurated; calcareous to slightly calcareous.		
Sandstone; less than 10 percent increasing to 60 percent; yellowish-gray (5 Y 8/1); medium to fine-grained; moderately sorted; composed of clear to frosted subrounded quartz grains; minor dark minerals; mod- erately indurated; calcareous. Coal; rare increasing to 30 percent at 1,060 to 1,070 ft and decreasing to 10 percent at 1,080 ft; medium-gray (N 5) to black (N 1); vitreous to dull -----	60	1,080

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Continued		
<p>Siltstone; 55 percent increasing to 95 percent; yellowish-gray (5 Y 8/1) to medium light-gray (N 6); minor dark minerals; moderately to weakly indurated; calcareous. Sandstone; 40 percent but disappearing with depth; yellowish-gray (5 Y 8/1); medium grained; composed of clear to frosted subrounded quartz grains, minor dark minerals; moderately indurated; calcareous. Coal; 5 percent; medium-gray (N 5) to black (N 1); vitreous to dull; (coal due to cavings) -----</p>	20	1,100
<p>Siltstone; 95 percent; light-olive-gray (5 Y 6/1) to yellowish-gray (5 Y 8/1); sandy at 1,130 to 1,140 ft; common carbonaceous streaks; minor dark minerals; moderately to poorly indurated; slightly calcareous. Coal; 5 percent; medium-gray (N 5) to black (N 1); vitreous to dull; (coal due to cavings) -----</p>	40	1,140

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Gibson Coal Member - Concluded		
Siltstone; 60 percent increasing to 95 percent; light-gray (N 7) to light-olive-gray (5 Y 6/1); common carbonaceous material; minor dark minerals; moderately indurated; slightly calcareous. Coal (due to cavings); 40 percent decreasing to 5 percent; medium-gray (N 5) to black (N 1); vitreous to dull. Siltstone fragments common throughout -----	40	1,180
Bartlett Barren Member:		
Siltstone; 100 percent; yellowish-gray (5 Y 8/1); sandy; minor dark minerals and carbonaceous material; moderately indurated; calcareous. Minor sandstone fragments at 1,200 ft. Rare coal fragments (from cavings) -----	20	1,200

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Continued		
Siltstone; 30 percent increasing to 100 percent; sandy; yellowish-gray (5 Y 8/1); minor dark minerals and carbonaceous streaks; moderately indurated; calcareous. Sandstone; 60 percent and decreasing to less than 5 percent with depth; yellowish-gray (5 Y 8/1); medium-grained; poorly to moderately sorted, composed of clear to frosted subrounded quartz grains; minor dark minerals; moderately to weakly indurated; calcareous.		
Coal; 10 percent decreasing to less than 5 percent; medium-gray (N 5) to black (N 1); (coal due to cavings) -----	50	1,250

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Continued		
Siltstone; 55 percent increasing to 90 percent; olive-gray (5 Y 6/1) to yellowish-gray (5 Y 8/1); minor dark minerals; carbonaceous material; moderately indurated; rarely calcareous. Coal; 40 percent decreasing to 5 percent; dark-gray (N 3) to black (N 1); (from cavings). Carbonaceous mudstone; 5 percent increasing to 35 percent; light-olive-gray (5 Y 6/1) to olive-gray (5 Y 4/1); poorly to moderately indurated. Sandstone; increasing from less than 5 percent to 20 percent; yellowish-gray (5 Y 8/1); fine to medium-grained; moderately sorted; composed of frosted to clear subrounded quartz grains. Minor dark minerals; moderately indurated; calcareous -----	30	1,280

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Continued		
Sandstone; 50 percent; yellowish-gray (5 Y 8/1); fine to medium-grained; moderately sorted; composed of frosted to clear subrounded quartz grains; minor dark minerals; moderately indurated; calcareous. Mudstone; 35 percent; light- olive-gray (5 Y 6/1) to olive-gray (5 Y 4/1); carbonaceous; often shaly; poorly to moderately indurated. Silt- stone; 15 percent; light-olive-gray (5 Y 6/1); minor dark minerals; moder- ately indurated -----		
	10	1,290

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Continued		
Sandstone; 65 to 75 percent; yellowish- gray (5 Y 8/1); medium to fine-grained; composed of clear to frosted subrounded quartz grains; minor dark minerals; rare pyrite; moderately indurated; calcareous. Siltstone; 15 to 30 percent; yellowish-gray (5 Y 8/1); minor dark minerals; moderately indurated; very slightly calcareous. Mudstone; minor to 10 percent; medium-gray (N 5) to light-olive-gray (5 Y 6/1); shaly; carbonaceous; moderately indurated.		
Minor coal fragments from cavings -----	40	1,330

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Continued		
Mudstone; 80 percent; medium-gray (N 5); carbonaceous; poorly indurated; very slightly calcareous.		
Sandstone; 20 percent; light-gray (N 7); fine-grained, moderately sorted; composed of frosted sub-rounded quartz grains and some dark minerals; common carbonaceous material; moderately to poorly indurated; calcareous. Common siltstone fragments -----		
	10	1,340

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Continued		
<p>Siltstone; 80 percent decreasing to 40 percent; yellowish-gray (5 Y 8/1); minor dark minerals and carbonaceous material moderately indurated; calcareous. Sandstone 10 to 20 percent; yellowish-gray (5 Y 8/1); absent at 1,360 to 1,380 ft; moderately sorted, fine-grained; composed of clear to frosted subrounded quartz grains; minor dark minerals; moderately indurated; calcareous. Mudstone; 5 percent increasing to 40 percent; yellowish-gray (5 Y 8/1) to medium light-gray (N 6); common carbonaceous material; moderately to poorly indurated; slightly calcareous. Shale; 15 to 20 percent at depths of 1,360 to 1,380 ft; light-gray (N 7); some carbonaceous streaks; well indurated. Coal; minor amounts to 10 percent; black (N 1); (from cavings)</p>	-----	50 1,390

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Bartlett Barren Member - Concluded		
Siltstone; 80 percent; light-olive-gray (5 Y 6/1); minor dark minerals and carbonaceous material; moderately indurated; slightly calcareous. Shale; 15 percent; olive-gray (5 Y 6/1); well indurated. Coal; 5 percent; black (N 1); (from cavings). Minor sandstone and mudstone fragments -----		
	10	1,400
Mudstone; 90 to 95 percent; light-olive-gray (5 Y 6/1); common carbonaceous material; poorly indurated. Shale; 10 percent; absent at 1,410 ft; olive-gray (5 Y 6/1); moderately to well indurated.		
Minor coal from cavings -----		
	15	1,415

Table 1.—Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dalton Sandstone Member:		
Mudstone; 40 percent decreasing to 30 percent; medium light-gray (N 6) to light-olive-gray (5 Y 6/1); carbonaceous; moderately to poorly indurated; calcareous. Sandstone; 30 percent; light-gray (N 6) to light yellowish-gray (5 Y 8/1); medium grained; moderately sorted; composed of clear to frosted quartz grains; minor dark minerals and carbonaceous material; moderately indurated; calcareous. Siltstone; 20 percent decreasing to 10 percent; light-olive-gray (5 Y 6/1); minor dark minerals and carbonaceous material; moderately indurated; calcareous. Shale; 10 percent increasing to 30 percent; medium light-gray (N 6); carbonaceous; moderately indurated -----	35	1,450

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dalton Sandstone Member - Continued		
Coal; 60 percent; black (N 1); vitreous to dull. Mudstone; 20 percent; light-olive-gray (5 Y 6/1); carbonaceous; weakly indurated; slightly calcareous. Shale; 10 percent; medium-gray (N 5) to dark-gray (N 3); carbonaceous; well indurated. Sandstone; 5 percent; yellowish-gray (5 Y 8/1); medium grained; moderately sorted; composed of frosted to clear sub-rounded quartz fragments; minor dark minerals; moderately indurated; calcareous -----	10	1,460

Table 1.—Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dalton Sandstone Member - Concluded		
Siltstone; 50 percent decreasing to 30 percent; yellowish-gray (5 Y 8/1); minor dark minerals and carbonaceous material; moderately indurated; calcareous. Sandstone; 30 to 40 percent; yellowish-gray (5 Y 8/1); very fine to fine-grained; composed of frosted sub-rounded quartz grains; some carbonaceous streaks and minor dark minerals; moderately indurated; calcareous. Shale; 5 to 15 percent; light-gray (N 7) to medium light-gray (N 6); carbonaceous; well indurated --	30	1,490
Dilco Coal Member:		
Coal; 85 to 95 percent; black (N 1); vitreous to dull. Mudstone; 10 percent or less; light-olive-gray (5 Y 6/1); carbonaceous; poorly indurated; slightly calcareous. Shale; 5 percent or less; light-olive-gray (5 Y 6/1) to medium light-gray (N 6); carbonaceous; well indurated -----	30	1,520

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dilco Coal Member - Continued		
Mudstone; 50 percent; light-olive-gray (5 Y 6/1); carbonaceous; moderately to weakly indurated; calcareous. Coal; 15 to 30 percent; black (N 1); vitreous. Siltstone; 30 percent decreasing to minor amounts; light-olive-gray (5 Y 6/1); common dark minerals and carbonaceous streaks; moderately indurated; very slightly cal- careous -----	20	1,540
Mudstone; 90 percent; light-olive-gray (5 Y 6/1); carbonaceous; moderately to poorly indurated; calcareous; common siltstone fragments throughout. Coal 10 percent; black (N 1); vitreous to dull -----	10	1,550

Table 1.—Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dilco Coal Member - Continued		
Mudstone: 30 percent; light-olive-gray (5 Y 6/1); carbonaceous; moderately to poorly indurated; calcareous; common siltstone fragments throughout.		
Siltstone; 30 percent; light-olive-gray (5 Y 6/1); common dark minerals and carbonaceous streaks; moderately to well indurated; calcareous. Coal; 30 percent; black (N 1); vitreous to dull.		
Shale; 10 percent; medium dark-gray (N 4); carbonaceous -----		
	10	1,560

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dilco Coal Member - Continued		
Sandstone; minor increasing to 35 percent at 1,580 to 1,600 ft; yellowish-gray (5 Y 8/1); medium-grained; composed of frosted to clear subrounded quartz grains; minor dark minerals; moderately indurated; calcareous. Mudstone; 60 percent decreasing to minor amounts; olive-gray (5 Y 4/1) grading to lighter olive-gray (5 Y 6/1); carbonaceous; often silty; poorly to moderately indurated; calcareous. Silt- stone; 40 to 60 percent (absent at 1,570 to 1,580 ft); light-olive-gray (5 Y 6/1) to yellowish-gray (5 Y 8/1); some mud matrix; minor dark minerals and car- bonaceous streaks; moderately indurated; calcareous. Coal; 30 percent becoming minor; black (N 1); vitreous to dull. Shale; 10 to 20 percent but absent at 1,550 to 1,560 ft and 1,580 to 1,590 ft; medium-gray (N 5); carbonaceous -----		
	50	1,610

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dilco Coal Member - Continued		
Sandstone; 30 percent increasing to 80 percent; yellowish-gray (5 Y 8/1); medium-grained; moderately to well sorted; composed primarily of sub-rounded clear quartz grains; well indurated. Mudstone; 60 percent decreasing to 20 percent; yellowish-gray (5 Y 8/1) to light-olive-gray (5 Y 6/1); with some silt particles and coal fragments; poorly to moderately indurated; very slightly calcareous. Shale; 30 percent at 1,620 ft; light-gray (N 7); some carbonaceous material. Siltstone; present in minor amounts; yellowish-gray (5 Y 6/1); with some carbonaceous streaks; moderately indurated; very slightly calcareous. Coal; minor amounts; black (N 1); vitreous to dull -----	40	1,650

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness</u> (feet)	<u>Depth</u> (feet)
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Continued		
Dilco Coal Member - Continued		
Mudstone; 10 to 45 percent; absent at		
1,680 ft; light-olive-gray (5 Y 6/1) to		
olive-gray (5 Y 4/1) at 1,690 ft; with		
common coal and silt particles; mod-		
erately to poorly indurated; slightly		
calcareous. Shale; 10 to 50 percent		
at 1,700 ft; medium light-gray (N 6)		
to medium dark-gray (N 4); carbon-		
aceous. Sandstone; 25 percent de-		
creasing to 5 percent; yellowish-gray		
(5 Y 8/1) medium-grained; moderately		
well sorted; composed of subrounded		
clear to frosted quartz grains; with		
minor dark minerals and occasional car-		
bonaceous material; moderately indurated;		
slightly calcareous. Siltstone; 5 per-		
cent increasing to 70 percent at 1,680 ft		
then decreasing to 20 percent; light-		
olive-gray (5 Y 6/1) to yellowish-gray		
(5 Y 8/1); some carbonaceous streaks and		
minor dark minerals; moderately indurated;		
occasionally calcareous. Coal; minor to		
20 percent; black (N 1); vitreous to dull- 60 1,710		

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Crevasse Canyon Formation - Concluded		
Dilco Coal Member - Concluded		
Mudstone; 80 percent; decreasing to		
30 percent at 1,730 to 1,740 ft;		
light-yellowish-gray (5 Y 8/1); with		
minor dark minerals; some silt and		
coal fragments; moderately to poorly		
indurated; calcareous. Siltstone; 5 to		
40 percent; yellowish-gray (5 Y 8/1);		
shaly; some carbonaceous streaks and		
minor dark minerals; moderately indu-		
rated; calcareous. Shale; minor to		
20 percent; medium light-gray (N 6) to		
medium-gray (N 5); carbonaceous. Coal;		
5 to 10 percent; black (N 2); vitreous		
to dull. Minor sandstone at 1,710 to		
1,720 ft -----	30	1,740

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness</u> (feet)	<u>Depth</u> (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone:		
Sandstone; 10 percent increasing to 35 percent; yellowish-gray (5 Y 8/1) to very light-gray (N 8); medium to very coarse-grained; poorly to moderately sorted; composed primarily of clear to frosted subrounded quartz grains; minor dark minerals; well indurated. Shale; 25 percent; medium light-gray (N 6) to greenish-gray (5 GY 6/1); carbonaceous. Siltstone; 30 percent decreasing to 25 percent; light-olive-gray (5 Y 6/1) to greenish-gray (5 GY 6/1); minor dark minerals and carbonaceous streaks; very slightly calcareous to calcareous. Coal; minor to 15 percent; black (N 1); vitreous to dull; (from cavings). Mudstone 15 percent at 1,770 to 1,780 ft only; medium light-gray (N 6); with common coal and silt fragments; moderately to poorly indurated; calcareous	-----	60 1,800

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
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Upper Cretaceous System - Continued

Gallup Sandstone - Continued

Sandstone; 20 percent increasing to 75 percent; very light-gray (N 8) to yellowish-gray (5 Y 8/1); very coarse to coarse-grained; poorly to moderately sorted; composed primarily of subrounded to subangular clear to frosted quartz grains; with minor dark minerals; uncemented to poorly cemented with calcite cement. Mudstone; 50 percent gradually decreasing to minor amounts; yellowish-gray (5 Y 8/1) to light-gray (N 7); with some silt and coal fragments; poorly indurated; calcareous. Shale; 10 to 20 percent; medium light-gray (N 6) to medium dark-gray (N 4); carbonaceous with minor amounts of calcite coating. Siltstone; 10 percent increasing to 25 percent at 1,825 ft then decreasing to 10 percent at 1,850; medium light-gray (N 6) to light-olive-gray (5 Y 6/1)

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Sandstone - Continued		
and greenish-gray (5 GY 6/1) at 1,830		
ft; with minor dark minerals and		
carbonaceous streaks; moderately to		
poorly indurated; sometimes cal-		
careous. Coal; minor to 10 percent		
but 25 percent at 1,840 ft; black		
N 1); vitreous to dull	50	1,850

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Sandstone; 60 percent decreasing to 5 percent; yellowish-gray (5 Y 8/1) to very light-gray (N 8); very course to medium-grained; poorly to moderately sorted; composed of sub-rounded to subangular clear to frosted quartz grains; minor dark minerals present; uncemented to moderately cemented; sometimes calcareous. Siltstone; 30 percent decreasing to 5 percent; yellowish-gray (5 Y 8/1) to greenish-gray (5 GY 6/1); with minor dark minerals and carbonaceous streaks; poorly to moderately indurated; very slightly calcareous. Shale; 20 percent to minor at 1,860 ft and increasing to 5 percent at 1,870 ft; medium light-gray (N 6) to medium dark-gray (N 4); carbonaceous. Mudstone; minor to 70 percent at 1,870 ft; yellowish-gray (5 Y 8/1) to greenish gray (5 GY 6/1); with common coal, silt, and sand fragments; poorly to moderately indurated; calcareous. Coal; usually minor but 70 percent at 1,865 ft; black (N 1); vitreous to dull -	20	1,870

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Sandstone; 50 percent; yellowish-gray (5 Y 8/1) to light-olive-gray (5 Y 6/1); fine to medium-grained; moderately sorted; composed of subrounded clear to frosted quartz grains and minor dark minerals; poorly to moderately cemented; slightly calcareous. Mudstone; 25 percent; light- olive-gray (5 Y 6/1); with common coal, silt, and sand particles; poorly in- durated; slightly calcareous. Silt- stone; 20 percent; light-olive-gray (5 Y 6/1); with minor dark minerals; moderately to poorly indurated; cal- careous. Coal; 5 percent; black (N 1); vitreous to dull -----	5	1,875

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Sandstone; 80 percent; very light- gray (N 8) to yellowish-gray (5 Y 8/1); medium to coarse-grained; moder- ately to poorly sorted; composed pri- marily of subrounded frosted quartz grains and minor dark minerals; poorly cemented; calcareous. Shale; 15 percent; medium-gray (N 5) to light- gray (N 7); carbonaceous. Siltstone; 5 percent; light-gray (N 7); moderately indurated; calcareous -----	10	1,885

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Siltstone; 60 percent; light-olive-gray (5 Y 6/1); with minor dark minerals; moderately to poorly indurated; calcareous. Mudstone; 15 percent; light-olive-gray (5 Y 6/1); with common sand, silt, and coal particles; very poorly indurated; calcareous. Shale; 10 percent; light-olive-gray (5 Y 6/1) to medium light-gray (N 6); carbonaceous. Sandstone; 10 percent; yellowish-gray (5 Y 8/1); primarily medium-grained with some coarser grains; composed of subrounded frosted to clear quartz fragments; minor coal streaks, and dark minerals; moderately to poorly cemented; calcareous. Coal; 5 percent; black (N 1); vitreous to dull	15	1,900

Table 1.—Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Sandstone; 60 percent; very light-gray (N 8) to yellowish-gray (5 Y 8/1); fine to medium-grained; moderately sorted; composed primarily of clear to frosted subrounded quartz grains; minor dark minerals; moderately indurated; slightly calcareous. Siltstone; 30 per- cent; light-gray (N 7) to light-olive- gray (5 Y 6/1); composed of fine silt and clay; moderately well indurated; mostly clay cement; slightly calcareous; Shale; 10 percent; medium dark-gray; (N 4); with some carbonaceous material; calcareous -----	10	1,910

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Siltstone; 50 to 60 percent; yellowish-gray (5 Y 8/1) to light-gray (N 7); some carbonaceous streaks; moderately indurated; calcareous. Sandstone; 10 to 40 percent; disappearing at 1,950 to 1,970 ft and 10 percent at 1,970 to 1,980 ft; very light-gray (N 8) to yellowish-gray (5 Y 8/1); fine to medium-grained; moderately well sorted; mostly clear to frosted sub-angular quartz grains; moderately to well indurated; calcareous. Shale; 15 to 30 percent; light-olive-gray (5 Y 6/1) to medium light-gray (N 6) and medium-gray (N 5); some carbonaceous streaks; calcareous. Mudstone; 10 percent at 1,970 to 1,980 ft; yellowish-gray (5 Y 8/1); minor carbonaceous streaks; moderately indurated; calcareous. Coal; minor to 10 percent; black (N 1); vitreous to dull -----	80	1,990

Table 1.--Sample-description log of Ray-1 pilot borehole, city of
Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Gallup Sandstone - Continued		
Sandstone; 40 percent increasing to 80 percent; yellowish-gray (5 Y 8/1); fine to medium-grained; moderate to well sorted; composed of subrounded clear to frosted quartz grains minor carbon- aceous material and dark minerals; moderate- to well cemented; slightly calcareous.		
Shale; 40 percent decreasing to 10 percent at 2,030 ft; medium light-gray (N 6) to medium-gray (N 5); sometimes carbonaceous.		
Siltstone; 20 percent at 1,990 ft only; light-olive-gray (5 Y 6/1); minor dark minerals and carbonaceous streaks; moderately indurated; calcareous. Mud- stone; minor increasing to 20 percent; yellowish-gray (5 Y 8/1) to light-olive- gray (5 Y 6/1); some coal streaks; mod- erately to poorly indurated; calcareous.		
Coal; 5 percent or less; black (N 1); vitreous to dull -----	60	2,050

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

<u>Stratigraphic unit and material</u>	<u>Thickness (feet)</u>	<u>Depth (feet)</u>
Upper Cretaceous System - Continued		
Gallup Sandstone - Concluded		
Shale; 50 percent decreasing to 10 percent at 2,070 ft and increasing to 50 percent at 2,100 ft; medium-gray (N 5); to very light-gray (N 8); carbonaceous. Siltstone; 20 to 30 percent; yellowish-gray (5 Y 8/1) to light-olive-gray (5 Y 6/1); sandy; minor dark minerals; moderately indurated; very slightly calcareous. Mudstone; 15 percent increasing to 65 percent and then decreasing to 10 percent at 2,100 ft; light-olive-gray (5 Y 6/1) to medium-light-gray (N 6); carbonaceous; common coal and sand fragments throughout 2,070 to 2,090 ft; moderately to poorly indurated; calcareous. Sandstone; 10 percent or less; yellowish-gray (5 Y 8/1); very fine-grained; moderately to well sorted; composed of frosted to clear subrounded quartz grains; minor dark minerals present. Coal; 5 percent increasing to 20 percent at 2,080 ft and decreasing to 10 percent; black (N 1); vitreous to dull -----	45	2,095

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Continued

Stratigraphic unit and material	Thickness (feet)	Depth (feet)
Upper Cretaceous System - Continued		
Mancos Shale:		
Coal; 80 percent; black (N 1); vitreous to dull; (coal not indicated in the electric logs so it is probably from cavings). Mudstone; 10 percent; olive-gray (5 Y 6/1); with some coal and silt fragments; poorly indurated; calcareous. Shale; 10 percent; light-olive-gray; (5 Y 6/1); carbonaceous -----	15	2,110

Table 1.--Sample-description log of Ray-1 pilot borehole, city of Gallup, McKinley County, New Mexico - Concluded

<u>Stratigraphic unit and material</u>	<u>Thickness</u> (feet)	<u>Depth</u> (feet)
Upper Cretaceous System - Concluded		
Mancos Shale - Concluded		
Shale; 60 percent decreasing to 25 percent; medium light-gray (N 6) becoming medium dark-gray (N 4); carbonaceous. Mudstone; 30 percent increasing to 50 percent at 2,130 ft and disappearing afterwards; yellowish-gray (5 Y 8/1) to light-olive-gray (5 Y 6/1); silty; with common coal and sand particles; poorly to moderately indurated; calcareous. Coal; 10 percent; black (N 1); vitreous to dull. Sandstone; absent at 2,120 ft and prominent (25 to 35 percent) thereafter; yellowish-gray (5 Y 8/1); very fine to fine-grained; moderately to well sorted; composed of frosted to clear sub-rounded quartz grains; minor dark minerals and carbonaceous streaks; moderately indurated; calcareous. Siltstone; 35 percent at 2,140 ft; very light-gray (N 8) to medium-gray (N 5); with minor dark minerals and carbonaceous streaks; moderately indurated; very slightly calcareous. Circulated for 30 minutes at total depth of 2,142 ft (by driller); then removed drill string prior to logging	38	2,148 (Total depth)