Geology and Occurrence of Ground Water at Jewel Cave National Monument South Dakota

By C. F. DYER

HYDROLOGY OF THE PUBLIC DOMAIN

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By C. F. Dyer

ABSTRACT

Jewel Cave National Monument occupies 2 square miles of a broad plateau of sedimentary rocks in western Custer County, S. Dak., and is at an altitude of about 5,400 feet above mean sea level. The sedimentary rocks that constitute the plateau range in age from Cambrian to Pennsylvanian. Rocks of Silurian and Devonian age are absent. The presence of rocks of Ordovician age has not been established definitely but they may be represented by 10 feet of sandstone directly beneath the Englewood limestone of Mississippian age. The sedimentary formations are underlain by schist of Precambrian age.

Study of outcrops in the vicinity of the monument confirms the existence of a fault about 1,500 feet north of the entrance to Jewel Cave. The fault trends generally east-west across the monument and has a displacement of about 120 feet about 1 mile west of the entrance to the cave. The effect of the fault on the occurrence of ground water near the cave is not known.

In addition to the spring that furnishes the present (1959) water supply for the facilities at Jewel Cave, three springs outside the monument were visited during the study. Combined yield of the 3 springs is less than 2 gpm (gallons per minute).

A single test well indicates that the monument at the well site is underlain by 665 feet of limestone, dolomite, and sandstone of Paleozoic age and an undetermined thickness of quartz-biotite schist of Precambrian age. Pumping tests using a cylinder pump indicate that the test well is capable of producing 15 to 18 gpm for a short time from 2 zones of sandstone below the Englewood limestone. These sandstones are believed to present the best possibilities for development of a permanent water supply at the monument.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

In cooperation with the National Park Service, an investigation was made of the surface geology and ground-water resources at Jewel Cave National Monument near Custer, S. Dak. The purpose of the investigation was to locate additional supplies of water and to determine the geologic source of the present water supply.

This report summarizes the surface geology and the lithology and water-bearing characteristics of the strata penetrated by drilling a test well during the investigation. The test well provides the only subsurface information available in the vicinity of Jewel Cave National Monument and is the only test well referred to in this report.

PREVIOUS INVESTIGATIONS

No previous detailed investigation has been made of the geology at Jewel Cave National Monument. Darton (1918, p. 53–60) discussed the general stratigraphy of the southern Black Hills region and described the artesian water supplies obtained in the foothills 15 to 30 miles south of Jewel Cave. Some of the wells listed by Darton obtained water from a sandstone of Cambrian age that underlies Jewel Cave National Monument. A more detailed stratigraphic and structural study of the region was made in 1925 and the faulting near Jewel Cave was briefly described by Darton and Paige (1925, p. 18).

METHODS AND PROCEDURES

The test well was drilled by a standard cable-tool drilling rig under a contract issued by the National Park Service. Samples of the cuttings were taken at 5-foot intervals. The samples were washed, dried, and carefully examined with a binocular microscope for such features as grain size, crystallinity, porosity, and color.

A weighted steel tape was used to make frequent checks on the drilling depth of the well. All depth measurements cited herein, whether to the water level or to different rock strata, are given in feet below land surface. Altitude of the land surface at the test hole is about 5,340 feet above mean sea level.

Estimates of thicknesses of formations at the test-well site were based upon calculations made from dip readings taken at the outcrop area 6 miles east of the monument.

LOCATION, AREA, AND EXISTING FACILITIES

Jewel Cave National Monument is in Custer County, S. Dak. about 12 miles southwest of the city of Custer and 9 miles east of the South Dakota–Wyoming State line. Boundaries of the monument enclose a rectangular area of 2 square miles; the longest dimension is 2 miles in an east-west direction. Jewel Cave and the test well are near the southeast corner of the monument.

Facilities at Jewel Cave in 1959 consisted of one small log building, a small parking lot, and a campground. The log building was used as a headquarters and as temporary lodging for the rangers who are seasonally employed as guides for tours of the cave.

PRESENT WATER SUPPLY

The water-distribution system at the cave site includes a drinking fountain, sink, shower, and restrooms at the headquarters building and a single faucet at the campground where campers may obtain water for cooking and drinking. These outlets are supplied from a buried concrete reservoir about 100 feet north and 15 feet higher than the headquarters building. The single line from the reservoir extends directly to the headquarters building and a branch line from the headquarters building supplies the campground outlet about 300 feet east.

Water to be stored in the reservoir is collected at a small spring (NW¼NE¼NE¼ sec. 2, T. 4 S., R. 2 E.) about 1,500 feet northeast of the headquarters building and is transported to the reservoir by gravity flow through a 2-inch galvanized pipe. Yield of the spring varies but the average yield during the summer is estimated to be 2 gpm.

Generally, the total water consumption ranges from 1,000 to 1,500 gpd (gallons per day) but on days when the number of visitors is unusually large (200 or more), the 3,000-gallon reservoir is frequently depleted. As the spring is the only source of water for visitors, campers, and maintenance personnel, the water supply is often inadequate.

GENERAL GEOLOGY

Formations at the monument range in age from Precambrian to Pennsylvanian but the sequence is not complete. As elsewhere throughout the Black Hills area, rocks of Silurian and Devonian age are absent (Darton and Paige, 1925, p. 2). Ten feet of sandstone penetrated by the drilling of a test well directly below the Englewood limestone is tentatively identified as Ordovician in age.

The monument is on a broad plateau of sedimentary rocks that begins about 6 miles east of the cave and slopes gently westward into Wyoming. Because most of the sedimentary formations do not crop out within the area, a reconnaissance was made of their outcrops at the scarp face of the plateau. The surficial geology of the consolidated rocks in the monument area is shown on figure 24.

Beginning with the oldest of the rock units, the lithology and stratigraphic relations apparent at the outcrops are briefly described below.

PRECAMBRIAN ROCKS

The sedimentary rocks that crop out at the scarp face of the plateau are underlain by quartz-mica schist of Precambrian age. Just east of the escarpment the schist is cut by many dikes of quartz, amphibolite, and granite pegmatite. Presumably the Precambrian rocks that crop out at the foot of the escarpment are representative of those that underlie the monument area.

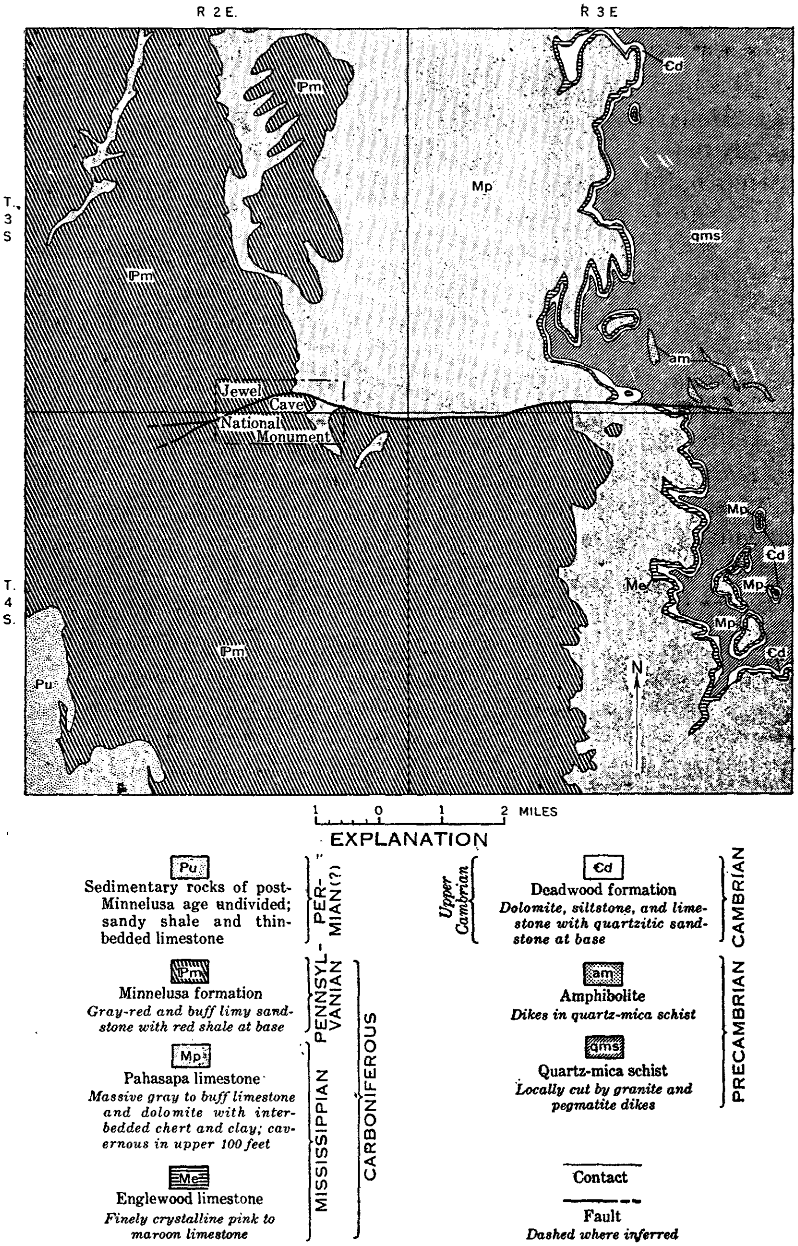

Figure 24.—Geologic map of the Jewel Cave National Monument area, South Dakota (modified after Darton and Paige, 1925).

CAMBRIAN SYSTEM

DEADWOOD FORMATION

Lying unconformably upon the Precambrian rocks at the base of the escarpment is an estimated 90 to 100 feet of the Deadwood formation that is largely covered by talus from the overlying Pahasapa and Englewood limestones. The parts of the formation that could be observed indicate that the Deadwood consists chiefly of quartzitic sandstone and dense to finely crystalline dolomite.

MISSISSIPPIAN SYSTEM

ENGLEWOOD LIMESTONE

The contact between the Deadwood formation and the overlying Englewood limestone is covered by talus, thus, the presence of a thin intervening sandstone penetrated by the test well at the monument was not recognized.

Although the total thickness of the Englewood at the outcrop is estimated to be 50 feet, the lower part of the formation is generally covered by talus. The uppermost 8 feet of the formation was examined at several locations and was found to consist of highly fossiliferous, massive, finely crystalline, pink and buff limestone.

PAHASAPA LIMESTONE

The upper part of the Englewood limestone grades upward into the Pahasapa limestone through a zone of impure buff limestone that ranges from several inches to 2 feet in thickness. Due east of the monument the Pahasapa constitutes the crest of the scarp face of the plateau and the formation is widely exposed between the escarpment and the west boundary of the monument. Average altitude of the top of the formation within the monument is about 5,400 feet above mean sea level.

Because of differential erosion, the thickness of the Pahasapa differs considerably along the escarpment. Within the monument the exposed thickness of the Pahasapa ranges from about 70 to about 300 feet. Nearly the entire thickness of the formation is exposed in Hell Canyon half a mile north of the entrance to Jewel Cave.

Although the thickness of the Pahasapa at Jewel Cave was estimated to be slightly more than 300 feet, on the basis of measurements at the outcrop along the escarpment, the test well penetrated 432 feet of the formation. The discrepancy between the estimated and actual thickness probably is caused in part by a difference in the attitude of the formation at the cave and at the escarpment.

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Where it was observed at outcrops, the Pahasapa is mostly fine grained and massive. Within the monument the upper part is generally more massive than the lower part and the top consists primarily of brown and light-gray chert. The lower part, exposed in Hell Canyon, consists of relatively thin bedded brown and buff limestone and dolomite with much brown earthy clay. In addition to the large caverns of Jewel Cave the formation contains many smaller cavities lined with calcite.

PENNSYLVANIAN SYSTEM

MINNELUSA FORMATION

The Minnelusa formation lies directly upon and obscures, the Pahasapa limestone on most of the prominent ridges in the monument area. On the east side of the monument most of the Minnelusa has been removed by erosion and only minor remnants are found in the immediate vicinity of Jewel Cave.

The total thickness of the Minnelusa at the outcrops east of the monument ranges from a few inches to about 100 feet. The formation thickens west of the cave and on the west side of the monument reaches a thickness of about 250 feet.

In general, the Minnelusa consists of interbedded limestone, dolomite, sandstone, and red shale. Within the monument it is composed chiefly of red shale and red-brown, yellow, or white, fine-grained sandstone.

RECENT SERIES

ALLUVIUM

The floors of the deeper canyons within the monument are covered with a deposit of rock fragments and soil and the slopes and summits of the higher ridges are overlain by thin deposits of soil. The rock fragments are chiefly Pahasapa limestone and a few scattered pieces of standstone from the Minnelusa formation.

The maximum thickness of the alluvium is not known but it may be as much as 30 feet in Hell Canyon south of Jewel Cave. At the test well, the Pahasapa limestone is overlain by 2½ feet of dark-red clayey soil containing many fragments of chert. The soil apparently is a product of residual weathering of the Pahasapa limestone combined with residual or slightly transported remains of the red shale of the Minnelusa formation.

FAULTING

A prominent fault crosses the monument about 1,500 feet north of the entrance to Jewel Cave. The fault begins in the Precambrian rocks to the east and extends westward to the west side of the monument, causing a pronounced offset in the escarpment. West of the monument the fault breaks into two diverging branches and disappears within a very short distance. Except for a gentle northward deflection along a distance of about half a mile, the fault trends nearly east-west across the monument.

U.S. Highway 16 follows the fault line from the escarpment to the east side of the monument and parallels cliffs of Pahasapa limestone that mark the edge of the upthrown fault block through most of this distance. South of the highway, along the downthrown block of the fault, the lower part of the Minnelusa formation lies opposite the upper part of the Pahasapa limestone. One mile west of the entrance to Jewel Cave the total displacement of the fault is about 120 feet (Darton and Paige, 1925, p. 18).

An interesting phenomenon observed during the reconnaissance of the surface geology was the scarcity of soil in Hell Canyon north of the fault. South of the fault the floor of Hell Canyon is covered with an estimated 6 to 10 feet of red clayey soil. North of the fault the alluvial fill is chiefly boulders and smaller fragments of limestone and little soil. It is not known if the soil has been removed by water moving down the valley and entering the fault or if limestone fragments are accumulating faster than soil can cover them.

Additional test drilling would be necessary to determine with certainty what effect the fault has on ground-water occurrence near Jewel Cave.

SPRINGS

In addition to the spring that furnishes the present water supply at Jewel Cave, three other springs, all outside the monument, were visited. Locations of the springs are shown on figure 25.

A spring in Hell Canyon about 1 mile north of the cave (SE¼NW¼NE¼ sec. 35, T. 3 S., R. 2 E.) supplied enough water in the late 1930's for a Civilian Conservation Corps camp in the canyon. Development of the spring consists of a concrete box about 5 feet square and 4 feet deep in an excavation at a seep in the bottom of the canyon. When the site was visited in May 1959, only about 2 inches of water covered the floor of the concrete box and no water was observed entering the box through the intake pipe about 6 inches above the floor. Whether enough water is now available at the site to again furnish a supply is unknown.

A second spring (NW¼SW¼SE¼ sec. 2, T. 4 S., R. 2 E.) about half a mile south of the entrance to Jewel Cave on the west side of Hell Canyon yielded about 1 gpm (gallon per minute) of potable water in May 1959. Visible development of the spring consists of

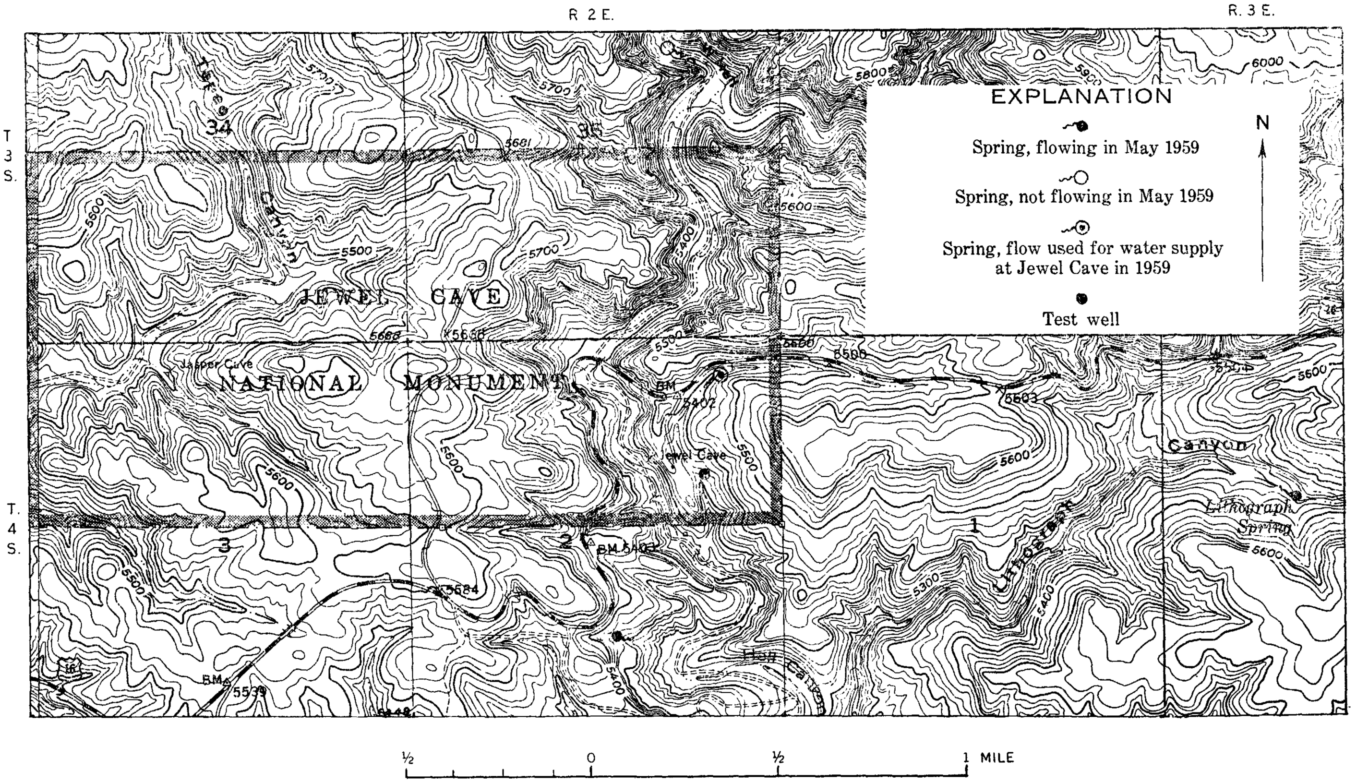

Figure 25.—Map of the Jewel Cave National Monument area, South Dakota, showing location of springs and test well.

a section of 1¼-inch pipe thrust into a seep on the side of the canyon. The pipe extends downhill to a stock tank about 20 feet east. Apparently much more water is escaping from the spring than issues from the pipe as the ground is waterlogged and soft in the floor of the canyon 150 feet below and 600 feet south of the spring.

The third spring (SW¼SE¼NW¼ sec. 6, T. 4 S., R. 3 E.), locally known as Lithograph Spring, is in Lithograph Canyon about 1¾ miles east of the entrance to Jewel Cave. The spring was yielding about half a gallon per minute when the site was visited in May 1959. A 1¼-inch pipe extends from a seep in the bottom of the canyon to a stock tank about 30 feet west and 4 feet lower than the seep.

Because of their distances from the monument facilities and their small yields, the springs are not considered to be potential sources of water supply for the monument.

RESULTS OF TEST DRILLING

On the basis of preliminary field investigations, a test hole was drilled in the NW¼SE¼NE¼ sec. 2, T. 4 S., R. 2 E. to determine the lithologic and water-bearing characteristics of the strata beneath the monument. Lack of subsurface information and other considerations indicated that the test hole might as well be close to the service area and be of sufficient diameter to permit finishing as a well in the event water-bearing rocks were penetrated. A test hole 8 inches in diameter and suitable for casing with heavy-duty 6-inch pipe was begun May 6, 1959, and completed on August 25, 1959, at a total depth of 700 feet. The location of the test well with respect to the service area is shown on figure 25.

The test hole penetrated 432.5 feet of Pahasapa limestone before reaching the underlying Englewood limestone. As revealed by the detailed long on page 151 the Pahasapa consists chiefly of finely crystalline to dense limestone and dolomite, and thin layers of chert and clay at irregular intervals. The 20 feet of clay and large calcite crystals in the interval 170 to 190 feet apparently represents a clay-filled extension of Jewel Cave.

Although some scattered intergranular porosity occurs in the limestone and dolomite of the Pahasapa, the formation contains very little water at the monument. The interval 390 to 400 feet supplied barely enough water (about 100 gallons in 12 hours) for the first drilling run each day.

From 435 to 475 feet the drill penetrated finely crystalline pink to maroon Englewood limestone. Virtually no porosity was observed in any of the cuttings from this interval, and the upper 10 feet of the formation contained appreciable red silt and clay. The Englewood limestone is not considered to be an aquifer at the site of the test hole.

Directly beneath the Englewood in the interval 475 to 485 feet, the drill penetrated 10 feet of clean white sandstone containing sand grains that were poorly sorted, and well rounded to subrounded. The upper few feet of the sandstone was coarser grained and softer than the lower; consequently, drilling progress was more rapid in the upper part than in the lower.

A significant amount of water entered the hole from this 10-foot sandstone interval. After standing overnight, the measured static water level was 389.6 feet. After the sandstone had been completely penetrated at 485 feet, the hole was bailed for 44 minutes at an average rate of about 12.5 gpm with a maximum drawdown of about 87 feet. The water level at the end of 44 minutes of bailing was about 476 feet. Fifteen minutes after bailing stopped the water level had recovered to 423 feet.

Before the bailing test was started a sample of water was tested for pH, iron, chloride, and hardness with a water-testing kit designed for field use. Results of the testing are approximate and are as follows:

pH		7
Fe	ppm	.5
Cl	do	25
Hardness	do	240

In the interval 485 to 665 feet the drill penetrated 180 feet of dolomite, siltstone, limestone, and sandstone comprising the Deadwood formation. The uppermost 115 feet of the Deadwood consists of brown and green limestone and dolomite with siltstone at 500 and 575 feet. No porosity was observed in any samples of limestone and dolomite of the Deadwood and they apparently contained little or no water.

The lower part of the limestone in the Deadwood was very compact at 593 feet as indicated by the description of the sample from this depth. The driller reported drilling through a "boulder" from 593 to 595 feet.

The upper 5 feet of the sandstone section of the lower part of the Deadwood was also hard and apparently was not water bearing. Of the 65 feet of sandstone in the lower part of the Deadwood only about 15 to 20 feet appeared clean and permeable enough to yield water. The samples from the sandstone intervals 630 to 635 feet and 640 to 650 feet were moderately clean and moderately well cemented; most of the water yielded by the Deadwood formation probably entered the hole from these two intervals.

After the entire thickness of the Deadwood formation had been penetrated at 665 feet, test drilling was continued for an additional 35 feet into the underlying Precambrian quartz-biotite schist. This schist is compact and, with the exception of the upper few feet which is generally weathered, is not an aquifer.

Upon completion of the test hole, a second bailing test was made. The static water level at the beginning of the test was about 390 feet, about the same as that for the sandstone at 475 to 485 feet. Thus, leakage from one zone to another probably is insignificant. After bailing for 70 minutes at an average rate of 14 gpm the water level was about 500 feet; a drawdown of about 110 feet. Because of the wet condition of the hole and the relatively great depth to water, accurate measurements of the water level during recovery were not possible. Measurement by use of the bail line, however, indicated that recovery was slow. About 20 hours was required for the water level to recover to 390 feet.

The test hole was cased with 700 feet of 6-inch (outer diameter) heavy-duty pipe. Slots were cut in the pipe in a regular pattern and were set opposite the sands at 475 to 485 feet and 605 to 665 feet. In order not to miss any possible thin water-bearing strata the casing was perforated from 475 to 495 feet and from 605 to 670 feet. Perforations were thus set opposite the uppermost 5 feet of Precambrian schist and all except the uppermost 5 feet of the sandstone in the lower part of the Deadwood formation. The casing was not perforated opposite the minor water-bearing zone in the Pahasapa limestone at 390 to 400 feet.

After the test well was completed, a cylinder pump was inserted in the well. During September 22–26, 1959, the well was tested at different pump settings for short intervals at rates that ranged from 10 to 26 gpm. The longest period of pumping that the contractor was able to maintain was 18 hours beginning at 5:35 p.m. on September 25. During this period the pumping rate ranged from 13 to 20 gpm and averaged 16 gpm. Drawdown and recovery data, necessary to predict a sustained yield for the well, were not obtainable because access to the water surface was prevented by the pump rods.

SUMMARY OF GROUND-WATER CONDITIONS

None of the streams within the monument are perennial and the possibility of finding substantial amounts of water in the valley alluvium does not seem favorable. The alluvium consists chiefly of fragments of Pahasapa limestone, with a few scattered pieces of sandstone from the Minnelusa formation, covered by a variable thickness of red clayey soil. Maximum thickness of the alluvium is unknown but may be as much as 30 feet in Hell Canyon south of Jewel Cave.

The problem of finding water at shallow depths in the alluvium in Hell Canyon is complicated by the presence of the large fault about 1,500 feet north of the cave. Effects of the fault on ground-water occurrence can be determined only by test drilling but there is a possibility that the fault intercepts water moving down the canyon from the north. If this is true, little water may be expected in the alluvium in Hell Canyon south of the fault near Jewel Cave.

Only one spring has been observed within the boundaries of the monument. The spring is well developed and the yield of about 2 gpm is believed to be the maximum yield that can be economically obtained. With very little effort, however, the spring could be maintained as a source of supply.

Three other springs were visited during the study; 1 was not flowing when visited and the other 2 had a combined yield of less than 2 gpm. These springs are too far from Jewel Cave and their yields are too low for them to be a suitable source of water supply.

The sandstone zones of the Minnelusa formation are excellent aquifers west of the monument where the formation is deeply buried. However, within the monument the thin remnants of the formation that cap the higher ridges probably contain only minor amounts of water. Near Jewel Cave on the east side of the monument, faulting combined with dissection of the formation by the Hell Canyon drainage system, has divided the formation into blocks of limited extent. It is doubtful that much water will be found in the formation near Jewel Cave.

Because the Pahasapa limestone is permeable and the upper 150 feet is cavernous, the water level in the formation is usually well below the outcrop area. West of the monument the formation is an excellent aquifer but within the monument boundaries, the extensive exposures of the formation indicate that it contains little if any water. Test drilling at Jewel Cave revealed only a small amount of water in the lower part of the Pahasapa limestone in the immediate vicinity of the cave.

The Pahasapa limestone is underlain by 40 feet of Englewood limestone. Generally the Englewood is moderately permeable but is rarely jointed or cavernous. These characteristics, and the fact that no water was found when the formation was penetrated by the test drill, indicate that the Englewood probably is not an aquifer in the vicinity of the monument.

The 10 feet of clean white sandstone immediately below the Englewood limestone and the sandstone section of the lower part of the Deadwood formation seem to offer the best possibilities for the development of permanent water supplies at the monument. Results of test drilling and bail tests indicate that the sandstone just below the Englewood limestone is the most productive aquifer penetrated.

The sandstone below the Englewood is separated from the sandstone section of the Deadwood by 115 feet of limestone, dolomite, and siltstone of the Deadwood formation. Samples obtained by test drilling indicate that 15 to 20 feet of the 65 feet of sandstone in the lower part of the Deadwood is sufficiently permeable to yield a significant amount of water. Combined yields of all the sandstones may be expected to be small and pumping lifts will undoubtedly be large.

CONCLUSIONS

Formations underlying Jewel Cave National Monument are not sufficiently permeable to yield abundant supplies of ground water. However, the 75 feet of water-bearing sandstones penetrated by the drill at depths of 475 to 485 feet and 600 to 665 feet are apparently capable of yielding 15 to 18 gpm for a short time. Other wells, drilled as far from the test well as practical, will furnish additional water if future demands exceed the output of the test well.

LOG OF TEST WELL

Jewel Cave National Monument test well, NW¼SE¼NE¼ sec. 2, T. 4 S., R. 2 E., Custer County, S. Dak. Drilled 1959. Altitude about 5,340 feet above mean sea level.

Material	*Thickness (feet)*	*Depth (feet)*
Quaternary system:		
Recent series:		
No sample, soil and broken rock	2.5	2.5
Mississippian system:		
Pahasapa limestone:		
Limestone, finely crystalline to dense, yellow-brown, gray to nearly white with gray chert	2.5	5
Limestone, same as unit above; with much gray chert	5	10
Limestone, very finely crystalline to dense, mottled red-brown, light-gray to white	5	15
Limestone, very finely crystalline to dense, mottled-red and gray to nearly white	3	18
Limestone, very finely crystalline to dense; with few pieces dense, buff limestone	3	21
Limestone, dense to finely crystalline, buff to nearly white	4	25
Limestone, dense to finely crystalline, mottled red and white to white	5	30
Limestone, dense to finely crystalline, white	5	35

Material	*Thickness (feet)*	*Depth (feet)*
Mississippian system—Continued		
Pahasapa limestone—Continued		
Limestone, dense to finely crystalline, with faint-pink tint	5	40
Limestone, finely crystalline, white to pale-yellow and faintly pink	5	45
Limestone, finely crystalline, white	5	50
Limestone, finely crystalline, white and very faintly pink	5	55
Limestone, same as unit above	5	60
No sample	5	65
Limestone, dense to finely crystalline, pale-brown and light-orange to nearly white	5	70
Limestone, finely crystalline to dense, light-olive, pink to nearly white	5	75
Limestone, finely crystalline to dense, light-gray and buff	5	80
Limestone, dense, buff to mottled-gray	5	85
Limestone, same as unit above	5	90
Limestone, dense to very finely crystalline, buff, with cleaved calcite rhombohedrons	5	95
Limestone, very finely crystalline, buff to pale-pink	5	100
Limestone, very finely crystalline, pink-gray to nearly white	5	105
Limestone, very finely crystalline, pink, pale-brown to nearly white	5	110
Limestone, dense, pale-brown mottled with orange	5	115
Limestone, dense to medium crystalline, white and pink; with much cleaved calcite	5	120
Limestone, fine to medium crystalline, pink and white	5	125
Limestone, finely crystalline, faint-pink and light-gray	5	130
Limestone, finely crystalline, white to faintly pink	5	135
Limestone, finely crystalline, white	5	140
Limestone, medium to coarsely crystalline, pale-yellow to white	5	145
Limestone, finely crystalline to dense, pale-yellow-brown to white	5	150
Limestone, finely crystalline to dense, with pink tint	5	155
Limestone, finely crystalline, pink to nearly white	5	160
Limestone, medium crystalline to dense, buff, pink, and white	5	165
Limestone, medium crystalline to dense, mostly buff	5	170
Clay, yellow-brown, calcareous; containing many large clear pieces of cleaved calcite; a few angular pieces of finely crystalline buff limestone	5	175
Clay, yellow-brown, calcareous; containing some pieces cleaved calcite three-fourths of an inch in longest dimension	5	180

Material	*Thickness (feet)*	*Depth (feet)*
Mississippian system—Continued		
Pahasapa limestone—Continued		
Clay, yellow-brown, calcareous; containing small amount black earthy MnO_2	5	185
Clay, yellow-brown, calcareous; containing a few pieces yellow or white decomposed limestone and much calcite	5	190
Limestone, medium to finely crystalline, buff and pink; with cavings of cleaved calcite	5	195
Limestone, medium to finely crystalline to dense, pink, brown, and gray to nearly white; with a few pieces showing dentrites of MnO_2; cleaved calcite as above	5	200
Limestone, coarse to finely crystalline, red, pink-gray and buff; with much light and dark gray-brown chert	5	205
Limestone, finely crystalline, pink, buff and nearly white; showing dendrites of MnO_2, and much chert as above	5	210
Limestone, coarse to finely crystalline, pink, buff, and gray; with much chert and cleaved calcite	5	215
Limestone, medium crystalline to dense, pink, buff to nearly white with light-gray and brown chert	5	220
Limestone, medium crystalline to dense, light-yellow-gray and pink; containing nearly white clay	5	225
Limestone, coarsely crystalline to dense, pink, light-yellow-gray and gray; with chert as above	5	230
Limestone, dense, light-gray spotted with black MnO_2, dolomitic in part; with chert	5	235
Limestone, dense; containing veinlets of calcite	5	240
Limestone, coarsely crystalline, light-yellow-gray and pink	5	245
Limestone, coarsely crystalline; containing small hematite-filled vugs, very porous	5	250
Limestone, coarsely crystalline, slightly porous	5	255
Limestone, coarsely crystalline; with light-brown to nearly white chert	5	260
Dolomite, coarsely crystalline, sugary textured, buff with spots of MnO_2	5	265
Dolomite, coarsely crystalline, with pink tint and tan to white chert, some intergranular porosity	5	270
Dolomite, coarsely crystalline (sample was overwashed)	5	275
Dolomite, coarsely crystalline, pink and yellow-gray, spotted with MnO_2 as in unit above	5	280
Dolomite, coarsely crystalline; containing few clear calcite rhombohedrons	5	285

Material	*Thickness (feet)*	*Depth (feet)*
Mississippian system—Continued		
Pahasapa limestone—Continued		
Dolomite, coarsely crystalline, light-gray to white with pink tint	5	290
Dolomite, coarsely crystalline, white and pink, intergranular porosity	5	295
Dolomite, same as unit above	5	300
Dolomite, medium crystalline, buff to pink	5	305
Dolomite, coarse to medium crystalline, buff to gray with brown clay	5	310
Dolomite, medium to finely crystalline, brown and gray with strong pink tint	5	315
Dolomite, coarst to medium crystalline, pink, buff, gray and white	5	320
Dolomite, coarse, gray and white; containing much red-brown and yellow calcareous clay and black earthy MnO_2	5	325
Limestone, finely crystalline to dense, dirty-gray, mottled-brown; containing veinlets of calcite; dolomitic in part	5	330
Limestone, finely crystalline to dense, mottled buff and pink	5	335
Limestone, dense, yellow-gray with faint-pink tint, earthy	5	340
Limestone, dense, buff to nearly white, dolomitic	5	345
Limestone, dense; much yellow-brown clay containing small calcite crystals; dolomitic	5	350
Limestone, dense, dolomitic; clay as above	5	355
Limestone, finely crystalline to dense, medium-yellow-gray to brown, with MnO_2; much calcite in small masses of crystals cemented with limonite	5	360
Dolomite, medium to coarsely crystalline, light-gray-brown and pink	5	365
Dolomite, fine to medium crystalline, tan with faint-pink tint	5	370
Dolomite, same as unit above	5	375
Dolomite, fine to medium crystalline, tan and white	5	380
Limestone, finely crystalline, pale-brown, dolomitic	5	385
Dolomite, finely crystalline, pale-brown with pink tint	5	390
Dolomite, coarsely crystalline, buff, intergranular porosity	5	395
Dolomite, coarsely crystalline, buff and orange, intergranular porosity	5	400
Dolomite, medium to coarsely crystalline, buff	5	405
Dolomite, medium to coarsely crystalline, pale-buff-orange and light gray	5	410
Dolomite, coarsely crystalline, buff, orange and gray	5	415
Dolomite, coarsely crystalline to dense, buff to mottled pink-gray	5	420
Dolomite, same as unit above	5	425

Material	Thickness (feet)	Depth (feet)
Mississippian system—Continued		
Pahasapa limestone—Continued		
Dolomite, medium crystalline, uniform light-yellow-gray	5	430
Dolomite, medium to coarsely crystalline, buff to orange, stained with iron oxides	5	435
Englewood limestone:		
Limestone, finely crystalline, pink to dark-red-brown, silty	5	440
Limestone, very finely crystalline to dense, pink-gray and maroon; containing much red clay	5	445
Limestone, very finely crystalline, gray and maroon; containing small amount of hematite	5	450
Limestone, same as unit above	5	455
Limestone, finely crystalline, buff, mottled-pink, pink and white	5	460
Limestone, same as unit above	5	465
Limestone, finely crystalline, uniform light-pink-gray to mottled-pink and gray	5	470
Limestone, finely crystalline, pink-gray strongly spotted with red	5	475
Ordovician system(?):		
Sand, medium to very coarse, subrounded to well-rounded frosted grains, white, poorly sorted	5	480
Sand, medium to very coarse, subrounded to well-rounded grains, white	5	485
Cambrian system:		
Deadwood formation:		
Dolomite, finely crystalline, buff, pink, and red-brown, silty, argillaceous	5	490
Dolomite, same as unit above	5	495
Dolomite, same as unit above; cavings of sand from 475 to 485	5	500
Siltstone, green; containing red clay and finely crystalline red-brown dolomite	5	505
Dolomite, fine to medium crystalline, red-brown to nearly white, silty, glauconitic	5	510
Dolomite, coarsely crystalline, pink, red and white, glauconitic; containing schist fragments	5	515
Dolomite, coarsely crystalline, pink and gray, very glauconitic; with a few fragments of siltstone	5	520
No sample	5	525
Limestone, coarsely crystalline, red, pink, gray and brown, glauconitic; with gray, brown, and green siltstone	5	530
Limestone, coarsely crystalline, pink, red and white	5	535
Limestone, same as unit above	5	540
Limestone, same as unit above, with green and red-brown siltstone	5	545

Material	Thickness (feet)	Depth (feet)
Cambrian system—Continued		
Deadwood formation—Continued		
Limestone, coarsely crystalline, red-brown, gray and white, very glauconitic	5	550
Limestone, same as unit above; containing embedded mica flakes and siltstone as above	5	555
Limestone, medium crystalline, red-brown to white, argillaceous	5	560
Limestone, same as unit above	5	565
Limestone, same as unit above, very argillaceous	5	570
No sample	5	575
Siltstone, brown and green with limestone cavings	5	580
Limestone, finely crystalline, white to mottled-gray and red	5	585
Limestone, coarsely crystalline to dense, red-brown, green, and gray, glauconitic; with green, gray, and red-brown calcareous siltstone	5	590
Limestone, coarsely crystalline, yellow-brown, red, pink and white, very glauconitic	3	593
Limestone, coarsely crystalline, green and gray, dolomitic, very glauconitic, hard (catch sample)	----	593
Limestone, same as unit above	2	595
Limestone, same as unit above, sandy	5	600
Sandstone, fine, quartzitic and iron-stained, pink, brown and white	2	602
Sandstone, medium, quartzitic, iron-stained, hard (catch sample)	----	602
Sandstone, fine, quartzitic and iron-stained	3	605
Sandstone, fine to medium, glauconite, quartzitic in part	5	610
Sandstone, fine to medium, very glauconitic; a few grains slightly coated with iron oxides	5	615
Sand and some sandstone, fine to coarse, white and brown; containing glauconite and pyrite	5	620
Sandstone, fine, quartzitic	5	625
Sandstone, very fine to fine, white, tight	5	630
Sand, medium to coarse, subrounded to well-rounded frosted grains	5	635
Sandstone, very fine to fine, quartzitic	5	640
Sand, medium to very coarse, well-rounded, white, pink, gray; frosted grains; clean	5	645
Sand, same as unit above; with trace of fine quartzitic sandstone	5	650
Sand, medium, angular to subrounded, white, gray and pink	5	655
Sand, same as unit above; containing quartz; minute flakes of mica, top Precambrian(?)	5	660
Sand, same as unit above; mica flakes(?)	5	665

Material	Thickness (feet)	Depth (feet)
Precambrian system:		
No sample; weathered quartz-biotite schist(?)	5	670
Quartz-biotite schist, unweathered	5	675
Same as unit above	25	700

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