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GEOLOGICAL SURVEY
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Geology and availability of ground water in the vicinity of Gila Cliff Dwellings National Monument, Catron County, New Mexico

By
Frederick D. Trauger

Prepared in cooperation with
the United States National Park Service

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Abstract

The four geologic units exposed in the vicinity of the Gila Cliff Dwellings National Monument are, from oldest to youngest: 1) Rhyolite tuffs and interbedded sandstones of the Datil Formation of Tertiary age; 2) Basalt and basalt-andesite of Tertiary age; 3) The Gila Conglomerate of Tertiary and Quaternary age; and 4) Alluvial deposits of Recent age. The rhyolite tuffs and sandstones of the Datil Formation are mostly dense and are not good aquifers. The basalt is almost everywhere intricately jointed and locally vesicular and zeolitic. It should yield moderate amounts of water where it occurs below the regional water table. The Gila Conglomerate is dense and moderately well to well consolidated. It is not a good aquifer because of the poor sorting and strong cementation. The alluvial deposits in the river valleys range from clay and silt to bouldery gravel. They are saturated with water and constitute the only sure source of an adequate water supply.

Fluoride concentrations in excess of permissible limits were found in thermal spring waters in the area. Non-thermal well and spring waters sampled contained fluoride in permissible concentrations and the waters were also acceptable with respect to other minerals.

An adequate supply of ground water can be developed from one-or-more of the rock units at each of the six locations examined for the proposed joint Forest Service-Park Service headquarters.

Introduction

The National Park Service in cooperation with the U.S. Forest Service plans to construct a joint administrative headquarters and public facilities in the vicinity of the Gila Cliff Dwellings National Monument, southeastern Catron County, N. Mex., (fig. 1). An integral

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Figure 1.--Aerial mosaic and overlay of the Gila Cliff Dwellings National Monument and environs, Catron County, N. Mex.

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part of the plan is the development of an adequate supply of potable water. An investigation of the geology and water resources in the vicinity of the monument was made in July, 1962, at the request of the Regional Director, ~~Region Three~~ Southwest Region, National Park Service, to determine if an adequate supply of potable ground water could be obtained in the area, and in particular at two sites designated by the Park Service--the T. J. Ruins area and the vicinity of Doc's Cienaga (fig. 1).

Conclusions given in this report are based on available geologic maps, on observations made in the field, on air photos, and on the results of chemical analyses of samples of water collected from streams, springs, and wells in the area. The "Reconnaissance geologic map of the Alum Mountain thirty-minute quadrangle," by Max E. Willard, Robert H. Weber, and Frederick J. Kuellmer, New Mexico Institute of Mining and Technology, 1961, was used as the basis for distinguishing geologic units. Township, range, and section lines indicated on the overlay to fig. 1 are approximate and were taken from the Forest Service "Hunters' map, Gila Wilderness Area," (1961). Section lines on the geologic map (Willard and others, 1961) were taken from the old state highway maps and are not in accordance with recently recovered corners in the vicinity of the monument. Air photographs were obtained from the U.S. Forest Service regional office, Albuquerque, N. Mex.

Rock units and their water-bearing characteristics

The rocks exposed in the walls of the canyons and on the slopes of the hills in the vicinity of the Gila Cliff Dwellings are either volcanic rocks or sedimentary rocks derived from volcanic rocks. They are all of Tertiary or Quaternary age.

Four geologic units are exposed in the area. These are from oldest to youngest: 1) A sequence of rhyolite tuffs and interbedded sandstones belonging to the Datil Formation of Tertiary age; 2) a thick sequence of basalt and basaltic-andesite rocks also of Tertiary age; 3) the Gila Conglomerate which unconformably overlies both the tuff and the basaltic rocks--the lower part of the Gila is of Pliocene (Tertiary) age and the upper part is of Pleistocene (Quaternary) age; 4) alluvial deposits of Recent age which underlie the floors of the river valleys and form a veneer on some terraces and upland plains.

Datil Formation.--Beds of the Datil Formation consisting of white to light-colored rhyolite tuff that contains much crystalline material, and interbeds of pumiceous sandstone and conglomerate are exposed in the north walls of the canyon at river level in the NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 22, T. 12 S., R. 14 W. (fig. 1). The tuff at that point has a gentle easterly dip; a short distance to the east it passes below the level of the valley floor and is covered by younger rocks. Rhyolite flows, not exposed in the immediate area, underlie the tuff. Rhyolite flows commonly are jointed, and rubbly zones may occur locally within flows and between individual flows.

The tuffaceous sequence generally is massive, but locally it is crudely stratified (fig. 2). The interbeds of sandstone and conglomerate

Figure 2.--Rhyolite tuff and interbedded tuffaceous sandstone and conglomerate of the Datil Formation unconformably overlain by the Gila Conglomerate. NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 22, T. 12 S., R. 14 W.

are mostly thin, poorly sorted, and composed of volcanic materials. Willard and others (1961) found in the sequence welded tuffs that locally exhibit pronounced columnar jointing. Both the thickness of the sequence and the character of the materials change laterally within short distances.

The rocks of the tuffaceous sequence are fine-grained and dense and are not a good potential source of water. The tuffs and the rhyolite rocks may yield adequate water to domestic and stock wells where joints are well developed or where rubble zones occur in the flows, but the occurrence of joints or rubble zones is unpredictable.

Basalt and basalt-andesite.--The basalt and basalt-andesite rocks are mostly black to medium-gray, purplish-gray, and locally reddish brown, dense to vesicular, fine-grained to porphyritic flows and flow breccias (Willard and others, 1961). Amygdaloidal structure is conspicuous locally; most of the amygdules are zeolitic (fig. 3). Joints in the basaltic rocks

Figure 3.--Amygdaloidal basalt; vesicles filled with zeolites. Matrix is typically reddish brown. SW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 12 S., R. 13 W.

are well-developed, closely spaced, and intricate. No columnar joints or well-defined sheet joints were observed in the vicinity of the ruins or the proposed administrative sites. Because it is not generally possible to determine macroscopically if these rocks are basalt or andesite, or gradations between, they will hereafter be referred to as basalts.

About 200 feet of basalt is particularly well exposed in the canyon of the Middle Fork of the Gila River from half a mile to one mile above the junction with the West Fork (fig. 4).

Figure 4.--North wall of the canyon of the Middle Fork of the Gila River, opposite Boundary Hot Spring. Rimrock is dense gray basalt underlain by buff sandstone (slope) and conglomerate (light colored cliff-rock) of Gila Conglomerate. Reddish to dark-gray intricately jointed basalt underlies the Gila. SW$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 24, T. 12 S., R. 14 W.

Several flows, all intricately jointed, can be seen in the canyon wall. The intricate close-jointed structure and intense zeolitic development are both conspicuous in the east wall of the canyon at the river crossing in the SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 24, T. 12 S., R. 14 W. (fig. 5a, b).

Figure 5a.--Reddish-brown basalt, intricately jointed, showing intense zeolitic zone, inflation pipe, and crude pillow structure.

5b.--Non-oriented intricate joint structure in the basalt at left in a. Dense basalt phase contiguous with highly vesicular phase. Base of canyon wall, east side of river, at trail crossing, SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 24, T. 12 S., R. 14 W.

The closely-spaced joints and the locally well-developed vesicularity in the basalt and basaltic-andesite sequence greatly enhance their ability to transmit and store water. Where the basalt is below the regional water table, generally at or a little above river-level, it should yield enough water to meet the needs of the proposed development. Rubble zones between basalt flows may yield appreciable amounts of water if the flows themselves are dense and do not have open joints or interconnected vesicles.

Faulting in the area has fractured the basaltic rocks locally, thereby increasing their water-storage capacity and ability to transmit water. However, increased transmissibility and capacity for storage cannot be expected to extend more than several hundred feet from the fault plane.

Gila Conglomerate.--The Gila Conglomerate is a thick sequence that was derived locally and deposited on the eroded surface of older rocks. The formation contains gray to buff beds of clay, silt, sandstone, conglomerate, and rhyolite tuff. Basalt flows are interbedded with the sediments and basalt occurs locally as dikes and sills.

The sediments in general are poorly sorted, dense, massive to well bedded, and moderately well to very well consolidated (fig. 6a, b).

Figure 6a.--Gila Conglomerate showing well-defined bedding and strong cementation.

6b.--Large boulders of dense hard volcanic rock in matrix of tuffaceous sandstone and smaller rocks. Terrace slope, $SW\frac{1}{4}SE\frac{1}{4}NW\frac{1}{4}$ sec. 25, T. 12 S., R. 14 W.

A few of the sandstone beds contain some carbonate but the principle cementing agent is silica.

Basalt flows interbedded with the sediments are likely to be jointed and to have scoriaceous and rubbly zones at the base. However, dikes and sills such as those observed near the junction of the West Fork and Middle Fork of the Gila are dense and do not have pronounced joint structure or scoriaceous zones.

The basalt rimrock at the top of the cliffs (fig. 4) is underlain by conglomerate and also overlain by conglomerate a short distance back from the rim. The contacts with the overlying and underlying conglomerate are concealed but the basalt is believed to be the same basalt that is exposed at river level below the T. J. Ruins, and there the contact shows the basalt to be intrusive into the conglomerate.

The Gila Conglomerate forms the prominent bluffs that border the river at the junction of the West Fork and the Middle Fork of the Gila River (fig. 7). Characteristic and prominent features of the Gila

Figure 7.--Gila Conglomerate exposed in bluffs on west side of the Middle Fork of the Gila River, at the junction with the West Fork. Differential erosion and weathering has etched the face of the bluffs and accentuated the bedding planes. The valley floor is underlain by alluvial fill to a depth of 30 to 50 feet. NW$\frac{1}{4}$ sec. 25, T. 12 S., R. 14 W.

Conglomerate in this region are the caves and holes in the bluffs and cliffs, such as the caves in which the Gila Cliff Dwellings were constructed. The larger caves and over-hanging ledges were formed primarily by the abrasive action of streams working laterally against the canyon walls at the time the stream bed was at the particular cave or ledge level; the softer beds in the conglomerate eroded more rapidly than the harder beds. Smaller holes, pits, and ledges are being developed presently on the faces of the cliffs by the erosion of softer beds by wind and by the wedging effect of ice when moisture around the grains of sand and larger fragments freezes. A hole may be started when a large boulder or rock fragment weathers out of the cliff.

The rocks of the Gila Conglomerate in general are not good aquifers because of the poor sorting and the moderate to strong cementation which has greatly reduced the porosity and water-transmitting capability of the beds. Scoriaceous facies and rubble zones in interbedded basalt flows may contain water locally, but the Gila generally occurs above the river level and therefore above the regional water table.

Alluvial deposits.--Alluvium occurs as unconsolidated fill in all the stream valleys and channels, and as veneer gravel on some of the terraces bordering the main streams. The unconsolidated deposits in the main valleys are derived from the older rocks and they range from clay and silt to bouldery gravel. The Gila River is an actively downcutting stream, and, as a result, the alluvial deposits in the valley are thin. The thickness of the alluvium ranges from a few feet along the smaller streams to 50 feet or so in the larger valleys. The average thickness in the larger valleys is probably about 30 feet. A well at the New Mexico Department of Game and Fish Gila headquarters in the NE$\frac{1}{4}$SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 25, T. 12 S., R. 14 W. (fig. 1) is 35 feet deep in alluvium, which probably is the total thickness of the alluvium at that point.

The alluvial fill in the stream valleys, particularly along the main branches of the Gila River, is saturated with water to the river level and in some places slightly above. The alluvium possibly is the only reliable source of potable water in the area.

The depth to water in the well at the Game and Fish headquarters is reported to range from 6 feet in late spring to about 11 feet in winter. The potential yield of the well is not known but it is reported to have always provided adequate supplies of water for the two houses at the headquarters, numerous stock, and a vegetable garden.

Water levels in the alluvial reservoir decline during dry periods of the year and rise in response to seasonal precipitation and stream runoff. The alluvial reservoir is replenished during the spring runoff, and during the mid-summer rainy season.

Quality of water

Chemical constituents other than fluoride were not present in quantities that would make the water sampled unsatisfactory for domestic, stock, or irrigation use. An analysis of water from the well at the Game and Fish headquarters (table 1) shows a total dissolved solids concentration of only 156 ppm (parts per million) and none of the constituents are disproportionately high. The fluoride concentration was 0.9 ppm -- a concentration about optimum, according to the Public Health Service (1962), for an area having an annual average maximum daily air temperature in the range 70.7°F to 79.2°F. The annual average maximum daily air temperatures at Gila Hot Springs according to the records of the State Climatologist, (oral communication, 1962) is about 72°F. The water from Cold Spring, at the monument, contained only 199 ppm total dissolved solids but the concentration of fluoride was 1.4 ppm which is slightly above the upper limit of 1.0 ppm recommended by the Public Health Service for the local air temperatures, but not high enough to cause the water to be rejected for public supply.

Some of the ground water in the area contains fluoride in concentrations detrimental to health if used for prolonged periods, according to Public Health Service standards (1962). However, high concentrations of fluoride can be removed by economical processes to make water potable. A high fluoride content is harmful in water only when the water is ingested.

Unusually high concentrations of fluoride occur in the water from Gila Hot Springs (6 miles east of study area) and Boundary Hot Spring (SE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$, sec. 24, T. 12 S. R. 14 W.) which is about 0.6-mile northeast of the proposed administrative site in sec. 25 (table 1). Other thermal waters in the region outside the immediate area of this investigation also contain large concentrations of fluoride. If thermal water is found in any wells drilled in the area the water probably will contain large concentrations of fluoride.

Table 1.--Chemical analyses of water from wells and springs near Gila

Cliff Dwellings National Monument, Catron County, N. Mex.

Analyses by Geological Survey, United States Department of the Interior

9-268 q (parts per million)

Location number	12.14.24.442	12.14.25.342	12.14.27.224	13.13.5.241		13.13.10.121
Date of collection	7-24-62	7-22-62	7-17-62	7-25-62	6-23-57	6-23-57
Silica (SiO_2)	81	31	35	68	33	
Aluminum				.31		
Iron (Fe)	.00	.00	.00	.00	.04	
Manganese (Mn)	-	-	-	.00		
Calcium (Ca)	16	26	36	12	11	
Magnesium (Mg)	.5	5.1	3.4	0	.2	
Sodium (Na)	} 148	} 11	} 22	121	} 129	
Potassium (K)				3.6		
Lithium (Li)				.03		
Bicarbonate (HCO_3)	128	90	152	106	109	108
Carbonate (CO_3)	0	0	0	0	0	0
Sulfate (SO_4)	79	20	17	45	40	22
Chloride (Cl)	107	5.1	4.8	102	104	59
Fluoride (F)	9.5	.9	1.4	9	12	
Nitrate (NO_3)	.4	6.3	.1	.7	.5	
Boron (B)					.07	
Dissolved solids						
Calculated	504	149	195	414	-	
Residue on evaporation at 180°C	505	156	199	421	369	
Hardness as $CaCO_3$	42	86	104	30	28	15
Noncarbonate hardness as $CaCO_3$	0	12	0	0	0	0
Alkalinity as $CaCO_3$						
Specific conductance (micromhos at 25°C)	767	219	289	638	653	432
pH	7.8	7.0	7.0	7.5	8.2	8.1
Color						
% Sodium	88	21	32	88	91	
Temperature, °F	141			147	147	126

12.14.24.442.--Boundary Hot Spring, flow estimated at 5 gpm.
12.14.25.342.--Dug well at New Mexico Dept. of Game and Fish headquarters place.
12.14.27.224.--Cold Spring, Cliff Dweller Canyon, flow 2 gpm.
13.13.5.241 .--Gila Hot Spring, aggregate flow about 100 gpm from many orifices.
13.13.10.121.--Hunting Lodge Hot Spring, flow estimated at 10 gpm.

The occurrence of thermal water containing fluoride is almost certainly the result of intrusive or volcanic activity in the rocks underlying the area. Hydrothermal fluorite deposits are common in southwestern New Mexico. Northrop (1959, p. 239) cites numerous localities in the Mogollon Mountains in Catron and Grant Counties where fluorite is found. The fluorite is found mostly as veins filling fractures associated with faults in areas where volcanic and intrusive activity has occurred. Gila Hot Springs and Boundary Hot Spring are close to major faults, and the Gila Conglomerate has been intruded by basalt in the vicinity of the proposed administrative site.

Ground water in the alluvium generally does not contain objectionable amounts of fluoride, except possibly near where thermal water is discharging into the alluvium, such as in the vicinity of Boundary Hot Spring.

Whether the basaltic rocks will yield water of high fluoride content will depend on the source of the water. The water likely will be chemically potable without treatment if recharge is mainly by stream flow or directly from precipitation on nearby land surfaces. The fluoride content probably will be high if an appreciable amount of the recharge is from thermal water.

Occurrence of ground water at selected sites

Six locations in the vicinity of the Gila Cliff Dwellings were examined as possible sites for development of a supply of ground water suitable for domestic use and public supply. The question of the locations with respect to monument, forest, and wilderness boundaries was not considered. State-owned lands were excluded from consideration. The six locations (fig. 1) are: Site A, T. J. Ruins area; Site B, Scorpion Corral area; Site C, Visitor Center (mouth of Cliff Dweller Canyon); Site D, Doc's Cienaga area; Site E, Pine Flat (Grudging's Cabin) area; and Site F, Pine Terrace area.

Sites A and F are on high ground bordering the Middle Fork and West Fork of the Gila River, respectively. Sites B, C, D, and E are on the flood plain of the West Fork and are subject to innundation in times of flood. Abandoned channels and cut-away banks on the valley floor show that in times of flood the river may take any course across the valley floor cutting new channels and abandoning old channels.

Site A, T. J. Ruins area.--A six-level system of stream terraces (fig. 1) has been cut by the Middle Fork of the Gila River, in the central part of sec. 25, T. 12 S., R. 14 W., just north of the junction with the West Fork. The Middle Fork has truncated all the terraces on the north and west and has exposed the rocks underlying the terrace levels.

The fifth terrace extends over an area of about 10 acres and is the proposed site for construction of the joint headquarters for the U.S. Forest Service and National Park Service. The proposed site is immediately west of and on the downthrown side of a northwest trending fault having a displacement of several hundred feet.

The surface of the fifth terrace is about 100 feet above the present level of the river, and is underlain by a veneer of uncondolidated gravel left by the river when the terrace was cut. Beds of the Gila Conglomerate (fig. 6) underlie the veneer of gravel to a depth of about 25 feet. Below these beds is a hard, dense, gray basalt sill in the Gila that may be as much as 75 feet thick. This rock extends down to river level and is exposed along the river at the foot of the slope up to the terraces. The base of the gray basalt is not exposed. The basalt probably is equivalent to the approximately 75 feet of gray basalt interbedded with the sandstone and conglomerate that is exposed in the cliffs high up on the canyon wall to the northeast, on the upthrown side of the fault.

The base of the gray basalt under the terraces is likely to be at or only slightly below the level of the river if the basalt is about the same thickness there as in the cliff exposure.

About 100 feet of tuffaceous sandstone and conglomerate of the Gila Conglomerate underlies the gray basalt exposed in the cliffs of the canyon, and an approximately equal thickness may be assumed to underlie the basalt exposed along the base of the terraces. About 200 feet of the reddish, intricately jointed basalt also may be assumed to underlie the lower part of the Gila Conglomerate in the vicinity of the terraces.

A well drilled at the north end of the fifth terrace would penetrate, from the top down, approximately 25 feet of consolidated tuffaceous sandstone and gravel, about 75 feet of gray, dense basalt, about 100 feet of tuffaceous sandstone and conglomerate, and then enter the intricately jointed basalt.

No water can be expected above river level. An adequate amount of water may be found in rubble or joints at the base of the gray basalt. Only a small yield of water can be expected from the tuffaceous sandstone and conglomerate underlying the gray basalt although it is possible that an adequate supply might be developed.

The jointed reddish basalt underlying the Gila Conglomerate will yield an adequate supply of water if the overlying rocks do not. The basalt probably will not need to be penetrated more than 25 to 50 feet to obtain adequate water if the basalt is as jointed in the vicinity of the well as it is in nearby exposures.

The static water level in a well drilled on the terrace should stand at or above the level of the river. Some artesian head may exist in the jointed basalt under the Gila Conglomerate and if so the water could rise appreciably above river level if the well is tightly cased into the basalt.

Water in the jointed basalt in the vicinity of the terraces may be thermal, and may contain high fluoride concentrations because of the proximity to the fault and series of hot springs and seeps along the base of the cliff upstream from the terraces. Individual strata of water should be sampled as drilled to test the quality of the water. The water probably will become hotter and more highly mineralized with depth.

Site B, Scorpion Corral area.--An area of approximately 30 acres on the north side of the Middle Fork of the Gila River, lying mostly in the $NW\frac{1}{4}$ of sec. 26, T. 12 S., R. 14 W., is referred to as the Scorpion Corral Flats. A fence line trending north divides the area into two nearly equal parts.

The rocks exposed near river level in the bluffs on either side of the flats are dense gray basalt overlain and probably underlain by tuffaceous sandstone and conglomerate of the Gila Conglomerate. The flats are underlain by 20 to 30 feet of valley fill consisting of unconsolidated gravel and sand. Not more than 30 feet of gray basalt is exposed in the bluffs, and if the gray basalt unit here is about 75 feet thick, as it is at the T. J. Ruins site, then about 15 to 25 feet of basalt underlies the valley fill. Not more than 75 feet of tuffaceous sandstone and conglomerate of the Gila Conglomerate should underlie the gray basalt. Reddish zeolitic basalt is exposed under the Gila Conglomerate at the cliff dwellings and presumably underlies the Gila beneath the valley floor. The thickness of the zeolitic basalt is uncertain but probably is not more than 25 to 50 feet as older tuffaceous sandstone and white tuff of the Datil Formation crop out a few hundred yards to the west. The tuff has a gentle easterly dip and presumably passes under the Scorpion Corral area at relatively shallow depth.

Only the valley fill in the Scorpion Corral area contains a large supply of water; the older rocks in general are not good aquifers. It is possible that a supply of ground water adequate for campground facilities could be developed in the basalt under the valley fill if the thickness of the basalt is 25 feet or more.

Any ground water developed in either the valley fill or underlying bedrock at the Scorpion Corral site should be of suitable chemical quality for domestic supply.

Site C, Visitor Center.--The Gila Conglomerate at the cliff dwellings lies on the reddish, zeolitic, intricately jointed basalt. The contact is exposed along the trail from the mouth of Cliff Dweller Canyon to about the point where the trail leaves the canyon floor and climbs the slope to the ruins. The basalt also underlies the valley fill opposite the mouth of the canyon.

An adequate supply of chemically suitable water can be obtained at this site from the alluvium or the underlying basalt, or by developing the supply at Cold Spring in Cliff Dweller Canyon. A well in the alluvium would not need to be more than 30 to 50 feet deep. A well drilled into the basalt probably would need to be 50 to 100 feet deep to obtain an adequate amount of water. The flow of Cold Spring was measured at 2 gpm (gallons per minute), or 2,900 gpd (gallons per day), on July 17, 1962, and the flow in the creek nearby was about 12 gpm (17,000 gpd). These flows were observed before the beginning of the summer rainy period; according to Ranger D. A. Campbell, the creek and the spring have a perennial flow that is seldom less than these amounts. The source of the water in both the creek and the spring is the Gila Conglomerate. The spring water issues from a joint in the conglomerate and the creek water issues from the rocks along the contact between the conglomerate and the basalt.

An analysis (table 1) of the water from Cold Spring shows the water to be of excellent chemical quality for domestic supply. A specific conductance determination only was made on a sample of water from the creek and it was the same as the conductance of the water from Cold Spring; presumably, the chemical quality would be similar. The absence of thermal springs in the immediate vicinity indicates that water in the basalt at this locality probably would not contain objectionable concentrations of fluoride.

Site D, Doc's Cienaga and Site E, Pine Flat.--A flat area 0.1 to 0.2 mile wide at one time extended along the north side of the Gila River from about a quarter of a mile west to 1 mile west from the Visitors' Center (fig. 1). The river swept across the valley during a comparatively recent flood, cut away part of the flat and a small alluvial fan at the mouth of a side canyon, and left a bouldery channel which now divides the flat into two parts. The eastern part of about 12 acres is referred to as Doc's Cienaga (Site D); the western part of about 15 acres is referred to as Pine Flat (Site E).

Both of the areas are bordered on the northeast by low bluffs of white crystal tuff and tuffaceous sandstone of the Datil Formation, and are underlain by unconsolidated valley fill to a depth of 20 to 30 feet. An unknown thickness of crystal tuff and interbedded sandstone and conglomerate lies under the valley fill; rhyolite of the Datil Formation lies under the tuff.

Bogs and meadowland along the lower (downstream) end of Doc's Cienaga suggest the possibility of springs. However, the surface of the wet ground is only a foot or two above the present level of the river and the alluvial fill under the cienaga is saturated with water up to and probably a little above the level of the river channel. Capillary rise in the alluvial fill is adequate to raise water to the ground surface in the vicinity of the meadows and bogs and to keep the ground damp.

A well drilled in these two areas would find water in the alluvial fill at a depth of 1 to 10 feet. A well fully penetrating the alluvial fill would produce a supply of water adequate for headquarters and public facilities. The chemical quality of the water would be good to excellent.

Some water might be obtained from the sandstone beds and from joints in the tuff underlying the alluvial fill, or from possible joints and rubble zones in the rhyolitic rocks underlying the tuff and sandstone.

Site F, Pine Terrace.--A broad terrace 50 to 100 feet above the level of the river has been cut on the south side of the river, opposite Pine Flat, and about one mile west of the Visitor Center. The terrace, which corresponds to the upper level of the terrace system at the T. J. Ruins, covers an area of about 60 acres. The terrace is attractively timbered with pine, is close to the river, and is out of sight of ruins areas proposed for excavation and restoration. The terrace is underlain by tuff and tuffaceous sandstone rocks of the Datil Formation; rhyolite flows underlie the tuff and tuffaceous sandstone.

An adequate supply of water of good quality can be obtained from alluvial fill in the river valley at the north edge of the terrace, and possibly also from the tuffaceous rocks and rhyolite underlying the terrace.

Conclusions

The basaltic ~~and andesitic basalt~~ rocks in the vicinity of T. J. Ruins, Scorpion Corral, and Visitor Center, probably will yield an adequate supply of water which may be thermal and may need treatment to remove fluoride to make it potable for continuous use. The availability of water in the rocks of the Datil Formation underlying Doc's Cienega, Pine Flat, and Pine Terrace, depends upon the existence of joints and interflow rubble zones, which can be determined only by test drilling.

The only certain source for an adequate supply of chemically suitable ground water at any of the sites examined is the alluvial fill in the valleys of the West Fork and Middle Fork of the Gila River.

Scorpion Corral, Visitor Center, Doc's Cienega, and Pine Flat areas are subject to inundation and possible severe damage by flash floods and extremely high water during spring runoff. Only the T. J. Ruin and Pine Terrace areas can be considered safe from flood waters because of their locations on river terraces well above any possible flood stage. The Pine Terrace area is closer to the main ruins of the monument than is the T. J. Ruins area, and is aesthetically the best site examined. However, an adequate supply of ground water is less likely to be available in the bedrock under Pine Terrace than in the vicinity of the T. J. Ruins.

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Geology and availability of ground water in the vicinity of Gila Cliff Dwellings National Monument, Catron County, New Mexico

By

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Figures 1-7

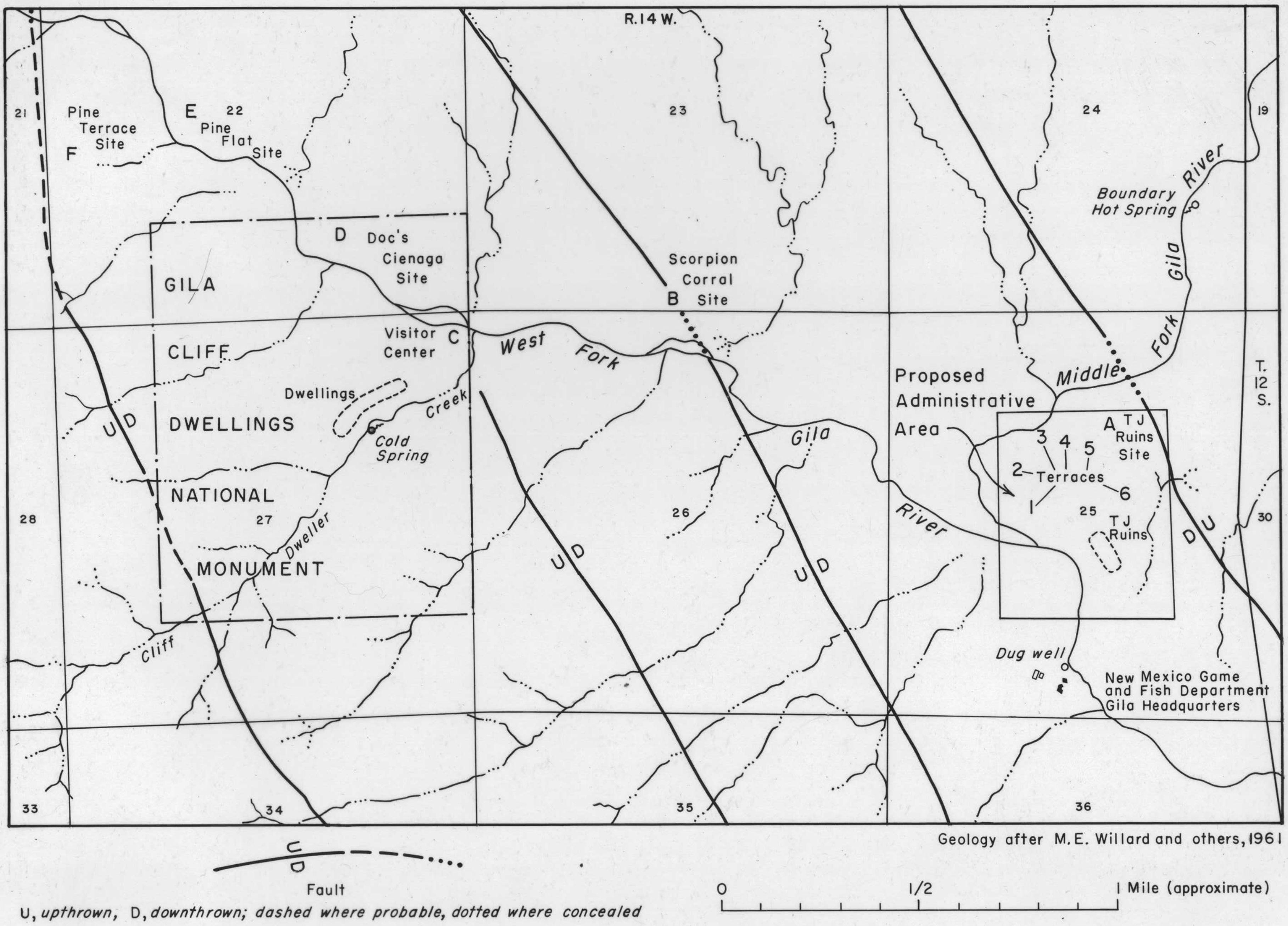


Figure 1.--Aerial mosaic and overlay of the Gila Cliff Dwellings National Monument and environs, Catron County, N. Mex.

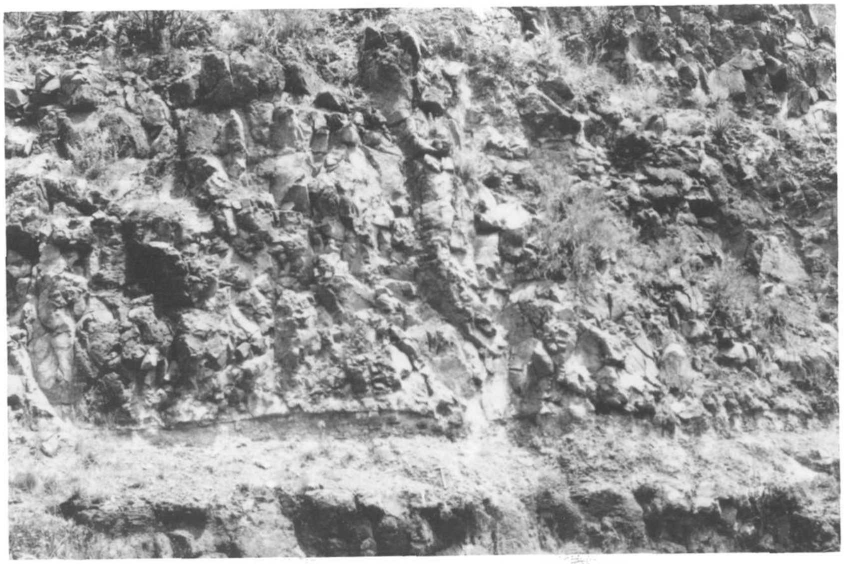
Figure 2.--Rhyolite ~~crystal~~ tuff and interbedded tuffaceous sandstone and conglomerate of the Datil Formation unconformably overlain by the Gila Conglomerate.
NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 22, T. 12 S., R. 14 W.

Figure 3.--Amgdaloidal ~~andesitic~~ basalt; vesicles filled with zeolites.

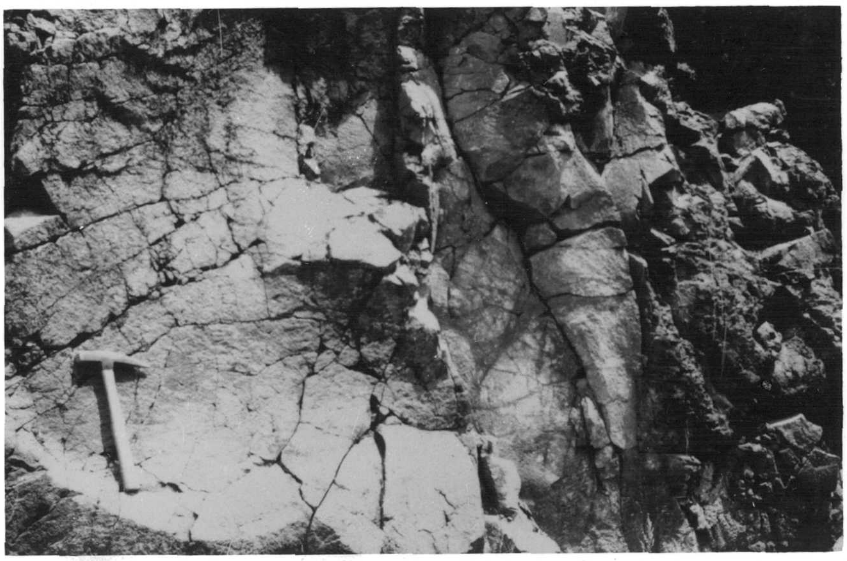
Matrix is typically reddish brown. SW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 12 S. R. 13 W.

Figure 4.--North wall of the canyon of the Middle Fork of the Gila River, opposite Boundary Hot Spring. Rimrock is dense gray basalt underlain by buff sandstone (slope) and conglomerate (light colored cliff-rock) of the Gila Conglomerate. Reddish to dark-gray intricately jointed basalt underlies the Gila.

SW$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 24, T. 12 S., R. 14 W.



a



b

Figure 5a.--Reddish-brown basalt, intricately jointed, showing intense zeolitic zone, inflation pipe, and crude pillow structure.

5b.--Non-oriented intricate joint structure in the basalt at left in a. Dense basalt phase contiguous with highly vesicular phase. Base of canyon wall, east side of river, at trail crossing, $SW\frac{1}{4}SE\frac{1}{4}SE\frac{1}{4}$ sec. 24, T. 12 S., R. 14 W.

a

b

Figure 6a.--Gila Conglomerate showing well-defined bedding and strong cementation.

b.--Large boulders of dense hard volcanic rock in matrix of tuffaceous sandstone and smaller rocks. Terrace slope, SW$\frac{1}{4}$SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 25, T. 12 S., R. 14 W.

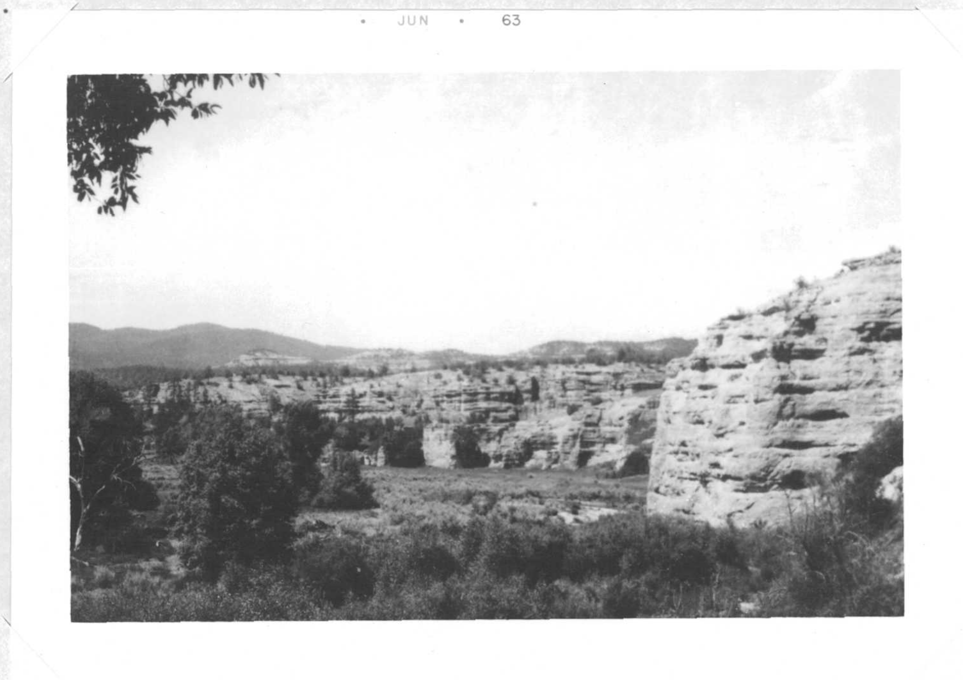


Figure 7.--Gila Conglomerate exposed in bluffs on west side of the Middle Fork of the Gila River, at the junction with the West Fork. Differential erosion and weathering have etched the face of the bluffs and accentuated the bedding planes. The valley floor is underlain by alluvial fill to a depth of 30 to 50 feet. NW$\frac{1}{4}$ sec. 25, T. 12 S., R. 14 W.