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UNITED STATES
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GEOLOGICAL SURVEY
Water Resources Division

THE GEOHYDROLOGY OF

PINNACLES NATIONAL MONUMENT

CALIFORNIA

By

J. P. Akers

Prepared in cooperation with the
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THE GEOHYDROLOGY OF PINNACLES NATIONAL MONUMENT, CALIFORNIA

By J. P. Akers

ABSTRACT

Water supplies for Pinnacles National Monument are obtained from a collection gallery in alluvium and from a flowing well which obtains water from fractured breccia and tuff near a fault.

Rocks other than alluvium, in all but the northern fourth of the monument, are dense igneous or metamorphic types that, unless fractured, have little potential for development of ground water. However, in some areas near faults these rocks probably will yield small supplies of water. The alluvium along Chalone Creek contains water of good chemical quality in quantities sufficient to supply the monument's needs. The Temblor Formation, a fanglomerate in the northeastern part of the monument, seems to be capable of absorbing and transmitting water but has not been drilled. A test well to determine the potential of the Temblor is suggested.

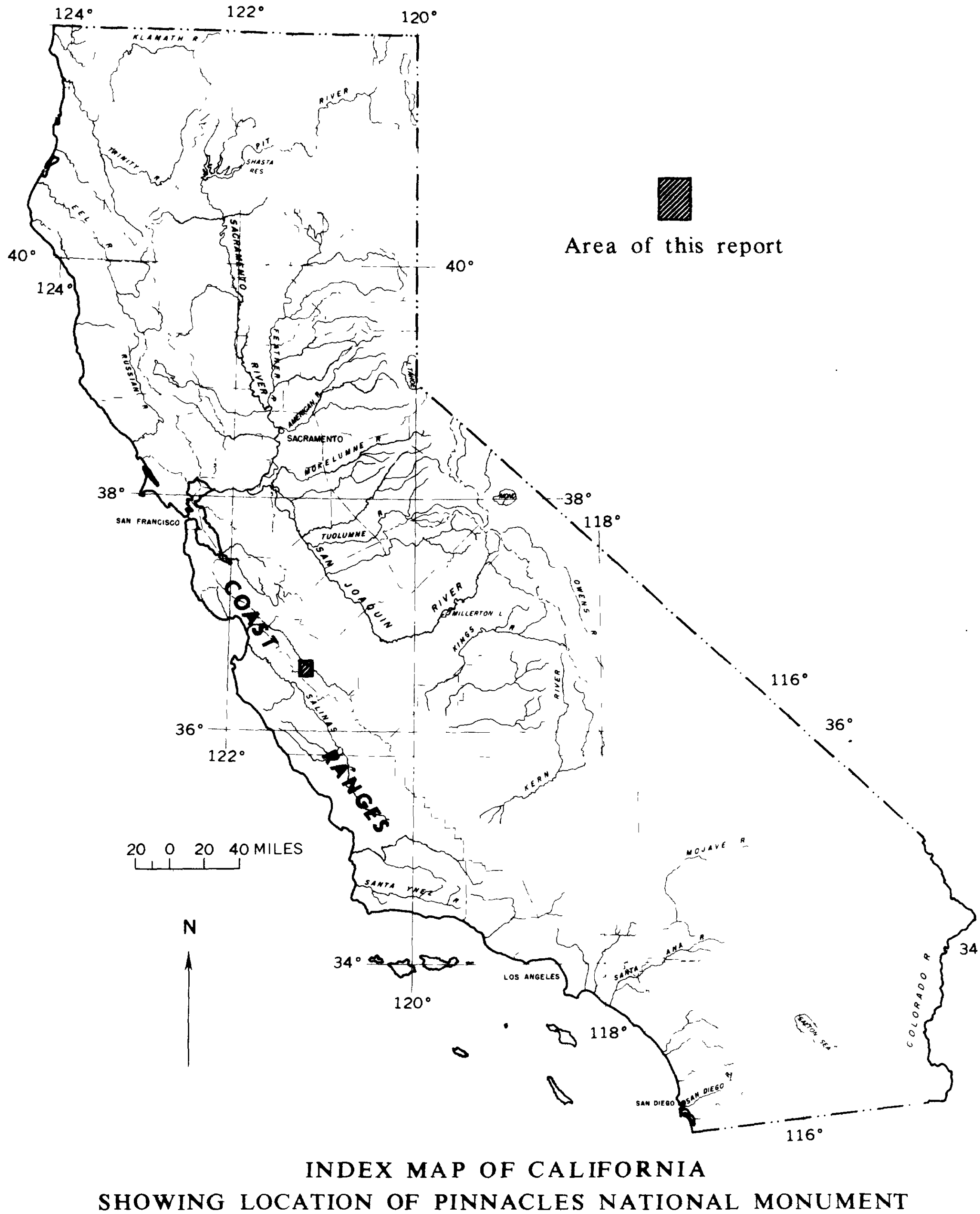
INTRODUCTION

Pinnacles National Monument was set aside for public recreation in 1908 because of its numerous beautiful spires, crags, and columns resulting from differential erosion of rhyolitic breccias. The monument area (fig. 1), about 23 square miles, is in the Gabilan Range, a part of the Coast Ranges about 130 miles southeast of San Francisco.

In recent years there has been increasing visitor use of the monument and on holidays and weekends in the spring and summer months, the camping facilities are overtaxed. Plans to enlarge the facilities to meet the increased use of the monument have been hampered by lack of adequate water supplies.

As part of a program to increase the water supply, the National Park Service in 1959 requested that the Geological Survey study the area for potential well sites. As a result of that study (Evenson, 1962), a successful well, 35R1 (fig. 2), was drilled in alluvium along Chalone Creek on the east side of the monument, and two test-well sites were chosen on the west side near West Fork of Chalone Creek. Subsequent to publication of the report by Evenson (1962) these sites were drilled and wells 33J1 and 33R1 yielded water in sufficient quantity and of suitable quality to supply camping facilities on the west side of the monument.

The present study was made to evaluate in more detail the ground-water potential of the entire monument area. Special study was made of the faults paralleling the east and west boundaries of the rhyolitic breccias and flows that form the central and scenic part of the monument. These faults, to a large degree, control the occurrence and movement of ground water in their immediate vicinity.



INDEX MAP OF CALIFORNIA
SHOWING LOCATION OF PINNACLES NATIONAL MONUMENT

GEOLOGY

The geohydrologic units of the monument area, described by Evenson (1962) are subdivided into three main groups: (1) Granitic and metamorphic rocks, (2) volcanic rocks, and (3) sedimentary rocks. These geohydrologic units include eight lithologic units. The geohydrologic character of the lithologic units is summarized in table 1 and their areal extent is shown in figure 2.

Most of the Pinnacles National Monument area is underlain by volcanic rocks, principally rhyolite and rhyolitic breccias and tuffs. However, the western and southeastern sides of the monument are underlain principally by granitic rocks and the northwestern corner by fanglomerate of the Temblor Formation. The volcanic rocks were downdropped by faults relative to the granodiorite to form a graben in the granitic and metamorphic rocks and the fanglomerate was downdropped relative to both the volcanic and granitic rocks. Vent tuffs and breccias crop out within the main mass of breccia and mark sites of centers of volcanism from which much of the volcanic rock probably was derived.

Granitic and Metamorphic Rocks

The granitic and metamorphic rocks in Pinnacles National Monument consists of the Gabilan Limestone and granitic rocks. The Gabilan Limestone, a white, coarse-grained marble with some quartzite and schist, occurs in thin isolated bodies within the granitic rocks on the west side of the monument area. Most of these bodies are less than 50 feet thick and are only a few hundred feet wide. Wilson (1943) was of the opinion that the Gabilan in the Pinnacles area represents roof pendants on the granitic rocks. Because of its limited extent and thickness, the Gabilan is not considered an aquifer.

The granitic rocks consist principally of granodiorite with some granite and gneiss. Locally, on the west and southeast sides of the monument area, this unit is intruded by sills and dikes of rhyolitic porphyry. These rocks are moderately to deeply weathered and fractured, but the fractures commonly are filled with calcite.

The water-yielding capacity of the granitic rocks was not determined, but wells tapping similar rocks in other areas commonly yield less than 1 gpm (gallons per minute). However, where extensively fractured, they may yield as much as 10 gpm.

Table 1.--Geologic units of Pinnacles National Monument and their Water-bearing Character
(Summarized mostly from Evenson, 1962)

System	Series	Formation	Lithology and water-bearing character	Where exposed
			Sedimentary Rocks	
QUATERNARY	Recent	Alluvium	Gravel, sand, silt, and clay; contains water along Chalone Creek at Chalone Creek campground in quantities adequate for present facilities.	Along Chalone Creek.
QUATERNARY	Pleistocene	Terrace deposits	Gravel, sand. Not considered an aquifer because of limited thickness.	In northern part of monument area on either side of Chalone Creek.
TERTIARY	Miocene	Temblor Formation	Fanglomerate; mostly silt, sand, and granule-sized particles; contains few boulders and cobbles near base. Not tested at present, but has potential for development of ground water.	East of Chalone Creek and in northern part of monument area.
			Volcanic Rocks	
TERTIARY	Miocene	Volcanic breccias and tuffs	Angular fragments of rhyolitic material and tuff. Contains granite boulders along western boundary of exposures. Weathers to form crags, spires, and pinnacles. Contain water in fractures along fault zones.	In central part of monument area.
TERTIARY	Miocene	Rhyolite	Massive and laminated flows. Includes minor flows of andesite and basalt. Possibly contains water in fractures in some areas.	Along eastern flank of "Pinnacle Rocks" and in isolated outcrops.
TERTIARY	Miocene	Vent tuffs and breccias	Masses of volcanic tuff within rhyolite flows. Not known to contain water.	Eastern part of monument area as scattered, more or less circular exposures in rhyolite flows.
			Granitic and Metamorphic Rocks	
PRE-TERTIARY		Granitic rocks	Principally fine-to-coarse-textured granodiorite. Weathered and jointed in most exposures. Contains some granite and gneiss and locally rhyolite, porphyry, dikes, and sills. Probably contains small amounts of water where fractured or weathered.	Along west and southeast borders of monument.
PRE-TERTIARY		Gabilan Limestone	Dense, white-to-gray. Metamorphosed to marble with some quartzite and schists. Not known to contain water.	Occurs as scattered patches in granitic rock.

Volcanic Rocks

Vent Tuffs and Breccias

The vent tuffs and breccias were described by Andrews (1936, p. 24) as "more or less circular masses of volcanic tuff within nonfragmental rhyolite." Except where fractured, rocks of these types have little capacity for absorbing and transmitting water. Because of this and because of their limited areal extent, the vent tuffs and breccias have little potential for the development of water in Pinnacles National Monument.

Rhyolite

The rhyolite in the eastern part of the monument consists of massive flows of laminated, dense, or glassy rock that, unless fractured, has little capacity to absorb and transmit water. In places near the Chalone Creek fault and just west of Chalone Creek, the rhyolite is extensively fractured and possibly would yield small quantities of water to wells.

The isolated exposures of rhyolite along the Pinnacles fault at the west-side campground have a different character. This rock is highly fractured and the fractures commonly are tightly filled with calcite. Probably, both the fractures and the calcite relate to the fault. Under the microscope, some drill cuttings from the rhyolite appear to be fault gouge, and the calcite probably was derived from mineralized water ascending along the fault.

Neither well at the west-side campground obtained any water from this rhyolite, which at the well sites, is about 120 feet thick. The calcite mineralization probably has closed all the fractures to render the rhyolite impermeable.

Volcanic Breccias and Tuffs

The volcanic breccias and tuffs forming the central part of the monument are, for the most part, dense, impermeable rhyolitic rocks having little potential for the development of ground water. However, in some areas, especially near faults, they are fractured and have permissive bedding planes. During the rainy season, numerous seeps emanate from these openings, indicating that water does enter and move through them and several perennial springs within the monument have their source in fractures in these rocks. The depth to which these fractures remain open is unknown.

Possibly, small water supplies can be developed from wells in the breccias down dip from exposed permissive bedding or in fractured zones near faults. However, before any drilling is attempted in the breccias at a particular site, the site should be studied in an attempt to determine the extent of the fractures.

The wells on the west side of the monument obtain water from the volcanic breccias and tuffs that have been fractured in a zone paralleling the Pinnacles fault. The plane of this fault strikes approximately north and is inclined about 60 degrees eastward (fig. 2). The wells were started just east of the fault which they penetrate at a depth of about 320 feet. The breccias in the wells extend from a depth of about 155 to about 320 feet. According to the driller and as indicated by electric logs, most of the water comes from permeable zones at depths of 165-195 and 230-245 feet.

The fact that the wells flow under considerable pressure indicates that the recharge area to the fractures is higher than the well sites. As indicated in figure 2, the recharge area is in the surrounding hills and could be in the fault zone itself or in fractures in the breccias to the east. Perhaps, some water moves westward down dip through the permissive bedding planes in the breccias.

The water from these wells is hard, but otherwise of a quality suitable for domestic use (table 2). The quality of water from these wells may not be representative of water from the breccias and tuffs in other areas within the monument. Water from these rocks in areas removed from the faults might be better quality, because there is evidence of mineralization along the faults.

Sedimentary Rocks

Sedimentary rocks in the monument area are fanglomerates of the Temblor Formation, terrace deposits, and alluvium. All of these units are composed largely of granitic and rhyolitic materials derived from nearby sources, and they occur only in the northern part of the monument area.

Temblor Formation

The Temblor Formation, exposed in the northeastern part of the monument on the downthrown side of Chalone Creek fault, is composed largely of medium- to coarse-grained sand containing abundant gravel of pebble-to-boulder size. In this area the Temblor is a fanglomerate, derived mostly from granite, that grades upward into diatomaceous shale. It is indurated to varying degrees, but seems to be capable of absorbing and transmitting water in most areas.

Several springs, including Willow Spring, discharge from the Temblor in topographic low spots at or near its fault contact with rhyolite in the area north of Chalone campground. All these springs have an altitude of about 1,200 feet which indicates they might derive water from the same water body. Several other seeps, including a large one in McCabe canyon, emanate at about the same altitude from the Temblor just north of Bear Valley near its junction with Chalone Creek. Whether or not the body of water from which these seeps obtain water is hydraulically connected with that near Willow Spring, is unknown.

The water from the Temblor is of good chemical quality (table 2), suitable for domestic use and for most other common uses.

Terrace Deposits

The terrace deposits occur only in a small area in the northern part of the monument near Chalone Creek. They are composed of unconsolidated silt and sand, and rounded-to-angular gravel of pebble-to-boulder size. These deposits occur at altitudes of about 200-300 feet above the present stream channel. The thickness of the terraces deposits is unknown.

The potential for developing water from the terrace deposits is unknown. They probably are permeable enough to accept and transmit water readily, but they seem to be thin and incapable of storing much water.

Alluvium

The most extensive and only alluvial deposits within the monument area that have a significant potential for the development of ground water are those along Chalone Creek. These deposits are composed predominantly of coarse materials, mostly pebbles-to-boulders, and coarse-grained sand, and are at least 38 feet thick as indicated by well 35R1. These deposits receive recharge from surface water and from Willow Spring. However, the amount of water stored in the alluvium upstream from well 35R1 at Chalone campground is not great, and much of the stored water moves past the well or is lost to evapotranspiration. During dry weather water levels in the alluvium decline to such a degree that little head remains to move water into the well, and the yield is not sufficient to supply the monument needs. A properly constructed well completely penetrating the deepest part of the alluvium near Chalone campground may provide an adequate supply of water throughout the year. However, as described in more detail below, a more desirable location from a hydrologic standpoint, would be downstream near the junction of Chalone Creek and Bear Valley.

Water also occurs for at least part of most years in the thin alluvial deposits along West Fork of Chalone Creek at the west-side campground. During construction of the facilities at this campground, several ditches dug in the alluvium intercepted water at a depth of a few feet. The test wells drilled at this campground penetrated less than 5 feet of alluvium and bedrock is exposed both up and downstream, indicating that the total volume of the alluvium, and hence the volume of ground water it stores, is small. Probably, most of this water is lost to evapotranspiration during the dry summer and fall months.

DESCRIPTION OF PRESENT WATER SUPPLIES

Split Rock Spring

Prior to the construction of wells in the alluvium along Chalone Creek, water for use at Pinnacles National Monument was obtained from Split Rock Spring (fig. 2) just upstream from a picnic ground near the park headquarters. This spring emanates from fractures in volcanic breccias and tuffs. The yield is reported to be less than 2 gpm.

The chemical quality of the water is good and is suitable for drinking (table 2). However, it is now used only as an emergency supply. Although the spring is developed and protected by a cement curbing, it is subject to pollution after rains and for this reason the water should be treated if it is used for drinking.

Chalone Campground

Test drilling in 1959 demonstrated that adequate water to supply headquarters and a sizable camping facility on the east side of the monument could be developed from the alluvium along Chalone Creek. Well 35R1, drilled to a depth of 41 feet, penetrated alluvium for 38 feet and bedrock from 38 to 41 feet. Its specific capacity was about 3 gpm per foot of drawdown at a pumping rate of 10 gpm. This well was tested in July in the dry part of the year.

To develop well 35R1 a horizontal-trench collection gallery, 215 feet long and 4 feet below the then-existing water level, was installed in Chalone Creek and connected to the well. Before the trench was backfilled it was pumped at 60 gpm for about 10 hours during which time the water level lowered only 0.50 foot. Calculations based on a comprehensive pumping test made as part of a master's dissertation by Donald Lee Brown, a graduate student from the School of Mines and Metallurgy of the University of Missouri, indicated that the well and gallery should sustain a yield of 70 gpm for 1,000 days.

The collector system was constructed by butting a 14-inch horizontal collector pipe against the cased drilled well. The well casing at its juncture with the horizontal pipe was perforated with ½-inch holes. A 10-gpm pump was installed in the vertical well and the system performed satisfactorily until the pump intakes and well-casing perforation became clogged with sludge and slime. In May 1966, the system delivered only 6 gpm with a drawdown of 0.44 foot. At this time the pump was removed and the area of the casing adjacent to the horizontal pipe was perforated with about 25 slits measuring 3/8 by 2 inches. After cleaning and perforating, the system delivered 30 gpm with a drawdown of 0.58 foot.

During the driest part of autumn in 1966, the yield of the system was not adequate to supply demand when the water level in the alluvium declined several feet and the system would sustain a yield of only about 1,500 gpd (gallons per day) or slightly more than 1 gpm. The water levels rose about 4 feet after rains in early December 1966 and the system again delivered enough water to supply the campground.

Willow Spring

Willow Spring is in a small canyon tributary to Chalone Creek about 1½ miles northwest of Chalone campground (fig. 2). This spring at one time served as a water supply for the campground but now is not used. It emanates from the Temblor Formation at the fault contact of the Temblor with volcanic breccias and tuffs. The discharge, estimated to be about 40 gpm in May 1966, is reported to be practically constant from season to season, indicating that the ground-water reservoir from which the spring derives water probably is large. This same reservoir also supplies water to several springs or seeps in canyons more than ¼ mile south of Willow Spring.

The water from Willow Spring is of good chemical quality suitable for domestic use (table 2).

West-Side Campground

One of the two wells drilled in the west-side campground was developed for a production well; the other was cased with plastic tubing and left for an observation well. A pump test in November 1965 indicated that the water in the production well and the observation well, about 150 yards apart, are hydraulically connected. The production well, 33J1, yielded about 40 gpm from a pumping level of about 170 feet below the top of the casing. This well flowed initially at a rate of about 15 gpm. After about 3 days of uncontrolled flow the discharge rate dropped to less than 3 gpm. The rate of flow in January 1967, after the flow was controlled and the well used as a campground supply for several months, was about 5 gpm.

The long-term yield of this well is conjectural. The water comes from a fracture system of unknown size in volcanic breccias and tuff. Probably, the fracture system is extensive and occupies a fairly broad zone along the Pinnacles fault (fig. 2).

An analysis of water from the well indicated that the water is hard but otherwise chemically suitable for domestic use (table 2).

Oak Tree Spring

Oak Tree Spring is in SW¼ sec. 34, T. 16 S., R. 7 E., on the side of a small canyon near the west-side campground. It is developed in soil or a thin undifferentiated veneer of alluvium that temporarily stores water emanating from fractures in volcanic breccias and tuffs. The average yield is probably less than 1 gpm. As presently constructed, a considerable amount of the water bypasses the storage sump and is lost to evaporation. The spring is unused.

The chemical quality of water (table 2) from this spring is suitable for domestic use and for most other common uses.

Table 2 .--Chemical analyses of water

[Analyses by U.S. Geological Survey, Sacramento, Calif.]

Values for sodium preceded by the letter "a" are a combination of sodium and potassium.

Values for dissolved solids indicate the residue on evaporation at 180°C, except those preceded by the letter "b," which have been calculated (sum of determined constituents).

Laboratory and sample number:

Well number	Date of collection	Depth of well (feet)	Water temperature (°F)	Results in parts per million																	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Laboratory and sample number
				Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$					
U.S. Public Health Service drinking-water standards (1962)					0.3							250	250	1.3	45		500							
16S/7E-33J1	2-10-67	335	68	40	0.03	45	1.1	53	0.4	228	8	9.0	21	0.1	0.1	0.0	b290	117	0.0	50	440	8.5	54882
35R1	3- 7-67	41	61	40	.01	24	7.2	47	1.7	111	0	26	50	.3	6.2	.1	b258	90	.0	53	407	6.9	55162
Spring																								
Willow	5-15-63	-	68	65	-	9.6	1.9	40	1.7	60	0	41	20	.7	.8	.1	b211	32	.0	-	250	7.0	43539
Split Rock	3- 7-67	-	59	85	.00	24	3.7	33	1.1	117	0	7.0	28	.1	2.4	.0	b242	75	.0	48	291	6.9	55163
Oak Tree	3- 8-67	-	-	85	.03	39	.2	37	.6	172	0	5.0	21	.1	2.8	.0	b276	98	.0	45	361	7.1	55161

SUGGESTIONS FOR FUTURE DEVELOPMENT

Two sites on the east side of Pinnacles National Monument seem favorable for wells. Both are on the eastern (downthrown) side of the Chalone Creek fault (fig. 2).

Site 1, SW¼ sec. 36, T. 16 S., R. 7 E., is about 20 feet northeast of a storage tank east of Chalone campground. A well 300 feet deep at this site would test the potential of the Temblor Formation along the Chalone Creek fault. The site has the advantage of being close to the present storage tank so that little work and expense would be needed to tie into the water-distribution system. Further, the well would not be as subject to contamination and to seasonal fluctuations in yield as the present collection gallery.

Site 2 is just inside the monument boundary in NW¼ sec. 1, T. 17 S., R. 7 E. A well 100 feet deep at this site would start in alluvium and probably would end in the Temblor Formation. Probably, a thicker section of the alluvium is saturated at this site than at well 35P1 because of the barrier formed by the Chalone Creek fault. According to Andrews (1936, p. 30), that barrier forces underflow east of the fault to the surface. A well at this site would draw from a much larger ground-water storage reservoir than well 35R1; it would draw not only from storage in the alluvium along both Chalone and Bear Valley Creeks but also from the Temblor Formation.

The Temblor Formation at this site is favorably located to receive water from the overlying alluvium and because it is near the fault, it may be more permeable than where undistrubed.

Geohydrologic conditions at site 2, with regard to the availability of water, are more favorable than at site 1. However, for a test-drilling program on the east side of the monument, site 1 is given first priority because of its more desirable location with regard to place of intended use and existing distribution facilities and because it is hydraulically above existing sewage disposal facilities.

The most favorable area for development of ground water on the west side of the monument is along the east side of the Pinnacles fault. Most of the area, indicated on figure 2, is easily accessible to a drilling rig and wells drilled within the area should encounter conditions similar to those in the existing wells.

Probably, additional water could be obtained by horizontal drilling at Oak Tree Spring. Also small water supplies might be developed from wells in weathered or fractured granitic rock at other sites in the western part of the monument. However, because those areas are generally unfavorable for development of water supplies, a hydrologist should examine particular sites to determine their potential before drilling is attempted.

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FIGURE 2

EXPLANATION

SEDIMENTARY ROCKS

Age	Symbol	Description	Period
Recent	Qal	Alluvium *Sand and gravel*	QUATERNARY
Pleistocene	Qt	Terrace deposits *Predominantly gravel*	QUATERNARY
Miocene	Tmt	Temblor Formation *Fanglomerate grading upward into gravel and diatomaceous shale*	TERTIARY

VOLCANIC ROCKS

Age	Symbol	Description	Period
Miocene	Tvb	Volcanic breccias and tuffs *Predominantly rhyolitic*	TERTIARY
Miocene	Tr	Rhyolite *Massive and laminated flows; also some andesite and basalt*	TERTIARY
Miocene	Tv	Vent tuffs and breccias *Rhyolitic; mark ancient volcanic vents*	TERTIARY

GRANITIC AND METAMORPHIC ROCKS

Symbol	Description	Period
g	Granitic rocks *Principally granodiorite, include some granite and gneiss and locally intruded by rhyolite porphyry dikes and sills*	PRE-TERTIARY
ls	Gabilan Limestone *Marble, with some quartzite and schists*	PRE-TERTIARY

Contacts
Dashed where approximately located

U D
Faults
Dotted where concealed;
U, upthrown side; D, downthrown side

35R1
Water well

Spring or seep

2
Proposed well site

Favorable area for development of ground water

AREA OF THIS REPORT

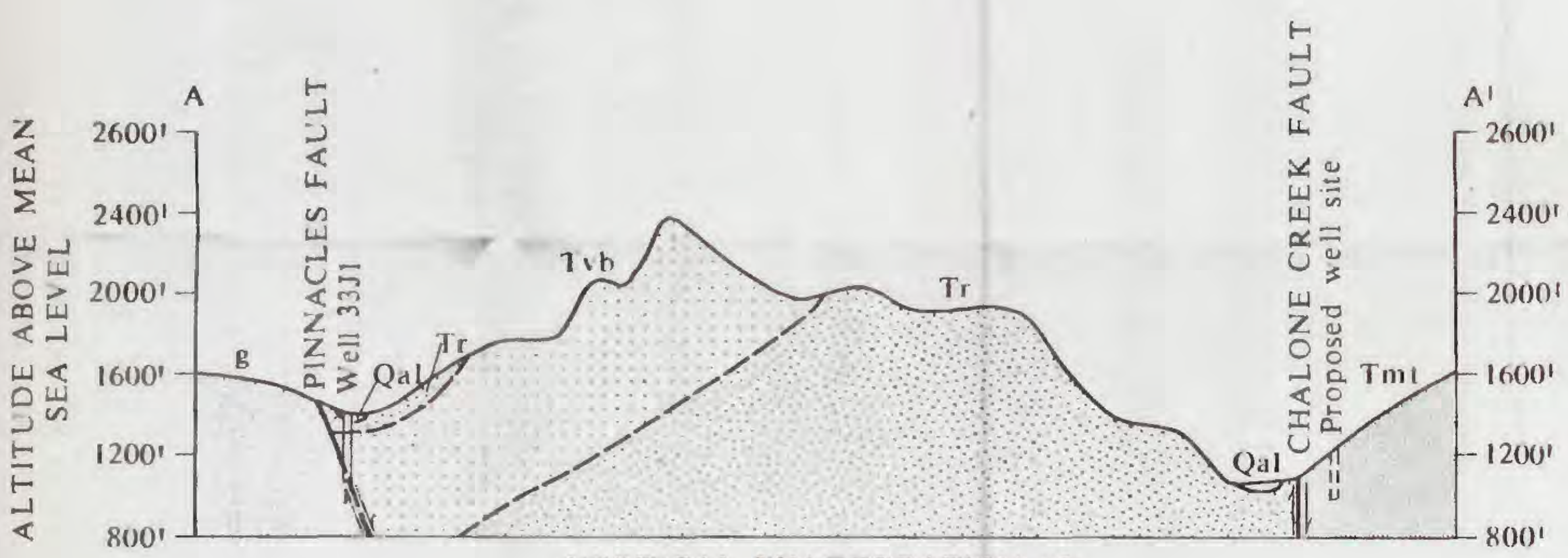
Base from Greenfield and San Benito topographic quadrangles, scale 1:62 500

Geology modified by R.E. Evenson, 1959, after Philip Andrews, 1936, and Ivan Wilson, 1943

SCALE 1:31 680

1 ½ 0 1 MILE

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL



VERTICAL EXAGGERATION ×5

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GEOLOGIC MAP OF PINNACLES NATIONAL MONUMENT, CALIFORNIA, SHOWING LOCATION OF WELLS FAVORABLE AREAS FOR GROUND-WATER DEVELOPMENT, AND PROPOSED WELL SITES