A BRIEF STUDY

OF

THE GEOLOGY AND GROUND WATER CONDITIONS

IN THE PAUMA VALLEY AREA

SAN DIEGO COUNTY, CALIFORNIA

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By

Thomas B. Howes

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CONTENTS

CONTENTS, continued

ILLUSTRATIONS

ABSTRACT

Pauma Valley is located in a widening of the San Luis Rey River Valley six miles southeast of Pala in northern San Diego County, California. The area mapped covers approximately 25 square miles. Ground-water investigation was confined to an area of about 15 square miles in the San Luis Rey River Valley and in tributary valleys.

Rocks of the Southern California batholith of Cretaceous age and Triassic meta-sediments are exposed throughout the area except along the floors of the stream valleys and alluvial fans, where Quaternary alluvial sediments have been deposited. The crystalline rock types present include gabbro, tonalite, and granodiorite. Pegmatite dikes occur in the gabbros and less commonly in the other igneous rocks.

The Elsinore fault zone crosses the northeastern portion of the area. The exposed rocks are distorted in an area as much as one mile wide along the fault zone. The Agua Tibia Mountains were raised about 4000 feet along the fault zone during Quaternary time. Here the Quaternary movement along the Elsinore fault zone was largely of a reverse nature, with some strike-slip motion.

Three alluvial fan deposits are present in the San Luis Rey River Valley. One of these, the Agua Tibia fan, was deposited so rapidly that the river was dammed and a lake formed upstream in the river valley.

Ground-water is produced chiefly from the flood plain deposits of the San Luis Rey River. The deposits of the Rincon alluvial fan have

yielded water in satisfactory amounts, but the Pauma Creek alluvial fan materials should be capable of more than their present ground-water production. The deposits of the Agua Tibia alluvial fan are poorly sorted and relatively impermeable, and do not appear to constitute an attractive aquifer. Ground-water in significant quantity may be moving laterally along the Elsinore fault zone. Locally, the ground-water table was lowered as much as 13 feet in the San Luis Rey River Valley during the period 1940-1950. However, the water supply in the lower parts of the river valley will remain adequate unless ground-water production is increased markedly.

INTRODUCTION

Pauma Valley, a diamond-shaped widening of the San Luis Rey River Valley about five miles long and two miles wide, lies six miles southeast of Pala in northern San Diego County, California. The valley is the site of a number of farms and ranches that produce citrus fruits and avacados. The climate is very favorable for this form of agriculture, and the crops are generally profitable. Irrigation is necessary to maintain the fruit trees, and ground-water produced from wells is commonly used for this purpose.

Water in ample quantities can be obtained readily from wells drilled into the porous sand and gravel aquifers that underlie much of the area of the existing flood plain of the San Luis Rey River. However, for those ranchers who cultivate the slopes of the alluvial fans that rise gradually northeastward from the river to the base of the Agua Tibia Mountains, the availability of irrigation water is a serious problem, and a factor which often determines more than any other the potential agricultural yield of their lands.

It was with the thought that perhaps additional sources of ground-water could be discovered that the writer conducted a brief investigation of the geology and ground-water conditions in the Pauma Valley area. This investigation was undertaken while the writer was completing graduate studies at the California Institute of Technology. Six weeks were spent in the field during the spring of 1948 and one additional week during the summer of 1950.

Reconnaissance geologic mapping was done in order to establish the general distribution and character of the rocks in the area as well as the principal elements of the geologic structure. In the mapping, horizontal and vertical angles were measured with a Brunton compass, and distances were determined by pacing. Enlargements of preliminary drafts of the Pala and Boucher Hill quadrangles of the U. S. Geological Survey were employed as field base maps, and the subsequently published sheets of these quadrangles served as final maps.

Water wells generally were located and their elevations determined by means of a plane table and telescopic alidade. A few wells were located by means of triangulation with a Brunton compass, and were referred to their plotted positions on the topographic sheet for elevation control. United States Geological Survey bench marks were employed as points of reference for both horizontal and vertical control.

The writer became interested in the subject area through discussions with Dr. R. H. Jahns of the California Institute of Technology, who had studied the pegmatite dikes of this and nearby areas for several years, and whose assistance and interest in this study is gratefully acknowledged. Dr. Jahns also reviewed the manuscript critically and offered many helpful suggestions.

Because of the great importance of irrigation in the agriculture of the valley, water rights are guarded jealously. Precise information relative to well capacities, well logs, and ground-water details was often difficult or impossible to obtain. Several residents of the valley, however, were helpful to the writer. Mr. Monta J. Moore and Mr. Jack Adams were particularly generous with their time and advice. Mr. Vaughan Maynard of Santa Ana, who drilled many of the water wells in Pauma Valley, very kindly furnished driller's logs for several of them.

GEOGRAPHY

Surface features

The San Luis Rey River flows in a northwesterly direction through Pauma Valley. At Pala the river curves to the southwest and follows a nearly straight course for 24 miles, emptying into the Pacific Ocean near the city of Oceanside. Pala is about 100 miles southeast of Los Angeles and 55 miles northeast of San Diego. Paved highways connect these cities with the Pauma Valley area.

The San Luis Rey River has developed a valley several hundred feet below the general level of the moderately dissected plain that borders it on the west and south. Elevations in the valley range from 600 to 900 feet above sea level, whereas the elevation of the plain adjacent to the valley is about 1500 feet. The plain slopes gently toward the Pacific Ocean, and isolated hills, which may be monadonocks, rise as much as 200 feet above its general level. To the southeast this flat upland gives way to more rugged terrain, and hills with altitudes of more than 3000 feet are present within two miles of the river valley.

North and east of the valley is a high range of mountains called the Agua Tibia Mountains that trends approximately 65 degrees west of north. Palomar Mountain, 6140 feet, and Boucher Hill, 5446 feet, are prominent high points in this range. To the northwest the mountains give way to a group of lower hills having elevations of 2000 to 2400 feet. The Elsinore-Temecula trough, a pronounced topographic and structural depression, lies on the far side of these hills about six miles north of Pala. The Santa Margarita Mountains rise northwest of Pala and west of the Elsinore-Temecula trough.

Climate and vegetation

A semi-arid climate characterizes this region. Summers are long, hot, and dry, whereas winters are short and mild. Most of the precipitation falls between December and April. The rainfall pattern is controlled largely by the topography; the higher mountains receive two to three times the amount of precipitation that falls in the lower areas. Most of the precipitation falls on the higher topographic features during the winter months -- a condition that sometimes results in severe erosion in places where local topographic relief is great. Landslides and mudflows are not uncommon. Run-off is appreciable; Ellis and Lee (1919, p. 95) estimated that ten per cent of the total precipitation falling in the area drained by the San Luis Rey River is wasted as run-off water.

The following data on temperature and precipitation were recorded by the United States Weather Bureau in 1947 and 1948:

	Palomar Mountain (Elev. 5560)		Escondido (Elev. 750)	
	1947	1948	1947	1948
Maximum Temperature (^{o}F)	91	93	103	102
Minimum Temperature (^{o}F)	8	16	25	24
Annual Mean Temperature (^{o}F)	56	55.1	61.8	59.9
Total Precipitation (in.)	14.7	17.81	8.75	9.27

The years 1947 and 1948 were notably dry. During the period 1901-1915, in contrast, precipitation averaged 46.47 inches annually at a station about one mile south of the present Palomar Mountain post office. The annual average rainfall for the same period at Escondido was 15.20 inches.

The rainfall pattern in northern San Diego County was described by Ellis and Lee (1919, p. 99) as follows:

> Average annual precipitation . . . ranges from about ten inches along the coast to 45 inches at the crest of the first range of mountains, increasing about 0.56 inch for each 100 feet of increase in elevation. East of the first range the precipitation rapidly

decreases to an annual average of about 18 inches in the high mountain valleys and only slightly more than 18 inches on the second mountain crest.

Vegetation in uncultivated areas consists mainly of sage brush, cactus, yucca, scrub oak, manzanita, and other chaparral-forming plants. Alder, cottonwood, sycamore, and California oak trees are commonly present along drainage lines and near springs. Dense, bushy undergrowth -- including such undesirable plants as poison oak and nettle -- occurs among many of these deciduous trees. The north slopes of hills and mountains commonly are so thickly overgrown with brush that they may be traversed only with great difficulty. Elsewhere, however, the region is characterized by sparser vegetation and numerous outcrops of rock.

GEOLOGY

General statement

The area described in the present paper is located in the Peninsular Ranges of Southern California. Paleozoic and Triassic meta-sediments, Jurassic (?) volcanics, and Cretaceous igneous rocks of the Southern California batholith underlie much of the region. A relatively narrow band of Cretaceous and Tertiary sedimentary rocks occurs along the shore of the Pacific Ocean, west of the exposures of crystalline rocks. Tertiary and Quaternary extrusives are present locally. Quaternary fluviatile deposits are present in stream valleys and alluvial fans. Of these, only pre-Tertiary crystalline rocks and Quaternary sediments occur in the Pauma Valley area.

Crystalline rocks

The Peninsular Ranges of Southern California are underlain largely by rocks of the Southern California batholith. Larsen (1948, p. 1) estimated the length of this great igneous body to be more than 1000 miles in a general north-south direction and its width to be about 60 miles. The batholith was intruded into Triassic meta-sedimentary rocks and Jurassic (?) volcanic rocks along its western margin and into Paleozoic (?) meta-sedimentary rocks along its eastern margin. Many separate injections occurred during its emplacement, and the rocks that were formed range in composition from gabbro to granite. The age of the batholith probably is Upper Cretaceous. (Larsen, 1948)

The main crystalline rock types present in the Pauma Valley area are the Julian schist of the pre-batholith sequence and the San Marcos gabbro, Bonsall tonalite, and Woodson Mountain granodiorite of the Southern California batholith.

Julian schist

The Julian schist occurs in the Pauma Valley area as a hard, fine-grained, platy, well-foliated, blue-gray quartz-mica schist. At the outcrop it weathers to a rusty light brown color. Injection gneisses are associated with the schist. The schist is relatively resistant to erosion, and it forms many hills, ridges, and buttresses. Good exposures can be seen in the canyon of Pauma Creek about one-half mile east of the Moore ranch and between Tin Can Flat and BM 3572 along the Nigger Grade road.

The Julian schist was described by W. J. Miller (1946, p. 484) as follows:

> The main constituents of the Julian schist are fine-grained, gray to bluish-gray, fissile, quartz-muscovite-biotite schists; quartzites which are variably impure with biotite and muscovite; phyllite mica schists; various non-fissile, coarse-grained, quartz-biotite schists; and lit-par-lit injection gneisses.

According to Larsen (1948, p. 16), the schists are probably Triassic sedimentary rocks which were metamorphosed prior to the emplacement of the batholith in early Upper Cretaceous time.

San Marcos Gabbro

The gabbroic rocks of the Pauma Valley area are herein correlated with the San Marcos gabbro, in conformity with Larsen's designation (1948) of similar rocks in the area immediately to the west. The name San Marcos gabbro was first applied by F. S. Miller (1937, p. 1399) as a field term for a great variety of rocks, including olivine gabbros, norites, hornblende gabbros, hypersthene gabbros, quartz-biotite norites, and quartz-biotite-hornblende gabbros.

The San Marcos gabbro can be recognized in the hand specimen as a light gray to dark bluish-gray, fine-to medium-grained crystalline rock, composed primarily of plagioclase feldspar with variable amounts of hornblende or pyroxene. The main distinguishing characteristics are the bluish cast of the feldspar and the occurrence of pyroxene or olivine. In most places the gabbro is less resistant to erosion than the more acidic rocks, and it occurs as a crumbly, reddish-brown grus with included hard, dark blue-gray boulders of relatively unweathered rock. Larsen (1948, p. 43) classified these boulders as norite. The San Marcos gabbro also crops out on Pala Mountain as a hard crystalline rock. Weathered gabbro is exposed on the hill about one mile north and slightly west of the Agua Tibia ranch house. Here large boulders of disintegration are quarried as "black granite" for use as dimension stone.

Bonsall tonalite

The most common rock type in this area is the Bonsall tonalite, which was named by Hurlbut (1935) for its exposures near the Bonsall post office, about ten miles southwest of Pala. As described by Larsen (1948, p. 60), the tonalite

> . . . is a medium-grained rock ranging from light to dark gray, depending on the proportion of dark minerals present. Hornblende is the chief dark material. . . .Biotite is present in moderate amount. . . . White to gray plagioclase . . . makes up from 55 to 60 percent of the rock. . . .Quartz averages about 20 to 25 percent. . . .Orthoclase makes up a few percent. . . .

The outstanding characteristic of the Bonsall tonalite is its large number of oriented tabular inclusions, mostly gabbroic in composition. The transitional nature of the contacts of these inclusions with the host rock has led to the conclusion that the Bonall tonalite was injected into the older San Marcos gabbro before the gabbro was entirely consolidated (Larsen, 1948, p. 60)

The Bonsall tonalite was identified in the field by occurrence of gabbroic inclusions, the predominance of light-colored plagioclase among the feldspars, and the presence of hornblende as the major dark mineral. Good exposures of this rock type can be seen on the eastern slopes of the hill one-half mile north of Rincon; along the Valley Center road three miles south of Rincon; and in the road cuts along the Cole Grade, one mile southwest of the Pauma Valley school.

Woodson Mountain granodiorite

The Woodson Mountain granodiorite was named by F. S. Miller (1937, p. 1399) for the excellent exposures of the rock on Woodson Mountain, which lies a few miles from the town of Ramona. The granodiorite is a medium- to coarse-grained, light gray, granitic rock. Larsen (1948, p. 78) listed the primary mineral constituents as quartz, 30 to 40 percent; plagioclase, 30 to 55 percent; and microperthite, 10 to 30 percent. Dark minerals usually make up less than ten percent of the rock. Biotite is the most common accessory mineral, and hornblende is commonly present.

The granodiorite is a very hard rock, quite resistant to erosion. Large boulders several feet in diameter cover most of the outcrops of this formation, and generally mask the underlying bedrock. This rock type commonly is identifiable in the field by the occurrence of the huge boulders of disintegration (which have been called "woolsack" boulders by Larsen), by the light gray color of the rock, and by the predominance of biotite among its dark minerals.

Pegmatite dikes

Light-colored pegmatite dikes are common in the Pauma Valley area. These tabular bodies range in thickness from a few inches to tens of feet. They are resistant to erosion and form rib-like protuberances on the larger topographic features. A general parallelism is exhibited by the dikes; attitudes measured by the writer revealed the strikes of these bodies to be from 14 to 25 degrees west of north, and their dips to be from 14 to 40 degrees to the southwest. The thin outer zones of the dikes are aplitic, and their centers commonly are composed of graphic granite. Muscovite, biotite, black tourmaline, and spessartite garnet occur as widespread accessory minerals. Near Pala the pegmatites have been mined for the semiprecious gemstones -- notably kunzite and pink tourmaline -- that occur in their centers. The San Marcos gabbro is the most common host rock for the dikes in the Pauma Valley area, although the

Bonsall tonalite is cut by a prominent group of pegmatites about one-half mile east of Rincon.

According to Larsen (1948, pp. 101-103), the pegmatites transect practically all of the major plutonic rock types of the batholith. Thus, they must be among the youngest of these rocks and probably resulted from a late-phase injection of magma rich in mineralizing solutions during Upper Cretaceous time.

Sedimentary rocks

Quaternary sediments are present in the valley of the San Luis Rey River. The valley floor is underlain by flood-plain deposits and alluvial-fan materials, and lake deposits are present locally.

The flood-plain deposits are composed of gravel, sand, silt, and clay. These sediments are moderately well sorted and stratified. Porous and permeable sands and gravels are common, and they are excellent aquifers. As much as 200 feet of these deposits has been penetrated by wells dug in the flood plain of the San Luis Rey River. The alluvial-fan deposits are heterogeneous and poorly sorted. The individual particles tend to be angular in outline, indicating that they have been transported only a limited distance from their original outcrop positions. As a whole, these deposits are less permeable than the stream deposits, and they do not contain particularly good aquifers.

Three distinct alluvial-fan deposits are present in the Pauma Valley area --the Agua Tibia, the Pauma Creek, and the Rincon fans. They have been built out across the valley of the San Luis Rey River, crowding the stream against its valley wall on the southwest. The fans are composed of materials carried down the steep slopes of the mountain range that flanks the river valley on the northeast. The surfaces of the Agua Tibia and Rincon fans slope toward the river at angles of about five degrees, whereas the surface of the Pauma Creek fan inclines in the same direction at an angle of about two degrees. The lesser slope of the Pauma Creek fan may be due to the destruction of much of its former surface by an out-pouring of water and coarse detritus from Pauma Creek canyon during a period of heavy rainfall in January of 1916. According to Mr. Jack Adams, a considerable amount of arable land was removed and the present-day dry wash was scoured out at that time.

A bed of black clay or mud containing decomposed vegetable matter has been encountered in many of the wells dug in the Pauma Valley area. The thickness of this deposit, determined from drillers' logs, ranges from four to ten feet. Probably the bed was formed by the settling of very fine clay particles and plant debris in a body of standing water, and it is interpreted as the sedimentary record of an extinct lake which existed in the Pauma Valley area sometime during the late part of the Quaternary period. The writer has chosen to refer to this extinct body of water as Lake Pauma.

The Agua Tibia alluvial fan

The Agua Tibia alluvial fan is particularly interesting because it is composed of exceptionally coarse material and because its rapid formation resulted in the damning of the Pleistocene San Luis Rey River to form a lake that occupied much of Pauma Valley. Ellis and Lee (1919, p. 70) gave the name "Pala congomerate" to this deposit and described it as follows:

> Valley type fill of a type not common to this area occurs in the valley of the San Luis Rey River, in the vicinity of Pala. This material is a conglomeratic mass of boulders and residuum, having a thickness of about 200 feet above and extending to an undetermined distance below the river. The boulders which make up a large part of this formation are all regular, most of them being prismatic blocks with slightly rounded corners showing that they have been transported only short distances.

The boulders commonly are as much as several feet in diameter, and for the most part are composed of Woodson Mountain granodiorite, a type of rock that underlies much of the mountain area immediately northeast of the fan.

Bottom deposits of a Pleistocene (?) lake have been encountered in many of the water wells drilled on the flood plain of the San Luis Rey River upstream from the Pleistocene Agua Tibia alluvial fan. The lake was probably at least four miles long and one mile wide, and its lower or downstream limit was southeast of, or upstream from the Agua Tibia alluvial fan. The great number of boulders present in the alluvial fan and the existence of buried lake

Figure 2. MUDFLOW DEPOSIT IN AGUA TIBIA ALLUVIAL FAN

Old highway cut north of Agua Tibia Creek. Coarse, inhomogeneous boulder deposit overlying well-sorted channel sand deposit.

deposits of similar age in the San Luis Rey River valley southeast of the fan indicate that this heterogeneous sedimentary body was formed rapidly enough to dam the San Luis Rey River and form a lake. Jahns (1949) has stated that the Agua Tibia fan was deposited by mudflows or debris flows.

Excellent exposures of the fan materials are present along the nearly vertical northeast wall of the canyon of the San Luis Rey River, where the river skirts Pala Mountain at the northern end of Pauma Valley. Here the canyon is more than 200 feet deep and over 1800 feet wide. The thickness of these coarse fan deposits is at least 700 feet where they have been penetrated by water wells drilled on the Agua Tibia ranch.

Lake Pauma

The deposits of Lake Pauma are present beneath much of the Pauma Valley area. Typically the lake bed is a bottom deposit composed of black mud or clay, but it seems to grade laterally into silt, as might be expected near a shore line. For example, in the Ide well, located two miles northwest of Rincon, the top of the black lake bed was encountered at a datum of 732 feet above sea level, yet the Hawes well, located only 1200 feet to the east, failed to penetrate a black mud stratum but did encounter a silty sequence at a datum of 757 feet -- a point at which the lake bed might well be expected (see Fig. 3 in pocket). Similarly, the McCormick well near Rincon did not encounter the typical lake bed, but did enter a stratum of silt at a datum of 759 feet. These silt layers probably are near-shore deposits of Lake Pauma.

The United States Government No. 3 well, located on the Rincon Indian Reservation south of Rincon, penetrated an eight-foot thickness of hard yellow clay at a datum of 765 feet above sea level. It is not certain that this deposit is related to Lake Pauma, for this well is located about one and one-half miles southeast of the McCormick well, which furnishes the nearest point of control for the lake bed.

On the basis of data currently available, Lake Pauma appears to have been at least four miles long and one to one and one-half miles wide.

The well data providing structural control for the lake bed, although sparse, indicate clearly that the bed now dips westward at the rate of about 100 feet per mile, or at an angle of approximately one degree. It is possible that this present dip is an initial or primary feature, or it may be in part a result of local post-depositional tilting caused by differential movement along either the Elsinore fault zone or the Tecolote fault, or both. The lake was formed after development of the Agua Tibia fan, which in turn post-dates the latest period of major block-faulting that raised the Agua Tibia Mountains to their present height. The present valley of the San Luis Rey River was carved out prior to deposition of the alluvial fan, so that Lake Pauma must have existed in a topographic setting similar to the Pauma Valley of today. The bottom deposits of the lake probably had a concave shape when originally formed, reflecting the configuration of the underlying valley floor. Since the present distribution of the lake deposits indicates that their lowest parts are beneath the present course of the San Luis Rey River, it is apparent that the river probably followed the same general course through Pauma Valley prior to formation of the lake.

The maximum depth of water in Lake Pauma was at least 147 feet. The lowest present point of control for the black clay bed is in the Adams well at a datum of 612 feet, and the highest point of control for the silt bed is in the McCormick well at a datum of 759 feet; the vertical difference between these two points is 147 feet. It is interesting to note that the present day surface of the Agua Tibia alluvial fan, if projected across the San Luis River to Pala Mountain, would intersect the mountainside at an elevation of about 760 feet. From these facts it is possible to conclude that the water level in Lake Pauma rose as high as the low point of the alluvial barrier, and that the subsequent overflow of lake waters contributed significantly to the destruction of the natural dam and the cutting of the present canyon of the San Luis Rey River.

STRUCTURAL GEOLOGY

General statement

The area described in this report is underlain largely by plutonic rocks of Cretaceous age. To gain an understanding of the regional structure it is necessary to consider the findings of earlier investigators.

Larsen (1948, p. 121) described the structure of the northern Peninsular Ranges and noted that in the southern part of the Elsinore quadrangle

> . . . the Triassic and Paleozoic rocks appear to be in part overturned. . . .The structural data is most simply interpreted as indicating that the Triassic and Paleozoic rocks are on one limb of a great fold.

The Southern California batholith intruded this older structure, but the batholith was not forcefully injected, and did not cause the folding (Larsen, 1948, p. 171). The same author states (1948, p. 119):

> It is remarkable that the trend of the general structure of the area here described has been approximately the same from pre-batholithic time to the present. The strike of the Paleozoic and the Triassic rocks, the elongation of the batholith as a whole, the elongation, contacts, and internal structure of each of the successive intrusives of the batholith, the general strike of the Upper Cretaceous and Tertiary beds, the Tertiary and Recent faults, the axes of the chief mountain ranges, and the general course of the coast line, all are approximately N. 35° W.

The outstanding structural element in the Pauma Valley area is the Elsinore fault zone. W. J. Miller (1940, p. 388) has described the Elsinore fault zone as follows:

> It [the fault zone] extends along the northeastern base of the Santa Ana Mountains, thence through the Peninsular Mountains of San Diego County, and for an unknown distance along the eastern foot of the Peninsular Mountains of Lower California. It is for the most part a fault zone with vertical displacements of several thousand feet.

However, Miller also states (1940, p. 395):

> . . . in addition to great vertical movements [along the Elsinore fault zone], strike-slip displacements have taken place in direction the same as along the San Andreas fault but much less in amount.

The San Andreas fault is a right-lateral fault, the rocks on the northeast side of the fault having moved southeast with respect to the rocks on the southwest side. In Miller's view, then, the Elsinore fault is also a right-lateral fault.

Local structure

In the Pauma Valley area the Elsinore fault zone separates the Agua Tibia Mountains positive block from the San Luis Rey River Valley and the relatively low and flat terrain to the southwest. Formation contacts adjacent to the fault zone tend to parallel its strike. Another major structural feature of the area is the Tecolote fault, which forms the boundary between the body of San Marcos gabbro underlying Pala Mountain and the extensive outcrop of Bonsall tonalite on the southwest.

Evidence for the existence of the Elsinore fault zone is largely physiographic, although impressive structural evidence is present locally. The steep slopes of the mountains immediately northeast of the San Luis Rey River Valley are characterized by triangular faceted spurs and hourglass valleys -- well known physiographic criteria for the recognition of faults in semi-arid regions. The triangular form of these facets results in part from the roughly equal spacing of the consequent gullies that occupy a considerable portion of the original face of the fault scarp; the ridges between the gullies are terminated by relatively flat, weathered fault scarp remnants. The hourglass gullies have a physiographically more mature, wider cross-sectional form at their upper ends than in their lower courses, and are indicative of repeated or prolonged uplift along the fault zone (von Engeln, 1942, pp. 377-379). The hourglass gullies developed along the southwest slopes of Gomez Trail Ridge, immediately northeast of Pauma Valley, are less than one mile long and as much as 500 feet deep, and their gradients are of the order of 4000 feet per mile .

A mature erosion surface is present along the crest line of the Agua Tibia Mountain uplifted block. Larsen (1948, pp. 6-8) suggested that this mature surface may be an up-lifted portion of the Bear Valley surface, a name he applied to the area of flatland topography extending southwest from the valley of the San Luis Rey River to the Escondido area. He stated that:

> If this surface represents the (Bear Valley) plane, the vertical displacement of the fault is about 4000 feet in the northwestern part of the mountains and less to the southeast.

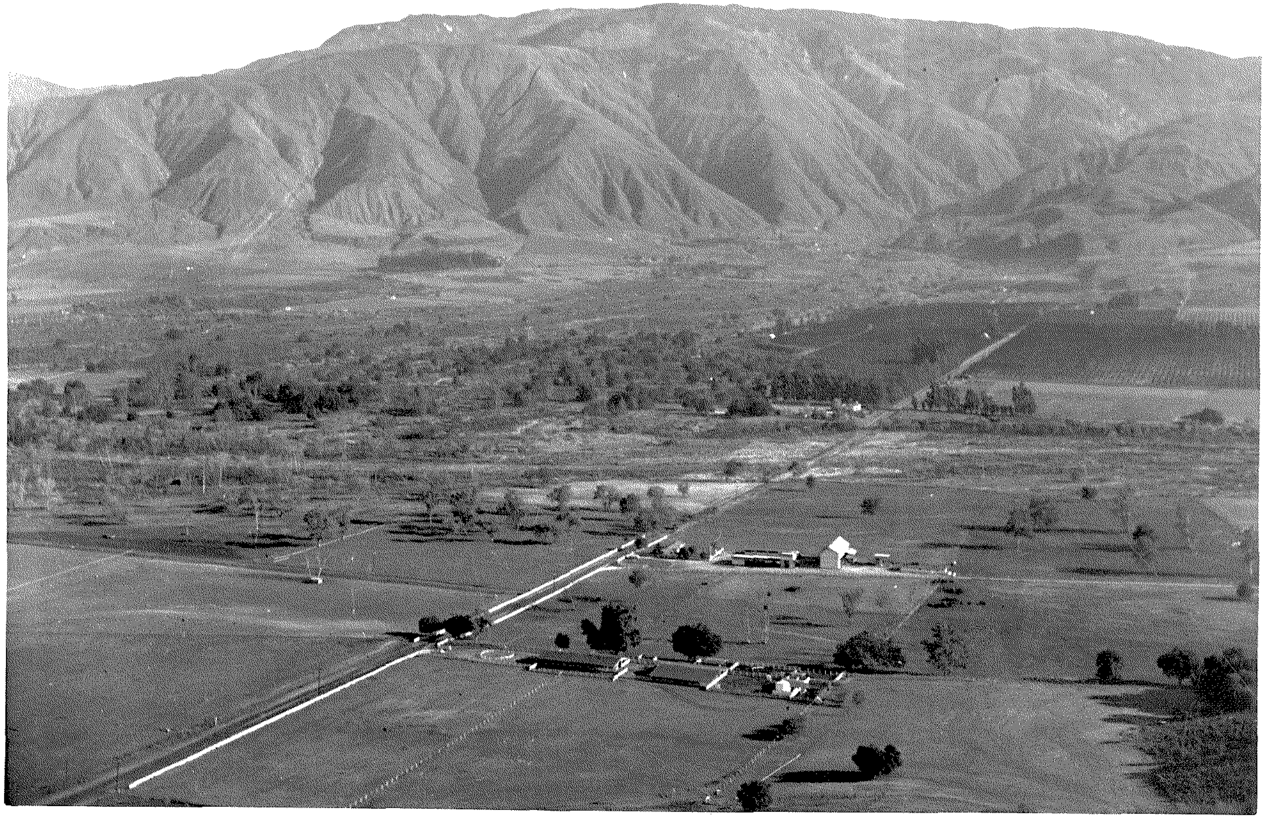

Figure 4. PHYSIOGRAPHIC FEATURES OF ELSINORE FAULT ZONE

View to the northeast across Pauma Valley. Triangular facets and hourglass gullies appear on mountain in left background. Small offset of fan at base of ridge on extreme left. Pauma Creek enters valley from canyon in right background.

The largest structural movements took place during Pleistocene time. However, Miller (1940, p. 388) reports that many earthquake shocks still originate along the Elsinore fault zone, particularly in San Diego County. The maximum vertical throw in the Pauma Valley region occurred in the Agua Tibia Mountain-Boucher Hill area. To the southeast, vertical throw in the vicinity of Lake Henshaw, on the basis of physiographic evidence only, appears to be relatively small. Thus, the Agua Tibia Mountain block appears to be tilted slightly toward the southeast. A compensating fault, whose strike should be roughly normal to the strike of the Elsinore fault zone, may be present on the northern slopes of Agua Tibia Mountain at the southern limit of Temecula Valley. The latter area was not visited, but topographic maps show a large amount of surface relief to be present there.

Structural evidence of faulting exists in many places along the Elsinore fault zone. From the head of the Agua Tibia alluvial fan southeast along the mountain front to Lake Henshaw, a distance of about 20 miles, the exposed rocks are considerably deformed in a belt as much as one mile in width. In the Pauma Valley area the rocks cropping out in Sycamore Canyon, in Nigger Canyon, and at the mouth of Pauma Creek Canyon are fractured extensively and zones of fault gouge are exposed in each of these defiles. A large spring of warm water existed for many years at the head of the Agua Tibia alluvial fan, and the rocks that crop out in that vicinity are intensely brecciated.

Attitudes were recorded by the writer on 19 individual fault planes or gouge zones exposed in the canyons of Marion Creek, Pauma Creek, Nigger Creek, and Yuima Creek. Sixteen of these features strike northwest and eleven of them dip northeast or vertical. The average of the northwest strikes is N. 31° W., and the average of the eleven dips is 48° northeast. These attitudes are interpreted as being suggestive of reverse movement along the fault zone. Some lateral movement also appears to have taken place. The gullies at the foot of Gomez Trail ridge, immediately northeast of the Pauma Creek alluvial fan, are offset to the northwest in a manner which indicates that the positive block may have moved southeast with respect to the negative block, and hence that the movement sense was right-lateral.

The trace of the Tecolote fault, although not observed directly, is inferred to be coexistent with a linear grove of oak trees trending northwesterly along the draw located immediately southwest of Pala Mountain. Water seeps to the surface at several places along this depression. The gabbroic mass comprising Pala Mountain may have been uplifted along the Tecolote fault, as the crest of the mountain is about 600 feet higher topographically than the relatively featureless erosion surface southwest of the fault. It is also possible that this topographic difference may be largely an erosional phenomenon.

The Tecolote fault extends to the north under the alluvium-filled valley of the San Luis Rey River, and it probably merges on the southeast with the Elsinore fault zone in the vicinity of Sycamore Canyon, where the outcropping rocks are highly brecciated.

A small fault has offset the Pauma Creek alluvial fan along its northeastern margin, bringing a body of Bonsall tonalite to the surface and producing a low fault scarp that faces southwest and has a maximum height of about 200 feet. The northeast side of the fault is upthrown. Alder trees have grown on the scarp at one locality where water seeps to the surface. A small reservoir was dug here in 1948 by Mr. Jack Adams of Pauma Valley, and a pond about 50 feet wide and four feet deep was formed within a few days by effluent seepage. In 1950 the pond was about the same size, and was overgrown by marsh grasses and small saplings. This small fault is a branch fault of the Elsinore fault zone. Its throw, while of uncertain magnitude, is conformable with the movement that has occurred along the Elsinore fault zone.

The pegmatite dikes of the area comprise another structural feature. The dikes have sub-parallel attitudes, and they characteristically occur in groups or swarms. The average strike of the dikes in the Pauma Valley area as measured by the writer is N. 20° W., and they have an average dip of 27° SW. It is interesting to note here that the average strike of individual faults measured by the writer in the Elsinore fault zone, as mentioned previously, is N. 31° W., and the average dip 48° NE. Although these dips are divergent, the strikes are remarkably near to being parallel. The dikes are Cretaceous in age, and the faults probably Pleistocene.

The Tecolote fault and the small fault cutting the Pauma Creek alluvial fan branch off the Elsinore fault zone at or near the prominent change in strike of the fault zone, immediately west and north of Pauma Valley. The strike of the fault zone is nearly straight between Lake Henshaw and the Pauma Valley area, where it turns abruptly northward. The change in direction of strike, the branching of the subsidiary faults, and the large amount of vertical displacement that has occurred in the Pauma Valley area permit the inference that the Agua Tibia Mountain block may have been thrust westward with respect to the negative block lying immediately west of the San Luis Rey River. If this inference is a valid one, it follows that the postulated fault bordering the Agua Tibia Mountains on the north, at the southern limit of Temecula Valley, may be characterized by strike-slip movement, with the Agua Tibia Mountain block having moved to the west with respect to the Temecula Valley block.

PHYSIOGRAPHY

The Peninsular Ranges have an interesting physiographic history. Faulting, tilting, regional uplift, and erosion have each had a definite effect in the establishment of the present land forms. The region now appears to be in the late youth stage of the normal fluvial cycle on an old land.

W. J. Miller (1935, pp. 1559-1561) outlined the physiographic history of the southern Peninsular Range, in brief, as follows:

1. Late Jurassic folding and intrusions.

2. Early Cretaceous erosion of the highland.

3. Upper Cretaceous sedimentation on the western margin of the area.

4. Continued erosion of the highland area during Eocene time, with some marine deposition along the coastal lowlands.

5. Continued erosion of the highland area in Eocene time, with some marine deposition along the coastal lowlands.

6. Early Quaternary regional uplift and block faulting along the Elsinore fault zone.

7. Later Quaternary erosion and valley cutting.

The present erosional stage of the region was given by Miller as late youth or early maturity in the normal fluvial cycle.

Larsen (1948, pp. 5-14) discussed the physiography of the northern Peninsular Ranges, and recognized the remnants of eight erosion surfaces in the San Luis Rey quadrangle. He named the Bear Valley surface and described it in the following manner:

> In Bear Valley, situated partly in the San Luis Rey and partly in the Ramona quadrangle, this surface has an area of about 30 square miles. It has a rolling topography cut on bedrock. The general relief is about 100 feet, but there are a few low hills within the main area and some higher mountains in the southern part. To the east and north this rather smooth surface gives place abruptly to the steep slopes that form the walls of San Luis Rey River and Paradise Canyon, but otherwise the surface is not much dissected. Near its western border it has an elevation of 1500 feet; it rises gently eastward to 1600 feet near its eastern margin.

The same writer recognized that (p. 8)

> In the mountains southeast of the Agua Tibia Mountains there is a conspicuous mature surface above the steep slopes northeast of the San Luis Rey River. This surface resembles the Bear Valley surface. In the northwestern part, at the head of Nigger Canyon, it has an elevation of 5200 feet. It slopes to the southeast and at Dycke Valley has an elevation of 4500 feet. It may be an upfaulted portion of the Bear Valley surface.

The comparison of elevations of the upfaulted surface and of the type Bear Valley surface of Larsen has led to the estimation of more than 3500 feet at vertical displacement along the Elsinore fault zone.

In the Pauma Valley area the San Luis Rey River has entrenched itself in a wide valley about 1000 feet below the level of the Bear Valley surface. East of Paradise Creek, at the southern (upstream) end of Pauma Valley, the river traverses a steep-walled narrow gorge in flowing across the structural grain of the region. The river gradient between Lake Henshaw and Paradise Creek is about 135 feet per mile, in sharp contrast with the gradient of 28 feet per mile that exists between Paradise Creek and the river mouth at the town of Oceanside. The river valley above Paradise Creek is obviously younger than the lower portion of the valley, and the San Luis Rey is actively downcutting here at present, whereas relatively little downcutting is taking place below Paradise Creek.

The Rincon alluvial fan, which is more than 600 feet thick, was deposited in a valley having bedrock relief in excess of 1000 feet and hence similar to the present Pauma Valley. The two valleys were probably developed at the same time by the ancestral San Luis Rey River.

Prior to the period of faulting that raised the Agua Tibia Mountains and the mountains on the southeast to their present height, the San Luis Rey River probably flowed through the valley in which the Rincon alluvial fan now lies. The river may have flowed northwest through the present Cuca Tract, curving southwest to pass through the Rincon valley and then swinging northwesterly toward Pauma Valley. The river was incised at least 1000 feet below the general level of an old-age topography that characterized this area at that time, and it probably crossed the position of the present high range of mountains in the vicinity of Lake Henshaw. The rise of the mountain block along the Elsinore fault zone was so rapid that the river could not maintain its course, and portions of its channel were abandoned.

Ellis and Lee (1919, p. 70) mention, but do not discuss, lacustrine deposits in the vicinity of Warner Valley, near Lake Henshaw. The presence of these deposits indicates that conditions of interior drainage prevailed at least temporarily in the vicinity of Lake Henshaw.

The rapid uplift of the mountains led to the deposition of the alluvial fans on the lower slopes of the mountain block, filling the valley of the San Luis Rey River with coarse sedimentary material. The Agua Tibia alluvial fan was formed at this time, and it effectively blocked the valley of the San Luis Rey River to form Lake Pauma. The Rincon and Pauma Creek alluvial fans also were deposited, filling other portions of the river valley. The river then began to cut its new channel east of Paradise Valley. The breaching of the dam impounding the waters of Lake Pauma may have followed the emptying of one or more other lakes upstream, in the vicinity of present-day Lake Henshaw.

The succession of events that followed the establishment of the Bear Valley erosion surface (in Pleistocene time?) can be summarized as follows:

1. Regional uplift of more than 1000 feet resulted in the entrenching of the San Luis Rey River in a canyon about 1000 feet below the level of the Bear Valley surface.
2. The region was depressed about 200 feet. The canyon of the river was widened, and flood-plain deposits more than 200 feet thick were laid down.
3. Movement along the fault zone raised the mountain block east of Pauma Valley. The course of the San Luis Rey River was interrupted, and conditions of interior drainage existed northeast of the fault zone. Alluvial fans were formed at the base of the mountain block. The Rincon fan filled a portion of the old valley of the San Luis Rey River, and the Agua Tibia fan completely blocked the river valley, resulting in the formation of Lake Pauma.
4. Lake Pauma was drained after the natural dam was destroyed by overflow and headward cutting. The San Luis Rey established a new, shorter channel between the Pauma Valley and Lake Henshaw areas, by headward cutting east of Paradise Valley.

5. A slight renewal of regional uplift allowed the San Luis Rey River to entrench itself slightly in its present flood plain.

WATER RESOURCES

General statement

In the Pauma Valley area, water for irrigation and domestic purposes is obtained from the surface discharge of tributary streams entering the valley from the mountains on the northeast, from water wells dug or drilled in the stream deposits of the San Luis Rey River and in the alluvial fan deposits, and from springs. Most of the water is supplied by the wells.

The San Luis Rey River is an important water source for the Vista Irrigation District; the town of Vista lies about 15 miles southwest of Pala. The Escondido Canal diverts water from the river at a point about 10 miles below Lake Henshaw. Surface flow through Escondido Canal was gauged as follows during the years 1948-1950:

1948	22,420	acre-ft.
1949	22,110	acre-ft.
1950	20,817	acre-ft.

During the ten years 1940-1950, the average annual flow through the canal was 22,320 acre-ft. The river becomes influent below the intake point of the canal, and surface flow is not attained again until the subsurface waters of the Pauma Creek fan merge with the river waters at a point southeast of Pala Mountain.

In 1950 at least 30 wells were producing water in the Pauma Valley area. Most of these were less than 200 feet deep, and most yielded large amounts of water with moderate draw-downs while retaining near-surface water levels (see Fig. 5, in pocket). Very few unsuccessful wells have been drilled. Many of those in the lower parts of the river valley are capable of producing at the rate of 100 miner's inches, or 900 gallons per minute (see Fig. 6, in pocket).

The San Luis Rey River is the trunk stream of this area, and all surface and subsurface waters within its drainage area move to the river valley and downstream within that valley. Thus the flood-plain sands and gravels of the San Luis Rey River are the best aquifers in the area. Almost all of the wells producing large quantities of water are drawing from these sediments.

Some evidence suggests that water is being withdrawn from the sediments of the river valley at a rate in excess of the rate of replenishment by rainfall. Decline has been recorded in the productivity of U. S. Government wells No. 3 and No. 9, which are located on the Rincon Indian Reservation. Between 1940 and 1950, the water level in well No. 3 dropped from 13 feet to 26 feet, 2 inches and the rate of production declined from 1017 to 920 gallons per minute, while the drawdown increased from 60 to 81 feet. In well No. 9, the water level fell from 15 feet in 1934 to 33 feet in 1950, and during the same period the producing rate diminished from 750 to 450 gallons per minute and the draw-down increased from 73 feet to 86 feet. No other records of this type were made available to the writer, but most of the ranchers who would comment on the performance of their wells in the flood plain of the river gave the impression that the water levels had declined slightly or not at all in the past several years.

Rincon fan

The Rincon alluvial fan is unusual in that it occupies a portion of a former entrenched channel of the San Luis Rey River. Built outward from the steep southwest slopes of Boucher Hill toward the present valley of the river, this fan is about three and one-half miles long and one-third of a mile to one mile in width, being bounded along its sides by low hills of Bonsall tonalite. The narrow point of the fan is at Rincon spring near its lower margin where the tonalite walls of the old river channel are especially resistant to erosion because of the presence of a group of large, west-dipping pegmatite dikes. In cutting its valley here, the ancestral San Luis Rey River apparently meandered laterally both above and below the location of the dikes, but was restricted to a relatively narrow gap in their immediate vicinity. The result is a valley characterized by an hourglass shape in its plan view. Rincon spring is a result of the rising to the surface of the underground waters at the narrow center of the "hour glass"; the spring waters are absorbed by the fan immediately below the spring. Tolman (1937, p. 236) has described this type of spring as follows:

> If the cross-sectional area (of pervious material) is variable, as is common in stream channels excavated in impervious material and filled with pervious stream deposits, the narrow portions of the channel (smallest cross-sectional area)have the smallest capacity to transmit water. Hence rising ground water may be forced to the surface at or above the narrow portions of the alluvium-filled excavation, and if the stream bed is dry, running water starts at this point and may be reabsorbed farther down stream if the cross-sectional area of the water-bearing material increases.

The deposits of the Rincon alluvial fan are very thick. The Rincon Ranch No. 1 well penetrated at least 616 feet of sands and gravels, and the Rincon Ranch No. 3 well encountered at least 505 feet of these sediments (see Fig. 8, in pocket). The existence of the springs at Rincon is an indication that a considerable amount of water moves beneath the surface of the fan. Excellent water wells have been completed on the Rincon ranch and on the Anderson ranch. The creeks that carry water to the Rincon fan drain a relatively small area -- about six square miles. Hence, the amount of runoff water that recharges the Rincon fan is definitely limited. However, since these creeks transect the Elsinore fault zone, it is possible that they, and hence the Rincon alluvial fan, may be charged by waters that may be moving laterally along fractures within the fault zone. If recharge is being effected only by runoff waters, and if the number of wells drilled and pumped increases drastically, it is quite possible that the available ground water reserve in the fan would soon be exhausted. The productivity of the wells would then become small and would be

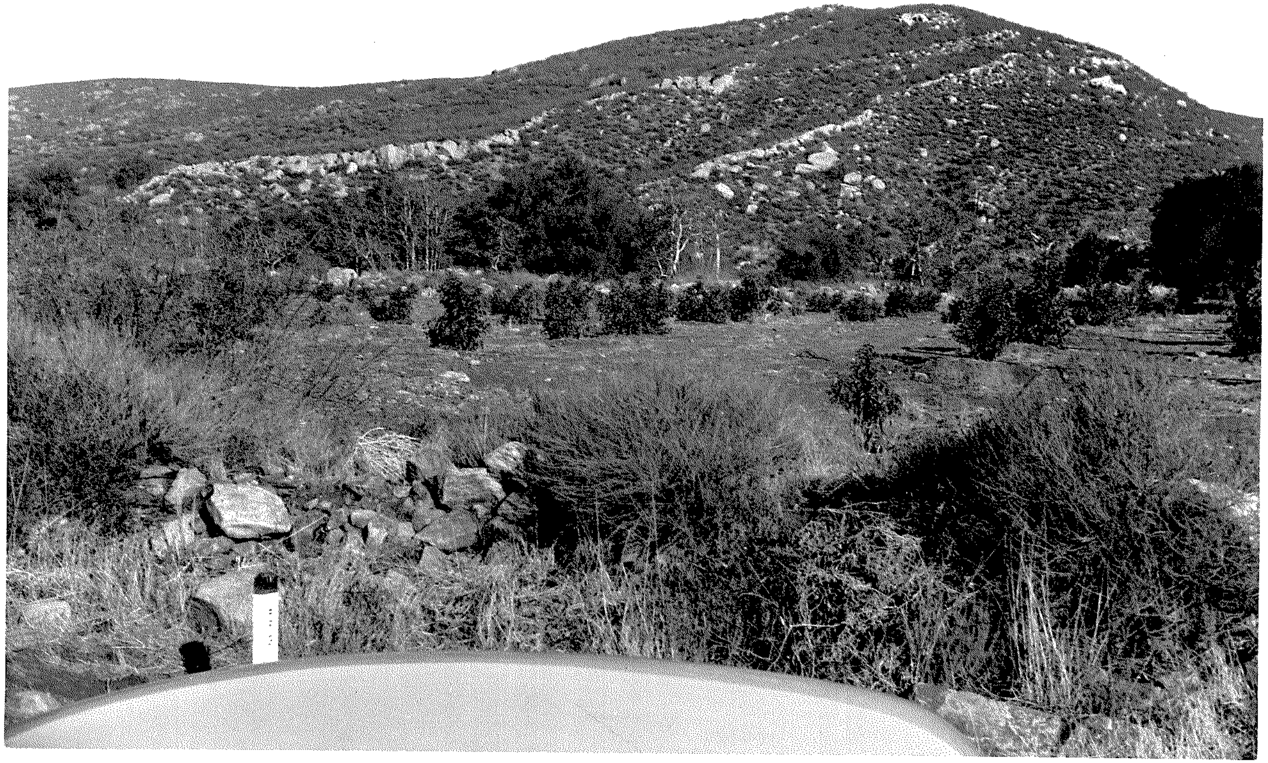

Figure 7. PEGMATITE DIKES CUTTING BONSALL TONALITE

View to north from highway near Rincon spring, one-half mile northeast of Rincon store. Large dike on left is as much as ten feet thick.

variable from year to year, depending on the amount of rainfall recharging the reservoir. A prolonged drying-up of the Rincon spring would be an indication that water is being withdrawn from the subsurface faster than replenishment can be accomplished by natural means.

Pauma Creek fan

Relatively few wells have been drilled on the Pauma Creek fan. Only three were recorded by the writer -- the Moore well and the two wells drilled by Mr. Vaughan Maynard on his ranch. The lenticular nature of the fan deposits is well illustrated by the results of the two Maynard wells. The first of these failed to encounter a good aquifer, but the second well, located about 600 feet northwest of the first, was more satisfactory. About 180 gallons per minute can be pumped from the second well, with a 55-foot draw-down.

The Pauma Creek alluvial fan was deposited on a very irregular bedrock surface. A "window" of San Marcos gabbro protrudes through the fan materials about one mile east of the Pauma Valley School, in the southeastern portion of the fan; yet at a point about 2000 feet east of and approximately 80 feet topographically higher than the bedrock "window", the Eakin well No. 4 was drilled through 300 feet of fan materials. The fan has been broken by faulting near its northeastern margin by differential movement along the Elsinore fault zone, and a body of Bonsall tonalite has been brought to the surface there. Displaced alluvial deposits can be seen along the east wall of Pauma

Creek Canyon, below the rocky gorge of the creek. The center of the fan, across which the two distributary streams now flow, is the location of the greatest thickness of the alluvial deposits.

The greater part of the surface waters discharged by Pauma Creek is diverted at the mouth of Pauma Creek Canyon and delivered to the Pauma Indian Reservation. However, the fact that the San Luis Rey River is influent above its junction with the dry bed of Pauma Creek and effluent below that point may indicate that an appreciable amount of water does pass through the fan materials. The fan should be a better producer of ground water than it was in 1950, when the writer last visited the area. It probably would be advisable to drill a few wells along the axis of the alluvial fan, this being just north of the present Pauma Wash. Another suggested location would be in Pauma Wash west of the Maynard wells.

Agua Tibia fan

Very little was learned concerning the subsurface waters of the Agua Tibia alluvial fan, as little information could be obtained from the proprietor of the Agua Tibia Ranch, which occupies most of the surface of the fan. At least three wells have been drilled on the ranch. Two of these, one a flowing well, are located near the ranch house; the third was sunk about one-half mile south of the ranch house, and is now abandoned.

An interesting feature of this area is the large spring of warm water that formerly issued at the head of the fan, near the present site of the ranch house. Larsen (1948, p. 128) mentioned this and several other hot springs in the region, stating:

> These springs may be related to igneous activity but are believed to be fed for the most part by surface waters that have penetrated deeply into the hotter part of the earth's crust and risen to the surface along faults.

The Agua Tibia spring flowed until a water well was drilled nearby. In 1948 the water well was flowing warm water and the spring was dry. Doubtless the well had tapped the fracture system through which water had been moving to the surface to the location of the spring.

Logs were obtained for the well drilled one-half mile south of the ranch house and for one of the wells drilled near the spring. The depths of these bore holes were 700 and 702 feet, respectively. The logs indicate that the fan materials are very coarse, and are composed almost entirely of boulders (see Fig. 4). In view of the nature of these deposits and the likelihood that they are the product of mudflows, a general sparsity of permeable aquifers seems probable, and hence this fan is not a favorable place to drill for ground water except near its head, where extensive faulting and fracturing of the bedrock have provided channels through which ground waters can migrate freely.

Influence of faulting on the ground water system

Ground-water reservoirs are present in the Pauma Valley area in fracture systems in crystalline rocks and in the Quaternary sedimentary deposits. These younger deposits occur in the topographically lower areas and are very slightly or not at all indurated. They carry a relatively large amount of water per unit of volume and hence are generally much better aquifers than the very dense crystalline rocks.

Ground-water moves through the hard crystalline rocks in fractures. Where the fractures are narrow and widely spaced, very little water flows through a given volume of the rock, but where they are wide and closely spaced, water can move more easily through the system.

In the vicinity of the Elsinore fault zone the crystalline rocks are intricately fractured, and there are indications that ground-water is moving through the fractures. The spring discovered and dug out by Mr. Jack Adams, which was cited in the section on structural geology, is one example. A highly fractured outcrop of Woodson Mountain granodiorite, located on the bluff across Pauma Creek from Mr. Monta Moore's ranch house, is said to be always saturated with water; the writer found this outcrop to be moist to a height of about 20 feet above the level of Pauma Creek, which contained some surface water here at the time. Similarly, the springs that occur along the trace of the Tecolote fault are the result of ground-water moving to the surface along a zone of fractured bedrock.

In the vicinity of these large faults it is likely that the greatest amount of fracturing has occurred parallel to the trend of the fault zone. Fault gouge should be present in many of the fractures along which movement has taken place, and this may provide seals or impervious barriers, so that subsurface water may not easily move across the fault zone. If a ground-water (potential) gradient exists across the fault zone, as it does in the case of the Agua Tibia fault zone because of the great topographic change that occurs across the fault zone, a hydrostatic head built up behind the impervious barrier may cause the trapped waters to rise to the surface and to issue forth as a spring. Such a phenomenon may have been responsible for the occurrence of the Agua Tibia spring. Ground-water trapped behind an impervious fault zone may also migrate laterally along the fault zone through fractured rocks, emerging as a seep or a spring in a canyon transecting the fault zone. Seeps of this type can be observed along the walls of Pauma Creek Canyon across from the Moore ranch house and in Jaybird Creek Canyon just north of BM 2093.

Wells to test for water trapped behind impervious barriers in the Agua Tibia fault zone could be drilled just east of the Pauma Indian Reservation adjacent to Pauma Creek; in Nigger Canyon at an elevation of about 1500 feet; and on the terrace east of Sycamore Canyon at an elevation of about 1800 feet. The bedrock is considerably fractured and trees grow in each of these places. Trees and other plants that make use of ground-water are an indication that the water table is relatively near to the surface.

Summary

In the pauma Valley area ground-water is produced from the flood plain deposits of the San Luis Rey River and from the deposits of the Rincon, Pauma Creek, and Agua Tibia alluvial fans.

The San Luis Rey River is the trunk stream of the area, and the flood plain deposits of its valley are, and will continue to be, the most important source of ground-water in the area. Limited evidence indicates that the ground-water table has been lowered about 13 feet during the period 1940-1950. This does not represent a major change, but the situation is worthy of further observation. A prolonged increase in the rate of production of water from the flood plain deposits could result in a serious lowering of the ground-water table. Further exploitation of the subsurface waters of the Rincon and Pauma Creek alluvial fans, which now flow into the river valley, would diminish the total amount of ground-water entering the valley and this also would contribute to the lowering of the ground-water table in the river valley.

The deposits of the Rincon alluvial fan are an important producer of ground-water. Although the area drained by the creeks that enter the fan is small and annual stream runoff into the fan deposits is limited, several highly productive wells have been drilled on the fan, and Rincon spring has continued to be active. Water that has migrated laterally through fractured rocks along the Elsinore fault zone may be moving into the creeks above the fan and thence down through the fan deposits. Unless the fault zone is supplying water to the Rincon fan deposits, a drastic lowering of the ground-water table here seems to be a future probability, should water production increase markedly through the drilling of additional wells.

At present, little ground water is produced from the alluvial deposits of the Pauma Creek fan, but these deposits should be capable of yielding water at satisfactory rates. The thickness of the fan materials is variable, owing to the irregularity of the bedrock surface on which they were laid down. It would seem advisable to drill a few wells along the present course of Pauma Creek, where the fan materials appear to be relatively thick.

Wells located near the head of the Agua Tibia alluvial fan produce water near the site of the old Agua Tibia spring. The warmth of the water produced formerly by the spring and now by the wells may indicate that it has risen along fracture zones from deep within the earth. The Elsinore fault zone crosses the fan in the locality at which the wells are located. The Agua Tibia fan is composed largely of boulders and is considered to be for the most part a deposit composed of mud flows and debris flows. It is unlikely that the deposits of this fan will assume any future importance as an aquifer, owing to their generally poor permeability.

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APPENDIX

WELL DATA

<u>Graham & Son Well</u> (Agua Tibia Ranch)

This well was drilled near the Agua Tibia spring, date unknown. Previously, another well was drilled nearby.

<u>Driller's Log</u>:

0-150 feet	Boulders, ordinary.
150-702 "	Boulders (diorite), some clay and a little cement.

<u>Remarks</u>:

Water rose to 50 feet at once, and gradually rose to 29 feet. Water level lowered to 68 feet after pumping adjacent well. It was understood that this well was flowing in 1948.

Source of information: Roscoe Moss Drilling Company, Los Angeles.

<u>Agua Tibia Well No. 3</u>

This well was drilled in 1929 by Roscoe Moss Drilling Company. In 1948 the well was not in operation; junk was in the hole.

<u>Driller's Log</u>:

0-307 feet	Pit (dug); all boulders.
307-365 "	Boulders.
365-465 "	Hill formation.
465-511 "	Hill and boulders.
511-540 "	Granite.
540-586 "	Hill formation.
586-590 "	Hard black granite.
590-596 "	Hill formation.
596-601 "	White granite.
601-628 "	Hill formation.
628-668 "	Hard gray rock.
668-678 "	White quartzite.
678-688 "	Hard gray rock.
688-700 "	White quartzite.

Remarks:

Water was first found at 368 feet. "Hill formation" is a driller term for rock that looks like the outcropping formation on the nearest hill. In this instance the term probably means large boulders and coarse arkosic sands.

Source of data: Roscoe Moss Drilling Company, Los Angeles.

Well elevation 1004 feet, estimated from map.

Gale Well (at lower end of Pauma Valley)

This well was drilled prior to the aquisition of the property by Mr. Gale. He stated that the well is about 100 feet deep, but was uncertain as to whether the lake bed was penetrated. No driller's log is available. The well is pumped regularly throughout the year, with only a very temporary drawdown. The water level returns to its normal position, about 10 feet below the ground level, almost immediately after pumping is discontinued. Pumping rate not established. Elevation of the well, 696 feet, estimated from map.

Adams Well (in Pauma Valley)

The well was drilled between 1948 and 1950; total depth is 200 feet. Casing was set at 195 feet. Although the actual pumping rate was not ascertained, Mr. Adams stated that the well could produce at a rate "better than 50 inches", or about 450 gallons per minute.

Driller's Log:

0- 15	feet	Surface formation.
15- 23	"	Sand.
23- 28	"	Quicksand
28- 72	"	Coarse sand and boulders; water.
. 72- 94	"	Blue clay (lake bed).
94-114	"	Sand and boulders.
114-131	"	Sand and boulders.

131-137	feet	Sand.
137-139	"	Clay.
139-140	"	Rock.
140-150	"	Sand and gravel.
150-151	"	Rock.
151-157	"	Sand and gravel.
157-163	"	Rock.
163-169	"	Water sand.
169-171	"	Rock.
171-181	"	Water gravel.
181-182	"	Rock.
182-194	"	Sand and boulders.
194-200	"	Rock.

Remarks:

Water level 22 feet below surface. Well drilled by Vaughan Maynard, using cable tools. Source of data: Mr. Jack Adams. Elevation of well, 706 feet, surveyed.

Gilbert Wells

Mr. Myron Gilbert has two wells on his property in Pauma Valley. Well No. 1 was drilled prior to 1948 to a total depth of 105 feet, penetrated the lake bed "at about 50 feet", and found a good aquifer below that bed. The well can be pumped at the rate of 900 gallons per minute. The water level in 1948 stood at ten feet from the surface. Source of information: Mr. Myron Gilbert. No driller's log available. Elevation of well, 706 feet, surveyed.

Well No. 2 was drilled in 1950. Mr. Vaughan Maynard, who drilled this well, estimated that it would be capable of producing 50 to 100 inches (450 to 900 gallons per minute).

Driller's Log (Well No. 2)

0- 50	feet	Surface formation.
50- 76	"	Good water gravel.
76- 80	"	Lake bed.
80-150	"	Gravel; lower part not good.
150-156	"	Clay.

Remarks:

Source of information: Mr. Vaughan Maynard, Elevation of well, 703 feet, surveyed.

Cawthorn Well

Drilled to a depth of 265 feet by Vaughan Maynard, this well is capable of producing 32 inches of water (288 gallons per minute). The water level stands at 105 feet. Although no driller's log was maintained, it is said that the lake bed was penetrated in the well. Source of information: Mr. Vaughan Maynard. Elevation of well, 825 feet, estimated from map.

Moore Well

Located near the head of the Pauma Creek fan, this well was drilled in 1936.

Driller's Log:

0- 27	feet	Sand and boulders.
27- 49	"	Clay and decomposed granite, water at 40 feet.
49- 68	"	Decomposed granite, streaks of clay.
68- 87	"	Same.
87-105	"	Hard clean blue granite.
105-155	"	Pink granite and clay.
155-175	"	Decomposed granite.
175-180	"	Pink granite.
180-192	"	Hard granite.

Remarks:

This well yields water at the rate of about 3 gallons per minute during the rainy season each year. No appreciable production can be obtained during the remainder of the year. The water level stands at 31 feet and the drawdown, while not known exactly, is excessive. The driller's log shows that the well penetrated coarse alluvial fan materials. Source of information: Mr. Monta Moore. Elevation, 1235 feet, estimated from map.

Maynard Wells

Two wells were drilled by Mr. Vaughan Maynard on his ranch on the Pauma Creek alluvial fan. Well No. 1 was a very poor well, yielding little water, and is not in use. No further information was available about this well.

Well No. 2, located about 500 feet northwest of No. 1, was drilled to a total depth of 344 feet. The water level is 75 feet from the surface, and the well can be pumped at the rate of 180 gallons per minute with a drawdown of 55 feet. The pumping of this well does not affect the water level in well No. 1; this interesting phenomenon probably indicates that the aquifer yielding water through the No. 2 well is not present at the location of the No. 1 well -- a situation which is not uncharacteristic of the lenticular alluvial fan deposits. Source of information: Mr. Vaughan Maynard. Elevation of well No. 2, 970 feet, estimated from map.

Palomar Ranch Wells

In 1950, nine wells were producing water on this ranch, which is located on the flood plain of the San Luis Rey River. Several of these are large wells producing water at the rate of about 500 to 600 gallons per minute, while two or three are small domestic wells. Water level in all wells is 10 to 13 feet below the surface except in one well, where it is at 20 feet. Source of information: Mr. Goss, ranch foreman.

Driller's Log (Well No. 4)

0- 9	feet	Dry sand.
9- 12	"	Coarse wet sand.
12- 16	"	Sand.
16- 25	"	Blue sandy shale.
25- 33	"	Coarse sand, pea gravel.
33- 39	"	Coarse gravel.
39- 43	"	Boulder.
43- 50	"	Coarse water sand.
50- 60	"	Decomposed granite.
60- 64	"	Coarse gravel.
64- 79	"	Blue shale and sand mixed.
79- 83	"	Coarse sand, some shale.
83- 93	"	Black mud -- lake bed.
93-115	"	Sand and gravel.
115-127	"	Blue shale and gravel.
127-133	"	Red clay.
133-135	"	Decomposed granite.
135-145	"	Coarse granite.
145-149	"	Decomposed granite.

Remarks:

Well No. 4 was drilled in December, 1947, by a contractor named G. E. Fritts. The well was cased and perforated from 145 to 135 feet and from 50 to 25 feet. Source of information: Webb Brothers Company, Escondido. Elevation, 745 feet, surveyed.

Harwood Well

Drilled in December, 1934 by Mr. Vaughan Maynard, this well can be pumped at the rate of 900 gallons per minute.

Driller's Log:

0- 12	feet	Soil.
12- 28	"	Loam.
28- 52	"	Sandy soil and boulders.

52- 78	feet	Silt with some rocks.
78-108	"	Good water gravel sandy at bottom.
108-112	"	Blue Clay.
112-126	"	Fine blue sand.
126-135	"	Silt soil.
135-146	"	Boulders and gravel.
146-148	"	Fine blue sand.
148-154	"	Boulders and gravel, lots of dirt.

Remarks:

The well bore is 20 inches in diameter; the water level stands at 55 feet. Source of information: Mr. Vaughan Maynard. Elevation, 808 feet, surveyed.

O. A. Lyall Wells

Mr. O. A. Lyall has at least three wells in Pauma Valley. Two of these were located in Pauma Wash; one was a 232-foot deep **failure**, and the other was drilled to a depth of 300 feet. Well No. 3, located about one-half mile southeast of Pauma Wash, was a good well at 292 feet.

Driller's Log (Well No. 3)

0-160	feet	Soil.
160-204	"	Gravel.
204-225	"	Tight gravel.
225-238	"	Sandy hard clay.
238-286	"	Gravel.
286-292	"	Sandy clay.

Remarks:

Water level 130 feet (in 1948). The well was drilled in August 1946 by Mr. Vaughan Maynard. Source of information: Mr. Maynard. Elevation, 899 feet, surveyed.

Driller's Log (Pauma Wash well)

0- 30 feet	Gravel and boulders.
30- 65 "	Silt and clay.
65- 70 "	Silty gravel.
70- 76 "	Silt and clay.
76- 77 "	Black silt.
77- 92 "	Silt and clay.
92-102 "	Fine sand.
102-112 "	Black silt -- tule (lake) beds.
112-124 "	Gravel.
124-144 "	Hard silty clay.
144-158 "	Red clay.
158-162 "	Gravel.
162-180 "	Silt.
180-183 "	Gravel.
183-194 "	Sandy clay.
194-197 "	Gravel.
197-208 "	Dirty sand.
208-232 "	Silt.

Remarks:

Drilled in January 1945 by Mr. Vaughan Maynard. Source of information: Mr. Maynard. Elevation, 800 feet, surveyed.

Eakin Wells

Four wells, all of them failures, were drilled on the Eakin ranch prior to 1948. Well No. 1 was terminated at 193 feet, No. 2 at 143 feet, and No. 4 at 300 feet; the depth of No. 2 is unknown. All were located within an area of a few thousand square feet, a short distance below the mouth of Nigger Creek Canyon. The driller's log of the deepest well, No. 4, is representative of the subsurface conditions at all of these well locations.

Driller's Log (Well No. 4)

0- 40 feet	Rocks and soil.
40- 44 "	Blue granite.
44- 47 "	Red clay.
47- 51 "	Sandy clay.

51- 60	feet	Yellow clay and rock.
60- 62	"	Yellow clay and sand.
62- 63	"	Sand getting coarse.
63- 66	"	Quicksand and decomposed granite.
66- 69	"	Yellow clay.
69- 75	"	Rock and mushy clay. Five feet of water in the hole.
75- 79	"	Starting to get sandy.
79- 84	"	Sand and light clay.
84- 88	"	Rock and sand.
88- 90	"	Gray clay and fool's gold.
90- 94	"	Sandy clay.
94- 96	"	Sand and clay.
96-100	"	Rock and clay
100-125	"	Gray clay and small boulders.
125-145	"	Sandy soil.
145-146	"	Pure sand.
146-182	"	Sandy soil.
182-184	"	Quicksand.
184-186	"	Yellow clay.
186-201	"	Rock and sand.
201-205	"	Rock and sand.
205-209	"	Sandy gray clay.
209-225	"	Rock and sand.
225-236	"	Gray clay and sand.
236-242	"	Very little clay; still seems to be sand between good sized rock.
242-243	"	Rock.
243-265	"	Gray clay and sand.
265-267	"	White clay and white quartz.
267-270	"	Rock.
270-280	"	Coarse gravel.
280-283	"	Rock.
283-294	"	Brown soil with some sand.
294-300	"	Hard rock.

Remarks:

Drilled to 300 feet with an 8-inch bit. Casing set at 296 feet. Source of data: Mr. S. V. Eakin.

Deemer Wells

Mr. M. J. Deemer has at least three producing water wells in the Pauma Valley area. Two of these were drilled by Mr. Vaughan Maynard, who kindly provided the driller's logs for these, one an un-numbered well, and the other known as No. 3.

Driller's Log (Un-numbered well)

0-148	feet	Soil.
148-165	"	Hard decomposed granite, clay, silt, and gravel.
165-220	"	Gravel.
220-266	"	Silt.
266-270	"	Clay.
270-280	"	Hard clay and rock.
280-286	"	Good gravel.
286-315	"	Clay.

Remarks:

Water level 125 feet. Lake bed was penetrated, according to Mr. Maynard. (Could be silt at 200 feet?) Drilled in November 1944. Elevation, 892 feet, surveyed.

Driller's Log (Well No. 3)

0- 90	feet	Soil.
90-160	"	Silt and clay, soft.
160-175	"	Soft silt.
175-195	"	Hard decomposed granite.
195-200	"	Silt.
200-220	"	Gravel.
220-226	"	Dirty gravel and silt.
226-228	"	Gravel.
228-270	"	Dirty gravel and silt.
270-280	"	Hard sandy clay.
280-285	"	Gravel.
285-304	"	Hard sandy clay.
304-305	"	Rock.
305-364	"	Good gravel, lots of fine silt.
364-372	"	Hard red clay.

Remarks:

Water level 126 feet; well would make 300 gallons per minute with no drawdown when completed, in October 1945. Source of information: Mr. Vaughan Maynard. Elevation, 896 feet, surveyed.

C. W. Ide Well

This well was drilled by Mr. Maynard in December 1946. After completion, it was pumped regularly at the rate of 585 gallons per minute, but on test it has yielded as much as 1800 gallons per minute.

Driller's Log:

0- 90	feet	Surface formation.
90-108	"	Sand.
108-114	"	Black tule (lake) bed.
114-132	"	Conglomerate, not porous.
132-190	"	Gravel.
190-200	"	Silt.
200-234	"	Gravel, lots of sand.

Remarks:

Water level 82 feet from surface. Source of information: Mr. Vaughan Maynard. Elevation, 846 feet, surveyed.

Hawes Well

Drilled in 1943 on the Pauma Vista ranch, the well was tested for a capacity of 900 gallons per minute. In 1948 the well was being pumped at the rate of 270 gallons per minute, which was the capacity of the pump.

Driller's Log:

0-105	feet	Alluvial soil.
105-117	"	Rounded rocks and gravel.
117-157	"	Silt and mica.
157-162	"	Water gravel.
162-185	"	Silt.
185-187	"	Gravel, fair.
187-198	"	Silt and small gravel.
198-220	"	Large gravel.
220-	"	Light clay.

Remarks:

Mr. Hawes drilled this well himself, He looked for the lake bed, but did not find any trace thereof. It is possible that the "silt and mica" encountered at 117-157 feet may be in part a shoreline phase of the lake bed.

The water level in 1948 was 110 feet; in 1950 it was still 110 feet, indicating no change. Elevation of the well is 874 feet, surveyed. Source of data: Mr. Hawes.

Sohl Well

This well was completed in November of 1950, at a total depth of 231 feet. No recognizable lake bed was encountered. Water level stood at 56 feet when completed. Production potential unknown. Elevation, 867 feet, surveyed. Source of data: Mr. Jack Squires.

Squires and Rogers Well

Drilled by a contractor named Kilpatrick, this well was tested for 24 hours after completion at the rate of 675 gallons per minute. It is said that the lake bed was encountered at a depth of 90 feet, and was 12 feet thick; this seems odd, since neither the Hawes nor the Sohl wells, located a short distance to the northwest, penetrated the lake bed. Date of completion, total depth of well, water level, and other data not ascertained. Source of information: Mr. Jack Squires. Elevation, 842 feet, surveyed.

Rincon Ranch Wells

At least eight wells have been drilled by the Rincon Ranch, which is located on the Rincon alluvial fan, northwest of the Palomar Mountain road.

Driller's Log (Well No. 1)

0- 40	feet	Rock and granite.
40- 48	"	Soft granite.

48- 50	feet	Hard rock.
50- 65	"	Soft rock.
65- 77	"	Soft dark granite.
77- 78	"	Sand.
78- 79	"	Hard granite.
79- 82	"	Soft granite.
82- 88	"	Hard granite.
88- 89	"	Sand.
89- 90	"	Soft granite.
90- 96	"	Solid rock.
96- 98	"	Soft granite.
98-106	"	Coarse sand.
106-114	"	Coarse sand (?), first water at 113½.
114-117	"	Very hard rock.
117-118	"	Hard granite.
118-127	"	Sand.
127-128	"	Hard granite.
128-130	"	Good coarse sand.
130-131	"	Good coarse sand.
131-132	"	Solid rock.
132-133	"	Good coarse sand.
133-135	"	Hard rock.
135-136	"	Soft granite.
136-137	"	Sand.
137-138	"	Granite and yellow clay.
138-140	"	Rock.
140-142	"	Sand.
142-143	"	Granite.
143-152	"	Good coarse sand.
152-153	"	Soft granite and clay.
153-169	"	Good coarse sand.
169-170	"	Rock.
170-172	"	Coarse sand.
172-174	"	Granite and clay.
174-177	"	Good gravel, some water.
177-179	"	Granite.
179-186	"	Sand.
186-187	"	Granite and dark clay.
187-190	"	Sand.
190-191	"	Granite and yellow clay.
191-193	"	Brown formation; looks like shale.
193-199	"	Good gravel.
199-202	"	Granite.
202-203	"	Solid rock.
203-205	"	Granite.
205-209	"	Yellow clay.
209-211	"	Good gravel. Had to set casing at 212.
211-217	"	Good gravel.
217-221	"	Decomposed granite.

221-226	feet	Hard granite.
226-229	"	Sand.
229-234	"	Sand, some gravel.
234-241	"	Hard granite.
241-248	"	Decomposed granite.
248-254	"	Yellow clay.
254-257	"	Decomposed granite.
257-262	"	Blue granite.
262-266	"	Decomposed granite.
266-271	"	Fair gravel.
271-277	"	Hard granite.
277-283	"	Decomposed granite.
283-287	"	Red clay.
287-291	"	Decomposed granite.
291-293	"	Hard granite.
293-298	"	Decomposed granite.
298-301	"	Hard granite.
301-304	"	Decomposed granite.
304-320	"	Sand, and steel (junk?)
320-405	"	Decomposed granite.
405-412	"	Hard granite.
412-445	"	Sand and gravel.
445-515	"	Soft decomposed granite.
515-520	"	Granite, hard.
520-600	"	Sand and boulders.
600-605	"	Hard granite.
605-609	"	Bentonite shale.
609-616	"	Granite, hard, broken.
616-644	"	Hard granite.

Remarks:

This well is located near a machine shed on the ranch, and it was drilled through the Rincon alluvial fan. It is possible that bedrock was encountered here at about 609 feet. Whether this was the fact or not, it is definite that the fan materials are over 600 feet thick at this point. The well was capable of production at the rate of 585 gallons per minute in 1948. No data were obtained regarding the water level. The elevation of the well, 1530 feet, was estimated from the map. Source of data: Mr. Barrett, owner of the ranch.

Driller's Log (Well No. 2)

0- 60	feet	Gravel and boulders.
60-104	"	River wash.
104-135	"	Decomposed granite.
135-148	"	Soft clay and granite.
148-170	"	Decomposed granite.
170-176	"	Clay and gravel.
176-186	"	Decomposed granite.
186-271	"	Granite.
271-273	"	Soft gray granite.
273-304	"	Granite.
304-306	"	Very hard granite.

Remarks:

Drilled by Mr. Vaughan Maynard; completed in June 1946. The well is located across the road from the Rincon Store, on the lower part of the Rincon alluvial fan. The water level was at 110 feet after completion of the well, and the capacity of the well was 135 gallons per minute. The well was not in use in 1948. Source of information: Mr. Vaughan Maynard. Elevation, 1015 feet, surveyed.

Driller's Log (Well No. 3)

0- 20	feet	Dobe sand.
20- 30	"	Hard boulders.
30- 50	"	Sand and boulders.
50- 85	"	Decomposed granite.
85- 87	"	Hard boulder.
87-109	"	Decomposed granite and boulders.
109-112	"	Boulder.
112-196	"	Decomposed granite and boulders.
196-217	"	Soft decomposed granite.
217-311	"	Decomposed granite and boulders.
311-321	"	Soft decomposed granite.
321-440	"	Soft decomposed granite, hard boulders.
440-485	"	Soft decomposed granite.
485-505	"	Decomposed granite, hard boulders.
505-547	"	Hard blue granite.

Remarks:

This well was drilled by Scroggins & Son, of Long Beach, and is located near the ranch house, on the Rincon alluvial fan. It was completed for a production rate of 400 gallons per minute, prior to 1948. In 1950 the well was still yielding 400 gallons per minute, and the water level was at 55 feet. It is possible that bedrock was encountered at 505 feet in the well. Source of information: Mr. Barrett and Mr. Martin of Rincon Ranch. Elevation of the well, 1215 feet, estimated from map.

Other Rincon Ranch Wells

Some information was gained relative to three of the other five wells owned by Rincon Ranch as of 1950. Wells No. 4 and Well No. 6 were drilled in the valley of the San Luis Rey River, and both reportedly encountered the lake bed. Well No. 6 was tested for a capacity of 1500 gallons per minute, and is 92 feet deep. Rincon Ranch No. 5 well is located high on the alluvial fan (exact location not ascertained), is 432 feet deep, was bottomed in decomposed granite, produces 63 gallons per minute, and has a water level 207 feet from the surface. Source of information: Mr. Vaughan Maynard, Mr. Hibbard (owner of a small ranch on the Rincon fan), and Mr. Colby, owner of the restaurant at Rincon Springs.

Anderson Well

This well, located just across the highway from the Rincon Ranch No. 3 well, was drilled in 1948. Upon completion, at a total depth of 265 feet, this well was capable of producing 65 inches (585 gallons per minute) with a drawdown of 85 feet. The water level, which was 30 feet, and the well capacity were unchanged between 1948 and 1950. Source of information: Mr. Gale, foreman of the Anderson ranch. Elevation of the well, 1205 feet, estimated from the map.

McCormick Well

This well was drilled by Mr. Vaughan Maynard, on the McCormick property in the San Luis Rey River Valley near Rincon.

Driller's Log:

0- 55	feet	Soil.
55- 60	"	Gravel.
60- 72	"	Dirty sandy formation.
72- 94	"	Gravel.
94-106	"	Silt.

Remarks:

The well tested for a capacity of 800 gallons per minute when completed. The water level was then 41 feet below the surface. Source of information: Mr. Vaughan Maynard. Elevation, 853 feet, estimated from map.

Schabelitz Well

Drilled in July of 1945, this well reached bedrock at a depth between 110 and 160 feet. The well is located on the southern portion of the Rincon alluvial fan, about one-quarter mile southeast of Rincon.

Driller's Log:

0- 10	feet	Rock and sand.
10- 30	"	Decomposed rock and sand.
30- 42	"	Some clay and decomposed rock.
42- 62	"	Rock.
62- 70	"	Sand and water.
70-110	"	Granite and decomposed rock.
110-160	"	Granite.

Remarks:

In 1948 the well was producing about 85 gallons of water per minute with a limited drawdown. Water level was 85 feet from the surface. The aquifer seems to be the decomposed granite resting on bedrock, or perhaps a fracture system in the bedrock. The writer inspected three core samples from the bottom of the hole, and found them to be composed of fresh Bonsall tonalite. Source of data: Mr. E. J. Schabelitz. Elevation of well, 1020 feet, surveyed.

U. S. Government Wells

The writer learned of four wells on the Rincon Indian Reservation, located immediately south of Rincon. Well No. 1 is a shallow well not now believed to be in use, located in the valley of the San Luis Rey River a few hundred feet east of the mouth of Paradise Creek. The water level in this well, according to Mr. Mark Golsh, stood at 36 feet in 1950. The well was not visited by the writer.

Mr. Golsh stated that there are two wells at the location of well No. 3: one of these is a large well producing about 900 gallons per minute, and the other is a small domestic well producing about 90 gallons per minute.

The following information was furnished by Mr. John S. Ryder, Irrigation Manager, Office of Indian Affairs, U. S. Department of the Interior, San Bernardino, California.

"Well No. 3 was drilled in 1929, is 105 feet deep, and 16 inches in diameter. In 1938 the water stood 11 feet below the top of the curbing and in the same month (November) of 1950 the water level was 26 ft. 2 in. This is the maximum and the minimum during this twelve year period as there has been a gradual lowering of the water table.

"In 1940 a new pump was installed in this well and it produced 1017 g.p.m. with a 60 foot draw down. The depth to water at this time was 13 feet. With the water at the present 26 ft. 2 in. level, the well is producing only 920 g.p.m. with an 81 foot draw down.

"The penciled notations on this well show the following formation:

0' to 54'	Top soil and fine sand.
54' to 76'	Quick sand and small boulders.
76' to 84'	Hard yellow clay.
84' to 105'	Yellow sand and cemented boulders.

"<u>Well No. 9</u> was drilled in March 1934, is 122 feet deep and 18 inches in diameter. Water stood at 15 feet from the top of the casing and the well produced 750 g.p.m. with a 73 foot draw down. In November 1950 water level stood at 33 feet.

"In 1949 this well was cleaned, reperforated and the pumping equipment overhauled. It then produced only 450 g.p.m. and the water level was lowered to the bottom of the suction which is 86 feet. The log of this well shows:

0' to 8'	Top soil and sand.
8' to 24'	Dead granite and boulders.
24' to 60'	Gravel, quick sand and boulders in hard silt.
60' to 79'	Cement boulders (very hard).
79' to 120'	Yellow sand, gravel and cemented boulders.
120' to 122'	Hard granite.