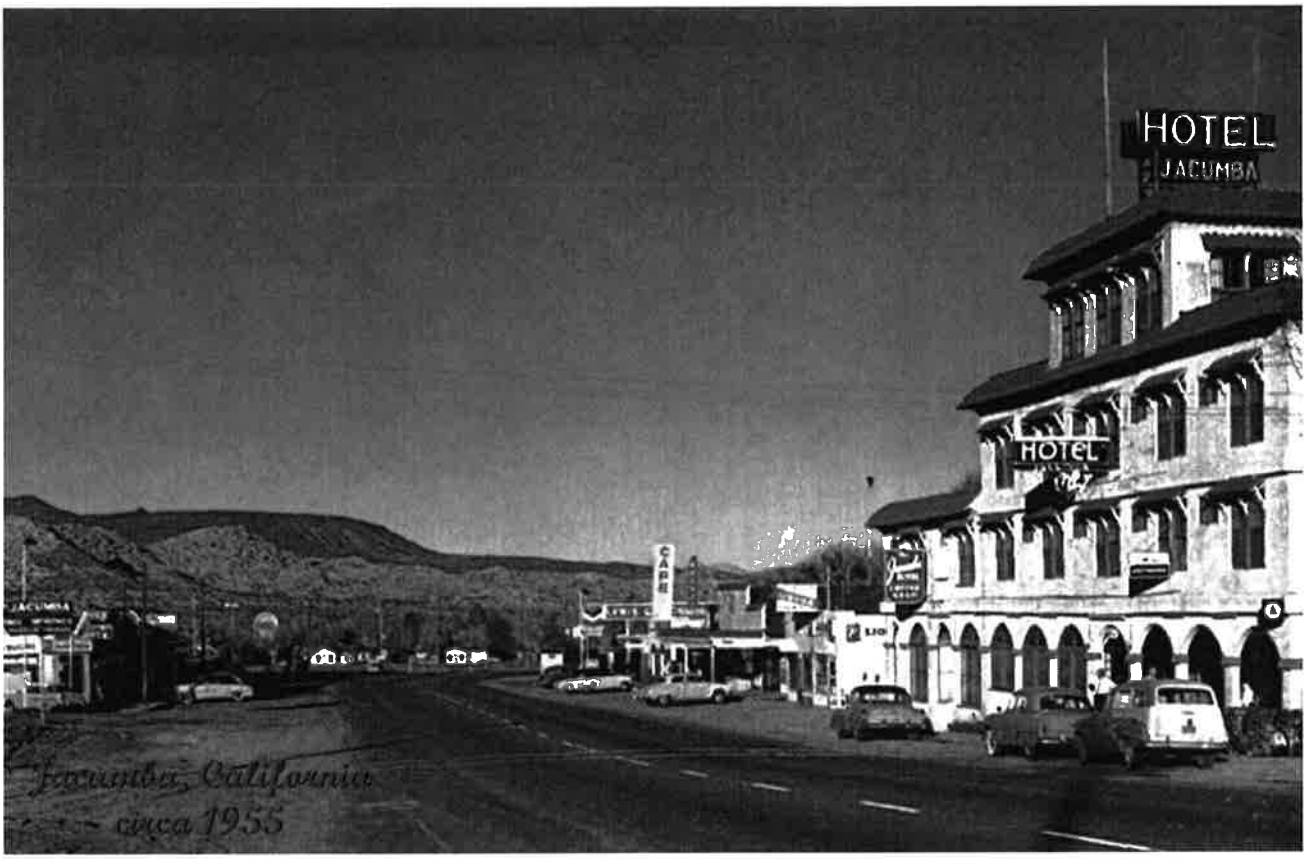

Figure 1. Jacumba Hotel and Jacumba, 1955 (photo provided by Jacumba Community Services District)

High Desert Lore and Hydrogeology of the Jacumba Valley, Jacumba Hot Springs, San Diego County, California

CHARLES E. HOUSER, ***chouserscsengineers.com, and*** **MONTE L. MURBACH,** ***mmurbach@murbachgeotech.com***

INTRODUCTION

SOMETIME IN THE MID-2000S, ONE OF THE CO-AUTHORS was interviewing a long-time resident of the town of Jacumba Hot Springs. (Jacumba was officially renamed Jacumba Hot Springs in early 2013.) This interview was not to learn of life in a backcountry high desert town, though Jacumba definitely fits that description. Having a population hovering around 600 at an elevation of 2,800 feet, businesses in town include a store, the library, the water district, the Jacumba Hot Springs spa/motel/restaurant, and a few others along a road that a dog could safely sleep on during a typical day. Winters are cool, summers are usually pretty hot. The town is surrounded by mountain highlands, but vegetation is somewhere between chaparral and desert sage. There are no pine forests in this area. The airport just southeast of town has a 2,500 foot gravel runway. WARNING, do not turn south on takeoff or you are over Mexico in about 15 seconds. If you land there (as one of the co-authors has), you might expect several US Border Patrol agents to come visit to confirm your intentions.

Agriculture seems to be a major activity in the valley east of town, though most has recently been fallowed due to a shortage of groundwater in that part of the valley. The community is dependent on groundwater for domestic water, and levels in the valley have declined enough to raise concern. Luckily the community's major groundwater supply wells are west of town and seem not to have been affected by agricultural usage.

Nevertheless, this is a desert community in a beautiful desert environment. Even the streets are named after other desert communities, including Calexico, El Centro, Heber, and, yes, Jacumba Street, to name a few. During a current regional drought condition, groundwater is not a resource to be used carelessly. More about groundwater later...

The interview was also not to collect information about the rich history of this small town. We were told that the town of Jacumba received on average 5,000 visitors each weekend during its heyday in the 1930s and 40s. But first, the area was originally inhabited by the Kumeyaay people, probably attracted to the area by the Jacumba hot spring. Jacumba is Kumeyaay for either "hut by the water" or "hot water," depending on who you ask, and was originally known as "Jacom." The Spanish first recorded the name of the village in 1795. The "ha" sound of the Spanish *ja* may be a variation on the Kumeyaay *ha*, which means "water." Jacumba was a mail station on the Yuma route, originally established by James McCoy in 1852. Sometime during the early 1860s, Peter Larkin had a cabin near the hot springs. Larkin ran the stage station at Mountain Palm Springs. The George Washington McCain family first homesteaded Jacumba. They claimed ownership of the land after they arrived in 1868 and began grazing cattle. Unfortunately, ranchers occupying the area in the 19th century were often in conflict with the Indians, and about 15 Indians were slain by ranchers for cattle rustling in the Jacumba Massacre of February 27, 1880.

In the early 20th century, hot springs began to be commercialized for their health benefits, and by the 1930s the town had developed around the hot springs to a population of about 1,150, with the world-class Jacumba Hotel (Figure 1) and large public baths. The hotel was originally called the Hotel Vaughn, built by Bert Vaughn who also built the Desert View Tower a few miles northeast of Jacumba. Since 1917 when the San Diego and Arizona Eastern railroad connected Jacumba to San Diego, the town blossomed with visitors including movie stars and celebrities such as Clark Gable and Marlene Dietrich. After World War II, however, Jacumba began to feel the pressure of competition from more northerly hot springs, such as Murrieta and Palm Springs.

If you've seen the movie "Cars," you may remember a scene where Lightning McQueen and Sally drive up to the Wheel Well motel and Lightning asks Sally how the town of Radiator Springs fell into such decline. Sally explained that when the interstate was built just a few miles from town, people began driving to get somewhere rather than to experience the trip. Radiator Springs was bypassed and, eventually, forgotten. This is the story of Jacumba Hot Springs. Drive west out of Jacumba on Old Highway 80. After passing within a stone throw of the border, you begin to wind northwest toward a pass. Just after you drive over that pass, as you come into a small town known as Bankhead Springs, you see the freeway in the distance, along with all the cars and trucks travelling through, their drivers unaware of the gem just over the hill to the south of the freeway.

In the 1960s, the Interstate 8 freeway bypassed Jacumba Hot Springs by two miles and the town was nearly forgotten. Figure 2 is a photograph of the front of the hotel in neighboring Bankhead Springs a few miles west of Jacumba Hot Springs. In the background of the photograph you can see the freeway, complete with a large tractor-trailer big rig, merrily sailing right past these small towns.

The Jacumba Hotel closed and, in 1983, was destroyed by an arson fire. The public baths closed though the bath house is empty but still standing today (Figure 3). Notice we said the town was nearly forgotten. In the 1980s, the Jacumba Motel and Spa was the only hotel in town. The town has continued to attract visitors, many foreign. We should mention that a small group of geologists from a local organization (SDAG) stayed there on October 22, 2005. They even had an evening presentation, projected on the side of one of the motel buildings, by none other than world renowned geologist Chuck Houser! After a series of failed business attempts and property sales between the 80s and mid-2000s, the facility was renovated and reopened in June of 2013 as the Jacumba Hot Springs Spa and Resort. For bicycling enthusiasts, Jacumba Hot Springs is a great destination when bicycling Old Highway 80!

Back to the interview. The interview, believe it or not, was to attempt to get historical information about a burn dump site located along the northwest edge of town. The authors have not given the name of the gentleman interviewed, partly because people living in this desert community enjoy a certain solitude, even anonymity, and we'll not be the ones to disrupt that. The gentleman interviewed explained how he would "fire" the dump once a week, meaning that he would ignite the dump pile. The last he remembered doing that, indeed the last he remembered the dump even receiving trash, was the late 1940s. For the co-authors interview

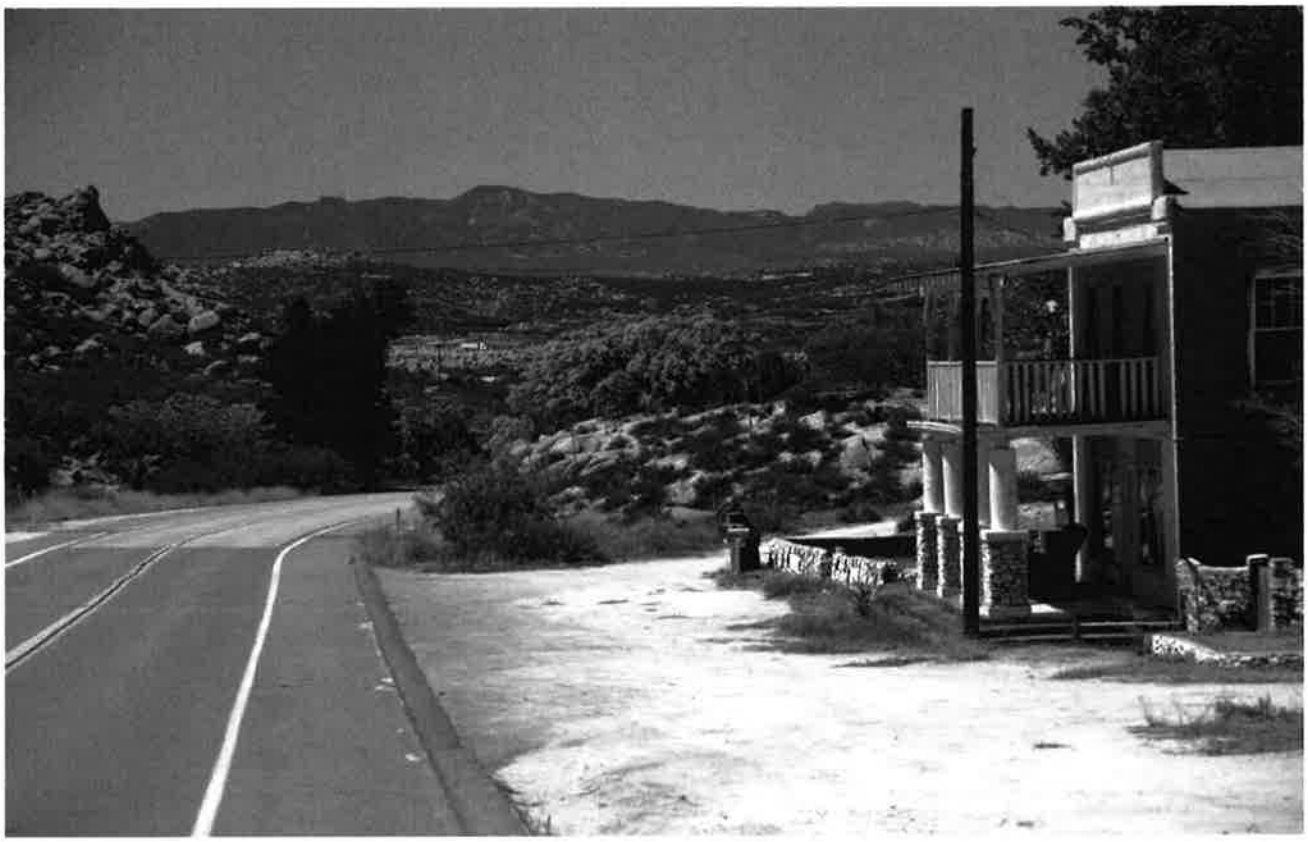

Figure 2. Hotel in Bankhead Springs, I-8 visible in the distance.

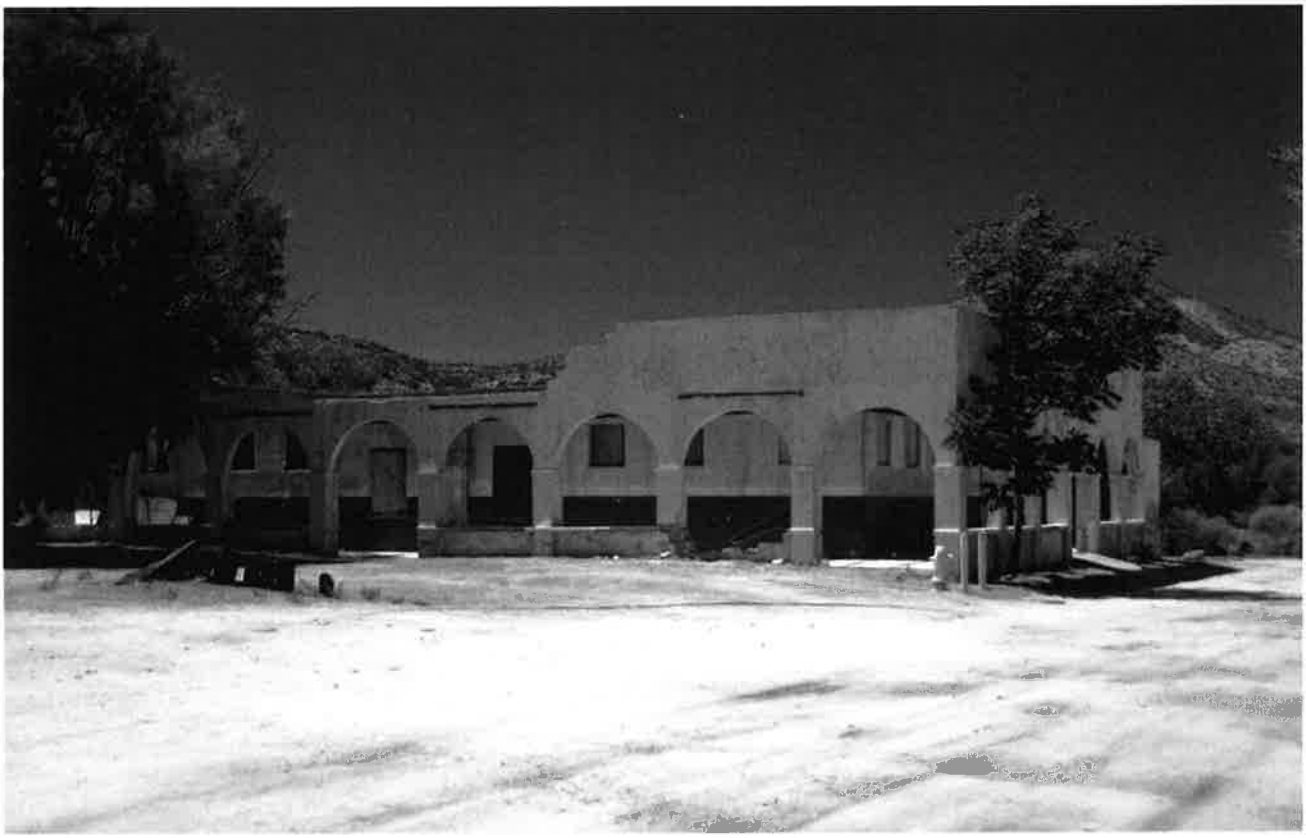

Figure 3. Abandoned bath house, Jacumba Hot Springs

with him, a series of specific questions needed to be asked in order to cover certain bases the LEA (Local Enforcement Agency, the County agency regulating such "landfills") expected be covered. Imagine the gentleman's reaction when asked if any radioactive material had been placed in the dump!

This paper is about the geology and hydrogeology of the Jacumba Valley, as related by two geologists. These geologists have not only worked professionally on various projects in the area, but have also shared a fascination with the history of this small town, and the interplay and balance between the tectonics of Jacumba and the distribution of thermal groundwater and springs in the area.

PROJECT BACKGROUND

While working on a project north of town just off the I-8 freeway, the authors contacted Jacumba Community Services District (JCSD), the water district servicing approximately 200 connections in the town of Jacumba, to evaluate their groundwater use and locations of supply wells. The challenge in Jacumba has been to find cool groundwater. Several of the wells drilled by JCSD produce groundwater that has a temperature in the mid-90s and a distinct sulfur odor. In mid-summer when daytime temperatures approach or exceed 100 degrees, 95-degree water that smells like sulfur is simply not refreshing! JCSD was interested in finding locations where they might obtain non-thermal groundwater.

We were subsequently engaged by JCSD to conduct a hydrogeological evaluation to assist them in further developing their groundwater resources. After an initial assessment consisting of geologic mapping and evaluation of existing wells, we drilled several test wells in and around the town to locate cool water, test groundwater quality, and evaluate potential well yield. Three test wells were drilled during this process. Well MW-1 (Library Well) was located just east of the town's library along the south side of Old Highway 80 in the central part of town. Well MW-2 was located north of the north end of Heber Street and was abandoned soon after installation due to water quality issues. Well MW-3 was drilled on private property west of town.

Well MW-1 contained cool water and aquifer testing conducted on this well revealed adequate production potential, but during subsequent groundwater sampling, low concentrations of dissolved petroleum hydrocarbons were detected, indicating migration of these constituents from a release at an historic gasoline service station site in town. Well MW-2, near the north end of Heber Street, was found to have an unusually high concentration of aluminum in the groundwater and was abandoned soon after it was installed.

Although water quality testing on well MW-3 showed good water quality, aquifer testing demonstrated relatively low well yield. Further evaluation including geologic and structure (fracture) mapping in the vicinity of MW-3 demonstrated the potential that a production well drilled and completed in fractured granitic rock in this area could provide adequate groundwater to benefit the town.

Two approximately 520 foot deep production wells (Well #7 and Well #8) were subsequently installed near MW-3. Both were completed in the granitic rock, encountered abundant fractures during drilling, and demonstrated exceptional well yield at several hundred gallons per minute each.

GEOLOGY

According to Todd (2004), the town of Jacumba lies in an alluvial valley surrounded by highlands comprised of Tertiary-aged volcanic rocks and Jurassic-aged crystalline rock. Dibblee (2008) maps Tertiary-aged volcanic rocks, Tertiary-aged table Mountain formation, and basement complex rocks consisting of quartz diorite and granodiorite, likely of Cretaceous age in the highlands surrounding the valley (Figure 4). In the study area, as mapped by Dibblee (2008), volcanic rocks are comprised primarily of basalt flows. Table Mountain Formation is comprised of moderately bedded sandstone and conglomerate sandstone. As mapped by the authors and logging in test borings drilled for JCSD, the geological units exposed in the study area include Cretaceous-aged granitic rock, Tertiary-aged volcanics, Quaternary-aged alluvial fan deposits, and Quaternary-aged valley-fill alluvium (Figure 5). Following is a description of these units.

Granitic Rocks

Granitic rock, consisting of medium to coarse-grained quartz-biotite granodiorite, is exposed in the southern portion and along the western edge of the study area. These rocks are generally highly fractured with the primary preferred fracture orientation striking north-northwest and dipping moderately southwest. A

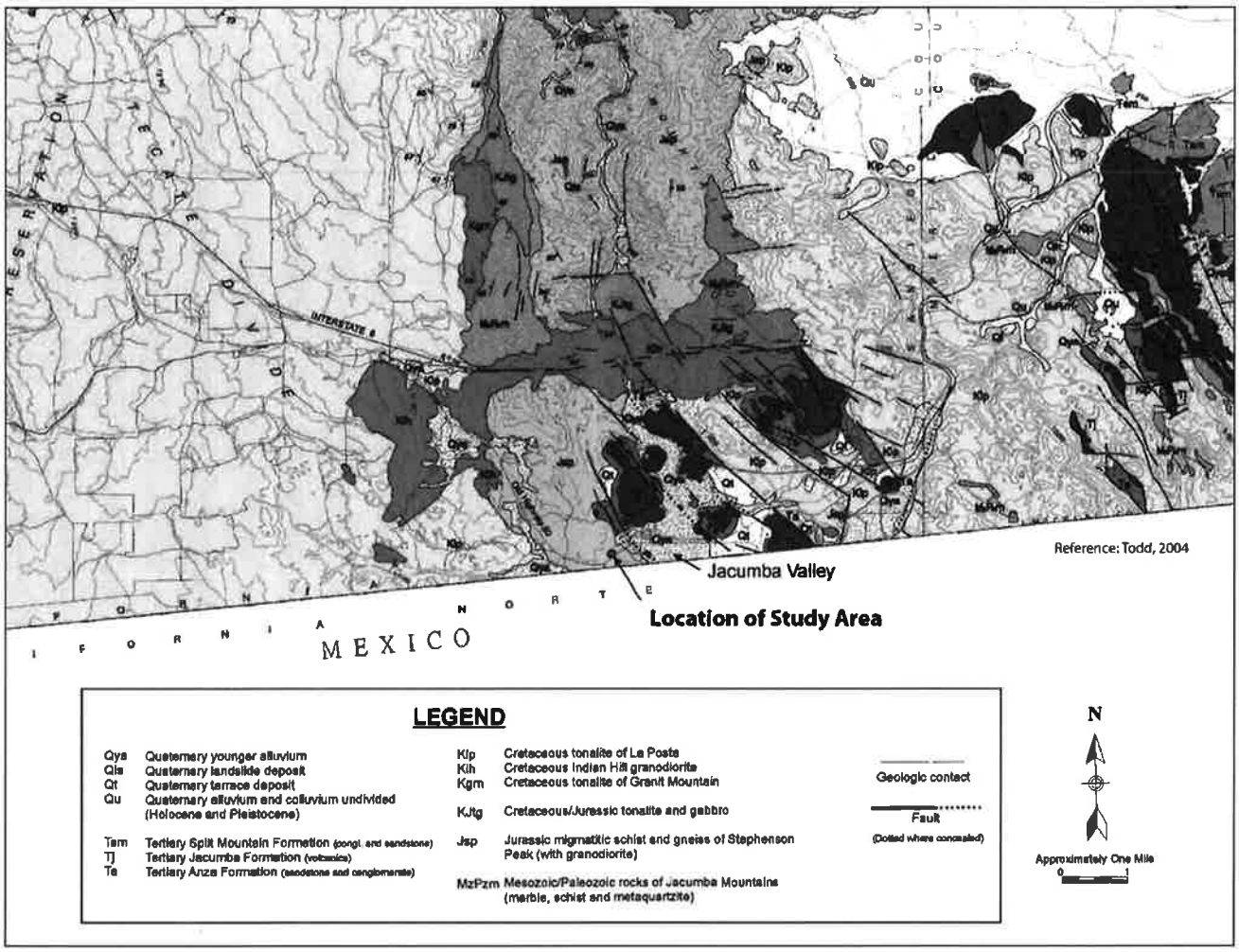

Figure 4. Geologic map of the Jacumba region, adapted from Todd (2004).

Figure 5. Geologic map of the Study Area

secondary preferred fracture set, orthogonal to the primary set, also strikes north-northwest and dips steeply northeast. Fractures associated with the primary fracture set are commonly intruded by aplite and pegmatite dikes of granite composition. These dikes range from a few centimeters up to approximately four meters or more as exposed in the study area and encountered in borings. The aplite and pegmatite dikes are generally highly internally fractured. Figure 6 is a photograph showing pegmatite dikes exposed in the road cut along Old Highway 80 in the western portion of town.

Figure 6. Granitic pegmatite dike in road cut in the western portion of Jacumba Hot Springs

Volcanic Rock

As mapped by the authors, the volcanic rocks are generally limited to the north edge of the study area, with one exposure also noted on the eastern portion of a low hill just south of the town. One of the best exposures of the volcanic rock in the study area was noted along the north side of Boundary Creek near the north end of Heber Street (Figure 7). Here the volcanic rock is exposed as a steep sided outcrop several meters high. In other portions of the study area, the volcanic rocks are exposed in more subtle topography and covered with slopewash.

Volcanic rocks are generally reddish brown and appear to be layered flows and clastic rocks. These rocks are generally highly fractured but do not appear to exhibit the well-developed orthogonal fracture system noted in the granodiorites.

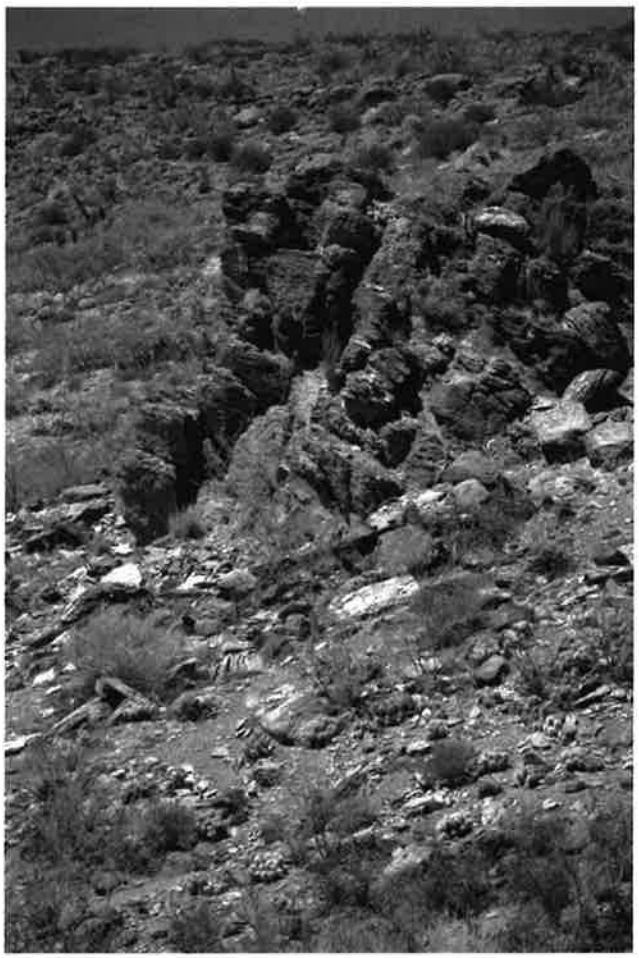

Figure 7. Volcanic rock exposed along the north side of Boundary Creek, northwest of Heber Street

Alluvial Fan Deposits

Alluvial fan deposits were exposed in the northwest corner of the study area. They consisted of moderately to well indurated, coarse sands and gravels. Note that Dibblee (2008) maps these deposits as Table Mountain Formation. It is the opinion of the authors that characterization of the fan deposits as Table Mountain Formation is appropriate.

Valley-Fill Alluvium

The central and eastern portion of the study area is comprised of Quaternary-aged alluvium. The alluvium consists of poorly graded sand with minor gravel, silt, and clay. These deposits were generally low to non-cohesive. In well MW-1, drilled at the library along Old Highway 80 in the central part of town (Library well), the alluvium was 127 feet thick and underlain by reddish-brown weathered volcanic rock.

STRUCTURE

The structure of Jacumba Valley and its watersheds are dominated by faults. Swenson (1981) describes the Jacumba Valley as a fault-bounded graben. According to Swenson (1981), there are three basic orientations of

faults in the valley: 1) a north-northeasterly trending fault which forms the scarp of the Sierra Juarez Mountains to the east of the valley, 2) faults which trend to the northwest (also mapped by Todd [2004] as well as others, see below), and 3) a north-south trending fault to the west of the valley (outside of this study area). Note that, regarding the north-northeasterly trending fault east of town, Swenson references a Mexican commission that mapped the fault and referred to it as "active." Their definition of "active" is not necessarily consistent with the way the State of California defines an active fault. The activity of this fault is unknown for the purposes of this paper.

As mapped by Dibblee (2008), Weber (1963), Brooks and Roberts (1954), and Todd (2004), a fault extends northwest/southeast just east of and roughly parallel to Railroad Street in the central portion of the town (Figure 5). Dibblee (2008) and Todd (2004) also place a second parallel fault to the west of Railroad Street. It is thought that the fault or faults influence the distribution of thermal (warm or hot) water in the Jacumba area. Swenson (1981) indicates that groundwater in the Table Mountain aquifer, located east of this fault, does not show any thermal contamination, and suggests that the fault restricts movement of thermal water by acting as a groundwater barrier. Figure 8 is an oblique aerial photograph of Jacumba Valley and the region south of the US-Mexico border. The fault, as well as the approximate locations of several known thermal springs and wells, are depicted on this figure. Research by the authors has indicated that wells east of the interpreted location of this fault have not encountered hot water, and wells west of the fault and deeper than approximately 50 feet generally have encountered hot water.

HYDROGEOLOGY

Groundwater in the Jacumba area occurs in both the alluvium and in the underlying and surrounding granitic and volcanic rocks. Two distinct watersheds intercept in the Jacumba Valley. The Boundary Creek watershed lies generally west to northwest of the town, and is approximately 35 square miles in size. The Flat Creek watershed lies south-southeast of town and is approximately 80 square miles in size. These two watersheds meet in the central portion of the valley where groundwater and surface water appears to flow toward the north toward Carrizo Gorge. The approximate locations of monitoring wells and production wells discussed in this paper are depicted on Figure 5.

Alluvium

In the alluvium, groundwater occurs at depths of about 20 to 40 feet, though shallower depths may have

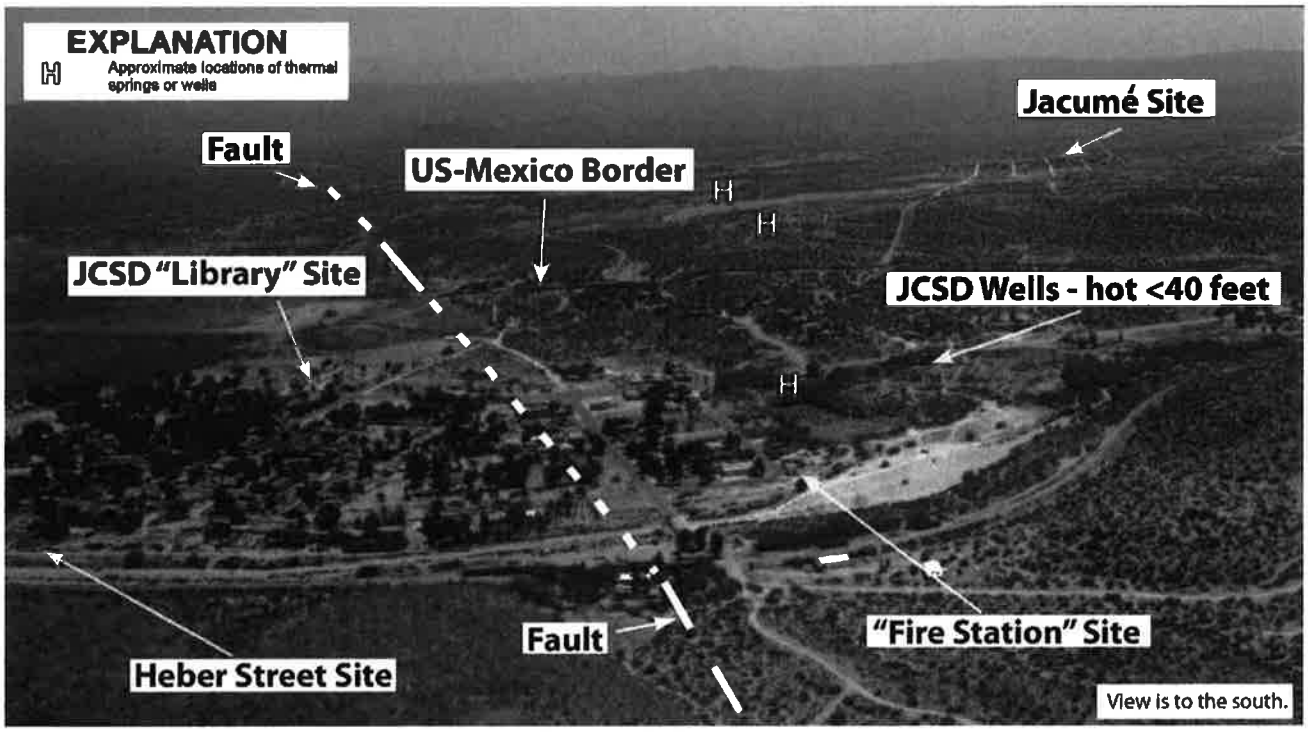

Figure 8. Oblique aerial photograph of the Jacumba area showing thermal springs and wells

been noted in the past. Groundwater was measured at a depth of 37 feet below grade in MW-1. As previously noted, the alluvium at this location is 127 feet thick. Therefore the groundwater occurs primarily in the alluvium overlying the volcanic rock. In well MW-3, groundwater occurs at a depth of approximately 20 feet below grade. These two test wells are depicted on Figure 5.

Aquifer testing conducted on well MW-1 included a step-drawdown test followed by a recovery test. The well was pumped for several hours each at discharges of approximately 17 to 18 gallons per minute (gpm), 39 to 41 gpm, 60 gpm, and 71 to 84 gpm. Using the Jacob time draw-down method, the step draw-down test yielded an estimated average transmissivity of 9,150 gallons per day per foot. The recover test yielded an estimated transmissivity of 9,131 gallons per day per foot. Based on the testing, it appeared that a production well completed in the alluvium in this location may be expected to yield 40 gpm or more.

Of note are agricultural supply wells in the eastern portion of Jacumba Valley. Anecdotal information suggests well yields as high as 1,700 gpm. While this may be an indication of the high groundwater production potential of the alluvium in the valley, it also may be an indication of an overdraft condition leading to concerns about groundwater levels and fallowing of agriculture previously mentioned.

Granitic Rock

For the two approximately 520 foot deep production wells near MW-3 (Well #7 and Well #8, Figure 5), both completed in granitic rock, static water levels were around 30 feet below grade. Approximately 20 to 30 feet of alluvium overlies the granitic rock in the vicinity of MW-3 and these two production wells.

Aquifer testing on these production wells included a 72-hour constant rate pumping test. The wells were pumped at a discharge of 200 gpm, each. Based on the drawdown observed during the pumping (113 feet in Well #7 and 153 feet in Well #8), and the percent recovery over 72 hours following the pumping (98 to 99 percent recovery), the two wells can be pumped at a total discharge of 100 gpm, according to California Department of Public Health (CDPH) guidelines.

Water Quality

As discussed above, though the potential well yield of a production well located near the Library and well MW-1 was acceptable, the results of water quality testing indicated that this area is impacted from a release of petroleum hydrocarbons from an historic gasoline station site in town. Water quality testing on the two production wells (Well #7 and Well #8) installed near MW-3, however, revealed good water quality as well as quantity. We understand that Well #8 has been fully developed and is expected to be "online" soon. Well #7 may be developed in the future as a backup well.

EASTER EARTHQUAKE OF APRIL 4, 2010

After the Easter earthquake of April 4, 2010, JCSD personnel reported that a number of groundwater and spring phenomena were occurring in and around Jacumba, including artesian wells and new springs. Co-author Charles Houser conducted a reconnaissance of the Jacumba area on April 15, 2010, to note and map the locations of surface groundwater phenomena, particularly new features not present prior to the April 4, 2010 earthquake, and changes in wells (higher or lower water level, artesian wells, etc.). The term "new," as used below, described features not noted prior to the April 4th earthquake. Such phenomena included springs and wells that had become artesian. Figure 9 depicts the locations of observed conditions described below. Following is a summary of Mr. Houser's observations.

New Spring Activity

Spring activity not previously noted by JCSD personnel was observed in several locations in the western portion of the town. Springs were noted as follows:

- 44409 Calexico Avenue. Spring activity was observed along Jacumba Street in front of the residence at this address. Small pockets of water discharge ("bubbling up") were observed and the water was observed to flow approximately 10 feet toward Jacumba Street. The water seemed to be warm. No sulfur odor was noted.
- Abandoned Jacumba Spa pool and Spa well. Abundant spring activity was observed along the east side of the concrete-lined pool located southwest of the abandoned bath house. The water discharging from this area flowed along the north side of Old Highway 80 toward the center of town at Old Highway 80 and Railroad Street. In addition, standing water (approximately 4 or 5 feet deep, according to JCSD

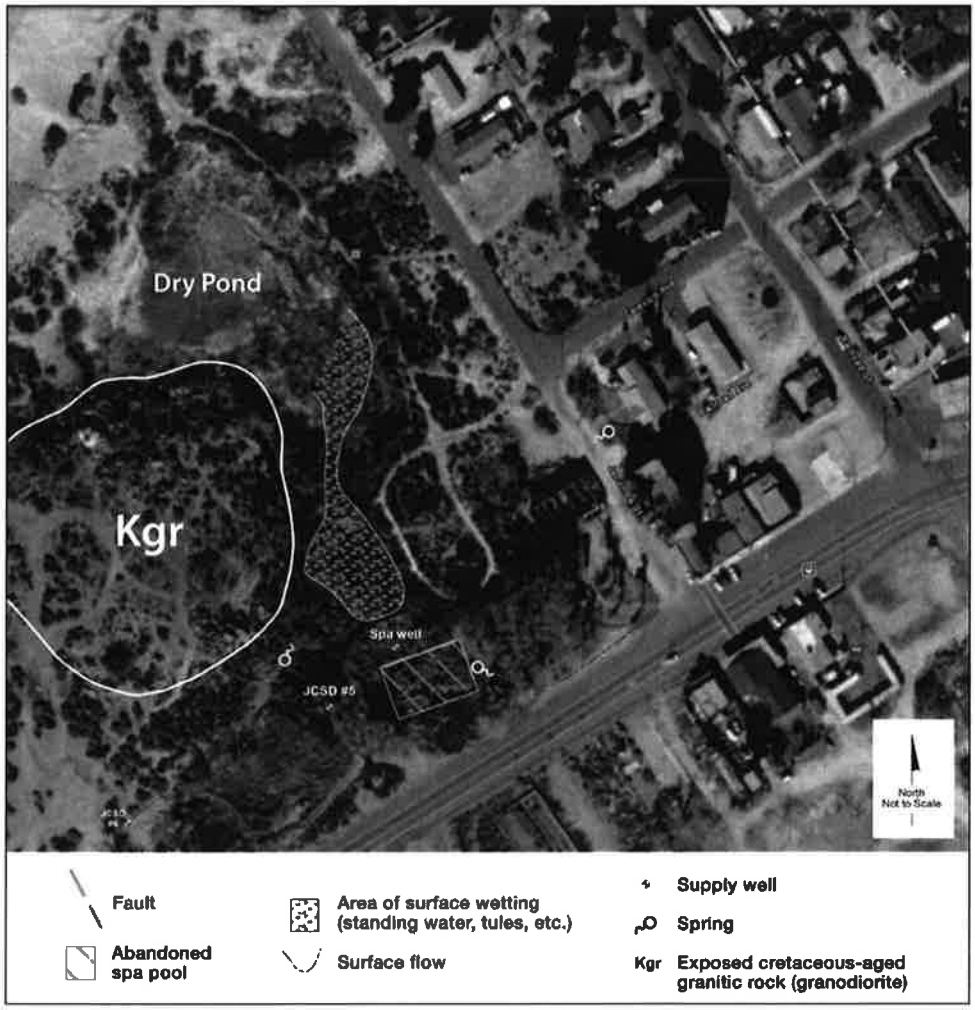

Figure 9. Map showing new springs and wells affected by the Easter earthquake of April 4, 2010

personnel) was present in the concrete-lined pool. A well, located near the northwest corner of the pool, was observed to be discharging warm water. The estimated discharge was less than one gallon per minute (gpm).

- Approximately 100 feet north of JCSD well #5, spring activity was observed in a shallow drainage course along the northeast side of a bedrock hill with outcropping granitic rock. Several pockets of water discharge were observed along the drainage course, and on the bank on the west slope of the drainage two to three feet above the bottom of the drainage. Water from these springs flowed generally toward the northeast and appeared to collect in a low area under some trees.
- In addition to the springs described above, SCS observed the dry pond north of the Spa pool and JCSD wells. The southern and eastern portion of the pond bottom was damp with some shallow standing water and possible seeps. Based on the abundance of dry reeds (tules) in this portion of the pond bottom, it appears that moisture may be typical for this area during the rainy season.

Artesian Wells

In addition to the discharge noted from the well associated with the Jacumba Spa pool, JCSD well #6 was observed discharging water. The discharge was estimated at 25 to 50 gpm. JCSD personnel noted that immediately after the April 4, 2010, earthquake, the discharge from this well was much higher, estimated at 100 to 150 gpm (Figure 10). The discharging water was warm and a distinct sulfur odor was noted. The discharged water flowed toward the southeast approximately 250 feet to a shallow valley west of JCSD well #5, where it appeared to dissipate into the ground. JCSD well #6 is reportedly approximately 470 feet deep and completed in the fractured crystalline rock underlying the area.

Figure 10. JCSD well #4 shown discharging after the Easter earthquake of April 4, 2010

Changes in Water Levels in Existing Wells

Water level measurements were made in JCSD wells #4 and #5. The water levels were approximately 9'10" below ground surface (bgs) and 4' bgs, respectively. As reported by JCSD personnel, the water level in well #4 approximately one month prior was approximately one foot lower and had shown a rising trend through the winter rainy season. The water level in well #5 was approximately 4 feet higher that the last water level reading from this well taken in November of 2005. Well #4 is reportedly approximately 39 feet deep and well #5 is reportedly approximately 75 feet deep. Both wells are reportedly completed in alluvium. JCSD personnel also reported that the water levels have not changed notably in wells #7 or #8.

SUMMARY

Jacumba began because of the abundance of groundwater and continues today to be dependent on that groundwater. Both hot and cold springs and hot and cold groundwater are hallmarks of this high desert community. While the fault along Railroad Street provides some understanding of the distribution of hot and cold water (important in developing the drinking water resources), there is apparently still much to be learned about the nature of the groundwater and spring resources of this area.

After the Easter earthquake, notable changes occurring in and around the town, including new spring activity and artesian wells, serve to highlight the interplay between groundwater and tectonics in this region. The 2014 SDAG fieldtrip provides a brief cross-section of the history, geology, tectonics, and groundwater of this small desert community with a big story!

ACKNOWLEDGMENTS

The authors would like to acknowledge Jacumba Community Services District for their cooperation and contribution to this paper. Most of the information contained in this paper is from work performed for JCSD by the authors. They have also graciously allowed us to visit their production and monitoring well sites during the 2014 field trip. We would like to recognize Mr. Tom Lindenmeyer, retired general manager of JCSD. In our early work in Jacumba, we had to assess groundwater resources in the area around Jacumba for a leaking underground gasoline tank project near the freeway. When interviewing Mr. Lindenmeyer about the locations and conditions of the JCSD supply wells, he asked if we could do hydrogeological assessments for clean water resource projects, and so began our work described in this paper.

REFERENCES

Brooks, B. and Roberts, E., 1954, *Geology of the Jacumba Area, San Diego and Imperial Counties*, in CDMG Bulletin 170, map sheet 23.

Dibblee, T.W., 2008, *Geologic Map of the Jacumba 15 Minute Quadrangle, San Diego and Imperial Counties, California*, Dibblee Geology Map Center, Santa Barbara Museum of Natural History.

SCS Engineers, 2010, *Geological Reconnaissance, Town of Jacumba, San Diego County, California*, report prepared for Jacumba Community Services District, June 14.

Swenson III, G.A., 1981, *The Ground Water Hydrology of Jacumba Valley, California and Baja California*, unpublished Master's thesis, San Diego State University.

Todd, V.R., 2004, *Preliminary Geologic Map of the El Cajon 30' x 60' Quadrangle, Southern California*, U.S. Geological Survey Open File Report 2004-1361, SCAMP – Southern California Areal Mapping Project.

Weber, H.F., 1963, *Geology and Mineral Resources of San Diego County, California*, CDMG County Report 3.