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James C. Witcher

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Third-day road log: From Las Cruces to Rincon Hills via I-25

Greg H. Mack, James Witcher, and Thomas Giordano

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THIRD-DAY ROAD LOG, FROM LAS CRUCES TO RINCON HILLS VIA I-25

GREG H. MACK, JAMES WITCHER, and THOMAS GIORDANO

SATURDAY, NOVEMBER 7, 1998

Assembly point: Days Inn parking lot, corner of University Avenue and Main Street, Las Cruces. Participants may wish to drive personal vehicles during this half-day trip, in order to leave directly from the last stop. Take University Avenue east to I-25. Go north on I-25. Road log begins where I-25 crosses US-70 and is keyed to highway milepost signs.

Departure time: 8:00 a.m.

Distance: 62.0 mi

Stops: 3

SUMMARY

The third day of the field conference is dedicated to economic geology and will only last a half day in order to provide ample travel time for those participants who live far from Las Cruces. Consequently, participants may wish to drive personal vehicles and leave directly from Stop 3. Adequate parking is available and the road is well maintained. All three stops of Day 3 are in the Rincon Hills, a late rift (latest Miocene–Pliocene) fault block whose eastern part juxtaposes latest Oligocene–Miocene Hayner Ranch and Rincon Valley Formations against the Plio–Pleistocene Camp Rice Formation (Seager and Hawley, 1973).

Stops 1 and 2 involve short hikes to see features associated with a recently discovered geothermal field, including siliceous alteration of the fluvial lithofacies of the Camp Rice Formation and an opal bed within the Camp Rice Formation. Stop 3, located a few miles from the first stop, also involves a short hike to a quarry, where barite and manganese were mined on a small scale. This ore deposit within the latest Oligocene–early Miocene Hayner Ranch Formation will be examined and compared to other rift-related ore deposits in southern New Mexico.

Mileage

Follow the First-day road log from Las Cruces to the Rincon Exit.

29.6 **Turn off I-25 at Rincon Exit. 29.6**

29.8 **Turn left at stop sign** on to gravel road. **0.2**

30.0 Road ascends small mesa. Outcrops of silica-cemented fluvial lithofacies of the Camp Rice Formation on either side of road (Fig. 3.1). **0.2**

THE RINCON SLH1 GEOTHERMAL WELL

James C. Witcher

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During January 1993, the Rincon SLH1 geothermal test hole was drilled to obtain subsurface temperature and geologic information. This mini-paper discusses the site selection, drilling technology, and a summary of the drilling results.

Site selection used several geochemical and geophysical surveys. These surveys, designed to identify shallow upflow zones or shallow reservoirs, were sited over an area with opal beds of probable hot spring origin in the Plio–Pleistocene Camp Rice Formation. The first survey used a new approach to radon soil-gas studies (Witcher, 1991a). The radon soil-gas survey determined anomalies in radon, based upon a model of constant vertical radon emanation and pure diffusion. With this approach, advective radon transport with geothermal upflow may be identified. A follow-up reconnaissance temperature-gradient survey across two positive diffusion model radon anomalies indicated very high-temperature gradients near the East Rincon Hills fault zone (Witcher, 1991b, and this guidebook). The radon and temperature-gradient surveys were followed by a SP (self-potential) geophysical survey to provide detail for selecting possible targets for deep exploration drilling (Ross and Witcher, 1992, and this guidebook). SP surveys can be sensitive to upflowing fluids and high-temperature gradients. The Rincon SLH1 borehole was sited on a SP closure of -120 mV (millivolts), a temperature gradient around 33°F/100 ft, adjacent a positive radon anomaly over 100 pCi/L, and 197–383 ft basinward of a hanging wall exposure of intense silicification along the East Rincon Hills fault.

Well control problems (steam blowout potential), excessive bit wear, and slow drilling rates were probable, because subsurface

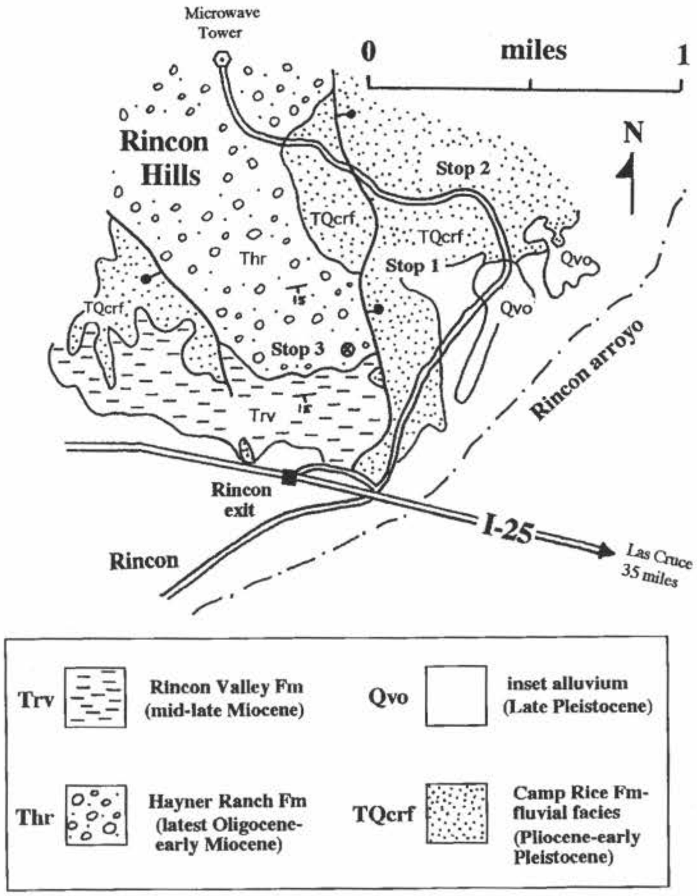

FIGURE 3.1. Generalized geologic map of the southeastern part of the Rincon Hills, adapted from Seager and Hawley (1973).

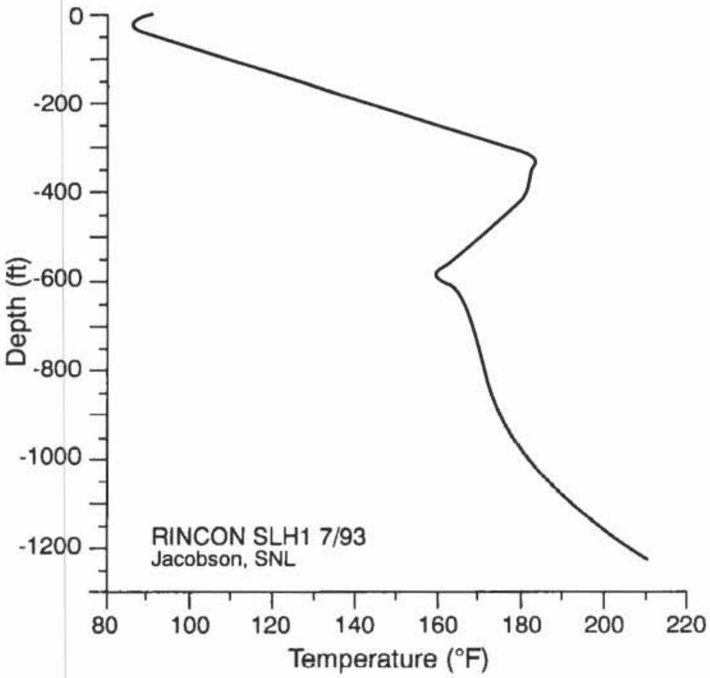

FIGURE 3.2. Temperature log of the Rincon SLH1 geothermal hole.

temperatures were known to be within 28°F of boiling near the water table in a regime of very high-temperature gradients and "quartzite" was encountered during drilling of nearby gradient holes. Also, convective geothermal reservoirs are notoriously underpressured with respect to drilling mud head in non-steam flashing situations. This results in constant lost circulation problems that fractured reservoirs exacerbate. A review of industry drilling in the region in the 1980s, primarily around the Tortugas Mountain area near Las Cruces, revealed that costs of rotary geothermal exploration wells typically exceeded $200/ft. In fact, many of the wells failed to reach target depths before lost circulation problems stopped all progress. It was clear that major drilling problems and expense were likely with conventional rotary drilling.

On the other hand, use of continuous-wireline core drilling equipment, in common use in the mining industry, was shown to be cost effective and safe by the Continental Scientific Drilling Program (CSDP) in the Valles caldera in northern New Mexico, when used with suitable well-control devices and other safety equipment (Goff et al., 1986; Rowley et al., 1987). Today, slim-hole geothermal exploration holes frequently utilize continuous-wireline core-drilling technology with total costs frequently under $110/ft (Goff et al., 1991; Finger et al., 1994 1997; Witcher et al., 1994).

FIGURE 3.4. Outcrop of opal bed within the Plio-Pleistocene Camp Rice Formation at Stop 2.

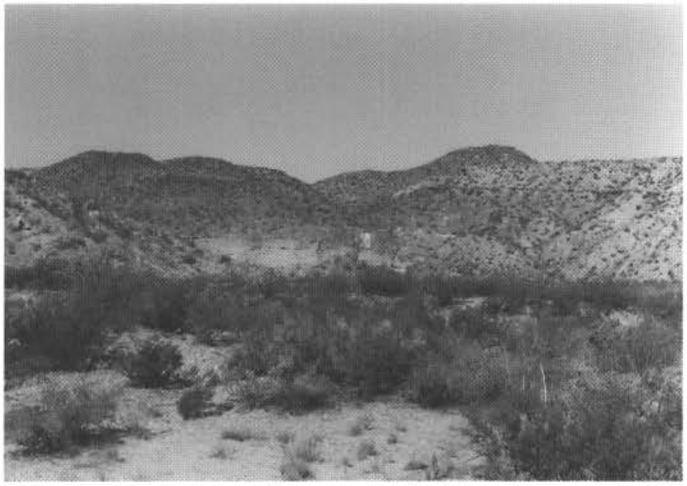

FIGURE 3.3. Outcrops of silica-cemented fluvial sandstones of the Plio-Pleistocene Camp Rice Formation at Stop 1.

Wireline-core drilling in geothermal exploration provides many advantages. Drilling "blind" is feasible and is commonly done successfully with lost circulation in core drilling. On the other hand, lost circulation with conventional rotary drilling requires potentially expensive remedial measures that may or may not be successful. Also, high-temperature well control in wireline-core drilling is much easier to achieve than with standard rotary equipment. This is because the hot upward return flow in the very narrow annulus between the core drill string and the formation is significantly cooled by downward cold mud inflow in the much larger drill string volume. With conventional rotary tools, the annular volume is much larger than the inner drill string volume, eliminating any chance of cooling the hot mud returns.

Loss of a drill string due to differential sticking does not stop a core-drilling project. In general, it is possible to reduce the drill string size and use the stuck drill string as relatively inexpensive casing. Because core-drilling equipment is smaller, site requirements are less. Best of all, the geologic information obtained from core drilling is far superior to that obtained from standard rotary drilling. The bottom line is less expensive drilling and greater assurance in reaching objectives in undrilled or under explored geothermal systems.

The Rincon SLH1 was drilled by placing a truck mounted Longyear 44 drill on a 5-ft steel substructure to allow installation of blowout prevention equipment (BOPE). Well head equipment included hydrogen sulfide monitors and alarms, kill and choke lines, and a BOPE that consisted of double gate rams, an annular device, and accumulator shut in. A HQ (3.782 in.) hole was cored to 276 ft and then reamed to 5.895 in. size. A HWL (4.5 in. outside diameter or OD) flush joint surface casing was cemented in place before mounting the BOPE and proceeding with HQ coring to total depth. A 500 bbl (~20,000 gal) tank provided backup water for high-temperature well control and for makeup water in case of excessive mud losses to the formation. The hole was drilled blind with lost circulation from about 250 ft to total depth. Lost circulation accounted for 292,500 gallons of water use. Because differential sticking became a problem as a result of swelling clays and caving of fractured "quartzite" in the 500 to 590 ft depth interval, the hole was not tripped when the last bit wore out; rather the bit was "burned" into the formation at 1218 ft depth and the hole cased with the HQ rods (3.0625 in. inside diameter or ID). This completion will allow further drilling at a later date with an NQ string (2.75

FIGURE 3.5. Opalized plant fossils at Stop 2.

FIGURE 3.6. View to the west from Stop 2 at the former site of Rincon SLH #1 geothermal well.

in. OD). Eastman single shot directional surveys indicated that deviation never exceeded 2°.

The Camp Rice Formation was cored from the surface to a depth of 373 ft with major lost-circulation zones (fractures) between 280 and 320 ft depth. Water was encountered at 305 ft. The Rincon Valley Formation alluvial-fan facies was cored from 373 to 590 ft. Again, major lost circulation zones (fractures) existed from 500 to 590 ft. Because the Rincon Valley Formation alluvial-fan facies shows formation dips of about 30°, actual cored thickness is about 185 ft. Both the Camp Rice Formation and the Rincon Valley Formation alluvial-fan facies show intense silicification. Formation thicknesses are minimum estimates as minor faulting may have tectonically-eliminated intervals in highly-brecciated zones.

After correcting for a 30° dip, at least 300 ft of Rincon Valley basinal facies was cored from 590 to 933 ft. The Rincon Valley basinal facies is largely unaltered except from 820 to 830 ft where an alteration aureole around a major fracture or small fault(?) at 826 ft was cored. From 933 to 1218 ft, the upper Hayner Ranch Formation was encountered. The contact between the Rincon Valley and Hayner Ranch was picked at the first significant purple-brown, medium sandstone. At 941 ft, a mixed-clast, cobbly sandstone was cored; otherwise, the presence of interbedded red-brown mudstone and siltstone and purple-brown, lithic sandstone indicates a depositional transition from Rincon Valley to Hayner Ranch. The Hayner Ranch sandstones are very indurated, but generally not highly silicified.

Fault displacement along the East Rincon Hills is estimated between 300 and 400 ft since the beginning of Camp Rice deposition. The Camp Rice-Rincon Valley angular unconformity on the hanging wall is at 373 ft depth in Rincon SLH1, as referenced to a surface elevation of 4370 ft. On the footwall, the unconformity is exposed at elevations ranging from 4300 and 4400 ft. With a minimum unconformity age of about 3.4 Ma (Mack et al. , 1993), this translates into a 1×10^{-3} in./yr to 1.4×10^{-3} in./yr vertical displacement rate. However, an earthquake interval of 104–105 yrs can be inferred if the average vertical throw is between 3 and 10 ft with each major seismic event.

Hydrothermal alteration is most intense in sandy units while thick clay-rich units, such as the Rincon Valley basinal facies, generally appear unaltered. Silicification is the most prominent alteration phase in the Camp Rice and Rincon Valley alluvial-fan facies. Sandy units are flooded by quartz with 2–10% disseminated sulfide. Pyrite is the most common sulfide, existing as either single euhedral crystals less than 0.0039 in. across or by globular clusters (glomerocrysts) of cubes less than 0.009 in. across. Other minor sulfide phases are tentatively identified as acanthite and hematite after pyrite, realgar, and orpiment. Highly silicified zones are accompanied by a relatively-intense gamma log response that is greater than 250 API units. A recent spectral gamma log indicates strong uranium and potassium sources (Joe Henfling, Sandia National Laboratories, personal comm, 1998). Limited and preliminary whole-rock geochemical analysis indicates enrichment in arsenic, molybdenum, uranium, and silver relative to an average granite. Manganese is depleted in these zones.

Fracture mineralogy changes with depth. Pyrite crystals are common only on fractures below 370 ft depth, while barite crystals are only common on fractures below 470 ft. Drusy quartz is found only on fracture surfaces deeper than 480 ft. Banded opal dominates fracture fillings above 400 ft, but opal decreases with depth and is largely absent below 600 ft. Fluorite is not observed as a fracture mineral.

A conductive temperature gradient (33.4°F/100 ft) is observed above 330 ft depth (Fig. 3.2). Between 330 and 580 ft a rollover in temperature (185–162°F) is observed. This interval represents a local outflow plume that could provide an excellent shallow reservoir for low-temperature, direct-use utilization such as a large geothermally-heated greenhouse. From 580 ft to total depth at 1218 ft, temperatures increase to over 212°F. An average temperature gradient over 7°F/100 ft characterizes the lower zone. This temperature gradient is likely to continue with depth in the approximately 2500-ft-thick Hayner Ranch Formation or until the East Rincon Fault zone is encountered. Reservoir temperatures of 260 and

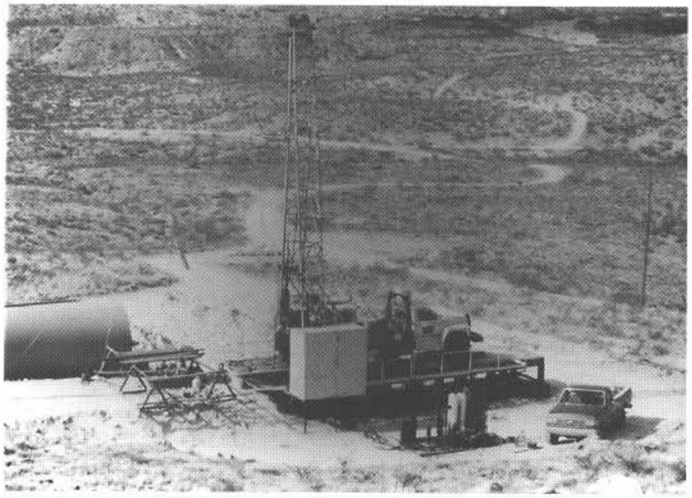

FIGURE 3.7. Rincon SLH #1 geothermal well being drilled in January 1993.

FIGURE 3.8. Quarry in the Miocene Hayner Ranch Formation, site of Stop 3.

300°F are likely within 500–1000 ft or less depth at this site. At reservoir temperatures over 220°F and good reservoir production, potential exists for economic and competitive binary-cycle electrical power potential. In 1997, about 1 MWe (megawatt electric) of geothermally-produced power became operational near Animas, New Mexico, with 226°F geothermal fluids.

Funding for the Rincon SLH1 geothermal test was sponsored by Representative William Porter through the New Mexico legislature.

30.3 Road descends on to Holocene geomorphic surface. **STOP 1** Silicified Camp Rice Formation. At 9:00 are reddish brown cliffs composed of silica-cemented sandstones of the Camp Rice Formation (Fig. 3.3). Walk along unimproved road to the northwest to reddish cliff face, where several multistory channels of the (Plio–Pleistocene) Camp Rice Formation are exposed. The channels display a basal mudstone rip-up clast lag that is overlain by trough crossbedded pebbly sandstone and capped by a thin red clay bed. The Camp Rice sandstones are moderately indurated, while the clay is brittle, brick red, and silicified. Stratigraphically higher, the Camp Rice sandstone is well indurated by silica cement. This outcrop records the shallow dynamics of a fossil geothermal system. The stratigraphically higher silica-cemented sandstone probably represents a lateral outflow plume of silica-rich and chemically reduced hot groundwater that originated as upflow along the East Rincon Hills fault zone. Stratigraphically lower, less indurated sandstones represent a mixing zone where oxidizing lateral inflow of colder ground water mixed with thermal waters. Hematite, carbonate, clay, and zeolite cements formed in the lower zone. In both cases, the fluvial channel sands provided excellent permeability. Floodplain mudstones are much less altered, most likely because of their low permeability. Preliminary analysis of primary fluid inclusions in calcite indicates that reservoir temperatures during cementation of the Camp Rice Formation near the fault zone were greater than 170°C, while aqueous geothermometry of the present systems suggest reservoir temperatures over 145°C (Witcher, 1991b).

Retrace route to main road and proceed northeastward on foot. **0.2**

30.5 Road ascends a late Pleistocene geomorphic surface. **0.2**

30.7 Road turns northwestward and crosses onto fluvial lithofacies of the Camp Rice Formation. **Turn right onto side road** toward outcrop of light-colored rock for **STOP 2**. This distinctive opal bed was originally mapped by Seager and Hawley (1973), and can be traced to the northeast for about 0.5 mi (Fig. 3.4). The opal bed contains silicified stems, tubers, roots, and grasses (Fig. 3.5; LeMone and Johnson, 1969). Although originally interpreted by LeMone and Johnson (1969) as a spring-fed marsh (cienega), the opal bed is believed by Witcher (1991b) to be the distal remnant of a siliceous sinter complex fed by hot springs discharging from the East Rincon Hills fault zone. The opal bed is overlain by channel sandstones and in places has a scoured upper surface, which is best viewed in an arroyo about 100 yds northeast of this site. **0.4**

Retrace route to main road. At junction it is possible to view to the west the former site of a geothermal well (Rincon SLH #1) drilled in January 1993 to a depth of 1218 ft (Figs. 3.6 and 3.7).

31.1 Retrace route to buses. Continue road log below. **0.5**

31.6 Buses retrace route toward interstate interchange. After descending onto a low geomorphic surface, the buses will park for **STOP 3**. Manganese and barite mine and gravel pit. Follow foot log below. **0.3**

31.9 Follow unimproved road toward the quarry. Route crosses the trace of the East Rincon fault, which places fluvial lithofacies of the Plio–Pleistocene Camp Rice Formation on the hanging wall in contact with southeasterly dipping redbeds of the late Miocene Rincon Valley Formation on the footwall. Conglomerates and sandstones of the Rincon Valley Formation are exposed in the arroyo west of the road. Just before reaching the quarry, the road crosses the contact between the Rincon Valley Formation and underlying Hayner Ranch Formation. Mineralization in the southern Rincon Hills is restricted to small deposits of barite and psilomelane in thin (<1.5 ft) veins and as a replacement of breccia (Seager and Hawley, 1973). The quarry was most recently mined for road aggregate, but also has evidence of minor barite and manganese mineralization (Figs. 3.8 and 3.9). One-quarter mile west of the quarry is the Rincon Mine, where psilomelane replaces fault breccia. The age of the mineralization is interpreted to have been Miocene, because it appears to be restricted to the late Oligocene–early Miocene Hayner Ranch Formation and because the overlying Rincon Valley and Camp Rice Formations contain clasts of mineralized Hayner Ranch. The Rincon Mine produced 471 st of 30–40% manganese ore prior to 1918 (Seager and Hawley, 1973). **0.3**

32.2 **Retrace route to buses. End of traverse and end of Third-day road log.**

FIGURE 3.9. Barite replacing Hayner Ranch breccia at Stop 3.