NOTICE CONCERNING COPYRIGHT RESTRICTIONS

Brawley—Resurrection of a Previously Developed Geothermal Field

Skip Matlick and Tim Jayne

Ormat Nevada Inc., Brawley, CA

Keywords

Brawley, Ormat, geothermal, Imperial County, California

ABSTRACT

The Brawley Geothermal Field was originally developed by Unocal. In addition to drilling geothermal wells, this development included building and operating a 10 MWe power plant. Corrosion and scaling issues resulted in Unocal abandoning the project in the 1980's. Ormat Nevada investigated the potential of the shallow sands in 2006. It was concluded that these matrix-permeable sands contained moderately saline water, high porosity, and could support a binary-type power plant. In 2007, Ormat Nevada drilled and tested five wells. These test results confirmed the earlier conclusions and a 49.9 MWe power plant is presently being constructed.

History

The Brawley Geothermal Field is located approximately two miles north of Brawley, CA, in Imperial County (Figure 1). In the 1970's, Union Oil Company (Unocal), Chevron Oil Company, and Grace Geothermal Company began the first exploration and development in the Brawley Field. Temperature gradient wells and geophysical surveys were completed in this initial exploration. Starting in 1975, Unocal drilled 14 deep wells (Figure 2, overleaf). Chevron Oil Company then moved in as a competitor in the late 1970's and drilled two deep wells on the western flank of the geothermal anomaly. Combining with Southern California Edison, Unocal built and operated a 10 megawatt (MWe) power plant from 1982-1985. Due to scaling and corrosion problems coupled with a lease disagreement, Unocal dismantled the plant and abandoned all wells before dropping the project in 1985. Starting in early 2006, Ormat Nevada Inc. (Ormat) began the exploration and development of the Brawley resource.

Unocal drilled 39 temperature gradient holes to depths of approximately 250 feet (ft), while Grace Geothermal Corporation drilled 13 temperature gradient wells to approximately 500 ft. These holes define a shallow thermal gradient anomaly that exceeds 19ºF/100 ft at the core and covers approximately 10 square miles (Layman Energy Associates Inc., 2003).

The Brawley Field is situated in the Salton Trough, which is the geological feature contributing to the heat for the known Imperial Valley geothermal resources; Brawley, Heber, East Mesa, and Salton Sea. The Salton Trough is a spreading-center that is filled with marine and non-marine sediments to a depth of approximately 15,000 ft .

The Brawley geothermal reservoir developed by Unocal has a 525ºF temperature at depths from 5000 ft to 7000 ft. This reservoir is a fractured, highly productive resource that yielded flow rates of 700,000 to over 1,000,000 pounds per minute at 450 psig wellhead pressure (Union Oil Company, 1983). The deep reservoir fluids have a salinity of approximately125,000 parts per million (ppm) and contain abundant heavy metals including 80-250 ppm lead, 500-900 ppm zinc, and anomalous silver concentrations (Laymen Energy Associates Inc., 2003). Deposits of these metals formed a hard, dark heavy metal scale which decreased the flow rate of the

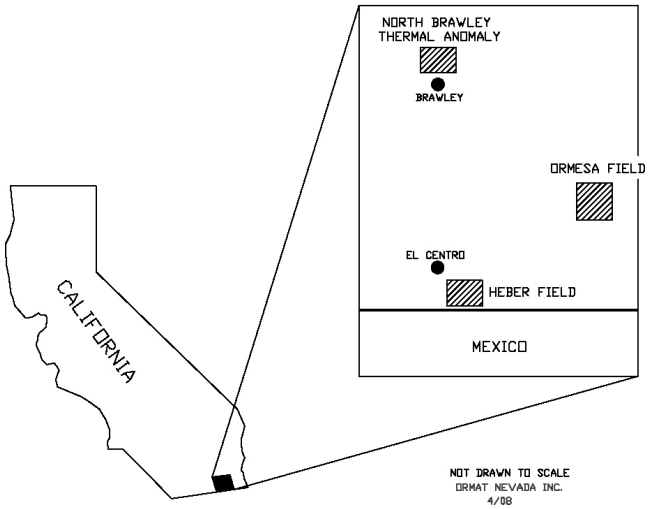

Figure 1. Location Map, Brawley Field, Imperial County, CA.

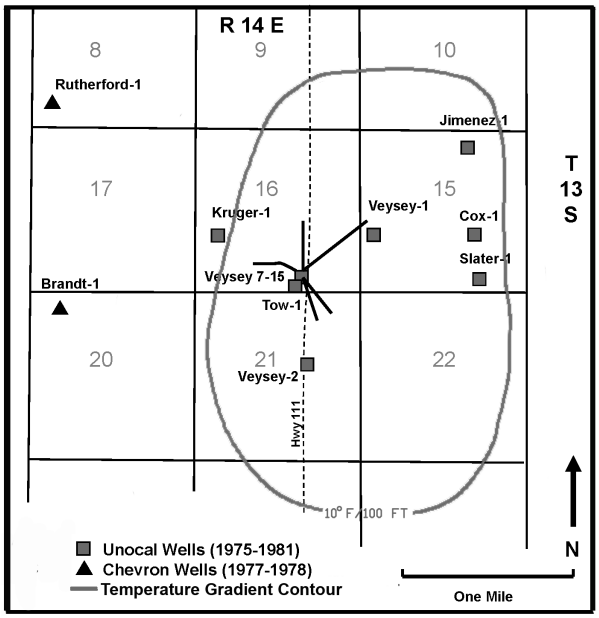

Figure 2. Unocal and Chevron Wells Drilled From 1975 to 1981, Brawley Field, Imperial County, CA

wells by 50 percent in six months. This scale assayed at 7.5 ounces (troy) per ton (opt) gold and 400 opt silver. High salinity water and the non-condensable gas also caused the carbon steel casing and surface equipment to corrode rapidly. As a result of these problems, Unocal abandoned the project.

New Exploration

Both Unocal and Chevron pursued only the deeper high-temperature resource at Brawley. Ormat studied the potential of generating electricity from the fractured Brawley reservoir, but determined that the hyper-saline fluid and non-condensable gases prevented an economical development. The existing well records were reviewed from the California Division of Oil, Gas, and Geothermal Resources (CADOGGR) files to investigate the potential of developing the shallower, 300ºF to 400ºF resource with matrix-dominated permeability. Fluids from these sands would be produced by pumping in a manner similar to the wells at the East Mesa (Ormesa) and Heber Fields.

Geology

The Imperial Valley is wedge-shaped with a flat alluvial floor. Marine deposits of sandstone and mudstone fill the valley at depths below approximately 2000 ft. From the surface to depths of 2000 ft, non-marine sediments of unconsolidated sand and clay occur. The total thickness of these sediments is over 15,000 ft, based on seismic refraction studies.

The shallow sands in this thick pile of sediments contain matrix permeability. Naturally the permeability decreases with depth, but studies at Ormesa and Heber have shown that sands with porosity values greater than 25% are capable of yielding geo-fluid during production (FPL Energy, 1999). This cutoff of 25% porosity value was used to determine the shallow pumping potential at Brawley.

The self-potential electric wireline logs were used to determine salinity of formation fluids shallower than 3000 ft below ground. These calculations showed Total Dissolved Solids (TDS) values ranging from 12,000 to 30,000 mg/l.

Resource Temperature

Static temperature logs were obtained from CADOGGR files for Unocal's Veysey #1 and #2 wells. The temperature profile from Veysey #2 shows a nearly conductive gradient from surface to a depth of approximately 4000 ft. The 300ºF temperature in Veysey #2 exists at a depth of 1800 ft and 400ºF was measured at a depth of 2800 ft.

Permeability

Four of the Unocal wells were electric wireline logged with porosity logs. Utilizing these porosity logs and a cutoff of >300ºF, the net sand footage and permeability were calculated using the average of Ormesa and Heber porosity to permeability correction. These computed permeability thickness (kh) range from 21,845 to 96,471 millidarcy/ft (Table 1).

Table 1. Brawley Permeability (kh) and Pumped Rates, Brawley Field, Imperial County, CA.

Well	KH (Milladarcy/ft)	Pumped Rate (GPM)
Veysey 1	96,471	1,780
Veysey 2	37,031	1,425
Veysey 8	21,845	1,000
Slater 1	66,154	1,650

Pumping Potential

The pumping potential of the four wells were then calculated from the available kh's. Productivity Indices (PI) used in these pump calculations were determined by a ratio of Ormesa and Heber wells. A static water level of 300 ft below ground and an allowance for normal pump wear was assumed. The calculated pumping rates (Table 1) ranged from 1,000 to 1,780 gallons per minute. These flow rates and expected temperatures, combined with the low TDS waters, suggested that the shallow Brawley reservoir could be commercially developed.

Recent Drilling and Testing Results

In March 2007, Ormat Nevada mobilized a drilling rig to the Brawley Field and commenced a drilling program to test the shallow sands for non-scaling/non-corrosive fluids that could be produced at commercial rates. Well OB-6 was spudded on March 30th (Figure 3) and was completed at a total depth of 4500 ft KB. This well and the wells to follow had 20-in. casing cemented to 300 ft KB and 13-3/8-in. casing cemented from surface to the top of the reservoir as defined by 300ºF. The wells were completed with slotted 9-5/8-in. casing hung from approximately 50 ft. above the 13-3/8-in. shoe to total depth. A total of five wells were drilled; OB-1, OB-3, OB-4, OB-5, AND OB-6.

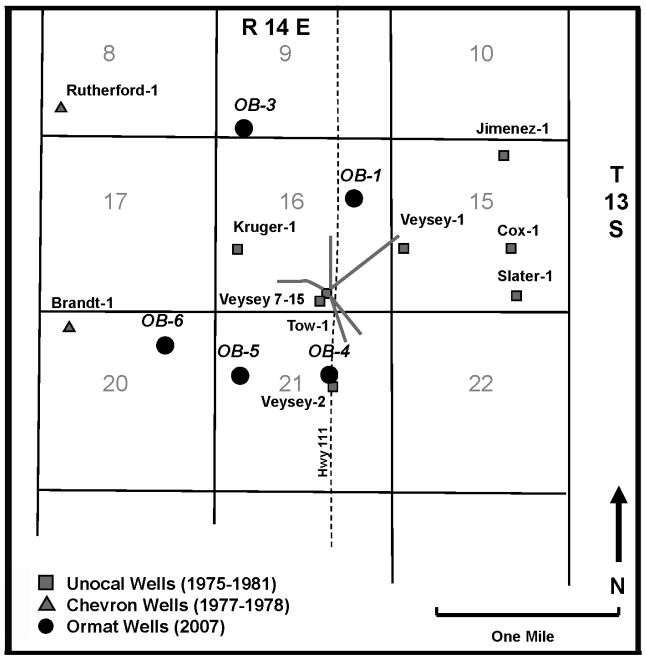

Figure 3. Brawley Well Locations in 2007, Brawley Field, Imperial County, CA.

After the rig was moved to OB-5, a test facility was erected at OB-6, and the well tested into an open-top flash tank. After the flow had stabilized, a temperature/pressure/spinner (TPS) log was ran. Then the well was shut-in with the logging tool hanging just above the slots and a pressure build up survey measured. This test measured a flowing temperature at the top of the slots in OB-6 of 335ºF. The calculated Production Index (PI) was 13.8 gpm/psi. The collected water samples had a TDS of approximately 15,400 mg/1 and heavy metal concentrations of less than 0.1 mg/1 per metal.

Table 2. Drilling Results, Ormat Nevada, Inc. Wells, Brawley Field, Imperial County, CA.

Well	Section Location (T13S-R14E)	Total Depth (ft KB)	Production Interval (ft KB)	Flowing Temp (°F)	Productivity Index (gpm/psi)	TDS (mg/l)
OB-1	16	3370	1704-3370	366	4.5	50,000
OB-3	9	4500	2004-4500	278	7.8	13,000
OB-4	21	3174	1678-3165	335	11.6	56,600
OB-5	21	3255	1762-3250	316	19.0	18,600
OB-6	20	4500	2237-4482	335	13.8	15,400

After drilling OB-5, a similar test showed a 316ºF flowing temperature at the top of the slots, a TDS of approximately 18,600 mg/1, and a PI of 19.0 gpm/psi.

Test results of the other three Ormat Brawley wells are shown in Table 2. All five wells indicate that a shallow, non-hypersaline brine with temperatures in the 315ºF to 366ºF range can be commercially produced at the Brawley field.

All wells were logged with electric wireline equipment. The logs indicate that the production interval contains an average of 43% permeable sand. The estimated kh of these sands averages approximately 50,000 millidarcy/ft.

Based on available information, the Brawly thermal anomaly, as defined by the temperature at 3,000 ft below sea level, is egg-shaped with the long axis trending north/south. The main central portion of this anomaly covers approximately five square miles, but it is open to the north and south. The highest measured temperature at this depth is 410ºF and the average temperature is 360ºF.

Conclusion

Ormat Nevada has drilled five new wells in the Brawley field previously developed by Unocal. These wells all produce from the shallow sands related to the Borrego Formation. The fluids produced have TDS values ranging from 21,000 to 45,000 mg/l and low heavy metal concentrations. The flowing temperatures are in the mid-300ºF range.

Based on these encouraging results, Ormat Nevada is drilling additional wells and constructing a 49.9 MWe (net) binary power plant that is scheduled to commence operation at the end of 2008.

Acknowledgements

The authors would like to extend their appreciation to Ormat Nevada Inc. for allowing publication of this paper.

References

FPL Energy, 1999, "Geological Model of the East Mesa Field", in-house report, pp.28.

Layman Energy Associates Inc., 2003, "Preliminary Feasibility Assessment for Electric Power Generation, Brawley Geothermal resource, Imperial County, CA", private report, pp.27.

Union Oil Company, 1983, "Study Conclusions", in-house report, pp 2.