PROCEEDINGS, Twelfth Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 20-22, 1987
SGP-TR-109

DEVELOPMENT DRILLING, TESTING AND INITIAL PRODUCTION OF THE BEOWAWE GEOTHERMAL FIELD

V. T. Hoang, E. D. James, I. J. Epperson

Chevron Resources Company
San Francisco, California

ABSTRACT

The Beowawe geothermal field in north central Nevada is generating 16MW using two production wells (Ginn 1-13 and 2-13) and one injection well (Batz). Drilling the second production well (Chevron Ginn 2-13) in 1985 led to the discovery of a second productive strand of the Malpais fault zone. The wells are completed in the Malpais fault zone and are capable of producing 420+°F geothermal fluid at rates exceeding 1,000,000 lbs/hr. Initial testing suggests that the completion zones of the two production wells have no pressure communication, therefore providing what is essentially a second production zone for future development. Injection of produced fluids into a fault parallel with the Malpais shows no pressure communication with other wells. One year of production in the system shows no pressure depletion or enthalpy decline in the producing area.

INTRODUCTION

This paper presents an overview of the Beowawe development drilling, testing and initial production of the 16 MW power plant. The 16 MW plant utilizes two production wells: the Ginn 1-13, drilled by Chevron in 1974 (Layman, 1984; Epperson, 1982 & 1983); and the Chevron Ginn 2-13, drilled during the summer of 1985. The Ginn wells are completed in separate strands of the Malpais fault zone (MFZ).

The Beowawe geothermal field is located in north-central Nevada, about 50 miles southwest of the town of Elko. The field is in the Basin and Range province at the boundary between a plateau of volcanics to the south and the downfaulted Whirlwind Valley to the north. Active surface manifestations in "The Geysers" area cover one-half square mile, and include a large sinter terrace, geysers, fumaroles, and hot springs (Figure 1). The reservoir is thought to be in lower Paleozoic carbonates at depths of perhaps 20,000 to 30,000 feet. No wells have penetrated the carbonates, but the low salinity, sodium-bicarbonate nature of the Beowawe thermal water suggests that these rocks are the ultimate deep reservoir. Geothermal fluid flows upward from the deep reservoir through the Malpais fault (MFZ) system, charges permeable horizons along the way and finally discharges at the surface.

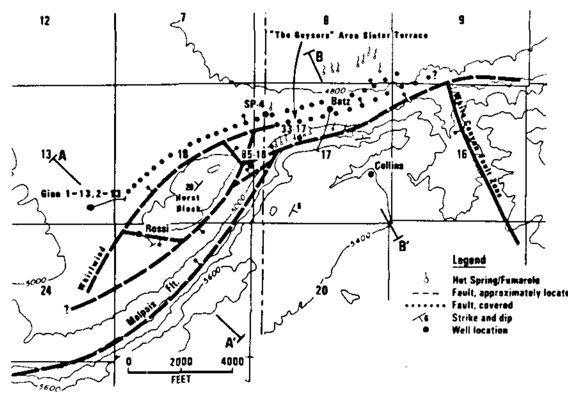

Figure 1. Well locations and surface features.

BEOWAWE GEOTHERMAL FIELD EVALUATION

The Beowawe area has been well known for many years due to the geysers, fumaroles, and boiling springs that exist there. These numerous geothermal surface manifestations led Magma Power Company and Sierra Pacific Power Company to drill 11 shallow wells in the sinter terrace area from 1959 through 1965. Chevron acquired the leases in 1973-1975 and began an extensive geologic study of the area. Chevron drilled five more wells, starting with Ginn 1-13 in 1974 to a depth of 9563 feet, and numerous shallow temperature holes in the evaluation and development process.

Magma conducted the first Beowawe well tests on four of their wells on the sinter terrace. During a year long flow, visual checks of the discharge indicated an apparent decrease in flow rate and temperature. Based on these data, it was concluded that the Beowawe reservoir was depleting and being invaded by cold water. Recent Chevron data indicates that the reduction in flow rate and temperature is due to the cooler fluid contribution from a high permeability fault below the main fault feeding these wells (Epperson, 1983).

Chevron began an extensive testing program to evaluate the reservoir with the completion of Beowawe 33-17 on the sinter terrace in 1979. During 1981, after drilling Beowawe 85-18, Chevron conducted numerous flow tests and monitored pressure interference effects in several surrounding shut-in wells to evaluate the degree of continuity between wells. A summary of Chevron flow test results prior to 1985 is presented in Table 1. Note that all wells except Rossi 21-19 flowed at rates of about 300,000 lbs/hr total mass. The relative low flow rates are due to mechanical completion restrictions. The permeability-thickness (kh) for most Beowawe wells is in the range of 200,000 to 800,000 md-ft., thus indicating the extremely prolific nature of the reservoir.

Interference tests conducted at Beowawe before completion of Ginn 2-13 show pressure communication between all the wells, excepting the Batz well (drilled by Magma.) Response times are less than one hour, irrespective of the distance between wells. Analyses of the interference data verifies the calculated kh from the individual drawdown and build-up analyses. These results are illustrated in Figure 2.

TABLE 1

BEOWAWE FLOW TEST SUMMARY

	Ginn 1-13	33-17	85-18	Vulcan 2	Rossi 21-19	Batz
Number of flow tests	1	6	4	1	3	3
Max. static temp., °F	420	365	360+	360+	386	240
Flow rate, Mlb/hr	285	305	320	240	280*	200**
Kh, md-ft	232,000	800,000	550,000	780,000	8,953	850,000x
PI, lb/hr/psi	8,900	200,000	7,800	24,000	300	27,070

*Flow with nitrogen gas lift. **Injection rate. x Upper injection zone.

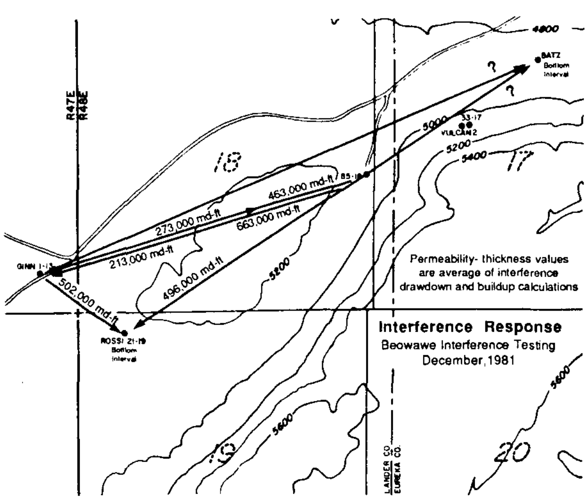

Figure 2. Interference response, December 1981.

SIMPLE FAULT MODEL FOR BEOWAWE GEOTHERMAL SYSTEM

Models proposed for thermal water flow in Beowawe system are varied, but all involved in the Malpais fault zone. The current model (Layman, 1984) incorporated temperature profiles, drilling history, cutting description, and kh distribution to show the importance of the MFZ as a primary conduit at Beowawe and provided a simple model to locate producing zones in the Beowawe field. Geologic mapping indicated that a simple planar fault can be constructed through MFZ intercepts in wells and the surface trace. The fault dip appears constant at 65-70° to the depth of the deepest well at 9563'.

Mapping of temperature in the MFZ shows that 420°F waters at depths greater than 9000' in Ginn 1-13 rise obliquely up the MFZ towards the northeast where there is an abrupt, up-dip diversion of flow at the prominent bend in the MFZ. This upwelling feeds the surface discharge at the Geysers.

Variations in permeability within the MFZ and siliceous vein - filling in the cuttings from low kh wells suggest that part of the fault zone is sealed-off. The region of the MFZ penetrated by Ginn 1-13, 85-18 and wells on the sinter terrace is open and very permeable. However, the MFZ at the Rossi and Batz wells is less permeable than other areas. Rossi was apparently drilled into the low permeability cap of the fault. At Batz, the MFZ does not seem to be in pressure communication with any other wells. The MFZ is tight at Batz probably due to silica sealing. The temperature and permeability data indicate good potential for expansion of the producing area down-dip of the MFZ from the 85-18 and Ginn 1-13 wells, and along strike south west of Ginn 1-13 (Figure 3).

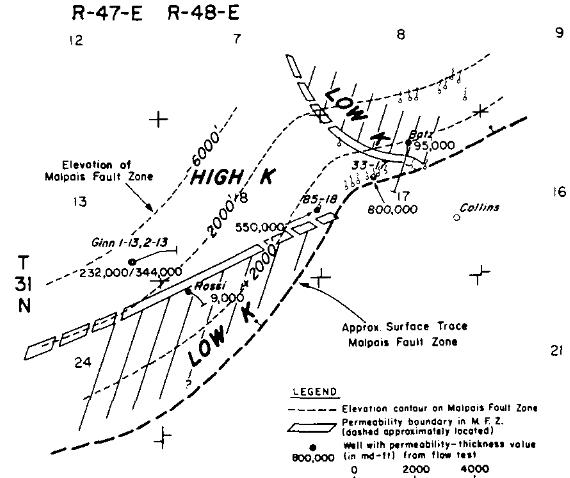

Figure 3. Permeability and elevation of the Malpais F.Z.

DEVELOPMENT OF THE 16 MW POWER PLANT

In 1985, Chevron drilled a second production well, Ginn 2-13, to supply steam for a 16 MW power plant which was built by Crescent Valley Energy Company. The well was programmed to penetrate the MFZ northeast of the Ginn 1-13. The well tested the concept that the MFZ was open over the large interval between the Ginn 1-13, Rossi wells to the west and the sinter terrace area to the east. The well, however, encountered a major lost circulation zone 500 feet above the target MFZ which was interpreted as a second fault. This fault trace is parallel with the main Malpais fault trace which was intersected in both the Ginn 1-13 and Rossi wells (Figure 4). Minor lost circulation and siliceous alteration mark the second fault in these wells.

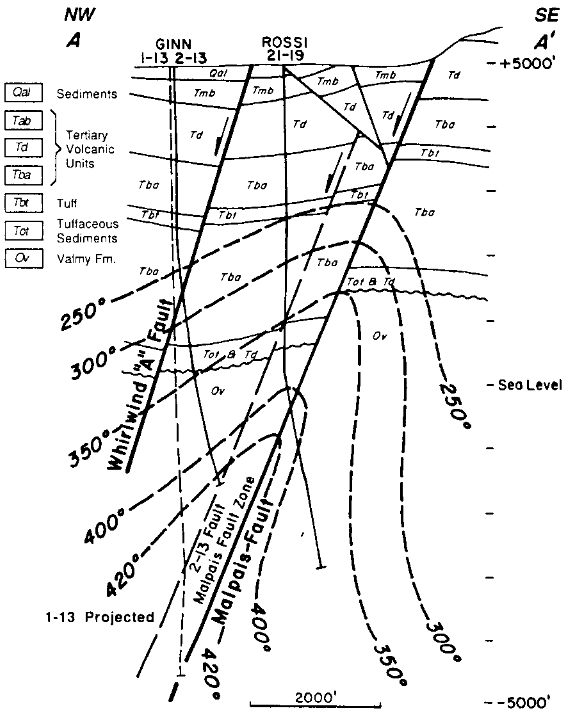

Figure 4. Geologic cross-section A-A'.

A short flow test soon after completion evaluated Ginn 2-13 productivity and reservoir properties. The Ginn 1-13 was monitored during the test to evaluate interference effects between the two fault strands. A James tube instrument was installed to gather data for flow rate and enthalpy estimation. Bottomhole flowing pressures were measured using helium filled capillary tubing and expansion chamber with a surface quartz transducer. The test results indicated that Ginn 2-13 encountered a very permeable zone, kh= 340,000 md-ft , containing 420$\pm$ $^{\circ}$F geothermal fluid. Ginn 1-13 produces the same temperature fluid from the main Malpais fault trace. A wellhead performance test showed that Ginn 2-13, after clean up of drilling damages, would provide over one million lbs/hr of fluid for the power plant. Pressure monitored during the test and during the plant start-up period indicated no interference between Ginn 2-13 and the other wells completed in the main Malpais fault trace.

The discovery of the second fault has greatly extended the development potential of the Beowawe field.

At present, the two production wells, Ginn 2-13 and 1-13, supply 1.3 million lbs/hr of 420°F fluid to a 16 MW dual flash power plant. The produced fluid contains a relatively low TDS ($\pm$ 1,200 PPM) and noncondensible gases ($\pm$ 550 PPM CO_2). The unflashed geothermal fluid returned from the plant is pressurized for injection at the plant and is transported via a 10" diameter two-mile insulated pipeline to the existing Batz well (Figure 5). At the Batz well, the fluid is injected into a shallow, cool zone of high permeability above the MFZ intercept. This zone is interpreted as a range-front fault parallel with and hydrologically unconnected to the MFZ (Figure 6), but is believed to be connected to the carbonate reservoir. During one year of operation, no injection effects were observed in the monitoring wells, indicating this range-front fault is an attractive target for future injection wells.

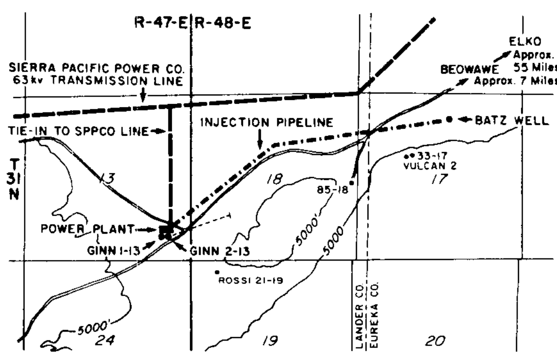

Figure 5. Plant and surface facilities.

During the October 1986 Beowawe power plant shutdown for maintenance and inspection, a small amount of calcite scale was recovered in the upper portion of the producing wells. However, the scale deposit did not affect the wells' performance significantly. Well performance tests, after the scale was milled out, indicated that Ginn 2-13 and Ginn 1-13 were capable of producing 1.2 million lbs/hr and 800,000 lbs/hr of fluid respectively at $\pm$ 102 psia wellhead pressure. Ginn 1-13 bottomhole pressure built up rapidly to the reservoir initial pressure after shut-in indicating no pressure depletion in the producing area. Enthalpy of the produced fluid, measured during the plant shutdown, showed no change from the value obtained before the plant start-up. The production data gathered during the first year of operation reconfirms the prolific nature of the Beowawe reservoir.

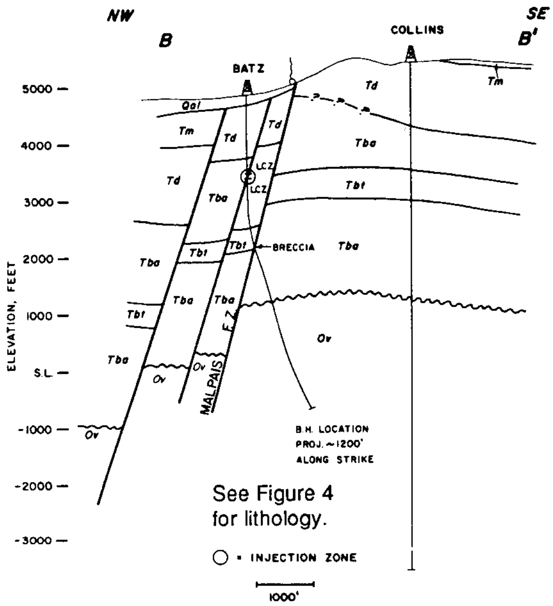

Figure 6. Geologic cross-section B-B'.

An important question to be answered is the estimated size of the reservoir and the ultimate development potential of the field. Due to the geologic complexity of Beowawe, this question can only be partially answered now. A semi-steady state analysis of the long term flow test data by Chevron indicates an extremely large fluid volume (in excess of 10^{10} bbls). The steady-state performance of Beowawe 33-17 after about 200 hours of flow in a 1980 test is indicative of a infinite reservoir or perhaps a constant pressure "boundary" (IJE 1983). Flow data from other Beowawe wells indicate fluid volume in excess of 10^{12} bbls. None of the tests have ever indicated a flow barrier or reservoir boundary, so these fluid volume estimates are only minimum values. The proven productive area of the two faults indicate a development of at least 200 MW.

CONCLUSIONS

1. Wells completed in the two strands of the Malpais fault zone are highly productive with potential to produce 420°F fluid at rates exceeding 1,000,000 lbs./hr. Testing indicates that the two faults are essentially separate production zones, thus providing a large area for future development.

2. Injection of produced fluid into a range-front fault parallel with the Malpais shows no pressure communication with other wells. This fault is an attractive target for additional future injection.

3. After one year of production no pressure depletion or enthalpy reduction has been observed within the producing area.

4. The minimum potential of the proven reservoir at Beowawe is 200 MW, based on 10 MW/well and 40 acre spacing between wells in the two fault zones.

ACKNOWLEDGEMENT

The authors would like to thank Chevron Resources Company for permission to publish this paper.

REFERENCES

1. Epperson, I. J. (1982), "Beowawe, Nevada, Well Testing: History and Results," GRC Trans., Vol. 6, p. 257-260.

2. Epperson, I. J. (1983), "1981 Interference Well Testing: Beowawe, Nevada," GRC Trans., Vol. 7, p. 413-416.

3. Epperson, I. J. (1983), "Beowawe Acid Stimulation," GRC Trans., Vol. 7, p. 409-411.

4. Layman, E. B. (1984), "A Simple Basin and Range Fault Model for the Beowawe Geothermal System, Nevada," GRC Trans., Vol. 8, p. 451-457.

5. Swift, C. M. (1979), "Geophysical Data, Beowawe Geothermal Area, Nevada," GRC Trans., Vol. 3, p. 701-703.