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A HYDROLOGIC MODEL BASED ON DEEP TEST DATA FROM THE WALKER "O" NO. 1 WELL, TERMINAL GEYSER, CALIFORNIA

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ABSTRACT

The Shasta Forest No. 1 Well (renamed Walker "O" No. 1) at Terminal Geyser, California was reentered and deepened from 1258 to 4008 feet.

Temperature logs indicate the well penetrated a laterally flowing thermal aquifer between 1400 and 2200 feet. Large amounts of drilling fluids were lost in that zone. Maximum temperature in the well (10 months after drilling) was 348°F at 2000 feet. A large "reversed" temperature gradient zone occurs below 2400 feet. Bottom hole temperature is 256°F.

After completion, the well was flowed for about five hours with nitrogen injection at 2000 feet. Samples taken throughout the flow indicate that fluids lost during drilling were not completely recovered. Salinity increased steadily during the flow period. Ratios of Na, K, and Ca were nearly constant, however, and application of Na-K and Na-K-Ca geothermometers indicate these fluids were in equilibrium with rocks at a temperature of 448°-449°F.

DRILLING HISTORY

In September 1978 Phillips Petroleum Company reentered the plugged and abandoned Shasta Forest No. 1 well at Terminal Geyser (total depth 1,258 ft.) and commenced operations to deepen it to ±4,000 feet. The well, renamed Walker "O" No. 1, was located on private land within the boundary of Mt. Lassen National Park (Section 36, T. 30 N., R. 5 E.). Ownership of the land has recently been obtained by the Federal Government by means of condemnation.

After cleaning out the cement plugs and running 7 inch casing to 1,253 feet, drilling began on September 28. During drilling, a steady loss of mud was reported below 1200 feet. Total depth of 4,008 feet (all in volcanic rocks) was reached for 4 1/2 hours with nitrogen injected at about 2,000 feet. Both times that the well was flowed with nitrogen injection, it died quickly when injection was terminated. Flow line temperature during the test reached a maximum of 240°F. Six water samples were collected during the second flow period.

FIGURE 1. TEMPERATURE LOGS OF WALKER "O" NO. 1 WELL

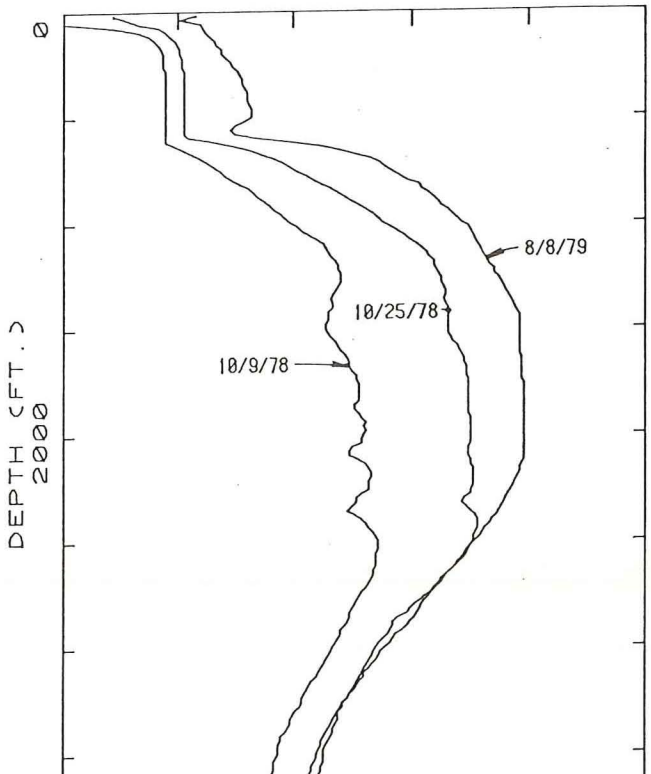


TABLE I

CHEMICAL VARIATION AND GEOTHERMOMETER TEMPERATURES
OF FLUIDS COLLECTED DURING FLOW
OF WALKER "O" NO. 1 WELL

SAMPLE NUMBER	DATE	TIME	pH	NH_3(ppb)	Cl(ppm)	SPECIFIC CONDUCTANCE (μmhos/cm)	Na-K GEOTHERMOMETER TEMP. (°C)	Na-K-Ca GEOTHERMOMETER TEMP. (°C)
#1	10/10/78	13:30	8.5	1,150.0	540	5,400.0		
#2	10/10/78	13:40	8.6	1,450.0	378	4,400.0		
#3	10/11/78	10:45	8.2	1,400.0	1380	9,800.0	232.1	230.0
#4	10/11/78	11:32	8.2	1,300.0	1230	15,000.0	236.3	232.5
#5	10/11/78	13:45	8.2	1,075.0	1680	15,000.0	235.7	231.3
#6	10/11/78	14:30	8.1	1,050.0	1980	16,000.0	231.8	232.5
#7	10/11/78	14:45	8.2	700.0	1890	21,000.0	228.3	231.1
#8	10/11/78	15:00	8.35	550.0	2100	21,000.0	225.4	230.7
							Ave. 231.6 (449°F)	Ave. 231.4 (448°F)

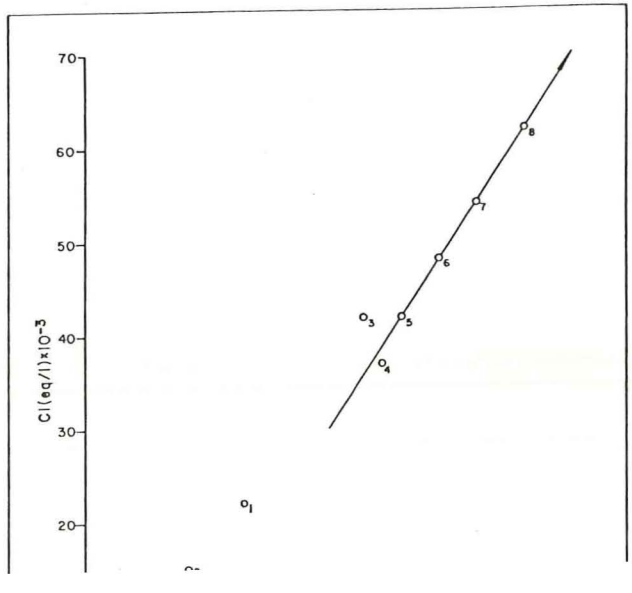
TEMPERATURE LOGS

As shown in Figure 1, a temperature log run on October 9, 1978 (before the well was flowed) indicated 286°F at 2,520 feet. On October 25, 1978, (thirteen days after the deepened well was flowed) the maximum temperature was 328°F at 2,420 feet. A presumably equilibrated temperature log on August 8, 1979, recorded a high of 348.2°F between 1,980 feet and 2,100 feet. The temperature logs exhibit large scale reversals below about 2,300 feet. The BHT of 256°F at 3,981 feet in the last log run represents a decline of 92°F over a depth of only 1,800 feet. The lower 60 feet of the hole is isothermal.

FLOW TEST SAMPLES

Eight samples were taken during the two periods of nitrogen stimulated flow. The salinity values of the fluids produced increased steadily as the well "cleaned out" (Table 1). However, upon application of the Na-K and Na-K-Ca geothermometers (White, 1970; Fournier and Truesdell, 1973), the Na, K and Ca values of analyses from the last six samples yield nearly constant geothermometer temperatures of about 498°-499°F. The ratios of the major ions remained nearly constant throughout most of the flow, as is shown in the graphs of Figures 2 and 3.

water remained essentially unchanged when mixed with the drilling water, as was the case while drilling with incomplete mud returns. The analyses show also that ammonia values decreased (Figure 4) with increasing salinity. Ammonia is con-



centrated in the vapor phase, which, as condensate was used for drilling water. The increasing salinity and decreasing ammonia content of samples collected during the flow periods indicates that drilling fluids lost in the well were never completely recovered.

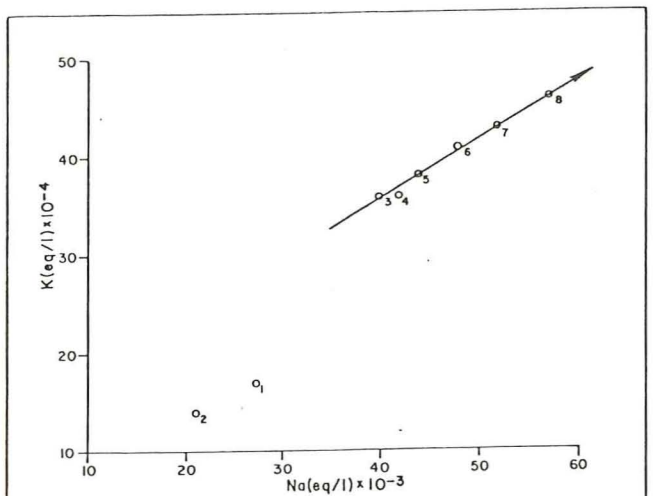


FIGURE 3.- Na vs K- Numbers indicate position in sampling sequence.

MODEL

The magnitude of the reversal shown in the equilibrated temperature log (Figure 1 and curve "C", Figure 5b) necessitates a geologically recent disturbance of the normal temperature gradient. This disturbance is interpreted to originate from lateral intrusion of geothermal fluids into the highest temperature zone (between 1,400 and 2,200 feet) encountered by the Walker "O" well. According to the model, the reversal in the temperature gradient should ultimately disappear as heat flows into the "reversed" gradient zone from above and below. Assuming that geothermal fluids continue to migrate through the 1,400-2,200 foot zone of the well, the temperature gradient curve should, over time, change toward curve "D" from the existing gradient of curve "C" (Figure 5b). Curves "A" and "B" represent, in a qualitative way, the change in the normal "predisturbance" gradient of curve "F" through curves intermediate to curve "C".

In Figure 5a, a fault provides plumbing for up-

An important question is whether or not 449°F fluids indicated by the geothermometers are located within the Terminal Geyser area. A definite answer is not possible. However, a thermal gradient of 5.3°F/100' is calculated using the BHT of 256°F and a mean annual temperature of 45°F (curve "E", Figure 8b). Extrapolating that gradient to 7,700 feet yields 450°F. A more conservative and perhaps more probable gradient of 4.8°F/100' (curve "F") is obtained by extrapolating curve "C" and drawing a tangential line from curve "C" to the mean annual temperature. Curve "F" obtains 450°F at 8,400 feet. This estimated thermal gradient (curve "F") assumes conductive heat flow below the thermal aquifer and that the bottom of the hole is sufficiently deep to be little affected by warming from the thermal aquifer.

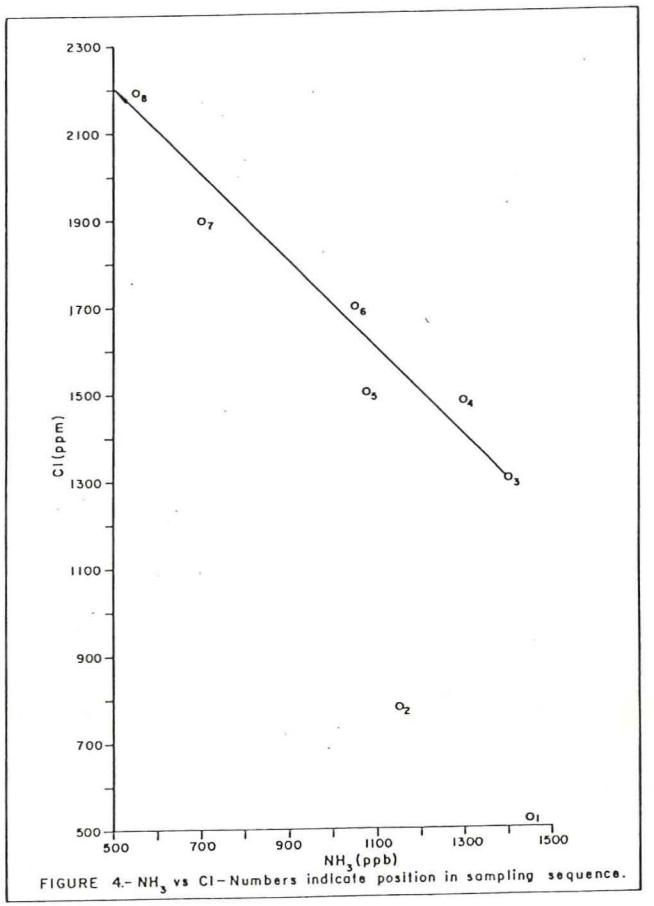


FIGURE 4.- NH_3 vs Cl- Numbers indicate position in sampling sequence.

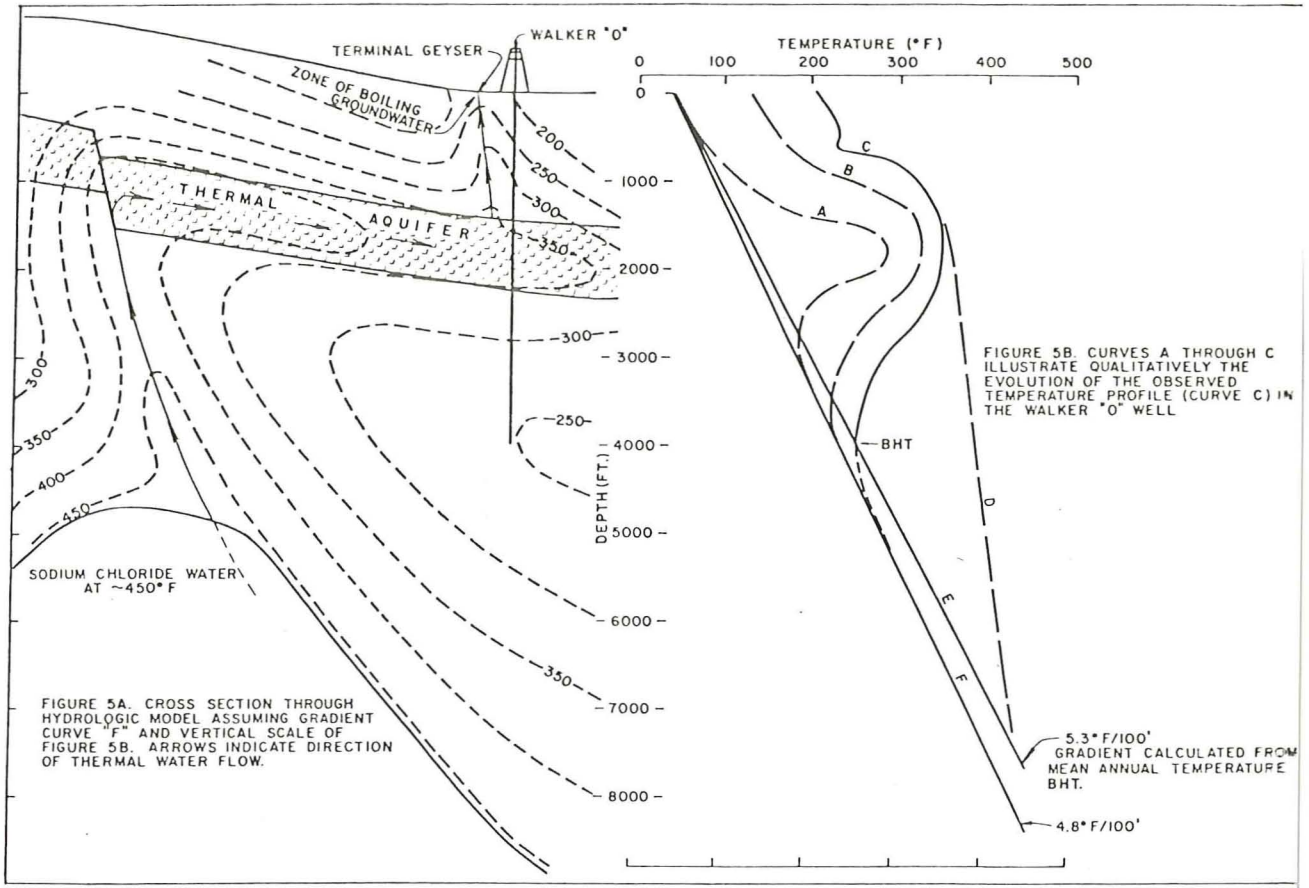


FIGURE 5A. CROSS SECTION THROUGH HYDROLOGIC MODEL ASSUMING GRADIENT CURVE "F" AND VERTICAL SCALE OF FIGURE 5B. ARROWS INDICATE DIRECTION OF THERMAL WATER FLOW.

FIGURE 5B. CURVES A THROUGH C ILLUSTRATE QUALITATIVELY THE EVOLUTION OF THE OBSERVED TEMPERATURE PROFILE (CURVE C) IN THE WALKER "0" WELL

REFERENCES

Fournier, R.O., and Truesdell, A.H., 1973, An empirical Na, K, Ca geothermometer for natural waters; Geochim. et Cosmochim. Acta V. 37, p. 1255-1275.

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