Salton Sea Scientific Drilling Program Monitor

A PERIODIC REPORT OF SSSDP EVENTS PREPARED BY THE U.S. DEPARTMENT OF ENERGY, IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY AND THE NATIONAL SCIENCE FOUNDATION.

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INTRODUCTION

The SSSDP well continues to be deepened into the hydrothermal system of the Salton Sea Geothermal Field. The most newsworthy events of this reporting period were flow testing and the obtaining of fluid samples, and the correction of wellbore deviation. By the end of this reporting period, fluid temperatures approaching 330°C (626°F) had been measured at a depth of 6,227 ft, and the well had been deepened to 6,772 ft.

DRILLING AND LOGGING ACTIVITIES

At 4:30 a.m. on December 7th, the 16th core was recovered from the 5,574 to 5,591 ft depth interval. The core was predominantly an indurated mudstone with brecciated fractures containing abundant epidote and hematite, with traces of sulfides. Drilling was resumed to a depth of 5,642 ft, where a deviation survey indicated a borehole drift of 7°45'N, 76°E. While drilling to this depth, loss of fluid pressure resulting from damaged packing and bump jars was noted in the circulation pump. After repair, drilling resumed at the rate of 17.5 ft/hr, and a depth of 6,000 ft was reached at midnight on December 8th.

Schlumberger began logging the openhole interval from 3,500 to 6,000 ft on December 9th. The logs obtained are summarized in Table 1. The U.S. Geological Survey

TABLE 1
SUMMARY OF SCHLUMBERGER LOGS

(12/9/85)

INTERVAL LOGGED:	3,500 ft to 6,000 ft
LOG TYPES:	* Dual Induction
	* Formation Compensated Density
	* Compensated Neutron
	* Gamma Ray
	* Sonic
	* 4-Arm Caliper

also began logging on the 9th of December and continued with various logging runs for the next 3 days. Their activities are summarized in Table 2. Several stationary bottom-hole temperature measurements were made over time periods sufficient to obtain consistent trends for projecting the equilibrium bottom-hole temperature. A maximum reading of approximately 320° Celsius (608°F) was obtained. USGS personnel also noted considerable character in the temperature logs, indicating a correlation to hot fluid in-flows after circulation ceased. Cursory comparisons by USGS between the lithologic and temperature logs indicated that the temperature anomalies were apparently related to lithologic changes (see Figures 1 and 2).

Reduction of hole diameter with time was noted when several logging tools (especially the 3-inch diameter tools) caught in the wellbore. Subsequent runs with the caliper tool showed hole constrictions at several specific depths. Both USGS and Schlumberger caliper tools, below a depth of 5,600 ft, measured hole diameters that were typically less than drill bit size by 1-inch.

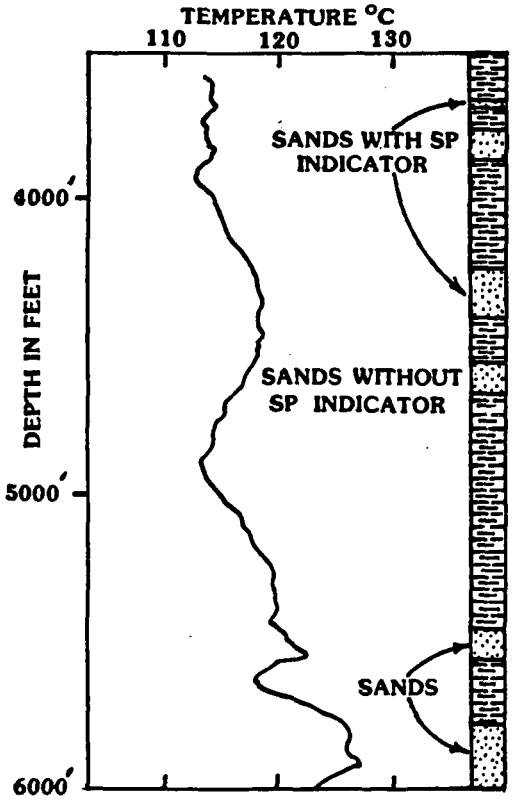
In addition to constriction of the wellbore, excessive mud buildup in the borehole has also become a logging problem. Preliminary correlation of logs by USGS indicated that buildup was occurring where the sediment grains appeared coarsest. A working hypothesis suggested by the USGS is

TABLE 2

CHRONOLOGY OF USGS LOGGING

LOG TYPE	DATE	TIME IN	TIME OUT	COMMENTS
Resis temp	12-4	24:00	14:00	Stationary readings on bottom
Resis temp	12-9	21:15	03:00	Stationary readings on bottom
Resis temp	12-10	14:00	18:00	
Caliper	12-1	18:00	20:00	
Televiewer	12-10	20:00	22:00	No pictures below casing
Nat gamma	12-10	22:00	02:00	
Gamma spec	12-11	02:00	04:00	Analyzer failed after one spec.
Acoustic DT	12-11	05:00	11:00	Poor analog record
Waveform #1	12-11	11:00	14:00	Total waveform
Waveform #2	12-11	14:00	17:00	Magnified first arrival
Caliper	12-11	17:00	19:00	Tool hangs near 4700 ft
Resis temp	12-11	19:00	24:00	Tool hangs near 5100 ft
Caliper	12-12	12:00	15:00	
Neutron	12-12	15:00	18:30	

FIGURE 1

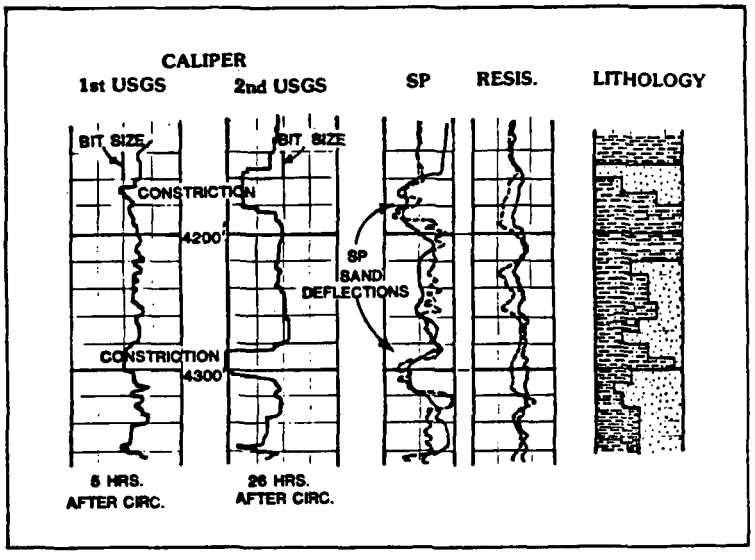


CORRELATION OF TEMPERATURE LOG IMMEDIATELY FOLLOWING CIRCULATION, SHOWING ASSOCIATION OF TEMPERATURE PEAKS WITH SANDSTONE BEDS ON LITHOLOGIC LOG.

that hot water circulating through the more permeable sandstone, but not necessarily into the wellbore, causes increased heating of the wellbore at specific depths, thereby producing coagulation of the drilling mud at these sites. Possible mitigating actions to be taken include circulating the wellbore more often or altering the mud properties to avoid excessive mud cake across zones of higher wellbore temperature.

Problems continued to be experienced in obtaining quality acoustic borehole televiewer logs. Both of the televiewers used by USGS stopped scanning at depths below 2,500 ft, presumably due to increased fluid pressure. At shallower depths, the televiewer would not function properly because of the thickness of the mud column in the larger diameter borehole. This latest problem was attributed to an electronic connection that becomes loose under downhole pressure. Since the televiewer is such a valuable tool for the detection of subsurface fractures, the USGS will make every effort to recondition one of the high-frequency televiewers prior to the next logging period. To reduce the mud effects experienced in the previous logging period, the intent is to run the televiewer as soon as possible after circulation in the wellbore.

FIGURE 2



EXAMPLE OF CORRELATION OF HOLE DIAMETER CONSTRICTIONS, SP INDICATORS OF SANDSTONE, RESISTIVITY AND LITHOLOGY.

On December 13th and 14th, the 9 5/8-inch casing string, consisting of 137 joints, was run into the well to 6,000 ft. The casing was cemented into place in two stages on December 14th and was then allowed to set. On December 17th, drilling resumed with 8.5-inch hole size to a depth of 6,026 ft, where it was decided to obtain Core No. 17. Coring proceeded to a depth of 6,044 ft, where a significant pressure drop was noted at the mud pump and drill string weight decreased 20,000 lbs. The drill stem had twisted off leaving ten 6 1/4-inch drill collars and the core barrel (341 ft total) in the well. Recovery was accomplished with a fishing tool comprised of a 7 3/4-inch overshot and 6 1/4-inch grapple. About 17 ft of epidotized mudstone with quartz veins and traces of pyrite was recovered from the 18-ft cored interval. A summary of coring is shown in Table 3.

On December 19th, the first of a series of attempts was begun to correct the well deviation problem using a downhole mud motor. Although the first attempt failed due to motor failure, turbo-drilling and reaming proceeded using a new downhole motor that lasted until the afternoon of December 20th, when the bit and turbo mandrell were lost in the hole at 6,112 ft. These were recovered 13 hours later and well deviation correction continued as the well was deepened to 6,227 ft.

FLOW-TEST ACTIVITIES

A lost circulation zone (34 - 66 barrels per hour), encountered on December 22 from 6,119 ft to 6,160 ft during directional drilling, led to the decision to flow-test the well from this estimated 40-ft interval within the total open-hole interval extending to 6,227 ft. This flow test, begun on December 28th, continued until the night of December 29th with remarkably good fluid sampling success from the four in-line sets of surface sampling ports. Prior to opening the well to flow, the USGS ran three temperature surveys and recorded a maximum temperature of 326.7°C at 6,227 ft. The

TABLE 3
CORING SUMMARY

Core #	Interval	Feet Cored	Recovered	% Recovery
16	5,574-5,591	17	17.5	100
17	6,026-6,044	18	17	94.4
18	6,506-6,517	11	11	100
19	6,758-6,772	14	7	61.5

well, stimulated with nitrogen, flowed at the rate of about 475,000 lbs/hr. At full flow, wellhead temperature and pressure was 220°F (104°C) and 180 psi, respectively. Total dissolved solids content of the brine reservoir is estimated to be 24.5 weight percent.

During the evening of December 28, the well was throttled back in order to modify the weirbox from "V" to rectangular notch to accommodate the higher flow-rate. After the well was throttled back (on choke), wellhead temperature was 450°F (232°C) and wellhead pressure was 450 psi. On the evening of December 29, after this modification and a subsequent shut-down to repair a wellhead leakage problem, flow-rate tests were again attempted using a modified "James" tube. The James tube-weirbox measurements, which were required for calculating the flowing enthalpy of liquid and vapor phases, were hampered by severe salt encrustation and back pressure.

On December 30, Kuster temperature and pressure tools were run into the well on the Otis slickline by Sandia personnel to test reservoir recovery. The tools were run-in tandem starting at about 2:00 p.m., and set with a 2 1/2-hour delay to account for the time incurred while making up the tools. At 5:30 p.m. the well was shut-in to allow pressure/temperature buildup. The Kuster tools were pulled out of the well at midnight and read. Maximum recorded temperature was 581°F (305°C) and the maximum recorded pressure was 2,492 psi.

Three unsuccessful attempts were made at downhole fluid sampling using the LANL fluid sampler. On the first attempt at obtaining fluid samples from a depth of 6,120 ft, the sample bottle failed to open, presumably due to an electrical problem in the cablehead. Voltage leakage was thought to be the cause for failure of the inlet valve to close on the second attempt at 5,000 ft. On the third attempt, the LANL sampler, coupled to the Sandia battery pack, was run-in on a slickline. Apparently, when the sample bottle opened, mineral precipitates formed instantaneously as the geothermal brine flashed into the two-liter chamber. The valve ports were encrusted preventing proper closure. This, in turn, caused the motor and battery pack, which operate the valves, to burn out. A total fluid volume of about 30 mL was recovered in the three attempts.

The scientists' satisfaction that the surface fluid samples taken were representative of reservoir fluid, and that sufficient reservoir production data were collected, led to termination of the flow test. Reinjection of the spent fluid was successfully accomplished on January 1 and 2. The brine pond (approximately 1 million gallon capacity) had only been half filled.

RESUMPTION OF DRILLING

Directional drilling was continued until January 2, to a depth of 6,316 ft. Conventional drilling was then resumed and the well was drilled to the next coring point at 6,506 ft. Core No. 18 consisted of highly fractured, silicified shale, fragments of which resembled sharp arrowheads. These sharp fragments were responsible for jamming the core barrel after only 11 feet of coring. Drilling then continued to 6,637 ft, where all circulation was lost. Five separate treatments with lost circulation material (LCM) failed to plug-off the lost circulation zone and produce returns. Drilling was resumed without returns to the next coring point at 6,758 ft. About 62 percent of the 13 feet cored was recovered. The predominant rock type in Core No. 19 was sandstone, containing abundant natural and drilling-induced fractures. Parts of the core were very lightweight and friable, likely contributing to poor core recovery.

Operations were temporarily suspended at 4:00 p.m. on January 6, 1986 as the rig was placed on "standby secured mode" after a cement plug had been set to control lost circulation. The shut-down was scheduled to allow the Imperial [County] Irrigation District to clean the canal that provides makeup water for drilling. Total well depth at this point was 6,772 ft. Operations resumed on January 10. A brief summary of drilling operations to the end of this reporting period is provided in Figure 3.

FIGURE 3
SSSDP DRILLING SUMMARY