SSSDP Monitor GL00545 Draft 12/12/85
Period: Nov. 7 — Dec. 6.
Superseded

IMPORTANCE OF THE SSSDP

The basic concept behind the Salton Sea Scientific Drilling Program (SSSDP) originated within the context of the Continental Scientific Drilling Program (CSDP). Specifically, one of the overriding objectives of the CSDP was to increase the scientific body of knowledge concerning "active hydrothermal systems related to young magmatic intrusions"; hydrothermal convection systems within the Salton Trough are thought to be driven by magma bodies that are being intruded as new crustal material along a buried spreading ridge. In order to understand hydrothermal-magma systems, one must understand the processes that take place when a body of magma is emplaced at high levels within the Earth's continental crust. Because the upper crust is normally saturated with meteoric water, the process of magma cooling does not simply involve conductive cooling, but rather a complex process related to the movement of meteoric water and the interaction of volatiles released from the magma body. Furthermore, the magma itself may convect, thereby adding to the heat source. Also, the emplacement of magma probably occurs over a long period of time, either continuously or episodically. The result of the combined processes is a complex pattern of events involving the movement of mass and heat through the Earth's crust.

Until the SSSDP, nearly everything known about the roots of hydrothermal systems had been based on inference:

- Experimental laboratory studies in the areas of fluid geochemistry, mineral phase equilibria, and stable isotopes
- Field studies of exhumed "fossil" hydrothermal-magma systems
- Theoretical modeling of heat flow, convection, and fluid flow in and around magma bodies
- Geophysical studies of young volcanic areas
- Drilling to depths of 2 to 4 km and to temperatures generally less than 360 Celsius.

Data from these various types of investigations have allowed geothermal models for hydrothermal-magma systems to be developed. However, no one model has been confirmed to any great extent because of the lack of critical information on the magma-hydrothermal transition. The major areas of uncertainty concerning hydrothermal-magma systems include: (1) the nature of the heat transfer processes; (2) the depth at which meteoric water can circulate in such a system; (3) the longevity of a magma-hydrothermal system with respect to size and shape of the instrusive body, the extent to which magma is replenished, the pattern of heat transfer, and the evolution of permeability over time in response to thermal and chemical factors; and (4) the source of the solutes carried in solution--are they derived from magmatic fluids, leached from the melt itself, or leached from the country rock? Essentially, the missing part to this puzzle has been that no direct investigation (measurements and sampling within a deep research borehole) of the "transition zone" has been conducted.

In the context of the CSDP, hydrothermal-magma systems in the United States have been placed into five classes:

- Dominantly andesitic centers
- Spreading centers
- Basaltic fields
- Evolved basaltic centers
- Silicic caldera complexes.

The Continental Scientific Drilling (CSD) Committee's application of various scientific and social-relevance criteria led to their conclusion (as outlined in a 1984 report by the National Research Council) that "silicic volcanic complexes and spreading centers should be the highest priority targets of a focused drilling program to investigate the roots of the associated hydrothermal system."

The figure below shows the location of such systems within the Western

United States. The Valles Caldera, Long Valley Caldera, and Yellowstone Caldera are the three large, young (less than 1 million years old) silicic caldera complexes in the U.S. that have been identified as high-priority targets for deep scientific drilling. The Coso volcanic area has been included as a potential target largely because of the extent of young volcanic rocks at the surface and an abundance of active thermal features.

The study of continental spreading centers was also highly recommended by the CSD Committee. Further, they strongly recommended the continued development of programs that take advantage of all available opportunities through add-on drilling to industry projects in the Imperial Valley. The Imperial Valley is contained within the Salton Trough, one of the most impressive examples of an active continental spreading center in world, and the only one in the United States. The reasons for including the Salton Trough in the CSDP can be summarized as follows:

- It contains a large number of existing drill holes and additional exploration and development is likely to continue into the future; therefore, there is considerable potential for add-on experiments with industry participation.
- The geothermal system has been well explored to depths of approximately 3.5 km, but little is known about the deeper regions.
- Drilling technology exists to extend drilling in this area to considerably greater depths.
- Very high temperatures have been measured at moderate depths; thus, it is likely that much higher temperatures can be reached without carrying out inordinately deep drilling.
- The Salton Trough is located in the rift zone where the East-Pacific Rise impinges upon the North American continent; therefore, geothermal systems in the Salton Trough are related to an important classof hydrothermal systems worldwide, in addition to a number of important ore deposits.
- The extremely high-salinity, high-temperature brines provide a unique opportunity to study the interactionof metal-rich brines and the surrounding wallrock.

RATIONALE FOR SCIENTIFIC EXPERIMENTS IN A DEEP HOLE

A report prepared by the Geophysics Study Committee, National Academy of Sciences in 1980 recommended that an important goal of earth science research in the next decade be to explore and understand the dynamics, structure, evolution, and genesis of the continents. One important aspect of this goal is to obtain a three-dimensional understanding of the dynamics of hydrothermal-magma systems in the Earth's crust. This understanding can be achieved through iterative use of various direct and indirect measurements to refine conceptual and mathematical models. Approaches used to date include extrapolation of surface geology, interpretation of surface geophysics, direct measurements in shallow and intermediate drill holes, inferences from fluid geochemistry, and comparison with fossil hydrothermal systems.

Geothermal wells have been drilled to depths greater than 4 km and to temperatures greater than 400°C, although most meaningful measurements are restricted to downhole environments having temperatures less than 250°C. Ideally, one would like to drill into and investigate the entire hydrothermal-magma system, to magmatic temperatures well within the Earth's crust. Such an objective requires certain advances in drilling and instrumentation technology. Because of these restrictions, it is realistic to focus the present objective on temperatures less than 500°C at depths less than 7 km, i.e., the "roots" of the hydrothermal systems. Direct sampling of this environment will provide important knowledge not obtainable in any other way.

SSSDP DRILLING ACTIVITIES

At the beginning of the reporting period, the U.S. Geological Survey (USGS) was finishing a first suite of research geophysical logs (see the table below). All logging instruments were used successfully with the exception of the Acoustic Borehole Televiewer, which would not perform (as expected) in the a T = 6000 ft

presence of heavy mud.

CHRONOLOGY OF USGS LOGS RUN

Log Type	Date	In Hole	Out of Hole
Resist temp.	11-5	09:00	13:00 (before circulation)
Natural gamma	11-5	21:00	23:00 (2 sec time const.)
Resist temp.	11-6	04:00	10:00 (after circulation)
Caliper	11-6	04:00	10:00
Televiewer	11-6	11:00	13:00 (no useful logs)
Resist temp.	11-6	13:00	17:00 (many stationary readings)
Caliper	11-6	13:00	17:00
Acoustic DT	11-6	18:00	21:00 (3 ft spacing)
Acoustic DT	11-6	21:00	23:00 (2 ft spacing)
Waveform	11-7	01:00	03:30 (2 microsec. sampling)
Resist temp.	11-7	04:00	06:00 (stationary readings temp vs. time)
Natural gamma	11-7	08:00	11:30
Gamma spec.	11-7	08:00	11:30 (spectrum at 5 depths)
Resist temp.	11-7	12:30	14:30 (stationary readings at bottom)

After completion of logging, the well was reamed to a depth of 3030 feet, and drilling was resumed. The fact that the wellbore was much cooler than expected, in addition to the fact that the flow test facility was only 40% complete, led to the decision to continue drilling to 3500 feet before setting 13 3/8 inch casing. At a depth of 3078 feet, two roller cones broke away from the drill bit and lodged at the bottom of the hole. At this point, fishing tools were used (including a basket tool that cut a wide shallow core, referred to as core #5 (3080 ft. to 3087 ft.), but failed to recover the lost cones. A milling tool was used to drill out the cones.

On November 10, drilling was resumed and the 6th core was taken within the interval from 3107 ft. to 3167 ft., showing laminated sandstone containing pyrite and calcite. The 7th core was taken from the interval 3470 ft. to 3505 ft., and the core barrel became jammed in the well for a short period. It was later determined that the well was deviated 3.45 degrees from vertical. A suite of Schlumberger logs were run at this point followed by a measurement of bottom hole temperature using one of the Kuster tools. The BHT measured was 358°F (181°C).

On November 14, 13-3/8 inch casing was started into the well, was eventually hung to a depth of 3500 ft, and cemented into place. Drilling was then continued to 3790 ft where the USGS ran a temperature profile of the well measuring a maximum temperature of 400°F (204°C). Estimated equillibration temperature at this point was not greater than 437°F (225°C). The expected value at this point was 500°F (260°C) based upon the nearby well--River Ranch No. 1. The 8th core was taken at this point with little or no fracturing or alteration noted. Drilling and coring continued (see summary table below) to 4676 ft where the USGS ran another temperature profile measuring maximum temperature of 414°F (212°C). The lower than expected temperatures being encountered in the SSSDP well are also indicated by the fact that the alteration minerals--epidote and chlorite -- which are pervasive in cores 4, 5, and 6, occur only in trace amounts in cores 8 through 11.

On November 23, after a decision was made to continue drilling in search of potential zones for flow testing, drilling difficulties were encountered and a Kuster temperature log was run while waiting for fishing tools. A maximum temperature of only 338°F (170°C) was recorded at 4,643 ft, but indicated a rapid temperature rise considering the short amount of time on bottom.

Core #12, which was taken on November 24, was shown to contain abundant epidote, hematite veins, and was extensively fractured. A continuous temperature log, run for the next 12 hours suggested an actual bottom hole temperature between 500 and 554°F (260 to 290°C).

Concern over the deviation of the wellbore came about as a directional survey on December 2, at a depth of 5,380 ft, showed the well deviating from the vertical by 6° 15' in the direction -- N 73° E. An attempt at controlling the weight-on-bit at that time, to correct the problem, was unsuccessful.

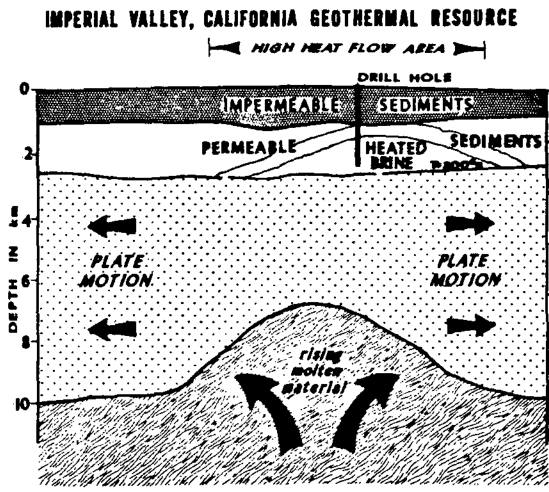
At a depth of 5,422 ft, after an inconclusive small scale injection test, it was decided to perform a full scale test. Drilling mud was circulated out of the well and replaced by a 2% KCl solution. Fluid was externally pressured to 1,500 psi for a period of 15 minutes, a pressure decline to 320 psi was noted. Additional pressure buildup-fall off tests yielded similar results. A temperature profile was run to note possible "loss zones". No significant zones were found. The conclusion was reached that, within the 1,922 ft of open hole, there were no zones indicated that would sustain a flow test.

After fishing for a "twisted-off" drill head assembly (the fish was recovered on the first try), drilling was resumed on December 6 and the 16th core was taken.

CORING SUMMARY

core #	interval (ft)	ft. cored	ft. recovered	% rec.
1	1553-1577.6	24.6	24.6	100
2	1983-2012.2	29.2	29.2	100
3	2447-2477	30.0	30.0	100
4	2970-3030	60.0	59.6	99.3
5	3080-3086 (recovered from junk)			
6	3107-3167	60.0	55	95.0
7	3470-3505	35.0	34.0	97.1
8	3790-3850	60.0	57	95.0
9	4007-4067	60.0	60.0	100
10	4241-4301	60.0	58.6	97.7
11	4301-4337	36.0	36.0	100
12	4643-4680	37.0	37.0	100
13	4676-4686	10.0	2.0	20
14	4718-4719 (recovered from junk)		1.0	
15	5188-5218	30.0	30.0	100
16	5574-5591	17	17.5*	100

* difference reflects broken condition of core



Possible figures for next issue.

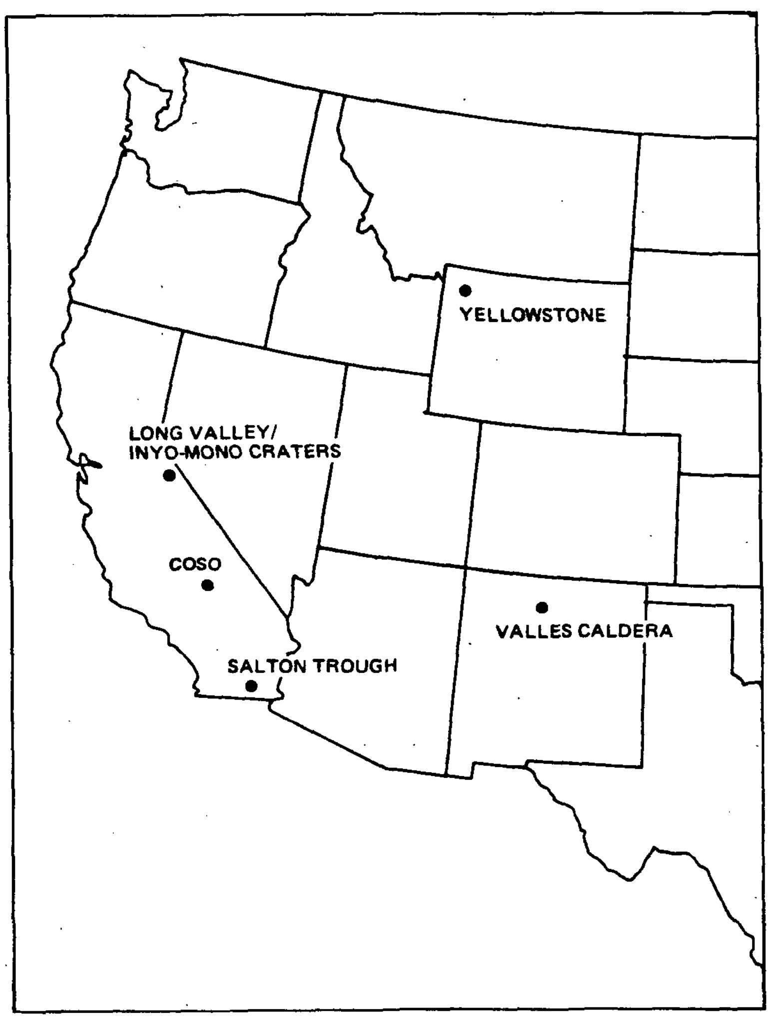


FIGURE Map of the western United States showing locations of the scientific research drilling targets discussed in the text.