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GEOTHERMAL EXPLORATION AND DEVELOPMENT DRILLING PROGRAMS FOR 50 HEAT FLOW HOLES AND A DEEP TEST WELL

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ABSTRACT

This paper describes the management and drilling techniques used to drill 50 heat flow measurement holes on the Atlantic Coastal Plain between July 1, 1978 through January 28, 1979. The organization and logistic support required for this effort are shown to be more important than drilling techniques for these shallow holes.

The plans for a geothermal test well near Crisfield, MD are described in some detail in the second part of this paper.

SHALLOW 1000 FEET HEAT FLOW HOLES

The drilling of heat flow measurement holes on the Atlantic Coastal Plain was begun in late June, 1978 on behalf of the Department of Energy's Division of Geothermal Energy. Dr. Jerry Brophy is the program manager for DOE. Dr. Costain of Virginia Polytechnic Institute and State University had selected 62 original sites as shown by the circles on figure 1 for exploratory drilling, and the Division of Geothermal Energy desired to have all sites drilled within six months after effective date of the contract between DOE and Gruy Federal, Inc. At the end of January, 1979, Gruy Federal and its drilling contractor, Energy Service Company, had completed 50 heat flow test holes, most of which were 1000 feet deep, but with several as deep as 2000 feet. The triangles on figure 1 indicate second pass holes which were drilled to detail the interesting areas found in the first pass drilling.

During the operations in Maryland, Virginia, and North Carolina in October through January, the drilling team was able to complete three holes per week provided that the holes were not more than 50 miles apart. No moves were permitted at night nor on weekends in any of the states. The moving schedule had to be carefully planned in advance so that moves could be made on Monday morning, Wednesday and Friday afternoon. This permitted a round the clock operation.

Since the Atlantic Coastal Plain is considered a frontier operation by most of the oil well service companies, including Halliburton and Christiansen, it was necessary to have dedicated Halliburton cementing and Christiansen coring crews accompany the drilling rig on a daily basis, thus providing service as needed with no transportation delays.

The time required to drill a typical heat flow hole is shown in figure 2. It is apparent that actual drilling and coring time is about equal to moving and rig up and rig down time, and the operation turned out to be a logistics problem, rather than a drilling problem. In

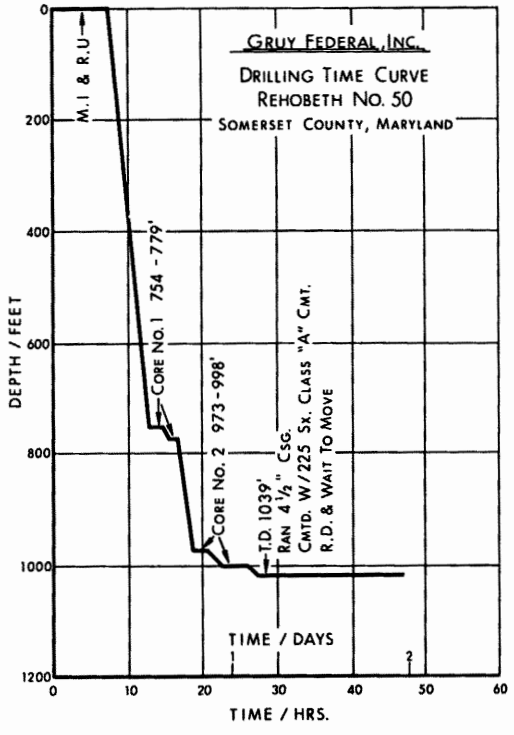
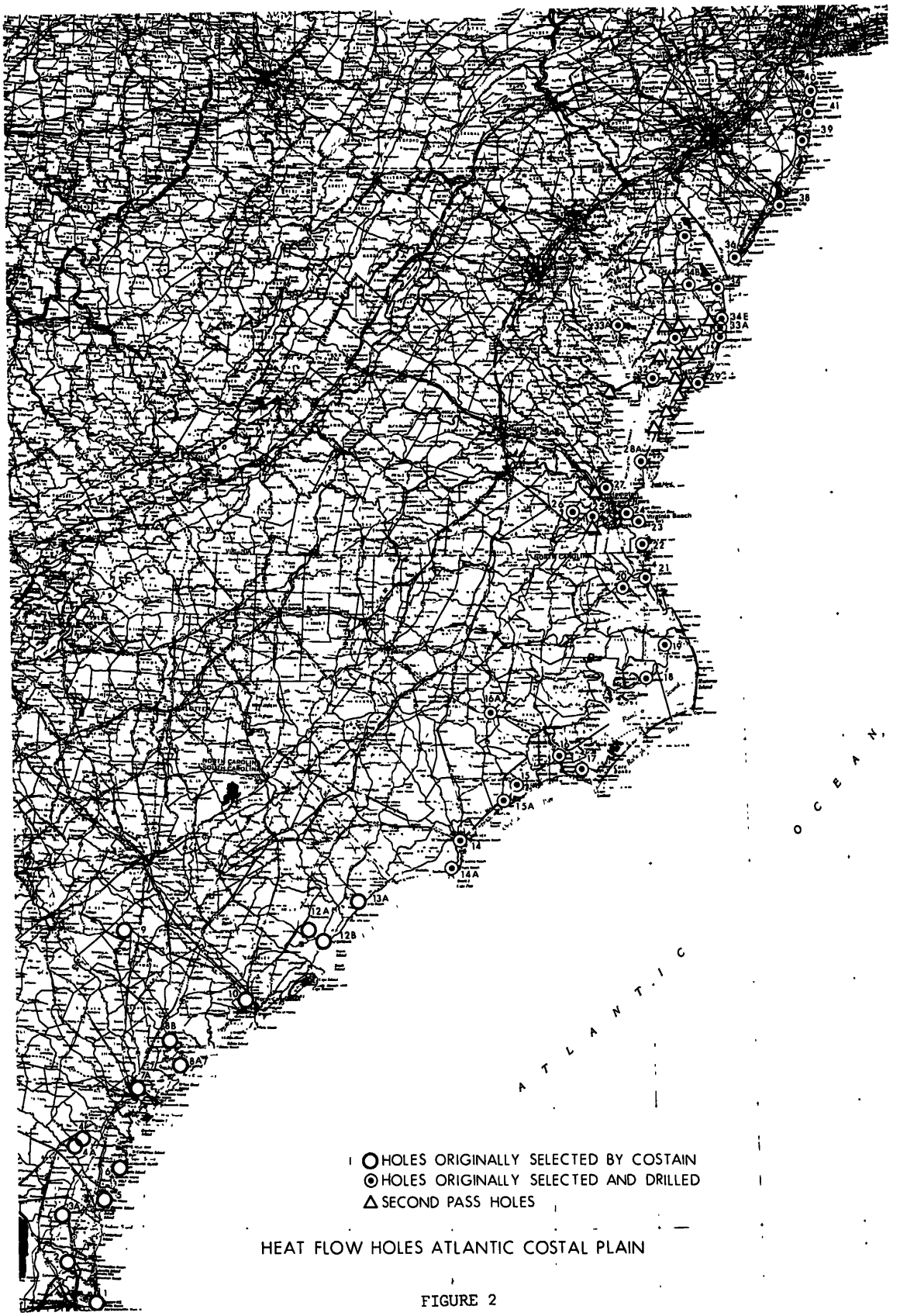


FIGURE 1



HEAT FLOW HOLES ATLANTIC COSTAL PLAIN

FIGURE 2

order to complete a hole every three days, the organization of this team had to provide for advance leasing, permitting, and site preparation as shown in figure 3. All of the people shown were in the field full time with the exception of the officer in charge. Col. McCain was obtaining leases one state ahead, Mr.Paul O'Connor was obtaining drilling and transportation permits daily for the rig and truck movements, Mr. Glascock was either preparing future sites, cleaning up past sites, or helping pull rig and heavy equipment out of the mud. Mr. Radford and Mr. Peace established engineering headquarters convenient to the rig operations as possible. The advance parties and on site management provided an efficient operation which resulted in reduced rig time, lower cementing and coring costs and yielded a hole cost well below that which would have been obtained on a single well serviced from West Virginia or Pennsylvania.

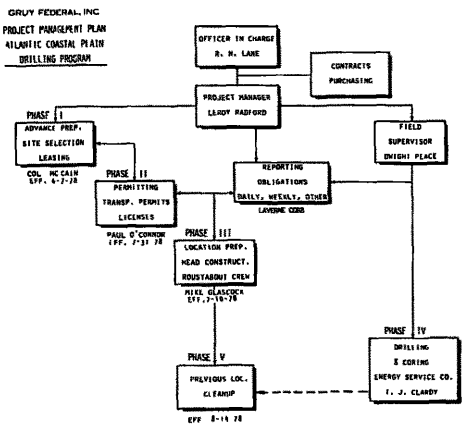


FIGURE 3

Figure 4 is a photograph of the rig in operation at Ocean City, MD and a schematic of a completed heat flow hole is shown in figure 5. The simple well head is used to insert Dr. Costain's temperature measuring device through the two-inch full opening valve after temperature gradient and static temperature stabilized. Dr. Costain intends to continue measurements in these holes for one to two years.

Two 25 foot cores were attempted during the drilling of each well. Figure 6 shows how the core was sent to the laboratories. Cores were taken in a PVC liner of 30 feet length and sawed in the field into five-foot lengths. Core recovery was variable due to the predominance of unconsolidated sands in the Atlantic Coastal Plain. However, it was a rare occurence when no core was recovered from a hole.

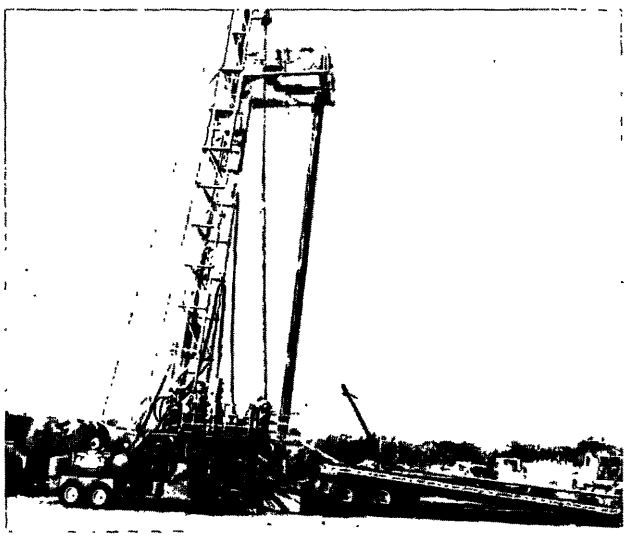
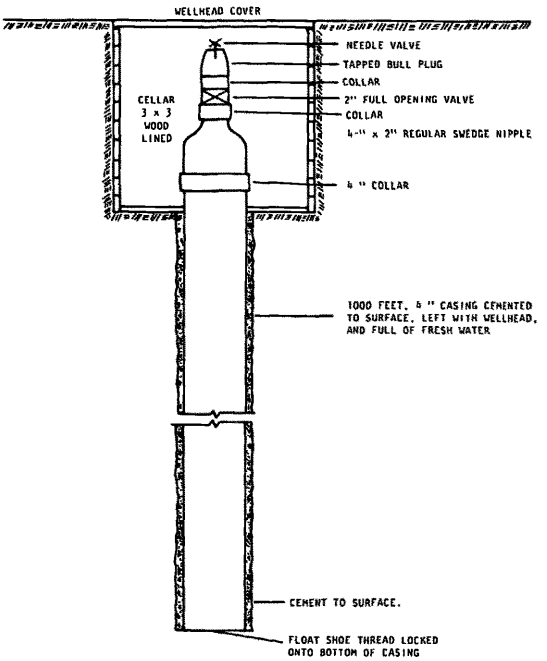


FIGURE 4



SCHEMATIC OF BASIC WELL DESIGN FOR 1000-FOOT HEAT FLOW MEASUREMENT WELLS.

FIGURE 5

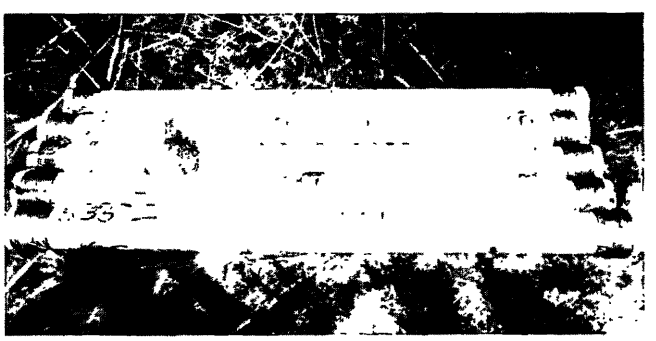


FIGURE 6

Table I summarizes the test hole drilling program to date.

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SUMMARY OF HEAT FLOW HOLES

STATE	NO. OF WELLS	CORE AVG. FOOTAGE/WELL	CORE %REC	DEPTHS FROM	DEPTHS TO
NEW JERSEY	5	55'/WELL	45	998	1047
MARYLAND	13	60'/WELL	55	1000	1666
DELAWARE	5	69'/WELL	45	980	1048
VIRGINIA	16	40'/WELL	50	1000	1800
NORTH CAROLINA	11	50'/WELL	60	731	1066
TOTAL	50				

TABLE 1

DEEP TEST WELL

From the heat flow data obtained from the wells shown in Table 1, a DOE Division of Geothermal Energy Selection Committee selected a site at Crisfield, MD for a deep test well to basement. The well will be approximately 5000 feet deep, the hoped for temperature near basement is predicted to be 80°C, and it is planned to test at least three aquifers within the salt water region of the well for chemical composition and flow.

Figure 7 shows the site for the deep test near Crisfield, MD. The test well, Crisfield Airport No. 1, will be located on property adjacent to the runways at the Crisfield Municipal Airport in Somerset County, Maryland. This property is jointly owned by the City of Crisfield and the County of Somerset. The drill site will cover approximately 3/4 acre at the production test well site and slightly less at the disposal well site.

Figure 8 shows the well schematic. A 17½ inch casing will be run and cemented to the surface. A 17½ inch hole will be drilled to approximately 1800 feet and 13-3/8 inch casing run and cemented to the surface. A 12-1/4 inch hole will be drilled to the top of the basement estimated at 5000 feet and 9-5/8 inch casing set and cemented to at least 200 feet inside 13-3/8 inch casing. While drilling the 12-1/4 inch hole before the 13-3/8 inch casing is set, a total of six cores will be taken at the discretion of the VPI&SU geologist. After the 9-5/8 inch casing has been set, the well will be drilled and cored approximately 700 feet into the basement. Upon reaching total depth (approximately 5700 feet), the basement will be hydraulically fractured to obtain at least two injection rates, utilizing a

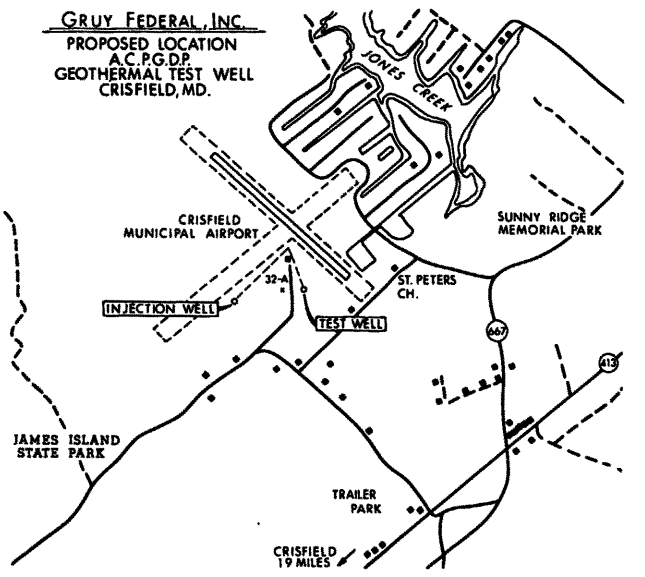

FIGURE 7

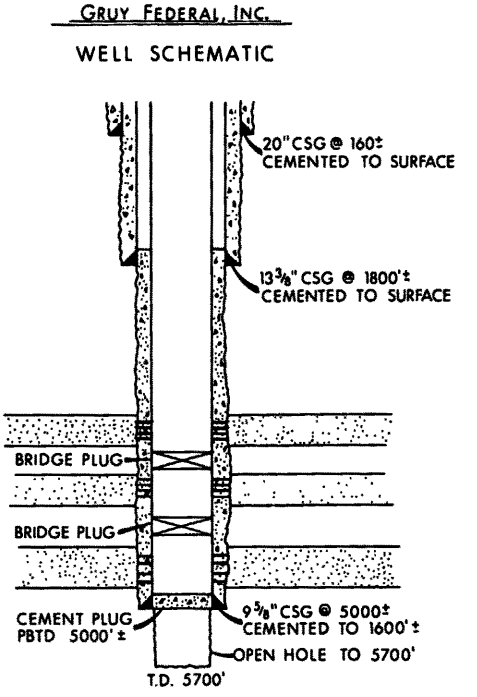

FIGURE 8

packer set in the 9-5/8 inch casing on 2-7/8 inch tubing. After fracturing, the open hole will be plugged and any prospective producing zones will be selectively perforated and tested.

Figure 9 shows the well logs which will be run in the open hole and subsequently in the cased hole. These logs were selected to yield all available useful information about the hole and the formation characteristics.

OPEN HOLE LOGS:

- SPONTANEOUS POTENTIAL
- SPHERICALLY FOCUSED INDUCTION
- SONIC
- CALIPER
- FORMATION DENSITY
- TEMPERATURE

CASED HOLE LOGS:

- CEMENT BOND
- GAMMA RAY
- CASING COLLAR LOCATOR
- CONTINUOUS NEUTRON

FIGURE 9
COMPLETION

The well will be completed as follows (see figure 7):

A permanent type packer will be set in the shoe joint of the 9-5/8 inch casing and the open hole squeezed with 100 sacks Class H cement, then 50 sacks Class H cement will be dumped on top of the packer. The zone or zones of interest will be perforated utilizing shaped charges at a density of four holes per foot. Only 20 feet of the zone will be perforated on each trip into the well. Several zones will be perforated and tested selectively by the use of additional drillable packers. Final completion will depend on preliminary test results.

TESTING

In each zone of interest the following analytical techniques will be used to estimate the aquifer properties:

1. Classical pressure drawdown and buildup analysis to determine skin effect (well bore damage) and permeability.

2. Non-linear regression analysis to determine skin effect, permeability, and porosity.

3. Core analysis to estimate the mean permeability and porosity.

4. Log analysis to estimate porosity and net porous thickness.

5. Single-phase, single-well numerical reservoir simulator to history match the pressures and determine permeability, porosity and skin effect.

Given permeability and porosity, the hydrologist will be able to compute the transmissibility and the storage coefficient.

SURFACE FACILITIES

The surface facilities will consist of a data header, a liquid meter, several settling tanks, two centrifugal injection pumps and two disposable cartridge filters. A schematic of these facilities is shown in figure 10. The data header will be manifolded to measure selectively the following properties of the flowing fluid:

- o temperature
- o pH
- o conductivity
- o scale deposition
- o sand detection

In addition, a port is provided to permit ease of sampling the flowing fluid. To analyze the composition of the fluid, a mobile chemical laboratory will remain on site.

The results from this test well should be available from the Division of Geothermal Energy in July or August, 1979.

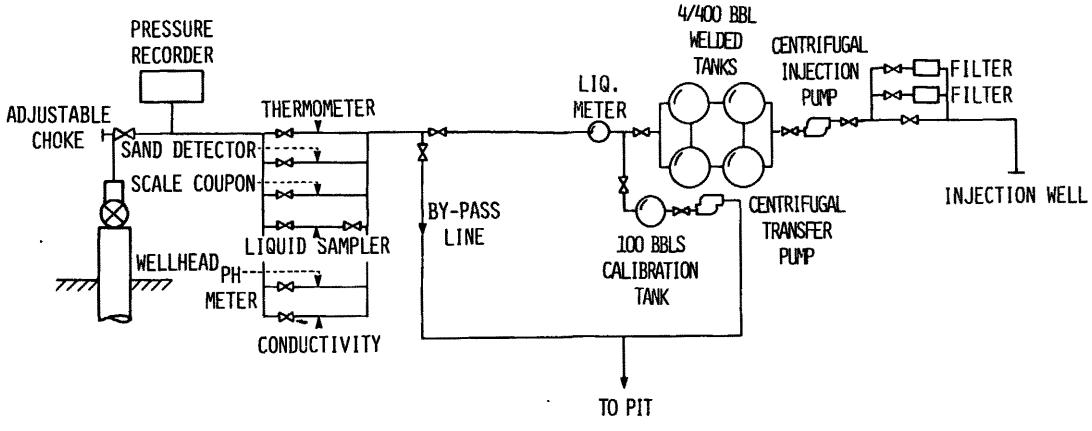

FIGURE 10