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DRILLING OPERATIONS PLAN FOR THE MAGMA ENERGY EXPLORATORY WELL

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ABSTRACT

This paper is a summary of the proposed drilling plan for the first phase (to 2500 feet depth) of the Magma Energy Exploratory Well. The drilling program comprises four phases, spaced approximately one year apart, which culminate in a large-diameter well to a total depth near 20,000 feet. Included here are descriptions of the well design, predictions of potential drilling problems, a list of restrictions imposed by regulatory agencies, an outline of Sandia's management structure, and an explanation of how the magma energy technology will benefit from this drilling.

INTRODUCTION

The first deep well of the magma energy program will be spudded this year near Mammoth Lakes, California. This will be an exploratory well, planned to yield essential results in both science and technology, and will be the focus of the magma program for the duration of its drilling. The drilling operation has four phases, spaced approximately one year apart, that will reduce the cost for any given year and will provide opportunities for scientific experiments after each phase. Since the science plan for this well is described elsewhere, this discussion is centered on the drilling activities.

Well Design

The well site is near the center of the resurgent dome in Long Valley Caldera (Figure 1). This point has undergone more than a half-metre uplift in the last nine years. This measurement, reinforced by much geophysical evidence of seismic anomalies beneath the site, is a strong indication that the site is approximately over a magma body. Our goal is to approach, but not penetrate, this body; our drilling permit specifically calls for total depth to be at 20,000 feet or a bottom-hole temperature of 500°C, whichever comes first. The well design (Figure 2) is based on known or expected lithology, casing strength requirements, and depths at which we can cement reliably. The 1989 Phase I drilling will take approximately 28 days and will culminate with setting 20" casing at a depth of 2500 feet.

This location was constructed as a drill site in 1984 by the lease holder, Santa Fe Geothermal, in preparation for drilling a 10,000 foot exploration well. It is graded (approximately 220 x 400 feet), there are three lined sumps (two 4500 and one 25,000 barrel), there is a water well approximately 880' deep that has been flow tested to 160 gpm, and site access is provided by an existing Forest Service road. Preliminary layouts of a typical rig footprint indicate that only minor modifications to the site will be necessary for our drilling.

Potential Phase I Drilling Problems:

Principal concerns in the first phase of drilling will be lost circulation, sloughing formation, and hole deviation. We know, from the existing water well and other drilling in this area, that there is an interval of unconsolidated ash at about 900' depth. It is also probable that fractured formations will be encountered above the 2500' casing point. Since temperatures in this interval will be low (approximately 100°C), we plan to control these conditions with conventional lost circulation material and/or cement plugs. The tendency for hole deviation in this interval is not known, but it is important to keep the hole straight at the top so that problems lower down will be minimized.

Restrictions by Permitting Agencies:

The drilling project is constrained by a suite of regulations from the Bureau of Land Management, the Forest Service, and the California Regional Water Quality Control Board. Although these are generally standard and straightforward, some are relatively new drilling requirements or are unique to this site:

Drilling schedule: Drilling or "other noise-intensive activity" is prohibited from April 15 - June 15 and from October 15 - November 15. "Noise-intensive activity" is broadly interpreted to mean loud, round-the-clock tasks such as drilling, mobilizing, etc. Because of the severe winters at this location, we assume that all drilling operations will take place between June 15 and October 15.

Testing cuttings: Cuttings must be tested at 300 foot intervals for the presence of arsenic or other toxic materials. Sites and methods for disposing of drilling fluids and cuttings must be approved by the CRWQCB.

Use of surface water: We plan to use the existing water well for water supply. If this supply becomes unavailable, use of surface water requires a sundry notice to the BLM and approval from the Los Angeles Water Board.

Hydrogen sulfide monitoring: Although H_2S is not likely to be a major problem, especially in the upper parts of the hole, we are required to have safety training for all personnel, emergency breathing equipment, and H_2S monitors around the rig.

Management Structure:

Santa Fe Geothermal holds the lease for this location, and Sandia National Laboratories acts as their agent in the drilling of this well. Sandia has responsibility and authority for all decisions concerning the drilling and scientific investigation. At the end of our drilling and scientific activities, we will offer the well, as is, to Santa Fe Geothermal; if they decline, it will be our responsibility to plug and abandon the well and to restore the site.

Sandia will place directly with suppliers several major contracts such as casing, cementing, and site services, but the largest commitment will be to the drilling contractor. Other third-party services (drilling fluids, mud logging, etc.) will be provided through the drilling contractor, who will be reimbursed by Sandia. We will place separate contracts for each phase of the drilling; selection of a supplier for Phase I does not assure selection for any subsequent phase. During the drilling operations, Sandia will employ contract drilling engineers for on-site supervision. These engineers will coordinate any major decisions with Sandia, but will have authority for day-to-day supervision of the operation.

Benefits of the Drilling Program:

This exploratory well will have its own value to science and technology, but it is also conceived as the precursor to a long-term energy extraction experiment in which a heat exchanger will be emplaced in a magma body. That experiment would require a different, deeper well; drilling it would be greatly simplified by the lessons learned in the exploration. There are several specific benefits:

Depth definition: It is important to have an accurate measure of the depth to the magma chamber's upper boundary. This depth is now uncertain within a 2 kilometre range. Downhole measurements can refine this estimate and give a definite target depth. Accurate knowledge of the target will allow the cheapest design of the casing program and drilling plan for the energy extraction experiment.

Prediction of drilling problems: Historically, much of the cost on big wells is a result of unexpected events -- trouble not foreseen in the drilling plan. Lost circulation, unstable formations, sudden changes in lithology that require a different bit, or zones of unusually high or low pressure are conditions that will, at least, increase the time and cost of the well. The exploration well will be near enough to experience the same formations, conditions, and problems as the experiment well, but finding and solving these problems will be much cheaper in the smaller well.

Materials compatibility: The high temperature and likelihood of corrosive gases or liquids in the formation make the tubular materials selection a crucial part of the well design. This becomes even more important in the experiment well, since it must be planned for data collection that might last years. Uncertainty about the local geochemistry would force the experiment hardware to be capable of resisting a range of corrosives, but rock and fluid samples from the exploration well would narrow that range and would identify specific corrosion hazards. This would lead to significant savings in buying drillpipe and casing.

Test insulated drillpipe: Drilling fluid temperatures affect so many other aspects of the well plan (tubular selection, choice of drilling fluid and additives, corrosion rates, bit cooling, wellbore stability) that controlling these temperatures appears to be a crucial part of a successful project. Our approach to this problem is the use of insulated drillpipe, which can make a dramatic difference in the fluid temperatures when drilling an energy extraction well (Figure 3). If we are not able to keep these temperatures relatively low, then we must face the prospect of solving all the problems associated with drilling a long, large diameter interval in unique and hostile conditions. To prove a valid solution, we must test prototype insulated drillpipe in a realistic, hot well.

CONCLUSION

This drilling project launches an exciting venture toward access to an enormous energy source. Commercial use of this resource lies far in the future, but the essential science and technology can only be addressed by this commitment to physical exploration of the arena in which development will take place.

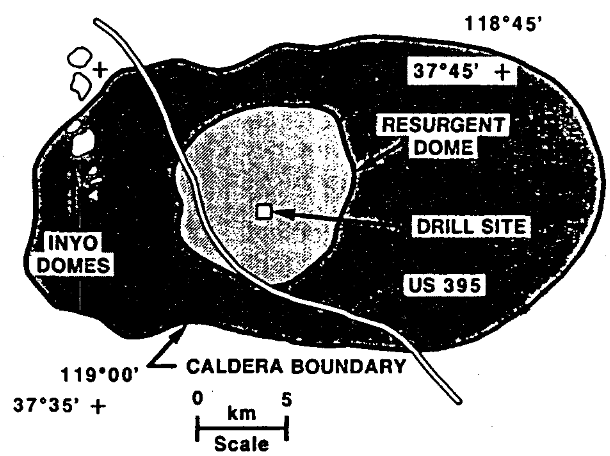

Figure 1 - Drill Site Location in Long Valley Caldera.

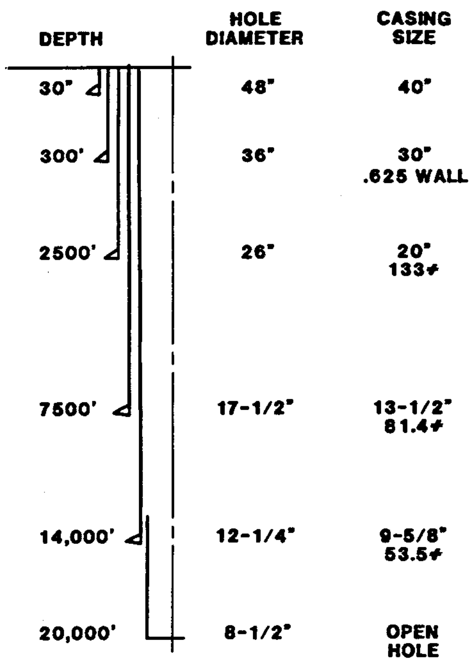

Figure 2 - Design of Magma Exploratory Well

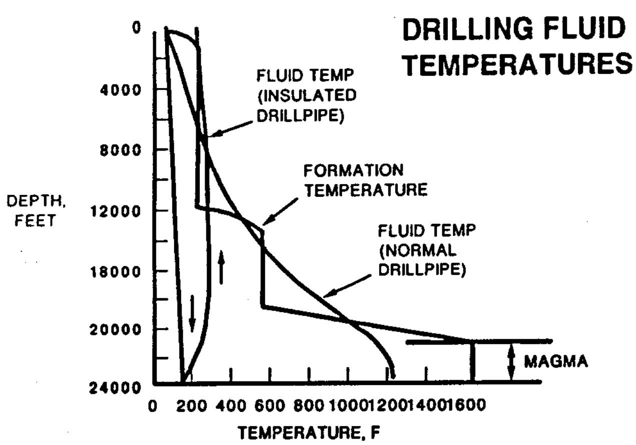

Figure 3 - Comparison of Drilling Fluid Temperatures in a Magma-Penetrating Wellbore

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