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# DRILLING PROGRAM FOR LONG VALLEY CALDERA

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## ABSTRACT

In September of this year, we will begin the first of four drilling phases in the Magma Energy Exploratory Well that is planned to reach a depth near 20,000 feet. This well will be used to verify the configuration of the magma body and to calibrate surface geophysical techniques against downhole data. It will also provide information of several kinds that is of interest to several groups: (1) We will resolve geologic uncertainties -- such as the location of fractured and abnormally pressured zones, chemistry of rocks and produced fluids, and magnitude of creep in the deep basement -- that affect the drilling of any subsequent well, (2) We will test drilling technology -- e.g., high temperature drilling fluid, bits, coring, logging tools and tubulars -- in a realistic environment, and (3) We will gain insight on the history of collapse, resurgence, and intrusion in a major young caldera.

## INTRODUCTION

The fundamental objective of Sandia's Magma Energy Program is to answer the question, "Can we locate magma bodies and produce power from them at a reasonable cost?" If analysis and laboratory work indicate that the answer to this question is "yes," we would demonstrate that feasibility by finding a magma body, drilling into it, emplacing an energy extraction system, and producing useful amounts of power in long-term experiments.

Drilling the well for this ultimate experiment is a profound technical challenge. The hole will be large, hot, deep, and expensive, but we can slash its risks and costs by learning from the experience of drilling a deep exploration well nearby. Our aim for this exploration well is to make it cheap, deep, and informative -- compared to the energy extraction well, it will have lesser requirements on diameter, depth, and service life, but we will learn a great deal from it.

## DRILLING PLAN

The exploratory well will be near the center of Long Valley Caldera's resurgent dome (Figure 1). Extensive geophysical evidence indicates that there is a magma body beneath the caldera and that its shallowest point lies approximately beneath the drill site. In the exploratory well, our goal is to drill near enough the magma for our technical objectives and we have tentatively set that criterion as being a bottom-hole temperature of 500°C, or a depth of 20,000 feet, whichever comes first.

Well design, shown in Figure 2, is based primarily on the pressure limitations of the casing and on the known stratigraphy of shallower wells drilled in the area. Because of budget constraints, and to give opportunities for scientific experiments between drilling operations, the well will be drilled in four phases at approximately yearly intervals. Figure 2 also shows completion dates for the phases and the corresponding depths. We believe that the temperature profile in the rock is very non-linear (Figure 3) because of groundwater convection, so the drilling temperatures may not become challenging until depths below 9,000 feet. The relative youth of near-surface intrusions, however, means that once we approach the magma closely, the rock temperatures may rise sharply. If these assumptions are correct, and there is sound geophysical reason to believe that they are, then the drilling in the first two phases should be nearly conventional. By the same argument, the temperatures in the lower reaches of this hole and the even more extreme conditions of the energy extraction well will dictate new technology to drill them successfully.

## BENEFITS OF THE EXPLORATORY WELL

There are several specific and important aspects of drilling for energy extraction that can be clarified by an exploration hole:

(a) Location confirmation -- It will allow us to make downhole seismic and heat flow measurements that confirm our magma location capability. Although an enormous amount of geophysical data supporting the existence of a magma chamber under Long Valley caldera has been collected, there is a chance that we could be surprised by a "dry hole" at the target location. If that happens, an exploration well will have been a cheaper experiment -- and it will signal our need to think carefully about the validity of geophysical interpretation if we cannot positively identify a magma body in a place as thoroughly studied as Long Valley.

(b) Depth definition -- After assuring ourselves that a magma chamber is truly there, it is still important to have an accurate measure of the depth to its upper boundary. This measure is now uncertain within a 2 kilometer range. Downhole seismic and heat flow measurements can refine this estimate and give a definite target depth. Since the casing program and drilling plan, and thus the cost, for any well are highly dependent on the depth, accurate knowledge of the magma will allow the cheapest design for the energy extraction experiment.

(c) 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, at best, will increase time and cost and, at worst, can endanger the hole and the crew. 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.

(d) 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.

(e) 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 4.) 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 rigorous, little known conditions. To prove a valid solution, we must test prototype insulated drillpipe in a realistic, hot well.

(f) Opportunities for science -- Because the drilling operations schedule will be driven by the budget and will be divided into phases approximately one year apart, the times between active drilling periods will give windows in which scientists will have access to an open hole deeper than any ever available in this unique location. A science program for this well is not yet completely defined, but we expect that most of the effort will concentrate on geochemistry, seismic experiments, and studies of caldera evolution. Downhole seismic data, free from interference of the shallow fractures and clutter, can be correlated with surface measurements and will be especially useful in clarifying the geological evolution of the caldera and the configuration of the magma chamber.

## CONCLUSION

The act of drilling this well will focus our research. We have tried to preserve as much generality as possible in looking at the questions of energy extraction, drilling technology, and geophysical interpretation, but it is valuable and necessary to design for a specific, unique site. Planning for an experiment here at the best available location will demonstrate the process that we must practice and extend for the Magma Energy Program to be a success.

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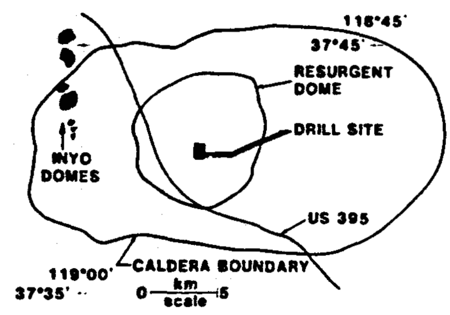


Figure 1 Drill Site Location

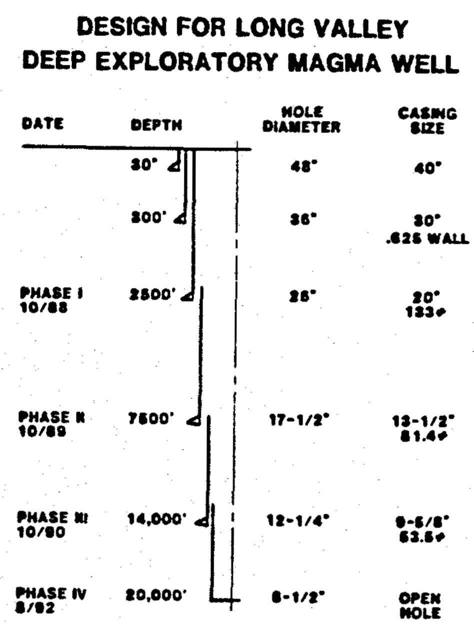


Figure 2

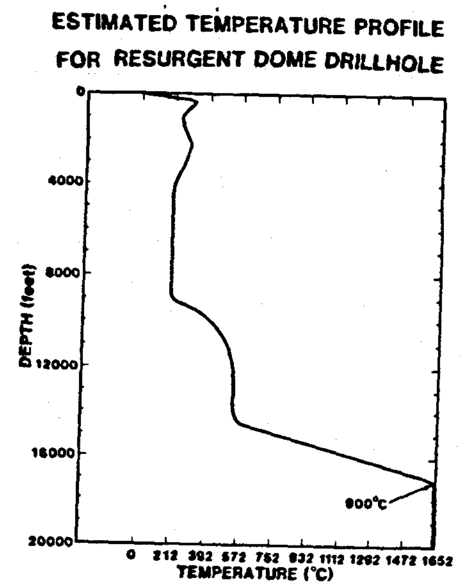


Figure 3

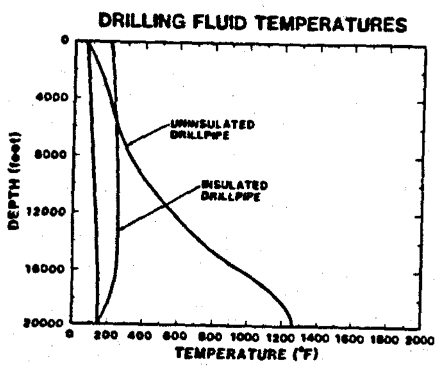


Figure 4

# DISCLAIMER