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ASPECTS OF DOE'S CURRENT GEOTHERMAL PROGRAM

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It is a pleasure to participate in the 10th Stanford University Geothermal Reservoir Engineering Workshop. The speakers and attendees at this gathering represent the vanguard of the many geoscientists and engineers who will be needed to characterize and develop geothermal reservoirs worldwide. Stanford has long been a leader in training and preparing personnel to join the ranks of the geothermal workforce, and the resulting technology transfer achievements of this university's Geothermal Research Program provide a model for us all in disseminating technical information to those who will use it to further the utilization of geothermal energy.

The geothermal training available in our universities and research institutions takes on an added importance when we consider that experts in the disciplines needed for geothermal exploration and development are in woefully short supply in many of the developing countries endowed with geothermal resources. For example, at the OLADE Latin American Seminar on Geothermal Exploration in the late 1983, the majority of the representatives cited the lack of trained manpower as an equal factor with the lack of funds as the causes for the slow pace of geothermal exploration in their countries. They also equated these two problems as major limiting factors to their potential for future energy development.

In bringing you up to date on DOE's geothermal R&D programs, we are going to emphasize first those elements that may be of special interest to a reservoir engineering audience, because our activities in support of an improved understanding of hydrothermal reservoirs deserve attention. Reservoir definition, brine injection, and reservoir stimulation technologies are major elements of our Hydrothermal Research Program, and in total they account for nearly 50 percent of the fiscal year (FY) 1985 hydrothermal research budget. These elements fall into our essential R&D category; that is, while some basic technologies have been borrowed from the petroleum industry for geothermal service, they are often ill-suited to geothermal requirements, and cannot be used without significant technological innovations. Into this category fall the current reservoir technology, brine injection, and reservoir stimulation projects that are listed in Table 1.

The reservoir technology projects include:
1) development of methods for characterizing and mapping reservoir parameters, processes, and spatial dimensions.
2) development of methods to predict and monitor reservoir changes from fluid extraction.
3) evaluation of existing methods and development of new methods for predicting the location and mapping faults and fractures in geothermal reservoirs.
4) testing of new analysis techniques using field case studies.

Brine injection projects include:
1) development of physical and mathematical models to determine the behavior of geothermal reservoirs during injection.
2) tracer testing to determine rapid flow paths between wells.
3) analysis of pressure responses in the field to injection into one or more wells.

Some of this work is carried out under cooperative research agreements with foreign institutions. These joint projects include work with ENEL of Italy on the adsorption of water on core samples from Larderello, the development and testing of down-hole fluid samplers, and injection testing in the field. Cooperative work with New Zealand includes interpretation of well tests in Broadlands, and injection and tracer testing at Broadlands, Wairakei, and Kawerau. Work in Mexico at the Los Azufres field focuses on reservoir behavior, well test analysis, injection and tracer testing, and wellbore deliverability.

The DOE reservoir permeability enhancement studies are based on earlier experiments which showed that the oil and gas stimulation techniques can be extrapolated to the higher temperatures associated with geothermal reservoirs. We are undertaking studies to improve our understanding of reservoir production phenomena in order to develop the capability of tailoring the stimulation techniques and methods to the characteristics of specific reservoir types. Research into the interaction between borehole and formation will include fracture permeability studies and fracture characterization. Advanced stimulation methods will be addressed through systems analysis and experiments. High energy gas fracturing (HEGF) employs high pressure pulses, produced by the controlled ignition of propellants, with burning rates adjusted for specific types of reservoir conditions, to form radial fractures in the rocks around wellbores. This concept has been verified in previous experiments in air-filled boreholes; current research is directed toward the fluid-filled boreholes common in geothermal applications.

We are planning to begin cooperative drilling in the Cascades Range to assess new approaches in exploration technology. Proposals are being requested to drill thermal gradient test holes to depths of 3,000 feet or greater, to be cost-shared with industry on a *50-50* basis. Through analysis of well logs, rock samples, and fluid specimens from these holes, we hope to determine the effectiveness of this exploration technology in characterizing the geothermal resources in the Cascades. DOE also is co-sponsoring investigations by the Oregon Department of Geology and Mineral Industries (DOGAMI) to identify other exploration technologies that are successful in the Cascades. In related research, the U.S. Geological Survey (USGS) has a major investigation underway to assess the geothermal resource potential of the Cascades. DOE is sharing the cost of two projects initiated by the USGS that will evaluate the usefulness of certain seismic and electrical exploration techniques in volcanic regions.

We also are approaching the drilling phase in the Salton Sea Scientific Drilling Program. This deep drilling program will test the existence of additional geothermal resources beneath the presently discovered hydrothermal reservoir in the Salton Sea area. Bechtel National Inc., the prime contractor for the project, has subcontracted several elements, including well design and geothermal tests and measurements. Additional subcontracting is in progress. We expect the well to be spudded sometime in April, and completion is expected about four months later. An injection well will be drilled consecutively. The scientific well is scheduled to be cored intermittently at five sections through the first 4000 feet, and the well will be logged prior to casing. Two short-term flow tests may be performed at selected fracture zones. Two long-term (30-day) flow tests are scheduled upon completing the well to a total depth of about 10,000 feet. The well will be available for scientific experimentation for about one year.

After we have completed the drilling of the Salton Sea well, other Federal agencies with interests in the scientific information to be gained will cost-share the research investigations. The proposals from researchers desiring to use the well for their studies have gone through three phases of evaluation. The Scientific Experiments Committee, composed of university, national laboratory, industry, and USGS representatives, determined the feasibility, timeliness, and potential for success of each proposed experiment. Qualifying proposals were then ranked and evaluated according to their scientific merit by the Peer Review Committee, a special joint committee composed of representatives of DOE's Office of Basic Energy Sciences and the National Science Foundation. The Science Coordinating Committee, consisting of representatives from DOE's GHTD and OBES, NSF, and USGS, is now in the process of determining funding levels for individual experiments. Many of you may be active participants in these various projects. With the application of your level of expertise, DOE has every reason to expect the projects to be successful. We will all be learning a great deal more than we know now about this resource in which we believe there is so much promise. Geothermal energy is a presently useful technology, but with better undtretanding of this resource, we can assure its place in the future.

A significant event in 1984 was the establishement of an industry peer review group of reservoir engineers and geologists to hold periodic discussions with the Lawerence Berkeley Laboratory (LBL) on future directions for research in understanding geothermal reservoirs. In the first meeting (August 21, 1984), the panel reviewed the current research and compared the progress to the needs of industry. Suggestions from the first meeting will be discussed by Gulati and Lippmann later in the workshop. LBL transmitted the panel suggestions to DOE, and we will take action on these suggestions. Only minor redirection will be possible for the projects this year, but some significant changes can be expected for future years.

We need the comments and advice of the geothermal industry for our research to maintain its relevance to the problems faced by industry, and we assure you that we value your advice very highly. Any suggestions we receive will be thoroughly considered, and we will use the industry needs to guide our geothermal programs. We look forward to increasing our cooperation with industry through cost-shared studies and other joint projects. Working with industry, we will provide the technology base needed to develop this nation's extensive geothermal resources.

TABLE 1. DOE FISCAL YEAR 1985 PROJECTS IN RESERVOIR DEFINITION, BRINE INJECTION, AND STIMULATION

Reservoir Technology: $3,117K

- Lawrence Berkeley Laboratory:
  - Program Guidance
  - Reservoir Analysis
  - Fracture Mapping
  - Vertical Seismic Profiling
- Stanford:
  - Workshop and Seminars
  - Adsorption of Water on Cores
  - Well-test Analysis and Experiments
  - Depletion Model
- Oregon DOGAMI:
  - Cascades Investigation
- Idaho Operations Office DOE:
  - Cost-shared Drilling
  - Measurements in Holes
- University of Utah Research Inst.:
  - Geophysical Fracture Detection
- U.S. Geological Survey:
  - Seismic Techniques
  - Electrical Techniques
  - Geochemical Techniques
  - Gravimetry Support

Brine Injection: $1,300K

- Lawrence Berkeley Laboratory:
  - Analysis of Injection
- Stanford:
  - Injection of Tracers
- Lawrence Livermore Laboratory:
  - Seismic Monitoring
- Idaho National Engineering Lab:
  - Injectioa Models
- University of Utah Research Inst.:
  - Injection Backflow

Stimulation: $ 650K

- Sandia National Laboratory:
  - Permeability Enhancement