LA-UR-97- 2166

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Title: **Reservoir Enhancement On the Impermeable Margins of Productive Geothermal Fields**

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Submitted to: DOE Office of Scientific and Technical Information (OSTI)

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Form 836 (10/96)
ST 2629

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Reservoir Enhancement On the Impermeable Margins of Productive Geothermal Fields

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Abstract

This is the final report of a one-year, Laboratory Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). The overall goal of the project was to evaluate the performance of Los Alamos technology in selected geothermal fields, to adapt the technology to the existing industry infrastructure where necessary, and to facilitate its application through demonstration and communication. The primary specific objective was to identify, collaborate, and partner with geothermal energy- producing companies in an evaluation of the application of Los Alamos microseismic mapping technology for locating fracture permeability in producing geothermal fields.

1. Background and Research Objectives

Perhaps the most elusive challenge in the geothermal energy industry is determining the location of fractures in geothermal reservoirs that control the flow of fluids to production wells. Knowledge of fracture location, when combined with well and reservoir production data, enables informed decisions on the management and further development of individual fields. Los Alamos through its Hot Dry Rock (HDR) Geothermal Energy Development Project developed a means to locate reservoir fractures. Through the HDR Project it was learned that fractures contributing to production undergo continuous stress changes that can give rise to minute, discontinuous displacements of fracture surfaces relative to each other. The displacements, called microearthquakes, in turn, release energy in the form of seismic waves. Sufficient information exists in the waveforms of microearthquake signals to determine their origin, and hence, the location of fractures.

Although the more energetic of microearthquakes can be observed on the earth's surface, instruments deployed in wells penetrating the host reservoirs detect several orders-of-magnitude less energetic microearthquakes that are several orders-of-magnitude more numerous. Consequently, the Los Alamos technology is centered about the development of a class of seismic instrumentation that, given proper temperature and pressure protection, are deployed in wells. The geothermal industry has had little exposure to this

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technology and has sparse information with which to assess the capability of the technology to solve common problems confronting reservoir management. Consequently, the overall goal of the project was to evaluate the performance of the Los Alamos technology in selected geothermal fields, to adapt the technology to the existing industry infrastructure where necessary, and to facilitate its application through demonstration and communication.

The primary specific objective of the project was to identify, collaborate, and partner with geothermal energy-producing companies in an evaluation of the application of Los Alamos microseismic mapping technology for locating fracture permeability in producing geothermal fields. This objective was accomplished and we were successful in obtaining DOE funding to support the Los Alamos contribution to follow-on collaborative evaluations.

2. Importance to LANL's Science and Technology Base and National R&D Needs

The instrumentation for mapping fractures in rock masses contribute to the Laboratory's ability to make measurements and conduct complex experiments in the earth sciences. The Los Alamos borehole instruments remain the only technology in the world for making seismic measurements in deep, high-temperature wells. Competency in this area enables the Laboratory to maintain the state-of-the-art in borehole seismic detection and to understand the capability and limitations of its application to problems in energy production (oil, gas, and geothermal) and national security, particularly in nonproliferation technologies.

3. Scientific Approach and Accomplishments

The potential for microseismic mapping was introduced to representatives of the geothermal industry at a DOE-sponsored workshop on "Subsurface Permeability Detection and Mapping" held in June, 1996, in Santa Rosa, California. Representatives from 80% of the major producers were present. Three potential industrial collaborators were identified, their fields visited, reservoir development and management needs assessed, and possible work plans scoped. Two geothermal companies were invited to participate in the preparation of a proposal for the evaluation of the technology and did so. The proposal was submitted to the DOE and received startup funding in September. A seismic instrumentation package was reassembled from salvaged parts; missing mechanical parts

were machined and fabricated; improved electronics circuitry designed and fabricated; and state-of-the-art sensors were procured and installed. The entire package was tested in a high temperature well and deemed fit for service.