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Geysers Reservoir Studies

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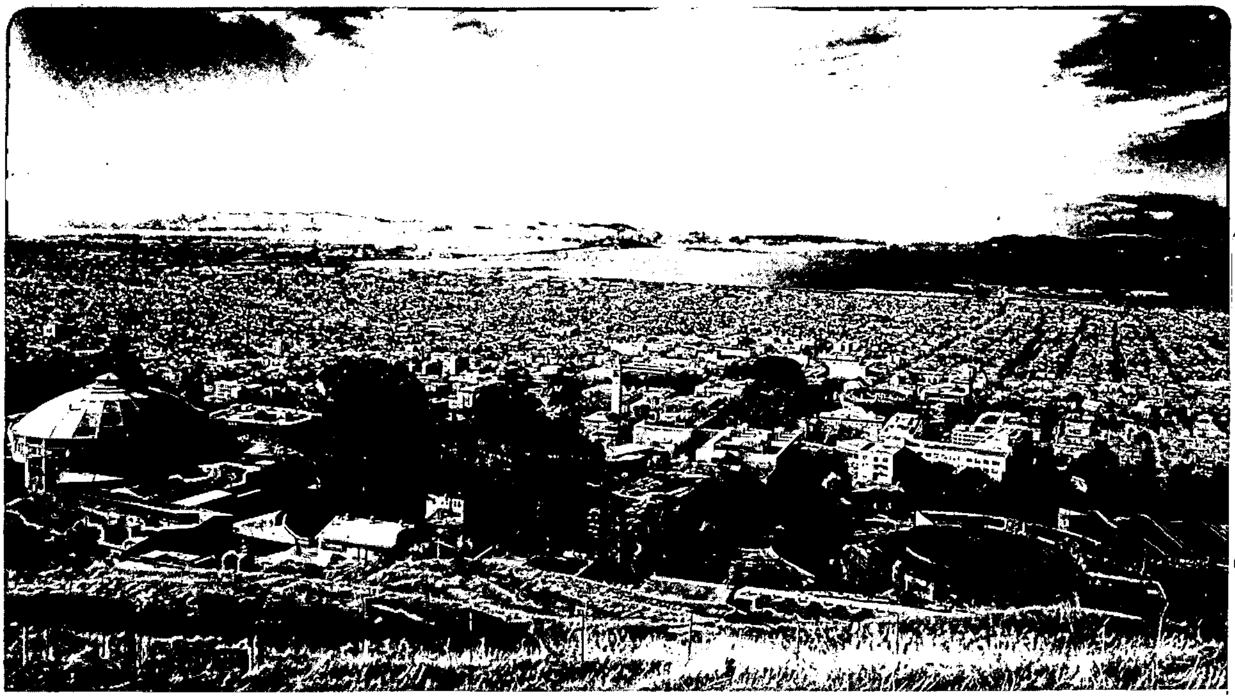

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GEYSERS RESERVOIR STUDIES

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INTRODUCTION

LBL is conducting several research projects related to issues of interest to The Geysers operators, including those that deal with understanding the nature of vapor-dominated systems, measuring or inferring reservoir processes and parameters, and studying the effects of liquid injection. All of these topics are directly or indirectly relevant to the development of reservoir strategies aimed at stabilizing or increasing production rates of non-corrosive steam, low in non-condensable gases. Only reservoir engineering studies will be described here, since microearthquake and geochemical projects carried out by LBL or its contractors are discussed in accompanying papers (i.e., Majer et al., 1993; Truesdell, 1993).

Three reservoir engineering studies will be described in some detail, that is: (a) Modeling studies of heat transfer and phase distribution in two-phase geothermal reservoirs; (b) Numerical modeling studies of Geysers injection experiments; and (c) Development of a dual-porosity model to calculate mass flow between rock matrix blocks and neighboring fractures.

There are two other on-going projects that should also be mentioned. The testing of the six-liter downhole fluid sampler in a high-temperature, high-pressure chamber is scheduled for early June 1993. After two disappointing experiments in a UNOCAL Geysers well, it was decided to test the tool in a controlled environment. It is felt that the sampler is failing to perform as planned because of field procedures and not due to design problems. However, before going to the effort and expense of a third field experiment, it was decided to test the tool in a chamber and then suggest changes in field procedures that might affect the electronic and mechanical components of the sampler.

The other project that will not be described here involves laboratory measurements of porosity, permeability and capillary pressure in Geysers cores. This low-key effort is just starting at LBL and results are expected to be reported during the next DOE-Industry Geysers Working Group meetings.

CONCEPTUAL MODEL STUDIES OF VAPOR-DOMINATED SYSTEMS

Although long exploited (i.e., Larderello, Italy, from 1904; The Geysers from 1960), vapor-dominated reservoirs are not fully understood. Over the years several quite different conceptual models have been proposed to explain the reservoir processes in these fields.[++] Early models involved vaporization only at a liquid-vapor interface or original deep upflow of supercritical steam with near surface condensation. Others proposed models involved counterflow of ascending steam and descending condensate. In these models boiling at a deep brine "water table" was assumed, with steam moving upward in large fractures along the pressure gradient produced by boiling, and then condensing at the top of the reservoir because of conductive heat loss to the surface. This condensate flowed downward by gravity through the rock matrix and small fractures.

Recently high-temperature zones have been found deep in the vapor-dominated systems at The Geysers and Larderello. A conceptual model for the origin of these high-temperature zones as relicts of hot rock not yet cooled by a downward expanding vapor-dominated reservoirs was suggested by Truesdell (1991). It is not possible to reconcile this model with those involving boiling brine or with movement of condensate from marginal zones of condensation to central boiling zones. Apparently conceptual modeling has reached its limits and more data from experiments and analytical/numerical studies are required.

Two-phase liquid-dominated systems can have shallow vapor-dominated zones (e.g., Olkaria, Kenya), single-phase shallow (e.g., Krafla, Iceland) or deep liquid zones (e.g., Ahuachapán, El Salvador), or present two-phase liquid-dominated conditions throughout. Two-phase vapor-dominated systems such as The Geysers, Larderello, and Kamojang (Indonesia) have a thick two-phase vapor-static zone but may be underlain by a superheated vapor zone or by a two-phase zone with sub-hydrostatic pressure and possibly overlain by a liquid-saturated condensate zone (D'Amore and Truesdell, 1979). For these reservoirs, the observed natural-state temperature and pressure in the main reservoir is approximately 240°C and 33.4 bars. These conditions have been hypothesized to be related to the enthalpy maximum of saturated steam (James, 1968).

Results of Recent Numerical Studies

Lai et al. (1993) conducted a numerical study of steady-state flow, phase distribution, and heat transfer processes in two-phase geothermal reservoirs using the computer code TOUGH2 (Pruess, 1991). A two-dimensional porous slab with a localized heat flux from below was used as an idealized model for a geothermal system (Figure 1). In the study effects of initial mass of fluid in-place (i.e., steam saturation), permeability and capillary pressure on the phase distribution and heat transfer processes were analyzed. The

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[++] *Relevant references are given in Lai et al. (1993).*

results showed that when an initial steam saturation of 25% and a rather high permeability of 1 × 10^{-13} m^2 are employed, a two-phase vapor-dominated zone overlying a single-phase liquid zone is formed (Figure 2). In the two-phase zone, a balanced liquid-vapor counterflow develops. The vapor rises up to the reservoir top where it is condensed to liquid by releasing latent heat which is transferred to the caprock by conduction. The condensate trickles down to the liquid zone. In the liquid zone, a convective flow field extends laterally over the entire reservoir. However, if the length of the heat source varies, the flow characteristics in the liquid zone may be different from that observed in this study.

The strength of the convective flow strongly depends on the mass of fluid in-place and the permeability of the reservoir. With an increase in initial steam saturation from 25 to 50%, the convective flow field extends only over the left half of the reservoir, resulting in lower heat transfer rates. As the steam saturation is increased to 70%, a vapor-dominated heat pipe prevails in the entire system. Because a heat pipe efficiently dissipates heat generated from the heat source, the temperature variation in the system is very small, ranging from 240 to 245°C. However, when the steam saturation is further increased to 75%, the amount of mobile liquid is reduced and the heat pipe does not develop in the entire system (Figure 3). Under such a circumstance, although a vapor convective flow exists, it is not as efficient as liquid convective flow in dissipating heat, resulting in a high-temperature superheated vapor zone underlying the two-phase vapor-dominated zone. Such a high-temperature zone has been found at The Geysers and Larderello.

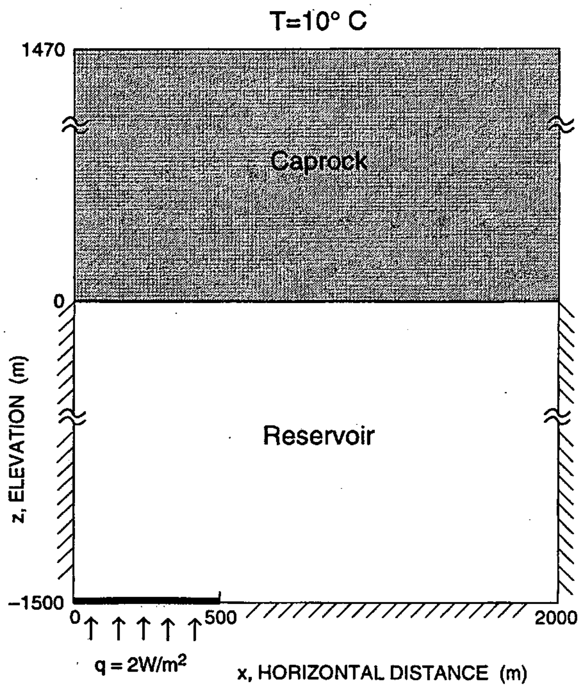

Figure 1. A schematic representation of the physical problem studied (from Lai et al., 1993).

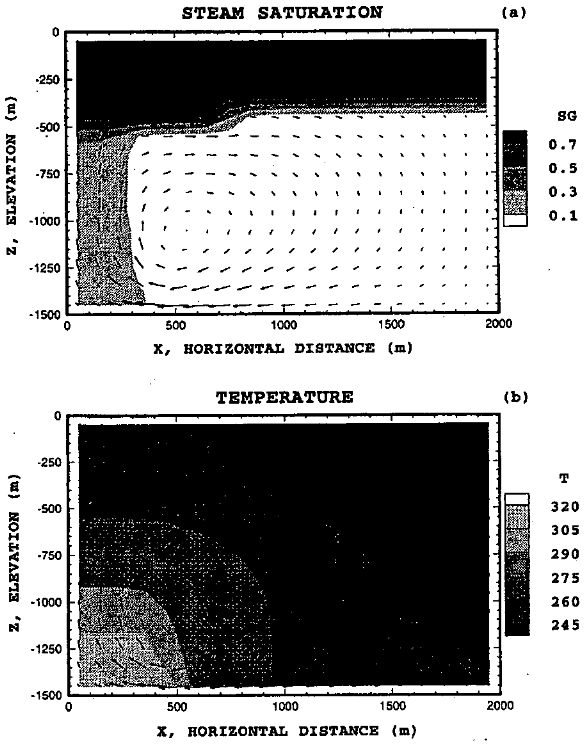

Figure 2. Computed steady-state distribution in the reservoir of (a) steam saturation and (b) temperature. Assumptions: Initial steam saturation 25%; permeability 1 × 10^{-13} m^2. Arrows indicate mass flux; their length is proportional to flux magnitude (from Lai et al., 1993).

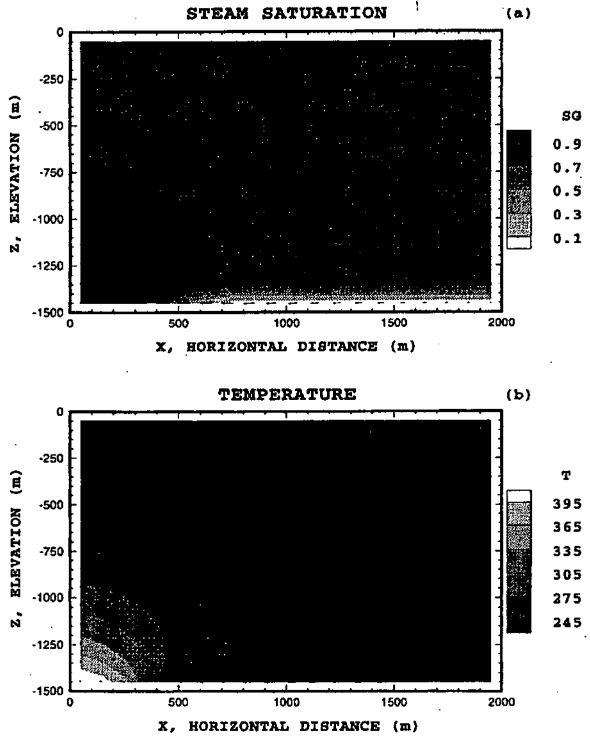

Figure 3. Computed steady-state distribution in the reservoir of (a) steam saturation and (b) temperature. Assumptions: Initial steam saturation 75%; permeability 1 × 10^{-13} m^2. Arrows indicate mass flux; their length is proportional to flux magnitude (from Lai et al., 1993).

In general, the smaller the permeability considered in the model, the smaller the portion of the liquid zone affected by convective flow, leading to a reduction in heat transfer rates. When a low permeability of 1×10^{-15} m^2 with an initial steam saturation of 25% is used, a two-phase liquid-dominated zone develops (Figure 4), which is consistent with field data from several geothermal fields including Olkaria. To investigate the effects of capillary pressure on features of two-phase geothermal reservoirs, Lai et al. (1993) performed a simulation considering a large capillary pressure, with a steam saturation of 25% and a permeability of 1×10^{-15} m^2. The results show that when a large capillary pressure is considered in the model, lower steam saturation is found in the upper two-phase zone, and a wider boiling zone is obtained in the vicinity of the heat source. In addition, the temperatures surrounding the heat source are much lower, because capillary pressure pulls liquid water into a relatively dry and high-temperature zone located above the heat source.

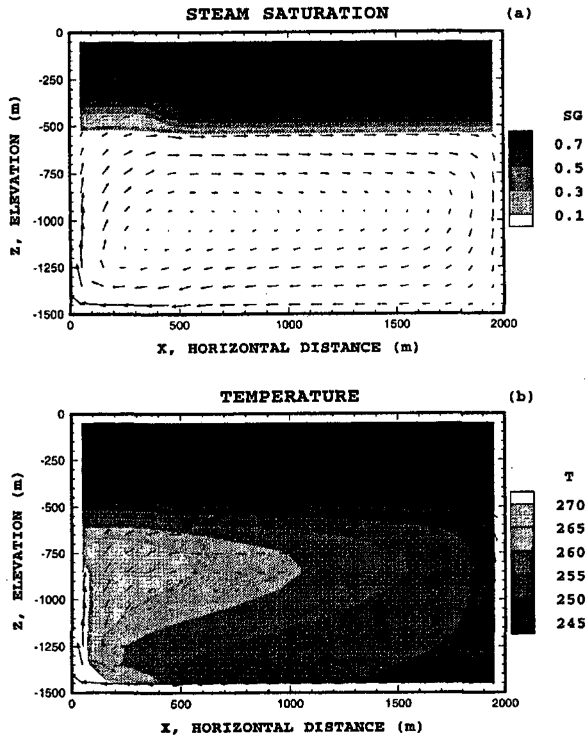

Figure 4. Computed steady-state distribution in the reservoir of (a) steam saturation and (b) temperature. Assumptions: Initial steam saturation 25%; permeability 1×10^{-15} m^2. Arrows indicate mass flux; their length is proportional to flux magnitude (from Lai et al., 1993).

NUMERICAL MODELING OF INJECTION EXPERIMENTS

In an attempt to identify reservoir conditions and processes that could cause the striking patterns of injection interference between wells Q-2 and Q-6 in the Southeast Geysers (Figures 5 and 6), Pruess and Enedy (1993) first developed hypothetical models that may explain such behavior. Subsequently the viability of proposed models was evaluated by means of numerical simulation, and conclusions were drawn for design and monitoring of injection systems.

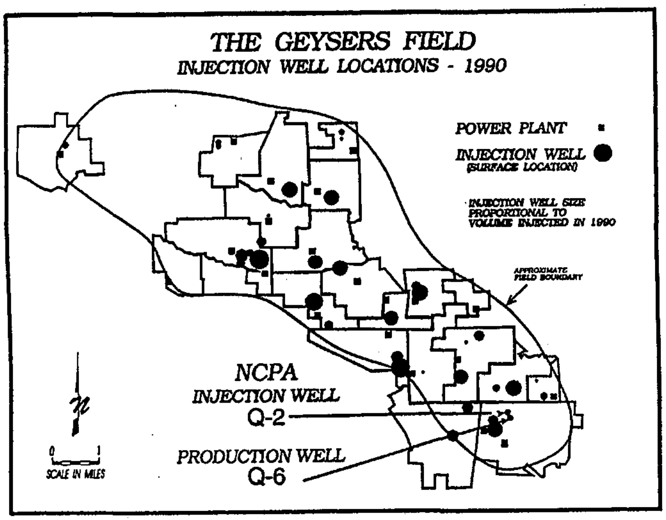

Figure 5. Injection well locations at The Geysers (from Pruess and Enedy, 1993).

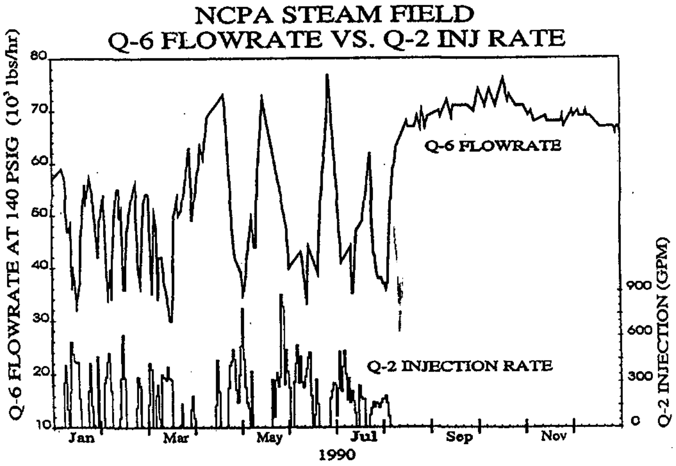

Figure 6. Injection rates into Q-2 and observed production from Q-6 (from Pruess and Enedy, 1993).

Conceptual Model

According to Pruess and Enedy (1993) the strong and fast interference between Q-2 and Q-6 (Figure 6) suggests that both wells intersect some of the same fractures or fracture zones. These fractures would accept much of the fluid injected into Q-2, and provide important paths for flow of reservoir vapor to well Q-6 steam entries. During injection a plume of heating and partially boiling liquid will spread around the injection well. Depending on rates of fluid injection, and heat transfer from the reservoir rocks to the injection plume, two-phase zones with declining temperatures may develop. Because of the one-to-one correspondence between temperatures and pressures in two-phase conditions, fluid pressures in parts of the injection plume and the surrounding reservoir may decline, causing flow rate declines in neighboring wells. In addition, injected liquid in the fractures may partially block the vapor flow paths from the reservoir "at large" to well Q-6 feeds. This interference of injection-derived liquid with vapor flow can be thought of as a relative permeability effect.

After injection is stopped the injected liquid will, in part, boil away, migrate to greater depth, or be sucked by capillary force away from the fractures into the low-permeability rock matrix. Removal of the liquid will clear the fracture flow paths for vapor, causing production to recover. The observed over-recovery indicates that the injected liquid becomes available as a significant additional source of steam, boiling close to Q-6 ("close" in the sense of good hydraulic communication), with excellent access to reservoir heat. Heat transfer to the fluid could occur either by conduction to the fractures, with fluid boiling in the fractures, or injected liquid could be imbibed into the rock matrix, boiling there from local heat exchange.

Based on the foregoing discussion, the most important component in the model will be the fractures that connect Q-2 and Q-6. The fractures will take a portion of the fluid injected into Q-2, and will supply part of the production to Q-6. They will be coupled to matrix rock of small but finite permeability, that will transfer heat to the fluids in the fractures by conduction, while absorbing liquid from the fractures by capillary force. In addition to the specific fractures that connect Q-2 and Q-6, there is a general "background" reservoir that supplies long-term production to the local fracture system, and may also absorb some of the injected fluid.

The available field data do not provide the detailed geometry of the local fracture system on the scale of the distance between Q-2 and Q-6 feeds, of order 300 m. Pruess and Enedy's (1993) approach was to start with the simplest assumptions and flow geometries that would seem capable of explaining the strong and rapid negative production interference during injection, and the (over-recovery) following injection shut-in. The modeling assumptions were then revised and refined to reduce discrepancies between predicted and observed behavior. The most "stripped down" model would seem to need two essential ingredients: (i) a single fracture intersecting both Q-2 and Q-6, and (ii) a large "background reservoir" connected to this fracture. Even in this most simplified model the flow geometry would be three-dimensional, and fluid and heat flows would need to be considered over a very large range of thermo-hydrologic parameters and spatial scales. Indeed, permeabilities range from microdarcies in the rock matrix to perhaps tens or hundreds of darcies in the fractures. Relevant spatial scales for the important flow processes are of the order of centimeters for flow in the fractures and imbibition into the rock matrix, several decimeters for penetration of heat conduction into wall rock over several days, and hundreds of meters for reservoir perturbation from long-term production. When coupled with the extremely non-linear process complexities of two-phase vaporizing flows, this leads to impractical computational demands, and further simplifications must be made.

Pruess and Enedy (1993) simplified the flow geometry by modeling the fracture and the background reservoir as two separate two-dimensional systems with appropriate coupling, although in reality the local fractures are of course embedded in the reservoir. The background reservoir was modeled as a large radially-symmetric layered (R-Z) system; the fracture as a rectangular vertical (X-Z) section. Although the fracture itself requires only 2-D gridding, consideration of fluid and heat flow between the fracture and the surrounding reservoir rock will still make the system three-dimensional.

Numerical Simulation Approach

A schematic of the fracture-reservoir flow model used is shown in Figure 7. The assumed model parameters are discussed by Pruess and Enedy (1993). These parameters were not specifically selected for the local conditions in the study area; rather, they were intended to be generically applicable to The Geysers reservoir. Generally speaking, hydrologic parameters needed for two-phase flow modeling are not well known for Geysers rocks. As in previous studies of vapor-dominated reservoirs (e.g., Pruess and O'Sullivan, 1992), Pruess and Enedy (1993) borrowed data for welded tuffs from nuclear-waste related studies. Welded tuffs have permeabilities in the microdarcy or fraction-of-a-microdarcy range, and are believed to have similar capillary and relative permeability behavior as unfractured graywacke or felsite from The Geysers.

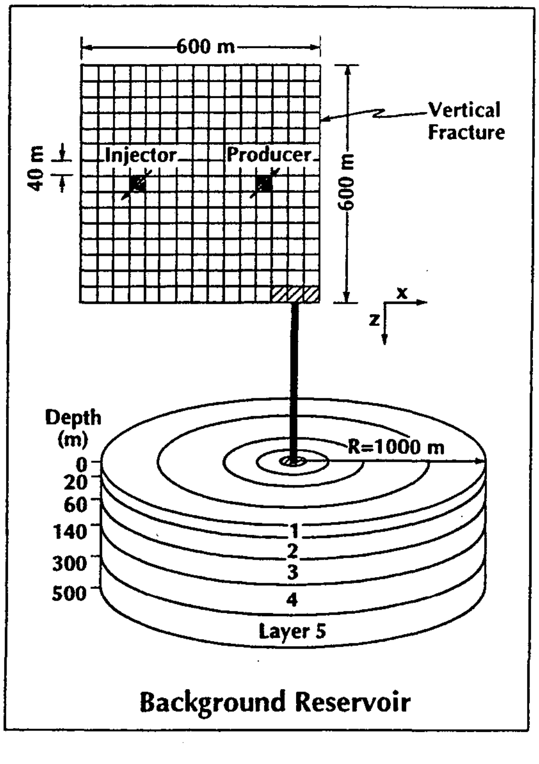

Figure 7. Schematic diagram of fractured reservoir model used in numerical simulations. Injection and production wells are intersected by the same vertical fracture, which is connected to a large background reservoir. Fluid and heat flow perpendicular to the fracture plane is also taken into account (from Pruess and Enedy, 1993).

Vertical fractures of different total area were modeled, from 300 x 300 m^2 to 600 x 600 m^2. The fracture was modeled as a high-permeability porous medium with a small effective void space thickness of 1 cm, and a permeability-thickness product of 40 Darcy-meter. Relative permeability and capillary pressure behavior of fractures is not well known. Recent theoretical and experimental studies by Pruess and Tsang (1990) and Persoff et al. (1991) have suggested that two-phase flow behavior of fractures may be similar to that of three-dimensional porous media of high permeability. It was assumed that fracture capillary pressures are negligibly small, and that relative permeabilities may be represented by standard Corey-curves.

In the model the distance between injection and production wells is 240 m. The background reservoir was modeled as a layered porous cylinder of 500 m height and 1,000 m radius. It was conceptualized as a dual-permeability fractured porous medium with average porosity of 4% and a total permeability-thickness product of 21.6 Darcy-meter. Dual permeability behavior was modeled with an "effective porous medium" description. Chiefly, this consists of an effective relative permeability with a very high (80%) irreducible liquid saturation (Pruess and Narasimhan, 1982). The "background reservoir" serves as a means to provide stabilized long-term flow to the local fractures; simulated injection interference is not sensitive to detailed specifications of the background reservoir.

As a starting point for simulating "natural" pre-exploitation conditions, the entire flow system was initialized with a temperature of 240°C and a corresponding saturated vapor pressure of 33.44 bars. Initial water saturation is 80% in the background reservoir and 0% in the fracture. Boundary conditions in the background reservoir were held constant to initial conditions at the cylinder mantle (R = 1000 m). Top and bottom boundaries were modeled as semi-infinite (thermally) conductive half-spaces. Lateral boundaries in the fracture were "no flow"; perpendicular to the fracture plane different boundary conditions were explored, including semi-infinite conductive half-spaces, and permeable matrix rock. The latter requires a fully three-dimensional fracture-matrix grid, while conductive boundary conditions can be efficiently modeled with a semi-analytical technique.

The production well representing Q-6 was placed on deliverability. Prior to startup of injection an extended production period of 5 years was modeled, to simulate appropriate reservoir depletion in the area of the NCPA injection experiments. Subsequently water injection was started into the fracture at a distance of 240 m from the production well, and at the same elevation. Water at a temperature of 20°C was injected at rates from 12 to 25 kg/s for periods of from 1 to 3 days. During injection the production well continued to operate at the same deliverability conditions as before, with interference effects manifest in changing flow rates and enthalpies. The simulation was continued past the termination of injection to investigate recovery behavior. Pruess and Enedy (1993) carried out only one single injection cycle; interference effects and constraints from repetition of many cycles have not yet been explored.

All calculations were done using LBL's general-purpose reservoir simulator TOUGH2 (Pruess, 1991). This code incorporates the general "MULKOM" architecture for multiphase fluid and heat flow (Pruess, 1983), and includes special provisions for modeling geothermal flows in fractured-porous media.

Results of Recent Numerical Studies

(1) The Pruess and Enedy (1993) numerical simulation studies predicted strong interference between injection into and production from the same fracture. During injection production rates mostly declined, with over-recovery observed after injection was stopped. The simulated behavior is similar to field observations in the Q-2/Q-6 experiments, lending credence to the underlying conceptual and numerical model.

(2) The most significant reservoir processes during injection include gravity-driven downward migration of injected water, local heat exchange with reservoir rock swept by the injection plume, conductive heat transfer from rocks of very low permeability to the injection plume, capillary-driven imbibition of injected liquid into the matrix rock, away from the fractures, vapor condensation in the cooler portions of the plume, and boiling in the hotter portions (Figures 8–10).

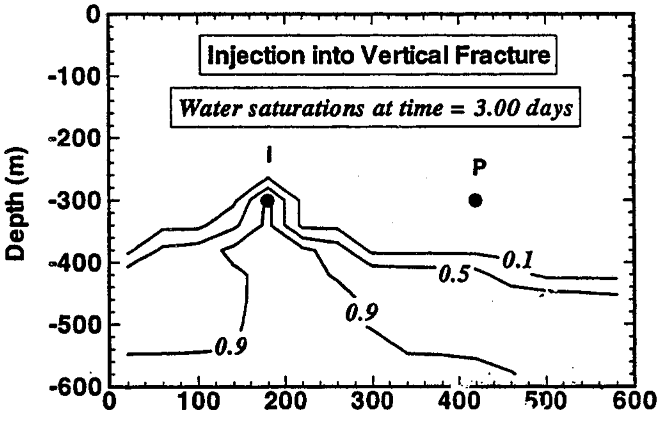

Figure 8. Water saturations in the fracture after 3.0 days of injection, case with permeable fracture wall (I-injector, P-producer; from Pruess and Enedy, 1993).

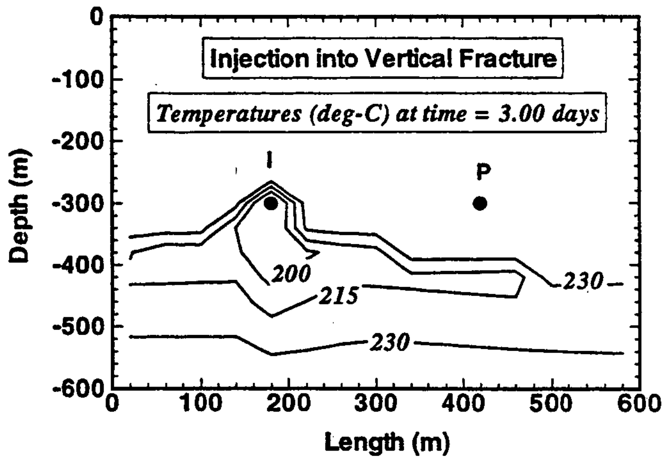

Figure 9. Temperatures in the fracture after 3.0 days of injection, case with permeable fracture wall (I-injector, P-producer; from Pruess and Enedy, 1993).

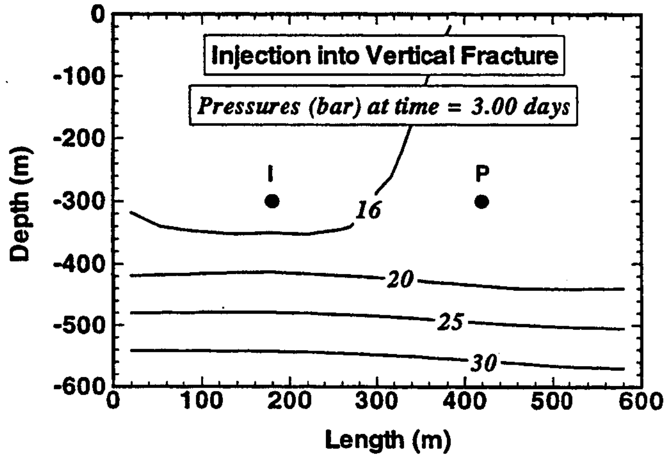

Figure 10. Fluid pressures in the fracture after 3.0 days of injection, case with permeable fracture wall (I-injector, P-producer; from Pruess and Enedy, 1993).

(3) The simulated production declines were stronger than seen in the field. This can be explained by noting that in Pruess and Enedy's (1993) model all injected water entered one single fracture, and all production came from that same fracture, whereas in the field several fractures will participate in taking up injectate, and delivering fluid and heat to the production well.

(4) The simulations clearly demonstrated that injection is subject to heat transfer limitations. Production rate decline from injection is caused primarily by temperature decline in the injection plume and associated drop in vapor pressure. Cool portions of injection plumes act as low-pressure sinks that can consume large amounts of vapor by condensation. Temperature decline depends on injection rate and on the heat transfer capacity of the reservoir, which is a function of available heat exchange volume, heat transfer area, and permeability for vapor flow.

(5) Based on the foregoing, Pruess and Enedy (1993) expected that each injection well has a limitation on the rate at which water can be injected without causing significant reservoir pressure decline, and consequently negative interference with neighboring producers. They concluded that acceptable limits for injection rates may be difficult to predict, as these depend on geometric properties of the local fracture system that usually are poorly known. However, in practice such limitations could be established empirically by monitoring neighboring production wells.

(6) Pruess and Enedy (1993) indicated that injection should not be concentrated into a few wells that would take up large rates. Because of heat transfer limitations, injection wells should generally be operated at moderate rates well below their capacity for accepting fluids (Enedy et al., 1991).

NEW SIMULATION METHODOLOGY FOR FRACTURED GEOTHERMAL RESERVOIRS

Although the majority of geothermal reservoirs reside in fractured rocks, most models developed to analyze their behavior have been based on porous medium approximations. In these models, the hydraulic behavior of the fractures and the matrix blocks are represented together as a locally-homogeneous porous medium. It is well-known, however, that porous medium models are poorly suited for predicting certain aspects of the behavior of geothermal wells, especially enthalpy transients, thermal front migration due to injection, and chemical tracer movement. Nevertheless, in many cases the porous medium approximation must be invoked, due to constraints of computer time or cost. There is, consequently, a great need for improved numerical capabilities for the modeling of fractured geothermal reservoirs, using accurate and appropriate models. Zimmerman et al. (1993) developed a new type of dual-porosity model to simulate two-phase flow processes in fractured geothermal reservoirs. The main concept behind their approach was to analyze the heat and mass flow processes occurring within the matrix blocks—processes generally governed by diffusion-type partial differential equations—by simplified equations that made a detailed discretization of individual matrix blocks unnecessary. The diffusive processes were modeled using nonlinear ordinary differential equations that relate the average thermodynamic properties in the block to those in the fractures.

The first stage of this work, dealing with isothermal flow of a single-phase fluid, was described in Zimmerman et al. (1992). Since then the general approach has been extended to treat thermal conduction within the matrix blocks. This extension is straightforward, as shown by Pruess and Wu (1993), since the governing equation for conduction is exactly analogous to that for single-phase flow. A further expansion of this approach to processes involving two-phase conditions in which the liquid phase is immobile, is described in Zimmerman et al. (1993). The newly developed semi-analytical dual-porosity model was implemented as a modification to the TOUGH2 simulator (Pruess, 1991).

Results of Recent Numerical Studies

To test the accuracy and computational efficiency of the modifications made to TOUGH2, Zimmerman et al. (1993) simulated various problems using essentially the computational grid and reservoir properties proposed by Spivak (1991) to test geothermal codes. This is a three-dimensional model of a vapor-dominated geothermal reservoir with properties considered appropriate for The Geysers. This hypothetical reservoir (see Figure 11) is 1524 m thick; the cross-sectional shape in any horizontal plane is a rectangle with sides of 914.4 m and 609.6 m. Each layer is broken up into 24 gridblocks, each of length 152.4 m in the two horizontal directions. The thicknesses of the five layers are as shown in Figure 11.

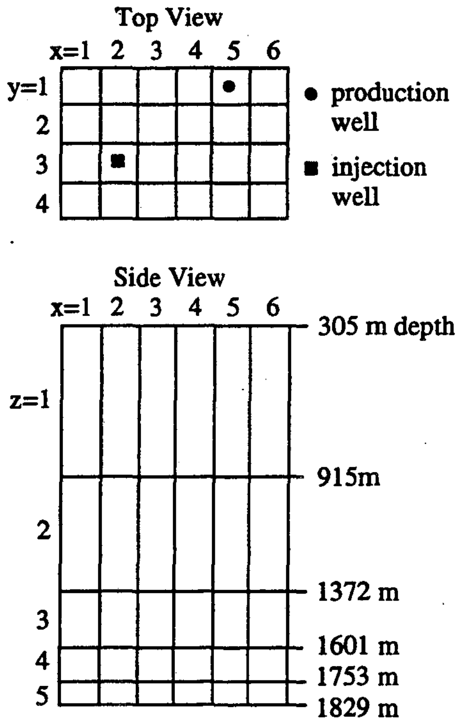

Figure 11. Schematic diagram of the grid used in simulations of a hypothetical geothermal reservoir. Dimensions of the gridblocks, and the physical properties of the fractures and the matrix blocks, are listed in the text (from Zimmerman et al., 1993).

A production well (Well #1) and an injection well (Well #2) are located in gridblocks xyz = 511 and xyz = 231 (see Figure 11), and are completed only in the topmost layer of the reservoir. The matrix blocks are cubes of 67 m on each side, with matrix permeability $k_m = 1 \times 10^{-19}$ m^2, matrix porosity $\phi_m = 0.04$. (A somewhat low matrix permeability is used so as to avoid having the liquid saturation rise above its irreducible value near the injection well). The rock has density $\rho_r = 2648$ kg/m^3, and heat capacity $C_r = 1000$ J/kg-K. The fracture network has an overall porosity $\phi_f = 0.01$, and permeability $k_f = 2.0 \times 10^{-14}$ m^2. The relative permeabilities of both the fracture network and matrix blocks are taken to be linear functions of saturation, with the irreducible saturations for the liquid phase, and for the vapor phase in the matrix blocks, set to zero. The irreducible saturation for the liquid in the matrix blocks is 0.25. Capillary pressure and thermal conductivity effects are neglected in both the fractures and matrix blocks. The initial conditions are that the liquid saturation in the matrix blocks is at its irreducible value of 0.25, and the pressure in the uppermost layer is 3.45 MPa. The initial temperature in the uppermost layer is therefore equal to the saturation temperature at this pressure, which is 242°C.

All outer boundaries of the reservoir are impermeable to fluid flow, and the lateral boundaries are also closed to heat conduction. A heat flux of 0.5 W/m^2 is conducted vertically upwards through the reservoir. The remaining initial conditions, such as the pressures in the lower layers and the saturations in the fractures, were found by running a simulation to steady state, with no injection or production from the wells. In the sample problem whose results are shown in Figures 12–14. Well #1 produces 5 kg/s of fluid, and Well #2 injects 5 kg/s of liquid water at 95°C.

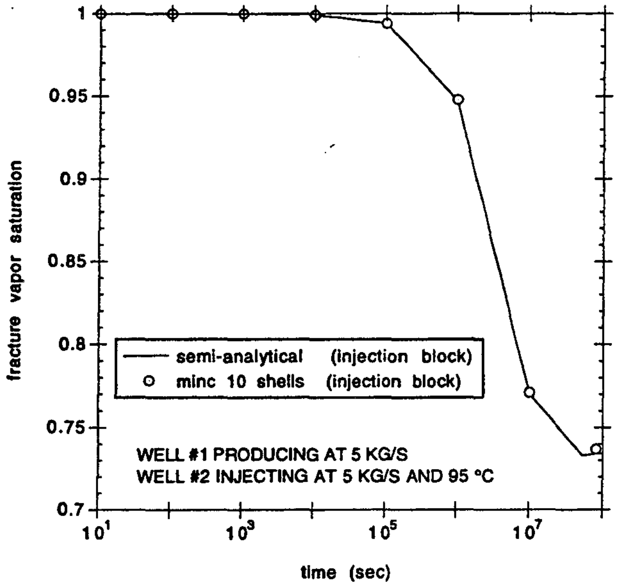

Figure 12. Vapor saturation in the fractures of gridblock 231, for the problem described in the text (from Zimmerman et al., 1993)

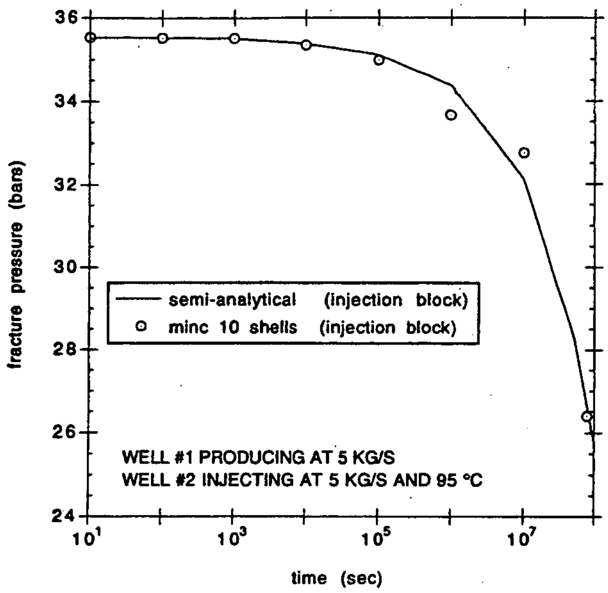

Figure 13. Pressure in the fractures of gridblock 231, for the problem described in the text (from Zimmerman et al., 1993)

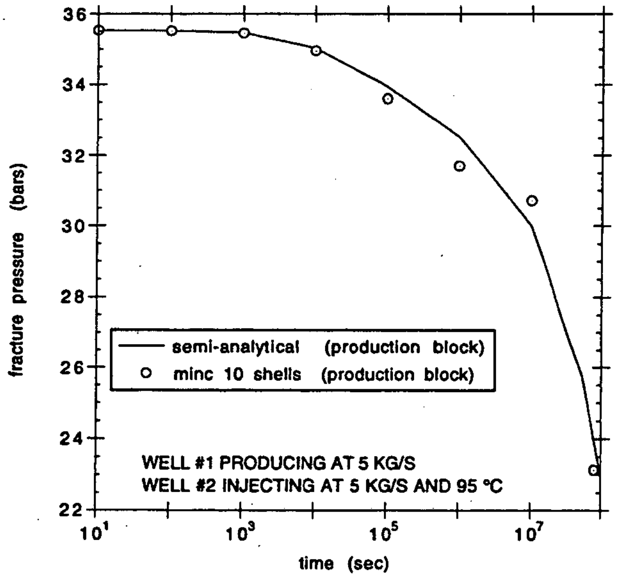

Figure 14. Pressure in the fractures of gridblock 511, for the problem described in the text (from Zimmerman et al., 1993)

The computed vapor saturations and pressures for the fractures in gridblock 231 are shown in Figures 12 and 13, respectively. The solid lines denote the values obtained using TOUGH2 with the modifications described above, whereas the open circles denote values computed with TOUGH2 using the MINC method (Pruess and Narasimhan, 1992) to discretize each equivalent matrix block into ten concentric gridblocks. The fracture pressure in gridblock 511 is shown in Figure 14. The vapor saturation in the fractures in gridblock 511 remains very close to 100% through both simulations, and is not shown. The predictions of the new method are in all cases very close to those of the MINC simulations. Due to the relatively complex geometry of this problem, and the physical nonlinearities arising from phase-changes, etc., no analytical solution is available for comparison.

Comments

At this time, the model developed by Zimmerman et al. (1993) is limited by the assumption that the liquid phase in the matrix blocks remains immobile. By utilizing the effective compressibility concept developed for water/steam mixtures in porous rocks (Grant and Sorey, 1979), flow within the matrix blocks can be modeled by a single diffusion equation. This equation is in turn replaced by a nonlinear ordinary differential equation that utilizes the mean pressure and mean saturation in the matrix blocks to find the rate of fluid flow between the matrix blocks and fractures. This equation has been incorporated into the numerical simulator TOUGH2, as a source/sink term for computational gridblocks that represent the fracture system. The accuracy of this new method has been tested by simulating a three-dimensional reservoir containing partially-penetrating injection and production wells, and comparing the results to simulations in which the matrix blocks are each discretized into ten concentric shells.

FINAL REMARKS

Lawrence Berkeley Laboratory continues to work in close cooperation with the US geothermal industry. Since FY-1991 about half of LBL's research has been devoted to understanding the behavior of The Geysers field and other vapor-dominated geothermal systems. Because of this emphasis and a recent decrease in funding levels, the study of other US fields, as well as basic research work at LBL has been adversely affected.

In light of the possibility of future increases in DOE's geothermal budget, LBL organized and hosted the March 16th, 1993 meeting of the LBL Industry Review Panel on Geothermal Reservoir Technology. The purpose of the meeting was to get input on how DOE's Geothermal Reservoir Technology Program can be tailored to respond to the short- and long-term needs of the US geothermal industry. Thirty-six industry representatives (field and power plant operators, and consultants) attended; a summary of the meeting and the recommendations made were discussed during this Review by the chairman of the Panel, Dick Benoit of Oxbow Power Services, Inc. In light of these recommendations it appears that LBL's geothermal activities continue to be well focused on industry's top research priorities (i.e., case studies, injection, instrumentation, well testing, reservoir modeling, field exploration and evaluation).

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