RAPPORTEURS' REPORTS

SESSION 1 - RESERVOIR PHYSICS - Paul A. Witherspoon

Session I on Reservoir Physics included nine papers covering a wide variety of topics. Kassoy summarized the research activities currently underway at the University of Colorado, where attempts are being made to characterize and model the various processes that occur in geothermal systems. The importance of faults in controlling the convective motion within geothermal systems is being examined from a number of standpoints, and the effect of a realistic variation in viscosity on convection in porous bodies has revealed that the convective motion is unlike the symmetric classical profiles that result from a fluid of constant viscosity. A considerable effort is being made to develop a better understanding of the East Mesa geothermal system in the Imperial Valley.

Brigham reviewed the laboratory investigations currently underway at Stanford University to develop a fundamental understanding of non-isothermal boiling two-phase flow in porous media. One of the critical problems is how the normally immobile liquid saturations vaporize with pressure reduction under non-isothermal conditions. Recent work on the effect of temperature on relative permeability suggested that absolute permeability was also a temperature dependent property of rocks. Laboratory measurements have revealed that the temperature effect on permeability depends on the nature of the saturating fluid, whereas the effect of confining pressure on permeability seems to be independent of the nature of the saturating fluid. The objective of this work has been to simultaneously measure the effect of thermal and mechanical stresses on permeability. Brigham also summarized the advances that have been made in several directions in modeling geothermal fluid production.

Manetti summarized some recent work that has been carried out in Italy to correlate the kh distribution with geological structure at Larderello. Data from about 50 wells in different parts of Larderello were analyzed by back-pressure and pressure build-up methods. Good agreement between the kh values for any given well was only possible when the skin-effect was taken into account. A correlation of these results shows a good correspondence between areas of high transmissivity and the various structural highs within the Larderello field. The permeability is believed to reach its maximum values along the crests because tectonic activity has resulted in a maximum of fracturing and fissuring at such locations.

Martin presented a review of an analysis that he has made on internal steam drive in geothermal reservoirs that are produced by pressure depletion with no water injection. He compares the pressure-temperature behavior of geothermal systems and shows how they differ depending on the initial conditions. He concludes that under certain conditions only a relatively small amount of the heat initially contained in a geothermal reservoir will be produced during pressure depletion. Where gravity segregation of the steam and hot water occurs during depletion, more of the total heat can be produced by completing wells high in the reservoir to enhance steam production and suppress water production.

Bodvarsson reviewed the analysis that he has been making of the "macro-permeability" that prevails in igneous rocks because of fracture conditions. From an analytical expression for flow to a horizontal fracture intersecting a borehole, he has analyzed the flow conditions that exist in fractured reservoirs. This approach has been used in Iceland to develop methods for testing wells, estimating reservoir permeability, and evaluating the results of well stimulation. Bodvarsson also discussed how the isotope chemistry of groundwaters in Iceland has been used to locate areas of recharge.

Natnenson summarized investigations that he has made to estimate the fraction of stored energy in hydrothermal convection systems that is recoverable. He has analyzed two possible methods for extracting energy: (a) boiling the water in the system to produce steam and (b) natural and artificial recharge of cold water to recover reservoir heat by a sweep process. It appears that the restricted range of porosity, temperature, and recharge over which the boiling method will work limits its application to rather special cases such as vapor-dominated systems. The fraction of stored energy that may be recovered is critically dependent on the average liquid saturation. In using recharging cold water to drive hot water to producing wells, conduction can be analyzed to a first approximation by superposition onto the movement of the temperature front. Another factor is the rotation of the initially vertical interface between cold and hot water. These processes can be combined qualitatively to yield an estimate of energy recovery.

Meidav presented a review of a method of using gravimetric data to estimate hydrothermal reservoir characteristics at the East Mesa geothermal field in California. Six positive gravity anomalies are associated with abnormally high temperature gradients in the Imperial Valley, and one of these anomalies is at East Mesa. The explanation for these observed effects is densification of the shallow sediments by deposition of temperature-sensitive minerals in the upward rising plume of geothermal waters. An excess mass of about 10 billion tons of matter is believed to have been deposited at East Mesa which would have required an upwelling of an estimated 2.5 trillion tons of thermal water. Assuming a period of 50,000 years was required leads to the conclusion that the vertical permeability ranges from 0.6 to 60 millidarcies. Although surficial evidence of geothermal activity is absent at East Mesa, this analysis sheds light on the very large underground movements of thermal waters that are possible when hydrogeological conditions do not favor outflow to the surface.

Tsang summarized an analysis he has recently made on screening geothermal production wells from the effects of reinjection. In the normal method of reinjecting cold water into a geothermal reservoir, breakthrough eventually occurs depending on several factors. In the simplest case of a doublet, one production and one injection well, this breakthrough time can be lengthened considerably by placing a screening well between the two wells so as to intercept the shortest stream line. By producing water from the screening well, not only can breakthrough be delayed, but a significant increase in energy recovery can also be achieved. A detailed economic feasibility study of the effects of screening has not yet been made.

Garg reviewed the work that he and his colleagues are carrying out in an effort to mathematically model land surface subsidence associated with geothermal energy production. This is potentially a serious problem, particularly for liquid-dominated geothermal systems. The theoretical model, developed within the framework of the Theory of Interacting Continua, describes the thermomechanical response of the rock and fluid composite material in terms of the isolated components. The stress-strain equations for the rock matrix are coupled with the diffusion equations for the fluid. The microscale details of the pore/fracture network in the rock are ignored, but the fluid pressures and the stress field in the rock matrix are permitted to assume distinct values within each computational region for the composite. Although most of the required material properties can be obtained from standard laboratory tests on cores, it should be noted that the reservoir behavior is frequently governed by fractures, formation inhomogeneities, and other large scale features such as faults. It, therefore, becomes important to supplement the laboratory measurements by suitable field data. An example of some preliminary results in modeling a hypothetical subsidence problem was presented.

SESSION 11 - WELL TESTING - Henry J. Ramey, Jr.

Data from nine different field tests were presented. This one fact sets this session apart from all previous meetings or workshops. The field cases considered ranged from vapor to liquid-dominated reservoirs, and liquid-dominated systems ranged from low to high salinity systems. The types of well tests included pressure buildup and drawdown, and interference testing. As a result, it appears the state of development and application of the technology is good. Application of existing petroleum engineering and groundwater hydrology theories were shown to reveal the need for new solutions, however. Problems identified include:

1. New solutions for transient well testing (both interference and individual well tests) in hot aquifers which contain a carbon dioxide gas cap. The solutions should consider either production of hot water from downstructure wells, and production of carbon dioxide from upstructure or gas-cap wells. What properties are detected in such tests?

2. New solutions are needed for partially-penetrating wells in a tall steam column supported by boiling of a deep liquid interface. All types of tests should be evaluated.

3. Studies should be aimed at the results of flashing in the reservoir rock and resulting non-condensable gas evolution.

Another finding was that there hasn't been much supported research in the area of well test analysis. Work to date has involved mostly a retreading of existing information. Some work has been underway as a joint project by ENEL of Italy and personnel of the Stanford Geothermal Program.

During the presentations, a plea for field data was made and several participants responded (Roger Stoker of the Raft River Project, and Alain Gringarten concerning data from the Afars and Issas Territory).

Significant findings were made as a result of the presentation of much field data. It is clear that geothermal reservoirs are fully responsive *to* all pertinent laws of physics. A careful study of field performance results will often indicate important factors which should be included in computer simulation models. Field data presented at the workshop indicated: (1) there are well testing equipment needs, and (2) there were important recent findings as a result of application of new instruments. One need for new equipment concerned running pressure recorders into very high velocity steam wells while producing. There is a need for pressure and temperature recorders which can withstand both high vibration and high temperatures. Fluid production rates on the order of one million pounds per hour were cited in several cases!

Very interesting earth tide effects were cited as measured with high-precision quartz crystal pressure recorders in the Raft River project. Pressures were measured to 0.001 psi. This high precision represents a major step forward. However, the device is limited to upper temperatures in the range of 300°F to 350°F. The Hewlett-Packard system was used in the Raft River project. However, the Sperry-Sun stainless capillary tube system has been used a few times, and it appears that a combination of the capillary tube with a quartz detector in an insulated chamber at the surface might have immediate use in some geothermal wells.

Finally, several important observations from the Geysers Field were made. Burmah ha5 observed water entry below a steam entry in two separate wells. Water samples were obtained, and it appears that the first significant information on the deep liquid interface postulated by Ramey, Bruce, and White may have been obtained. Another important observation was reported from the current Shell well drilling at the Geysers. Hydrogen sulfide concentrations as high as 3000 ppm were observed. This part of the well was plugged and the well sidetracked. Both the Burmah and Shell wells are in the eastern portion of the Geysers Field.

Throughout the discussions *of* various field well tests, it became obvious that most reporters considered presence of fractures common to geothermal reservoirs. As a result it appears that a "holistic" approach via well testing was usually necessary. Most field tests were characterized by a dearth of conventional electric log and core data. Well test analysis is an important technology that has largely been neglected to date. Because of the potential importance of this technology, one major finding of the workshop was identification of the need for more work in this area.

SESSION 111 - FIELD DEVELOPMENT - G. A. Frye

The authors present a maturing approach to field development., As mentioned in the opening session, the birth of geothermal reservoir engineering is accomplished and this session reflects early childhood development. Many authors express a cautious optimism about geothermal energy potential. Considerations about optimal energy extraction rather than concerns about economical production reflect this optimism. Several times the authors express the need for engineering design data and improved correlations from geophysics and well testing. Even though the geothermal energy field is relatively young in the United States, comments such as "I would have done it differently if I had to do it over again," indicate development of geothermal reservoir engineering.

Specifically the discussion sessions after the presentations reflected the needed development of high temperature, high resolution tools for greater confidence and shorter observation periods. Reinjection will be extremely dependent on anisotropic features of the reservoir found by these tools. Hinrichs discussed Magma's efforts in Imperial County to obtain data for establishing optimum production and injection techniques. He then introduced Mr. James Nugent of San Diego Gas and Electric Company (SDG&E) who presented the efforts of SDGEE and now along with ERDA on the geothermal test facility associated with the Magma wells. In some cases the geophysical analyses of economic fields can be expanded to new prospects. Wooding, while recommending this approach, cautioned that the same geophysics don't necessarily yield the same well test. More correlation between well test data and the geophysical data are required. Gould presented the task TRW Systems and the Bureau of Reclamation has assigned to Intercomp. The initial phase of this assigment involves analysis of current geophysical data in consideration of five wells on East Mesa operated by the Bureau of Reclamation. Later phases of this study concern reserves, field development and injection. Intercomp is also working with Republic Geothermal on the north end of East Mesa.

Another thrust of the discussion expressed concern about the length of time and initial capital investment that characterize electrical power production from geothermal energy. While not specifically field development, Woitke discussed PG&E's relationship with steam developers. The schedule for The Geysers development is typical of Burmah's experience. Also presented were two items now causing some concern or delay in field development at The Geysers. The first was a status report on H_2S abatement. Since this presentation, PGEE has made additional commitments to abate existing plants before development is expanded. The second item expressed an investor-owned utility's concern about certain Federal leasing regulations. Unless these concerns are resolved in a timely manner, power plant construction may be delayed. Comments such as the need to optimize the cost per kilowatt-hour and not maximize total energy recovery reflect this concern. Kuwada cautioned in his presentation that some optimal field development for energy may not minimize production problems. Specifically there is an early requirement that the effects of dissolved gases and solids be considered. Scherer's approach to optimal rate of energy extraction appears to apply not only to geothermal developers, but also to governmental agencies as a planning guide.

Also expressed was the need for valid data for economic models and reservoir stimulators. Dorfman expressed the need for modeling of geopressured prospects to know how to best produce geopressured fluids. However, he pointed out there is limited published data on flow characteristics of these fluids for model validation. Some sensitivity analysis and examination of methodology is required to obtain assured forecasts from reservoir stimulators. Knutsen of BPNL presented Bloomster's paper. Preliminary results indicated the most important variables that determine the cost of geothermal energy.

SESSION IV - WELL STIMULATION - Manuel Nathenson

The stimulation of geothermal reservoirs involves techniques for artificially creating higher permeability in the region near a well over a distance of a few centimetres to an order of 10^3 m. Current geothermal practice involves hydraulic pumping to reopen producing horizons clogged during drilling, to remove vein deposits, and to fracture to a minor extent the region very near to the well (Tómasson and Thorsteinsson, 1975). Current research concerns massive hydraulic fractures and the creation of rubble chimneys and enhanced permeability zones using explosives. Articles in the volume edited by Kruger and Otte (1973) give an overview of several types of stimulation proposals. The two major questions to be answered about the schemes are: will they work in the idealized world of the computer or laboratory model and will they work in the field? Because *of* the expense of field experiments and the difficulty of obtaining enough data to interpret field experiments, physical and mathematical models are important tools for research.

Several papers were given on hydraulic fractures and the extraction of energy from hot rock using water injected into flat cracks. Abé, Mura and Keer (this volume) discuss the problem of how to solve the equations for the shape of a crack under stress and pressure gradients along the crack. They plan to build up a solution by using dislocation theory. The equations for the coupled fluid-and solid-mechanical problem of crack growth were presented and various approximations introduced that will allow the problem to be solved. Secor and Pollard (1975) have solved for the shape of a crack under the influence of a hydrostatic gradient in the crack and a constant gradient of lithostatic pressure far from the crack by superimposing a number of plane strain elasticity solutions. They apply this solution to discuss at what length the crack becomes unstable as a function of fracture toughness and the difference in gradient between lithostatic stress and hydrostatic pressure.

Pollard (1975) has also investigdted the influence of the ground surface on crack shape and stability and the deformation of the ground surface during subsurface cracking. Dundurs (this volume) is modeling fractures by drilling fine holes into a block of epoxy resin, cementing tubes into the holes and supplying mercury under pressure to form hydraulic fractures. One of the experiments was for a crack propagating parallel to an existing pressurized crack at a distance less than the size of the first crack. The second crack turned and joined the first crack. The joint was on the side (not tip) of the first crack and was of a very small size. Further pressurization of the second crack enlarged the first crack but the second crack did not expand. Byerlee, Lockner, and Weeks (1975) have studied hydraulic fractures in sandstone at confining pressures to 1000 bars and differential stresses to 4000 bars. At high injection rates, hydraulic tension fractures were formed, but at low injection rates, shear fractures were formed.

Murphy (this volume) is analyzing the heat transfer to a circular crack whose fracture gap width varies across the crack for the limiting case of no mechanism for porosity generation, so that heat is transferred to the crack only by conduction. The crack is assumed open so that the formula for flow resistance in a thin channel can be used and the conduction problem is solved to provide a kernel for the solution of the fluid flow equation (including buoyancy) and energy equation in the crack. McFarland (1975) has solved several problems for heat transfer and fluid flow including buoyancy in a crack. The flow in circular cracks of elliptical cross section is solved for cases in which the crack is either partly filled with porous material or is open. The crack may contract or retain its shape. Bažant, Nemat-Nasser, and Ohtsubo (this volume) are using finite element methods to solve for the initiation and extension of fractures in hot dry rock and for the circulation of water and heat transfer in the fractured zone. In an example, they compare analytical and numerical solutions for the temperature distribution for water flowing in a stream tube and gaining heat by conduction from the surrounding rocks.

The progress of field studies to develop the extraction of energy using hydraulic fractures has been recently described by Smith, Aamodt, Potter, and Brown (1975). A well drilled to a depth of 2928 m has a bottom-hole temperature of 197°C. Various fracturing experiments have been performed. For example, with a packer set at 2917 m, a single hydraulic fracture was created at a surface pumping pressure of 120 bars with a calculated crack radius of 57 m. A second well recently drilled to a depth of 3060 m has a bottom-hole temperature of 203°C (H. D. Murphy, Written Commun., 1976; Aamodt, 1976). These two wells have been connected by what is thought to be a system of hydraulic fractures.

The second stimulation technique discussed at the workshop was the creation of Permeability by explosions. McKee and Hanson (this volume and 1975) propose that the permeability in the fractured zone beyond the cavity should scale as $1/r^5$ for a spherical blast and $1/r^4$ for a cylindrical blast where r is distance from the shot point., Kruger (this volume) and his colleagues are looking at various aspects of heat and mass transfer. relevant to stimulated reservoirs. Hunsbedt, Kruger, and London have built a laboratory model of a rubble chimney to study the processes of in-place boiling, moving flash fronts, and two-phase flow. The initial rock loading has a high porosity and permeability so that pressure gradients needed to drive the flow are small. The system is initially filled with liquid water. As it is produced from the top, either no recharge or recharge of cold or hot water is added from the bottom. Plans are underway to scale these experiments to field-size systems. Kuo, Brigham, and Kruger describe another experiment to measure heat and mass transfer rates from a sphere of porous material in a bath of circulating fluid to check if heat transfer rates are enhanced by mass diffusion. Results indicate that mass transfer by molecular diffusion is such a slow process that heat transfer rates are not affected. Stoker, Kruger, and Umana have been looking at the properties of radon as a diagnostic for reservoir studies. Since the emanating power of a rock material for releasing radon is proportional to the exposed surface area, it may be possible to relate radon measurements to the increase in surface area caused by stimulation. Since field data are not available for stimulated reservoirs, measurements are being made on production from natural systems to develop interpretive techniques.

Barnes and Rimstidt (this volume) are studying equilibriurn chemistry of silica solubility and kinetics of the dominant reactions. Data obtained will be useful for suggesting ways to manipulate wells in order to prevent scale formation during the flow of hot water in wells and pipes. Sammis (this volume) discusses the modeling of chemical reactions in geothermal reservoirs. Natural fluids in hydrothermal convection systems have long aquifer residence times at high temperatures so that they tend to be in chemical equilibrium with their host rocks. The injection of cold water into a natural or stimulated geothermal reservoir will provide a fluid that is not in equilibrium leading to possibilities of deposition, solution, and redeposition depending upon the initial dissolved-solids content of the fluid and its subsequent temperature history. Summers, Winkler, and Byerlee (1975) have found significant permeability reductions in flowing water through granite at high temperatures, and Charles and Valagna (1975) describe alteration products in the flow of water through monzogranite at high temperature. The results of these and further studies must be integrated into models of fluid injection processes in order to assess potential difficulties.

REFERENCES

Aamodt, R. L., 1976, Hydraulic fracturing in and communication between two adjacent wellbores: EOS Trans., *Am.* Geophys. Union, v. 57 (in press).

Byerlee, J., Lockner, D. and Weeks, J., 1975, Tension fractures and shear fractures produced during hydraulic fracture: EOS Trans., Am. Geophys. Union, v. 56, p. 1060.

Charles, R. W. and Balagna, J. P., 1975, Monzo-granite alteration in a hydrothermal system: EOS Trans., *Am.* Geophys. Union, v. 56, p. 913.

Kruger, Paul and Otte, Carel, 1973, Geothermal energy-resources, production, stimulation: Stanford, CA., Stanford Univ. Press, 360 pp.

McFarland, R. D., 1975, Geothermal reservoir models--crack plane model: Los Alamos Sci. Lab. Report LA-5947-MS, 18 pp.

McKee, C. R. and Hanson, M.E., 1975, Explosively created permeability from single charges: Soc. Petroleum Engineers SPE 5414, 7 pp.

Pollard, D. D., 1975, On the interaction between the ground surface and hydraulic fractures: EOS Trans., Am. Geophys. Union, v. 56, p. 1060.

Secor, D. T., Jr. and Pollard, D. D., 1975, On the stability of open hydraulic fractures in the Earth's crust: Geophysical Research Letters, v. 2, No. 11, pp. 510-513.

Smith, M. C., Aamodt, R. L., Potter, R. M., and Brown, D. W., 1975, Man-made geothermal reservoirs: United Nations Symposium on the Development and Use of Geothermal Resources, 2nd, San Francisco, 1975, Proc. (in press).

Summers, R., Winkler, K., and Byerlee, J., 1975, Permeability changes during fluid flow through hot granite: EOS Trans., Am. Geophys. Union, v. 56, 1060.

Tómasson, J. and Thorsteinsson, T., 1975, Use of injection packer for hydrothermal well stimulation in Iceland [abs.]: U.N. Symp. on Development and Use of Geothermal Resources, 2nd., San Francisco, abs. no. VI-45.

SESSION V - MODELLING - James W. Mercer

The goal of this report is to summarize the present status of: geothermal reservoir modelling, and to indicate the future goals of geothermal modelling research. The geothermal modelling effort presented at this workshop is categorized in Fig. 1. The major subdivisions are modelling of natural geothermal systems and modelling of producing geothermal systems. These two subdivisions were chosen because, in general, they emphasize two different viewpoints. Modelling of natural geothermal systems is usually done in the vertical cross-section and emphasis is placed on examining free convection in order to gain insight into the natural (pre-exploitation) behavior and formation of geothermal reservoirs. Modelling of producing geothermal systems is usually done in the areal plane. This approach emphasizes simulating exploitation effects in order to reproduce observed field conditions, and hopefully predict future field conditions. Modelling associated with production can be subdivided further as shown in Fig. 1. These divisions will be discussed later.

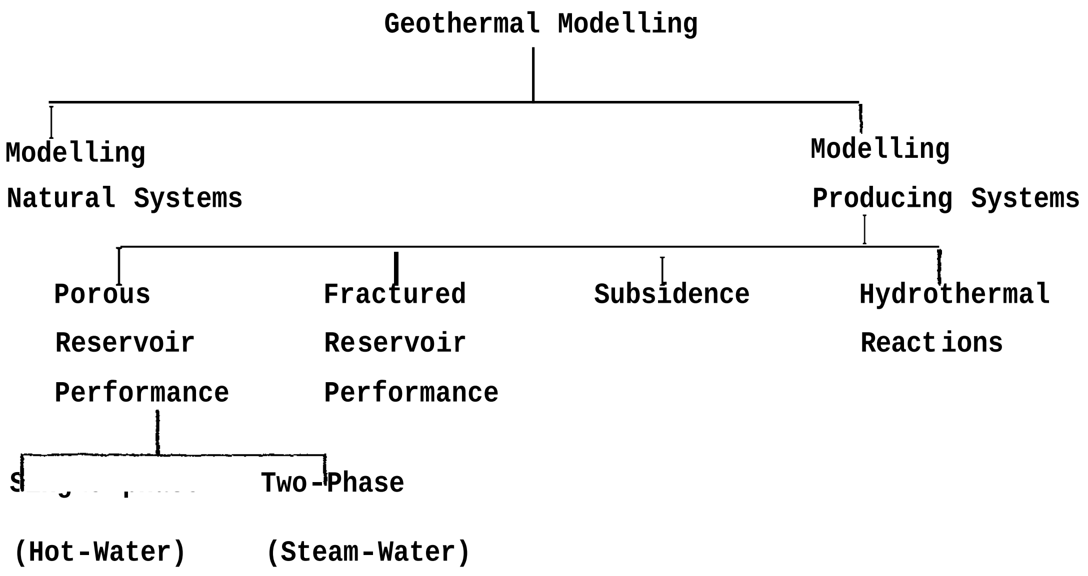

Figure 1.--Status of Geothermal Modelling.

Researchers involved with the modelling of natural geothermal systems include (in the order of their presentations): R. A. Wooding, H. W. Shen, P. Cheng and M. Sorey. Dr. Wooding considers analytical and finite-difference techniques applied to free convection. For reasons of economics, he generally restricts his models to two dimensions. To examine the three-dimensional aspects of the problem, he is collaborating with Dr. Shen, who is using physical modelling (Hele-Shaw cell models) to examine free convection. The physical models developed by Dr. Shen are also being used to verify the numerical models. Dr. Cheng uses finite-difference techniques to examine the free convection associated with volcanic islands, such as the Hawaiian Islands. He has also developed analytical solutions for free convection caused by various types of magmatic intrusions. Dr. Sorey examines the heat and mass transfer associated with various hot spring geometries. He uses a numerical method based on an integrated finite-difference scheme.

It is interesting to note that all of the above models consider single-phase (hot-water) flow. A logical extension of this work would be to include the vapor phase. Such a two-phase, cross-sectional model could aid in testing the various hypotheses concerning vapor-dominated geothermal systems. Although such a model was not presented at this workshop, Dr. T. Lasseter (who was invited to the workshop but could not attend) has considered this problem using a model based on integrated finite-difference techniques.

Researchers involved with the modelling of producing geothermal systems include (in the order of their presentations): C. R. Faust, J. W. Mercer, G. F. Pinder, W. G. Gray, J. W. Pritchett, Z. P. Bafant, S. Nemat-Nasser, H. Ohtsubo, C. G. Sammis, A. Barelli, R. Celati, G. Manetti, G. Neri, S. Bories, and T. Maini. Drs. Faust and Mercer have developed finite-element and finite-difference models for simulating production of geothermal reservoirs. These models can treat single- and two-phase (steam-water) flow, and are capable of simulating the conversion of a compressed-water region to a two-phase region. Drs. Pinder and Gray have concentrated on theoretical equation development and computer code implementation (using finite-element techniques) for multiphase flow (steam-water), subsidence, and flow in fracture media. Dr. Pritchett has developed a finite-difference model for multiphase flow and heat transport. It is proposed that this model be coupled with a consolidation model developed by S. K. Garg in order to simulate subsidence and induced seismic activity. Drs. Bafant, Nemat-Nasser and Ohtsubo use finite-element techniques to examine the formation of fractures (both hydraulically and thermally induced) and the subsequent flow of water in the fractures. Dr. Sammis examines rock-water interactions using finite-difference and experimental techniques. He considers dissolution and precipitation reaction and alteration reaction effects on: (1) reaction heat (chemical energy), (2) changes in permeability and porosity, and (3) changes in the thermodynamic properties of water. Drs. Barelli, Celati, Manetti and Neri examine analytically the pressure history of a partial penetrating well in a hot-water reservoir. Dr. Bories is attempting to determine experimentally the heat transfer coefficients between fluid and rock in a porous system undergoing conversion from single- to two-phase flow. Finally, Dr. Maini uses analytical solutions to examine downhole heat exchange.

Another paper, which does not fit directly into the scheme in Fig. 1, but which encompasses all of the modelling work, was given by R. Atherton on general sensitivity theory. By appropriately modifying a given set of partial differential equations, a sensitivity analysis may be performed on both equation parameters and boundary conditions to determine in which space domains they are important.

Before discussing future goals of modelling, it should be noted that there were other papers which dealt in part with modelling; however, they will be included in the other rapporteurs' reports.

Returning to Fig. 1, it is evident from the papers presented that modelling of porous reservoir performance, both single- and two-phase, is at an application stage. However, modelling of fractured reservoir performance, subsidence and hydrothermal reactions needs further research and development before field applications of this type are possible. Extensions of the models presented include: (1) incorporate a wellbore model and/or near-wellbore model with a reservoir model, (2) include the equation of state for saline water, (3) couple the reservoir model with a management model, (4) perform further sensitivity analysis, and (5) include more rock-water interaction.

One *of* the most important points made at this workshop is the need for people in modelling to work more closely with people doing laboratory and field work, in order to determine what data are needed and what assumptions are valid. Some of the contributions from laboratory work include: (1) thermal effects on relative and absolute permeability, (2) thermal effects on dispersion, (3) chemical reaction rates, (4) capillary pressure effects, and (5) heat transfer rates between fluid and rock. Contributions from field work include: (1) determination of permeabilities and porosities, (2) reservoir boundaries and thickness, (3) initial pressure and temperature/enthalpy distributions, and (4) reservoir geology.

It is the opinion of this rapporteur that the most important goal for geothermal modelling indicated at this workshop, is the need to make field applications, and if these applications are to be successful, it is essential to have good communication between people doing modelling and people doing well testing and field work.