Proceedings Seventh Workshop Geothermal Reservoir Engineering
Stanford. December 1981. SGP-TR-55.

OVERVIEW - UNIVERSITY RESEARCH IN GEOTHERMAL RESERVOIR ENGINEERING

Roland N. Horne

Stanford University

University research into reservoir engineering aspects of geothermal utilisation has undergone a long development since work first gathered speed in the early 1970's. University research, appropriately enough, has remained somewhat academic throughout that time although with a constant watch over the philosophically troubling problems associated with industrial utilisation of the resource. Research in the university environment is charged with finding the answer "why?" as much as "how?".

The Past One of the earlier popular areas of university research was the behaviour of convection in porous media--a region of interest stimulated by fundamental questions of how geothermal reservoirs form and what mechanisms are important in their behaviour. Work in this area was done at the University of Hawaii by Prof. Ping Cheng, at University of Colorado by Prof. David Kassoy, at Stanford University by Profs. George Homsy and Roland Horne, and at UCLA by Prof. George Schubert and Dr. Joe Straus. Physical situations in which non-isothermal fluid flow through porous media is important also appear in other engineering fields and have been studied in other universities with frequent cross references to geothermal energy. Much productive work was generated in the area of convection, however most activity drew to a close with a subtle change of emphasis towards more practical problems, perhaps originating with ERDA's 1975 catch-phrase of "megawatts on-line".

Methods for reservoir modelling have been investigated continuously from the beginning and still are of current interest. The field can be split somewhat untidily into the regions of analytical modelling, physical modelling and numerical modelling. Full scale numerical modelling has been undertaken at the university level by Prof. George Pinder at Princeton University and Prof. Paul Witherspoon at U. C. Berkeley who have made major contributions in philosophical insights into aspects of the field. Nuts-and-bolts code development has remained principally outside the academic environment and has been tackled by commercial companies and the national laboratories.

Analytical modelling is somewhat inappropriately named since most examples use numerical methods, however the term has come to be used with reference to lumped parameter, linearised or otherwise simplified models. Some of these models such as University of Colorado's fault-charged model (Kassoy and Goyal, 1979) grew out of earlier convection work, while others at Stanford University originated from petroleum engineering material balance techniques (Brigham and Neri, 1980, and Westwood and Castanier--this conference). Prof. Gunnar Bodvarsson of Oregon State University has also contributed a wide range of conceptual models from his geophysical background. The arguments concerning the appropriateness of this type of model compared to full scale distributed parameter models have yet to be resolved, and it is likely that work in both areas will continue in research, as it does in industry.

Physical modelling of full scale systems has never been undertaken in university research (despite suggestions of sand box models at Colorado State University - Fort Collins), but laboratory studies of large scale heat transfer has been undertaken in the chimney model at Stanford.

With the change in the later 1970's towards more immediate practical problems, greater attention was placed upon well testing and well test analysis. Research in this area had been in progress at Stanford under the direction of Prof. Ramey since considerably before that time, however Stanford was joined by the University of Hawaii and other non-university establishments in the renewed interest. Well testing is an area on which all sectors of the geothermal reservoir engineering area depend, including numerical simulation, economics, reservoir modelling, station design, pipeline design and even environmental impact investigation.

Interest in fundamental rock and fluid properties has been maintained because of the continued importance that physical and chemical behaviour have in exploration, well test analysis and simulation. Work in fluid flow has been followed at Stanford University in the bench scale experiments investigating absolute permeability, steam/water relative permeability and adsorption. The impact of the adsorption experiments has been far reaching in the engineering of vapor dominated systems, but the determination of steam/water relative permeability (which is of major importance in reservoir simulation) continues to be elusive. The difficulty in measuring relative permeabilities may well arise philosophically in their definition, making their study an ideal candidate for academic research.

The chemical behaviour of geothermal fluid flow has also been investigated in university research, with the mineralogical and stable isotope studies performed at U. C. Riverside and the non condensable gas studies at Stanford.

The Present and Future The principal philosophical problem suffered by geothermal reservoir engineering is the application of techniques developed for porous media to systems which have substantial fracture permeability. A great deal of effort in university research is now being applied in this direction. Tracer testing has been perceived as one of the clearest means to define fracture systems and the design and interpretation of a major tracer field test has been undertaken by Stanford in cooperation with the Instituto de Investigaciones Electricas in Mexico. Well test analysis, and non condensable gas monitoring techniques are being developed for this use also, and the heat transfer behaviour of fractured systems is also in progress.

In September 1980, LBL drafted an updated plan (Howard, Goldstein and Graf, 1980) for the support of geothermal reservoir engineering research by the U.S. Department of Energy. Twenty top priority research needs were identified and presently 8 of these research topics are under investigation (either formally or informally) at universities.

References

Brigham, W. E., and Neri, G.: "A Depletion Model of the Gabbro Zone," Proc. Second DOE-ENEL Workshop Cooperative Research Geothermal Energy. LBL report 11555, January 1981.

Howard, J. H., Goldstein, N. E., and Graf, A. N.; "An Updated Plan for Support of Research Related to Geothermal Reservoir Engineering," LBL report 10807, September 1980.

Kassoy, D. R., and Goyal, K. P.; "Modelling Heat and Mass Transfer at the Mesa Anomaly, Imperial Valley, California," LBL, GREMP Series #3 (LBL-8784), 1979.

Westwood, J. D., and Castanier, L.M.; "Application of a Lumped Parameter Model to the Cerro Prieto Geothermal Field," Geothermal Resources Council, Transactions, 5 (1981) (also this meeting).