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   Hydraulic fracturing and geothermal energy
Hydraulic fracturing and geothermal energy


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Hydraulic fracturing has been and continues to be a major technological tool in oil and gas recovery, nuclear and other waste disposal, mining and particularly in-situ coal gasification, and, more recently, in geothermal heat recovery, particularly extracting heat from hot dry rock masses. The understanding of the fracture process under the action of pressurized fluid at various temperatures is of fundamental scientific importance, which requires an adequate description of thermomechanical properties of subsurface rock, fluid-solid interaction effects, as well as degradation of the host rock due to temperature gradients introduced by heat extraction.

Considerable progress has been made over the past several years in laboratory experiments, analytical and numerical modeling, and in-situ field studies in various aspects of hydraulic fracturing and geothermal energy extraction, by researchers in the United States and Japan and also elsewhere. However, the results have been scattered throughout the literature. Therefore, the time seemed ripe for bringing together selected researchers from the two countries, as well as observers from other countries, in order to survey the state of the art, exchange scientific information, and establish closer collaboration for further, better coordinated scientific effort in this important area of research and exploration.

This book is the proceedings of the First Japan-United States Seminar on Hydraulic Fracturing and Geothermal Energy, held in Tokyo, November 2-5, 1982, under the auspices of the Japan Society for the Promotion of Science, with assistance by the Mining and Metallurgical Institute of Japan (MMIJ), and the National Science Foundation of the United States. It also includes the proceedings of a post-seminar Symposium on Fracture Mechanics Approach to Hydraulic Fracturing and Geothermal Energy, held at Tohoku University in Sendai, November 8-9, 1982.

The Seminar focused attention on the following four related and complementary areas:

1. Subsurface structure and hydraulic fracturing.
2. Rock mass properties in the presence of pressurized fluid at elevated temperatures.
3. Mapping of subsurface fractures.
4. Simulation of geothermal reservoirs.

These research areas bear strongly on all technological activities that require hydraulic fracturing, e.g. nuclear waste disposal, gas, oil, and coal recovery and mining, and in-situ coal gasification. While these applications were not ignored, greater emphasis was placed on geothermal heat extraction processes, including both "wet" and "dry" heat reservoirs.

Both the United States and the Japanese sponsoring agencies restrict the number and the distribution of the participants in this kind of seminar. Therefore, the scientific committee made a serious
effort to include a representative cross-section of scientists from universities, industry, and government laboratories. As a result, the seminar, as well as the post-seminar symposium, provided an excellent forum for scientific exchange between the two countries and observers from France, Germany, and Australia. While the participants obtained better appreciation of the scientific achievements in hydraulic fracturing, geothermal energy extraction processes, and related topics, they also developed international friendship and closer relations with their peers, which we expect will bear significant fruit for many years to come. The present book, which includes the articles presented at the meetings, is published in an effort to disseminate some of the latest achievements in hydraulic fracturing, rock mechanics, and mining of the earth's heat energy.

We wish to thank the United States National Science Foundation and the Japan Society for the Promotion of Science who provided support for the Seminar. We also thank the Mining and Metallurgical Institute of Japan (MMIJ), the Geothermal Research Society of Japan, Japan Geothermal Energy Association, the New Energy Foundation, and the New Energy Development Organization for sponsoring the Sendai Symposium and for their assistance with the two meetings. The support of many Japanese industries is also gratefully acknowledged.

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SUMMARY

It is useful to provide a summary of the proceedings of the First Japan-United States Seminar on Hydraulic Fracturing and Geothermal Energy, and the associated post-seminar Symposium on Fracture Mechanics Approach to Hydraulic Fracturing and Geothermal Energy. However, the range of interdisciplinary topics covered by the participants renders the task essentially impossible. The pre-printed lectures included contributions ranging from the most fundamental study of rock fracture and properties to the geological subsurface structure of geothermal reservoirs and the associated design procedures for effective heat extraction. Balanced theoretical and laboratory experimental results were presented. Therefore, so many significant technical points were examined that identification of individual contributions would not be possible in the form of a short summary. It was therefore decided to restrict comments to a brief survey of the diverse nature and status of the main subject of the seminar, namely "hydraulic fracturing and geothermal energy." To provide an overview, Fig. 1 was prepared. Though possibly deficient in draftsmanship, we trust it will accentuate the major areas that were discussed at the two meetings. The following comments may help to bring out some of the features implied by this illustration.

Subsurface Structure and Hydraulic Fracturing: The feasibility of a fracture mechanics approach to the design of hydraulic fracturing in geothermal applications was extensively discussed, though no consensus on a design philosophy was achieved.

Rock Mass Properties in the Presence of Water at High Temperatures: The significance of experimental investigations of rock fracture behavior in the presence of water at high temperatures was demonstrated. It was emphasized that the experimental procedure for determining the fracture toughness of rocks urgently requires standardization.

Fracture Mapping: Hot dry rock geothermal energy extraction requires accurate fracture mapping. Refined three-dimensional mapping techniques must be developed, in order to provide detailed subsurface data.

Simulation of Geothermal Reservoirs: Theoretical models of reservoirs were extensively discussed, with the main focus on three-dimensional cracks in layered subsurface media and in geological faults. In addition, theoretical and experimental results on growth regimes, stability, and general configurations of thermally induced cracks in hot dry rock masses were discussed, and their relation to the efficiency and life expectancy of the reservoir was considered.

In reference to Fig. 1, one observes a crowd of rock mechanicians, geoscientists, and geothermal engineers making unintelligible noises when they do not fully comprehend what Mother Nature seems to be suggesting to them. Nonetheless, some in the crowd have come away better informed and certainly inspired, as a result of the Seminar and the follow-up Symposium.

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