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Geothermal Technologies Program

Enhanced Geothermal Systems Research and Development: Models of Subsurface Chemical Processes Affecting Fluid Flow

Project Summary (DOE Award DE-PS36-04GO94001):

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1. Introduction: Successful enhancement of water deficient, low permeability reservoirs would significantly advance geothermal energy as an economically competitive contributor to the nation's energy supply. However, there is insufficient knowledge about subsurface chemical processes controlling fluid flow in enhanced geothermal systems (EGS) to predict the behavior of the resource. Available thermodynamic data are limited to specific composition, temperature and pressure (XTP) values, and application of this information to EGS that experience large variations in XTP is difficult. The goal of our research project is to expand the EGS knowledge base by providing new modeling technologies that accurately characterize EGS chemistry and effectively support geothermal industry efforts to solve EGS problems related to **subsurface chemical processes affecting fluid flow** (Announcement, Res. Area D).

2. Proposed Project: With funding from the DOE Renewable Energy Program, DOE Basic Energy Sciences, the National Science Foundation and Petroleum Research Fund, we have developed advanced equation of state (EOS) and simulation technologies for accurately modeling the chemical behavior of complex aqueous systems in subcritical and supercritical TP ranges. Our research goals are to: ●Utilize technology gained from these research activities plus recently acquired data to develop the first highly accurate chemical models of hydrothermal fluids and rock-forming minerals for XTP ranges of interest to EGS. ●Construct models capable of predicting the effect of subsurface processes such as mixing, dissolution, precipitation and mineral alteration on reservoir rock permeability and thereby fluid flow. ●Assess and summarize large amounts of high TP mineral solubility and activity data. ●Provide easy-to-use, inexpensive methods of defining, developing, and demonstrating productive EGS strategies related to chemical behavior. ●Make flexible chemical models that support other geothermal industry efforts. ●Rapidly transfer our technologies to the geothermal industry.

(a) Modeling Activities: We will emphasize temperatures below 350°C, a range suitable for most EGS R&D. We have shown that our implementation of the Pitzer liquid density (LD) free energy modeling approach calculates solute activities and solid-liquid-gas equilibria in complex aqueous solutions to high concentration and temperature with remarkably high accuracy. Using our models of the H-Na-K-Ca-OH-Cl-HSO_4-SO_4-HCO_3-CO_3-H_2O-CO_2-SiO_2 system (0-250°C) and H-Na-K-Al-OH-H_2O system (extended from 120°C to 250°C), we will develop a comprehensive and accurate solution model for hydrothermal fluids. We will evaluate available extrapolated mineral thermodynamic properties data bases for their consistency with our models. Making the necessary adjustments to incorporate these data, we will construct the first high-accuracy model that describes chemical interactions of hydrothermal fluids and rock-forming minerals, for a wide composition range to 250°C. The LD modeling approach may be extended to 350°C and higher pressure by using polynomial expansions to provide the pressure dependence of parameters and by including the effects of the ion association occurring in this temperature range. High quality activity data exist for a limited range of species to 350°C. Using these data, we will make a model of hydrothermal fluids within the limited Na-K-H-Cl-H_2O system (includes major ions in geothermal well waters) to 350°C. We will use this model to calculate measured mineral stabilities. These calculations will provide a check of mineral properties databases and a means to improve them, if necessary. Recently, major advances have been made in the measurement of fluid inclusions compositions using new advanced light source and ICP methods. The information these data provide about mineral stabilities can be used to check model predictions and greatly improve our ability to model hydrothermal systems. We will also conduct exploratory calculations using our high TP EOS, developed to treat the special problems of supercritical fluids, to calculate relative (co-existing) hydrothermal mineral stabilities. There is enough high XTP data to provide a comprehensive assessment of this EOS.

(b.) Technology Transfer: We will develop user interfaces so that our models can be added to our interactive web site (geotherm.ucsd.edu). We will continue our emphasis on the rapid transfer of our technologies to the geothermal industry via this site as well as transfer via conferences and publications.