Geothermal data analysis and optimisation

Geothermal energy production is a worldwide industry with many open problems of potential interest to the applied mathematical community.

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A geophysicist’s-eye broad-brush classification of geothermal energy production might separate out three different styles of exploitable geothermal energy plays: 1) volcanic, 2) hot sedimentary aquifer, and 3) the more recent enhanced/engineered geothermal systems (EGS) which involves enhancing the hydraulic permeability of rock masses through the stimulation of fracturing. The volcanic style has many open problems for systems in (e.g.) New Zealand, Iceland, the Philippines, Indonesia, and the United States.

A very small sampling of such problems might include topics such as: plug-flow (i.e. water-steam phase-changing flow in near vertical wellbores); and reactive-flow problems where chemical species dissolved in geothermal brines are exsolved/precipitated at economically problematic locations (such as scaling in the interior of surface equipment, or nearby any injection wellbores of an operating field). The hot sedimentary aquifer style has open problems for systems in (e.g.) the Rhine graben, the United States (the Imperial Valley in California), and now in Australia (e.g. the Ottway basin in southern Victoria, or the Perth Basin in Western Australia). A small sampling of such problems might include topics such as: the presence or absence of unforced porous-media convection; thermo-haline (double diffusive) porous-media convection problems; and mixtures between forced and unforced convection in active aquifer systems. All of these finite-amplitude-flow in porous-media problems occur in multiple geometric scenarios, some significantly more complex than the horizontally layered strata of previous analyses.

The EGS style of geothermal play has many open problems in terms of rock mechanical and reactive flow problems. A small sampling here might include: the formation and maintenance of significant aperture fractures in the presence of flowing geothermal brines and thermally activated creep flow of the surrounding rockmass; the efficacy of different approaches to stimulating fractures; and the refinement of various geophysical techniques to improve locations of the microseisms associated with the stimulation of fractures.

Finally; all geothermal exploitation systems share some similar open problems in such fields as: geophysical inverse problems, both to monitor the operations of active fields, and to find new ones in the first place; operations research, to optimally design an exploitation system by trading off investment in aboveground technology vs. drilling deeper to obtain a hotter resource; and more traditional reservoir engineering issues, specialised to the conditions found in individual geothermal fields.

MISG problem
To assess the economically feasibility of extracting geothermal power from the deep sedimentary Perth Basin, the WA Geothermal Centre of Excellence has (e.g.) been collecting thermal data from down boreholes as well as examining remotely sensed observations of surface temperatures. The data are noisy so the issue is how best to massage the data and interpret it in the geothermal context?

Time permitting the drill hole optimization problem may also be addressed.