THERMOCHEM RESOURCE EVALUATION CONSULTING SERVICES

Thermochem geochemists, geologists, geophysicists and reservoir engineers have many decades of experience in resource evaluation, conceptual model development, numerical simulations, and geochemical process modeling. Often in geothermal ventures clients are in varying stages of resource development or operations which requires that a thorough resource evaluation starts with a review of the field history and existing geoscience data. In some cases, only a limited amount of resource data may exist and in others there may be extensive historical data that must be organized, cataloged, and digitized. Resource evaluation and feasibility studies may be initiated at any point in a project's lifetime, ranging from the feasibility of developing a greenfield resource to understanding the feasibility and impacts of an expansion to a currently operating field.

Thermochem has experienced geoscience personnel who are able to manage resource evaluation projects from start to finish, as illustrated in Figure 1. The preliminary stage of a resource evaluation is to organize and catalog existing resource data, perform a rigorous review of data quality, identify data gaps and define value added for additional data acquisition, and assess the uncertainties of the geoscience data inputs that will be used to create the resource conceptual models. The validated data may then be processed for interpretation in the "3G" disciplines of geochemistry, geology, and geophysics.

The 3G interpretations and models are applied to illustrate the key components of a geothermal system including the upflow, outflow, and recharge, temperature and pressure distributions, barriers or conduits to fluid flow and primary fluid flow directions, chemical distributions that reflect reservoir processes such as mixing, boiling, or steam condensation, phase distributions, and the reservoir boundaries as defined by clay cap distribution and its relationship to geologic structures. Geochemical data may also be used to understand possible risks in geothermal development related to the presence of corrosive gases such as H_2S or volatile chloride, fluids that are susceptible to scale formation, or possibly immature geothermal systems that may produce acidic fluids that are difficult to manage. Geological, geophysical, thermal manifestation, and well data may be integrated into a 3D Leapfrog model that serves as the visualization platform for conceptual model development.

The 3D Leapfrog model may be used to create conceptual model cross-section lines to illustrate the geometry and distribution of the geothermal system. The key uncertainties defined in the data validation and interpretation stages of will be proportional to the number of conceptual models that may illustrate the system. As the uncertainty in the geoscientific data increases, so does the number of models that could plausibly explain the observed field data. If the conceptual models are not sufficient to propose drilling targets with an acceptable level of risk, then it is possible that follow-up surveys for additional data acquisition are required before exploration drilling may begin. If the preferred conceptual model is agreed by all members of the geoscience team to be the most plausible base case model, then drilling targets, well pad locations, and well design should be selected to commence the exploration drilling campaign.

The size and duration of the exploration drilling program will vary from project to project, but each well is important to gather information about the subsurface thermal, pressure, and phase distributions, rock properties, structural relationships and feed zones, fluid chemistry, and the well productivity and injectivity index. The conceptual model will evolve with drilling results, and well targets may change depending on the outcome of each well. Using the well test data and base case conceptual model, a numerical model is constructed and calibrated. The model calibrations include inferred natural state reservoir pressure and temperature from the downhole PT data, production history matching, interference tests, reservoir tracer tests, and heat and mass loss models compared to thermal manifestation heat loss and mass flow surveys. The conceptual model will undergo multiple revisions as new subsurface data and numerical model results become available.

The project feasibility depends not only on the outcome of the simulated reservoir size and performance from drilling results and numerical model forecast simulations, but also on the feasibility of power plant design, transmission system, economic and financial feasibility, as well as potential environmental and social impacts of the geothermal prospect.

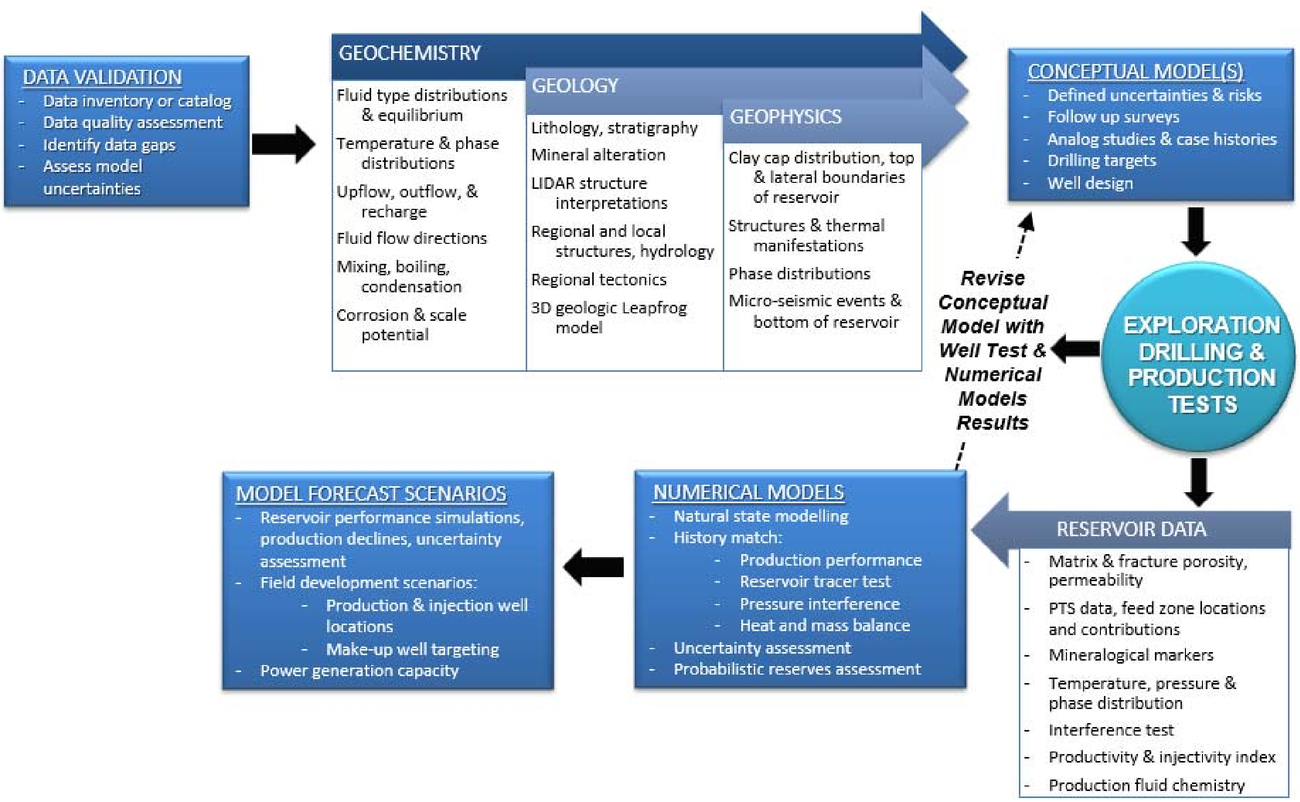

Figure 1. Illustration of resource evaluation process

Thermochem has project management experience for large-scale interdisciplinary resource evaluation projects, including conceptual model construction, numerical model development, production forecast scenario simulations, and feasibility studies for power plant installations.

The major outcomes of these interdisciplinary resource and power plant evaluation projects have highlighted critical field management issues, including injection strategy, make-up well targeting, long-term forecasts, the feasibility of adding binary bottoming cycles and the optimization of existing bottoming cycles.