A SUGGESTED GEOSCIENTIFIC STUDY OF THE HEBER, CA EXPLORATION DATA BASE

by

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February 15, 1983

INTRODUCTION

The success or failure of the Heber Demonstration Project depends on availability of sufficient quantities of high-quality geothermal fluids, which in turn depends to a very significant extent on the availability, correct interpretation and use of a myriad of geoscientific data, some of which are apparently proprietary to Chevron Resources Company and others of which are yet to be collected. For example, there is only a sketchy geologic model of the reservoir available publically while Chevron apparently retains rights, even from its resource partner, Union Geothermal, not only to a much more detailed model but to the drilling and other exploration data upon which it is based. Moreover, at this point in time it is only an assumption that Chevron even has enough data to understand the reservoir. Yet a novel, untried production/injection scheme, whose design is necessarily rooted in an accurate geologic model, is planned for furnishing thermal fluids to the demonstration plant. Regarding uncollected data, the wells that are to produce the geothermal fluid have not yet been drilled, much less sampled. There are, therefore, no reliable data on chemistry, enthalpy, or mass flow rate for the actual geothermal fluids upon which to base the plant design, and the quality of, at least, the chemical data that are available from other wells in the area has been questioned. Yet the plant is in the final design stage.

It would appear that the same sort of problems that led to the failure of the Baca Demonstration Project could easily crop up at Heber. DOE would be unwise to assume that Chevron and Union can actually deliver the quantity and quality of fluid to the Heber plant that they say they can without looking into this assumption in depth.

We understand that DOE participation in the Heber Demonstration Project is to be restricted to financial and technical assistance in construction, testing and operation of the plant and does not concern itself with the resource. Commitments to the design, construction and possibly even ordering of expensive hardware for the plant are all to be made before the production wells are drilled, flow tested and sampled. With all due respect to the engineers involved, geothermal reservoirs just are not the predictable, cooperative creatures we would like them to be, but are instead quite individual and capricious. Just when you expect the next eight wells to produce large quantities of thermal fluids of known enthalpy and chemistry, based upon experience with the last eight, they don't. It is encumbent upon DOE to know far more about the Heber reservoir than it presently knows and to assure itself that fluids meeting the design specifications of the plant can actually be delivered, before extensive financial commitment is made to the project. Once burned, twice shy.

The purpose of this document is to discuss some of the information and data analyses that must be well in hand at Heber as early on as possible to characterize the geothermal reservoir, and to suggest a plan for a data synthesis and interpretation.

BACKGROUND

A significant amount of geotechnical information is needed to evaluate the production rate, temperature and chemistry of geothermal fluid and to estimate the longevity of the resource at any reservoir site. Data obtained in all three spatial dimensions from the disciplines of geology, geochemistry, geophysics and hydrology each provide part of this information base. Appropriate, often highly sophisticated analyses and interpretation must be carried out with the objective of synthesizing a conceptual resource model from which reliable predictions can be made. This process is illustrated schematically in Figure 1, which shows the nature of input data required in order to most reliably make the predictions that are needed from a conceptual model of the resource. We hope, but have no present assurance, that the Chevron geothermal team has done a state-of-the-art job of this complex task. Their data, interpretations, predictions and resource development plans merit close scrutiny and independant evaluation on DOE's behalf because there are all too many pitfalls along the way.

Geologic investigations provide factual information on the nature, location and distribution of subsurface rock types, structures and zones of high permeability. Geochemical studies are made to assess the chemical and physical properties of the thermal brines, their potential for mineral deposition in the formation and scaling in the wellbore and surface equipment, their distribution, extent and uniformity. Geophysical anomalies, when correlated with data on fluid and rock properties, are used to extrapolate information obtained from borehole data, to map the distribution of hot fluids at depth and to assess certain potential environmental impacts of production such as subsidence and seismic activity.

The program of data collection and integrated interpretation discussed here is designed to develop the geoscientific data base necessary for evaluating the reservoir and production characteristics of the Heber geothermal field. Some of these data have already been collected as a result of exploration and development efforts by Chevron and Union Geothermal personnel. The intent is not to duplicate collection of available data but to fill, if necessary, critical gaps in the data base and then to perform an objective, independent integrated analysis and interpretation of the data base for the purpose of helping DOE to track the technical progress of the project and to make the best decisions in its own behalf as the project moves along. It is anticipated that such ongoing independent evaluation of the data will allow DOE to remain current and, hopefully, avoid many of the problems which arose during and eventually lead to the downfall of the Baca Demonstration Project. If such a concept is deemed by DOE to be viable and valuable, it would be wise to form the geoscience evaluation team and begin work quickly so that their advise and conclusions can be available to DOE as early as possible.

Geologic Investigations

Detailed subsurface data from geothermal systems in the Imperial Valley suggest that fluid movement is controlled both by faults and permeable stratigraphic horizons. Although detailed geologic data from the Heber field are not available, sketchy data on temperature distributions at depth strongly indicate that faults and fractures act as important fluid conduits here as well. Fracture characteristics such as aperature, continuity and spacing will thus have a profound effect on reservoir productivity. If fractures are widely spaced (say, more than 200 ft. mean separation) they will behave as oriented flow channels whose thermal depletion will be rapid if cool fluid is injected as is planned in the current "heat sweep" scheme. If fractures are closely spaced they will appear and behave as an equivalent porous matrix material and rapid thermal depletion may be avoided. In order to develop a reliable model of how the resource will behave, the fracture distribution and geometry must be known. Proper location of production and injection wells relative to fluid flow paths will have a profound influence on the success or failure of the proposed heat sweep injection-production system. Not only must the wells be positioned such that communication is possible, the injection must be carefully managed so that short circuiting does not occur.

The distribution of fractures and rock types can be most directly determined through detailed lithologic examination of cuttings from wells already drilled into the reservoir and the new production and injection wells yet to be drilled. Correlation of stratigraphic horizons between wells can be used to form a basis for interpretation of structures such as faults both beyond the current boreholes and between boreholes. Mineralogic and geochemical changes can be mapped to help provide information on the distribution of permeable zones and past and present reservoir temperatures. The mineralogic changes that occur as fluids migrate through the reservoir rocks may also produce significant changes in the physical properties of these rocks, leading to spatial variations in the geophysical responses and, more importantly, in the formation permeability. Thus, detailed geologic data are also needed to interpret accurately both downhole and surface geophysical data.

Geochemical Investigations

Knowledge of the chemistry of the geothermal brines and gases is essential for nearly all aspects of field development and planning. Chemical sampling of the fluids prior to production provides information needed for design of the power station and waste disposal procedures as well as baseline data on the undisturbed reservoir. During production, the chemistry of the fluids discharged from the wells can be compared to these baseline data to assess changes in the deep water supply, mineral deposition in the wells or formation, influx of lower-temperature water into the field, or mixing of fluids from separate reservoirs.

Figure 2 illustrates an example of baseline data calculated from chemical analyses of fluids from the Roosevelt Hot Springs hydrothermal system in Utah. These data indicate that even though the wells produce fluids from fractures located at depths of several thousand feet, the compositions of the discharged fluids are highly variable and consist of mixtures of a common reservoir fluid with varying proportions of nonthermal groundwater. The amount of nonthermal water entrained within the production fluid affects both its temperature and its composition. Careful chemical monitoring of the discharged fluids during production may aid in predicting the rate of thermal degradation in the field before large scale temperature drops are recorded.

Despite the importance of chemical data in evaluating reservoir performance, determining the chemical parameters of the thermal fluid is frequently not a simple process. Several factors, such as boiling within the borehole or formation, separation of gases from the brine at the collection port, or mineral deposition (scaling) may produce a fluid that differs drastically in composition from the reservoir brine. Nevertheless, detailed and useful chemical information can be obtained through careful sample collection and accurate analyses of the separated water, condensable and noncondensable gases, coupled with on site measurements of separator pressure and total fluid enthalpy.

Geophysical Investigations

Reservoir evaluation depends significantly on data obtained by borehole geophysical logging. The tools, lowered in the well by wireline, record various parameters of the rock such as density, porosity, natural gamma radiation and electrical properties. The objectives of geothermal well logging parallel those of petroleum logging and include: the identification of lithologies and of lithologic changes; the location and identification of fracture zones and structures; determination of borehole conditions such as lost circulation, mud invasion, borehole enlargement or washout; porosity determinations; and temperature identification of fluid entries (i.e., hot or cold fluids). The logged data, together with flow test data, provide estimation of potential production from the reservoir.

The need for well logging is reinforced if the recovery of drill cuttings decreases, and with increases in sloughing of material into the well or mixing of cuttings within the well. A much more accurate location (in depth) of lithologic features and potential production zones is possible through logging and interpretation than is possible any other way, and accurate locations are required for successful hole stimulation and well completion activities.

The extrapolation of borehole data across the reservoir can be accomplished through the interpretation of surface-to-borehole and surface geophysical studies. A variety of effective techniques is currently available and some of these undoubtedly been used already at the Heber site. These data should be reviewed and integrated with the geological and geochemical data to develop the best conceptual model of the thermal system at Heber.

Hydrology and Reservoir Engineering

There are perhaps two primary phases to normal reservoir engineering efforts at a geothermal site. First the various production and injection wells are flow tested to determine their transient pressure behavior and their mutual interference, if any. From the resulting data average porosities and permeabilities for the formation around each well can be determined in addition to any existing wellbore damage, drainage volume of the well and nearby aquifers or aquicludes. All of this information along with the geological, geochemical and geophysical data is then used to form a conceptual reservoir engineering model of the reservoir, from which predictions of power available, individual well life and reservoir longevity can be made, and upon which a design for the production/injection scheme can be based.

APPROACH

For reasons discussed above, DOE would be wise to concern itself with progress on development of the resource. In our opinion, the drilling results to date are far from adequate to guarantee success either of adequate production from the new wells to be drilled or of the heat sweep production/injection scheme. DOE should avail itself of the best geoscientific talent available to act as advisors and to keep DOE current on progress and problems throughout the drilling and testing of production and injection wells.

We suggest a team approach. The team should be composed of experienced geologists, geochemists, geophysicists and reservoir engineers. It should report directly to the DOE-SAN and DOE-HQ project management. The purpose of this team, its raison d'etre, would be to become thoroughly familiar with geotechnical aspects of the Heber reservoir, to function as advisors to DOE on the project and to lend expertise to other, non-DOE, participants on the project as requested by DOE. Specifically, the team would:

1. Review available data for the reservoir, including those data publically available, and, more importantly, those data now held in the files of Chevron and Union;
2. Identify items of data that may be missing but are considered to be critical to reducing risk on the project;
3. Make recommendations for acquisition of needed data;
4. Perform an independant analysis and scientifically integrated,

internally consistent interpretation of the data;

5. Describe a conceptual model of the resource that is state-of-the-art and from which predictions about the reservoir and its fluids can be made.
6. Examine project plans, especially those of Chevron and Union, on development of the resource, including siting, drilling and testing of production and injection wells;
7. Analyze and interpret new data as they come in during the course of the drilling program; and,
8. Advise DOE of the results of these steps on a periodic or as requested basis so that DOE will always be in the best possible position to make good decisions regarding its interest in the project.

We suggest that the entities having the most expertise in these matters are UURI, LBL and the U. S. Geological Survey, and that the team be drawn from their staffs. UURI can contribute high-quality technical expertise in the fields of geology, geochemistry and geophysics, but has no reservoir engineering capability. Reservoir engineering expertise could be drawn from LBL. The U. S. Geological Survey could be of help both on geochemistry and on reservoir engineering.

We envision the work being done in two phase as follows:

Phase I. Development of an integrated interpretation of the complete data package, with collection and incorporation of any new data required. A broad, diverse expertise is required for this phase. A report documenting the conceptual resource model and commenting on reservoir development plans would conclude this phase.

Phase II. On-going technical advise to DOE at a lower low level of effort during the drilling of production and injection wells and their subsequent testing to keep abreast of new results and their implications for the project. The Phase II team members would be drawn from the larger Phase I team to ensure continuity.

The ideal team would have a composition something like the following, although obviously a great deal more consideration should be given to this matter if there is approval by DOE of this general scheme.

Table I

Proposed Team[1]

	Phase I			Phase II		
	UURI	LBL	USGS	UURI	LBL	USGS
Geologists	2	0	0	1	0	0
Geochemists	1	0	1	1	0	1
Geophysicists	1	0	0	1	0	0
Reservoir Engineers	0	2	1	0	1	0

ESTIMATED MANPOWER, COSTS AND SCHEDULE

If the general approach proposed herein is accepted by DOE, details of manpower, costs and schedule would have to be worked out among participants and would clearly have to fit overall program goals. The figures given in this section are first guesses made by the author without consultation with

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[1] This table does not indicate full-time assignments, but only part time.

either LBL or the USGS.

Manpower

Tables II and III show estimated manpower requirements. Phase I has relatively heavy manpower loading in order to accomplish development of a reliable conceptual model of the resource. In Phase II loading for geologists and reservoir engineers is heavier than for other disciplines in Phase II in order to keep abreast of new information generated during drilling and testing of the production and injection wells.

Costs

Estimated costs are shown in Table IV. In view of the major financial commitment that the Heber Demonstration Project represents for DOE, these costs seem like inexpensive insurance against realizing too late that there are resource problems.

Schedule

Phase I could be completed to a satisfactory degree within 3 to 6 months of the time that all of the data are assembled depending on extent of new data gathering, if any. Somewhat more time may be required if data gathering tasks are more than anticipated herein.

Phase II would be ongoing during drilling and testing of the production and injection wells, prior to plant startup.

Table II

ESTIMATED MANPOWER -- PHASE I
(man-months)

	UURI	LBL	USGS
Geologists	10	0	0
Geochemists	6	0	2
Geophysicists	6	0	0
Reservoir Engineers	0	10	4

Table III

ESTIMATED MANPOWER -- PHASE II
(man-months per year during drilling)

	UURI	LBL	USGS
Geologists	6	0	0
Geochemists	3	0	1
Geophysicists	2	0	0
Reservoir Engineers	0	6	2

Table IV

ESTIMATED COSTS ($K)

	UURI	LBL	USGS	Totals
Phase I	170	100	50	320
Phase II (costs per year during drilling)	90	60	30	180