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RECOMMENDATIONS OF THE INDUSTRY ADVISORY PANEL ON GEOTHERMAL RESERVOIR DEFINITION

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INTRODUCTION

During FY 1984 the Geothermal and Hydropower Technologies Division (GHTD) of the Department of Energy (DOE) designated Lawrence Berkeley Laboratory (LBL) as the cognizant laboratory for the Reservoir Definition Program. Under this role, LBL's fundamental responsibility is to assist GHTD in formulating the research plan for Geothermal Reservoir Definition Technology under DOE's Hydrothermal Research Subprogram (Tables 1 - 6). The main goal of DOE's activities in Reservoir Definition Technology is to improve the technologies needed to locate, delineate, characterize, assess, and manage hydrothermal reservoirs.

As part of its responsibility as cognizant laboratory, LBL was given the task of determining the research needs of the geothermal industry and of reviewing the appropriateness of DOE-funded projects for meeting those needs. For that purpose, LBL invited a group of industry representatives to be part of an advisory panel on Geothermal Reservoir Definition, which met for the first time on August 21, 1984. The input from this industry panel will be requested periodically (probably every six months) by LBL.

The main objectives of the August 1984 meeting were to

1) Review DOE's current and planned activities in Geothermal Reservoir Definition and evaluate their relevance to industry needs.

2) Review industry needs in Geothermal Reservoir Definition both near-term and long-term, and determine priorites for these needs.

3) Assess industry's likely contributions in meeting its own needs, identify needs it might cost-share with DOE, and determine needs that will have to be wholly funded by DOE.

4) Identify possible areas for DOE's technology transfer to industry in Geothermal Reservoir Definition.

A total of 13 persons attended the meeting, nine panel members and four observers (Table 7). A tenth industry representative, Donald R. Lindsay of Occidental Geothermal Incorporated, could not attend, but contributed to the preparation of the minutes of the meeting. The main role of the observers--principal investigators of LBL, Stanford University, and the University of Utah Research Institute--was to outline DOE's Geothermal Program and describe the projects being carried out by their groups under this program.

In addition to DOE's activities and plans in Reservoir Definition Technology, the Panel heard and discussed the Brine Injection Technology Program and DOE's Geothermal Program during the one-day meeting.

The results of the meeting were summarized in the minutes of the meeting [1] which include a number of comments on different aspects of GHTD's programs, a prioritized list of industry needs in matters related to Reservoir Definition, a list of research topics that industry might be willing to cost-share with DOE, and some recommendations for making GHTD's Technology Transfer Program more effective from industry's point of view. These comments and recommendations were then transmitted by LBL to GHTD for consideration and possible implementation, and are reviewed below.

PANEL'S COMMENTS ON DOE'S GEOTHERMAL PROGRAM

Upon reviewing DOE's budget history for the Geothermal Energy Program from FY 1980 to FY 1985 and for Hydrothermal Technology Development in particular and after learning about the possibility of a phase-out of the Hydrothermal Research Program in the next few years, the Panel

1) Recommended the continuation of GHTD's Hydrothermal Research Program because of its relevance to industry's needs. The Panel believed that during the last few years this program had been "underfunded" in comparison with the "nonhydrothermal" research programs (i.e., Hot Dry Rock Research and Geopressured Resources). The

Panel felt that continued underfunding of the Hydrothermal Research Program might result from an "oversized" Magma Energy Extraction Program. It was expressed that the Hot Dry Rock Research, Geopressured Resources, and Magma Energy Extraction Programs are only marginally interesting to industry and should not adversely affect the future funding of the Hydrothermal Research Program, especially Reservoir Definition and Brine Injection.

2) Requested details about DOE's latest Geothermal Energy budgets for FY 1985, FY 1986, and beyond (i.e., total budget, breakdown by programs and activities), to be provided before the next meeting of the Advisory Panel.

3) Concluded that the funding allocated to Cascades-related studies in the FY 1985 Reservoir Definition budget is excessive (see Table 6). Some panel members questioned DOE's emphasis on this area and requested more details about DOE's overall program in the Cascades.

4) Recommended that DOE issue periodical memoranda describing the overall Geothermal Program, indicating program objectives, present and future budgets, and project descriptions. These memoranda should be distributed to the geothermal community and published in widely distributed journals, such as the Geothermal Research Council (GRC) Bulletin.

5) Concluded that industry is unlikely to use the huff-and-puff technique of water injection. The funds set aside for this project should be used for solving one of the field-oriented injection problems.

INDUSTRY'S NEEDS AND PRIORITIES

In order to be able to prioritize industry's needs in Reservoir Definition, the Panel defined nine areas of research: Measurements, Chemical Interactions, Mathematical Modeling, Field Surveys, Secondary Heat Recovery Techniques, Geology, Geochemistry, Boundary Mapping, and Fracture Mapping. In turn, these general areas are further divided.

Measurements. This area is divided into surface and subsurface measurements. Surface measurements include flow tests and sanpling methods, especially related to two-phase flow conditions. The subsurface measurements comprise pressure-temperature logs, spinner logs, geophysical logs, casing tool analysis, and subsurface (fluid) sampling.

Chemical Interactions. This area covers topics related to chemical treatment of brines and to rock-fluid and fluid-fluid interactions. It includes problems related to brine injection, scaling, deliberate precipitation (for isolating/sealing-off a given reservoir region), and mineral extraction, as well as general uncertainties in high-temperature kinetics and brine geochemistry.

Mathematical Modeling. This area is divided into modeling in general, modeling of chemical transport, and upgrading of existing codes.

Field Surveys. This area comprises studies covering large parts of, or entire, geothermal fields. It includes tracer studies, flow tests, skin damage evaluations, and case studies.

Secondary Heat Recovery Techniques. This area covers research related to improving the heat extraction from reservoir rocks by fluid reinjection, especially in vapor-dominated systems. It includes studies on fracture geometry, seismicity, tracer surveys, and numerical modeling.

Geology. The needs for better models of geothermal fields and better exploration strategies were recognized and identified as categories of research.

Geochemistry. This area is divided into monitoring the effects of exploitation and the development of geochemical zonation models.

Boundary mapping. This area includes such methods as seismic techniques, magneto-telluric and electromagnetic methods, and (cost-shared) deep drilling to delineate boundaries or fronts in geothermal systems.

Fracture mapping. This area covers techniques such as surface, near-borehole, and cross-borehole methods to detect and characterize fractures in the subsurface and techniques to determine maximum depth of open fractures.

Because of disagreement about industry's needs and priorities on the short- and long-term (more than 3 years), the Panel members voted on the importance of the different areas of research. The results of the rating are given in Tables 8 and 9; details of the voting are included in the minutes of the meeting.'

The Panel found that for the short-term industry needs (i.e., less than 3 years from now), the highest priority was given to improving fracture mapping techniques, determining fracture geometry, subsurface fluid sampling, geophysical logging, improving flow test measurement techniques (especially under two-phase flow conditions), solving chemical problems related to brine injection and the geochemical characteristics of the geothermal brines (including noncondensible gases), and developing geochemical techniques to monitor reservoir exploitation.

For the long-term industry needs (more than 3 years from now), the highest priority was given to chemistry problems related to

mineral extraction from geothermal brines and brine injection, (cost-shared) deep drilling for boundary mapping, techniques to determine the maximum depth of open fractures, numerical modeling of brine injection into vapor-dominated systems to increase the heat extraction from reservoir rocks, flow test techniques (especially under two-phase conditions), and downhole pressure and temperature measurement methods. Lower priority needs are detailed in Tables 8 and 9.

Cost-Shared Projects

The Panel members concluded that industry would be willing to cost-share projects on (1) mineral extraction from geothermal brines, (2) deep drilling (e.g., at The Geysers and in the Cascades), and (3) development of tools and techniques for surface and subsurface measurements. According to the Panel, industry is already doing what it can in other areas of research, and these areas will continue to need DOE funding.

Technology Transfer

The Panel recommended that DOE should

1) Publish an annual bibliography of reports and papers produced under the different programs. The bibliography could be published in the GRC Bulletin, which has a wide industrial readership. It was felt that the references given in DOE'S Geothermal Energy Technology Bulletin were generally not up to date.

2) Report GHTD's activities on a regular basis in the GRC Bulletin.

3) Provide funding for workshops on special topics like fracture mapping and reservoir engineering and continue the GRC short courses because of industry's interest.

FINAL REMARKS

Some of the questions raised by the Advisory Panel, especially on industry needs and priorities for geothermal research, should be given immediate attention by GHTD. Other questions, such as those directed toward the continuity of the Hydrothermal Research Program, the cost-shared programs, and the recommendations on Technology Transfer, should be taken into consideration and incorporated in the geothermal programs for FY 1986 and beyond.

Judging from conversations with GHTD managers, it is expected that by early 1985 DOE will have responded to some of the comments and recommendations made by the Industry Advisory Panel. These would be reviewed during the second meeting of the Panel, tentatively scheduled for March 1985.

ACKNOWLEDGEMENTS

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REFERENCE

1. Minutes of the First Meeting of the Industry Advisory Panel on Geothermal Reservoir Definition, August 21, 1984, Berkeley, California. (Copies are available from the Earth Sciences Division of Lawrence Berkeley Laboratory.)

Table 1. Budget History of DOE Geothermal Energy Program.

Activity	$ (Millions) FY 80	FY 81	FY 82	FY 83	FY 84	FY 85*
Hydrothermal Industrialization	59.6	44.8	31.2	33.0	2.0	1.1
Direct Heat	10.8	10.6	0	0	0	0
Geopressured Resources	36.0	31.9	16.7	8.4	5.0	5.2
Geothermal Technology Oevelopment	41.0	47.9	20.4	14.9	22.4	26.1
Program Direction	2.0	2.3	1.6	1.3	1.0	1.0
TOTAL	$149.4	$137.5	$ 69.9	$ 57.6	$ 30.4	$ 33.4

*as of 12/01/84

Table 2. Budget History for Geothermal Technology Development.

Activity	$ (Millions) FY 80	FY 81	FY 82	FY 83	FY 84	FY 85*
Hot Dry Rock Research	15.0	14.0	10.0	7.5	7.5	9.4
Hydrothermal Research	26.0	33.9	10.4	7.4	5.4	8.7
Hard Rock Penetration Research	0	0	0	0	2.6	4.3
Magma Energy Extraction Research	0	0	0	0	.9	1.4
Scientific Drilling Project	0	0	0	0	5.9	1.0
Technology Transfer	0	0	0	0	.1	0.9
Capital Equipment	N/A	N/A	N/A	0	0	0.4
TOTAL	$ 41.0	$ 47.9	$ 20.4	$ 14.9	$ 22.4	$ 26.1

*as of 12/01/84

Table 3. FY 1984 Budget for DOE/GHTD Hydrothermal Research.

Activity	$ K
Brine Injection Technology	1,948
Reservoir Definition Technology	1,443
Heat Cycle Research	1,536
Support Services	507
TOTAL:	$ 5,434 K

Table 4. FY 1984 Budget for DOE/GHTD Reservoir Definition.

Activity	$ K
Reservoir Characterization (LBL)	550
Fracture Mapping-Electrical Techniques (UURI)	300
Heat Extraction Research (STANFORD)	300
Cascades Resource Definition (USGS)	200
Ocean Hydrothermal (INEL)	93
TOTAL:	$1,443 K

Acronyms:

LBL: Lawrence Berkeley Laboratory
UURX: University of Utah Research Institute
STANFORD: Stanford University
USGS: U.S. Geological Survey
INEL: Idaho National Engineering Laboratory

Table 5. FY 1985 Budget (as of 12/01/84) for DOE/GHTD Hydrothermal Research.

Activity	$ K
Brine Injection Technology	1,613
Reservoir Definition Technology	3,175
Heat Cycle Research	1,580
Permeability Enhancement	900
Geothermal Materials/Fluid Chemistry	1,160
Support Services	250
TOTAL:	$ 8,678 K
Capital Equipment for Hydrothermal Research:	$ 200 K

Table 6. FY 1985 Budget (as of 12/01/84) for DOE/GHTD Reservoir Definition.

Activity	$ K
Reservoir Definition Program (LBL)	200
Reservoir Characterization (LBL)	600
Fracture Mapping-Electrical Techniques (UURI)	200
Heat Extraction Research (STANFORD)	402
Cascades Resource Definition (USGS)	198
Cascades Measurements (IDO)	375
Newberry Caldera Testing (DOGAMI)	160
Cost-Shared Cascades Characterization (IDO)	1,000
Reservoir Characterization (SAN)	40
TOTAL:	$ 3,175 K

Acronyms:

LBL: Lawrence Berkeley Laboratory
UURI: University of Utah Research Institute
STANFORD: Stanford University
USGS: U.S. Geologic Survey
IDO: DOE's Idaho Operations Office
DOGAMI: Oregon Department of Geology and Mineral Industries
SAN: DOE'S San Francisco Office

Table 7. List of Participants of the first meeting of the LBL Industry Advisory Panel on Geothermal Reservoir Definition.

Panel Members	
Mohinder S. Gulati (Chairmain)	Union Oil Company of California
W. T. (Tom) Box	Aminoil, Inc.
Louis E. Capuano, Jr.	Therma Source, Inc.
Herman Dykstra	Consultant
Keshav Goyal	Phillips Petroleum, Co.
Joe Iovenitti	Thermal Power, Co.
William F. Isherwood	Geothermex, Inc.
Walter Randall	GRI Operator, Co.
Ronald C. Schroeder	Berkeley Group, Inc.
Observers	
B. Lea Cox	Lawrence Berkeley Lab
Jon S. Gudmundsson	Stanford University
Marcelo J. Lippmann	Lawrence Berkeley Lab
Phillip (Mike) Wright	University of Utah Research Institute

Table 8. Recommendations of the Industry Advisory Panel on Geothermal Reservoir Definition: Industry short-term needs.

FIRST PRIORITY

Fracture Mapping

Near-borehole methods
Cross-borehole methods
Surface techniques
Determination of maximum depth of open fractures

Field Surveys

Flow tests

Secondary Heat Recovery Techniques

Fracture geometry

Measurements

Subsurface sampling
Subsurface logging
Surface flow tests (especially two-phase flow)

Chemical Interaction

Brine injection
Brine geochemistry (including noncondensible gases)

Geochemistry

Monitoring effects of exploitation

SECOND PRIORITY

Field Surveys

Tracer surveys
Skin damage
Case studies for model validation

Chemical Interaction

High temperature kinetics
Scaling tendencies
Mineral extraction

Measurements

Subsurface spinner
Subsurface P-T measurements
Surface sanpling (especially two-phase flow)

Geology

Better models of geothermal fields
Exploration strategies

Boundary Mapping

MT method
EM method
Cost-share deep drilling
Seismic techniques

Secondary Heat Recovery Techniques

Nunerical methods
Tracer surveys

Mathematical Modeling

Chemical transport
Upgrade existing codes
Modeling in general

Geochemistry

Geochemical zonation models of geothermal systems

THIRD PRIORITY

Measurements

Casing tool analyses

Secondary Heat Recovery Techniques

Seismicity

Chemical Interaction

Deliberate precipitation to keep water out

Table 9. Recommendations of the Industry Advisory Panel on Geothermal Reservoir Definition: Industry long-term (>3 years) needs.

FIRST PRIORITY

Chemical Interaction

Mineral extraction
Brine injection

Fracture Mapping

Determination of maximum depth of open fractures

Secondary Heat Recovery Techniques

Numerical modeling

Boundary Mapping

Cost-share deep drilling

Measurements

Surface flow tests (especially two-phase flow)
Subsurface P-T measurements

SECOND PRIORITY

Chemical Interaction

Scaling tendencies
High temperature kinetics
Brine geochemistry (including noncondensible gases)
Deliberate precipitation to keep water out

Boundary Mapping

MT methods
EM methods
Seismic techniques

Secondary Heat Recovery Techniques

Tracer Surveys
Fracture geometry

Measurements

Subsurface logging
Surface sanpling (especially two-phase Flow)
Subsurface spinner

Fracture Mapping

Surface techniques
Cross-borehole techniques
Near-borehole techniques

Field Surveys

Case studies for model validation
Flow tests
Skin damage

Geology

Exploration strategies
Better models of geothermal fields

Mathematical Modeling

Chemical transport
Modeling in general

Geochemistry

Geochemical zonation models of geothermal systems

THIRD PRIORITY

Measurements

Casing tool analyses
Subsurface sanpling

Field Surveys

Tracer surveys

Geochemistry

Monitor effects of exploitation

Mathematical Modeling

Upgrade existing codes

Secondary Recovery Techniques

Seismicity