GLO1821

CASCADE GEOCHEMISTRY

During the past several years, it has become increasingly apparent that the exploration techniques applied to basin and range geothermal systems are poorly suited for use in the Cascades. At the same time, there is little doubt that each of the geoscientific disciplines, geology, geochemistry, and geophysics can each play an important role in the exploration of resources associated with stratovolcano complexes.

Presently, however, there is a significant gap in our understanding of the geometry of geothermal systems in volcanic terranes. For example, there is some data to suggest that fluid compositions in volcanic systems are zoned around the heat source and that the extent of the water-rock interactions varies systematically upward. Other data from volcanic systems, such as Newberry and Meager Creek, seem to suggest that there may be individual convection cells or paths and that fluids having different paths evolve independently.

Geochemical techniques are well suited for obtaining fundamental information of this type. Chemical data on the geothermal fluids can be obtained directly when sampling is possible or through analyses of fluid inclusions contained within secondary mineral phases. Information on the relative amount of water that has passed through the rocks is determined from the extent of isotopic exchange that the rock and water has undergone. It is noteworthy that studies of hydrothermal mineral assemblages using petrographic techniques only provide evidence that hydrothermal fluids were present, not their abundance. Supplemental chemical analyses of the rocks may provide additional data on water-rock ratios through mass-balance calculations. Finally, information on the evolution and source of the fluids can also be obtained from the isotopic composition of the waters and from the distribution of their chemical constituents.

Studies of this type have been conducted at Meager Creek and initiated at Newberry. However, additional studies of other geothermal systems are needed before the systematics of water-rock interactions in volcanic systems are understood and general concepts developed. Study of core and cuttings from the wells drilled under the DOE Cascades Program should provide significant new data on these important questions.

TECHNICAL ASSISTANCE

CASCADES THERMAL GRADIENT DRILLING PROGRAM

Geothermal systems in the Cascades have remained elusive exploration targets, with confirmed resource temperatures present only at Meager Creek in British Columbia, Newberry Caldera in Oregon, and Lassen Peak in California. Numerous reasons have been proposed for the apparent lack of geothermal systems in this province rich in volcanic heat sources, including the proposition that geothermal systems are not present. If they are present, it is clear that exploration will be both expensive and risky. Both the risk and expense can be mitigated somewhat through the development of application of valid exploration strategies. Each strategy must be developed and applied with cost in mind, progressing from less expensive methods early in the program to more expensive methods utilized to site expensive production-scale wells. In this way, the financial risk can be limited.

Although few high-temperature geothermal systems are known in the Cascades Province, producing geothermal systems occur in similar settings in other parts of the world. These include the Neovolcanic Belt of Mexico, the volcanic belt of Central America, and the island arc environments of New Zealand, Japan, Indonesia, and the Philippines. Data are available for most of these environments and can be used in establishing conceptual models for geothermal systems in andesitic volcanic environments in general. In addition, abundant data are available for fossil hydrothermal systems in these environments, that is, hydrothermal ore deposits in sub-volcanic settings. This literature can provide valuable information on the character of fracturing and faulting in these environments and the ability of these channels to carry hydrothermal solutions.

The Cascades Thermal Gradient Drilling Program is expected to contribute materially to knowledge of heat flow and other aspects of potential Cascades geothermal environments. Data generated from this program will require integration into available data bases, and interpretation and publication in order to maximize their utility to industry and stimulate geothermal development. The program of work proposed below is designed to maximize results from the impending Cascades Thermal Gradient Drilling Program.

UURI Tasks

1. Planning Assistance. UURI will provide Idaho Operations with assistance in planning research activities, exploration programs, the Cascades Thermal Gradient Drilling Program, technology transfer, and other aspects of the Cascades program as requested.

2. Techical Assistance for Drilling. UURI will provide technical assistance and advice to DOE for the drilling operations on this program as required. We will review drilling plans, track drilling progress, provide advice as requested during drilling and document drilling experience for the benefit of subsequent exploration in the Cascades. We will provide on-site assistance as requested by DOE.

3. Data Collection and Dissemination. UURI will establish sampling procedures for lithologic samples acquired in the drilling operation. We will archive splits of the drill chips and fluid samples in the Geothermal Sample Library. We will archive all data in our library and will release data to the public by open-filing as instructed by DOE.

4. Lithologic Logging. We propose to produce lithologic logs of the cuttings and core, to interpret the logs in relation to the local surface

geology, and to produce geologic cross sections.

5. Aquifer Characterization. One of the key objectives of DOE's program is the evaluation of the effects of stacked aquifers and cold water flow that has been postulated in these aquifers, on surface geothermal manifestations. We propose to evaluate the extent of cold water overflow in each drill hole. We will obtain several temperature profiles in each hole until an equilibrium profile is obtained.

Another component will be to add chemical tracers to the drilling fluid as necessary. These tracers will allow the determination of the amount of drill fluid contamination of water samples collected for chemical analyses and the calculation of chemical geothermometers. We propose to investigate hydrothermal alteration in drill chip and core samples to determine the maximum temperatures experienced by the rocks and compare those with the present temperatures measured in the holes.

6. Supplemental Data Collection. UURI will collect supplemental data that may be deemed necessary to the evaluation of the drilling project as a case study, or to evaluation of specific exploration techniques. For example, in some areas it may be judged important to have electrical resistivity geophysical data, which the proposer does not already have, to either site the drill hole, to evaluate the effectiveness of the resistivity technique for a specific project or to round out a specific case study. We will work closely with DOE-ID to determine what data need collection under this task.

7. Case Studies. To be of maximum use to geothermal developers in the Cascades, the data acquired through this program will be compiled into a case study of the entire program. This case study will include a review of existing literature, a discussion of the siting criteria used for the thermal

gradient holes, and the results of topical reports, open-file data, and other geoscientific work done on each hole, both by us and by others.

8. Cascades Exploration Strategies. Using all of the information developed from the program, we will formulate optimum exploration strategies for the Cascades region. We will examine the contribution of each of the commonly used exploration and reservoir assessment techniques to siting discovery and step-out wells, and will evaluate cost effectiveness of each method. The results will be one or more suggested strategies, i.e. combinations of existing exploration techniques that appear to be the most effective in discovery and assessment of geothermal resources in the Cascades region.

9. Technology Transfer. It will be important to communicate results of the above work to industry, and a series of workshops and conferences will be conducted. Transactions of these meetings will be published to help document results. In addition, the results of these efforts will be presented at professional meetings and reports will be submitted for publication in professional journals.

Other Work

1. Heat Flow Studies. David Blackwell of Southern Methodist University has been measuring and interpreting heat flow values in the Cascades region for many years, and is the recognized expert on this topic. He should be funded to measure precise temperature gradient and thermal conductivity on the DOE wells and core samples for the purpose of heat flow determination, and to interpret the results.
2. Environmental Aspects. It will be important to be sure that environmental concerns are accounted for in the drilling program. EG&G Idaho, Inc. will

be funded to perform this function.

3. <u>Data Integration and Evaluation</u>. A certain amount of funds should go to the State Resource Assessment Teams in Oregon, Washington and California to integrate and interpret the new data developed on the Cascades Thermal Gradient Drilling Program.

Funding

	FY 85	FY 86	FY 87
UURI	325	250	100
EG&G Idaho, Inc.	50	50	25
Southern Methodist University	---	75	40
Oregon Division of Geology and Mineral Industries	---	50	25
Washington Department of Natural Resources	---	50	25
California Division of Mines and Geology	---	25	10

GEOTHERMAL EXPLORATION STRATEGY FOR THE CASCADES VOLCANIC PROVINCE

Background

In an effort to simulate geothermal development in the Cascades region of the United States, DOE is sponsoring the Cascades Thermal Gradient Drilling Program. Geothermal development in the Cascades has been limited by the paucity of surface thermal expresssions, perhaps resulting from extensive cold water flushing of near-surface aquifers. The objective of DOE's program is to cost share drilling which will hopefully sample thermal zones beneath the influence of the near-surface cold aquifers. Proposals have been solicited for the drilling of 2000- to 3500-foot holes with DOE sharing in up to 50 percent of the cost of the holes. For their contribution, DOE requires that certain samples and data be collected, including but not limited to, the following: geophysical well logs, cuttings and core samples, fluid samples, and aquifer test data. The data will be released to the public to further stimulation exploration interest. In addition, it is expected that State Geothermal Resource Assessment Teams will conduct field studies in the areas of drilling, and that this work will contribute valuable site-specific information to the project through topical reports.

Geothermal systems in the Cascades have remained elusive exploration targets, with confirmed resource temperatures present only at Meager Creek in British Columbia, Newberry Caldera in Oregon, and Lassen Peak in California. Numerous reasons have been proposed for this, including the proposition that geothermal systems are not present. If they are present, it is clear that exploration will be both expensive and risky. Both the risk and expense can be mitigated to some extent through the application of a valid strategy for exploration in this environment. We have proposed a strategy for the Basin and Range Province (Ward, Ross and Nielson, 1981) which utilized our experience with DOE's Industry Coupled Drilling Program. That strategy began with a conceptual model of the resource and then applied specific exploration methods to both locate the resource and update the conceptual model. These methods were applied with cost in mind, progressing from the less expensive methods early in the program to more expensive methods which are utilized to site expensive production-scale wells. In this way the financial risk is decreased since the prospect can be dropped at any time prior to the application of a more expensive method.

Although few high-temperature geothermal systems occur from the Cascades Province, producing geothermal systems occur in similar settings in other parts of the world. These include systems in the Neo-Volcanic Belt of Mexico, the volcanic belt of Central America, and the island arc environments of New Zealand, Japan, Indonesia, and the Philippines. Data is available for most of these environments and can be used in establishing conceptual models for geothermal systems in andesitic volcanic environments in general. In addition, abundant data is available for fossil hydrothermal systems in these environments. That is, hydrothermal ore deposits in sub-volcanic settings. This literature can provide valuable information on the character of fracturing and faulting in these environments and also the ability of these channels to carry hydrothermal solutions.

We propose to apply existing data bases, the new data to be generated under DOE's Cascades Thermal Gradient Drilling Program, and our experience with geothermal exploration programs and techniques to formulate an exploration strategy for the Cascades Province.

Statement of Work

Task 1 - Literature Review. The available literature for the Cascades province and for geothermal systems in similar settings, including hydrothermal ore deposits, will be reviewed. This review will concentrate on 1) the establishment of conceptual models of geothermal resources in this environment, and 2) the application and success of various exploration methods in defining or locating these systems.

Task 2 - Data Compilation and Reduction. Numerous geophysical surveys have been completed in the Cascades. In particular, aeromagnetic and some electrical resistivity data is available. This data will be acquired and analyzed to provide a determination of their potential effectiveness in the exploration for geothermal systems in the Cascades.

Task 3 - Integration of Data. The available information will be analyzed to form a conceptual model or series of conceptual models of Cascades-type geothermal systems.

Task 4 - Exploration Strategy. The data on exploration techniques will be combined with a knowledge of their costs and applied to the conceptual models of the geothermal systems. This will result in a proposed exploration strategy for Cascades-type geothermal systems.

Task 5 - Reporting. The results of these efforts will be presented at a professional meeting and a report will be submitted for publication in a professional journal.

Reference

Ward, S. H., Ross, H. P., and Nielson, D. L., 1981, Exploration strategy for high-temperature hydrothermal systems in Basin and Range province: American Association of Petroleum Geologists Bulletin, v. 65, no. 1, p. 86-102.

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July 22, 1985

MEMORANDUM

TO: Sue Prestwich

FROM: Mike Wright

SUBJECT: Additional Negotiations Items for Cascades Drilling

The following items should be negotiated into contracts for Cascades drilling in addition to those in my memo of last week.

1. During intervals when core is not being collected (rotary or plug bit drilling), drill cuttings will be collected. Plug bit cuttings are very fine, and special care will be required to collect a sample.

2. The participant should agree to provide any special training needed for the drill crew in proper sample collection and handling procedures. These procedures are the topic of a separate brief which is attached, and the participant should agree to follow these procedures. The participant will be responsible for quality control of the sample collection and data handling.

3. The participant should agree that there will be no splitting or other selected sampling of core or cuttings until after the on-site lithologic log is made and until such selected sampling is agreed with DOE.

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July 19, 1985

MEMORANDUM

TO: Sue Prestwich

FROM: Mike Wright

SUBJECT: Notes on SOW's for Cascades Drilling Negotiations

General Items

1. It is deemed adequate for the contractor to have only 1 geologist on the drilling project provided that:

   (a) The geologist is experienced and has been successful in drilling holes of the nature proposed;
   (b) The geologist will be on 24-hr call;
   (c) There is access to supplemental geologic expertise on 24-hr notice with quick response time in case of need;
   (d) The drilling supervisor for the drilling contractor is well experienced and is available on 24-hr call; and
   (e) There is access to a drilling consultant.

2. There is probably no need to split the core in view of the cost for the large amount expected. DOE should try to negotiate that the contractor retains a suitable skeleton core, with the rest going to DOE. The State of Oregon should also have access to a skeleton core if they desire. UURI can archive the majority of the core, and it may or may not ultimately go to Grand Junction.

   In order that appropriate skeletons be made, representatives of the contractor, the State of Oregon and UURI should agree by all being present. No core or other samples are to be removed independently by any party. No party should take the entire core interval of a particular lithologic unit. Regarding chip samples, enough should be available for everyone.

   DOE will probably have to pay for shipping of samples to UURI.

3. Regarding the geophysical well logs, DOE should try to negotiate delivery to DOE of a magnetic tape containing the digitized logs. They will greatly facilitate the analyses that UURI will undertake of the well logs. Paper copies of the analog logs should be available also.

4. During negotiations it will be important to agree with the contractors that fluid samples are required and an effort will be made to obtain them. The choices of fluid sampling methods were given to Sue Prestwich in my memos of 29 May 85, copies of which are attached.
   Water samples should be taken in accordance with the best geothermal industry standards. UURI will furnish specific instructions for each project for DOE's samples. The contractors should be free to collect theirs any way they want.

Blue Lake Geothermal Company Proposal

1. The proposed "core garden" will expose the core to unnecessary risks. The core would be exposed to the elements with the chance that some of the clayey portions may be washed away or that the wind could turn the corregated fiberglass over and jumble the core. We would prefer that the core be boxed and marked properly in accordance with standards which UURI will furnish. DOE may have to pay for the boxes under this plan.

2. Under 2.0 Scope on page 2 of the SOW, the location is wrong. We believe it should be T13S.

GEO Operator Corporation Proposals

1. Under 2.0 Scope on page 2 of the SOW, the location is wrong. It cannot be "3500 feet north and 2400 feet north" of the ... Should underlined north above be west?

2. According to the information given, the black iron pipe to be used will have a weight of 3.15 lbs/ft and the couplings will have a minimum tensile strength of 20,000 lbs. The maximum tension on a coupling would be 3.15 lbs/ft x 4000 ft = 12,600 lbs. The maximum tension that the string of pipe is exposed to could increase appreciably if the pipe needed to be removed and became stuck. Otherwise, for completion for heat flow studies, the pipe and couplings are adequate. If fluid sampling will require removal of the black iron pipe at a later date, the strength may not be enough.
   This subject should be considered when DOE negotiates fluid sampling. Will fluid samples be obtained before the black iron pipe is set? If so, the pipe is adequate.

3. Regarding GEOOC Item 2 in their letter of 3 July 1985 to Hyster,

   (a) The Hg survey may or may not be warranted and at this time we recommend that the core be evaluated before a decision. If $7500 is DOE's share, it's too high. If DOE's share is 1/2 x $7500, it's reasonable. Th Hg survey should be included as an option.

   (b) The oriented core may or may not be worthwhile depending on lithology. This should be an option to be decided later. Equipment for obtaining oriented cores will not function in temperatures above about 100°C.

(c) Seismic monitoring should not be considered at this time.

Thermal Power Company

1. On page 8 of SOW, "Maximum Temperature Reading", it is probably overkill to take a temperature reading every core run, which would be time consuming. It will be adequate to measure BHT at each shift change or other similar opportunity.

2. On page 10, last sentence first paragraph, there is a missing word.

3. On page 15, Hole Design, Point 4. 6-1/2" casing is probably OD. ID would be almost exactly 6", and a 6" bit probably will not fit. The drilling engineer will undoubtedly see this problem.

attachments

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CONFIDENTIAL

MEMORANDUM

May 29, 1985

TO: Susan Prestwich

FROM: Mike Wright

SUBJECT: Recommendations on Cascades Scientific Drilling

As a result of the meeting which I convened in Menlo Park at your request and of further thinking on the specific Cascades proposals in light of what I have learned of the gaps in knowledge of Cascades geothermal systems, I would like to make some points and recommendations that may be of use to you.

1. In my opinion, a serious omission of the current proposals for Cascades drilling is lack of adequate plans for obtaining fluid samples. Especially at the Thermal Power and Blue Lake proposed locations for drilling, there are unanswered questions about movement of fluids at depth. None of the research programs to date (USGS, DOGAMI, SMU) have answered the questions about possible westward flow of thermal waters from the volcanically active High Cascades. If the known thermal springs along the boundary between the High Cascades and Western Cascades are an indication of this outflow, the net permeability along the flow path is high, which has great exploration significance. We need subsurface fluid samples (as well as very deep drilling) to get at this problem.

2. Adequate temperature-gradient and heat-flow values can be obtained by periodically reading bottom-hole temperature during drilling with a

maximum-reading thermometer. Precise temperature logs in cased holes taken at intervals after drilling would be nice, but could be done without if the sacrifice meant being able to obtain fluid samples.

3. I recommend that if possible the contacts be so negotiated that either; (a) The holes are left uncased until a fluid sample can be obtained, even at the risk of losing part of the hole before a precision temperature log can be made. If the hole is lost we could rely on BHT's during drilling; or (b) the black iron pipe is not cemented in. It would then be possible to remove it with an appropriate rig and to try to produce the well by air lift, and/or to obtain downhole fluid samples. The casing could be left in the hole long enough to obtain an equilibrium temperature profile.

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May 29, 1985

MEMORANDUM

TO: Susan Prestwich

FROM: Mike Wright

SUBJECT: Meeting on Scientific Objectives of Drilling in the Cascades Range

On 23 May 1985 I convened a short meeting at your request of a select group of scientists who were attending the USGS Cascades workshops in Menlo Park for the purpose of discussing potential scientific objectives of drilling in the Cascades Range. The information gained at that meeting may be useful to you in evaluating the proposals written in response to the latest SCAP on the same topic. Several people in attendance at the meeting were also on the Technical Advisory Panel for the SCAP. We deliberately stayed away from discussion of any material related to the response to the SCAP, and instead treated the topic in a generic sense, i.e. what specific types of information do the scientific community want and what are the priorities.

In attendance at the meeting were: Marshall Reed, Clay Nichols, Marty Molloy, Norm Goldstein, Marcelo Lippman, Patrick Muffler, Bob Mariner, Mike Sorey, George Priest, Dave Blackwell and Mike Wright.

A summary of conclusions from the meeting is given below:

1. Three types of information are nearly equally important to obtain from the drilling:

   (a) core or cuttings samples, carefully acquired, for lithologic information;
   (b) a temperature log; and
   (c) fluid samples from the various aquifers.

   These items are in their order of priority, but they are all very important.

2. Blackwell noted that it will be important to get bottom-hole temperatures at each stopping point in the drilling by lowering a maximum-reading thermometer in the hole. This will help in planning completion and temperature logging.

3. It was agreed that fluid samples from drill holes are important for research into the fluid flow regime in the Cascades. Speaking as a member of the TAC, I believe that a serious deficiency exists in lack of plans in the current proposals to obtain water samples. There are essentially three ways in which water samples could be collected:

   (a) By producing and sampling water at the well-head. This will require either a down-hole pump or an air lift. Provision must be made at the surface to handle and dispose of a sufficient volume of water to thoroughly clean the hole of drilling fluids before sampling;

   (b) By use of a down-hole sampler. Slim-hole samplers are available. If used in conjunction with (a) above, it may be possible to separate the effects of various aquifers. Otherwise the sampler would have to be used weeks to months after drilling in the hope that fluid flow in aquifers had flushed drilling fluids away. This is clearly not compatible with putting permanent casing in the holes.

   (c) By doing one or more drill stem tests during drilling. The test would have to be conducted for a large enough period to acquire uncontaminated samples, which would require fluid handling facilities on the surface. The availability of slim-hole DST equipment was questioned.

4. For the purpose of obtaining good heat-flow measurements, it will be better to cement casing into the well. However, this precludes other useful work, such as removing the casing at some time to acquire fluid samples after casing is set.

5. Another important parameter, but of lesser importance than those listed in (1) above, is obtaining a measure of permeability at depth. This could conceivably be done with an injection test, but injecting cool water into a hot zone will perturb the data interpretation.

6. Geophysical well logs are important to obtain in the well and can be used to help characterize porosity, permeability and perhaps changes in native fluid characteristics.

7. There was some discussion on the advisability of setting up a steering committee to help advise DOE on matters such as potential completion techniques, etc. as the drilling progresses.

CASCADES DEEP THERMAL GRADIENT DRILLING PROGRAM
PROPOSED FY 86 EFFORT

The following budget breakdown is proposed for the Cascades program in FY 86:

Drilling	$500 K
Technical Support to Drilling	
UURI	100
EG&G	25
Research	
UURI	225
DOGAMI	100
SMU - Blackwell	50
	$1,000K

Drilling

Two more drilling projects would be initiated through the SCAP process. Because the Thermal Power project, obligated in FY 85, is to be drilled in the summer of 1986, there would be three holes drilled in 1985 and three in 1986. The SCAP would be issued in late November, 1985 with awards in February and contracts negotiated in March/April, 1986, in plenty of time for the summer season.

Technical Support to Drilling

The objectives of this budget item are: (1) to assure that the drilling projects are safely and successfully completed, (2) to assure the quality of the rock and fluid samples and the data collected during and after drilling, (3) to release data to the public, and (4) to curate the samples and data. Tasks to be performed include:

1. Daily contact with DOE contractor. UURI would maintain daily phone contact with the DOE contractor and/or the driller during drilling, logging and completion, including weekends. More frequent contact would be made as necessary. UURI would keep drill records, progress reports, reports of problems, casing reports, etc. up to date, and would also keep a running estimate of expenditures to date.

2. Daily contact with DOE. UURI would make daily reports on project status to DOE. These reports would include status, daily drilling progress,

assessment of problems, plans, anticipated problems, noteable events such as lost circulation, stuck rods, etc. and mitigation measures. The Friday reports would anticipate occurrences expected during the weekend.

3. Site Visits. UURI would be prepared to visit the site at any time to lend advice, give first-hand status reports to DOE, and act as DOE's representative to the extent legally allowed.

4. Quality Assurance. UURI would perform an independent assessment of sample and data collection techniques and of the quality of data collected. This quality assurance program would include collection of rock samples, collection of fluid samples, geophysical well logging, lithologic logging of samples, mud logs and reports kept on the rig by the DOE contractor, and all other items. UURI would endeavor to work with the site personnel to maximize quality of data, samples and procedures.

5. Data Archiving and Open-Filing. UURI would collect and archive copies of all data as well as DOE's share of samples collected in this program. UURI would make samples available for inspection and use by others and would open-file copies of all public data according to procedures used during the Industry Coupled Program.

6. Environmental Concerns. EG&G would assess environmental concerns for each project and assess the plans that each contractor has to meet these concerns. EG&G would advise DOE of the adequacy of plans and of the actual environmental mitigation measures through site cleanup and plugging and abandoning.

7. Documentation. UURI would publish written reports on each project to document the project and all data collected.

Research

The gradient wells to be drilled in the Cascades will generate a great deal of valuable new data. It is DOE's obligation to release these data to the public and to document each drilling project, including interpretation of the data. In order to derive optimum results from the program, it is anticipated that other new data, not generated directly by the drilling, will be needed. For example, it may be advisable to complete new geophysical or geochemical surveys of one or more sites to evaluate specific explanation techniques to expand knowledge gained by the drilling.

At the same time, it is likely that not all of the holes will succeed in intersecting a geothermal resource. Although studies on those holes that fail to find anomalous temperatures could be interesting and productive, limited research money and effort may be more wisely spent at sites where conditions are anomalous. Because it is not possible prior to drilling to predict the outcome of the drilling projects, it is not meaningful at this time to specify what research data should be collected and in which areas.

It is ID's recommendation that before a program of research is undertaken, a preliminary study of the drilling results of the 1985 season be made. The objective of this preliminary study would be selection of both the research areas and techniques so that the research results would be optimized.

Because of the limited research funds available, only a limited number of groups can be supported. We must avoid scattering small amounts of money too widely to be of real use in completing an integrated research program. With this in mind, we recommend that UURI be tasked to do a comprehensive geological, geochemical and geophysical research program, that DOGAMGI be tasked to do geologic analysis and interpretation of one or more selected drilling areas, and that SMU be tasked to obtain detailed temperature logs in the wells and perform thermal conductivity measurements and heat flow studies. A cooperative research effort is envisaged among these three groups, with selection of research topics and approval of a research program to be given by DOE. We would also involve the industry by determining what research they would like to see accomplished. In general terms, the program would consist of the following:

UURI Program. UURI would:

(a) select one or two areas for study based on the 1985 drilling results. In these areas, an evaluation would be made of what data are missing that might contribute substantially to knowledge of the area. An evaluation would also be made of which exploration techniques merit testing. Surveys to acquire the data and test selected techniques would then be performed.

(b) continue studies begun in FY 85 of the nature of permeability development in the Cascades province. One of the critical topics missing from the USGS Cascades program (as presented at their workshop in May, 1985) is the nature of permeability, especially of the deeper horizons, perhaps characterized in the High Cascades by rocks now exposed in the geologically deeper and older Western Cascades. Models for permeability development could be combined with USGS models from their research on the nature of heat sources. We may then be able to develop tools to predict the location of hydrothermal systems around the heat centers.

DOGAMI Program. DOGAMI is in a good position to help evaluate the drilling results and to perform certain research work. DOGAMI would participate in the research program as approved by DOE after the preliminary evaluation of 1985 drilling results. UURI and DOGAMI would work closely together on this task.

Southern Methodist University Program. Dave Blackwell would be funded to provide temperature logs and heat flow studies from the drilled wells. To the extent possible, he may be able to furnish 2 or 3 temperature logs at different times after drilling, including an equilibrium log. These would be useful in distinguishing permeable zones.

Other Research. Other researchers, working on separate DOE funds or on other funds, would be integrated into this cooperative program. For example, we suggest that part of the DOE funding to LBL under the Reservoir Definition Program could be spent in Cascades research. The work of the USGS program in the Cascades would also be considered in DOE's program with the objective of cooperation to optimize DOE's program.

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MEMORANDUM

May 9, 1984

TO: Clay Nichols and Sue Prestwich

FROM: UURI

SUBJECT: Thoughts on Cascades Cost-Shared Drilling Program

This memo discusses some potential philosophies for the Cascades Cost-Shared Drilling Program.

OBJECTIVE

We believe that the basic objective of the program must be an industry-oriented one, rather than one directed more along scientific lines. We suggest the following:

Objective: To stimulate discovery and development by industry of high-temperature geothermal resources in the Cascades province.

In order to stimulate development in the Cascades, the biggest problem to be overcome is in finding effective means to explore for and discover resources there.[1] Therefore, the program should not be limited to drilling,

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[1] At the direction of Ron Toms, development of exploration technologies is not a funded activity in the Reservoir Definition Program plan, but it is clear that such research is needed to assist industry in the Cascades as well as elsewhere.

but should embrace a carefully formulated research program based upon testing various exploration and reservoir definition techniques against the ground truth that the drilling data will provide.

STRATEGIES

In order for the program to achieve maximum success, it will be necessary that significant geothermal temperatures ($\geq$ 90 °C) be found in at least one test hole. This requirement would dictate that the maximum number of holes be drilled to the maximum depth in the best areas as presently known. Such a goal is not financially compatible, however, with obtaining an acceptable amount of scientific information from the holes. At minimum, the holes will require proper logging, casing, and completion in order to preserve them in an appropriate condition for subsequent experimentation. This means that an idea of experiments that are likely to be run on the holes is needed now so that logging, casing and completion can be specified. Leaving the holes in good condition for subsequent experiments will be costly, but not so costly as the experiments themselves.

We suggest that the Cascades Program needs to be viewed as a two-year program at minimum. This would allow the following strategy:

FY 85 -	Spend the maximum amount possible on drilling, logging and completing the holes.
FY 86 -	Perform appropriate experiments on the holes. Deepen selected holes, if necessary. Drill new holes as appropriate.
FY 87 and beyond -	The program could conceivably go through several phases of drilling and experimentation.

Several other items of strategy need to be considered. One such item is the following: It is unlikely that we will know for sure during drilling when we have drilled below the zone of cold-water overflow. It is considerably less likely that we will know how deep to drill at the outset, before drilling starts. We are therefore in the position that we may be discouraged by our results at a site which actually has a resource at depth simply because we have not drilled deep enough.

The question is, do we pick, say, 2 sites and drill and log until we are satisfied that we are below the "rain curtain", even though it may cost more than we hoped, or do we commit to spend a certain fixed amount, say $150K (with an additional $150K from the participating company), on 7 sites and take what we get? This question needs to be thoroughly explored before the SCAP is written--it affects the entire program.

PARAMETERS TO BE DEFINED BY PROPOSERS

Assuming that a maximum of the FY 85 funds will be spent on drilling and appropriately preserving the wells and that scientific work will be funded in FY 86, at least the following parameters need to be defined or limits placed in the solicitation so that the FY 85 program is properly done:

Hole Diameter and Casing Program. The larger the hole, the more costly. However, if the diameter is too small, deepening may be impossible and installation of a pump may be precluded. The SCAP should specify potential experiments to be done later and that some evaluation criteria will be based on an adequate drilling and casing program that results in a hole useful for future purposes. The SCAP should also specify that we need to know the level of the water table at proposed each site (if known).

Logging. We believe that the wells should be comercially logged. This way, a certain expenditure will more or less guarantee us usable logs. We suggest a conservative logging program, but one to include not less than caliper, temperature, resistivity, SP and perhaps sonic velocity or neutron density or televiewer. These logs are designed to measure temperature and detect fractures rather than map lithologies. We will know the lithology well enough from chip logging.

Core Intervals. Obviously coring the entire well would be scientifically valuable, but perhaps not cost effective in terms of getting the most hole for the money. The question of how much to core and its cost should be looked at before the SCAP is written so that general guidelines can be given.

Site Selection. The concept that the best possible sites must be prioritized and drilled from highest priority to lower seems acceptable to all. The selection committee that DOE is setting up should help to ensure this.

ROLES OF GOVERNMENT ORGANIZATIONS

Clearly, UURI and the States will overlap to some degree in what we would propose to do. There will also be some overlap with the USGS. Here are our tentative suggestions:

1. USGS. Their role should be primarily in hydrology, since this will be important to site selection and subsequent drilling and they have strengths here. Ed Sammel will be a big help, and we may also want to get some of Mike Sorey's time, too.
2. States. We suggest that the States be heavily involved in site selection, that they log the drill chips/core during drilling and that they help provide supplementary data for drill site selection as needed. A split of the chip/core samples should go to the States.
3. UURI. We suggest that UURI be involved in site selection, provide technical liasion between drillers and loggers and DOE, provide mineralogic and X-ray work on samples as needed, collect water samples

and provide chemical analyses as needed and collect and open file all of the data. A split of the chip/core samples would be stored in the Geothermal Sample Library. UURI can also provide supplementary data collection if needed.

4. LBL. We suggest that LBL be needed in site selection only. Since as scientific work is likely, unless funded out of SAN's reservoir definition program, they probably can't contribute beyond this.

AGREEMENT WITH PARTICIPATING COMPANIES

We suggest that DOE agree with participating companies as follows:

1. DOE will put up a contaminant per hole or drill with certain set objectives are met. ~~The~~ participating company will be expected to match this in money or in kind.
2. The holes will be drilled, cased and completed as appropriate under contracts issued by the participating company. The participant will be responsible for logging contracts, and a minimum logging program, as agreed with DOE, will be performed.
3. All data generated by the cost-shared drilling will be in the public domain after a 6-month confidentiality period (no confidentiality period unless the participant requests it).
4. The participant is welcome to do work beyond his committment, and if such work is done within 12 months of the DOE cost-shared drilling, DOE will have rights to certain of the data thereby generated, as agreed with the participant.
5. Chip samples will be collected by the drilling contractor as agreed to with DOE, and made available to UURI and to the state geologic team.
6. More favorable evaluation will be given to those companies that put a

larger or more meaningful data package to be released into the public domain than to those who release little.

7. Promises of cooperation with government representatives and researchers will be favored in evaluation of proposals. This concept could be explored to include favorable evaluation to those also proposed to actively work with government research, i.e. contribute staff time and data to research objectives.

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9-23-85
DATE

Marshall Reed	DOE / DC	
TO	ORG./LOCATION	TELEPHONE NUMBER
Mike Wright	UURI	
FROM	ORG./LOCATION	TELEPHONE NUMBER

THIS TRANSMITTAL CONSISTS OF 1 PAGES.
(excluding cover sheet)

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GEOPHYSICAL TECHNIQUES APPLIED TO GEOTHERMAL EXPLORATION IN THE CASCADE RANGE, WESTERN UNITED STATES

Most of the reported applications of geophysics to geothermal exploration in the Cascades have been made for research purposes by the U. S. Geological Survey, which has maintained a geothermal research program in this area since 1979. The U. S. Department of Energy has provided partial funding for this program. Several universities and state geological surveys have also contributed. Geophysical techniques have been applied for essentially three purposes; (1) understanding of regional geology, (2) detection of geothermal heat sources (magma bodies < 10 km deep), and (3) detection of fracture systems and associated hydrothermal convection.

Measurement of heat flow in the Cascades requires holes more than about 1 km deep in order to avoid influence from the shallow hydrologic regime. Based on relatively few reliable data points, the belt of active volcanism, called the High Cascades, appears to have an average heat flow of 70-100 mw/m^2. There appears to be a sharp western transition to lower heat flow values ($\approx$ 40 mw/m^2) in the Western Cascades, which are comprised of volcanic rocks 18-40 my in age.

The gravity technique has assisted in placing constraints on rock type beneath active volcanic areas. Positive anomalies are found beneath Medicine Lake, Crater Lake, Mt. Lassen and Newberry caldera when a density of 2200 kg/m^3, corresponding to the average density of the volcanic cones, is used in the Bouguer reduction. This indicates subsurface rocks of density 2800-2900 kg/m^3 beneath the volcanos. The aeromagnetic technique has been used to map faults and similar structures and to indicate the depth to the Curie-point isotherm. It has been found to be only marginally useful.

Seismic techniques have been used to study subduction beneath the Cascades and, more importantly, to try to detect magma bodies beneath known volcanos. P-wave travel-time studies from teleseisms and high resolution travel-time studies from nearby blasts have surprisingly known high-velocity bodies beneath Mt. Hood, Mt. Lassen, Mt. Shasta, Medicine Lake, and Newberry caldera. There have been no indications of the low velocity expected to be associated with crustal magma. One interpretation is that the high-velocity zones are due to intensive diking by andesitic rocks and any magma chamber too small to be detected with present techniques.

Electrical techniques have been applied to map regional geology as well as to try to detect hydrothermal convection systems. The area of most concentrated study has been Newberry caldera, where drilling by the U.S.G.S. found temperatures greater than 200°C below depths of about 800 m. These high temperatures are accompanied by resistivity lows on magnetotelluric, DC resistivity and time-domain electromagnetic surveys. Numerous surveys in other areas show zones of high conductivity, but drilling data to verify the sources is lacking. MT data has also shown a pervasive conductor of 1-5 ohm-m about 20-25 km deep beneath much of the Cascades. The significance of this conductor is not presently understood.

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July 22, 1985

MEMORANDUM

TO: Sue Prestwich

FROM: Mike Wright

SUBJECT: Additional Negotiations Items for Cascades Drilling

The following items should be negotiated into contracts for Cascades drilling in addition to those in my memo of last week.

1. During intervals when core is not being collected (rotary or plug bit drilling), drill cuttings will be collected. Plug bit cuttings are very fine, and special care will be required to collect a sample.

2. The participant should agree to provide any special training needed for the drill crew in proper sample collection and handling procedures. These procedures are the topic of a separate brief which is attached, and the participant should agree to follow these procedures. The participant will be responsible for quality control of the sample collection and data handling.

3. The participant should agree that there will be no splitting or other selected sampling of core or cuttings until after the on-site lithologic log is made and until such selected sampling is agreed with DOE.

DRILL SAMPLE COLLECTION AND CURATION POLICY FOR THE CASCADES DEEP THERMAL GRADIENT DRILLING PROGRAM

Introduction

Core and cuttings recovered during exploration drilling are an important resource for research and evaluation of the geothermal potential. When the cost of drilling is considered, it is evident that the core and cuttings are an expensive and valuable product of the exploration effort. Lithologic samples are the first products recovered from a drill hole and the possibility that the hole may be lost before wireline logs are run or fluid samples are collected further indicates the value of the core and cuttings recovered.

The Cascades Deep Thermal Gradient Drilling Program is a combined effort of industry and public agenices in a potential resource area where subsurface data, particularly in the public domain, are very limited. The data gained through this program will be of value to industry, public agenices and private researchers. It is therefore the purpose of this drill sample collection and curation policy to provide procedures for sample handling that will ensure preservation and equitable distribution of sample for the maximum benefit of the program. Sample handling procedures must be uniform enough to protect sample integrity and reasonable enough for well site personnel to follow without undue extra work.

Well-Site Core Handling

The core will be transferred from the core barrel either to the core trough or directly into core boxes if a core trough is not available. Care will be taken during handling to ensure that all pieces of core remain in their original orientation and sequence. Directly after removal of core from the core barrel, all core pieces with length equal to or greater than core diameter will be marked with an arrow pointing downhole using a grease pencil or permanent felt tip marker (Fig. 1). If the core needs to be washed this will be done while it is in the core trough. When the core is placed in the core box, a wooden block labeled with the bottom depth of the core run will be placed at the end of the core from that run. If a core run did not directly follow the previous core run because of rotary drilling or other non-coring operations, a wooden block labeled with the beginning depth of the core run will be placed at the top of the run such that beginning and ending depth of each run will be indicated. All core will be placed in core boxes following a uniform system: with the box orientation label on the left, the box will be filled from upper left to lower right (Fig. 1). The label on each core box will be completely filled out using care to ensure that lettering is easily legible, as large as practical and done with an appropriate permanent marker. The drilling crew will be responsible for marking orientation arrows on the core, placing the depth labeled blocks at the top and bottom of each core run, and labeling core boxes unless the well-site geologist does these duties personally.

Drill Cuttings Sampling

Drill cuttings samples will be collected from any intervals which are rotary drilled or drilled with a core plug bit. Cuttings will be collected at 10-foot intervals from the shaker table or if a shaker table is not being used, caught from the blooie line with a bucket and/or screen device. Samples will not be taken from a drain ditch or catchment where contamination from surface materials or earlier cuttings may occur. DOE will require 1 kilogram of sample for each 10-foot interval. Drilling mud will be rinsed from the cuttings if needed and the samples placed in bags labeled with hole name and drilling depth. Proper and timely collection of drill cuttings samples is the responsibility of the drilling crew. Bagging and labeling of the sample bags are also the responsibilities of the drilling crew unless the drill site geologist assumes this task while logging the samples.

Logging of Core and Cuttings

Whenever a geologist is present, the samples (core or cuttings) will be logged on site or at a nearby convenient operations base prior to sample splitting or transfer to curation facilities. Responsibility for the initial sample logging will be coordinated between the operating company and Department of Energy, Idaho Office (DOE) or their representative. On-site sample logging is important for several reasons: 1) the log will provide a data base upon which drilling and well-test decisions can be made; 2) the on-site log will be made before any sample split or sampling by collaborating investigators; 3) the on-site log will be made prior to possible sample degradation due to sample drying, disaggregation due to drying and pressure release, oxidation, vibration during transport, possible loss or damage during transport and storage; 4) the on-site log will provide a data base for interpreting wireline logs and for subsequent detailed studies of the rocks drilled; and, 5) on-site logging provides the best opportunity for the geologist to interface with the drilling crew to note any drilling operations or conditions which may affect the quality of sample recovery and reasons for sample loss.

Core and cuttings should be logged on a standard form (see Appendix for our example), previously approved by the operating company and DOE, which provides both uniformity of format and flexibility to facilitate different lithologies drilled. All involved companies, government agencies and collaborating investigators, who request a copy of the field log, will receive a copy in a timely manner consistent with DOE's policies on release of data.

The lithologic log will include project name, well name or number, location, well-head elevation, geologist and date logged. For each core run, the box number, depth in feet and tenths of core recovered, and recovery will be recorded (Fig. 2). Next the lithology will be described followed by fractures, joints, faults and alteration if present. Lithologic descriptions are best given by rock unit which may be thicker or thinner than coring runs. The depth of upper and lower contacts (unit interval) will be stated, followed by a one- to two-word lithologic name, then a description of the unit in appropriate detail. Additional comments may be added for each core run after the unit description for thick but variable units. Lithologic descriptions will be observations rather than interpretations. Core size or bit type, drilling fluid and lost circulation material will be noted as it affects the sample's condition. Cuttings samples for intervals not cored will be logged in the same manner with cuttings and bit type noted. Also depth of all significant drilling operations or events such as setting casing, loss of fluids or bit change will be noted on the core log at the drilling depth that these occur.

Although field lithologic classifications are hand-sample names which may be found to be incorrect by later petrographic or chemical study, they will provide the basis for sample selection and contact depth picks for later, more detailed studies.

Sample Split and Sample Cutting

No sample splits or selected sampling of the core and/or cuttings will be done by any party prior to completion of lithologic logging. After logging, the core will be split and/or selected samples taken by the involved entities and collaborating investigators as agreed upon by the operating company and DOE or their agent(s) for the particular well. Appropriate and timely sample splits and sample selection will be the responsibility of the operating company's site personnel and the project manager or agent for DOE or their delegated representatives. Any samples cut on the drill site after logging will be noted on the field lithologic log and a block of wood or note with the sample interval and entity taking the sample will be placed in the core box in place of the sample taken. After the sample split between the operating company, DOE or their agent and any other involved agencies (i.e. state geologic survey), the curation and sample availability of the DOE split will be the responsibility of DOE or their agent.

Water and Gas Samples

Water and/or gas samples may be collected during drilling or at the completion of a well as agreed upon by the operating company and DOE. Such factors as hole condition and cost may require on site geologist to make final decisions concerning water and gas sample collection. Sample collection, on-site analysis and treatment of samples for proper preservation will be the responsibility of the authorized DOE representative or collaborating investigator. Instructions for fluid sampling are the topic of a separate memorandum.

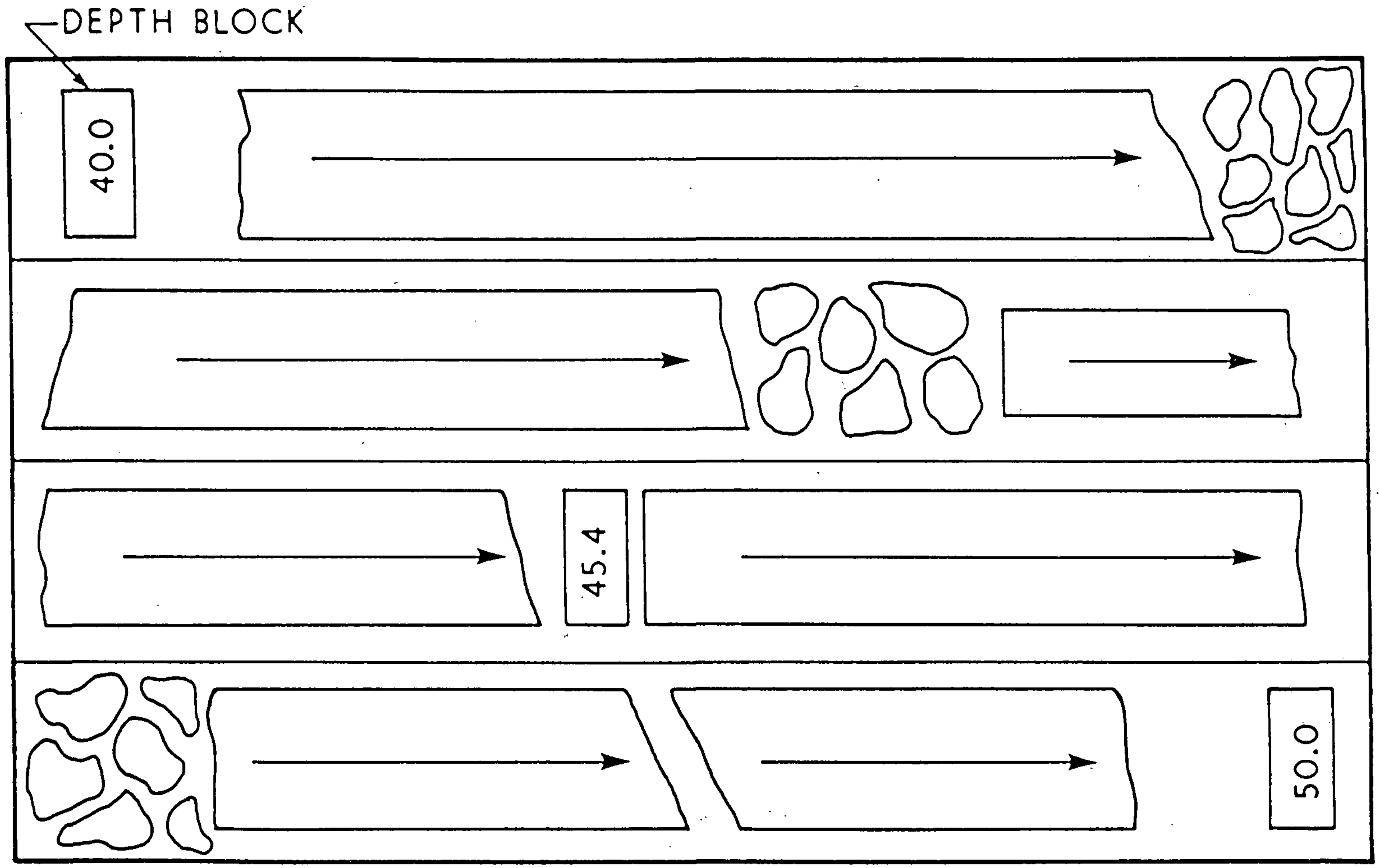

Figure 1. Core box is filled from upper left corner with depth blocks at the end of each run and arrows pointing downhole on core pieces.

CORE LOG

PROJECT ______________________ WELL NUMBER ______________ LOCATION ______________

WELL HEAD ELEV. ____________ LOGGED BY ______________ DATE ____________ PAGE ________

BOX #	Depth	Recovery	Graphic Symbol	LITHOLOGIC DESCRIPTION	Fractures & Alteration	Drilling Information

Figure 2 .