



GLO/826

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December 20, 1984

Marshall Reed, Program Manager  
Geothermal and Hydropower Technologies Division  
DOE Headquarters, CE-324  
1,000 Independence Ave. SW  
Washington, DC 20585

Subject: Cascades Geothermal Exploration

Dear Marshall,

As we discussed today, I believe there are several Cascades geothermal exploration actions that need to get underway in FY'85 in order to locate geothermal anomalies for confirmation by drilling.

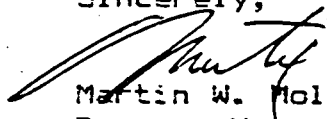
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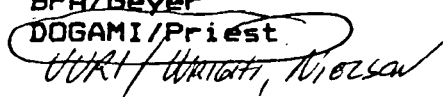
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Sincerely,

  
Martin W. Molloy, Ph.D  
Program Manager  
Geothermal Reservoir Definition

cc: USGS/Muffler, Sammel  
UURI/Lippmann, Goldstein  
ID/Prestwich  
BPA/Geyer  
DOGAMI/Priest



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cc JOHN ✓  
MIKE  
GEORGE

CASCADES GEOTHERMAL EXPLORATION PROGRAM

USGS Meeting

On September 28, DOE-SAN/Marty Molloy and BPA/John Geyer met with the USGS's Chief of geothermal geology, Dr. Patrick Muffler and his Cascades consultant, Ed Sammel at USGS Menlo Park. Our purpose was to review the basic issues and status of the proposed Bonneville Power/DOE Geothermal R&D/USGS interagency program for determination of the Cascades geothermal energy potential.

Pat Muffler observed that the Cascades is "a hell of a tough nut to crack; the nature of the beast is not very geologically tractable." After the learning experiences at Yellowstone and Long Valley, we have a better idea where to start looking. By analogy with other geothermal reservoirs in the circum-Pacific "Ring of Fire", there is clearly something there. We ought to be looking for 100's of MW systems, rather than 2,000 MW "elephants" equivalent to The Geysers. These Cascade geothermal systems include Lassen, which is off-limits to commercial development. At this point, the goal is to try to describe what the Cascades consists of, in terms the total volcanic chain, regions, broad aspects, reservoir work, etc. The guts of the problem is hydrological, due to masking by the "rain curtain". The crux of the solution is deep hydrology, in terms of unraveling the path of cold groundwaters down to the heat source, and then up to storage in possible geothermal reservoirs. Fifty drillholes in the right places can produce the answer, but we have to drill. USGS/Muffler is convinced that we are never going to get there without drillhole data. But the Survey is not in the business of exploratory drilling; the USGS is a research, not a development agency. Drilling is the business of DOE and industry. The USGS provides a stable group of scientists to interpret the data. Such a program fits with both USGS and DOE goals. A considerable part of the Survey's geothermal research program is devoted to multidisciplinary studies of the Cascades, on a regional and subregional scale, to improve the geothermal resource assessment in USGS Circular 790. In a few years this work will result in an update of these geothermal MW estimates (not the evaluation of individual reservoirs). Bonneville's assignment from the Council provides the focus which has been lacking. BPA is the constituency for which USGS scientists and DOE contractors are working. "You are the gorilla in the Northwest." We clearly have to focus our efforts, or we could go on for years without finding out what is there. The merit of an agreement between the Federal agencies would be just that, to encourage us to focus our efforts to accomplish what is possible. A specific thrust from BPA might be useful as a goad. The Survey is prepared to do what it can, and has one of the best sets of hydrologists. In fact, this is something that we must do.

A realistic geological model is needed as the context within which to read the geophysical exploration data. Resistivity and AMT surveys may be useful, but the present methods of analysis are only remotely based on the actual geologic structure and stratigraphy. The geochemists and hydrologists will be key. At Lassen, for example, USGS/Mike Sorey has developed a geologic model by reasoning from the few bits of information available from the hydrology and gas chemistry of a single well; an equally difficult path lies ahead in the Cascades. We must first learn and calibrate our tools at type localities, and then apply them throughout the

## High Cascades.

Oregon is geographically central to Cascades exploration. Knowledge gained here can be extrapolated into southern Washington and northern California. The Three Sisters is a young, igneous center. A geologic cross-section through Belknap-Foley Hot Springs KGRA to the west, the Sisters, and Newberry Caldera to the southeast, would allow us to infer the heat source, and whether the high peaks heat source and the western hot springs are connected. We could then try to extrapolate this geologic model north: to the Breitenbush Hot Springs-Mt. Jefferson-Warm Springs Indian Reservation axis, the Mt. Hood axis in northern Oregon, and the Mt. St. Helens-Mt. Adams axis in southern Washington; and south into northern California, to the Mt. Shasta-Medicine Lake/Glass Mt. axis, and the Lassen axis at the southern end of the Cascades. B. C. Hydro's results from Meager Creek in British Columbia, can clearly be extrapolated south into central Washington, to understand the geologic model for the north end of the Cascades, including Mt. Baker and Mt. Rainier. The GS would be delighted to have the opportunity to work with our neighbors to the north.

Private industry is a major player - with extensive data at Medicine Lake/Glass Mountain and Newberry Caldera.

Our goal is a set of conceptual geologic models that are testable by drilling. We need to focus our efforts at two levels: the Cascades as a whole; and, the sites of specific geothermal reservoirs. The program needs to deal with specific areas, as well as tie the whole system together with regional geologic mapping, gravity, aeromagnetics, MT and deep seismic surveys. The program should start with a geophysical conference which is discussed on the axis of the best cross-section. There has been a lot of geophysical effort, but very little data has been synthesized. Geophysics has not been pushed to the limit - as the primary guide for targeting the drilling at depth. We need to mount a major geophysical effort - on the assumption that it will be followed by drilling. There is serious question whether geophysical surveys are effective in the Cascades, or can even be carried through the rough terrain. On the question of effectiveness, USGS/Sammel has proposed the more promising techniques be tested and calibrated at known geothermal sites in the Cascades, and then extended with care into the high mountains. On the question of terrain coverage, it may be necessary to support the geophysical surveys with helicopters. However, the geophysical gear must still be powerful enough for deep penetration (several km.), and not limited to shallow penetration because of helicopter capability.

The 40-mile wide belt from Salem to Bend, Oregon is crucial to understanding the nature of the Cascades geothermal resource. If geothermal energy is not there, it will not be anywhere except at Crater Lake and Lassen. Access on the ground is available through Santiam Pass, and exploration is possible in terms of private land, environmental and political concerns. A concerted effort on this belt, targeted at magma centers and associated hydrothermal systems, should be the primary approach. We know the deep picture at a broad, general scale from crustal seismics, but we haven't focussed on the detailed scale in the upper crust, where commercial geothermal reservoirs might be found.

A structural geologist/hydrologist is needed to take the leadership, bring together the proper scientific disciplines, deal with a wide set of data,

and pull it all together into a single conceptual model. It will take the actions of somebody who is knowledgeable in the region. Hopefully, we will be able to invite other knowledgeable experts to join in, and have the opportunity of looking at their data.



UURI-  
wright

## Department of Energy

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### MEETING REPORT BPA-DOE-USGS-USFS CASCADES GEOTHERMAL EVALUATION MARCH 27, 1985 PORTLAND, OR

#### SUMMARY

A working meeting was held at Bonneville Power Administration (BPA) in Portland, Oregon on March 27, 1985. The purpose was to review the draft memorandum for interagency cooperation in evaluation of the geothermal energy potential of the Cascades Range. The Federal representatives discussed arrangements for continued cooperation of agency activities relating to Cascades geothermal evaluation. The draft memorandum was accepted with comments. The revised memorandum will be circulated for signature at the appropriate levels in each Federal agency.

#### PARTICIPANTS

Representing the responsible Federal agencies were:

- BPA: Walter E. Myers, Director, Division of Resource Engineering  
Douglas B. Seely, Chief, Generation Engineering Branch  
John D. Geyer, Energy Resource Specialist  
Thomas White, Generation Engineering Branch.
- USGS: Dr. Patrick Muffler, Chief, Branch of Igneous and Geothermal Processes.
- USFS: Jerry Patchen, Group Leader, Division of Lands and Minerals, Region 6.
- DOE-SAN: Terry A. Vaeth, Director, Fossil, Geothermal and Solar Energy Division  
Dr. Martin W. Molloy, Program Manager, Geothermal Reservoir Technology

#### BPA OBJECTIVES

Walt Myers opened the meeting by stating Bonneville's need to have some direction in looking into the geothermal resource for power development in the Northwest Region. He noted BPA's present vulnerability in accepting the claims of geothermal resource developers. Bonneville recognizes the mandates of other Federal agencies for the geothermal resource evaluation and technology development stages, that precede conversion of steam to electricity and distribution of geothermal power. Bonneville welcomes the opportunity to join with those responsible Federal agencies, which are looking for the Cascades geothermal resource.

The quantity and location of the geothermal resource in the Cascades is not currently known. As a consequence, Bonneville is unable to determine whether Cascades geothermal energy fits into the Northwest's long-term regional power mix. Therefore, BPA is interested in building up expertise in this area.

Bonneville's first objective is a valid assessment of the Cascades geothermal resource: what is where? what magnitude? and what quality? At the present time, there are different opinions; the answer is hidden from our sight.

Bonneville's second objective is to determine how much energy is recoverable, and at what cost, in order to input the geothermal energy forecast into the Northwest power planning mix.

These objectives are consistent with Bonneville's "optioning" approach; that is, banking the resource after all the planning and steps preceding development are accomplished. The Northwest Power Planning Council stated that the Cascades have substantial geothermal potential. Therefore, Bonneville foresees quantifying large known reservoir(s) so that when the power need develops, 100-200 megawatts can be developed rapidly.

BPA load forecasts tell the load/resource balance; the load forecasts show power surplus in the Northwest for about 12 years. Bonneville's responsibility is to look at all energy resources, based on cost and availability. The trouble with geothermal energy is that we don't know how much there is, where it is, or how to integrate it into the power network. There are also serious exclusions, such as wilderness areas, with respect to the specific location of the geothermal resource.

#### USFS OBJECTIVE

Jerry Patchen stated that the Forest Service needs similar geothermal resource expertise and key, known technology, in order to carry out Federal land management responsibilities. The USFS' objective is to provide developers with the opportunity to produce the resource; that is the limit of Forest Service responsibility and authority.

Jerry noted that valid Federal assessment of Cascades geothermal potential is the paramount initial objective. Without a decent handle on the resource potential, decisions on valid use of the land are made, like creation of wilderness areas, which can lock in land use for decades. Making land management decisions without resource information is like hunting elephants with flashlights. The Forest Service's basic mission stops at providing developers with the opportunity to proceed. At that point, it becomes power generation.

## CASCADES GEOTHERMAL BACKGROUND

Pat Muffler noted that it has taken 20 years after substantial drilling began in the 1960's to develop that major geothermal resource in California's Imperial Valley.

Science (the USGS) has the initial responsibility for the assessment that leads to the nation's identified geothermal resource. Then DOE develops the technology for how to explore for and develop the geothermal energy. Once the geothermal resource is found and know to be attractive, then BPA must get involved in evaluation of the power potential. The USFS, which is responsible for Federal lands management in the Cascades, will be involved all the way through the geothermal resource evaluation.

Unlike similar volcanic chains in Indonesia (Japan, Philippines and Central America), the Cascades are very ambiguous. The basic problem is that we do not have surface expressions of the existence of geothermal energy at depth, like hot springs. Italy has carried out a systematic program of geothermal exploration, moving south from the major dry steam field at Larderello. Japan is conducting a classic program of systematic regional geothermal exploration. It is important that the US Government not be stampeded into an unplanned program.

## CASCADES GEOTHERMAL RESOURCE ESTIMATES

Pat Muffler pointed out that the inventory of known Cascades geothermal resources in USGS Circular 790 is quite small. Yet, every other volcanic area in the world has significant geothermal potential. From models of other volcanic provinces, the USGS believes there should be substantial geothermal potential in the Cascades. The resulting USGS estimate for the large undiscovered Cascades geothermal resource represents a best guess. There is a big difference between what is known, and what is inferred from geologic and tectonic considerations.

It is to BPA's credit that they have to study this discrepancy, and to be hard-nosed in settling it. Even at the low end of geothermal energy estimates, there is significant Forest Service involvement.

## USGS OBJECTIVE

Evaluating the discrepancy between the known and estimated geothermal resource figures is the scientific and technical challenge for the Government. It is also the industrial and commercial challenge to industry.

What kind of science do you develop to look for geothermal resources? How much effort is required to find the resource, and how is it related to development activities?

The Cascades are a very big target; there are lots of actors involved. We have focussed on an obvious volcano (Mt. Hood in 1978-81) without first having the necessary geologic framework. As a result of premature focus on Mt. Hood, there has been a relative lack of consideration of the rest of the Cascades. As a consequence, the USGS has learned to have extreme skepticism of published Cascades geothermal resource estimates.

## DISCUSSION

Walt Myers observed that the Northwest Power Planning Council's direction to Bonneville is to do something on geothermal energy. However, Bonneville is not going to do exploration or drilling.

Muffler cautioned that the Government has to be very careful with respect to "exploration" that it is not in competition with the oil and mining industry. However, in view of the legislative mandates, the Government cannot just sit back and wait for industry to do something.

Terry Vaeth observed that the deep research drilling program is fractured in the geothermal community and in Government. Various Congressional initiatives have put DOE into research drilling. We need to start focussing Federal geothermal research drilling efforts. There are now 7 different programs, including Geopressure, Magma, and the Salton Sea Scientific Drilling Program. We are making a little progress in a lot of areas; we need to make a lot of progress in a few areas.

Muffler and Vaeth noted that there is substantial support for deep (10'000 ft) continental scientific drilling, as there has been for ocean-going scientific drilling programs like JOIDES, Glomar Challenger, etc. This strong support extends up to the President's Scientific Advisor, Dr. Keyworth. There has been lots of draft legislation for exploring the earth's crust directly by deep drilling. A university consortium has proposed to contract for the deep continental drilling; the Federal agencies would not be as involved. The deep sea drilling program run by Scripps Institute of Oceanography is their model.

However, a scientific deep drilling program does not appear to meet Federal geothermal resource and power planning objectives in the Cascades.

Perhaps deep drilling for scientific research and power planning purposes could be tied together. A possible way to focus programs and get costly research drilling done is to tie Cascades resource evaluation to something like Deep Continental Scientific Drilling. Otherwise, the necessary deep drilling won't happen to the extent that is necessary to define the geothermal resource.

Muffler agreed that deep Cascades drilling won't just happen to the extent that is necessary in order to define the resource; we are talking about deep drilling bucks. The current USGS' budget proposal (FY'86) represents a cut 26%. Yet each year, Congress has restored such cuts. This yo-yo approach does not allow for continuity in planning over the 10-20 year context required for Cascades geothermal resource evaluation.



We need to put together a program that will bridge the gap between science and industry goals in the Cascades, and achieve the mutual objectives of each. Both are interested in drilling deep thermal gradient holes to get beneath the hydrologic mask; this drilling program is coming out of DOE-Idaho Operations Office. The ultimate goals of the scientific drilling program will not meet our specific economic and power planning objectives. (The scientists are interested in the roots of the Cascades andesitic volcanoes, and the tectonics of the oceanic plate descending beneath the Cascades Range.)

What is needed is a science-industry interface, and a flagship program to which to tie the geothermal power search, which results in a statement and rationale for funding. We need a good understanding of the various roles of the agencies in this group, of the scientific community, and of the typical roles of industry. In order to ask people to coordinate their efforts, you must have a leader (not a single agency, but the Federal agency group).

#### FEDERAL CASCADES OBJECTIVES AND STRATEGY

What the Survey, DOE and Bonneville need are hard data to underpin various geophysical surveys and geological models for regional geothermal resource assessment.

What makes the Cascades particularly difficult is that the volcanic rocks are like a sponge. Rain water sinks into surface volcanic rocks to depths where cold near-surface waters mask the regional thermal gradient. Significant, deep temperature gradient and stratigraphic drilling is needed for regional Cascades geothermal resource assessment. The major problem in evaluating the Cascades' geothermal energy potential is the difficulty of funding a program of extensive deep drilling, in addition to the problem of locating the drill sites. Deep exploratory wells are the critical path toward the collective Federal objective in the Cascades - they require big bucks!

3,000 - 6,000 ft. deep thermal gradient test holes are needed just to get past the surface hydrologic mask, and to provide calibration for interpretation of seismic and other geophysical surveys. 10,000 ft. wells are not unreasonable depths for future completion of commercial geothermal production wells.

A series of about a half dozen 10,000 ft. holes are needed across the axis of the Cascades at an appropriate transect location, like Santiam Pass in Central Oregon. From the resulting information, the USGS could develop an accurate geologic cross-section for the Cascades at the location of the transect. If the Geological Survey knows what the cross-section of the Cascades looks like at one transect location, then they have a hope of forcing that understanding north and south along the axis of the Range, to the rest of the Cascades.

The USGS "discovery" in the middle of Newberry Caldera may be a place to start gaining insight into the geothermal resource, and identifying the potential for common efforts. All sorts of forces are marshalled against commercial development at Newberry, so governmental efforts should be limited to scientific and technological understanding of the geothermal resource, as a conceptual model for extrapolation elsewhere in the Cascades.

Jerry Patchen emphasized that it is imperative to make every "lick" count, when such big bucks are required.

#### CASCADES GEOTHERMAL EVALUATION PLAN

The first step is for this group to come up with a comprehensive strategy: (DOE has had only one Presidential geothermal program request in the last four years). The second step is a Cascades Planning Document. If it is available by September 1985, the Cascades Plan can be reflected in the language proposed for FY'86 authorization and appropriation bills to the Interior Energy Committee. If steps 1 and 2 can be accomplished, DOE-SAN will carry the plan forward for budget approval.

A Cascades Geothermal Evaluation Plan should be drafted which contains the roles of the agencies in this group, their areas of expertise, and the areas requiring industry competition. There is a lot of opportunity to accomplish objectives of various interested groups. A Program Outline should be available in September 1985 as input to FY'86 Congressional appropriations decisions. The common thread is that something is produced at the end of the evaluation effort, and that is power. That central theme will provide adequate continuity for long-term planning. Potential lease rentals, revenues and royalties will capture the interest of OMB (and governmental bodies in the region). Congressional figures, like Sen. Hatfield of Oregon, are very supportive.

#### CASCADES STEERING GROUP

John Geyer suggested that this group should function as a Steering Group to provide an ongoing opportunity for these knowledgeable Federal managers to compare Cascade goals, agency roles, program needs, and to come to the consensus required for coordinated commitments and actions.

As Forest Service representative, Jerry Patchen welcomed the cooperative efforts of the other agencies, since they will increase USFS's understanding and ability to act effectively with respect to the Cascades geothermal resource.

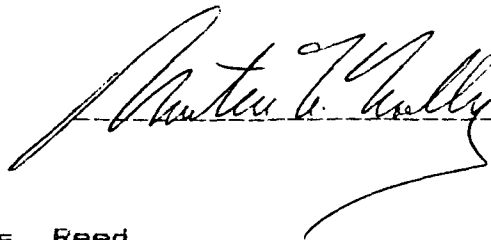
As USGS representative, Pat Muffler strongly supported the concept of a Cascade agreement which would permit the programs of each agency to fit together in this part of the country. Such Federal cooperation is very appropriate.

The first issue is where does the group want to get to next. This can be addressed by forming a Steering Group of the four agencies, with regular meetings to scope issues, to define, and to guide the Cascades program, in concert with the efforts of industry.

#### USGS CASCADES GEOTHERMAL WORKSHOP

Muffler stressed that his May 22-23 USGS Cascades Geothermal Workshop in Menlo Park is not a program planning meeting; it is not explicitly for agency program managers. The USGS Workshop will bring together earth science investigators whom the Survey has supported through external (e.g., university) and internal (USGS scientist) funding. The purpose is to learn who has done what, where; to get in hand and to sort out the USGS program. Pat expects the USGS coordination and leadership to galvanize future geothermal efforts in the Cascades of government, university and industry.

The USGS Cascades Workshop is open; everyone is welcome. They should start building communications and working relations with the scientific experts. Muffler expects the scientific approach of the USGS Workshop to focus on conceptual models of the Cascades; these models can also be used by industry to define drilling targets in the Cascades.



4-2-85

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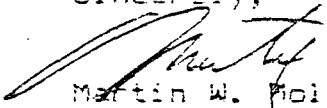
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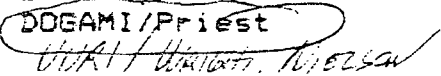
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Martin W. Polloy, Ph.D.  
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Geothermal Reservoir Definition

cc: USGS/Muffler, Sammel  
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DEVELOPMENT OF GEOTHERMAL EXPLORATION STRATEGIES  
FOR THE  
CASCADES VOLCANIC PROVINCE

SUGGESTIONS FOR PROGRAM PLANNING

for

U. S. Department of Energy  
San Francisco Operations Office

by

Earth Science Laboratory  
University of Utah Research Institute

9 February 1985

## CONTENTS

Page

- 1.0 EXECUTIVE SUMMARY
- 2.0 INTRODUCTION
- 3.0 BACKGROUND
- 4.0 DEFINITION OF PROBLEMS
- 5.0 RESEARCH OBJECTIVES
- 6.0 PROPOSED APPROACH
- 7.0 STATEMENT OF WORK
- 8.0 SCHEDULE AND DELIVERABLES
- 9.0 BUDGET

## 2.0 INTRODUCTION

U. S. Geological Survey Circular 790 (Muffler et al., 1978) states that the identified accessible hydrothermal resource base in the Cascades province is estimated to be 57 quads, whereas the undiscovered, accessible base is crudely estimated to be twenty times this amount, of 1140 quads. Estimates such as these are recognized as being quite rough at the present time because of lack of hard data. There are few discovered resources. However, the geologic setting of the Cascades province lends credence to the idea of a large resource base, and it is on this promise that industry has proceeded with limited exploration.

Industry progress, however, has not been rapid, and it appears that industry will continue to be reluctant to spend much money on Cascades exploration unless clear-cut ideas can be developed of the discovery potential and of cost-effective exploration methods. Beyond that, proof of economic viability will require thorough exploration and testing of any resource discovered. It is clear that stimulation of development in the Cascades is needed and that the promise of pay back of federal research funds is substantial.

### 3.0 BACKGROUND

The abundance of young volcanic rocks and the isolated occurrences of thermal springs along the Cascades range suggest that a large geothermal resource base may exist. It is probable that Cascade Mountains overlie a subduction zone, and magma generated at depth rises into the crust transporting large amounts of heat into the upper crust under the range. In spite of these favorable geologic capabilities, few hydrothermal resources have been discovered as compared to the widespread occurrence of heat sources. Precipitation is high over much of the area, and the resulting abundance of shallow cold water is likely to be masking underlying convection systems.

Geothermal systems in the Cascades have remained elusive exploration targets, with confirmed high-temperature resources 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. The risk and expense can each 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 geologic settings in other parts of the world. These include the Neovolcanic Belt of Mexico, the volcanic belt of Central and South America, and the island arc



environments of New Zealand, Japan, Indonesia, and the Philippines. Data are available for most of these environments that 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. These data can provide valuable information on the character of fracturing, faulting and hydrothermal processes in such environments with important bearing on subsurface processes occurring today in active hydrothermal systems.

During the past five years, the U. S. Geological Survey, working partly under funding provided by DOE-DGHT, has been conducting fundamental earth science studies in the Cascades region aimed at obtaining a better understanding of the geothermal resources. Most of this work has been regional in nature. It has consisted of collection and interpretation of a large variety of data including geologic mapping, aeromagnetic surveys, gravity surveys, active and passive seismic surveys and geochemical studies. These data have been evaluated largely in terms of developing a regional geologic picture and have been applied specifically in only a few areas. The results of this work, as well as the basic data and to a certain extent the USGS personnel working on the project, will be available to researchers on the present program and will provide substantial assistance.

In an effort to stimulate geothermal development in the Cascades region of the United States, the U.S. Department of Energy is sponsoring the Cascades Thermal Gradient Drilling Program. Geothermal development in the Cascades has been limited by the paucity of surface thermal expressions, perhaps resulting from extensive cold water flushing of near-surface aquifers. The objective of

DOE's program is to sample thermal zones beneath the influence of the near-surface cold aquifers. Proposals have been solicited by the Idaho Operations Office for the drilling of intermediate-depth thermal gradient holes with DOE sharing as much as 50 percent of the cost. 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, and fluid samples. The data would be released to the public to further stimulate exploration interest. In addition, it is expected that State Geothermal Resource Assessment Teams would conduct field studies in the areas of drilling, and that this work would contribute valuable site-specific information to the project through topical reports.

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.

We have previously proposed an exploration 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 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.

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.

#### 4.0 DEFINITION OF PROBLEMS

Although from a scientific viewpoint there are numerous interesting questions to be answered in the Cascades, from a practical exploration viewpoint, as industry sees its problems, they can be summarized in such pragmatic questions as stated below.

1. What is the potential for occurrence of undiscovered, economic hydrothermal resources in the Cascades?
2. Where, specifically, are hydrothermal systems most likely to be found with respect to visible geologic features and other geoscientific data that can be obtained on the surface?
3. Which of the available exploration techniques can be fruitfully applied to discovery and assessment of hydrothermal resources, and how can exploration techniques be improved?
4. How can cost and risk be minimized during hydrothermal development, i.e. what are the most cost effective exploration and resource assessment strategies?

##### Potential for Occurrence

At the present state of knowledge, we know that there are substantial sources of heat in the crust in the Cascades because of the long volcanic history of the region, a history which continues to the present day. We suspect that the Cascades may be underlain at depth by intrusions of 1/4 to 10 sq mi or more that have been emplaced at different times during the past 10 million years. We do not know the range in depths of magma chambers large enough to be interesting as resource/geothermal heat. By analogy with eroded areas, where we can now see the roots of former volcanos, we suspect that the intrusions have a tendency to cluster due to repeated injection of magma along

certain lines of preferred upward mobility or due to more vigorous generation of magma beneath certain areas. Also by analogy with eroded areas, we know that active hydrothermal convection systems will exist in association with only some intrusions and then only on certain parts of these intrusions. How, then, do we ascertain the frequency of occurrence of hydrothermal systems presently hidden?

#### Location of Hydrothermal Systems

Clearly, at our current stage of development, we should confine our exploration to the youngest volcanic features--the active and recently active volcanic areas. Beyond that, little is known. Where, specifically, relative to a surface volcanic feature will a hydrothermal system most likely be. The Three Sisters field in central Oregon, for example, comprises perhaps 150 sq mi, whereas a viable geothermal system might occupy 2 sq mi. Drill testing of each square mile is a possible exploration method, but is not financially feasible. How does one pick the best 2 sq mi to drill test? We cannot answer this question--and we do not even know how deep we must drill.

#### Application and Improvement of Exploration Techniques

Many potential exploration techniques exist, but the applicability of few is known. In addition, there are practical problems due to topography and limited access in applying some techniques. Is a helicopter supported resistivity survey cost effective? Can the seismic method be used effectively? Do hydrothermal systems at depth relate to geologic structures that can be mapped on the surface?

There are two needs in order to evaluate and improve exploration techniques. They are: (1) areas where techniques can be tested and funds to test them, and (2) conceptual geologic models from which the expected responses of

a hydrothermal system can be predicted. Appropriate areas for technique testing exist, but to date little testing has been done. No reliable conceptual resource models exist.

### Minimizing Cost and Risk

Cost and risk can be minimized if exploration strategies can be devised that minimize the amount of exploration work needed to site successful drill holes while at the same time maximizing odds of success. To devise such exploration strategies, we need solid conceptual resource models and a variety of exploration tools that work.

### Key Problems

A number of key problems can be listed whose answers would assist very substantially in furthering geothermal development in the Cascades.

#### Geological Problems.

1. Do sizable heat sources (magma bodies) exist in the shallow crust (< 10 km) in the Cascades, where and at what depth?
2. How do surface volcanic manifestations relate to shallow crustal intrusions?
3. Is surface geologic mapping of lithology and structure pertinent to locating hydrothermal resources in the Cascades?

#### Geochemical Problems.

1. Is the geochemistry of thermal and non-thermal springs pertinent to locating hydrothermal resources in the Cascades?
2. Is knowledge of hydrothermal alteration on the surface and in shallow thermal gradient drill holes pertinent to locating hydrothermal resources in the Cascades.

### Geophysical Problems.

1. Would a Cascades-type hydrothermal system be expected to yield an anomaly detectable at the surface on a magnetic, galvanic resistivity, MT or AMT, CSEM, seismic or other geophysical survey?
2. As a rule, how deep is the so-called "rain curtain", beneath which one must presumably drill to get valid heat flow/thermal gradient data?
3. Can geophysics be of assistance in mapping surface and/or subsurface geology?

### Hydrological Problems.

1. How can the "rain curtain" effect be evaluated for specific areas?
2. What are the expected fluid flow patterns for hydrothermal systems in the Cascades?

## 5.0 PROJECT OBJECTIVES AND STRATEGIES

The objectives of the proposed research are as follows:

1. Establish valid conceptual geologic models of Cascades hydrothermal resources;
2. Improve and test exploration methods and techniques, and,
3. Establish valid exploration strategies that minimize risk and cost in developing Cascades hydrothermal resources.

A number of strategies are appropriate to reaching these objectives.

Among these are:

1. Direct the research work at the key geoscience problems that currently inhibit resource discovery and development in the Cascades;
2. Make maximum use of available data, both from the Cascades and from other geologically analogous areas;
3. Cooperate to the maximum extent with industry and other organizations seeking geothermal resources in the Cascades;
4. Make optimum use of talents at UURI and recognize and cooperate with programs conducted by other groups.

### Statement of Work

Task 1 - Planning Assistance. UURI will provide DOE and other designated entities, such as BPA, with assistance as requested in planning research activities, exploration programs and technology transfer.

Task 2 - 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 3 - 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 4 - Integration and Interpretation of Data. The available information will be analyzed to form a conceptual model or series of conceptual models of Cascades-type geothermal systems.

Task 5 - Testing of Techniques and Models. We anticipate that there will be a need to acquire additional field geologic, geochemical and/or geophysical data for the purpose of testing either specific exploration techniques or specific ideas developed from conceptual models. Several test areas are readily available--among them are Newberry Caldera, Lassen Peak, Meager Creek, Mt. Baker, Glacier Peak and Mt. Rainier. Geothermal occurrences are known at each of these areas and each could become a focus for testing of ideas that would be applied to covered areas in the Cascades.

Task 6 - 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 DOE-sponsored drill hole and in other available holes. 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 in DOE-sponsored holes. 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.

Task 7 - 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.

Task 8 - 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.

Task 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.

**memorandum**

DATE:

April 17, 1984

REPLY TO  
ATTN OF:FGS/Dr. Martin W. Molloy, Manager  
Geothermal Reservoir Definition Program

SUBJECT:

Cascades Cost Shared Drilling Program  
March 21, 1984 Meeting at Portland OR

TO:

FGS/Anthony Adduci  
USGS/Edward SammelBackground

The meeting with DOE-HQ/Ron Toms was organized by C. Gerard Davidson, and attended by representatives of the principal institutions interested in development of geothermal resources in the Cascade Range. Ron requested ID/Clay Nichols and me to attend; Idaho Operations Office will be responsible for drilling contracting, SAN will be responsible for any reservoir definition activities.

"Jebby" Davidson's letters (attached) state that he has "been working on the proposed exploration program for the Cascades in Washington and Oregon that we discussed at some length during the Geothermal Resources Council meeting here in Portland". He was Asst. Secretary of Minerals and Energy in Interior under Truman, and Solicitor for Bonneville Power Administration (BPA). He claims to be able to influence government actions through Senator Hatfield of Oregon, Chairman of the Senate Appropriations Committee, and Secretary Hodel, former Administrator of BPA. As an example, if DOE's procurement regulations cause difficulties and delays, "we can get them changed".

Davidson picked up Ron and me at the airport, and drove us to his home in Portland. There we met his wife Sylvia, who is on a HHS-HQ advisory committee on medical costs. From there we went to Trader Vic's for an excellent dinner, and on to our hotel.

BPA Meeting

On the morning of the 21st, Ron and I met first with BPA. Doug Seeley, chief of Bonneville's Generation Engineering Section, hosted the day's meetings. He was joined by Steve Monfort, chief of the Office of Power Planning, Mike Berger, chief of the Assessment Section, John Geyer, and others. Doug and Steve briefed us on Bonneville's origin from Corps of Engineers and Bureau of Reclamation hydroelectric projects; Bonneville's responsibilities for power marketing - as opposed to construction and operation of powerplants; BPA's supply and demand forecasts; and the outlook for geothermal power in BPA's planning. Bonneville's forecasts include WPPSS 2 output, and show oversupply into the 1990's. WPPSS 1 and 3 are expected to come on line when needed, with small hydro and cogeneration from pulp and paper mills making up the rest. BPA's internal, high growth.

are expected to come on line when needed, with small hydro and cogeneration from pulp and paper mills making up the rest. BPA's internal, high growth, Federal loads scenario shows the earliest that geothermal power might enter the northwest power mix is 1988, in competition with new coal-fired powerplants.

Under the Regional Power Planning Act of 1981, the four states of Idaho, Montana, Oregon and Washington are conducting energy research, development and demonstration, including hardware engineering. As part of BPA's activities in support of the Regional Council's 2 year Action Plan, Doug Seeley is conducting studies on geothermal power generation. He expects to fund feasibility studies on a 10 MW binary powerplant, and to purchase the power output from such a plant located at a geothermal field with a 100 MW potential. BPA's Conservation Department is responsible for geothermal direct heat and is interested in municipal heating and other hot water applications, which utilities can use to displace electric power consumption. However, Bonneville is \$25 B behind in repaying their hydro debt, and their cash flow - from power sales - is tight. Doug concluded that: no Cascades geothermal resource has been confirmed; eventual power generation is very long term - an estimated 7 years after leasing; and, the geothermal program needs some seed money.

### Objective

USGS/Pat Muffler had previously summarized the objectives of a Cascades drilling program as:

- a significant number of stratigraphic test wells;
- which yield an evaluation of the Cascades geothermal resource, despite the hydrologic problems - the 'rain curtain' which has masked subsurface temperatures on prior 2,000' holes; and,
- which result in significant drillhole data in the public domain.

The objective in Davidson's letters is cost-sharing of Cascades geothermal exploration wells in Washington and Oregon; (Mt. Shasta and Lassen are Cascades volcanoes in Northern California, but were not mentioned). Davidson's interest seems limited to temperature test (gradient) holes, but this is not specified.

Ron Toms stated that DOE is interested in trying to characterize the geothermal potential of the Cascades. The US Geological Survey is responsible for, and currently working on, the inventory of Cascades geothermal resources. We are beginning to understand the Cascades; industry is the driving force; we need to define the Cascades' geothermal energy potential; and, add to the Nation's energy resources.

Davidson's associate, John Hook, former District Geologist for Reynolds Metals, recommended that we should be looking for "elephants", the size of The Geysers (2,000 MW+). These would be high temperature geothermal fields, each with the potential of thousands of megawatts, which would profoundly change the power generation picture of the Pacific Northwest.

Hook estimates that Cascades geothermal resources are in the 2,000 - 20,000 MW range (attached).

Additional thoughts on geothermal exploration of the High Cascades are contained in Tsvi Meidav's letter, which was distributed at the meeting (attached).

Walt Youngquist, a former Exxon geologist, concluded that we need a good discovery in the Cascades; a viable geothermal resource which moves the whole development process along. Management must be convinced; funding to put up a plant must be raised, e.g., in New York. In order to benefit the Cascades Region, geographically representative sites must be chosen for the temperature holes.

### Attendees

Attendees represented a consortium with geothermal land positions in the Cascades. (BLM says that Davidson and Hook have filed extensive geothermal lease applications in the Oregon Cascades). The remaining attendees represented interested utility, state and federal agencies, as follows:

- Amax Exploration (eastern OR)
- California Energy Corp. (Crater Lake OR)
- Chevron (Clackamas area, south Mt. Hood OR)
- Eugene Water & Electric Board
- Munson Geothermal
- Reynolds Metals (south Mt. St. Helens OR, Sea-Tac leases)
- Seattle City Light (Mt. Baker WA)
- Trans-Pacific Geothermal (Blue Lake & Clackamas area, Mt. Hood OR)
- Union Oil (various Cascade locations)
- United States Forest Service, and
- Washington State Energy Board

### Budget

Ron's FY 1985 budget contains \$1.4 M for Cascades research. (According to Geothermal Report, March 15, 1983, there is \$700 K in DOE's budget for caldera reservoir investigations to evaluate Cascades geothermal prospects, and \$897 K for measurement of Cascades reservoir characteristics under impermeable basalt flows). His budget has been approved by DOE, OMB, and both Houses; appropriation by Congress is the final step. Ron expects to allocate about \$1 M for cost-shared drilling with the remaining \$400 K for supporting research, such as data analysis and reservoir modeling. (Coring, logging and well testing costs are presumably included in the drilling budget.)

## Program Outline

Davidson summarized the point of the meeting as the determination of what the problems are to the government providing 50% funding for drilling on privately owned geothermal leases in the Cascades. He defined the proposal as a number of 3,000-4,000 ft. holes, costing \$250,000-300,000 each, where the participating company has exclusive geothermal lease rights, and can come up with \$150,000 for cost-shared drilling.

Ron noted that the White House is urging joint activities with industry. However, he is concerned that DOE's budget not respond to an industry lobby, and that other interested parties are not excluded. The Administration stresses increased competition in government procurements.

DOE is responsible for understanding the economic potential of US geothermal resources, and taking them to the point of commercial development. We do not understand the Cascades potential enough to go ahead with commercial development. DOE needs to know if there is enough evidence, such as geology and geophysics, of geothermal potential at the proposed site(s). Ron would prefer to get the best 5 - 8 sites which are meaningful in terms of providing information to advance for industry's strategy of future energy development. There will probably have to be a public announcement in Commerce Business Daily. A likely model is the Request For Proposals (RFP) which led to the DOE-Industry Coupled Geothermal Drilling Program.

ID/Clay Nichols reviewed potential contracting methods:

- In order to justify sole source procurement, the proposing group would have to represent everybody with a geothermal lease position in the Cascades.
- Contracts for joint ventures must be issued by DOE-HQ Procurement in Washington, DC.
- Interested leaseholders could respond to an RFP from Idaho Operations Office for cost-shared drilling.

Data can be held proprietary for a reasonable period (e.g., 6 mos.). The RFP contracting process normally requires at least 6 months. If the RFP is issued promptly after the beginning of the Fiscal Year on Oct. 1, companies could be under contract by Spring. Because of deep mud after snowmelt, drilling season in the Cascades really begins in mid-June and lasts to first snowfall (Sept. - Oct.).

There was extensive discussion involving USFS/Jerry Pachon on leasing status of federal lands, and the many environmental concerns, such as wilderness areas, endangered species, and environmental impact reports.

## Conclusion

In response to Davidson's going around the table, the following attendees indicated potential interest by their institutions in a cost-shared geothermal temperature drilling program with DOE:

1. Amax Exploration (in kind contribution - drilling rig)
2. California Energy Corp.
3. Chevron
4. Eugene Water & Electric Board
5. Munson Geothermal
6. Reynolds Metals, and
7. Trans-Pacific Geothermal (Tsvi Meidav)

Seattle City Light is prohibited from proposing, but may respond favorably if invited by another participant. Union's representatives will discuss the proposal with Dick Dondanville, who is in charge of geothermal exploration.

Davidson will spend the first week of April in Washington DC, finding out if an unsolicited proposal approach by the group of attendees is possible.

Att.: Davidson letters to BPA/T(h)oms 12/8/84, and Chevron/Loose 12/8/84  
Hook presentation to DOE - BPA 3/21/84  
Trans-Pacific Geothermal/Meidav letter to DOE/Toms 3/16/84

cc: HQ/Toms, Wallace  
ID/Nichols, Prestwich  
BPA/Seeley, Geyer  
USGS/Muffler  
LBL/Goldstein, Lippmann  
UURI/Wright  
FGS/Crawford  
MR/Wright

LAW OFFICES OF  
C. GIRARD DAVIDSON  
PARK WASHINGTON BUILDING  
519 SOUTHWEST PARK  
PORTLAND, OREGON 97203

(503) 223-3800

*Let's From Ron Thoms, 12/27/83  
cc: Maurice of LBL  
Naam  
Tony/John  
CURI/WRIGHT*

December 8, 1983

Mr. Ron S. H. Thoms, Assoc. Director  
Division of Geothermal Energy  
Resources Application Division  
Room 7104 Federal Building  
1200 Pennsylvania Avenue  
Washington, D.C. 20461

Dear Ron:

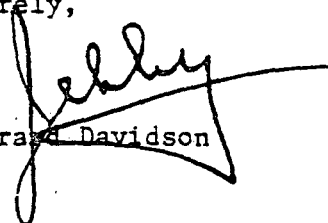
I have been working on the proposed exploration program for the Cascades in Washington and Oregon that we discussed at some length during the Geothermal Resources Council meeting here in Portland.

While at a meeting of the Pacific Northwest Section of the Council in Seattle on Tuesday, I made it a point to discuss the proposed program with representatives of Seattle City Light, and they were extremely interested and gave me the impression that they would be happy to participate in such a program with DOE paying half the cost of such a well. As you know, Tsvi Meidav of Trans-Pacific Geothermal has said that he would participate, and I have discussed it briefly by phone with Ollie Loose of Chevron who asked me to write him a letter on the subject that he could kick upstairs. A copy is enclosed for your information. John Hook and I are going to talk to Reynolds Metals, California Energy and others. Tsvi agreed to talk to Union. I will, of course, keep you advised of developments, but if you have any suggestions, please let me know.

T. L. Sadlier Brown, who represents City Light and also British Columbia Hydro, was at the meeting Tuesday in Seattle. He is recommending that Seattle City Light participate in such a program. It was obvious in the discussion with him that British Columbia Hydro would jump at a chance to get half of a deep well paid for in the Meager Creek area. As you know, this is the one place, other than Newberry Crater, in the Cascades that has produced steam. I told him that I would mention this to you, but I felt sure DOE would not wish to participate in financing any exploration outside of the United States. (Maybe you have some deal with the State Department that I don't know anything about, but I thought I would mention this for what it is worth.)

Sincerely,

C. Girard Davidson



RECEIVED  
RONALD S. H. TOMS  
DEC 13 1983

Enclosure

cc: John Hook  
Tsvi Meidav

RM



LAW OFFICES OF  
C. GIRARD DAVIDSON  
PARK WASHINGTON BUILDING  
518 NORTHWEST PARK  
PORTLAND, OREGON 97205

(503) 228-3600

December 8, 1983

Mr. Ollie Loose  
District Land Supervisor  
Chevron Resources Co.  
P. O. Box 7147  
San Francisco, CA 94120-7147

Dear Ollie:

This is in further reference to our telephone conversation relating to a proposed geothermal exploration program of the Washington and Oregon Cascades.

While at the Geothermal Resources Council recent meeting in Portland, Ron Thoms of the U. S. Department of Energy, talked to Tsvi Meidav of Trans-Pacific Geothermal, Inc. and me about his desire to see a geothermal exploration program in the Oregon and Washington Cascades. He says that DOE has money for this purpose and felt that his Agency would probably be able to match contributions by private industry if a proper program could be developed. One of the problems that he raised was the difficulty of the government providing funds which would tend to prove the existence of geothermal resources on a particular company's holding. He understands, however, that as a practical matter, non-competitive geothermal lease applications have been filed on practically all of the prime areas of the Cascades where geologists feel the most likely geothermal potential exists, and nothing can be done about this. Obviously, if these areas on which filings exist are the best prospects, they would be the best areas in which to conduct an exploration program.

In the discussion that ensued, it developed that if we can get 6 to 10 different companies or individuals whose geothermal lease applications cover the Washington and Oregon Cascades and who are willing to pay half of the cost of a well on one of its leases, this problem could possibly be solved. Thus the government would not be financing just one entity but several, with the result being a broad exploration program of the Cascades under government sponsorship. For example, a program such as the following may be possible and meet the problem since geothermal exploration wells would be drilled in the Cascades from Northern Washington to Southern Oregon. The following is purely an example of what I have dreamed up, and I have not discussed it with the companies I have taken the liberty to name, with the exception of those mentioned later. I envisage something as follows:

- 1) Seattle City Light might be interested in putting up one-half of the cost of a 2,000 or 3,000 foot well on some of its lease applications or leases on Mt. Baker in Washington.

Mr. Ollie Loose

Dec. 8, 1983

Page 2

2) Reynolds Metals might be interested in placing a well on lease applications or leases in the Trout Creek area south of Mt. St. Helens in Washington which Sea-Tac Geothermal controls.

3) Any one of several companies with whom we have talked might be willing to pay one-half the cost of such a well in the Red Hill-McGee Creek-Clear Branch area on the north side of Mt. Hood.

4) Chevron might be interested in paying one-half of the cost of a well on one of its leases in the Clackamas area of Mt. Hood National Forest.

5) Trans-Pacific Geothermal might be interested in such a program in the Blue Lake area of Oregon. (Since Chevron and Trans-Pacific have leases or lease applications in both this area and the Clackamas area, you two might decide which area each of you would like to tackle, or possibly do a joint venture for two wells.)

6) California Energy might be interested in such a program on its lease applications in the vicinity of Crater Lake.

7) Union Oil has a number of land positions throughout the Cascades and might well be interested in paying half the cost to see the results or information derived from a well put down on one of its areas.

There are other companies that have holdings in the Cascades which may wish to participate in such a program. But if a sufficient number will participate, it would accomplish Ron Thoms' objective of getting six or more exploratory wells drilled in the Cascades from Northern Washington to Southern Oregon. Since some of the companies may already have their budgets fixed for 1984, I feel we should consider this as a two-year program for 1984 and 1985. But, of course, it will be preferable if we can get some of the wells drilled during the 1984 season.

We are thinking in terms of each well being approximately 3,000 feet, and it is my understanding the cost would be about \$250,000 per well. Thus if Chevron and any of the other companies are interested in drilling such a well on one of its leases, it would agree to commit up to \$125,000 for this purpose, to be matched by DOE for a similar amount. Obviously there are a great many details which would have to be worked out, but at this point I am trying to ascertain which companies may be interested in pursuing such a program.

As I told you over the phone, Tsvi Meidav of Trans-Pacific Geothermal says that his company is interested in having a well drilled in one of his areas of interest, and will participate in the program. Tuesday at the meeting of the Pacific Northwest Section of the Geothermal Council in Seattle, I discussed this program with representatives of Seattle City Light. Recognizing that certain problems have to be worked out, they felt that City Light would like to participate in the program and have a well drilled on its Mt. Baker applications or leases with City Light paying only one-half of the cost.

Mr. Ollie Loose

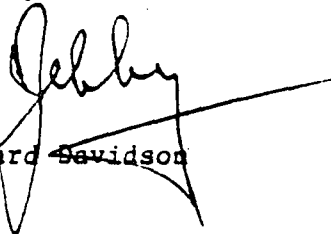
Dec. 8, 1983

Page 3

Obviously I am not suggesting a commitment at this time. I am merely trying to ascertain whether such a program is interesting to you and you wish to explore it further. Please let me have Chevron's reaction.

Should you wish to discuss it further, please give me a ring.

Sincerely,

A handwritten signature in cursive script, appearing to read "C. Girard Davidson". The signature is written in black ink and is positioned above the typed name.

C. Girard Davidson

cc: John W. Hook

## GEOHERMAL PROSPECTS OF THE CASCADE RANGE

Presentation by John W. Hook to DOE - BPA, Portland, OR, 3-21-84

BEFORE STARTING THE SLIDE PRESENTATION, I WOULD LIKE TO MAKE A BRIEF STATEMENT OF MY VIEWS ON THE GEOHERMAL PROSPECTS OF THE CASCADE RANGE.

WITH THE 1980 ERUPTIONS OF MOUNT SAINT HELENS, THE GEOHERMAL INDUSTRY STARTED BELIEVING WHAT SOME OF US GEOLOGIC TYPES HAVE BEEN PREACHING FOR YEARS: WE SHOULD BE CHASING VOLCANOS AND LEAVE THE HOT SPRINGS FOR THE SKINNY DIPPERS. OVER 1.5 MILLION ACRES OF GEOHERMAL LEASE APPLICATIONS HAVE BEEN FILED ALONG THIS 800 MILE CHAIN OF VOLCANOS.

THE GEOHERMAL RESOURCES OF THE CASCADES ARE UNTESTED AND THUS UNKNOWN. OPINIONS OF WHAT THEY MIGHT BE VARY FROM ZERO TO HUNDREDS OF THOUSANDS OF MEGAWATTS.

THE ZERO CAME IN THE BATTELLE REPORT TO THE NORTHWEST POWER PLANNING COUNCIL (June, 1982): "WE ARE NOT INCLUDING THE CASCADE RANGE IN OUR ANALYSIS BECAUSE IT IS A GEOLOGIC PROVINCE RATHER THAN A SPECIFIC SITE". THIS BIT OF REASONING CAME IN A REPORT WHICH ALSO QUOTED THE USGS CIRCULAR 799 THAT THE IDENTIFIED PLUS THE UNDISCOVERED ACCESSIBLE RESOURCE BASE IN THE CASCADES IS ESTIMATED TO BE 1,197 QUADS, NEARLY 15 TIMES THE CURRENT U. S. ENERGY CONSUMPTION. THE REPORT ALSO MENTIONED DOGAMI'S LARGER ESTIMATES, BUT STILL CRUNCHED A ZERO INTO THE COMPUTER.

RECENT REPORTS BY THE OREGON AND WASHINGTON GEOLOGIC DEPARTMENTS HAVE BEEN VERY OPTOMISTIC ABOUT THE CASCADES (DOGAMI Special Paper 15 and DNR Open file 83-7). FOR THE OREGON CASCADES ALONE, DOGAMI ESTIMATES A WORSE CASE OF 2,485 TO AS MUCH AS 401,760MWe FOR 30 YEARS. MY OWN ESTIMATES ARE IN THE 20,000 TO 200,000 MWe RANGE. IF SUCH RESOURCES EXIST, BOTH GOVERNMENT AND INDUSTRY NEED TO KNOW IT.

AS DISTRICT GEOLOGIST FOR REYNOLDS, I WROTE A REPORT IN 1971 RECOMMENDING EXPLORING THE CASCADES FOR GEOHERMAL ENERGY. I AM STILL MAKING THE SAME RECOMMENDATIONS. WE NEED TO BE LOOKING FOR HIGH TEMPERATURE GEOHERMAL FIELDS WHICH HAVE THE POTENTIAL FOR THOUSANDS OF MEGAWATTS. WE SHOULD HUNT FOR ELEPHANTS, NOT GNATS. DOZENS OF GEOHERMAL FIELDS THE SIZE OF THE GEYSERS COULD, AND POSSIBLY DO, EXIST IN THE CASCADE VOLCANIC PROVINCE. FINDING RESOURCES OF THIS SIZE AND QUALITY IS NOT AN UNREALISTIC EXPECTATION.

THE POINT I WISH TO MAKE IS THAT IF WE DRILL HOLES IN THE CASCADES, WE MAY FIND A RESOURCE WHICH IS BIG ENOUGH, CHEAP ENOUGH, AND CLEAN ENOUGH TO PROFOUNDLY CHANGE THE ELECTRIC POWER GENERATION PICTURE IN THE NORTHWEST. GIVEN THE LEAD TIME NEEDED TO IDENTIFY AND DEVELOP SUCH RESOURCES, WE NEED TO BE MOVING AHEAD WITH THE EXPLORATIONS.

TRANS-PACIFIC GEOTHERMAL, INC.

1419 Broadway, Suite # 415, Oakland, CA 94612  
(415) 763-7812

3-21-84  
cc: Tony  
✓ USGS / Summer  
(MVFLEX)

March 16, 1984

Mr. Ronald Toms  
Department of Energy  
Washington, DC

Dear Ron:

Due to a schedule conflict, I regret that I am unable to personally attend the panel meeting of geothermal exploration research of the High Cascades, which will be held Tuesday, March 21, 1984. I wish to share some thoughts on this subject with you.

It is clearly evident that the High Cascades are perceived by the geothermal industry as a very high risk target for geothermal exploration and development. This is due to two reasons: Firstly, there is no commercial electrical grade geothermal reservoir discovery in the U.S. High Cascades of despite millions of dollars that have been spent. The Newberry Caldera discovery by the U.S. Geological Survey offers little comfort to industry, because it is in a national park of restricted access. Secondly, the current official projections of future power demand in the northwest conceived in the period of economic gloom of 1982-85 by the Bonneville Power Authority (BPA), suggest that the northwest may not need any new electrical capacity additions to 1990 or beyond. This projection further increases the perception of business risk by industry, since it implies that even if a commercial-grade geothermal discovery was to be made by the geothermal industry, there may be no buyers for electricity for a long time to come. Since the lead time between drilling a discovery well and the completion of a small geothermal power plant is only two to three years nowadays, there is no incentive to industry to spend significant amounts of cash on exploration when the payoff is so far in the future, if any discovery is ever made.

The absence to date of any industry success in locating a commercial grade geothermal discovery in the High Cascades may be partially attributable to an unusually deep rain-water circulation in the subsurface. This deep circulation would tend to mask temperature gradient anomalies that are characteristics of geothermal systems. Normally, temperature gradient holes to a depth ranging from 500 to 2000 feet in depth are sufficient to map promising targets for full-depth, production-diameter exploration wells. In geothermal systems, however, the temperature gradient should be of a commercial reservoir. Deeper temperature gradient holes must be drilled to obtain a more reliable assessment of the deeper temperature picture. The U.S.G.S. hole in Newberry Caldera clearly demonstrates the veracity of the above stated assertion. Some exploration holes for lithologic and temperature data to depths of 2,000 to 4,000 feet are mandatory for any

~~serious assessment of the deep temperature regime in the High Cascades.~~  
Such holes cost between ~~\$80 to \$100 per foot~~ at present. Hence, an expenditure in the range of about one-third of a million dollars per hole is required. Independent geothermal companies will consider such an amount of expenditure per hole far too high at this time, when both the exploration risk and the electrical power market risk are so high. This is true despite the fact that many of us believe that the High Cascades possess a high potential for some major geothermal reservoir discoveries in years to come. If nothing is done to mitigate the high risk perception by industry, geothermal exploration of the High Cascades will continue for a number of years at the same snail's pace as currently practiced by industry.

The current low pace of geothermal exploration will not accelerate, unless stimulated by external factors which must include both exploration risk reduction as well as encouragement of small geothermal power demonstration projects. Recent history of major nuclear power development in the Northwest demonstrates the fallibility of projections regarding demand and nuclear power costs. As a consequence, current projections of future capacity needs may prove to be an overcompensation of last decade's bullish projections, this time in underestimating the future.

~~Major geothermal resource areas indeed exist in the High Cascades region and if demand for electricity will outstrip the currently held gloomy growth projections. Serious exploration of the resource must start now, if it is desired that a meaningful capacity addition from geothermal resources be provided by 1990 and beyond. The U.S. Department of Energy and associated Federal and State bodies must spur on the development by providing support for the early exploration phases and by encouraging early demonstration plant construction.~~

Three forms of exploration support are viewed as reasonable:

1. Matching-fund support. ~~Industrial companies will nominate areas in which they wish to drill deep temperature gradient wells and the proportion of the cost thereof that they are prepared to contribute. (The DOE will select the best opportunities based upon conditions of knowledgeable consultant panel and objective financial criteria)~~ *DOE & GO FURTHER,*  
*Com/11/165*
2. Non-recourse loan. Industrial companies will be provided forgivable loans *DOE HAS* for the program. The loan will bear interest and will be payable in part *USDO IN* if and when the company receiving it decides to drill a deep exploration *CITIZEN* well in the same area. *AREAS -*
3. Federal program. ~~Companies will nominate areas for drilling, to be fully funded by the government. An independent panel of experts will select those areas which, in its opinion, show the greatest light on the deep geothermal gradient regime in the region.~~ *? Policy CURRENTLY,*

*VERY MUCH INTERESTED, WILLING TO CONTRIBUTE SIGNIFICANT AMOUNT OF \$, HAVE SUBSTANTIAL LOANS*

The drilling of 9 to 12 deep temperature gradient holes in the High Cascades in the course of the next year ~~may provide a significant stimulus for deeper exploration of the region.~~ Parallel activities by governmental bodies may further accelerate industry's interest in spending the large sums of money required for a ~~meaningful assessment of the geothermal potential of the High Cascades.~~

Sincerely yours,



Tsvi Meldav  
President

TM/lkp



Department of Energy  
San Francisco Operations Office  
1333 Broadway  
Oakland, California 94612

*Send to  
Mike Wright*

December 20, 1984

Marshall Reed, Program Manager  
Geothermal and Hydropower Technologies Division  
DOE Headquarters, CE-324  
1,000 Independence Ave. SW  
Washington, DC 20585

Subject: Cascades Geothermal Exploration

Dear Marshall,

As we discussed today, I believe there are several Cascades geothermal exploration actions that need to get underway in FY'85 in order to locate geothermal anomalies for confirmation by drilling.

First, we need to start work on the conceptual geologic model of the High Cascades, including their relation to the major geothermal anomalies (like Newberry caldera) to the east, and the line of hot springs to the west. This conceptual model must be based on an integrated analysis of the many discipline results that are available.

Second, we need to review and modify our Exploration Architecture, developed for the Basin and Range, in order to lead geothermal exploration in the High Cascades.

Third, we need to complete detailed analysis of available data (esp. geophysical surveys) and identify critical gaps. This effort will also build in-house Cascades geophysical expertise for subsequent drill targeting.

I suggest that Mike Wright of UURI be requested to lead these tasks for DOE, working closely with the USGS and Norm Goldstein of LBL. Funds from the \$1.4 M allocated for Cascades temperature gradient drilling and associated investigations appear proper for these related purposes.

Sincerely,

Martin W. Holloy, Ph.D  
Program Manager  
Geothermal Reservoir Definition

cc: USGS/Muffler, Sammel  
UURI/Lippmann, Goldstein  
ID/Prestwich  
BPA/Geyer  
DOGAMI/Priest





DATE 9-27-84

Department of Energy  
San Francisco Operations Office  
1333 Broadway  
Oakland, California 94612

TO: UURI-ESL/MIKE WRIGHT  
(801) 524-3439

FROM: DOE-SAN/MARTY MOLLOY  
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3 PAGES (EXCLUDING COVER)

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THIS MESSAGE CONTAINS ONLY UNCLASSIFIED INFORMATION

Marty Molloy  
signature

MIKE:  
DRAFT RESPONSE TO BPA/ ASST. POWER MANAGER (RESOURCES, PLANNING & EQUIPMENT) WALTER POLLOCK'S REQUEST FOR 1) RATIONALE AND 2) LETTER OF ASSIGNMENT (LIST OF RESPONSIBILITIES). WILL REVIEW WITH GEYOR TODAY AND MUFFLER FRIDAY - BACKGROUND FOR OUR MTC @ BPA 10/2 MWIN

## CASCADES PROGRAM RESPONSIBILITIES

- Basis for Letter of Agreement -

### Cascades Interagency Task Force

#### Bonneville Power Administration

- Interagency coordination and leadership
- Interface with NW Power Planning Council and regional institutions
- Results of \$500 K 4-state geothermal study re. Cascades
- Cascades program milestones, schedule and systems analysis
- Cascades environmental and institutional issues
- Phasing with pilot/power plant development, transmission networks, and long-range power planning.

#### US Geological Survey (with DOGAMI)

- Summary of Cascades geothermal knowledge
- Identification of critical gaps in Cascades geothermal data
- Proposed next steps for Cascades geothermal resource assessment
- Proposed exploration priorities, including area/site screening
- Conceptual Cascades geothermal geologic model(s)
- Link to ongoing USGS Cascades research and results.

#### US Department of Energy - Geothermal R&D Program (with UURI and LBL)

- Cascades exploration strategy
- Exploration and drilling technology development
- Exploration survey and drilling contract management
- Drill targeting model(s) for primary sites
- Interface with geothermal industry.

#### US Forest Service

- Geological engineering and access to priority sites
- Permitting of exploration surveys and drilling on USFS lands
- EA's and EIR's for priority USFS drilling sites.

#### Bureau of Land Management

- Geothermal leasing of federal lands.

#### Geothermal Industry (Exploration, Drilling, Service, Utility, etc.)

- Cooperation with and review of Interagency Cascades Program
- Continued Cascade exploration and drilling
- Commercial testing of known geothermal reservoirs (low-mod. temp.)
- Development of low-moderate temperature projects (direct use and binary electric).

## CASCADES PROGRAM RATIONALE

This is an interagency response, led by BPA, to an initiative of the Northwest Power Planning Council.

On the basis of hearings and staff analysis, the Council "has concluded that a large geothermal potential exists in the region for both electric generation and direct applications that decrease the need for electricity".

The "Cascades Geothermal Energy Potential" program is proposed as one of three responses to the Council's finding. The other two geothermal responses are:

1. Direct utilization of known low-moderate geothermal resource for space heating, industrial processing, etc. These "conservation" approaches, like the North Bonneville direct use study, have higher priority than electric power generation, and are expected to be implemented in the near-term.
2. 10 MW binary powerplant at a 100 MW resource, in response to a specific order from the Council to BPA. This powerplant is expected to be an intermediate-term project at known a hot spring in the four state region, not in the High Cascades.

These three efforts are complimentary, and time phased. Exploration of the Cascades is expected to take at least 5 years of major effort for location of a major geothermal reservoir, comparable to the Geysers 2,000MW, if one exists. Developmental drilling, reservoir confirmation, and powerplant construction is expected to take 5-10 years after the discovery is made. In the interim, direct use and binary powerplant projects are expected to come on-line at known low-to-moderate geothermal sites outside the High Cascades.

The agencies involved are the same as those which participated in geothermal exploration and drilling in the late 1970's: the resource and energy agencies at both federal and state level. The role of industry has yet to be defined: the objective is to create a framework of mutual cooperation, so that existing information can be shared, the most effective exploration techniques and strategy employed, and duplication avoided. The intent is to achieve increasing industry participation and cost sharing, so that, as a major reservoir is confirmed, government withdraws and industry takes over without loss of information or momentum. At that point, government could contribute substantially by accelerating leasing, environmental, and permitting reviews.

The initial step, the primary responsibility of the US Geological Survey, is to summarize existing geothermal knowledge of the Cascades, and to point the way for an effective exploration program. Assistance of geologic experts from the states, industry and DOE are crucial to the success of the USGS effort. The result should be an agreed strategy for geothermal exploration of the High Cascades, with site priorities and conceptual geologic model(s) to guide geophysical surveys, sampling, and exploratory

drilling.

Deficiencies in knowledge and exploratory techniques are expected to be uncovered, which will require specific tasks, tests, and analyses to bridge. In particular, the severe topography, "rain curtain" masking, and unknown signature of High Cascades reservoirs are expected to require development and testing of geophysical survey techniques at known geothermal sites in comparable settings. Development of exploration technology is particularly well suited to DOE's R&D mandate, and the geothermal "Exploration Architecture" developed by the University of Utah Research Institute for DOE.

Oregon will play a central role, since the State leads in High Cascades acreage, available information, and expertise (DOGAMI). Washington and California are welcome to join from the beginning, as interest and support permit.

The final question is "Why the Cascades?". Simply put, the majority of the world's high-temperature (electric quality) geothermal reservoirs are associated with active volcanism (Italy, New Zealand, Iceland, Mexico, Japan, Philippines, Indonesia, etc.). Most of the major geothermal fields, including The Geysers CA, and Cerro Prieto Mexico, are located in the "Ring of Fire" that surrounds the Pacific Basin. The Cascades remain one of the areas of very high geothermal potential which has seen relatively little systematic exploration by the US geothermal industry. There are relatively few surface features, such as hot springs, which mark underlying geothermal activity. Cascades exploration is principally concerned with the discovery of "blind" systems. It is thus very risky, despite the potential for discovery of Geysers-sized resources, or "elephants".